EFFECTS OF SEED, FERTILIZER, AND MULCH APPLICATION ON VEGETATION RE-ESTABLISHMENT ON REDWOOD NATIONAL PARK REHABILITATION SITES

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ABSTRACT

Rehabilitation projects begun in 1977 on disturbed lands in the Redwood Creek watershed have used numerous techniques to accelerate revegetation. Treatments encouraging natural successional patterns on disturbed ground have appeared most promising. Plots were established in 1980 to determine the effects of grass, fertilizer and mulch applications on recently rehabilitated road surfaces. Colonizing trees, shrubs, and herbs were systematically sampled to determine total cover and density achieved by different treatments. Treatments resulting in extremely high total vegetative cover of seeded plants discouraged establishment of colonizing seedlings. Species diversity and cover increased with fertilization and mulching. Various long and short range revegetation management objectives can be achieved by site specific vegetation prescriptions.

INTRODUCTION

Redwood National Park was established in 1968 to preserve outstanding examples of coastal redwood forests, including the world's tallest trees. Subsequent timber harvesting and related road construction in the Redwood Creek watershed outside the park, combined with naturally high erosion rates, threatened downstream park resources (Agee 1980). Vegetation removal, alteration of hillslope drainages and development of an extensive logging road/skid trail network caused increased runoff, sediment yield, and accumulation of sediment deposits in major stream channels (Madej et al. 1980). In 1978, to protect park resources, congressional action (Public Law 95-250) amended the Redwood National Park Establishment Act to expand the park by 48,000 ac, including 36,000 ac of recently logged old-growth redwood forest. The National Park Service was directed to develop a watershed rehabilitation program to minimize man-induced erosion and to encourage the return of a natural pattern of vegetation (see USDI 1981).

A significant component of the watershed rehabilitation effort is the revegetation program. The objectives of the revegetation program are: 1) accelerate the restoration of redwood forests and associated vegetation systems, 2) contribute to long-term slope stability through vegetation re-establishment, and 3) aid in the reduction of surface erosion.

Rehabilitation sites include former logging haul roads, skid trails and stream crossings, logging decks and landings, and prairie ranch roads. While natural revegetation in the area is often quite rapid, on many sites compaction, nutrient-poor substrates, and surface erosion significantly increase the time necessary for successful natural revegetation.

A variety of revegetation techniques are employed on these rehabilitation sites, including the use of traditional erosion control techniques such as grass seeding and mulching (Hektner et al. 1981). Grass provides vegetative cover while mulches protect the soil surface, reduce loss of soil moisture through evaporation and trap fine soil particles essential to accelerating vegetation re-establishment. Use of these techniques in 1977 and 1978 raised a number of questions regarding their effectiveness. On many sites the fall seeded grass failed to provide adequate cover until the next spring, too late to control surface erosion from first year winter storms. Experiments were begun in 1979 (Popenoe 1981) to study the effects of these traditional treatments. Based on the results of these observations and studies, seed mixes, fertilizer rates and mulch prescriptions were modified for use in 1980. Legumes were included in the 1980 seed mixes to provide a rapid vegetative cover while adding nitrogen to

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sually nitrogen deficient substrates (Sugihara 1983). To investigate these new prescriptions, a research roject was implemented to evaluate the effects of straw mulches, grass and fertilizer on revegetation, oil moisture, soil compaction and soil nutrients.

METHODS

tudy Area

The most difficult revegetation problems in Redwood National Park occur on the more xeric east ide of the Redwood Creek basin which is underlain by Franciscan sandstone and shale. A portion of ne east-side rehabilitation site, the 1980 Dolason Prairie/W-Line Road, was utilized as an xperimental area to evaluate revegetation treatments. W-Line was a major haul road built by the rcata Redwood Company across Dolason Prairie to provide access to a tractor yarded clearcut unit and wo cable yarded units logged in 1977, just prior to park expansion. Roadbed material varied from clay o silty loam in texture with 15 to 55% rock fragments and pH 4.5 to 6.0. The general aspect of the site as south. Some sections were exposed to drying winds while others were well protected by adjacent ld-growth forest. The forest provided good seed source for natural regeneration of redwood *Sequoia empervirens,* Douglas-fir *Pseudotsuga menziesii,* and tanoak *Lithocarpus densiflora.* Site conditions ppeared generally favorable for successful plant growth. While not as harsh as many sites, W-Line rovided opportunity for controlled experimentation.

