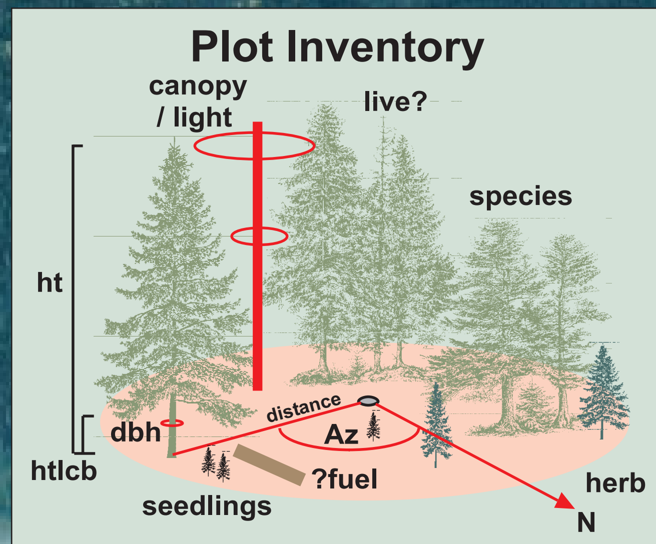
Mineral King Risk Reduction Project



Monitoring, Inventory, and Research

1998 Annual Report

January 2000

Note: The 1998 Annual Report on Research, Monitoring, and Inventory for the Mineral King Risk Reduction Project is the fourth annual report produced for the burn project. The earlier reports contain some introductory and additional background material that has not been duplicated in this report. Copies of all the reports are being made available by web browser over the Internet. Full copies of the 1995 through 1998 reports can be downloaded in Adobe Acrobat PDF format from the ***Fire Information Cache*** on the Sequoia and Kings Canyon National Parks web site at www.nps.gov/seki/fire. If you do not have Internet access and would like to obtain one of the earlier reports from 1995 to 1997 contact Anthony Caprio at Sequoia and Kings Canyon National Parks, Division of Science and Natural Resources Management, 47050 Generals Highway, Three Rivers, CA. 93271-9651.

Cover Caption: Aerial view of a portion of the Atwell segment burning during the fall of 1995 with the Mineral Lakes in the near distance and the Great Western Divide in the far distance. The inset is a diagram of the plot inventory methods used in the Landscape Analysis Project by Kurt Menning (see **Fig. 3.11-1**).

Annual Report 1998
Research, Inventory, and Monitoring
Mineral King Risk Reduction Project

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Executive Summary

The Mineral King Risk Reduction Project (MKRRP) was initiated out of a need to assess the operational requirements and cost effectiveness of large scale prescribed burning for wildland management in a setting altered by a century of fire suppression. The local objectives of the project are to initiate the reduction of unnatural fuel accumulations (these accumulations can create hazardous conditions for visitors, developments, and natural resources) and begin restoration of ecosystem structure and function within the East Fork drainage of Sequoia and Kings Canyon National Parks. However, because the scale of the project is unprecedented, a number of integrated monitoring and research projects were also initiated to assess the impacts and responses of key components of the watershed to prescribed fire. Additional projects have also been initiated to utilize this opportunity to gain additional insights into fire's role in Sierran ecosystems. These projects and their results are important in providing information about short- or long-term resource responses and impacts when burning at this scale, a relatively new management strategy, and whether the planned objectives for the MKRRP are being met. This information will feed back into management planning and permit modification and fine tuning of the burn program in addition to providing information to the public and policy makers.

The MKRRP area encompasses 21,202 ha (52,369 ac) within the East Fork watershed with elevations ranging from 874 m (2,884 ft) to 3,767 m (12,432 ft). Vegetation of the area is diverse, varying from foothills chaparral and hardwood forests at lower elevations to alpine vegetation at elevations above about 3,100 m (10-11,000 ft). About 80% of the watershed is vegetated with most of the remainder being rock outcrops located on steep slopes and at high elevations.

Support for the monitoring and research projects is coming from a variety of sources. Projects funded directly out of the Mineral King Risk Reduction Project include fire effects monitoring, fuel and wildlife inventories, and a study on the relationship between fuel loads and fire impacts on giant sequoia fire scars. Additional projects are being supported from within the Parks and include resampling old vegetation plots and fire history studies. Other projects are using resources from within and the Sequoia and Kings Canyon Field Station (Biological Resources Division of the USGS). These include natural resource inventory, watershed hydrology, stream chemistry. Cooperative research projects are also underway using the dedication, energy, and support of graduate students from several universities (University of California, Davis; University of California, Berkeley).

Several noteworthy observations or findings were made by the monitoring/research projects from 1995 to 1998. The small mammal trapping project found that small mammal populations roughly doubled in the burned sequoia plot compared to preburn population densities. Fire effects plots showed overstory tree mortality varied by vegetation type: 22% red fir forest (ABMA), 50% sequoia mixed-conifer forest (no mortality of overstory sequoias was noted), and 98% in low elevation mixed-conifer forest (CADE). These plots also showed total fuel reductions of 77% (CADE) to 91% (ABMA). A significant increase in giant sequoia seedlings was noted in the burned Atwell sequoia plots. Watershed sampling completed its second full water year of sampling, providing preburn data on trends within the East Fork. Initial results suggest similar annual shifts in flow, pH, and ANC (acid neutralization capacity) when compared to other unburned Sierran watersheds.

Burning in the watershed during 1998 amounted to 142 ha (350 ac) centered in chaparral vegetation near to Lookout Point. This was the first significant area of this type of vegetation burned during the project. A total of 1,346 ha (3,325 ac) have been burned in the watershed since 1995. Burning during 1999 will concentrate on Tar Gap, Deadwood, Redwood, and the Lookout Point chaparral segments.

1. Project Year Synopsis: Accomplishments for 1998 projects.

- **Fire Effects Plots -** Fire effects plots are being established within the Mineral King Risk Reduction Project (MKRRP) area to allow park staff to monitor both the short- and long-term effects of the management ignited prescribed burns on park vegetation and fuels (primary emphasis is placed on fuel loads and tree density). These plots provide important feedback to park managers on how well they are meeting their management goals and will help refine the goals of future burn plans. A total of 18 fire effects plots have been set up in the East Fork since 1995. These include seven forest plots (five in the Atwell segment, three in Tar Gap segment, and a control plot adjacent to the Atwell segment) and nine brush plots (located on the north side of the East Fork). Five forest plots burned following the ignition of the Atwell segment during the fall of 1995 with one and two year postburn rechecks completed during 1996 and 1997. The rechecks showed overstory tree mortality varied by vegetation type: 22% red fir forest, 50% sequoia-mixed conifer forest (no mortality of overstory sequoias was noted), and 98% in ponderosa pine forest. Total fuel reductions of 77% were found in ponderosa pine forest, 89% in sequoia-mixed conifer forest, and 91% in red fir forest. Additionally, giant sequoia seedlings increased from no seedlings preburn to 88,300 seedlings • ha^{-1} 1-year postburn then decreased to 5,800 seedlings • ha^{-1} 2-years postburn in the Atwell sequoia plots.

- **Wildlife Monitoring -** Four permanent small mammal live-trapping plots have been established and sampled between 1995 and 1997. Understanding changes in the composition and numbers of common small mammals is important because they represent an important component in the food chain for less-common wildlife species and thus make good indicators of habitat status. Rodent populations respond readily to changes in vegetation structure and composition due to fire, they are easy to handle, and are a cost-effective tool for monitoring fire effects. The plots are located in sequoia/mixed-conifer forest (Atwell), chaparral/oak shrubland (Traugers), in ponderosa pine/black oak transition forest (Camp Conifer), and Jeffery pine (Mineral King). The mid-elevation sequoia plot, located in the Atwell segment, burned during November 1995 has been resampled annually. Initial results indicate a doubling of small mammal biomass since the burn. The ponderosa plot burned during November 1997 and was resampled in 1998. Serendipity trapping (non-permanent trap locations) was also carried out at a number of locations in the watershed.

- **Watershed Sampling: Stream Chemistry and Hydrology -** Stream chemistry and hydrological information have been sampled by staff of the Biological Resource Division of the USGS at regular intervals (weekly) since May 1995. Three sites are being sampled in the East Fork (the East Fork itself and two tributary creeks, one in chaparral and one in mixed-conifer forest) which will provide data to help assess the effects of watershed scale prescribed fire on important chemical components and flow characteristics. Data will be compared to the "reference" unburned Log Creek watershed in Giant Forest, sampled as part of another long-term watershed study. Watershed sampling completed its second full water year of sampling, providing preburn data on trends within the East Fork. Initial results suggest similar annual shifts in flow, pH, and ANC (acid neutralization capacity) when compared to other Sierran watersheds.

- **Watershed Sampling: Benthic Macro-Invertebrate Survey -** Ian Chan, Don Erman, Nancy Erman (UC Davis) are conducting a preburn survey of benthic macro-invertebrates in the East Fork. This study will assess the structural components of aquatic macro-invertebrate communities and provide baseline inventory of composition, abundance, and diversity. Six treatment streams (situated in areas that will be burned) and four non-treatment reference streams (which will remain unburned) have been located and sampled in the Middle Fork watershed. Benthic macro-invertebrates are collected through a combination of quantitative sampling and qualitative description in three habitat types: riffles, pools, and slickrock glides. In addition, several artificial substrates (unglazed clay tiles) were placed in slickrock area to help quantify colonization rates. The initial postfire sampling has been completed on the Redwood and Atwell Creek sites that burned during 1995.

- **Fire History -** Fire history samples were obtained from Atwell, Lookout, Redwood, Tar Gap, Eden Grove, Mineral King, Empire, Silver City, High Bridge and Purple Haze segments from 1995 to 1998. These samples will become part of an effort to reconstruct the spatial scale and pattern of pre-European settlement fire events from throughout the East Fork watershed and to provide baseline data on past fire occurrence in a variety of habitats, vegetation types, and aspects in the drainage. Predictions of past fire occurrence in the Sierra Nevada based on computer models suggest differences in burn patterns/frequencies on different aspects with these differences most notable between south and north slopes. However, at this time almost no data exists on pre-European settlement fire history for north aspect forests in the southern Sierra Nevada. Thus information collected in the East Fork will be important in verifying these models, in addition to providing park staff with better information about fire over the landscape.

- **Giant Sequoia Fire Scars and Fuel Loading -** A total of 60 giant sequoia trees (30 scarred and 30 unscarred) have been measured in the Atwell Grove to help determine the effects of prescribed burning on fire scar formation and how changes in fire scar dimensions and bark charring relate to the fuel accumulations and consumption of the fuels surrounding trees by prescribed burning. All trees examined within the study area burned during November 1995 and were resampled during 1996 with fuels remeasured during 1997. No sequoia mortality resulted from the fire although small new fire scars were noted on some trees by the field crew doing the postburn sampling.

- **Fuel Inventory and Monitoring -** Fuel-load sampling was carried out during 1995 and early summer of 1996 to obtain field information on forest fuels (tons per acre) that are available to forest fires. During 1997 permanent fuel plots were established This information will provide improved fuel model data for input into the FARSITE fire spread model which will be used to more accurately predict fire spread following an ignition. Most sampling has concentrated on the south aspect of the East Fork and in segment #10. To date over 580 plots have been sampled including 44 permanent fuel plots established during 1997. In addition to estimating fuel loads at each plot, additional forest attribute measurements were obtained on tree height, basal area, height to lowest branches, and on litter and duff depths.

- **Red Fir (Pitcher) Plots -** In the late 1970's Donald Pitcher (graduate student at UC Berkeley) established three permanent plots in red fir forest along the Tar Gap Trail near Mineral King to study forest structure and composition (what species are present and how are they arranged in a forest), and fuel dynamics (fuels available for burning). These plots were relocated in 1995 and are now being resampled prior to the burning of segment #10 (sampling of two plots is complete). Because of little long-term data from red fir forest these plots will provide important information to park managers on changes in forest structure and composition, and fuel loads over a 20 year period. Initial estimates indicate a significant increase in fuel loads and 22% mortality of all saplings/trees in the plots (most mortality, 75%, is a result of the death of young seedling and sapling as the forest naturally thins itself over time). Postburn sampling of these plots will also provide detailed information on forest changes and fire effects which has been little studied in this forest type.

- **Landscape Analysis - Fire and Forest Structure -** Kurt Menning's (graduate student at UC Berkeley) research will address questions revolving around the means and the landscape-scale consequences of selecting differing mechanisms for restoring forest structure to something near pre-Euroamerican conditions. Using high resolution aerial imagery and field sampling he will describe the current structure and pattern of mixed conifer forest over the landscape and then how the qualities of these change as fire is restored to the ecosystem. Field sampling was carried out this past summer in the Redwood, Tar Gap, Purple Haze, Deadwood, High Bridge, and Eden Grove Segments. Plots burned during 1997 were resampled in 1998. High resolution digital multispectral imagery was recently acquired by an overflight over the East Fork. The imagery will have high enough resolution (one meter) that individual tree crowns should be discernable, allowing detailed observations on tree health and species to be made.

- **Natural Resource Inventory -** The Natural Resource Inventory (NRI) staff of the Biological Resources Division of the USGS (formerly NBS) have been establishing permanent inventory plots within the drainage. The general purpose of the NRI plots is to provide a systematic, plot-based inventory for detecting and describing the distribution of vascular plants, vertebrate animals, and soils throughout the Sequoia and Kings Canyon National Parks. Within the East Fork, the plots document the preburn floristic composition and structure of vegetation. Since 1995, 18 plots have been established as part of the MKRRP. These supplement 32 plots that already existed in the watershed. Plots that burned during 1995 have been revisited during 1996 (seven of nine were relocated) to assess burn impacts and first year postburn vegetation responses. An effort was made to also sample locations falling within the little known, dense chaparral vegetation of the East Fork.

2. Overview of Project

2.1 - Objectives

The direct objectives of the Mineral King Risk Reduction Project (MKRRP) for Sequoia and Kings Canyon National Parks (SEKI) focus on reducing unnatural fuel accumulations that have resulted from a century of both direct and indirect fire suppression activities in southern Sierran ecosystems (NPS 1995, Stephenson 1995). In many instances these fuel accumulations create hazardous conditions for visitors, developments, and natural resources. The overall objectives of the project are to assess the operational requirements and cost effectiveness of large scale prescribed burning for wildland management (NPS 1995). The latter evaluation will be accomplished through the use of information derived from the field operations and their outcome within SEKI.

The conditions resulting from unnatural fuel accumulations have resulted in wildland managers being called upon to modify fuels in order to reduce wildland fire hazard and restore ecosystems to some semblance of pre-Euroamerican conditions. Current national management issues are forcing land managers to use two main tools for fuels management: mechanical removal (cutting) and/or prescribed burning. However, both of these tools remain controversial and managers are being asked to justify their choices. These issues motivated a major effort by the National Interagency Fire Center (NIFC) to begin an assessment of the operational requirements and cost effectiveness of using large-scale prescribed burning as a tool in fuels management. As part of this effort NIFC funded Sequoia and Kings Canyon National Parks to carry out a watershed-scale burn program with an objective of prescribed burning about 12,000 ha (30,000 acres) over a five year period (1995-2000) in the East Fork of the Kaweah River (**Fig. 2.1-1**). A collateral objective of the burn project is to evaluate the cost effectiveness of a hazard fuel reduction program of this magnitude by Colorado State University.

Since the scale of the burn project is unprecedented a number of integrated resource related studies are being undertaken and are an integral part of the project. These research, inventory, and monitoring projects in the Mineral King burn are designed to meet the following objectives (Stephenson 1995) :

> ***To supply the information needed to practice adaptive management*** *(1) by determining whether the burn program's objectives are being met, (2) by identifying unexpected consequences of the program on the ecosystem, and (3) if objectives are not being met, by suggesting appropriate program changes.*
>
> ***To provide information for public education, response to public and governmental inquiries, and to document legal compliance.***

These research and monitoring objectives are particularly important because SEKI's watershed scale burn program will be one of the first national attempts at using fire on a watershed scale for fuels management. The various research and monitoring studies are being integrated with the project's management objectives. Support for new studies that compliment or enhance the currently implemented studies are being sought (for example, proposals for funding for a watershed sediment transport study are being developed by the Biological Resource Division of the USGS). Additionally, unsolicited studies by non-MKRRP funded researchers (primarily from universities) are also integrated with the overall project goals to the greatest degree possible

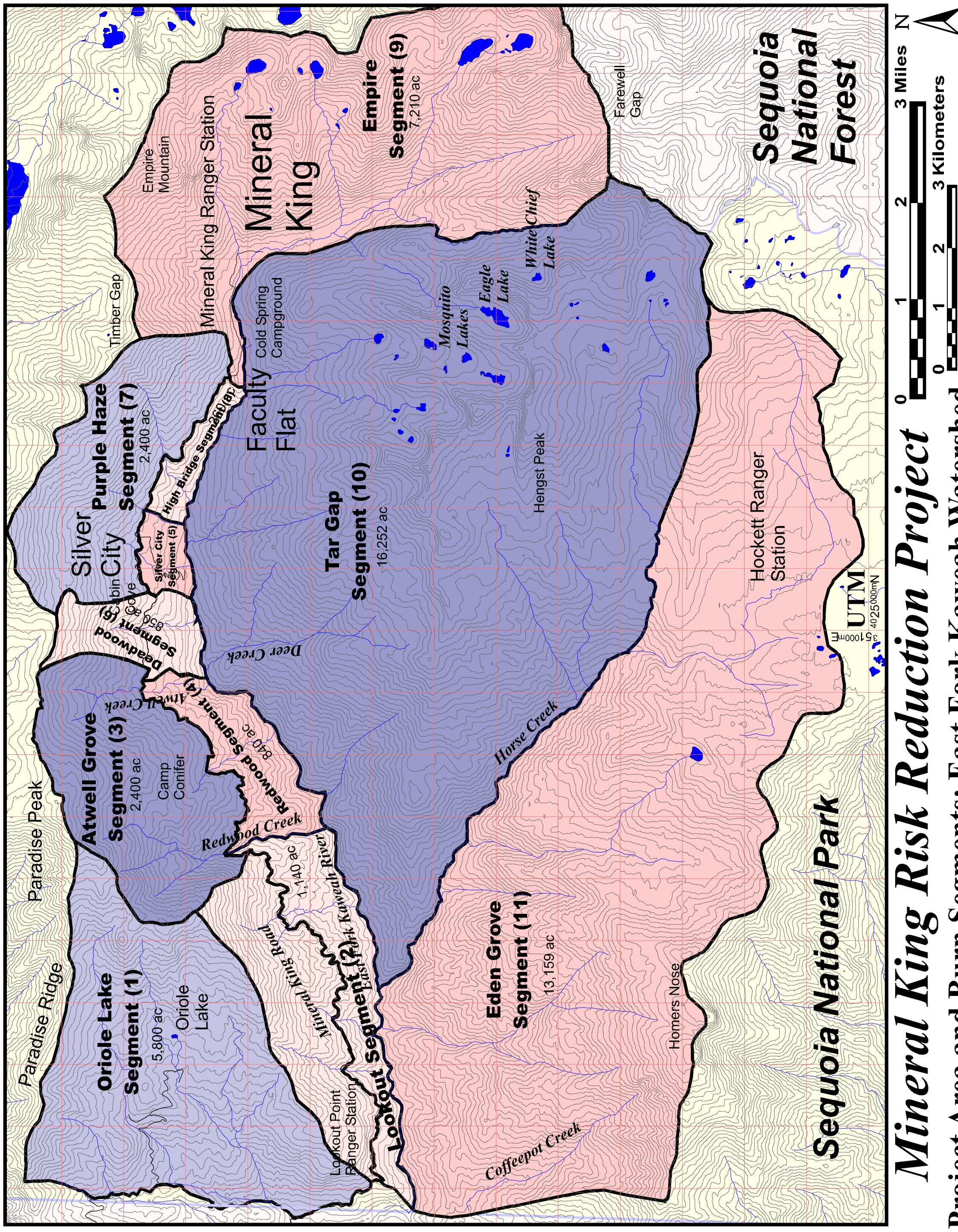

Figure 2.1-1. Mineral King Risk Reduction Project project area and segment boundaries. Not all area within the segments is burnable vegetation. Approximately 20% of the watershed within the Parks is barren rock.

consistent with the study objectives. Descriptions of studies and the East Fork are available in the 1995, 1996 and 1997 MKRRP Annual Reports (Caprio 1996, 1997, 1998).

2.2 - Description - East Fork Project Area

The East Fork watershed (**Fig. 2.2-1**) which encompasses the MKRRP is one of five major drainages comprising the Kaweah River watershed which flow west (historically but is now heavily diverted for agriculture) into the Tulare Lake Basin in the southern Central Valley. Terrain in the watershed is rugged, elevations range from 874 m (2,884 ft) to 3,767 m (12,432 ft) within the project area. The watershed, 21,202 ha (52,369 ac) in size, is bounded by Paradise Ridge to the north, the Great Western Divide to the east, and Salt Creek Ridge to the south. Major topographic features of the watershed include the high elevation Mineral King Valley, Hockett Plateau, Horse Creek, the high peaks producing the Great Western Divide, and the Oriole Lake subdrainage (with an unusually low elevation lake for the Sierras at 1,700 m elevation).

Table 2.2-1. Segment number, size (approximate - revised 1999) and percent of area vegetated .

Segment	Hectares	(Acres)	% Veg.
Oriole Lake (#1)	2,352	(5,811)	94.4
Lookout Point (#2)	439	(1,084)	91.0
Atwell Grove (#3)	962	(2,377)	96.8
Redwood (#4)	289	(716)	98.5
Deadwood (#5)	121	(300)	100.0
Silver City (#6)	135	(335)	100.0
Purple Haze (#7)	989	(2,445)	93.7
High Bridge (#8)	121	(299)	96.9
Empire (#9)	2,917	(7,210)	34.1
Tar Gap (#10)	6,577	(16,252)	90.9
Eden Grove (#11)	5,325	(13,153)	94.3

Eleven burn segments have been outlined within the watershed by fire management staff (**Table 2.2-1** and **Fig. 2.1-1**). Eight segments were designated on the south facing slope (north side of the East Fork) and three large segments on the more remote north slope (south side of the East Fork). Segment locations were established to facilitate prescribed burning operations and protection of primary developments within the watershed.

Vegetation Class	Hectares	(Acres)
Foothills Chaparral	1,119	(2,764)
Foothills Hardwoods &	1,432	(3,536)
Ponderosa Pine Mixed Conifer	1,919	(4,741)
White Fir Forest	3433	(8,479)
Red Fir Forest	4,042	(9,983)
Xeric Conifer Forest	1,342	(3,315)
Montane Chaparral	473	(1,167)
Mid-Elevation Hardwood Forest	170	(420)
Lodgepole Pine Forest	935	(2,310)
Subalpine Forest	96	(237)
Meadow	130	(320)
Giant Sequoia	994	(2,454)
Other (primarily water)	97	(241)
Barren Rock	4,092	(10,109)
Missing or No Data	130	(320)

Table 2.2-2. Updated vegetation type classification for the East Fork watershed and the area occupied by each class.

Vegetation of the area is diverse, varying from foothills chaparral and hardwood forest at lower elevations to alpine vegetation at elevations above 10-11,000 feet. About 80% of the watershed is vegetated with most of the remainder rock outcrops located on steep slopes and at high elevations. Lower elevation grasslands and oak woodland, while common at low elevations in the Kaweah drainage, are uncommon within the park's portion of the East Fork watershed. Sequoia groves within the project area include Atwell, East Fork, Eden, Oriole Lake, Squirrel Creek, New Oriole Lake, Redwood Creek, Coffeepot Canyon, Cahoon Creek, and Horse Creek. Vegetation is dominated by red and white fir forest with pine and foothill types of somewhat lesser importance (**Table 2.2-2**). No endangered species are known from the watershed although several sensitive species have been located during surveys (Norris and Brennan 1982).

Access to the area by road is limited to the narrow winding Mineral King Road, 25 miles long. The Mineral King Valley is popular with backpackers and packers as a starting point for many high country trips. Higher elevations of the watershed receive considerable recreation use while lower elevations receive relatively little use. Developed or semi-developed areas within the watershed include Silver City, Oriole Lake (private lands), Cabin Cove, Mineral King, Faculty Flat (lease cabin sites), Lookout Point, and the Atwell Mill areas (administrative sites). NPS campgrounds exist at Atwell Mill and Mineral King.

Figure 2.2-1. Main drainage of the East Fork of the Kaweah from Case Mountain. Photo does not show the Oriole Lake subdrainge (left of view). Photo by Linda Mutch.

3. Project Year 1998

The Mineral King Risk Reduction Project was initialized during March 1995 with inventory and monitoring field work and burn operations begun during the summer and fall (2,100 ac/850 ha in the Atwell Segment (segment #3), **Fig. 2.1-1**). No burns were conducted during 1996 due to the extent of resource demands during the summer of 1996 inside and outside the parks (more acres burned in the western USA than any year since 1920). The critical Redwood Segment, below and west of Atwell Mill, was burned during November 1997 (184 ha/455 ac). This completed the basic buffer of burned areas across the East Fork drainage (Atwell and Redwood Segments, and the Deer Creek Burn) which will provide better fire protection for Atwell, Cabin Cove, Silver City, and Mineral King from wildfires burning up out of the chaparral. Burning in the watershed during 1998 amounted to about 150 ha (371 ac) in two segments (**Fig. 3-1**).

