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PROCEEDINGS of the WESTERN JUNIPER ECOLOGY AND MANAGEMENT WORKSHOP

BEND, OREGON
JANUARY 1977

PACIFIC NORTHWEST FOREST and RANGE EXPERIMENT STATION
FOREST SERVICE U.S. DEPARTMENT of AGRICULTURE
PORTLAND, OREGON

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PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
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INTRODUCTION

Western juniper (*Juniperus occidentalis* subsp. *occidentalis*) is an important invader of range lands in central and eastern Oregon. Many people have asked questions about its control, effect on range productivity, and its benefits. The papers in this proceedings resulted from a conference held in Bend, Oregon, January 1977, to summarize our knowledge of western juniper and to evaluate research needs.

THE SPREAD OF WESTERN JUNIPER IN CENTRAL OREGON

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ABSTRACT

The probability that western juniper is increasing at a phenomenal rate throughout its range is shown, drawing upon written record, photographic record, and casual observation. Scarcity of knowledge about this plant leaves land managers to make uninformed decisions about its management. Meanwhile, a much needed research campaign to answer principal questions about western juniper has yet to be organized.

Keywords: Western juniper, invasion, range, Oregon

OCCURRENCE AND DISTRIBUTION

Western juniper (*Juniperus occidentalis* Hook.) is principally a native to central Oregon, with some distribution extending east into Idaho, north into southeastern Washington, and south into California and Nevada. It lives nowhere else.

Stand Characteristics: Cause for Concern

Where they grow, stands of western juniper are generally accepted as a characteristic part of the landscape. They appear to be well established and form a logical transition between the open plains and the pine timber. They look like they belong. A closer look raises some doubts.

First of all, many dense stands of western juniper, ones that appear to be a forest, conspicuously lack dead standing trees and logs. Furthermore, there are often no big older trees, so common to other forests, and no scattering of seedlings or saplings in the understory. Instead, these western juniper forests appear as a collection of uniform trees. These facts lead us to two important speculations: one, these stands are relatively young; and two, the trees within them originated at about the same time.

Through increment boring, that is removing a core sample of the trunk's growth rings, we can often confirm both speculations for a given stand. The year of germination varies, but mostly falls between 1870 and 1910.

Supporting Evidence

Written Records. In 1870, land surveyors under contract to the federal government came to central Oregon to set township and section corners as a necessary prerequisite to homesteading. Part of their task was to observe and record information about soils and vegetation. As it turns out, they were the first to make such a systematic survey here. We still have their notes, which unfortunately are sketchy in soils and vegetation data. Nonetheless, they are descriptive, and they are also official, which lends credence to the descriptions.

On October 15, 1870, having finished a survey of Township 13 South, Range 13, East of the Willamette Meridian, deputy surveyor John W. Meldrum wrote the following summary description:

> "The land in this township is gently rolling except in the southwestern part which is hilly: soil generally good second rate. There is some juniper timber in the south western part, but quite scattering. Good bunchgrass in abundance grows all over the township......"

That is a very sketchy record, but it is also very specific about location. Since we still use this original survey for land location, we can easily find the place just described. Instead of juniper being "quite scattering", we find the junipers form a veritable forest with 80 to 100 trees per acre.

Photographic Record. Long-time residents of central Oregon confirm that the juniper dominance we now see has come about during their lifetime. Occasionally they have the pictures to prove it.

In 1888, pioneer Richard Breese made his homestead in Gravy Gulch, just south of Prineville in central Oregon. His original cabin is still standing, and now looks like so many other shacks around the countryside. However, unlike so many others, this one was photographed when it was still new, and when, in sharp contrast to Gravy Gulch now, there were no junipers. A second photograph taken in 1976 documents the contrast.

A 1915 photograph of the town of Ashwood (just north of central Oregon) shows just a few junipers dotting the hills in the background. A second photo, taken of the same hills in 1968, shows the kind of heavy juniper cover that we have come to accept as natural.

Other old photographs, taken in other parts of western juniper's geographic distribution from Dayville in eastern Oregon to the Lava Beds National Monument just below the southern Oregon border, show the same phenomenon. It appears that in the last 100 years, western juniper has been increasing at an alarming rate.

IMPLICATIONS OF THE INCREASE

The cause for alarm comes from two sources. First, we suspect that the juniper requires enormous amounts of water and can outcompete all other plants surrounding it. If this is true, thousands of acres of rangeland and watershed will be affected.

The second cause for alarm is that a mature juniper tree is a formidable plant. Traditional plant control methods of chemical or mechanical means are proving to be too expensive or ineffective.

Management Questions

The prospect of a formidable plant drastically reducing the productivity of thousands of acres of rangeland quickly raises four questions:

1. Is western juniper really invading rangeland?
2. If there is an invasion, is that bad?
3. What's causing it?
4. What can we do about it?

Is western juniper really invading rangeland? Old survey notes and old photographs can present convincing evidence, but not the definitive, quantitative kind of support on which to launch a major research or control program. We need to be far more specific. Within this major question, there are a series of sub-questions.

- How many acres did western juniper occupy before 1900 and where were they?
- How many acres does it occupy now and where are they?
- What, if any, is the percent of increase?
- Left unchecked, what is the forecast of acres to be occupied 10 years from now?

If there is an invasion, is it bad? Land managers, especially range managers have learned that plant invasions in general are bad. Plants that increase their cover, range or density at a phenomenal rate are weeds. They have no value and they live at the expense or detriment of plants that do have value. What about juniper?

We suspect, that left unchecked, in 50 years western juniper will dominate most of the rangelands where it now grows. Will soil erosion be increased from these sites by the tons per year? Will forage plants be gone, having been unable to compete with juniper for water? Will lower elevation rangeland, even if not occupied by juniper, suffer from lack of soil moisture, because upland juniper is using what used to come down as sub-surface flow?

On the other hand, it is possible that as a result of some silvicultural and wood technology advancements, western juniper wood will become a commodity. With this possibility, harvest may or may not keep up with the rate of juniper increase. We may learn that wildlife variety and numbers increase as junipers increase.

The possibilities are endless. The point is, we don't know what to expect because juniper's effect on soil moisture, plant competition, or wildlife have not been identified. We can't launch a major control effort by assuming juniper is bad; we're going to have to find out what effect it has on other components of the ecosystem.

What is causing the invasion? We ask this question usually because we assume that the key to curing a problem lies with its cause. Unfortunately with juniper there is a long term time lag involved. The chances are that once we find the cause, it will help 20 years from now, and not tomorrow. But we still must be interested in cause, because it will probably be our cheapest solution in the long run. Without trying to answer the question here, I will just point out that as land managers we have reason to suspect

- birds are involved--they transport the seed to new locations
- fire is involved, we know it kills juniper; without fire, there seems to be no natural check on juniper
- sagebrush may be involved; many new juniper are born under a sagebrush where they were planted by birds
- grazing may affect the rate of juniper invasion

What can be done about juniper invasion? Just asking this question assumes that there is at least some level of juniper invasion going on, and that some of it is bad. If those assumptions prove true, then land managers will need to know more about juniper control methods than they do now. We need to know what works, what works best in what circumstances, and what are the costs and impacts of different control methods.

CONCLUSION

We suspect that western juniper is increasing at an alarming rate. We also suspect that this increase will ultimately destroy thousands of acres of range. Currently, land managers have to base these suspicions on educated guesses, personal observations and experience. There is very little information available on the management of western juniper. Management decisions are based on the same weak footing as are suspicions.

We don't know much about western juniper and we need to know a great deal. However, that is only half of the problem. The other half is that as of the date of this paper, there is no known effort to find the needed answers; meanwhile, western juniper is still growing.

SECTION I

BIOLOGY

COMMUNITIES OF WESTERN JUNIPER IN THE INTERMOUNTAIN NORTHWEST

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ABSTRACT

This paper presents a broad picture of western juniper (*Juniperus occidentalis* var. *occidentalis*) communities primarily from literature with some recent work by the authors. Vegetation-soil-site information is summarized from studies and surveys of central and southeast Oregon, northeast California, and southwest Idaho. Western juniper occurs on soils derived from a broad variety of parent materials--igneous, sedimentary, and metamorphic in origin. It occurs most commonly in association with big sagebrush (*Artemisia tridentata*), bluebunch wheatgrass (*Agropyron spicatum*), and/or Idaho fescue (*Festuca idahoensis*). Effective soil moisture and fire cycles are probably the main factors determining presence or absence of juniper under natural conditions. Since advent of efficient fire control measures and with overuse of rangelands by livestock during the same period, it appears that juniper has significantly increased its distribution and density in the zone. The entire mountain big sagebrush (*A. tridentata* subspp. *vasseyana*) type may be suitable for juniper expansion although lack of seed source has probably prevented it in the past.

Keywords: *Juniperus occidentalis* var. *occidentalis*, plant communities, vegetation-soil relationships.

INTRODUCTION

Western juniper (Juniperus occidentalis var. occidentalis) occurrence in the Intermountain Northwest is considered the northwest extension or representative of the pinyon-juniper woodland of the Intermountain Region (Cronquist et al. 1972, Driscoll 1964b, Billings 1952). The range of this variety of western juniper includes southeast Washington, southwest Idaho, eastern Oregon, northwest Nevada, and northeast California (Cronquist et al. 1972, Vasek 1966, and Little 1971) (Figure 1). The center of western juniper community development appears to be the large continuous woodland of central Oregon.

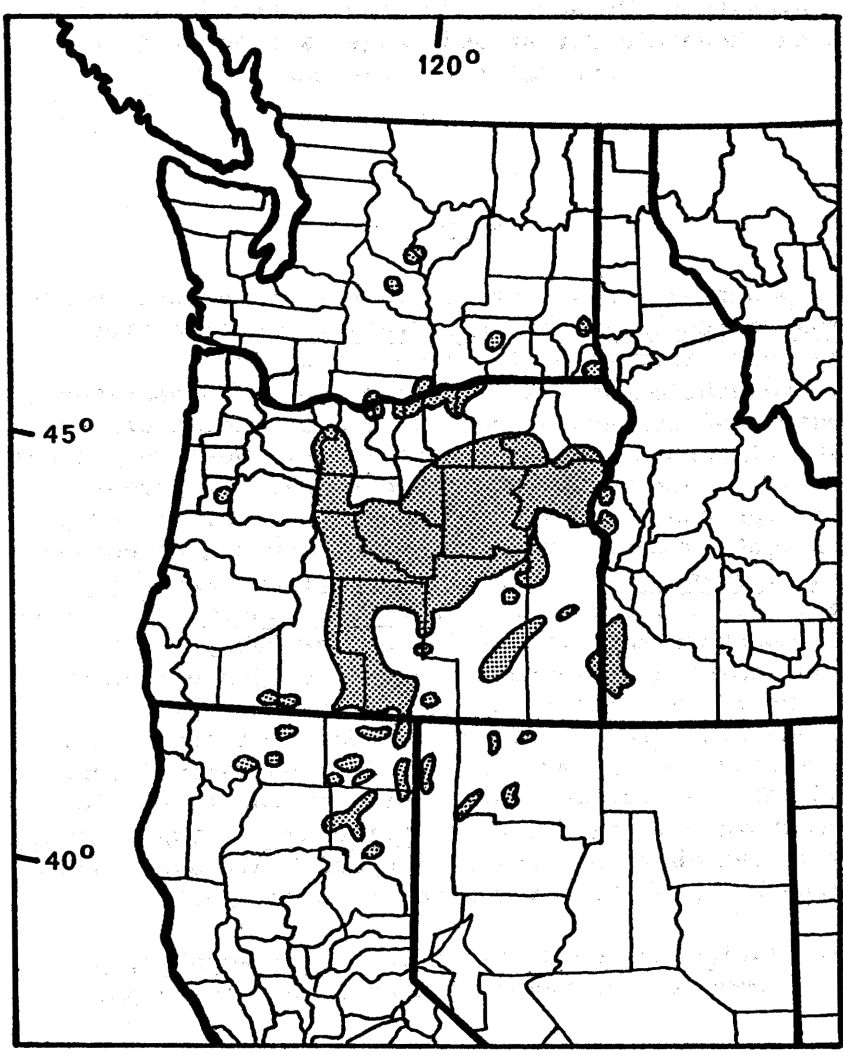

Figure 1.--Generalized distribution of western juniper (shaded portion). Tree densities vary among and within the different localities.

This paper presents a broad picture of these communities primarily from literature with some recent work by the authors. Vegetation-soil-site information will be discussed as well as some evaluation of western juniper in relation to interfacing high desert steppe communities such as big sagebrush (Artemisia tridentata) and curlleaf mountain-mahogany (Cercocarpus ledifolius).

WESTERN JUNIPER ZONE

The western juniper zone is spread across the Intermountain Northwest, being heavily concentrated and highly developed only in central and south-central areas of Oregon and to a lesser degree in northeastern California (Figure 1). The species occurs as single trees or small clumps throughout southeastern Oregon with a few stands in Harney and Malheur Counties developing significant woodland types. Burkhardt and Tisdale (1969) describe a study area in southwest Idaho as having approximately 161,878 hectares (400,000 acres) of juniper in various stages of succession or in climax stands.

The most intensive area of juniper study has been central Oregon where Driscoll (1964a, 1964b) analyzed nine associations including two variants, classifying them following polyclimax concepts. A large portion of the central Oregon juniper woodland zone in Driscoll's study area was so disturbed by overgrazing and farming, that it was unsuitable for analysis and placement in a hierarchy of successional and climax stages.

A standard soil survey was conducted by Leighty (1958) during the late 1940's and 1950's in this same area of disturbed communities. Leighty's vegetation notes indicated, of 1362 square kilometers (526 square miles) surveyed, over 99 percent had juniper occurring either as scattered trees or in more dense woodland situations.

To illustrate further extent of western juniper occurrence, we have compiled acreage data for soils supporting juniper in a north-south belt of central Oregon from Washington to the California border. These data are taken from a more recent compilation of soils information containing a supplemental generalized soil survey for purposes of reporting irrigable acreages in Oregon (Oregon Agric. Exp. Stn. and S.C.S. 1969). Although more general than a standard soil survey, the information provides an adequate guide to addressing occurrence of western juniper. This area is made up of the Deschutes River, Goose and Summer Lakes, and Klamath River drainage basins (Oregon Agric. Exp. Stn. and S.C.S. 1969). In the Deschutes River basin of 2,460,542 hectares (6,080,000 acres), juniper woodland occupied 8 percent of the area and scattered juniper occurred on 11 percent of the area. In the Goose and Summer Lake basins, juniper stands occurred on 14 percent of the 1,778,632 hectare (4,395,000 acres) area; no distinction was made between juniper woodland and scattered occurrence there. In the Klamath River basin of 1,410,360 hectares (3,485,000 acres), woodland stands occupied 15 percent of the area with scattered stands on another 15 percent.

We can present a general picture at best with these statistics since available plant data from our source was sketchy and land use of these areas changes continually. Further, we do not imply with these data that all areas are equally occupied in either "woodland" or "scattered tree" classes. However, these acreages are significant not only in size but also in terms of considering potential increased occupancy of these areas by western juniper.

Western juniper stands, though widely dispersed, constituted a very small percentage of area in southeastern Oregon. Eckert (1957) studied juniper dominated ecosystems over a large study area in this portion of the state.

Considerable information has been reported on western juniper communities of southwestern Idaho by Burkhardt and Tisdale (1969, 1976). They studied the nature and successional status of western juniper on the Owyhee Plateau and adjacent mountains in the west-central part of Owyhee County. The study effort was concentrated on two major vegetation communities--one considered climax and one seral.

Climate

Climate in this area is continental but modified somewhat by marine air from the Pacific Ocean. It is semiarid with typical intermountain characteristics of dry hot summers and cold winters with precipitation of 25 to over 51 cm (10 to over 20 inches) occurring principally as snow during winter and rain during spring and fall. Summer precipitation is generally sparse and ineffective. Frost can occur during any month in higher elevation areas; however, July and August are generally frost-free. Temperatures range from a low of $-47^{\circ}C$ ($-53^{\circ}F$) during January to a high of $46^{\circ}C$ ($114^{\circ}F$) during August (USDA 1941).

Soil and Site Characteristics

The following commentary represents a composite of soil-site data we found available for the western juniper zone and applies to essentially all occurrences of the species (Eckert 1957, Driscoll 1964b, Leighty 1958, Anderson 1956, Burkhardt and Tisdale 1976, Oregon Agric. Exp. Stn. and S.C.S. 1969, Franklin and Dyrness 1973).

Driscoll (1964b) recognized three physiographic subdivisions of this Northwest representative of the pinyon-juniper zone based on soil parent material. The first (his study area) was primarily eolian mixed igneous and pumice sands but included soils from coarser pumice, second was soils from igneous flows (mostly Miocene), and third was soils from Clarno and John Day sedimentary formations (Eocene and Oligocene epochs). At this time we see no reason to challenge this concept but have approached he following discussion more generally.

Western juniper occurs on soils derived from a broad variety of parent materials--igneous, sedimentary, and metamorphic in origin. These include basalt, andesite, rhyolite, pumice, volcanic ash, tuff, welded tuff, and colluvial, alluvial or eolian mixtures of the preceeding. The mixtures may be rather homogeneous to highly stratified. As a result, western juniper is found on zonal, intrazonal, and azonal soils in a complex pattern over its present range of occurrence. Existing and potential stem density as well as growth and overall adaptability of western juniper vary over this spectrum.

Profile development differs among soils, but is often weak. Total depth ranges from deep (over 122 cm or 48 inches) to shallow (between 25 and 38 cm or 10-15 inches). They are commonly stony or gravelly and when shallow, broken indurated subsoil layers or fractured bedrock occur.

Textures vary from sandy to clayey. Surface horizons are usually medium textured with medium to fine textured subsoils. Hard pans or indurated layers occur in some cases and are associated with clay, calcium carbonate, and silica accumulations. These accumulations may be continuous or intermittent and vary in thickness from a thin band less than 1.5 cm (1/2 inch) to several centimeters. Surface soils are commonly dark brown when moist and gray brown to yellowish brown when dry.

Most soils supporting juniper have a mean annual soil temperature between 8^{o}-15^{o}C (48^{o}-59^{o}F), in the mesic temperature class; however, some are in the frigid class, <8^{o} to >5^{o}C (<48^{o} to >41^{o}F).

Western juniper occurs on essentially all exposures and slopes. The species is common on level to gently undulating topography of the High Lava Plains typified by the area between Redmond and Bend, Oregon. Moving away from this situation juniper occurs less continuously on moderately sloping alluvial fans, low terraces, canyon sideslopes, and steep escarpments. Elevational occurrence extends from 488 to 1982 meters (1600 to 6500 feet).

Very scattered juniper is found in fractured rockland areas on relatively flat topography resulting from geologically recent igneous flows. Occasional juniper plants are also found on steep rockland or talus slopes.

Soils mapped in the western juniper zone are primarily Brown, Regosol and Chestnut great soil groups within the old system of classification (Leighty 1958, Eckert 1957, Burkhardt and Tisdale 1969, Franklin and Dryness 1973). Within the latest soil taxonomic system, soils supporting juniper at higher densities are usually Mollisols; Argixerolls, Haploxerolls, and Haplaquolls are common great groups. Soils supporting scattered juniper are often Aridisols including Camborthids, Durargids, and Haplargids; however Argixerolls are also common. Substantial acreages of Durixerolls, Cryoborolls, Torriorthents, and Chromoxererts also support varied stands of juniper (Oregon Agric. Exp. Stn. and S.C.S. 1969).

Soil series common to the area include Agency, Deschutes, Madras, Merlin, Lorella, Tournquist, Lamonta, Metolius, Day, Maupin, Hack, Ayres, Courtrock, Fopiano, Ochoco, and Era.

Communities

Central Oregon. Western juniper is the primary conifer in the area and represents the driest tree-dominated zone in the Pacific Northwest. Occasional ponderosa pine (*Pinus ponderosa*) occurs in canyon bottoms, on north slopes or ridges extending out from the edge of the pine forest. Curlleaf mountain-mahogany interfaces with juniper at the edge of the high desert. Juniper is dominant in much of the area as an open woodland providing the aspect of a savanna (Figure 2). Big sagebrush is the dominant shrub understory in most communities; however, on some poor condition sites rabbitbrush (*Chrysothamnus* spp.) takes its place. On more moist sites big sagebrush is either replaced or shares the understory with antelope bitterbrush (*Purshia tridentata*). Other shrubs which occur in the area are low sagebrush (*Artemisia arbuscula*), horsebrush (*Tetrademia canescens*), granite gilia (*Leptodactylon pungens*), wax currant (*Ribes cereum*), spiny hopsage (*Grayia spinosa*), desert gooseberry (*Grossularia velutina*), and a suffrutescent erigonum (*Eriogonum* spp.). The grass layer varies between dominant stands of bluebunch wheatgrass (*Agropyron spicatum*) and Idaho fescue (*Festuca idahoensis*) or mixes of these two. Other grasses commonly occurring are Sandberg's bluegrass (*Poa sandbergii*), Thurber's stipa (*Stipa thurberiana*), bottlebrush squirreltail (*Sitanion hystrix*), and cheatgrass (*Bromus tectorum*). Generally forbs are a small constituency of relatively undisturbed communities. Common species include yarrow (*Achillea millefolium*), milkvetch (*Astragalus* spp.), fleabane (*Erigeron linearis*), woolly eriophyllum (*Eriophyllum lanatum*), and lupine (*Lupinus* spp.) (Driscoll 1964).

Figure 2.--The western juniper area in central Oregon has a savanna-like aspect.

Western juniper occurs in a wide spectrum of densities on most slopes and all aspects. Driscoll (1964b) described one association on level topography and eight associations and two variants on rolling to hilly topography (Table 1). He found slope direction limited antelope bitterbrush occurrence and influenced relative dominance of Idaho fescue and bluebunch wheatgrass. Bitterbrush occurred most commonly on east to southeast facing slopes. Idaho fescue dominated the herbaceous

Table 1. Vegetation-soil-site values illustrating the spectrum of communities studied in central Oregon and their differences (after Driscoll 1964).

Association	Association Number	Aspect	Juniper Cover (Percent)	Soil Moisture Storage (2-14")	Understory Cover (Percent)
Juoc/Artr/Feid[1]	1	NW to NE	12.0	1.41	28.5
Juoc/Artr/Feid-LUPIN	2	N to NE	12.3	1.98	24.5
Juoc/Feid	3	NW	76.7	1.81	16.7
(Bitterbrush variant)	4	(SE to E)		2.14	14.1
Juoc/Artr/Agsp-CHAEN	5	NW to NE	46.0	.87	14.9
Juoc/Artr/Agsp	6	Level	10.0	2.31	23.9
Juoc/Agsp	7	E to NE	43.0	1.34	10.5
(Bitterbrush variant)	8	(SE)			
Juoc/Artr-Putr	9	N to NE	6.6	1.54	20.8
Juoc/Agsp-Feid	10	E	32.0	.97	14.4
Juoc/Artr/Agsp-ASTRA	11	S to SW	27.7	1.21	17.4

[1] Alpha symbols for species abbreviations from Garrison et al. (1976).

layer on northerly slopes, whereas bluebunch wheatgrass tended to be dominant on southerly slopes and on level topography.

Eight of Driscoll's nine associations and both variants were considered topo-edaphic climax situations, with the other, western juniper/big sagebrush/bluebunch wheatgrass, being considered as the climatic climax association.

Much of the western juniper woodland in central Oregon occurs on level to rolling topography. Leighty's soil survey of 1362 square kilometers (526 square miles) in the heart of the juniper zone is probably one third or more of the zone we consider as occurring in the Jefferson-Deschutes County area (1958). Of this, 85 percent had slopes no greater than 7 percent. He observed that the more extensive stands of juniper woodland occurred in the southern portion of the survey area on Deschutes loamy sand and sandy loam (Xerollic camborthids), the most common soils, accounting for 22 percent of the area (Figure 2).

Two juniper sites studied by the authors near Redmond in central Oregon were identified as members of the juniper/big sagebrush/bluebunch wheatgrass association with a fenceline contrast separating them into two strikingly different condition classes due to apparent livestock disturbance. Both were on a 10 percent west slope. The undisturbed area appeared in excellent condition and the disturbed one appeared in poor to fair condition with an obvious increase in juniper, big sagebrush, and cheatgrass, and a decrease in bitterbrush, bluebunch wheatgrass, and Idaho fescue. Also, big sagebrush was present in all age classes on both sites whereas bitterbrush occurred only in a mature age class on the disturbed site (Table 2).

The soil here was mapped in the Deschutes Survey (Leighty 1958) as rough stony land, derived from Agency and Deschutes series parent materials. The former material is of sedimentary origin containing pumiceous or tuffaceous sandstones, agglomerates, gravels, sands, and ashes of parent rock containing much rhyolite and andesite. The Deschutes materials are primarily of pumiceous sand origin with some ashy materials and may contain some basalt fragments in the subsoil. Deschutes soils have weakly developed profiles, essentially sandy loam throughout with horizonation primarily the result of coloration changes and some weak lime veining. Agency soils express considerable development and are finer textured throughout than the Deschutes. Common textures in the surface and subsoil horizons are loams and clay loams, respectively, with moderate structural development in both. Lime veins occur in the lower subsoil.

Southeastern Oregon. Western juniper is generally in marginal situations in southeastern Oregon. Eckert (1957) placed juniper in relatively mesic sites on north slopes with understories primarily of big sagebrush and bunchgrass, or on rocky ridges in conjunction with

Table 2. Ecosystem values from undisturbed and disturbed sites in central Oregon.[1]

	Undisturbed				Disturbed			
	Percent Cover	Dominance	Stems/ Acre	Maximum Juoc Age	Percent Cover	Dominance	Stems/ Acre	Maximum Juoc Age
Juoc[2]	10	5	80	85	25	5	168	115
Artr	2	5	All age classes		5	5	All age classes	
Putr	2	3	All age classes		1	2	Mature only	
Gutie	1	2			-	-		
Agsp	25	5			1	3		
Feid	10	3			1	3		
Posa	3	3			3	5		
Stth	3	3			1	3		
Kocr	1	3			1	1		
Brte	1	5			2	5		
Acla	1	3			1	3		
PHLOX	1	2			1	3		
ARABI	1	1			-	-		
CALOC	1	2			-	-		
LOMAT	1	3			1	5		

[1] Minor species present with equal values on both sites: Chvi, Sihy, Feoc, ASTRA.

[2] Alpha symbols for species abbreviations from Garrison et al. (1976).

low sagebrush and bunchgrass. In any case juniper was quite widely spaced where it did occur. Eckert described four associations where juniper exhibited dominance. Where juniper was dominant it was interpreted as an arborescent community usually associated with escarpments and stony ridges and was considered a topo-edaphic climax. Analysis of vegetation-soil-site data showed that the only consistent differences apparent between juniper and non-juniper types were rockiness and topographic positions.

Soils supporting Eckert's associations were not correlated with named series but were in the Brown and Chestnut great soil groups. They were primarily residuum or colluvium from basalt and rhyolite with some developed on alluvial fans. Soil profiles were similar in many respects to those described by Driscoll (1964b). They were frequently rather shallow and stony with fine textured, well-developed B horizons. Some were underlain by an indurated layer cemented by calcium carbonate or siliceous materials which restricted rooting. Where the indurated layer was broken, there appeared to be an association with juniper, for example, in his western juniper/low sagebrush/Idaho fesuce association.

Southwestern Idaho. Burkhardt and Tisdale (1969, 1976) analyzed vegetation, soils, and site in two communities, one with old-growth juniper situated on shallow soils of rimrock sites, and the other with young juniper on downslope sites with deeper soils. The former was considered a topo-edapic climax community and the later a seral community (Table 3). They concluded that protection from natural fires during the last 100 years has resulted in expansion of juniper into mountain big sagebrush (*Artemisia tridentata* subspp. *vasseyana*) communities downslope from climax juniper stands which provided a seed source.

The authors concluded that under current fire control attitudes, it appears ecologically "...quite possible that the potential limit of western juniper in the study area may be the full extent of the mountain big sagebrush-Idaho fescue community or even of drier sagebrush communities" (Burkhardt and Tisdale 1976).

Table 4 displays some of the physical and chemical soil properties reported in the preceding research studies. Analytical methodology was frequently not presented in detail so the validity of the direct comparison is in question. The reader is encouraged to consult original references for further detail if such data are of particular interest. Eckert's (1957) chemical and physical soil data associated with western juniper was minor and is included in the discussion section only. He did report considerable data for soils associated with big sagebrush.

DISCUSSION

There are critical questions which must be answered before we can understand the role or potential role of western juniper in ecosystems

Table 3. Abbreviated association table of species under climax and seral juniper stands in southwestern Idaho. (after Burkhardt and Tisdale 1969)

Species	Percent Frequency																	
	Climax							Seral										
	1	2	3	4	5	13	19	6	7	11	12	14	15	16	17	18	20	21
Artrv [1]	7	3				5		3	5	45	13	40	38	31	35	43	8	36
Putr	3	3				3		8			5	3	3	3	5	8		10
Syva								8	8		3	20						25
Chvi									3	18	5					8	8	23
Agsp	18	18	18		3	18	20	15	18	23	48	45	25	58	38	30	53	68
Feid	20	43	38	13	5	30	32	40	15	40	75	78	58	10	13	45	60	73
Posa 3 (Pose)	43	60	33	40	38	52	70	65	35	100	83	43	65	65	53	83	43	38
Sihy	15	30	13	23	18	3	5	3		8			5	8		3	8	30
Stth	30	8	20	15	18	20	5								33	3	5	
Kocr								3	23	10								10
Stco								3	8			5						
Brte	5	10	45	58	33	48	3	23	23	5			15	60	100	10	80	15
Siin								5	18			3	10	13	3	3	3	63
Erpu										28	8			13		10		
Basa												5	13				13	8
Melo									5	8	20	20				15		58
Erhe										5	8				3			5
Erum								3		3				3				3
Phle												60		3				10
Asbe								8		3	5	3					3	
Lula										25	5		18					
Alac											18	3						8
Pesp								3						5	3			
Sein										3		3	10					
Erbl													10	3				3
Toru [2]	45	48	28	20	13	10	13	8	5	5		5	10			5		20

[1] Alpha symbols for species abbreviations from Garrison et al. (1976).

[2] *Tortula ruralis* (Moss)

Table 4. Soil characteristics in western juniper zone exemplary of findings by various researchers.

Source, Horizon or depth (inches), community or other	pH --	Organic Matter %	Extractable Bases Ca (Me/100g)	Mg	Na	K	Total	Cation Exchange Capacity Me/100g	Base Saturation %	Available P ppm	Total N %	Organic C/N --	Bulk Density g/cc	Soil Moisture Storage in 2-14 inch zone inches
Driscoll (1964), A horizons														
Juoc/Artr/Feid[1]		4.78								--	.21	13	--	1.4
Juoc/Feid		3.91								--	.17	12	--	2.0
Juoc/Artr/Agsp		1.50								--	.08	11	--	2.3
Juoc/Agsp		2.12								--	.10	12	--	1.3
Juoc/Agsp-Feid		1.32								--	.07	11	--	1.0
Juoc/Artr/Agsp-ASTRA		1.63								--	.08	12	--	1.2
Dealy and Geist (Redmond, Oregon area, (Juoc/Artr/Agsp)														
Disturbed 0-6	5.9	2.0	20.6	11.0	0.2	1.3		--	--	6.4	.20	6	--	--
6-12	6.4	1.7	34.4	21.8	0.3	1.5		--	--	1.6	.12	9	--	--
12-18	7.3	1.5	81.3	21.7	0.6	1.2		--	--	2.0	.22	5	--	--
Undisturbed 0-6	6.3	2.1	21.6	9.2	0.2	1.3		--	--	8.0	.13	9	--	--
6-12	6.6	1.7	38.3	17.7	0.3	1.4		--	--	2.5	.11	9	--	--
12-18	7.3	1.5	84.5	18.8	0.4	1.2		--	--	2.1	.19	5	--	--
Burkhardt and Tisdale (1969)														
Climax Soils All horizon	7.0	--	8.8	--	--	--	--	14	83	--	--	--	1.50	--
B2	6.4	--	5.5	--	--	--	--	12	76	--	--	--	1.60	--
C	--	--	--	--	--	--	--	--	--	--	--	--	1.69	--
Seral Soils All	6.4	--	9.0	--	--	--	--	19	71	--	--	--	1.23	--
B2	6.5	--	7.0	--	--	--	--	14	79	--	--	--	1.56	--
C	6.5	--	--	--	--	--	--	--	81	--	--	--	1.54	--

1 Alpha symbols for species abbreviations from Garrison et al. (1976).

of the Intermountain Northwest. For example:

1. What is juniper's potential distribution among ecosystems?

2. What is juniper's potential competition among ecosystems?

3. What is its successional status?

4. What is the influence of fire or lack of it under various site conditions and on distributions and density?

Present distribution of western juniper, its current densities and age structure tell us little about these questions. Valuable work has been done in central Oregon (Driscoll 1962, 1964a, 1964b, Leighty 1958, Adams 1975), in southeastern Oregon (Eckert 1957), and southwestern Idaho (Burkhardt and Tisdale 1969, 1976) on certain phases of western juniper ecology. However, only the surface of knowledge on this subject has been scratched. There have been several authors who place western juniper in the position of invader and/or successional component in some ecosystems (Burkhardt and Tisdale 1969, 1976, Anderson 1956). Burkhardt and Tisdale (1976) developed strong historical evidence that fire prevented spread of juniper from relic or old topo-edaphic climax communities on rocky ridges and rimrocks. In our study in central Oregon, higher density of juniper in the disturbed area appeared related to reduced competition by overgrazing because both sites were equally vulnerable to fire and neither community had stands of old-growth juniper, but had similar maximum stand ages. Actual presence of juniper was possibly a result of fire protection.

Some of Driscoll's (1964b) communities had young stands of juniper which he related to fire but did not consider as seral to big sagebrush. It is difficult to consider western juniper in a subordinate role, successionally, to a shrub such as this. It is, however, acceptable to the authors to consider a big sagebrush community as held in a successional stage by short fire cycles, disallowing juniper its full expression as the climax dominant. Burkhardt and Tisdale (1976) found no evidence of fire in the stand of juniper they considered seral and thus considered the occurrence of juniper in this community to have begun 88 years ago in the absence of fire. It is reasonable that a fire cycle could historically have allowed juvenile juniper stands to become established only to be later obliterated. Thus, we would have in reality a juniper site where young juniper stands occur periodically but are kept from full expression because of fire. In other words, the ecosystem might be considered in a pyroclimatic situation. Further, because of distance to seed source and lack of seed carrying bird populations, large areas of mountain big sagebrush having no evidence of juniper occurrence may actually be potential juniper sites. Burkhardt and Tisdale (1969) suggested this type in general may be suitable for juniper establishment. We believe the important thing is to recognize juniper in its fullest potential expression so managers are not continually shocked or surprised when this species pops up in a "new" situation. Managers tend to consider it a "weed" which is out of place, when in reality it may only be changes in management (e.g., fire control or overgrazing) which produce an unfamiliar situation.

With knowledge of western juniper's potential expression, we as managers and scientists can develop and provide guides to insure intelligent management of this species.

