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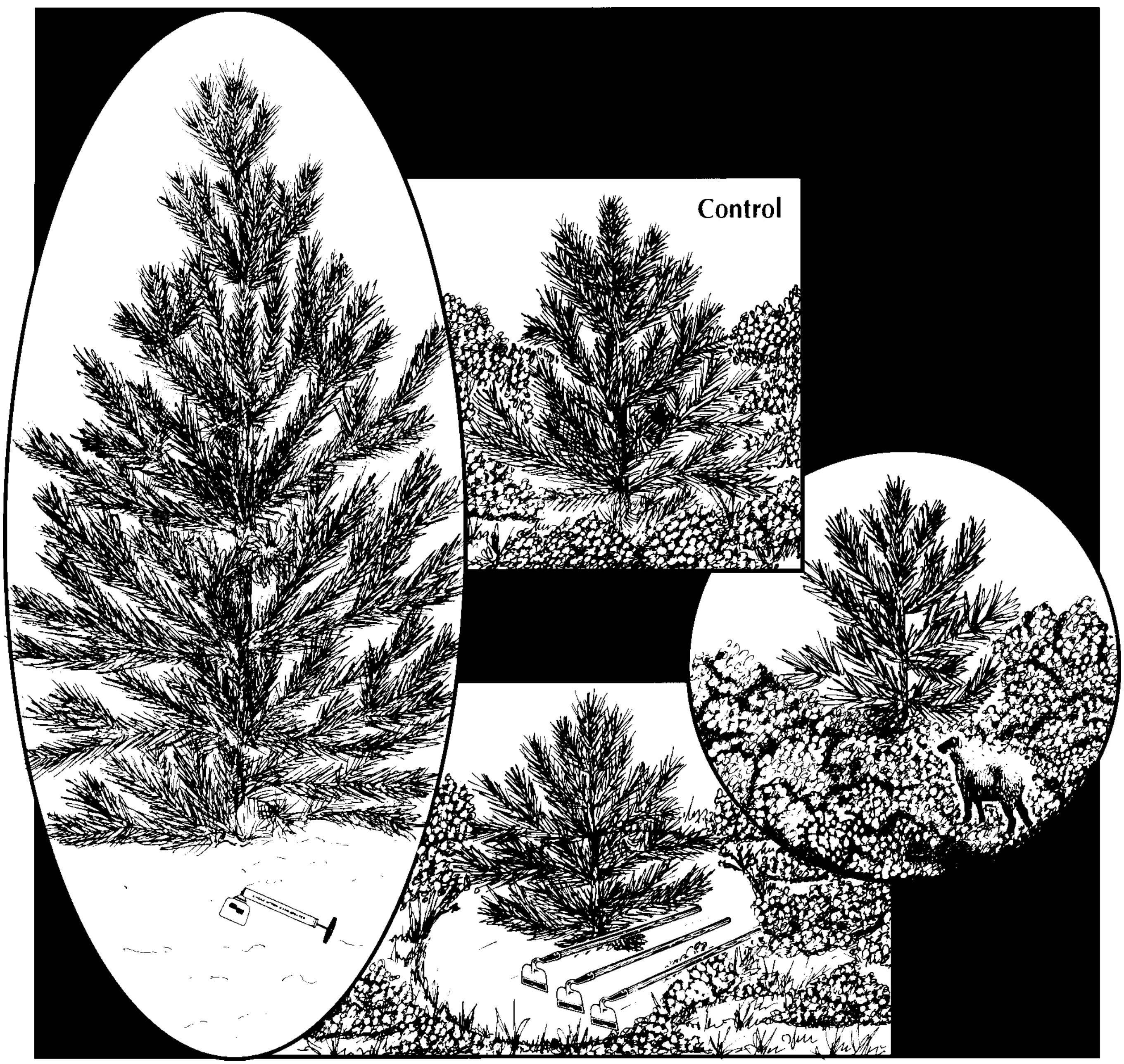
Vegetation Trends in a Young Conifer Plantation after Grazing, Grubbing, and Chemical Release

Philip M. McDonald **Gary O. Fiddler** **Peter W. Meyer**



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Abstract

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A 3-year-old Jeffrey pine (*Pinus jeffreyi* Grev. & Balf.) plantation in northern California was released by grazing with sheep for 5 years, manual grubbing for 3 years, and applying a herbicide 1 year. These treatments plus an untreated control provided an opportunity to evaluate density and developmental trends for the pine, shrub, and grass components of the plant community during 1986-1994. Creating a near free-to-grow condition by applying Velpar herbicide modified the plant community by controlling the shrubs, reduced cheatgrass in the second and third years, and caused mean pine diameter, foliar cover, and height to be significantly greater than counterparts in all other treatments. Grazing caused two significant, but opposing changes in the plant community. Nipping of twigs by sheep stimulated foliar cover of snowbrush to more than three times that of similar plants in the control. Grazing significantly reduced greenleaf manzanita cover. Grubbing a 4-foot radius around pine seedlings, and grazing with sheep did not increase Jeffrey pine development relative to the control. Because of this ineffectiveness, the efficacy of grazing as a silvicultural tool is questioned and suggestions for its betterment are presented.

Retrieval terms: density, development, grasses, pines, sheep, shrubs

The Authors

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In Brief

A major development in managing natural resources is the increasing emphasis on ecosystems and the many species in the plant community. Much needs to be learned about the shrubs, forbs, and grasses that currently have no recognized value. Key to this need is the realization that each species has intrinsic worth, not necessarily for wood or wood products, but as food for wildlife, to fulfill the variety and contrast requirements of pleasing scenery, or as components in ecosystems that the manager wishes to sustain or enhance. This study, conducted in northern California in 1986-1994, provides some knowledge on the species composition and early development of a pine plantation and the plant community that ensued after a wildfire. An untreated control, manual grubbing, herbicide application, and grazing with sheep provided a wide range of treatments and an opportunity to study the density and development of planted pines, shrubs, forbs, and grasses in a natural and manipulated condition.

The early natural plant community that developed after the wildfire was composed of snowbrush, greenleaf manzanita, several grasses, and more than 20 forbs. Planted Jeffrey pines and invading cheatgrass soon became major components of this community. By study end in 1994, total plant density in the control was more than 189,000 plants per acre, 97 percent of which were cheatgrass. Total foliar cover was 49 percent, a proportion that recognizes the small contribution to aboveground biomass typical of grasses.

