A PRELIMINARY INVESTIGATION ON THE FEASIBILITY OF PREHARVEST PRESCRIBED BURNING FOR SHRUB CONTROL

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ABSTRACT

Historically, fire was a natural component in ponderosa pine (*Pinus ponderosa*)-mixed conifer ecosystems in the Sierra Nevada of California. Wildfires may have reduced the number of shrub seeds in the soil, as well as the density of mature shrubs and young hardwoods, thereby allowing conifers to reinvade a site after disturbance, and grow with reduced competition. With fire suppression activities beginning around the turn of the century, seed populations in the soils of the forest floor, and densities of resprouting shrubs, have increased and created a serious reforestation problem after harvest. In 1983, a study was initiated to examine the feasibility of prescribed preharvest burning as a method of shrub control. Four burn treatments of varying seasonal and fuel consumption levels were tested. Shrub mortality rates higher than 80 percent were observed in high consumption burns. The late spring burns appeared to have the most impact as it relates to killing resprouting shrubs. This season corresponds to the time in which the shrubs are actively growing and, presumably are more susceptible to damage by fire. Densities of shrub seedlings that germinated following the prescribed

burns were as high as 275,000 per acre.

INTRODUCTION

Natural fires were a dominant influence on ponderosa pine-mixed conifer ecosystems. Virtually all plants present in these ecosystems have developed adaptations to survive under a regime of recurrent fires. Throughout the Sierra Nevada, historical evidence indicates that fire occurred on the average of every eight years with many areas having a fire return interval as low as two years (Biswell 1967).

Fire influenced the structure of ponderosa pine ecosystems, just as strong winds with high salt contents influence the composition and morphology of coastal forests, or high water tables determine the structure of riparian ecosystems. The major difference in ponderosa pine ecosystems is that man has drastically reduced this factor through fire exclusion policies. These fire exclusion policies were adopted with hardly any research or knowledge that they would be a wise decision (Biswell 1972). Fire suppression resulted in the removal of one of the most important environmental factors that had functioned over the centuries to maintain the balance and stability of this kind of forest (Biswell 1972). Potential changes due to fire suppression include increases in the fire hazard, increases in soil seed population of shrubs, and increases in resprouting shrubs. In chaparral ecosystems, Keeley (1977) stated that fire suppression (i.e. a long fire return interval) has resulted in decreased densities of resprouting shrubs. However, in forested ecosystems it can be hypothesized that resprouting species have increased in density due to fire suppression. Resprouting species such as tanoak (Lithocarpus densiflorus) have a greater capacity to reproduce by seeds as compared to chaparral species. Therefore, fire suppression may result in increased densities of both obligate seeding and resprouting shrubs. Fire suppression has also resulted in increases in densities of shade tolerant species. This dense undergrowth has increased the fire hazard of the communities, decreased growth of the overstory dominants (Barrett 1973), decreased the aesthetics and recreational values of those areas, and created severe problems for logging and conifer regeneration.

Natural fire may have been a mechanism through which competing vegetation was reduced enough to allow for conifer regeneration and enhanced growth (Martin 1982). Possibly, the frequent surface fires reduced the shrub seed populations and lowered the density and vigor of resprouting shrub species. Prescribed burning in the understory of conifer dominated communities can be used to simulate the actions of natural fires (van Wagtendonk 1974). Increased knowledge of the fire ecology and adaptations of conifers and competing vegetation to fire, may enable managers to successfully utilize fire as a silvicultural tool. These adaptations include thick bark on ponderosa pine, the necessity of fire or some other scarification mechanism for shrub seed germination, and the resprouting capacity of some shrub species after fire.

Unfortunately, there are many misconceptions and gaps in knowledge concerning the relationships of many plant species to fire. This is particularly evident for resprouting species. Shrub responses to fire have only been reported in such qualitative terms as a "vigorous resprouter" or a "nonsprouter". The literature is lacking on information concerning the influences of various seasons in which a burn was implemented, as well as the consumption and intensity level of the prescribed fires. The additional influence of an overstory canopy which could affect the vigor, growth and resprouting capacity of shrubs is also unknown.

Current methods of controlling competing vegetation generally have one or more drawbacks. This includes a lack of knowledge of the ecological processes of a forest stand which ultimately may produce unsatisfactory results. Environmental risks, personal safety risks, increased erosion, damage to conifer seedlings, high or prohibitive costs, and political sensitivity are also problems encountered today. Land managers are becoming increasingly aware that people and their politics are important ecological and sociological components of any wildland system (Biswell 1972). Many of these important considerations could possibly be alleviated or minimized by prescribed burning, either alone or in combination with other methods. This would be a method of managing for successful conifer regeneration by imitating the effects of natural fires in forested ecosystems.

In 1983, a study was initiated to examine the effects of prescribed-preharvest burns, conducted at various seasons and levels of consumption, on the resprouting and shrub seed composition. The objective of the study was to collect preliminary baseline data for the determination of the feasibility of utilizing prescribed preharvest burning as a tool for brush control after harvest.