Even a brief personal encounter with variability in soils, climate, topography, management history, vegetation, etc. conveys the complexity of unravelling the ecology of western juniper areas.

There are no simple rules of thumb to present in summing up vegetation-soil-site relationships in the western juniper zone. Juniper is not uniquely associated with a fixed set of soil conditions, a soil series, type or phase nor even a strongly related set of soils as we now view our knowledge. Effective moisture is probably the main factor determining the potential of a site for juniper.

Some conditions appear more conducive to juniper occurrence than others but we now lack the ability to define the limits of those conditions and their combinations. Combination is a key concept here as is compensation. Juniper seems to grow reasonably well in deep, well-drained, medium to coarse textured soils or in shallow soils of poorly structured, heavy textured subsoils with higher coarse fragment percentages and fractured bedrock. Apparently clayey subsoil zones and/or accessibility to deep moisture in bedrock fissures can compensate for a shortage in moisture storage in shallow soils. This is but one example of seemingly numerous compensating soil-site factors over the zone.

Burkhardt and Tisdale (1976) suggest deeper soils of valley bottoms are most conducive to seedling establishment in contrast to shallower, better drained soils being most conducive to growth after establishment. Eckert (1957) suggests that western juniper is a species requiring relatively high amounts of moisture and that the requirement may be met by a number of compensating factors.

Some rather exclusive vegetation relationships are in evidence between western juniper and other species, and we speculate that more could be found if specifically sought. Eckert (1957) noted Cusick tickweed (Hackelia Cusikii) to exist only under juniper crowns. We have observed association of grass species such as Idaho fescue on one side of the crown perimeter but not on others. Eckert further noted that cover of Idaho fesuce and moss (Tortula ruralis) deteriorate with death of the associated juniper individual. Burkhardt and Tisdale (1969) also noted a greater abundance of moss under older trees.

The above relationships appear closely related to soils. Eckert noted that soil surface pH under older juniper crown averaged 1.0 unit higher than bare soil interspaces and under shrub crowns. He added that associated herbaceous species may contribute to this influence. He found no increased salinity levels associated with pH increases. Burkhardt and Tisdale found higher average soil pH and percentage base saturation values associated with climax juniper stands compared to "seral" stands. These data raise an important question about the significance of nutrient cycling differences associated with western juniper and their relation to companion species composition, growth, and synecology.

Possible differential nutrient cycling is not unique to juniper systems. Geist (unpublished data) found soil nutrient differences under shrub versus non-shrub vegetative components in eastern Oregon as have other workers in southeastern Washington (Rickard et al. 1973). The latter workers followed up their findings with bioassays which showed cheatgrass growth was greater and higher in nitrogen when grown in shrub-influenced soil than in interspace soil.

There are some important vegetation-soil-site relationships to be gleaned from research of other juniper species. Clary and Morrison (1973) found that essentially all early spring forage in central Arizona was produced under crowns of large alligator juniper (Juniperus deppeana) trees and they cautioned managers about potential forage loss with removal of these trees in "control" projects.

Jameson (1970) reported that seedling growth-inhibiting substances were present in fresh leaves, litter and humus from Utah juniper (Juniperus osteosperma) which affected blue grama (Bouteloua gracilis) germination. He noted this influence was primarily associated with poorly aerated soils.

Hence, we see that soil and plant chemical factors associated with juniper, juniper companion species, or both must be recognized if we are to properly interpret species interactions. These factors should be included when analyzing plant communities both for the purpose of establishing range trend and for management evaluation.

Published data and personal experiences with highly contrasting indicator species on seemingly homogeneous soils and sites makes us aware of the difficulty in defining unique vegetation-soil units in some cases. Eckert (1957) reports that in western juniper/low sagebrush communities where a juniper tree dies, big sagebrush becomes established around the dead tree. Further investigation showed soil under the tree was considerably deeper than under low sagebrush and was better suited to juniper or big sagebrush. Our personal experience with a bitterbrush-low sagebrush complex was similar in central Oregon near Silver Lake, where deeper soil favored bitterbrush (unpublished data).

Hence, vegetation indicators may be misleading to managers without associated soil data. Therefore, we must be cautious in choosing where and what benefits may be gained in juniper stand management.

RESEARCH AND MANAGEMENT

Research Objectives

Determine:

1. Influence of fire on the distribution and density of juniper.

2. Optimum soil-site conditions for juniper.

3. Successional ecology of western juniper in the core area of central Oregon to aid in relating seral understory stages to potential plant communities.

4. Localized influence of juniper presence on species composition, nutrient cycling, and current and potential productivity particularly regarding control of juniper expansion.

5. Age structure of western juniper in the core woodland area of central Oregon.

6. The effect of variable juniper density on forage production and other resource values, e.g., wildlife, water yield and storage, and erosion.

Management Implications

1. Juniper has a localized influence on soil properties, plant composition, and forage productivity:

   a. Under crown vs outside crown
   b. North side vs south side of crown

2. Localized influences must be recognized in sampling vegetative changes following removal of juniper in order to separate effects due to its absence and that due to other factors.

3. Soil removal or displacement in juniper control programs can greatly alter the potential plant community since soil depth is frequently marginal for many existing communities. Managers should know soils and possible localized effects on the resulting mosaic of plant communities.

4. SCS range site classficiation data should be used to refine vegetation relationships to identified soils. Such information will provide predictive insights to the spread of juniper to sites currently unoccupied by trees.

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WESTERN JUNIPER IN ASSOCIATION WITH OTHER TREE SPECIES

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ABSTRACT

Juniper plant communities occur within the forest zone on shallow, stony soils with moderately cracked bedrock. A perched water table is common during the winter. Desert pavement on the soil surface is common. Four kinds of plant communities are described: juniper/bunchgrass, juniper/low sage/bunchgrass, juniper/low sage/scabland, and juniper/stiff sage/scabland.

Keywords: Plant communities, soil description, bedrock, desert pavement, range condition, revegetation.

INTRODUCTION

Drs. Ed Dealy and Jon Geist have discussed western juniper plant communities as they occur within the general climatic zone for juniper. This paper discusses juniper occurrence within the forest zone. It is divided into two parts: the concept of why juniper grows within the forest zone and kinds of juniper plant communities with some of their characteristics.

CONCEPTS OF FOREST ZONE JUNIPER

The concept of forest zone used here is the same as general ecology textbook definitions. It extends from the edge of ponderosa pine (*Pinus ponderosa*) at lower elevations through Douglas-fir (*Pseudotsuga menziesii*) and true fir types (*Abies concolor*, *A. grandis*) ending at subalpine fir (*Abies lasiocarpa*), whitebark pine (*Pine albicaulis*), or mountain hemlock (*Tsuga mertensiana*) forest at upper elevations. In central Oregon, this zone starts about 3500 feet and extends up to 7500 feet elevations.

The change from juniper zone to forest zone is traditionally marked by an intergrade between juniper and ponderosa pine. Typical examples occur in and east of Sisters, Oregon and around Bend. The criteria for defining a "juniper type" compared to a "ponderosa type" is established by individual investigators. Regardless of the criteria used, some juniper types adjacent to the forest zone will contain occasional individuals of ponderosa pine, and ponderosa stands at the lower edge of the forest zone will invariably contain individual juniper trees. Some people consider the transition from juniper to pine important and give it habitat type status such as Ponderosa-Juniper/Big sage/Bunchgrass.

In addition, juniper seems to be a good competitor and is sensitive to underburning. Many ponderosa stands have been maintained in pine by underburning. They are now gradually shifting to a Douglas-fir or true fir climax with fire suppression. We commonly find occasional young juniper trees in these stands. Juniper appears to compete reasonably well with Douglas-fir and sometimes true fir until crown cover becomes too dense.

The real point of this paper, however, is discussion of plant communities within the forest zone which are clearly dominated by western juniper (Hall, 1973). My criteria for a "juniper type" is two or more trees per acre. Using this criteria, juniper types in the forest zone are common in the Blue Mountains and occur with reasonable frequency in and around the Fremont National Forest. They are uncommon in the Deschutes and Winema Forests on pumice soils (Volland, 1976) and they seldom occur on the east slope of the Washington Cascades.

Juniper seems to dominate on what might be termed environmentally drier sites within the forest zone. They usually have shallow, stony soil with moderately cracked bedrock. A perched water table during the winter seems to be common. The soil's surface is often covered by desert pavement.

Desert pavement is not "erosion pavement" (Springer, 1958). Desert pavement is a natural phenomenon caused by freezing and thawing as well as wetting and drying of the surface soil. It is characterized by a pavement of gravel ranging from 1/8 inch to 2 inches diameter overlying a vesicular A horizon 1 to 2 inches thick. The A horizon is free of gravel because frost heaving has moved gravel out of the soil and onto the soil surface. Soil below 1 to 2 inches commonly contains gravel. Naturally occurring desert pavement is desirable because it breaks up raindrop impact, greatly reduces wind erosion of fine particles, reduces surface water movement of fine particles, and reduces soil surface erodibility under freezing-thawing situations. "Erosion pavement" is the result of surface soil erosion in which fine particles have been removed by wind and/or water, leaving gravel. The soil 1 to 2 inches under it is not vesicular and usually contains a reasonable amount of gravel. Thus erosion pavement and desert pavement can be differentiated in the field.

Juniper plant communities above the ponderosa pine zone, within the Douglas-fir or true fir zones, tend to have dramatically different soil and bedrock characteristics from forest stands. Intergrades between the two are seldom encountered.

FOREST ZONE JUNIPER TYPES

Four major kinds of juniper plant communities will be discussed. The order of presentation will be: soil-site description, herbage description and production, revegetation characteristics, and when needed a general discussion.

Juniper/bunchgrass

This type is most common in the central Blue Mountains. Soils are 8 to 18 inches deep, stony to very stony silt loam to clay loam. Bedrock is moderately broken. Desert pavement and a winter perched water table are common.

Herbage dominants are bluebunch wheatgrass (Agropyron spicatum) and/or Idaho fescue (Festuca idahoensis) with reasonably abundant Sandberg bluegrass (Poa sandbergii var. secunda). Needlegrass (Stipa spp.), squirreltail (Sitanion hystrix), and junegrass (Koeleria cristata) are common. Cheatgrass (Bromus tectorum) tends to do poorly on the site because shallow, stony soil and a winter perched water table due to restricted subsoil drainage are detrimental to good cheatgrass establishment and growth. Lomatiums (Lomatium spp.) are common in poor range condition. Average herbage production is 250 to 500 pounds per acre. A major portion of this in good range conditions is contributed by wheatgrass and fescue.

Revegetation opportunities are limited by soil characteristics. Deeper soils, less stony soils, and darker soils are best revegetation opportunities. The crested wheatgrass (Agropyron cristatum, A. desertorum) group of domestic plants are most suitable for this site. In addition, lack of abundant old-growth juniper and presence of younger-age classed juniper suggest better sites. In general, abundant old-growth juniper indicate a site inherently so poor that ground fires either have not been common or have not been of sufficient intensity to eliminate juniper.

Juniper/low sagebrush types

Low sagebrush (Artemisia arbuscula) is a common shrub dominant under juniper in the Blue Mountains and in the Fremont National Forest area. Unfortunately, it is not a real good indicator of site potential. It does indicate a site poorer than those areas dominated by big sagebrush (Artemisia tridentata). However, it tolerates environmental conditions ranging from good bunchgrass productivity down to scabland. The two following types are used to illustrate this relationship.

Juniper/low sage/bunchgrass

The site is very similar to Juniper/bunchgrass, but this plant community occurs in the southern Blue Mountains and on the Fremont. Soils are 8 to 18 inches deep, stony, silt loam to clay loam, over moderately cracked bedrock. A perched water table during the winter is common. At lower elevations, a well cracked bedrock tends to support Ponderosa/wheatgrass, Ponderosa/big sage/wheatgrass, or Ponderosa/low-sage/wheatgrass.

Understory vegetation in good range condition is dominated by low sagebrush of 2 to 10 percent crown cover. Wheatgrass and/or Idaho fescue are dominant with Sandberg's bluegrass. Needlegrass, squirreltail, and junegrass are also common. Cheatgrass does poorly on this site. Herbage production ranges from 350 to 500 pounds in good condition. Tueller (1962) evaluated reaction of sagebrush to overgrazing. He found that sagebrush does not tend to increase significantly.

Revegetation on this type can take either of two forms: sagebrush control, or seeding of grass. Low sage can be reduced in crown cover by spraying, burning, or other treatment. However, it tends to be palatable to big game. Since this type often occurs in winter or spring-fall game range areas, each case of sagebrush control should be carefully considered. Deeper, darker soils respond best to seeding. However, the site is generally poor and response to the crested wheatgrass group of plants is moderately low to low.

Juniper/low sage/sandberg bluegrass scabland

Old growth juniper is always present on the low sage/scabland plant community type. It is one means of separating the juniper/low sage/scabland from juniper/low sage/bunchgrass types. Soils are less than 8 inches deep, stony, on moderately cracked bedrock. When bedrock cracking becomes moderately fine to fine, a low sage/scabland without juniper seems to result. Desert pavement is always present in good soil condition and is highly desirable.

Wheatgrass and Idaho fescue are generally absent (or very low in dominance) in good range condition. Instead, Sandberg bluegrass and one-spike oatgrass (Danthonia unispicata) are dominant. These plants, increasers in other juniper types, should be classified as decreasers in this plant community. Cheatgrass is absent in poor range condition because the site is much too poor. Instead, Lomatiums tend to be common. Herbage production in good range condition varies from 150 to 300 pounds per acre.

Revegetation is not feasible because the site is too poor. In most cases, the crested wheatgrass group of plants cannot withstand this kind of site. A perched water table is always present during part of the winter. On the other hand, soils dry to wilting point by the first to the middle of July. Fluctuation from standing water to wilting point within the soil greatly limits plant species adapted to the site.

These two types characteristically occur in the southern Blue Mountains and in the Fremont National Forest area. They are an excellent example of end points in a continuum between vegetation types. As soil depth changes from 6 to 12 inches, good range condition changes from a dominance of bluegrass-oatgrass to wheatgrass-fescue, herbage production changes from 150 to 450 pounds, desert pavement changes from always present and continuous to often present and not continuous. At soil depths of 7 to 10 inches, wheatgrass and fescue can colonize the site but in limited density. They tend to become ice cream plants in comparison to bluegrass and oatgrass. At 10 to 12 inches soils depth, wheatgrass and fescue become dominant enough to carry sufficient livestock grazing that they can be considered decreasers.

If all ranges were in good condition, we would have little trouble evaluating where on this continuum gradient a site might lie. However, recognition of site quality in poor range condition is difficult. Juniper/low sage/scabland sites can be differentiated from wheatgrass-fescue sites by considering the following: Scabland types have no cheatgrass or yarrow (Achillea millefolium) in poor condition; a greater proportion of juniper trees show old-growth form (diameter at a 12 inch stump is greater than 10 inches); nearly continuous cover of desert pavement; reddish hue to soil color instead of a brownish cast: soil surface moderately stony to stony; bedrock occasionally to commonly exposed; and of course, soil depth 8 inches or less.

Juniper/stiff sage/bluegrass scabland

This is the most common juniper/scabland type in the Blue Mountains. For some reason, it is seldom found elsewhere; it is replaced in the Fremont area by juniper/low sage/scabland. Soils are less than 8 inches deep, stony, silt loam to clay loam, over moderately cracked bedrock, and have a winter perched water table. Fine to moderately fine cracked bedrock results in no juniper. Desert pavement is almost continuous in good range condition.

Stiff sage (Artemisia rigida) occurs at 2 to 10 percent crown cover. It has a deeply three-cleft leaf that looks rather similar to three-tipped sage (Artemisia tripartita). However, the key identifying characteristic of stiff sage is its deciduous nature. This separates it from any other three-tipped sage found in the Pacific Northwest. Stiff sage is an excellent indicator of scabland. Herbaceous vegetation is dominated by Sandberg's bluegrass, one-spike oatgrass, and often bighead clover (Trifolium macrocephalum) in good range condition. Cheatgrass and yarrow are absent in poor range condition due to site limitations. Poor condition commonly is dominated by Lomatiums. Herbage production ranges from 150 to 250 pounds per acre.

Revegetation is not feasible because the site is too poor. Stiff sage is highly palatable to big game and livestock. Sage seedheads in August and September seem to be a prized forage. The low, compact shape of stiff sage is a result of grazing rather than the natural life form of this shrub.

SUMMARY

Juniper types within the forest zone in the Pacific Northwest are topo-edaphic climaxes. They occur on rather precise limits of shallow, stony soil overlying moderately cracked bedrock. These are environmentally drier sites than the associated forest. A perched water table during winter is almost universal. Due to site restrictions, forage production tends to be limited and revegetation is questionable to undesirable.

Juniper does occur in ponderosa pine stands at the lower edge of the forest where the pine and juniper zones meet. In addition, young juniper are often found in open pine, fir, or associated forests probably as a result of fire suppression.

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INTERRELATIONSHIPS OF WILDLIFE AND WESTERN JUNIPER

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ABSTRACT

The structure of a western juniper tree changes as it matures increasing available opportunities or niches for wildlife use. In most cases, juniper habitat in central Oregon supports larger bird populations and more species than does ponderosa pine, lodgepole pine, or big sagebrush habitats. The western juniper habitat apparently creates a relatively benign environment for many species of wildlife. A provisional list of wildlife that utilizes western juniper includes 83 species of birds and 23 species of mammals. The western juniper community can be improved for wildlife by development of water impoundments, openings, and placement of bird nesting and roosting boxes. The most pressing wildlife research needed in western juniper communities are: (1) inventories of wildlife, (2) wildlife use of individual trees and of the communities as a whole, and (3) effects of manipulation of western juniper communities on wildlife.

Keywords: Western juniper, birds, mammals.

INTRODUCTION

So far as we have been able to determine, little work has been done on the interrelationships of wildlife and western juniper[2] in Oregon.

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[2] Due to the number of scientific names in this paper that will be largely unfamiliar to managers, common and scientific names used in the text are given in Appendix 1.

Neither Bailey's (1936) study of Oregon mammals nor Gabrielson and Jewett's (1940) study of Oregon birds took the western juniper community into account per se. However, this community is defined and discussed by Driscoll (1964) and Franklin and Dyrness (1973) so we will not repeat it here. Our objective is to discuss the structure and function of western juniper as it pertains to those species of wildlife that utilize it--some opportunistically, some dependently. Opportunistic use of juniper is defined as utilization when it is available, but the presence or absence of the trees does not dictate the presence or absence of the animal, e.g., the ubiquitous deer mouse. An animal's dependence upon juniper is denoted by its presence in an area only so long as juniper is available. For example, the yellow pine chipmunk (Fig. 1) is primarily an inhabitant of pine forests, but in the absence of pine it will occur in an area where juniper is present. Some species, such as the bushy-tailed woodrat, may be independent of juniper in areas where cliffs, rim-rocks, or talus occur, but dependent upon juniper in areas where these structures are absent.

Figure 1.--Yellow pine chipmunk, Cabin Lake, Lake County, Oregon (U.S. Fish and Wildlife Service photograph by J. S. Gashwiler).

THE WESTERN JUNIPER COMMUNITY

Structure and function

Western juniper changes in structure as it matures (Burkhardt and Tisdale 1969, Sowder and Mowat 1958); these changes provide different uses of an individual tree for wildlife. The number and types of uses increase or change as a tree matures (Table 1). Due to the considerable variation between individual trees, the following discussion is generalized.

The seedling: The small seedling, < 1 m tall with its sparse foliage provides two basic functions. For small animals it can be used as shade or wind protection, but not as hiding cover. Its foliage may also be used as food.

The sapling: A sapling, 1 to 2 m tall with a crown reaching to the ground, is large enough to provide both hiding and thermal cover and food for some animals. A young tree without a full-length crown provides primarily forage and thermal cover. It is often used by some species of birds as a singing or perching tree and is occasionally used for nesting.

The young-mature tree: A mature juniper > 2 m tall is large enough that birds and mammals can nest in it and primary cavity nesters can excavate in dead portions of the trunk. With a full-length crown, a tree offers both thermal and hiding cover for large animals. The trunk, limbs, and crown are large enough to sustain birds that feed by gleaning (searching for) insects. Berry crops, though not regular, are a substantial source of food for birds and mammals. A mature tree is also tall and stout enough for raptorial birds to use as a perch.

The decadent tree: As a juniper becomes decadent, its top starts to break apart and the trunk and limbs frequently become hollow. These natural cavities form protected sites in which some birds and mammals rear their young and rest. Bats may use them for hibernation sites. When a hollow tree dies and falls to the ground, it offers shelter and lookout sites for ground-dwelling mammals. If a stump remains, it is similarly utilized.

In a juniper community composed of trees representing all-age groups, a diversity of reproductive and feeding habitats and protective cover for both opportunistic and dependent wildlife are present.

Habitat diversity

We recognize that the western juniper community abutts pine forests in many areas, but the structural contrast is not as great as the ecotone between juniper and sagebrush range types. Furthermore, habitat diversity is magnified in localities where juniper stands are isolated from other forested communities. We have confined our discussion to the structural

Table 1. Provisional wildlife use of different aged western juniper trees. (These data are based largely on the authors' interpretations of information taken from several sources.)

Species	Young	Mature	Old and decadent	Stumps and downed logs	Source
BIRDS					
VULTURES					
Turkey vulture			X		Gashwiler (Notes and Obs.)
HAWKS and EAGLES					
Goshawk		X	X		Gashwiler (Notes and Obs.)
Cooper's hawk		X	X		Gashwiler (Notes and Obs.)
Sharp-shinned hawk		X	X		Gashwiler (Notes and Obs.)
Marsh hawk					
Ferruginous hawk		X	X		Gabrielson and Jewett (1940) Gashwiler (Notes and Obs.)
Red-tailed hawk		X	X		Gashwiler (Notes and Obs.) Jewett (1936)
Swainson's hawk			X		Gashwiler (Notes and Obs.)
Golden eagle			X		Gashwiler (Notes and Obs.)
FALCONS					
Prairie falcon		X	X		Gashwiler (Notes and Obs.)
BIRDS					
American kestrel		X	X		Gashwiler (Notes and Obs.)
Merlin		X	X		Gashwiler (Notes and Obs.)
GROUSE					
Sage grouse		X	X		Gashwiler (Notes and Obs.)
QUAILS, PARTRIDGES, and PHEASANTS					
California quail		X	X		Gashwiler (Notes and Obs.)
Chukar					
PIGEONS and DOVES					
Mourning dove		X	X		Gashwiler (Notes and Obs.)
OWLS					
Screech owl		X	X		Maser (Notes and Obs.)
Great horned owl		X	X		Gashwiler (Notes and Obs.)
GOATSUCKERS					
Common nighthawk		X	X		Gashwiler (Notes and Obs.)

Table 1. Provisional wildlife use of different aged western juniper trees. (These data are based largely on the authors' interpretations of information taken from several sources.)(Continued)

Species	Young	Mature	Old and decadent	Stumps and downed logs	Source
BIRDS					
HUMMINGBIRDS					
Rufous hummingbird		X	X		Gashwiler (Notes and Obs.)
WOODPECKERS					
Common flicker			X	X	Gashwiler (Notes and Obs.)
Lewis' woodpecker			X		Bent (1964a), Gashwiler (Notes and Obs.)
Yellow-bellied sapsucker		X			Maser (Notes and Obs.)
TYRANT FLYCATCHERS					
Western kingbird					
Ash-throated flycatcher		X	X		Gabrielson and Jewett (1940), Gashwiler (Notes and Obs.)
Say's phoebe					
Dusky flycatcher		X	X		
Gray flycatcher		X	X		Gashwiler (Notes and Obs.)
SWALLOWS					
Barn swallow			X		Gashwiler (Notes and Obs.)
BIRDS					
Cliff swallow			X		Gashwiler (Notes and Obs.)
Tree swallow			X		Gashwiler (Notes and Obs.)
JAYS, MAGPIES, and CROWS					
Steller's jay		X	X		Gashwiler (Notes and Obs.)
Pinyon jay		X	X		Gashwiler (Notes and Obs.)
Black-billed magpie		X	X		Gashwiler (Notes and Obs.)
Clark's nutcracker		X	X		Gashwiler (Notes and Obs.)
Common raven		X	X		Gabrielson and Jewett (1940), Gashwiler (Notes and Obs.)
Common crow					
CHICKADEES and BUSHTITS					
Black-capped chickadee					
Mountain chickadee		X	X		Gashwiler (Notes and Obs.)
Bushtit	X	X			Gashwiler (Notes and Obs.), Maser (Notes and Obs.)

Table 1. Provisional wildlife use of different aged western juniper trees. (These data are based largely on the authors' interpretations of information taken from several sources.)(Continued)

Species	Young	Mature	Old and decadent	Stumps and downed logs	Source
BIRDS					
NUTHATCHES					
Red-breasted nuthatch		X	X		Gashwiler (Notes and Obs.)
Pygmy nuthatch		X	X		Gashwiler (Notes and Obs.)
CREEPERS					
Brown creeper					
WRENS					
Rock wren		X	X		Gashwiler (Notes and Obs.)
MOCKINGBIRDS and THRASHERS					
Sage thrasher	X	X	X		Gashwiler (Notes and Obs.)
THRUSHES, SOLITAIRES, and BLUEBIRDS					
American robin		X	X		Gashwiler (Notes and Obs.)
Townsend's solitaire		X	X		Gashwiler (Notes and Obs.)
Hermit thrush					
BIRDS					
Western bluebird		X	X		Gashwiler (Notes and Obs.), Maser (Notes and Obs.)
Mountain bluebird		X	X		Gashwiler (Notes and Obs.)
GNATCATCHERS and KINGLETS					
Ruby-crowned kinglet		X	X		Gashwiler (Notes and Obs.)
WAXWINGS					
Bohemian waxwing		X	X		Gashwiler (Notes and Obs.)
Cedar waxwing		X	X		Gashwiler (Notes and Obs.)
SHRIKES					
Northern shrike	X	X			Gashwiler (Notes and Obs.)
Loggerhead shrike	X	X			Gashwiler (Notes and Obs.)
STARLINGS					
Starling			X		Gashwiler (Notes and Obs.)
WOOD WARBLERS					
Orange-crowned warbler					

Table 1. Provisional wildlife use of different aged western juniper trees. (These data are based largely on the authors' interpretations of information taken from several sources.)(Continued)

Species	Young	Mature	Old and decadent	Stumps and downed logs	Source
BIRDS					
Yellow-rumped warbler		X	X		Gashwiler (Notes and Obs.)
Townsend's warbler		X	X		Gashwiler (Notes and Obs.)
Black-throated gray warbler		X	X		Gashwiler (Notes and Obs.)
Wilson's warbler		X			Gashwiler (Notes and Obs.)
BLACKBIRDS and ORIOLES					
Western meadowlark	X	X			Gashwiler (Notes and Obs.)
Brewer's blackbird		X			Gashwiler (Notes and Obs.) Maser (Notes and Obs.)
Red-winged blackbird					
Brown-headed cowbird		X	X		Gashwiler (Notes and Obs.)
Northern oriole		X			Gashwiler (Notes and Obs.)
TANAGERS					
Western tanager		X	X		Gashwiler (Notes and Obs.)
BIRDS					
GROSBEAKS, FINCHES, SPARROWS, and BUNTINGS					
Evening grosbeak		X	X		Gashwiler (Notes and Obs.)
Lazuli bunting					
Purple finch		X	X		Gashwiler (Notes and Obs.)
Cassin's finch		X	X		Gashwiler (Notes and Obs.)
House finch		X	X		Gashwiler (Notes and Obs.)
Green-tailed towhee	X	X			Gashwiler (Notes and Obs.)
Rufous-sided towhee					
Vesper sparrow					
Black-throated sparrow					
Lark sparrow					
Dark-eyed junco		X	X		Gashwiler (Notes and Obs.)
Chipping sparrow	X	X	X		Gashwiler (Notes and Obs.)

Table 1. Provisional wildlife use of different aged western juniper trees. (These data are based largely on the authors' interpretations of information taken from several sources.)(Continued)

Species	Young	Mature	Old and decadent	Stumps and downed logs	Source
BIRDS					
Brewer's sparrow	X	X			Gashwiler (Notes and Obs.)
White-crowned sparrow		X			Gashwiler (Notes and Obs.)
Lincoln's sparrow		X	X		Gashwiler (Notes and Obs.)
Song sparrow					
MAMMALS					
BATS					
Little brown myotis		X	X		Maser (Notes and Obs.)
Long-eared myotis		X	X		Bailey (1936), Maser (Notes and Obs.)
California myotis		X	X		Maser (Notes and Obs.)
Silver-haired bat		X	X		Hansen (1956), Maser (Notes and Obs.)
Big brown bat		X	X		Maser (Notes and Obs.)
Hoary bat		X	X		Bailey (1936)
RABBITS and HARES					
Mountain cottontail	X	X	X	X	Maser (Notes and Obs.)
MAMMALS					
Black-tailed jackrabbit	X	X	X	?	Maser (Notes and Obs.)
RODENTS					
Yellow pine chipmunk		X	X	X	Kindschy (1976), Maser (Notes and Obs.)
Townsend ground squirrel				X	Gashwiler (Notes and Obs.)
Mantled ground squirrel		X	X	X	Kindschy (1976), Maser (Notes and Obs.)
Deer mouse	X	X	X	X	Maser (Notes and Obs.)
Pinyon mouse		X	X	?	Baker and Frischknecht (1973), Gashwiler (Notes and Obs.)
Dusky-footed woodrat		X	X	X	Hammer and Maser (1973)
Bushy-tailed woodrat		X	X	X	Hammer and Maser (1973), Maser (Notes and Obs.)
Porcupine		X	X	?	Maser (Notes and Obs.)
CARNIVORES					
Coyote	X	X	X	?	Maser (Notes and Obs.), Shaver (1976)
Long-tailed weasel		X	X	X	Maser (Notes and Obs.)

Table 1. Provisional wildlife use of different aged western juniper trees. (These data are based largely on the authors' interpretations of information taken from several sources.)(Continued)

Species	Young	Mature	Old and decadent	Stumps and downed logs	Source
MAMMALS					
Spotted skunk		X	X	X	Maser (Notes and Obs.)
Bobcat		X	X	?	Maser (Notes and Obs.) Shaver (1976)
EVEN-TOED MAMMALS					
Elk	X	X			Leckenby (1976)
Mule deer	X	X	X		Leckenby and Adams (1976), Maser (Notes and Obs.)
Pronghorn	X	X	X		Leckenby (1976), Dealy (1977)
Subtotal Birds	8	58	56	1	
Subtotal Mammals	7	22	21	9	
Total	15	80	77	10	

diverstiy of sagebrush vs juniper communities in Oregon.

There is great variation within sagebrush communities (Adams 1975, Culver 1964, Dealy 1971, Eckert 1957, Hall 1967), but they all have shrubs as the structurally dominant plant (Fig. 2). Without the structural diversity of associated cliffs, rimrocks, talus, or water, only five "Life Forms" (Thomas et al. 1976) (Table 2) occupy these sagebrush communities: Life Form 5, 6, 7, 8, and 15. Within sagebrush communities, the presence of suitable cliffs, rimrocks, or talus, particularly when situated within 0.4 to 0.8 kilometer of water, adds Life Form 4.

Figure 2.--Big sagebrush habitat, Whitehorse Ranch Road, Malheur County, Oregon (photograph by C. Maser).

The western juniper community (Fig. 3) adds increased structure by the nature of the trees, individually and collectively. Presence of this community allows the addition of four more Life Forms: 11, 12, 13, and 14. Furthermore, the edge between the sagebrush and juniper communities creates additional diversity (Fig. 4).

Table 2. Description of vertebrate life forms occurring in the Blue Mountains (Thomas et al. 1976).

Life form number	Reproduces	Feeds
1	in water	in water
2	in water	on ground, in bushes and/or trees
3	on ground around water	in water, on ground, in bushes, and trees
4	in cliffs, caves, rims and/or talus	on ground or in air
5	on ground without specific water, cliff, rim, or talus association	on ground
6	on ground	in bushes, trees, or air
7	in bushes	on ground, in water or air
8	in bushes	in bushes, trees, or air
9	primarily in deciduous trees	in bushes, trees, or air
10	primarily in conifers	in bushes, trees, or air
11	in trees	on ground, in bushes, trees, or air
12	on very thick branches	on ground or in water
13	excavates own hole in a tree	on ground, in bushes, trees, or air
14	in a hole made by another species or naturally occurring	on ground, in water, or air
15	underground burrow	on or under ground
16	underground burrow	in water or air

Figure 3.--Western juniper habitat, Horse Ridge Research Natural Area, Deschutes County, Oregon (U.S. Fish and Wildlife Service photograph by J. S. Gashwiler).

Figure 4.--Ecotone between western juniper and big sagebrush communities, Horse Ridge Research Natural Area, Deschutes County, Oregon (photograph by C. Maser).

WILDLIFE USES OF WESTERN JUNIPER

Due to the large number of vertebrate animals (birds, Table 3, and mammals, Table 4) that utilize juniper, the following is a general discussion.

Birds

Importance of western juniper habitat: A recent 3-year study was conducted to compare bird populations among relatively undisturbed big sagebrush, western juniper, lodgepole pine, and ponderosa pine habitats in central Oregon (Gashwiler 1977). The investigations showed that during spring and summer western juniper habitat had the largest estimated number of territorial males for two years. Juniper and ponderosa

Table 3. Provisional use of juniper trees by birds.

Species	Courting	Nesting[1]: Ground--stumps, limbs, and logs	Nesting[1]: Trunk and limbs--natural and excavated holes	Nesting[1]: Behind loosened bark	Nesting[1]: On branches and/or in foliage	Feeding[2]: Ground-fallen berries	Feeding[2]: Trunk and limb excavations--insects and/or sap	Feeding[2]: Trunk, limbs, and foliage--gleaning	Feeding[2]: In tree--berries	Feeding[2]: Perching and lookout--often pursues prey	Feeding[2]: Dwarf mistletoe--gleaning and berries	Cover: Thermal	Cover: Hiding, roosting, and escape	Season of Use[3]: Summer	Season of Use[3]: Winter	Season of Use[3]: Year-long	Source
VULTURES																	
Turkey vulture										X				X			Anderson and Anderson (1971), Anderson et al. (1972), Gashwiler (Notes and Obs.)
HAWKS and EAGLES																	
Goshawk										X					X		Gabrielson and Jewett (1940), Gashwiler (Notes and Obs.)
Cooper's hawk										X					X		Gabrielson and Jewett (1940), Gashwiler (1977)
Sharp-shinned hawk										X						X	Anderson et al. (1972), Gashwiler (Notes and Obs.)
Marsh hawk														X			Anderson and Anderson (1971), Anderson et al. (1972), Gabrielson and Jewett (1940)
Ferruginous hawk					X											X	Bent (1961), Gabrielson and Jewett (1940), Gashwiler (Notes and Obs.)
Red-tailed hawk					X					X						X	Anderson and Anderson (1971), Gashwiler (Notes and Obs.), Jewett (1936), Maser (Notes and Obs.)
Swainson's hawk					X					X				X			Gabrielson and Jewett (1940), Gashwiler (Notes and Obs.), Jewett (1936)
Golden eagle										X						X	Anderson et al. (1972), Gabrielson and Jewett (1940), Gashwiler (Notes and Obs.)
FALCONS																	
Prairie falcon										X				X			Anderson and Anderson (1971), Gabrielson and Jewett (1940), Gashwiler (1977)
American kestrel			X							X				X			Anderson and Anderson (1971), Anderson et al. (1972), Gashwiler (Notes and Obs.) Maser (Notes and Obs.)
Merlin										X					X		Gabrielson and Jewett (1940), Gashwiler (Notes and Obs.)
GROUSE																	
Sage grouse														X			Anderson et al. (1972), Gashwiler (Notes and Obs.)