For treated plots, plant density and cover varied significantly. If the treatment was the soil-active herbicide, Velpar, applied to the full 0.5-acre plots, plant competition was reduced and the pines developed significantly better in diameter, foliar cover, and height than seedlings in other treatments. Less competition for critical site resources, and specifically a low number of shrubs and grasses for the first 3 years, are the likely reasons. When the treatment was manual grubbing a 4-foot radius around Jeffrey pine seedlings for the first 3 years of the study, the density of greenleaf manzanita and forbs was larger than in any other treatment, although not significantly so. Development of pine seedlings in the grubbed treatment did not differ significantly from counterparts in the control.

For grazed treatments, little effect of foraging by sheep for the first 5 years of the study was found. Of note was that the sheep actually stimulated snowbrush plants to develop significantly more cover than in any other treatment. More cheatgrass resided in grazed plots although it did not differ significantly among treatments. Pine seedling development in grazed plots did not differ significantly from seedlings in the control.

Because results from this and another grazing study in northern California showed no significant improvement in pine seedling development, the use of grazing as a silvicultural release tool should be questioned. As currently practiced, grazing with sheep does not meet critical tenets of vegetation management. Competing vegetation is not being manipulated soon enough or strongly enough to be effective. Some suggestions for enhancing grazing as a silvicultural release tool are presented.

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Retrieval terms: density, development, grasses, pines, sheep, shrubs

Introduction

As the USDA Forest Service embraces the philosophy of ecosystem management and increasingly incorporates it into management plans, a disturbing weakness and a major need are recognized. The weakness is that very little is known about the shrubs, forbs, and grasses in the community; the need is for knowledge on silvicultural treatments that will provide specific plant communities at given times in the future. And because of differences in plant species composition and structure, the number of plant communities is huge, and because the number of environments in which they grow also is large, providing knowledge to fulfill this need is a major task.

The silvicultural treatments can be used for a variety of reasons: to create a future forest; provide an economic crop; encourage forbs and grasses in a plantation environment that provide seeds needed to sustain a desired species of wildlife; or simply to make possible a broad base of species and age classes so that forest stands will be in position to provide a broad range of amenities and commodities for future use.

Of the silvicultural treatments investigated in this study, the least information is available on grazing with sheep. Indeed, "forest managers' acceptance of sheep as a biological tool is currently limited by lack of site-specific data detailing the ecological and economic costs and benefits associated with prescription sheep grazing in forests" (Sharrow 1994). Young conifer plantations often contain palatable shrubs and herbaceous plants that provide forage for grazing animals until the tree crowns close and shade out the lower vegetation. Utilizing this forage, or transitory range as it sometimes is called, is increasing worldwide (Oregon State University 1983). Providing forage and wood constitutes a joint production strategy that gives the landowner income from the animals while the forest is developing (Ritters and others 1982). Sheep often are the grazing animals selected because they are well-suited to the dry, rough, and often shrub-inhabited terrain typical of plantations in the western United States. In general, weight gains and number of lambs have been satisfactory (Hall and others 1959, Sharrow and Rhodes 1983). And through proper herding techniques, the sheep can be controlled to minimize damage to conifer seedlings (Fullmer 1987, McDonald and Fiddler 1993). That sheep consume competing vegetation is generally accepted. For example, "Plenty of evidence supports the use of livestock grazing as a useful management tool to reduce unwanted vegetation in plantations" (Allen 1987).

Several recent studies with the herbicide Velpar, used in young conifer plantations in northern California (McDonald and Fiddler 1990, McDonald and others 1994) and elsewhere in California (Ballew 1991), have shown that it historically has controlled grasses, forbs, shrubs, and hardwoods during the establishment period. Other plantation release studies with herbicides and manual release (grubbing) have consistently shown that the treated plot must have at least a 5-foot radius to provide significant control of competing vegetation, principally shrubs and hardwoods (McDonald and Fiddler 1986, 1990).

This paper documents trends in vegetation after a wildfire, after the planting of Jeffrey pine seedlings, after the installation of a wide range of treatments, and after grazing was terminated. Cost data also are presented so that the manager can determine the cost effectiveness of each treatment.

Methods

Location and Site Characteristics

The study site was located on the Milford Ranger District of the USDA Forest Service's Plumas National Forest, about 20 airline miles southeast of Susanville, California. The area was burned in a 5,700-acre lightning-caused wildfire known as the Elephant Burn in 1981. Before burning, the site was occupied by a mixed conifer forest composed mostly of Jeffrey pine *(Pinus jeffreyi* Grev. & Balf.), California white fir *(Abies concolor* var. *lowiana* [Gord.] Lemm.) and occasional incense-cedar *(Libocedrus decurrens* Torr.). Snowbrush *(Ceanothus velutinus* Hook.), squawcarpet, *C. prostratus* Benth.), and greenleaf manzanita *(Arctostaphylos patula* E. Greene) were common shrubs. A few species of forbs and grasses were present in more open areas.

After burning, the plant community consisted of these shrub species, but no conifer seedlings—no seed source remained. Many of the shrubs originated from the root crown and, fueled by the established root system, grew rapidly. Seedlings of these and a few other species also were present, originating from dormant seeds in the soil. Grasses, chiefly of the genera *Bromus*, *Achnatherum* (formerly *Stipa), Sitanion*, and *Poa,* became abundant quickly as did forbs of the genera *Phacelia, Epilobium, Agoseris, Collinsia,* and *Paeonia.*

Site quality of the study area is low (IV) with conifers growing well for the first 30 years and then slowly thereafter. Dominant Jeffrey pines average 70 feet tall at a breast-height age of 100 years (Meyer 1938). The study area is located at an elevation of 6,600 feet on a northwest aspect with a slope of about 15 percent. The soil, which is of the Haypress series (Entic Haploxeroll) that formed in residuum weathered from granitic rocks, is moderately deep (30 inches), somewhat excessively drained, and has a texture of loamy coarse sand throughout. Large rock outcrops are common *(fig. 1).* Annual temperatures range from a high of 70 °F to a low of -25 °F. Average annual precipitation is 32 inches with 80 percent falling as snow. Summer drought and drought years are common with 1987-1992 and 1994 being particularly dry.

Figure 1—Overview of the study area. Note the large granite rocks, recently grubbed Jeffrey pines, and developing plant community. June 1985.

Study and Design

The study presents density and development data on pine seedlings and shrubs, forbs, and grasses collected from 1986 through 1994. It includes information gathered on plants developing naturally (control) and after several treatments.

