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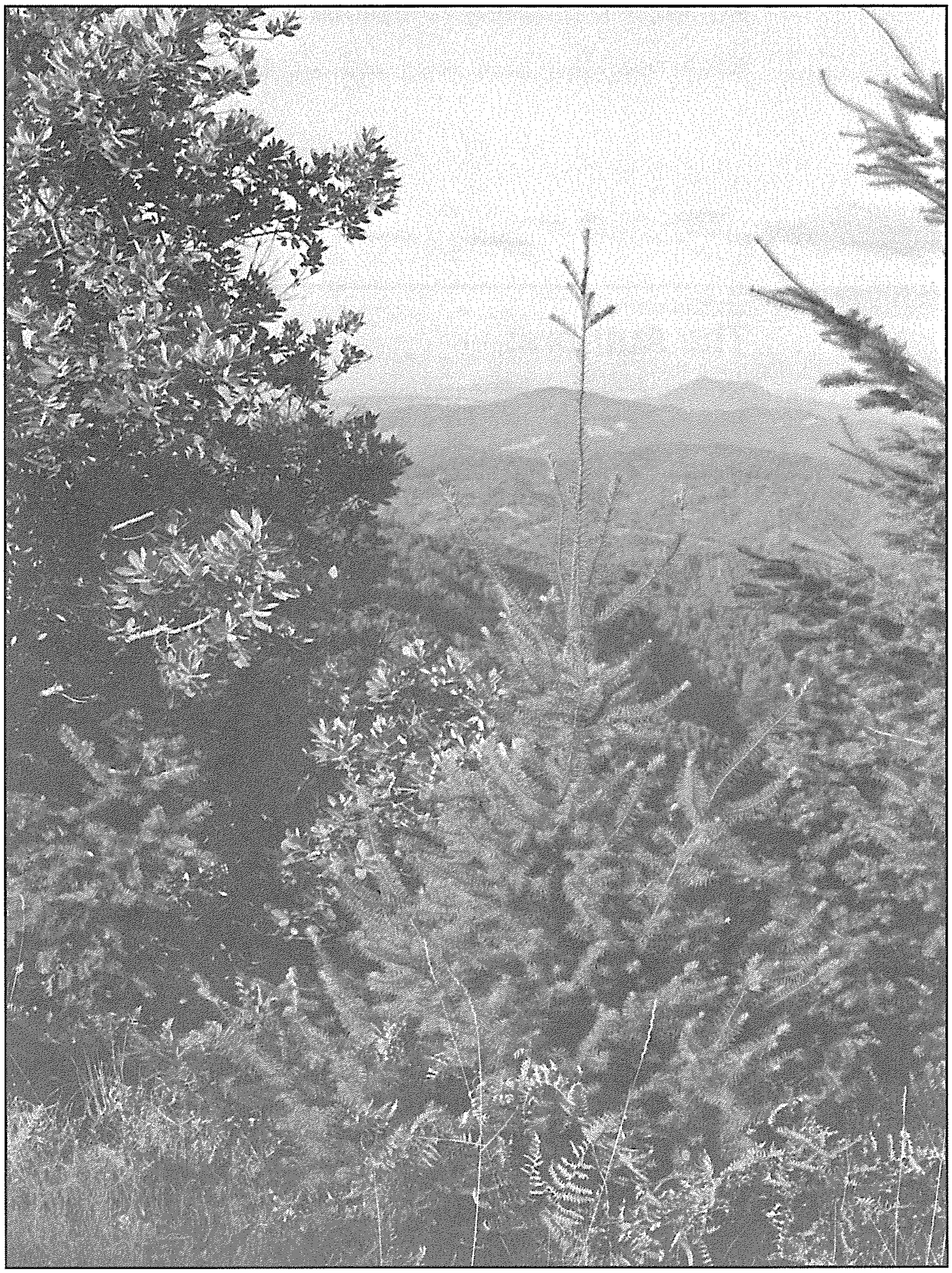
Repeated Manual Release in a Young Plantation: Effect on Douglas-fir Seedlings, Hardwoods, Shrubs, Forbs, and Grasses

Philip M. McDonald **Gary O. Fiddler** **Henry R. Harrison**



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Douglas-fir seedlings on the Arcata Resource Area, Bureau of Land Management, U.S. Department of the Interior, in central coastal California, were released by chain sawing and grubbing competing vegetation around them at different frequencies (0, 2, and 3 grubbings) over a 5-year period. After 5 years, average Douglas-fir stem diameter (measured at 12 inches above mean groundline) of seedlings grubbed at ages 1, 2, and 5 was 0.91 inches, and of seedlings grubbed after the first and fifth growing season was 0.95 inches. Both were significantly larger than counterparts in the control (0.57 inches). Tanoak, the most competitive species, constituted 84 percent of total plant cover in the control after 5 years, but only 25 percent on treated plots. Combined shrubs varied little between the untreated control and treated plots and averaged about 7 percent of total foliar cover. Grasses were not present in the control and only for the fifth year in treated plots. The most abundant forb, a hedge nettle, increased greatly in density in both control and treated plots. These relationships and others denoted in the paper yield valuable ecological information on species and community dynamics in both a natural and treated environment. Crew time (no overhead or travel costs) for the three grubbings was 52 hours and for the two grubbings was 44 hours.

Retrieval Terms: ecology, growth, manual release, cost, Douglas-fir, central California

The Authors:

Philip M. McDonald is a research forester assigned to the Station's Vegetation Management Research Unit, with headquarters at Redding, Calif. **Gary O. Fiddler** is a silviculturist assigned to the Timber Resource Planning Unit, Pacific Southwest Region, USDA Forest Service, with headquarters in San Francisco, and stationed at Redding, Calif. **Henry R. Harrison** is a lead forester with the Arcata Resource Area, Bureau of Land Management, U.S. Department of the Interior, and is stationed at Arcata, Calif.