Table 3. (continued)

Species	Courting	Nesting [1]: Ground--stumps, limbs, and logs	Nesting [1]: Trunk and limbs--natural and excavated holes	Nesting [1]: Behind loosened bark	Nesting [1]: On branches and/or in foliage	Feeding [2]: Ground-fallen berries	Feeding [2]: Trunk and limb excavations--insects and/or sap	Feeding [2]: Trunk, limbs, and foliage--gleaning	Feeding [2]: In tree--berries	Feeding [2]: Perching and lookout--often pursues prey	Feeding [2]: Dwarf mistletoe--gleaning and berries	Cover: Thermal	Cover: Hiding, roosting, and escape	Season of Use [3]: Summer	Season of Use [3]: Winter	Season of Use [3]: Year-long	Source
QUAILS, PARTRIDGES, and PHEASANTS																	
California quail													X			X	Anderson and Anderson (1971), Anderson et al. (1972), Gabrielson and Jewett (1940), Gashwiler (Notes and Obs.)
Chukar																X	Anderson and Anderson (1971), Anderson et al. (1972), Pough (1957), Roest (1957)
PIGEONS and DOVES																	
Mourning dove	X				X									X			Anderson and Anderson (1971), Anderson et al. (1972), Gabrielson and Jewett (1940), Gashwiler (1977, Notes and Obs.)
OWLS																	
Screech owl			X							X						X	Gabrielson and Jewett (1940), Maser (Notes and Obs.)
Great horned owl					X					X			X			X	Anderson and Anderson (1971), Anderson et al. (1972), Gashwiler (1977, Notes and Obs.), Jewett (1936)

Table 3. (continued)

Species	Courting	Nesting[1]: Ground--stumps, limbs, and logs	Nesting[1]: Trunk and limbs--natural and excavated holes	Nesting[1]: Behind loosened bark	Nesting[1]: On branches and/or in foliage	Feeding[2]: Ground-fallen berries	Feeding[2]: Trunk and limb excavations--insects and/or sap	Feeding[2]: Trunk, limbs, and foliage--gleaning	Feeding[2]: In tree--berries	Feeding[2]: Perching and lookout--often pursues prey	Feeding[2]: Dwarf mistletoe--gleaning and berries	Cover: Thermal	Cover: Hiding, roosting, and escape	Season of Use[3]: Summer	Season of Use[3]: Winter	Season of Use[3]: Year-long	Source
GOATSUCKERS																	
Common nighthawk												X	X	X			Anderson and Anderson (1971), Anderson et al. (1972), Gashwiler (1977, Notes and Obs.)
HUMMINGBIRDS																	
Rufous hummingbird										X				X			Anderson et al. (1972), Gashwiler (Notes and Obs.)
WOODPECKERS																	
Common flicker	X		X				X									X	Anderson and Anderson (1971), Anderson et al. (1972), Gashwiler (1977, Notes and Obs.), Maser (Notes and Obs.)
Lewis' woodpecker			X			X								X			Anderson et al. (1972), Bent (1964a), Gabrielson and Jewett (1940), Gashwiler (Notes and Obs.)
Yellow-bellied sapsucker							X							X			Gabrielson and Jewett (1940), Maser (Notes and Obs.)
TYRANT FLYCATCHERS																	
Western kingbird					X					X				X			Anderson and Anderson (1971), Anderson et al. (1972), Bent (1963a), Maser (Notes and Obs.)
Ash-throated flycatcher			X							X				X			Anderson and Anderson (1971), Anderson et al. (1972), Gabrielson and Jewett (1940), Gashwiler (Notes and Obs.), Maser (Notes and Obs.)
Say's phoebe														X			Anderson and Anderson (1971), Anderson et al. (1972), Gabrielson and Jewett (1940)
Dusky flycatcher										X				X			Anderson and Anderson (1971), Anderson et al. (1972), Bent (1963a), Gabrielson and Jewett (1940)
Gray flycatcher	X				X					X			X	X			Anderson et al. (1972), Bertrand and Scott (1971), Gashwiler (1977, Notes and Obs.), Hansen (1956)

Table 3. (continued)

Species	Courting	Nesting[1]: Ground--stumps, limbs, and logs	Nesting[1]: Trunk and limbs--natural and excavated holes	Nesting[1]: Behind loosened bark	Nesting[1]: On Branches and/or in foliage	Feeding[2]: Ground-fallen berries	Feeding[2]: Trunk and limb excavations--insects and/or sap	Feeding[2]: Trunk, limbs, and foliage--gleaning	Feeding[2]: In tree--berries	Feeding[2]: Perching and lookout--often pursues prey	Feeding[2]: Dwarf mistletoe--gleaning and berries	Cover: Thermal	Cover: Hiding, roosting, and escape	Season of Use[3]: Summer	Season of Use[3]: Winter	Season of Use[3]: Year-long	Source
SWALLOWS																	
Barn swallow														X			Anderson and Anderson (1971), Gabrielson and Jewett (1940), Gashwiler (Notes and Obs.)
Cliff swallow														X			Anderson et al. (1972), Gabrielson and Jewett (1940), Gashwiler (Notes and Obs.)
Tree swallow														X			Gabrielson and Jewett (1940), Gashwiler (Notes and Obs.)
JAYS, MAGPIES, and CROWS																	
Steller's jay	X							X	X				X			X	Gabrielson and Jewett (1940), Gashwiler (Notes and Obs.)
Pinyon jay	X				X	X			X				X			X	Gabrielson and Jewett (1940), Gashwiler (1977, Notes and Obs.)
Black-billed magpie					X			X					X			X	Anderson and Anderson (1971), Anderson et al. (1972), Gashwiler (Notes and Obs.), Maser (Notes and Obs.)
Clark's nutcracker	X				X	X			X							X	Gabrielson and Jewett (1940), Gashwiler (1977, Notes and Obs.), Martin et al. (1961)
Common raven					X					X						X	Anderson and Anderson (1971), Anderson et al. (1972), Gashwiler (Notes and Obs.), Jewett (1936)
Common crow															X		Bent (1964c, part 2), Gabrielson and Jewett (1940), Gashwiler (1977)
CHICKADEES																	
Black-capped chickadee														X			Gabrielson and Jewett (1940), Gashwiler (1977, Notes and Obs.)
Mountain chickadee			X					X					X			X	Anderson and Anderson (1971), Anderson et al. (1972), Bent (1964c, part 2), Gashwiler (1977, Notes and Obs.), Maser (Notes and Obs.)
VERDIN and BUSHTITS																	
Bushtit								X								X	Anderson and Anderson (1971), Anderson et al. (1972), Gashwiler (Notes and Obs.), Maser (Notes and Obs.)

Table 3. (continued)

	Nesting [1]					Feeding [2]						Cover		Season of Use [3]			
Species	Courting	Ground--stumps, limbs, and logs	Trunk and limbs--natural and excavated holes	Behind loosened bark	On branches and/or in foliage	Ground-fallen berries	Trunk and limb excavations--insects and/or sap	Trunk, limbs, and foliage--gleaning	In tree--berries	Perching and lookout--often pursues prey	Dwarf mistletoe--gleaning and berries	Thermal	Hiding, roosting, and escape	Summer	Winter	Year-long	Source
NUTHATCHES																	
Red-breasted nuthatch								X					X			X	Gabrielson and Jewett (1940), Gashwiler (1977, Notes and Obs.)
Pygmy nuthatch	X							X					X			X	Gabrielson and Jewett (1940), Gashwiler (Notes and Obs.)
CREEPERS																	
Brown creeper								X						X			Gabrielson and Jewett (1940), Gashwiler (1977, Notes and Obs.)
WRENS																	
Rock wren										X				X			Anderson and Anderson (1971), Anderson et al. (1972), Gashwiler (Notes and Obs.)
MOCKINGBIRDS and THRASHERS																	
Sage thrasher	X									X				X			Bent (1964b), Gashwiler (1977, Notes and Obs.)
THRUSHES, SOLITAIRES, and BLUEBIRDS																	
American robin	X				X	X			X		X	X	X			X	Anderson and Anderson (1971), Anderson et al. (1972), Gabrielson and Jewett (1940), Gashwiller (1977, Notes and Obs.), Maser (Notes and Obs.)
Townsend's solitaire	X					X			X	X		X	X			X	Gabrielson and Jewett (1940), Gashwiler (1977, Notes and Obs.), Maser (Notes and Obs.)
Hermit thrush														X			Anderson et al. (1972), Gashwiler (1977, Notes and Obs.)
Western bluebird	X		X						X		X		X			X	Gabrielson and Jewett (1940), Gashwiler (Notes and Obs.), Maser (Notes and Obs.)
Mountain bluebird	X		X						X	X	X		X			X	Bertrand and Scott (1971), Gashwiler (1977, Notes and Obs.), Maser (Notes and Obs.)

Table 3. (continued)

Species		Nesting[1]				Feeding[2]						Cover		Season of Use[3]			Source
	Courting	Ground--stumps, limbs, and logs	Trunk and limbs--natural and excavated holes	Behind loosened bark	On branches and/or in foliage	Ground-fallen berries	Trunk and limb excavations--insects and/or sap	Trunk, limbs, and foliage--gleaning	In tree--berries	Perching and lookout--often pursues prey	Dwarf mistletoe--gleaning and berries	Thermal	Hiding, roosting, and escape	Summer	Winter	Year-long	
GNATCATCHERS and KINGLETS																	
Ruby-crowned kinglet								X					X	X			Anderson and Anderson (1971), Anderson et al. (1972), Gabrielson and Jewett (1940), Gashwiler (Notes and Obs.)
WAXWINGS																	
Bohemian waxwing									X		X		X		X		Bertrand and Scott (1971), Gashwiler (1977, Notes and Obs.)
Cedar waxwing	X								X		X		X			X	Anderson and Anderson (1971), Anderson et al. (1972), Gabrielson and Jewett (1940), Gashwiler (1977, Notes and Obs.)
SHRIKES																	
Northern shrike	X									X						X	Bertrand and Scott (1971), Gabrielson and Jewett (1940), Gashwiler (1977, Notes and Obs.)
Loggerhead shrike	X				X					X				X			Anderson and Anderson (1971), Anderson et al. (1972), Gabrielson and Jewett (1940), Gashwiler (Notes and Obs.)
STARLINGS																	
Starling									X							X	Gashwiler (Notes and Obs.)
WOOD WARBLERS																	
Orange-crowned warbler														X			Anderson and Anderson (1971), Gabrielson and Jewett (1940)
Yellow-rumped warbler								X					X	X			Anderson et al. (1972), Gabrielson and Jewett (1940), Gashwiler (1977, Notes and Obs.)
Townsend's warbler								X					X	X			Anderson and Anderson (1971), Anderson et al. (1972), Gabrielson and Jewett (1940), Gashwiler (1977, Notes and Obs.)
Black-throated gray warbler	X							X					X	X			Bent (1963b, part 1), Gabrielson and Jewett (1940), Gashwiler (1977, Notes and Obs.)

Table 3. (continued)

Species		Nesting [1]				Feeding [2]						Cover		Season of Use [3]			Source
	Courting	Ground--stumps, limbs, and logs	Trunk and limbs--natural and excavated holes	Behind loosened bark	On branches and/or in foliage	Ground-fallen berries	Trunk and limb excavations--insects and/or sap	Trunk, limbs, and foliage--gleaning	In tree--berries	Perching and lookout--often pursues prey	Dwarf mistletoe--gleaning and berries	Thermal	Hiding, roosting, and escape	Summer	Winter	Year-long	
Wilson's warbler								X					X	X			Anderson and Anderson (1971), Anderson et al. (1972), Gashwiler (1977, Notes and Obs.)
BLACKBIRDS and ORIOLES																	
Western meadowlark	X												X			X	Anderson and Anderson (1971), Anderson et al. (1972), Gabrielson and Jewett (1940), Gashwiler (Notes and Obs.)
Brewer's blackbird	X				X				X				X	X			Anderson and Anderson (1971), Anderson et al. (1972), Gashwiler (1977), Notes and Obs.), Maser (Notes and Obs.)
Red-winged blackbird														X			Anderson et al. (1971)
Brown-headed cowbird	X												X	X			Anderson and Anderson (1971), Anderson et al. (1972), Gashwiler (1977, Notes and Obs.)
Northern oriole	X											X		X			Anderson and Anderson (1971), Anderson et al. (1972), Gashwiler (1977, Notes and Obs.), Maser (Notes and Obs.)
TANAGERS																	
Western tanager					X								X	X			Anderson and Anderson (1971), Gashwiler (Notes and Obs.), Maser (Notes and Obs.)
GROSBEAKS, FINCHES, SPARROWS, and BUNTINGS																	
Evening grosbeak						X			X				X		X		Bent (1968a, part 1), Gashwiler (1977, Notes and Obs.), Martin et al. (1961), Maser (Notes and Obs.)
Lazuli bunting	X													X			Anderson and Anderson (1971), Anderson et al. (1972), Gabrielson and Jewett (1940)
Purple finch	X				X					X			X	X			Gabrielson and Jewett (1940), Gashwiler (Notes and Obs.), Hansen (1956)
Cassin's finch	X				X					X			X			X	Gabrielson and Jewett (1940), Gashwiler (1977, Notes and Obs.)
House finch	X				X			X				X	X			X	Anderson and Anderson (1971), Anderson et al. (1972), Gashwiler (1977, Notes and Obs.), Maser (Notes and Obs.)

Table 3. (continued)

Species	Courting	Nesting [1]: Ground--stumps, limbs, and logs	Nesting [1]: Trunk and limbs--natural and excavated holes	Nesting [1]: Behind loosened bark	Nesting [1]: On branches and/or in foliage	Feeding [2]: Ground-fallen berries	Feeding [2]: Trunk and limb excavations--insects and/or sap	Feeding [2]: Trunk, limbs, and foliage--gleaning	Feeding [2]: In tree--berries	Feeding [2]: Perching and lookout--often pursues prey	Feeding [2]: Dwarf mistletoe--gleaning and berries	Cover: Thermal	Cover: Hiding, roosting, and escape	Season of Use [3]: Summer	Season of Use [3]: Winter	Season of Use [3]: Year-long	Source
Green-tailed towhee	X									X				X			Anderson and Anderson (1971), Bertrand and Scott (1971), Gashwiler (1977, Notes and Obs.)
Rufous-sided towhee													X	X			Anderson and Anderson (1971), Anderson et al. (1972), Gashwiler (Notes and Obs.)
Vesper sparrow														X			Bent (1968b, part 2), Gashwiler (Notes and Obs.)
Black-throated sparrow														X			Bertrand and Scott (1971)
Lark sparrow														X			Anderson and Anderson (1971), Anderson et al. (1972), Bertrand and Scott (1971), Gabrielson and Jewett (1940)
Dark-eyed junco	X							X		X		X	X			X	Anderson and Anderson (1971), Anderson et al. (1972), Gashwiler (1977, Notes and Obs.), Maser (Notes and Obs.)
Chipping sparrow	X				X					X			X	X			Anderson and Anderson (1971), Anderson et al. (1972), Bent (1968b, part 2), Gashwiler (1977, Notes and Obs.)
Brewer's sparrow	X												X	X			Anderson and Anderson (1971), Anderson et al. (1972), Gashwiler (1977, Notes and Obs.)
White-crowned sparrow	X												X	X			Anderson and Anderson (1971), Anderson et al. (1972), Gashwiler (1977, Notes and Obs.)
Lincoln's sparrow														X			Gashwiler (Notes and Obs.)
Song sparrow														X			Gabrielson and Jewett (1940), Gashwiler (Notes and Obs.), Martin et al. (1961)
Total - 83	29		8		19	6	2	14	12	29	5	6	34	48	6	29	

1 Discussion in text is based upon data for 27 species.

2 Discussion in text is based upon data for 54 species.

Table 4. Provisional use of juniper trees by mammals.

Species	Reproduction: Ground--stumps and logs	Reproduction: In hollow trunks and limbs	Reproduction: In cavities excavated by birds	Reproduction: On limbs and in foliage	Feeding: Ground--fallen berries	Feeding: Trunks and limbs--gleaning	Feeding: Foliage--eaten	Feeding: In tree--berries	Cover Tree: Thermal	Cover Tree: Hiding	Cover Logs: Thermal	Cover Logs: Hiding	Observ. Post: Logs and stumps	Observ. Post: Trees	Season of Use: Summer	Season of Use: Winter	Season of Use: Year-long	Source
BATS																		
Little brown myotis		X	X						X	X					X	?		Maser (Notes and Obs.)
California myotis		X	X						X	X					X	?		Maser (Notes and Obs.)
Big-eared myotis		X	X						X	X					X	?		Maser (Notes and Obs.)
Silver-haired bat		X	X						X	X					X	?		Maser (Notes and Obs.)
Big brown bat		X	X						X	X					X	?		Maser (Notes and Obs.)
Hoary bat [1]				?					X	X					X			Bailey (1936)
RABBITS and HARES																		
Mountain cottontail	X						X		X	X	X	X					X	Maser (Notes and Obs.)
Black-tailed jackrabbit							X		X	X							X	Orr (1940)
RODENTS																		
Mantled ground squirrel [2]	X				X						X	X	X		X			Kindschy (1976), Maser (Notes and Obs.)

Table 4. (continued)

Species	Reproduction: Ground--stumps and logs	Reproduction: In hollow trunks and limbs	Reproduction: In cavities excavated by birds	Reproduction: On limbs and in foliage	Feeding: Ground--fallen berries	Feeding: Trunks and limbs--gleaning	Feeding: Foliage--eaten	Feeding: In tree--berries	Cover Tree: Thermal	Cover Tree: Hiding	Cover Logs: Thermal	Cover Logs: Hiding	Observ. Post: Logs and stumps	Observ. Post: Trees	Season of Use: Summer	Season of Use: Winter	Season of Use: Year-long	Source
Townsend ground squirrel [2]												X	X		X			Gashwiler (Notes and Obs.)
Yellow pine chipmunk [2]	X	X	X		X	X		X	X	X	X	X	X	X	X			Johnson (1943), Kindschy (1976), Maser (Notes and Obs.)
Deer mouse	X	X	X		X			X	X	X	X	X					X	Maser (Notes and Obs.)
Pinyon mouse [3]	?	?	?						?	?	?	?					?	Baker and Frischknecht (1973), Gashwiler (Notes and Obs.)
Dusky-footed woodrat	X	X	X	X			X		X	X	X	X					X	Hammer and Maser (1973)
Bushy-tailed woodrat	X	X	X				X		X	X	X	X					X	Hammer and Maser (1973), Maser (Notes and Obs.)
Porcupine		?					X			X							X	Gashwiler (Notes and Obs.)
CARNIVORES																		
Coyote					X				X								X	Hammer (1973), Maser (Notes and Obs.), Shaver (1976)
Long-tailed weasel	X	X	X								X	X					X	Maser (Notes and Obs.)
Spotted skunk	X										X	X					X	Maser (Notes and Obs.)
Bobcat									X	?							X	Maser (Notes and Obs.)
EVEN-TOED HOOFED MAMMALS																		
Elk							X									X		Leckenby (1976)
Mule deer [4]							X		X	X		X				X	X	Dixon (1934), Leckenby and Adams (1976), Sounder and Mowat (1958)
Pronghorn									X	X								Leckenby (1976), Dealy (1977)
Total - 23	8	10	10	1	4	1	7	2	16	15	8	10	3	1	9	2	11	

1 Probably during migration only.
2 These squirrels are listed as active above ground only during the summer but are in fact year-long residents, hibernating underground during the winter.
3 Although these mice were caught in the juniper in the Horse Ridge Research Natural Area near Bend, Deschutes Co., we do not know how they use the juniper.
4 Some deer are resident in the juniper community, but most utilized it as winter range.

pine habitats were dominant on the third year. Western juniper habitat also had the greatest number of territorial species each year. Winter censusing indicated that juniper had the greatest population for two years and was second in the third year. The value of the western juniper habitat for wintering birds was also noted by Gabrielson and Jewett (1940). They wrote: "In good berry years in the extensive juniper forests near Redmond [Oregon], the robins gather in great winter roosts that in the evening look like huge swarms of bees as the birds swirl over the treetops in the twilight before settling down for the night. It is one of the real winter bird sights of eastern Oregon, and it is worth a trip to that section to watch the great numbers of birds entering and leaving the roost. In February or early March, these roosts begin to break up as the arrival of birds from farther south swell the robin population."

Number of species in the western juniper habitat: The provisional list of birds includes 83 species (Table 3). Of these, 48 are summer residents, 6 are winter residents, and 29 were year-long residents (Table 3). The list includes only those birds definitely identified with the western juniper habitat, but some of these birds, like the marsh hawk, are no doubt visitors. As more data become available, this preliminary list will probably change.

Courting: Juniper trees served as perching and singing sites for territory establishment and maintenance, courtship, and mating. The spike tops also function as a fine drumming site for the common flicker. Some of the birds, such as the mountain bluebird, spend hours in the top of a juniper keeping a close lookout over its mate as she lays eggs, incubates, and broods the young.

Nesting: Structurally western juniper appears to be an ideal tree for bird nesting (see Table 3). It has dense foliage, horizontal forks, and many little tufts of twigs on horizontal or slightly angled limbs (Fig. 5). Old decadent junipers are often hollow and supply natural cavities suitable for nesting and roosting. Natural holes also develop at limb sites. In addition, entrance holes to cavities and entire cavities are constructed by flickers. These nest-sites are later used by secondary cavity nesters such as the mountain bluebird, mountain chickadee, and others. There always seems to be more cavity nesters in forests than suitable sites (Jackman 1974); in western juniper many birds settle for marginal sites thereby increasing mortality. Juniper furnishes a variety of nest materials. The finer twigs and coarse bark are used in the outer part and finely shredded inner bark is utilized to make a smooth, soft lining for nest cups.

Nesting sites have been identified and documented, but references to trees in general; specific references to western juniper are sparse. Twenty-seven bird species are known to nest in western juniper: 30% in natural and excavated cavities and 70% in open nests on branches

Figure 5.--Mourning dove, Cabin Lake, Lake County, Oregon. The structure of western juniper trees is well suited to nesting by mourning doves. Horizontal limbs and forks afford good sites for their loosely constructed nests (U.S. Fish and Wildlife Service photograph by J. S. Gashwiler).

and/or in foliage. This is 10% fewer cavity nesters than was reported by Jackman (1974) for other coniferous forest habitats.

Feeding: Western juniper trees appear to be populated by many species of insects. Insect production is one of the habitat's important contributions to the bird community because of the positive correlation between food availability and time of nesting (Davis 1933). Insects provide food for nestlings and adults. Succulent spring and early summer larvae provide moisture; this source of moisture may account for the presence of robins in some of the arid juniper habitats. Adult and larval insects are harvested by birds gleaning (searching) the trunk, limbs, and foliage. Twenty-six percent of the 54 species found in the feeding portion of Table 3 are considered to be gleaners. On the other hand, 4% of the 54 species feed by excavating trunks and limbs for insect larvae and sap (Table 3, Fig. 6).

Figure 6.--Sapsucker holes in western juniper, Horse Ridge Research Natural Area, Deschutes County, Oregon (photograph by C. Maser).

Juniper berries are an important source of food for wintering birds (Martin et al. 1961). Thirty-two percent of the 54 species in the feeding portion of Table 3 feed on western juniper berries. Birds eat berries off of the tree and also harvest ripe ones which have fallen to the ground. The hard nutlet(s) within the berries often pass unharmed through the birds alimentary tracts and are distributed widely.

Birds use western juniper trees as lookout stations for hunting and for protection. Some birds, such as the flycatchers, have developed this aerial method (perching--swooping) of feeding to a high state of perfection. Many birds, especially the raptors, have favorite perching trees, generally where they have a wide overlook, and can be observed frequently using the same perch. Fifty-five percent of the 54 species in the "feeding" portion of Table 3 are in the perching and lookout category.

Juniper dwarf mistletoe, indigenous to western juniper, produces a small pearl-like berry eaten by waxwings, robins, and other species in fall and winter. Birds may also glean insects from mistletoe clumps. Nine percent of the 54 species obtain food from mistletoe (Table 3).

Cover: Western juniper habitat is influenced by the presence of the trees in that they dampen wind velocity. Wind velocity in juniper habitat is often sufficiently abated so that birds will remain active when nearby sagebrush areas exhibit reduced bird activity. This is especially important in winter when the day length is short, energy requirements are high, and birds need to forage steadily to survive. The decreased wind velocity also lowers the chill factor thus decreasing the birds' food requirements. The interior of tree crowns also provides important thermal cover during hot summer days.

Mammals

Reproduction: Of the 23 species of Oregon mammals that utilize western juniper, only 7 depend upon it as sites for rearing young--5 species of bats and 2 species of woodrats (Table 4). The bats, with the possible exception of the silver-haired bat, are known to form nursery colonies in hollow trees (Barbour and Davis 1969). Although silver-haired bats probably roost singly, they may also bring forth their young in hollow trunks and limbs. (Albeit there are no data available for Oregon bats, there is a strong possibility that some of the species listed in Table 4 may also hibernate in hollow junipers.) Bushy-tailed and dusky-footed woodrats nest and rear their young in hollow juniper trees and hollow logs (Figs. 7 & 8). In the absence of suitable cliffs, rimrocks, or talus, bushy-tailed woodrats are dependent upon hollow juniper trees and/or logs as nesting sites, but dusky-footed woodrats also construct sturdy nests of sticks on juniper limbs (Fig. 9). Where the two species occur together, the dusky-foots out-compete the bushy-tails for nesting sites in juniper (Hammer and Maser 1973).

Feeding: Woodrats are dependent upon juniper foliage as food (Fig. 10). In fact, dusky-footed woodrats in south-central Oregon (Klamath and Lake Counties) are predominantly dependent upon juniper foliage as food. They occasionally cut all the foliage off of a tree, killing it (Hammer and Maser 1973). Porcupines also use juniper twigs and foliage for food, especially in winter. Mountain cottontails and black-tailed jackrabbits feed on juniper foliage to some extent as do mule deer and elk (Table 4).

Deer mice and coyotes eat juniper berries during the fall and winter. Juniper seeds opened by deer mice (Fig. 11) can be found wherever there is a berry crop and coyote droppings composed solely of juniper berries are frequently encountered. Yellow pine chipmunks and mantled ground

Figure 7.--Nest of a bushy-tailed woodrat in a hollow, decadent western juniper, 9.6 kilometers south of Prineville, Crook County, Oregon. Note sticks and food-twig at entrance to nest cavity (photograph by C. Maser).

Figure 8.--Hollow western juniper log inhabited by a bushy-tailed woodrat, 9.6 kilometers south of Prineville, Crook County, Oregon (photograph by C. Maser).

Figure 9.--Nest of a dusky-footed woodrat in a western juniper tree, 2.4 kilometers southwest of Bonanza, Klamath County, Oregon (photograph by C. Maser).

Figure 10.--Twigs of western juniper cut and stored by a bushy-tailed woodrat, Connley Caves, Lake County, Oregon (photograph by C. Maser).

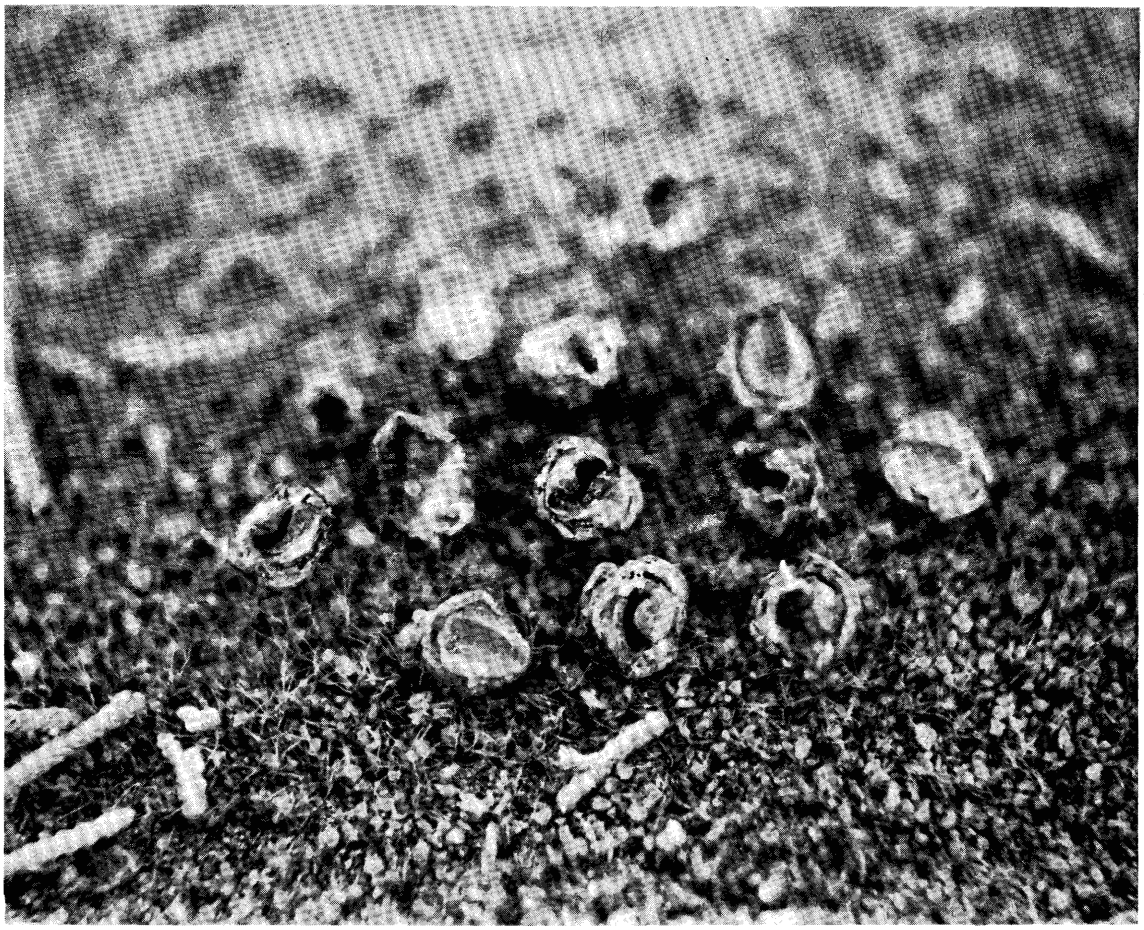

Figure 11.--Nutlets of western juniper opened by deer mice, Connley Caves, Lake County, Oregon (photograph by C. Maser).

squirrels also consume juniper berries (Kindschy 1976).

Cover: Junipers, with full-length crowns, provide critical hiding and thermal cover protection for non-climbing animals. Hollow trees and hollow logs are important resting places for several species, especially bats and woodrats. In this instance, the emphasis is on hiding cover which provides security.

Shade during hot weather is important to diurnal species. Shade from trunks, crowns, and downed material is also used. During winter months, on the other hand, large, full-crowned junipers often keep the ground beneath their crowns snow-free by snow interception, and reduce heat reradiation from the ground and animals to the sky. Such areas are utilized by deer, coyotes, bobcats, and other animals as places to sun themselves, helping to conserve vital energy required to maintain body heat during inclement weather.

ENHANCEMENT OF JUNIPER COMMUNITIES FOR WILDLIFE

In spite of our meager knowledge of the juniper communities as a whole, there are several ways in which they can be enhanced as wildlife habitat; these are discussed in general terms.

Water

Since many, or most, juniper areas are situated away from a source of free water, the establishment of water impoundments would benefit wildlife. Although permanent water would probably be the most beneficial, a supply of water during the reproductive season would add substantially to the potential importance of an area.

Careful location of water impoundments is important for maximum utilization by wildlife. The areas which receive the heaviest animal use are mature and decadent stands of juniper, cliffs within 0.4 to 0.8 kilometers of permanent water, and along ecotones between plant communities (Maser et al. 1978, Thomas et al. 1978a, Thomas et al. 1978b).

The design of a water impoundment determines which species of animal can use it; proper designing, therefore, is essential. If a trough is too high, small animals cannot reach the water. Round troughs and guzzlers do not offer enough surface area for bats, swallows, and nighthawks--which drink on the wing. Deep troughs without ramps or piles of rocks within are not safe for birds or small mammals.

Bird boxes

Since the density of cavity nesters is limited by the number of available cavities (Jackman 1974), the placement of nesting boxes in the western juniper habitat would seem to be a good method of supplementing the natural and excavated cavities for nesting and roosting, thus increasing the potential bird population, particularly in younger juniper stands.

Boxes placed in the proximity of water would probably be most productive.

Development of openings

When openings (chainings, cuttings, burnings, etc.) are created in a juniper community, the following should be considered: (1) Openings should be irregular in shape to maximize the edge effect. (2) Juniper trees should be left in stringers to form travel lanes and in islands to create habitat diversity. (3) Trees being used by cavity nesters, hollow trees and logs, should be protected and left for hiding cover and reproductive habitat whenever possible. (4) Debris piles should be of a size, shape, depth, and placement which allows maximum use by wildlife. (5) A diversity of food and cover, such as forbs, grasses, and shrubs, should be seeded within an opening or within the juniper community where such plants are lacking. (6) Perching and lookout trees should be left at strategic places for the use of hawks, owls, flycatchers, and other species (see Table 3).

RESEARCH NEEDS

There is much to be learned about the interrelationships of wildlife and juniper in Oregon. (1) Resident and transient wildlife in juniper communities need to be inventoried. (2) Wildlife use of trees individually and of communities as a whole needs to be determined. (3) Along with basic wildlife inventories, we need to know how and why wildlife respond to different, undisturbed western juniper communities (*sensu stricto*) so that we may know how to interpret cause and effect relationships and predict these with respect to habitat manipulation. (4) Effects of manipulation of juniper communities on wildlife need to be specifically studied. The first three research needs are self-explanatory, but the fourth (effects of manipulation) requires clarification.

Type of manipulation

Fire: Some studies of the effects of fire on wildlife have been conducted (Chew et al. 1959, Cook 1959, Eastman 1976, Howard et al. 1959, McCulloch 1969, and others), but we found nothing specific to western juniper communities in Oregon. There is, however, a metalic wood-boring beetle (*Melenophila miranda* LeC., Buprestidae) that is so adapted to fire in juniper that females normally lay their eggs on trees that have been just burned. As a tree cools, the female lays eggs near the ground in the wood which sometimes is so hot that her feet are burned off (Beer 1976). Such a relationship points to a long history of fire within the juniper community and to the naturalness of fire as a management tool.