RATIONALE

Few studies have quantitatively examined the effects of understory burning on the shrub component of conifer dominated communities (Biswell et al. 1955, Martin 1982). These studies indicated that prescribed burning could be successfully utilized to kill or reduce the vigor of mature shrubs, deplete the amount of seed in the soil, and prepare a better seedbed for pine regeneration.

One of the advantages of preharvest/prescribed burning is the multiple stress factors operating against the resprouting shrubs or shrub seedlings, as compared to post harvest shrub control methods. Because they are influenced by the presence of mature conifers, they may be subject to stress factors not present in open, harvested sites. Two important stress factors include decreased light for photosynthetic activity, and decreased soil water availability. At the Challenge Experimental Forest, predawn water potentials were significantly lower for tanoak in the forest understory compared to those growing in open sites (Kauffman unpublished). In these same communities, photosynthetically active radiation (incident photon flux density, 400-700 nm) reaching the forest floor was only 5 percent of that in an adjacent clearcut. Therefore, it is hypothesized that forest managers could make optimum use of the stress factors associated with one or more fires before harvest; the environmental limitations to growth in the understory; and, the additive effects of browsing by wildlife and livestock to increase the mortality of shrub species.

Shrub seeds have been found to have distinct germination requirements for growth. Optimum ranges for scarification of deerbrush (Ceanothus integerrimus) seeds have been found to occur in the range of 75-100°C (Kauffman unpublished). Temperatures of 120°C result in a high mortality and low germination success of these seeds. The purpose of prescribed preharvest burning would be to kill as many of the seeds in the duff and soils as possible, and stimualte the rest to germinate. A major question posed by Martin (1982) was whether two or even three fires can kill enough seeds to significantly reduce the number of shrub seedlings. The objective of preharvest burning would not be to necessarily eliminate the shrubs from a site but to reduce their negative effects on tree regeneration and growth during the early part of the rotation.

METHODS

Three study areas were located in ponderosa pine-mixed conifer stands of the northern Sierra Nevada of California. These locations were at the Blodgett Forest Research Station, the Massak Unit of the Quincy Ranger District, Plumas National Forest, and the Challenge Experimental Forest on the La Porte Range District, Plumas National Forest. Hereafter, these sites shall be referred to as the Blodgett, Quincy and

Challenge sites, respectively.

Blodgett Forest is located approximately 15 miles (24 km) east of Georgetown, California, on the west slope of the Sierra Nevada. Elevation is approximately 4300 ft (1300 m). The study site is located in a very productive stand dominated by white fir (*Abies concolor*), ponderosa pine, incense cedar (*Calocedrus decurrens*), and Douglas fir (*Pseudotsuga menziesii*). Topography is nearly level with slopes of one to twelve percent.

The Challenge experimental units are located 2.5 miles (4.0 km) southeast of Challenge, California. Elevation is approximately 3300 ft. (1005 m). Overstory vegetation layers of this productive site are dominated by ponderosa pine, Douglas fir, and sugar pine (*Pinus lambertiana*). Aspects of all blocks are generally west, with slopes ranging from 35-50 percent.

The Quincy experimental units are located 10 miles (16 km) east of Quincy, California. Elevation is approximately 4400 ft (1351 meters). Study locations are located in less productive stands dominated by ponderosa pine and Douglas fir. Site index productivity classes (Dunning 1933) are classified as Site III-IV as compared to site I-II for the Blodgett and Challenge units. Half of the prescribed burn treatments are on south slopes and half are located on north slopes. The slopes range in steepness from 35 to 75 percent.

At each location, five blocks containing four burn treatments and a control (no burn) were established. Burn treatments include an early spring/moderate consumption burn, a late spring/high consumption burn, an early fall/high consumption burn, and a late fall/moderate consumption burn. Each treatment in each block was at least 79 x 79 ft. (24 x 24 m) in size.

The fall prescribed burns were conducted from mid-September to mid-October, 1983. Spring burns were conducted from April to June, 1984.

Fall high consumption burns were conducted before a significant winter precipitation event had occurred. The lower duff moisture (O1 horizon or fermentation layer) was less than 20 percent moisture content. Cessation of above ground shrub growth had occurred by this time. Moderate consumption burns in autumn were conducted one to two weeks after significant precipitation had occurred. Mean moisture content of the lower duff ranged from 43 percent at Challenge, to 77 percent at Blodgett. Leaf abscission by the deciduous shrubs was occurring at the time of these burns. Spring moderate consumption burns were conducted as early in the season as was possible. Lower duff moistures were variable at this season of the year, ranging from 26 percent at Quincy to 134 percent at Blodgett. These burns were conducted prior to the active growing season of the shrub species. Spring high consumption burns were conducted late in the active prescribed burning season. Duff moistures at this time ranged from 19 to 52 percent. These burns correspond to the active leaf and stem growth period of the shrub species.

General prescription criteria for all burns followed guidelines for a reasonably safe burn. These included understory wind speeds of less than seven miles per hour, relative humidities greater than 15 percent, and temperatures in the 50-75^{o}F (10-24^{o}C) range.

Fuel loads were measured before and after burning by planar intersect (Brown 1974). Four permanent fuel transects were established in each treatment, in each block. Duff depth was measured at 45 permanent sampling points distributed throughout the burn unit.

