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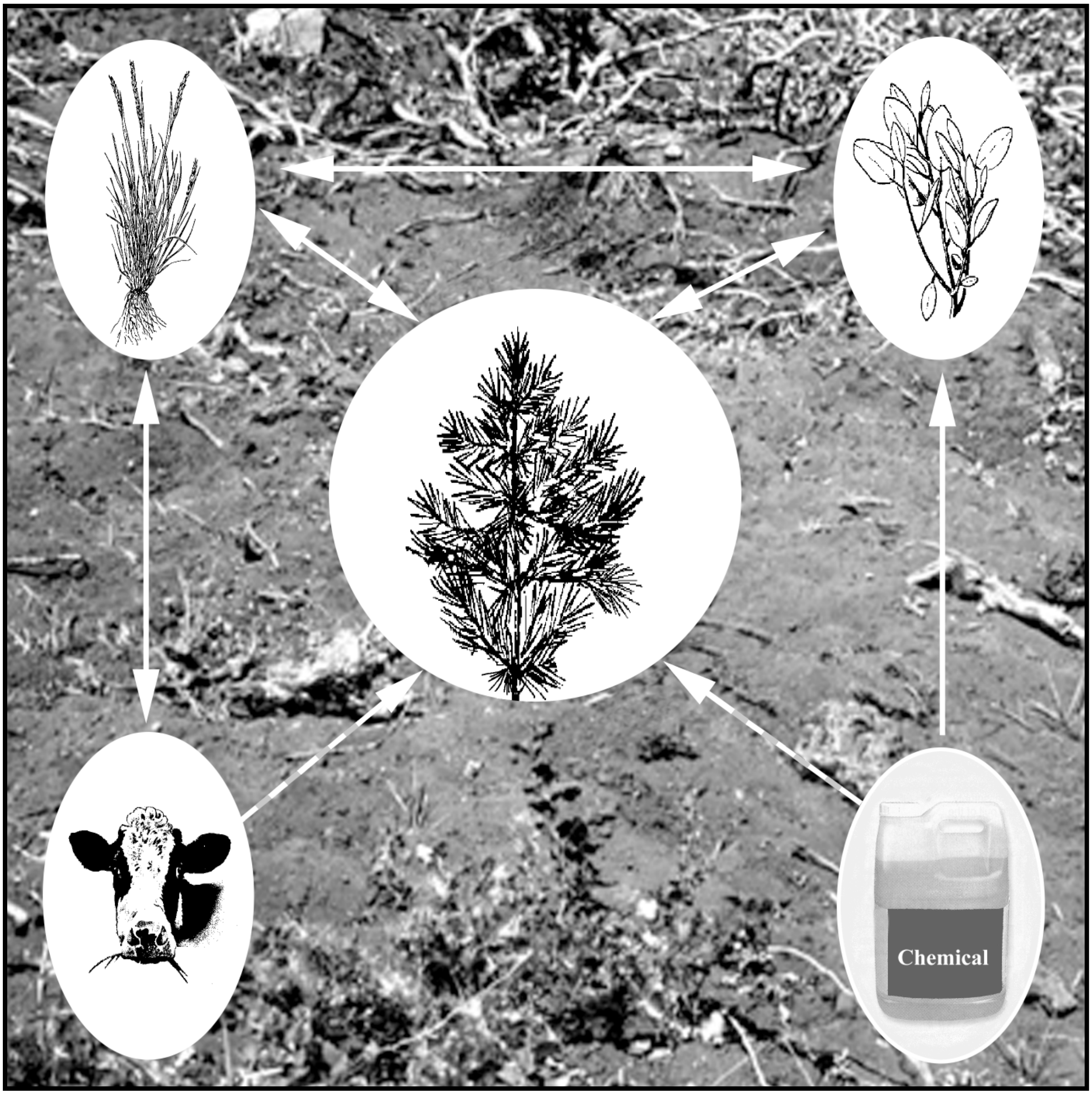
Effect of Cattle Grazing, Seeded Grass, and an Herbicide on Ponderosa Pine Seedling Survival and Growth

Philip M. McDonald **Gary O. Fiddler**



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Abstract

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On a site of above-average quality in northern California, an early shrub-forb-grass plant community was treated by artificially seeding two forage grass species at plantation age 3, cattle grazing with and without seeded grasses, and applying a soil-active chemical (Velpar). Planted ponderosa pines were part of this community. Results for a 10-year period (1988-1997) are presented for planted pines, manzanita, other shrubs, forbs, and grasses (natural and seeded). In general, the pines, manzanita, and grasses were numerous and developing well after 10 years, and the other shrubs and forbs were declining in density or foliar cover or both. Velpar was the only treatment that significantly improved pine seedling growth. Grazing did not. The seeded (introduced) grasses, which were heavily grazed, probably reduced damage to the pines. The grasses also helped reduce manzanita foliar cover when grazed. No evidence was found that the introduced grasses served as a biological control in terms of reducing the density of manzanita or other shrubs.

Retrieval Terms: cattle grazing, northern California, plant community dynamics, ponderosa pine, seeded grasses, vegetation management

The Authors

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In Brief...

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Although plantations are established and maintained to ensure that conifer and hardwood seedlings grow at the potential of the site, some bare ground usually is present, particularly when the seedlings are small. This bare ground is susceptible to erosion and is considered by some people to be unsightly. Covering the ground with plants that have low competition potential in terms of moisture use would mitigate or solve the problems of erosion and unsightliness. If this vegetation was palatable and of sufficient quantity, the cattle that it sustains could serve as another yield from the land and help pay for the cost of establishing the plantation. Furthermore, if the cattle concentrated on it, it could mean less damage to the conifer seedlings. And, if this vegetation would inhibit the germination of shrub seeds in the soil, or seeds of other weeds that were carried into the area, it would act as a biological control.

