EFFECTS OF GRASS-SEEDING, FERTILIZER AND MULCHES ON SEEDLING PATTERNS AT THE COPPER CREEK WATERSHED REHABILITATION UNIT

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Abstract. Several experimental combinations of grass seed, fertilizer and organic mulches were tested on newly reshaped ground in Redwood National Park. Results were monitored for two years. Total vegetative cover increased with rate of seed or fertilizer application, but decreased under mulches. Species composition was as follows: Control areas were colonized by ruderal herbs and the native shrub, *Baccharis pilularis* var. *consanguinea*. When fertilized and seeded with perennial grasses, the seeded grasses dominated, ruderals decreased in number and *Baccharis* was absent. When fertilized and seeded with barley, ruderals dominated and a few *Baccharis* appeared the second year. Ruderals were less vigorous in treatments using straw or Monterey pine mulch and no fertilizer, but *Baccharis* seedlings were more numerous.

INTRODUCTION

In 1978 Redwood National Park was expanded to provide additional protection or irreplaceable resources within the Redwood Creek drainage. The new park ands contained much cutover forest. Disturbed areas threatened to discharge oluminous sediment into tributary basins of Redwood Creek in the event of ajor winter storms. Congress authorized the park to develop a rehabilitation lan for its portion of the watershed to minimize man-induced erosion and to ncourage return of a natural pattern of vegetation. In 1979 the program was till in a developmental, primarily experimental phase. Many techniques were eing tested for evaluation and potential incorporation into the rehabilitation lan. This paper is based on the monitoring of one set of revegetation xperiments at one unit that year.

Experiments at Copper Creek were planned to answer a number of practical uestions: How well do mulches and/or grass control erosion? To what extent o mulches interfere with or bolster efforts at revegetation? How much does rass compete with and suppress natural revegetation? How much fertilizer is eeded to establish a good stand of grass? My task was to monitor and

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evaluate the vegetation. I felt it was important to evaluate recovery in the context of the natural system. Revegetation is rapid in the redwood region. Since natural processes would play the largest role in the recovery of the ecosystem, monitoring needed to include:

1) natural revegetation independent of the park's effort to plant bare ground (controls), and
2) the effect of park treatments on the course and rate of revegetation as a whole.

The Study Area

Copper Creek is a major tributary stream to Redwood Creek 20 km southeast of Orick, California. It drains about 730 ha and, for planning purposes, the basin was subdivided into several units to be restored over a period of years. Copper Creek Watershed Rehabilitation Unit 79-4 is south of Copper Creek in Section 26, T.9N., R.2E., Humboldt B.L. & M. The area of study is a portion of former logging road "1930" and its associated landings.

The climate is mild year round with strong marine influence. Mean annual precipitation is about 200 cm and mean annual temperature is about 12°C. Elevations in the study area range from 500 to 700 m and slopes are predominantly 30 to 50 percent. The unit faces generally northwest toward Copper Creek, but is dissected by many small tributary streams. There are sites with SW, W, NW, N and NE aspects. On former roads and landings, slopes range from 2 to 30 percent.

The unit was logged from 1959 to 1971. Prior to logging the principle overstory species included Sequoia sempervirens,[2] Pseudotsuga Menziesii, Lithocarpus densiflora, Acer macrophyllum and Arbutus Menziesii with an understory of Vaccinium ovatum, Rhododendron macrophyllum and Gaultheria shallon. Following logging the pioneer shrub, Baccharis pilularis ssp. consanguinea, and subshrub, Whipplea modesta have become prominent in the area. These two species dominate and are associated with lesser numbers of herbaceous pioneers, including Lathyrus Torreyi, Trientalis latifolia and Iris Douglasii where surface soil is present. On abandoned skid trails, roads and landings without surface soil the vegetation is dominated by ruderal herbs and Baccharis. Sprouts and seedlings of former forest species are gradually becoming established throughout the area under all but the worst soil conditions.