Densities of all woody plant species were estimated by counting the number of individuals in 15 permanent nested microplots in each treatment unit. Results are from microplots that are one and two meter^2 in size. All conifers less than 6.6 ft (2 m) in height, and all shrubs, were identified by species and measured during the growing season prior to burning, and the following growing season after burning. Differences in mean densities of species before and after burning were tested using a Wilcoxen matched-pairs signed-rank test. Significance levels unless otherwise specified, were at $P \leq 0.10$.

Prior to burning, randomly selected shrubs were tagged and mapped. At the end of the growing season following the prescribed burns, the percentage of shrubs that were top killed, the percent that resprouted, and the percent that were completely killed, were measured. In blocks with a high shrub density, 35 to 50 shrubs were randomly selected and tagged. In areas of lower shrub densities all individuals were tagged. Shrub species selected include white leaf manzanita (Arctostaphylos viscida), green leaf manzanita (A. patula), deerbrush ceanothus, tanoak, whitethorn ceanothus (C. cordulatus), black oak (Quercus kellogii), Sierra chinquapin (Castinopsis sempervirens) and Sierra goosecurrant (Ribes roezlii). Standard analysis of variance, and Student-Newman-Keul's test were used to test for differences in shrub mortality following the different burn treatments.

RESULTS AND DISCUSSION

Fuel Consumption

The mean total fuel loads for Challenge and Blodgett were 66.5 tons/acre (149MT/ha) and 63.8 tons/acre (143 MT/ha), respectively. Fuel loads for Quincy were much lower with means of 38.8 tons/acre (87 MT/ha). On all sites, the litter and duff component accounted for 62-84 percent of the total fuel load.

Generally, the greatest amount of fuels were consumed during the high consumption burns (late spring and early fall) (fig. 1). When comparing all treatments, the total amount consumed varied by season, prescription, and site characteristics. The unique characteristics of each site were a tremendous influence on consumption. For example, the site with the highest fuel consumption during the early spring/moderate burns was the Quincy site. This can be explained by the open nature of the stands which allowed them to dry out earlier and hence, greater fuel available for consumption. Even though the Blodgett site was the last study area burned during the early spring burning period, consumption

