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Recovery of a Bearclover (*Chamaebatia foliolosa*) Plant Community after Site Preparation and Planting of Ponderosa Pine Seedlings

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Bearclover inhabits thousands of acres of forest land in northern and central California, but little quantification of its recovery after timber harvest, site preparation, and planting is available. And the species composition and development of the ensuing plant community is largely unknown. Density, foliar cover, and height of planted ponderosa pine seedlings, bearclover, whiteleaf manzanita, forbs, and grasses were documented from 1986 through 1996 in northern California. After 11 growing seasons, bearclover and planted ponderosa pines were dominating, whiteleaf manzanita was increasing, grasses were still numerous, and the forbs had come and gone. A total of 12 plant species were present at the beginning and end of the study, although 20 species were found during the study period. Elongation of bearclover rhizomes took place for 2 years after site preparation and then abruptly ceased.

Retrieval Terms: bearclover, plant community, ponderosa pine seedlings, recovery, species development, vegetation management.

Introduction

Bearclover (*Chamaebatia foliolosa* Benth),[1,2] Rosaceae, is a perennial evergreen shrub, endemic to northern and central California, that is prevalent on south- and west-facing slopes at elevations between 1,000 and 6,000 feet in the Sierra Nevada of California, and to a lesser extent on lower slopes in the southern Cascade Range. With the exception of isolated stands near Burney in Shasta County, near Greenville in Plumas County, and in Kern County in southern California, most stands of this shrub are located between Yuba and Tulare Counties in the Sierra Nevada. The stands occupy areas that range from small patches to hundreds of acres. The species excels in partial shade, particularly in that cast by an overstory of scattered ponderosa pines (*Pinus ponderosa* Dougl. ex Laws. var. *ponderosa*)[1,2] and incense-cedars (*Libocedrus decurrens* Torr.), and it grows well in sunlit environments. Bearclover persists in shade, but has thinner crowns and taller stems in this setting. Although less common on north and east exposures, bearclover is capable of occupying almost all aspects, site qualities, and soil types within its natural range.[3]

Bearclover produces heavily scented, glandular, and fern-like foliage on short flexible stems that arise from below-ground structures. Large numbers of stems (up to 104 per square foot)[4] and rapid growth (6 to 8 inches the first year) combine to make bearclover a very competitive species. The root system contributes even more toward the species' competitiveness. It consists of an extensive network of roots and rhizomes 4 to 16 inches below the soil surface and taproots that often extend to depths of 6 feet or more.[5] Lateral extension of rhizomes from mature plants in undisturbed areas is reported in general as slow[5,6] and fairly rapid after burning.[7] But whether slow or rapid, extension over time is impressive. One rhizome in a previous study was traced for a distance of almost 90 feet.[4]

Together, the above- and below-ground plant parts portray the mechanism of competition in bearclover.[8,9] In the spring, the roots efficiently gather moisture and the plant uses it to attain a maximum amount of photosynthesis and early growth. In midsummer, when soil moisture is low, bearclover plants endure high internal moisture stress, reduced photosynthesis, and low growth rates. But they survive. The strategy of maximizing early growth, using all available soil moisture, and then withstanding the environmental stress of summer and fall, denies soil moisture to competing plants and helps to ensure their absence.

Bearclover's competitiveness probably is enhanced by additional mechanisms: fine roots are nodulated and may be active nitrogen fixers, the species reproduces from seed, and visual evidence of allelopathy has been noted.[5]

Heisey and others[10] found direct evidence of nitrogen fixation on nodulated bearclover plants in an area with little organic matter on the soil surface because of an intense forest fire a decade earlier. No nodulation was found in an undisturbed area nearby that had a deep organic layer. They noted that nodulation was uncommon on nonleguminous plants, especially among the Rosaceae (which includes bearclover). Furthermore, in cross-section, the nodules were strikingly similar to those of snowbrush (*Ceanothus velutinus* Hook., family Rhamnaceae)[11] and in a later study[12] to deerbrush (*Ceanothus integerrimus* Hook. & Arn.)—two common associates of bearclover.

Foresters first began studying bearclover in California in 1911.[4] Early studies detailed the capability of the species to recover rapidly from disturbance and quantified its ability to restrict the establishment of both natural and planted conifer seedlings. Indeed, survival of planted conifer seedlings often is less than 20 percent. In addition to erosion control, beneficial attributes of bearclover include browse for deer,[13,14] and use as a medicine by Native-Americans.[15]

This note reports the diversity, density, and development of bearclover, planted ponderosa pines, whiteleaf manzanita, forbs, and grasses from the time of mostly bare ground after site preparation through the next 11 years.

