A NATIONAL STUDY OF THE CONSEQUENCES OF FIRE AND FIRE SURROGATE TREATMENTS

Sequoia National Park Site

Study Plan

Prepared by:

Eric Knapp
Ecologist/ FFS Sequoia Site Manager
U.S. Geological Survey, Western Ecological Research Center
Sequoia and Kings Canyon Field Station
Three Rivers, CA 93271

Jon Keeley
FFS Steering Committee Representative
U.S. Geological Survey, Western Ecological Research Center
Sequoia and Kings Canyon Field Station
Three Rivers, CA 93271

Other Contributors/ Collaborators:

Tony Caprio (Fire Ecologist, Sequoia NP), Bill Kaage (Fire Management Specialist, Sequoia NP, MaryBeth Keifer (Ecologist, Sequoia NP), Steve Zack (Wildlife Ecologist, Wildlife Conservation Society), Kerry Farris (Wildlife Ecologist, Wildlife Conservation Society), Philip Rundel (Professor, University of California Los Angeles), and Jamie Barbour (Wood Scientist, Portland Forestry Sciences Laboratory)

April 27, 2001

Introduction

Management practices have altered both structure and function of many forests nationwide. Some of the most dramatic changes have occurred due to fire suppression, especially in forests with a historical fire regime of relatively frequent stand-thinning variable intensity fire. The result has been an increase in the quantity of forest fuels and the probability of large, high-severity, stand-replacing fires. The impact of unnaturally high fuel loads on forest health and ecosystem integrity is being increasingly recognized. Destructive wildfires of the past few seasons have provided an additional catalyst for incorporating new management practices designed to move forest structure and forest processes closer to historical conditions. The need for widespread use of restorative management practices is clear. What are less clear are the best methods for achieving the desired result. Reintroducing fire alone may be insufficient in forests that have diverged greatly from historical conditions. Mechanical thinning or manual fuel reduction treatments have been proposed as surrogates for fire, or as treatments to be applied prior to the re-introduction of fire. Unfortunately, very little information is currently available about the ecological consequences of these alternative management practices.

The frequent, low- to moderate-severity fires that characterized pre-settlement disturbance regimes in many forests affected not only overall forest structure, composition, and fuel levels, but also a wide range of other ecosystem components and processes (Agee 1993, Chang 1996). What components or processes are altered or lost when “fire surrogates" such as cutting and mechanical fuel treatments are used instead of fire, are poorly understood. Economic and technical feasibility of various treatments, as well as social and political acceptability, are additional important considerations in managers' decisions about tools to use. For the most part, information necessary to answer such key biological and economic questions is anecdotal or absent.

In January 2000, the national Joint Fire Sciences Program funded a five-year study to evaluate the effects of alternative fire and fire-surrogate treatments on forest health. Eleven sites were chosen nationwide to conduct this study. One of these sites is Sequoia National Park.

Objectives

The primary objectives of the national study are to:

1. Quantify the initial effects of fire and fire surrogate treatments on response variables including vegetation, fuel and fire behavior, soils and forest floor, wildlife, entomology, pathology, and treatment costs/ utilization economics.

2. Provide an overall research design that (a) establishes and maintains the study as an integrated national network of long-term interdisciplinary research sites utilizing a common “core” design to facilitate broad applicability of results, (b) allows each site to be independent for purposes of statistical analysis and modeling, as well as being a component of the national network, and (c) provides flexibility for investigators and other participants responsible for each research site to augment (without compromising) the core design as desired to address locally-important issues and to exploit expertise and other resources available to local sites.

3. Establish cooperative relationships, identify and establish network research sites, collect baseline data, implement initial treatments, document treatment costs and short-term responses to treatments, report results, and designate FFS research sites as demonstration areas for technology transfer to professionals and for the education of students and the public.

4. Develop and maintain an integrated and spatially referenced database to archive data for all network sites, facilitate the development of interdisciplinary and multi-scale models, and integrate results across the network.

5. Identify and field test, in concert with resource managers and users, a suite of response variables or measures that are: (a) sensitive to the fire and fire surrogate treatments, and (b) both technically and logistically feasible for widespread use in management contexts. This suite of measures will form much of the basis for management monitoring of operational treatments designed to restore ecological integrity and reduce wildfire hazard.

6. Quantify the ecological and economic consequences of fire and fire surrogate treatments in a number of forest types and conditions in the United States. Develop and validate models of ecosystem structure and function, and successively refine recommendations for ecosystem management.

Literature Review

Since the 1960's, Sequoia National Park has been a leader in restoring natural processes to forested landscapes through prescribed burning. Impetus for the use of fire was the discovery of the importance of fires to regeneration of giant sequoia (*Sequoia gigantea*)(Agee and Biswell 1969, Hartesveldt 1964, Hartesveldt and Harvey 1967, Kilgore 1972), a tree species found at less than 80 sites along the western slope if the central and southern Sierra Nevada. Partly as a result of this relatively long history of conducting prescribed burns, a substantial amount of research has been conducted on fire and the relationship between fire and forest ecology at Sequoia National Park and surrounding lands in the mixed conifer zone of the Sierra Nevada. This wealth of background information will be a tremendous asset to the FFS study.

Sequoia National Park was established in 1890. Fires were actively suppressed within the park until the 1960's, when prescribed burning was initiated. This period of fire suppression is thought to have resulted in widespread vegetation changes, most notably an increase in the density and cover of white fir (*Abies concolor*) (Kilgore 1973, Kilgore and Biswell 1971, Parsons and DeBenedetti 1979, Rundel 1971, Stephenson 1999, Vankat and Major 1978). In a reconstruction of pre-settlement mixed conifer forest conditions in Kings Canyon National Park, adjacent to Sequoia National Park, Bonnickson and Stone (1982) found that vegetation aggregations dominated by white fir increased from 27% in 1890 to 37% in 1977. In contrast, shrub and hardwood aggregations declined from 19% to 11%, and 10% to 6%, respectively. Fire suppression has also increased the abundance of fuels, enhancing the likelihood of fires of unnatural intensity (Kilgore and Sando 1975, Parsons and DeBenedetti 1979, Stephens 1998).

Fire plays an integral role in seedling establishment for several important tree and shrub species of the mixed conifer forest. Many species of *Ceanothus* and *Arctostaphylos* are almost entirely fire-dependent (Kilgore 1973). Studies have shown that giant sequoia and deerbrush (*Ceanothus integerrimus*) seedlings are found in abundance only in burned areas (Kilgore and Biswell 1971, Kilgore 1973). Intense fires resulted in the most giant sequoia seedlings and the fewest shrub seedlings, while lower-intensity burns resulted in more shrub and fewer sequoia seedlings (Kilgore and Biswell 1971, Kilgore 1973). The most intense fires, by consuming the litter and duff, allow seeds to reach the mineral soils. Fire may result in a decrease in fungal populations, which Kilgore (1973) hypothesized might benefit seedling survival. Fire also benefits germination of other Sierran mixed conifer forest species including ponderosa pine, jeffrey pine, sugar pine, and white fir. Unlike the other conifer species, white fir also germinates well without fire (Kilgore 1973).

Fire return interval and severity

Caprio and Swetnam (1995) determined that the interval between fires along an elevational transect near Giant Forest, Sequoia National Park, ranged from 1 to 36 years since year 1600. Fire frequency varied greatly over time. Fires occurred frequently in the 1700's, declined around 1800, then increased again between 1830 and 1850. By 1900, fire incidence nearly ceased completely. Prior to 1900, time between fires showed a trend of increasing with elevation from the chaparral/ black oak zone (1550 m) through the mixed conifer zone (2200 m). Historical patterns of fire are as patchy and heterogeneous as the landscape. South-facing slopes burned with higher frequency than adjacent north-facing slopes. South-facing slopes are not only drier, but often contain a greater abundance of ponderosa pine. Surface fuels deposited by pines typically burn more readily than the denser surface fuels deposited by other tree species. Other estimates of fire return interval in the vicinity of the study plots ranges from 4-20 years (Kilgore 1973) to 20-40 years on more mesic north-facing slopes (Caprio, personal communication). Within and just outside of Kings Canyon National Park, Kilgore and Taylor (1979) reported a 9 year fire return interval on west-facing slopes, a 16-year fire interval on east-facing slopes, a 5 year fire return interval in ponderosa pine forest, and a 15-18 year fire return interval in moister sites dominated by white fir. A mean 65 year fire return interval for the period up to the year 1886 was found for red fir dominated forests in the Mineral King area of Sequoia National Park (Pitcher 1987). These forests were located on north-facing slopes at higher elevations than the mixed conifer forest.

Fires within mixed conifer/ giant sequoia forests during the most recent pre-settlement period were probably of low intensity with patchy high intensity (Stephenson et al. 1991). These higher intensity patches likely occurred in areas with higher fuel loading, or when time since the previous fire was longer than normal. Evidence also suggests that occasional high intensity fires, with patchy low intensity, also occurred in this area (Stephenson et al. 1991). Swetnam (1993) determined, through giant sequoia fire scars, that the frequency and intensity of fires has likely changed through time, in response to temperature variation at the decade to century scale. Frequent small fires occurred during a warm period from AD 1000 to AD 1300. Fires during cooler periods were typically less frequent, but burned over a wider area.

Season of burning

Within years, Caprio and Swetnam (1995) determined that fire scar positions from trees in Sequoia National Park were commonly found in the latter portion of the annual rings, indicating that most fires burn relatively late in the growing season (mid summer to early fall). The peak period of lightning ignitions in the Sierra Nevada occurs during July and August, with the greatest area often burning in August (Caprio and Swetnam 1995). This is in agreement with the within-season tree ring data. August is also typically among the hottest and driest months, with low (decreasing) foliage moisture content (Caprio and Swetnam 1995). In the Sierra Nevada, early season surface fires are typically less intense than fall burns, and have little impact on heavy fuels or decomposed duff layers (van Wagtendonk 1972, Kilgore 1973).

Season of burning can affect the abundance of new seedlings that germinate post-fire. Kilgore (1971) reported that sequoia seedlings were much more numerous on a site that burned in August than on a site burned in November. The earlier burn allowed two months of seed fall prior to the onset of winter rains. Kilgore (1971) hypothesized that the loose, friable soils created by fire enhance seed germination and that these conditions are transient. With the onset of rains and snows, soil density increases again. Mortality of different plant species with fire may differ with season of burning. Fire damage is thought to be more severe if fire occurs during or soon after the period of rapid shoot growth. In a study conducted at three northern Sierra Nevada sites (including Blodgett forest), Kauffman and Martin (1990) found the greatest mortality of shrubs and hardwoods to occur after early fall burns and the lowest mortality to occur after early spring burns. The early spring burns preceded shrub growth. At all sites, mortality was highest in the season when fuel consumption was greatest.

Little research has been conducted on the impact of season of prescribed burning on forest small mammal, bird, and amphibian populations. Fire can result in direct mortality and can modify the environment in deleterious as well as beneficial ways. The direct effect of fire can vary depending on season. In a review of the literature, Russell et al (1999) summarized studies showing that altering the historical season of burning can negatively impact herpetofauna populations. Fire intensity, which is a function of seasonal fuel moisture, is often correlated with mortality (Russell et al. 1999). With birds, fire during breeding may negatively impact nest success.

Effect of burning: vegetation/ fuels

Prescribed fires in mixed conifer forests near the proposed FFS study plots were found to substantially reduce basal area and change the size structure of stands. Percent mortality ranged from 0.8% to 1.4% per year in unburned plots and was 17.2% per year in burned plots (Mutch and Parsons, 1998). Mutch and Parsons (1998) found that the highest mortality rate occurred in the first year after the burn (42.3%), but mortality rate was still elevated relative to unburned plots five years after the burn. Prescribed fire caused basal area to decline an average of 5% per year for the five year post-burn period. Total mortality was 75% for trees with a dbh of less than 50cm and 25% for trees with a dbh of greater than 50cm (Mutch and Parsons, 1998).

The amount and condition of fuels in a forest stand plays a significant role in the effect on living vegetation when fire is introduced. Stohlgren (1988a) documented a large amount of variation in litter fall among plots in a mixed conifer forest stand in Sequoia National Park. Litter decomposition rates also varied with tree species. After 3.6 years, percent decomposition for sugar pine, white fir litter, and incense cedar litter averaged 40.0%, 45.1%, and 56.9%, respectively (Stohlgren 1988a). Cover, mass, and volume of coarse woody debris has been estimated (Harmon et al. 1987) in the vicinity of our proposed study plots. Boles of white fir, the dominant species in the stand, had almost disappeared after 60 years, and had a half-life of 14 years. The chronosequence at which different decomposers colonized fallen logs and carbon nitrogen ratios of decomposing wood over time was determined.

Agee et al. 1978 quantified fuel loads and percentage reduction in fuels resulting from prescribed burning in different seasons in mixed conifer forest, adjacent to Sequoia National Park. Prescribed fire reduced fine fuel loads 60-70%, with the greatest reduction in fuels composed of pine litter and duff. Sequoia and white fir fuels were more compact and burned with less intensity. Fuels of pines were effectively reduced by burning in spring, summer, or fall. Drier summer or fall conditions were required to reduce fuel loads of white fir and giant sequoia. Prescribed fire reduced fuel by 85% in several prescribed fires in Sequoia and Kings Canyon National Parks (Mutch and Parsons 1998, Kilgore 1971). In comparing early spring, late spring, early fall, and late fall burns in Sierra Nevada mixed conifer forests, Kauffman and Martin (1989) found that late spring burns had the highest fire-line intensities and the greatest potential for damaging the forest overstory. In contrast, early fall fires were lower in fire line intensity but had greater fuel consumption. Early spring burns were found to consume 15% of total fuels, while early fall burns consumed 92% of total fuels (Kauffman and Martin 1989).

Multiple prescribed fires at 5-8 year intervals may be required to sufficiently reduce fuels and prevent crown fire in giant sequoia/ mixed conifer forests (Kilgore and Sando 1975). Burning was found to have very little impact on larger diameter sequoia trees, and resulted in higher mortality for only the smallest diameter classes (Lambert and Stohlgren 1988).