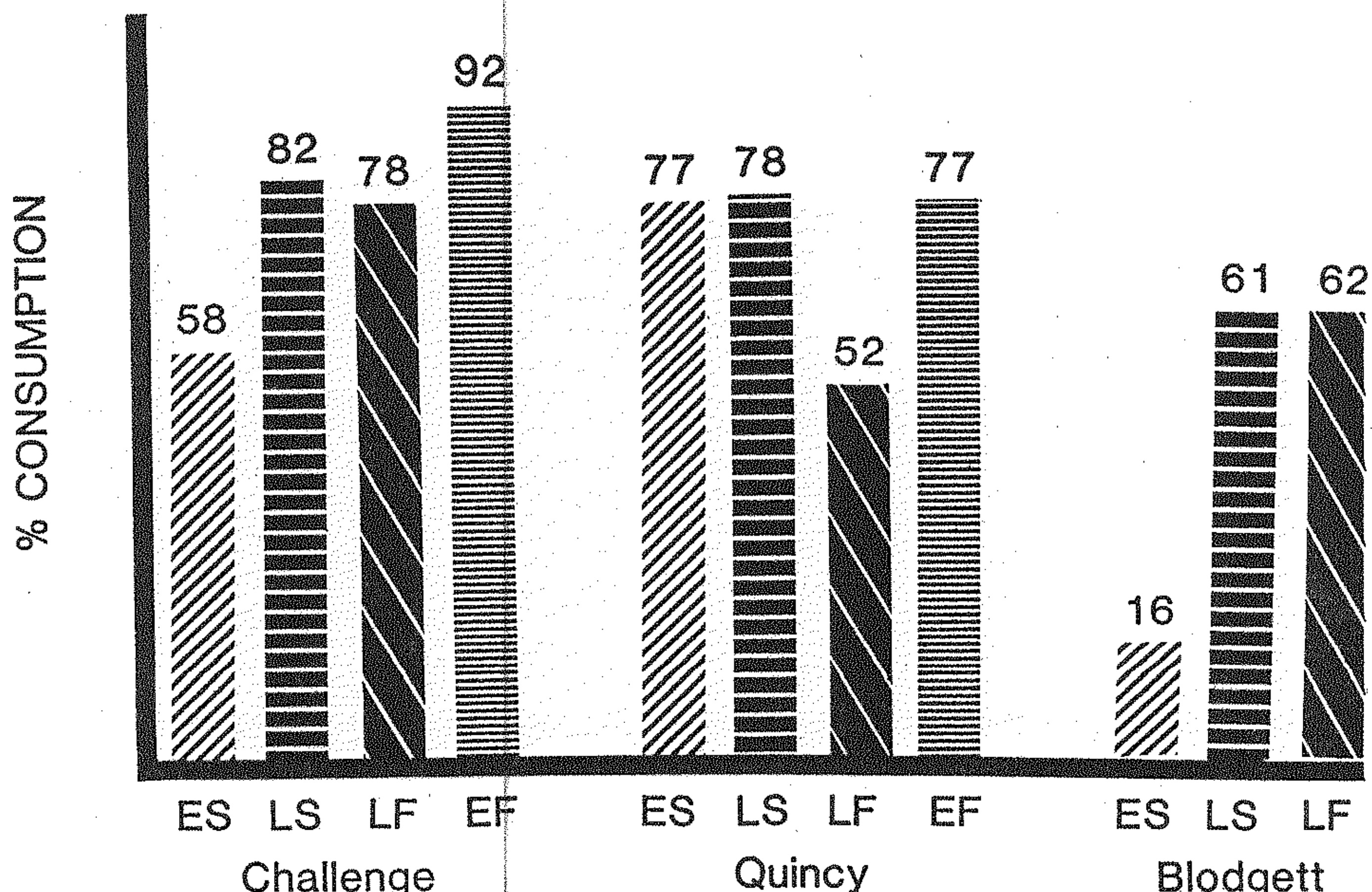

Figure 1.— The percent of total dead and downed fuels that were consumed on experimental burn units during fall, 1983 or spring, 1984 prescribed burns. ES=early spring/moderate consumption burns, LS=late spring/high consumption burns, LF=late fall/moderate consumption burns and EF=early fall/high consumption burns.

was lowest. The dense canopy, nearly level slopes, and higher elevation contributed to the higher moisture conditions later into the season for this site. Fuel moisture contents were higher well into the burning season as Blodgett also had the lowest fuel consumption during the late spring/high consumption burns.

Consumption of 1000 hour time lag fuels was not significantly different among fall prescribed burns. Consumption of heavy fuels ranged from 78 to 83 percent. In contrast, consumption of heavy fuels during spring burns ranged from 0 to 47 percent. Regardless of consumption level, the spring season burns were apparently conducted before downed logs were sufficiently dry enough for a significant amount of consumption to occur.

The duff/litter component is assumed to be the most important element of the total fuel load with respect to affecting the shrub seed populations and resprouting shrubs. Site and prescription differences were apparent when comparing amounts consumed (fig. 2). Generally, the highest percentages of the duff component consumed was at the Challenge unit. In addition to moisture contents, fuel particle composition could also be a factor in explaining differences in consumption. Duff particle composition was predominantly ponderosa pine needles at Challenge, and a mixture of pine, cedar, and fir needles at Blodgett. The increased flammability of pine needles due to lower packing ratios and lower surface to volume ratios may be another factor in accounting for the higher consumption. At the Quincy site, duff composition was