The objectives of this 10-year (1988-1997) study were fourfold: (1) to identify and quantify the vegetation that became present in a young ponderosa pine plantation in the northern Sierra Nevada of California; (2) to evaluate the effectiveness of two direct vegetation management treatments—herbicide and cattle grazing—for reducing the size and number of plants in various categories of competing vegetation; (3) to evaluate two species of introduced forage grasses for their ability to rapidly cover the land and grow well, for their potential to inhibit the density and development of other species of vegetation, and for their potentially negative effect on the growth of planted ponderosa pine seedlings; and (4) to quantify the survival and growth of the pine seedlings in these treatments.

Some of these objectives were achieved, and others were only partially successful. For the first objective, plant diversity increased from 17 species in fall 1987 to 35 species in 1997, and trends in density, foliar cover, and height were determined for manzanita, other shrubs, forbs, and grasses over the 10-year study period. In general, manzanita and grasses (native and introduced) prospered, and other shrubs and forbs declined. Total number of plants in the fenced and ungrazed control was 298,400 per acre at the beginning of the study and 128,750 per acre at the end. For the second objective, the herbicide Velpar lowered the density and foliar cover of plants in most of the vegetation categories, although most differences were not statistically significant. The cattle grazed the grasses heavily but not much else. Overall, cattle grazing was not a significant treatment for reducing the vegetation that was competing for site resources with the pine seedlings.

For objective three, the introduced grasses became established quickly, grew well, and spread to other treatment areas. No evidence was found that they reduced the density and development of other species or the growth of ponderosa pine seedlings. They probably did prevent the cows from damaging the terminal shoots of the pine seedlings. For the fourth objective, only Velpar significantly increased the average diameter, height, and foliar cover of the ponderosa pine seedlings relative to most of the other treatments. None of the other treatments differed significantly among themselves. Thus, introduced grass, grazing, their combination, and interaction with the pines did not produce significant results.

Forest vegetation managers have many techniques to manipulate unwanted vegetation in young conifer plantations. If the vegetation is palatable, one such technique is to use cattle. Increasing evidence shows that to be effective, release must take place when the conifer seedlings are young. However, young seedlings are vulnerable to consumption and trampling by cattle. In this study, cattle grazed the area only 3 months after planting—a possibly risky, but sound option that enhances grazing as a vegetation management technique. In spite of this effective beginning, grazing by cattle never significantly enhanced the growth of ponderosa pine seedlings. Although the pines did not benefit, the cattle did, and the owner was pleased with their performance and probably with the economic return. Thus, the acceptability of grazing the transitory range in plantations should be judged on the basis of both the growth of the trees and that of the animals.

Introduction

Planting conifer and hardwood seedlings to create a new forest or reestablish an old one will always be necessary. Reforesting the land after wildfire, timber harvest, or many other kinds of disturbance is essential to minimize erosion and begin the process of growing a crop that will provide future amenities and commodities desired by society. Young plantations have value, not only in terms of future yields, but also for immediate ones as well. A young pine plantation may provide a pleasant view to the passing traveler, it may give sustenance to several species of wildlife, or it might provide forage for cattle, thus contributing to the Nation's rural economy. In a world ever in need of more food and fiber, the dual yield of animal and wood products is attractive. To the landowner, the money from the sale of animal products while the pines are growing is welcome because it helps to compensate for the costs incurred in site preparation and the purchase and planting of pine seedlings.

Plants from many species develop rapidly in the post-site preparation environment, and competition for available resources is fierce. The capability of competing vegetation to capture soil moisture and nutrients often exceeds that of young conifer seedlings (McDonald and Fiddler 1989). The vegetation manager often has no choice but to release the plantation from this competition or risk its failure.

Although the effectiveness of chemicals as a means of controlling undesirable vegetation is well recognized (Gjerstad and Glover 1992, McDonald and Fiddler 1989, Stewart and others 1984), grazing is less certain. In the past, damage to conifer regeneration by livestock has caused land managers to be skeptical of grazing forest land (Dutton 1953). In places, losses have been severe. In a study on the effect of year-long grazing on longleaf pine (*Pinus palustris* Mill.) in Alabama, Boyer (1967) found that even light grazing caused a seedling mortality rate of 23 percent after the first year. McClean and Clark (1980) found damage to heavily stocked stands of lodgepole pine (*Pinus contorta* var. *latifolia*) seedlings in British Columbia to be 46 percent. Trampling and poor cattle management were the causes of damage. Heidmann and others (1982), in Arizona, recommended that cattle be excluded for the first 5 years in areas naturally regenerated by ponderosa pine (*Pinus ponderosa* var. *scopulorum* Engelm.)

Many studies, especially more recent ones, where animals were closely controlled and season of use was carefully monitored, have shown that grazing can be compatible with, and even enhance, the establishment of conifer plantations (*fig. 1*). In eastern Washington, Townsend and Guenther (1981) found that height growth of ponderosa pine *(Pinus ponderosa* Dougl. ex Laws. var. *ponderosa*) seedlings was up to 27 percent greater on grazed units. In eastern Oregon, Edgerton (1971) noted that damage to ponderosa pine regeneration from cattle was light. Proper timing of use was the major factor in minimizing damage. Monfore (1983) found that not only could seedling damage be minimized but that grazing actually became an opportunity for vegetation control in ponderosa and lodgepole pine (*Pinus contorta* var. *murrayana* [Grev. & Balf.] Engelm.) plantations in eastern Oregon. Careful timing of grazing the first season, placement, numbers of livestock, and herd distribution were key considerations.

In California, Sindel (1962) stated that heavy cattle grazing on fresh burns, where deerbrush (*Ceanothus integerrimus* Hook. & Arn.) was abundant, gave beneficial results to ponderosa pine seedling establishment and growth. Site preparation costs were reduced or eliminated, seedling survival and growth were improved, and grazing contributed to the local economy. In the same general area and also with deerbrush as the primary shrub species, Fulmer (1994) found that cattle grazing significantly improved ponderosa pine seedling growth over that in an untreated control. In northeastern California, Ratliff and Denton (1995) found that season-long cattle grazing promoted significantly taller stems on ponderosa pine seedlings than on ungrazed seedlings. In southwestern Oregon, Doescher and others (1989) noted that controlled cattle grazing improved plant water relations and enhanced the growth performance of young conifer seedlings. More specifically, significantly larger stem volume was noted for 3-year-old ponderosa pine and Douglas-fir seedlings on grazed plots than on ungrazed plots.