Soils of the unit are youthful, most colluvial Inceptisols in fine-loamy and loamy-skeletal families. Depth to the C horizon is usually one to two meters and depth to bedrock usually exceeds two meters. Roadbed material is loam or light clay loam in texture with 20 to 75 percent rock fragments and pH 5 to 6. Levels of nutrient elements in the roadbed average near those in the upper B horizon of a typical profile adjacent to the road.

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[2]Plant names follow Munz and Keck (1968).

METHODS

Heavy equipment work was done in July and August 1979. The unit was seeded, fertilized and mulched on August 30 to 31. The first significant storm was on September 4, with 2.5 cm of rain. Seedling emergence was observed on September 12, and thereafter enough rain fell to sustain seedlings through the winter. A mixture of perennial grass seed called "RNP mix" was applied on many sites. The mixture contained equal parts by weight of Agrostis tenuis, Dactylis glomerata, Festuca rubra and Lolium perenne. Common barley (Hordeum vulgare) was seeded on some other sites. The type of fertilizer used was ammonium phosphate/sulfate (16-20-0). Mulch types tested included straw, chipped Douglas-fir and chipped Monterey pine. The pine chips contained a much higher proportion of needles and smaller proportion of woody branches than the fir chips. Straw mulch was applied at rates of zero and 2240 kg/ha (0, 2000 lbs/acre). The Douglas-fir mulch was applied at a heavier, less controlled rate. Rates of grass seed application were zero, 34 and 56 kg/ha (0, 30, 50 lbs/acre). Fertilizer was applied at rates of zero, 280 and 560 kg/ha (0, 250, 500 lbs/acre).

I monitored from June 3 to June 19, 1980, and from June 18 to June 19, 1981. My objective was to evaluate and compare treatments in terms of how each was meeting rehabilitation goals. Sampling had to include two kinds of data: an index of erosion-control effectiveness, and an index by which to measure return of a natural pattern of vegetation. C values (fluvial erosion rates relative to fallow ground) have been shown to lower with increasing surface cover for a wide range of surface treatments (Darrach, 1978). Therefore, I measured cover as an index of erosion control effectiveness.

Depth of soil removal accounts for much of the variation in early floristic composition of types within logged units (Muldavin, et al. 1981). Former roads, landings and skid trails generally lack O and A horizons and rate near maximal disturbance on the authors' scale. The freshly ripped or reshaped surfaces may offer a seedbed to light-seeded species, but one would expect poor representation from species that reproduce by sprouting or from buried seed (Bormann and Likens 1979). When openings occur in a redwood forest, I suspect that Ceanothus, Lathyrus and Whipplea pioneer mostly from buried seed. Species of the forest floor which sprout from bulbs, rhizomes or tubers include Gaultheria, Iris and Trientalis. Species above seem poorly adapted for dispersal onto broad, open disturbed areas. It is likely that species with winged or plumed seeds would quickly colonize newly reshaped ground, including Baccharis, Acer, Alnus, Pseudotsuga and Sequoia. And since Arbutus and Lithocarpus are prevalent at Copper Creek and were not harvested, their less mobile seeds could fall directly onto roadbeds as well. Non-native species are conspicuous on former logging roads. Short-lived ruderals established populations during the years since harvest. Other non-natives were introduced with rehabilitation in the form of grass seed treatments and seed in purchased straw. Some of these species might compete aggressively with natives under the open site conditions. Treatments could affect survival of seedlings from various sources differentially in initial years. While most seedlings would be pioneer herbs, presence of woody seedlings would demonstrate the potential for those woody species to dominate in years to follow. This was my reasoning and why I used the composition and density of species as an index of the potential of the system to recover toward a more natural pattern of vegetation.

