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Vegetation Responses Following Three Management Strategies in a Giant Sequoia Forest on Mountain Home Demonstration State Forest

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Background

Giant sequoia *(Sequoiadendron giganteum)* occurs within scattered groves in the Sierra Nevada from Placer to Tulare County (Willard 1994). Giant sequoia rarely occurs in pure stands but is almost always associated with other tree species in the mixed conifer forest. Groves are managed by various public land management agencies and private owners using various management strategies. Information on vegetation responses to disturbances in giant sequoia forests is important for land managers making management decisions for individual groves.

Adequate natural regeneration of giant sequoia may be dependent on forest disturbances. Established forest stands that have been protected from natural and human caused disturbances generally exhibit a shaded forest floor covered with a thick layer of organic debris. Hartesveldt (1975) reported that these conditions do not provide the optimum environment for seed germination and seedling survival.

Disturbances in giant sequoia stands that alter the forest floor can be either natural or human caused. Natural processes include wildfire, landslides, avalanches, windthrow, insect attacks, disease, and animal activity while human caused disturbances would include logging, prescribed fire, road building and other construction activities.

In many groves, there is a lack of young giant sequoia in the understory (Hardesveldt 1975) (Rundel 1971). Regeneration that does occur in these stands consists mainly of the more shade tolerant species, particularly white fir. Giant sequoia groves that have had a recent history of disturbance, such as fire or logging, are found to contain at least some young giant sequoia (Schlobohm 1986).

Objective

The objective of this study was to measure vegetational changes within a giant sequoia grove managed using various strategies. The three management strategies undertaken in this study included:

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A) preservation and protection from fire and human-caused disturbances, B) selective timber harvesting of non-sequoia species, and C) prescribed burning. The vegetative elements studied included the overstory forest, understory forest, tree seedlings, brush species and other minor vegetation.

Setting

The study plots were located in a mixed-conifer, giant sequoia forest within Mountain Home Demonstration State Forest, Tulare County. Tree species on the plots included giant sequoia, sugar pine *(Pinus lambertiana)*, and white fir *(Abies concolor)*. Average elevation of the plots is 6,800 feet.

Soils are of the Dome Series, a moderately deep timber soil with granitic parent material. Timber site is rated as a Dunnings Site I. Aspect is southerly.

At the time of plot establishment, the timber stand could have been classified as an old-growth forest. No logging had ever taken place within the stands and fire had been excluded for at least 60 years.

Plot Establishment

In 1966, two plots, each five acres in size, were selected for the study. The plots measured 330 feet by 660 feet. The goal in the selection of the plots was to find suitable sized areas with vegetation attributes as nearly alike as possible. Emphasis was placed on similarities in numbers of giant sequoia trees, total giant sequoia basal area, numbers of merchantable sized sugar pine and white fir, site quality, degree and exposure of slopes, quantities of pole-sized reproduction, brush species present, soils, and amount of exposed rock. Buffer zones were provided between plots to reduce external effects.

All trees larger than 11 inches in diameter at breast height (dbh), were measured for diameter to the nearest 1/10 inch, assigned a number, and tagged. To ensure consistency, subsequent diameter measurements were taken at the tag location. Pole sized trees, 5 to 11 inches in diameter, were tallied by species. Also, conifer reproduction, brush species, and minor vegetation were sampled using 100 four milacre subplots, arranged in two strips through each plot.

Management strategy "A", preservation and protection from fire and human caused disturbances, was applied to Plot 1 from 1966 until 1984. Management strategy "C", prescribed burning, was practiced in Plot 1 when it was control burned in the summer of 1985. Measurements were taken on Plot 1 in 1966, 1971, 1976, 1981, 1986, 1990, and 1994.

Management strategy "B", selective timber harvesting of non-sequoia species, was applied to Plot 2. The plot was selectively logged in 1968 and has had no other management activity since. Measurements were taken in 1966, 1968, 1971, 1976, 1981, 1986, 1990, and 1994.

Table 1 on the following page illustrates the timber stand on both plots at the time of plot establishment in 1966.