Effect of burning: Soils

The impact of prescribed burning on soil properties and nutrient dynamics has been studied in mixed-conifer forests adjacent to Sequoia National Park. Research has shown that a large proportion of forest nutrients are retained in the litter (Stohlgren 1988b). These nutrients are unavailable to plants until the litter is broken down and the nutrient elements are mineralized, which can occur through the action of soil organisms, or fire. St. John and Rundel (1976) determined that fire in the Sierra Nevada sequoia-mixed conifer forest caused a significant decrease in nitrogen, carbon, and cation exchange capacity, and a significant increase in phosphorus, calcium, magnesium, potassium, and pH. These authors concluded that fire was an effective mineralizing agent, and that despite the loss of some nutrients, fire generally enhanced the nutritional environment for plants. The impact of fire may differ for other components of the soil. Stendell et al. (1999) evaluated the effect of prescribed fire on the ectomycorrhizal fungus community in the Sierra National Forest, adjacent to Sequoia National Park, and found an eight-fold reduction in total ectomycorrhizal biomass after fire.

The effect of prescribed fire on soil stream water and solution chemistry profiles has been studied in the vicinity of our proposed plot locations (Williams and Melack 1997, Chorover et al. 1994). The concentration of many solutes in stream water was significantly elevated after prescribed burning (Williams and Melack 1997). Average composition of soil solutes closely resembled stream profiles (Chorover et al 1994). Chorover et al. (1994) found a 10-fold increase in Calcium, Magnesium, and Potassium ions in soil solution and in stream water post-burn. Sulfate concentrations rose even more, and a sharp increase in Ammonium ions was observed, followed by a decrease to below pre-burn levels. Nitrate ion concentration was higher postburn in all three years monitored after fire.

Agee (1979) determined that water-repellency of litter, duff, and surface soil increased after fire, but predicted significant acceleration of surface runoff would not result. Kilgore (1971) also postulated that decreased wetability might occur with fire, but he witnessed no erosion problems in his study plots.

Effect of burning: Birds and wildlife

Kilgore (1971) documented change in bird species composition but not bird biomass in response to removal of white fir and incense cedar thickets by cutting and prescribed fire within a mixed conifer/ giant sequoia forest in Kings Canyon National Park. Three species of ground feeding and nesting birds disappeared, but the abundance of flycatchers and robins increased after treatment. Bock and Lynch (1970) evaluated the effect of wildfire on adjacent burned and unburned plots in a mixed conifer forest in the northern Sierra Nevada. The wildfire killed most trees in the burned plot, and led to an increase in the number of ground-dwelling bird species and timber-drilling species, but a decrease in the number of tree foliage searching species. Of the 32 breeding species observed, 28% were found only in the burned forest, while 19 percent occurred only in the unburned forest. Burning slightly increased species richness. Because small pockets of trees remained after the fire, the burned area was more heterogeneous.

Some studies have been conducted in Sequoia National Park to evaluate the impact of prescribed fire on small mammal populations. In an experiment of limited scale and power, during (1981) reported insignificant differences in small mammal abundance between two burned plots and two control plots. Werner (2000) found lodgepole chipmunks (*Tamias speciosus*) in traps only after prescribed burning in the Mineral King area of Sequoia National Park. Lodgepole chipmunks presumably were able to colonize the area due to the 56% decrease in tree density. Populations of other small mammals also increased after burning, but for these species, it was more difficult to separate the effect of burning from overall population trends.

Effect of burning: Pathology and Entomology

The impact of fire on pathogens and bark beetles has not be studied within Sequoia National Park, but research at other sites has shown that the killing and weakening of trees through fire can lead to increased attack and mortality by these organisms. Forest gaps in Yosemite Valley are believed to be caused often by root diseases, most commonly *Heterbasidion annosum* (Slaughter and Rizzo 1999). This fungus spreads through root to root contact, kills pines rapidly, and can live in dead tissue for 30-50 years after the host tree has died (Slaughter and Rizzo 1999). Gaps are maintained because the fungus can infect newly germinating trees. Gaps typically grow from 0.5-1.5 meters per year (Slaughter and Rizzo 1999). The effect of fire on disease development is poorly understood, but fire may cause trees to be more susceptible, due to fire scar wounds, which can act as entry points for the fungus (Slaughter and Rizzo 1999). Over time, prescribed fire may reduce the incidence of root diseases within stands. Root diseases are thought to be more prevalent in forests containing large numbers of firs (Filip and Yang-Erve 1997), which have increased in abundance due to fire suppression.

Although fire can kill fungi in the soil, the net effect may be negligible because much of the damage occurs only in the surface soil layer. Filip and Yang-Erve (1997) found that rate of recovery of *Armillaria ostoyae* to be significantly slower after a hotter fall burn than after a cooler spring burn.

In the Lake Tahoe Basin, Bradley and Tueller (2001) found a significant correlation between burning and bark beetle presence. One year after a prescribed fire, more than 24% of Jeffrey pine trees were infected by at least one bark beetle species in burned plots, while less than 1% of trees were attacked in the unburned control plots. Multiple logistic regression models showed that presence of bark beetles was most often positively associated with crown scorch, bole char height, and burn severity.

Economic considerations

Nichols (1988) presented data from Sequoia National Park suggesting that expenses associated with fire suppression are greater than expenses associated with prescribed burning. Cost of suppressing lightning or human caused fires were estimated to range from $248 per acre (Yosemite), to over $800/ acre, while the costs of prescribed burning in Sequoia National Park generally range from $100-$300/ acre (Nichols 1988). Much of the cost of prescribed fire is associated with pre-burn preparation, including removing large fuels from the bases of live trees.

Research Approach

At all ten other sites in the nationwide network, the following four treatments will be applied.

1. Untreated control
2. Prescribed fire only, with periodic reburns
3. Initial and periodic cutting, each time followed by mechanical fuel treatment and/or physical removal of residue; no use of prescribed fire
4. Initial and periodic cutting, each time followed by prescribed fire; fire alone also could be used one or more times between cutting intervals

These four treatments reflect realistic management options on many federal lands such as national forests.

The Sequoia NP site differs from others in the FFS network in containing old-growth forest, and being on Department of the Interior Lands where tools available to resource managers for reducing excessive fuels are more limited. At the Sequoia National Park site, the following three treatments will be applied.

1. Untreated control
2. Early season prescribed fire, with periodic reburns
3. Late season prescribed fire, with periodic reburns

At all sites the non-control FFS treatments will be guided by a desired future condition (DFC) or target stand condition. The goal or DFC is to achieve stand and fuel conditions such that, if impacted by a head fire under 80th percentile weather conditions, at least 80 percent of the basal area of overstory (dominant and codominant) trees will survive. This minimum standard is subject to revision.

The Sequoia National Park site is considered to be a satellite site to the Blodgett Forest Research Station site, where the full complement of treatments will be applied. Both sites occur in the mixed conifer forest zone of the west slopes of the Sierra Nevada. Sequoia National Park is located at the southern end of the Sierra Nevada range (Figure 1). Climate is characterized by relatively mild wet winters and warm dry summers. Average yearly rainfall is approximately 45 inches, much of it falling as snow.

The Sequoia National Park site is the only FFS site where treatments varying in the season of burning will be applied, thus adding a valuable dimension to the nationwide study. Early season prescribed burning during the early to middle part of the growing season has the potential to affect trees, shrubs, and other forest species in different ways than prescribed burning late in the growing season, but little quantitative data is available. In addition, concern exists about the potential impact of early-season fire on terrestrial amphibians and other animal and insect species that may be more active during this time of year and as a result, vulnerable to fire. Prescribed burning in Sequoia National Park is typically conducted from mid to late July and continuing until November or even beyond (A. Caprio, C. Conover, M. Keifer, J. Manley, personal communications). The acreage over which prescribed burning treatments can be applied in any given year is frequently limited by few windows of opportunity and complicated by air quality concerns. Resource managers in Sequoia National Park are interested in the possibility of including prescribed burning applied earlier in the season than was historically typical as a management option. The FFS study at the Sequoia National Park site is designed to provide resource managers with the ecological information needed to better understand the impact of the season of burning on forest species and forest processes. Sequoia National Park has a long history of involvement in fire research and representatives from the Division of Fire Management and the Division of Science and Natural Resources Management are enthusiastic about cooperating with this project. In addition, Sequoia National Park already cooperates with researchers from various universities throughout the country. Future collaborations are expected to increase due to the anticipated construction of the new University of California campus at Merced, and the proposed focus of this new campus on problems of the Sierra Nevada.

Figure 1. Location of the Sequoia National Park site for the National Fire and Fire Surrogate Study

Methods

Plot location and experimental design

Plot locations were chosen based on a lack of recent fire history, accessibility, and ease in applying prescribed fire treatments. All nine study plots (three early season burn, three late season burn, and three control) are in the vicinity of the Giant Forest Grove of giant sequoias (*Sequoia gigantea*), within the watershed of the Marble Fork of the Kaweah River on 15 to 25 degree west and northwest facing slopes (Figure 2). Plots were located on similar slopes and aspects, and at similar elevations in order to reduce among plot variation. Elevation ranges from 6,200 to 7,000 feet. Forests in this area are dominated by white fir (*Abies concolor*), with some ponderosa pine (*P. ponderosa)*, sugar pine (*P. lambertiana)*, and incense cedar (*Calocedrus decurrens*). Although the study plots were selected to occur outside of the area containing giant sequoia trees, a few scattered trees of this species are also found within the plots. The proposed plots average 17 hectares each in size. Plots include a 10-hectare central measurement area, and a buffer of varying width around the perimeter.

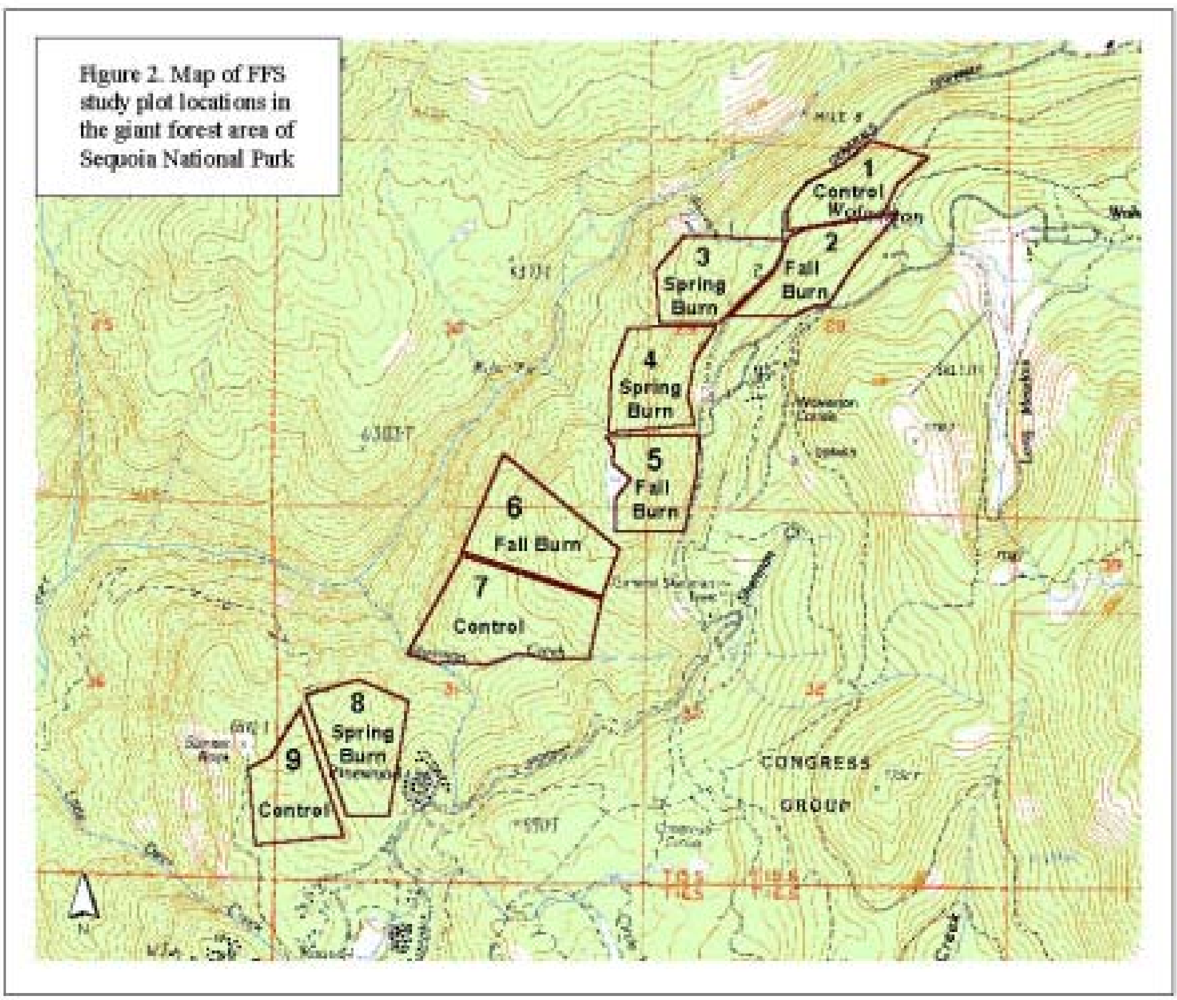


Figure 2. Map of FFS study plot locations in the giant forest area of Sequoia National Park

Forests in the study area are old growth, with no history of logging or other disturbance. The pre-settlement fire return interval for forests and aspects of the type found at the study site has been estimated to range from 20 to 40 years (Tony Caprio, personal communication). Fire suppression since the creation of the park in 1890 lengthened the interval between fires, leading to a buildup of fuels and enhancing risk of catastrophic fire. White fir, which can germinate and grow in more shaded environments, has increased in abundance, reducing opportunities for establishment of other forest species. A significant fraction of the proposed sites are within the Prescribed Fire Operations Five Year Work Plan for Sequoia National Park. Fire management personnel are confident they can work within the proposed time frame and restrictions imposed by the random site selection criteria.