Burn operations plans developed by the Fire Management Office during the spring of 1998 called for burning portions of the Tar Gap and Lookout Segments (segments #10 and #2 respectively) during the summer/fall. Ignitions in the Tar Gap Segment were planned to begin as fuels at higher elevations in the unit dried during the summer. The primary goal of the plan was to burn areas above the Tar Gap Trail with the trail being the main holding line. Depending on circumstances burning might continue below the Tar Gap Trail with the Hockett Trail being the secondary and lower holding line. The burn was to extend from the Mosquito Creek/Mineral Creek area in the northeast portions of the segment to Horse Creek to the south. Additional burning in chaparral and oak woodland in the Lookout Segment were planned to take place following significant rainfall. The plan is for rainfall to wet down heavy forest fuels while brush fuels would dry rapidly following precipitation.

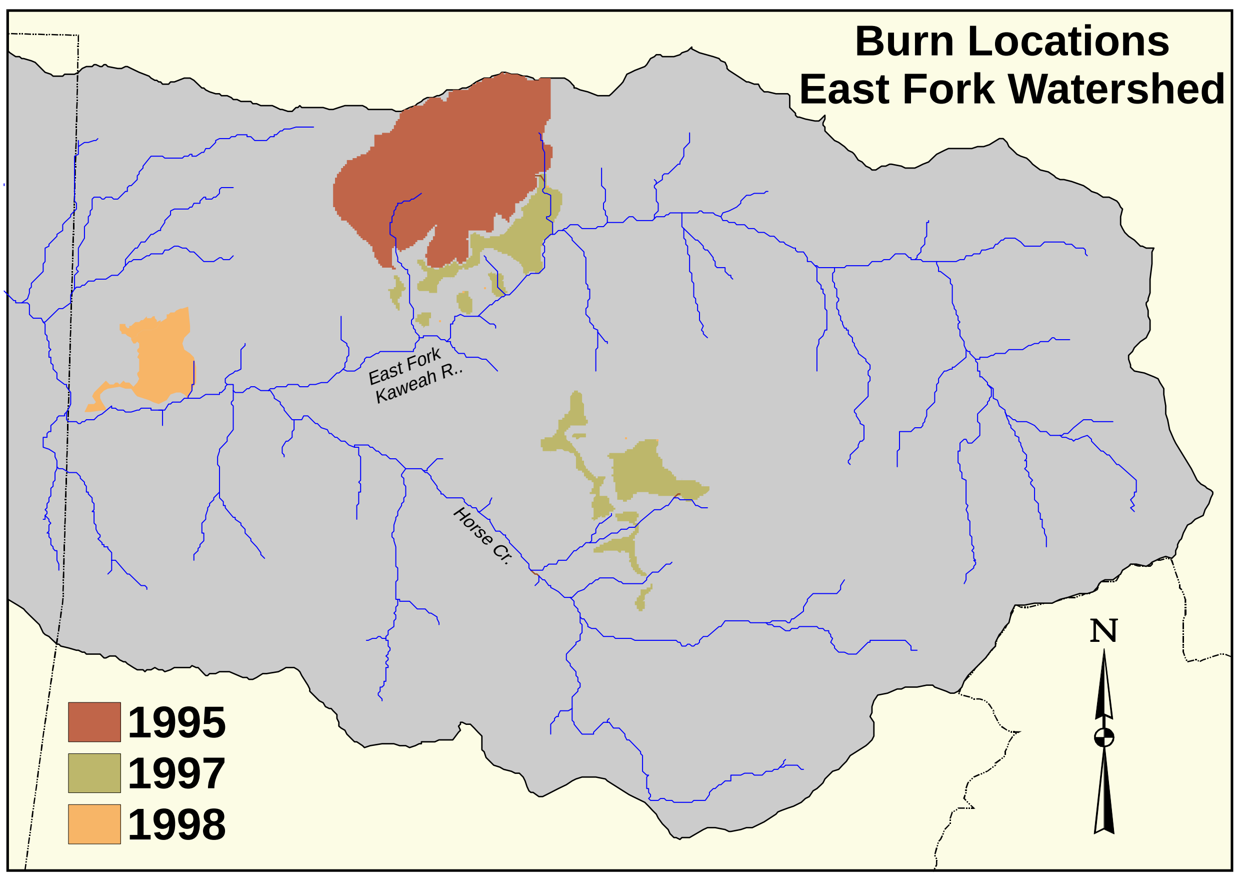

Figure 3-1. Locations of areas burned in the East Fork watershed from 1995 through 1998.

Figure 3-2. Prescribed burn in chaparral vegetation at Lookout Point entrance station. Area below structures was backfired prior to main unit ignition.

Portions of the Lookout Segment were burned during late October 1998. Ignitions were carried out at Lookout Point below and to the east of the entrance station structures (**Fig. 3-2**) and along the Mineral King Road toward Trauger's Creek. Both hand crews and a helitorch (**Fig. 3-3**) conducted ignitions. Unexpected weather and fire behavior eventually carried the burn from the road to the crest to Conifer Ridge where it burned out of the burn segment. Fire activity outside the burn unit was suppressed and a line constructed on Conifer Ridge to prevent future slop-overs. Vegetation burned in this portion of the unit was primarily chaparral and oak woodland communities.

Monitoring, inventory, and research progressed, covering a large portion of the watershed (**Fig. 3-4**). Projects included studies begun during 1995 and several new investigations. The former include: (1) fire effects plots; (2) sequoia fire scars; (3) natural resource inventory; (4) fuels; (5) wildlife-small mammal populations; (6) fire history; (7) watershed-chemistry and hydrology; (8) watershed-aquatic macroinvertabrates; (9) resampling of red-fir plots established by Donald Pitcher. The latter include: (1) fire and red fir regeneration; (2) landscape analysis of changes in forest structure over time; (3) population and niche requirements of bark-foraging birds; and (4) establishing permanent fuel plots. A significant amount of information has been collected from throughout the East Fork during summer over the past four seasons.

Figure 3-3. Helitorch ignition of main Lookout Point segment below entrance station.

3.1 - Vegetation Sampling

3.11) Mineral King Landscape Assessment[1] in support of the Mineral King Risk Reduction Project

Principle Investigators:

Kurt Menning, Dr. Tracy Benning, and Dr. John Battles, University of California, Berkeley, in conjunction with Dr. Nathan L. Stephenson, Biological Resources Division of United States Geologic Survey, Sequoia and Kings Canyon Field Station.

1998 field crew: Kurt Menning, Adrian Das, Brian Knaus, Jeannette Owen, Jonny Beals-Nesmith, and Ryan Slack.

PROJECT OBJECTIVES and BACKGROUND

As coordinators of the Mineral King Landscape Assessment (MKLA) we are about to begin our fourth year of investigating forest conditions of the mixed conifer forest in the Mineral King watershed. As in many western forests, the suppression of wildfires has altered forests over the last century in Mineral King. The lack of fire has directly affected regeneration of many tree species, availability of habitat for birds and wildlife, susceptibility of the forest to insect attacks and disease, and diversity of small forest plants. As a result, many park managers and scientists believe we should restore forests to within some range of historic conditions at the same time we reduce risk. To test the effects of restoring forests with fire we are monitoring the effects of the Mineral King Risk Reduction Project (MKRRP) to discover how re-introduced fire alters this forest.

In order to address the questions of *when* and *where* prescribed fire can be used to restore some components of historic forest structure, pattern and composition, we need to understand what historic forests were like when these forests were experiencing more frequent fire, how these forests have changed up to the present with the suppression of fire, and what effect re-introduced fire has on altering current forest conditions. To answer these questions we need data from three time periods: past, present (pre fire), and post-fire. Historic data are necessary to establish a baseline from the past to present and to act as targets for restoration through the re-implementation of fire. Current data are used to measure the change from historic conditions and to act as a benchmark for change to the post-fire state. Finally, post-fire data are used to determine the effect fire has on changing forest structure, composition and pattern, and to compare resultant forests with targets—states or range of conditions derived from past landscapes—established using the historic data.

By collecting data over several spatial scales and across these three time periods we hope to assemble many pieces of the puzzle of forest landscape change, disturbance and restoration. This large picture view of dynamics in this watershed will help us better understand:

> How variability in microclimate and topography in the forest affect stand heterogeneity?

[1] The Mineral King Landscape Assessment represents a broad collaborative effort involving Sequoia and Kings Canyon National Park; U. S. Geological Survey, Biological Resources Division; and the University of California, Berkeley's Laboratories of Forest Community Ecology (Dr. John Battles) and Landscape Ecology (Dr. Tracy Benning). Kurt Menning, a Ph.D. candidate at the University of California, Berkeley, is the lead analyst in the project.

How fires interact with stand heterogeneity to modify landscape mosaics of patches, gaps, and gradients?

What changes in structure and pattern have occurred in the system during the period of suppression?

What compositional shifts have resulted during fire's absence?

How a sampling strategy across a landscape could provide useful measures of landscape patterns and change (and perhaps could lay the groundwork for standard protocols for forested landscape monitoring)?

And, as a result,

When and where prescribed fire can be used as a restoration tool.

In 1996 we started the project and established 52 forest plots (**Fig. 3.11-3**). None of the plots burned between the summers of 1996 and 1997, and so in the summer of 1997 we continued focusing on the current conditions in the watershed. We expanded our sampling throughout the watershed by increasing our number of forest plots to over 200. With the fires that burned in Mineral King in autumn of 1997 we targeted summer 1998 as our opportunity to revisit plots that had been burned.

We entered the 1998 field season with preliminary fire extent maps that indicated that 25 to 40 of the MKLA plots should have burned. In the course of the summer, our crew re-inventoried 68 MKLA plots and found that only nine plots had burned. Seven of these burned plots were west of Atwell Creek and two were along the Tar Gap Trail. Of the plots that did burn, five are mixed-conifer plots, two are mixed-conifer/oak woodland, and two are red fir. With such a small sample of burned plots we have been unable to draw meaningful conclusions about the effects of fire. Unfortunately, there were no fires in the autumn of 1998 and spring of 1999 near the plots and so we will have no new fire data in the summer of 1999. As a result, we have turned our short-term attention to a more robust examination of the current (pre-fire) conditions in the watershed. These analyses are described below.

METHODS

Data collected in support of this project come from three time periods—historic, pre-fire (current conditions), and post-fire and three spatial scales—within plots, between plots and across the landscape. Current conditions and post-fire data are collected both within forests by use of an extensive forest inventory approach, and from the air, using aerial photographs. Historic data have not yet been examined closely.

Field data for pre- and post-fire conditions are collected from forest plots ten meters in radius (**Fig. 3.11-1**). These are located precisely using a precision global positioning system (GPS) unit. Within each plot, trees are identified by species, measured and mapped; fuel conditions are recorded; brush and plant

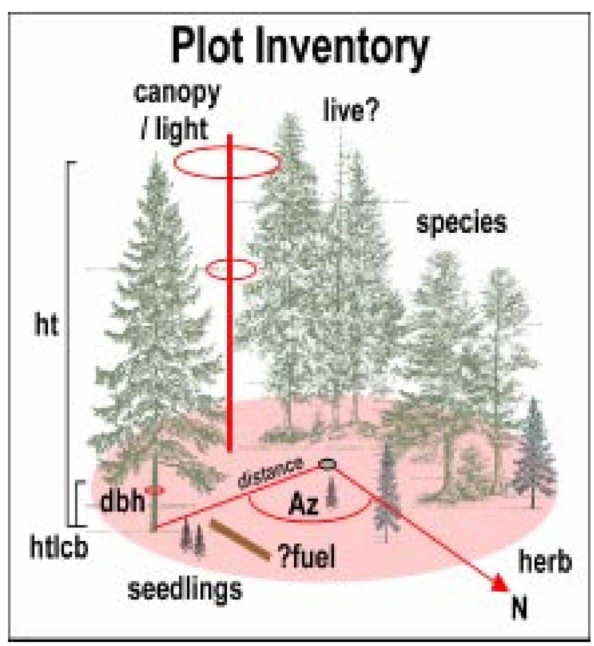

Figure 3.11-1.

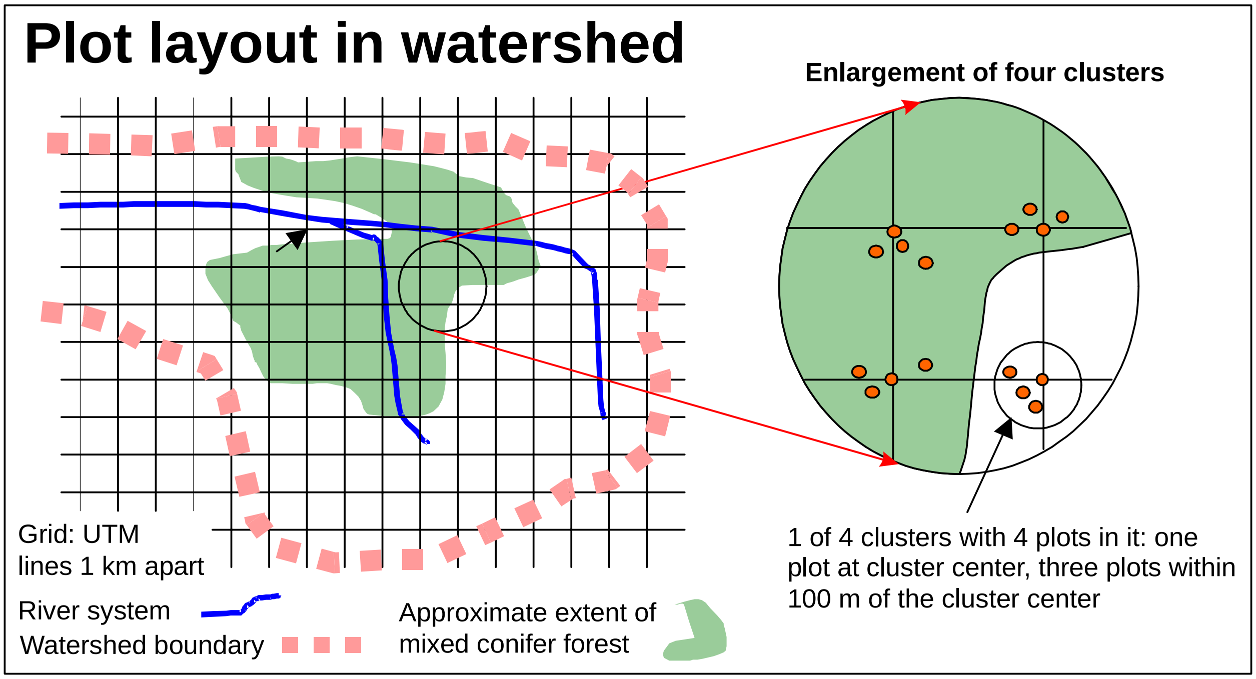

Figure 3.11-2.

cover are described; slope and aspect are recorded; and light penetrating through the forest canopy is measured.

Collection and processing of the remote imagery data is a more elaborate process. High resolution, digital photographs were collected during an overflight in the summer of 1997. The digital photographs, with a resolution of about one meter, are actually four simultaneous pictures in different bands of light—blue, green, red, and near infrared. The instrument digitally records the time, flight conditions and position of each set of photographs. It is hoped that this special imagery will allow us to determine individual tree species and detect subtle changes in forest conditions due to stress or insect attack.

WORK COMPLETED IN 1998

The 200+ plots in the Mineral King Landscape Assessment span the range of the mixed conifer forest type. Over 2500 trees taller than breast height (1.37 m, or 4.5 feet) have been described and mapped covering a total area greater than six and a half hectares (16 acres). In addition, data from 1800 soil depths, litter and duff measurements, and seedling counts have been tallied. Of the 68 plots re-inventoried in 1999 only nine plots had burned. Due to the small nature of the plots, a large number of plots is necessary to draw statistically-valid results. Hence, we have shifted the short-term focus of our analysis from the effects of fire to a more robust investigation of current conditions.

Some fire scientists have contended, for example, that current forests are too evenly structured to experience highly variable mortality from fire. To test this contention prior to the reintroduction of fire, we examined the current structure and composition of the mixed conifer forest in Mineral King using 128 10m radial plots in clusters of four (32 clusters)[2] (**Fig. 3.11-2**) A modified Gini coefficient was used to measure changes in the frequency distributions of diameter, basal area and tree height as a function of macroaspect,

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[2] These plots were chosen from the overall total of 200 because they represent complete clusters of mixed conifer plots whereas some plots have only red fir.

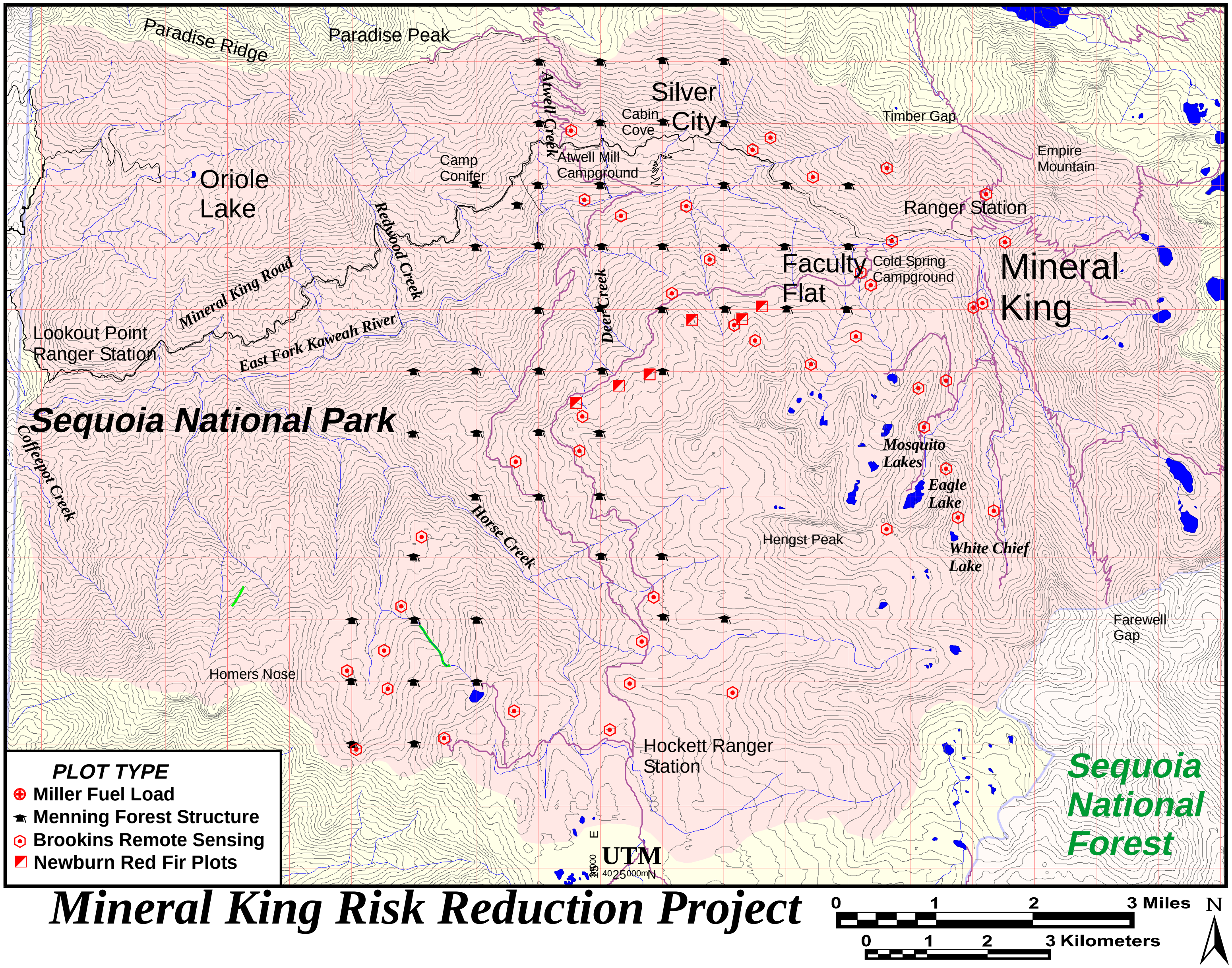

Figure 3.11-3. Plot locations for graduate students working on vegetation studies within the East Fork.

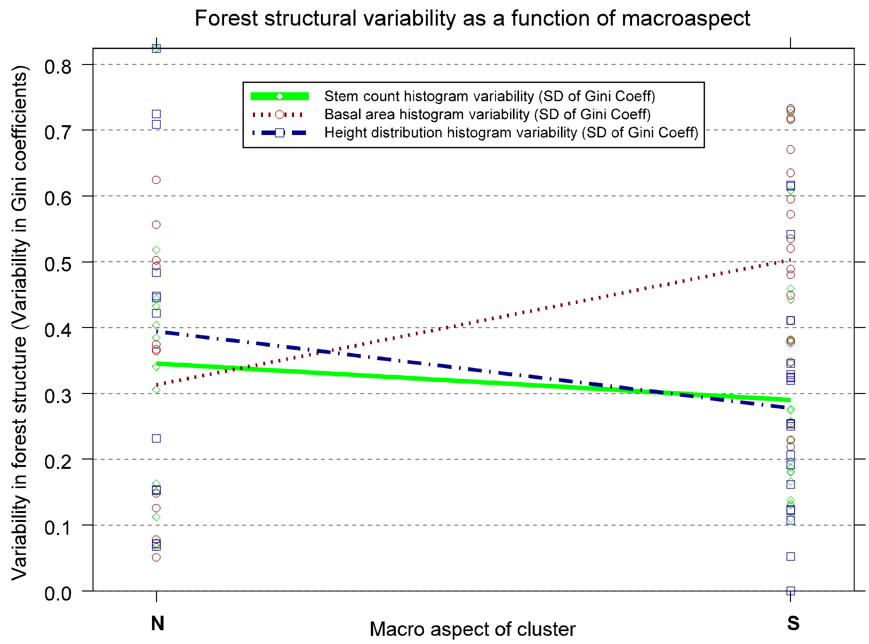

Figure 3.11-4

elevation, and local variation in topography at the scale of 10's to 1000's of meters (**Fig. 3.11-4** and **3.11-5**). Statistically significant differences exist between distributions of height, diameter and basal area as functions of macroaspect, with distributions on southern aspects skewed toward more, smaller trees. Total numbers of trees per plot are not significantly different from clusters on opposite macroaspects. On southern aspects the total basal area per plot is lower and varies less per cluster than on northern aspects. The distribution of basal area by size class, however, is more variable on the southern aspect. Structural variability in the distribution of height, diameter and basal area of the forest between the two macroaspects indicates post-fire structure may also vary between the two macroaspects. High structural diversity on the southern aspect indicates post-fire structural diversity may be higher than comparable locations on the northern aspect, which have a more evenly distributed forest structure. Post-fire analysis will help us determine if this is true.

Having examined the variability in forest structure we decided to examine the variability in ground and surface fuels as well. Do they vary in the same way in relation to topography? The same plots as described above were inventoried for litter (Oi) depth, duff (Oe) depth, and woody surface fuel mass. All three fuels measures are examined as functions of elevation, aspect, and variability in local surface topography. The fuel measures were found to vary with elevation on different aspects of the watershed but not to change predictably with local topography. As a result, we conclude that variability in fuel loads is not as predictable as variability in forest structure. Based on this, we believe that it is important to have detailed ground-based information on both the distribution of fuels and forest structure, in addition to fuels continuity, in order to predict fire behavior and to examine changes to forest structure due to fire.

An additional source of information we are currently processing is the remote imagery. Over seven hundred digital aerial photographs were successfully taken in 1997. Processing and analyzing the images is not yet complete. A heavy workload with the field data and a lack of supporting terrain information from USGS has delayed the process.

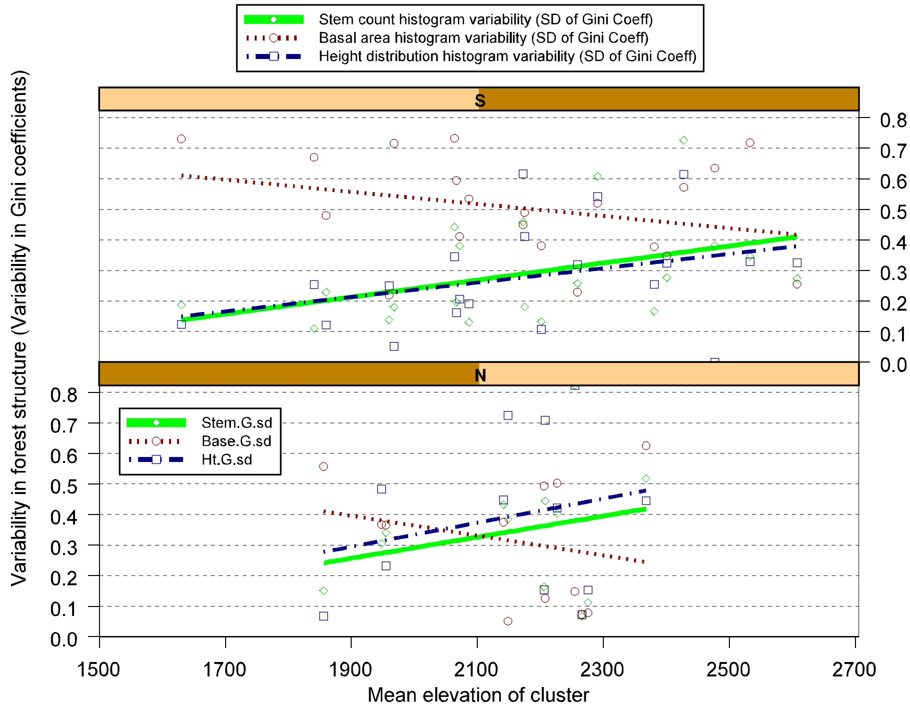

Figure 3.11-5.