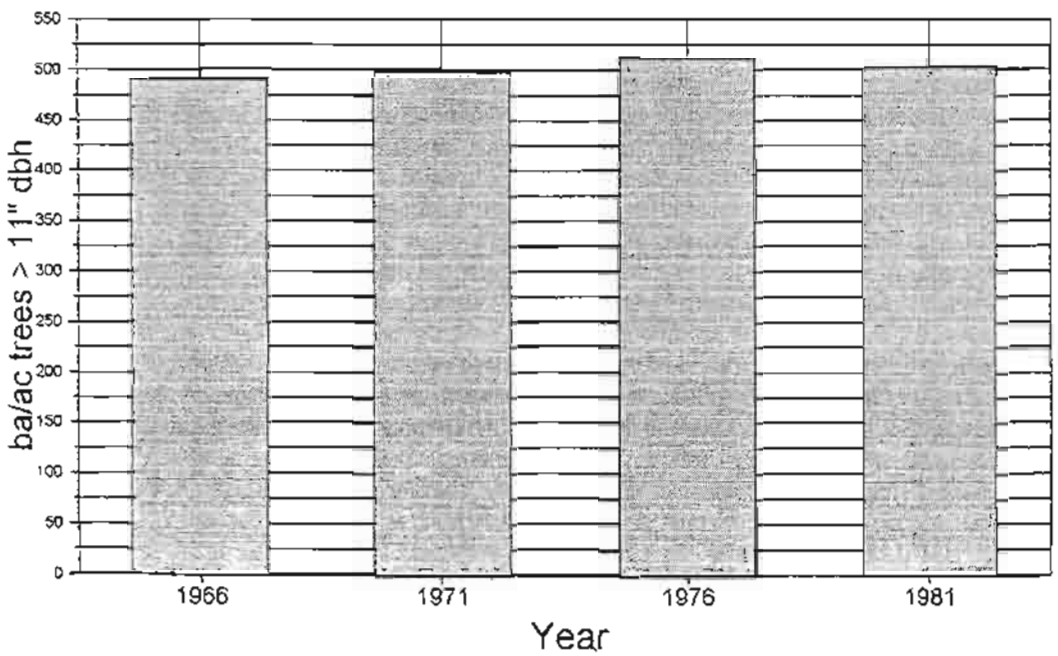
Plot 1				
	GS	SP	WF	TOTAL
# Trees/Acre	10	6	39	55
BA/Acre	296	52	143	491
Avg DBH (trees 11"+)	60	36	24	32
Plot 2				
	GS	SP	WF	TOTAL
# Trees/Acre	4	9	31	44
BA/Acre	299	72	130	502
Avg DBH (trees 11"+)	105	36	25	35

Table 1

Management Strategy "A" - Preservation and Protection from Fire and Human-Caused Disturbances

Plot 1 was evaluated from 1966 to 1984 with no disturbances introduced into the stand. Basal area per acre throughout the measurement period for all trees 11 inches and greater in dbh is shown in Figure 1.