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(Mailing address: P.O. Box 245, Berkeley, California 94701-0245
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In Brief...

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As we move toward forest ecosystem management, the need for knowledge on plant communities that develop naturally or after a deliberate manipulation will become increasingly important. Manipulation could be for a variety of reasons: to create a future forest, to provide an economic crop, to grow plants whose seeds would be critical to wildlife, or simply to provide more diversity and thus be in a position to capitalize on values and commodities that might be needed in the future. In this study, for example, a wildfire had left the plant community with no conifer trees, even though one species (Douglas-fir) was part of the climax vegetation. Planting Douglas-fir seedlings restored the natural community and promulgated a mixture of species.

But, in order for the Douglas-fir seedlings to have a chance to become established, the existing shrub and hardwood community had to be treated to free site resources for the seedlings. Competition was intense. For example, total plant density in the untreated control after five growing seasons was more than 37,000 plants per acre with total foliar cover of more than 23,000 ft^2/acre. Such levels of competition can kill conifer seedlings or severely limit their growth.

Manual release, a combination of chain sawing and grubbing, was employed to release the conifer seedlings. Five years after release, Douglas-fir seedlings in treatment R2X (released two times) and R3X (released three times) had significantly larger stem diameters and foliar cover than counterparts in the control. After 5 years, Douglas-fir seedlings were the tallest vegetation (4.7 feet) on treated plots, with fast-developing crowns and low mortality.

The plant community on treated plots contained almost the same species as the control after five growing seasons, but the proportion of hardwoods, shrubs, and forbs changed: mean cover of tanoak in the control was 19,467 ft^2/acre, or 84 percent of total cover—on treated plots it was 2,208 ft^2/acre or 25 percent of total cover; cover of shrubs in the control amounted to 1,567 ft^2/acre or 7 percent of total cover—on treated plots it was 700 ft^2/acre or 8 percent of total cover. Mean cover of ferns in the control was 1,867 ft^2/acre or 8 percent of total cover—on treated plots it was 2,925 ft^2/acre or 33 percent of total cover. Grasses were not present in the control during the study period, nor on treated plots until the fifth growing season. At this time they averaged about 7,000 plants per acre or about 8 percent of total density. Because they were young and small, their cover was very low.

One forb, a species of hedge nettle, opportunistically invaded both the treated and untreated plots. On treated plots it constituted 69 percent of total plant density after five growing seasons. In the untreated control, its density increased from 10 to 41 percent of total density during the 5-year study.

The labor-intensive job of manual release was done by Conservation Camp crews closely supervised by foresters. They did an excellent job, only one seedling disappeared, and no injuries occurred.

Introduction

In this era of beginning forest ecosystem management, the need to establish conifer plantations and have them grow at the potential of the site is as important as ever. A fast-growing new stand of conifers and hardwoods can provide a full spectrum of desired values, commodities, and amenities at a given place and at a predictable time. The alternative—in this instance, a nearly pure tanoak forest minus the naturally-occurring Douglas-fir—cannot.

Where no seed source is present or where natural regeneration is undependable, planting is necessary. But planted seedlings are rarely as well adapted to a given site as are naturally established native plant species, especially those that sprout from burls or rhizomes (McDonald 1982, 1986). Rare is the plantation that does not need some form of vegetation management (Fiddler and McDonald 1990). Indeed, in almost all plantations, even those with a good site preparation, competing plant species either kill the seedlings outright or reduce their growth below the potential of the site (McDonald and Fiddler 1986). That competing vegetation must be controlled to provide site resources to conifer seedlings is almost universally agreed upon (Gjerstad and Glover 1992, Stewart and others 1984).

Manual release, the physical removal of competing vegetation by grubbing, snipping, or cutting with hand tools or a chain saw, is rarely even considered when most of the competing plant species are sprouts of fast-growing shrubs and hardwood trees or rhizomes from ferns and herbaceous plants. This is because plant stems reappear after a few months and grow rapidly, fueled by carbohydrates stored in root burls and rhizomes. Removing the stems year after year is discouraging, time consuming, and expensive (Bernstein 1977, Click and others 1989, Hobbs 1986, McDonald and Fiddler 1986, 1989, 1990). Manual release is also strenuous and dusty work (Lottritz 1983), and hazardous (Bernstein 1977, Newton 1983). Moreover, damage to conifer seedlings can be prohibitive (Bernstein 1978, Roberts 1980), and the method controversial as to effectiveness (Click and others, 1989, Lottritz 1983, Roberts 1980). Click and others (1989) separated hand grubbing from hand slashing (chain saws). They stated that hand grubbing was ineffective for sprouts, with numerous contract failures because the amount of labor required was underestimated. The effectiveness of slashing was described as being controversial, with at least two applications necessary for enhancing conifer seedling growth.

In many instances, plantation release is needed, but its application is limited by geographical and societal considerations. Where mechanical site preparation is not feasible, as on steep slopes; where social pressures or legal restrictions prohibit the use of herbicides; or where air quality standards prohibit broadcast burning, manual release is a viable alternative. In these situations, about all the silviculturist can do is try to reduce the leaf surface area and vigor of competing species to the point that conifer seedlings can survive, grow, and eventually dominate.