The year after the fire (1982), the area was logged by tractor, and all merchantable trees were removed. Jeffrey pine seedlings from the Placerville Nursery were then planted in spring 1983. They had spent 2 years in the nursery and were large and healthy. Spacing was 10 by 10 feet. In August 1985, each seedling was released by hand-grubbing a 4-foot radius around it. Consequently, when we began the study in 1986, the Jeffrey pine seedlings had developed with the natural post-burn plant community for three growing seasons.

The band of sheep initially consisted of 1,000 ewes and 23 rams, all experienced with wildland conditions. They were trucked to an area near the study site, unloaded, and allowed to browse for a week to become accustomed to the wildland environment *(fig. 2)*. Then, under the vigilant eye of a Basque shepherd and three sheep dogs, they were guided through about a 400-acre area that included the study site. The study site was grazed each year from 1986 through 1990. At least 1,000 sheep were present each year, with over 1,500 in 1987. The daily routine began at about 5:30 a.m. with the sheep foraging through an area for 5 hours and then bedding down in a shaded area having water. This was repeated from 4 to 8 p.m. each evening. The band passed through the study site at least 10 times each summer. The length of the grazing season depended on the availability of water. The sheep usually arrived at the study site from mid-May to mid-June and departed around October 1. If the water sources dried up, the sheep were moved out earlier. They departed August 24, 1990, for example.

The experimental design was completely randomized with four treatments and three replications. Treatments were grazing (no fence), manually maintaining a 4-foot radius (fence), applying Velpar (fence), and control (fence). The 4-foot tall fence, which was installed shortly before the study treatments were applied, was constructed of hog wire and maintained each year to exclude the sheep. The 4-foot radius, initially installed in fall 1985, was maintained each year for the first 3 years (1986-1988) by grubbing new plants within the radius and clipping plant

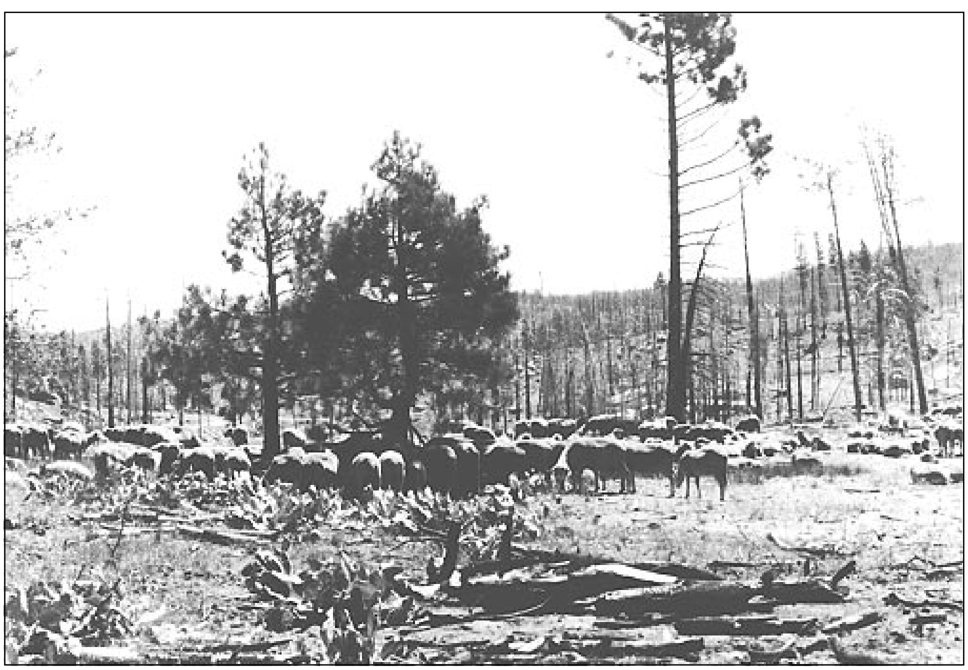

Figure 2—These sheep have just been offloaded from the trucks and are beginning to graze near the study area.

parts that leaned into it *(fig. 3)*. Near free-to-grow replications (plots) were created by applying Velpar L[1] one time in mid-October 1986. Velpar is a soil-active herbicide. It was applied from a backpack apparatus and a carbon-dioxide pressurized boom at the rate of 2 pounds acid equivalent per acre *(fig. 4)*. Nozzles on the boom were the same as those used in helicopter applications; therefore, the rate of application and droplet size were similar. The boom, which covered a 9-foot swath, was held about 12 inches above the shrubs, and the spray was directed downward. Trial runs with water determined the proper walking speed needed to apply the correct amount of herbicide to each plot. The entire plot and half the buffer were sprayed. Application took place in clear, calm weather between 8 and 9 a.m. PST.

[1]This paper neither recommends the pesticide uses reported nor implies that the pesticides have been registered with the appropriate governmental agencies.

The cost of installing each treatment was calculated from hourly records and a wage of $8.74 per hour, the rate for a WG-1 laborer, U.S. Department of Labor, as of June 1993.

Each plot was roughly rectangular and consisted of about 0.5 acre with at least 40 seedlings surrounded by two rows of buffer (seedlings receiving similar treatment). About 20 healthy seedlings, identified as potential crop trees, were flagged. As their name implies, these were thrifty seedlings that had good potential of becoming harvestable trees. Small, misshapen and discolored seedlings were excluded—their chance of being alive at the end of the study was remote, given the large populations of rapidly growing shrubs and grasses. For each of the sample seedlings, stem height and stem diameter at 12 inches above mean groundline were measured. The seedlings also were checked for possible injury by sheep, herbicide, and other agents.

Sampling intensity for shrubs, forbs, and grasses was five randomly selected subplots in each plot. Subplots were centered around Jeffrey pine seedlings. They were square and contained 1 milacre (0.001 acre). The most abundant species were measured for density, foliar cover (the sum of shadows that would be cast by leaves and stems of individual species expressed as a percentage of the land surface [Daubenmire 1968], and average dominant height (average of the three tallest stems measured from mean groundline to bud). Less abundant species were not measured, but noted in a species list.