Figure 1: Plot 1 Basal Area Per Acre - All Species

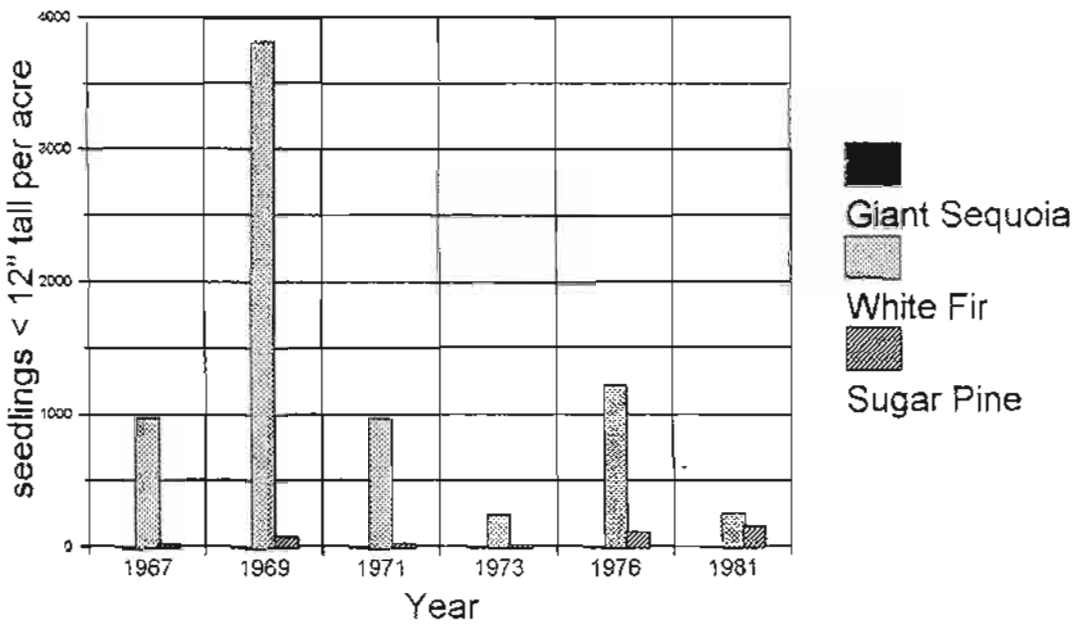


Total stand basal area remained very stable during the protection period from 1966 to 1984.[2] Small fluctuations in basal area were the result of residual stand growth, ingrowth, and mortality. The stability of basal area indicates that the stand had reached a fully stocked condition and would not substantially exceed the average for the measurement period. Stand growth was being offset by mortality over time.

Duff layers on the plot averaged 3.2 inches in depth and crown closure averaged 47% percent.

The number of tree seedlings per acre, one year old to 12 inches in height, is shown by species in Figure 2. No giant sequoia seedlings were found during the measurement period although sugar pine and white fir regeneration occurred in every measurement year. Highest seedling occurrence followed good seed crop years. The seedlings tallied each measurement year were almost all one year old indicating that there was very little survival of white fir or sugar pine seedlings from one year to the next.

Figure 2: Plot 1 Seedlings Per Acre



The most common understory plant found in Plot 1, having an average of over 600 plants per acre, was wintergreen (*Pirola picta*). Significant other vegetation with densities greater than 100 plants per acre, listed in order of predominance, included: Draperia (*Draperia systyla*), Phacelia (*Phacelia mutabilis*), whitethorn (*Ceanothus cordulatus*), bracken fern (*Pteridium aquilinum*), and Sierra gooseberry (*Ribes roezlii*). Thirty other plant species were recorded on Plot 1, with each plant having a density of less than 100 plants per acre. Very little change in understory vegetation occurred during the measurement period.

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[2]The last measurement year for the protection period, which ended in 1984, was 1981.

Management Strategy "B" - Selective Timber Harvesting of Non-Sequoia Species

Plot 2 was evaluated from 1966 to 1994. The plot was selectively logged in the summer of 1968 and the slash was burned in the fall of the same year. The objectives of the harvest were to remove a portion of the overstory and disturb enough soil to provide a seedbed for natural regeneration while providing protection for the residual stand. No tree planting, vegetation control, or other cultural activities were performed on the plot after slash burning was completed.

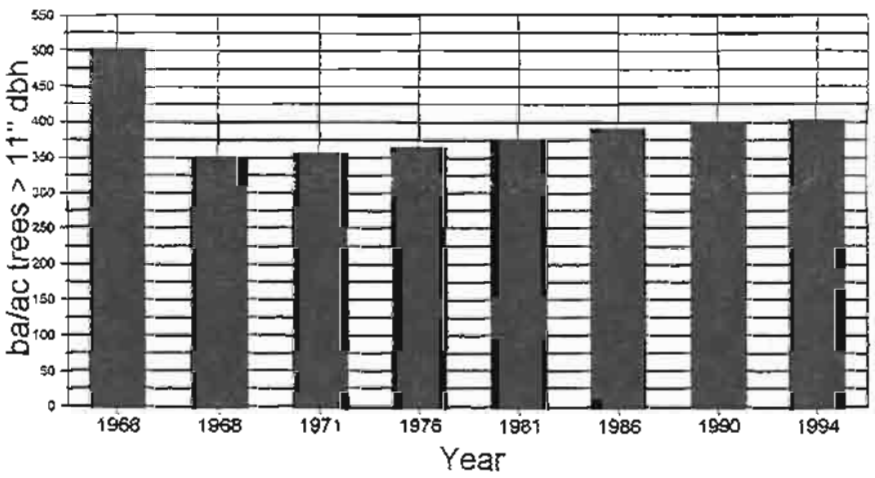
Logging was accomplished by the use of track laying ground skidding equipment. All timber to be felled and skid trail locations were designated prior to the start of harvesting operations. The entire project was supervised by State Forest staff.

An average of 20 trees per acre were removed during the harvesting operation. An average volume of 52,000 board feet per acre was harvested with white fir comprising approximately two-thirds of the volume removed and sugar pine representing the remainder.