Methods

The study area was located about 16 airline miles north of the small town of Pioneer in Amador County, California. Elevation is about 4,000 feet, and aspect is northeast with 20 percent slopes. Annual precipitation is about 40 inches with 60 percent falling as snow. The soil is of the Cohasset Series and is deep, reddish, and moderately well drained. Surface texture is loam, grading to clay loam below 20 inches. This environment is considered above average for growing ponderosa pines. Before timber harvest, the forest consisted of scattered trees and clumps of trees, which were mostly ponderosa pine and incense-cedar. An almost continuous cover of mature bearclover that was 15- to 18-inches tall and of scattered larger whiteleaf manzanita (*Arctostaphylos viscida* C. Parry) was present beneath the trees. In fall 1985, after timber harvest, the site was prepared for planting by piling slash and remaining vegetation with a brushrake-equipped bulldozer. During the two operations (harvesting and site preparation), the tractor crushed, scraped, and severed the bearclover at groundline. It sprouted the following spring.

The three plots in this study were randomly chosen and located throughout a 5-acre relatively homogeneous area. Each encompassed about 0.15 acre and contained 25 to 30 ponderosa pine seedlings. The pine seedlings, from seed gathered in the appropriate seed zone, were grown for 1 year in the Placerville Nursery and out-planted in March 1986 at a 10- by 10-foot spacing. This was the equivalent of 436 seedlings per acre. For them, density was fixed at their spacing, and height was averaged over the number of surviving seedlings in the plot. All vegetation was sampled annually for the first five growing seasons and again at 11 years after planting.

All natural vegetation was measured and remeasured at the end of the growing season on five randomly selected, seedling-centered, square milacre subplots in each plot. Each milacre contained 0.001 acre or 43.56 ft^2. Stem density, stem height, and foliar cover were quantified for several species and categories of vegetation. More specifically, density was the number of stems per species or category, counted on each milacre, and presented on a per-acre basis. Foliar cover, recorded for ponderosa pine seedlings and other vegetation, was estimated to the nearest square foot and also recorded as a per-acre value. If less than 0.5 square foot, foliar cover was denoted as a trace (T). Height was calculated as the average of the three tallest stems per species or category in the milacre subplots.

To study rhizome elongation, two 10-foot long permanent transects with 11 evenly spaced metal pins were installed in a randomly selected, site-prepared area within the study area in fall 1986. Both transects were located in the middle

Table 1—*Natural vegetation in study plots, Amador Ranger District, 1986-1996.*

Species	1986	1987	1988	1989	1990	1996
Trees						
Libocedrus decurrens	-	-	-	-	X	X
Shrubs						
Arctostaphylos viscida	X	X	X	X	X	X
Ceanothus integerrimus	X	X	X	X	X	X
Chamaebatia foliolosa	X	X	X	X	X	X
Ribes roezlii	X	X	X	X	X	X
Chrysothamnus spp.	-	-	-	-	X	X
Forbs						
Cirsium vulgare	X	X	X	X	X	-
Dichelostemma congestum	-	-	-	X	X	-
Fritillaria spp.	X	-	-	-	-	-
Galium bolanderi	X	X	X	X	X	X
Lotus purshianus	-	X	-	-	-	-
Madia qracilis	-	X	X	X	X	-
Montia parvifolia	X	-	-	-	-	-
Polygala cornuta	X	X	X	X	X	X
Vicia americana	X	X	X	X	X	X
Viola purpurea	X	X	X	X	X	X
Grasses						
Achnatherum spp.	-	-	-	-	X	X
Bromus diandrus	-	-	-	-	X	-
Bromus tectorum	X	X	X	X	X	X
Vulpia bromoides	-	-	-	X	X	X
Total	**12**	**12**	**11**	**13**	**17**	**13**

of an area of bare ground with a patch of bearclover at least 3 feet away. On one transect, the bearclover grew uphill toward the transect; on the other, downhill. The slope was about 12 percent in both instances. No vegetation or roots of vegetation other than bearclover was present, and no trace of bearclover stems was noted in the bare area. After each growing season, a pin was placed on the bearclover stem nearest the corresponding metal pin on the transect. The 11 distances from transect pin to the pin on the bearclover were averaged each season to arrive at the amount of annual rhizome elongation.

Results

Plant Diversity

Twenty naturally-established plant species were found on study plots during the 1986 to 1996 period and ranged from 11 to 17 species in a given year (*table 1*). Their number was primarily governed by the high density and foliar cover of the bearclover. When the study began, no tree seedlings, four shrubs, seven forbs, and one grass were present; when it ended, one tree seedling, five shrubs, four forbs and three grasses were present.