Not only is the effectiveness of cattle grazing as a direct means of controlling unwanted vegetation uncertain, but using an introduced plant species to enhance it is

Figure 1 — Carefully planned cattle grazing has aided height growth of young ponderosa pines in northeastern California. (Photograph: Renee Denton).

even more uncertain. However, if this introduced species served as a plant favored by cattle, used few site resources, spread over the landscape rapidly, and inhibited the establishment of aggressive plant competitors, it could be useful both for reducing damage to conifer seedlings and serving as a biological control. Several species of grass have the potential to serve in this manner. But grass is notorious for limiting the establishment of conifers in plantations by both physical and chemical interference (Baron 1962, Rietveld 1975, Roy 1953). Grasses can be especially harmful if they constitute favorable habitat for pocket gophers (*Thomomys* spp.), who can invade or multiply rapidly and destroy a young pine plantation (Crouch 1986). However, if the grasses become established after the pines are growing well, they may reduce competition and help more than hinder (McDonald 1986).

Consequently, information is lacking on the interaction of ponderosa pine growth, introduced (artificially seeded) grasses, competing plant species, and cattle. In addition, little is known about the effect of grazed grass on conifer seedling growth, or grazed grass's ability to exclude aggressive competing species, or its ability to lessen damage to pine seedlings because of its preference by cattle.

This paper presents information on the plant community that invaded a new conifer plantation in the western Sierra Nevada; evaluates the effectiveness of direct vegetation management treatments such as grazing and chemicals; investigates the role of seeded grass to rapidly cover the ground and grow well, serve as forage for cattle, and inhibit the establishment of competing vegetation; and quantifies the survival and growth of planted ponderosa pine seedlings in these treatments.

Methods

Location and Site Characteristics

The study area was located on the Foresthill Ranger District of the Tahoe National Forest about 9 airline miles northeast of Foresthill, California. The area burned in a stand-replacement fire in 1960 and became a brushfield. Thus, specific tree and shrub species before it became a brushfield are unknown. However, nearby vegetation suggests that at one time it was mixed conifer forest with ponderosa pine and coast Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco var. *menziesii*) being the most abundant tree species, with occasional sugar pine *(Pinus lambertiana* Dougl.), incense-cedar (*Libocedrus decurrens* Torr.), and California black oak *(Quercus kelloggii* Newb.) scattered throughout. Scientific and common names of trees are from Little (1979) and all other vegetation from Hickman (1993). Prominent species in the pre-study brushfield were whiteleaf manzanita (*Arctostaphylos viscida* C. Parry) and greenleaf manzanita (*A. patula* E.Greene), with scattered plants of Sierra gooseberry (*Ribes roezlii* Regel), serviceberry (*Amelanchier alnifolia* [Nutt.] Nutt.), and western chokecherry (*Prunus virginiana* L. var. *demissa* [Nutt.] Torrey). Plants of these species were tall and well developed, often from large burls located just below the soil surface.

Because of the potential for heavy competition to planted conifer seedlings from these and other shrubs, site preparation and plantation release were judged as necessary. Site preparation by brushrake-equipped bulldozer took place in May 1986 with brush piles burned in the fall. Very little soil was piled, but that which was present was spread by the bulldozer shortly after burning.

The plant community when the study began consisted mostly of plants that originated from dormant seeds in the soil and from windblown seeds. A few California black oak root masses escaped site preparation, but virtually no manzanita or other shrub burls were present. The early community was characterized by many species and large numbers of shrubs, forbs, and grasses. Genera such as *Arctostaphylos*, *Cirsium*, *Horkelia*, *Mimulus*, *Vicia*, *Navarretia*, *Viola*, and *Stipa* (now classified as *Achnatherum* by Hickman [1993]) were especially prominent.

Ponderosa pine seedlings from a local seed source were raised in the USDA Forest Service nursery at Placerville, California, and out-planted in augured holes in spring 1987 as 1-0 bare-root seedlings. Spacing was 10 by 10 feet. Survival in the fall of 1987 was 95 percent.

The study area is traversed annually by migratory deer *(Odocoileus hemionus columbianus*). The herd passes through the area to lower elevations in the fall and to upper areas in the spring. Passage normally is fairly rapid, but sometimes is delayed by spring storms. When this happens, the animals concentrate in the area and eat whatever is available, including the tops of ponderosa pine seedlings. A few resident deer and pocket gophers also are present.

Site quality of the study area is above average with height of dominant mixed conifers averaging about 70 feet in 50 years (Dunning and Reineke 1933). The soil is of the Crozier-Cohasset complex. It is derived from a weathered tuff-breccia mudflow and is 20- to 40-inches deep. It is brown and of a loamy texture. The surface soil is well drained and the subsoil is poorly drained. The elevation is 4,250 feet, the slope is about 8 percent, and the aspect is north. The area is remarkably uniform with respect to slope, aspect, and soil. Precipitation averages about 65 inches per year, with about 80 percent falling as rain. The mean January temperature is about 35 ^{o}F, and the mean July temperature is about 70 ^{o}F. The frost-free season is 170 days.

Study and Design

The experimental design was completely randomized with one-way treatment structure. Five treatments were each replicated four times. A replicate (plot) consisted of about one-seventh acre on which were about 50 ponderosa pine seedlings surrounded by two or more rows of buffer (seedlings receiving similar treatment). Components and treatments were:

- Pines operationally free to grow, in fenced exclosure
- Pines with seeded grasses, grazed
- Pines with seeded grasses, in fenced exclosure
- Pines in untreated control, grazed
- Pines in untreated control, in fenced exclosure.