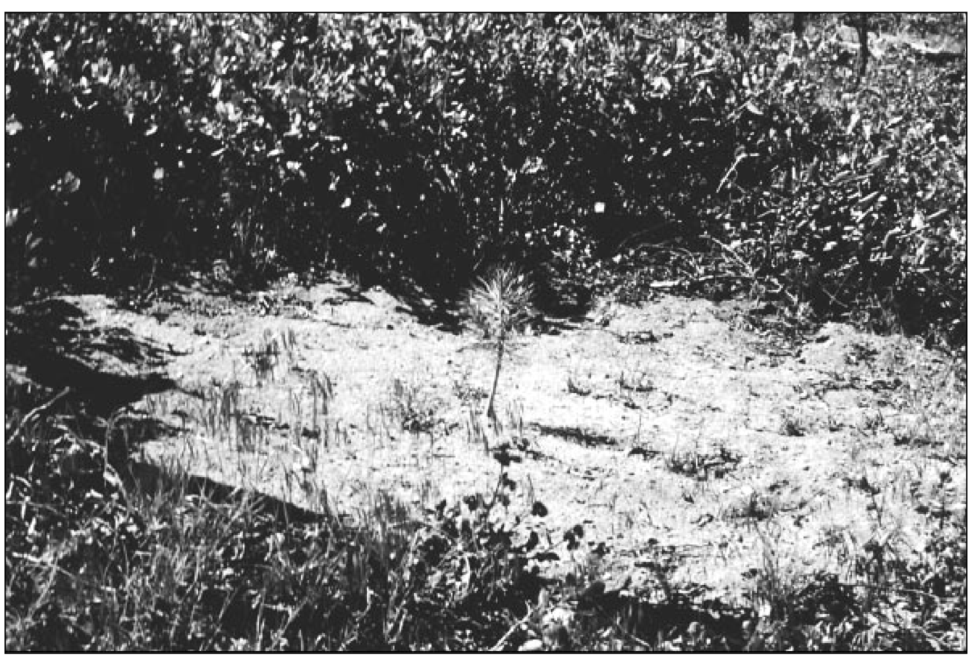

Figure 3—A Jeffrey pine seedling in the center of a 4-foot grubbed area. A few grasses and forbs are invading the treated area.

Figure 4—Applying Velpar herbicide from a backpack and boom apparatus. The man in the background is moving to another swath width as a guide to ensure that areas are not double-treated or missed.

Vegetation was measured in late summer/fall 1986-1988, 1990, and 1994, and data were statistically analyzed each year. To test for treatment effects and significant differences among treatments, one-way analysis of variance of treatment means (fixed model, Steel and Torrie 1980) and Tukey tests were the analytical tools (Wilkinson 1989). Significance in all tests was at $\alpha = 0.05$. Data were gathered from permanent plots measured each year, and where analyses of means from repeated measurements are concerned, the data are not truly independent. The levels or type I errors given for various tests apply to each measurement and year separately.

Results

Manipulating vegetation in young conifer plantations involves more than just reducing the density and development of the tallest and most competitive plant species. Large numbers of shorter plants may be just as capable of capturing available resources and limiting conifer seedling survival and growth. Because we wanted to denote vegetative trends associated with grazing and other treatments, we quantified several growth parameters not only of Jeffrey pine, but also of two aggressive shrub species and one abundant alien, but naturalized, grass species. We also listed all the plant species in our area at the beginning and end of the study, and noted the effect of treatment on plant diversity.

Plant Diversity

At the beginning of the study in 1986, the plant community consisted of 4 shrubs, 24 forbs, and 8 graminoids. At the study's end in 1994, 4 shrubs, 22 forbs, and 6 graminoids were recorded *(table 1)*. Seven species that were present in 1986 were not found in 1994 and three species found in 1994 were not recorded in 1986. At the end of the study, the number of shrub, forb, and graminoid species by treatment was:

Treatment	*Number*
Grazed 5 years	21
Grubbed 3 years	17
Velpar 1 year	14
Control	21

Table 1—*Plant species in each treatment, Elephant Burn, Plumas National Forest, California, 1994*

	Species	Control	Grazing 5 years	Grubbing 3 years	Velpar 1 year
Shrubs	*Arctostaphylos patula*	X	X	X	–
	Ceanothus prostratus	–	X	X	X
	Ceanothus velutinus	X	X	X	X
	Purshia tridentata	X	–	–	–
Forbs	*Achillea millefolium*	X	–	–	–
	Agoseris spp.	–	–	X	–
	Anaphalis margaritacea	X	–	–	–
	Apocynum androsaemifolium	–	–	X	X
	Collinsia parviflora	X	X	X	–
	Cryptantha spp.	X	–	–	–
	Epilobium spp.	X	X	X	X
	Eriogonom parishii	X	X	–	–
	Hypochaeris spp.	–	X	–	–
	Linanthus ciliatus	X	–	–	–
	Lotus spp.	X	X	–	X
	Mentzelia congesta	–	–	X	–
	Mimulus spp.	–	X	–	X
	Montia spp.	X	X	X	X
	Navarretia spp.	X	X	–	X
	Paeonia brownii	X	X	X	X
	Penstemon heterodoxus	X	–	–	–
	Phacelia hastata	–	X	X	X
	Stephanomeria spp.	–	X	X	–
	Tragopogon dubius	X	X	X	X
	Wyethia mollis	–	X	–	–
Graminoids	*Achnatherum occidentalis*	X	X	X	X
	Bromus tectorum	X	X	X	X
	Carex spp.	X	X	X	–
	Muhlenbergia filiformis	X	–	–	–
	Poa spp.	–	–	–	X
	Sitanion hystrix	X	X	X	–

In the plots treated by Velpar, the tree crowns were so full that they often touched the ground and occupied almost all of the area. Little unshaded ground was available for forbs and grasses. Lack of available space also characterized the manually grubbed 4-foot radius plots. Here the combination of tree crowns in the plots and shrub crowns leaning into the plots from 1991 to 1994 was the probable cause of the lower number of species in this treatment at the end of the study.

Snowbrush

In fall 1986, plants of this fast-growing evergreen shrub varied from almost 700 to 2,400 per acre *(table 2).* About half were sprouts from root crowns, and half originated from dormant seeds in the soil. Their crowns covered from 1 to 3 percent of the plot area, and their height ranged from 0.3 to 1.3 feet. In the Velpar treatment, a few short plants from seed were recorded. These plants died the following spring when their roots grew deep enough to encounter the herbicide—a process that was repeated in 1987 but not thereafter. Plant density and development did not differ among treatments.