This paper reports the efficacy of manual release, especially chain sawing and grubbing, in a young Douglas-fir plantation where the primary competing species developed from below-ground structures. Further, the paper reports results for a high-precipitation environment in an area of California—the Central Coast—where knowledge on the ecology and dynamics of the plant community and the results of its manipulation are unknown.

Methods

Location and Site Characteristics

The study site is located on the Arcata Resource Area, U.S. Department of the Interior, Bureau of Land Management, 14 airline miles west of the town of Garberville in a part of California known as the Lost Coast and more specifically in the King Range National Conservation Area. This Coast extends along the shores of the Pacific Ocean from just north of Shelter Cove to Petrolia, California and inland for 8 to 10 miles. The Conservation Area occupies about 60,000 acres. Its environment is described as "unique" not only because of very high rainfall, but also for the long summer drought (Bain and Matis 1989).

Before burning in a wildfire in September 1973, the study site was occupied by a forest that consisted of a mixed conifer-hardwood stand with Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) above and tanoak (*Lithocarpus densiflorus* [Hook. & Arn.] Rehd.), the majority species, below. Pacific madrone (*Arbutus menziesii* Pursh) and California-laurel (*Umbellularia californica* [Hook. & Arn.] Nutt.) were much less abundant beneath the Douglas-fir and of scattered, rather than patchy, distribution. In places, Douglas-fir was absent or scattered, and the hardwoods comprised the overstory. Several shrub species, including poison-oak (*Toxicodendron diversilobum* T. & G.), Coast whitethorn (*Ceanothus incanus* T. & G.), California coffeeberry (*Rhamnus californica* Eschsch. ssp. *californica*), and manzanita (*Arctostaphylos canescens* Eastw.), were abundant, mostly in more open places within, rather than under, the forest. All are vigorous sprouters, and all but poison-oak are evergreen. This vegetation corresponds to the Douglas-fir—tanoak—Pacific madrone forest cover type (SAF 234) (Sawyer 1980).

The evergreen species belong to the worldwide class of vegetation known as broad sclerophylls. They are well adapted to the Mediterranean climate characterized by long, hot, dry summers and cool, moist winters typical of

California, and are particularly adept at surviving and growing well on poor sites with limited soil moisture. Specific adaptations include a large and deep-thrusting root system, two modes of reproduction (seed and vegetative propagation) with large and frequent seed crops and rapidly growing sprouts, many kinds of leaf coatings and structures that limit loss of moisture from leaves and stems, capability to photosynthesize at low internal moisture levels, respiration control at high temperatures, and propensity to use all available moisture without penalty of high respiration or wilting (water wasting) (McDonald 1982, Mooney and Dunn 1970).

After burning, the plant community consisted of the hardwood and shrub species above, but no new Douglas-fir seedlings—no seed source remained. After chain-saw slashing and broadcast burning in 1987, the plant community consisted of resprouts of the above species plus numerous forbs, especially an abundant hedge nettle (*Stachys ajugoides* var. *rigida*) (Hickman 1993), bracken fern (*Pteridium aquilinum* (L.) Kuhn var. *pubescens* L. Underw.), and a developing component of grasses, chiefly of the genera *Aira, Vulpia, Agrostis*, and *Bromus*.

Site quality of the study area is medium (III) with height of dominant Douglas-firs averaging 90 to 110 ft at a breast-height age of 50 years (King 1966). Slopes range from 50 to 75 percent and average about 65 percent. The elevation is 2300 feet. The aspect is east. The predominant soil is of the Honeydew series (Typic Haploxerult). Such soil is formed in material that has been weathered from sedimentary rock (sandstone). The soil is moderately deep (36 inches) and well drained, with a texture of dark brown very gravelly loam grading to very gravelly clay loam below 12 inches. Average annual precipitation, all falling as rain, is 125 inches. In spite of the high amount of precipitation, summer drought is common and often lasts at least 95 days. It is ameliorated somewhat, however, by occasional fog. Annual temperatures range from a high of 90 °F to a low of 30 °F.

Study and Design

The study includes density and developmental data on conifer seedlings and hardwoods, shrubs, forbs, ferns, and grasses collected from 1988 through 1992. It includes information gathered on plants developing naturally (untreated control) and after one or more treatments. If possible, sprout removal treatments were performed in May, the time of year in this area when sprout elongation is rapid, most carbohydrate reserves have been expended, and not enough time has elapsed for their replacement.

The experimental design was randomized block with three blocks and four treatments. Each treatment was replicated three times. Blocking was thought necessary because of slight differences in slope and soil depth. After the cutting and broadcast burning of 1987, very little slash remained. Sprouts were killed to groundline, but resprouted in spring 1988. Initial release was in May 1988.

Treatments were:

R10X (Released 10 times). Cut shrub and hardwood sprouts with chain saws and hand tools and grub herbaceous vegetation each year on entire plot for 10 years to achieve as complete control as possible;

R4X. Cut shrub and hardwood sprouts and grub herbaceous vegetation as above for years 1, 2, 5, and 7 on entire plot to approximate early cutting followed by two maintenance cuts;

R2X. Cut as above before first and fifth growing seasons to alleviate over-topping of Douglas-fir seedlings and provide additional light;

Control. Untreated control.

Unfortunately, fiscal restrictions did not allow release for years 3 and 4 in R10X, and it has been eliminated in this report. Because the timespan reported here is 5 years, R4X will be denoted as R3X henceforth. Manual release consisted of a combination of chain sawing and grubbing with hoes and pulaskis. Grubbing consisted of hacking the sprouts off large burls and digging out root systems of smaller plants.