The first and last treatments provide extremes in competition to the pines. In the first treatment a 5-foot radius was manually grubbed around each pine in April 1987, and the herbicide Velpar L[1] was applied in March 1988 at a rate of 3 pounds per acre to the entire plot. Velpar is a soil-active chemical that persists in this soil for about 3 years. Thus, not until after the 1990 growing season was competing vegetation potentially able to invade. Little did, however, because the vigorous pines were occupying most of the available

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

space and capturing most of the available site resources. The last treatment, with only site preparation and no subsequent release, allowed the competing vegetation to develop without restriction.

Grazing was by cattle, or more specifically, by 20 to 100 mature cows with calves that roamed through the study area from June through mid-September. The animals were familiar with mountain topography and wildland grazing. Although we wanted the study area to be grazed every year, it took place only in years 1988, 1989, 1991, 1994, and 1996, or for 5 of the 10 years in the study. Lack of water in drought years and a change in ownership were the main reasons for no grazing in some years. The exclosures were made of wooden posts and barbed wire and completed in summer 1987. They were maintained and effective, and no cattle got through them.

Because confounding of the effects of cattle grazing by deer browsing was possible and indeed likely, the study area was monitored twice each year for deer damage: before cattle began to graze the area in the spring and after the cattle left it in the fall.

Requirements for the artificially seeded species were that they had to become established and grow well in the local environment and be palatable and nutritious to cattle. The species were preinocculated Lana vetch (*Vicia dasycarpa*), seeded at the rate of 2.5 pounds per acre; Potomac orchard grass (*Dactylis glomerata*), seeded at 6.5 pounds per acre; and pubescent wheat grass *(Agropyron trichophorum*), also seeded at 6.5 pounds per acre. The vetch is an annual species, the grasses are perennial. The mix was hand-seeded in November 1987. In spite of almost immediate rain and subsequent frosts that carried the seeds into the soil, this application failed for unknown reasons. The seeding was repeated on October 10, 1989, and seeded areas 1 year later were described as "a sea of grass." The fate of the vetch is unknown. Some plants could have resulted from the seeding, but they were not abundant and were not differentiated from the native vetch species, which was abundant. Thus, in this paper the introduced species are the two grasses.

Sampling

In each plot, 25 healthy ponderosa pine seedlings were randomly chosen from the population of healthy trees and permanently tagged. As their name implies, these were well-developed seedlings that had good potential of becoming harvestable trees. Small, misshapen, and chlorotic seedlings were not included because their chance of being alive at the time of first thinning was small. On each of the sample seedlings, stem diameter and height were measured. Stem height was measured from mean groundline to base of bud, and stem diameter was recorded at 12 inches above mean groundline. Seedlings were checked periodically for injury from cattle, deer, pocket gophers, and chemical and weather-related effects.

Sampling intensity for evaluating all vegetation and ponderosa pine foliar cover and needle length was five randomly selected subplots in each plot. Subplots were centered around pine seedlings in all treatments and consisted of a square milacre (0.001 acre or 43.56 ft^2 of area). Foliar cover was defined as 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). Needle length was measured to the nearest 0.1 inch on 1-year-old needles.

All vegetation other than ponderosa pine was sampled for density in terms of number of plants per milacre subplot and expanded to a per-acre basis. Foliar cover of vegetation was as defined for ponderosa pine. Height was described as "average dominant height" and was the average of the three tallest stems measured from mean groundline to base of bud or top of stem.

Unfortunately, limitations in budget and staffing affected sampling, and only partial data sets were obtained for shrubs, forbs, and grasses early in the study.

To test for treatment effects and significant differences among treatments, one-way analysis of variance of treatment means (fixed effect model, Steel and Torrie 1980) and Tukey tests were applied (SAS Institute Inc. 1988). Statistical significance in all tests was at $\alpha = 0.05$. Data were gathered from permanent plots measured periodically, and data from analyses of means from repeated measurements are not truly independent. The α levels or type I errors given for various tests apply to each measurement and year separately.

To quantify plant diversity on study plots, species were noted whenever the plantation was visited. All species were recorded at the beginning and end of the study.

Results

The first full growing season of the study was 1988, which was the first time that all the planned components of the study were in place (*fig. 2*). The fenced exclosures were completed, the grass and vetch mixture had been applied and presumably was growing, and the chemical (Velpar) had been applied. The cattle had grazed the area, and salt blocks had been strategically placed nearby to enhance utilization. In addition, the vegetation had been surveyed and the species recorded. Data on vegetation that provided pre-study or baseline information had been taken in the fenced control plots.

Figure 2 — A typical ponderosa pine seedling in October 1988 with small new plants, cowpies, and the 5-foot radius grubbed the year before.

Plant Diversity

In fall 1987, the natural plant community consisted of 0 species of conifer from seed, 1 hardwood, 8 shrubs, 7 forbs, and 1 grass (*table 1*). At the end of the study in 1997, the number of species in the study area had increased from 17 to 35—a 106 percent gain. In 1997, the plant community consisted of 0 species of naturally seeded conifers, 1 species of hardwood, 13 shrubs, 17 forbs, and 4 grasses (*table 1*). A total of 43 species were present in the study plots during the 1987-1997 period. Thus, of the 42 study areas currently in our vegetation management research program, this study ranks second in terms of species diversity.

Number of natural species by treatment at the end of the study in 1997 was:

- Velpar, fenced 17
- Grass-seeded, grazed 15
- Grass-seeded, fenced 17
- Control, grazed 24
- Control, fenced 20

The fewer species in the first three treatments suggest that the soil-active Velpar and the introduced grasses created a less opportune environment for new species to become present than in the controls.