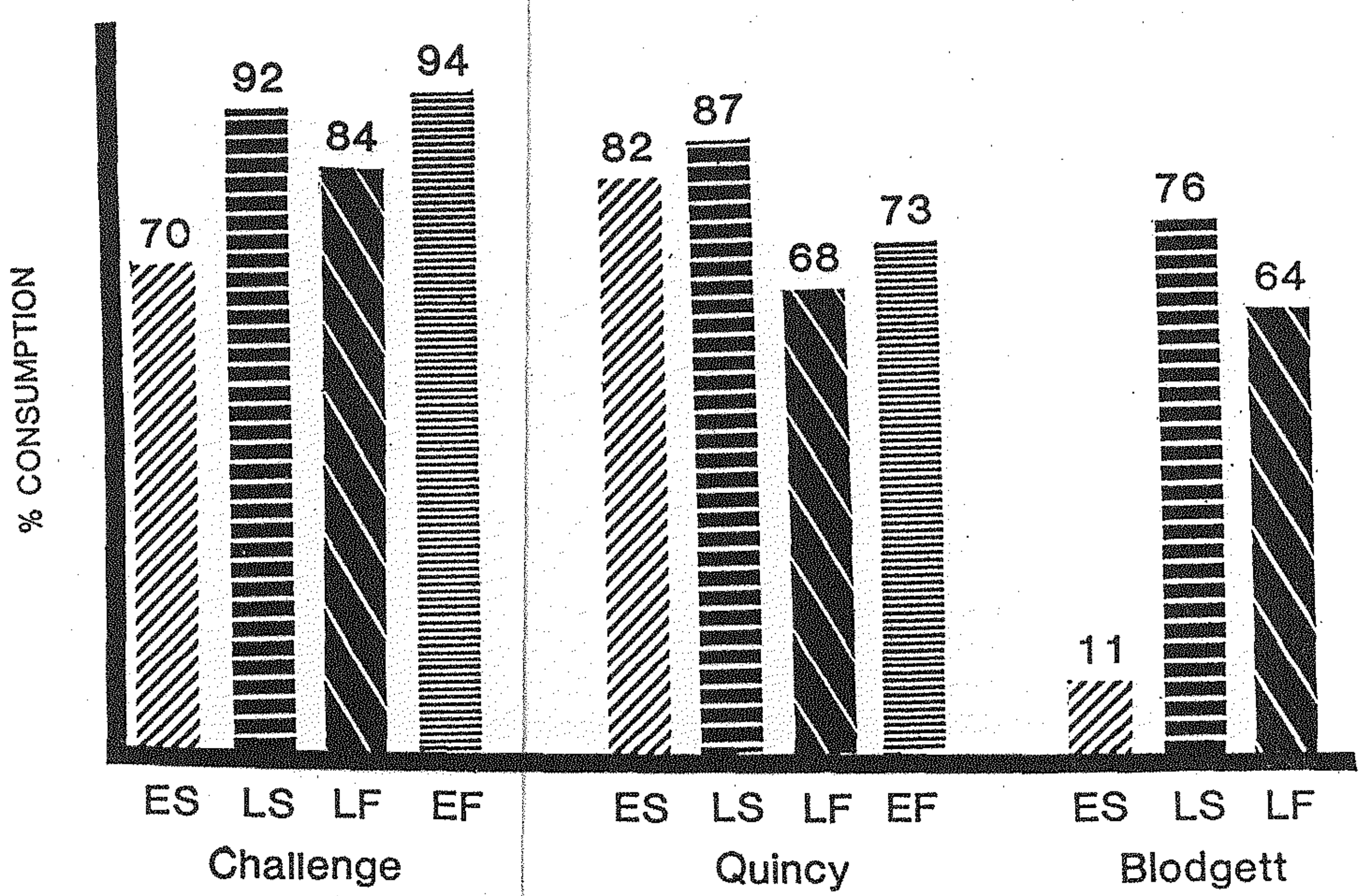

Figure 2.-- The percent consumption of the duff layers (O horizons) on experimental burn units that were burned during the fall, 1983 or the spring 1984. ES=early spring/moderate consumption, LS=late spring/high consumption, LF=late fall/moderate consumption, and EF=early fall/ high comsumption burns.

predominantly that of ponderosa pine needles. The lowered duff consumption as compared to Challenge, may be partially explained by the lower fuel loads and related effects on preheating fuels and fire spread which could lower the total amount of fuels available for consumption.

Shrub Seedling Density

No shrub seedlings were present in any plots burned under spring prescription (Table 1). This can be partially explained by laboratory data describing the germination requirements of shrub seeds (Kauffman unpublished). In order for seeds of deerbrush and manzanita to germinate, it has been found that they require a scarification treatment (heat) followed by a stratification treatment (cool, overwintering period). Though seeds in the soils have potentially experienced hundreds of overwintering periods, it appears that they cannot germinate until the physiological requirements of one over winter (stratification) period, after burning, are met. It is expected that seedlings will appear in 1985 in plots that were burned under a spring prescription in 1984. Similar observations were made by Biswell (1972) where areas burned before April 1, generally produced shrub seedlings the same year, and areas burned after April did not contain seedlings until the following year.

Shrub seedling species composition varied for all sites. At the Blodgett site, predominant seedlings present in late fall/moderate burns were white-thorn ceanothus with 6290 seedlings per acre (15,545/ha), and greenleaf manzanita with 1551 seedlings per acre (3834/ha). Similar to

Table 1. -- Density of selected shrub and conifer species (numbers/ha) before and after burning (1983-1984).

LOCATION/SPECIES	BURN TREATMENT: EARLY SPRING Before	EARLY SPRING After	LATE SPRING Before	LATE SPRING After	EARLY FALL Before	EARLY FALL After	LATE FALL Before	LATE FALL After
CHALLENGE								
Tanoak	2,801	1,400**	1,934	167**	1,234	233*	1,934	600*
Incense Cedar	3,834	100**	4,934	0**	2,000	0**	1,734	0**
Bear Clover	2,267	1,567	10,669	3,867*	11,136	4,901*	42,175	32,706*
Deerbrush-S[1]	0	0	0	0	0	215,977**	0	264,486**
QUINCY								
Black Oak	367	300	467	133	889	389*	633	233**
Incense Cedar	2,367	233**	2,534	67**	4,557	56**	2901	333**
Squaw Carpet-S	0	0	0	0	0	10,530**	0	2,000**
Deerbrush-S	0	0	0	0	0	17,893**	0	1,534**
BLODGETT								
Black Oak	700	467	434	334	-	-	334	42*
Incense Cedar	22,371	567**	19,367	67**	-	-	1,750	0**
Bear Clover	14,003	14,069	8,967	967**	-	-	18,504	6,335*
Pine Rose	70,270	78,004	7,467	9,601	-	-	55,503	58,003
Whitethorn Ceanothus-S	0	0	33	0	-	-	0	15,545*

* $P \leq 0.10$
** $P \leq 0.05$

[1] S = seedlings

all sites, most seedlings were observed to have originated either at the duff/mineral soil interface or just below the mineral soil surface.

At the Quincy site, a mean of 13,031 seedlings per acre (32,220/ha) was found in early fall/high consumption burn sites, and 1861 seedlings per acre (4601/ha) were found in late fall/moderate consumption sites. Deerbrush and squaw carpet (Ceanothus prostratus) were the most abundant seedlings present. Deerbrush seedling densities were 7241 seedlings per acre (17,893/ha) in early fall/high consumption burns and 621 seedlings per acre in (1534/ha) in late fall/moderate burns. Squaw carpet had mean densities of 4261 seedlings per acre (10,530/ha) and 809 seedlings per acre (2000/ha) in early/fall/high and late fall/moderate consumption burns, respectively (Table 1). Other shrub seedlings encountered in the composition include sierra goosecurrant, green-leaf manzanita, and white-leaf manzanita.