The experiment was set up as a completely randomized design, with three replicates of the three treatments (early season burn, late season burn, and control) randomly assigned to the nine study plots (Figure 2). Final decisions about plot location, shape, and size will be made in May, 2001, at the time of plot installation and after a final review by resource management and fire management specialists at Sequoia National Park.

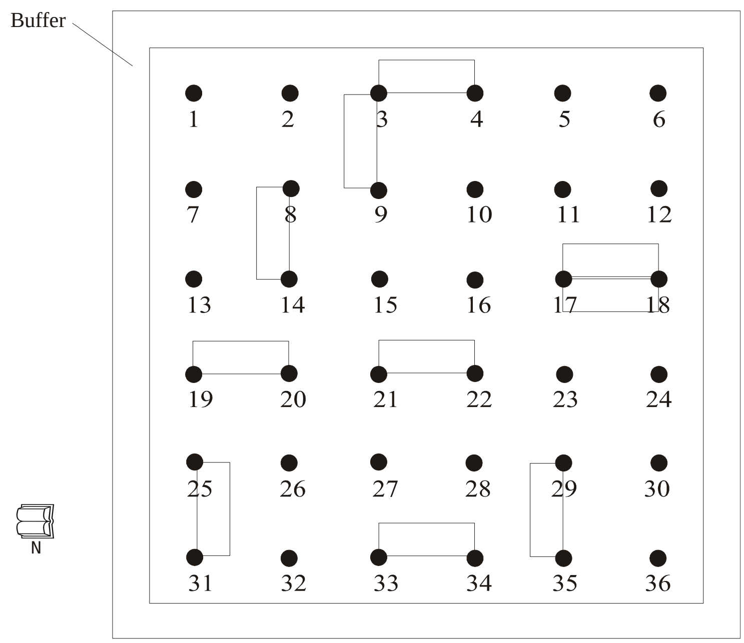
Sampling will be conducted in reference to a series of 36 permanent grid points installed within each plot (experimental unit). Grid points will be spaced 50m apart and oriented in the cardinal directions. The grid will be a six by six square in large plots, but will need to be adjusted in smaller plots with less regular boundaries. Using ArcView GIS software, a 50m by 50m grid will be overlaid onto either a map of the study site or orthorectified aerial images (if available). One grid point will be located on the ground using either identifiable visible objects or a GPS unit. From this grid point, the remaining 35 gridpoints will be placed using either survey equipment or a compass and measuring tapes. All grid points will be marked with variable length 0.5 inch rebar (length of the rebar depending on rockiness of site) driven into the ground. A fire-resistant aluminum cap will be placed over the top of each rebar marker. To identify the grid point, the cap will be stamped with a unique number. Where possible, a GPS reading will be made to establish the exact location of each grid point. By convention, grid point number one will always be located in the northwest corner of the plot.

Aerial photographic imagery from prior to and after application of the prescribed fire treatments will be obtained for our plot locations. Color infrared images (1:15000 scale) were taken throughout Sequoia National Park for a vegetation-mapping project in July 2000. These images will be orthorectified (if necessary) in order to accurately overlay the FFS plot boundaries. Additional aerial photographic imagery is scheduled to be taken after treatment application and prior to completion of the FFS study. Utilizing sources of aerial photographs taken for other projects but including the FFS study area will result in cost savings to the FFS project.

I. Vegetation

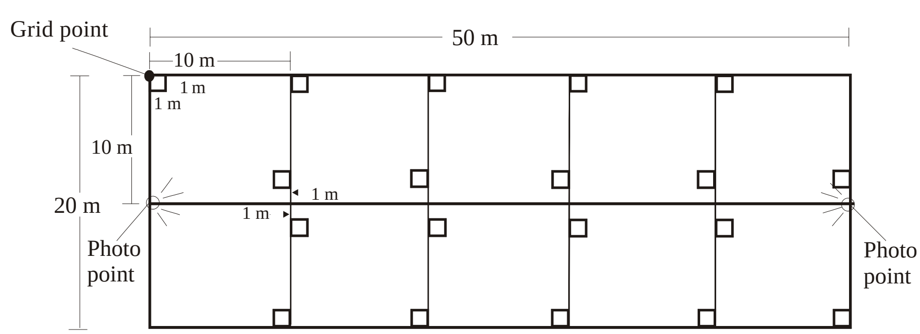
Vegetation variables will be measured in ten modified Whittaker 50m x 20m (0.1 hectare) subsample plots within each experimental unit/ treatment area. These ten subsample points were selected using stratified random methods. The selected grid point numbers are 3,4,8,17,18,20,22,29,31, and 33 (Figure 3). The final location of the subsample plot relative to the grid point will be based on a random number between one and four (1 = long end extending North, 2 = long end extending East, 3 = long end extending South, and 4 = long end extending West) (Figure 3). If the random number results in a subsample plot extending into the buffer zone, or results in overlap with other previously selected plots, a different random number between one and four will be chosen. Some vegetation variables will be measured within the entire 0.1 hectare subsampling plot, while others will be measured on smaller plots nested within this plot (sub-subplots).

Figure 3. Diagram of grid layout, showing location of 50m x 20m modified Whittaker vegetation sampling plots.



At the time of variable measurement, the subsampling plot will be divided into grids to facilitate location of the sub-subplots (Figure 4). Nine measuring tapes will be used to define the boundaries of all ten 10m x 10m sub-subplots within the 50m x 20m sampling plot. In addition, two 1m by 1m sampling plots will be systematically placed within each of the 10m x 10m sub-subplots (Figure 4). The boundaries of these 1m by 1m meter sampling plots will be defined by placement of a plot frame of the same dimension made out of PVC pipe.

Figure 4. Diagram of sub-sample plots for evaluating seedling density within 50 m x 20 m plots



Trees

Within each 50m x 20m subsample plot, data will be taken on all individual trees with a diameter at breast height (dbh) exceeding 10 cm. Each tree will be labeled with a numbered fire-resistant metal tag nailed into the bark. Tree species, and status (alive, standing dead, or dead and down) will be noted and dbh measured with a diameter tape and recorded to the nearest cm. If dead, determination of the probable cause of death will be attempted. General notes on tree condition will be taken, including bole scarring, vigor, and evidence of disease or bark beetle attack. Height of each tree as well as height to live and dead crown will be estimated using an impulse laser device or a clinometer and measuring tape. Crown cover will be estimated by measuring the width of the vertical projection of the edge of the canopy in two directions (North-South and East-West). Height of bole char and crown scorch will be scored on trees during the second or third monitoring years, after application of the burn treatments.

Saplings

Saplings, defined as trees with a height of greater than 1.37m and a dbh of less than 10cm, will be sampled in five randomly chosen 10m x 10m sub-subplots within the 50m x 20m subplots. All saplings rooted within the subplot will be recorded by species. Dbh will be determined to the nearest cm using a ruler or a dbh tape and status (alive or dead) noted. If dead, we will attempt to determine the probable cause of death.

Shrubs

Shrubs, defined as any non-tree vegetation with a woody stem, will be sampled on the same five randomly chosen 10m x 10m sub-subplots as the tree saplings were evaluated in. Shrubs will be identified to species, and percent cover for each species will be estimated visually, based on the following scale:

0 = 0% cover
1 = <1% cover
2 = 1-10% cover
3 = 11-25% cover
4 = 26-50% cover
5 = 51-75% cover
6 = 76-100% cover

Percent cover will be for the vertical projection of the entire canopy within the 10m x 10m subplot, whether or not the shrub is rooted within the boundaries of the plot.

Shrub cover will also be estimated a second way, by height class rather than species. Using the same cover categories listed above, cover will be separately scored for:

Ground cover = all shrubs <0.1m tall
Short shrubs = 0.1 to 1.0 m
Tall shrubs = > 1.0 m

Seedlings

Seedlings of tree species, defined as individuals with a height of less than 1.37m, will be sampled on twenty 1m x 1m sampling plots systematically arranged within the 50m by 20m subplot. Seedlings will be identified to species, and number of each species within three height categories will be counted. These height categories are:

1 = short (<0.1m)
2 = medium (0.1m to 0.5m)
3 = tall (0.5m to 1.37m)

Percent cover for each species will also be estimated visually, based on the following scale:

0 = 0% cover
1 = <1% cover
2 = 1-10% cover
3 = 11-25% cover
4 = 26-50% cover
5 = 51-75% cover
6 = 76-100% cover

Percent cover will be for the vertical projection of all vegetative parts within the 1m x 1m plot, whether or not the plant is rooted within the boundaries of the plot. Because canopies of different species can overlap, the total cover of all species could exceed 100%. In addition to the canopy cover estimates, the entire 50m by 20m subplot will be examined to locate and record any additional species of tree seedlings not already noted from within the twenty 1m by 1m sampling plots.

Herbaceous species

Herbaceous species (grasses, sedges, and forbs) will be sampled on the twenty 1m x 1m sampling plots systematically arranged within each 50m x 20m subplot. Percent cover for each species will be estimated visually, based on the following scale:

0 = 0% cover
1 = <1% cover
2 = 1-10% cover
3 = 11-25% cover
4 = 26-50% cover
5 = 51-75% cover
6 = 76-100% cover

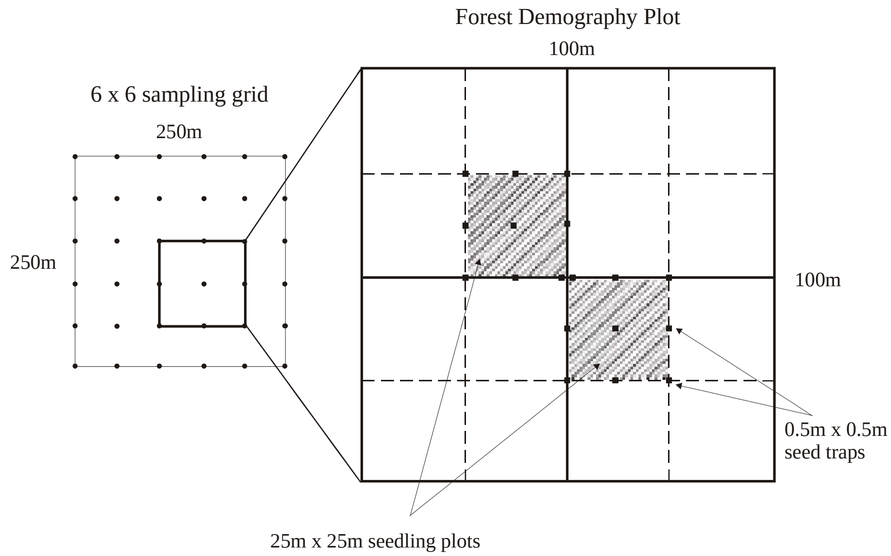
Percent cover will be for the vertical projection of all vegetative parts within the 1m x 1m sampling plot, whether or not the plant is rooted within the boundaries of the plot. Because canopies of different species can overlap, the total cover of all species could exceed 100%. In addition to the canopy cover estimates, the entire 50m by 20m subplot will be examined to locate and record any additional herbaceous species not already noted from within the twenty 1m by 1m subplots.

Note: All species will be identified on data sheets using standard NRCS abbreviations
http://plants.usda.gov/plants/index.html

Seedling demography

Seedling establishment dynamics of most conifer species at the Sequoia NP site are expected to be strongly regulated either directly or indirectly, by fire. To collect information on seedling and tree demography before and after fire, a one hectare (100m by 100m) forest demography plot will be established within each of the three late season burn FFS plots and within the three control plots. While data collected within these plots will focus on seedling dynamics, data on tree species, status (live or dead), and size will be collected as well, in order to develop a better understanding of the potential seed sources and the competitive environment within the plots. Forest demography plots will be located within the approximately 250m x 250m sampling area of the FFS plots. Using the gridpoints as guides, exact location will be randomly selected from among the four possible locations in the center of the FFS sampling grid (not including the outermost row of grid points).

Figure 5. Location of tree and seedling demography plots within the FFS six by six grid. Nine seed traps will be placed within each $25m^2$ seedling plot.



Within plots, all trees taller than 1.37 m will be identified to species, mapped, tagged, and measured for diameter. A numbered aluminum tag will be nailed to each tree at breast height. These tags will contain a different numbering system than the tags for trees within the FFS study plots. Location of trees will be precisely mapped using survey equipment (a Topcon total station). The one-hectare forest demography plots will be further divided into sixteen 25m x 25m subplots. Data on seedling/ sapling recruitment and seed dispersal will be collected from two 25m x 25m of these subplots. The two sampled subplots will be chosen from the central four subplots (Figure 5). Selection will be random except for the criteria that chosen subplots can't be directly adjacent to each other. Seedling and sapling density within subplots will be recorded by species for three categories: first year seedlings, 2^{nd} year seedlings, older seedlings (<10cm tall), and saplings (≥10cm tall). Saplings will be marked with numbered tags, and height individually recorded according to the following classes: 11-25cm, 26-50cm, 51-75cm, 76-100cm, and 101-137cm. If extraordinarily dense thickets of seedlings and saplings of particular age classes are encountered, the 25m x 25m subplot will be further subsampled by subdividing the subplots into 5m x 5m sub-subplots. Sub-subplots will be randomly selected and sequentially sampled until a threshold of seedling and sapling numbers have been obtained. These numerical thresholds will be determined at a later date. Subplots will be numbered starting at the northwest corner. In all cases, location of subplots will be mapped on data sheets. Seedling plots will be revisited each year and trees will be visited again in the final year of the study to check for ingrowth, mortality, and probable cause of mortality. Additional funding will be sought to continue collecting data on these plots after the end of the current study.

Conifer seed traps (0.5m x 0.5m) will be placed at the corners and mid-points on all sides just outside of the 25m x 25m subplot, and one additional seed trap will be placed in the center. Traps consist of wood frames that lie on the ground and have a fine mesh screen on the bottom and one inch hardware cloth on the top. Traps will be checked twice a year - in late summer and again soon after snowmelt in the spring. Contents will be collected, bagged, dried in the lab, and seed sorted/ counted by species.

