Changes in Plant Communities After Planting and Release of Conifer Seedlings: Early Findings

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Abstract—Plant diversity, density, and development data from an extensive research program in conifer plantations in northern California suggest changes in plant community composition after site preparation and many kinds of release. Based on 17 studies, the average number of species per study area after 10 years was 25 with composition of 1 conifer, 1 hardwood, 8 shrubs, 12 forbs, and 3 graminoids. Species ranged from 13 to 46. Density, foliar cover, and height varied by treatment and type of vegetation present. Density in a mixed shrub community, for example, ranged from 902 to 18,168 plants/acre after 10 years and in a mixed shrub-grass community from 147,400 to 254,900 plants/acre. Additional data are presented on the fate of a serious invader, side-by-side development comparison of two vigorous shrubs, and changes in species composition in several vegetation density classes in a plantation after 27 years.

Introduction

To manage the land effectively, the forest ecosystem manager of the future will need information on plants, animals, fish, insects, fungi, and even genes (McDonald 1999). For plants, knowledge of species composition, density, and development could be critical, both for individual species and for communities of species. Although much information is available on economic species like pine and fir seedlings, little is available on currently uneconomic species that often have worth by providing wildlife, scenic, water, medicinal, and other amenity and commodity values to society. The conventional plantation may even provide values of equal or greater worth than those derived from the eventual harvest of trees.

Recognition that the vegetation management base must be broadened to include detailed information on currently uneconomic species is increasing. Gordon (1979) recommended that foresters begin to build a database for vegetation that is expected in specific areas. Wagner and Zasada (1991) stated that forest managers across North America need to consider the potential effect of non-crop vegetation on nearly every acre of newly forested land. O'Hara and others (1994) noted that future forestry must embrace "a mix of commercially valuable and non-valuable species." Aune and others (1993) suggested that greater within-stand species variation will be desired in the future and "the growing and planting of high-quality seedlings of hardwood trees, shrubs, and other flowering plants is now expanding to meet multi-resource objectives." Rietveld (1992) noted an increased demand for diverse tree and shrub nursery stock, especially for species that provide food and shelter for wildlife.

McDonald and others (1996) noted that within the ecosystem management concept, a major need is for knowledge on silviculture treatments that will provide desired plant communities at specific times in the future. Silvicultural treatments imply disturbance, and that in turn implies planned disturbance, such as that caused by site preparation and plantation release.

The importance of disturbance in forest ecosystems has long been of interest to ecologists and in general has been focused on the successional relationships of plant communities. In general, succession was thought to be governed mostly by competition and predation. Disturbance was viewed as an uncommon event that occasionally caused major changes to the composition and structure of communities. More recently, however, interest has focused on the nature of disturbance itself and on the cause and effect of disturbance events. For example, Reice (1994) argued that disturbance is ubiquitous and frequent relative to the life spans of the dominant taxa. Thus communities are always recovering from the last disturbance. Furthermore, the size and extent of the disturbed areas modifies the ensuing disturbances—creating an ever-changing environment. To the silviculturist, this condition means that modeling plant succession is even more difficult. Considerations of competition, predation, and ubiquitous (but ever-changing) disturbance must be considered.

Sousa (1984) provides some specifics of disturbance applicable to patches ("plantations" in this paper) that are helpful. First of all, the environment of plantations differs with size, and the environment within a plantation is seldom, if ever, homogeneous. This difference alone allows for much variation in the composition, abundance, and development of species in plantations. Second, small plantations have a greater perimeter-to-area ratio than large plantations and thus are filled more quickly with fewer species than large ones. These species tend to be similar to those on the edge and less opportunity is available for succession. Conversely, large plantations tend to have more species present, and those with wind-dispersed and soil-bank reproductive strategies (Grime 1979) are favored, along with the usual species from root crowns, rhizomes, and large propagules.

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Each plantation is different, and therefore each has various amounts of different species with different growth and competition potentials. This characteristic presents both an opportunity and a challenge to the vegetation manager. The opportunity is to manage for one or more of the additional values noted above; the challenge is to recognize that competition levels to the planted conifer seedlings may vary, and could be excessive.