The area was planted (hoedads) to 2-0 bareroot Douglas-fir seedlings in January 1988 on a 10- by 10-foot spacing. Because damage from deer (*Odocoileus* spp.) is common in the area, each seedling was fitted with a vexar leader protector. Each replicate (plot) was roughly rectangular and consisted of about 0.25 acre with 40 to 50 conifer seedlings surrounded by two or three rows of buffer (seedlings receiving similar treatment). About 25 of the best seedlings, identified as potential crop trees, were flagged. As their name implies, these were thrifty seedlings that had good potential of becoming harvestable trees. Small, misshapen and discolored seedlings were not part of the study—their chance of being alive at the end of the study was remote, given the large population of rapidly growing hardwoods and shrubs. On each of the sample seedlings, height and stem diameter were measured. Diameter was recorded at 12 inches above mean groundline. The seedlings also were checked for possible injury by humans, deer, and insects.

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

Vegetation was measured in 1988, 1989, 1991, and 1992. Statistical analysis was performed each year. To test for treatment effects and significant differences among treatments, two-way analysis of variance (mixed model, no interaction, Steel and Torrie 1980) and Tukey tests were the analytical tools (SAS Institute Inc. 1988). Data were gathered from permanent plots measured each year, and where analyses of means from repeated measurements are concerned, the data are not truly independent. The α levels or type I errors given for various tests apply to each measurement and year separately.

All release was manually performed by 8- to 15-person Conservation Camp crews with close supervision by foresters. Hourly production data, the basis for economic evaluation, was limited to the time it took to perform the manual release. No overhead, transportation, or other costs were included. Consequently, the production rate data presented in this paper are unique to Conservation Camp crews, relatively small plots, and the experimental nature of the job. The quality of the job, for example, was described as "better than operational" by the lead forester. However, because much valuable work in the natural resource field is done by such crews, a record of their production may be useful to others who utilize this source of labor.

Results

The pressing need for ecological knowledge, and specifically information on the composition and structure of plant communities and the abundance and dynamics of individual species, suggested that results be presented both for individual and groups of species. Consequently, we present data on survival, stem diameter, and height for planted Douglas-fir seedlings; and information on density, foliar cover, and height for tanoak, combined shrubs, bracken fern, grasses, and the hedge nettle, which was the most abundant and best distributed forb. Equally needed is knowledge on plant species abundance, dynamics, and development in a natural and manipulated condition. Consequently, we present results both for the untreated control and for treated plots.

All Vegetation

For the first growing season after treatment and four growing seasons later, total vegetation (except conifer) in the control and treated plots (average of R2X and R3X) was:

Treatment	Year	Density	Standard Error	Foliar Cover	Standard Error
		Plants/acre		*Ft²/acre*	
Control	1988	21,028	4,270	11,381	2,355
	1992	37,299	9,062	23,067	3,779
Treated Plots	1988	23,841	5,636	8,079	2,113
	1992	90,881	35,766	8,855	2,391

The density and development of most species varied over time and with the different environments inherent to the treatments. The control, for example, was fast becoming occupied with mostly rapidly growing hardwoods and shrubs that left little area or site resources for smaller, shorter plants. After 5 years, plots treated several times, especially R3X, had noticeably more forbs, ferns, and grasses than in the control.

Douglas-fir

Mortality of Douglas-fir seedlings over the 5-year period was 10 seedlings (16 percent) in R2X, 13 seedlings (20 percent) in R3X, and 22 seedlings (29 percent) in the control. Most seedlings died the third and fourth year after planting—a delayed mortality phenomenon also noted by Tesch and Hobbs (1986) for Douglas-fir seedlings in southwestern Oregon. Only 2 seedlings died the fifth year. Drought appeared to be the primary cause of mortality. One seedling disappeared and probably was cut during treatment. Other than this, damage from the treatments was remarkably absent. Some branches in the vexars were twisted, but growth of the leader was not impaired. Survival of Douglas-fir seedlings after five growing seasons, by treatment, was R2X, 84 percent; R3X, 80 percent; and control, 71 percent. Transformed (arc-sine, Snedecor 1956) mean survival values after the fifth growing season were examined by ANOVA. Survival did not differ significantly among treatments.

Statistically significant differences among treatments for Douglas-fir stem diameter, measured at 12 inches above mean groundline, first showed up in fall 1991. Mean diameter of Douglas-fir in treatment R2X was significantly larger than counterparts in the control (*fig. 1*). This trend continued through 1992 when mean stem diameters of seedlings in both R2X and R3X were significantly larger than for seedlings in the control. Foliar cover of Douglas-fir seedlings was first measured in fall 1991. In both 1991 and 1992, seedlings in R3X (not in R2X) continued to have significantly more foliar cover (about two and one-half times) than counterparts in the control (*fig. 2*). Mean stem height (standard error in parentheses) did not differ significantly among treatments during the study period (*fig. 3*). After five growing seasons it was 4.7 feet (0.5 feet) in R2X, 4.7 feet (0.2 feet) in R3X, and 4.1 feet (0.3 feet) in the control.

Tanoak

This hardwood tree species was present in all plots and was by far the most abundant of the arborescent vegetation. Before the wildfire of 1973, most "trees" were from clumps that ranged from 2 to 6 stems. After cutting and burning in 1987, each clump sprouted, and after one growing season the number of sprouts per clump ranged from 10 to 80.