***Table 1** – Natural vegetation in study plots, Foresthill Ranger District, Tahoe National Forest, 1987-1997*

Species	1987	1990	1993	1997
Conifers				
Pinus ponderosa	-	X	X	-
Hardwoods				
Quercus kelloggii	X	X	X	X
Shrubs				
Arctostaphylos patula	X	X	X	X
Arctostaphylos viscida	X	X	X	X
Amelanchier pallida	X	X	X	X
Ceanothus integerrimus	-	X	X	X
Ceanothus prostratus	X	X	X	X
Prunus emarginata	X	X	X	X
Prunus subcordata	-	X	X	X
Prunus virginiana, demissa	X	X	X	X
Rhamnus spp.	-	X	X	X
Ribes spp.	X	X	X	X
Rosa spp.	-	-	-	X
Rubus glaucifolius	-	X	X	X
Symphoricarpos spp.	X	X	X	X
Forbs				
Brodiaea hyacinthina	-	X	X	-
Campanula prenanthoides	-	-	X	-
Cirsium vulgare	X	X	X	X
Erigeron spp.	-	-	-	X
Euphorbia crenulata	-	X	X	-
Frageria vesca	-	-	-	X
Galium spp.	-	-	X	-
Gayophytum spp.	-	X	X	X
Gnaphalium spp.	-	X	X	X
Horkelia tridentata	X	X	X	X
Kelloggia galioides	-	X	X	X
Lotus spp.	X	X	X	X
Madia gracilis	-	X	X	X
Mimulus leptaleus	X	X	X	X
Navaretia spp.	-	X	X	X
Phacelia spp.	-	-	-	X
Polygala cornuta	-	-	X	X
Potentilla spp.	-	-	X	X
Sidalcea glaucescens	X	X	X	-
Stephanomeria paniculata	-	X	X	-
Tragapogon spp.	-	X	X	-
Vicia americana	X	X	X	X
Viola lobata	X	X	X	X
Unknown	-	X	X	X
Grasses				
Achnatherum nelsonii	-	X	X	X
Bromus spp.	X	X	X	X
Elymus glaucus	-	X	X	X
Poa spp.	-	-	-	X
Total	17	34	38	35

Manzanita

The two manzanitas in this category, greenleaf and whiteleaf, were the most abundant shrubs. Together, their density in the fenced control in 1990 was 22,100 plants per acre with 2,850 ft^2 per acre of foliar cover and a mean height of 0.8 foot (*table 2*). At the end of the study in 1997, mean density had decreased 26 percent to 16,300 plants per acre, cover had increased 149 percent to 7,100 ft^2 per acre, and height had more than tripled to 2.9 feet.

Among treatments in 1997, mean density ranged from 6,950 to 17,400 plants per acre with no statistical difference noted (*table 3*). Foliar cover of manzanita was significantly lower in plots treated with Velpar (1,050 ft^2 per acre) and in plots seeded with grass and grazed (1,800 ft^2 per acre) than in other treatments (7,100 to 8,100 ft^2 per acre). Average height of manzanita also was significantly lower in the Velpar treatment (2.2 feet) relative to grass seeded and fenced (3.6 feet) and in the fenced control (2.9 feet).

***Table 2** – Average density, cover, and height, with standard errors (SE) of manzanita, other shrubs, forbs, and grasses in the fenced control, Foresthill Ranger District, Tahoe National Forest, 1988-1997*

Year	Density	SE	Cover	SE	Height	SE
	Plants/acre		*Ft^2/acre*		*Ft*	
			Manzanita			
1990	22,100	10,187	2,850	1,195	0.8	0.1
1993	15,850	6,646	4,850	1,473	1.7	0.2
1997	16,300	6,599	7,100	2,283	2.9	0.2
			Other shrubs			
1990	3,450	1,081	2,250	802	0.9	0.1
1993	3,200	927	750	275	1.0	0.2
1997	2,750	723	150	150	1.1	0.1
			Forbs			
1990	197,650	33,258	7,600	1,134	1.7	0.2
1993	138,300	44,137	2,550	1,274	1.2	0.1
1997	27,300	12,389	550	550	0.6	0.2
			Grasses			
1990	75,000	17,073	4,250	750	3.6	0.2
1993	142,000	14,291	6,400	548	3.8	0.2
1997	82,100	8,083	3,550	1,072	3.7	0.2

Other Shrubs

Of the 11 shrubs other than manzanita in this category (*table 1*), Sierra gooseberry and western chokecherry were the most abundant, at least when the study began. At the end of the study, many gooseberry plants had died from competition and shade. In the fenced control, density of other shrubs ranged from 3,450 plants per acre in 1990 to 2,750 per acre in 1997 or after 10 years (*table 2*). Foliar cover values also were low and became much lower by the study's end, decreasing from 2,250 to 150 ft^2 per acre. Mean height of other shrubs in the control ranged from 0.9 to 1.1 feet, increasing slightly at the study's end.

Among treatments after 10 years, other shrubs were least numerous (550 plants per acre) and had less cover (trace) in the fenced Velpar plots than in the other treatments where density ranged from 2,500 to 3,500 plants per acre and foliar cover ranged from 150 to 450 ft^2 per acre. However, the differences were not significant at the 5 percent level (*table 3*). Average height ranged from 1.1 to 1.9 feet and did not differ statistically among treatments.

Table 3 *– Average density, cover, and height of manzanita, other shrubs, forbs, and grasses by treatment, Foresthill Ranger District, Tahoe National Forest, 1997*

Treatment	Density		Cover		Height	
	Plants/acre		*Ft²/acre*		*Ft*	
	Manzanita					
Velpar, fenced	6,950	a[1]	1,050	a	2.2	a
Grass-seeded, grazed	7,000	a	1,800	a	2.8	ab
Grass-seeded, fenced	17,400	a	8,100	b	3.6	b
Control, grazed	11,000	a	7,150	b	3.2	b
Control, fenced	16,300	a	7,100	b	2.9	ab
Standard error	4,568		1,737		0.2	
	Other shrubs					
Velpar, fenced	550	a[1]	T[2]	a	1.2	a
Grass-seeded, grazed	3,250	a	450	a	1.7	a
Grass-seeded, fenced	3,500	a	600	a	1.9	a
Control, grazed	2,500	a	500	a	1.2	a
Control, fenced	2,750	a	150	a	1.1	a
Standard error	810		243		0.3	
	Forbs					
Velpar	4,500	a[1]	600	a	0.8	a
Grass-seeded, grazed	5,300	a	T	a	0.4	a
Grass-seeded, fenced	11,500	a	T	a	0.6	a
Control, grazed	24,050	a	450	a	1.9	a
Control, fenced	27,300	a	550	a	0.6	a
Standard error	6,267		377		0.2	
	Grasses					
Velpar, fenced	89,350	a[1]	650	a	3.8	a
Grass-seeded, grazed	91,400	a	3,650	a	3.3	a
Grass-seeded, fenced	75,850	a	2,400	a	3.7	a
Control, grazed	81,800	a	1,700	a	3.6	a
Control, fenced	82,100	a	3,550	a	3.7	a
Standard error	8,445		978		0.2	

[1] For each species and combination, treatment means in each column followed by the same letter do not differ statistically at the 0.05 level.