In 1987, mean snowbrush density, foliar cover, and height increased in all treatments except Velpar. Mean foliar cover was significantly greater in grazed than in Velpar treatments—a trend that remained constant throughout the study. By 1990 mean foliar cover of snowbrush in grazed plots was significantly larger than in any other treatment. By 1994, mean foliar cover in grazed plots was three times greater than in the control. Grazing actually stimulated foliar cover of

Table 2—*Average density, cover, and height of snowbrush, Elephant Burn, Plumas National Forest, California, 1986-1994*

Year	Treatment	Density	Cover	Height
		Plants/acre	*pct*	*ft*
1986	Grazed 5 years	2,400 a[1]	3 a	0.9 a
	Grubbed 3 years	2,267 a	1 a	0.8 a
	Velpar 1 year	733 a	1 a	0.3 a
	Control	667 a	1 a	1.3 a
	Standard error	991	1.2	0.24
1987	Grazed 5 years	3,867 a	14 a	1.6 a
	Grubbed 3 years	2,467 a	5 ab	1.3 a
	Velpar 1 year	67 a	0 b	0.1 a
	Control	1,867 a	5 b	1.6 a
	Standard error	979	2.4	0.27
1988	Grazed 5 years	4,533 a	18 a	1.9 a
	Grubbed 3 years	3,000 a	5 ab	1.8 a
	Velpar 1 year	0 a	0 b	0 a
	Control	2,000 a	8 ab	2.1 a
	Standard error	1,014	3.2	0.13
1990	Grazed 5 years	4,600 a	33 a	2.2 a
	Grubbed 3 years	3,133 ab	8 b	1.8 a
	Velpar 1 year	0 b	0 b	0 a
	Control	2,000 ab	14 b	2.4 a
	Standard error	797	3.8	0.27
1994	Grazed 5 years	3,000 a	30 a	2.3 a
	Grubbed 3 years	1,867 a	8 b	1.9 a
	Velpar 1 year	0 a	0 b	0 a
	Control	1,267 a	10 b	2.4 a
	Standard error	700	2.9	0.21

[1]For each year, treatment means in each column followed by the same letter do not differ significantly according to a Tukey Test (α = 0.05).

snowbrush. The sheep would browse only the tender twigs and the flowers. Each twig then developed several buds that produced more twigs that led to horizontal expansion of the plants. Another agent that affected snowbrush was the California tortoise shell butterfly *(Nymphalis californica* Boisduval) *(fig. 5).* Infestation by larvae occurred from June 20 to July 20, 1987, when almost every plant in the study area was denuded *(fig. 5).* Most plants responded by producing a few leaves that were promptly eaten by the sheep before they fully developed. Little long-term effect from this defoliation could be discerned, however, and the large amount of nutrient-rich frass provided by the larvae probably enhanced shrub growth the following year.

The overall trend for snowbrush was an increase in density and development for all treatments (except Velpar) through 1990 and then a decrease in density and foliar cover in 1994. The decrease in density was caused by mortality to young snowbrush seedlings that could not compete with snowbrush sprouts, pine seedlings, and other shrubs and grasses. The decrease in plant cover in grazed and control treatments probably was caused by the cumulative effect of the drought years. Almost every large plant had one or more dead or dying stems in each clump.

Greenleaf Manzanita

In fall 1986, plants of this hardy evergreen shrub varied from 200 to more than 700 per acre *(table 3).* Most plants were sprouts from root crowns, except in the 4-foot-radius plots maintained for 3 years where new seedlings from dormant seeds in the soil represented the species. Aggregate crown development, as quantified by

A

B

Figure 5—(A) Tent and larvae of the California tortoise shell butterfly in a snowbrush crown. (B) Severely defoliated snowbrush plant in study area. Fall 1987.

foliar cover, was poor (1 percent), and height was average (0.6 to 1.2 feet) for this site. In the Velpar treatment, a few small plants from seed were recorded. These died the following spring when their roots encountered the herbicide in the soil. No manzanita seedlings were found on Velpar plots after 1986.

Although greenleaf manzanita is given only a marginally palatable designation (USDA Forest Service 1947), it was browsed heavily by the sheep each year. Indeed in 1987, utilization was visually rated at 75 percent of greenery. The trend of increasing manzanita density in radius plots continued through 1990 but then declined slightly. In general, manzanita height was similar among treatments throughout the study and no statistical differences were noted. None

Table 3—*Average density, cover, and height of greenleaf manzanita, Elephant Burn, Plumas National Forest, California, 1986-1994*

Year	Treatment	Density	Cover	Height
		Plants/acre	*pct*	*ft*
1986	Grazed 5 years	467 a[1]	1 a	1.2 a
	Grubbed 3 years	733 a	1 a	0.7 a
	Velpar 1 year	200 a	0 a	0.2 a
	Control	333 a	1 a	0.6 a
	Standard error	360	0.5	0.36
1987	Grazed 5 years	733 a	1 a	1.3 a
	Grubbed 3 years	867 a	2 a	1.0 a
	Velpar 1 year	0 a	0 a	0 a
	Control	867 a	1 a	1.4 a
	Standard error	392	0.8	0.41
1988	Grazed 5 years	867 a	1 a	1.4 a
	Grubbed 3 years	1,267 a	2 a	1.3 a
	Velpar 1 year	0 a	0 a	0 a
	Control	1,200 a	2 a	1.6 a
	Standard error	482	1.0	0.45
1990	Grazed 5 years	600 a	1 a	1.6 a
	Grubbed 3 years	1,465 a	2 ab	1.5 a
	Velpar 1 year	0 a	0 a	0 a
	Control	1,600 a	5 b	2.2 a
	Standard error	601	0.9	0.41
1994	Grazed 5 years	467 a	2 a	1.5 a
	Grubbed 3 years	1,400 a	4 ab	1.8 a
	Velpar 1 year	0 a	0 a	0 a
	Control	933 a	7 b	2.1 a
	Standard error	427	1.0	0.24

[1]For each year, treatment means in each column followed by the same letter do not differ significantly according to a Tukey Test ($\alpha = 0.05$).

was found for plant density as well. Only for foliar cover in 1990 and 1994 were statistical differences found; significantly more cover was present in the control than in grazed plots.

Cheatgrass

Cheatgrass *(Bromus tectorum* L.) is an annual alien species that invaded North America from Eurasia in 1889-1894 and spread throughout what is now its naturalized range by 1928 (Mack 1981). It has several adaptations that allow it to effectively colonize and become established in disturbed areas. It produces huge seedcrops, has an extensive root system, a high root-shoot ratio, capability for root growth in cold soils, and maturity early in the growing season (Jackson 1985).

By spring 1986 when we began the study, cheatgrass had spread throughout the study area. In general, it was well established, but differed somewhat in density and distribution *(table 4).* Density values ranged from 200 to 702,000 plants per acre and foliar cover from 0 to 15 percent. Both density and foliar cover increased and decreased yearly, and no chronological trend was noted. A general trend was that density and cover were greater in the less intensive treatments (grazed, control) than in the more intensive treatments (grubbed radius, Velpar). Of particular note was the relatively low density values of cheatgrass in the Velpar treatment through 1988 followed by a huge increase. This abrupt change in density suggests that the herbicide was present and effective in the soil through 1988 but not thereafter.