Ponderosa Pine

Planted ponderosa pine seedlings also were affected by the bearclover. Survival at the end of the study was 69 percent. Mortality was recorded from 1987 through 1996 with more seedlings dying in 1989, 1990, and 1996 than in other years. Competition/suppression was the primary cause of death. Foliar cover ranged from a trace in 1986 to 12,193 ft^2 per acre in 1996, and height averaged 0.52 foot at the beginning of the study and 16.67 feet at the end of the study (*table 2*).

Table 2—*Average density, foliar cover, and height with standard errors (SE) of pine, bearclover, whiteleaf manzanita, forbs, and grasses, Amador Ranger District, 1986-1996.*

Year	Density	SE	Cover	SE	Height	SE
	stems/acre		ft^2/acre		ft	
Ponderosa Pine						
1986	-	-	T[1]	-	0.52	0.03
1987	-	-	467	176	0.96	0.09
1988	-	-	1,067	333	1.73	0.29
1989	-	-	2,200	902	2.68	0.58
1990	-	-	3,667	1,568	4.03	0.93
1996	-	-	12,193	139	16.67	0.29
Bearclover						
1986	152,200	38,504	8,667	1,288	0.59	0.03
1987	200,330	24,420	11,867	1,462	0.66	0.04
1988	224,533	24,195	17,067	2,293	0.75	0.02
1989	190,667	16,170	22,067	546	0.83	0.02
1990	152,333	32,119	24,867	1,110	0.82	0.05
1996	117,200	21,803	15,700	5,701	1.44	0.08
Whiteleaf Manzanita						
1986	600	305	T	T	0.24	0.03
1987	867	92	T	T	0.34	0.01
1988	800	231	67	67	0.49	0.01
1989	1,067	67	200	36	0.85	0.41
1990	1,067	67	467	177	1.30	0.01
1996	1,100	100	2,200	1,800	4.25	0.04
Forbs						
1986	-	-	-	-	-	-
1987	867	553	400	231	0.71	0.40
1988	2,067	1,157	800	416	1.00	0.50
1989	1,667	1,182	600	305	1.25	0.60
1990	7,333	481	467	240	1.60	0.20
1996	-	-	-	-	-	-
Grasses						
1986	-	-	-	-	-	-
1987	133	133	T	T	0.76	0.17
1988	2,699	1,858	67	67	0.90	0.06
1989	133	90	67	67	2.60	0.76
1990	438,400	73,302	2,400	305	1.30	0.42
1996	37,600	25,204	600	600	1.88	1.21

[1]T=trace

Table 3—*Average bearclover rhizome elongation along an uphill and downhill transect, with standard errors (SE), Amador Ranger District, 1987-1989.*

Year	Uphill		Downhill	
	Mean	SE	Mean	SE
	inches			
1987	6.82	1.87	4.60	1.41
1988	22.27	3.96	5.00	0.81
1989	0.64	0.30	0.00	-
Total	**29.73**		**9.60**	

Bearclover

Bearclover was checked for sprout or seedling status by gently pulling on the stems. All appeared to be connected below ground, which indicated vegetative reproduction. Although vigorously searched for, no seedlings were found. The initial density, foliar cover, and height values for bearclover (152,200 stems per acre, 8,667 ft^2 per acre, and 0.59 foot) reflect this species strong resurgence soon after disturbance (*table 2*). Mean bearclover density peaked in 1988 with 224,533 stems per acre; foliar cover was best in 1990 at 24,867 ft^2 per acre, and height peaked in 1996 at 1.44 feet. At the end of the study, both average density (117,200 stems per acre) and foliar cover (15,700 ft^2 per acre) had decreased from peak values.

After three successive growing seasons, bearclover rhizome extension, as denoted by above-ground stems, was 29.7 inches if growing uphill and 9.6 inches if extending downhill (*table 3*). Growth was best the second year and virtually nonexistent the third growing season. During the fourth season, tiny new bearclover plants appeared within the bare area. Pulling on them revealed that they originated from deep in the soil, apparently from structures deeper than the rhizomes whose elongation we were quantifying. The transect part of the study ended at this point.

Whiteleaf Manzanita

In this study, manzanita can best be characterized as starting weak and finishing strong. It was almost nonexistent at the beginning of the study with only 600 plants per acre, a trace of foliar cover, and a mean height of 0.24 foot (*table 2*). By the end of the study, however, average density had increased to 1,100 plants per acre, foliar cover to 2,200 ft^2 per acre, and height to 4.25 feet.