An extensive research program on vegetation management alternatives in northern and central California was begun in 1980 and continues today (Fiddler and McDonald 1987; McDonald and Fiddler 1993). Forty-two related studies, mostly installed between 1981 and 1990, comprise the program. Two other studies, entitled "Shrub Development Comparison" and "Long-term Plant Succession," are included in this paper to complement the research program. All are concerned with plantation release, not site preparation. The overriding objective was to provide a scientific basis for the application of new and existing vegetation management techniques.

Although the planted conifer seedlings are readily seen in a young plantation, only the largest and most competitive of the other plant species are noticed, and even they are seldom counted or their development studied. In truth, almost all plant species in young plantations are unknown, the number and development of plants of each species is not quantified, and the future role of most species in the plant community is only surmised. The literature is scant. McDonald (1999) recorded the diversity, density, foliar cover, and height of every species that was present in a small clearcut over a 5-year period in the northern Sierra Nevada; and Bailey and others (1998) and Schoonmaker and McKee (1988) studied the understory vegetation and the species composition and diversity of vegetation in western Oregon.

This paper describes the post site-preparation plant community and changes in its diversity, density, foliar cover, and height over a 10-year period; contrasts the early development of two common and aggressive shrub species, and reports succession over a 27-year period in one plant community in northern California.

Methods

Physical and Biological Environment

Study locations, including the two complementary studies, range from latitude of 39°N to 42°N and from longitude 121°W to 124°W. The climate is best described as Mediterranean with long, hot, dry summers and cool, moist winters. Daily summer temperatures vary from 60°F to 106°F and winter temperatures from –10°F to 50°F. Average annual precipitation ranges from 35 to 80 inches, with 40 to 80 percent falling as snow. No precipitation from mid-May through mid-September is common. Soil moisture is the factor most limiting to growth. Elevations vary between 3,000 and 6,500 feet, and slopes between 5 and 35 percent. The study areas are located in conifer plantations in the general forest zone; not in riparian, roadside, or slash disposal areas. Site quality of study areas rates as average to above average. An above-average site, for example, would support ponderosa pines (*Pinus ponderosa* Dougl. ex Laws. var. *ponderosa*) that average 70 feet tall in 50 years.

Ponderosa pine and Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) seedlings were the conifer species most often studied, with Jeffery pine (*Pinus jeffreyi* Grev. & Balf.), red fir (*Abies magnifica* A. Murr.), and California white fir (*Abies concolor* var. *lowiana* [Gord.] Lemm.) occasionally examined.

Because the climate and site quality of the study areas were conducive to colonization and rapid growth by a myriad of plant species, the logged areas or converted brushfields must be prepared for planting. Mechanical clearing, usually with a bulldozer, created piles or windrows of slash and other vegetation, which almost always were burned. Broadcast burning was used as a site preparation tool as well.

After site preparation, each study area was temporarily bare and in a condition receptive not only to planted pines and firs, but also to propagules of many hardwoods, shrubs, forbs, and graminoids. Common hardwoods included vigorous sprouts of Pacific madrone (*Arbutus menziesii* Pursh), tanoak (*Lithocarpus densiflorus* [Hook. & Arn.] Rehd.) and California black oak (*Quercus kelloggii* Newb.). Prominent shrub species, both from seeds and root-crown sprouts, were several species of manzanita (*Arctostaphylos* spp.), ceanothus (*Ceanothus* spp.), wild cherry (*Prunus* spp.), and others. The most abundant forbs were from the genera *Cirsium*, *Phacelia*, *Chimaphila*, *Trientalis*, *Stephanomeria*, *Lotus*, *Galium*, and *Vicia*. Graminoids included species from the genera *Carex*, *Bromus*, *Achnatherum* (*Stipa*), and *Festuca*. Bracken (*Pteridium aquilinum* [L.] Kuhn var. *pubescens* Underw.) was the most common fern.