Damage to the residual stand was less than normal considering the timber's large size and the relatively high volume removed per acre. Four trees per acre, greater than 11 inches in dbh, were damaged to an extent that they required removal. Damage to poles and saplings in the stand was more extensive. An average of 6 trees per acre 5 to 11 inches in dbh were damaged and removed. A per acre average of 127 trees between 12 inches tall and 5 inches dbh were also damaged during the operation.

Slash was piled by hand and machine on approximately ½ acre within the plot area and piles were burned in November of 1968. One fire escaped from a slash pile and burned about ½ acre. The total acreage burned was approximately one acre, or nearly 20% of the plot area. Fire intensity varied from extremely hot in the piles to low intensity in the escape area.

Figure 3: Plot 2 Basal Area Per Acre - All Species



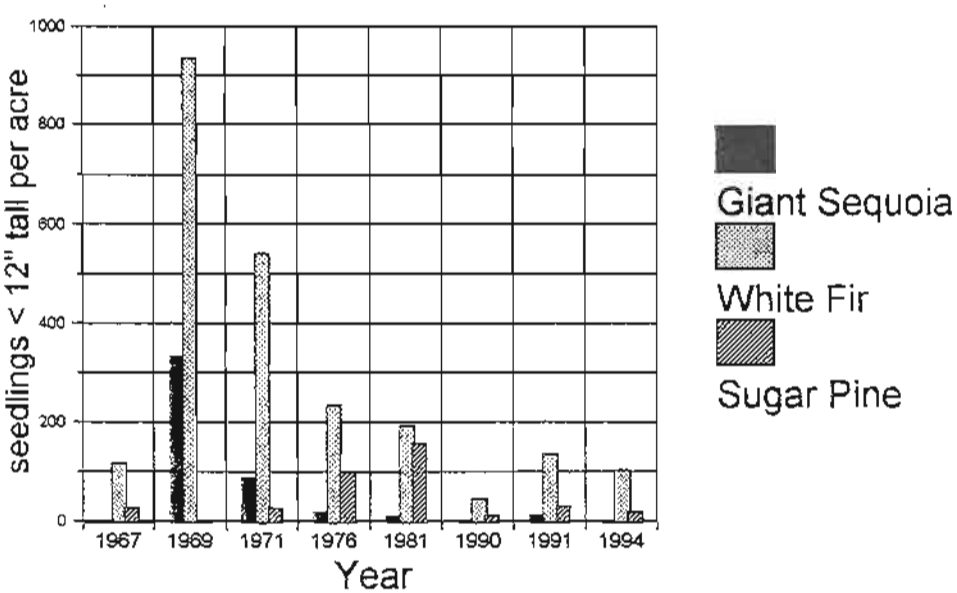
The total stand basal area for all trees greater than 11 inches dbh during the measurement period is shown in Figure 3. Approximately 150 square feet of basal area was removed in the logging operation, leaving a total of 350 square feet per acre. Basal area figures have shown a steady increase since harvesting took place. In 1994

basal area was slightly over 400 square feet per acre, indicating that approximately ⅓ of the amount removed in the harvest of 1968 had been regained by 1994. Although there has been an increase in poles and saplings on the plot since timber harvest, these trees had not reached the 11 inch dbh size to be included in these basal area figures. The increase in basal area on this plot after logging is a result of residual stand growth of all species, including old-growth giant sequoia.

Duff layers on the plot averaged 2.9 inches in depth prior to harvest and 0.4 inches deep after timber harvest. Duff depth had increased to 1.6 inches by 1994. Crown closure before harvesting was 52%, decreasing to 28% after harvest. By 1994, crown closure had increased to 37%.

The number of seedlings per acre less than 12 inches in height are shown in Figure 4. Giant sequoia seedlings first appeared in the 1969 measurement year with an average of 332 seedings per acre. This dropped to 17 giant sequoia seedlings per acre in 1976. Many of these seedlings survived to become saplings in later measurements. In 1994 there were an average of 5 giant sequoia trees per acre taller than 3 feet in height but less than 11 inches dbh.

Figure 4: Plot 2 Seedlings Per Acre



Understory vegetation changed significantly during the measurement period. The most common understory plant found in Plot 2 before logging, having an average of over 600 plants per acre, was Draperia. Seven other plants which had densities greater than 100 plants per acre, listed in order of predominance, included: wintergreen, bracken fern, chinquapin *(Castanopsis sempervirens)*, sedge (*Carex* spp.), bear clover (*Chamaebatia foliolosa*), Phacelia and Iris (*Iris* sp.)