I sampled with a 50 cm x 50 cm square frame split into four quarters. All seedlings were monitored, without regard to source. Quadrat sample area was reduced to 25 cm x 25 cm quarter if the sample would include a count of more than 50 for a given species. If not, the area was increased to 25 cm x 50 cm, 50 cm x 50 cm, 50 cm x 100 cm, and up to 50 cm x 200 cm on sites with low plant densities. This enabled sampling of densities that ranged from about 2 to 2000 per m^2. Counts were made of inflorescences, by species or of individuals, if plants were large enough to be recognized by species and they were not flowering. Cover was recorded in cover classes of 0-1, 2-4, 5-10, 11-20, 21-33, 34-50, 51-75, 76-90, and 91-100 percent. Sampling intensity ranged from three to six samples per treatment at one or two sites.

RESULTS

Total plant cover and the composition of seedlings in terms of ecological classes is depicted for selected treatments in Table 1 and figure 1.

Table 1. Average total plant cover the first spring. Cover was essentailly unchanged the second spring for all treatments except straw mulch sites. On straw mulch sites the cover of Baccharis seedlings increased the second year to 2 - 4 percent.

Grass Seed type-rate (kg/ha)	Fertilizer rate (kg/ha)	Mulch type	Average vegetative cover class percentage
None	None	None	5 - 10
RNP - 56	None	None	5 - 10
None	None	Straw	2 - 4
None	None	Pine	0 - 1
None	None	Fir	0 - 1
Barley - 34	280	None	34 - 50
Barley - 56	280	Straw	11 - 20
Barley - 56	560	Fir	0 - 1
RNP - 34	280	None	21 - 33
RNP - 34	280	Straw	34 - 50
RNP - 56	280	None	51 - 75
RNP - 56	560	None	76 - 90