Chaining: Baker and Frischknecht (1973) studied the effect of chaining on small mammals in juniper rangeland in Utah, but little or nothing has been done in Oregon.

Cutting: Although we found no data on the effects of felling juniper vs chaining, one of us (CM) has looked at cuttings and found them to have excellent potential for creating diversity of wildlife habitats.

Size of manipulation

We need to examine different sizes of openings--cuttings, chainings, and burns--to determine the minimum and the maximum sizes needed to accommodate various types of wildlife and their uses of the areas.

Debris piles

Size, depth, shape, and placement of debris piles should be studied to determine which type allows maximum use by wildlife over time.

Cost-benefit analysis of juniper manipulation

There have been some studies of the multiple-use benefits of pinyon-juniper management, e.g., Clary (1975) in Arizona and Jensen (1972) in Nevada. However, while we need to address ourselves to the multiple-use benefits of juniper management, we also have to consider the cost-benefits of such management, including non-game wildlife.

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Appendix 1. Common and scientific names of plants and animals referred to in text.

Family	Common Name	Scientific Name
PLANTS [1]		
Juniper (Cupressaceae)	Western juniper	*Juniperus occidentalis*
Pines (Pinaceae)	Lodgepole pine Ponderosa pine	*Pinus contorta* *Pinus ponderosa*
Mistletoe (Loranthaceae)	Juniper dwarf mistletoe	*Phoradendron juniperinum*
Sagebrush (Compositae)	Big sagebrush	*Artemisia tridentata*
BIRDS [2]		
Vultures (Cathartidae)	Turkey vulture	*Cathartes aura*
Hawks and eagles (Accipitridae)	Goshawk Cooper's hawk Sharp-shinned hawk Marsh hawk Ferruginous hawk Red-tailed hawk Swainson's hawk Golden eagle	*Accipiter gentilis* *Accipiter cooperii* *Accipiter striatus* *Circus cyaneus* *Buteo regalis* *Buteo jamaicensis* *Buteo swainsoni* *Aquila chrysaetos*
Falcons (Falconidae)	Prairie falcon Merlin American kestrel	*Falco mexicanus* *Falco columbarius* *Falco sparverius*

Grouse (Tetraonidae)	Sage grouse	Centrocercus urophasianu
Quail, partridges, and pheasants (Phasianidae)	California quail Chukar	Lophortyx californicus Alectoris chukar
Pigeons and doves (Columbidae)	Mourning dove	Zenaida macroura
Owls (Tytonidae)	Screech owl Great horned owl	Otus asio Bubo virginianus
Goatsuckers (Caprimulgidae)	Common nighthawk	Chordeiles minor
Hummingbirds (Trochilidae)	Rufous hummingbird	Selasphorus rufus
Woodpeckers (Picidae)	Common flicker Lewis' woodpecker Yellow-bellied sapsucker	Colaptes auratus Asyndesmus lewis Sphyrapicus varius
Tyrant flycatchers (Tyrannidae)	Western kingbird Ash-throated flycatcher Say's phoebe Dusky flycatcher Gray flycatcher	Tyrannus verticalis Myiarchus cinerascens Sayornis saya Empidonax oberholseri Empidonax wrightii
Swallows (Hirundinidae)	Barn swallow Cliff swallow Tree swallow	Hirundo rustica Petrochelidon pyrrhonota Iridoprocne bicolor
Jays, magpies, and crows (Corvidae)	Steller's jay Pinyon jay Black-billed magpie Clark's nutcracker Common raven	Cyanocitta stelleri Gymnorhinus cyanocephalus Pica pica Nucifraga columbiana Corvus corax

	Common crow	Corvus brachyrhynchos
Chickadees and bushtits (Paridae)	Black-capped chickadee Mountain chickadee Bushtit	Parus atricapillus Parus gambeli Psaltriparus minimus
Nuthatches (Sittidae)	Red-breasted nuthatch Pygmy nuthatch	Sitta canadensis Sitta pygmaea
Creepers (Certhiidae)	Brown creeper	Certhia familiaris
Wrens (Troglodytidae)	Rock wren	Salpinctes obsoletus
Mockingbirds and thrashers (Mimidae)	Sage thrasher	Oreoscoptes montanus
Thrushes, solitaires, and bluebirds (Turdidae)	American robin Townsend's solitaire Hermit thrush Western bluebird Mountain bluebird	Turdus migratorius Myadestes townsendi Catharus guttatus Sialia mexicana Sialia currucoides
Gnatcatchers and kinglets (Sylviidae)	Ruby-crowned kinglet	Regulus calendula
Waxwings (Bombycillidae)	Bohemian waxwing Cedar waxwing	Bombycilla garrulus Bombycilla cedrorum
Shrikes (Laniidae)	Northern shrike Loggerhead shrike	Lanius excubitor Lanius ludovicianus
Starlings (Sturnidae)	Starling	Sturnus vulgaris

Wood warblers (Parulidae)	Orange-crowned warbler Yellow-rumped warbler Townsend's warbler Black-throated gray warbler Wilson's warbler	*Vermivora celata* *Dendroica coronata* *Dendroica townsendi* *Dendroica nigrescens* *Wilsonia pusilla*
Blackbirds and orioles (Icteridae)	Western meadowlark Red-winged blackbird Brewer's blackbird Brown-headed cowbird Northern oriole	*Sturnella neglecta* *Agelaius phoeniceus* *Euphagus cyanocephalus* *Molothrus ater* *Icterus galbula*
Tanagers (Thraupidae)	Western tanager	*Piranga ludoviciana*
Grosbeaks, finches, sparrows, and buntings (Fringillidae)	Evening grosbeak Lazuli bunting Purple finch Cassin's finch House finch Green-tailed towhee Rufous-sided towhee Vesper sparrow Lark sparrow Black-throated sparrow Dark-eyed junco Chipping sparrow Brewer's sparrow White-crowned sparrow Lincoln's sparrow Song sparrow	*Hesperiphona vespertina* *Passerina amoena* *Carpodacus purpureus* *Carpodacus cassinii* *Carpodacus mexicanus* *Chlorura chlorura* *Pipilo erythrophthalmus* *Pooecetes gramineus* *Chondestes grammacus* *Amphispiza bilineata* *Junco hyemalis* *Spizella passerina* *Spizella breweri* *Zonotrichia leucophrys* *Melospiza lincolnii* *Melospiza melodia*
MAMMALS [3]		
Bats (Vesperlilionidae)	Little brown myotis	*Myotis lucifugus*

	Long-eared myotis California myotis Silver-haired bat Big brown bat Hoary bat	Myotis evotis Myotis californicus Lasionycteris noctivagans Eptesicus fuscus Lasiurus cinereus
Rabbits and hares (Leporidae)	Mountain cottontail Black-tailed jackrabbit	Sylvilagus nuttalli Lepus californicus
Chipmunks and ground squirrels (Sciuridae)	Yellow pine chipmunk Townsend ground squirrel Mantled ground squirrel	Eutamias amoenus Spermophilus townsendi Spermophilus lateralis
Native mice and rats (Cricetidae)	Deer mouse Pinyon mouse Dusky-footed woodrat Bushy-tailed woodrat	Peromyscus maniculatus Peromyscus truei Neotoma fucipes Neotoma cinerea
New world porcupines (Erethizontidae)	Porcupine	Erethizon dorsatum
Dogs (Canidae)	Coyote	Canis latrans
Weasels and skunks (Mustelidae)	Long-tailed weasel Spotted skunk	Mustela frenata Spilogale putorius
Cats (Felidae)	Bobcat	Lynx rufus
Elk and deer (Cervidae)	Elk Mule deer	Cervus canadensis Odocoileus hemionus
Pronghorn (Antilocapridae)	Pronghorn	Antilocapra americana

Appendix footnotes

1 Plant nomenclature follows Hitchcock and Cronquist (1974).

2 Bird nomenclature follows Robins et al. (1966) except where they are superseded by the American Ornithologists' Union (1973).

3 Mammal nomenclature follows Hall and Kelson (1959) except where they are superseded by Burt and Grossenheider (1964).

COMPETITIVE MOISTURE CONSUMPTION BY THE WESTERN JUNIPER (*JUNIPERUS OCCIDENTALIS*)

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ABSTRACT

Western junipers are not only strong competition for soil moisture, but appear to utilize much of the winter-accumulated soil moisture before herbaceous plant competition for soil moisture begins.

Keywords: Western juniper, soil moisture, transpiration, wilting range, winter dormancy.

INTRODUCTION

The invasion of the western juniper in arid lands in eastern Oregon has become a matter of grave concern by land resource managers during the last decade. The invasion of western juniper in the west is attributed to man's control of its natural enemy, fire, and the removal of understory fire fuels by grazing practices (Burkhardt and Tisdale 1976). As western juniper plant communities increase in density, they develop a dominance in soil moisture consumption that hampers all other plants' efforts to re-establish themselves. This paper will attempt to show that western juniper utilizes winter soil moisture while most other plant species are dormant and that juniper competes vigorously with other species throughout the year to maintain its edge on overall moisture consumption.

LITERATURE REVIEW

Few soil moisture pattern studies in juniper and juniper-cleared areas have been made. Skau (1964) found in Arizona that clearing alligator juniper (*Juniperus deppeana*) and Utah juniper (*Juniperus osteosperma*) on the Beaver Creek watershed resulted in only 1 to 3 percent moisture increase in cleared juniper areas. He explained that such a small difference may have been due to the accumulation of one to nine times as much ground cover plants on the thinned plots. Forage often increases more than 100 percent by the removal of woody plants (Fanning 1964, Clary 1971, Clary 1974).

Studies by Gifford and Shaw (1973) on cleared pinyon-juniper sites in southwestern and southeastern Utah indicate that greater moisture accumulation occurred under a debris-in-place treatment as compared to woodland controls during the first 6 months of each year at Milford, and regardless of season at Blanding. Woodland soils had the least soil moisture throughout most of the year. Most moisture flux took place in the upper (24 to 36 inches) of the soil profile, with only minor changes occurring at greater depths.

STUDY AREA AND METHODS

The study areas are located about 25 miles southeast of Prineville, Oregon, in the Bear Creek drainage. Bear Creek is a tributary to the Prineville Reservoir, located on the Crooked River in the Deschutes River basin. Soil parent materials are alluvium and surficial aeolian deposits of the John Day Formation (Swanson 1969).

The average rainfall is about 12 inches. Soils are deep, loam, Calcic Haploxerolls of the fine-loamy, mixed, mesic family at Hook Ridge near Fisher Canyon, and at Long Hollow are sandy loam, Cumulic Haploxerolls of the coarse-loamy, mixed, mesic family and loam, Calcic Pachic Argixerolls of the fine-loamy, mixed, mesic family. The soil pH is 7.8 near the surface and 8.6 below 30 inches. Elevation is 4000 feet and frost may occur in any month. Even though suborders and the soil families vary at each site, soil textures are relatively similar to all depths.

Natural vegetation for each site would be similar to a Soil Conservation Service Juniper Rolling Hills range site.

An automatic recording Belfort rain gage was installed in the natural juniper woodland at Hook Ridge and a fiberglass soil moisture-temperature cell was placed 5 feet southeast of the rain gage at a depth of 20 inches. A similar installation was made on the lower end of Bear Creek at 3500 feet elevation, and the fiberglass soil moisture-temperature cell was placed in a pole line corridor. On or near the 15th of each month, the 30-day gain gage charts were changed and the electrical resistance of the fiberglass cells was read for soil temperature and moisture with a soil moisture-temperature meter MC-300B from Soil Test.

After observing the apparent winter soil moisture loss, we dug a pit 5 feet east of the Hook Ridge rain gage on July 2, 1976. The soil profile was described and additional fiberglass cells were installed at the 6-, 12-, 20- and 30-inch depths. Pits were dug and the soils described at Long Hollow in adjacent thinned and unthinned juniper woodland area. Fiberglass cells were also installed at the 6-, 12-, 20- and 30-inch soil depths. Readings were made after major storms and on or near the 15th of each month.

The juniper in the Long Hollow thinned area were hand-cut with debris left in place in 1973. Terrific native grass plant release was apparent with many herbaceous species more than 2 feet tall. A point transect method of measuring frequency of vegetation in the Long Hollow adjacent sites had been made in the late summer of 1975. A 100-foot tape was laid out between two steel fence posts and point vegetation was recorded at 1-foot intervals. The woodland site had 1 percent understory vegetation, 29 percent litter and 70 percent bare ground. The thinned site had 34 percent vegetation, 59 percent litter and 30 percent bare ground. Hand clippings of vegetation in 1976 indicated 61 pounds dry weight of herbaceous species in the woodland site and 357 pounds in the thinned site.

RESULTS AND DISCUSSION

Winter Soil Moisture

The soil profile at Hook Ridge was moist as a result of heavy fall rains when the fiberglass cell was installed on November 15, 1975. Snow continued through January 7, 1976, but surface ground conditions were frozen and it is felt that little winter moisture reached the 20-inch depth. The available soil moisture at 20 inches, with warmer soil temperatures, was depleted rapidly in the woodland juniper area (fig. 1). In comparison, soil moisture at lower Bear Creek (fig. 2) and High Desert (fig. 3) remained much higher through the winter months. Because of the winter dormancy of the associated vegetative species, low number of total plants and frozen ground near the soil surface, the loss of winter soil moisture at Hook Ridge was attributed to juniper winter transpiration. The soil moisture content at 20 inches went from near field capacity to the wilting range between the 15th of December and the 15th of January. The soil temperature remained between 33 to 39° Fahrenheit during this period.

Summer Soil Moisture

A record 4.4 inches of rain fell in the first 2 weeks of August 1976, one month after the additional soil moisture cells were installed. Greater concentrations of moisture were found in the thinned woodland site at the 6- and 12-inch depth before and after the heavy rains (fig. 4). Woodland sites at the same depths returned to wilting range in October, while soil moisture remained in the 6-inch level thinned site until November, and the site continued to be very moist at the 12-inch level throughout the remainder of the year. Moisture reached the 20-inch level sometime after the August rains and disappeared by the end of November at each site. The 30-inch level showed very little influence from the August storm except at the Long Hollow woodland site, which has the lightest soil texture and thus the lowest water holding capacity of the three sites. The figures indicate a more rapid depletion of moisture in the fall on the juniper woodland site than on the thinned woodland sites

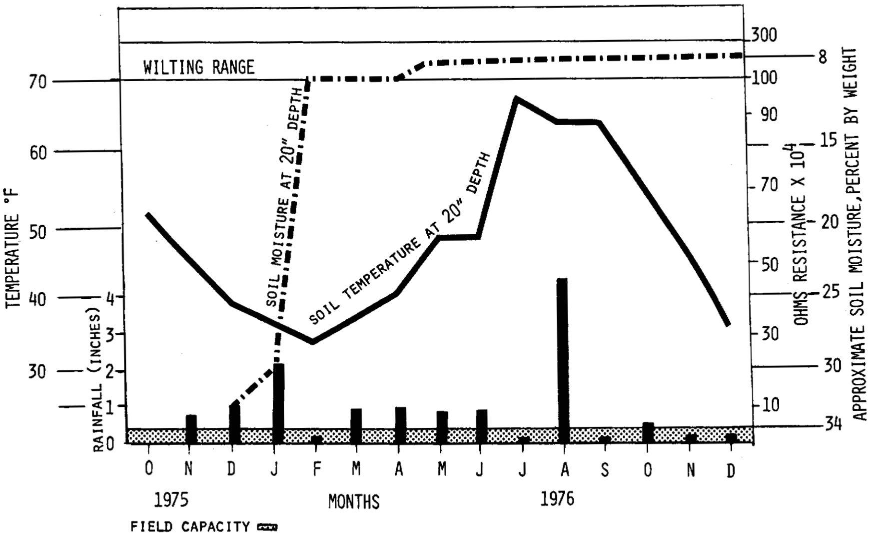

Figure 1.--Rainfall and soil moisture and temperature at the 20-inch depth for the Hook Ridge Study Area, 1975 and 1976. Rainfall is presented as bars for each month. The site has a south aspect with 5 percent slope at 4000-foot elevation.

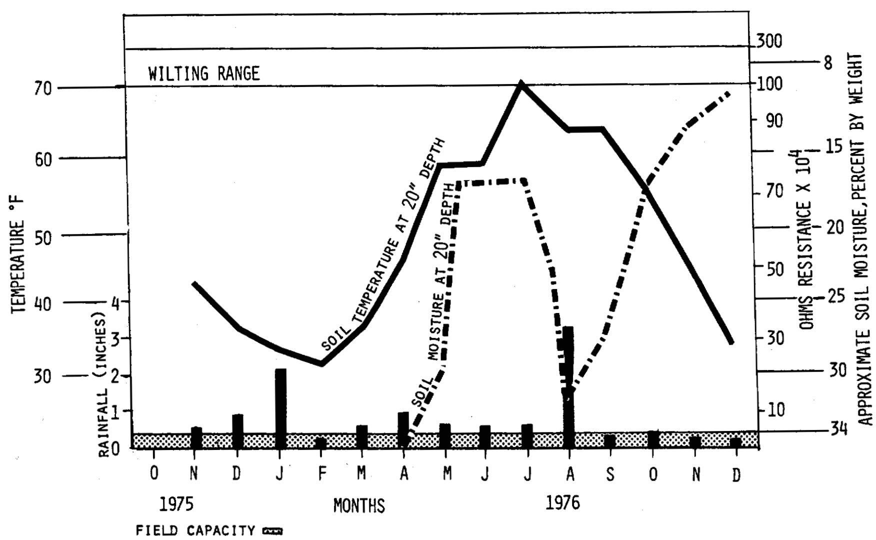

Figure 2.--Rainfall and soil moisture and temperature at the 20-inch depth for Lower Bear Creek Study Area in 1975 and 1976. Rainfall is presented as bars for each month. The site has a southeast aspect with 4 percent slope at 3500-foot elevation.

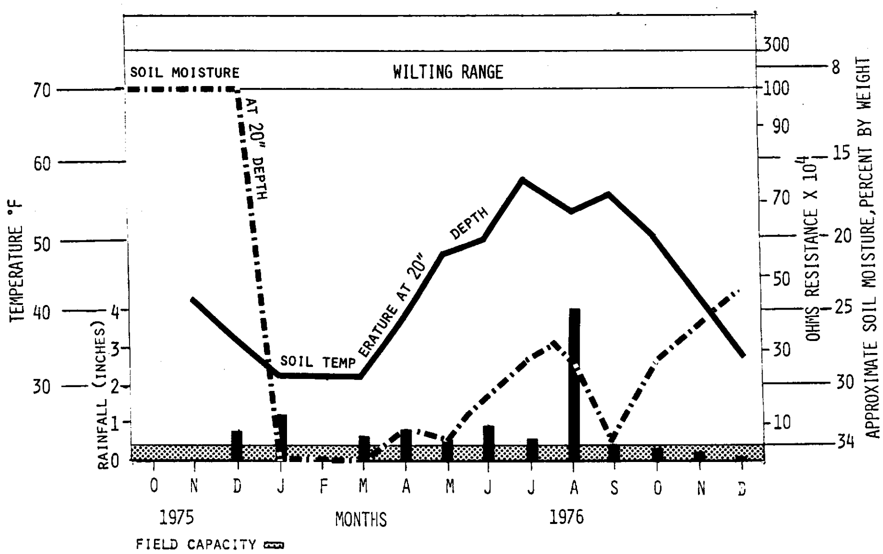

Figure 3.--Rainfall and soil moisture and temperature at the 20-inch depth for the High Desert Study Area (no juniper) in 1975 and 1976. Rainfall is presented as bars for each month. The site has a southeast aspect with a 3 percent slope at 4460-foot elevation.

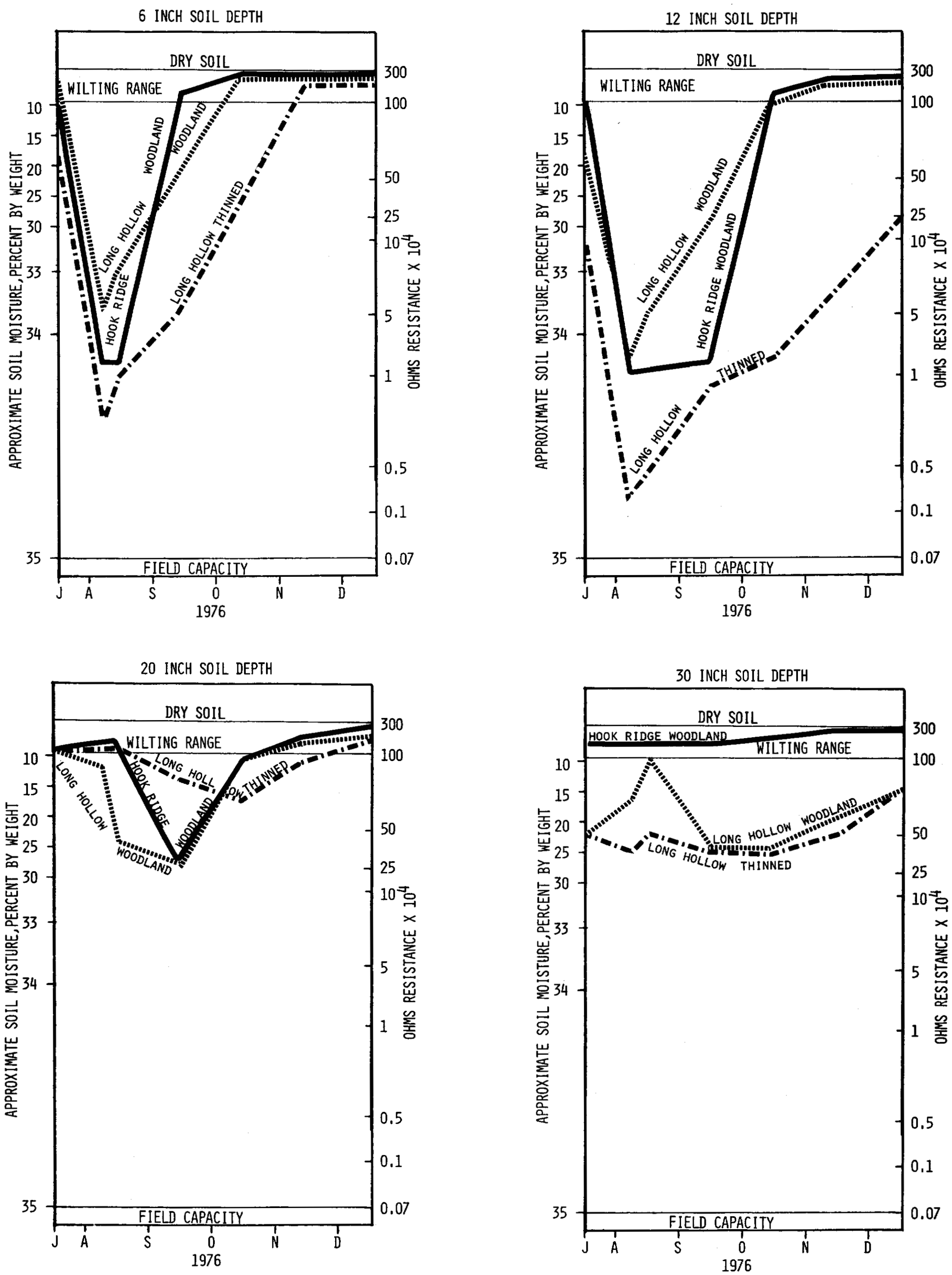

Figure 4.--Comparison of soil moisture content from July through December 1976 for woodland and thinned sites at the 6-, 12-, 20-, and 30-inch depths.

with high native grass plant populations. The data also indicate that most of the moisture flux occurs between the 6- to 20-inch soil depth in the summer.

CONCLUSIONS

There is a strong indication that western juniper uses a great deal of soil moisture for transpiration during the winter months. If subsoils are not frozen, western juniper can apparently use soil moisture rapidly throughout the year. In low rainfall areas where soil moisture storage is light, western juniper utilizes most of the stored soil moisture with its apparent year-around transpiration ability and gains a plant dominance in existing plant communities.

The use of deep soil moisture during winter months by heavy stands of western juniper, while most other species are dormant, will have a considerable effect on most spring and summer plants during most years. This may explain slow understory species re-establishment in juniper woodland areas and lack of plant vigor by most species throughout the season, even under ungrazed conditions.

Additional research should be conducted to establish the validity of the above findings, and to measure the transpiration and evapotranspiration rate for the western juniper for both winter and summer. Research is also needed to determine proper juniper management methods and their ecological effect.

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WEATHER STRESS DIFFERENCE BETWEEN TWO LEVELS OF JUNIPER CANOPY COVER

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ABSTRACT

Weather index values and differences between two mule deer winter range situations were obtained by measuring the difference in microclimate between a juniper forest and open shrubland. The cumulative weather stress in the shrubland was 2.2 times more severe than in the juniper forest through the winter period.

Deer observations during the Silver Lake Research Study have documented specific deer use of cover and forage areas dependent upon certain weather conditions. Predominant deer use occurred in juniper stands during weather stress and in open shrublands during less severe conditions.

The presence of thermal protection in juniper stands of 25 percent crown canopy cover was shown by the results of this study. The value of thermal protection to mule deer has been demonstrated during other studies.

The presence of measurable thermal value supports the need for developing proper guidelines for management of juniper stands on deer winter ranges. Thermal values would also benefit livestock wintering in juniper areas.

Keywords: Juniper, deer, thermal cover, weather index.

INTRODUCTION

Habitat improvement projects for mule deer on winter ranges have historically centered on forage development with little regard for cover value either by itself or in conjunction with forage values. The importance of proper size and distribution of forage and cover areas have been well documented (Moen 1973). The value of thermal cover provided by juniper (*Juniperus occidentalis* Hook.) stands is thoroughly discussed and related to work by Geiger (1966) describing microclimate changes related to canopy cover. During periods of severe stress, usually characterized by subfreezing temperatures, chilling winds and snow cover, the value of thermal cover is far more important than a wide open expanse of forage. Under these conditions the forage is (1) unavailable under snow most of the time and/or is (2) located in a microclimate that costs the deer more energy to obtain the forage than is received from it in terms of metabolizable energy. Analysis of deer observations during the Silver Lake Research Study documented animal behavior and use patterns in forage and cover areas that prove the need for proper distribution of thermal cover and forage for wintering mule deer (Leckenby, in manuscript).[1]

OBJECTIVE

The objective of this study was to determine the difference in the microclimate between two levels of juniper cover as measured by the weather stress index from two weather stations.

TECHNIQUES

A weather index which simulates relative stress values to mule deer based upon animal physiology was developed by Leckenby and Adams[2] while working on the Silver Lake Research Project. The numerical stress values are developed from functions of percent snow cover, snow depth, total wind, hours recorded in certain temperature ranges and measured precipitation. The techniques used are described (Adams and Leckenby 1972).[3]

Each station was equipped with the following instruments including a standard design instrument shelter:

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[1] Leckenby, D.A. Mule deer occupancy of plant communities on a south-central Oregon winter range. Oregon Dept. Fish and Wildlife. In manuscript.

[2] Leckenby, D.A., and A.W. Adams. A weather severity index for mule deer on a south-central Oregon winter range. Oregon Dept. Fish and Wildlife. In manuscript.

[3] Adams, A.W., and D.A. Leckenby. 1972. Suggestions for the development of a weekly weather index. Oregon State Game Comm. Mimeo.

1. Hygrothermograph
2. Dial-type recording anemometer
3. Precipitation collecting drum
4. Maximum-minimum thermometer in Townsend support
5. Standard maximum-minimum thermometer in Townsend support
6. A Forschner's improved circular milk scale, Model 69 MD

A computer program was written to compute a weekly and cumulative stress index from data obtained at each weather station on a weekly basis.

During the winter of 1974-75, recordings were analyzed from two weather stations located near the Stratton Place on the Fort Rock winter range from November 4, 1974 through June 2, 1975. The more open "shrubland station" has been in operation since 1968-69 and is located on a rabbitbrush flat with less than 5 percent crown canopy cover provided by scattered juniper. The plant community is gray rabbitbrush/squirreltail-cheatgrass (*Chrysothamnus nauseosus* (Pall.) Brit.)/(*Sitanion hystrix* (Nutt.) J.G.Sm.)-(*Bromus tectorum* L.). The other station was placed on a 15 percent south facing slope in a juniper stand of approximately 25 percent crown canopy cover. This community is juniper/big sage (*Artemisia tridentata* Nutt.)/needlegrass (*Stipa* spp.)-squirreltail.

Data collected from the two stations provided sound information from which to determine and measure the difference in microclimates.

RESULTS

The weekly and cumulative index values for each station are plotted on Figures 1 and 2. The zero (0) line is the threshold below which mule deer enter a stress situation, i.e., they start using more energy for maintenance than is being obtained from forage. Index values above the line indicate positive conditions when mule deer can gain body condition and store energy reserves above levels required for maintenance.

The weekly index plotted in Figure 1 illustrates the difference between microclimates in terms of weather stress for each week throughout the winter. Deer use during severe stress situations has been observed to shift heavily to juniper forest stands and away from shrubland browse communities (Leckenby, in manuscript). The main reason is shown in Figure 1 where the thermal stress is more severe in the shrubland compared to the juniper stand. It should be pointed out that there is a rather minimal difference between these two stands in terms of canopy cover (5 and 25 percent) and that proportionally more thermal protection is provided in stands with increased canopy cover.

The difference as illustrated in Figure 1 is not visually dramatic due to the scale of the graph, but is significant in terms of numerical values.

During milder periods, deer use of shrublands increases substantially when they can obtain metabolizable energy at a benefit/cost ratio greater than 1. These periods can be seen on Figure 1 and they also occur on a daily basis when weather allows. As daytime microclimate conditions in shrubland improve to equal that of juniper forest, deer forage use of open areas increases. Deer return to juniper (thermal) protection as the shrubland microclimate approaches the physiological limits to exposure to cooler temperatures.

The cumulative index as shown in Figure 2 illustrates the overall difference in microclimate between the two levels of canopy cover throughout the winter. The shrubland microclimate stress factor was 222 percent more severe than in the juniper forest. A subpopulation of deer which have depended upon a particular juniper stand for thermal cover each winter would suddenly find themselves in a critical, if not fatal, situation if the stand were to be removed in order to improve forage conditions. Under severe stress conditions they could eat all the new forage supplies and still die of undernutrition. The forage could not supply sufficient nutrition to replace additional energy losses to increased stress conditions created by thermal cover removal. Body condition is lost much faster while feeding in open range under severe stress than would be lost while not feeding, but under thermal protection energy can be conserved.

CONCLUSIONS

The difference in microclimate between the shrubland and the juniper forest as shown in Figures 1 and 2 is a strong indication of the relative value of thermal protection to wintering mule deer. Studies of climatic changes as discussed in Moen (1973), Geiger (1966) and Leckenby (in manuscript), and the effects of climatic conditions upon ruminant physiology have revealed sound knowledge for developing guidelines to manage juniper stands and thus maximize thermal protection and use of forage in terms of the most efficient benefit/cost ratio to the deer's energy balance.

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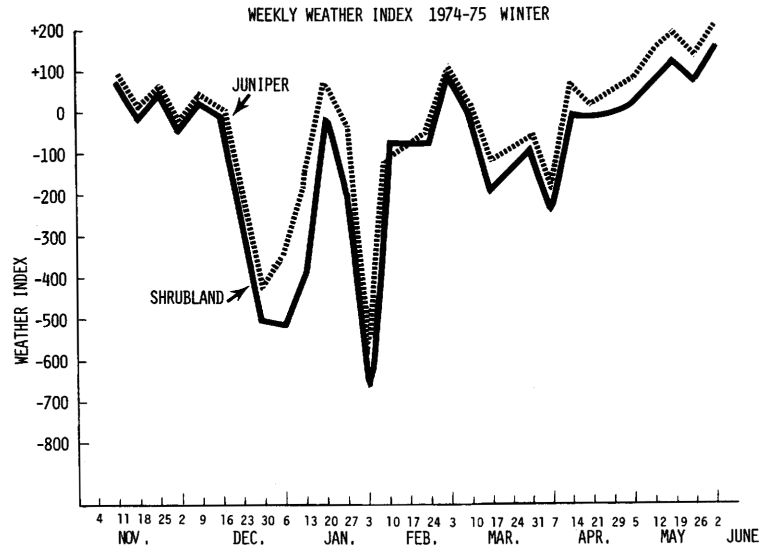

Figure 1.--Weekly weather index for shrub and juniper cover in the Silver Lake Study area, winter 1974-1975. Below the zero level, deer use more energy than they obtain from forage.

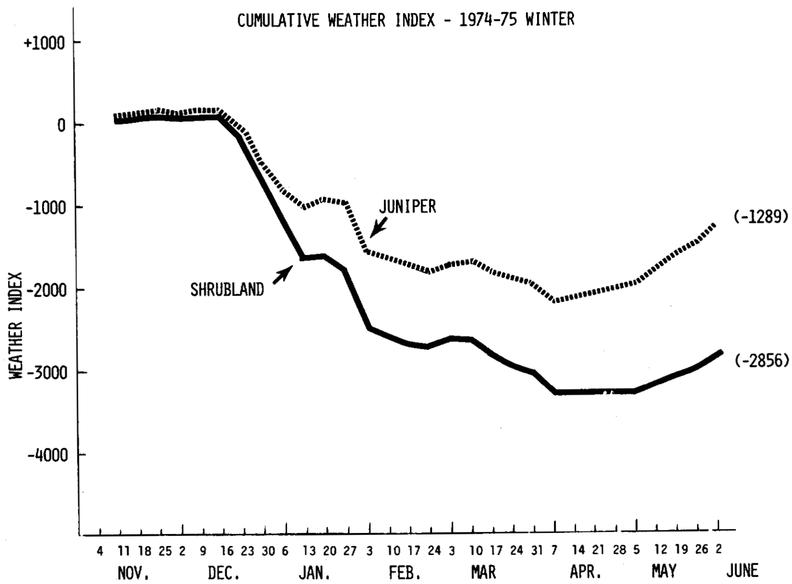

Figure 2.--Cumulative weather index for shrub and juniper cover in the Silver Lake study area, winter 1974-1975.

CURRENT RESEARCH ON PINYON-JUNIPER IN THE GREAT BASIN

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ABSTRACT

Research in progress on pinyon-juniper woodlands in the Great Basin is summarized. The program includes woodland inventory techniques, methods of classifying biotic potentials, use and effects of fire, invasion processes, and methods of revegetation of burned and cutover areas. The goal is increased forage production in harmony with woodland product utilization, soil stability, and recreation.

Keywords: Pinyon, juniper, Great Basin, Nevada.

A number of recent publications summarize results of past research in the pinyon-juniper woodlands of the western United States (Barger and Ffolliott 1972; Clary et al. 1974; Gifford and Busby 1975; Springfield 1976), and a comprehensive cross-referenced bibliography has been assembled by West et al. (1973). However, most of this research was in the Southwest and has limited applicability to the western juniper type. The purpose of this paper is to present a summary of current, unpublished research on pinyon-juniper in the Great Basin. Some of this research should be applicable to the western juniper type and there may be opportunities for coordinating the western juniper research program with the Great Basin pinyon-juniper research program.