Study and Design

Among the 42 individual studies, 25 were located in National Forests, 2 on State of California land, 2 on USDI Bureau of Land Management acreage, 2 on privately owned land, and 1 on an Indian Reservation. The two complementary studies were located on the Shasta-Trinity National Forests near Mt. Shasta. The studies embraced the full range of vegetation management techniques, which included direct, indirect, and conifer seedling enhancement (genetics). Direct manipulation treatments included manual release, chemicals, mulching, mechanical (machines), and grazing. Indirect methods involved using such environmental factors as shade and organic matter, and conifer enhancement was through breeding. In all the studies, density and development of the conifers and other vegetation in the various treatments were compared to an untreated (not released) control. The study period was 10 years, which was about the time that crowns of the conifers would be closing in the treatments with the least competing vegetation.

All studies had three to six replications. The experimental design was completely random, or randomized block with analysis of variance and Tukey tests as the analytical tools. Each replicate (plot) in each treatment consisted of about one-seventh acre on which were 30 to 35 conifer seedlings surrounded by two or three rows of buffer. Of these seedlings, 15 to 30 were randomly selected for sampling, which usually was performed in the fall.

Sampling of shrubs, forbs, and graminoids took place on five randomly selected, seedling-centered milacre (0.001 acre or 43.56 ft^2 of area) subplots. Quantified parameters included density, foliar cover, and height. In most instances, number of plants was quantified for density, but for a few species the number of stems or fronds was recorded. A list of all plant species on study plots was maintained and monitored at each visit. Study areas were measured annually for the first 2 years after treatment, with most areas being measured the third through fifth, seventh, and tenth years as well.

In the first complementary study, deerbrush (*Ceanothus integerrimus* H. & A.) and greenleaf manzanita (*Arctostaphylos patula* E. Greene) from a local seed source were grown in small peatpots and outplanted in spring 1992 on a site of high quality. The study area was open (no overstory) and maintained constantly to be free of competing vegetation. The experimental design was 3 plots with 25 plants of each species per plot. Number of stems per plant, crown diameter, height of tallest stem, and phenology (leaf development, onset and duration of flowering, seed production and dissemination, leaf fall) were recorded at various times throughout the year from 1992 through 1995.

The second complementary study was located in a large, mature brushfield on a below-average site near Mt. Shasta. Before site preparation by windrow and burn, the principal shrubs were greenleaf manzanita, snowbrush (*Ceanothus velutinus* Hook.), and Sierra plum (*Prunus subcordata* Benth.). After site preparation, greenleaf manzanita and snowbrush invaded mostly from dormant seeds in the soil and Sierra plum originated vegetatively from belowground structures. In addition to the planted ponderosa pines, a few herbaceous species from seeds in the soil or from seeds that blew in on the wind became established. Earlier work from 1961 to 1965 had left a wide range of shrub densities, and when the study began in 1966, these were separated into four shrub categories: no-shrub, light, medium, and heavy shrubs with values of about 5,000, 10,000, and 15,000 plants/acre separating the categories.

Results

Plant Community Relationships

The post-site preparation plant community on average or better sites in northern and central California is characterized by rapid colonization of species having several regeneration strategies. Hardwoods and shrubs from root crowns, shrubs and forbs from dormant seeds in the soil, and forbs and grasses from seeds that are wind-blown comprise the categories of species from the most common strategies. A few shrubs and ferns also develop from belowground structures, such as rhizomes and root sprouts. Together, the various species of vegetation gain in abundance and grow rapidly. In general, species that arise from root crowns or rhizomes dominate. But many early seral species become established during the first few years after site preparation. Their populations can be huge and, at least for a year or two, temporarily exclude nearly all other species. Bull thistle (*Cirsium vulgare* [Savi] Ten.) is a good example. Its peak density in a new plantation on a good site in the northern Sierra Nevada of California was 34,000 plants/acre at age 2 (McDonald and Tappeiner 1986). Two years later, its density had fallen to just over 3,400 plants/acre.