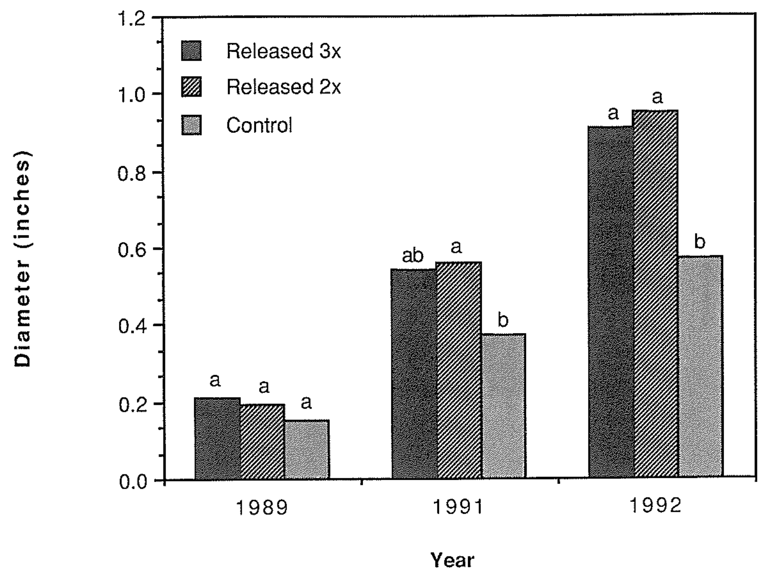

Figure 1—Average Douglas-fir stem diameter at 12 inches above mean groundline, 1989-1992. Standard errors each year ranged from 0.02 to 0.07 inch. For each year, treatment means followed by the same letter do not differ significantly at the 0.05 level.

In the control, the number of tanoak clumps ranged from 2450 to 2200 per acre over the 5-year study period and reflected a slight decrease over time due to natural mortality (*fig. 4*). Foliar cover and height more than doubled during this timespan. After five growing seasons, average tanoak cover was 19,467 ft^2 per acre (standard error [SE] = 3,735 ft^2/acre) and height was over 4.7 feet (SE = 0.2 ft).

On treated plots, no statistical difference among treatments for tanoak clump density was noted after five growing seasons (*fig. 5*) or at any time during the study period. This is because the root systems of most of the clumps are huge and it is impractical to remove them with hand tools. However, a few were small enough to remove, and mean tanoak density was consistently lower in R3X plots—those that were grubbed the most. Also in R3X, repeated grubbing caused three sprout clumps to die, but other than these, no decline attributable to repeated grubbing was visually discernible. Mean foliar cover of tanoak did not differ significantly between R2X and R3X, but R2X differed significantly from the control each year of the study. Average height of tanoak sprouts differed significantly only after the fifth growing season when all three treatments differed from each other.

Combined Shrubs

With the exception of poison-oak, which is ubiquitous in this part of the Coast Range, no single shrub species was present on more than 9 of the 12 plots. Because of this uneven distribution, shrub species were combined to best show their response to the different treatments. In the control, number of plants per acre decreased steadily and after five growing seasons was 62 percent lower (5,095 [1,703] vs 3,150 [333]) (*fig. 4*). Mean foliar cover and height, however, increased by 155 and 421 percent, respectively, over the 5-year period.

On treated plots, density and foliar cover of combined shrubs did not differ significantly among treatments during the study period. Height differed only after the fifth year when sprouts in R2X and R3X were significantly shorter than counterparts in the control (*fig. 5*).

Bracken Fern

This opportunistic species was present in all plots when the study began and was even more so after 5 years—even in the control where its density (standard error in parentheses) increased by 44 percent from 11,480 (3,359) to more than 16,500 (1,368) plants per acre (*fig. 4*). Foliar cover in the control decreased 35 percent, and height increased 94 percent over the 5-year study period. On treated plots, fern density and foliar cover did not differ significantly among treatments during the study period (*fig. 5*). Height of ferns differed only in 1989 when plants in R3X were significantly shorter than counterparts in R2X and the control.

Grasses

When the study began, grasses were absent from the study area. None became present in the control during the study period. On treated plots, grasses began to invade during the fifth growing season but did not differ in density, foliar cover, or height during the 5-year period. Many grass plants were new and small and consisted of

Figure 2—Foliar cover and overall development of Douglas-fir seedlings in fall 1993 in (A) Control, (B) Treated 2 times, and (C) Treated 3 times.

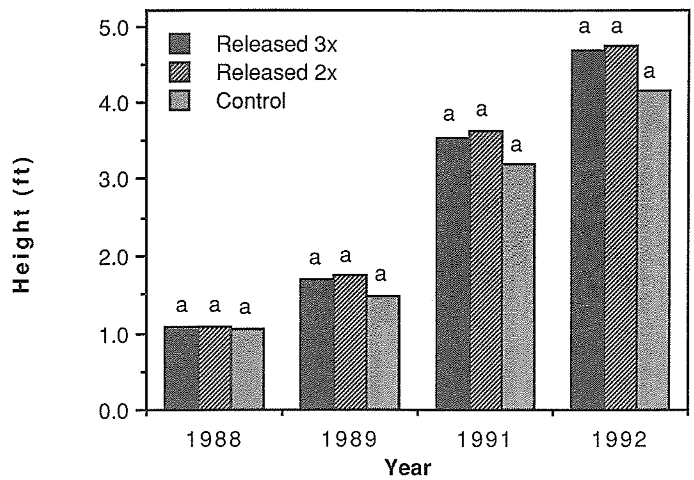

Figure 3—Average Douglas-fir stem height, 1989-1992. Standard errors each year ranged from 0.02 to 0.09 feet.

poorly developed stems and leaves, without flowering stocks. Consequently, the low foliar cover and height values in *figure 5* reflect this early developmental stage.