To set the stage for our discussion of research in the pinyon-juniper woodlands in the Great Basin, a few words should be said concerning the distribution, extent, and values of the type. There are more than 200 mountain ranges in the Great Basin and pinyon-juniper occurs on most of them. According to estimates made from LANDSAT-1 imagery, there are about 11.7 million acres (4.7 million ha) of pinyon-juniper in Nevada and 4.1 million acres (1.7 million ha) in the

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[1]Located at the Intermountain Station's research laboratory at the Renewable Resources Center, University of Nevada Reno.

Utah portion of the Great Basin (Beeson 1974). Throughout Nevada, the stands are usually composed of varying proportions of singleleaf pinyon (*Pinus monophylla* Torr. & Frem) and Utah juniper (*Juniperus osteosperma* [Torr.] Little), but pure stands of either singleleaf pinyon or Utah juniper can be found in some areas. In Utah, true pinyon (*Pinus edulis* Engelm.) and its hybrids with singleleaf pinyon become increasingly prevalent as one moves eastward. Western juniper (*Juniperus occidentalis* Hook.) occurs in and near the Sierra Nevada on the western edge of the Great Basin.

These woodlands are key winter range for big game. Livestock grazing also has been and is a major use. In many areas, overgrazing of the understory vegetation in the woodland has reduced the forage resource and allowed the density of pinyon and juniper trees to increase. Also, in many areas, the woodland is expanding into adjacent shrub and grasslands, reducing their forage resource. Opinions differ on the magnitude and causes of this invasion; the consensus is that fire exclusion, overgrazing, and perhaps, climatic changes are allowing pinyon and juniper to advance into adjacent communities.

Among the woodland products are pinyon nuts, fenceposts, fuelwood, pulpwood, and Christmas trees. Pinyon nuts have been harvested by Indians for centuries and are still important to their economy. Utilization of the other products is hampered by the high cost of harvesting and transportation. Recreational use of the woodlands is growing rapidly. In addition to game hunting, Christmas tree cutting, and nut gathering, the woodlands are being used more and more for camping, picnicking, rock hunting, and other kinds of outdoor recreational activities.

The main goal of current research on pinyon-juniper in the Great Basin is to obtain information to improve woodland management for increased wildlife and livestock forage production, woodland product utilization, soil stability, esthetics, and recreational opportunities. The research program includes woodland inventory techniques, methods of classifying biotic potentials, an understanding of succession, including invasion dynamics and fire effects, and methods of revegetation of burned and cutover areas.

Development of techniques to measure and predict biomass of singleleaf pinyon and Utah juniper. This is a cooperative study by the University of Nevada and the Intermountain Forest and Range Experiment Station. The objectives are (1) to develop equations to estimate aboveground biomass components from such tree characteristics as stump diameter, tree height, crown diameter, and number of forks; and (2) to obtain data for analysis of growth rates and site quality.

The biomass components include fresh and ovendry mass of wood, bark, twigs, and foliage. These components are determined by actual weighing in the field and ovendrying of samples in the laboratory. Specific gravities are measured to permit conversion of mass to volume. Height growth and radial growth rates of each tree are measured. Slope, aspect, elevation, topographic position, and other site factors are recorded.

Last summer, 50 pinyon and 28 junipers from 13 sites across Nevada were measured. The data have been compiled and regression equations have been developed which show a very good fit of the data. The data base will be doubled this coming field season. The study will be completed and the results submitted for publication by June 1978.

This study is coordinated with the Intermountain Station's Forest Resources Inventory Research unit, which is doing similar work on pinyon-juniper stands on the Carson National Forest in northern New Mexico.

Classification of pinyon-juniper woodlands in the Great Basin. This is another cooperative study of the Intermountain Station and the University of Nevada. Originally, we planned to develop a habitat-type classification system for pinyon-juniper woodlands, including adjacent plant communities susceptible to invasion by pinyon and juniper, and then to quantify the resource potentials of the major habitat types in terms of wood and forage production. However, extensive fieldwork in 1975 indicated that the development of a classification system based on habitat types would be extremely difficult because of the extent of disturbance throughout the type and of doubtful value because the aggressive nature of pinyon and juniper tends to exclude indicator understory species. If a habitat-type classification were developed, it would be subject to considerable error and would probably be too broad to be useful for the quantification of resource potentials.

Since our primary objective is the quantitative evaluation of resource potentials and classification is only a tool, it was decided to reverse the procedure and shift the emphasis from classification to determination of resource potentials in relation to site factors. Once the relations among resource potentials and site factors have been determined, a classification system will be attempted.

In 1976, the study was modified to attempt the following objectives:

1. To develop a model for estimating periodic annual biomass increment of pinyon-juniper stands on the basis of site factors, stocking, structure, and species composition.

2. To determine potential annual biomass increment (resource potential) in relation to site factors by optimizing stocking, structure, and species composition in the above model.

3. To relate potential forage production to potential tree growth.

During 1976, intensive measurements were made on 48 pinyon-juniper stands across Nevada. At least 50 more stands will be sampled in 1977. We also measured productivity and site characteristics of 16 sagebrush stands (*Artemisia tridentata*, *A. arbuscula*, and *A. nova*) within or adjacent to pinyon-juniper woodlands. Measurements of 40 more sagebrush stands are planned for 1977. Analysis and presentation of results will be completed in 1978.

Climate in the pinyon-juniper zone of the Great Basin. Past research and observation indicate that the distribution and biotic potentials of pinyon-juniper woodlands are highly dependent on local climate. Climatic data from within the pinyon-juniper zone are scarce. Most weather stations are in valleys below the pinyon-juniper belt and most storage gages and snow courses are above it. The Intermountain Station is sponsoring University of Nevada research to synthesize models to predict annual and monthly means and ranges of precipitation and temperature within the pinyon-juniper belts. These models are to be based on presently available climatological data. This effort, to be completed June 1978, will augment the classification research described above. We will attempt to correlate growth potentials derived from stand measurements with local climate predicted by these precipitation and temperature models.

Patterns and rates of Great Basin pinyon-juniper woodland invasion and suppression of understory vegetation. This study is being conducted in southwestern Utah by Neil West and Robin Tausch of Utah State University. Its major objectives are: "(1) to identify the patterns and rates of pinyon and juniper tree invasion and the degree of suppression of understory forage species and relate them to site differences by way of a mathematical model; and (2) to develop a means of determining the rates at which acreage has been removed from production in the past and is likely to be removed in the future." This study includes the development of a successional model including both intraspecific and interspecific competition. Several manuscripts are being prepared by Tausch and West.

Controlled fire as a management tool in the pinyon-juniper woodlands of Nevada. This study is a cooperative effort of the University of Nevada, the Humboldt National Forest, and the Intermountain Station. It was started in 1974 to evaluate fire as an alternative to chaining for removal of pinyon and juniper. The objectives were to determine:

1. When, where, and how to burn safely and effectively.

2. The response of various plant species to various fire intensities as affected by phenological stage and soil moisture conditions.

3. Response of wildlife to fire and vegetation succession following fire.

4. Effects of burning on infiltration rates and sediment production.

This study was conducted on the White Pine Ranger District in eastern Nevada. During the past 3 years, there have been 12 successful burns out of 29 attempts. All of these have been in stands with 3% to 30% tree cover. Stands with more than 30% cover are not suited to control burning because so little understory exists in such stands that the fire must be carried by wind from crown to crown. It is too hazardous to burn when the wind is high enough to carry a crown fire. The requisites for a good controlled burn are light winds (about 5 to 10 miles per hour) and sufficient understory to carry the fire from tree to tree. William Frandsen of the Northern Forest Fire Laboratory in Missoula has been studying the behavior of these fires and is developing a fire spread model.

A final report on this cooperative study was submitted in June 1977. Manuscripts are being prepared for each of the four objectives.

<u>Alternatives in utilization of western juniper woodlands</u>. In cooperation with the University of California and private ranchers, Agricultural Research Service scientists at Reno are studying alternatives for improvement and utilization of western juniper woodlands in Lassen County, California. The alternatives being evaluated are: (1) no treatment; (2) complete conversion to grassland by mechanical control and burning; (3) harvesting wood from 1/4-acre blocks and then seeding; (4) applying picloram to 1/4-acre blocks and then limbing the junipers to facilitate revegetation; and (5) applying picloram to 1/4-acre blocks with no further treatment. All levels of vegetation (the tree, shrub, and herbaceous components) must be manipulated to insure success in revegetation with desirable grasses, legumes, and browse species. The cycling of nutrients from juniper litter and slash is being traced and evaluated in terms of its influence on plant succession and revegetation success. Mule deer use of the various alternatives is being evaluated also.

Revegetation of burned and cutover pinyon-juniper stands. A major portion of the Intermountain Station's pinyon-juniper research effort is devoted to revegetation research. A number of studies are in progress to determine proper species to plant, to improve seeding methods, to reduce rodent and bird depredation of planted seed, and to develop seed orchards. These studies involve cooperation with the University of Nevada, Nevada Division of Forestry, Agricultural Research Service, Soil Conservation Service, the Intermountain Station's Shrub Improvement and Revegetation unit at Provo, Utah, and several other organizations. Field trials for species adaptability and seeding methods are being conducted on the control burns on the White Pine Ranger District and at a number of other sites across Nevada.

Utilization of woodland products. The Nevada Division of Forestry is exploring possibilities for new pinyon-juniper products and markets. They have been particularly interested in whole-tree chips for particleboard, paper products, cattle feed, livestock bedding, and erosion control. Last Spring, Division of Forestry personnel arranged a pilot chipping operation to get an idea of the problems and costs of whole-tree chipping. In the 4-day trial, they found that 50 to 60 tons of green material could be chipped per day at a cost of about $30.00 per ton. When transportation costs are considered, it is unlikely that pinyon or juniper can compete with other sources of chips. However, analyses by Dr. Fred Shafizadeh of the University of Montana show that pinyon and juniper foliage and branches contain a large amount of potentially useful oleoresins. If these oleoresins can be extracted in conjunction with chipping or firewood operations, economically feasible harvesting is a distinct possibility.

Timber harvesting for fuelwood, chips, extractives, or other products is potentially the best way of removing overstory to release understory forage and to permit reseeding. It is particularly attractive where there is a suppressed understory of desired species, such as bitterbrush. It is better than chaining or burning because it yields products of value, it is less damaging to the understory and to soil stability, and it permits selective removal. Unfortunately, harvesting of pinyon and juniper trees is not economically practical at present, except in localized areas close to population centers, because of current market conditions and low volumes per acre. However, we expect the demand for woodland products to increase and, eventually, tree harvesting will be our principal means of removing overstory competition.

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S E C T I O N I I

M A N A G E M E N T

MECHANICAL MANIPULATION OF WESTERN JUNIPER -- SOME METHODS AND RESULTS

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ABSTRACT

Mechanical manipulation of western juniper (Juniperus occidentalis Hook.) has been performed on 47,700 acres in Oregon. Two methods are briefly discussed including costs, design, vegetative response, site location, livestock and wildlife implications. Methods discussed are single and double chaining and cutting with chainsaws. The discussion centers around juniper control, revegetation, and related resource management.

Keywords: Juniper, revegetation, wildlife relationships, mechanical control.

TWELVE YEARS OF MECHANICAL MANIPULATION, REVEGETATION, AND SOME WILDLIFE RELATIONSHIPS IN WESTERN JUNIPER IN OREGON

Harold Winegar

To date, western juniper (Juniperus occidentalis Hook.) has been mechanically manipulated on approximately 47,700 acres in Oregon. Of these acres treated, 20,258 are private and 27,442 are public. Three mechanical treatment methods or combinations thereof have been used: (1) chaining, (2) dozing and (3) cutting with chainsaws.

The method employed in each particular juniper control project was determined mainly on the basis of cost and understory condition. For example, to treat a large (100+ acre) mature stand on potentially productive soil with trees dominating a decadent understory, chaining and seeding was usually employed. In treating a small stand (1 to 100 acres with the same site condition), dozing and seeding, seeding and cutting, or cutting, piling and seeding have been employed. In young or mixed age stands containing desired live understory species not requiring soil disturbance and seeding, cutting for understory release was the practice used.

An exception to these criteria was employed by the Bureau of Land Management, Prineville District, on the Bear Creek watershed improvement project. Handcutting was the method used on approximately 6,400 acres with releasable understory, much of which also required seeding. Treated areas were up to 1,000 acres in size. In this case, it was thought that excessive watershed damage might be incurred by chaining or dozing equipment.

Camp Creek Chaining

The first large juniper manipulation project was performed in 1964--the 3,000 acre Camp Creek BLM single-chaining in Crook County. This project was planned and performed primarily for livestock range improvement. About one-fourth pound per acre of bitterbrush (*Purshia tridentata* (Pursh.) DC.) seed, however, supplied by the Oregon Game Commission, was included with grass seed applied aerially for mule deer browse. Additional bitterbrush seed was broadcast, drilled and applied with a Hansen browse seeder on about one-third of the project by the Oregon Game Commission. Bitterbrush and fourwing saltbush (*Atriplex canescens*) seed were also broadcast in juniper root cavities by OGC.

The 3,000-acre chaining was done in three blocks of 800, 1,600 and 600 acres. Growth and survival of seeded bitterbrush was measured for 5 years following the treatment. The average mortality of bitterbrush in all chaining blocks in 5 years was 52 percent. Mortality is estimated to be at least 80 percent at the present time and few bitterbrush plants can be found in the chainings except within fenced exclosures. Saltbush seeding results were nil.

Results of the treatment for livestock grazing have been good. Range surveys were made before and after treatment in the pasture units within which chainings were done. It was estimated that an average change in acres per animal unit month from 22 to 7 occurred within the three chaining blocks. Grazing by livestock has since concentrated within the treated areas which has also resulted in improved range condition within the remainder of the pasture units.

Evaluation of wildlife response was made for deer only by reading 20 one-tenth acre pellet group transects. Ten transects were read within the chainings and 10 in adjacent untreated juniper communities for 6 years following the chaining. The total number of pellet groups counted on all transects decreased by 71 percent in the 6-year period, reflecting population declines which occurred generally throughout mule deer range. Deer were attracted to the treatment for the first 2 years, with a decline in occupancy through the next 4 years. Decrease in deer occupancy within chainings compared to unchained areas was much greater in an 800-acre block on flat table land than in blocks containing numerous draws, ridges, and small patches of standing juniper.

Although significant improvement was made for livestock range, several shortcomings in the treatment layout and method were recognized. (1) Most of the stands chained were of uneven age with a high proportion of young and seedling trees, which were undamaged by chaining. Less than 50 percent of the larger trees were removed from the soil and killed. It now appears that live tree density has increased from pretreatment density. (2) Portions of the area chained could have been improved by grazing management only. (3) Harsh, rocky, unproductive sites were chained. These sites have shown little improvement in forage production, and their principal value as cover for livestock and wildlife was lost. (4) Single chaining did not provide sufficient soil disturbance for good results from aerial seeding. (5) No consideration was given to wildlife cover.

Declining deer populations during the late 1960's prompted wildlife managers to look to juniper control as a means to improve forage on deer winter range. Winter range food was at that time considered by many to be the limiting factor for mule deer.

The trade-offs between wildlife and timber have been specified through northeastern Oregon wildlife habitat management guidelines and findings from the mule deer research project at Silver Lake, from which a physiological definition of deer winter range has been proposed.[1] Winter ranges are those habitats occupied during seasons of the year when deer are either just maintaining body stores of energy or are depending on those reserves for survival. This definition plainly indicates that factors other than food are also important. Conservation of energy reserves can be maintained by having adequate thermal cover in proportion to feeding areas.

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[1] Roberts, R. W. 1975. Project No. W-70-R, Silver Lake Mule Deer Research, Winter Range Habitat Improvement, Job Completion Report.

Some of us were slow to learn. However, in describing methods, costs, and results of some major mechanical juniper manipulations, I attempt to show important changes in project design for wildlife. Although experience was gained from all the numerous projects in which this author and wildlife financing were involved, only certain ones representative of major changes in design and techniques will be described.

Willow Valley Chaining

In the fall and winter of 1967, 1,400 acres of juniper were double chained and aerially seeded between chainings. One-fourth pound per acre of bitterbrush and fourwing saltbush were broadcast in root cavities during February 1968 to complete the treatment. This project, known as Willow Valley juniper chaining and revegetation project, is located near Willow Valley Reservoir on Lost River on BLM lands in Klamath County.

Principal changes in treatment from Camp Creek were seed application between first and reverse chainings and number of species seeded. The species and approximate pounds per acre aerially seeded were: Crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.) 8; intermediate wheatgrass (*A. intermedium* (Host.) Beauv.) 1.5; pubescent wheatgrass (*A. trichophorum* C. Right.) 1; Russian wildrye grass (*Elymus junceus* Fish.) .5; sainfoin (*Onobrychis viciaefolia* Scop.) 1; sweet clover (*Melilotus* Mill.) 2; Nomad alfalfa (*Medicago sativa* L.) 1; and bitterbrush (*Purshia tridentata* (Pursh.) DC.) 1. Results of the project were briefly as follows: Control of juniper was considered to be good. Good release of native vegetation occurred. Results were fair to good from seeded grasses but poor from seeded forbs and shrubs. Increase in production of total annuals and perennials, measured after six growing seasons, was found to be 219 pounds dry weight per acre. Livestock grazing was measurably improved. Again, little consideration was given to wildlife cover within the treatment, and no significant improvement in wildlife habitat has been documented. Cost of the project was approximately $15.00 per treated acre.

Harpold and Nine Mile Ridge Chainings

Two large double chainings were performed in 1969, also on BLM lands. These were the 600 acre Harpold project in Klamath County and the 1,100 acre Nine Mile Ridge project in Lake County. In these projects, more emphasis was placed on establishment of forbs and shrubs by seeding. In addition to aerial seeding, shrub seed was applied through seed dribblers mounted over tracks of crawler tractors during chaining operations. This was the first use of tractor-mounted dribblers on juniper control work in Oregon.

The Nine Mile Ridge chaining has been studied as part of the Silver Lake Mule Deer Research by the research section of the Oregon Department of Fish and Wildlife. Since publication of that research work is in progress, analysis, results, or interpretations will not be attempted here. The following description and comments refer to Harpold only.

Bitterbrush seed was applied at 1.3 pounds per acre through four dribblers on two tractors. Species and pounds per acre aerially seeded were crested wheatgrass 2; sainfoin 1.25; small burnet (Sanguisorba minor Scop.) .5; bitterbrush .5, and big sagebrush (Artemisia tridentata Nutt.) .02. Bitterbrush at approximately one-third pound per acre was broadcast into root cavities.

Climatic conditions in the first year were comparatively unfavorable for seeding establishment, and 125 acres were reseeded by drilling in the spring of 1972. Again, the principal project objective was forage improvement, and little consideration was given to the treatment size, or cover, left within treated areas.

Juniper control was only fair because numerous young and seedling trees were released. Response of native and seeded grasses was considered good. Small burnet establishment was fair. Sainfoin results were poor after the second year. Shrubs per acre after 4 years, including bitterbrush, grey rabbitbrush (Chrysothamnus nauseosus (Pall.) Brit.), green rabbitbrush (C. viscidiflorus (Hook.) Nutt.) and big sagebrush, average of 14 one-tenth-acre transects was 477. Of this, 39 percent was bitterbrush. Serviceberry (Amelanchier Medik.), snowberry (Symphoricarpos Duhamel), horse-brush (Tetradymia DC.), low sagebrush (Artemisia arbuscula Nutt.), and gooseberry (Ribes L.) were present on transects, but usually represented by fewer than 10 plants per acre. Total herbage production has not been measured. Again, livestock grazing was improved, but we do not know the over-all net benefits of the treatment. Cost of Harpold, not including reseeding, was $18.00 per treated acre.

North Harpold and Spring Creek Chainings

The 180-acre North Harpold chaining in Klamath County and the 300-acre Spring Creek chaining in Crook County were performed in 1970. Cover requirements for deer received more consideration in the design of these projects. Width of chained openings, especially at right angles to prevailing winds, were reduced to a 400-foot maximum. The width of unchained cover areas left between clearings was usually determined by height and density of trees. Leave area width equal to clearings was a general aim, with a minimum of 150 feet. Numerous smaller openings were interspersed with cover, providing greater edge.

Seeding methods were not changed, except that no shrub seed, other than a trace amount of big sagebrush, was applied aerially.

The following species and pounds per acre were applied on North Harpold: Bitterbrush 3.3 through dribblers and .3 broadcast into root cavities. Crested wheatgrass 2.2, big sagebrush .083, sainfoin 3.3, Ladak alfalfa .28, and small burnet 4.4 were aerially seeded.

Results on North Harpold were briefly as follows: Release of native grasses and establishment of crested wheatgrass was considered good. Frequency of AGDE was found to be from 10 to 80 percent with an average of about 30 percent. Shrubs per acre average of six transects in the third year was 1,210. Bitterbrush and saltbush comprised 90.6 percent and 4.4 percent, respectively. Sainfoin establishment was poor to fair. Small burnet stand is fair to good.

Species and pounds per acre seeded on Spring Creek were as follows: Bitterbrush 1.9 through dribblers and .3 in root cavities, fourwing saltbush .95 through dribblers and .15 in root cavities, crested wheatgrass, sainfoin and small burnet were aerially seeded at 3 pounds each.

Response of native vegetation was good, except perhaps for plants adapted to microclimate under juniper. Crested wheatgrass frequency averages about 30 percent. Establishment of sainfoin was poor, small burnet fair. Shrubs per acre average of 11 transects in the fourth year was 1,797 of which bitterbrush and saltbush comprised 44 percent and .02 percent, respectively.

Although control of juniper was considered to be successful, approximately 30 man-days were devoted to cutting young live trees not killed by chaining, on about one-half the Spring Creek project. Numerous small trees are still growing on the remainder. Control of juniper was more nearly complete on North Harpold, as seems to be the case with other Klamath County projects.

Improved livestock grazing was provided on both projects. Utilization by deer of vegetation in both projects has been noticeably higher than in adjacent untreated areas. However, populations are not known to have been directly affected by the treatments. Parallel population trends are seen generally throughout herd ranges. Total cost of these two projects not including follow-up control efforts was approximately $33.00 per acre treated.

Sheep Mountain and Ward Lake Chainings

The last two major chaining projects were performed in 1971 and 1972; the Sheep Mountain project, 300 acres in Crook County, and 500 acres near Ward Lake in Lake County. Description and results given here refer to the Sheep Mountain work only. The Ward Lake project is being studied as part of the Silver Lake Mule Deer Research for which publication is in progress.

Sheep Mountain chaining was done in ten separate treatment units within an area about 4 miles long, around the southeast edge of the Maury Mountains. Essentially the same cover considerations were followed in design as were used at Spring Creek. Aerial seeding between chainings, in pounds per acre were: Crested wheatgrass 3, small burnet 3, sainfoin 4, and fourwing saltbush 1. Dribbler seeding, pounds per acre Bitterbrush 3, and fourwing saltbush 2. Growth and survival data collected between 1966 and 1971 on bitterbrush broadcast into root cavities indicated poor results. This practice was, therefore, omitted.

Juniper control again was not complete as numerous live trees remained in treated areas. The average increase in production of combined annuals and perennials, after 2 years, from measurements in four representative pretyped communities was 646 pounds per acre. Over-all net benefits to deer or other wildlife are not known. Total cost of the Sheep Mountain chaining and revegetation project was approximately $41.00 per acre treated.

Chainsaw Cutting

Up to the present time, chainsaws have been used to thin or clear approximately 1,545 acres of private lands and 10,962 acres of public lands. Cost of contracted chainsaw work has varied from $5.00 to $28.00 per acre.

Cover trade-offs have been generally less severe, and where care was used in project layout, cover losses have been negligible. Vegetative results have been generally good and especially good where the most productive sites were selected for treatment. Vegetative production was measured on the 17.5 acre Dairy Hill understory release cutting in Klamath County. Measured in the fourth year following cutting, the increase of combined perennials and annuals was shown to be 436 pounds per acre. The 85 acre Salt Creek drilling and cutting project in Crook County measured in the second year showed an increase in combined perennials and annuals of 274 pounds per acre.

HAND CUTTING WESTERN JUNIPER ON THE BEAR CREEK WATERSHED PRINEVILLE, OREGON

Wayne Elmore

The Bear Creek watershed improvement project, initiated by the Prineville District of the BLM, began in 1973. The primary objective of the plan was to "increase vegetation and litter cover from 45 percent to 60 percent to reduce erosion." Ground cover percentages were derived using the standard "step-toe" transects (Gifford et al. 1973). Percent plant cover-soil loss relationships are based on research by Branson and Owens (1970).

The recommended method was to thin western juniper by hand cutting with chainsaws. Hand thinning prevents damage to native grasses and shrubs and causes less disturbance to fragile soils. The "debris in place" method also provides additional protection by forming small check dams, providing protection for plants from grazing animals.[2] and increases soil moisture by reducing evaporation (Gifford and Shaw 1973). The procedure was slightly altered in 1975 and 1976 with the aerial seeding of crested wheatgrass at 5 pounds per acre on 3,800 acres to help accelerate revegetation on low density sites. To date, establishment of these seedings has been poor, apparently because of the low occurrence of covered seed and low surface soil moisture. Frost heaving was expected to aid in seed coverage but apparently gave little benefit.

Approximately 6,400 acres of cuttings have been completed, with 2,600 planned for fiscal year 1977, and another 3,000 programmed for fiscal year 1978. This will make a project total of approximately 12,000 acres, nearly half of that originally planned. Reasons for the reduction in acreage include: (1) An omission of leave (uncut) areas in the original acreage estimate, (2) most of the highly productive sites have been cut, and (3) large percentage of the remaining areas have a low number of trees per acre (100 or less), making it uneconomical at the present expected cost per acre.

Early cuttings were located on highly productive simas, tub and alluvium soils because these presented the greatest vegetative release potential. Projects have ranged in size from 85 acres to 1,000 acres

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[2] Rollins, M. B. 1973. Bear Creek Watershed Management Plan, Bureau of Land Management, Prineville, Oregon.

with an average of 600 acres. Contract costs varied from a low of $13.00 per acre to a high of $28.00 per acre. No correlation has evolved between the per acre costs and site characteristics. Prices vary with project size, trees per acre, availability and experience of bidders, access to the site, and time of cutting. Projects expected to go high have received low bids and vice-versa.

Project layout, after site location from soils maps, consists of flagging the boundaries in an irregular pattern and designating 10 to 20 percent of the site for leave areas. These leave sites range in size from 10 to 15 acres depending on the topography and the number of trees per acre. Contract specifications also preserved snags, other conifers, hardwoods, and approximately four live juniper trees per acre. The snag and tree provisions were incorporated to reduce visual impacts after heated protests against the project from environmental groups. The leaving of four live trees per acre has not seemingly reduced the total understory vegetative response but does leave a fairly uniform seed source for future reinvasion of juniper seedlings.

Wildlife considerations, primarily mule deer cover areas, were altered from those recommended by the Oregon Department of Fish and Wildlife. They requested approximately 25 percent of the area be segregated into 2 to 5 acre leave areas to help meet mule deer cover requirements. Although total acreage of leave sites closely approaches the desired percentage, the acreage in each leave area was much larger, as previously mentioned.

Major reasons for this diversion were the cost of layout and possible confusion for contractors. Mixtures of irregular leave areas and several colors of flagging develops into a maze for some contractors and a continual supervision problem for the contract administrator.

Advantages and Disadvantages

Problems encountered have been far from crippling, but do present a dollar outlay and should be considered in future project work.

1. Available labor force almost necessitates winter work schedules (winter mill and logging layoffs).

2. Winter projects make effective kills more difficult because snow covers smaller trees and makes falling larger trees difficult.

3. Work days are shorter in winter and more physically demanding.

4. Access to projects is more difficult in the winter. Muddy conditions can also create erosion problems.

5. Down trees present a problem of aesthetics.

6. Down trees draw woodcutters who travel throughout the project increasing soil disturbance.

7. A leave of four live trees per acre is hard to administer and difficult for contractors to judge.

8. Frequency of uncut seedlings, and recovery and regrowth of cut trees is consistently high.

9. Establishment of juniper is obvious on most sites within 2 to 3 years. Transects in cuttings completed in 1973 revealed from 300 to 500 live stems per acre, including seedlings and trees that were felled but not killed during the original project.

10. Maintenance costs to kill establishing juniper, if done by hand, can be very high.

Observed and documented advantages of using the hand cutting debris-in-place method is hard to reference in the literature. Several articles allude to this type of work but little has been recorded outside of chaining, cabling, and dozing (West 1975). Some observations and study results that have been identified as positive developments using the debris-in-place method are:

1. Desirable understory vegetation for watershed protection and livestock forage increased. Studies done by BLM on the Long Hollow thinning, after the third growing season, indicated a vegetative increase from 61 pounds per acre to 357 pounds per acre. Other areas have indicated even greater responses.

2. Data collected to date indicate the primary project objectives of increased litter and vegetation are being accomplished. Ground cover percentages on project site transects versus uncut juniper areas were as follows:

	Vegetative	Litter	Rock	Bare Ground
	- - - - - - - - - - -	percent	- - - - - - - - -	
Natural Woodland	5 (includes JUOC overstory)	30	4	61
Thinned	30	38	4	28

The above data shows a total ground cover increase from 35 percent to 68 percent. The increase is even more impressive considering that a large percent of the total vegetation in the untreated area is juniper.

3. Debris-in-place removes an insignificant amount of area from production as compared to windrowing in chainings, where up to 40 percent of the land surface is covered, such as in Nine Mile Ridge double chaining.[3]

4. Down trees provide protection for plants from grazing animals, providing a seed source for revegetation.

5. Tree branches provide mechanical barriers slowing runoff.

6. Destruction and disturbance of existing vegetation is minimal.

7. Hand cuttings increased habitat for small mammals. Small mammal trapping data collected by the BLM in the summer and fall of 1976, on thinned and unthinned sites, revealed twice as many species in the thinned sites (six) as in the unthinned (three). There were also 60 percent more individuals trapped in the thinned sites than in the control. Small mammal winter track counts conducted in the same areas reflected a parallel to the trapping data. However, overall net benefits to wildlife are still unknown.

8. Winter bid schedules receive more interest, resulting in more competitive bidding.

9. Available work force generally includes timber workers experienced in the use of chainsaws.

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[3] Roberts, op. cit.

10. Down trees and increased vegetation create a situation, seemingly desirable, for control of juniper by controlled burning.

11. Down trees provide mule deer with a food source after needles lose their volatile oils. Usability lasts until needles lose their color and begin to fall from the stem. The period varies with the time of year trees are cut.

SUMMARY

For the past 10 years, papers have been written concerning the vegetative and hydrologic responses to juniper manipulations performed in western States. In most reports, favorable results were shown for increased production of food for livestock and wildlife. Increased AUMs for livestock have been well documented in most juniper control project reports, and livestock benefits are virtually unquestioned. Based upon increased production of vegetation and some observed use of this vegetation by mule deer, great benefits to mule deer and most other wildlife have been assumed. The assumption that equivalent or parallel benefits for livestock and wildlife result from juniper manipulation has not been made. Therefore, for this workshop to develop multiple resource juniper management guidelines, we must rely on the known physiological and sociological requirements of wildlife. Three papers in this workshop are addressed to these requirements in juniper communities for our consideration and use. If we were to design a juniper manipulation specifically to improve wildlife habitat, our principal aims should be: Quality and quantity of food plants, habitat diversity, and retention of required cover.

Points to Consider

1. It was consistently noted with each mechanical manipulation of juniper performed, regardless of the method, results were only partial control. If it is determined both economically and ecologically to have complete juniper control, for better resource management, mechanical methods currently employed are inadequate.

2. It was apparent that chainsaw cuttings, especially after one to two growing seasons, were in a burnable condition. This leads us to consider the combination of mechanical treatment and burning as a more efficient and complete method of control.

3. Crested wheatgrass was shown to provide the greatest contribution to forage production, of all species seeded, in juniper manipulations.

4. Bitterbrush has been successfully established in several juniper control projects. It appears, however, that bitterbrush cannot attain a stature necessary to contribute significantly to the volume of available forage with yearly livestock grazing and current wildlife use. Fourwing saltbush has demonstrated some possibility in this respect.

5. Observations of utilization by deer and livestock of released vegetation indicate improvements in palatability.

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FIRE MANIPULATION AND EFFECTS IN WESTERN JUNIPER (*Juniperus occidentalis* Hook.)

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ABSTRACT

Fire has long been part of juniper, shrub, and grass ecosystems. Lightning and Indians were responsible for fires, and juniper generally was less common than today, judging from written reports of early explorers and settlers, and from early photographs (Johnson and Smathers 1976).

What is the relationship of western juniper to fire? How easily is juniper killed by fire? Under what conditions can we burn in western juniper? Survival data of western juniper by size class following four burning prescription levels are given in the paper. Other information on the relationship of western juniper to fire are inferred from work by others in western and other juniper species.

Keywords: Juniper, western juniper, fire, prescribed burning, range, Juniperus, mortality.

FIRE AND WESTERN JUNIPER

Fire will generally retard ecological succession of communities that would move toward a climax of juniper (*Juniperus occidentalis* Hook.) (Adams 1975; Burkhardt and Tisdale 1976; Johnson and Smathers 1976; Martin and Johnson 1978[1]). Other papers in this volume cover more

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[1] Martin, R. E., and A. H. Johnson. 1978. Fire management of Lava Beds National Monument. Paper presented at the 1st Conference on Research in the National Parks. Natl. Sci. Found. and Natl. Park Serv., New Orleans, November 1976. In press.

completely the ecological relationships between fire and juniper. In the early stages of succession when trees are small (less than 6 feet, or 2 meters tall), it is easiest to control the amount of juniper with fire. As trees become larger, more intense fire is generally needed, both to get the fire to spread and to kill the trees. If a site has gone to an essentially closed stand of juniper, it is extremely difficult for us to use fire in the stand under any conditions in which we're willing to burn.

Hall (1973) and Volland (1976) cite several plant communities which may move toward juniper dominance without the disturbing influence of fire or similar agent. We might generalize this in a diagram of ecological succession (Figure 1). In the pioneer stage, grasses and forbs generally dominate. Rabbitbrushes (*Chrysothamnus* Nutt.) and horsebrush (*Tetradymia canescens* DC.) may be common, depending on their frequency before burning and availability of seed after burning (Johnson and Smathers 1976, Martin and Johnson op. cit.). As succession proceeds into the seral stages, sagebrush (*Artemisia tridentata* Nutt). and bitterbrush (*Purshia tridentata* (Pursh.) DC.) may become dominant, depending on the site. Grasses generally become less prominent, and composition may change from the pioneer types such as bottlebrush squirreltail (*Sitanion hystrix* (Nutt.) J.G. Sm.), to the wheatgrasses (*Agropyron* spp. Gaertn.) and fescues (*Fescue* spp. L.). Heavy grazing may enhance movement toward shrub and juniper dominance and also reduce the frequency and cover of wheatgrass and fescue in favor of the pioneer grasses or the exotic cheatgrass (*Bromus tectorum* L.). Juniper now appears as scattered trees of varying sizes and ages.