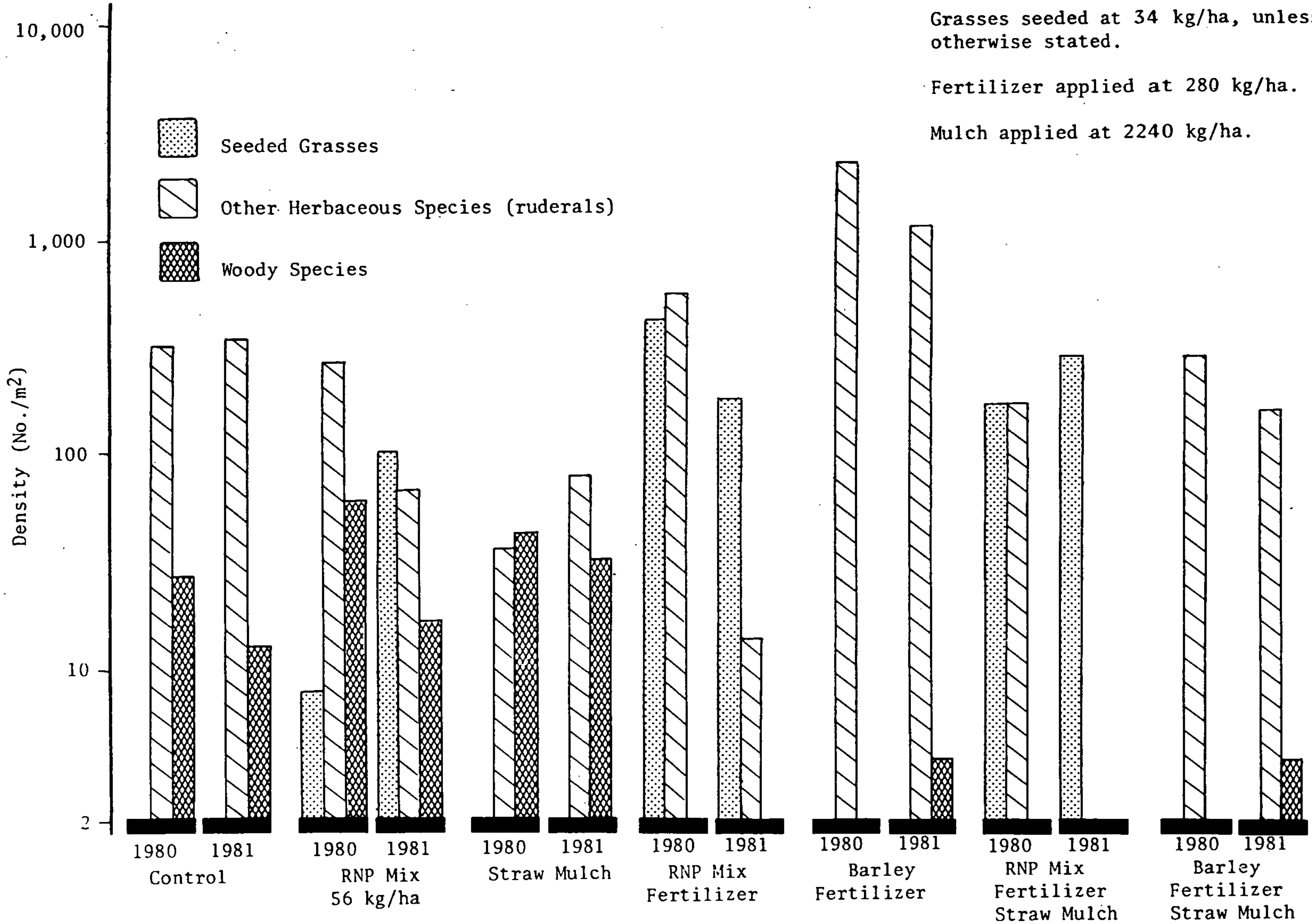

Fig. 1. Seedling Densities at Copper Creek (79-4) under different vegetal treatments.

Of the species introduced in grass seed treatments, only Lolium and Agrostis produced appreciable cover. Lolium was dominant the first spring but was largely replaced by Agrostis during the second year. Festuca averaged 5 to 10 percent in stands the first year with only scattered individuals remaining in the second. Lolium probably gained a head start the first year by virtue of its larger seeds. Given time, Agrostis outcompeted Lolium. Based on a previous study by Dyrness (1975), Agrostis is expected to persist for several years with Lolium gradually decreasing. The other seeded grasses, Hordeum and Dactylis, were observed only as widely scattered individuals. H. vulgare seed was contaminated, as evidenced by the presence of scattered first year seedlings unique to this treatment. Seedlings included Amsinckia intermedia, Avena fatua, Bromus diandrus, Hordeum leporinum, and Raphanus sativus. Careful observations were made the second year to see if any of these species would persist, spread or begin to compete with other vegetation during the second year. However, only one individual of B. diandrus was found the second spring.

The dominant ruderals were grasses, including Festuca megalura, Aira caryophyllea, Deschampsia elongata, Holcus lanatus and Bromus mollis. Seeds of these grasses would have been present in the roadbed prior to rehabilitation. Forbs with plumed, wind-dispersed seeds were present in smaller numbers than the grasses. These included Epilobium, Erechtites and Gnaphalium species. A tarweed, Madia gracilis became important the second year, probably due to late rains. Another ruderal which increased the second year was the rosetted perennial, Hypochoeris radicata. Hypochoeris was consistently present under all kinds of treatments the second year at densities of 1 to $10/m^2$ and some individuals were up to 10 cm across. Except for Madia and Hypochoeris, the proportions of different ruderal species were generally unchanged the second year on unfertilized areas. With fertilizer, Agrostis outcompeted and at least partially excluded ruderals during the second year. In the fertilized barley treatment, the perennial, Holcus, increased at the expense of other, smaller, mostly annual species. With fertilizer, Deschampsia elongata, a native bunchgrass, flowered prolifically the first year and then died.