Data collected within the forest demography plots will be analyzed together with the data collected in the same way for 20 existing permanent forest demography plots that were established in or prior to 1991 in the coniferous forest belts of Sequoia National Park and Yosemite National Park, for the Sierra Nevada Global Change Research Program. Existing forest demography plots range in elevation from lower treeline (1500 m) to upper treeline (3100 m) and range in size from 0.9 to 2.5 hectares. Since plot initiation, all trees taller than 1.37m have been identified to species, mapped, tagged, and measured for diameter at approximately five year intervals. Number and species of seedlings have been evaluated in subplots contained within the larger plot in both 1999 and 2000.

Light environment and gap/patch distribution

Percent canopy closure will be estimated at each grid point using a spherical densiometer or hemispherical photographs taken of the canopy, using methods described in Battles (1999). Estimates will be made one prior to application of the burning treatments (2001) and once after (2004).

Photo points

A photograph, using slide film, will be taken from the mid-point of both of the long ends of each of the 50m by 20m plots (Figure 4). At the time photographs are taken, a photo board, with information including experimental unit number, plot number, plot end (north, east, south, or west), and date will be placed in the plot approximately five meters from the photo point. Photographs will be taken during the middle of the day. (Ideal conditions for taking photographs are when the sun is obscured with a thin cloud cover.) Type of camera and lens will be noted on a data sheet for documenting the photographs. A tripod may be necessary if film speed is low or lighting is poor.

II. Fuels and Fire Behavior

The primary goals of the fuel and fire behavior analyses are to characterize the changes in fuel loading resulting from prescribed fire treatments, and to document fire behavior during the fire treatment applications. Ground, surface, understory, and overstory fuels will be measured once before application of treatments (2001) and once after application of treatments (2003). In addition, fuel moisture content, fire behavior measurements (flame length, rate of spread, and smoldering duration), and fire weather data will be collected at the time fire treatments are applied.

The fuel components to be measured are:

Ground Fuels

L layer (newly cast litter)
F layer (litter that is beginning to break down, yet still identifiable)
H layer (humus consisting of unidentifiable organic material)

Surface Fuels

Course woody debris
Ground-level plant biomass

Understory Fuels

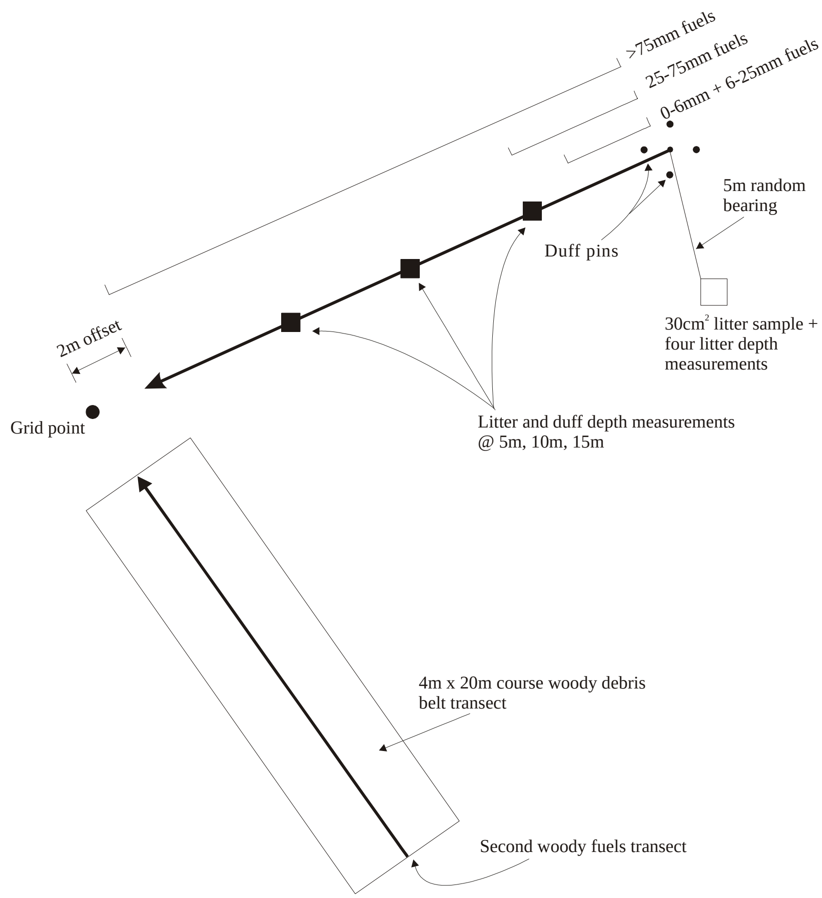
Live and dead shrub and sapling biomass

Overstory Fuels

Standing live and dead tree and tall shrub biomass The L- and F-layers contribute significantly to fire behavior in the fire treatments, whereas changes in the H-layer as a result of fire are more important in affecting below ground variables. The mass of the ground fuel component will be indirectly estimated for each experimental unit by developing a regression equation relating forest floor depth to forest floor mass or loading. Developing this equation requires limited destructive sampling of forest floor material in order to predict forest floor mass over a wider area, using duff pins. The use of duff pins will reduce the amount of disturbance to the forest floor. Such disturbance could potentially influence other variables measured within plots, including fire behavior.

Fifty forest floor samples provide the minimum number needed to produce a predictive equation. Since the plots at the Sequoia site are located in close proximity to each other and no blocking variable is used in the experimental design, one predictive equation should be sufficient. In addition, data on litter depth and mass collected in earlier studies may be suitable for use in predictive equations, meaning that fewer samples need to be collected.

Figure 6. Diagram of sampling protocol for fuels and course woody debris. Each transect is based on a random bearing.



A forest floor sample will be collected five meters from the ends of each fuel sampling transect, at a random bearing (Figure 6). A square metal frame (30cm on a side) will be used along with a cutter to remove each sample by layer (L, F, and H). Each layer will be bagged separately. After carefully removing the frame, depth of each layer will be measured in the center of each side of the square sample and averaged by layer for that sample. To ensure collection of all organic material, the sample will be collected past the soil surface, then washed (floated in water) to remove the soil and rock portion. Samples will be dried in an oven set at 85°C until a constant weight is attained. To determine if constant weight has been reached, samples will be weighed after 48 hours and re-weighed in 6-8 hour intervals. When all of the moisture has been removed, a total oven-dry weight will be recorded for each sample. [Note: The different size classes of woody material (0-6mm, 6-25mm, and 25-75mm) and other components (cones, bark and other vegetation parts) will then be separated out of the individual samples. The separation process will supplement the woody material inventory by determining the woody component incorporated in the forest floor.]

The amount of forest floor material removed by the prescribed fire is critical for defining vegetation and soil responses as well as smoke production. A series of four duff pins will be used per woody fuels transect to determine the amount of forest floor material removed. The four steel pins will be located on two perpendicular axes (the four cardinal directions) around the rebar post marking the far end of the woody fuels transect. Each pin will be pushed into the forest floor and mineral soil until the head of the pin is flush with the top of the litter layer. The exact location of the pins will be determined once other activities around the grid points are defined so that they are located in undisturbed areas. Distance and direction of the pin from transect end-point should be recorded. After the fire, each pin will be relocated and the distance from the top of the pin to the top of the remaining forest floor will be measured. The total distance from the top of the pin to mineral soil will also be recorded. These measured depths will then be applied to the prediction equation to estimate the tons per acre of forest floor material present and what amount is removed by burning.

The down dead woody fuels will be measured using Brown's (1974) planar intercept method. This fuel inventory will need to be done prior to and after application of spring and fall burn treatments. Two 20m transects will be randomly placed at each of the 36 grid points with the proximal end offset 2 meters from the grid point to minimize excess disturbance in this area (Figure 6). The distal ends of each transect will be considered the start-point of sampling and marked with rebar. [Note: due to the proximity of plots to the road and park visitors, we may explore not marking the end points of the woody fuels transects to minimize the number of rebar markers used.] Each line represents a plane and sampling will be done by counting the number of downed woody stems in different size classes that cross this plane. Dead and down woody material except for cones, bark, needles, and leaves will be counted and classified by size class (0-1/4"=0-6mm, 1/4-1"=6-25mm, 1-3"=25-75mm, and 3+"=75+mm), and the number of intercepts by species (if possible). For the 75+mm category, the diameters will be measured and decay class condition (sound or rotten) will be recorded. Stems and branches still attached to standing brush and trees will not be counted. Fuels in the two smallest categories (0-6mm and 6-25mm) will be evaluated in the most distal 2 m of the transect; fuels in the 25-75mm category will be evaluated in the most distal 4 m of the transect, and fuels greater than 75mm will be evaluated over the entire 20 m length of the transect. In addition, the maximum depth of elevated dead woody fuel will be measured in 30-cm increments centered at meters 9, 10, and 11. Litter and duff depth measurements will be taken at three locations along the transect (5m, 10m, and 15m) and recorded to the nearest mm. Litter is recognizable leaf litter, while partially decomposed and decomposed leaf litter is called duff. If a tree trunk or stump occurs at a litter and duff depth data collection point, litter depth will be recorded as zero. If a log occurs at a litter and duff depth data collection point, the data collection point will be moved 0.5 meters perpendicular to the transect.

Course woody debris

Course woody debris (CWD) has implications for wildlife and entomology, but data will be collected by the fuels crew simultaneously with fuels data collection. At every grid point, one of the two woody fuel transect lines will be randomly selected to serve as the centerline for the CWD survey strip plot. A 4 m wide and 20 m long belt transect will be established with the fuels transect as the centerline. Starting at the end farthest from the grid point, all logs or portions of logs that are at least 1m in total length and have a large end diameter of at least 15 cm (in or out of the transect) will be measured and counted. Logs are assumed to end when the diameter falls below 7.6 cm.

1. The large end and the small end (>7.6 cm) diameters will be measured on all logs or parts of logs that fall within the boundaries of the belt transect. If a piece extends outside the belt transect, diameters will be measured at the line of intercept with the belt transect boundary and the CWD piece.

2. Two log lengths will be measured:

   Belt log length – this is the length of the CWD within the belt transect area.
   Total log length – this is the length of the entire piece.

The midpoint of the log will be calculated from the total log length measurement. If this midpoint is within the belt transect, an additional rating of "1" is given to the piece. If the midpoint is outside of the belt transect, the piece is given a rating of "0".

3. Decomposition class of each log and, if possible, the species of the log will be recorded.

The following five log decomposition classes will be used to rate the CWD:

Decomposition class 1). Bark is intact; twigs are present; wood texture intact; log is round; original wood color; log may be elevated on support points.

Decomposition class 2). Bark is intact or beginning to flake off; twigs are absent; wood texture is sound or becoming soft; log is still round; original wood color, log elevated on support points but sagging slightly.

Decomposition class 3). Bark is falling off; twigs are absent; wood texture is hard; log is still round; wood is faded from original color; can penetrate sapwood with a penknife, log is sagging near ground.

Decomposition class 4). Bark is absent; twigs are absent; wood texture is soft, blocky pieces; shape of log is round to oval; wood has faded to light yellow or gray; all of the log on ground; can kick a piece apart.

Decomposition class 5). Bark is absent; twigs are absent; wood texture is soft and powdery; shape of log is oval; wood has faded to light yellow or gray, log fully on ground.

If biomass of grass, forb, and dwarf shrub vegetation is high enough to be considered an important contributor to fire behavior or effects, biomass estimates will be made. This will be done by developing allometric equations for species present, relating fuel type, percent cover, density, and depth or other non-destructive measure to plant biomass. Data taken during the vegetation sampling can then be used to estimate biomass for the plot. Equations for live fuel types found within our plots developed by previous research will be used, if available. If not, sampling of plants of the same species growing outside of the central data collection area of each plot may be used to develop equations.

Overstory fuels will be evaluated through variables including tree species, tree density, dbh, ladder fuel height, number of canopy layers, height to live crown, total height, and percent canopy closure. This information will be obtained from the data collected by the vegetation monitoring crew.

Fuel moisture measurements will be made on the day the burn treatments are applied. At least 10 samples of each of the key fuels will be collected throughout the plot and immediately put into watertight containers (one liter wide-mouth autoclavable Nalgene bottles) that can be placed directly into a drying oven. These fuels include the L, F, and H ground fuel layers (layers bagged separately), each size class of down and dead woody fuels (0-6mm, 6-25mm, 25-75mm, 75+mm), as well as live herbaceous (grasses, sedges, and forbs), shrubby, and foliar fuels. The fuels that show the greatest diurnal changes in moisture content (litter layer, 0-6mm, and 6-25mm down and dead woody fuels) will be collected as close to the time of burning as possible. Samples will be brought back to the lab, weighed, oven dried at 95°C until there is no more weight loss, and then re-weighed.

Weather data (ambient temperature, relative humidity, wind speed, and wind direction) will be collected, either with a nearby remote weather station or periodic manual measurements, prior to and during application of the burning treatments. During the prescribed burning operation, flame length will be measured using ocular estimates on the flame front. Rate of spread will be estimated by timing the movement of the flaming front to cover a known distance. Rate of spread will be estimated for both heading and backing fire fronts. Flame length and rate of spread data will be taken at regular intervals (i.e.

every 15 minutes), and as the fire passes selected grid points. Flaming and smoldering duration will be estimated, using ocular methods, at the same selected grid points.