[2] T = Trace.

Forbs

The forb population in the study area was characterized by the presence of many species (*table 1*), consistently high density of several species, and high ephemeral density of a few species. In 1990, plants from the genera *Lotus*, *Vicia*, *Stephanomeria*, *Mimulus*, and *Cirsium* were abundant throughout the study area. In 1993, plants from the genera *Vicia* and *Mimulus* continued to be abundant, with plants of *Navarretia* and *Horkelia* becoming very dense in places, numbering 150 to 200 plants per species per milacre. By fall 1997, the density of plants from most of these genera had decreased dramatically, with most of the contribution to forbs coming from such shade tolerant species as *Viola* and *Horkelia*. By this time, most forbs tended to be short and thin, with little foliar cover.

In the control in 1990, forbs averaged 197,650 plants per acre, had a foliar cover of 7,600 ft^2 per acre, and were 1.7 feet tall (*table 2*). These values decreased in 1993, and by fall 1997 had decreased even farther to 27,300 plants per acre of density, 550 ft^2 per acre of cover, and 0.6 foot of height.

On treated plots, forb density ranged from 4,500 plants per acre in the fenced Velpar areas to 27,300 plants per acre in the fenced control (*table 3*). Foliar cover ranged from only a trace in both grass seeded areas to 600 ft^2 per acre in the Velpar areas. Height of forbs averaged 0.4 to 0.9 foot. No statistical differences among treatments were found for any forb variable.

Grasses

A few plants of needlegrass (*Achnatherum nelsonii* [Scribner] Barkworth) and brome (*Bromus* spp.) were noticed in the area before the study began. Needlegrass was a particularly successful invader and by fall 1989 was established throughout the study area, including plots that were designated for artificially seeded grasses. In fall 1990, grasses in these plots were best described as a mixture of native needlegrass and introduced pubescent wheat grass and orchard grass. That description was pertinent throughout the study period.

All grass variables in the control peaked in 1993: density at 142,000 plants per acre, foliar cover at 6,400 ft^2 per acre, and height at 3.8 feet (*table 2*). These declined in 1997 to 82,100 plants per acre, 3,550 ft^2 per acre, and 3.7 feet. The 1997 values represent a 9 percent gain over the 1990 value for density, a 16 percent decrease in foliar cover, and a 3 percent increase over the 1990 value for height.

On treated plots in 1997, no significant differences were found for density, foliar cover, or height. Mean grass density ranged from 75,000 plants per acre in grass-seeded and fenced plots to 91,400 plants per acre in the grass-seeded and grazed plots (*table 3*). Foliar cover ranged from 650 ft^2 per acre in the fenced Velpar plots to 3,650 ft^2 per acre in the grass-seeded and grazed plots. Only minor differentiation among treatments was found for height, which ranged from 3.3 to 3.8 feet.

Ponderosa Pine

Survival and growth of ponderosa pine is a function of the kind and amount of competing vegetation, which in turn is a consequence of the various treatments. Of the 42 pine seedlings that died during the study, 74 percent died by fall 1988. Cause of death was typically that associated with planting and suppression by taller shrubs. Most dead seedlings either had brown needles or simply disappeared. Some of those that disappeared could have been killed by pocket gophers as evidence of these animals was noted in 1988, 1990, and 1993, especially in exclosures with grass-forb mixtures. Mortality after 1988 was minor and appeared to be random. Competition was the chief cause of death. Survival by treatment in 1997 was:

Treatment	**Percent**
Velpar in fenced exclosure,	95
Seeded grasses, grazed,	96
Seeded grasses in fenced exclosure,	82
Control, grazed,	91
Control, in fenced exclosure.	94
Average	**92**

A test of survival using analysis of variance and transformed (arc sin) data showed that it did not differ significantly among treatments. Damage to pine seedlings was almost nonexistent. One seedling was browsed by deer and none were harmed by cattle, Velpar, or abiotic agents during the study.

Statistically significant differences among treatments for ponderosa pine were first noted in 1988 when stem diameter at 12 inches above mean groundline in the fenced Velpar treatment (0.40 inch) was significantly larger than counterparts in the grass-seeded and fenced treatment (0.24 inch) (*table 4*). However, the first seeding of introduced grass had failed, and the second seeding was not effective until the 1990 growing season. A possible explanation for this significant difference was the large amount of needlegrass and new manzanita seedlings noted visually and recorded in the chronological file of the study. By fall 1990, seedlings in the Velpar plots were significantly larger in diameter (1.90 inches) and height (4.13 feet) than counterparts in all other treatments (diameter:

0.99 to 1.19 inches; height: 2.67 to 3.16 feet) Needles also were significantly longer for pines in the Velpar treatment (8.62 inches) than for those of seedlings in the grass-seeded and fenced treatment (6.52 inches). In 1993, the significant diameter and height relationships continued, needle length no longer was significant, and foliar cover became significant. Cover was significantly larger for pines in the Velpar treatment (34,150 ft^2 per acre) than in any other treatment (12,050 to 20,600 ft^2 per acre) in 1993. In 1997 the major significant difference in diameter, height, and foliar cover was between pine seedlings in the Velpar treatment and those in most of the other treatments.

Ranking the treatments in terms of average pine diameter and height (*table 4*) leads to three groups. In descending order, these were: (1) Velpar, (2) grazing (regardless of grass seeding), and (3) fencing (regardless of grass seeding). Although no conclusions can be drawn from this relationship because of lack of statistical differences, the relationship suggests that grazing had some effect.