Hedge Nettle

This abundant forb was present in all treatments and exhibited both wide ecologic amplitude and high variability in density and development. In the control, mean density, cover, and height increased and decreased from year to year (*fig. 4*). Overall trends in the control between the first and fifth year were that density increased over sevenfold between the first and fifth year; foliar cover declined after the second year and by the fifth year had decreased 91 percent; mean height also declined after the second year and decreased by 27 percent. On treated plots, plant parameters also varied greatly from year to year, and no significant differences among treatments were found at any time (*fig.5*).

Plant Species Dynamics

Given that foliar cover is probably the most practical (easily seen and evaluated) estimator of shrub, hardwood, and fern competition to young conifer seedlings, and density the most practical for herbaceous competition (McDonald and Fiddler 1989), these parameters are discussed in the material that follows as a means of showing relative changes in the plant community.

Tanoak clearly was the dominant species. As noted in the control, it initially had more than twice the cover of all naturally occurring species combined; after five growing seasons it had over four times more cover than all other species combined. On treated plots, tanoak cover after five growing seasons was about one-fourth of total plant cover and was less than the cover of bracken fern and hedge nettle. Plainly, the net effect of manually cutting and grubbing tanoak reduced its dominance and allowed a larger component of ferns and forbs to be present.

Combined shrub cover remained relatively constant throughout the study. It was 5 percent of total cover in the control in 1988, 7 percent of total cover in the control in 1992, and 8 percent of total cover in treated plots in 1992.

Bracken fern cover was 25 percent of total cover in the control in 1988, 8 percent of total cover in the control in 1992, and 33 percent of total cover in treated plots in 1992. The strategy of this species is to persist in shady environments by sacrificing cover for height, and to excel in more open areas by increasing cover and density.

Density of grasses was relative only to treated plots. After five growing seasons, grass density constituted about 8 percent of total plant density. The density of hedge nettle in the control relative to total density was 10 percent in 1988 and 41 percent in 1992. In treated plots the density of hedge nettle constituted 69 percent of total density. Plainly, this species was well adapted to both the shade environment of the control and the sunlit environment of the treated plots.

Plant Diversity

The total number of naturally occurring plant species on study plots from 1988 through 1992 was 36. This included 3 trees, 7 shrubs, 20 forbs, 1 fern, and 5 grasses. Nearly all were present throughout the study period in all treatments. Grasses were an exception, not being present in the control during the study period.

Production Rates

The production rates denoted here are just for R2X and R3X treatments, but it should be remembered that work also was being done in the R10X treatment as well. This tended to spread the work over more acreage