FUTURE WORK: SUMMER 1999 and BEYOND

In summer 1999, the MKLA project will expand. We expect to conduct ten weeks of intensive fieldwork. During the six weeks, four field crew members will take hemispherical photographs of forest crown structure in the MKLA plots. Additionally, we will collect more detailed information on soil depth and texture as it affects the retention of water. These factors are important in understanding variability in the way forests grow in the absence of fire and, as a result, the way in which they generate fuels and respond to fire. During a long period of fire suppression, as much of Mineral King has experienced, site-potential differences may have resulted in uneven forest growth. This, in turn, may have resulted in highly variable fuel loads and could lead to a patchy fire pattern. By collecting these additional data we hope to be able to examine these relationships.

We are also beginning related work looking at the effects of fire suppression on the mortality of large sugar pines. Many fire scientists believe that re-introducing fire with prescribed burning can lead to increased mortality of large pines. During fieldwork in Mineral King, however, we have observed another trend that complicates the argument that burning around old pines can kill them. In Mineral King, large sugar pines (***Pinus lambertiana***) appear to be dying with greater frequency than other large trees even *without* fire. It is probable that in the course of fire suppression individual large sugar pines are being out-competed by the many small white fir (***Abies concolor***) and other species that are normally killed in light or moderate fires. The death of large trees due to competition by many small trees during fire suppression has been the source of some conjecture but little direct research. High mortality may also result from manifestation of blister rust or climate change; however, mature trees are not as susceptible to blister rust and the wetter weather this century should favor mature sugar pines in the mixed conifer forest. Hence, we believe the increased mortality of large sugar pines to be due to elevated biotic competition that has resulted from fire suppression.

To address this question, we are going to selectively core and geo-reference large living and dead sugar pines. We would like to determine date of death (through cross dating) and recent rates of growth. If there is a substantial decrease in growth rate over this warmer, wetter century, we may intuit that it is due to increased competition. If this is observed and can be correlated with air photos showing an increased density of small trees in these locations we may be able to show a relationship between the absence of fire and compositional and structural change: the loss of the large pine component of this forest.

3.12) Evaluation of Multispectral Data for the Determination of Fuel Loads in Forested Environments*.

- William Miller and Mitchell Brookins, Arizona State University, Tempe Arizona.

Effective fire management in forested environments is dependent on the knowledge of levels and distribution of fuel loads. Past methods of collecting this information have depended on costly, and frequently inadequate, grand sampling. This study was designed to examine the feasibility of using remote sensing (multispectral TM data) to predict levels and distribution of forest fuels in the Mineral King region of Sequoia National Park. Data on actual fuel loads were collected from 70 randomly located, 0.025 ha macro-plots within the designated study area. Data collected at each plot included overstory characteristics (tree density, height and size parameters by species), midstory characteristics (shrub density, height and volume), understory characteristics (herbaceous cover and height), fine fuel (deadfall and litter). These data were used in the development of hierarchical classification of vegetative communities and fuel load classification. Multispectral (TM) data used were from a July 1992 Landsat overflight. All data were corrected for atmospheric error using flat field correction, and further processed using three techniques; normalized difference vegetation index (NDVI), modified soil adjusted vegetative index (MASSIVE), and linear spectral unmixing (LSU). Community and fuel classes identified from the ground data were used as the basis for supervised classifications. A maximum of 35 of the field collected locations were used to identify training areas. The remaining were used for accuracy assessment. The results suggest a usable relationship between multispectral data and fuel loading in forested environments.

* Abstract for presentation at the annual Photogrammetry and Remote Sensing Conference, Portland, OR in May 1999. See 1996 MKRRP Annual Report (Miller and Brookins 1997; Caprio 1997) for detailed description of project and methods.

3.13) Fire Effects Monitoring

- MaryBeth Keifer, Science and Natural Resources Management, SEKI

Lead: MaryBeth Keifer; Field crew supervisor: Georgia Dempsey; Field crew: M. Buhler, M. Cox, A. Huber, K. Williams.

INTRODUCTION

Fuels and vegetation monitoring has been part of the parks' fire management program for the last two decades. Fire effects monitoring information is used to assess whether the prescribed fire program is meeting intended objectives. The Mineral King Risk Reduction Project (MKRRP) represents a large step in the parks' move toward increased prescribed fire on a landscape scale. Fire effects monitoring in the project area is critical to: 1) evaluate the achievement of fire management objectives; 2) examine changes in vegetation structure and composition; 3) detect any unexpected or undesirable changes in vegetation that may be a result of the project; and 4) provide the above information to fire managers, other park staff, and the public.

Fire effects monitoring work within the MKRRP area is based on the relative need for information in various vegetation communities. Monitoring data are needed both to confirm that results in the Mineral King watershed are similar to those in other areas of the parks, as well as to fill in information gaps in certain vegetation communities.

High elevation vegetation types in the Sierra generally have longer fire-return intervals than at lower elevations. Consequently, unnaturally heavy fuel accumulation found at lower elevations due to exclusion of fire over the last century is not as common in higher elevation vegetation types. The effects of changes in fire regime, and subsequent increased risk, are not as critical at higher elevations. Although both ecological and life/property risk is likely to be lower, limited information is available for upper elevation vegetation types, therefore, moderate efforts to monitor vegetation change in these types is warranted in the project area.

Past research and monitoring efforts in the parks have concentrated on the mid-elevation forests, especially the giant sequoia-mixed conifer type. Although the mixed conifer forest has been monitored relatively intensively in the past, fire effects information for all vegetation types in the project area are needed for public information distribution. Accordingly, the mixed conifer forest vegetation types are monitored at a minimal level in the MKRRP area. Within the mixed conifer forest types, monitoring information is least available in the xeric, low elevation type, therefore, mixed conifer monitoring efforts will be increased in this type if time allows.

Historically, the lower elevation vegetation type fire regimes consisted of generally more frequent and/or higher intensity fire than at higher elevations. A disruption in this fire regime, such as fire exclusion attempts, may have had a great effect on vegetation structure and function in these lower elevation types. With few studies concerning lower elevation vegetation fire effects, more information is needed about the potential effects. Of the lower elevation types, chamise chaparral has been more thoroughly studied than other foothill vegetation communities (Rundel and Parsons 1979; Rundel 1982). Consequently, the MKRRP vegetation monitoring efforts focus on the lower elevation vegetation types of oak woodland and mixed evergreen chaparral.

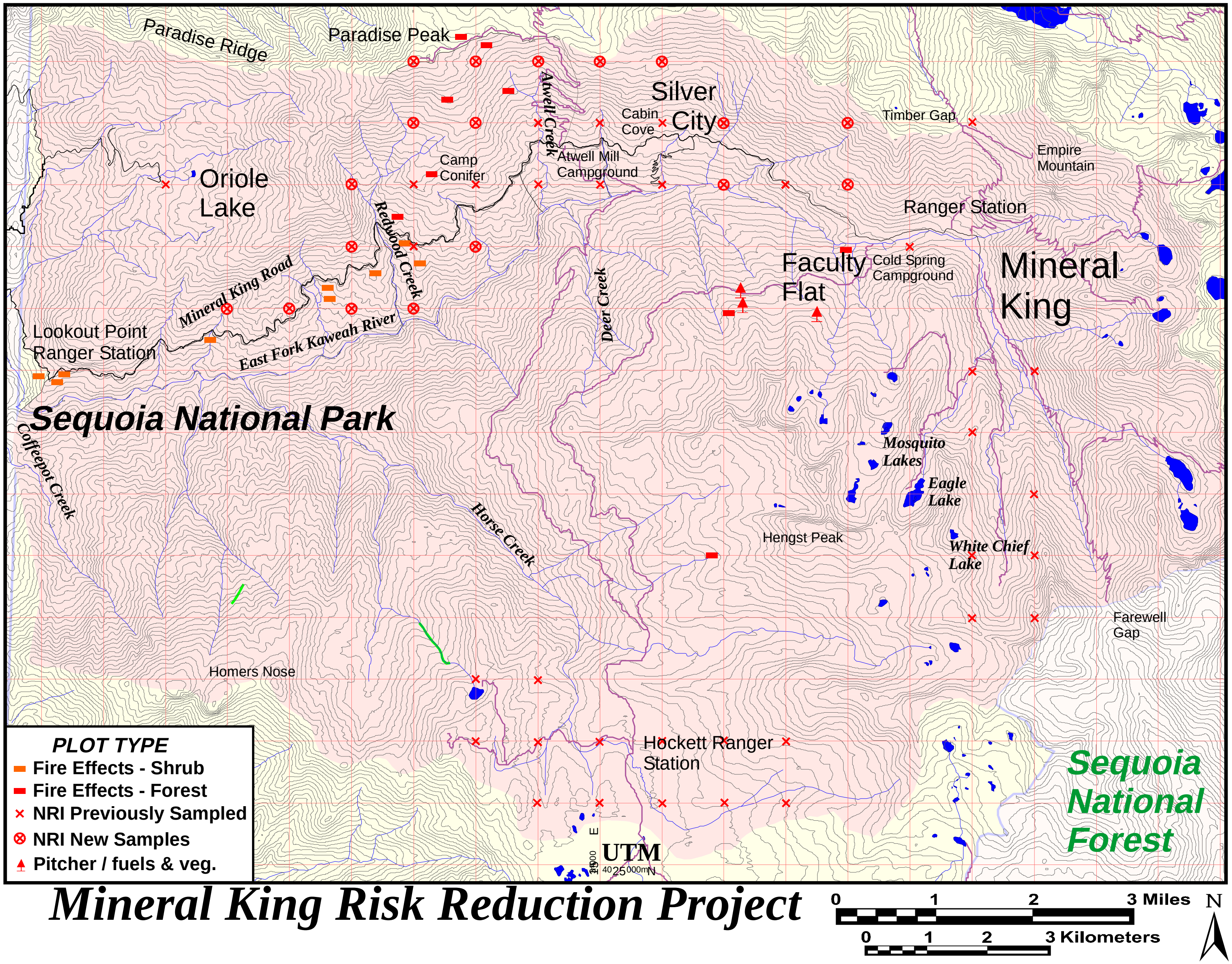

Figure 3.13-1. Plot location for vegetation sampling projects.

METHODS

The National Park Service's Western Region Fire Monitoring Handbook (1992) standardized methods are used for monitoring fire effects on vegetation and fuels. Monitoring plots in burn units are located randomly on a 100 x 100 meter grid within each of the vegetation types designated for monitoring. Criteria for grid point exclusion include proximity to roads/trails, riparian areas, anomalous physical or biological characteristics, and inaccessibility (both safety and time constraints). Location of plots by burn segment, monitoring (vegetation) type, dominant species, and UTM coordinates are presented in **Table 3.13-1** and shown in **Fig. 3.13-1.**

Plots are installed in a sequence according to segments scheduled to burn. Monitoring occurs according to the following schedule: preburn, immediately postburn (within 2 months of burning), and 1, 2, 5, and 10 years postburn. Data from these monitoring plots are summarized for the project after each step of the monitoring schedule and results are promptly distributed to park staff and the public. The data may also be included in monitoring type summaries for the parks' overall fire effects monitoring program.

Unburned monitoring plots in other areas of the parks may be used to compare with burn project results. If existing unburned plots are not available, additional plots may be established adjacent to the project area in areas that are not currently scheduled for prescribed burning.

Table 3.13-1. Plot locations and information (an asterisk in the UTME column indicates the plot was geo-referenced using a global positioning system with an accuracy of ± 3-30 meters).

Plot ID	Monitoring Type	Dominant Species	Burn Segment	UTM-E	UTM-N
CADE 094	Low elevation-mixed conifer forest	incense cedar	Atwell (#3)	347570	4035590
SEGI 093	Giant sequoia-mixed conifer forest	white fir	Atwell (#3)	348280	4036200
SEGI 095	Giant sequoia-mixed conifer forest	white fir	Atwell (#3)	349513*	4037639
ABMA 096	Red fir forest	red fir	Atwell (#3)	349120*	4038347
ABMA 097	Red fir forest	red fir	Atwell (#3)	348428*	4037631
ABMA 098	Red fir forest	red fir	unburned	348602*	4038256
ABMA 100	Red fir forest	red fir	Tar Gap (#10)	352809*	4030052
ABMA 101	Red fir forest	red fir	Tar Gap (#10)	353059*	4034063
ABMA 102	Red fir forest	red fir	Tar Gap (#10)	354987*	4034922
ADFA 012	Chamise chaparral	chamise	Lookout (#2)	342251*	4032915
ADFA 013	Chamise chaparral	chamise	Lookout (#2)	342214*	4032867
ADFA 014	Chamise chaparral	chamise	Lookout (#2)	342233*	4032845
ARME 007	Mixed chaparral	manzanita	Lookout (#2)	347391*	4034592
ARME 008	Mixed chaparral	manzanita	Lookout (#2)	346596*	4034345
ARME 009	Mixed chaparral	manzanita	Lookout (#2)	346568*	4034144
ARME 015	Mixed chaparral	manzanita	Lookout (#2)	344635*	4033573
ARME 010	Mixed chaparral	manzanita	Redwood (#4)	348001*	4035021
ARME 011	Mixed chaparral	manzanita	Redwood (#4)	348112*	4034811

CHANGES IN MKRRP MONITORING PROGRAM SINCE 1997

A change that affects the fuel load results is the recent availability of equations to calculate litter load in addition to duff and woody fuel load. Litter depth measurements have been recorded in the field since the project began, and this year, litter load has been calculated for all previously collected data. As a result, the mean total fuel load values have increased in most cases, because of the added litter component. In addition, all fuel load values previously reported in tons per acre have been converted to, and graphically presented in, metric units for consistency.

WORK COMPLETED IN 1998

During the 1998 field season, two Mixed chaparral monitoring type plots were measured 1-year postburn and three Chamise chaparral type plots were burned and measured immediately postburn.

RESULTS TO DATE

Results are presented for: 1) three forest monitoring types that burned in 1995 and were monitored in 1996 and 1997 in the Atwell segment (#3); 2) one brush monitoring type that burned in 1997 and was monitored in 1998 in the Redwood segment (#4); and 3) one brush monitoring type that burned in 1998 in the Lookout segment (#2). Although the forest plots were not monitored this year, forest type results are presented to update the fuel information and add postburn condition results to the results previously described in the MKRRP 1997 annual report. The forest plot results include: dead and down fuel reduction and accumulation; burn severity estimates; overstory tree postburn conditions (maximum bark char height, maximum crown scorch height, crown scorch percent); changes in live overstory tree (>1.37 m in height) species composition and stand structure; and tree seedling (<1.37 m in height) density. The brush plot results include burn severity estimates and changes in percent cover by lifeform and by dominant species.

Monitoring types are referred to by their dominant species common name. Where more than one plot is included in the analysis, results are presented as mean values ± one standard error. In the figures, only the error bars for the dominant species or category are displayed. Results related directly to quantitative fire management objectives are indicated in bold typeface. Note that the results are not representative of all areas within the monitoring type in the watershed or the park and only apply to the plot areas measured due to small sample sizes (at most, three plots per monitoring type).

<u>Low elevation-mixed conifer forest monitoring type (incense cedar)</u>

Fuel Reduction and Accumulation

In one incense cedar plot, the fire **consumed 77% of the total fuel load**, from 31.76 kg/m^2 (141.6 tons/acre) preburn to 7.39 kg/m^2 (33.0 tons/acre) immediately postburn (**Fig. 3.13-2**). The

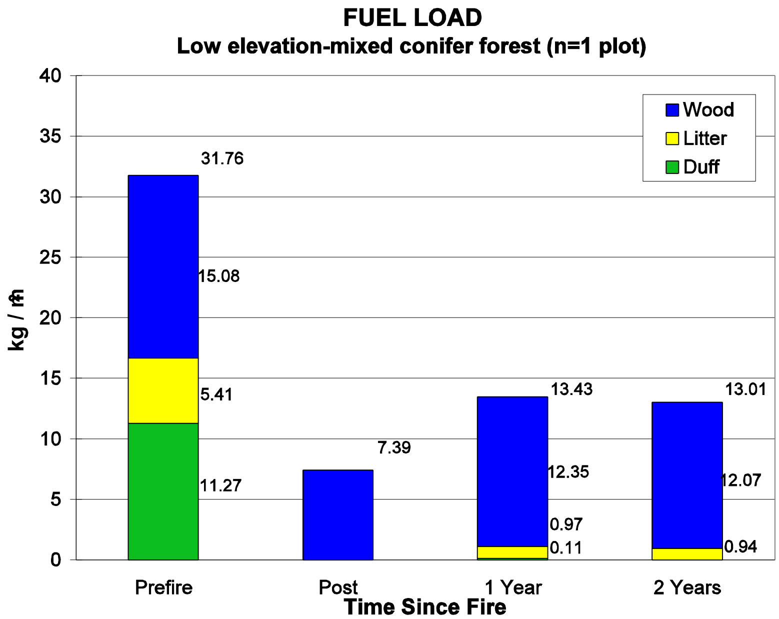

Figure 3.13-2. Fuel load changes in the low elevation-mixed conifer forest plot.

litter and duff components were completely consumed (100%) while woody fuels were reduced by 51%. Woody fuels increased by 67% over immediate postburn levels within 1-year, indicating that postburn branch and tree mortality was already contributing heavily to the downed woody fuel layer (**Fig. 3.13-2**). A small decrease in fuel load from 1- to 2-years postburn is likely due to slight differences in fuel transect locations repeated from one year to the next (error associated with the sampling technique).

Postburn Conditions

Using a burn severity scale from 1 to 5, where 1 is heavily burned and 5 is unburned, the mean burn severity for organic substrate in the incense cedar plot was 1.9 (moderately to heavily burned). Overstory tree mean bark char height varied by species ranging from 4.5 to 13.0 m (**Table 3.13-3**). Mean crown scorch height varied from 5.4 to 37.0 m while percent crown scorch ranged from 63.6 to 100% (**Table 3.13-3**).

Overstory Tree Density (Species Composition and Stand Structure)

Total overstory tree density was 1270 trees/ha preburn and 30 trees/ha 2-years postburn, indicating 98% overstory mortality* in the plot two years following fire (**Fig. 3.13-3**). Preburn composition was dominated by incense cedar (68% of all trees; **Fig. 3.13-3**), most of which were less than 50 cm in diameter at breast height (DBH) (**Fig. 3.13-4**). Incense cedar was reduced from 860 trees/ha preburn to 20 trees/ha 2-years postburn (98% mortality) while its relative species composition remained unchanged from preburn condition to 2-years postburn (68-67%; **Fig. 3.13-3**). Black oak, sugar pine, and white fir overstory tree densities were reduced to 0. The only ponderosa pine tree in the plot survived the fire, and therefore, ponderosa pine relative density increased from 1% to 33% (**Fig. 3.13-3**).

Table 3.13-2. Overstory tree postburn conditions by species.

Monitoring Type	Species	Number of Trees	Mean Bark Char Height (m)	Mean Crown Scorch Height (m)	Mean Crown Scorch %
Incense cedar (n=1 plot)	incense cedar	91	8.2	9.2	94.6
	black oak	17	5.8	6.9	63.6
	sugar pine	8	13.0	12.1	90.0
	California nutmeg	7	4.5	5.4	100
	white fir	2	5.5	6.5	100
	ponderosa pine	1	10.0	37.0	90.0
giant sequoia (n=2 plots)	white fir	90	2.2	4.9	43.1
	sugar pine	23	1.3	4.4	25.2
	giant sequoia	10	1.8	0.2	0.2
	red fir	9	1.5	7.0	40.6
	incense cedar	3	2.3	4.5	100
red fir (n=1 plot)	red fir	11	0.6	0	0

*Note on fire effects: Only one incense cedar plot has been established and burned in the East Fork watershed. This plot was located adjacent to a 0.8-1.2 ha (2-3 acre) area where 100% overstory mortality occurred in a draw above Redwood Creek (visible when driving up the Mineral King Road). The topographic influences, combined with weather and fuel conditions, resulted in fire effects that were more severe relative to effects normally observed in incense cedar plots elsewhere in SEKI. Additional incense cedar plots are being established within the project area in segments scheduled to burn in the future that may help determine whether these types of effects are common in this watershed.

Tree Seedling Density

Total tree seedling density increased by 62% from 3,280 seedlings/ha preburn to 5,320 seedlings / ha 2-year postburn.

Giant sequoia-mixed conifer forest monitoring type (giant sequoia)

Fuel Reduction and Accumulation

Total fuel load was reduced by 89% in one giant sequoia plot, from 40.65 kg/m^2 (181.3 tons/acre) preburn to 4.36 kg/m^2 (19.5 tons/acre) immediately postburn. The litter was reduced by 91%, duff was reduced by 92%, while 88% of the woody fuels were consumed. Due to the late season burn, the second giant sequoia plot was not measured immediately postburn and, therefore, was not included in the fuel reduction estimate. Woody fuel increased greatly 1-year postburn, surpassing the preburn woody fuel load (**Fig. 3.13-5a**). Note that standard error bars are very large, indicating high variability in total fuel load between the two plots for all visits

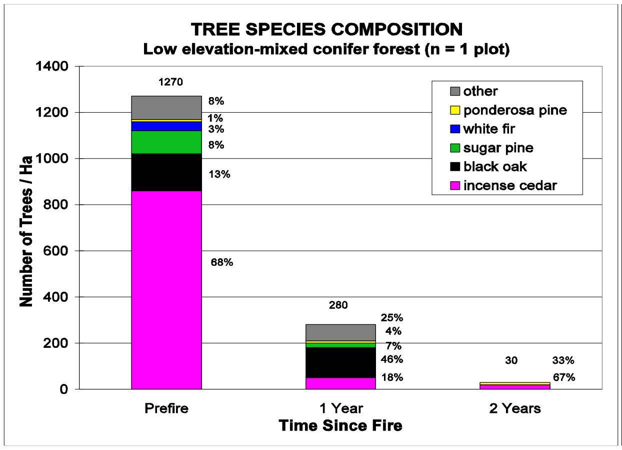

Figure 3.13-3. Overstory tree species composition changes (by density) in the low elevation-mixed conifer forest plot. Percentages indicate the relative density of each species.

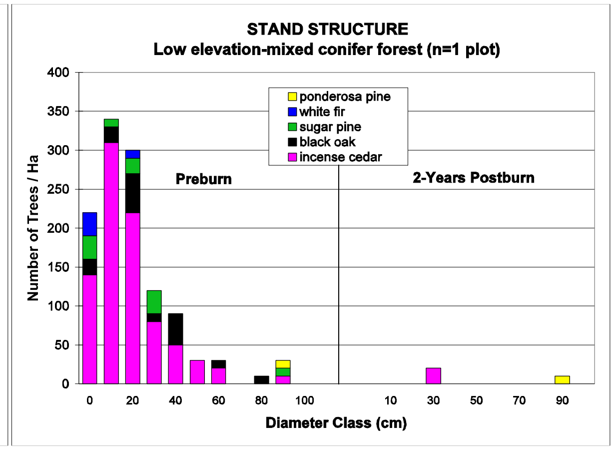

Figure 3.13-4. Stand structure changes between preburn and 2-years postburn by species and 10 cm diameter classes in the low elevation-mixed conifer forest plot.

(**Fig. 3.13-5**). The large postburn increase occurred in only one of the plots and is a result of a large fallen white fir that intercepted 3 of the 4 fuel transects. The arrangement of this downed tree gives the plot a very high fuel load which is not representative of the plot area in general and not typical of other plots throughout the parks in this monitoring type (**Fig. 3.13-5b**). Results from the second plot is much more representative of the postburn fuel accumulation pattern seen in the giant sequoia-mixed conifer forest type in the park (**Fig. 3.13-5c**).

Postburn Conditions

Organic substrate burn severity rating mean was 3.2 and vegetation burn severity was 3.4 for the giant sequoia plots (lightly to moderately burned). Overstory tree mean bark char height varied from 1.3 to 3.3 m (**Table 3.13-3**). Mean crown scorch height ranged from 0 to 7.0 m while mean percent crown scorch varied widely by species from 0.2% for giant sequoia to 100% for incense cedar. Giant sequoia postburn conditions were on the low end of the range for both bark char (1.8 m) and crown scorch measurements (0.2 m height and 0.2% crown scorch percent) (**Table 3.13-3**).

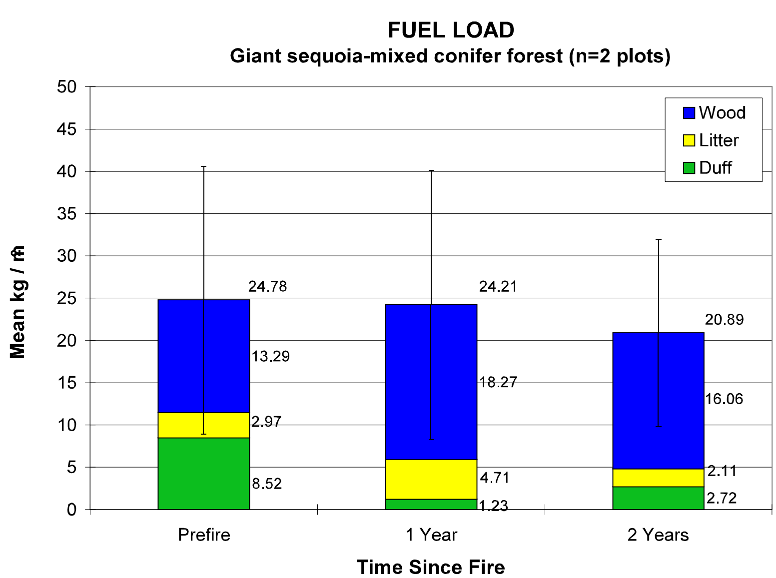

Figure 3.13-5. Fuel load changes in the giant sequoia-mixed conifer forest plots. Error bars represent ± one standard error of the mean for total fuel load.