High densities of shrub seedlings were present in the fall prescription treatments of the Challenge site. Deerbrush was the most abundant shrub species with sierra goosecurrant and white-leaf manzanita seedlings also present in the composition. In some areas, densities were as high as 275,192 seedlings per acre (680,000/ha). Mean density of deerbrush was 87,404 seedlings per acre (215,977/ha) in early fall/high, and 107,036 seedlings per acre (264,486/ha) in late/fall moderate consumption burns (Table 1). It is interesting that deerbrush seedlings were in greater abundance in the moderate consumption treatment. In both of these fall burn treatments, duff consumption was relatively high

(94 percent in the early fall/high and 84 percent in the late fall/moderate burn units, fig. 2). With the higher consumption of duff in the early fall/high consumption burns, it can be presumed that a greater amount of heat was produced and transferred into the duff and upper mineral soil. Possibly, enough of the total soil seed population was killed by high temperatures in the high consumption burns to reflect this decreased abundance of seedlings.

Effects on Conifers and Mature Shrubs

Densities of conifer seedlings and saplings less than 7 ft in height decreased significantly after burning at all prescription levels, at all sites. Prior to burning, incense cedar was the most abundant conifer seedling present at all sites with densities as high as 8900 per acre, (22,000/ha) (Table 1). The significant decline in density of incense cedar reflects the extreme susceptibility of this shade-tolerant species to fire-induced mortality. In many locations where mortality of incense cedar approached 100 percent, more fire resistant conifer seedlings and saplings suffered lower mortalities. After burning, many treatment blocks had in excess of 500 living ponderosa pine, Douglas fir and sugar pine saplings (1 to 3 inch dbh) per acre. No conifers greater than 6 inches dbh were killed by fire at any prescription level.

Mortality of shrubs in the composition varied by season of burn, prescribed consumption level, site differences, and specific characteristics of each particular species. In general, the greatest mortality of shrubs was during the high consumption burns regardless of season