Table 4 *– Average diameter, height, foliar cover, and needle length of ponderosa pine seedlings by treatment, Foresthill Ranger District, Tahoe National, 1987-1997*

Year	Treatment	Diameter	Height	Foliar cover	Needle length
		Inches	*Ft*	*Ft^2/acre*	*Inches*
1987	Control, grazed [1]	-	0.54	-	
	Standard error	-	0.05	-	
1988	Velpar, fenced	0.40 a[2]	1.02 a	-	
	Grass-seeded, grazed	0.33 ab	1.01 a	-	
	Grass-seeded, fenced	0.24 b	0.88 a	-	
	Control, grazed	0.31 ab	0.94 a	-	
	Control, fenced	0.29 ab	0.96 a	-	
	Standard error	0.03	0.05		
1990	Velpar fenced	1.90 a[2]	4.13 a	3,550 a	8.62 a
	Grass-seeded, grazed	1.19 b	3.16 b	2,750 a	7.43 ab
	Grass-seeded, fenced	1.02 b	2.67 b	2,350 a	6.52 b
	Control, grazed	1.17 b	2.76 b	2,500 a	6.85 ab
	Control, fenced	0.99 b	2.69 b	2,750 a	6.94 ab
	Standard error	0.09	0.18	356	0.42
1993	Velpar fenced	3.99 a[2]	9.60 a	34,150 a	7.62 a
	Grass-seeded, grazed	2.98 b	6.95 b	20,600 b	7.87 a
	Grass-seeded, fenced	2.58 b	6.11 b	14,300 b	7.64 a
	Control, grazed	2.81 b	6.36 b	12,050 b	7.70 a
	Control, fenced	2.51 b	5.81 b	14,900 b	7.50 a
	Standard error	0.20	0.41	2,480	0.18
1997	Velpar fenced	6.59 a[2]	16.51 a	40,900 a	7.76 a
	Grass-seeded, grazed	5.30 ab	12.66 ab	33,950 ab	7.54 a
	Grass-seeded, fenced	4.58 b	11.09 b	28,450 b	7.57 a
	Control, grazed	5.10 b	12.39 ab	29,800 b	7.60 a
	Control, fenced	4.58 b	10.94 b	27,850 b	7.38 a
	Standard error	0.33	0.96	2,449	0.20

[1] Fence not yet completed.
[2] For each year, treatment means followed by the same letter do not differ significantly at the 0.05 level.

Discussion and Conclusions

After site preparation, the study area consisted of mostly bare ground and planted ponderosa pine seedlings. The ground did not remain bare for long, however, as plants from buried seeds and seeds that blew in on the wind, quickly invaded the plantation. By the end of the first growing season, several categories of vegetation, including shrubs, forbs, and grasses, were well represented. Two species of manzanita, needlegrass, and several forbs were noteworthy. After two seasons, many more species and plants became present.

By fall 1990, total density of all vegetation (including ponderosa pine) in the fenced control was 298,400 plants per acre with a total foliar cover of 19,700 ft^2 per acre or 45 percent of the ground surface. By the end of 1993, density had peaked at 299,550 plants per acre and cover had increased to 68 percent. At the end of the study in 1997, total vegetative density had declined to 128,750 plants per acre, but total foliar cover had increased to 39,200 ft^2 per acre or 90 percent horizontal coverage. Foliar cover of all vegetation ranged from 90 percent in both control treatments to 98 percent in the Velpar plots (*table 5*). Of these values, ponderosa pine foliar cover ranged from 64 percent in the fenced control to 94 percent in the Velpar treatment. The burgeoning ponderosa pines were probably the primary reason for the decrease in total plant density and the increase in total plant cover.

The composition of the plant community, as noted in the fenced control, also was changing. The manzanitas indicated a stable density and increasing trend in foliar cover and height, but the other categories of vegetation had peaked and were generally declining. The decline in foliar cover of the other shrubs and forbs was noteworthy. Based on average foliar cover and height and to a lesser extent on density, ponderosa pine, manzanita, and the grasses are likely to be the main components of the plant community in the near future.

Among treatments in 1997, the general lack of statistically significant differences was the singular most important finding. Neither manzanita, other shrubs, forbs, or grasses differed in density. For foliar cover and height, only manzanita showed a significant difference among treatments. In general, manzanita plants in the fenced Velpar treatment were significantly fewer and shorter than counterparts in the other treatments. Although not significant at the 5 percent level, this was generally true of foliar cover for most other categories of vegetation as well. Grass density and height, in general, were higher in the Velpar treatment. Orchard grass was adept at growing among the pine branches and producing stems more than 5 feet tall.

Given the generally lower competition in the Velpar treatment, it was no surprise that both diameter and height of ponderosa pine were significantly larger in this treatment from 1990 through 1997 than in most others. Foliar cover of pines in the Velpar treatment also was significantly greater than for counterparts in most treatments from 1993 through 1997 as well.

Table 5 *– Average percent foliar cover by category of species and treatment, Foresthill Ranger District, Tahoe National Forest,1997*

Treatment	Ponderosa pine	Manzanita	Other shrubs	Forbs	Grasses	Total
			percent			
Velpar, fenced	94	2	0	1	1	98
Seeded, grazed	78	4	1	0	8	91
Seeded, fenced	65	19	1	0	6	91
Control, grazed	68	16	1	1	4	90
Control, fenced	64	16	1	1	8	90

McDonald and others (1992) showed that ponderosa pine needle length was a good indicator of pine growth, and that it was a useful gauge of treatment effectiveness in the future. More specifically, 1-year-old needles, measured 2 to 4 years after treatment, were strongly related to treatment response for at least 7 years after treatment. In this study, needle length measured 3 years after the treatments were fully implemented indicated a significant difference 3 years after treatment, but not in subsequent years. Significantly longer needles, measured in 1990, were on pines in the fenced Velpar treatment and the shortest were in the grass-seeded and fenced treatment.