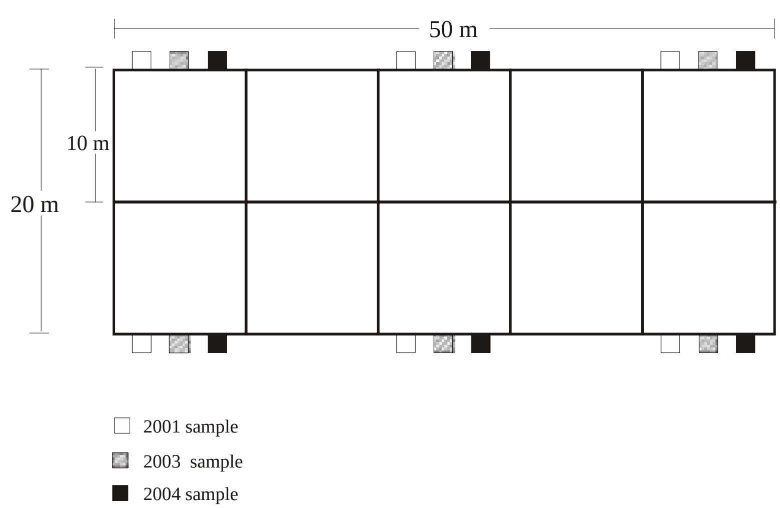
III. Soils and the Forest Floor

Evaluation of soil properties in relation to prescribed fire will be conducted by Phil Rundel (UCLA) and funded through a contract with the University of California. Soil organic matter and nutrient capital will be sampled according to FFS protocols. Soil and forest floor samples will be collected during the pretreatment year (2001), the immediate post treatment year (2003), and in the final year of the project (2004). Some additional samples will be collected in 2002 as well to evaluate N-mineralization and nitrification after the early season prescribed burn.

Soil C:N ratio and macronutrient content

In order to understand the role of litter dynamics in the nutrient cycling of the forest with and without prescribed fire, both litter and duff layers and underlying mineral soil will be collected and evaluated for C and N content. Mineral soil samples will also be sampled for macronutrient content. Six samples will be taken from each of the ten 0.1 ha (50m x 20m) vegetation sampling subplots per treatment unit. The 50m x 20m subplots are further divided into ten 10m x 10m sub-subplots. Forest floor and soil samples will be taken from the outer edge of the four corner sub-subplots and the two central sub-subplots (Figure 7). In each sampling year, collections will be made at a slightly different point along this edge. For example, in 2001, samples will be collected 2m from the subplot corner, in 2003, samples will be collected 3m from the subplot corner etc.). [Note: unless heterogeneity within plots is very high, soil samples may only be taken at three locations within each subplot – one each at two opposing corners, and one in the middle.]

Figure 7. Location of forest floor and soil sample collection points in relation to the 50m x 20m modified Whittaker vegetation plots



Forest floor samples will be collected using a litter frame of known area (i.e. 0.01m^2). Samples will be separated by horizons (litter and duff). Mineral soils will be sampled to a depth of 15cm, air dried for several days, and stored for nutrient analyses. We expect that the six forest floor samples and the six mineral soil samples collected from each vegetation plot will be combined (composited) into one or two total samples per type (forest floor vs. soil) for chemical analyses. A pilot analyses of at least 6-12 individual samples from each of at least three sample plots will be required to establish the degree of acceptable compositing. The standard error of the mean of the composited samples from a given sample plot shall not exceed 20% of the magnitude of the mean of those samples. If the standard error does exceed 20% of the magnitude of the mean, too much compositing has been done and more individual samples will be analyzed from each sample plot.

Subsamples of the composite forest floor samples and mineral soil samples will be analyzed for organic C content by the loss of ignition method (Nelson and Sommers 1982). If carbonates are present in the parent material, the Walkley-Black oxidation/titration method (Nelson and Sommers 1982) will be substituted. Subsamples of forest floor will also be digested in H_2SO_4:H_2O_2 and analyzed for total:N by colorimetry on a Lachat Autoanalyzer or similar automated N analyzer. Mineral soil samples will be extracted for Ca, Mg, and K with 1M NH_4OAC (Thomas 1982), for Al with 2M KCl, and for P with 0.01M $CaCl_2$ (Olsen and Sommers 1982). Cation exchange capacity analysis will be done by atomic absorption spectroscopy, and P analyses by stannous chloride/molybdate or ascorbic acid colorimetric methods (Olsen and Sommers 1982). Soil pH will be determined in a 1:5 w/v slurry.

A subset of the composite forest floor samples will also be analyzed for macronutrient content to determine the significance of the litter pool of macronutrients in the cycling of these elements with and without prescribed fire. Litter samples may also be collected under representative trees of each species and analyzed for nutrient content using the same methods as for mineral soils. Estimates of species composition and litter mass determined by the vegetation and fuels crews will then be used to calculate an estimate of the macronutrient content of the forest litter, in relation to macronutrient content of the mineral soils.

Little is currently understood about how patterns of forest structure are influenced by patterns of soil and litter nutrient availability and the scale of variation in these parameters. The sampling design will enable information to be gained about the spatial patterning of soil and litter nutrient distribution and whether fire acts to reduce or increase this variability. The protocols as written explore variation at several spatial scales: among experimental units (plots), among subplots within a plot, and within subplot. If a large amount of variability is noted among soil and litter collections at even the within subplot scale, some additional sampling will be conducted in a nested fashion within these subplots to determine the scale at which soil sample nutrient composition becomes relatively homogeneous. The overall sampling regime may be modified somewhat, depending upon scales at which variability is found.

N-mineralization and nitrification

In situ incubations for measuring N mineralization and nitrification will be conducted in order to evaluate the impact of season of burning on the short-term dynamics of nutrient cycling. Spring and fall burns are both expected to provide significant ashfall, which is rapidly mineralized. The dynamics of nitrogen cycling following early season burns is, however, likely to be very different than the dynamics of nitrogen cycling following late season burns. Late season burns followed by low winter temperatures allow for a buildup of ammonium with only a slow transfer of this inorganic nitrogen to nitrate through nitrification. The process of nitrification is expected to be faster following early season burns, due to warmer temperatures.

Analysis of nutrient availability (i.e. N mineralization and nitrification) will be done for four samples per 50m x 20m subplot at approximately two week intervals for several months following the burn. After each burn (scheduled for late season 2001 and early season 2002, N mineralization and nitrification will be evaluated in the three burned plots as well as the three control plots. Soil samples will be taken from the corners of the plots, and separated into two subsamples. One subsample will be placed into a polyethylene bag and returned to the hole that the sample came from and the other subsample will be taken to the laboratory for immediate extraction with 2M KCl and subsequent analysis of NH_4 and NO_3 concentration by automated colorimetry (Keeney and Nelson 1982). After 20-30 days, the samples that remain *in situ* in the polyethylene bags will be recovered and extracted for inorganic N using the same methods. The four incubated samples will be composited and the four non-incubated samples per plot will also be composited prior to laboratory testing to reduce the number of analyses. Thus, 180 samples will be analyzed both prior and after application of treatments (360 samples total). Net N mineralization is calculated as the difference in total inorganic N (NH_4+NO_3) between the initial samples and those incubated *in situ* for 20-30 days. Net nitrification is calculated as the difference between NO_3 in the initial samples and the incubated samples. Proportional nitrification is calculated as the net difference in NO_3 concentration between the initial and incubated samples divided by the total NH_4 available for nitrification (i.e. initial NH_4 + net N mineralization). Eno (1960) should be consulted for basic design issues for this method, and Plymale et al. (1987) and Boerner et al. (2000) for examples. [Note: number of days of incubation, sampling depth, and bag thickness will be similar to that used at other sites, for increased consistency.]

Soil biodiversity assessment

Activity of four groups of soil enzymes will be used to assess soil biodiversity. Soil enzyme activity can be linked to soil processes such as N-mineralization as well as the quantity and quality of soil organic matter (Decker et al. 1999). Biodiversity assessments will be conducted twice - during the pretreatment year and in either 2003 or 2004, and will ideally be done on the same samples used to evaluate nutrient availability.

Soil samples will be collected in late summer from three positions within each 50m x 20m subplot (two opposite corners and one in the middle). Using a sterile soil corer, approximately 150g of soil will be extracted to a depth of 15cm. The corer will be sterilized between samples with 50% ethanol. All samples will be brought to the laboratory under refrigeration and will be kept refrigerated until analyzed for enzyme activity.

The laboratory methods, taken directly from Boerner et al. 2000, are as follows:
Approximately 5 grams of fresh soil from each sample will be diluted with 120ml of 50 mM NaOAc buffer (pH 5.0) and homogenized by rapid stirring for 90 seconds. To minimize sand sedimentation, stirring will be continued while aliquots are withdrawn for analysis. For each of the enzymes, four analytical replicates of each sample using 2.0 ml of soil slurry and 2.0 ml of enzyme substrate for each analytical replicate will be analyzed. In addition, soil-free blanks consisting of 2.0 ml of buffer and 2.0 ml of enzyme substrate will be analyzed to correct for non-enzymatic hydrolysis of substrates.

Acid phosphatase (EC 3.1.3.1.), b-glucosidase (EC 3.2.1.21), and chitinase (EC 3.2.1.14) activities will be assayed using p-nitrophenol (pNP) linked substrates: pNP-phosphate for phosphatase, pNP-glucopyranoside for b-glucosidase, and pNP-glucosaminide for chitinase. Acid phosphatase and b-glucosidase samples will be incubated for 1 h and chitinase samples will be incubated for 2 h, both at 20C with constant mixing on a platelet mixer. [Note: the b-glucosidase analyses may not be conducted, as they have not proven useful at other sites (Boerner, personal communication.] Following incubation, samples will be centrifuged to remove soil particles, and 0.1 ml of 1.0 M NaOH will be added to the soil-free supernatant to halt enzymatic activity and facilitate color development. Prior to spectrophotometric analysis the sample will be diluted with 8.0 ml of distilled, deionized water. Phenol oxidase (EC 1.14.18.1 and 1.10.3.2) activity will be measured by oxidation of L-DOPA (L-3,4-dihydroxyphenylalanine) following 1hr of incubation at 20C. Parallel oxidations utilizing standard Horseradish Peroxidase (Sigma Chemical) will be used to calculate the L-DOPA extinction coefficient. Absorbance will be determined spectrophotometrically at 410 nm for the pNP assays and 460 nm for phenol oxidase. To minimize errors due to hydrolysis of the pNP-linked substrates by the NaOH, all absorbances will be determined within 30 minutes after the addition of NaOH. All enzyme analyses follow methods described by Sinsabaugh et al. (1993) and Sinsabaugh and Findlay (1995).

Abundance and diversity of soil microarthropods will be evaluated on a limited scale as a secondary soil biodiversity measure. One soil sample will be collected per 50m x 20m subplot using an approximately 10cm diameter soil corer. Soil will be sampled to a depth of 10cm. The Berlese funnel method will be used to extract soil microarthropods. Organisms will be identified to genus and morphological types. [Note: Data will be collected by the entomology field crew.]

Mineral Soil Area

Each vegetation sample plot will be searched every spring for areas of exposed mineral soil >30 cm^2 in area. Area of each exposure will be measured and position recorded for later re-survey. If feasible, each exposure should be marked for re-survey on a biannual basis.

Additional variables:

Erosion

Resource managers at Sequoia are interested in impact of prescribed fire on soil erosion rates. Preliminary estimation of erosion rates using existing rebar markers placed in plots will be explored, by measuring the height of rebar markers above ground in each year. Measurements will be related to microtopography (whether higher, lower, or equal to immediate surrounding soil elevation) to evaluate whether erosion should be measured as loss or deposition of soil around a rebar marker. Sediment collection pans may also be placed within several minor run-off channels as similar in size and on as similar slopes as possible, and amount of sediment collected after the end of spring snowmelt determined.

IV. Wildlife

(Modified from Zack et al. 2000)

Understanding the effect of season of burning on wildlife is key to developing ecologically sound fire prescriptions. Evaluation of abundance, diversity, and habitat use of birds, small mammals, and herpetofauna will be conducted by a wildlife crew under the direction of Steve Zack and Kerry Farris, and work will be funded by a purchase order agreement. Data will be collected in each year of the study (2001-2004).

A. Birds

Diversity and abundance of birds in the study will be assessed through the use of point count censuses. Nest productivity (number of young fledged per nest initiated) of nesting birds will be monitored in a subset of sites. Finally, the functional response of foraging woodpeckers and other bark-gleaners will be evaluated.

Diversity and abundance

Point counts are a standardized method (Ralph et al. (1993)) of assessing the diversity and abundance of birds by counting (detected by hearing and by sight) at points. Wildlife teams will assess birds at predetermined marked gridpoints every 200 m, with 50-m radii of detection. The target number of gridpoints surveyed within each plot will be four to five, but may be less, depending on the shape of the plot. Each site (the three replicates of control, early season burn, and late season burn) will be assessed a minimum of three times (up to six) during the two-month spring-summer breeding season. At each point, the count (beginning at first light) will last five minutes exactly. Observers will wait 2-4 minutes at each point before counting. All individuals of all species detected will be counted, and birds seen first will be distinguished from birds heard first. Horizontal distance of the bird relative to the survey point will be recorded for distances up to 100m away. Birds observed closer than 50m will be recorded in one column of the data sheet, and birds observed between 50-100m away will be recorded in a second column. A complete replicate count of all units will be completed before the second replicate of any unit is done. A random number table will be used to determine the sequence of units sampled within each replicate. Subsequent replicates of a particular unit will take place 7-10 days after the last count. Bird species will be recorded on data sheets using standardized four letter codes (see http://www.pwrc.usgs.gov/bbl/manual/aspeclst.htm or Pyle (1997)). The main output of this method will be an assessment of the kind (diversity) and number (abundance) of birds detected as a function of controls and treatments.

Nest productivity

Nest productivity (production of young/nest of a given species) will be assessed by standardized methods (Martin and Geupel (1993); Ralph et al. (1993)), using the BBIRD (Breeding Biology Research and Monitoring Database) protocol (http://pica.wru/umt.edu/BBIRD/protocol/protocol.htm). Wildlife crews will randomly assign two replicates of each treatment (including controls) to be searched. When a nest is found, flagging will be placed nearby (10-15 m away) to indicate the species and nest number. A drawing of nest location will be made and data collected, following the BBIRD protocol. Nest sites will later be visited (after fledging or failing) to measure some simple vegetation variables (to be decided). Data will also be collected for cavity nesting birds in snags, although information on egg number and fledgling number may not be obtainable. The data will be analyzed in terms of overall productivity, and analyzed by categories (cavity vs. cup-nesters vs. ground nesters) and by species.