With time, succession would probably proceed to a juniper-dominated climax in which the shrubs and grasses are very much subdued. The juniper stand may now be very resistant to fire except under severe fire conditions. Even light grazing tends to keep the grasses at such a low level that very little fuel exists to carry a fire from one tree to the next.

PREVIOUS WORK

Burning prescriptions to accomplish various management objectives in juniper trees are not well developed, but general guidelines for prescribed burning in range, shrub, and juniper types have been developed. In the Southwest, Jameson (1962) reported 70 to 100 percent of the small juniper killed by fire in his study. Dwyer and Peiper (1967), working in New Mexico, found that fire killed all pinyon-juniper less than 4 feet (1.2 m) tall, but killed 24 percent of the pinyon and 13.5 percent of the juniper taller than 4 feet (1.2 m).

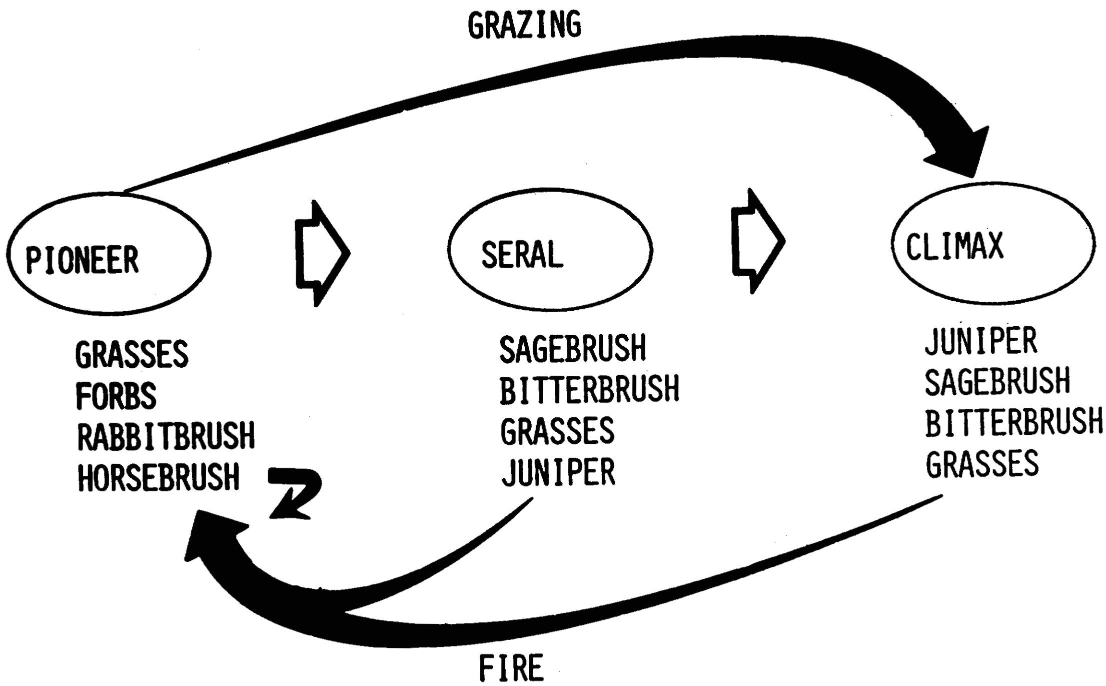

Figure 1.--Ecological succession in many juniper habitats would move from pioneer grass and forb dominated communities through shrub dominated seral stages to a juniper-dominated climax. Heavy grazing may hasten succession, and fire will generally return succession to the early stages.

Dalyrymple (1969), according to Wink and Wright (1973), obtained ashe juniper (Juniperus ashei Buchholz) mortalities of 100 percent in trees less than 2 feet (61 cm) tall, 77 percent in trees 2 to 6 feet (61 to 183 cm) tall, and 27 percent mortality in trees over 6 feet (183 cm) tall when burning in 500 to 1000 lbs/acre (560 to 1120 kg/ha) of herbaceous fuels. The overall average mortality was 68 percent.

Aro (1971) discussed several aspects of pinyon-juniper control. He recommended burning as the most effective and economical means of manipulation. Dozing trees into windrows and seeding grasses was the most effective mechanical treatment with 95 to 100 percent kill. Single chaining killed an average of 30 percent of the trees, and double chaining, 60 percent (see paper by Winegar and Elmore for mechanical treatment of western juniper). Aro also reported one site produced 1300 pounds of grass per acre (1460 kg/ha) after burning compared to 100 pounds per acre (112 kg/ha) on the unburned area.

Wright (1972, 1974) developed prescription limits for burning several range types with and without juniper in Texas. His 1974 publication outlines procedures for setting up and conducting prescribed burns. He recommends burnout of a 400-foot (120 m) strip of grasses and piled juniper on the downwind side under very moderate burning conditions before burning a unit. Relative humidities of 45 to 60 percent are used for burnout and 25 to 40 percent for the main fire. Recommended winds range from 8 to 10 mph (13-16 kph) for burnout and 8 to 15 mph (13 to 24 kph) for the main fire.

Wink and Wright (1973) report that where 1000 kg/ha (900 lb/ac) of fine herbaceous fuels were present only 1 of 368 ashe juniper trees less than 1.8 m (6 ft) tall survived prescribed burns. Many larger trees were killed by the fires, and when 2240 kg/ha (2000lb/ac) of fine fuels were present, kill was obtained on all trees present. They did not give percentages of mortality.

Blackburn and Bruner (1975) reported on burning in pinyon-juniper types in Nevada. Pinyon-juniper crown cover was 27 and 13 percent of the total area and about 53 and 34 percent, respectively, of total plant cover. Burning was conducted in November with temperatures of 11 to 12° C (52 to 54° F), relative humidities of 26 and 27 percent, winds of 5 to 19 kph (3 to 12 mph). Bruner[2] has used

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[2] Bruner, A. D. 1977. Personal communication. Univ. of Nevada, Reno.

the sum of air temperature, windspeed, and plant cover percent to predict fire spread.

Martin and Johnson (op. cit.) have used winds of 5 to 19 kph 3 to 12 mph) and recommended relative humidities of 15 to 25 percent for burning in western juniper-sage-grass types. Martin and Dell[3] discuss general prescribed burn planning in the Inland Northwest. Frandsen[4] is working with fire spread predictions in pinyon-juniper types occurring in Nevada, where others have used a summation of air temperature (°F), windspeed (mph), and plant cover (percent) to predict fire spread and intensity.

We might consider two extremes which limit our use of fire in western juniper. On the one end, fire will not spread consistently because spaces between fuel concentrations, such as spacing between bunchgrass plants or shrubs, are too great for flame contact to occur and spread the fire. As wind and the amount of available fine fuel in each concentration increase, both the probability of spread and the rate of spread increase. Increases in spacing relative humidity will reduce probability of spread and the rate of spread. Thus, in well stocked bunchgrasses with dead fuels in the bunches, fire will spread under more moderate conditions than it will when spacing is greater, or the grasses are grazed. As we move to the wider spacing usually encountered in shrubs and finally juniper, both higher wind and lower relative humidity are needed. Often, the conditions to burn juniper stands with little grass understory are so drastic (e.g., 35 mph or 55 kph wind) that we would not want to risk burning.

EFFECT OF FIRE ON WESTERN JUNIPER

Our documented prescribed burns in western juniper represent only a limited range of fuel and weather conditions (Table 1), but they provide a basis for managerial use of fire to improve range and reduce juniper (Figure 2). The curves are drawn as percent survival on the vertical scale versus height of juniper on the horizontal scale. The four curves represent survival of juniper the first year after fires under four ranges of conditions. Fuel amounts were similar in

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3 Martin, R. E. and J. D. Dell. 1978. Planning for prescribed burning in the Inland Northwest. USDA For. Serv. Gen. Tech. Rep. In Press.

4 Frandsen, W. H. 1977. Personal communication. Northern Forest Fire Laboratory, Missoula, Mont.

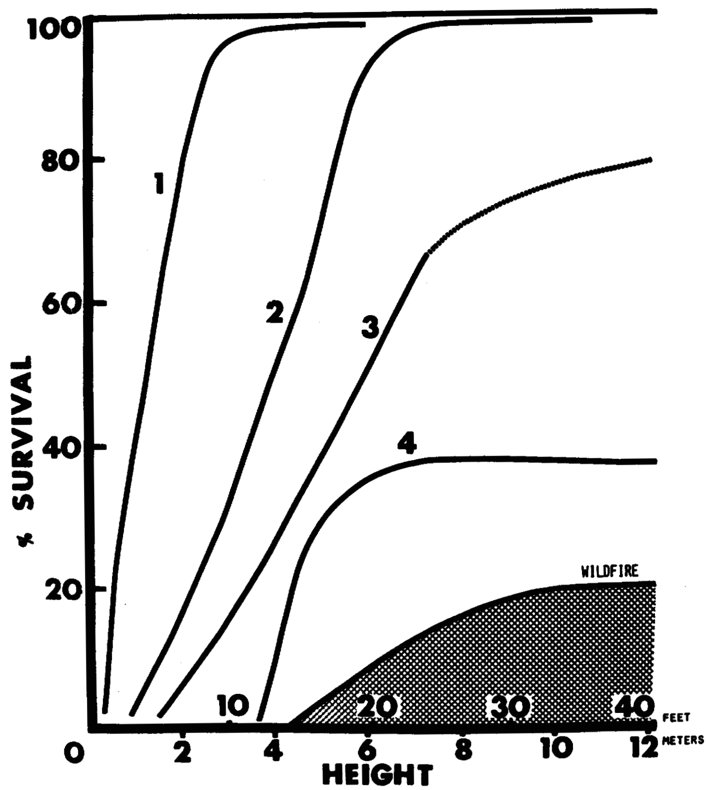

Figure 2.--First year survival of western juniper following four prescribed burning conditions as given in Table 1. Under conditions 1 and 2, survival of larger junipers was nearly 100 percent, whereas only 73 and 37 percent of the larger trees survived the more severe conditions of fires under conditions 3 and 4. General observation of wildfires indicates less than 30 percent survival in most fires.

all areas, and ranged from 1.4 to 4.3 tons per acre (3 to 9 metric tons per hectare) primarily of bunchgrasses, sagebrush and bitterbrush. Some cheatgrass, rabbitbrush, and forbs were also present. Grasses contained high percentages of dead material which provided for fire spread and heat to scorch or ignite juniper crowns.

In all conditions, survival of bunchgrass plants was high, 80 percent or more in the drier burns and almost 100 percent in the wetter burns. Percent cover of grasses was reduced 30 to 50 percent in the first year. Sagebrush in burned areas was killed, as was most gray rabbitbrush (*Chrysothamnus nauseosus* (Pall.) Brit.). Most green rabbitbrush (*C. viscidiflorus* (Hook.) Nutt.) was not killed. On burns with high soil moisture, up to 30 percent of bitterbrush sprouted, but never more than 10 percent were left the second year.

Condition 1 was a backing fire under very moderate burning conditions (Table 1). Only small trees were killed consistently by the backing fire, and almost all trees in the 6 to 10 foot (1.8 to 3 m) height class and larger survived.

Fire condition 2 also represents a backfire, but temperatures and winds were slightly higher than in condition 1. Grasses were more abundant, and a burning time in early September contributed to generally drier live fuel and soil moisture. Essentially all trees in the 16-20 foot (4.8 to 6.0 m) height class and larger survived.

Fire condition 3 represents headfiring under slightly more drastic burning conditions. Temperature has increased and humidity decreased from the backfires in condition 2. The season is also early September in the same habitat type as 2. In this condition, essentially all trees in the 1 to 5 foot (0.3 to 1.5 m) class have been killed. Survival of trees greater than 6 feet (1.8 m) tall is roughly proportional to their height. The average highest survival is 73 percent for trees in the 21 to 26 foot (6.3 to 7.8 m) class, but no trees larger than this were present. Probably increased height would not have increased survival substantially, as tree crowns would still have been completely scorched or consumed by the fire.

Condition 4 represents the most severe conditions for which we have any documentation. The season was July with high temperature and very low humidity. Essentially all trees below 15-foot (4.5 m) height were killed, and survival averaged 37 percent in the classes above 16-foot (4.8 m) height. The relatively constant survival of larger size classes indicates that the probability of scorching or consuming the crown of junipers remained about the same.

Table 1.--Prescribed burning conditions related to juniper survival in Figure 2

Conditions		Line number 1	2	3	4
Type fire		Backfire	Backfire	Headfire	Headfire
Temperature	°F	70	70-75	75-85	80
	°C	21	21-24	24-29	24
Wind	mph	5-10	5-10	5-10	5-12
	kph	8-16	8-16	8-16	8-19
Gusts	mph	15	13	15	15
	kph	24	21	24	24
Relative humidity	(%)	25-30	25-30	18-20	10
Habitat type		Juniper/big sagebrush/ bunchgrass	Juniper/big sagebrush/ bunchgrass	Juniper/big sagebrush/ bunchgrass	Juniper/big bitterbrush/ bunchgrass

All the sites reported here had good carrier fuels in the grasses and shrubs present. When juniper stands become closed and carrier fuels die out, or when grazing greatly reduces grass cover, fires will not spread readily except under severe fire weather conditions of high wind and low relative humidity. Burning at this time may be more hazardous than the manager will accept. One alternative is to use chemical or mechanical treatments alone or in conjunction with fire. A second alternative is to condition a wide barrier strip around the area so danger of escape is reduced. A third alternative is to build up carrier fuels by restricting or eliminating grazing 1 or 2 years prior to burning if shrubs and grasses are still present. The last alternative will not work in closed stands. It should be borne in mind that the lost grazing potential may be recovered rapidly in the years following burning. One should also remember that once the area is reclaimed for grasses, future burning should not require such severe weather conditions for fire spread.

SETTING UP A PRESCRIBED BURN

Prescribed burning involves skillful use of fire as planned to meet specific objectives on a given piece of land. Let's look at the different parts.

If you work for an agency, the discussion might begin when the range manager starts looking for ways to increase red meat production on Section 37 or the wildlife manager feels less juniper and more variety in habitat would increase numbers or variety of wildlife. The discussions may then widen to involve other disciplines. More specific objectives are set, such as:

> "Reduce juniper and shrub cover to 20 percent or less" (or to so many stems per acre).
> "Increase forage production to 350 pounds per acre."
> "Eliminate 90 percent of junipers under 10 feet in height."

Prescribing the fire to accomplish the objectives will take some time, and presently we need more data on successful prescriptions. The data in Table 1 and Figure 2 should be helpful.

Eventually, you should develop prescribed burning plans that fit into your total land management planning. These plans will involve many resources and a long-range program of how much you'll burn under what conditions to accomplish what objective.

Next, define the area in which the prescribed burn will take place. Up to this time, discussions may have been general such as prescribed burning of Section 37 (Figure 3A). Now, using maps, aerial photographs, and the manager's knowledge of the area, detailed boundaries can be set up. Vegetation should be mapped if not already done. Information should be marked on maps, then checked in the field and lines flagged (Figure 3B). Special leave areas which are not to be burned and line problems should be noted. Type of line construction and specifications for lines should be stated. Where possible, existing roads, rocky outcrops, trails, and easy line-building areas should be used. Where line-building is necessary, manual, mechanical, or wet-line techniques (Martin et al. 1977) may be used, the latter techniques being least expensive and non-damaging to the landscape.

Develop a map of the area, indicating all fire lines, special problem areas, firing pattern, and holding crew locations (Figure 3C). Since most areas can be burned under a range of conditions, you might prepare a series of maps with different firing and holding crew plans.

Using a form to consider all aspects of planning, operation and evaluation is very helpful. A planning sheet such as that offered by Martin and Dell (op. cit.) can be helpful.

It's important to begin planning Environmental Analysis Reports early so approval can be granted. The EAR also helps you to discover new facets of fire effects you should be considering in your prescription.

You decide your objective will be to remove 60 to 90 percent of the juniper under 15 feet (4.5 m) but retain 90 percent of juniper over 15 feet (4.5 m). Another objective will be to save 90 percent of the bunchgrass plants.

From the objectives, you can use Figure 2 and Table 1 to arrive at prescription levels, assuming the fuels are similar. You decide on the following conditions.

Season	:	June or September
Precipitation	:	0.5 inch (1.3 cm) or more within week if September burn
Relative humidity	:	17 to 23 percent
Temperature	:	65-80° F (18 to 27° C)
Wind	:	5 to 12 mph (8-19 kph) Gust to 15 mph (24 kph)

The firing pattern will be to backfire 100 feet (30 meters) on the downwind side except where backed by lava flows (Figure 3D). Strip headfires will then be used to burn the next 100 feet (30 meters) and the southern fourth of the unit (Figure 3E). Finally, a headfire will be lighted to spread entirely across the unit (Figure 3F).

Holding and burning crews consisting of the following will be located as indicated on map.

2 - 200 gallon pumpers (T1, T2)
1 - 500 gallon pumper (T3)
2 - 10 man holding crews with hand tools
1 - weatherman
radios in vehicles and 2 for each 10-man crew
3 - burners with drip torches and radios
1 - burning boss

As burning progresses, you'll move your crews so they're in better position should trouble occur (Figure 3D-F).

More details could be put in here, but consulting other publications, observing prescribed burns, and assessing one's own needs by beginning with smaller fires will probably be more useful. Evolving different plans can eventually lead to more effective, less expensive burning.

You've decided on a specific piece of land for burning, decided on prescribed burning objectives to meet overall land management goals, and have planned the burn. The prescribed conditions have arrived, so it's now time for your skillful application of fire. It has to be just that! You'll first want to try a small test fire where you'll begin backfiring (Figure 3D). If the fire fails to spread satisfactorily, you will have to postpone burning until the fuels dry some--later in the day or week. When conditions are too wet or calm, you may spend all day trying to burn and never get an adequate fire. If the fire spreads too rapidly, tends to spot, or consumes too much fuel, put it out. These conditions may be too dangerous for prescribed burning or damaging to the vegetation and soil. It's generally less expensive in the long run to wait for conditions to give you the fire you want. Remember, the fire is the final integrating factor of all the elements in the prescription.

If you decide to keep burning, adjust your burning to get the fine tuning you want. Once you have a black line established, perhaps you can go to very narrow strip headfires to speed things up and keep costs down. Be sure the fire is what you want. Keep watching it. Don't speed up to save money or because you're impatient--and in doing so fail to meet your objectives. Also, don't mechanically follow through your plan; adjust as conditions and fuels change. Remember--skillful application!

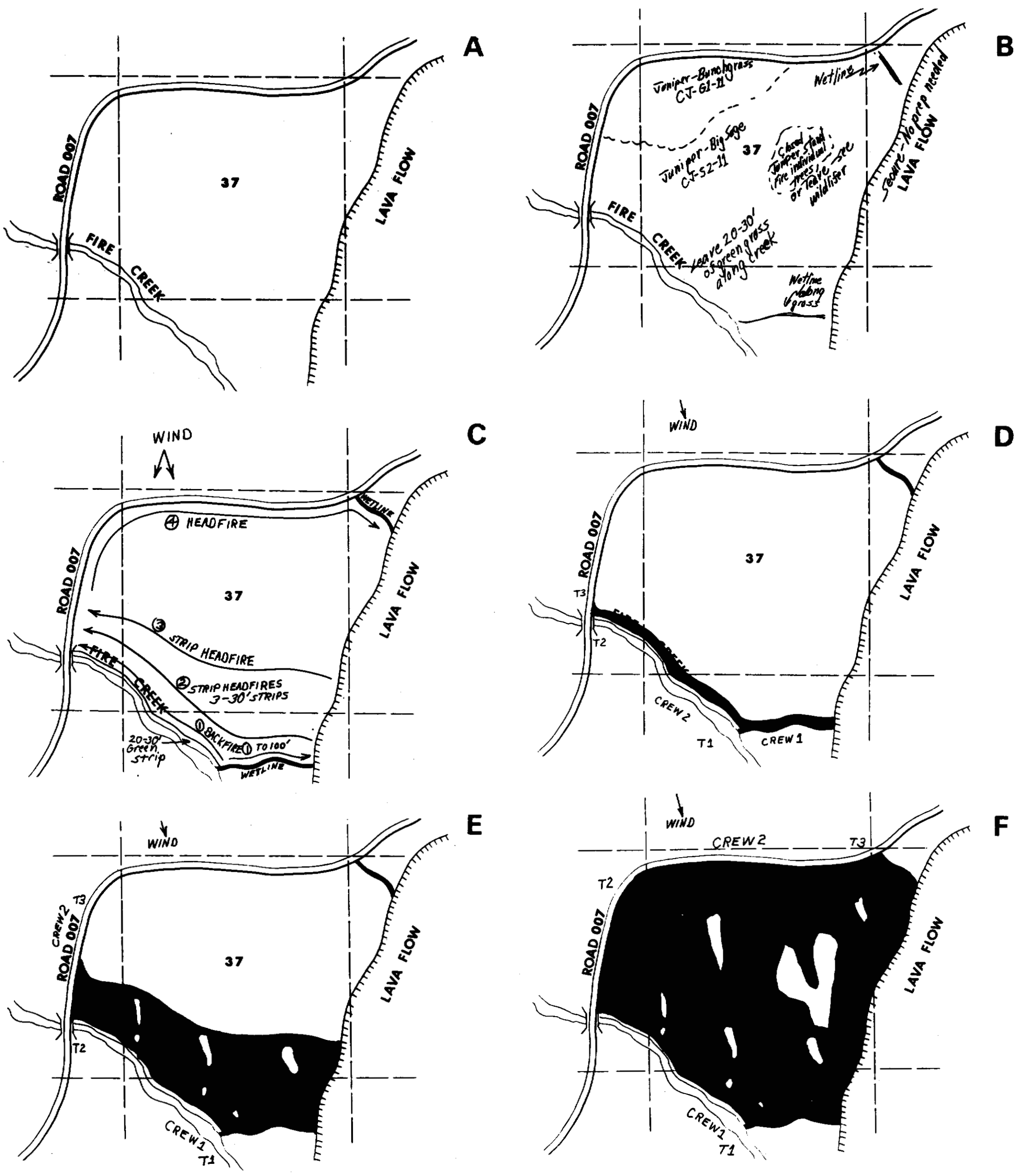

Figure 3.--Progression of planning and executing a prescribed burn. (A) General map of area to be burned. (B) Field reconnaissance of vegetation, fireline locations, and special problems has been conducted. (C) Prescribed burning plan has been developed and mapped. (D) After briefing, final weather check, and test fire, the downwind line has been backfired. Holding crews and tankers are at south edge of unit. (E) Strip headfires have been used to provide a secure line: some interior areas have not burned, as expected and desired, but present no fire control problems. (F) Headfire has been used to burn out entire unit. Holding crews and tankers have been moved to new positions. Unburned areas will provide habitat diversity for wildlife.

COSTS OF PRESCRIBED BURNS

Costs of prescribed burning can be quite variable, depending on conditions. Beginning a prescribed burning program in range areas is much cheaper than beginning in timbered areas. As crews are trained and develop experience, and as the areas to be burned become better conditioned, costs drop dramatically.

Costs should include those for planning, preparing, and conducting the burn. Early in a program planning, costs will be high; however, once a plan for a district or large area involving several sequencing burn units is developed, only minor adjustments in the plans may be necessary. Preparation for burning will decrease as more effective techniques are developed. Old burning lines may be used for subsequent burns with only minor reworking. Even where new lines are made, difficulty in constructing the lines may be easier because of less fuel and better accessibility. Costs of conducting the burn should drop because of training and experience, lower fuel load, and lower chance of escape, or of damage should escape occur.

Costs of burning given by various individuals and organizations vary due to factors considered, pay scales, size and condition of areas, and the stage of burning program. Where mechanical treatment is needed in closed stands, costs will be much higher (see paper by Winegar and Elmore in this volume). For a well-established program of range burning where fine fuels will carry the fire, costs should be under $1 per acre. Little revision of plans is necessary, firelines are established, fuel-loadings are not high, crews are trained, and danger of escape is low. All these factors contribute to lowering costs.

MANAGEMENT GUIDELINES

Based on what has been presented here and in other papers, we can make some general statements concerning what is presently available for managers who wish to use fire in manipulating western juniper.

1. Prescribed burning can be used inexpensively and effectively to control western juniper encroachment.

2. Conditions and data given in Table 1 and Figure 2 can be used as preliminary guides for prescribing fires in western juniper types where herbaceous plants and shrubs will carry the fire. Experienced fire personnel should conduct the burning.

3. Prescribed burning entails:

a) Describing piece of land and its boundaries.

b) Defining prescribed burning objectives to meet land management goals.
c) Setting prescription and planning to meet objectives.
d) Skillful and observant application of fire.

4. Costs are variable, but drop dramatically as prescribed burning programs develop. Costs range from less than $1 per acre to over $10 per acre for range burning.

RESEARCH NEEDS

Although general information is available concerning the effects of fire on western juniper communities, there is need for specific effects of fire on the soils, plants and animals in these communities. We also need to know more about the fuels, fire behavior and fire prescription in juniper communities. I would list research needs as follows:

1. Effects of fires on juniper under a wide range of prescribed burning conditions.

2. Effects--short and long-term--of fire on associated vegetation under a wide range of burning conditions.

3. Develop prescriptions and methods for burning juniper, perhaps in conjunction with mechanical treatment, where little or no carrier fuel exists between trees.

4. Develop biomass estimates and fuel characteristics for western juniper.

5. Develop estimates of the effect of juniper on growth of associated species.

6. Describe the effects of prescribed fires on soils, nutrients, water, and air in western juniper ecosystems.

7. Describe the effects of prescribed fires on various wildlife species.

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WESTERN JUNIPER MANAGEMENT FOR MULE DEER

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ABSTRACT

As managers of the western juniper woodland, we need flexibility to meet the changing needs of society. We should adopt rationales that dictate management prescriptions which preserve the ecosystem even though our goal is to benefit a featured species such as mule deer. Effective planning and implementation must draw upon interdependencies among behavorial and physiological requirements of animals, preserved diverstiy of plant communities, and the multiple-use sustained-yield concept. In order to effectively manage habitat for a deer herd, the needs of the subpopulation and the individual respectively must be met within the home ranges they traditionally occupy. Annual cycles of reserve storage and depletion document how well habitat quality meets the daily physiological requirements of mule deer. Occupancy of habitats by deer illustrates how management for preserved diversity of plant communities and successional stages will provide options that maintain or enhance productive survival of mule deer subpopulations; forage quality helps deer endure weather stresses; structure of cover types diminishes the severtiy of weather. Though commonly considered to be browsers, deer are in fact opportunistic foragers; they eat the best that is available under prevailing conditions. Browse is not digested quickly enough to compensate for energy losses due to severe weather stress; at such times, cover becomes critical because it helps lessen drains on body reserves. Since the microclimate can be predicted from vegetation height, crown closure, crown depth, stem size, and stem density, cover quality can be measured. If knowledge is sufficient to indicate that juniper control is necessary, created openings should average between 5 and 10 tree heights in width, but should not exceed 120 meters. Managers should plan for about 40% of the subpopulation range in cover and 60% in forage areas. The relative values of cover and forage must be carefully weighed when management decisions are made. To approach mutiple-use management of the western juniper woodland, we need to simultaneously consider the multitude of products and their many

interdependencies which constitute the ecosystem. Future research should address those facets of the system which are now vaguely perceived.

Keywords: Western juniper, mule deer, subpopulations, behavior, physiology, microclimate

INTRODUCTION

One of our obligations to future generations is to preserve options that we may think are not viable. We all face problems today which did not exist 15 years ago. We, as managers, need flexibility to meet the changing demands of society. By preserving our management options (Bella and Overton 1972) we gain the flexibility required for responsible, long-range management of western juniper (*Juniperus occidentalis*)[1] communities. We should develop rationales that lead to management prescriptions which preserve the ecosystem even though our goals are to benefit a featured species mule deer (*Odocoileus hemionus hemionus*). We should examine rationale behind each program and determine why it is desirable for mule deer management over the long run. I will present such a rationale and prescription for management of western juniper communities to meet the requirements of mule deer. To be effective, planning and execution must address the following: 1) behavioral and physiological needs of deer, 2) diversity of plant communities, and 3) multiple-use, sustained-yield concepts. The following discussion is an interpretation of the literature, plant communities, and mule deer which constitutes a rationale for management of western juniper communities for the benefit of deer.

We traditionally think of herds and ranges of deer, but we should think of mule deer subpopulations (Leckenby a., in manuscript) and the parts of the ranges they traditionally and exclusively occupy. Basically we can not effectively manage habitat for the entire herd unless the needs of the individual and the subpopulation are met.

Deer in general exhibit an annual cycle where nutrient storage precedes reserve depletion. Animals are exposed daily to variable periods of energy gain, balance, and loss due to the interplay between forage quality and weather stress. Severity and length of weather stress are diminished by plant community structure, but each community protects deer only within a limited range of conditions. Since the value to deer of each community changes with weather severity, habitat diversity is insurance against the uncertainties of weather. Their use of habitat illustrates how managing for diversity of plant communities will preserve options for maintaing or enhancing productive survival (Leckenby a., in manuscript; Leckenby and Adams, in manuscript) of mule deer subpopulations.

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[1] Plant names according to: Hitchcock, C. Leo and Arthur Cronquist, 1973. Flora of the Pacific Northwest, an Illustrated Manual. Univ. of Washington Press, Seattle and London, 730 p.

To benefit mule deer and justify management efforts, programs for western juniper communities should include the following points: 1) We should examine how all resources in the area will be affected over time. 2) We should focus on subpopulation home ranges as the basic management unit. 3) We should adopt the plant community and successional stage as a habitat planning unit. 4) We should seek to maintain or enhance plant community diversity within each basic management unit. 5) We should focus on each vegetation stand as a treatment unit. (Vegetation stand is defined as the concrete example of a plant community as observed in the field; stand is not used in the traditional sense, i.e., a forest stand (Figure 1). 6) We should manipulate only where knowledge shows what is specifically lacking--forage, cover, or both. 7) We should first examine the option to maintain or enhance forage without altering the structure of the original vegetation stand. 8) If that option (i.e. 7) is not viable, then in order to retain management flexibility which can accommodate future options, we should leave enough of the vegetation stand untreated to maintain its essence. 9) We should make treatment widths multiples of tree heights and manage for a minimally acceptable level of energy stress over time.

Research is needed to increase predictibility and effectiveness of western juniper management for benefit of mule deer.

RATIONALE FOR MANAGEMENT

Requirements of mule deer should be examined and provided for if management of western juniper is to be beneficial. A management unit should be large enough to accommodate the behavioral patterns of a subpopulation. Size, interspersion, composition, and structure of plant communities within management units should accommodate the deer's physiological traits. Management should provide for community diversity to meet varying forage and cover requirements of deer throughout the seasons. To attain maximum benefit from vegetational manipulation, structural features of communities should be preserved.

Subpopulations and traditional ranges

Habitual behavior confines subpopulations to their traditional areas even though better habitat may exist in other parts of a seasonal range. Of 300 plus deer marked on the Silver Lake and Fort Rock winter ranges between 1959 and 1969, about 90% of the retrappings and sightings were made within two miles of the initial capture site (Leckenby a., in manuscript). Locations of marked deer, extremes over the years, were aligned across elevational contours and were concentrated in a small area, about one and one-half by four miles (Figure 2). Sightings of individuals within years further emphasized fidelity for specific areas of the winter range (Figure 3). Research conducted elsewhere in Oregon and other states presents evidence compatible with subpopulation and traditional range hypotheses (Bright 1966, 1967; Cronemiller and Bartholomew 1950;

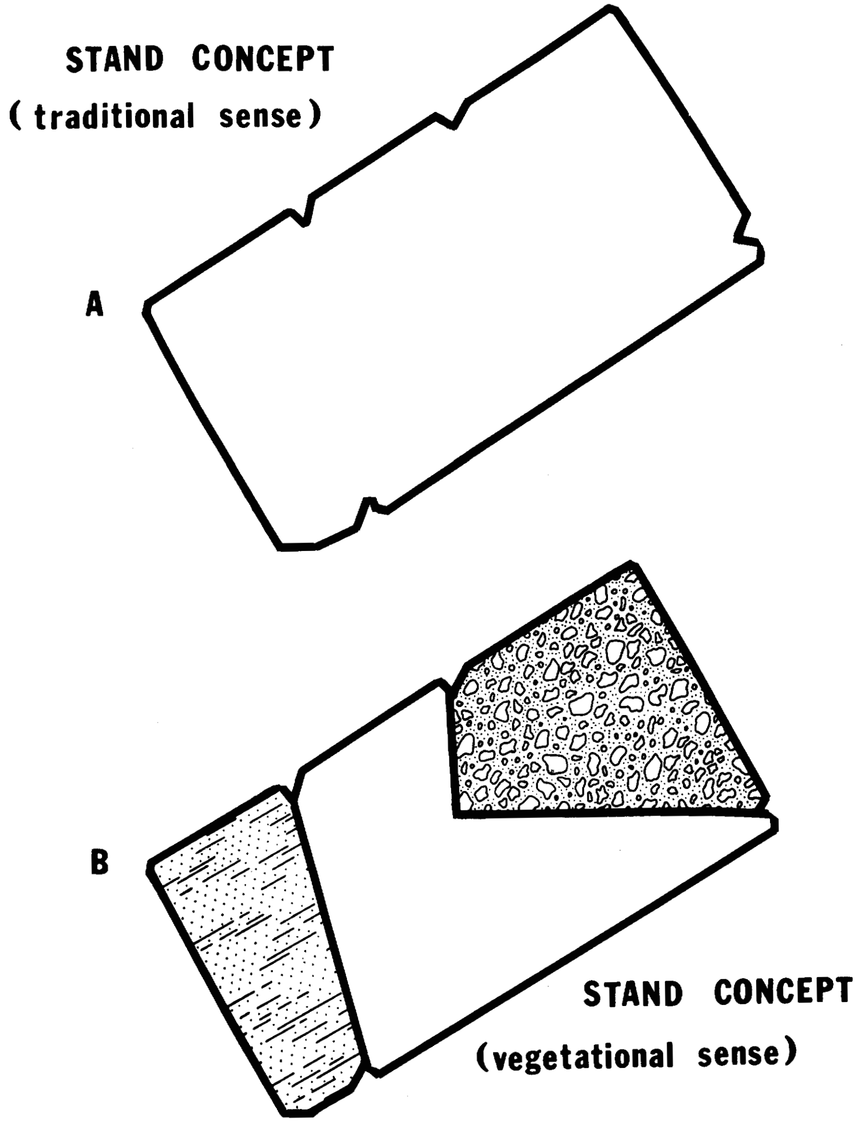

Figure 1. A woodland stand in the traditional management sense consists of a continuous grove of trees (A). The same woodland stand in the ecological sense generally contains vegetation stands which belong to different plant communities (B).

Dasman and Taber 1956; Gruell 1958; Linsdale and Tomich 1953; Mackie 1970; Murie 1940; Terrel 1973; Wallmo and Gill 1971; Zalunardo 1965).