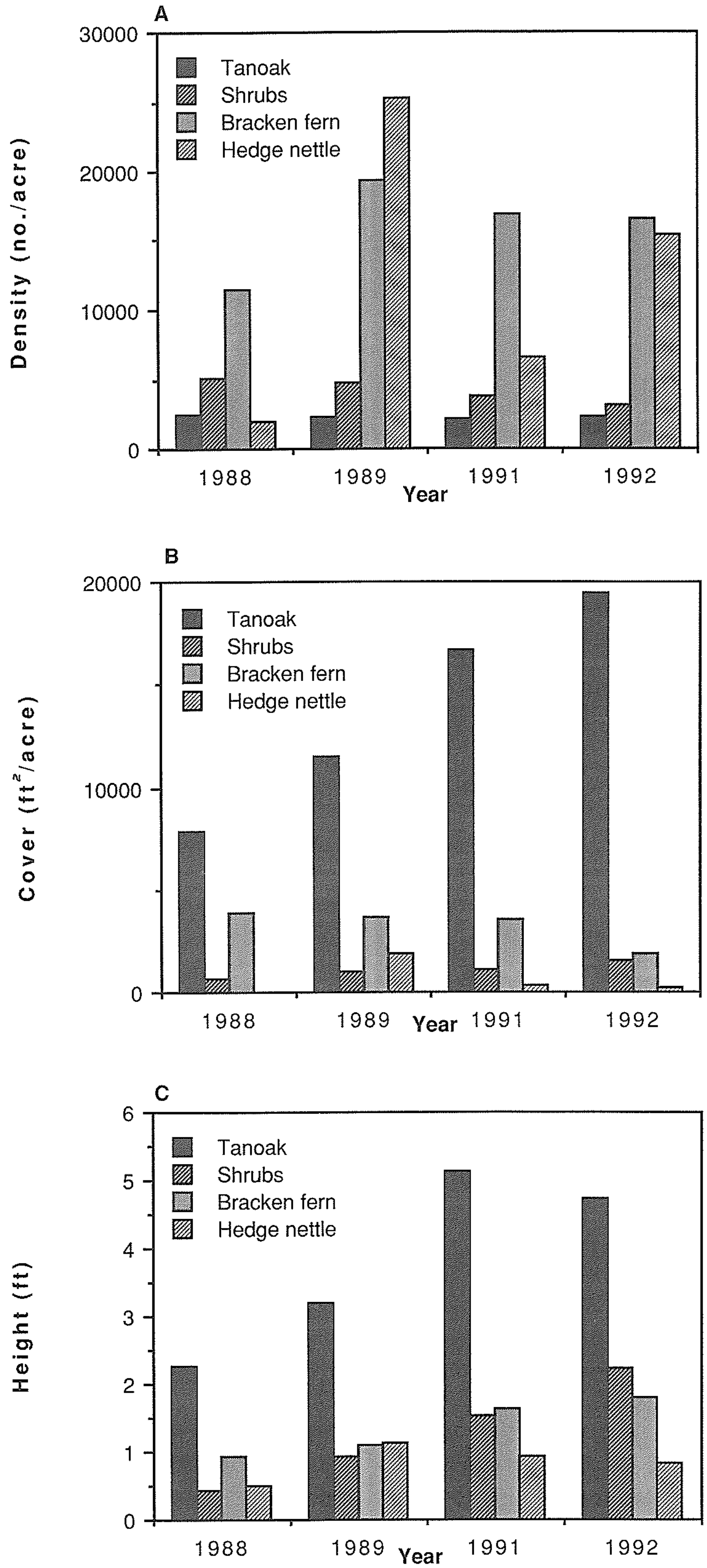

Figure 4—Average density (A), cover (B), and height (C) of tanoak, combined shrubs, bracken fern, and hedge nettle in the control, 1988-1992. Standard errors for each species and year for density ranged from 174 plants per acre for tanoak in 1989 to 19,175 plants per acre for hedge nettle in 1989; for cover, from 111 ft^2/acre for combined shrubs in 1991 to 3735 ft^2/acre for tanoak in 1992; and for height from 0.03 feet for combined shrubs in 1988 to 1.7 feet for tanoak in 1991.

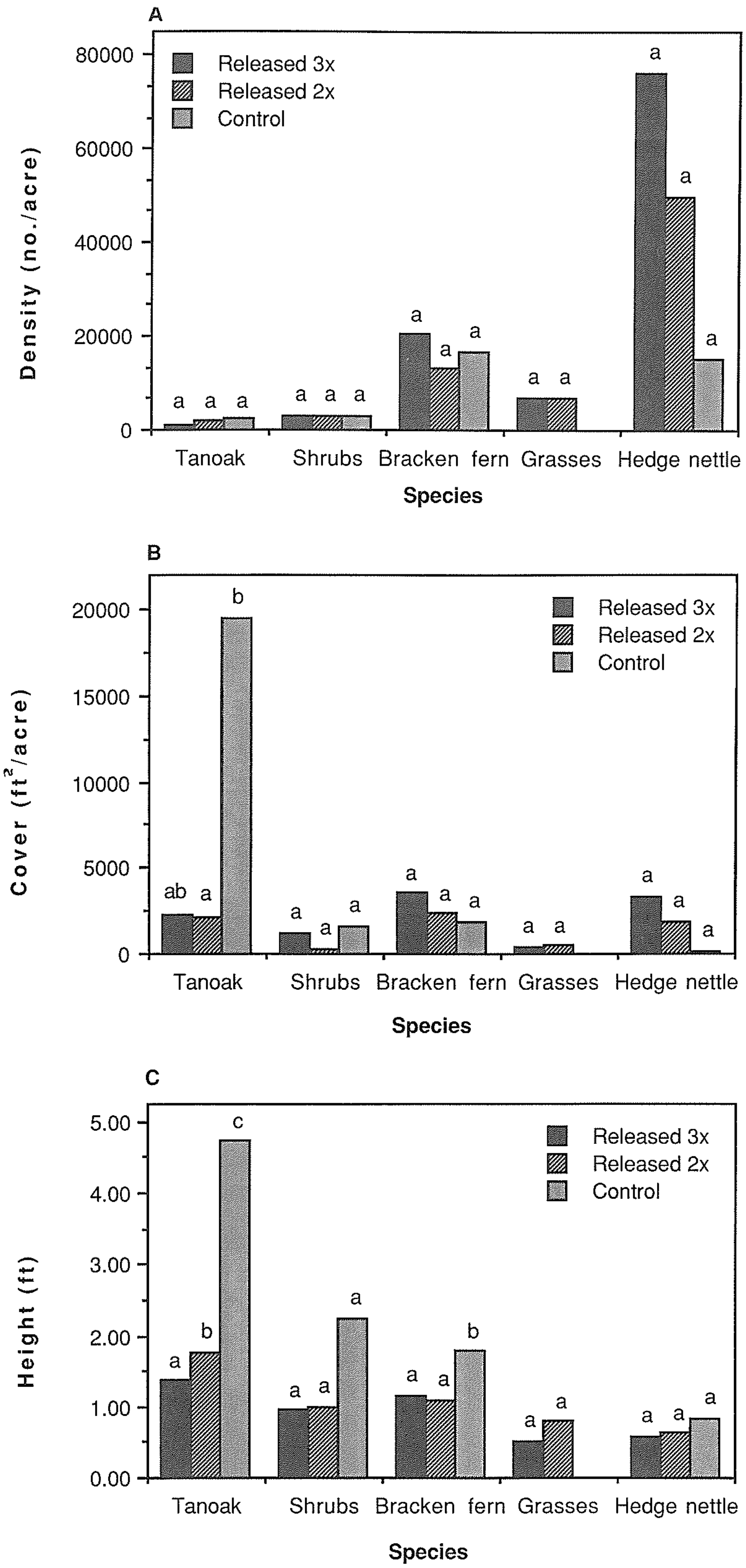

Figure 5—Average density (A), foliar cover (B), and height (C) of tanoak, combined shrubs, bracken fern, grasses, and hedge nettle 5 years after initial treatment, 1992. Standard errors for each species and treatment for density ranged from 378 plants per acre for combined shrubs to 22,249 per acre for hedge nettle; for cover, from 221 ft^2/acre for grass to 2129 per acre for tanoak; and for height from 0.04 feet for tanoak to 0.23 feet for ferns.

and lower the average cost. Over the 5-year period, the amount of time to perform manual release for R2X was 44 hours and for R3X was 52 hours (*table 1*). The modest difference in cost reflects the interplay of the additional treatment in R3X in 1989 and the larger vegetation that needed to be cut and grubbed in R2X in 1992.