Resource managers at Sequoia National Park are interested in understanding the impact of prescribed fire on ground nesting birds. Therefore nest productivity surveys will be conducted in the spring burn and control plots in the spring and summer of 2002, immediately prior to and after application of the burning treatments (in addition to the full bird survey protocols carried out in 2001, 2003, and 2004).

Functional Response

Emphasis in this portion of the work will be on "bark gleaners" (Paridae: genera *Baeolophus* (titmice) and *Poecile* (Chickadees), Sittidae: *Sitta* (Nuthatches), Certhiidae: *Certhia americana* (Brown Creeper), and "bark probers", the woodpeckers (Picidae: all genera). Evaluating the "functional" response of woodpeckers and other bark-gleaning birds means observing their foraging patterns on trees at each site. Methods modified from Weikel and Hayes (1999), which emphasizes tree condition (including "risk rating"), dbh, and a measure of fire-scarring, will be used. Two one-hour observation sessions will be conducted in each plot six times during the field season (12 total hours per plot). Observations will be made while walking the plot systematically along the grid points, with a different route walked each sampling time. Data will only be collected for birds clearly foraging (not singing, cavity drilling etc.) in trees. To avoid biasing the recording of conspicuous behaviors, observers will wait 10 seconds upon locating a foraging individual before recording any behavior. In order to address concerns about statistical independence of samples, sequential observations will be made on the same species only if the observations are at least 200 meters apart. In addition, a maximum of three observations of any one species will be made per plot on a given day. Because woodpeckers forage on larval bark beetles and other insects infecting tree tissue, and ultimately create cavities essential for several taxa of wildlife, the response of woodpeckers to the proposed treatments will be emphasized. When many bark gleaning and probing species are present, woodpeckers will be chosen first. Behaviors noted will be gleaning, probing, pecking, scaling, and excavating. Additional species (non-bark gleaners) may be sampled if bark gleaner densities are very low, but bark gleaning species will always be sampled when detected.

Microhabitat measurements will be made near each nest and each woodpecker or bark-gleaner tree chosen for foraging. Data will be taken on vertical strata, horizontal strata, fire effects, percent of tree containing bark, and presence of beetles. These data will be correlated with the plot data taken by the vegetation team so that both teams can collect data in a compatible manner. All of the foraging and microhabitat observations will be referenced to the nearest grid point. After a bird foraging observation, a random number table will be used (two numbers: one for compass direction, another for meters distant*) to find tree of same category (conifer, deciduous, snag), taking the same microhabitat data as done for trees chosen by foraging birds.

(*- use numbers to designate N, S, E or W; distance should be < 50 m)

Woodpecker – Bark Beetle interactions

Woodpecker activity will be surveyed on a portion of trees determined by the entomology crew to be dead or in decline due to bark beetles. These data will be collected late in the field season, after the entomology crew has surveyed plots for bark beetle activity. First, one plot will be randomly selected per treatment. At every other gridpoint, two trees will be randomly selected from among the infected trees identified (36 trees per plot, 108 trees total). The wildlife team will interact on a regular basis with the entomology team in order to match the status of infected trees (time since infection, source of infection) with woodpecker foraging patterns and drilling patterns. This will allow tree mortality to be correlated with onset of cavity excavation. For woodpeckers and the other bark-gleaners the wildlife team will record the tag number of the individual trees (on metal tags installed on trees by the vegetation crew) identified during foraging observations in order to correlate bird utilization patterns with tree characteristics. Woodpecker abundance and activity will be noted on these trees, using the same methods as proposed for the overall plot survey.

Data collection for woodpecker activity will be recorded within a “plot” placed on the bole of sampled snag or tree. Upon locating the sample snag or tree, the diameter at breast height (the diameter measured at 1.37 meters from the base) will be measured and recorded. Using this value as the width, a 1.0m long rectangle will be created on the north side of the snag centered at breast-height level. Four nails will be used to mark the corners and twine will be wrapped around the nails to mark the perimeter. Within this rectangle, the data will be collected for variables listed on the accompanying data sheet. Detailed descriptions of the woodpecker and beetle variables are listed below, and abbreviated definitions for the complete list of variables can be found on the sample data sheet.

Definitions:

Woodpecker Excavating: Woodpeckers foraging for subsurface bark and wood boring insects leave evidence of their activity in the form of holes punctured in the bark. These range in size from 0.5 to 6.0+ cm. They usually penetrate the bark down to the sapwood, but often times are superficial wounds. All woodpecker sign should be counted.

Woodpecker Scaling: Woodpeckers often “scale” the bark in small areas, creating patches of foraging which can be difficult to quantify by counting individual “hits” or holes. In this case, you should estimate the proportion of area within the rectangle, which has been “scaled”.

Dendroctonus Exit Holes: These symmetrical round holes measure between 2-3 millimeters in diameter.

Buprestid Exit Holes: These oblong shaped holes measure between 3-6 millimeters (measured on the longest side).

Cerambycid Exit Holes: These symmetrical round holes are similar to Dendroctonus holes, but are larger, usually measuring between 3-6 millimeters in diameter.

B. Small mammals

Sampling of ground dwelling small mammals will be conducted by trapping within the 6X6 grid. Both Sherman XLK and Tomahawk #201 traps will be used, but set up at different spacing. Tomahawk traps will be placed on the 50m grid, referenced to the nearest grid point, but placed away from the gridpoints themselves (36 total traps per plot). Sherman traps will be placed on a 25m grid, utilizing the central 4 x 4 of the 50m grid and adding extra traps in between (49 total traps per plot). Duff, bark and other natural features will be used to shade and insulate traps. All traps will be closed when not in use.

Standard baits will be used for the Sherman and Tomahawk traps. However, some adjustments may have to be made to make baits less attractive to bears, as bears have tampered with and destroyed traps during previous small mammal experiments conducted in this area.

Two plots will be sampled at a time. The order of walking the trap grid will be reversed every other day. Captured small mammals will be weighed and individually marked with ear tags or by clipping fur in particular patterns.

Traps will be inspected morning and night for approximately 10 day/night periods at each experimental area. [Fewer trap day/ night periods may be required if the number of recaptures levels out in fewer than 10 days.] This inspection interval will reduce mortality. It will also ensure that traps are available in both daylight and night hours, thereby affording the greatest potential for capturing specimens of all species present. Trapping will be completed within an approximately one-month period after the juvenile mammals appear.

For the more abundant taxa, estimates of absolute abundance or, at a minimum, relative abundance will be developed. For less abundant taxa, presence vs. absence information may be the most quantitative analysis possible. Taxa will be aggregated as appropriate to develop analyses of population differences among functional groups.

Microhabitat measurements will be made near each trap setting (Sherman + Tomahawk trap). The wildlife team will interact with the vegetation team to obtain data on microhabitat variables associated with wildlife use. These variables (e.g., tree density, shrub and herbaceous cover, volume of coarse woody debris) will be correlated with wildlife abundance on a per site basis.

C. Herpetofauna

Because of an increasing interest on the effect of season of prescribed burning on amphibian populations, both at Sequoia NP and throughout forested lands of the western U.S. (see Russell et al. 1999), we may devote more effort to this aspect of the study at this site than is being proposed at several other network sites.

Pitfall traps will be installed at each grid-point. Size of pitfall traps will be determined based on discussions with amphibian experts and park archeologists. When possible, pitfall traps will be kept dry in order to reduce mortality of small mammals and herpetofauna. We will also explore placing a piece of string from the bottom to one edge of each pitfall trap, to allow small mammals a means of escaping.

Minimal activity by terrestrial salamanders is expected during the summer due to extended periods of dry weather typical for the southern Sierra Nevada. Trapping using pitfall traps will therefore be done in the spring after snowmelt, and later in the season, after the first fall rains. Pitfall traps will be kept covered during the summer field season so as not to interfere with small mammal trapping.

If a pilot amphibian sampling method evaluation this spring using one foot square cover boards is shown provide adequate capture rates, we will sample terrestrial salamander populations using this method in addition to pitfall traps. Cover boards will be placed near every other grid point. These cover boards will be kept in place as long as possible prior to and after application of the burning treatments. At the time of sampling, boards will be lifted and the number and species of amphibians recorded. Due to timing, much of the herpetofauna sampling may not be conducted by the FFS wildlife crew, but may be completed by other FFS research staff in collaboration with wildlife biologists at Sequoia National Park.

Table 1. Outline of Wildlife Methods

Measurement	Season	Scale	Effort	"Output"
Bird Point Counts	May-August	Every 200 m	All plots 6 repeat visits	Density and diversity
Bird Nest Productivity	May-August	Where found on sampled plots	2 plots each treatment (= 8 plots total)	Young/nest per nesting species
Bird "Functional Response"	May-August	Sampling foraging "bark gleaners"	2 plots each treatment (= 8 plots total)	Foraging response to "treated" trees
Mammal Capture-Recapture	May-August Pre- and Post-Treatment	6X6 grid, 50 m apart, Sherman trap and Tomahawk trap at each grid point	All plots, sampled one time/yr (10day-night periods)	Density and diversity (productivity?)
Herpetofauna Pitfall Trapping	April/May and October/November Pre- and Post-Treatment	Pitfall trap at every gridpoint in a 6X6 grid array (above)	All plots, sampled one time/yr (10day-night periods)	Density (?) and diversity

V. Pathology and Entomology

Pathogens and invertebrates are key elements in the forest ecosystem, influencing patterns of mortality and decomposition. Fire can affect the soil fungal community and forest pathogens in a number of ways, ranging from direct effects on inoculum density, inoculum viability, and wound/fire scar infection to indirect effects such as influences on stand composition, vigor, changes in soil microbial communities, and changes in woody debris and litter accumulation. Bark beetles preferentially attack trees weakened or killed by fire, and/or pathogens. Woodpeckers and other bark gleaning birds in turn forage for bark beetles on infected trees. Thus, the data collection for pathology and entomology related variables would be closely tied to data collection by the wildlife and vegetation teams.

The following variables will be addressed: Assessment of root disease incidence and impact on tree mortality prior to and after fire, dwarf mistletoe incidence, patterns and magnitude of tree mortality resulting from bark beetles prior to and after a fire (by insect and tree species), interactions between bark beetle activity and cavity dependent wildlife species, and the abundance and diversity of entomofauna that utilize down coarse woody debris. Data will be collected during the pretreatment year (2001) and in two years after treatments have been applied (2003, and 2004).

Protocols

An initial survey of all treatment plots will be conducted in order to mark trees that have pre-existing symptoms so as not to confuse these with subsequent treatment effects. The entire 10 hectare sampling area within each treatment plot will be surveyed for trees with a dbh of greater than 10cm with symptoms of pathogen infection or insect attack. At each successive grid point an 180^o scan will be conducted for trees that are clearly in decline or devoid of needles. As such trees are found, the direction and distance from the grid point will be determined. This will allow data to be spatial referenced for GIS analysis. Observations will consist largely of aboveground crown symptoms based upon a rating scale developed by the Institute of Tree Root Biology. Five symptom classes will be recognized for live trees, ranging from healthy to moribund. Determinants involved in these crown symptom classes are based on foliar color, needle/leaf size, and internode length, with color being the primary character defining symptomatic trees. The crown symptom classes are:

0 = healthy
1 = green, slight thinning
2 = mostly green, slight yellowing, shortened internodes
3 = pronounced yellow-green color, shortened needles and/ or internodes
4 = at least 50% of crown yellow/yellow-brown, 10% of needles green

Dead trees will be scored as a sixth category (5 on the data sheet).

Symptoms for different classes may need to be adjusted depending upon the pathogen and host species. Such adjustments will be made in the field with assistance from qualified experts, after viewing trees in each plot.

Distance and direction to the nearest grid point will be measured in order to develop a map of symptomatic trees. Symptomatic trees will be tagged with fire-resistant metal tags that are numbered sequentially. Tags will be attached to trees via an aluminum nail and will be placed in a consistent direction at a consistent height, to aid in relocation.

Data collection on all symptomatic, putative root diseased trees will consist of recording the above mentioned crown symptoms, dbh, crown position, and signs of other distress agents (such as bark beetle pitch tubes, exit holes, etc.). A preliminary assessment of cause of death will be made based on spatial pattern of infection/ incidence and other visual cues. Bark beetles often attack and kill clusters of trees at the same time, while mortality within clusters of trees caused by root diseases typically occurs over a period of years (oldest deaths at the center, dying trees as the periphery), due to the slower movement of the pathogen (D. Rizzo, personal communication). A single agent rarely causes tree mortality; bark beetles frequently kill trees weakened by pathogens or abiotic stress factors such as competition or drought. Due to this complexity, precise evaluation of cause of mortality may not be possible.

Root diseases

Root disease infection will be tested on approximately 20% of symptomatic trees, unless the number of dead and dying trees is too high to make this sampling intensity practical. Pre-treatment data collection for pathology involves woody root samples taken from symptomatic trees via careful excavation of lateral roots that are near the soil surface. A minimally invasive procedure will be used that involves the sampling of intact root tissue by means of an increment hammer or increment borer. Such minimally invasive procedures are necessary, because wounding can lead to insect attraction, which in turn may confound results. Root samples will also not be taken from identified symptomatic trees until the insect flight season has passed (late fall).

Several samples of wood per root will be obtained by coring the excavated (or exposed) root from the root collar to approximately one-meter distally along the root. At least two such woody roots having a minimum diameter of approximately five cm will be sampled per symptomatic tree. The increment hammer or borer will be sterilized with 95% ethanol between each root sampling. Roots from a few (two to three) healthy, asymptomatic, randomly selected trees in each treatment plot will also be sampled. These trees will also be labeled with numbered tags. While it is necessary to tag all symptomatic trees during the sampling of each treatment plot, root samples from all these trees are not necessary, particularly if there are large numbers of symptomatic trees in a plot or the disease can be readily identified by symptom characteristics.