Based on 17 studies with 10 years of data, the average number of natural species (not planted seedlings or non-native species) per study area, by vegetation category, were conifers, 1; hardwoods, 1; shrubs, 8; forbs, 12; graminoids, 3; and ferns 0. Thus the mean number of species after 10 years was 25. The range was 13 to 46 species per study. In eight studies, the number of species increased over that present one year after site preparation, in eight studies the number of species decreased, and in one study the number remained the same. However, for studies with a species gain, the increase was 38 percent; for those with a decline, the decrease was 12 percent.

In six study areas, we recorded number of species by treatment. Average number of species after 10 years was chemical (Velpar), 13; manual release, 22; grazing, 22; and control 20.

For those study areas where the various categories of vegetation were present, average density in the controls ranged from 2,604 ceanothus plants/acre to 82,250 forbs/acre (table 1). And values after 10 years showed that density had increased from 19 to several hundred percent over initial values. Foliar cover values, which ranged from 2 to 38 percent, also had huge increases after 10 years except for forbs, which had declined by 93 percent. Average height also showed large increases over the 10-year period.

For results among treatments, data (including that for planted ponderosa pine) for all treatments after 10 years, are reported for three typical study areas having different plant compositions. In a community composed primarily of

Table 1—Average density, foliar cover, and height of vegetation in the control, northern California, 10 years after treatment.

	Density			Foliar cover			Height		
Category	Mean	Pct[1]	Range	Mean	Pct[1]	Range	Mean	Pct[1]	Range
		plants/acre			*pct*			*ft*	
Manzanita[2]	14,495	+19	933–60,267	26	+H[3]	1–62	4.1	+H	1.8–7.2
Ceanothus[2]	2,604	+20	900–4,933	16	+H	3–56	4.4	+H	1.5–11.5
Combined shrubs[2]	24,608	+H	950–118,300	38	+H	1–71	3.9	+H	1.1–9.5
Graminoids[2]	64,172	+H	3,333–184,000	3	+H	T[5]–8	1.8	+H	0.5–3.7
Forbs[2]	82,250	+H	27,300–137,200	2	–93	0	1.2	+92	0.6–1.8

[1]Percent change between initial value at beginning of study and value in table.
[2]Number of study areas with manzanita was 12; ceanothus 7; combined shrubs 13; graminoids 8; forbs 2.
[3]+H = more than three-fold increase.
[4]Trace.

mixed shrubs, average density over all treatments ranged from 902 to 18,168 plants/acre. Foliar cover ranged from 40 to 73 percent (McDonald and Fiddler 1995). If the community was composed primarily of mixed shrubs and grass, similar values were 147,400 to 254,900 plants/acre and 32 to 75 percent foliar cover (McDonald and others 1996). If the community was made up of shrubs, forbs, grass, and ferns, its density over all treatments after 10 years ranged from 182,345 to 223,500 plants/acre and its foliar cover from 65 to 71 percent (McDonald and Fiddler 1997).

The density and development of the various categories of vegetation in a young conifer plantation is a function of the release treatment, and the survival and growth of the conifer seedlings in the plantation is a function of the kind, amount, and timing of the vegetation with which they compete. Thus the response of the various categories of vegetation and the planted pines to treatment is interrelated. In general, manual release, if applied two times as grubbing, discriminates against shrubs from dormant seeds in the soil and leads to a community of forbs and grasses. Here the planted conifers grow well. If release is chain-sawing shrubs and hardwoods, the plant community is little affected unless the shrub stubs are treated with a selective herbicide. If the release treatment is grazing or mechanical (large machines), the plant community is not significantly affected, and the conifer seedlings develop according to the degree of competition present. Mulches of various kinds and sizes of material, if large enough and present long enough, obviously stifle invasion and lead to competition-free conifer seedling growth. Because most foliar herbicides are selective, the ensuing community can be manipulated as desired. In general, the plant community after treatment consists of what is originally there minus most plants from the most competitive species.

Timing of treatment is critical. Release the first year after planting is most effective, but done in the next 2 years is worthwhile (McDonald and Fiddler 1993). Early release allows the pines and firs to continue the growth trajectory established in the nursery without interruption, which in turn enables them to capture site resources in an accelerating manner. Interruption of the growth trajectory by competing vegetation often means death of the seedling or unacceptable development.