Woody species encountered include Baccharis, Acer, Arbutus, Alnus, Lithocarpus and Pseudotsuga. Baccharis was, by far, the dominant woody species and the combined density of all others was generally $2/m^2$ or less. Baccharis survived in greatest numbers under straw or pine mulch treatments where herbaceous vegetation was held in check. Compared to controls, mulch treatments had more Baccharis seedlings the first year, a higher proportion of first-year seedlings which survived until the second year, and more new, second-year seedlings, too. When fertilizer was applied, sown grasses or ruderals increased at the expense of Baccharis.

Although common in the clearcuts all around, none of the species which I hypothesized might arise from forest floor seeds and tubers was encountered in a sample. Population levels of Ceanothus, Iris, Lathyrus, Trientalis and and Whipplea were essentially zero on former roads and landings at Copper Creek.

DISCUSSION

Cover and Erosion Control Effectiveness

Grass was tested as a temporary erosion-control cover, not to restore a natural pattern of vegetation. Based on spring cover, I would have predicted 56 kg/ha RNP mix with 560 kg/ha fertilizer to be as effective at controlling erosion as even the heaviest mulch. However, observations made during the course of this study show that timing is of at least as much importance as the final cover. For grass, what are measured as vegetative cover and erosion-control effectiveness will vary from year to year. Grass may form a near-perfect cover in years with early gentle rains, but very little cover in years that begin with heavy rains, especially on steeper slopes. Until the soil has settled, reworked ground is loose and highly vulnerable to erosion. Grass can be washed away before it forms a sod, or even before it germinates. Although the 1979 grass had good coverage in spring, there was evidence of sheet erosion and rilling. While the majority of rills were no longer active, grass alone had simply failed to produce ground coverage early enough to control erosion during the critical early part of the season. To really control erosion, there should be good cover right after ground disturbance, prior to the first rains. Mulches provide this timely cover. According to Dyrness' measurements in western Oregon, more soil loss occurred from grass plots in the first year than from mulch plots in five years, regardless of the fact that the mulches had less cover. In Redwood National Park, mulching bare soil areas with straw has proven to be the most effective erosion-control technique (Weaver and Seltenrich, 1981).

Mulches and Revegetation

Mulches inhibited development of plant cover but seeded grasses and ruderals were more affected than *Baccharis* and chipped Douglas-fir was much more inhibitory than chipped pine or straw. Each of the mulches appears to have had a strong effect upon the seedbed environment.

2240 kg/ha straw just slightly filters and diminishes sunlight striking the ground. It may have had a greater effect on moisture retention and soil chemistry. Fresh straw has a C:N ratio of approximately 100:1. During initial stages in decomposition of mulches, there is a rapid increase in decomposer organisms. These microbes take up nitrogen from soil near the ground surface and make it mostly unavailable to seedlings. As decomposition proceeds, the most easily decomposed organic material is consumed. With a reduced food supply, some of the microbial population dies off, and there is a release of mineral N back into the soil (Tisdale and Nelson, 1975). Depletion of available N during fall would account for the reduced success of fall-germinating species: species in grass seed treatments and volunteer ruderal grasses and forbs. Release of N in spring may have contributed to the success of species which germinate in winter, particularly the native woody species, *Baccharis*. In short, straw mulch proved to be valuable in two ways. In controlled erosion and it favored establishment of native species through its modification of the seedbed environment.

There was practically no vegetation under the Douglas-fir mulch. It was applied heavily and light may have been limiting for seedlings of some species. In addition, Douglas-fir branches have a C:N ratio greater than 400:1. Wood chips immobilize nitrogen at the soil surface more strongly than straw and their larger particle size results in slower decomposition. Wood chips suppressed new seedlings too much for use as a broadcast mulch, but they would be valuable around individual planted trees and shrubs to suppress weeds and conserve soil moisture. The chipped pine, with more needles and less wood, had an abundance of *Baccharis* seedlings, a result more like that under straw than under the Douglas-fir chips.