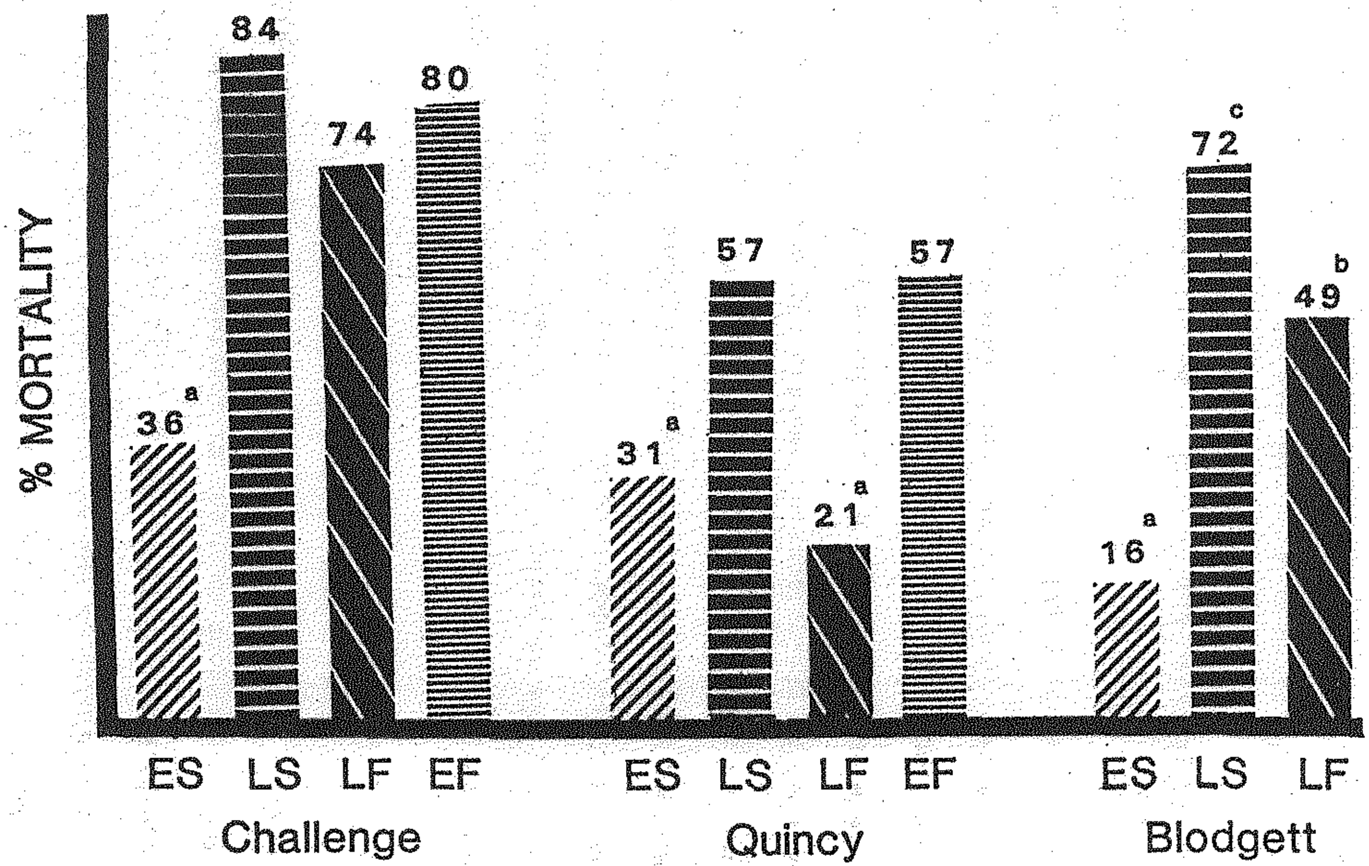

Figure 3.— The percent mortality of shrubs in experimental units that were prescribed burned in the fall, 1983 or the spring, 1984. ES=early spring/moderate, LS=late spring/high, LF=late fall/moderate and EF=early fall high consumption burns. Superscripted letters indicate a significant difference in mortality between treatments.

(fig. 3).

Two interrelated variables which need further examination are the consumption level and season of burn. There were distinct differences in seasonal mortalities as they relate to shrub phenology, however, they are confounded by the different consumption levels. It appeared that shrubs were most resistant to fire-caused mortality during the early spring burns. At this season, treatment burns were lower in duff consumption, and subsequently, lower heat loads were present. However, during this season, shrub phenology can not be discounted as an important factor. The spring burns at the Quincy units are a good example. Duff consumption during the early spring/moderate burns was not significantly different from the late spring/high consumption burns (82 and 87 percent, respectively) (fig. 2). However, total shrub mortality was significantly different in the late spring/high burns as compared to the early spring/moderate burns (57 versus 31 percent) (fig. 3).

In shrubs, stored carbohydrates have been found in the roots, crowns, old growth stems, and twigs just below developing buds (Boo and Pettit 1975, Garrison 1971). Fires which topkill the shrubs, would limit reserve carbohydrate "sources" for regrowth to underground organs. Therefore, fires would be expected to have the most negative effects on shrub species from late spring, to the middle of the growing season when carbohydrate storage in the roots would be lower, and the products of photosynthesis, being utilized for growth, would be destroyed. Late in the season and during dormancy, a high percentage of carbohydrates would be present in below ground plant parts (i.e. areas not as easily affected by lower consumption burns).

It is apparent that when fire is the agent utilized for brush control, the consumption level as well as shrub phenology is an important factor contributing to mortality. Though shrubs can be assumed to be in a more resistant phenological condition during the fall burns, more fuels are available for consumption, therefore more destructive heat can be generated around the meristematic tissue associated with the root crowns. This factor may partially explain the high mortality of shrubs during the fall prescribed burns, particularly the early fall/high consumption burns (fig. 3).

Bear clover (Chamaebatia foliolosa), another problem species in forest regeneration, is of particular interest as it was observed to have the capacity to resprout from meristematic tissues located on basal crowns and from root tissues well below the soil surface. This species occurred in densities as high as 7488 stems per acre (18,504/ha) at the Blodgett site, and in densities as high as 17,068 stems per acre (42,175/ha) at the Challenge site (table 1). Bear clover was not present at the Quincy site. At both the Challenge and Blodgett sites, significant decreases in densities were measured in all treatment prescriptions with the exception of the early spring/moderate consumption burns. Late spring/high consumption prescriptions appeared to be the most effective treatment in decreasing bear clover densities with reduction of 89 and 64 percent at the Blodgett and Challenge sites, respectively.

Not all shrub species were found to have negative responses to fire. Pine rose (*Rosa pinetorium*) actually increased in density after fire at the Blodgett site (Table 1). However these increases were not significant.

CONCLUSION & MANAGEMENT IMPLICATIONS

Utilization of prescribed-preharvest burning in the understory of mature conifers as a method of controlling competing vegetation after timber harvest would probably necessitate two or possibly three burns before harvest. Results presented here are the effects of one prescribed burn.

The first burn may be strictly to "condition" the stand for additional burn treatments. Under an idealized management scheme, a preliminary burn, of lower consumption may be necessary, particularly where high hazards associated with heavy fuel loads and/or a continuous vertical arrangement of fuels are present. This low to moderate consumption burn would lower the probability of damage by future burns by "conditioning" the forest stand (e.g. reducing the probability of crown and bole damage by lowering fuel loads, and breaking up the vertical continuity of the fuel structure). The second burn could then be prescribed to consume as much duff as possible. A third burn might be necessary to kill shrub seedlings and to kill more mature resprouting shrubs. This may include another underburn or a slashburn following timber harvest. Following this fire management scheme, minimal damage to the mature conifers and wood products would occur, and the desired objectives of the prescribed burns could be achieved.