Cattle grazing, in general, had no major effect as a vegetation management treatment in this study, and no consistent trends could be found for cattle grazing and plant diversity, density, cover, or height. Similarly, trends could not be discerned for grazing and damage to young pine seedlings, or their diameter, height, and foliar cover. A strength in this study was that the cattle were present and grazing when the pine seedlings were very small—about 3-months-old—which was a time of great risk to them and a time when grazing is usually avoided. This is an important time because grazing typically damages or eliminates the competing vegetation when the pine seedlings are just getting started and need as many site resources as possible. Furthermore, vegetation that is weakened early, often cannot recover, allowing the pines to stress the competing vegetation rather than the competing vegetation to stress the pines.

Thus, grazing as a vegetation management treatment began effectively and continued the next year (1988). Grazing was described as heavy in 1988 with evidence of the cattle everywhere. Cattle trails and trampling of vegetation was common, and small needlegrass plants were actually pulled out of the ground by the hungry animals. In subsequent years, less evidence of cattle grazing was visible. Although shrub twigs were nipped here and there, the main evidence of cattle was on the grasses. They were heavily grazed, especially pubescent wheat grass and orchard grass. After the cattle had departed, orchard grass often had only one or two very tall stems in a clump of very short ones.

Did the cattle eat the more palatable grass and avoid the pine terminal shoots? In the grass-seeded and grazed plots in 1990, average pine height was 3.2 feet and average grass height was 2.8 feet; thus, both were well within the grazing range. Because not one pine was damaged by cattle, even when they were young and small, and the grass was heavily grazed each time the cattle were present, it is likely that the grass acted as a diversionary food that kept the cattle from browsing the pines.

The role of deer was minimal. No data or visual observations indicated that the migratory deer impacted the study area in spring or fall. Scattered nipping of shrub stems and occasional deer beds and pellet piles indicated the presence of resident deer. However, their impact was minor.

The effect of grazing on this transitional range (range that is present only from the time of planting to when the tree crowns shade out the palatable plants) apparently was beneficial to the cattle. One of the owners inferred that the cattle were healthy and had gained weight by saying that he wished he had put more of them into the area. This also implies that utilization of available browse was less than it could have been. A Tahoe National Forest range conservationist estimated that utilization of palatable forage in the study area during the 10-year period was moderate.

Did the introduced grasses serve as a biological control and restrict the emergence of more competitive shrub plants from dormant seeds in the soil? Comparison of the grass-seeded and fenced treatment to the fenced control showed no statistical difference for any variable for pine, manzanita, other shrubs, forbs, or grasses. Thus, no direct evidence exists to support the biological control or replacement vegetation phenomenon. However, had the introduced grasses become established in the first seeding in fall 1987, their role as a biological control agent might have been stronger.

Did the introduced grasses encourage the invasion of undesirable insects (especially grasshoppers, McDonald 1986) or animals? Visual evidence suggested that pocket gophers were more plentiful in the exclosures that had been seeded with the grasses and that also had a plentiful population of forbs. Although early pine mortality could have been caused by these animals, the overall effect was minimal. Because no insect damage was noted at any time, the introduced grasses obviously did not encourage their presence.

Did the grazed introduced grasses have an effect on the natural plant community? In the grass-seeded and grazed treatment, manzanita cover in 1997 averaged 1,800 ft^2 per acre; in the grass-seeded and fenced treatment, manzanita cover averaged 8,100 ft^2 per acre—a statistically significant difference. The lower cover value (1,800 ft^2 per acre) and the statistically insignificant but much lower density of the manzanita and forbs (12,300 combined plants per acre in the grass-seeded and grazed treatment versus 28,900 combined plants per acre in the grass-seeded and fenced treatment) suggest that the introduced grasses, if grazed, did have some effect on reducing the density of plants in these categories. This finding is similar to that of Stein (1997), working in the Coast Range of Oregon, who found that "rapid and dense development of grass prevented as abundant development of other annuals" (p. 79) in the grass-sown treatment as in other treatments. Furthermore, development of the primary shrub in the area was "little affected" by the sown grass. Why the ungrazed grasses did not lower the density and cover of the manzanita and forbs is unknown. The effect of the introduced grasses on natural plant diversity was not addressed in the Oregon study and showed no effect in this study.

Because the role of grasses in young conifer plantations is often confusing, it should be understood that they can be both a hindrance and a help (McDonald 1986). Grasses can be a formidable competitor if they become established before the pines are planted or established. They usually are not formidable if they become established 3 to 5 years after the pines are established. In the latter situation, the grass often reduces the abundance of shrub seedlings because it inhibits the germination of their seeds in the soil. Conversely, if the shrubs become established before the grasses, they dramatically reduce the abundance and development of the grasses (McDonald and Abbott 1997).

Much empirical evidence exists that grasses in plantations on sites of average or better quality on west-facing slopes of the Sierra Nevada have little effect on the growth of ponderosa pine seedlings if they become established after the pines (McDonald and Fiddler 1986). This study adds to that evidence. The minor effect of grasses on pine seedlings in plantations in the western Sierra Nevada is different from that in plantations in the eastern Sierra Nevada where grass can reduce pine growth for scores of years (Gordon, 1962, McDonald 1983).

That only one short-lived natural ponderosa pine seedling was found in the entire study area in 10 years indicates that virtually no seed source was present, or that the level of competition was such that seedlings could not become established. Because ponderosa pine was a component of the original forest, its absence denotes an altered ecosystem lacking a key arborescent species. Without planting, the community would have consisted of scattered hardwoods, a mass of shrubs, and a few grasses. It would have remained in this altered condition for many years.

Chemical release with Velpar created a plant community that consisted almost entirely of rapidly growing ponderosa pines and a few shrubs and grasses. Many of the pine crowns in this treatment are currently touching, and more will do so in the near future. As the crowns close, the shrubs and grasses will find the shady environment less favorable, their numbers will decline, and even more site resources will be available to the pines. In the other treatments, ponderosa pine growth was not as vigorous, and more and larger plants of manzanita, other shrubs, and forbs were present, and will be for some time. Nevertheless, the plant community in all treatments in the near future will have about the same species composition and differ only in the relative proportion of the same species.

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