Table 4—*Average density, cover, and height of cheatgrass, Elephant Burn, Plumas National Forest, California, 1986-1994*

Year	Treatment	Density	Cover	Height
		Plants/acre	*pct*	*ft*
1986	Grazed 5 years	8,067 a[1]	1 a	0.6 a
	Grubbed 3 years	200 a	0 a	0.7 a
	Velpar 1 year	5,467 a	0 a	0.5 a
	Control	153,467 a	9 a	0.9 a
	Standard error	60,718	3.0	0.13
1987	Grazed 5 years	15,800 a	4 a	0.9 a
	Grubbed 3 years	1,200 a	1 b	1.1 a
	Velpar 1 year	1,667 a	0 b	0.9 a
	Control	89,733 b	12 c	1.1 a
	Standard error	17,305	0.5	0.11
1988	Grazed 5 years	57,067 a	6 ab	0.9 a
	Grubbed 3 years	3,800 b	1 a	0.9 a
	Velpar 1 year	7,333 b	3 a	1.2 a
	Control	68,267 a	10 b	1.0 a
	Standard error	11,228	1.7	0.08
1990	Grazed 5 years	702,200 a	14 a	1.2 a
	Grubbed 3 years	80,600 a	3 a	1.0 a
	Velpar 1 year	316,867 a	11 a	1.3 a
	Control	411,533 a	15 a	1.0 a
	Standard error	188,447	4.9	0.07
1994	Grazed 5 years	251,000 a	8 a	0.9 a
	Grubbed 3 years	148,000 a	3 a	0.7 a
	Velpar 1 year	147,000 a	3 a	0.8 a
	Control	184,000 a	7 a	0.7 a
	Standard error	45,059	2.2	0.06

[1]For each year, treatment means in each column followed by the same letter do not differ significantly according to a Tukey Test ($\alpha = 0.05$).

Combined Forbs

Forbs in the study area seemed to be distributed in two ways, depending on species and treatment. Some species tended to be scattered with a few plants here and there regardless of treatment. Others were present in widely scattered aggregations in specific treatments. Some species preferred openings, however small; others found the shade of taller plants to provide a desirable environment. Several species favored the continuously disturbed environment of the grubbed radius plots, but few could compete in the Velpar plots dominated by the full-crowned Jeffrey pines.

Data from 1990 serve as an example of forb density and development. At no time during the study did we find statistically significant differences among treatments. In 1990, mean density of combined forbs ranged from 3,133 plants per acre in grazed plots to 6,000 plants per acre in grubbed radius plots *(table 5).* Average foliar cover ranged from 0 to 2 percent, and mean height spanned the 0.2- to 0.5-foot range.

Jeffrey Pine

Survival of Jeffrey pine seedlings varied only slightly among treatments during the 1986-1994 period. At the end of the study, survival was 100 percent in grazed and grubbed radius treatments, 93 percent in Velpar plots, and 92 percent in the control. Pocket gophers *(Thomomys* spp.) were the principal cause of mortality. In

Table 5—*Average density, cover, and height of combined forbs, Elephant Burn, Plumas National Forest, California, 1990*

Treatment	Density	Cover	Height
	Plants/acre	*pct*	*ft*
Grazed 5 years	3,133 a[1]	0 a	0.2 a
Grubbed 3 years	6,000 a	1 a	0.4 a
Velpar 1 year	4,800 a	2 a	0.5 a
Control	5,733 a	0 a	0.5 a
Standard error	2,658	0.6	0.18

[1]For each year, treatment means in each column followed by the same letter do not differ significantly according to a Tukey Test ($\alpha = 0.05$).

Table 6—*Average diameter, height, and cover of Jeffery pine, Elephant Burn, Plumas National Forest, California, 1986-1994*

Year	Treatment	Diameter	Cover	Height
		inches	*pct*	*ft*
1986	Grazed 5 years	0.4 a[1]	0 a	0.9 a
	Grubbed 3 years	0.4 a	1 a	1.0 a
	Velpar 1 year	0.4 a	1 a	1.1 a
	Control	0.5 a	0 a	1.0 a
	Standard error	0.05	0.3	0.14
1987	Grazed 5 years	0.4 a	3 a	1.3 a
	Grubbed 3 years	0.5 a	3 a	1.6 a
	Velpar 1 year	0.7 a	4 a	1.8 a
	Control	0.5 a	3 a	1.6 a
	Standard error	0.07	0.7	0.21
1988	Grazed 5 years	0.5 a	5 a	1.5 a
	Grubbed 3 years	0.7 b	6 a	2.2 a
	Velpar 1 year	1.2 b	11 a	2.6 a
	Control	0.6 a	5 a	2.0 a
	Standard error	0.11	2.1	0.30
1990	Grazed 5 years	0.9 a	5 a	2.3 a
	Grubbed 3 years	1.3 a	8 ab	3.2 ab
	Velpar 1 year	2.6 b	19 b	5.2 b
	Control	1.1 a	8 ab	2.9 a
	Standard error	0.23	2.6	0.52
1994	Grazed 5 years	1.9 a	19 a	4.7 a
	Grubbed 3 years	2.4 a	17 a	5.8 a
	Velpar 1 year	4.6 b	72 b	10.5 b
	Control	2.2 a	25 a	5.2 a
	Standard error	0.40	7.4	0.93

[1]For each year, treatment means in each column followed by the same letter do not differ significantly according to a Tukey Test ($\alpha = 0.05$).

spite of resident deer *(Odocoileus* spp.), rodents, and other animals, damage to pine seedlings was minimal. The only browsing damage noted was in 1987 when the sheep nipped a few lateral buds in the grazing treatment. No damage from the herbicide was observed.