Overstory Tree Density (Species Composition and Stand Structure)

In two giant sequoia plots, mean total overstory tree density was reduced by 50%,

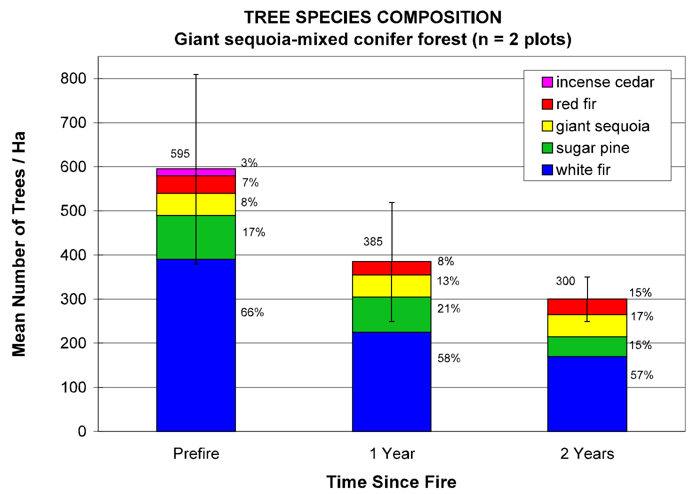

Figure 3.13-6. Overstory tree species composition changes (by density) in the giant sequoia-mixed conifer forest plots. Percentages indicate the relative density of each species. Error bars represent ± one standard error of the mean for total tree density (all species combined).

from 595 ± 215 trees/ha preburn to 300 ± 50 trees/ha 2-years postburn (**Fig. 3.13- 6**). White fir dominated preburn (66%) and most mortality occurred in the smaller diameter white fir (less than 30 cm; **Fig. 3.13-7**). Relative density changed from preburn condition to 2-years postburn. Incense cedar, white fir, and sugar pine decreased (from 3% to 0%, from 66% to 57%, and from 17% to 15% respectively) and relative increases occurred in red fir (from 7% to 15%) and giant sequoia (from 8% to 17%; **Fig. 3.13-7**). No mortality of any giant sequoia trees occurred in either plot.

Tree Seedling Density

Mean total seedling density for all species on two giant sequoia plots was 3,520 ± 2,080 seedlings/ha preburn. Density increased by 86% to 6,560 ± 5,880 seedlings/ha 2-years postburn. This increase was due to the postburn establishment of giant sequoia seedlings (from 0 preburn to a mean of 5,800 seedlings/ha 2-years postburn); for all other species, seedling density decreased by 2-years postburn. This result corroborates previous studies that show that fire greatly increases the establishment of giant sequoia seedlings. Seedling density is, however, highly variable between plots (evidenced by the high standard error values) and indicates that seedling establishment varies greatly at this spatial scale.

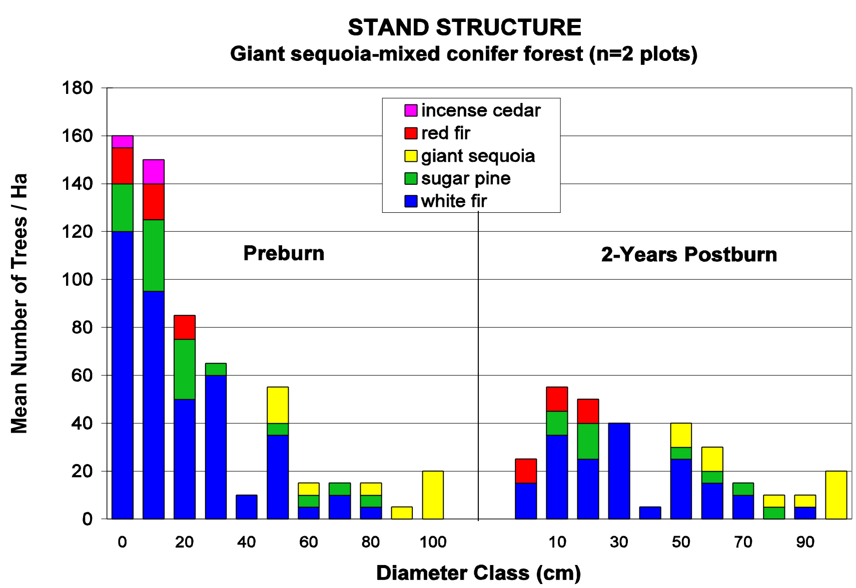

Figure 3.13-7. Stand structure changes between preburn and 2-years postburn by species and 10 cm diameter classes in the giant sequoia-mixed conifer forest plots.

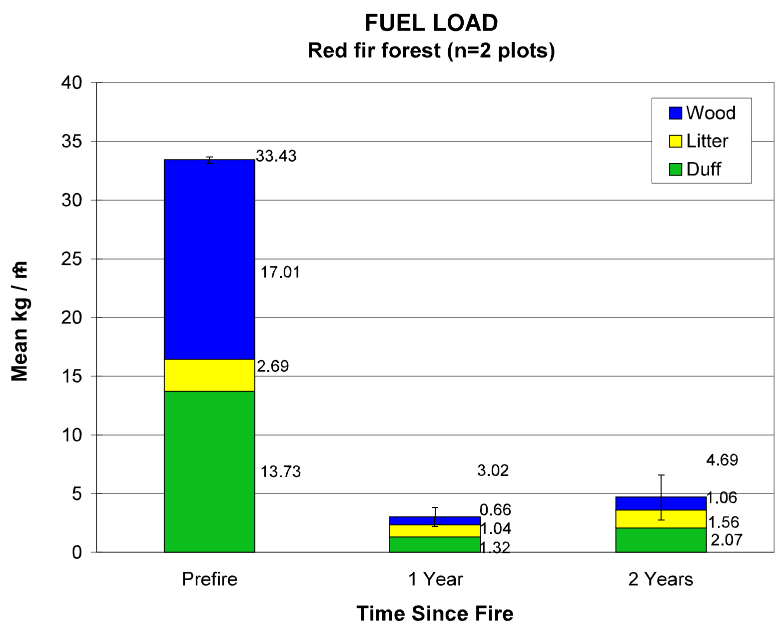

Figure 3.13-8. Fuel load changes in the red fir forest plots. Error bars represent ± one standard error of the mean for total fuel load.

<u>Red fir forest monitoring type (red fir)</u>

Fuel Reduction and Accumulation

In two red fir plots, the mean total fuel load was 33.43 ± 0.28 kg/m^2 (149.1 ± 1.3 tons/acre) preburn and 3.02 ± 0.80 kg/m^2 (13.5 ± 3.6 tons/acre) 1-year postburn, which indicates a **91% total fuel reduction** (**Fig. 3.13-8**). The plots were not revisited immediately postburn due to the late season burn and arrival of snow. Litter was reduced by 61%, duff was reduced by 90% and 96% of the woody fuels were consumed. Some fuel may have accumulated from the time the plots burned until they were measured the following summer, therefore, the fuel reduction results are conservative. Woody fuel, litter, and duff all accumulated slightly between the 1 and 2-years postburn (**Fig. 3.13-8**).

Postburn Conditions

Burn severity ratings estimated in the red fir plots are not included because they were not measured until 1-year postburn and therefore may not be representative of actual postburn conditions. Mean bark char height was 0.6 m, and crown scorch height and percent volume were both 0 (**Table 3.13-2**). Overstory tree postburn conditions may be conservative, especially for crown scorch, as scorched needles may have fallen during the 1-year before measurements were made.

Overstory Tree Density (Species Composition and Stand Structure)

Mean red fir overstory tree density for two plots was 205 ± 95.0 trees/ha preburn and 160 ± 50 trees/ha 2-years postburn (**Fig. 3.13-9**). While no overstory red fir mortality was detected in either of the red fir plots during the first year following the fire, 22% mortality occurred within two years after the fire. Most of this mortality occurred in the smaller diameter red firs (**Fig. 3.13-10**).

Tree Seedling Density

Mean red fir seedling density for two plots was reduced by 99%, from 17,380 ± 3,900 seedlings/ha preburn to 100 ± 100 seedlings/ha 2-years postburn.

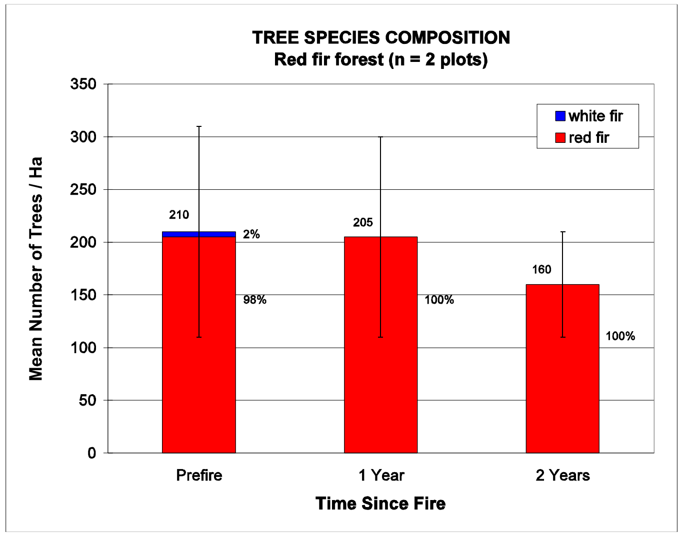

Figure 3.13-9. Overstory tree species composition changes (by density) in the red fir forest plots. Percentages indicate the relative density of each species. Error bars represent ± one standard error of the mean for total tree density (all species combined).

<u>Mixed chaparral monitoring type (manzanita)</u>

Postburn Conditions

The burn severity rating mean was 4.5 (unburned to scorched) for organic substrate and 4.0 (scorched) for vegetation indicating very low severity fire burned through these two plots.

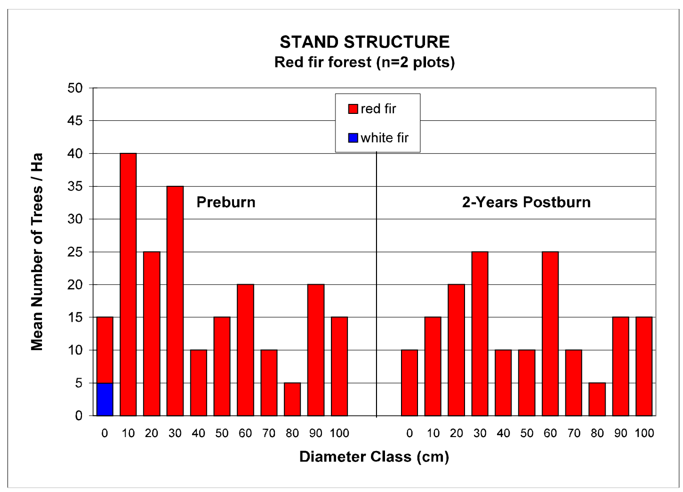

Figure 3.13-10. Stand structure changes between preburn and 2-years postburn by species and 10 cm diameter classes in the red fir forest plots.

Cover by lifeform

Mean percent cover decreased only slightly for live shrubs (all shrub species combined), from 88.6 ± 6.4% preburn to 82.5 ± 1.5% 1-year postburn (**Fig. 3.13-11**). Live tree (all tree species combined) and substrate mean cover also decreased slightly, while mean percent cover for grasses (all grass species combined) was reduced by about half. Substrate includes organic material (leaf litter or wood) as well as mineral soil, ash, or rock. Mean percent cover for forbs (all forb species combined) increased from 2.0 ± 2.0% preburn to 11.0 ± 5.0% (**Fig. 3.13-11**). Note that percent cover can total more than 100% as more than one lifeform (or species) can occur at a sampling point. These results indicate that major changes in cover of vegetative lifeform categories did not occur in these plots by 1-year postburn.

Cover by species

Mean percent cover for live *Arctostaphylos mewukka*, the dominant species, changed very little between preburn (70.2%) and 1-year postburn (69.0%) visits (**Fig. 3.13-12**). Black oak (*Quercus kellogii*), flannelbush (*Fremontodendron californicum*), and bear clover (*Chamaebatia foliolosa*) all decreased somewhat in mean percent cover. Mountain mahogany (*Cercocarpus betuloides*) mean percent cover increased from 16.4 ± 4.6% preburn to 28.5 ± 12.5% 1-year postburn. With the small sample size (2 plots) and high variability between plots, these results indicate that the burn had little effect on changing species vegetative cover within these plots. Cheatgrass (*Bromus tectorum*), a highly invasive exotic grass, was found within these plots before burning. The mean percent cover of cheatgrass decreased slightly, from 2.5 ± 0.5% preburn to 1.5 ± 1.5% 1-year postburn. The sample size is too small to make any conclusions about changes observed in cheatgrass cover following burning.

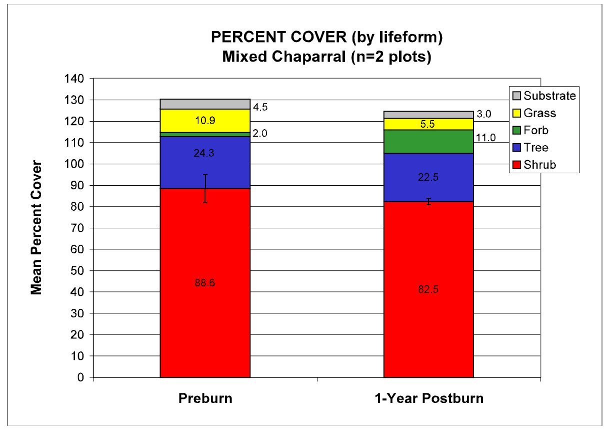

Figure 3.13-11. Percent cover by lifeform (all species combined) in the mixed chaparral plots. Error bars represent ± one standard error of the mean for shrub cover.

<u>Chamise chaparral monitoring type (chamise)</u>

Postburn Conditions

The burn severity rating mean for both organic substrate and vegetation was 1.9, indicating that the estimate of severity ranged from moderately to heavily burned.

Cover by lifeform

Mean percent cover for live shrubs (all species combined) decreased by 84% from 93.0 ± 3.5% preburn to 15.0 ± 15.0% postburn (**Fig. 3.13-13**). A corresponding increase in mean percent cover of substrate occurred, from 7.0 ± 3.5% preburn to 74 ± 16.1% postburn indicating that much of the vegetative cover was consumed during the burn.

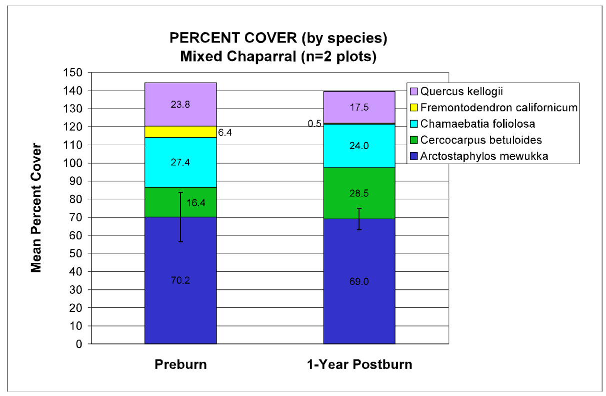

Figure 3.13-12. Percent cover by major species in the mixed chaparral plots. Error bars represent ± one standard error of the mean for *Arctostaphylos mewukka* cover.

Cover by species

Mean percent cover for live chamise, the dominant species, was reduced by 88% from 90.3 ± 6.2% preburn to 11.0 ± 11.0% postburn (**Fig. 3.13-14**). *Arctostaphylos mewukka* mean cover increased slightly, between the preburn and immediate postburn measurements, likely due to slight differences in transect location from one visit to the next (an artifact of sampling).

MANAGEMENT IMPLICATIONS

While the plot results do not represent results for the entire burn unit or monitoring type, the results are an indication of the effectiveness of burning within a smaller area. In the forest types, the parks' 60-80% total fuel reduction objective was met or exceeded within the monitoring plots. The park staff is in the process of developing objectives to address forest structure and process in addition to fuel reduction.

Currently, quantitative fire management objectives do not exist in the parks' brush types. The park staff recognizes the need for burning in chaparral to reduce fuel hazard and to restore fire to vegetation communities where fire has historically been an important component. At the same time, fire management objectives for chaparral will need to be developed in order to assess whether prescribed burning is effective in these types.

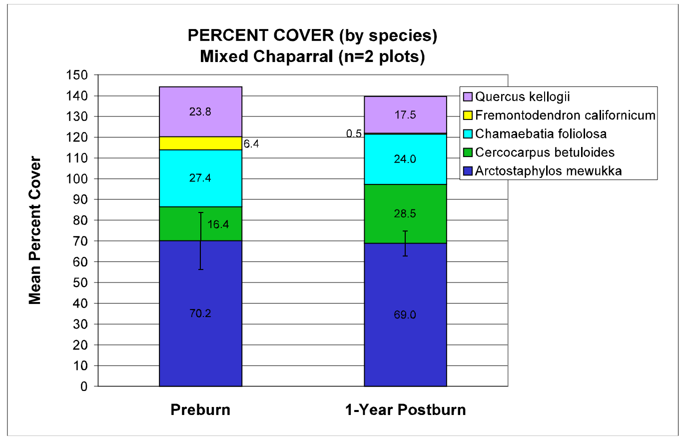

Figure 3.13-13. Percent cover by lifeform (all species combined) in the chamise chaparral plots. Error bars represent ± one standard error of the mean for shrub cover.

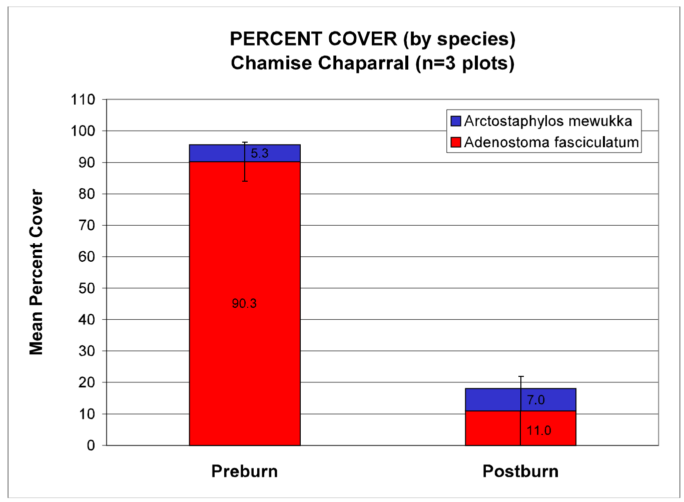

Figure 3.13-14. Percent cover by major species in the chamise chaparral plots. Error bars represent ± one standard error of the mean for chamise cover.

PLANS FOR 1999

Two Mixed chaparral plots that burned in 1997 will be visited for 2-year postburn assessments and three Chamise chaparral plots that burned in 1998 will be visited for 1-year postburn measurements. If the remaining four Mixed chaparral plots in the Lookout segment (#2) burn next year, they will be visited to record the immediate postburn measurements. New plots will continue to be installed as necessary as the burn segments are scheduled.

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3.14) Prescribed Fire and Heavy Fuel Effects on Mature Giant Sequoia Trees

- MaryBeth Keifer, Science and Natural Resources Management, SEKI

Lead: Georgia Dempsey, MaryBeth Keifer

INTRODUCTION

As a result of public concern about the visual effects of fire, giant sequoia trees located in Special Management Area (SMA) restoration burn units were subject to preburn large fuel removal as specified in Appendix H of the SEKI Fire Management Plan. The appendix stated that unnaturally high fuel levels around sequoia trees greater than four feet in diameter must be removed prior to burning to limit bark char and crown scorch. Although Appendix H was amended in 1996 to relax this internal policy requirement (based on a compilation of studies), this study will provide managers with information about the actual impacts of burning the unnatural fuels around the giant sequoias. For the complete study plan for this investigation, see Keifer (1995) **Appendix 1** in the MKRRP 1995 Annual Report.

OBJECTIVES

This study was designed to assess the relationship between the amount of fuel surrounding giant sequoias prior to burning and the resulting fire effects. The specific objectives of the study are to: 1) determine the amount of heavy fuels surrounding giant sequoia trees prior to and following prescribed burning, and measure the resulting fire effects characteristics; 2) from these measurements, determine the relationship between the amount of large fuel and duff surrounding giant sequoia trees and resulting changes in fire effects characteristics (bark char, crown scorch, fire scars, and mortality); 3) provide the fire management staff with the study results to assist in making decisions regarding heavy fuel clearance in giant sequoia groves.

PRELIMINARY RESULTS

The study area, consisting of 60 giant sequoia trees located in the Atwell (#3) segment, was burned in 1995. Due to the late season burn and subsequent snowfall, the trees were not revisited until 1996, one-year postburn. In eight 7.6 m (25 foot) transects radiating out from the base of each tree, mean preburn litter depth was 2.03 cm (0.8 inches) and mean 1-year postburn litter depth was 0.03 cm (0.01 inches). Duff depth was also greatly reduced from a preburn mean depth of 11.68 cm (4.6 inches) to a 1-year postburn mean depth of 0.76 cm (0.3 inches). Fuel consumption (load, in kg/m^2) for litter, duff, and large woody fuel has not yet been analyzed.

Eleven of the study trees sustained crown scorch as a result of the prescribed burn. For these trees (trees without scorch not included), mean scorch height was 17.6 m while the mean proportion of the crowns scorched was 5.3%, ranging from 1 to 15%. New scars formed on 33 of the trees sampled, noted by the presence of areas on the trees where the cambium was lethally damaged and the bark exfoliated. Many of these new scars formed on the upslope side of the trees. No mortality occurred in any of the 60 study trees within 2-years following the fire. Complete results for the giant sequoia fuel and fire effects study are still being processed.

3.15) Red Fir Regeneration and Fire

- Dave Newburn, Science and Natural Resources Management, SEKI

Lead: David Newburn, UC Berkeley, California

INTRODUCTION

Gap-phased dynamics have been used as a framework to understand forest successional pathways (Pickett and White 1985). Forest stands are often comprised of populations of similar-aged trees which can be associated by groups each composing a successional stage in the complex forest mosaic. Forests typically have several disturbance agents (i.e. fire, disease, windthrow) which form canopy gaps within intact forest canopy, ranging in scale from individual canopy trees to several hectares. In many forest types, regeneration occurs in patches following gap-initiating disturbances.

In the higher elevations of the Sierra Nevada, red fir (***Abies magnifica***) comprises nearly monospecific stands (Barbour and Woodward 1985). Groups of red fir trees may be even-aged, resulting from synchronous post-disturbance establishment, or multi-aged, reflecting continuous recruitment of seedlings moderately tolerant of shade. Red fir seedlings, saplings, and small understory trees exhibit clumping (**Fig. 3.15-1**) at scales roughly equivalent to the size of canopy gaps (Taylor 1991). Even though fire is the major disturbance within red fir forest, little has been studied regarding the persistence of these regeneration clumps after fire and their importance in forming later successional seres.

This study will attempt to understand the role of fire in thinning red fir understory trees within regeneration patches (**Fig. 3.15-2** and **Fig. 3.15-3**). To this end, we will measure the distribution and intensity of patch regeneration within red fir forest. The understory tree survival rates after fire also will be evaluated to determine the relative importance of patch and non-patch areas in forming later successional seres. Lastly, canopy gap sizes will be measured before fires to see how regeneration patch area correlates with gap size.

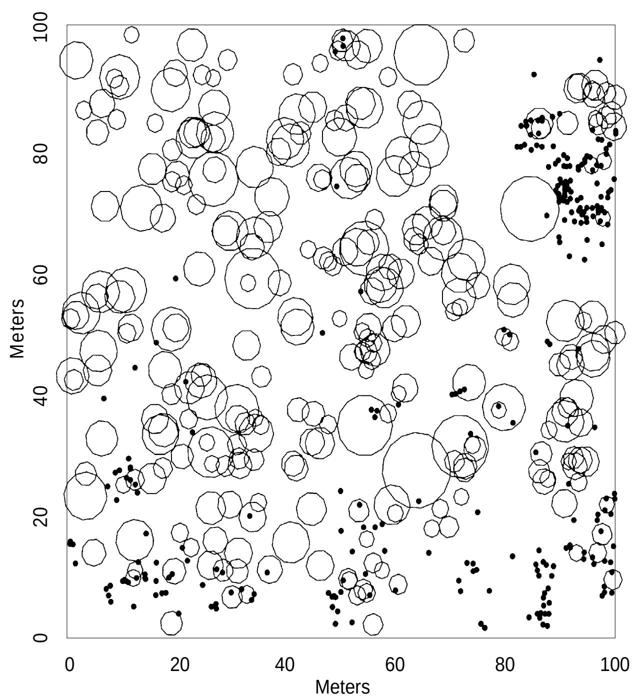

Figure 3.15-1. Spatial clumping of red fir seedlings at Panther Gap. Open circles show locations of the canopies of large overstory trees and small solid dots show locations of saplings (data from BRD global change plot).