Table 1—***Production rates for manual release by year and treatment, Nooning Creek study area, Arcata District, Bureau of Land Management, 1988-1992***

Year	Treatment	Production rate
		Laborer hours/acre
1988	R2X[1]	24
	R3X	24
1989	R3X	15
1992	R2X	20
	R3X	13
Total	R2X	44
	R3X	52

[1]R2X, R3X means released 2 and 3 times, respectively.

Discussion and Conclusions

Slashing and broadcast burning created an opportunity for root crown sprouts of several hardwood tree species and woody shrubs, ferns from rhizomes, and numerous forbs and grasses from wind-blown seeds to develop. The tree and shrub species have many morphological and physiological adaptations that allow them to capture resources and grow rapidly. Utilizing the well developed, in-place root systems of parent trees, shrubs, and ferns certainly is one of the most important. Having thick leathery leaves with built-in structures to minimize water loss is another.

The need to manipulate the dominant vegetation that ensues after fire in this area seems obvious. Without some form of treatment, the entire area would resemble the control in 1992: more than 5,400 clumps of shrubs and hardwoods per acre, between 2.2 and 4.7 feet tall, with crowns that covered almost half the area so closely that they cast a solid shadow.

Changes in the density and development of a hardwood/shrub/Douglas-fir community over a 5-year period give insight into both individual and mixed-species responses to various intensities of manual release and to natural development. In the control, clumps of tanoak root-crown sprouts dominated both in terms of foliar cover and height. Bracken fern and Douglas-fir seedlings grew tall and thin, with skimpy crowns, to keep from being overtopped. Combined shrubs had a consistent amount of foliar cover. Grasses did not find the crowded control conducive to establishment, but the hedge nettle adapted well and increased in density, foliar cover, and height.

On treated plots, Douglas-fir seedlings survived well and excelled in growth. The hedge nettle and grasses increased greatly in density, and along with bracken fern, are capturing the space occupied by tanoak. The combined shrubs, like tanoak, continue to decline as their density and development are negatively affected by the repeated treatments.

The dominance of tanoak in the control suggests that plant diversity should be lower here than for treated areas. But it did not lessen, at least for the first 5 years after clearing, because not quite all of the area in the control was occupied by shrubs and hardwoods. A few small areas in spaces between sprout clumps were not occupied, and here, with the exception of the abundant hedge nettle, was where a few poorly developed members of other forb species were present. Although their future is precarious, they are present and contributing to plant species diversity.

The key to successful vegetation management is to create an environment for members of the desired species, in this instance the Douglas-fir seedlings, to grow at the potential of the site from the moment they are planted through at least the first three growing seasons (Fiddler and McDonald 1987, McDonald and Fiddler 1990). In this manner, the propensity for rapid growth, begun in the nursery, is continued. This means that controlling competing vegetation is most effective if done when it is young and small and unable to limit site resources available to the desired species. This suggests that to be effective, manual release must be done soon after the planting of conifer seedlings. And if it is done before carbohydrate reserves of the competing vegetation can be accumulated, so much the better. Early treatment is more gentle on the land and inconspicuous to the public. Other advantages of early treatment include lower costs, reduced damage to seedlings, lessened chance of injury to crew members, no shock to shade leaves from sudden release, and less slash that possibly could harbor damage-causing rodents or constitute a fire hazard.

Another key to successful vegetation management is to convert the vegetation from very competitive species to less competitive species. Less competitive means less use of site resources, including soil, light, and growing space. In this study, the treatments greatly reduced the foliar cover of tanoak and replaced it with high numbers of much shorter forbs and grasses.

The practical significance of R3X relative to R2X appears to be slight. The only significant difference from the additional cutting was that mean tanoak height was shorter in 1992. Douglas-fir stem height and diameter and foliar cover did not differ significantly between R2X and R3X during the study period. Although mean diameter and cover are slightly greater in R3X in 1992, it is doubtful that they will differ significantly by fall 1994 or just before the next release. Consequently, the gain in Douglas-fir growth from a second early treatment appears to be small. However, when this gain is coupled with that anticipated from the fourth release in 1994, the effect might be more pronounced. Little is known about the cumulative growth effects from a series of release treatments or when that growth becomes manifest. At this juncture, it is too early to say that the second early treatment should or should not be done.

The nature of the treatments had some special ramifications for the plant community. The fifth-year treatment in R2X created large amounts of organic material that matted to the ground—in places so dense that no plants could grow through it. The plant density data for this treatment in 1992 (*fig. 5*) reflects this phenomenon. Another interaction concerned California-bay, the R3X treatment, and deer. Grubbing and sawing this species reduced the sprouts to a size that was conducive to browsing by deer. Browsing has been so heavy that mats of sprouts have formed. These are about 1.3 feet tall and so dense that no other vegetation can penetrate through them. For this species, the chronic and severe nature of the browsing is such that the treatment is manual release plus deer, rather than manual release alone.

Manual release as practiced here was a combination of chain sawing and grubbing. Its impact on the soil and the local ecosystem in general can be described as more beneficial than detrimental. Because of high plant density, rapid regrowth of the vegetation, and much organic material on the ground, soil erosion has been minimal and limited to movement of soil only for short distances. As noted earlier, the treated plots have reduced the dominance of tanoak, allowed a broader species mix, and through planting, reestablished the native conifer species (Douglas-fir). This conifer is now well established and subsequent release treatments should promote rapid growth. A stand of Douglas-firs with scattered tanoaks, not a stand of tanoak, is likely. Overall, the new community in treated plots will present more opportunities for wildlife and scenery variation, plus high potential for commodities and other values from the eventual forest.

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