In 1981, fourteen years after logging, the understory vegetation was different in relative species abundance and also in overall density. The most plentiful plant found after logging was again

Draperia, having an average density of over 2000 plants per acre. Thirteen other plants, which had densities exceeding 100 plants per acre, listed in order of predominance were: Phacelia, gooseberry, bracken fern, whitethorn, manzanita (*Arctostaphylos* sp.), wintergreen, sedge, Gayophytum (*Gayophytum diffusum*), bear clover, grass (*Gramineae* family), stickseed (*Lappula* sp.), Silene (*Silene* sp.), Iris, and purple nightshade (*Solanum xanti*). The three species that made the most dramatic increase in densities after logging were whitethorn, gooseberry, and manzanita. Whitethorn occurred on the plot in very dense thickets soon after logging.

Management Strategy "C" - Prescribed Burning

Plot 1 was broadcast burned on August 19, 1985. The objectives of the burn were to consume a large portion of the duff layer, kill a portion of the small saplings and some pole sized trees to create openings in the stand, consume dead ground fuels, generate enough heat to open some giant sequoia cones in the lower crowns of old-growth trees, and prepare a seedbed for giant sequoia reproduction.

Ignition of the prescribed fire was done by strip burning along the contour, working downslope. Ignition started in late morning and continued into late afternoon. The prescribed fire burned with varying intensities depending on available fuels and their moisture contents.

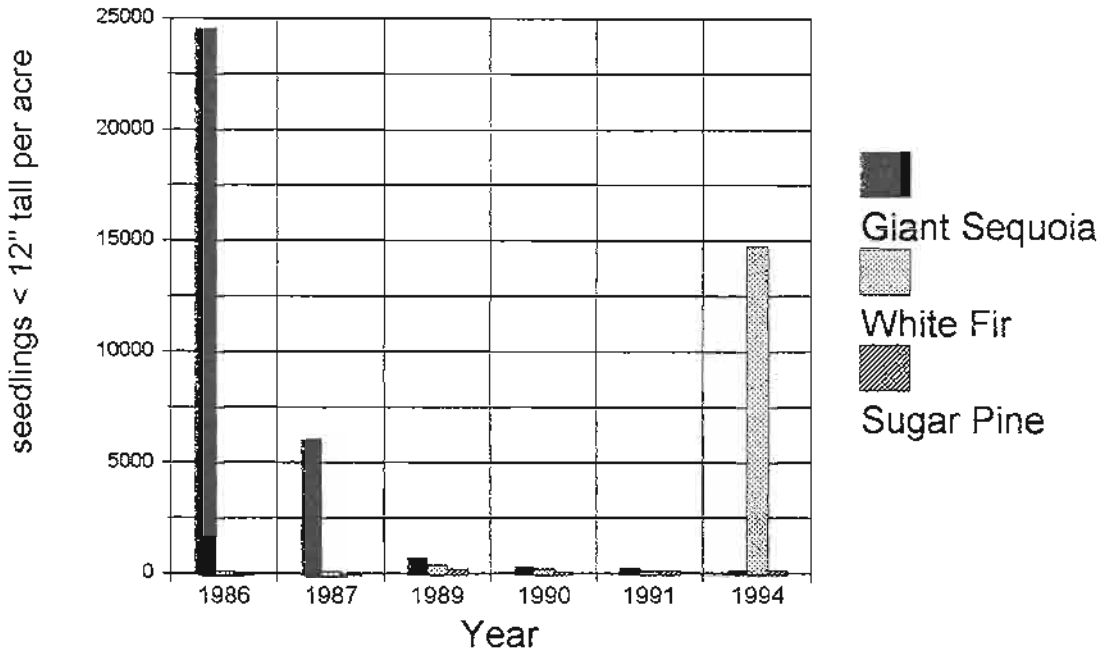
The fire had a significant impact on duff layers. The average duff depth was reduced from 3.2 inches before burning to 1.3 inches after burning. Crown closure was also reduced from 47% before burning to 43% one year after the fire.