RESEARCH OBJECTIVES

The initial two sections of the proposed research develop the basis for the application of a patch dynamics model. Subsequently, fire effects will be determined on small trees to evaluate the persistence of patches after fire.

I. Spatial patterning of red fir regeneration

- Determine patterns in the distribution of small trees (seedlings/saplings) and find the scale of regeneration patches.
- Compare the relative abundance of small trees in patches (clumps) versus non-patch areas (in remaining plot area).
- Overlay small tree distributions with canopy gap distribution to determine if relationships exist between patches of small trees and canopy gaps..

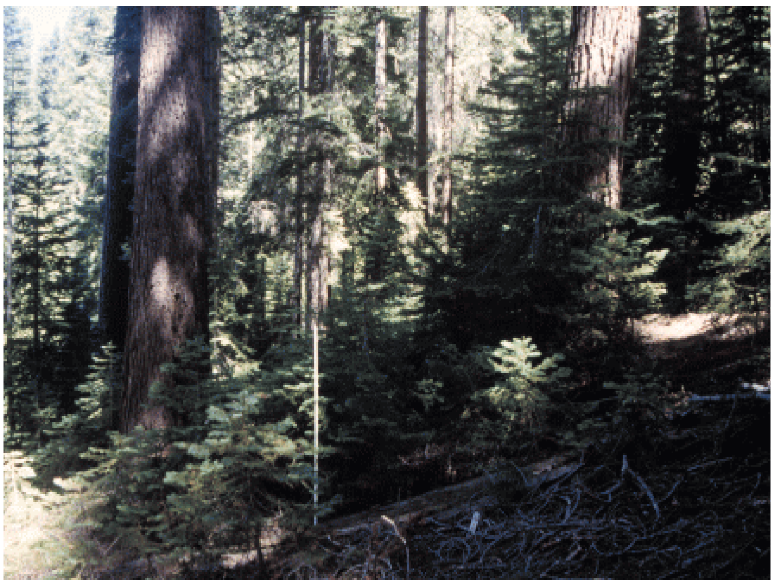

Figure 3.15-1. Preburn view of red fir plot 3.

Figure 3.15-2. Postburn view of plot 3 (view is not a photo pair with Fig. 3.15-1).

II. Gap size and regeneration patch size

- Calculate the threshold of the gap diameter and/or minimum gap size required before regeneration patches establish.

III. Fire effects on red fir regeneration

- Determine whether the fine fuel and duff amounts are lower within regeneration patches versus non-patch areas, presumably because there are fewer canopy trees near patches which can contribute to fuel buildup.
- Ascertain whether the incidence of duff measurements which strike rotten logs in patches is higher than non-patch areas to indicate that the patches (or gaps) had been previously colonized by canopy trees.
- Determine the relative mortality rate of small trees in patch versus non-patch areas.

- Determine whether a

dominant agent (fuels, weather, topography, etc.) exists which causes increased red fir mortality within patches.

METHODS

Experimental Design

Sampling units (1 ha area) were randomly selected in red fir forests along a north-facing aspect. In an attempt to find more homogenous, continuous forested areas, the following criteria were imposed for the sampling units: 1) >50 meters from talus slopes and riparian corridors; 2) rock cover <20%; and 3) high canopy cover with red fir dominance.

In order to delineate boundaries of clumped red fir regeneration within the one hectare area, plots were established when there was 10 or more trees within a 5 x 5 m area which satisfied the following size class distribution: 1) 2/3 or more of the trees must have a dbh <10 cm and 2) 3/4 or more of the trees must have a dbh <15cm. (Note: Trees were only counted if they were taller than 30 cm). Any area with an aggregation was mapped in 5 x 5 m grid cells referenced to the hectare coordinate system. The xy coordinate system for the hectare was structured such that the top right and bottom left corners were assigned coordinates (0,0) and (100,100), respectively. While the aggregation must have a center of 10 or more trees, the aggregation is expanded in a contagion manner into neighboring grid cells that have at least 3 or more trees and satisfy the two rules stated above. In the patch areas, all seedlings and saplings were tallied by dbh and species within each grid cell. In low density areas that failed to satisfy the criteria for patches, all trees <10 cm dbh were measured by dbh and species but were not spatially referenced to a grid cell. In other words, a distinction is made between plots which represented clumps of regeneration and the remaining area of more sparsely distributed understory trees.

In order to measure regeneration patch area, the patch area of the entire aggregation was traced using the crown edge of the small trees (<20 cm dbh) within the grid cells which satisfy the criteria for plot establishment. Additionally, trees (<20cm dbh) which have their crown within 3 meters from any tree within the established grid cells are also included within the patch area. Estimates of canopy gap size will be made after crowns were mapped for all canopy trees (> 20 cm dbh) within a 15 m buffer of any patch. The dbh, species, and XY position was recorded for each tree. Crown areas will be estimated from the dbh using a regression equation. Regeneration patch area was correlated to canopy gap area to determine the minimum gap size required before regeneration patches establish.

Fine-scale variations in fuel load will be correlated to the mortality of red fir regeneration. Fuel transects were sampled in each 5 x 5 m grid cell considered a patch area. The transects were orientated horizontally and vertically which extends 5 meters in each direction and cross the grid cell center. Fuel size classes follow the Brown's transect guidelines: 0-¼", ¼-1", 1-3", and 3+". Additionally, five evenly-spaced duff/litter measurements were made for each grid cell. Random fuel plots (four 10 m x 10 m plots per hectare) were measured to characterize average fuel conditions for the hectare in non-patch areas.

Prescribed fire management plans are based on forest type, fuel load, and weather conditions to facilitate fire control, prescription objectives, and to mimic the historical fire regime. Thus, burning is usually performed in the late summer/early fall and ignitions will be located at least 50 meters from any sampling units to reduce the bias attributed to human-initiated fires. Subsequent to all fire events, recensus of all canopy and understory trees for survival rates will occur in addition to measuring several indices of fire intensity, including scar and char height. Several mapped plots of red fir surveyed in 1978 (Pitcher 1987) within the Mineral King study area will provide information on fire history and help to calculate a dbh versus crown area regression curve (Caprio 1998).

PROPOSED ANALYSIS

I. Global Change plots

- Use point pattern analysis by Ripley's K statistic to find clumping patterns for small trees and the size of clumps.
- Plot the positions of small trees (0-10 cm dbh) and overlay crowns of canopy trees (>20 cm dbh). Determine whether the number of small trees not underneath canopy crowns is greater than would be expected from a random distribution, confirming that small trees are positively associated with gaps.

II. Pre-fire analysis of field plots

- Displaying the outline of regeneration patch perimeters and overlay for crowns of canopy trees (>20 cm dbh). Determine the degree of asymmetry of patches toward the southern edge of the gap. Asymmetric distribution of regeneration may indicate that light/water requirements are more significant than nutrients.
- Form buffer strips along the border of the regeneration patch and calculate the proportion of canopy crown area ineach buffer strip. Determine the relationship between proportion of canopy closure and distance t patch edge in order to find the threshold distance of gap diameter before regeneration establishes.

III. Post fire analysis of field plots

- Determine mortality rates for smaller-sized trees by size class (seedlings, 0-5 cm, 5-10 cm, 10-15 cm, and 15-20 cm) in both patch and non-patch areas. Apply multivariate regression to correlate understory mortality rate with several factors influencing fire behavior including fuels, weather, and site conditions.

PROJECT YEAR 1998

During the summer of 1998 an additional plot was established in the tar Gap area to increase sample size. UTM coordinates for the new plot are: 4034148 N and 353376 E. No additional field work was carried out with further research pending until burning of this area of Tar Gap is complete.

3.16) Fuels Inventory and Monitoring

- Corky Conover, Science and Natural Resources Management, SEKI

Lead: C. Conover, Crew Leader: L. Uhr, Crew: J. Sevier, D. Loveland, K. Webster, J. Ogren

INTRODUCTION

Recent advances in computerized technologies have given resource managers more tools to help make critical resource management decisions. The development of a Geographic Information System (GIS) based fire spread model called *FARSITE,* is an example of one of these new tools. The *FARSITE* model, like most models, requires quality-input data in order to produce reliable output. The fuels model and canopy characteristic data are the most important inputs to any fire growth model. Currently, the fuel model map for Sequoia and Kings Canyon National Parks is based on 1970's vegetation maps.

The purpose of this study is to improve the parks GIS fuels theme and collect data on forest canopy characteristics. The canopy characteristics data will be used to develop tree height and height to live crown base GIS themes that are used within *FARSITE* to model crown fire activity (torching, spotting, and crowning).

Figure 3.16-1. Typical fuel load in a white fir-mixed conifer stand.

DESCRIPTION OF THE STUDY AREA

The study is being conducted in the East Fork of the Kaweah watershed. Terrain in the watershed is rugged, elevations range from 874 m (2,884 ft.) to 3,767 m (12,432 ft.). The watershed, 21,202 ha (52,369 ac) in size, is bounded by Paradise Ridge to the north, the Great Western Divide to the east, and Salt Creek Ridge to the south. The Parks administrative boundary to the west defines the study area's western extent. The vegetation of the area is diverse, varying from foothills chaparral and hardwood forest at lower elevations to alpine vegetation at elevations between 3,049-3,354 m (10-11,000 feet). The study is being conducted in the mixed conifer belt and Red Fir Forest. Ponderosa Pine mixed conifer communities occur at lower elevations < 1,982m (6,500 ft). The middle elevations 1,982-2,439m (6,500-8,000 ft) are dominated by the White Fir mixed conifer community including the sequoia groves. The Red Fir Forest community dominates the higher elevations 2,440-3,049m (8,001-10,000 ft).

METHODS

Permanent fuel plots were established in order to track fuel accumulation over time. The permanent fuel plots were established using the planar intercept method (Brown, 1974). The plots consisted of four fifty foot transects running north, south, east and west from the center point. Ten litter and duff measurements were taken along each of the 50 foot transects. These plots will be re-read about every 5 years to track fuel accumulation. Based on the previous years data the permanent plots were located in the short needle (includes sequoias) and long needle conifer forest types in the following elevation classes; low ≤ 1,982m (6,500 feet), mid 1,982-2,439m (6,500-8,000 feet) and high > 2,440m (8,001+ feet).

The forty-two permanent fuel plots that were established during the 1997 field season were re-read during the 1998 field season (**Fig. 3.16-2**). The plots were re-inventoried in an attempt to eliminate the bias of collecting all of the small diameter woody fuels near the plot origin. The transects were read from the far end back towards the plot origin, which meant that the small diameter fuels were all read from distinctly different areas.

Tree basal area was measured at each permanent plot using Basal Area Factor (BAF) prisms. The prism was selected so that a minimum of five trees would be included. The prism was swung 360° around the sampling point and the number of trees that were "***in***"(edges still touching, not totally offset) was recorded along with the factor number of the prism used. Every other borderline tree was counted. Three trees were selected as being representative of the

Table 3.16-1: Current fuel model parameters.

Fuel Model Description	Model #	Fuel Loads					Surface to Volume Ratios (S/V)			Depth	Heat	Moist. Ext.
		1 Hr	10 Hr	100 Hr	Herb	Woody	1 Hr.	Herb.	Woody			
Low Elev. Short Needle Conifer	14	3.7	2	2.2	0	6.15	2000	190	1500	0.6	8000	30
Low Elev. Long Needle Pine	15	3.1	1	2.3	0.2	7.37	3000	3000	1500	0.9	9000	25
Mid Elev. Short Needle Conifer	16	3.32	1.2	3.37	0	3	2000	190	1500	0.5	8000	30
High Elev. Short Needle Conifer	18	2.4	1.7	3.1	0	3.32	2000	190	1500	0.25	8000	30

average diameter "in tree" and

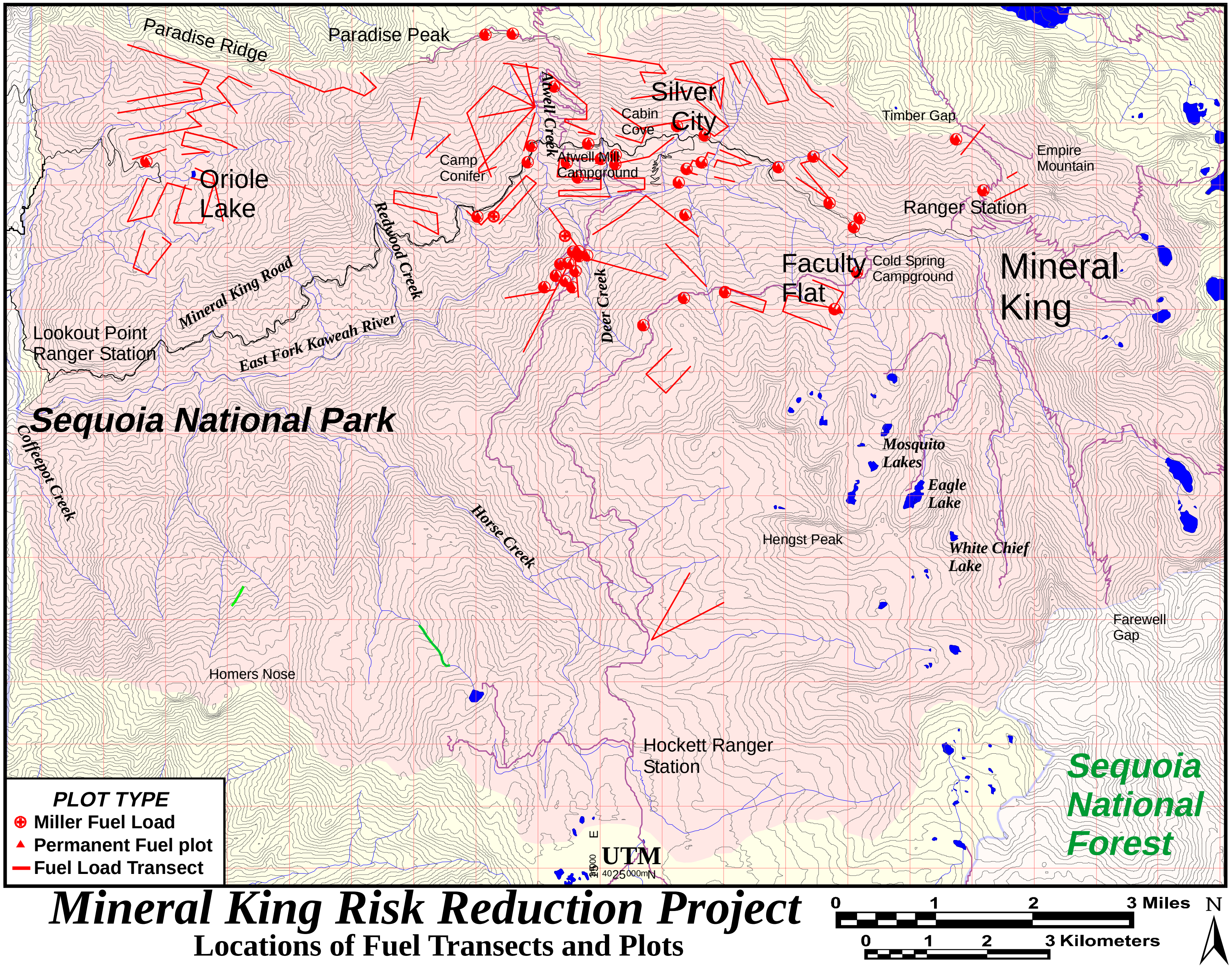

Figure 3.16-2. Fuel data collection sites in the East Fork.

Table 3.16-2: Quantitative stand information by vegetation type broken into aspect and elevation. Where field data did not exist, sample size (n) was listed as a zero and the numbers were based on expert opinion.

Vegetation Description	Aspect	N	Veg. Code	Tree Height (m)	Height to Live Crown Base (m)
Ponderosa Mixed Conifer		274	1	31.2	0.7
White Fir Mixed Conifer < 1,818 m	N	27	2	35.4	1.2
White Fir Mixed Conifer >= 1,818 m	N	139	2	40.2	0.7
White Fir Mixed Conifer < 1,982 m	S	44	2	35.4	1.2
White Fir Mixed Conifer >= 1,982 m	S	159	2	40.2	0.7
Red Fir Mixed Conifer	S	157	3	34.7	0.5
Red Fir Mixed Conifer North	N	95	3	34.7	0.8
Lodgepole Pine		132	4	10.2	0.5
Xeric Conifer Forest		27	5	30.0	1.0
Sub Alpine Conifer		819	6	14.4	1.0
Foothill Hardwoods & Grass		0	7	15.0	2.5
Foothill Chaparral		N/A	8	0	0
Mid Elevation Hardwoods		0	9	20.0	1.5
Montane Chaparral		N/A	10	0	0
Meadow		N/A	11	0	0
Barren Rock/Rock & Sparse Veg.		N/A	12	0	0
Water			13	0	0
Sequoia North Aspect < 1,818 m	N	11	14	46.0	1.7
Sequoia North Aspect >= 1,818 m	N	18	14	46.7	0.8

their diameter at breast height (DBH) was measured and recorded. An average value was be calculated from the three trees measured and used to represent the trees at that sampling point.

The following measurements were also taken at each permanent plot with a clinometer and recorded: overstory tree height, height to live crown base for each distinct canopy layer (dominate, intermediate, understory). Canopy cover was measured with a densiometer and recorded using the following codes: 0=0%, 1= 1-20%, 2= 21-50%, 3= 51-80%, 4= 81-100%.

RESULTS

The ponderosa pine forest had fuel loads of 0.69 kg/m^2 (litter), 4.23 kg/m^2 (duff), 12.47 kg/m^2 (woody) for the south aspects (105-285°) and 0.80 kg/m^2 (litter), 6.87 kg/m^2 (duff), and 10.21 kg/m^2 (woody) on the north aspects (286-104°, aspect determination based on analysis by Caprio and Lineback [in review]) (**Table 3.16-1**). The basal area for the south aspects was 36.8 m^2/hectare compared to 38.8 m^2/hectare on the north aspects. The overstory tree heights were similar for the south (44.9 m) and the north (44.3 m) aspects (**Table 3.16-2**). The diameter at breast height (dbh) was similar for the south (83.4 cm) and the north (85.5 cm) aspects. The heights to live crown base of the understory were higher for the south (1 m) than for the north (0.5 m) aspects.

The low elevation short needle forest had fuel loads of 1.85 kg/m ² (litter), 10.14 kg/m ² (duff) and 5.04 kg/m ² (woody) for the south aspects (105-285°). There were no plots installed in this elevation range on the north aspects. The basal area was 54.5 m²/hectare. The overstory tree heights averaged 36.45 meters while the dbh averaged 52.85 cm for these plots. The height to the live crown base of the understory was 1.0 meter.

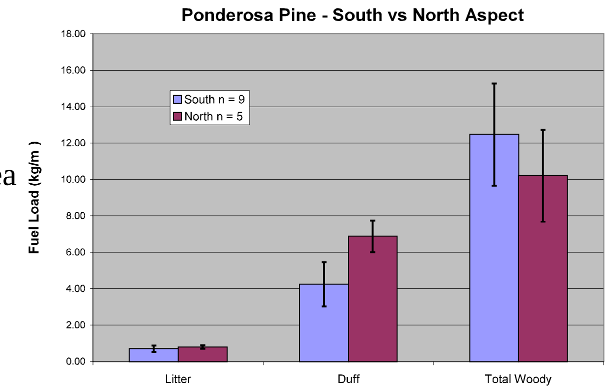

Figure 3.16-3. Fuel load, Ponderosa Pine North vs. South.

As stated in last years report, there are very few mid elevation pine dominated forests on the north aspects, so plots were only installed on the south aspects for the mid elevation pine type. The middle elevation pine forest had fuel loads of 0.72 kg/m² (litter), 5.30 kg/m² (duff), and 3.74 kg/m² (woody). The basal area was 50.0 m²/hectare. The overstory tree heights averaged 38.93 meters while the dbh averaged 73.71 cm for these plots. The height to the live crown base of the understory was 0.6 meters.

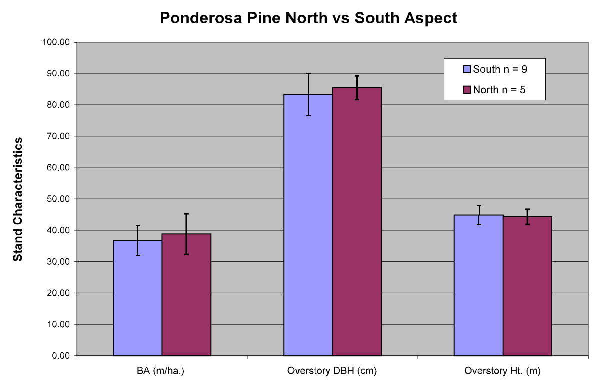

Figure 3.16-4. Stand Characteristics, Ponderosa Pine North vs. South.

The middle elevation fir forest had fuel loads of 1.7 kg/m² (litter), 6.5 kg/m² (duff), 6.1 kg/m² (woody) for the south aspects (105-285°) and 1.5kg/m² (litter) 5.3 kg/m² (duff) and 5.1kg/m² (woody) on the north aspects (286-104°). The basal area for the south aspects was 55.13 m²/hectare compared to 42 m²/hectare on the north aspects. The overstory tree heights were higher for the south (40.0 m) than for the north (34.3 m) aspects. The diameter at breast height (dbh) was larger for the south (83.48 cm) than for the north (74.3 cm) aspects. The heights to live crown base of the understory were higher for the south (0.6 m) than for the north (0.5 m) aspects.

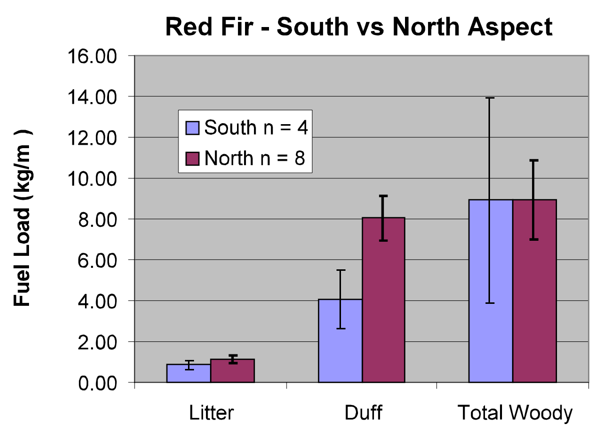

Figure 3.16-5. Fuel load, red fir north vs south aspect.

The high elevation fir forest had fuel loads of 0.9 kg/m² (litter), 4.0 kg/m² (duff), 8.9 kg/m² (woody) for the south aspects (105-285°) and 1.1kg/m² (litter) 8.1 kg/m² (duff) and 8.9 kg/m² (woody) on the north aspects (286-104°). The basal area for the south aspects was 67 m²/hectare compared to 62.4 m²/hectare on the north aspects. The overstory tree heights were higher for the south (40.4 m) than for the north (38.5 m) aspects. The diameter at breast height (dbh) was larger for the south (92.7 cm) than for the north (78.7 cm) aspects. The heights to live crown base of the understory were lower for the south (0.5 m) than for the north (0.9 m) aspects.

In the summary of last year's report it was stated that the custom fuel models would be updated with any changes from the new data. The custom model that was created for the middle elevation pine forest (custom model 17) was eliminated due to being too similar to the standard fuel models (NFFL models 8, 9).

In the introduction section above it was mentioned that one of the objectives of this study was to develop new GIS themes for overstory tree height and height to live crown base. During this past winter I acquired tree height data from the following sources: White Pine Blister Rust Survey (Duriscoe, unpublished data), Yellow Pine Ozone Injury Study (Duriscoe, unpublished data), the Clover Creek Fir Project (Duriscoe/Stephenson, unpublished data) and the Natural Resources Inventory project [NRI] (Graber et al. 1993). All data were arrived at by direct measurement except for the NRI data where the data was put into size classes. The NRI data was only used for the Lodgepole Pine Vegetation Type where we previously had no data. The White Pine Blister Rust data also gave us data for the Sub-Alpine Vegetation type where we previously had no data. The Yellow Pine Ozone Injury study increased our sample size by 34%. The Clover Creek fir Project increased our sample size by 50% for White Fir and 67% for Red Fir Vegetation types. **Table 3.16-1** includes data from all the sources listed above, the sample size (n) is listed with the Vegetation Description. If the sample size (n) listed ia a zero, the numbers are a subject matter expert guess.