With respect to resprouting shrubs, the first burns would topkill most of the individuals present and many would be totally killed. As compared to open environments (harvested areas) these resprouting shrubs would be growing in an environment of increased stress due to the presence of the overstory conifer canopy. The subsequent burns may possibly kill a greater percentage of remaining shrubs than the first burns due to this increased stress condition. Prescribing and implementing the second burn as soon as is possibly feasible after the first burn, may be most effective in reducing resprouting shrub density. Hedrick (1951) and Zedler et al. (1983) found shrub mortality was greater when areas were burned during consecutive years and that mortality decreased as the burn interval periods increased.

A similar effect on the shrub seed population may occur due to repeated understory burns. The first burns may kill many seeds in the soil and stimulate others to germinate. These germinants would also be exposed to the same stress factors associated with surviving under the conifer canopy. The subsequent prescribed fire(s) would kill the germinants, kill additional seeds in the duff and soil, and stimulate others to germinate.

The greatest costs associated with a fire/brush management plan such as this would be incurred during the first prescribed burn.

Subsequent burns would utilize the same fire lines, and would take fewer people to implement and patrol the fires. Therefore, costs for subsequent burns should be lower at the planning, preparation, actual conduction, and follow up steps of the management plan.

Other positive effects are also realized by prescribed underburning, which could possibly offset some of the costs. These would include no post-harvest brush shrub control measures, increased ease and efficiency in logging and a short-term improvement of livestock and/or big game forage supplies. The seedlings and resprouts could provide a ~~nutritious forage supply for these animals. The browsing activities~~ would also place additional stresses on the shrub resprouts and seedlings. Finally, the fuel loading of the stand would be greatly reduced, thereby lessoning potential losses of valuable timber from loss by wildfire.

It will not be possible to evaluate the efficacy of this brush control method until after timber harvest, but preliminary results are encouraging. These prescribed burns demonstrate that high percentages of competing resprouting shrubs such as tanoak can be killed before timber harvest. In addition, it is apparent that the shrub seed population has been affected by these burn treatments. Results beneficial for silvicultural practices are particularly evident when high percentages of the duff component are consumed. This prescribed burning plan serves to control competing vegetation in a manner that is similar to the natural ecology and fire history of the forests prior to European man's arrival.

Further studies to evaluate the effects of a second burn are planned. Additional follow up research evaluating both the positive and negative effects of this silvicultural treatment are needed. Results from this study and future studies may solve many of the problems associated with prescribed preharvest understory burning, and may eventually provide a safe technique for brush control that is both effective and acceptable to the general public.

LITERATURE CITED

Barrett, J. W. 1973. Latest results from the Pringle Falls ponderosa pine spacing study. USDA For. Ser. Res. Notes PNW299. 22 p.

Biswell, H.H. 1967. Forest fire in perspective. In: Proceedings, 6th Annual Tall Timbers Fire Ecology Conference. Tall Timbers Research Station, Tallahassee, FL. p. 43-64.

Biswell, H.H. 1972. Fire ecology in ponderosa pine-grassland. In: Proceedings, 12th Annual Tall Timbers Fire Ecology Conference Tall ~~Timbers Research Station, Tallahassee, FL. p. 69-96.~~

Biswell, H.H., A.M. Schultz, and J.L. Launchbaugh. 1955. Brush control in ponderosa pine. Cal. Agric. 9:3-14.

Boo, R.M. and R.D. Pettit. 1975. Carbohydrate reserves in roots of sand shin-oak in west Texas. J. Range Manage. 28:469-472.

Brown, J.K. 1974. Handbook for inventorying downed woody material. USDA For. Serv. Gen. Tech. Rep. INT-16. Intermt. For. and Range. Exp. Sta., Ogden, Utah. 24p.

Dunning, D. and L.H. Reineke. 1933. Preliminary yield tables for second growth stands in the California pine region. U.S.D.A. Forest Service. Tech. Bull. No. 354. 23 p.

Garrison, G.A. 1972. Carbohydrate reserves and response to use. In: Wildland Shrubs-Their Biology and Utilization. USDA-Forest Service.

Gen. Tech. Rep. INT-1. pp. 271-278.

Hedrick, D.W. 1951. Studies on succession and manipulation of chamise brushlands in California. Ph.D. Dissertation. Texas A&M University College. Sta., TX

Keeley, J.E. 1972. Fire dependent reproductive strategies in Artostaphylos and Ceanothus. In: Mooney H.A. and C.E. Conrad (Tech Eds.). Proceedings of the Symposium on the Environmental Consequences of Fire And Fuel Management in Mediterranean Ecosystems. U.S.D.A. For Serv. Gen. Tech. Rep. WO-3. Palo Alto California. pp 391-397.

Martin, R.E. 1982. Shrub control by burning before timber harvest. In: Baumgartner, D.M. (Ed.), Site Preparation and Fuels Management of Steep Terrain. Wash. State Univ. Coop. Ext. Pullman. pp 36-40.

van Wagtendonk, J.W. 1974. Refined burning prescriptions for Yosemite National Park. U.S.D.I. - NPS Occasional pap. No. 2. 21 p.

Zedler, R.H., G.R. Bautier, and G.S. McMaster. 1983. Vegetation change in response to extreme events: The effect of a short interval between fires in California chaparral and coastal scrub. Ecology 64:809-818.