Statistically significant differences among treatments for pine stem diameter first showed up in fall 1988 *(table 6).* Seedlings in the Velpar treatment were larger than counterparts in grazed and control areas. This trend continued thereafter as seedlings in herbicide-treated plots had significantly larger diameters at 12 inches above mean groundline than seedlings in all other treatments. Statistically significant differences for foliar cover and height first

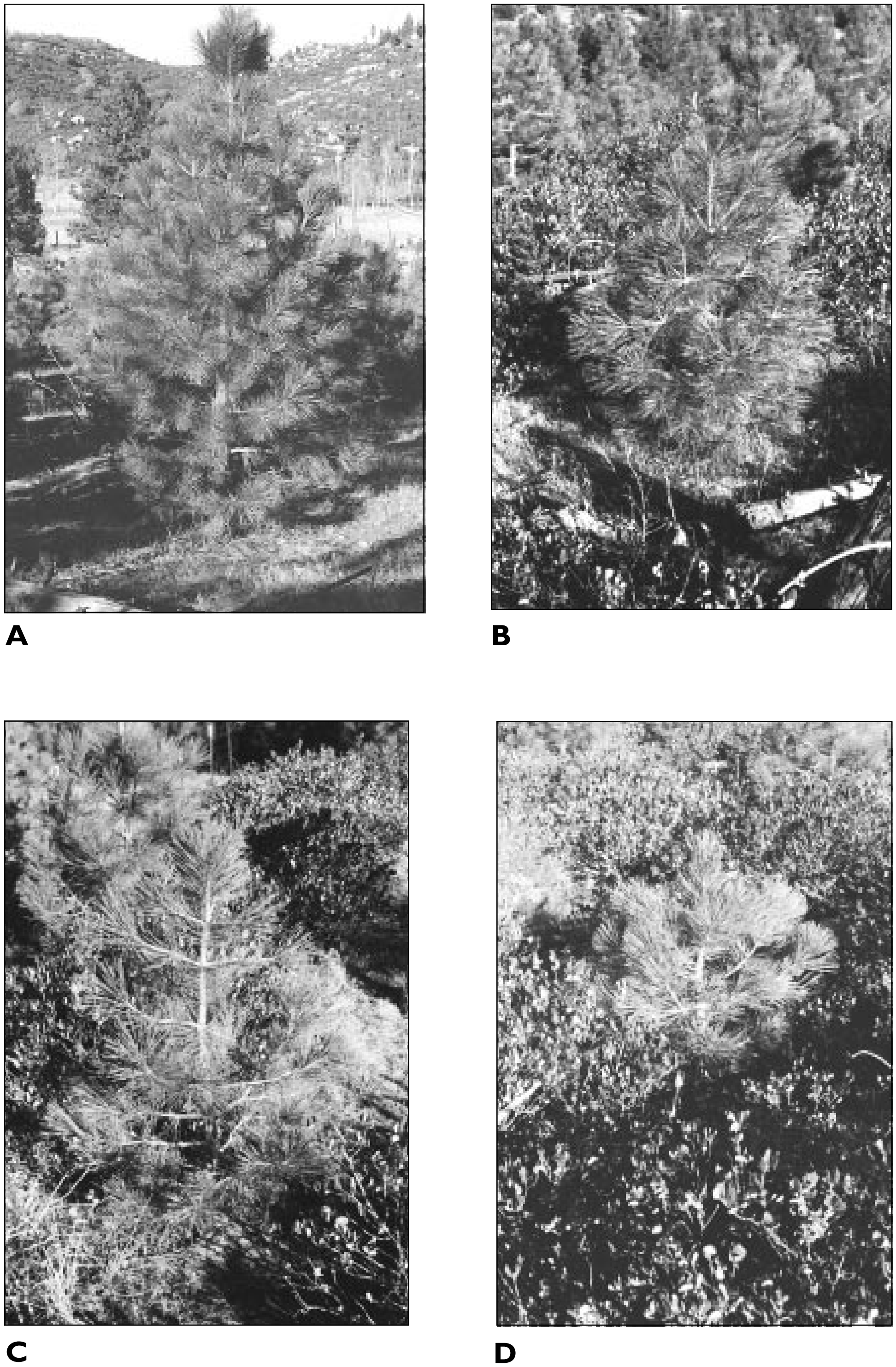

Figure 6—Relative development of Jeffrey pine and surrounding plant community, by treatment, fall 1994. (A) Velpar herbicide, (B) 4-foot radius grubbed three times, (C) control, (D) grazed 5 years.

showed up at the next measurement in 1990. By study end, mean foliar cover and height of seedlings in the Velpar treatment were significantly larger than seedlings in all other treatments *(fig. 6).* In fact, herbicide-treated seedlings had 92 percent more girth and 324 percent more cover, and were 81 percent taller than seedlings in the next closest treatment.

Treatment Costs

The cost of grazing with sheep was considered to be zero. The money paid by the permittee equaled the Forest Service's cost of inspecting the area and moving the sheep to the allocated area each year. The cost of manually grubbing a 4-foot radius around conifer seedlings for 3 years involved two components: removing plants, and clipping plants that leaned into the radius. For the first year, both grubbing and clipping were required; by the third year, retreatment consisted almost entirely of clipping. Grubbing a 4-foot radius three times proved expensive. Applying Velpar was inexpensive although the chemical itself was costly:

Treatment	*Dollars per acre*
Grazed 5 years	0
Grubbed 3 years	420
Velpar 1 year	
Chemical	75
Application	27

Discussion and Conclusions

The individual treatments comprising this study, applied in an area burned by wildfire, provide a means for portraying plant succession in a natural state (control), after an effective plot-wide second disturbance (herbicide), after an ineffective, small-scale disturbance that was applied continuously for 3 years (4-foot radius grubbed), and after an ineffective area-wide disturbance that took place continuously for 5 years (grazing by sheep). Ecologists, foresters, wildlife biologists, ranchers, and others should find the interrelationship of snowbrush, greenleaf manzanita, cheatgrass, forbs, and ponderosa pines *(tables 2-6)* useful because of the wide range of disturbance.

When we began this study in fall 1985, treatment "effectiveness" was geared mostly to increasing growth of the conifer seedlings. They were the economic crop. Money had been spent to gather their seeds, propagate them in nurseries, and plant them where a new forest was desired. The effect of grazing was unknown but suspected to be moderate/low in effectiveness; Velpar was known to be an effective herbicide; grubbing a 4-foot radius, which was thought to be a large treated area at that time, was given moderate to high marks; and no treatment (control) would provide no effect.

In 1986, the first year of the study, most plant species were well established, but not fully so. Some bare area remained and colonization, at least through 1990, resulted in increasingly higher densities of shrubs, graminoids, and forbs. After 1990, mean plant density and foliar cover tended to decrease although height increased slightly. Too many plants per unit area and the effect of cumulative drought are possible reasons for this decrease.

By the end of the study, vegetation in the various treatments ranged from more than 256,000 plants per acre in grazed areas to 150,000 plants per acre in Velpar areas. More than 97 percent of this vegetation was cheatgrass. This high percentage tended to mask species/treatment relationships. However, noting treatments with "most" and "least" amounts of specific vegetation helps portray them. Of all the treatments, grazing resulted in the most snowbrush and cheatgrass, the smallest Jeffrey pines, and a tie with the control for the highest number of plant species. The 4-foot radius plots that were grubbed for 3 years had the most manzanita and forbs. The Velpar plots had the least snowbrush, manzanita, and cheatgrass, the largest Jeffrey pines, and the lowest number of plant species.