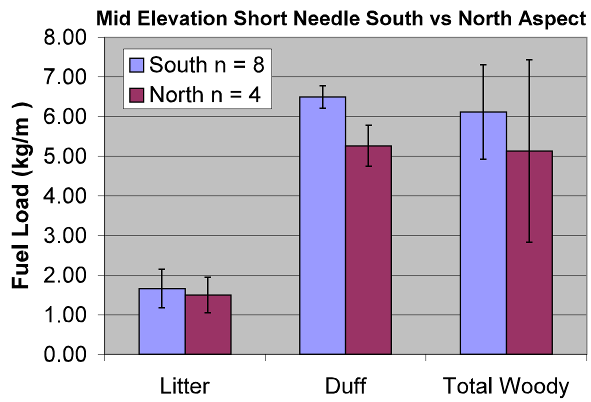

Figure 3.160-6. Fuel load, Mid Elevation Short Needle North vs. South Aspect

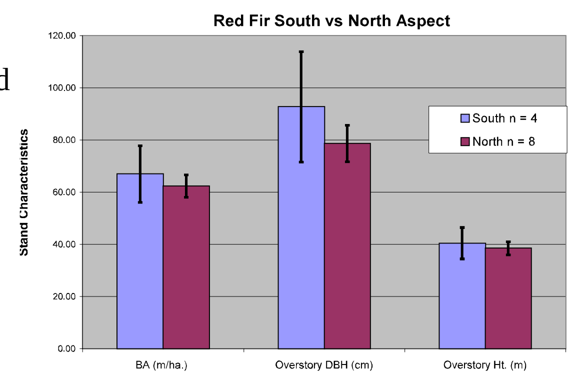

Figure 3.16-7. Stand Characteristics, Red Fir North vs. South Aspect

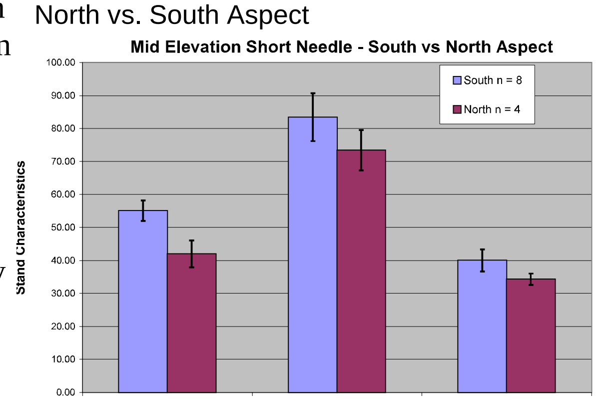

Figure 3.16-8. Stand characteristics, mid-elevation short needle north vs south aspect.

DISCUSSION

The difference in fuel loading from north to south aspect appears to vary by elevation and vegetation type (results presented in the graphs are mean values ± one standard error). The ponderosa pine forest appears to have higher duff fuel loads on the north aspects and higher woody fuel loads on the south aspects (**Fig. 3.16-3**). The ponderosa pine stand characteristics for basal area, overstory dbh and tree heights appear to be the same for both south and north aspects (**Fig. 3.16-4**). The high elevation red fir forest have higher fuel loading on the north aspect (**Fig. 3.16-5**), while the mid elevation fir forest have higher fuel loading on the south

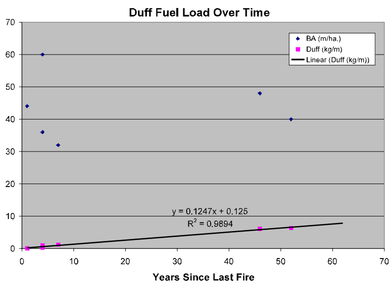

Figure 3.16-9. Duff fuel load and time since last fire.

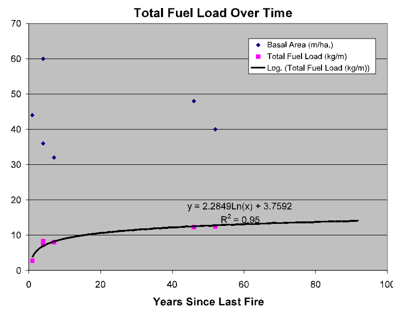

Figure 3.16-10. Total fuel load and time since last fire.

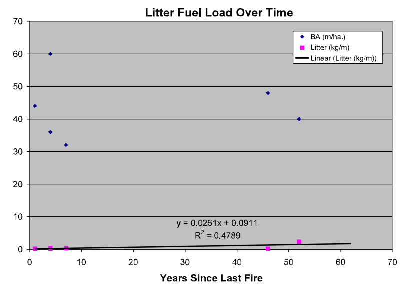

Figure 3.16-11. Litter fuel load and time since last fire.

aspect (**Fig. 3.16-6**). When we looked at the basal area of the high and middle elevation fir stands, the south aspects have higher basal areas and tree sizes (**Fig.s 3.16-7 and 3.16-8**). The difference in fuel loading is probably due to the different fire regimes (frequency and intensity) on each aspect.

When we compared the known fire history with our plot locations we came up with six plots that occurred in areas that we knew the date of the last fire. As stated in last year's report we were going to see if a relationship exists between the number of years since the last fire and the fuel loading. Keeping in mind that our sample size is only six (n=6), there appears to be a strong linear relationship (R^2 = .9894) of duff accumulation with time (**Fig. 3.16-9**). There also appears to be a good logarithmic relationship (R^2 = .95) of total fuel load with time (**Fig. 3.16-10**). The relationship for litter (**Fig. 3.16-11**) and woody (**Fig. 3.16-12**) fuel loads with time appears to be poor. The litter load is probably related to the scorch height post fire and the stand mortality as time passes. The woody fuel load is probably related to stand mortality as time passes and it appears that after the first few years, higher fuel loads are associated with higher basal areas for locations with similar years since disturbance (**Fig. 3.16-13**).

SUMMARY

Last years report indicated that we would take photo series estimates at the same location that we installed the permanent plots, to see if a correlation exits between the two methodologies. The crew took photo series estimates at the permanent plots, but they forgot to record the data! We will take photo series estimates when we revisit the 31 plots to take the digital photos, and we

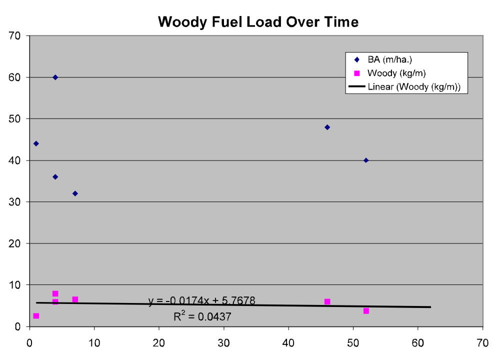

Figure 3.16-12. Woody fuel load and time since last fire.

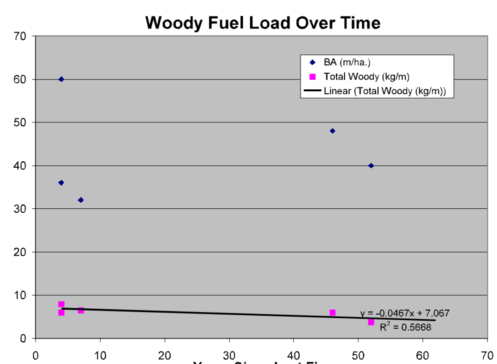

Figure 3.16-13. Woody fuel load and time since last fire starting after 3 years.

will create a space on the data sheet and record the data next season! When installing future permanent fuel plots, we will take photo series estimates at the same location and record the data. We will try to see if a correlation exists between the two methodologies. If a correlation can be established, we will use this correlation to survey future areas because you can collect about five times as many sample points with the photo series when compared to the planar intercept method.

Our goal was to have enough permanent plots by elevation and fuel type so that the percent error of our total fuel loading estimates was less than twenty percent. We will need to install additional plots in the following types: Red Fir South aspect, Middle Elevation Short Needle North aspect, Low Elevation Pine South aspect, Low Elevation Short Needle South, and Low Elevation Short Needle North aspect to lower the percent error of the total fuel loading estimate. It will probably take between 2-5 new plots in each of these fuel types to achieve our goal of less than twenty percent error. When we install these new plots we will try to place them in areas of known previous fires in order to increase our sample size and improve on our correlation between time since last fire and fuel load.

Lastly, we acquired a digital camera in the middle of last season (see cover photo) and have digital pictures for 16 of the 47 permanent fuel loading plots. During the 1999 field season we will revisit the 31 plots that need a digital photo.

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3.17) Fire History

- Anthony Caprio, Science and Natural Resources Management, SEKI

Lead: A.C. Caprio, Field crew: Bob Meadows

OBJECTIVES

Over the last three decades the parks' fire management program has evolved to where it now includes restoration of fire at a landscape scale. However, burning at such scales has raised a variety of new management and resource questions. Among these has been questions about our understanding of pre-Euroamerican fire regimes at such large ecosystem scales. While substantial fire history research, based on fire scars recorded in trees (**Fig. 3.17-1**) has been carried out in Sequoia and Kings Canyon National Parks (Kilgore and Taylor 1979; Pitcher 1987; Swetnam et al. 1992; Swetnam 1993; Caprio and Swetnam 1995; Swetnam et al. 1998) a considerable number of gaps still remain in our knowledge and understanding at many levels (Caprio and Lineback in press). Acquiring this information would be of great value to managers when planning and reintroducing fire in park ecosystems, in evaluating the success of the Park's burn program (Caprio and Graber in prep) and to ecologists interested in understanding dynamics of pre-Euroamerican plant and wildlife communities.

A growing body of evidence indicates considerable variation in pre-EuroAmerican fire regimes, both temporally and spatially, across the landscape. However, because reconstructing past fire regimes is difficult, requiring considerable effort and experience our current knowledge about this variation is sparse. For example, we have little information about past fire regimes at a scale that encompasses 1000+ hectares and includes varying slope, aspect, vegetation type, and elevation. This also includes a lack of knowledge about past fire regimes from several common vegetation types. An example best illustrates the difficulty in capturing this variation. Unlike our current terrestrial vegetation, where variation in species composition and structure are obvious and sampling strategies to adequately capture this variation designed, the historical fire regime is largely hidden from direct view and thus its attributes are easily under sampled or overlooked. To capture some semblance of this variation a substantial effort in acquiring a large number of sample sites is required. Such sampling intensity would not be unexpected if variation in terrestrial vegetation were being sampled within diverse habitats.

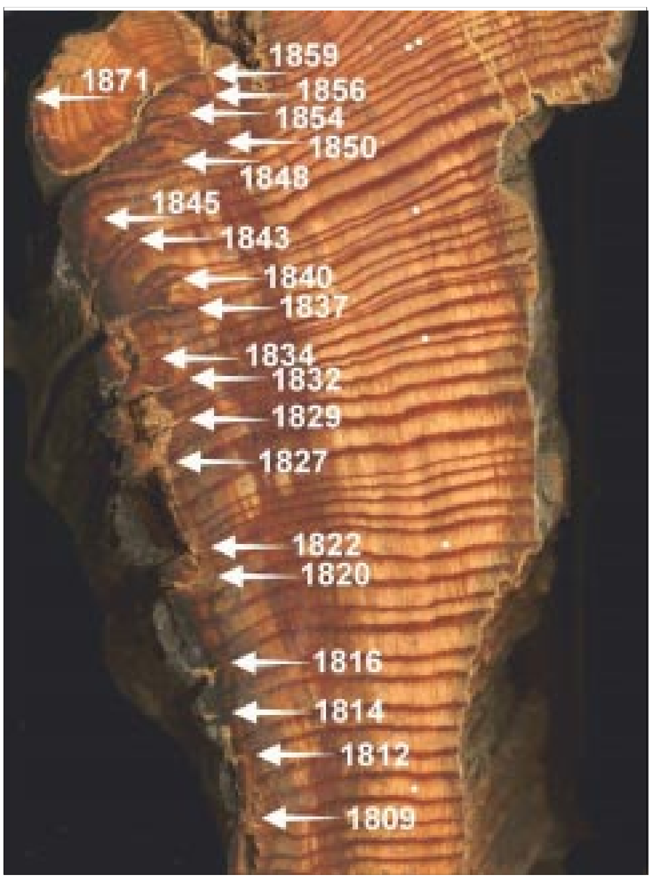


Figure 3.17-1. Example of high fire frequency area shown by dated fire scar sample from low elevation ponderosa pine/black oak forest. A minimum of 19 fires were recorded between 1809 and 1859 with a maximum interval of five years (1822 to 1827).

The fire history information being developed in this study will have both a direct impact on fire management decision making and a less direct but equally important impact on park management over the long term. For example, fire history data forms the foundation on which fire management planning using GIS fire return interval departure (FRID) analysis is based (Caprio et al. in press). Using fire return interval information that is of poor quality, in some cases simply an estimate, may result undesired management consequences (Caprio and Lineback in press). A significant unknown is how past fire regimes varied spatially across differing aspects. Recently, Miller (1998) developed computer models that look at surface fire regimes and forest patterns across elevation gradients in the southern Sierra Nevada. The models examined connectivity and spatial extent of fire over elevational gradients. Their output suggests that differences in burn patterns/frequencies exist by aspect and these differ most notable between south and north slopes (Carol Miller personal communication). Structural and landscape differences in vegetation by aspect have also been suggested from the preliminary results of the Landscape Analysis Project (Kurt Menning personal communication) which may be related to differing fire regimes on the north versus south aspects. However, other than the preliminary results from the current fire history collections in the East Fork, little data exists on pre-European settlement fire history for north aspect forests in the southern Sierra Nevada. Thus the information collected in the East Fork will be critical in verifying these models and as input for more rigorous parameterization to improve their predictive ability.

The goal of this data collection effort is to: 1) obtain information on the spatial extent of pre-Euroamerican fire on a watershed scale (fire size, spread patterns, and frequency variation), 2) acquire data on pre-Euroamerican fire regimes from the wide array of vegetation types within a watershed, and 3) integrating this information to provide input for advancing the Parks' fire management program. Specifically, these data will provide improved information on fire frequency regimes from a range of vegetation associations that are being used as input into fire/GIS analyses to reconstruct past fire frequency regimes throughout the parks (Caprio and Lineback in press). Additionally, reconstructing the large scale spatial pattern fire in the East Fork will assist managers in determining whether they are meeting management objectives in restoring fire as an ecosystem process (Caprio and Graber in prep).

DATA COLLECTION and ANALYSIS

During 1998, emphasis was placed on collecting sites in higher elevation conifer forest and on aspects or vegetation types for which we have little fire history information. A substantial number of new sites were sampled on the north aspect in the Eden Grove area. Sampling also concentrated on burn segments scheduled for ignition during 1998 and 1999--Tar Gap, Deadwood, Silver City and Purple Haze (**Fig. 3.17-2**). Additional sites were also located in the Eden, Empire and High Bridge segments. These increased the sampling resolution for this portion of the drainage. Additional collections are needed from the Park boundary area east of Case Mountain, the upper forest zones above Hockett meadow and above Silver City.

Specimens are being dendrochronologically crossdated to determine precise calender years (**Fig. 3.17-3**) in which past fires occurred (Stokes 1980). Crossdated fire chronologies provide results with precise temporal information that allows consistent comparison of fire dates among sites separated spatially across the landscape. Additionally, intra-annual position (or approximate season) of fire dates are also being determined when scar quality makes this possible. Sample preparation and crossdating is most advanced from sites collected during 1995 though 1997.

Area burned within a given year by pre-Euroamerican fires is being reconstructed using Thiesson polygons (Davis 1986). Each irregular polygon represents the area around a point (representing a single sample site), in a field of scattered points, determined by Euclidean distance that is closer to that point than any other point. The resulting field of polygons represents the most compact division of area, given the specific arrangement of points. This approach is commonly utilized for rainfall gauging networks when stations are not

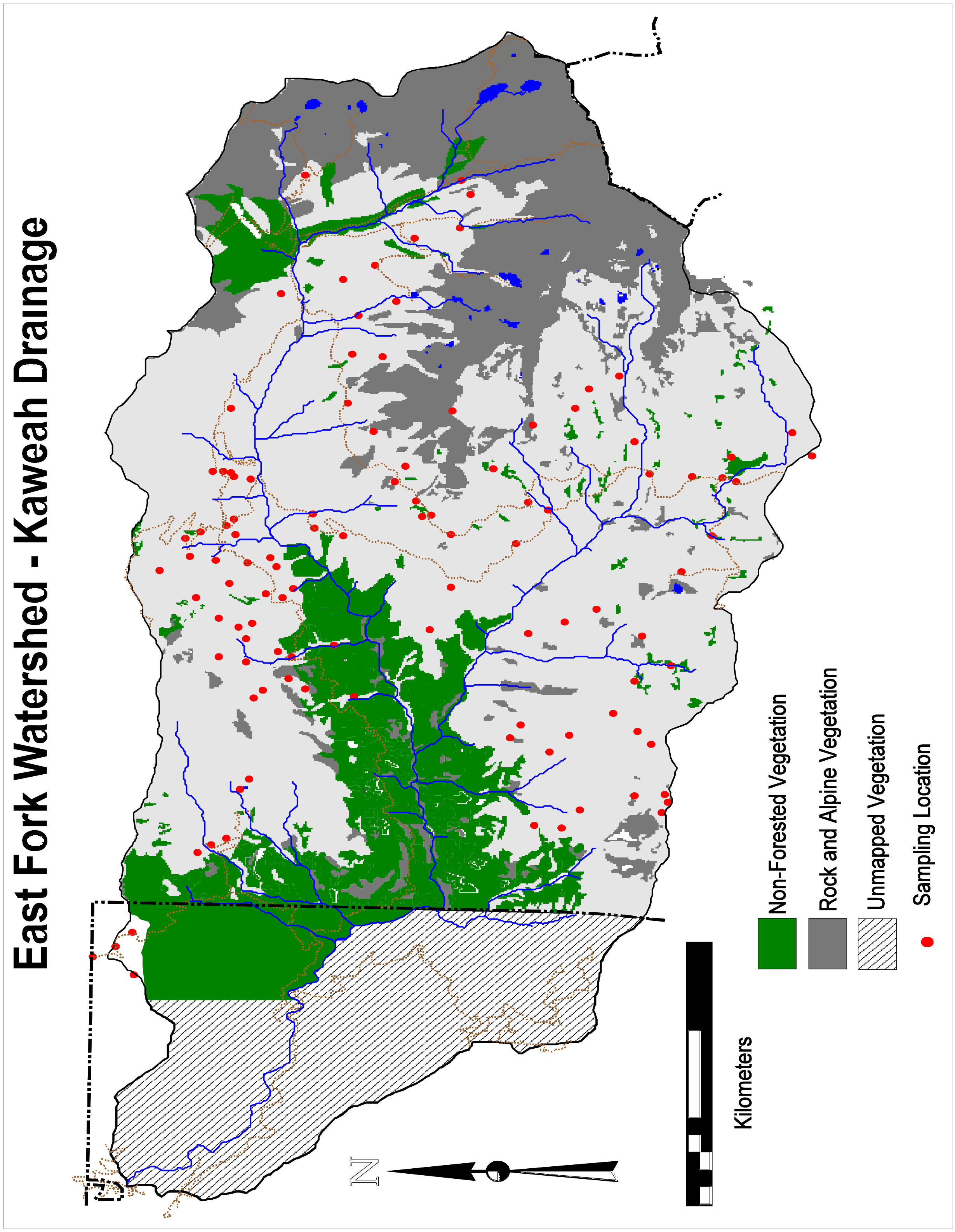


Figure 3.17-2. Fire history collection sites in the East Fork.

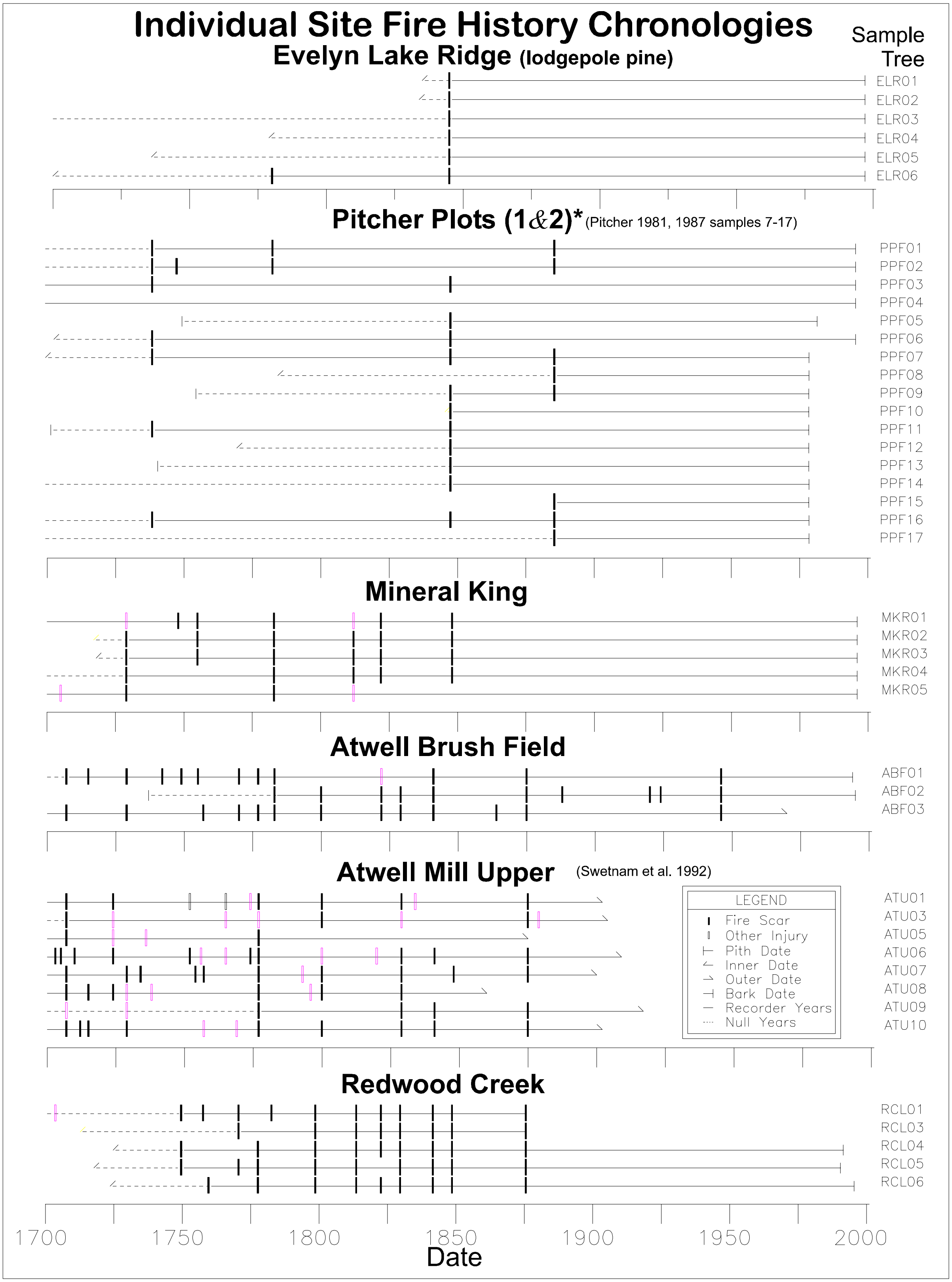


Figure 3.17-3. Examples of reconstructed fire history data from five sites in the East Fork drainage for the period from 1700 to the present. Sites illustrate varying pre-Euroamerican fire regimes from differing vegetation types and aspects in the watershed. Horizontal lines represent a particular sample (one tree) with vertical bars indicating crossdated fire dates.

Table 3.17-1. Summary of site collections within the East Fork by vegetation class through 1998.

Vegetation Class	Number of Sites
Ponderosa Pine	2
Ponderosa/Mixed Conifer	27
White Fir Mixed Conifer	20
Sequoia Mixed Conifer	9
Red Fir	33
Lodgepole Pine	10
Subalpine Forest	2
Xeric Conifer	5
Foothill	1
Chaparral*	**(7)**
Total	**109**

uniformly distributed and strong precipitation gradients occur (Dunne and Leopold 1978), both characteristics of the network of fire history sites sampled in the East Fork. Its use provides a valuable tool for quantifying and portraying spatial patterns of over a landscape. For the fire history sampling sites, polygons were constructed around the center point of each site using ArcView 3.1 Spatial Analyst (ESRI 1996) and area of each polygon determined. This allowed maps of annual burn area to be created for the watershed. While not computed for this report, future iterations of polygon calculation will use aspect as a constraint on polygon boundary delineation.

RESULTS and DISCUSSION - Preliminary Analysis

Approximately 139 specimens (logs, stumps, snags, or trees) were collected from 30 sites during 1998. This supplements samples from 79 sites previously collected (Caprio 1997, 1998). Samples have been obtained from 10 of the 11 major vegetation classes currently designated in the Parks (**Table 3.17-1**). Sites have also been obtained from both north and south aspects over a range of elevations (**Table 3.17-2**). These collections have greatly supplemented and added to previous work that was carried out in the watershed (Pitcher 1987; Swetnam et al.1992). Additionally, the collections are a source of new fire regime information for vegetation types not previously sampled in the parks. These include Jeffery pine, lodgepole pine, and oak woodland while others, such as red fir and nearly all vegetation types located on north aspect, have only been sparsely or not sampled at all.