In only one study was a nonnative species noted. It was yellow star-thistle (*Centaurea solstitialis* L.), probably brought into the area on a hunter's pickup. Although it persevered for 10 years, it had peaked in density and foliar cover, and was declining at the end of the study (table 2).

Revegetation of new plantations is best described as chaotic. Not only do plants originate from all five classical regeneration strategies that Grime (1979) described; past stand history, and the type of treatment that we employed also influence them. Many species, a huge variety in density and development, and every conceivable distribution pattern for every species characterized the vegetation. However, plant succession 10 years after site preparation and release seems to have a few common threads. In general, plant species that develop the most roots and the deepest root systems are the ones that dominate. Replacement of annuals and biennials by perennials is another trend.

Competition relationships also are numerous and the subject of other papers. However, one fact stands out, and that is that release is not an option—it is essential. Competing vegetation is well adapted to the plantation environment—perhaps better adapted than the nursery-grown conifer seedlings. Study after study has shown that the conifer seedlings must be released if they are to grow at the potential of the site (McDonald and Fiddler 1993).

Shrub Development Comparison

Early survival and development of deerbrush and greenleaf manzanita clearly favored deerbrush although there were both similarities and differences (McDonald and others 1998). As to similarities, deerbrush and manzanita both sustained moderate early mortality (17 versus 11 percent, respectively) and almost no subsequent mortality, developed multiple stems on most plants (5.6 versus 3.6 stems per plant, respectively), maintained the initial proportion of plants with multiple stems (89 versus 76 percent), and grew rapidly. For differences between species, deerbrush showed the most dynamic development. Its strategy was to develop a clump of stems on most plants during the first growing season; manzanita had a similar strategy, but it did not become manifest until the second season. By the end of the second growing season, deerbrush produced significantly more stems per plant, was taller, and had wider crowns than greenleaf manzanita (table 3). Deerbrush also began producing flowers and setting seed during the third growing season, while greenleaf manzanita did not produce flowers or seed during the 4-year study.

Long-Term Plant Succession

When this study began in 1966, the natural plant community in all density classes consisted of 6 shrubs, 10 forbs, and

Table 2—Density, foliar cover, and height of yellow star-thistle on 15 milacre plots in one study in the northern Sierra Nevada, 1983–1992

Year	Density		Foliar cover		Height	
	Mean	Range	Mean	Range	Mean	Range
	plants/acre		*pct*		*ft*	
1983	438	0–2,250	1	T[1]–7	1.5	0.6–2.3
1988	10,138	250–30,250	4	T–12	1.9	0.9–3.0
1992	1,850	0–7,125	T	T	1.6	1.3–2.1

[1]T = trace.

Table 3—Mean height and crown width of 62 deerbrush and 67 greenleaf manzanita plants, Mt. Shasta, California, 1992–1995.

Item	Year	Species	Mean	Root mean square error	F[1]	P[1]
				inches		
Height						
	1992	Deerbrush	5.5	3.99	0.81	0.370
		Manzanita	4.9			
	1993	Deerbrush	18.8	9.52	15.73	0.001
		Manzanita	12.3			
	1994	Deerbrush	32.1	12.26	39.97	0.001
		Manzanita	18.6			
	1995	Deerbrush	40.4	13.88	41.21	0.001
		Manzanita	24.9			
Crown						
	1992	Deerbrush	5.6	3.24	4.29	0.040
		Manzanita	4.3			
	1993	Deerbrush	29.4	11.85	80.20	0.001
		Manzanita	10.9			
	1994	Deerbrush	42.9	12.37	125.70	0.001
		Manzanita	18.8			
	1995	Deerbrush	51.5	12.79	120.45	0.001
		Manzanita	27.0			

[1]Statistical terms: F denotes the F ratio; P is the probability of a greater effect than measured.

1 grass (McDonald and Abbott 1997). When the study ended in 1992 the community consisted of five shrubs, two forbs, and one grass. However, two shrubs, both forbs and the grass consisted of only a few plants in the entire study area. Thus the plant community before intervention by silviculturists consisted of essentially 3 shrub species, increased to 17 species plus planted ponderosa pines after site preparation and release, and after 27 years was back to the original 3 shrubs plus the planted pines.