Averaging 10.5 feet in height and 4.6 inches in diameter, the Jeffrey pine saplings in the Velpar treatment constituted the tallest vegetation in the area—4.3 times taller than the tallest shrubs. The effect of the herbicide-treated environment was to provide a plant community of tall, vigorous, wide-crowned trees that were growing at the potential of the site. This treatment, however, did not provide an environment that was totally free of vegetation. Cheatgrass was present. And although this grass used site resources, the vigorous growth of the pines suggests that its effect must have been small. Furthermore, the grass could have interfered with the germination of dormant shrub seeds in the soil (McDonald 1986). Excluding the aggressive shrubs with their high resource use would be a net gain.

A principal tenet in vegetation management is that treatment be applied as soon as possible after disturbance, and before the competing vegetation can become established. In this study, naturally occurring vegetation was present for 4 years before the treatments were applied, and planted pine seedlings had to endure competition from it for 3 years. Plainly, competing vegetation was well established before the study began, and the need for strong treatments that would remove competing vegetation from enough area for enough time to release the conifer seedling was obvious.

Previous work has shown that the minimum area needed to allow statistically significant conifer seedling development (relative to a control) is a 5-foot radius (Fiddler and McDonald 1984, McDonald and Fiddler 1989). Smaller radii do not provide a nursery-grown conifer seedling enough time to develop its root system well enough to get to, and stay in, a zone of adequate soil moisture. The better adapted, naturally occurring shrubs and grasses with faster-developing and more massive root systems (Jackson 1985, Logan 1983, McDonald 1982, McDonald and Fiddler 1989, Mooney and Dunn 1970) reach the zone of adequate soil moisture first, use the moisture, and deny it to the conifer seedlings. The grubbing and grazing treatments were ineffective because too much well-established competing vegetation remained.

Another important tenet of vegetation management is that, to have value, release must be effective soon after treatment. Otherwise, the competing vegetation has even more time to develop and capture site resources. The herbicide treatment, by virtue of the near free-to-grow environment that it created, allowed pine seedling diameter to become significantly larger than that of seedlings in the control three growing seasons after treatment. This duration is about as soon as can be expected, given the 3-year delay between planting and treatment.

An objective of this study was to quantify the recovery of the vegetation after the sheep were removed. Recovery from grazing can happen only if damage, and particularly chronic damage, has occurred. The only damage that we could detect was minor—manzanita cover with grazing was significantly lower than that in the control. Consequently, quantifying recovery was not possible because there was virtually no damage to recover from.

Heightened public concern and increased restrictions on use of herbicides have caused many natural resource managers to look for other methods to control unwanted vegetation in young conifer plantations. Livestock grazing has been suggested as an alternative silvicultural tool (Doescher and others 1987, Sharrow and others 1989, Thomas 1984). Wray (1987) claimed that sheep "graze off unwanted brush, help trees grow, save money, and provide fertilizer in the bargain." In spite of this belief, a key question remains: Do sheep consume enough competing vegetation to *significantly* enhance the growth of the planted conifer seedlings? Are they an effective vegetation management tool? Although studies in the moist Oregon Coast Range indicated that diameters of Douglas-fir *(Pseudotsuga menziesii* [Mirb.] Franco) seedlings increased by 7 to 14 percent in grazed areas as compared to ungrazed controls (Sharrow and Leininger 1983), a more recent study in summer-dry northern California showed that 10 continuous years of grazing deerbrush *(Ceanothus integerrimus* H. & A.) by sheep did not significantly increase diameter or height of ponderosa pine seedlings (McDonald and Fiddler 1993).

Because this study and another (McDonald and Fiddler 1993) did not demonstrate a significant gain in ponderosa and Jeffrey pine seedling growth, the use of sheep as a release tool for silviculturists seems questionable. Current grazing practice has several weaknesses, at least as practiced in northern California. To begin with, sheep are seldom used the first season after logging or burning—the perception is that not enough forage is present and that damage to planted conifer seedlings will be severe. In addition, when sheep are used in subsequent growing seasons, the timing is poor. Traditionally, they feed at lower elevations until the forage is gone, then they are trucked to higher elevations in the forest zone. Usually this is too late. Most of the early, tender, and more nutritious growth has become hard and mature, or eaten by other herbivores. And even when the sheep are present for wildland grazing, the tendency is to herd them to the most nutritious forage, and remove them before secondary species and plant parts are all that remain. The end result is that grazing is too little, too late, and utilization is never high enough to make a significant difference in the competitive ability of the shrubs, forbs, and grasses.

Plainly, the basic tenets of vegetation management must be met if grazing by sheep is to become a viable silvicultural alternative. This means the sheep must be allowed to graze new plantations as soon as possible—preferably during the first growing season after planting. And they should be brought to the plantation each spring as soon as possible to utilize the vegetation before carbohydrate reserves are replenished. Once there, the sheep should be held in the area to graze as much vegetation as possible even if it means consuming less than prime forage. If these conditions cannot be met, the range deteriorates, or damage to conifer seedlings becomes intolerable, then grazing with sheep will be recognized as an inviable tool for enhancing conifer seedling growth.

Grazing, however, still should be considered from the viewpoint of the other return from the land—the sheep—and more specifically their wool, meat, and lambs. The owners' records indicate that each ewe gained an average of 126 pounds during the summer. About 20 percent of ewes had twins. More than once, the owner indicated that he was pleased with grazing in the area, and protested vigorously when he could not return.

The cost data presented in this study reflect the interplay between amount and size of competing vegetation and the cost of controlling some of it. For manual release, the dollars spent achieved little gain; for applying herbicide, a large gain resulted; for grazing, little gain and no cost characterized the treatment.

The grazing, grubbing, and herbicide treatments in this study created two vegetative assemblages that probably will lead to different plant communities in the future. The future community on herbicide-treated areas likely will be primarily Jeffrey pine with scattered plants of cheatgrass and a few forbs. The crowns of the pines will close in the near future and even fewer plants with less biomass will be present. The potential for a fully stocked forest developing in the shortest time possible is high. The other treatments will lead to a plant community composed of pines and shrubs with grasses and a few forbs in small openings or under crowns. The time it will take to become a forest will be longer and the tree canopy likely will be more open.

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