One-hundredth ha plots, 10 m by 10 m, were established along the last 2.4 km (1.5 mi) of the ehabilitated W-Line Road. Slope aspect, soil texture, percentage clay, percentage coarse fragments, pH nd soil moisture regime were recorded for each plot. Compaction and soil moisture contents were etermined from soil samples collected for nutrient analysis on selected plots. Combinations of grass, egumes, fertilizer and straw mulch were applied in a randomized design beginning in the fall of 1980. he resulting 36 treatments (Table 1) were replicated three times.

Table 1

Experimental Road Treatments

+ Fertilizer	Grass + Fertilizer + Mulch	Fertilizer + Mulch	Fertilizer
Grass only	(2) Grass + 2,222 kg/ha mulch	(4) 2,222 kg/ha mulch only	(6) Control
	(3) Grass + 4,444 kg/ha mulch	(5) 4,444 kg/ha mulch only	
Grass + 111 kg/ha (F)	(10) Grass + 111 kg/ha (F) + 2,222 kg/ha	(13) 111 kg/ha (F) + 2,222 kg/ha	(16) 111 kg/ha (F)
Grass + 111 kg/ha (S)	(11) Grass + 111 kg/ha (S) + 2,222 kg/ha	(14) 111 kg/ha (S) + 2,222 kg/ha	(17) 111 kg/ha (S)
Grass + 111 kg/ha (T)	(12) Grass + 111 kg/ha (T) + 2,222 kg/ha	(15) 111 kg/ha (T) + 2,222 kg/ha	(18) 111 kg/ha (T)
Grass + 222 kg/ha (F)	(22) Grass + 222 kg/ha (F) + 2,222 kg/ha	(28) 222 kg/ha (F) + 2,222 kg/ha	(34) 222 kg/ha (F)
Grass + 222 kg/ha (S)	(23) Grass + 222 kg/ha (S) + 2,222 kg/ha	(29) 222 kg/ha (S) + 2,222 kg/ha	(35) 222 kg/ha (S)
Grass + 222 kg/ha (T)	(24) Grass + 222 kg/ha (T) + 2,222 kg/ha	(30) 222 kg/ha (T) + 2,222 kg/ha	(36) 222 kg/ha (T)
	(25) Grass + 222 kg/ha (F) + 4,444 kg/ha	(31) 222 kg/ha (F) + 4,444 kg/ha	
	(26) Grass + 222 kg/ha (S) + 4,444 kg/ha	(32) 222 kg/ha (S) + 4,444 kg/ha	
	(27) Grass + 222 kg/ha (T) + 4,444 kg/ha	(33) 222 kg/ha (T) + 4,444 kg/ha	

ll fertilization

rly spring fertilization

lf of total fertilizer spread in fall and half in early spring

Seed application rate was 56 kg/ha (50 lbs/ac) and was applied to half of the plots. Species used in the seed mix were Durar hard fescue ***Festuca ovina*** var. ***duriscula,*** Highland colonial bentgrass *Agrostis tenuis* 'Highland', both perennial grasses; Blando brome *Bromus mollis,* an annual grass; Mt. Barker subclover *Trifolium subterraneum* 'Mt. Barker', a perennial legume and Lana woolypod vetch *Vicia dasycarpa* 'Lana', an annual legume. The percentages were based on the number of seeds rather than weight (Table 2). The legume seeds were inoculated with the appropriate inoculum prior to application. The seed mix and fertilizer were applied with a Cyclone seeder ("belly grinder"). Due to differences in seed size and weight, grasses were mixed and seeded separately from the legumes.

Table 2

Grass and Legume Seed Mix

Species		% of Seeds in Mix	Seeds/kg	kg/ha	Seeds/ha
Festuca ovina var. *duriscula*	(P)	40	1,246,000	9.9	12,388,000
Agrostis tenuis 'Highland'	(P)	20	18,739,000	0.3	6,384,000
Bromus mollis	(A)	30	584,000	15.9	9,297,000
Trifolium subterraneum 'Mt. Barker'	(P)	9	165,000	16.9	2,785,000
Vicia dasycarpa 'Lana'	(A)	1	24,000	12.9	310,000
TOTAL				55.9	31,164,000

(P) = Perennial
(A) = Annual

Ammonium phosphate/sulfate (16-20-0-13) was applied at two rates, 222 kg/ha (200 lbs/ac) and 111 kg/ha (100 lbs/ac). Because the timing of fertilizer application was suspected to be significant, three variations were used: fall, early spring, and both fall and spring. When fertilizer was applied twice, half the total quantity was applied each time. This was done to determine any differences in vegetation patterns resulting from the timing of nutrient availability.