Fertilizer and Revegetation

Fertilizer increased overall plant cover but, as with mulches, the seeded grasses and ruderals responded most strongly. Since the fertilizer was applied in fall, it would have been most available at that time, just when the seeded grasses and ruderals were germinating. The fertilizer speeded establishment and led to a rapid increase in the size of individual plants. By winter, fall-germinating species had preempted nearly all the available space, largely excluding later germinating species. *Baccharis* was the most obviously excluded species at Copper Creek. It was present in the largest numbers in areas left unfertilized. Fertilized areas had less than one percent as many seedlings per unit area as those without fertilizer, although the huskiest individuals were the few in openings on fertilized sites. *Baccharis* seeds are wind-dispersed during winter. Emerging seedlings probably cannot survive amidst vigorously growing grass, whether weedy or introduced.

If the competitive exclusion of *Baccharis* with fall fertilization is typical of native woody species, then this treatment is inimical to re-establishment of the natural vegetation. Herbaceous competition is very important in parts of the redwood region. Fritz and Rydelius (1966) observed lower survival rates of planted *Sequoia sempervirens* and *Pseudotsuga menziesii* with broadcast fertilizer than without it. They observed higher survival rates when grass was scalped away around trees than when it was not. Results of recent studies initiated within the park support these findings.

Summary of Findings and On-going Research

Experimental treatments at Copper Creek were intended to provide immediate erosion control. Mulches controlled erosion more effectively than grass. Straw was the most available and least costly of the mulches. Straw and Monterey pine mulches favored invasion of many light-seeded native woody species. Seedlings of some other natives were absent or poorly represented. Prescriptions need to go beyond reliance on natural seed dispersal to restore such species. Currently, of these, *Sequoia* and *Whipplea* are established by outplanting. Widely spaced conifers can be established at modest cost. However, since *Whipplea* requires dense planting, costs would be reduced substantially if success were achieved with seed. I am investigating ways to reestablish *Whipplea* and other species which may arise from buried seed or vegetative parts. In plots spread last year with topsoil from adjacent to roads, there are now many *Whipplea* seedlings. Fertilizer timing is also important. In plots straw-mulched in fall and fertilized in early spring, Baccharis are just as numerous and more robust than Baccharis in unfertilized plots. By making use of the population processes and phenology of native species, more natural and lasting patterns of vegetation may be encouraged. I trust that as hypotheses are tested and a better ecological foundation developed, the revegetation program in Redwood National Park will continue to move forward.

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LITERATURE CITED

Bormann, F.H. and Likens, G.E. 1979. Pattern and process in a forested ecosystem. Springer-Verlag, N.Y. 253 pp.

Darrach, A.G. 1978. Estimating sheet-rill erosion and sediment yield on rural and forest highways. U.S.D.A. Soil Conservation Service Western Technical Service Center Woodland Tech. Note #12.

Dyrness, C.T. 1975. Grass-legume mixtures for soil erosion control along forest roads in western Oregon. J. Soil and Water Conservation 30: 169-173.

Fritz, E. and Rydelius, J.A. 1966. Redwood Reforestation Problems. An Experimental Approach to their Solution. Foundation for American Resource Management, Buena Park, California. 130 pp.

Muldavin, E.H., Lenihan, J.M., Lennox, W.S. and Veirs, S.D., Jr. 1981. Vegetation succession in the first ten years following logging of coast redwood forests. Technical Report #6, Redwood National Park, Arcata, California.

Munz, P.A. and Keck, D.D. 1968. A California flora and supplement. University of California Press, Berkeley, California. 1905 pp.

Tisdale, S.L. and Nelson, W.L. 1975. Soil fertility and fertilizers. MacMillan Publishing Co., N.Y. 694 pp.

Weaver, W. and Seltenrich, M. 1981. Summary results concerning the effectiveness and cost effectiveness of labor-intensive erosion control practices used in Redwood National Park, 1978-1979. Unpublished report, Technical Services Division, Redwood National Park, Arcata, California.