Extracted cores will be put into plastic straws, sealed in labeled zip-lock bag, and stored in ice chests or refrigerators until they can be transferred to a laboratory. Pathogen isolations from these root samples will be conducted according to standard lab techniques using media specified by the Institute of Tree Root Biology (TRB).

After light surface disinfection with a 10% chlorox solution (rinsed with sterile distilled water), cores will be cut into 1mm thick cross sections. Five to six cross sections from each core will be placed in different agar media for specific pathogens. If multiple roots are cored per tree, these may be placed on the same plate, but kept separate. Plates will be sealed with parafilm and incubated at room temperature. After at least 10 days, plates will be visually inspected for fungal colonies growing from each chip or cross section. Plates will be periodically visually inspected after continued incubation to detect slower growing fungi.

Post treatment sampling will be similarly conducted. Newly symptomatic trees will be tagged, noted, and root samples taken and analyzed as above. Few changes in disease incidence may be evident among treatments within the relatively short temporal scale of this study. It is expected that forest thinning will eventually reduce the incidence of tree root diseases, but changes may only be apparent over decades (D. Rizzo, personal communication). Details of a contract to enable personnel from the laboratory of Dr. Dave Rizzo (Dept. of Plant Pathology, UC Davis) to assist in field identification of foliar symptoms of root disease, and to culture and identify the root diseases found within the study site are being worked out.

A list of pathogens found at Teakettle experimental forest, a Sierra Nevada mixed conifer site approximately 30 miles northwest of our plots, has been compiled by Dave Rizzo (UC Davis). Similar pathogens are expected to occur at Sequoia NP. These include:

Host	Pest
Abies concolor (white fir)	*Arceuthobium abietinum* f. sp. *concoloris* (dwarf mistletoe) [ab] *Melamsporella caryophyllacearum* (broom rust) [b] *Heterobasidion annosum* (root disease)[ab] *Phaeolus schweinitzii* (root disease)[ab] *Echinodontium tinctorium* (trunk rot)[b]
Abies magnifica (red fir)	*Arceuthobium abietinum* f. sp. *magnificae* (dwarf mistletoe) [ab] *Melamsporella caryophyllacearum* (broom rust) [b] *Heterobasidion annosum* [ab] *Echinodontium tinctorium* [b]
Calocedrus decurrens (incense cedar)	*Phoradendron juniperinum* subsp. *libocedri* (true mistletoe) [b] *Gymnosporangium libocedri* (broom rust) [b] *Oligoporus amarus* (trunk rot)[b]
Pinus jeffreyi (Jeffrey pine)	*Arceuthobium campylopodum* (dwarf mistletoe) [ab] *Elytroderma deformans* (needle cast) [b]
Pinus lambertiana (sugar pine)	*Cronartium ribicola* (white pine blister rust) [a]

[a] major cause of mortality
[b] primarily cause of growth loss; may cause mortality under certain conditions

One additional tree species found in our study plots is giant sequoia. This species can be infected by the fir type of *H. annosum*. (Harrington et al 1989, Otrosina 1992?). A pine type *H. annosum*, which infects pines and incense cedar, may also be present. Two other diseases to look for include black stain root disease (*Leptographium wageneri*) and *Armillaria* sp. The former affects ponderosa and jeffrey pines. The latter is most commonly found on oaks and thus may not be found in our plots.

Dwarf Mistletoe

Dwarf mistletoe infection will be evaluated on individual trees using the Hawksworth six-point scale (Hawksworth 1977). The stacked live crown of each tree will be divided into equal thirds, and each third will be assigned a mistletoe rating of 0, 1, or 2.

0 = no visible branch infections
1 = less than one half of branches infected
2 = greater than one half of branches infected, or a large broom as the dominant feature in that third.

For a single tree, the minimum score is 0, and the maximum score is 6.

Mistletoe infection may be subsampled, depending on the density of infected trees. One option may be to evaluate mistletoe on trees within the ten 50m x 20m plots within each treatment unit. If this is the case, scoring will be conducted by the vegetation team at the time of vegetation sampling.

Bark beetles

Data on bark beetle species and abundance will be collected on all labeled symptomatic trees. Bark beetle galleries will be exposed by removing a piece of bark in the vicinity of pitch tubes or boring frass. Species will be identified by the host species attacked, characteristic gallery patterns, presence and appearance of pitch tubes, presence and color of boring frass, presence and number of gallery ventilation holes, and by living and dead adults that may be present in the galleries. Bark beetle attacks will be rated as successful (brood production, tree killed), or unsuccessful (no brood production, tree not killed). Response variables to detect treatment effects will include percent mortality/tree species/bark beetle species/year, percent of mortality represented by group kills, mean number of trees per group kill, distribution of mortality by diameter class/bark beetle species, incidence (percentage) of bark beetle attacked trees also attacked by secondary insects, percent of tree mortality caused by secondary insects acting alone, and DBH distribution of tree mortality caused by secondary insects.

A list of insect pests found at Teakettle experimental forest, a Sierra Nevada mixed conifer site approximately 80 miles north of Sequoia NP, has been compiled by Dave Rizzo (UC Davis). Similar insects are expected to occur at Sequoia NP. These include:

Host	Pest
Abies concolor (white fir)	*Scolytus ventralis* (fir engraver beetle) [ab] *Orygia pseudotsgata* (Douglas fir- tussock moth) [b]
Abies magnifica (red fir)	*Scolytus ventralis* [ab] *Orygia pseudotsgata* [b]
Calocedrus decurrens (incense cedar)	no major insects
Pinus jeffreyi (Jeffrey pine)	*Dendroctonus jeffreyi* (bark beetle) [a] *Dendroctonus valens* (red turpentine beetle)[b] *Ips* spp. (pine engraver beetles)[b]
Pinus lambertiana (sugar pine)	*Dendroctonus ponderosae (mountain pine beetle)* [a] *Dendroctonus valens* [b] *Ips* spp. [b]

[a] major cause of mortality
[b] primarily cause of growth loss; may cause mortality under certain conditions

On ponderosa pines, we expect to find the mountain pine beetle (*D. ponderosae*), the red turpentine beetle (*D. valens*) and *Ips* sp.

Course Woody Debris

The value of course woody debris as habitat for vertebrate and invertebrate fauna will be determined by examining the amount present in each plot, and data will be collected by the fuels monitoring team (described in fuels protocols). The entomology team will collect data on diversity and abundance of ground macroinvertebrates. Ground macroinvertebrates will be sampled during late summer of each year using pitfall traps installed at every gridpoint. These same pitfall traps will be used to sample for terrestrial amphibian populations in the spring after snowmelt, and in the fall, after the first rains. To reduce the impact of pitfall trapping on small mammal data collection, pitfall traps will be covered with a piece of wood when small mammal trapping is in progress and anytime the traps are not in use. We will also explore placing a piece of string from the bottom to one edge of each pitfall trap, to allow small mammals a means of escaping. Pitfall trapping will be conducted for a period of several weeks and traps will be checked once a day. Ground macroinvertebrates will be identified to species or morphological types and diversity and abundance calculated.

VI. Economics: Treatment Costs

Economic costs and benefits are associated with reducing fuel loading, whether this reduction is attained through uncontrolled wildfires, prescribed natural fire, prescribed burning, mechanical removals of coarse fuels, or some other means. Since treatments at the Sequoia National Park site consist only of early and late season prescribed fire, the treatment cost aspect of the study will be substantially scaled back in comparison to other sites where both prescribed fire and mechanical thinning treatments will be applied. The costs associated with prescribed fire treatments may differ with the season of burning due to variation in fire intensity and fire duration. Estimates of burning costs will use an “expert opinion” methodology. Analysis will be based on information provided by individuals knowledgeable about burning under local conditions on similar plots of land with units sized and staffed for operational treatments, and supplemented by a compilation of actual number of person hours, supplies, and equipment required. This information will be related to the treatment units.

The expertise of fire management specialists at Sequoia National Park may be useful for extrapolating costs associated with prescribed burning to the landscape scale. With an active prescribed fire program, prescribed fire at Sequoia National Park is being applied at a range of scales; however, the typical treatment unit is often much larger than the plot size for the FFS study. Comparison of costs across scales may permit a better understanding of the relationship between cost and treatment area to be developed. Such information may prove to be useful for all sites in the FFS network.

Quality assurance and quality control procedures

Data collection at the Sequoia National Park site will generally follow the protocols outlined in the national FFS proposal. Any modifications have been made in consultation with experts in the respective fields of data collection. Protocols described in this study plan are consistent with the best available and scientifically accepted methods.

Prior to data collection, all seasonal personnel will be trained in methods outlined in the study plan. Data collection will initially be closely supervised. For any variable where visual estimates are made (i.e. percent cover of vegetation), scoring will be checked among field crewmembers to ensure consistency. Randomly selected plots may occasionally be resampled for the same purpose. For laboratory analyses (i.e. soils), blanks or samples with known concentration will be included for calibration.

Data will be collected in written form on data sheets. Organization of data sheets will be coordinated in the field by the vegetation crew leader. The names of individuals collecting data will be noted on all data sheets so that discrepancies can be addressed efficiently. Data sheets will be copied every evening upon return to the office, and spare copies archived in several different safe locations. Data will also be input into Microsoft Excel spreadsheets, in a manor consistent with the developing database for the national study, within the week of collection. Accuracy of data input will be verified by comparison to the raw data sheets and any discrepancies corrected. Electronic data will be backed up frequently, and stored on disks as well as on a local network. A copy of data collected by contractors will be stored, and input into an electronic format as soon as obtained.

All statistical analysis, reports, and articles resulting from this study will be peer reviewed to assure that data collection and presentation have been conducted to the highest professional standards.

Communication plan: Application of research results

Data collected through the FFS study at the Sequoia NP site will have broad applicability to resource management professionals both within the park and throughout forested landscapes of the western United States. Communication tools will be developed to target these different audiences.

Within Sequoia and Kings Canyon National Parks

One of the most effective means of disseminating information about the study is through regular meetings with park resource management professionals. Meetings during the planning phases have been very productive, allowing a two-way transfer of expertise and ideas between resource managers and the research team. The proposed research outlined in the study plan is, as a result, weighted towards issues of greatest interest to Park, while also fully coordinated with data collection at the other network sites. Resource managers in the park are enthusiastic about contributing to and benefiting from this project.

A MS PowerPoint slide presentation will be developed, using the national network presentation as well as site-specific images, in order to introduce Park personnel to the FFS project. This slide presentation will be targeted to audiences including resource managers, interpretive programs, and the general public. As data become available, findings will be included in this slide presentation. The study objectives and results will also be described in written brochures and report summaries. All data collected will be added (in summary form) into the park database.

The proximity of our plots to roads in the vicinity of major tourist attractions at Sequoia National Park presents uncommon opportunities for transfer of information to the general public. Nearly 1.4 million people visited Sequoia and Kings Canyon National Parks in 2000. We plan to work with the park visitor interpretive program personnel to potentially develop interpretive exhibits and programs about the FFS study. Offices and labs of key researchers and contributors to the FFS study at Sequoia NP are located within the park in close proximity to the study plots, which will additionally facilitate information exchange.

Outside Sequoia and Kings Canyon National Parks

The network structure of the FFS study will facilitate transfer and comparison of information among sites, allowing sharing of information and the development of generalizations with applicability across a broader range of environments and sites. We will participate in the proposed yearly or more often meetings and workshops. We could also potentially host one of these meetings, if desired by the FFS network.

We have been and will continue to develop collaborative relationships with resource managers and scientists interested in collecting additional data from our plots to address questions beyond the scope of the national effort. So far one graduate student will study effect of season of burning on small mammal populations and another graduate student plans to evaluate patterns of herbaceous understory vegetation in relation to fire, both within the FFS plots. Another study utilizing vegetation data collected within the plots before and after fire to model potential effects on forest carnivores at larger scales is being developed.

Results will be presented at scientific meetings, particularly meetings attended by resource management professionals. Results will also be published in refereed scientific journal articles targeted to different audiences. Collaboration with other researchers, faculty, and graduate students will result in additional publications. Informational workshops and tours, for technology transfer to professionals and for the education of students and the public, will be developed in the final two years of the study, after prescribed fire treatments have been applied. The FFS network will provide a unique integrated set of experimental studies whose value may increase with time. The sound, common experimental design, together with a geo-referenced database of many layers of interdisciplinary, interrelated data, should attract the participation of a variety of future scientists and managers. Once the study is established and productive, these same factors also should attract funding from a variety of sources, thereby multiplying the early investment by the JFSP.

Safety and Health

Personnel involved in this study will be exposed to hazards typical of forested and laboratory environments. Safety precautions will be addressed through periodic safety training and crew meetings, led by the field crew leader and the site manager prior to data collection. Field crews will be divided up so that at least some members of each crew have had first aid training. All crews working independently will carry radios in the field.

Hantavirus is a concern in the Sierra Nevada. All personnel handling small mammals will wear gloves and respirators, and will carry solutions in spray bottles to disinfect traps and other items.

Application of prescribed fire treatments will be conducted by certified fire crews. Any personnel from our data collection crews that monitor fire variables will first obtain basic fire training (I-100, S-130, S-190, pack test).

Literature Cited

Agee, J. K., and H. H. Biswell. 1969. Seedling survival in a giant sequoia forest. California Agriculture 23:18-19.

Agee, J. K. 1979. The influence of prescribed fires on water-repellency of mixed-conifer forest floor. In Proceedings of the first conference on scientific research in the national parks. R. Linn (ed), USDI National Park Service Transmissions and Proceedings. Series #5, Washington D.C. Volume 2:695-701.

Agee, J. K. R. H. Wakimoto, and H. H. Biswell. 1977. Fire and Fuel dynamics of Sierra Nevada conifers. Forest Ecology and Management 1:255-265.

Bock, C. E., and J. A. Lynch. 1970. Breeding bird populations of burned and unburned conifer forest in the Sierra Nevada. The Condor 72:182-189.