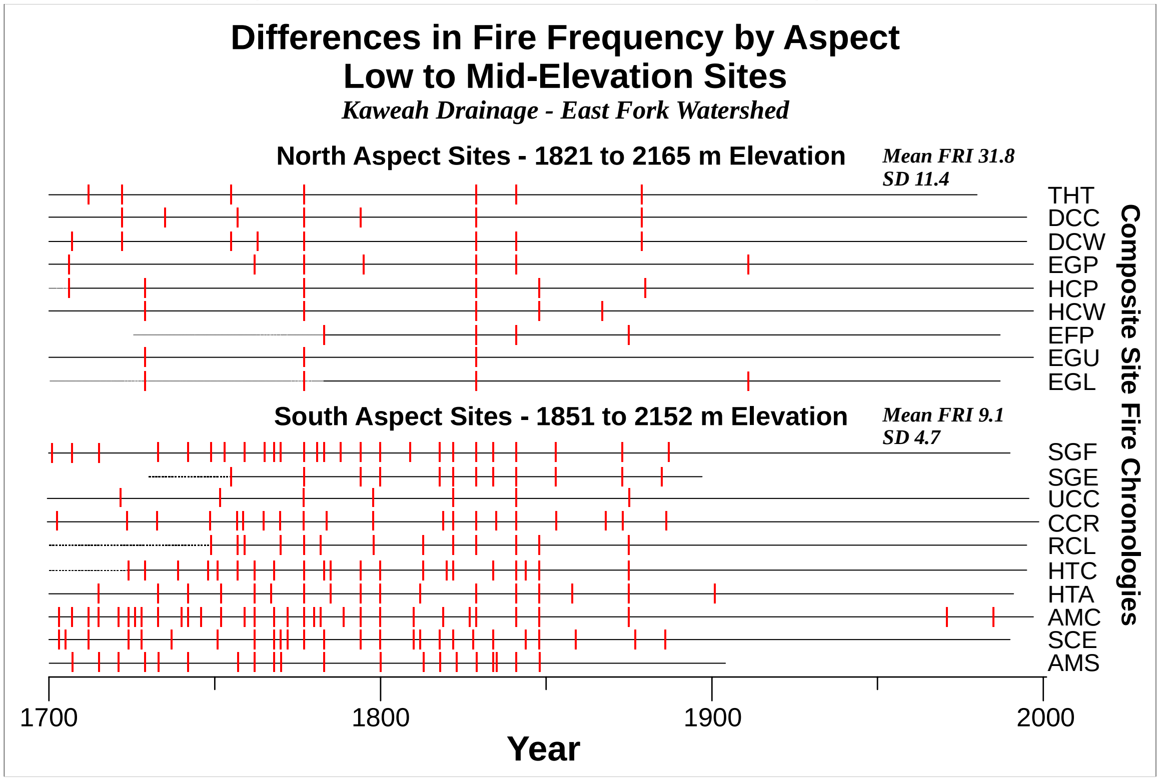
Fire Frequency

Considerable variation in fire frequencies have been found among sites with some obvious patterns from individual within site fire chronologies. For example, fire chronologies presented in **Fig. 3.17-3** show (1) both differences in fire return intervals (FRI) among the sites related to elevational differences, as described by Caprio and Swetnam (1995), and (2) occurrence of common fire years among sites--years such as 1848 and 1875. Further analyses are possible when these results are summarized into composite fire chronologies for each site. Initial comparisons of FRI between north and south aspects for a subset of sites at low-to-mid elevations (1800-2200 m) have provided the most interesting results to date (**Fig. 3.17-4**). These data suggest that there were considerable differences in FRI between north and south aspects in this elevational range. FRI averaged about 3X greater on the south aspect relative to the north aspect (~9 years versus ~31 years). Sampling during 1999 will be partially directed at obtaining collections from north/south aspects in other drainages to determine whether such aspect differences can be generalized to larger areas of the Parks. If consistent, such differences in fire return intervals by aspect will have important implications for fire managers in terms of burn planning, on anticipating

Table 3.17-2. Breakdown of sites collected in the East Fork by elevation and aspect through 1998.

Elevation (m)	Total	South	North
<1000	0	0	0
1000-1250	0	0	0
1250-1500	1	1	0
1500-1750	10	8	2
1750-2000	25	17	8
2000-2250	24	17	7
2250-2500	11	5	6
2500-2750	30	9	21
>2750	10	5	5
Total	109	62	47

Figure 3.17-4. Composite fire chronologies from lower elevation sites showing differences in return intervals by aspect. Mean fire return interval (MFRI) is for the period from 1700 to 1850.



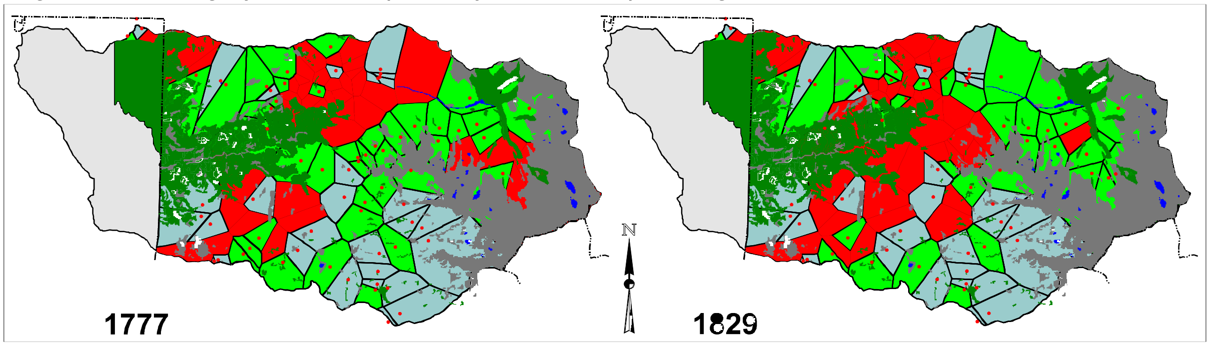
potential fire effects on these sites, and understanding mechanisms responsible for initiating or maintaining attributes of past forest structure.

Fire Size

Striking patterns of past fire occurrence are emerging as more sites are collected and crossdated from a broad array of areas in the watershed. Initial mapping of fire occurrence indicates that patterns of area burned by past fires can be reconstructed over the landscape with a moderate amount of reliability (**Fig. 3.17-5** and **Fig. 3.17-6**). However, the resolution of the final burn map is commensurate with the sampling intensity and while rough estimates of past fire size can be obtained, specific locations of burn boundaries cannot be determined. Additionally, the distribution of point estimates over the landscape represent a minimal area burned by a particular fire or fires in a given year. This is because the presence of a scar is a definitive record of the occurrence of a fire while the lack of a scar could be the result of either the area not having been burned by a fire or that the fire left no record (did not scar trees or a sample with the scar was not collected) even though it occurred..

Several years provide examples of reconstructed area burned. The map displaying the 1873 fire date shows a burn, or possibly more than one burn, with a well defined burn area confined to south aspect slopes although specific burn boundaries are unknown (data based on those areas from which fire dates have been collected and dated). Other fire dates show different patterns of fire on the landscape. The current information for the 1829 burn(s) shows that it occurred in both the main East Fork drainage and the Horse Creek drainage (**Fig. 3.17-5**). The maps for 1777 and 1829 indicate widespread burns and show areas that burned in both the main East Fork drainage and the Horse creek drainage. Of interest are comparative maps of the extent of the 1873 and 1875 burns (**Fig. 3.17-6**). The area of the 1873 burn shows that it was centered on the central portion of the Atwell Grove while the map for the 1875 burn indicates it burned predominantly to the east and west of this area and into lower portions of the north aspect. Overlaying burn maps of these two burns suggests that they were nearly 100% mutually

Figure 3.17-5. Preliminary reconstruction of area burned by fires in 1777 and 1829 in the East Fork. Red color represents areas where samples have been dated with fires observed in the fire scar record during these two years and light green color represents areas where samples have been dated and these fire dates have not been observed. Dark green areas are non-coniferous forest vegetation while gray areas are primarily rock and alpine vegetation.



exclusive. There is also an interesting historical footnote for the 1875 burn. While traveling through the Atwell area in 1875 John Muir made natural history observations about a fire that appears to be this 1875 burn (Muir 1878). He observed the fire burning intensely up-canyon through chaparral vegetation but with decreasing intensity once it entered the sequoia grove where fuel levels were low and consisted primarily of conifer needles. These observations, that the fire burned through the intervening chaparral vegetation, verify the burn pattern reconstructed on the burn map from the fire history samples.

SUMMARY

The current sample set greatly improves the resolution and spatial accuracy for reconstructing past burn history within the East Fork watershed. It is important that fire history information be obtained from a large set of areas to present a complete picture of past fire regimes over the landscape with less bias than previous sampling that centered on specific vegetation types, aspects, or elevations. As data from the current sample set is developed it will provide information about attributes of past fire regimes from throughout the watershed. Data will also be used as input into the GIS/Fire model being developed for Sequoia and Kings Canyon National Parks (Caprio et al. in press, Caprio and Graber in prep.).

<u>Main Findings</u>

• ***<u>Aspect difference</u>*** - The current results show a dramatic difference in the length of fire return

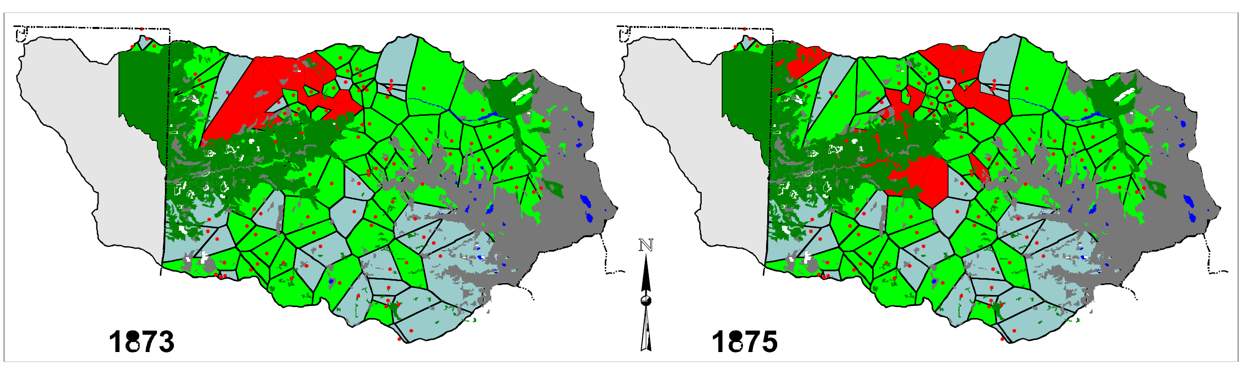


Figure 3.17-6. Preliminary reconstruction of area burned by fires in 1873 and 1875 in the East Fork. Red color represents areas where samples have been dated with fires observed in the fire scar record during these two years and green color represents areas where samples have been dated and these fire dates have not been observed. Dark green areas are no-coniferous forest vegetation while gray areas are primarily rock and alpine vegetation.

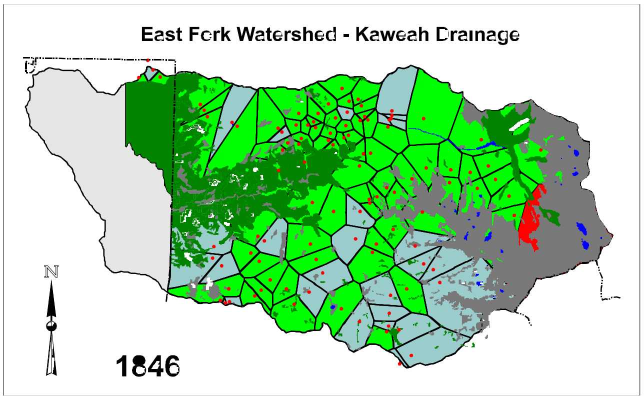


Figure 3.17-7. Illustration of a fire year (1846) where the data suggests only a small area burned in higher elevation red fir forest. Color scheme is the same as **Fig. 3.17-5.**

intervals between south and north aspects at mid-to-low elevations sites. Differences in average FRI indicate that intervals between fires were approximately three-times longer on north aspects compared to south aspects. If these differences occur consistently within other watersheds this information will provide valuable input into the fire management program.

• ***Estimates of past fire size*** **-** The results suggest that past fires can be reconstructed with a moderate amount of resolution and that distinct patterns can be observed across the landscape. These data will allow patterns of fire size over the landscape to be explored and include variation by aspect and vegetation type. The fire size data will also provide baseline information for other investigations being conducted in the drainage currently and into the future.

PLANS FOR 1999

Limited sampling will continue in the East Fork during 1999, again concentrating on segments scheduled for burning during 1999 and 2000 and on locations having north aspects. Particular target areas include upper elevation red fir and lodgepole pine forests, where some stand replacing burns may have occurred in the past. Sampling is planned to fill gaps in the spatial network of sites and will include: areas in the Oriole Lake drainage, higher elevation south aspects, upper Hockett Plateau, and in the Coffeepot Canyon area. Crossdating of collected material will continue and should begin producing results about past fire regimes for individual vegetation classes.

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3.2 - Wildlife

3.21) Wildlife Monitoring - Science and Natural Resources Management, SEKI

Lead: H. Werner; field-crew members: T. Keesey, C. Ray, and C. Mustric (volunteer).

EXECUTIVE SUMMARY

Wildlife fire effects monitoring was initiated in the East Fork Kaweah River drainage as part of the Mineral King Risk Reduction Project. The monitoring focused on rodents because of the large number of species present, their specificity to habitat structure and composition, and their importance to the ecosystem. In 1998, the monitoring concentrated on two components: 1) permanent monitoring plots to document long-term changes in rodent populations at a few of the most widespread or important habitats, and 2) serendipity surveys to determine the species and relative abundance of rodents in a majority of the drainage's major habitats for drainage-wide evaluation of fire effects (**Fig. 3.21-1**).

In the East Fork one-hectare long-term monitoring plots were monitored in mature sequoia forest at Atwell Grove and in westside ponderosa pine forest. The 1,020 trapnights at the Atwell Plot produced 645 rodent captures. The postburn population estimate of 70 rodents/ha in 1998 was twice as high as the 1996 and 1997 postburn population estimates and over four times as many rodents in the preburn population. With ninety-four percent of the captures, the deer mouse (*Peromyscus maniculatus*) was the most abundant postburn rodent at the Atwell Plot. Other rodents included a few captures of the lodgepole chipmunk (*Tamias speciosus*), northern flying squirrel (*Glaucomys sabrinus*), long-tailed vole (*Microtus longicaudus*), and brush mouse *(Peromyscus boylii*). The 1,138 trapnights at the Ponderosa Plot produced 178 rodent captures with a population estimate of 20 rodents. This was similar to the preburn estimates. The species composition changed from a nearly equal balance between deer mice (*Peromyscus maniculatus*) and brush mice (*Peromyscus boylii*) to a population that is predominantly deer mice.

Serendipity sampling in the East Fork was done in aspen/sagebrush, aspen wetland, boulder field, black oak, canyon live oak, conifer/lake edge, foothill annual grassland, wet meadow, and wet meadow/palustrine environments. Deer mice (*Peromyscus maniculatus*) dominated all but the oak sites which contained primarily brush mice (*Peromyscus boylii*). Areas favored by deer mice were characterized as high-elevation dry, grassy, and mid-elevation moist sites. In the perimeter of the 1996 Kaweah Fire, deer mice, California pocket mice (*Chaetodipus californicus*), and western harvest mice (*Reithrodontomys megalotus*) increased in areas of chamise. This was an expected response to the increase in herbaceous vegetation and loss of shrub cover following the fire. Of the larger animals, both ringtail (*Bassariscus astutus*) and fisher (*Martes pennanti*) were found in mixed conifer forest, and pine martin (*Martes americana*) and chickaree (*Tamiasciurus douglasi*)

Additionally, in the Middle Fork watershed, two two-tenths hectare long-term plots were sampled in chamise chaparral with a total of 1,680 trapnights and 326 captures. The plots were burned November 10, 1980. One plot (Plot 1CHF) was burned by a headfire, and the other (Plot 2CHF) straddled the burn perimeter. Seventeen and a half years after the burn, the population estimate of 26 rodents at Plot 1CHF was forty-three percent less than the preburn population and about sixty-seven percent less than the first early-summer postburn population. Species composition varied between the preburn condition, the first two years after the burn, and the summer of 1998. Originally the site was dominated by pinion mice (*Peromyscus truei*) and dusky-footed woodrats (*Neotoma fuscipes*). In 1998, it was primarily California mice (*Peromyscus californicus*) and brush mice (*Peromyscus boylii*). Plot 2CHF had an estimate of 44 rodents, predominantly brush mice and California mice. The rodent fauna was similar on both sides of the 1980 burn perimeter even though the structure of the vegetation was very different with the burned side having less height and greater stem density. were caught in sequoia grove. Ringtail were also captured in riparian forest.

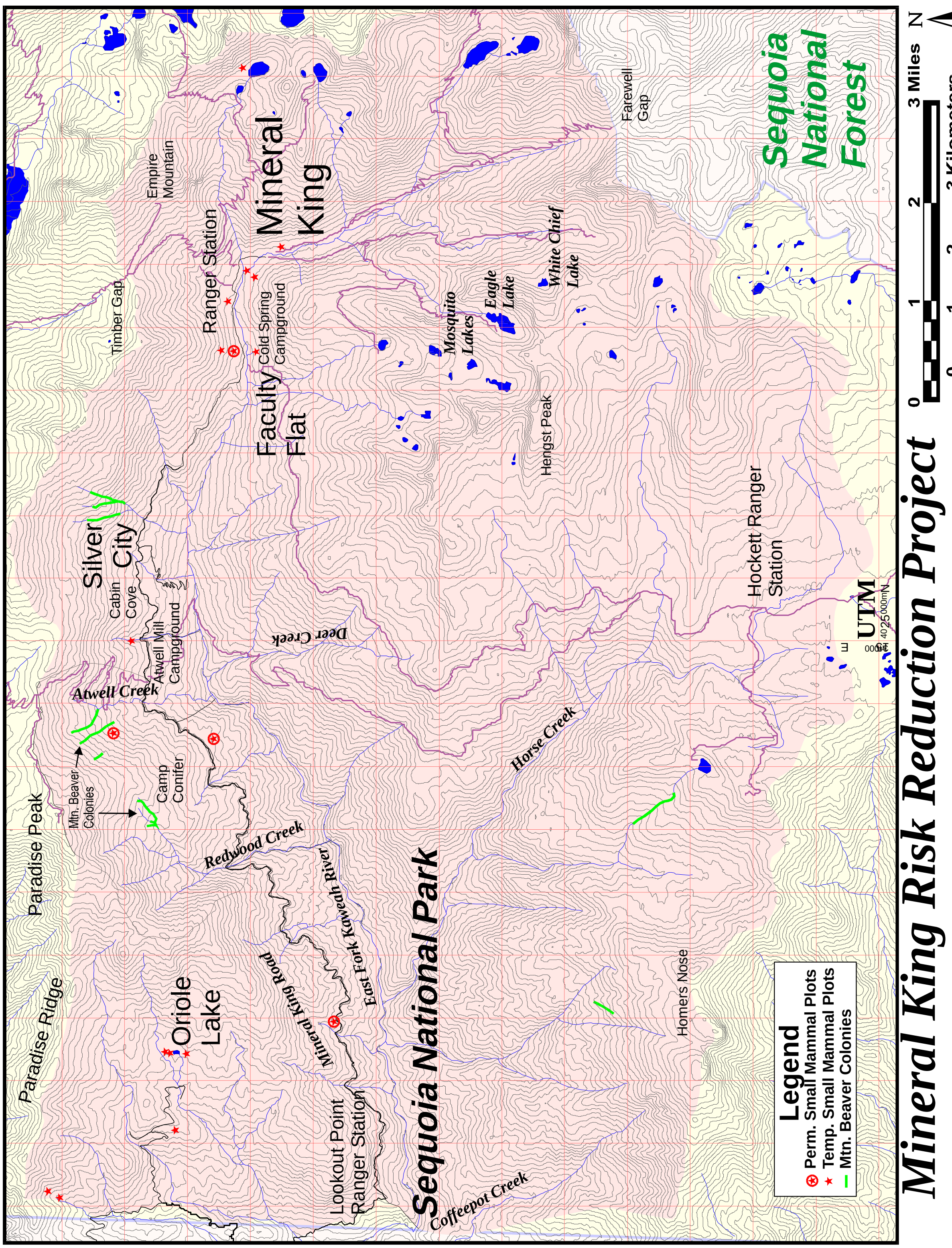

Figure 3.21-1. Location of small mammal live trapping sites and location of mountain beaver colonies.

Four more colonies of mountain beaver (*Aplodontia rufa*) were located in the East Fork Kaweah. All were in combustible vegetation types. One site burned in 1995.

INTRODUCTION

This work was initiated to evaluate the effects of the Mineral King Risk Reduction Project (MKRRP) on selected fauna. There is considerable existing literature on fire effects on wildlife, and it demonstrates a broad range of responses from favorable to unfavorable for individual species. It is very likely that fire will cause changes in the small mammal community. To understand local responses, it is prudent to have local data under conditions typical of local burns. This report summarizes the fourth year of field surveys. Two other additional sites were also monitored. These include plots with the 1996 Kaweah Burn and several plots established following a 1980 prescribed burn in the Middle Fork of the Kaweah River.

This work concentrated on small mammals for several reasons. a) First, the Mineral King area contains a relatively large number of sympatric native rodents. There are at least eleven species of rats and mice present. They range from generalists like *Peromyscus maniculatus* which occurs in a wide range of habitats and elevations to other species like *Chaetodipus californicus* which has much more specificity in its habitat requirements. b) Most rodents consume significant quantities of vegetation, and some are arboreal or otherwise dependent on plants for cover. This links them to floral composition and structure, two things that are normally affected by fire. c) Rodents do not have large home ranges. The species of rats and mice present in the East Fork Kaweah drainage typically have home ranges that are under 0.6 ha (Zeiner *et al.* 1990). Because the individuals do not roam far, rodent populations can be correlated to more discrete features of their environments than animals occupying larger areas. d) Rodents have short life histories with rapid development and maturation. Some of the species present in the MKRRP have been reported to be reproductive in about 50 days after birth, and most small mammals survive little more than a year in the wild (Orr 1976), some even less. Young disperse after being weaned. This all contributes to high potential for measurable adjustments to the rodent population structure as the habitat changes. e) Rodents are a major source of food for predatory birds, mammals, and reptiles. Rodent success or failure has a major influence on the success or failure of many larger animals. f) Finally, rodents are easy to trap, handle, and mark. It takes little time to become familiar with the local species, and there is an abundant literature providing methodologies. Until the recent discovery of hantavirus, their handling seemed to present little risk to the investigators.

Because fire can have significant effects to both the structure and vegetative composition of the habitat and because rodents present a diverse array of easy to handle respondents to habitat changes, they make good cost-effective, ecologically-significant animals for monitoring fire effects. Other major groups for which we would like to have local data, but which was not collected on this study for lack of resources include birds and insects. Both of the these groups are represented by large numbers of species, but their documentation requires more observer skill and larger plots for birds.

There are a number of smaller groups for which we have special interest. These include mountain beaver, forest carnivores (e.g. martin, fisher, ringtail, etc.), mule deer, bats, and brown-headed cowbirds. These represent a range of public and agency interests.

METHODS

Rodent populations were investigated from two perspectives: 1) long-term monitoring of select areas, and 2) serendipity surveys of the most common and unique habitats. The long-term monitoring is intended to document long-term changes in rodent populations and their habitat following fire under known conditions. Serendipity surveys inventory rodent species and their relative abundance within both common and unique environments to facilitate large-scale assessment of potential fire effects.

Two one-hectare permanent long-term monitoring plots were surveyed. The Atwell Plot was located in a mature sequoia forest in Atwell Grove with plot center at UTM coordinates 4037.147 northing and 349.506 easting. The Ponderosa Plot was located in westside ponderosa pine forest with plot center at UTM coordinates 4035.466 northing and 349.415 easting. Plot locations and elevations were determined with a Rockwell AN/PSN-11 PLGR geographic positioning system (GPS) on averaging mode. The plots are 75 m by 135 m (flat distance) with 6 mm diameter steel stakes marking the trapping grid at 15 m intervals. Each plot contains 60 trap stations with one Sherman live trap (Model LFATDG, 7.6 x 8.9 x 22.9 cm) normally within one meter of each station stake. The traps were normally run four nights per week. The Atwell Plot was run for a total of 17 nights from August 24, 1998 through September 26, 1998 (1,020 trapnights). The Ponderosa Plot was run for a total of 19 nights from July 14, 1998 through August 15, 1998 (1,138 trapnights). The traps were baited with a dry mixture of rolled oats and peanut butter. A high-low thermometer was located in each plot at a shady location about 1.5 m above the ground, and a rain gage was located nearby.

In addition. Two 0.2 ha permanent long-term monitoring plots established in 1980 in the Middle Fork were surveyed in chamise chaparral. The one plot (1CHF) was established with plot center at UTM coordinates 4043.572 northing and 339.005 easting in July 1980 and burned November 10, 1980. A second plot (2CHF) was established with plot center at UTM coordinates 4043.676 northing and 338.944 easting in February 1981 on the burn perimeter, leaving half of the plot burned and half unburned. The plots are 40 m by 60 m (surface distance) with rebar stakes marking the trapping grid at 10 m intervals. Each plot consists of 35 trap stations with one Sherman trap at each station in Plot 1CHF (except in 1980 when there were three traps per station) and two traps at each station in Plot 2CHF. Preburn data was collected on the first plot (1CHF) during July through August 1980. he plots were monitored for two years following the burn. The second plot (2CHF) allows comparison of rodents inhabiting the burned and unburned sides of the plot over the same time interval. It consisted of fifteen stations on either side of the 1980-burn perimeter and five stations on the perimeter. The resurveys done June 2-July 3, 1998, describe the rodent population eighteen and a half years after it was burned.

Captured rodents were marked with numbered self-piercing 1 monel ear tags (Style # 1005-1 from National Band and Tag Company). Captured rodents were ear tagged, and recorded information included tag number, species, sex, age (adult, subadult), weight, hind foot length, ear notch length, tail length, and general comments. The handlers wore respirators, rubber gloves, and eye protection for hantavirus protection (Mills *et al.* 1995). Plot populations were estimated using a modified Jolly-Seber Method (Buckland 1980). Data was stored in dBase III$^+$ files.