Visual observations immediately after burning revealed a large amount of seed falling from the old-growth giant sequoia trees on the plot. This seedfall continued for many weeks. Fire intensity around the old-growth trees was moderately high due to the accumulation of down limbs and logs near them. The fire intensity was high enough to open a substantial amount of the cones in the lower crowns, allowing seed to fall to the ground.

Measurements of tree seedlings were made the year after burning and continued until 1994. The number of tree seedlings less than 12 inches high is shown in Figure 5. Giant sequoia seedlings were most numerous the first year after burning, averaging 24,525 per acre. This number had dropped to 113 per acre in 1994.

Plot 1 Following Burning - 1985

Figure 5: Plot 1 Seedlings Per Acre After Prescribed Burning



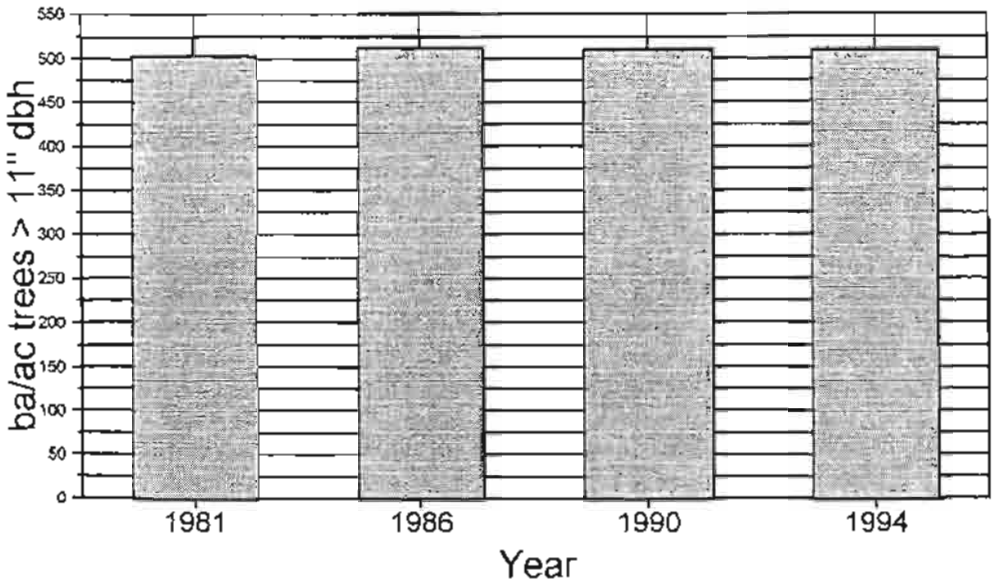
The distribution of giant sequoia seedlings in the plot was not uniform. Some areas had extremely high densities of seedlings while others were lacking seedlings entirely. Data are lacking in this study to correlate microsite differences with seedling density.

A surge of white fir seedlings occurred in 1994 following a good seed crop. The lack of white fir seedlings immediately after the burn can be attributed to poor seed production during that period. The long term survival of these white fir seedlings will not be known since 1994 represented the last measurement year for the plot.

The numbers of poles and saplings were reduced immediately after the fire, reflecting the fire caused mortality of these small trees. Pre-fire densities of trees greater than 12 inches tall and less than 11 inches in dbh averaged 110 per acre. Post-fire density of trees in the same size class averaged 73 per acre. Basal area per acre of trees greater than 11 inches in dbh was relatively constant before and after the burn as shown in Figure 6.

Understory vegetation increased following the prescribed fire. Nine years after burning the abundant plant was Draperia, with over 1000 plants per acre. Ten other plants had densities exceeding 100 plants per acre and are listed below in order of predominance: Phacelia, Sierra gooseberry, hawkweed *Hieracium* sp.), wintergreen, bracken fern, bedstraw (*Galium* sp.), grass, whitethorn, Lotus (*Lotus* sp.), and Sierra currant (*Ribes nevadense*).

Figure 6: Plot 1 Basal Area Per Acre - All Species



Conclusions and Management Implications

There are limitations in this study that must be considered when applying this information to other stands or sites. The study lacked repetition and consisted of only two study plots. Burning and logging can occur in a wide range of intensities while this study looked at only one level of treatment. Also, implementation of the different management strategies occurred during different time frames and measurement periods. We can make some general observations and conclusions based on this study keeping in mind the limitations of the data.

Data from Plot 1 indicated that mature giant sequoia stands that are protected from wildfire and other disturbances will have a stable basal area stocking level over time. Mortality will be offset by growth of the residual stand. On the site studied in this example, the upper limit of basal area stocking appears to be around 500 square feet per acre.