Wheat straw *Triticum aestivum* was utilized as mulch. Three rates were tested: 1) no mulch, 2) 2,222 kg/ha (2000 lbs/ac), and 3) 4,444 kg/ha (4,000 lbs/ac). The higher rate is more effective for control of surface erosion but was thought to inhibit vegetation establishment.

Containerized seedlings of redwood, Douglas-fir, and coyote brush *Baccharis pilularis* ssp. *consanguinea* and rooted cuttings of whipplea *Whipplea modesta* were grown under contract with the Simpson Timber Company nursery. Three redwood, three Douglas-fir, eight coyote brush and eight whipplea seedlings were planted in each plot. These species are used in the rehabilitation program and were included to study the effects of treatments on survival and growth. Coyote brush and whipplea are common shrub and subshrub species invading after timber harvest (Muldavin et al. 1981).

Vegetation sampling, using a 20 x 50 cm frame, was conducted during the summers of 1981 and 1982. Plots were divided into quarters with the sampling frame placed along a diagonal between corner stakes in the middle of each quarter. Sample position was predetermined for all plots to reduce subjective bias. Where the sample was obviously unrepresentative, a representative location was subjectively chosen within that quarter. Fallen logs and game paths were considered unrepresentative.

Total vegetative cover based on the six Daubenmire cover classes (Daubenmire 1968) was estimated for each species found within the frame. In addition, overall vegetative cover for each plot and straw mulch cover for each sample were estimated. A list was compiled of all species found within each plot. The numbers of naturally invading Douglas-fir, redwood, coyote brush, whipplea and alder *Alnus oregona* seedlings were counted in one quarter of every plot. Due to complications, chiefly from cattle grazing, only the effects of seed, fertilizer and mulch on natural revegetation were monitored after the first year.

RESULTS AND DISCUSSION

After 1 yr, seeded plots had higher vegetative cover than unseeded plots (Table 3). Fertilization did not significantly increase cover on seeded plots but did produce an increase on unseeded plots. There was little difference between plots fertilized at 111 kg/ha and those fertilized at 222 kg/ha. Fall fertilization and/or split fall and spring fertilization resulted in higher cover than spring fertilization alone, except on the plots with 4,444 kg/ha mulch and 222 kg/ha fertilizer, where timing did not have as much effect. As mulching rate increased, cover on seeded, fertilized and unseeded, unfertilized plots generally increased. Cover on unseeded, fertilized plots decreased with no trends apparent on seeded, unfertilized plots.

After 2 yrs, seeded plots maintained higher vegetative cover than unseeded plots. Vegetative cover increased on all unfertilized plots, regardless of mulch or seed treatments. On unmulched fertilized plots, cover on those that were seeded increased, while cover on unseeded plots decreased. No trends are apparent on fertilized mulched, seeded and unseeded plots.

Only three species produced average total cover greater than 5% the first year, Blando brome and subclover, which were planted, and invading perennial ryegrass *(Lolium perenne)* which the timber company had seeded on adjacent logged areas. Subclover was the only species to maintain a cover greater than 5% the second year.

Seeded plots had an average cover of 73% in 1981 and 82% in 1982. Subclover dominated with average cover of 54% the first year and 77% the second. The subclover formed dense mats with some individual plants spreading to more than 3 ft across. Subclover invasion to adjacent unseeded plots was minimal. Bentgrass cover increased the second year to 2.7% from 2.0%. Blando brome decreased in cover from 5% to 1.6% the second year. The vetch and fescue averaged less than 2.5% cover in both years but were well represented in some plots. Patchy distribution of seeded species may be an artifact of seeding techniques and equipment. Unseeded plots averaged 32% cover in 1981 but only 26% in 1982, mainly consisting of short-lived weedy herbs.

Species diversity was greatest in plots left unseeded. Approximately 100 species were found during sampling. Twenty-three species occurred with greater than 5% frequency in the first year, dropping to 18 species with greater than 5% frequency the second year.

Plots with high subclover cover had few invading species. Several weedy species ***Erechtites, Epilobium*** and ***Gnaphalium*** were conspicuously absent from seeded plots but abundant on adjacent unseeded plots. Colonizing Douglas-fir, coyote brush and whipplea seedlings were found less frequently on seeded plots. The number of Douglas-fir seedlings found in unseeded plots was 3 times that in the seeded, coyote brush eight times as many, and whipplea 10 times as many. The numbers of Douglas-fir, coyote brush and whipplea seedlings were inversely related to the total vegetative cover (Table 4). The density of coyote brush and whipplea seedlings increased the second year. The density of naturally seeded Douglas-fir seedlings decreased the second year, indicating low survival of the seedlings and fewer seedlings established the second year. Few redwood or tanoak seedlings were found either year. Alder seedlings were sparse the first year but more numerous the second. Cover values are expected to increase dramatically for alder by the third year, based on previous work (Reed and Hektner 1981).