Subpopulation home range appears to be a discrete unit within which to manage western juniper for deer on winter and summer ranges; each should be mapped separately. Management for each subpopulation should

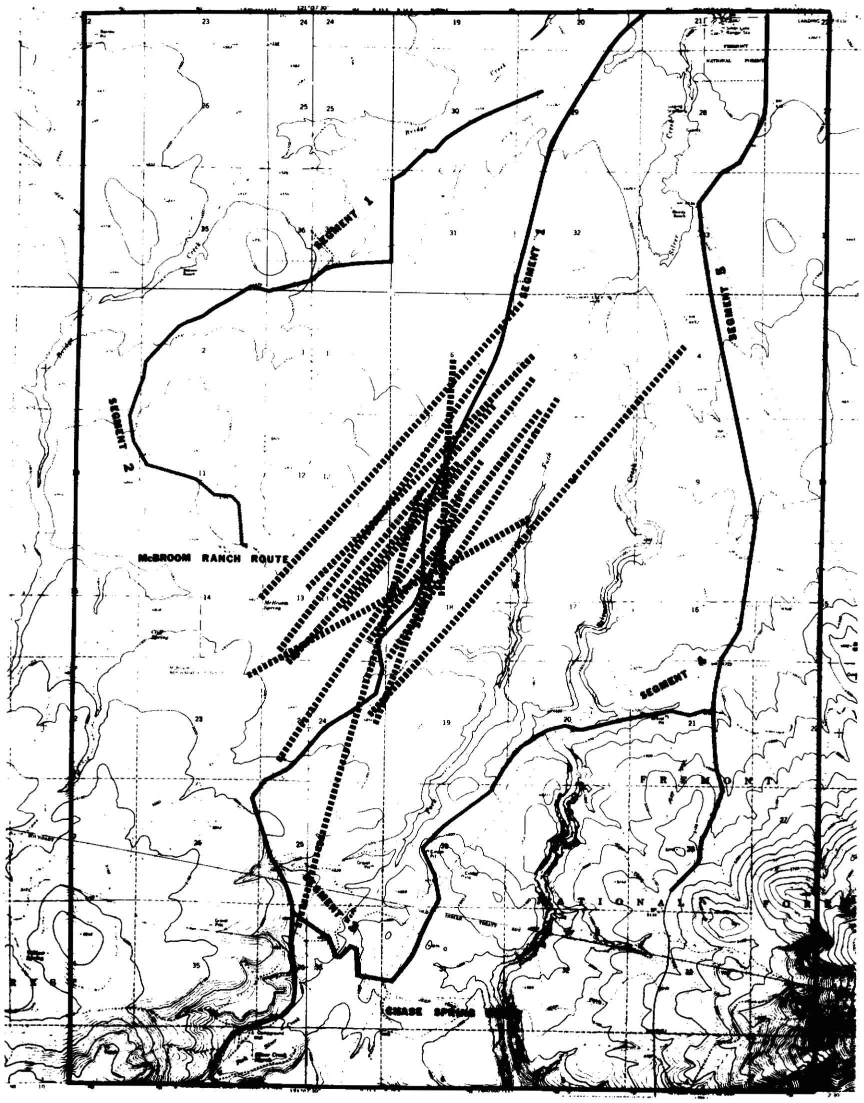

Figure 2. The size and location of a mule deer subpopulation winter range is suggested by the greatest linear distance between sightings for several individual deer. Although only the extreme locations are connected, there are more than two sightings for each individual.

maintain plant community diversity over time in order to accomplish the following: 1) to preserve management flexibility that can accommodate future options, 2) to accomplish multiple-use objectives as dictated by law, and 3) to provide for physiological needs of deer within subpopulation ranges.

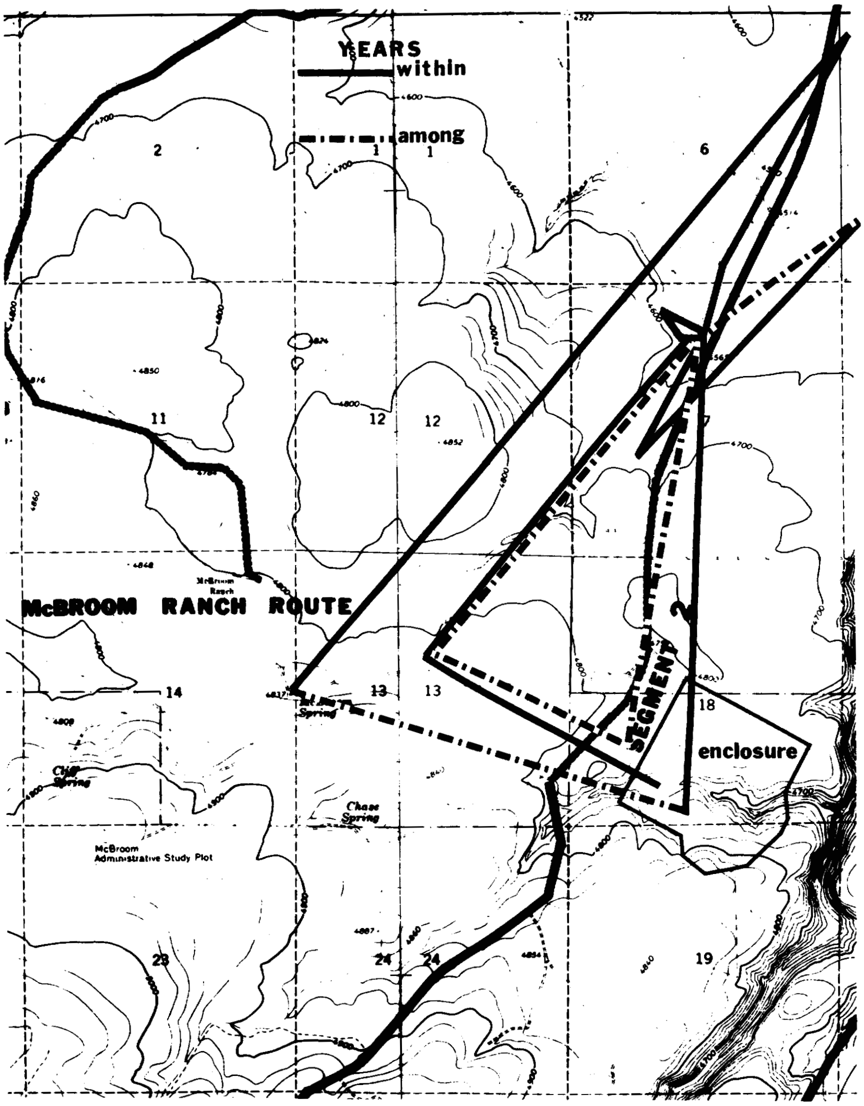

Figure 3. Individual mule deer returned to a subpopulation range for several years. They frequented the entire area, but showed centers of concentrated occupancy.

Physiological responses

Productive survival of a mule deer subpopulation is dependent upon how well and how often physiological needs of the individuals are met. Dead deer do not contribute to population growth; they contribute to the ecosystem only by recycling of nutrients. There are, however, various levels of aliveness (Moen 1973). 1) A deer may be barely surviving (not contributing to maintenance of a subpopulation) and thus only using resources from the ecosystem. 2) A deer can be maintaining itself and contributing to the subpopulation because it reaches sexual maturity in two years instead of three and it may successfully produce one fawn where the first deer produced none. 3) An idividual may be doing well and is maintaining the subpopulation because it reaches sexual maturity in one year and produces three fawns. This scale of aliveness illustrates what I term productive survival. In essence, the quality of the habitat determines the level of productive survival.

Mule deer follow an annual cycle of energy storage and reserve depletion caused by hormonal and nutritional balances (Wood et al. 1962; Wood and Cowan 1968; Robinette et al. 1973). Timing of the body-weight cycle is known to be related to breeding and lactation periods (Figure 4).

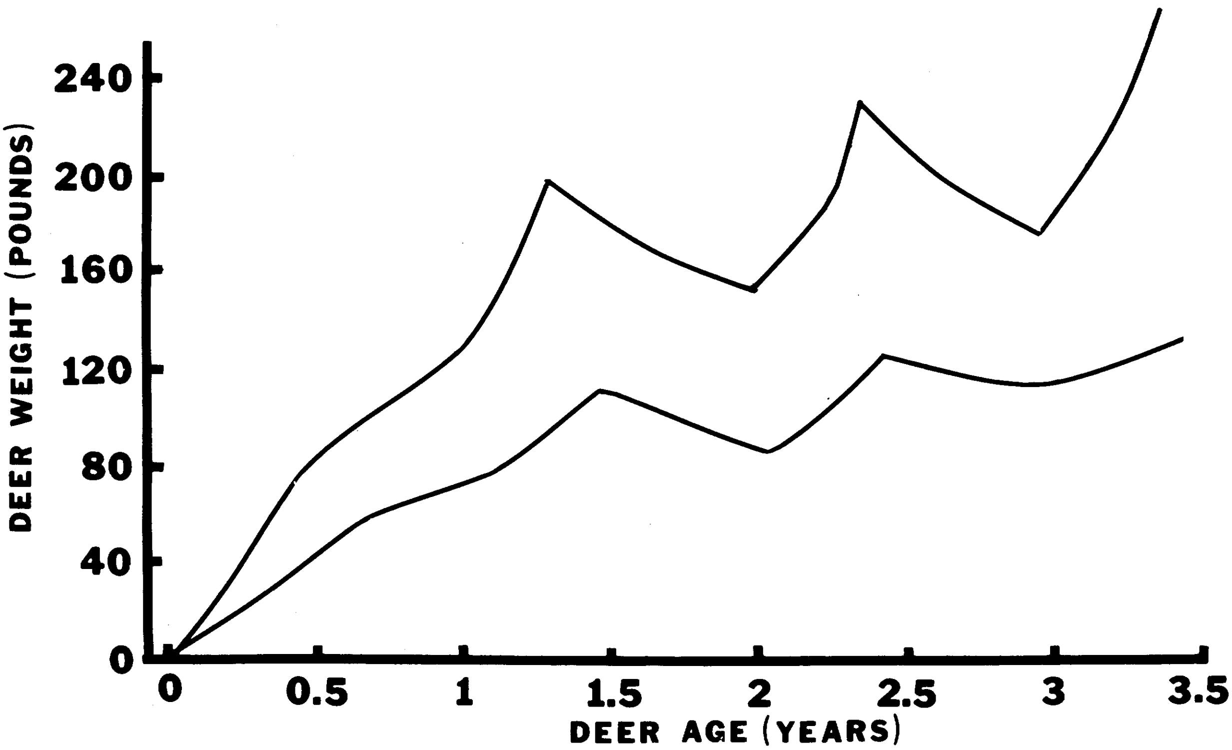

Figure 4. Wild ruminants generally and mule deer specifically undergo seasonal cycles of body weight which reflect physiological adjustments to changing nutritional opportunity. The quality and quantity of forage and cover within two subpopulation's annual ranges are suggested by these generalized weight curves which express moving averages of daily gains and losses of nutrients and energy.

Magnitudes of weight changes are determined by forage quality, particularly available energy (Moen 1968; Nordan et al. 1970; Short et al. 1969). The lower curve (Figure 4) typifies a deer somewhere between the first and second levels of productive survival; whereas, the upper curve suggests a deer approximating the third, highest, level of productive survival. Poor quality forage plus environmental stress contribute to large, rapid losses of reserves irrespective of time of year. Poor quality cover permits environmental stress more frequently and for longer periods. Changes in body weight of all age classes reflect how well forage and cover balance energy losses to (and gains from) the environment.

The annual cycle of weight and condition is the net average of daily changes in energy gain, balance, and loss. Potential losses of condition from stress at various times each day are moderated by forage quality, particularly energy content. There must be a surplus of energy beyond the daily maintenance requirement, otherwise productive processes or storage of reserves are not possible. The energy required to maintain a deer each day is largely, but not only, determined by heat loss to the environment (Figure 5). Like us, mule deer must keep their body temperature (39°C, 102°F) within narrow limits or they die. As conditions create more extreme heat drains, deer must metabolize more reserve energy to maintain their internal temperature. At some point the effective temperature (analogous to wind chill versus measured air temperature) becomes either too hot or too cold for the deer to find adequate forage or cover; then, and for as long as such stress persists, productive survival of the individual declines (Blaxter 1962; Brody 1945; Brody 1956; Kleiber 1961; Moen and Jacobsen 1974; Moen 1976; Porter and Gates 1969; Silver et al. 1969; Silver et al. 1971).

Observed occupancy of plant communities

The adequacy of forage and cover for each subpopulation is limited by diversity, amount, and interspersion of plant communities within a subpopulation's traditional range (Duffey and Watt 1971). Occupancy of plant communities by mule deer reflected changing needs for forage and cover in different seasons and with daily vagaries of weather (Leckenby b., in manuscript). Mild weather was associated with considerable use of grassland plant communities (Leckenby and Adams, in manuscript) (Figure 6). These communities were forage areas containing highly nutritious foods at critical times, but such stands offered no cover from stress of cold or hot environments. Thus, occupancy of open habitats was inversely correlated with weather severity. Use of shrubland communities did not fluctuate so extremely (Figure 7). The pattern was similar to occupancy of grasslands, but minimal use occurred later in the season (Figures 6 and 7). Shrublands were forage areas too, but they offered more cover against temperature and wind stress than could grassland communities. Juniper communities were primarily used when deer needed protection from extreme weather severity (Figure 8). Western juniper stands provided cover analogous to cedar-swamp deer yards (Ozoga 1968; Verme 1965), in that wind velocity was reduced, temperatures were

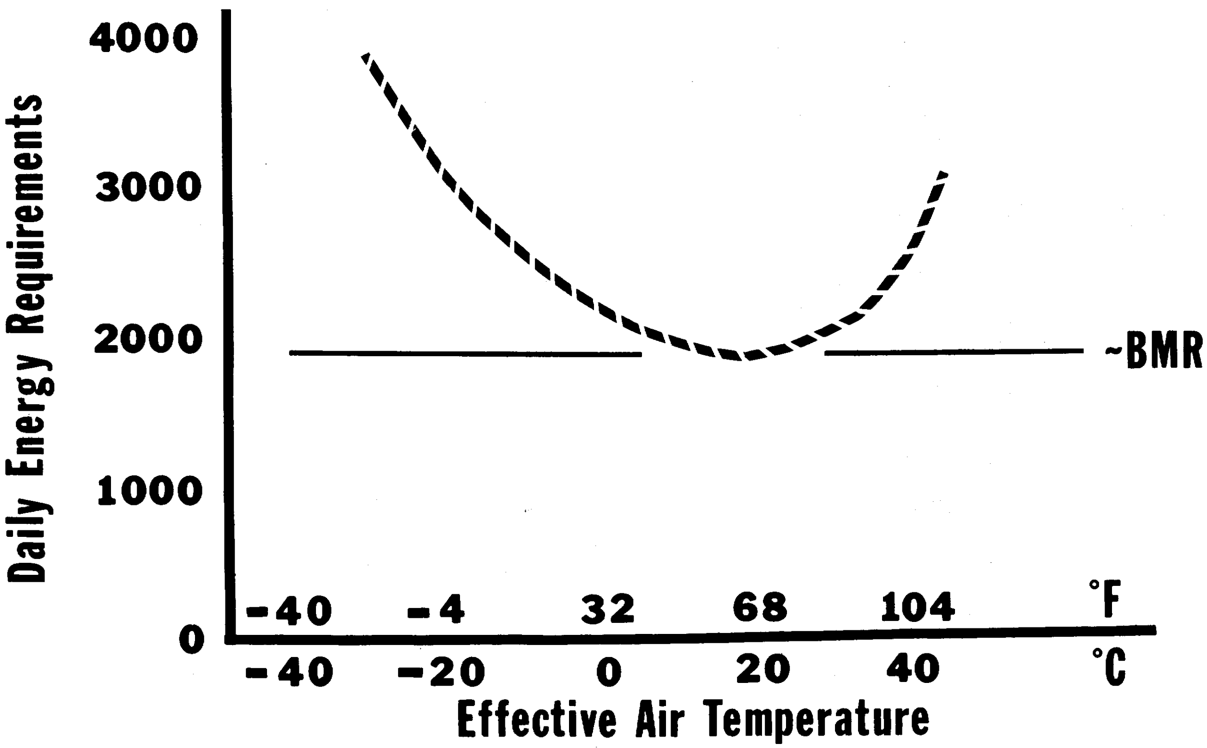

Figure 5. Daily energy requirements of ruminants generally and mule deer specifically increase as effective temperature becomes too warm or too cold. The energy demand at any instant is the sum of requirements for body maintenance (similar to basal metabolic rate, BMR, of humans), body temperature regulation (compensation for heat lost to the environment), and body growth (including storage of fat reserves). Effective temperature represents the combined influence of weather factors on energy flows between an animal and its environment.

more stable and less extreme, and snow conditions were less severe than in adjacent shrubland (Bright 1976; Leckenby and Adams, in manuscript). Most juniper communities contained little forage, but they provided the best protection against thermal stress, and occupancy was positively correlated with weather severity (Leckenby and Adams, in manuscript).

The central importance of western juniper stands on two winter ranges was emphasized by the deer's differential occupancy of plant communities. Results from those areas were comparable, suggesting a prediction factor useful in management (Figure 9). Occupancy of grassland and shrubland communities was strongly correlated with the forages they contained. Conversely western juniper communities were occupied to the same degree regardless of forage--suggesting their value was cover oriented. The value of plant community diversity within subpopulation ranges was therefore demonstrated.

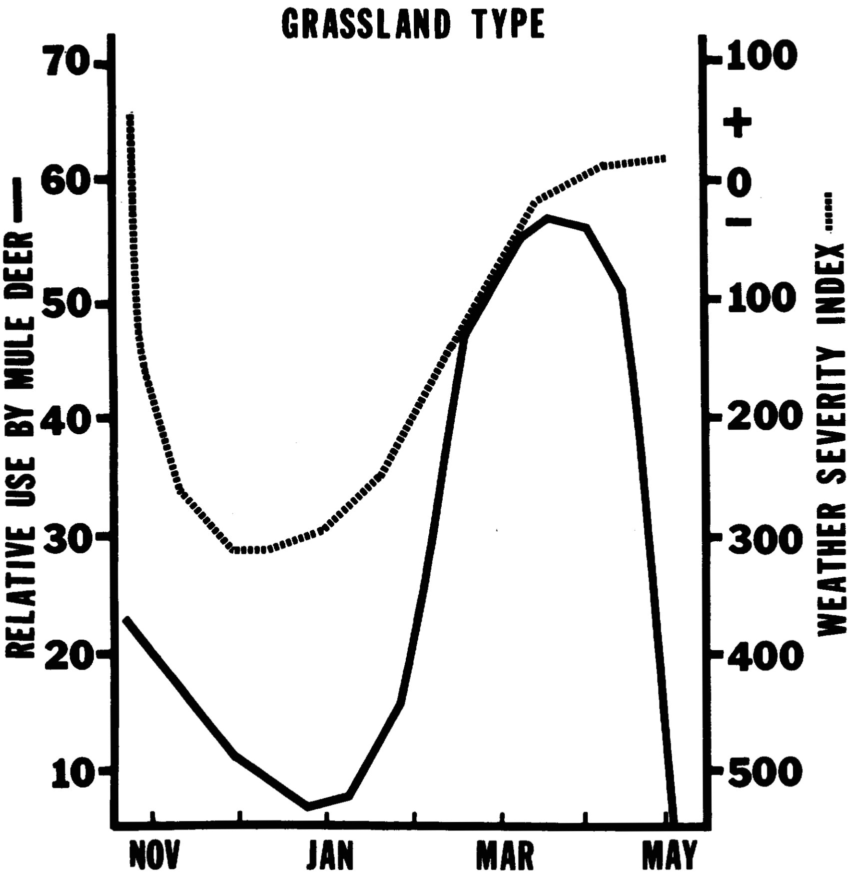

Figure 6. Mule deer occupied grassland type communities principally when young forage was available and effective temperature was least stressing (when weather severity indices averaged less than - 150). The weather severity index was constructed from temperature, wind, and snow measures to approximate effective temperature and consequent heat losses of deer. Relative use calculated as (deer per acre in type/total deer per acre all types) x 100.

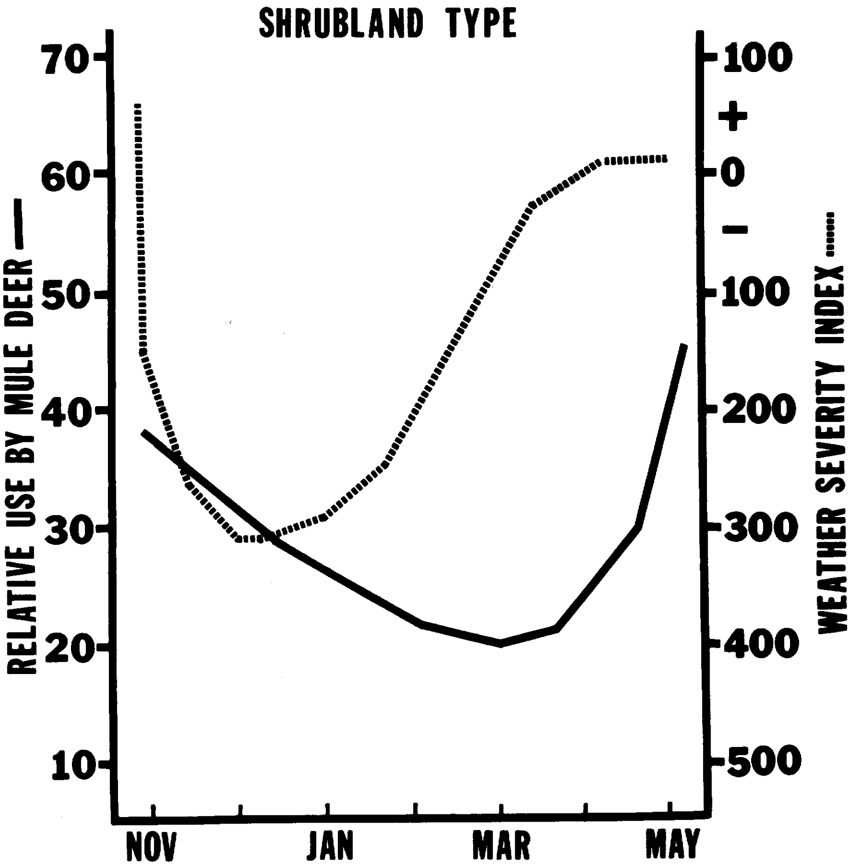

Figure 7. Mule deer occupied shrubland type communities principally when these stands provided the best forage and effective temperatures increased the need for cover (when weather severity indices averaged greater than - 150). The weather severity index was constructed from temperature, wind, and snow measures to approximate effective temperature and consequent heat losses of deer. Relative use calculated as (deer per acre in type/total deer per acre all types) x 100.

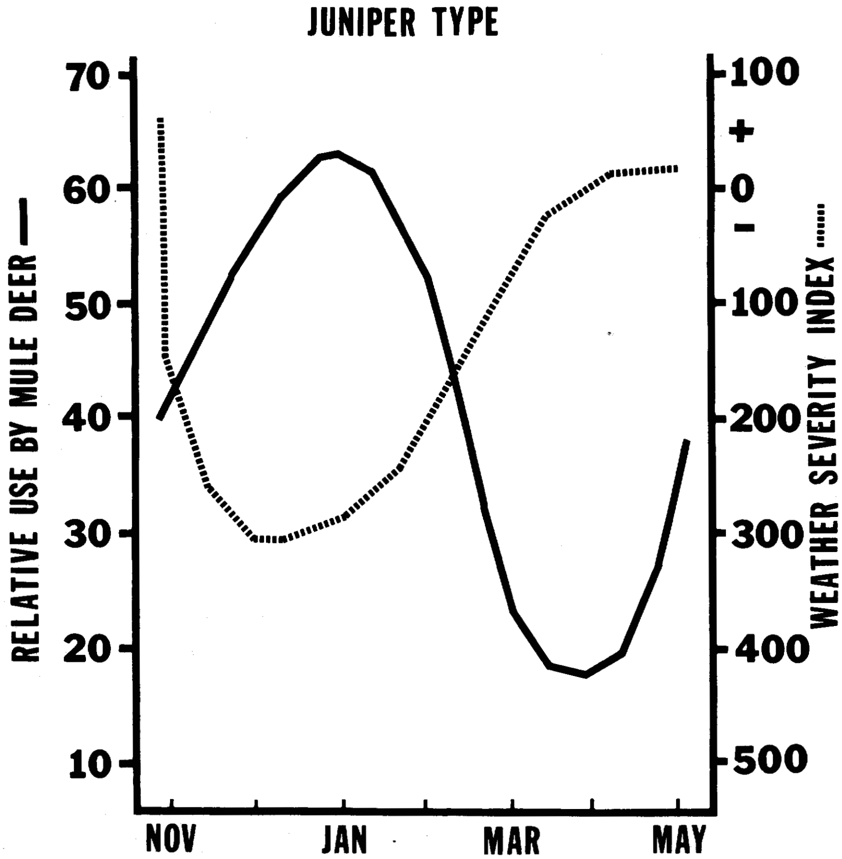

Figure 8. Mule deer occupied juniper type communities when the woodlands provided protection from stressing effective temperatures (when weather severity indices averaged greater than - 200). The weather severity index was constructed from temperature, wind, and snow measures to approximate effective temperature and consequent heat losses of deer. Relative use calculated as (deer per acre in type/total deer per acre all types) x 100.

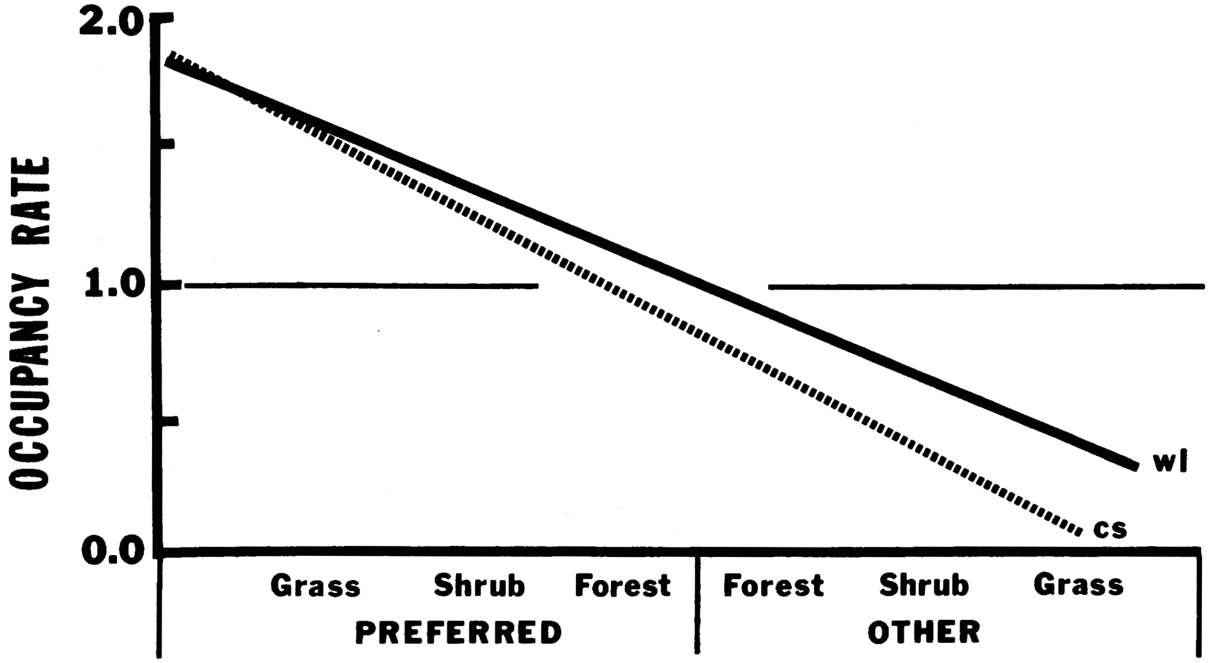

Figure 9. Juniper (forest) essentially provides cover for mule deer; woodland communities containing preferred forages and those lacking such forages were occupied at equivalent rates. Preferred shrubland and grassland communities contained important forages and were occupied at higher rates. Results were similar on the Chase Spring (CS) and Ward Lake (WL) winter ranges.

Deer forage-cover relationships of western juniper communities

Juniper stands constitute the sole woodland type over much of central Oregon; therefore, they offer the only forest-like structural features. Although there is a great variety of plant species within juniper communities, forage diversity is low during the time of deer occupancy.

Forage. Diversity of juniper communities provides some diversity of forage, and forage diversity is required to meet the needs of deer in all seasons. Varying age, height, density, etc. of juniper creates different microclimates favoring some plants over others; thus, their presence depends partly on juniper itself. Many species, such as Sandberg bluegrass (*Poa sandbergii*), are deer forages which persist in otherwise harsh sites due to the juniper's ameliorating effect on the microclimate.

Normally considered to be browsers, deer are in fact opportunistic with respect to food habits (Kufeld et al. 1973). In order to survive at a viable level of productivity, deer must eat the best they can find under prevailing conditions (Figure 10). Deer do show preference, however, for some species and subspecies of browse, grasses, and forbs. Preferences change according to phenological age of plants. Deer select those stages which are rapidly growing and highly digestible. Standard analyses show that such stages contain most nutrients in balanced amounts (Subcommittee on Feed Composition 1969). Availability limits choices, yet deer tend to eat species at those stages which meet or exceed current requirements. Consequently, forbs, such as cinquefoil (*Potentilla newberryi*), are important during a mild winter so long as they are available (Figure 11), but less preferred browses, such as big sagebrush (*Artemisia tridentata*) and rabbitbrush (*Chrysothamnus*), are used of necessity during severe winter weather (Figure 12).

Ruminants in general consume great quantities of highly digestible forage when it is available (Figure 13). One of the keys to plant-use

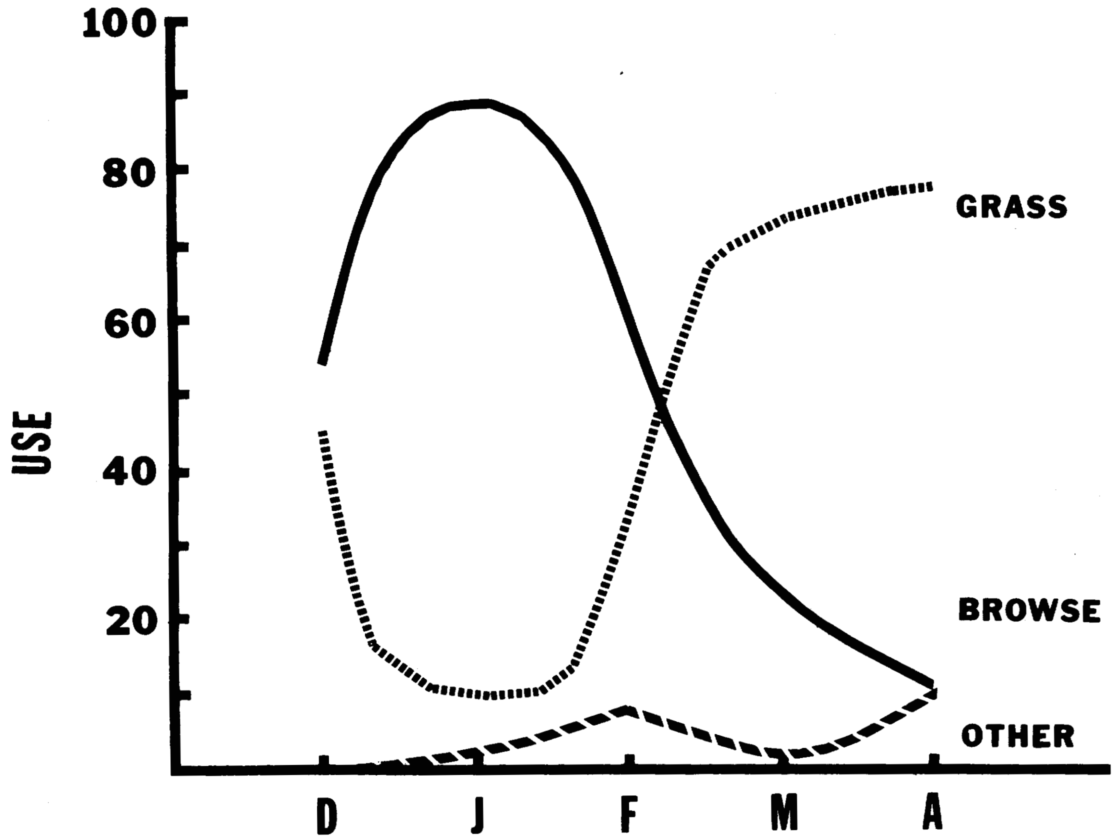

Figure 10. Mule deer are opportunistic foragers. They concentrate on the most digestible foods that are available. Browsing occurs predominantly when grass and forb herbage is cured or when their new growth is covered with snow (use is relative frequency).

FEEDING OBSERVATIONS
WARD LAKE 1967-68

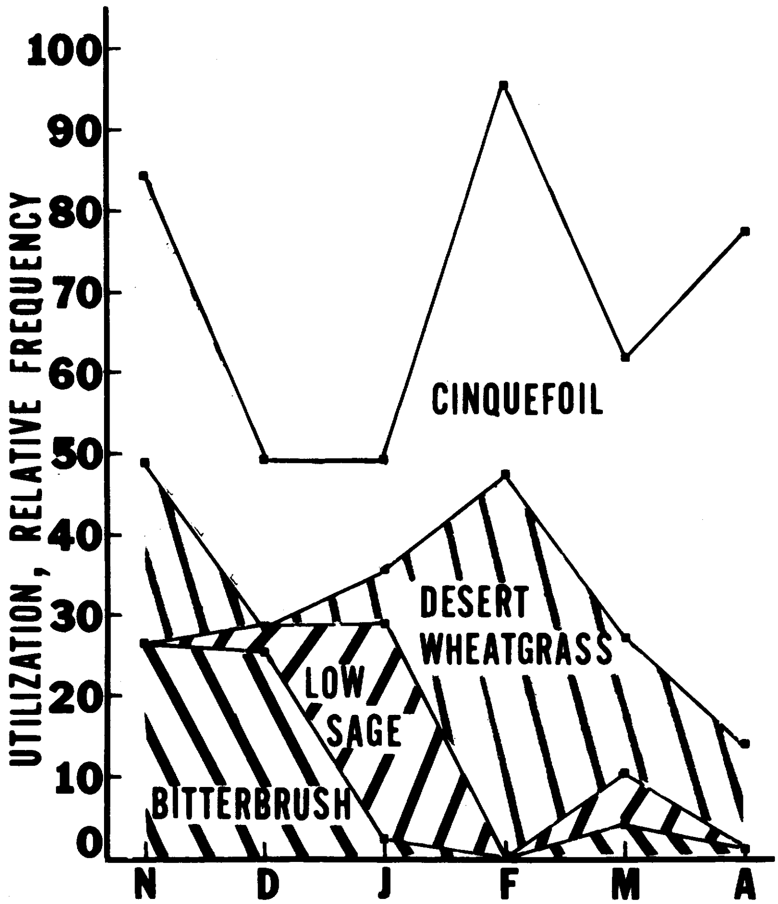

Figure 11. Mule deer usually fed on the highly digestible, growing herbage of forbs and grasses during the mild, snow-free winter of 1967-1968. Browse was unimportant after January. (Plant names: bitterbrush, Purshia tridentata; cinquefoil, Potentialla newberryi; desert wheatgrass, Agropyron cristatum, A. pectiniforme, A. sibiricum; low sage, Artemisia arbuscula).