Boerner, R.E.J., K.L.M. Decker, and E. Kennedy Sutherland. 2000. Prescribed burning effects on soil enzyme activity in a southern Ohio hardwood forest: a landscape scale analysis. Soil Biology and Biochemistry 32:899-968.

Boerner, R.E.J., E. Kennedy Sutherland, S. Jeakins Morris, and T.F. Hutchinson. 2000. Spatial variations in the effect of prescribed fire on N dynamics in a forested landscape. Landscape Ecology 15:425-439.

Bonnicksen, T. M. and E. P. Stone. 1982. Reconstruction of a presettlement giant sequoia-mixed conifer forest community using the aggregation approach. Ecology 63: 1134-1148.

Caprio, A.C., and T.W. Swetnam. 1993. Historic fire regimes along an elevational gradient on the west slope of the Sierra Nevada, California. USDA Forest Service GTR INT-320. pp. 173-179.

Chorover, J., P. M. Vitousek, D. A. Everson, A. M. Esperanza, and D. Turner. 1994. Solution chemistry profiles of mixed-conifer forests before and after fire. Biogeochemistry 26:115-144.

Decker, K. L. M., R. E. J. Boerner, and S. J. Morris. 1999. Scale-dependent patterns of soil enzyme activity in a forested landscape. Canadian Journal of Forest Research 29:232-241.

During, M.M. 1981. Impact of prescribed burning on small mammal populations in Sequoia and Kings Canyon National Parks, California. Final report (NPS contract).

Eno, C.F. 1960. Nitrate production in the field by incubating the soil in polyethylene bags. Soil Science Society of America Proceedings 24: 277-299.

Filip, G. M., and L. Yang-Erve. 1997. Effects of prescribed burning on the viability of Armillaria ostoyae in mixed conifer forest soils in the Blue Mountains of Oregon. Northwest Science 71:137-144.

Harmon, M. E., K. Cromack, Jr., and B. G. Smith. 1987. Coarse woody debris in mixed-conifer forests, Sequoia National Park, California. Canadian Journal of Forestry Research 17: 1265-1272.

Hartesveldt, R. J. 1964. Fire ecology of the giant sequoias: controlled fires may be one solution to the survival of the species. Natural History Magazine 73:12-19.

Hartesveldt, R. J., and H. T. Harvey. 1967. The fire ecology of sequoia regeneration. Proceedings, Annual Tall Timbers Fire Ecology Conference 7:65-77.

Hawksworth, F. G. 1977. The 6-class dwarf mistletoe rating system. USDA Forest Service, General Technical Report RM-48. Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Kauffman, J. B., and R. E. Martin. 1989. Fire behavior, fuel consumption, and forest-floor changes following prescribed understory fires in Sierra Nevada mixed conifer forests. Canadian Journal of Forestry Research 19:455-462.

Kauffman, J. B., and R. E. Martin. 1990. Sprouting shrub response to different seasons and fuel consumption levels of prescribed fire in Sierra Nevada mixed conifer ecosystems. Forest Science 36:748-764.

Kilgore, B. M. 1971. Response of breeding bird populations to habitat changes in a giant sequoia forest. American Midland Naturalist 85:135-152.

Kilgore, B. M. 1972. Fire's role in a sequoia forest. Naturalist 23:26-37.

Kilgore, B. M. 1973. The role of fire in a giant sequoia-mixed conifer forest. Journal of Quaternary Research 3:496-513.

Kilgore, B. M., and R. W. Sando. 1975. Crown-fire potential in a sequoia forest after prescribed burning. Forest Science 21:83-87.

Kilgore, B.M., and D. Taylor. 1979. Fire history of a sequoia mixed conifer forest. Ecology 60(1): 129-142.

Lambert, S., and T. J. Stohlgren. 1988. Giant sequoia mortality in burned and unburned stands: does prescribed burning significantly affect mortality rates? Journal of Forestry 86:44-46.

Martin, T. E., and G. R. Geupel. 1993. Nest-monitoring plots: methods for locating nests and monitoring success. J. Field Ornithology 64:507-519.

Mutch, L. S., and D. J. Parsons. 1998. Mixed conifer forest mortality and establishment before and after prescribed fire in Sequoia National Park, California. Forest Science 44:341-355.

Nelson, D.W. and L.E. Sommers. 1982. Total carbon, organic carbon, and organic matter. In: Page, A.L. (ed.) Methods of Soil Analysis, Part 2: Chemical and Microbiological Properties. American Society of Agronomy, Madison, WI. Pp. 539-580.

Nichols, H. T. 1989. Managing fire in Sequoia and Kings Canyon National Parks. Fremontia 16:11-14.

Olsen, S.R. and L.E. Sommers. 1982. Phosphorus. In: Page, A.L. (ed.) Methods of Soil Analysis, Part 2: Chemical and Microbiological Properties. American Society of Agronomy, Madison, WI. Pp. 403-430.

Parsons, D. J., and S. H. DeBenedetti. 1979. Impact of fire suppression on a mixed-conifer forest. Forest Ecology and Management 2:21-33.

Pitcher, D. C. 1987. Fire history and age structure in red fir forests of Sequoia National Park, California. Canadian Journal of Forestry Research 17:582-587.

Plymale, A.E., R.E.J. Boerner, and T.J. Logan. 1987. Relative nitrogen mineralization and nitrification in soils of two contrasting hardwood forests: Effects of site microclimate and initial soil chemistry. Forest Ecology and Management 21: 21-36.

Pyle, P. 1997. Indentification guide to North American birds. Slate Creek Press, Bolinas, CA.

Ralph, C. J., G. R. Geupel, P. Pyle, T.E. Martin, and D. F. DeSante. 1993. Handbook of field methods for monitoring land birds. General Technical Report PSW-GTR-144. Pacific Southwest Research Station, Forest Service, U. S. Department of Agriculture, Albany, CA. 41pg.

Russell, K. R., D. H. Van Lear, and D. C. Guynn, Jr. 1999. Prescribed fire effects on herpetofauna: review and management implications. Wildlife Society Bulletin 27:374-384.

Sinsabaugh, R. L., R. K. Antibus,, A. E. Linkins, C. A. McCaugherty, L. Rayburn, D. Repert, and T. Weiland. 1993. Wood decomposition: nitrogen and phosphorous dynamics in relation to extracellular enzyme activity. Ecology 74:1586-1593.

Sinsabaugh, R. L., and S. Findlay. 1995. Microbial production, enzyme activity, and carbon turnover in surface sediments of the Hudson River estuary. Microbial Ecology 30:127-141.

Slaughter, G. W., and D. M. Rizzo. 1999. Past forest management promoted root disease in Yosemite Valley. California Agriculture 53:17-24.

Stendell, E. R., T. R. Horton, and T. D. Bruns. 1999. Early effects of prescribed fire on the structure of the ectomycorrhizal fungus community in a Sierra Nevada ponderosa pine forest. Mycological Research 103:1353-1359.

Stephens, S. L., 1998. Evaluation of the effects of silvicultural and fuels treatments on potential fire behavior in Sierra Nevada mixed-conifer forests. Forest Ecology and Management 105: 21-35.

Stephenson, N. L. 1999. Reference conditions for giant sequoia forest restoration: structure, process, and precision. Ecological Applications 9:1253-1265.

Stephenson, N. L., D. J. Parsons, and T. W. Swetnam. 1991. Restoring natural fire to the sequoia-mixed conifer forest: should intense fire play a role? Proceedings of the 17th annual Tall Timbers Fire Ecology Conference, Tallahassee, FL, pages 321-337.

St. John, T. V., and P. W. Rundel. 1976. The role of fire as a mineralizing agent in Sierra Coniferous forest. Oecologia 25:35-45.

Stohlgren, T. J. 1988. Litter dynamics in two Sierran mixed conifer forests. I. Litterfall and decomposition rates. Canadian Journal of Forestry Research 18:1127-1135.

Stohlgren, T. J. 1988. Litter dynamics in two Sierran mixed conifer forests. II. Nutrient release in decomposing leaf litter. Canadian Journal of Forestry Research 18:1136-1144.

St. John, T. V., and P. W. Rundel. 1976. The role of fire as a mineralizing agent in a Sierran coniferous forest. Oecologia 25:35-45.

Swetnam, T. W. 1993. Fire history and climate change in giant sequoia groves. Science 262:885-889.

Thomas, G.W. 1982. Exchangeable cations. In: Page, A.L. (ed.) Methods of Soil Analysis, Part 2: Chemical and Microbiological Properties. American Society of Agronomy, Madison, WI. Pp. 159-166.

Vankat, J. L., and J. Major. 1978. Vegetation changes in Sequoia National Park, California. Journal of Biogeography 5:377-402.

Van Wagtendonk, J. W. 1972. Fire and fuel relationships in mixed conifer ecosystems of Yosemite National Park. Ph.D. dissertation, University of California, Berkeley. 163pp.

Weikel, J., and J. P. Hayes. 1999. The foraging ecology of cavity-nesting birds in young forests of the northern coast range of Oregon. The Condor 101:58-66.

Werner, H. W. 2000. Fire effects monitoring on wildlife, 1999. Unpublished report, Sequoia and Kings Canyon National Parks, Three Rivers, CA. 11p.

Williams, M. R., and J. M. Melack. 1997. Effects of prescribed burning and drought on the solute chemistry of mixed-conifer forest streams of the Sierra Nevada, California. Biogeochemistry 39:225-253.

Zack, S., W. F. Laudenslayer, and K. Farris. 2000. Wildlife protocols. In: A national study of fire and fire surrogate treatments. Final proposal amended March 2000.

Appendix A. Budget

SEQUOIA NATIONAL PARK

	FY00	FY01	FY02	FY03	FY04
Salaries and Benefits					
Site Manager (GS-11 Term 100%)	0	53,095	54,685	56,325	58,015
Technicians					
Veg/fuels (GS-6 Temp 50%)	0	13,515	13,915	0	14,765
Veg/fuels (GS-5 Temp 30%)	7,850	8,085	8,325	0	8,835
Veg/fuels (GS-5 Temp 30% 2 positions)	0	16,170	16,650	0	17,670
Fire Monitoring (GS-6 Temp 7%)	0	1,890	1,925	0	0
Wildlife (GS-6 Temp 30%)	0	8,109	8,300	8,575	8,730
Wildlife (GS-5 Temp 20% 4 positions)	0	14,000	14,400	14,800	15,200
Soil crew (as per national protocol)	0	18,000	18,000	0	18,500
Pathology crew (as per national protocol)	0	20,000	20,000	0	20,000
Entomology crew (as per national protocol)	0	29,000	0	29,000	0
Total Salaries and Benefits	**7,850**	**181,894**	**156,200**	**108,700**	**161,720**
Travel					
National Travel	0	0	0	1,200	2,400
Field	2,000	14,600	14,850	8,000	15,400
Total Travel	**2,000**	**14,600**	**14,850**	**9,200**	**17,800**
Nonexpendable Equipment					
Traps/scales	0	7,000	0	0	0
Servis recorder	0	2,000	0	0	0
Laptop computer	0	3,000	0	0	0
PC computers	0	5,500	0	0	0
Digital camera/storage	0	975	0	0	0
Printer	0	1,900	0	0	0
Convection oven	0	4,500	0	0	0
Refrigerator	0	1,300	0	0	0
Balance	0	1,500	0	0	0
pH meter	0	950	0	0	0
Total Nonexpendable Equipment	**0**	**28,625**	**0**	**0**	**0**
Supplies					
Vegetation/plot setup	500	4,000	1,000	0	1,000
Wildlife	0	5,100	1,500	1,000	500
Soils	0	8,000	2,900	0	3,000
Pathology	0	1,000	1,100	0	1,400
Entomology	0	1,000	0	1,000	0
Total Supplies	**500**	**19,100**	**6,500**	**2,000**	**5,900**
Contracts					
Office space/housing	0	12,000	10,000	10,000	10,000
Aerial Photography	0	5,000	0	0	5,500
Aerial Interpretation	0	3,500	0	0	3,750
Soils Lab	0	17,000	17,000	0	17,500
Pathology analysis	0	10,000	10,000	0	10,000
Total Contracts	**0**	**47,500**	**37,000**	**10,000**	**46,750**
Total Direct Costs	**10,350**	**291,719**	**214,550**	**129,900**	**232,170**

SEQUOIA NATIONAL PARK (continued)

	FY00	FY01	FY02	FY03	FY04
Indirect Costs USGS (15%)	**1,553**	**43,758**	**32,183**	**19,485**	**34,826**
Annual Funding Requested	**11,903**	**335,477**	**246,732**	**149,385**	**266,996**
Total Funding Requested	**1,010,493**				

Timeline
2001: Preburn sampling for all variables, conduct fall prescribed burn
2002: Conduct spring prescribed burn, sample all first-year post-burn variables except entomology
2003: Second-year post-burn sampling for wildlife and entomology.
2004: Third-year sampling for all variables except entomology

SEQUOIA NATIONAL PARK—Contributed Costs

	FY00	FY01	FY02	FY03	FY04
Salaries and Benefits					
Jon Keeley (USGS)	10,460	16,165	16,535	16,920	17,285
Nate Stepehenson (USGS)	1,525	3,920	4,010	4,130	4,255
Anne Pfaff (USGS)	1,020	1,050	1,075	1,100	1,200
Anthony Caprio (NPS)	1,020	1,050	1,075	1,100	1,200
Bill Kaage (NPS)	1,300	3,250	3,325	1,420	1,455
Jeff Manley (NPS)	1,175	2,940	3,010	1,280	1,310
Total Salaries and Benefits	**16,500**	**28,375**	**25,445**	**24,850**	**26,705**
Operations					
GIS work (NPS)	1,500	0	1,000	0	0
Prescribed Burning ($11/ha* x 14 ha x 3 sites)	0	4,725	4,725	0	0
Total Operations	**1,500**	**4,725**	**5,725**	**0**	**0**
Travel (meetings)	**1,100**	**1,200**	**1,200**	**1,200**	**1,500**
Annual Contributed Costs	**19,100**	**34,300**	**32,370**	**26,050**	**28,205**
Total Contributed Costs	**140,025**				