Table 3

Average Vegetative Cover (%) on Treated Plots in 1981 and 1982

Treatments			1981 Fertilizer Rate 111 kg/ha	1981 Fertilizer Rate 222 kg/ha	1982 Fertilizer Rate 111 kg/ha	1982 Fertilizer Rate 222 kg/ha
Unmulched	Seeded	No Fertilization	70.4		81.5	
Unmulched	Seeded	Fall Fertilization	70.2	73.8	68.4	75.4
Unmulched	Seeded	Spring Fertilization	51.9	54.8	70.8	86.5
Unmulched	Seeded	Split Fertilization	64.6	87.5	76.7	89.4
Unmulched	Unseeded	No Fertilization	12.7		25.2	
Unmulched	Unseeded	Fall Fertilization	40.0	37.9	49.0	32.5
Unmulched	Unseeded	Spring Fertilization	17.5	18.1	13.8	15.4
Unmulched	Unseeded	Split Fertilization	39.2	34.0	20.2	32.1
2,222 kg/ha Mulch	Seeded	No Fertilization	66.7		82.5	
2,222 kg/ha Mulch	Seeded	Fall Fertilization	92.5	74.2	89.4	81.1
2,222 kg/ha Mulch	Seeded	Spring Fertilization	59.8	74.6	93.5	68.5
2,222 kg/ha Mulch	Seeded	Split Fertilization	86.6	81.5	82.5	84.4
2,222 kg/ha Mulch	Unseeded	No Fertilization	18.8		25.0	
2,222 kg/ha Mulch	Unseeded	Fall Fertilization	28.3	29.4	37.3	9.8
2,222 kg/ha Mulch	Unseeded	Spring Fertilization	18.5	19.4	14.4	18.8
2,222 kg/ha Mulch	Unseeded	Split Fertilization	37.3	23.8	37.1	25.9
4,444 kg/ha Mulch	Seeded	No Fertilization	73.8		80.4	
4,444 kg/ha Mulch	Seeded	Fall Fertilization	-	77.5	-	92.3
4,444 kg/ha Mulch	Seeded	Spring Fertilization	-	78.5	-	76.7
4,444 kg/ha Mulch	Seeded	Split Fertilization	-	87.5	-	93.3
4,444 kg/ha Mulch	Unseeded	No Fertilization	24.4		29.4	
4,444 kg/ha Mulch	Unseeded	Fall Fertilization	-	33.9	-	32.0
4,444 kg/ha Mulch	Unseeded	Spring Fertilization	-	33.3	-	20.4
4,444 kg/ha Mulch	Unseeded	Split Fertilization	-	32.1	-	35.4

Table 4

Seedling Densities by Total Vegetative Cover Classes

Daubenmire Cover Class	Total Vegetative Cover Value (%)	Average Seedling Density Per Plot					
		Douglas-fir		Coyote Brush		Whipplea	
		1981	1982	1981	1982	1981	1982
1	0 - 5	57	82	72	106	6	50
2	5 - 25	57	47	78	147	14	16
3	25 - 50	42	24	74	94	19	43
4	50 - 75	24	7	26	70	8	11
5	75 - 95	14	7	17	37	7	5
6	95 - 100	10	4	4	25	2	1

As with the seeded species, it was found that the amount of fertilizer had less effect on invading species than the timing of application (Table 5). Fall fertilization produced the highest total cover values, mostly grasses and forbs. Native shrubs did poorly with fall fertilization but increased significantly with spring fertilization. When plots were fertilized in both fall and early spring, both density and total cover of native shrubs were lower than for spring fertilization alone. Coyote brush was more adversely affected than the whipplea. Douglas-fir density was lower with fall fertilization than either spring, fall-spring or no fertilization. Laboratory testing showed that fertilizer applied in the fall did not persist until spring (Popenoe, pers. comm.). Fall fertilization stimulated the forbs, apparently outcompeting the woody species, especially where fertilizer was re-applied in spring.