FEEDING OBSERVATIONS
WARD LAKE 1968-69

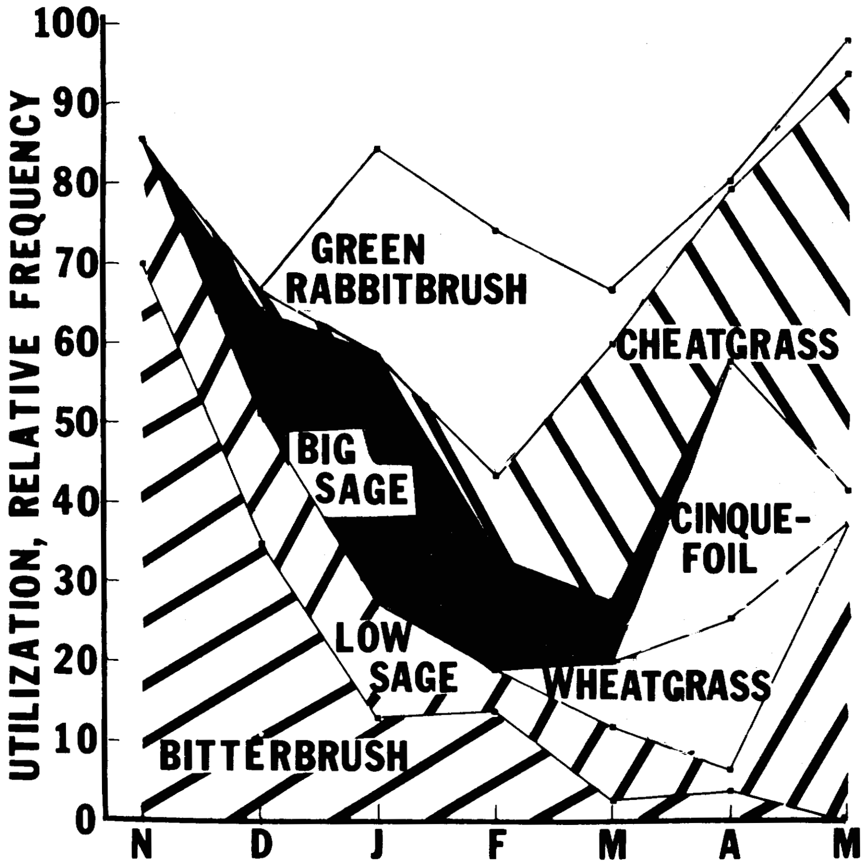

Figure 12. Mule deer usually fed on poorly digestible but available shrubs during the severe, persistently-snowy winter of 1968-1969. Forbs and grass became important only after the snow melted in March. (Plant names: big sage, Artemisia tridentata; bitter-brush, Purshia tridentata; cheatgrass, Bromus tectorum; cinquefoil, Potentialla newberryi; green rabbitbrush, Chrysothamnus viscidiflorus; low sage, Artemisia arbuscula; wheatgrass, Agropyron cristantum, A. pectiniforme, A. sibiricum).

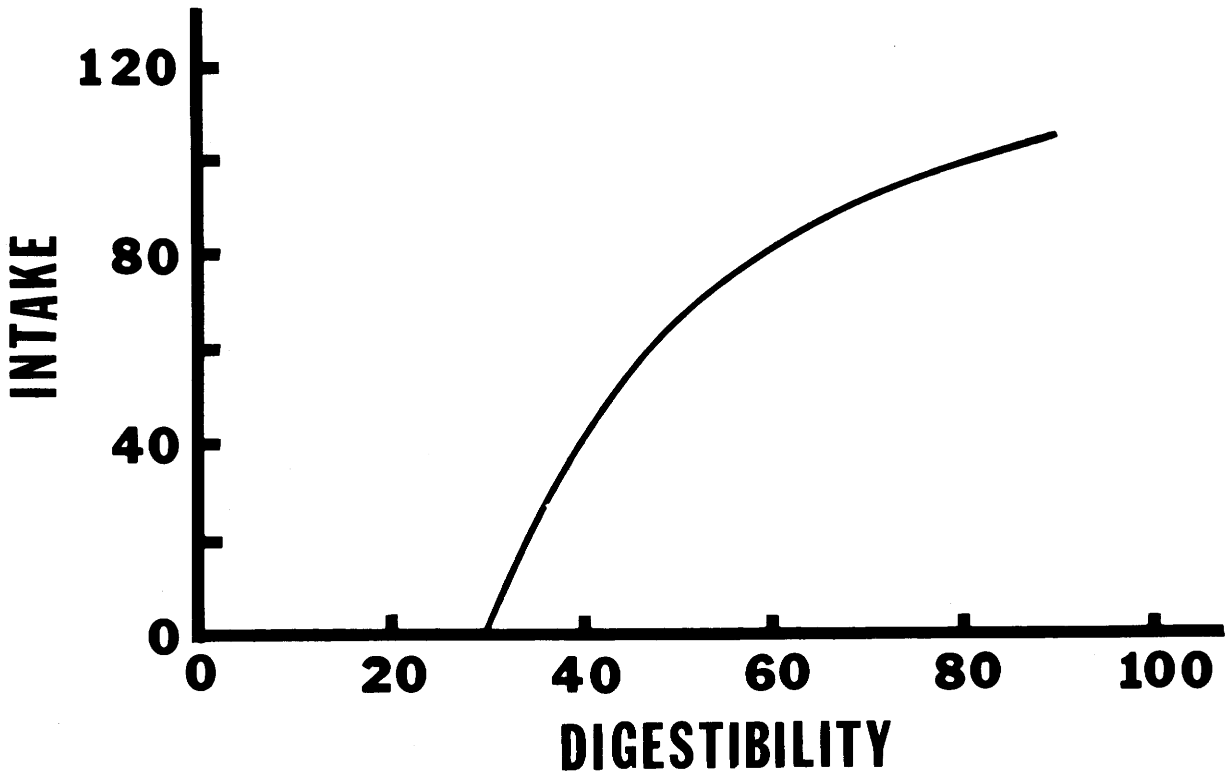

Figure 13. Ruminants generally and mule deer specifically can eat more per day as forage quality improves because food is digested faster and residues travel more quickly through the system. Digestibility of browse averages under 50 percent while that of young grasses and forbs averages over 60 percent.

appears to be digestibility (quality) (Ammann et al. 1973). Deer may even gain weight during a mild winter when grasses and forbs are available and digestibility of the diet may be as high as 80 percent. However, digestibility of browse is about 50 percent; so if conditions are sufficiently stressing, the energy in browse can not be obtained quickly enough to meet the animal's needs. The volume of a deer's rumen in fact becomes limiting. For example, deer consuming bitterbrush may still lose weight because they must draw on body reserves to offset energy losses. Juniper is nutritionally as good as other browse such as bitterbrush and low sagebrush, but in our study it was used less frequently. Juniper is essentially an emergency forage which often is not sufficiently digestible to meet deer needs, but at the same time it may be all that is available. Foraging on juniper occurs primarily during weather stress as attested by many examples of extreme use.

Cover. Cover value can be predicted because the microclimate varies with vegetation height, crown closure, crown depth, stem size, and stem density (Bergen 1971, 1974; Cochran 1969; Gary 1974; Geiger 1966; Gifford 1973; Reifsnyder and Lull 1965). Cover is valuable to deer because it helps reduce energy losses. A specific example of structural qualities of one juniper stand in which we monitored weather severity were as follows: 1) average height about 4.5 meters (15 feet), 2) 25 to 30 percent crown closure, 3) crown depth near 3 meters (10 feet), 4) density of about 33 stems per hectare (80 per acre), and 5) a juniper/big sagebrush-bitterbrush (*Purshia tridentata*)/bluebunch wheatgrass (*Agropyron spicatum*) community. These stand conditions created a microclimate that was 40 percent less severe than that in the adjacent shrubland (Bright 1976; Leckenby and Adams, in manuscript) and provided essential thermal cover for deer by moderating intensity and duration of weather severity.

MANAGEMENT OF WESTERN JUNIPER FOR MULE DEER

Management of western juniper communities can preserve the system as well as provide for needs of mule deer. Diversity of plant communities and successional stages can be preserved or enhanced if the interrelationships are accounted for in planning.

Winter and summer ranges require different management plans. On winter range, thermal cover is vital for deer to survive temperature extremes, but hiding cover is not as important. Exposure and movement cost more energy than animals can afford; therefore, diversity and interspersion of forage and thermal cover are critical (Malecheck and Smith 1976; Moen 1976). On summer range, thermal cover is essential for optimum reserve storage and protection from heat stress (Brody 1956); hiding cover, on the other hand, is an important buffer during fawn rearing and hunting seasons.

Prescription

How should western juniper communities be treated to effectively benefit mule deer? If information suggests treatment is necessary, no more than 1/3 of each vegetation stand should be altered until more specific knowledge is available. Created openings should average between 5 and 10 tree heights in width, but none should exceed 120 meters (400 feet). Known high-use thermal cover, hiding cover, and travel ways should be maintained. Overall, we should manage for about 40 percent of the basic management unit in cover and 60 percent in forage areas (Thomas et al. 1976).

Management for small openings is more likely to present a net gain of energy to the subpopulation, because forage can be increased with only minimal loss of cover--the best of two worlds. Weather severity is greater in shrub or grass dominated clearings within juniper stands than in the woodland itself. Wind, heat radiation, and other effects increase proportionately with width of openings (Bergen 1972; Cochran 1969; Geiger

1966; Gifford 1973). Furthermore, height of vegetation adjacent to a clearing and weather severity are inversely correlated within a narrow band from the edge toward the center of an opening. The relative values of thermal cover and forage areas in each situation must be carefully weighed when management decisions are made.

Prescription tips

Under multiple-use concepts, juniper has positive aspects, but some management is justified for increasing particular products. Some of the following management tips may be helpful:

1) The management plan for each project should coordinate use of all resources over time (grazing, wood cutting, etc.).

2) If treatment appears necessary, it should be planned according to knowledge of values, animal-plant community interrelationships, and the predictibility of results.

3) Treatment areas should be selected on the basis of sound knowledge of the area and demonstrated need. We can not afford to manipulate in desperation as if there were no tomorrow.

4) Various treatment methods should be tested and adapted to the plant community as well as to project objectives.

5) Techniques should be adapted to insure aesthetically acceptable treatments. Public sentiment definitely affects programs.

6) Fire should be used as a tool in itself or to supplement other techniques.

7) Replacement of a juniper monoculture with another monoculture, e.g. crested wheatgrass, should be avoided.

8) To operate in the most economical manner, forage should be planted in such a way that it is totally available to the deer.

9) Native forages should be considered to augment diversity. These should be easier to establish than exotics.

10) Results of each project should be objectively evaluated in terms of goals, accomplishments, failures, and total resource consequences.

11) Criteria other than minimal cost per acre should be used to measure treatment success.

RESEARCH NEEDS

To approach multiple-use management of the western juniper ecosystem, we need to simultaneously consider the multitude of products and the many interdependencies which constitute the system. Most facets of this ecosystem are, at best, vaguely perceived. Future research then should address the following:

1) Interrelationships of animal and plant communities need to be considered in total perspective with management of the ecosystem, management of featured species, and needs of society over time.

2) A simple system is needed to help us objectively evaluate goals and objectives for overall management of western juniper communities.

3) The consequences of management alternatives with respect to all wildlife should be investigated and publicized.

4) Our files of descriptions of and keys to natural and induced juniper communities should be expanded so managers will have the necessary tools to identify site potentials within each project area.

5) Juniper communities should be mapped and measured so land-use planners have the data required to coordinate resource uses in time and space.

6) The successional stages produced by each treatment of each community need to be described. Longevity of a stage is obviously important to the management time frame.

7) Predictibility of response of the various treatment-community combinations should be quantified.

8) Economic values and tradeoffs of alternate methods should be compared. Appropriate economic measures of success which reflect total cost to society are needed.

CONCLUSIONS

Our responsibility as custodians of the western juniper ecosystem includes an obligation to future generations. They cannot afford our ignorant and desperate attempts to fulfill short-term, single-use goals. By retaining management options for future generations, we can gain the flexibility we seek today. Management founded on guiding theory and evaluated by deciding experiment should progress toward fulfillment of that responsibility.

Predictibility will increase if we use the integrating factors of plant community structure for cover management over broad areas and community composition for forage management on local ranges.

Behavior and physiology suggest a requirement for habitat diversity within mule deer subpopulation ranges. Plant community diversity, structural and compositional, met varying seasonal requirements of mule deer; such diversity provided insurance against the vagaries of weather within and between years.

Preservation of habitat diversity for deer will not satisfy our obligation to future generations. Mule deer are only one product of the western juniper ecosystem.

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EFFECTS OF WESTERN JUNIPER ON FORAGE PRODUCTION AND LIVESTOCK GRAZING MANAGEMENT

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ABSTRACT

Western juniper has a serious effect on livestock production. Unless checked by effective control and subsequent management measures, forage production on sites containing seral stands of juniper will continue to decline regardless of grazing management. Beef cattle stocking rates have increased from 50 to 300 percent from juniper removal alone. Coupled with seeding and improved grazing management, juniper control has changed production from 15-20 acres per AUM to 3 acres or less per AUM.

Keywords: Livestock forage, forage production, livestock management

What effect does a particular population of western juniper (Juniperus occidentalis subsp. occidentalis) have on the ability of a site to produce usable range forage? If the answer to this question were known with certainty there would be no need for a presentation on this subject. Our conclusions after several somewhat frustrating hours of investigation left us little better off than at the beginning. We did conclude, however, that western juniper has a serious effect on livestock production. Effective preventive measures, if not taken when populations are small and trees young, commits a site to continued and increasingly lower forage production.

Several investigators have described sites or habitat types in which juniper is an important component (Eckert 1957; Driscoll 1964; Soil Conservation Service 1967, 1969, 1970; Burkhardt and Tisdale 1969; Hall 1973). Only the Soil Conservation Service and Hall publications provide any herbage production or stocking rate data. Difficulty exists in knowing whether such data were derived from climax or seral juniper stands.

Although juniper has been controlled by a variety of techniques throughout its ecological range with varying degrees of success, there are virtually no published studies on the effects of western juniper control on subsequent forage production and composition. Evidently the responses obtained were sufficient to justify control efforts.

Juniper is no respector of range condition. Burkhardt and Tisdale (1976) made studies which indicated that little or no repressive effect on juniper seedlings could be attributed to herbaceous competition. From this and numerous personal observations, we cannot expect grazing management alone either to keep out juniper seedlings, or if seedlings are present, to suppress their growth and influence on associated vegetation. Burkhardt and Tisdale also observed that there was better juniper seedling establishment on deep, less well-drained bottom sites but a higher growth rate on the upper slopes with well-drained soil.

No doubt juniper will not invade extremely arid range sites, but where it already exists, most observers agree that its influence is increasing. From a livestock-forage management standpoint, arresting the increase shortly after it has invaded and before range condition and/or forage production declines significantly, should be more economical and effective in the long run.

Juniper trees can provide desirable winter habitat for cattle and sheep and are especially beneficial during calving or lambing for physical protection. Conversely, during hot weather, protective shade is provided. Most other effects would probably be judged harmful for forage production and livestock management, at least by the livestock owner or manager.

Juniper competes for moisture and nutrients and, in effect, contributes to a more arid environment. Erosion hazard increases as a larger percentage of the soil surface becomes bare. Shade directly beneath the canopy sometimes results in more herbage than around the periphery of the tree. This may be due to lower evaporation and transpiration coupled with protection from grazing livestock by the lower branches.

In the central Blue Mountains of Oregon, Hall (1973) described four juniper (more than two trees per acre) plant community types and reported herbage production from sites in good range condition. About 350 pounds air dry herbage per acre was produced annually from the juniper-bunchgrass community type and about 400 pounds from the juniper-big sagebrush (*Artemisia tridentata*) type.

Both of these vegetation community types could be successfully seeded. The other two types are juniper-stiff sagebrush (Artemisia rigida) scabland with about 200 pounds per acre and juniper-low sagebrush (Artemisia arbuscula) with about 400 pounds per acre. Successful reseeding on the latter two types is questionable. In 1976 on a site with 12-20 trees per acre at the Squaw Butte Experiment Range in Harney County, Britton (1977) recorded 150 pounds of oven dry grass and forbs per acre. Range condition was estimated to be in the high fair category.

If one assumes that 50 percent of the herbage should remain after grazing to maintain the plant community then the stocking rates would be 3-3/4, 4-1/4, 3-3/4 and 7-1/2 acres per animal unit month (AUM) for the juniper-big sagebrush, juniper-bunchgrass, juniper-low sagebrush and juniper-stiff sagebrush types, respectively. These data correspond closely to Soil Conservation Service (1967) estimates of 3-7 acres per AUM for a juniper south exposure site in good condition and Burkhardt (1977) in southwestern Idaho. At Squaw Butte, 10 acres of fair condition range would be needed per AUM based on Britton's measurements.

As juniper trees become more dense, forage production declines. Because livestock numbers are often not balanced to the declining amount of available forage, range condition may decline at an accelerated rate. Consequently, many areas with thick stands of juniper do not have sufficient populations of desirable perennial species to respond if juniper competition were removed. Seeding after juniper removal is suggested when this described situation occurs. The degree of success will be limited by site characteristics.

For the livestock owner, juniper control must result in measurable management benefit. Most improvements show up in higher stocking rates regardless of the kind and class of livestock. Interviews with central Oregon cattle ranchers indicate from 50 percent to 300 percent improvement in stocking rates from juniper removal alone. One stockman indicated a four-fold improvement in grazing capacity when all of the juniper was removed and part seeded to crested wheatgrass. Depending upon the site, up to 3 acres per AUM stocking rates have been achieved with juniper removal and good grazing management alone. From 4-5 acres per AUM would probably be more common.

Areas of high site potential but with sparse understory and dense trees respond well to drilling of crested wheatgrass (Agropyron desertorum) following juniper removal. Areas with practically no available forage, producing at 15-20 acres per AUM, commonly are improved to a stocking level of 3 acres or less per AUM with crested wheatgrass or other appropriately adapted species.

Soil disturbance, even if not seeded, can be beneficial. One rancher observed that cheatgrass (Bromus tectorum) was 6 to 8 inches tall where juniper was removed by a bulldozer but only 1 inch tall in the undisturbed area.

Forage utilization under trees has been noted by several observers. Idaho fescue (Festuca idahoensis) is often left ungrazed under a juniper canopy, yet when juniper is removed it is readily grazed. Dealy (1972) noted the same phenomenon with ponderosa pine (Pinus ponderosa). He attributed it to a buildup of pine duff and continual carryover of fescue litter. Something similar may contribute to poor fescue utilization under juniper.

It is not uncommon for juniper ranges to contain an almost sod-like cover of Sandberg's bluegrass (Poa secunda). Removal of juniper competition will not result in improved forage production. Seeding is necessary but will not be successful until bluegrass competition is controlled through cultivation or an appropriate herbicide. Once established, crested wheatgrass will out-compete many other species and the stand can remain productive for years. Ranchers observe that juniper invasion is suppressed more by crested wheatgrass than native grasses.

The degree of improvement in a range-livestock operation largely depends upon the managerial skill of the operator. More forage may result but such forage must be efficiently and effectively converted into livestock output to be economical. Range improvements should improve grazing capacity of the area treated and the entire ranching unit if properly managed. Improved individual animal performance may occur. Better nutrition coupled with appropriate livestock husbandry should result in higher percent of conception and subsequent calving percentage. Often the improved grazing capacity will mean that fewer males per 100 females are necessary. This could translate into the purchase of higher quality males and thus greater and more rapid herd improvement than without range improvement.

SUMMARY

Although many thousands of acres of western juniper have been controlled through a number of procedures throughout the large juniper zone from northern California to southern Washington, no forage production response research preceded or accompanied this control effort. There is no doubt that substantial forage increases occur on favorable sites when juniper and associated shrub species are controlled and appropriate followup procedures carried out. Often, little or no forage increases are observed where juniper on rocky and shallow soil sites is controlled.

We recommend that quantitative guidelines be developed whereby forage production changes can be accurately predicted site by site. This will involve some additional research but sufficient juniper removal projects have occurred and will occur so that accurate information can be developed. As an example, in the Grant County area some of this kind of information should come out of the Oregon Range Validation Project.

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PHYSICAL PROPERTIES AND COMMERCIAL USES OF WESTERN JUNIPER

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ABSTRACT

Western juniper (*Juniperus occidentalis* Hook.) has several properties which could be commercially marketed. Historically, western juniper has been used for fenceposts, decorative boughs, and firewood. Volatile and essential oils can be extracted from foliage and terminal branches as well as from the wood of western juniper. These oils are valued as flavoring and scenting agents. Presently the wood is being used for making furniture as well as paneling. The wood can be successfully dried, cured and made into products. The wood of juniper has a very attractive smooth finish with pleasing coloration and aroma. Veneer, hardboard and particleboard have all been successfully manufactured from juniper.

Keywords: Juniper, properties, oils, wood, lumber, utilization.

INTRODUCTION

The intent of this paper is to present information on the physical properties of western juniper (*Juniperus occidentalis* Hook.) as well as some of its properties which limit its commercial usefulness. The paper was going to be fashioned around future potential commercial uses of western juniper. However, the crystal ball is out of order and "future" implies that there are no present commercial uses of juniper. Presently, there are no large concentrated markets for western juniper. Like any other material or product which is marginal, these markets need to be developed. Will there be markets for windfall gains for those whose lands are overtaken by western juniper? Not likely! There are many costs involved with harvest and manufacture of juniper which negate the likelihood that it will be a valuable species on the stump in the near future.

HISTORIC PRODUCTS

Some of the historic products for which western juniper has been used are: fenceposts, decorative boughs, and firewood. Within western juniper's range it is touted as a fencepost. According to results from Oregon State University's post farm (Miller and Graham 1971), western juniper posts have lasted as long as 40 years in western Oregon's damp climate. The average life of posts which had decayed by that time was 22 years. This indicates an exceptionally good service life, especially when compared to lodgepole and ponderosa pine in the same area which have an untreated service life of between 3 to 6 years. It should be noted however, that the post farm was set up in 1927 and the posts used contained a high percentage of heartwood. Today, many juniper posts are being used that are largely sapwood. Untreated, these have no more decay resistance than lodgepole pine.

Western juniper is a good fuel wood, burning clean with little smoke and ash. One complaint is that in windy desert areas the shaggy bark tends to pick up wind blown sand and debris, therefore dulling chainsaws more rapidly than other fuel woods. In protected areas this is no problem. Decorative boughs are marketed every year around Christmas time.

INSECTS AND DISEASE OF WESTERN JUNIPER

Western juniper is commonly host to two mistletoes. They are dense mistletoe (*Phoradendron densom* Torr.), and constricted mistletoe (*P. ligatum* Trel.). While the mistletoe may sometimes cause witches'-broom, there are at least two rusts attacking western juniper that also commonly cause witches'-broom. These are *Gymnosporangium kernidium* (Bethel) and *G. betheli* (Kern).

There are at least two rots which commonly attack western juniper, sometimes rendering the wood unsuitable for any product. These are juniper pocket rot (*Fomes juniperinus* V. Schr.), a white pocket rot, and a brown cubicle rot usually found in the basal portions of the trunk. The pocket rot generally will extend farther up the tree than will the brown cubicle rot. A few feet of "long butting" will often get rid of the brown cubicle rot. Some trees which have been affected for long periods of time are hollow for most of their length. In some trees both rots occur and other times they appear singularly.

A longhorned wood borer (*Callidium californicum* Casey) attacks western juniper; the larvae bore into wood, both wet and dry. Kiln drying kills the larvae of this roundheaded borer, but if material is air dried, the insect will eventually work its way out. There are also some flatheaded borers which occasionally attack western juniper.

PHYSICAL PROPERTIES

Oils

Fahey and Kurth (1955) completed a chemical analysis of the volatile oils from the foliage and terminal branches of western juniper in 1953. They found that the volatile oils included the following: α-pinene, β-phellandrene, dipentene, ρ-cymene, sabinene, terpinolene, α-terpinene, terpinen, δ-borneol, borneolacetate, cadinene, acetic acid, phenols, and traces of aldeydes.

In 1972 and 1973, the Four Corners Regional Commission funded a juniper oil demonstration project (1973). This project was an economic pilot project to produce essential oils from *Juniperus osteosperma* (Torr.) and *J. scopulorm* (Sarg.). Professor Walter H. Johnson of Utah State University isolated essential oils from these species in 1964. The essential oils are valued as a flavoring or scenting agent in soaps, aerosols, insecticides, beverages, medicines, and many other products. The volatile oils from western juniper are quite similar to the volatile oils that were collect from *Juniperus osteosperma* and *J. scopulorum*. There are markets for these oils.

Kurth and Ross (1954) extracted essential oils from western juniper wood in 1954. Entire trunks and bark were used in this experiment. The major oil derived was cedrol. At that time adequate amounts of cedrol could be extracted from juniper wood to make an economic process, but western juniper cedrol contains an oily odor which is not desirable for scenting or flavoring. The investigators however, obtained crystalized cedrol with a pleasant odor by using low steam pressures. The investigators commented that the oily odor could probably be removed from cedrol obtained under higher pressure to make it competitive in the essential oil market. A substantial increase in total amounts of oil recovered occurred under higher pressures.

Lumber

Logs coming into the mill are rough with rapid taper and short lengths. Most of the logs are extremely limby except those grown on better sites among ponderosa pine and Douglas-fir. On most sites bark inclusions go deep into the wood. The logs have insect and disease problems along with nails, lead, wire, and the like.

Juniper has a reputation of warping and twisting when drying, being difficult to plane smooth, and for splitting. It does not deserve this reputation. The wood has been air dried by entrepreneurs for making furniture and novelty products for many years. The wood, especially if cut into fairly thin boards, kiln dries very well. Kozlik (1976) reports on kiln drying schedules for western juniper. Besides kiln drying, any slow drying process appears to work quite well for juniper.

During 1973 and 1974, Gary Johnson, State Service Forester, and the author attempted air drying by several methods with varying results. Rough lumber in 1-inch, 2-inch, and 4-inch stock was dried. The methods of drying were principally a slow, even drying process through different means (Brown 1976). One sample included juniper wrapped in a tarp and hung in a shed where air drying wouldn't remove moisture too rapidly. Other methods of air drying included storing under a dry building and curing in dry sawdust. Drying resulted in little warp or checking in the 1-inch boards. In the 2-inch and 4-inch boards, cracking and splitting was substantial except in the sample wrapped in a tarp. One craftsman recommends drying on end in the shade out of the breeze. Drying juniper properly is no mystery. Craftsmen who suggested these techniques were mostly from central Oregon and include Ralph Bailey and T. D. Sexton of Bend and Bill Koi of Sisters.

Finishing sawn products causes some difficulty. Juniper grain continually picks up when planed. Gary Gumpert of Juniper Products, Inc. in Prineville solved this problem by using abrasive planers, essentially a series of industrial sanders, to obtain a satisfactory finish. While abrasive planing is not commonly used in this area, it is not, by any means, a new method used in the wood products industry.

The color of the wood can vary a great deal. The most common colors found are a strikingly white sapwood with heartwood which varies from a light yellow to a yellowish orange and rarely almost red. In some areas individual trees may be close to red, some close to black and some may be greasy in composition. The wood has a pleasant aromatic quality but it is not as aromatic as many members of the cedar family. If the aroma fades over time, it can be revived by sanding.

Veneer

Juniper can be either turned or sliced to obtain a high quality facing product for plywood. Barger and Ffolliott (1972) report on physical characteristics of some juniper species in New Mexico and Arizona stated that veneer turned or sliced makes an attractive product. The Edward Hines veneer mill in Mt. Vernon, Oregon, rotary cut some juniper veneer. The Edward Hines Plywood plant at Hines, Oregon dried and glued the veneer. The lathe was set for cutting Douglas-fir at three-sixteenths of an inch. Consequently, there was some cracking and splitting of veneer which would not take place if the bolts were either steamed before turning or the lathe pressure changed slightly. Mr. Asher, Manager of the Plywood Plant, was of the opinion that there would be no difficulty in successfully turning juniper.

Manufactured Boards

Frashour and Nixon (1956) of the Oregon Forest Research Laboratory in Corvallis produced some hardboard from extracted juniper chips. The juniper chips were the ones from which Kurth and Ross had extracted essential oils. The hardboard obtained possessed superior bending strength and water resistance but did not have toughness properties that some other western species have. An advantage to using juniper as hardboard was the uniformly colored and semi-glossy finish obtained without the use of water spray. Frashour and Nixon indicated that the inferior toughness could probably be traced to the extended chip steaming in order to obtain volatile oils.

A technical action panel of Wheeler County headed by Mr. Hubert Asher of Spray looked into the feasibility of producing particleboard from whole juniper trees. This project took place in the period of 1964 to 1966. The results of the study reported by Ray Currier, Oregon Forest Research Laboratory, were that the particleboard could easily be formed and did possess aromatic qualities. At that time the amount of material available as residue for mills for particleboard outcompeted the harvesting of juniper for this type of product.

COMMERCIAL USES OF JUNIPER

The Forest Products Laboratory at Madison, Wisconsin, conducted a brainstorming session on utilization of juniper and developed the following ideas: toys, sporting goods, compost, jewelry boxes, chicken feed to make gin flavored eggs, block flooring, patio flooring, stems for plastic trees, condiment for cooking, wildlife feed, suitcase liners, humidors, pipe bowls from roots, furniture, decorative fences, planters, inlay products, paneling, Christmas decorations, novelties, closet liners, additive for men's cosmetics, volatiles, flavoring, bedding from shavings, condiment for cooking game from berries, and signs. The California Division of Forestry has shipped some logs to Japan which were peeled and finished by sanding to a high gloss and used as exposed interior studs. The extent of this type of market is unknown. There has been interest expressed by an eastern cedarchest manufacturer in using juniper for chests.

What are some of the more feasible juniper products? Aromatic oils may be a possible market. Western juniper oils may need some refining before they are competitive with oils from eastern redcedar (*Juniperus virginiana* L.) and Mexican juniper (*J. ashei* Bucholz). The pilot plant in Blanding, Utah was successful in extracting volatile oils which were saleable. However, the company formed to take over the pilot project on a full scale basis never did that. This does not mean that is is not economically feasible. More times than not, pilot projects of this sort are not followed up even though they prove out to be economically feasible.

Juniper Products, Inc., in Prineville is manufacturing a three-eighths inch tongue and groove sawn paneling for use on both walls and closets. Presently their product is being sold in Washington, Oregon and California. This is a family operation, and consequently they are not selling large quantities. Some marketing research has shown that there is a market for the product if there were enough suppliers to produce it in larger quantities.

Another product being manufactured by Juniper Products, Inc., and other craftmen in the area is furniture. The easy workability, good color, and fine finish of juniper makes it an excellent furniture wood. In fact, it is in the same genera as the eastern redcedar used for cedarchests and other fine furniture and closet liners. The aromatic qualities are not as good as eastern redcedar, but they are nonetheless present.

Juniper's fine finishing qualities also lend it to veneer manufacture. The veneer could be manufactured either by rotary lathe or by slicer. Total recovery in this process, as in sawing, would not be high. Expected recovery rates would be in the 40 to 60 percent range.

It is feasible to manufacture aromatic particleboard from juniper using the total tree. However, until particleboard plants run out of residue materials from mills which produce other wood products, it is not likely that juniper will be used for this process.

The wood of juniper makes excellent wood pencils. One of the difficulties in manufacturing this product is attempting to find enough clear stock without knots with straight grain from which to make the pencils. The wood apparently has excellent qualities as far as wood pencils are concerned.

Another small continuing market that is always available is for decorative boughs. Around Christmas time buyers are always around juniper areas buying boughs that are well laden with berries for use in the Christmas market.

Other product possibilities for smaller markets are the novelty products which are already being produced over quite an extensive area as well as fenceposts and even charcoal.

MARKET POTENTIAL

The technology is available to make products from juniper. Juniper is not an impossible wood with which to work. It is economical to make products from juniper. There is a branch of economics that will have to be dealt with before many people start manufacturing juniper. This is market research and development. The market research and development done by Juniper Products, Inc., for instance, in manufacturing of paneling and furniture indicates that there are people desiring to purchase substantial amounts of products made from juniper at present prices.

Logging and handling of juniper is an expensive process and recovery rates are low. However, the cost of handling and manufacturing are not the criteria which define whether a product is economic to market. The important criterion is whether the value of the product is able to cover those costs plus the needed profit margin.

Before many years there likely will be a substantial market for juniper products. Historically, it takes 5 to 10 years following an innovator and entrepreneur who opens the market for a product before the product really sells. Because Juniper Products, Inc., started operating in 1974, I would predict that by 1984 there will be a fair sized market for juniper products. A curious thing about these types of markets is that Juniper Products, Inc., quite likely will not be one of those supplying this market. New, more conventional manufacturers will probably supply the market. The market for juniper products will develop faster if and when a good housing boom occurs, or if there is an upswing in the economy of either the United States or Japan.

MANAGEMENT IMPLICATIONS

One of the reasons for giving this paper is an attempt to set some management criteria for juniper, especially if it is going to be looked at from a products standpoint. The management implications for juniper products would vary depending on the product for which you are trying to manage. For instance, if boards and veneer are the desired product, it would be best to manage juniper on the moister end of its range, although not necessarily in deep soil. A straighter, taller tree with fewer small branches and not as much bark inclusion seems to be produced where juniper grows in mixed stands with other forest trees. Quite often the heartwood is a deeper color which gives better grain contrast as far as these products are concerned.

If juniper is to be managed for lumber or veneer products, insects and diseases would need some control. Both the longhorned wood borer and the pocket rots and brown cubicle rot are problem areas.

If management is for production of oils, juniper on open grown or invasion-of-rangeland conditions may be the best. These junipers tend to produce many branches and needles from which more essential oils can be extracted. Branches and needles tend to give more of the aromatic flavor that may be desired in a particleboard product.

Unless the market for juniper products becomes much larger and much more stable than predicted from present conditions, juniper stands should not be managed for a product. Instead management might include eradication methods while riding on the novelty of juniper markets. This way the wood will be utilized and perhaps the cost of range rehabilitation will be decreased.

RESEARCH NEEDS

Research needs mentioned here are in regards to products made from juniper. These needs certainly are not listed in order of importance as the importance will depend somewhat on the eventual development of markets.

1. Insect and disease incidence.
2. Influence of environmental factors on quality of product.
3. Veneer slicing. Contact with one veneer slicing mill found them reluctant to try slicing juniper. They did not think there was a large enough supply to keep them going in this market.
4. Marketing of products. As indicated earlier in this paper, this may be the most important research need at this time.
5. Research on the modification of the properties of cedarwood oils from western juniper. This would make them more competitive with oils from other junipers.
6. Product research to find uses for western juniper oil in its natural condition.
7. Inventory of amount and quality of juniper. This would be necessary information for market development.

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