Forbs

The most common forbs, present throughout the study period, were *Galium bolanderi* A. Gray, *Polygola cornuta* Kellogg, and *Vicia americana* Willd. Although present in 1986, these and other forbs were few, poorly distributed, and consequently not quantified. In 1987, average forb density was 867 plants per acre, foliar cover was 400 ft^2 per acre, and height was 0.71 foot (*table 2*). In 1990, forb density had increased to 7,333 plants per acre, foliar cover to 467 ft^2 per acre, and height to 1.6 feet. Because few forbs were present in 1996, they were not quantified.

Grasses

Like the forbs, grasses were few and poorly distributed and not measured in 1986. In 1987 they numbered 133 per acre, had only a trace of foliar cover, and were 0.17 foot tall (*table 2*). In 1990, the grass population exploded. Average density of the three plots was 438,400 plants per acre, foliar cover was 2,400 ft^2 per acre, and height was 1.3 feet. By the end of the study in 1996, density had decreased to 37,600 plants per acre, and foliar cover to 600 ft^2 per acre, but height had increased to almost 1.9 feet.

Discussion

The diversity, density, foliar cover, and height values of the various species and categories of species in this study portray the dynamic nature of this plant community and provide an idea of its future composition. The many adaptations of bearclover, especially its reproductive mode, enabled it to dominate early and to maintain this status for at least the first 5 years of the study. However, by the end of the study 6 years later, the planted ponderosa pines were impacting the bearclover, particularly its foliar cover. Normal development would have been for bearclover cover to increase during the entire study period, not decrease as it did in 1996. Thus, by the end of the study, the community was dominated by both ponderosa pine and bearclover.

As components of the plant community, the other species/categories contributed less during the study. Whiteleaf manzanita was able to begin, increase, and develop well in an environment of extremely strong competition. The grasses were enigmatic. Their presence, especially in terms of density, was slight for the first 4 years, then high, and then modest at the end of the study. That the grasses became very dense the fifth growing season meant that they had to do so in an atmosphere of strong and rapidly increasing competition. The trend of increasing density and development of whiteleaf manzanita, and the low early density, peak, and decline of the grasses also was noted in a previous study in the central Sierra Nevada.[16] The forbs were the most ephemeral of the species/categories in this study, but they too had some success (7,333 plants per acre) in 1990 or during the fifth growing season.

Cheatgrass (*Bromus tectorum* L.) comprised most of the grass population and was the species that exploded in 1990. Where it came from is a mystery. It was not abundant in the surrounding forest, and how it could become abundant quickly is unknown.

Based on the density and development of the various species/categories in this study, the composition of the plant community in the near future can be postulated. Certainly, the main constituents will be ponderosa pine and bearclover, with whiteleaf manzanita a lesser component. The forbs will be few and consist of those species that can persist in a shady, competitive environment. The contribution of the grasses in the near future is more difficult to estimate, but it is likely that some also will persist in small openings in the bearclover or under the pines.

McDonald and Everest[17] studied the planted ponderosa pine/bearclover/cheatgass interaction on a similar site on the same USDA Forest Service district. Results were somewhat similar. Cheatgrass was not present the first year, invaded the second year, and exhibited a high density the fourth year (130,300 plants per acre), which was the last year of the study. Also after 4 years, bearclover averaged 282,000 stems per acre, a foliar cover of 27,400 ft^2 per acre or 63 percent, and 1.2 feet of height.

That bearclover rhizomes elongated for 2 years after disturbance, developed very little the third year, and then occupied new territory from deep underground structures the fourth year, adds to the confusion on when, where, and how bearclover spreads over the landscape. Numerous observers have noted the remarkable lack of mature bearclover extension into treated areas, the propensity of bearclover to sprout in the centers of disturbed areas,[18] the lack of extension of rhizomes from disturbed areas into undisturbed areas, and the sporadic nature of rooting from nodes of extending rhizomes. Plainly, much more study is needed.

Extensive literature and numerous observations denote the propensity of bearclover to produce abundant flowers almost every year. But how much sound seed is produced by these flowers, and how many plants originate from this seed is not addressed in the literature. In any case, the proportion of reproductive tissue in bearclover is very low, with only 0.4 percent of above-ground biomass allocated to flowers and fruits.[7] This supports the finding that sprouting from underground rhizomes is the primary reproductive mode. Nevertheless, it is likely that the seed serves the species well. Where bearclover is present, vegetative propagation keeps the species in place; where bearclover is absent, the seed allows it to potentially colonize new areas. Of course, disseminators such as birds, rodents, and perhaps other animals are necessary.

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