Table 5

Seedling Densities by Fertilizer Timing

Fertilizer Regime		Average Seedling Density Per Plot					
		Douglas-fir		Coyote Brush		Whipplea	
		1981	1982	1981	1982	1981	1982
Not Fertilized		37	23	17	69	6	32
111 kg/ha:	Fall	12	2	10	32	1	7
	Spring	39	27	88	80	7	6
	Fall and Spring	33	26	8	37	4	12
222 kg/ha:	Fall	19	6	6	14	7	7
	Spring	28	33	84	158	31	26
	Fall and Spring	21	11	62	74	10	9

Species diversity increased where straw mulch was applied. The seedbed was probably better protected, with fewer fine soil particles lost, organic matter added to the soil, and some measure of shading provided by the mulch. By the second year, most of the mulch had decomposed. In some areas the straw was highly wind blown. Heavy sprouting of wheat seed in the straw occurred in the majority of plots the first year. Sprouting occurred in early fall before other species germinated but did not persist to sampling time. Little seed sprouted the second year. The effects of the sprouting were not determined.

Species reaction to the mulch was varied and often inconsistent. Coyote brush seedling density doubled with mulching and was even higher with the heavy mulch rate. Douglas-fir density doubled with the lower mulch rate. Mulch treatment did not significantly vary the whipplea density (Table 6).

Table 6

Seedling Density by Mulch Application

	Average Seedling Density Per Plot					
	Douglas-fir		Coyote Brush		Whipplea	
Mulch Rate	1981	1982	1981	1982	1981	1982
Not Mulched	20	9	22	39	8	17
2,222 kg/ha	37	28	36	72	8	15
4,444 kg/ha	20	13	61	100	16	14

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

Where a seed source for natural revegetation is lacking or exposure and soil conditions are too harsh for colonizing species to survive, grass and legumes may be useful to ameliorate site conditions. One section of rehabilitated road which was seeded but excluded from the study because of its extremely rocky nature achieved a dense stand of subclover and vetch. In this study, the legumes comprised only 10% of the total number of seeds, yet provided no vegetative cover. The legumes may also be more suited for harsh sites because they do well without fertilization. Subclover accounted for most of the vegetative cover on seeded plots but was not greatly increased by fertilization. The subclover has potential as a rooted mulch since it is less susceptible to being wind blown and it provides a rapid cover in the fall and winter when surface protection is needed. It dies back by early summer before moisture becomes limiting to planted and invading species. Whereas straw mulch decomposes within 2 to 3 yrs, the subclover will reseed itself. As a nitrogen-fixer, subclover can improve nitrogen-poor rehabilitation sites. The persistence of the subclover has not been established. Grasses may increase if the subclover decreases since the bentgrass, brome, and fescue are still present in the plots. Refinements in the seed proportions may result in a better representation of grasses.

The results of spring fertilization were encouraging. This has potential for accelerating natural successional patterns, especially in areas otherwise left untreated. In a practical aspect, however, there may be a few difficulties. Fertilizer was delivered to sites prior to heavy equipment activities. Many of the sites are not readily accessible after rehabilitation activities have been completed. Carrying 80 lb sacks of fertilizer for several miles over rough terrain during muddy early spring conditions is not appealing. Storing fertilizer in double plastic bags over winter was not successful either. Animal damage was noted in almost all cases producing water sodden sacks of fertilizer which could not be moved or spread.

There has recently been a de-emphasis on mulch to control surface erosion because of expense. The cost of the labor required to spread the mulch is many times the cost of the straw. Park geologists have determined the amount of surface erosion is minimal when compared to the amount contributed by stream crossing failures (Weaver and Seltenrich, pers. comm.). Where natural revegetation is adequate, mulching may not be cost-effective. However, the benefits to revegetation by applying mulch on harsh sites are considerable.

Revegetation prescriptions must be site specific to be cost-effective. It is counterproductive to maximize revegetation efforts on an area that will adequately recover naturally. Sites requiring management are those which do not recover rapidly. On many of these sites, treatments encouraging natural successional patterns are most successful. By providing colonizers as well as the climax species natural revegetation patterns can be accelerated and planted conifer survival can be increased.

ACKNOWLEDGMENTS

We would like to thank all of the Redwood National Park Resource Management and Technical Services staff for suggestions. Geologists on the rehabilitation site, Terry Spreiter and Louise Johnson, were very cooperative and supportive of the project. The Redwoods United Inc. crews who provided the labor for installing the plots and Redwood National Park laborers who planted trees and shrubs were essential. Many of the park vegetation personnel participated in project planning, plot installation, soil and vegetation sampling and plant identification: Donna Cobb, John Day, Bonnie Griffith, Gary Lester, Roy Martin, Jim Popenoe, Gregg Reigel and Neil Sugihara. Special thanks are due Jim Lenihan for producing computer programs to analyze the mountain of raw data.