Discussion and Conclusions

Silviculturists traditionally apply a controlled disturbance to a forest ecosystem to create a desired species composition, number of plants, and stand structure that will yield the amenities and commodities needed by society. Inherent in this disturbance is a goal to guide the course and rate of secondary plant succession toward a mature forest. This goal is accomplished by enhancing the environment for desired species and making it less suitable for undesirable species. Eliminating or reducing the number of species is not a goal, but reducing the number of plants of the most competitive species is.

We found that colonization of plant species after site preparation is rapid and dynamic. Many plants of many species from all major categories quickly invade and occupy the area. During the first 10 years, 13 to 46 species were present. Number of species increased in some study areas and decreased in others. Composition of the typical natural plant community after 10 years was 1 conifer, 1 hardwood, 8 shrubs, 12 forbs, and 3 graminoids. Except in the Velpar treatment, species composition did not differ markedly among treatments, including the control. Although the number of plants differed greatly among treatments, the number of species did not.

For the Velpar treatment, the decrease in number of species was mostly in the shrub category, although all vegetation categories showed reductions. On our study sites, Velpar persists in the surface soil for about 3 years—a timespan that allowed the conifer seedlings to grow rapidly in a virtually competition-free environment. After 3 years, the surface 4 to 6 inches of soil is free of Velpar and species of forbs and annual grasses with shallow root systems can become established. Taproot-developing shrubs from dormant seeds in the soil still cannot become establish, however. By the time that deeper-rooted species are free to establish, the shade and capture of site resources limit the survival and growth by the conifer seedlings.

Not only is the number of species quite large, so is the number of plants. Data from the three typical, but different, plant communities, showed densities that ranged from 902 to 254,900 plants/acre and foliar cover values that ranged from 32 to 75 percent after 10 years.

The density and development data for the non-native yellow star thistle portrayed the resilience of the native plant community to it. After 10 years, this serious invasion was being contained, and although density and height values on some plots were still high, they were declining. And horizontal development, as manifest in foliar cover, was reduced to only a trace. Given enough time and the lack of further disturbance, forested ecosystems tend to be remarkably resilient.

The comparison of deerbrush and greenleaf manzanita was an attempt to answer the question: “Which is the more competitive species?” However, two shrub species having similar dates of origin and growing side-by-side, are almost impossible to find in nature. Thus, we grew and outplanted the deerbrush and greenleaf manzanita seedlings to facilitate the comparison.

At least for the first 4 years and based solely on plant size (as opposed to soil moisture and nutrient use), deerbrush was the most competitive species. More stems per clump mean a wider clump, and this, plus being taller, allows occupation of a larger area sooner than rival greenleaf manzanita. And by being able to produce seed soon after disturbance enables at least some new plants to occupy favorable microsites that would quickly become occupied by other vegetation, especially on good sites.

The progression from 3 to 17 and then back to 3 species in the long-term plant succession study cuts to the very heart of vegetation management. Purely in terms of number of species, the time and labor of converting the brushfield into a plantation seems questionable. But, although the number of species is small, one huge difference in the most successful (no shrub) treatment has been achieved—a traditional arborescent pioneer, ponderosa pine, has been established by vegetation management, and 30 years later is growing at the potential of the site. Establishing trees is the critical first step. Eventually, shade-tolerant conifers also will become established (or be planted) and form the mixed-conifer forest that originally occupied the area. Certainly more species of plants and animals will find the forest environment more conducive to establishment than if the area had remained a brushfield. And because the stand-destroying frequency of fire in a forest is lower than that in a brushfield, the chance of a debilitating fire has lessened.

Vegetation management can direct trends in early plant development and species succession, and through various treatments achieve specific combinations of species desired by the ecosystem manager. Our extensive study in northern and central California is providing insight to the density and development of many species and categories of vegetation in conifer plantations that have been released in many ways. The extensive database and the relationships so formed should be helpful to managers who are attempting to restore ecosystems on disturbed forestland.

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