Different management strategies have the potential to change stand density. Information from Plot 2 showed that logging activity results in decreased basal area of the stand and increased growth of residual trees. Prescribed fire, of the intensity used in this study on Plot 1, did not significantly decrease stand basal area except for the removal of a portion of the understory.

Natural regeneration of giant sequoia in protected stands is nonexistent or very rare, as demonstrated in Plot 1. Regeneration of fir and sugar pine occurs in some years but mortality of the seedlings may reach 100%. Throughout the protection period, the site appeared to be fully occupied for both understory and overstory vegetation. Shade tolerant species such as white fir and wintergreen were predominate in the understory. Protection of stands such as these for a long period of time should result in a shift of species distribution, favoring white fir. Although it was not regenerating, old-growth giant sequoia will remain in the stand for some time because of the longevity of individual trees.

Disturbances created during the course of this study in the forms of logging and prescribed fire resulted in increased regeneration of giant sequoia. Duff layers and canopy closure were reduced more from the logging activity than from the prescribed burning. Visual observations showed more giant sequoia seed released after the prescribed fire than following logging activity because of heat from the fire opening cones in the lower crown.

Each disturbance resulted in a large amount of regeneration the following year with prescribed fire resulting in the greatest number of one-year-old seedlings. Seedling establishment slowed to insignificant levels by the second year after each disturbance.

Mortality of seedlings was very high following both treatments. Giant sequoia seedling mortality nine years after the prescribed fire was 99.5%. Because of the very high initial seedling density (24,525/acre), numbers were still very high in parts of the burn area in 1994 (113/acre) with additional seedling mortality expected. Giant sequoia seedling mortality eight years after the logging activity was 94.9%. Even though initial seedling density was lower than the prescribed fire treatment, enough seedlings have survived so that twenty five years after logging, five trees per acre had become established in the stand as saplings.

Giant Sequoia Sapling on Plot 2 - 1995

Seedling vigor in the burned plot appeared to be very low. Height growth has been slow and many of the seedlings have a twisted and contorted form. This suppression of seedlings is most likely a result of extremely high initial seedling densities and existing competition from the overstory.

Contorted Giant Sequoia Seedling on Plot 1 - 1995

Understory vegetation was stimulated by both logging and prescribed burning. The logging activity resulted in the greatest increase in plant density. Whitethorn formed very dense stands and was a competitor to tree seedlings, suppressing them for many years. Once the seedling height exceeded the height of the whitethorn, growth was very rapid. Understory vegetation in the burned plot did not reach levels where severe competition with tree seedlings existed.

In summary, this study has shown that the lack of disturbances in giant sequoia forests will result in the formation of a fully stocked stand with little or no regeneration of any of the tree species. The most likely tree species to regenerate will be white fir, leading to a long term shift in species composition. Either logging or prescribed fire will result in giant sequoia regeneration immediately after the disturbance but large amounts of seedling mortality can be expected following initial seedling establishment. Even with substantial early seedling mortality, survival will be adequate after either treatment to ensure the establishment of giant sequoia in the understory.

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Appendix: Plot Data

PLOT 1

TOTAL BASAL AREA PER ACRE

year	ba/ac
1966	490.8
1971	497.9
1976	511.6
1981	502.7
1986	511.9
1990	510.1
1994	509.2

SEEDLINGS PER ACRE, 0 TO 12 INCHES IN HEIGHT

year	giant sequoia	white fir	sugar pine
1967	0	970	15
1969	0	3810	77
1971	0	963	23
1973	0	240	20
1976	0	1215	112
1981	0	255	155
1986	24525	65	15
1987	6038	125	15
1989	675	375	180
1990	275	205	40
1991	260	80	110
1994	113	14752	120

PLOT 2

TOTAL BASAL AREA PER ACRE

year	ba/ac
1966	502.5
1968	350.8
1971	355.9
1976	364.5
1981	374.8
1986	390
1990	397.1
1994	402.9

SEEDLINGS PER ACRE, 0 TO 12 INCHES IN HEIGHT

year	giant sequoia	white fir	sugar pine
1967	0	115	25
1969	332	935	0
1971	87	540	25
1976	17	232	98
1981	8	190	157
1990	0	43	10
1991	10	135	28
1994	0	102	18