Serendipity trapping for rodents was done at nine sites in the Mineral King drainage: annual grassland (70 trapnights; UTM coordinates 4036.005 northing, 341.986 easting), aspen/sagebrush (51 trapnights; UTM coordinates 4035.012 northing, 356.828 easting), aspen wetland (23 trapnights; UTM coordinates 4035.016 northing, 356.736 easting), black oak forest (60 trapnights; UTM coordinates 4037.527 northing, 341.869 easting), boulder field (80 trapnights; UTM coordinates 4034.937 northing, 355.697 easting), canyon live oak forest (10 trapnights; UTM coordinates 4037.125 northing, 341.856 easting), conifer/lake edge (105 trapnights; UTM coordinates 4036.169 northing, 344.456 easting), and wet meadows at Oriole Lake (35 trapnights; UTM coordinates 4036.230 northing, 344.413 easting) and north of Oriole Lake (57 trapnights; UTM coordinates 4036.490 northing, 344.537 easting). In addition, serendipity trapping was done at five sites within the 1996 Kaweah Fire, located within the Kaweah River's main-stem drainage. These habitats included chamise burned by a high intensity headfire and little rock (UTM coordinates 4040.6 northing, 333.2 easting; 96 trapnights), chamise burned by high-intensity headfire and much rock (UTM coordinates 4040.7 northing, 333.5 easting; 80 trapnights), chamise burned by medium-intensity fire (UTM coordinates 4040.6 northing, 333.4 easting; 40 trapnights), a riparian area in which all leaves and twigs were consumed by fire (UTM coordinates 4040.6 northing, 333.2 easting; 40 trapnights), and burned blue oak wood-land (UTM coordinates 4040.2 northing, 334.2 easting; 64 trapnights). Sherman live traps were scattered loosely through these sites at approximately 15 m intervals (not measured). Serendipity sites were surveyed from

July 28, 1998 through October 31, 1998 for a total of 491 trapnights in Mineral King drainage and 320 trapnights on the Kaweah Fire. Catch per unit effort (captures/ trapnight) was used as a measure of relative abundance among sites. An ink spot on the fur was used to recognize recaptures.

Serendipity surveys also included some trapping for medium-sized mammals (e.g. forest carnivores) using mid-sized Tomahawk traps baited with meat and covered with burlap bags. This sampling was done from June 29, 1998 through October 31, 1998. It amounted to 81 trapnights. This trapping included blue oak woodland (8 trapnights), chamise chaparral (8 trapnights), mixed chaparral (4 trapnights), mixed conifer forest (10 trapnights), riparian forest (17 trapnights), sequoia grove (29 trapnights), and westside ponderosa pine forest (5 trapnights).

Vegetation density was determined using T-square procedures as described in Krebs (1989). The station stakes were used for random points making the procedure systematic. The same plots surveyed for density were used to characterize the species composition and size. Shrubs were measured at ground level. Only living stems >1 cm diameter at point measured were surveyed.

RESULTS AND DISCUSSION

Permanent Plots*:*

Atwell Plot: The Atwell Plot is located in a mature giant sequoia forest. The plot was burned on or about November 20, 1995. The plot's location, topography, preburn vegetation (trees only), preburn rodent population, and duff/litter consumption is described in Werner (1996). The postburn condition is described in Werner (1997). In 1997 and 1998, the herbaceous vegetation looked similar to the preburn condition, and litter was beginning to provide some soil cover.

Seventeen nights of trapping (1,020 trapnights) produced 645 rodent captures (131 different individuals). The mean population estimate during the survey period was 70 individuals (95% CI = 66-74 individuals). This was over four times as high as the preburn population estimate and twice as high as the population estimates during the first two postburn summers (Werner 1996, 1997, 1998). Because the Atwell Plot was sampled later in the summer than normal, it is possible that some of the differences are due to time of year effects. All surveys from early summer show gradual population increases during the survey period, and surveys during the late summer show a declining population during the survey period (**Fig. 3.21-2**). Ninety-four percent of the individuals (91.6% of the captures) were *Peromyscus maniculatus* (mean plot population = 64 individuals, 95% CI = 60-67 individuals). *Peromyscus maniculatus* was far more common than all other species combined: *Tamias speciosus* (3.8% of the individuals, 2.2% of the captures), *Glaucomys sabrinus* (2.3% of individuals, 1.6% of the captures), *Microtus longicaudus* (1.5% of the individuals, 0.9% of the captures), and *Peromyscus boylii* (0.8% of the individuals, 1.6% of the captures). Captures of non-rodents included two *Sorex trowbridgii* (Trowbridge shrew). There were several changes in species captured between the preburn sampling in 1995 and the two years of postburn sampling in 1996 and 1997. *Peromyscus boylii* was only captured in the postburn sampling, and *Microtus longicaudus* was only captured in the preburn sampling and after two

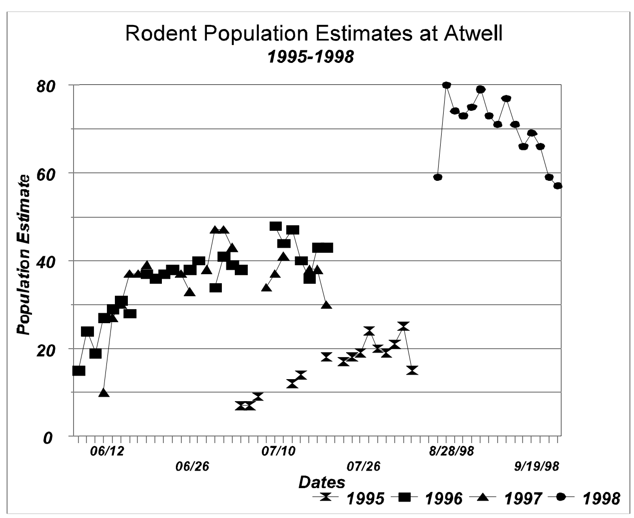

Figure 3.21-2. Comparison of population estimates at the Atwell Plot. The 1995 estimates were preburn sampling. Estimates for 1996 through 1998 are postburn.

and a half years of postburn floral recovery. *Microtus longicaudus* was usually associated with wetland vegetation, which was limited to a small perennial seep near the center of the plot. After the burn, wetland vegetation seemed smaller and more isolated.

Catch rates for the five rodent species were 0.593, 0.014, 0.010, 0.010 and 0.006 captures/trapnight for *P. maniculatus*, *T. speciosus*, *G. sabrinus*, *P. boylii*, and *M. longicaudus*, respectively. Like the mean population size, the catch rate for *P. maniculatus* increased from 0.133 captures/trapnight preburn to 0.593 captures/trapnight during the third year postburn.

The sex ratio for *P. maniculatus* sampled was about equal for the individuals sampled (♀ = 47%, ♂ = 53%, n=609). Sex ratios for other species included: *T. speciosus* (♀ = 7%, ♂ = 93%, n=14), *G. sabrinus* (♀ = 100%, n=10), *P. boylii* (♀ = 100%, n=10), and *M. longicaudus* (♀ = 100%, n=6).

Eighty-six percent of the *P. maniculatus* captured were adults. For the other species, the percent that were adult were: *T. speciosus* (100%), *G. sabrinus* (90%), *P. boylii* (100%), and *M. longicaudus* (100%).

Ponderosa Plot: The Ponderosa Plot was located in westside ponderosa forest. The plot was burned during the week of November 2, 1997. The plot's location, topography, preburn vegetation (trees and shrubs only), and the preburn rodent population are described in Werner (1997). In 1998, the vegetation was very different from the preburn condition. In 1998, the crew counted 24 live trees (Live is defined here as having green leaves in the preburn canopy.) in this plot which we estimated to have 1,456 trees and shrubs in 1996 (preburn; Werner 1997). Those live trees included 24 *Calocedrus decurrens*, 17 *Pinus ponderosa*, and eight *Quercus kelloggii*. Many of the oaks appeared to be regrowing from stump sprouts. The immediate postburn condition of the plot is described in Werner (1998). During the 1998 sampling period, the forest looked largely denuded. Trees remained as black sticks, and much of the soil was exposed. There was some herbaceous cover and much of the non-conifer woody vegetation was beginning to sprout at ground level.

Nineteen nights of trapping (1,138 trapnights) produced 178 rodent captures (45 different individuals). The mean population estimate during the survey period was 20 individuals (95% CI = 18-22 individuals). This was 29% less than the preburn population estimate in 1996 (Werner 1997). However, where postburn survey dates overlapped the preburn survey, postburn population estimates were higher (**Fig. 3.21-3**). There were several changes in species captured between the preburn sampling in 1996 and the postburn sampling in 1998. Eighty percent of the individuals (82.0% of the captures) were *Peromyscus maniculatus* (mean plot population = 15 individuals, 95% CI = 14-17 individuals). In the preburn surveys, *P. maniculatus* was slightly less than half of the population. *Peromyscus boylii* went from being slightly dominant in the preburn sampling to being only seventeen percent of the individuals (15.7% of the captures) in the postburn sampling. The remaining two *Peromyscus* individuals (three captures) were too young to identify to species. There were no captures of non-rodents.

The change in relative abundance between *P. maniculatus* and *P. boylii* might be explained by their preburn distribution. In the preburn surveys, *P. maniculatus* was general found in the dryer areas, and *P. boylii* was more prevalent in the more moist areas of the plot (Werner 1967). Following the burn, the plot has become more xeric, favoring *P. maniculatus*.

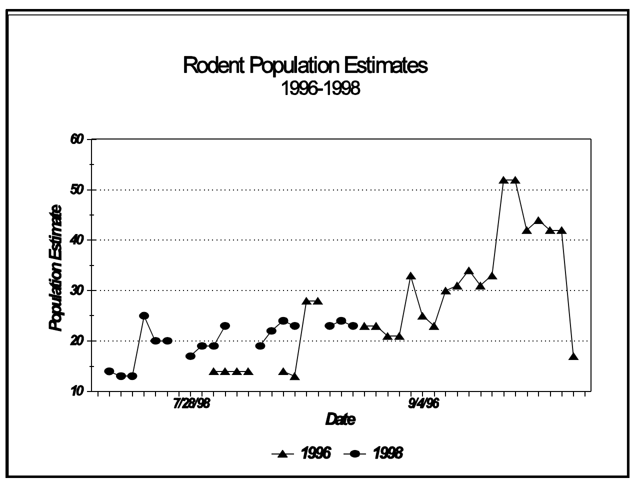

Figure 3.21-3. Comparison of preburn (1996) population estimates with first-year postburn (1998) estimates.

Catch rates for the two rodent species were 0.128 captures/trapnight for *P. maniculatus* and 0.025 captures/trapnight for *P. boylii*.

The sex ratio for the sampled population of *P. maniculatus* was about equal for the individuals sampled (♀ = 49%, ♂ = 51%, n=146). The sex ratio for *P. boylii* was more skewed, but the sample was smaller (♀ = 57%, ♂ = 43%, n=28).

Ninety-eight percent of the *P. maniculatus* captured were adults. For *P. boylii*, only seventy-five percent were adults, suggesting that they were experiencing a different population dynamic than *P. maniculatus*.

Chamise Plots: The vegetation at both chamise plots (**Fig. 3.21-4**), 1CHF and 2CHF, continued to be dominated by *Adenostoma faciculatum*. Visually the plots resembled the tall, dense, preburn condition. Plot 1CHF, the original 1980 plot burned by a headfire in November, had 48,762 stems/ha (95% CI = 30,647-119,256 stems/ha) and 11,420 shrubs/ha (95% CI = 10,793-12,124 shrubs/ha). The vegetation height was 2.2 m (95% CI = 1.9-2.4 m). The sampled stems (n=70) consisted of *Adenostoma faciculatum* (95.7%), *Ceanothus cuneatus* (2.9%), and *Eriodictyon crassifolium* (1.4%). Large patches of grass, believed to be primarily *Achnatherum lemmonii*, were present. Plot 2CHF, the 1981 plot established on the perimeter of the burn, had 26,746 stems/ha (95% CI = 16,796-66,024 stems/ha) and 5,057 shrubs/ha (95% CI = 4,779-5,368 stems/ha). This plot showed dramatic differences between its burned and unburned sides. While there was not a large difference in the number of shrubs (5,293 shrubs/ha [95% CI = 4,631-6,176 shrubs/ha] in the burned area versus 4,384 shrubs/ha [95% CI = 3,836-5,116 shrubs/ha] in the unburned area), the burned side contained over twice as many estimated stems (17,058 stems/ha [95% CI = 8,877-21,743 stems/ha] in the unburned area versus 40,192 stems/ha [95% CI = 21,553-297,240 stems/ha] in the burned area). Mean vegetation height on the unburned side (2.6 m [95% CI = 2.3-2.9 m]; n=15) was taller (P = 0.014) than on the burned side (1.9 m [95% CI = 1.4-2.4 m]; n=15). Visually the two areas appeared as different as the numbers suggest. Vegetation on the burned side appeared shorter, denser, and thinner than the unburned side. The burned side had large stems growing from larger basal trunks. Dead wood was more plentiful on the unburned side. The unburned side is believed to be at least fifty years since it was last burned, and it might be much older. There is no park record of it ever burning. From a distance, both sides appear indistinguishable. The vegetative composition of Plot 2CHF was similar to the other plot. Most of the stems (94.3%; n=70) were *Adenostoma faciculatum*. Other species sampled included *Toxicodendron diversilobum* (2.9%), *Arctostaphylos viscida* (1.4%), and *Lonicera interrupta* (1.4%). The *T. diversilobum* and *A.*

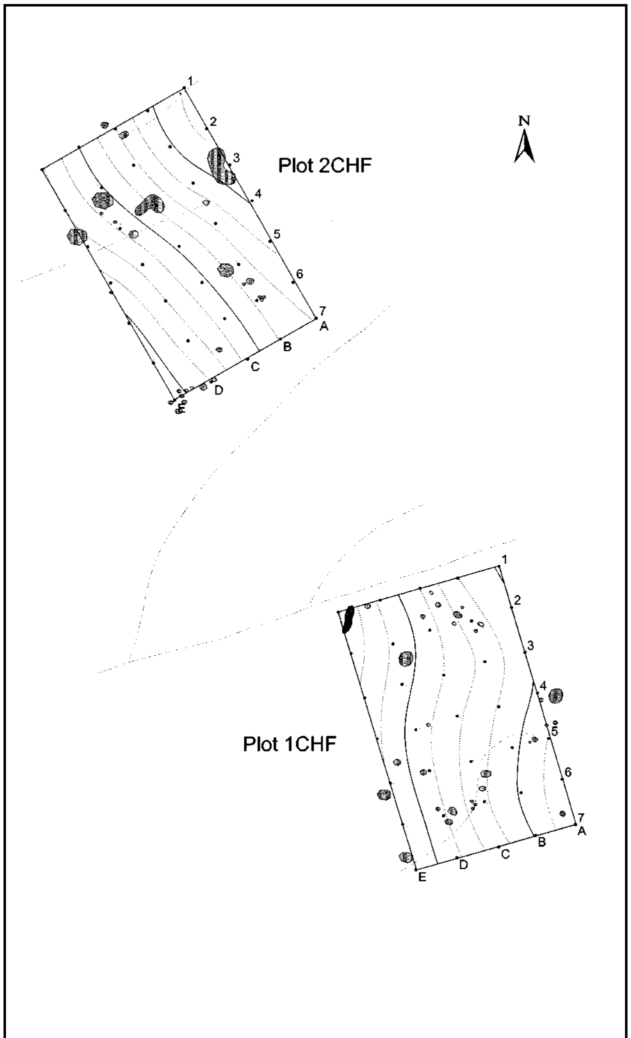

Figure 3.21-4. Map of the chamise plots showing trap stations, general surface contours (within plots), large boulders, and dry stream beds. distance between stations is 10 m.

viscida were in unburned areas. *Lotus scoparius* was conspicuous on both plots.

At Plot 1CHF, fourteen nights of trapping (490 trapnights) produced 83 rodent captures (38 different individuals). The mean population estimate during the survey period was 26 individuals (95% CI = 21-31 individuals). This was 43% less than the 1980 preburn population and about 67% less than the first June postburn population estimate (Werner 1981). Sixty-three percent of the individuals (73.5% of the captures) were *Peromyscus californicus* (mean plot population = 16 individuals, 95% CI = 14-18 individuals). Other species in descending order of abundance include *Peromyscus boylii* (21.0% of individuals; 14.5% of captures), and *Peromyscus truei* and *Neotoma fuscipes* were tied for least abundant (7.9% of individuals; 6.0% of captures). This is a significant change from the 1980 preburn population which was primarily *Peromyscus truei* (50.7% of captures) and *Neotoma fuscipes* (20.8% of captures; Werner 1981). A year later (postburn), the rodent fauna was primarily *P. boylii* and smaller numbers of *P. truei* (Werner 1981). During the second postburn summer, trap success declined; and *Chaetodipus californicus* was the predominate rodent captured. Fall, winter, and spring during the first two postburn years, saw other species appearing and sometimes dominating the rodent fauna (Werner 1982). these include *Peromyscus maniculatus*, *Microtus californicus*, and *Reithrodontomys megalotus*. Overall, this plot has seen a lot of change in faunal composition since 1980. Populations have gone up and down. The current rodent community is different and less populous than the preburn or immediate postburn community.

Catch rates for the rodents were 0.124 captures/trapnight for *P. californicus*, 0.024 captures/trapnight for *P. boylii*, 0.010 captures/trapnight for both *P. truei* and *N. fuscipes*.

The sex ratio for the sampled population of *P. californicus* was somewhat equal for the individuals sampled (♀ = 56%, ♂ = 44%, n=61). The sex ratios for *P. boylii, P. truei*, and *N. fuscipes* were less balanced (♀ = 17%, ♂ = 83%, n=12; ♀ = 60%, ♂ = 40%, n=5; ♀ = 100%, ♂ = 0%, n=5, respectively).

Seventy-seven percent of the *P. californicus* captured were adults. Observed adulthood for other species included: *P. boylii* (75%), *P. truei* (100%) and *N. fuscipes* (100%).

At Plot 2CHF, seventeen nights of trapping (1,190 trapnights) produced 243 rodent captures (84 different individuals). The mean population estimate during the survey period was 44 individuals (95% CI = 38-50 individuals). Forty-six percent of the individuals (34.5% of the captures) were *Peromyscus boylii* (mean plot population = 18 individuals, 95% CI = 14-21 individuals). *Peromyscus californicus* were captured more frequently (50.6% of captures), but involved less individuals (39.3% of individuals). Other species in descending order of abundance included *P. truei* (8.3% of individuals; 9.0% of captures), *Chaetodipus californicus* (3.6% of individuals; 4.9% of captures), and *Peromyscus. maniculatus* (2.4% of individuals; 0.8% of captures). I was surprised by the complete absence of *Neotoma fuscipes* in the plot. However, it was not common during the sampling in the early 1980s (Werner 1982). Non-rodent (and non-mammal) captures included one *Crotalis viridis*.

Catch rates for the rodent species were 0.103 captures/trapnight for *P. californicus*, 0.070 captures/trapnight for *P. boylii*, 0.018 captures/trapnight for *P. truei*, 0.010 for *C. californicus*, and 0.002 captures/trapnight for *P. maniculatus*.

The sex ratio for most species sampled were very unbalanced: *P. boylii* (♀ = 63%, ♂ = 37%, n=122), *P. californicus* (♀ = 63%, ♂ = 37%, n=82), *P. truei* (♀ = 41%, ♂ = 59%, n=22), *C. californicus* (♀ = 83%, ♂ = 17%, n=12), and *P. maniculatus* (♀ = 0%, ♂ = 100%, n=2).

Ninety-one percent of the *P. boylii* and eighty-four percent of the *P. californicus* captured were adults. Other species (*P. truei*, *C. californicus*, and *P. maniculatus)* were all adults. There was little difference in the rodent population abundance or species composition on the two sides of Plot 2CHF (**Table 3.21-1**). An

Table 3.21-1. Comparison of rodent captures from the fifteen trapping stations on either side of the 1980 burn perimeter. These results are from 510 trapnights per side.

Species	Percent of Captures		Percent of Individuals	
	Unburned	Burned 1980	Unburned	Burned 1980
Peromyscus californicus	54.9	47.4	46.5	38.5
Peromyscus boylii	32.8	34.7	44.2	46.2
Peromyscus truei	11.5	5.3	7.0	7.7
Chaetodipus californicus	0	11.6	0	7.7
Peromyscus maniculatus	0.8	0	2.3	0

exception, *Chaetodipus californicus* was only captured on the side burned in 1998. Population densities were almost identical on both sides of the plot. Population estimates varied from twenty-two rodents on the unburned side to twenty-four on the burned side.

In 1981 and 1982, there were conspicuous differences in the rodent captures on the burned and unburned sides of the plot. The rodent community on the unburned side of the plot was predominately *Peromyscus californicus* and *Peromyscus boylii*. *Neotoma fuscipes* was present, but they were captured much less frequently than *P. californicus* and *P. boylii*. The rodent fauna on the burned side of the plot resembled Plot 1CHF though there were some differences like *Chaetodipus californicus* being more common at Plot 2CHF (Werner 1982).

Serendipity Surveys*:*

Rodents: The results of serendipity surveys for rodents in the East Fork Kaweah drainage are summarized in **Table 3.21-2.** *Peromyscus maniculatus* was the most frequently captured rodent at all of the sites except

Table 3.21-2. Serendipity trapping results in the East Fork Kaweah River drainage.

Site Description	Species Capture Rate (captures/trapnight)					
	PEMA	PEBO	MILO	NEFU	TASP	ALL
aspen/sagebrush (51 TN)	0.588		.078			0.667
aspen wetland (23 TN)	0.609		.261			0.870
boulder field, Mineral King (80 TN)	0.400	0.088			0.050	0.525
black oak woodland (60 TN)	0.017	0.400				0.417
canyon live oak forest (10 TN)		0.100				0.100
conifer/lake edge, Oriole Lake (105 TN)	0.590	0.086	0.010			0.695
foothill annual grassland (70 TN)	0.514	0.029		0.014		0.557
wet meadow, Oriole Lake (35 TN)	0.714	0.029				0.771
wet meadow/palustrine forest (57 TN)	0.579	0.035				0.667

PEMA = *Peromyscus maniculatus*, PEBO = *Peromyscus boylii*, MILO = *Microtus longicaudus*, NEFU = *Neotoma fuscipes*, TASP = *Tamias speciosus*, TN = trapnight

Table 3.21-3. Summary of serendipity trapping results for mid-sized mammals.

Site Description	Species Captures/Trapnight			
	BAAS	MAAM	MAPE	TADO
blue oak woodland (8 TN)				
chamise chaparral (8 TN)				
mixed chaparral (4 TN)				
mixed conifer forest (4 TN)	0.100		0.200	
riparian forest (17 TN)	0.059			
sequoia grove (29 TN)		0.034		0.034
westside ponderosa pine forest (5 TN)				

BAAS = *Bassariscus astutus*, MAAM = *Martes americana*, MAPE = *Martes pennanti*, TADO = *Tamiasciurus douglasii*, TN = trapnight

for the black oak woodland. *P. maniculatus* tends to be the high-elevation generalist that seems to dominate all but wet sites at high elevations. At lower elevations, the species seems to be most abundant in areas that are grassy or moist. *Peromyscus boylii* dominated the oak stands. This is consistent with observations elsewhere. I was surprised by the lack of *Microtus longicaudus* captures in the wet areas.

Mid-sized Mammals: Few larger mammals were captured (**Table 3.21-3**). The site in mixed conifer forest that produced two species was located by a stream in the Oriole Lake vicinity. The *Martes pennanti* were believed to be the same specimen captured twice.

Kaweah Fire: Postburn data on the Kaweah Fire is summarized in **Table 3.21-4.** The table provides for a comparison with all trap results following the fire.

The increase in *P. maniculatus*, *C. californicus*, and *Reithrodontomys megalotus* is consistent with other postburn observations in chamise chaparral (Werner 1982). *P. truei* appears to be common only in very rocky areas. All of these species should decrease in abundance as the chamise returns to its preburn structure, especially after the grasses and forbs begin to disappear.

<u>Mountain Beaver:</u> Four more colonies of *Aplodontia rufa* were located during 1998 (**Fig. 3.2-1**). All were in combustible habitats, though two of the sites had not yet burned. Two of the unburned sites were located on the south aspect of the East Fork below the road on Deadwood Creek and north of Silver City along the creek that flows through the developed area. The third unburned colony was located in Eden Grove where the abandoned Eden Grove Trail crosses a small unnamed tributary to the east branch of Eden Creek (Anthony Caprio, personal observation). The other site was along Atwell Creek where it is crossed by the Paradise Ridge Trail. This last site burned in 1995.

PLANS FOR 1999

1. Conduct post-burn survey of the Atwell Plot and Ponderosa Plots.
2. Conduct serendipity surveys in the Hockett area.
3. Visit burned *Aplodontia rufa* colonies and record observations that may be fire related.
4. Continue development of guide to wildlife fire environments.
5. Continue postburn sampling of the Kaweah Fire if time permits.

Table 3.21-4. Summary of rodent capture success following the Kaweah Fire. Within each box, the first number describes results from trapping in 1996, immediately postburn. The second value is capture data for 1997, and the third number is 1998.

Site Description	Species Capture Rate (captures/trapnight)							
	CHCA	MILO	NEFU	PEBO	PECA	PEMA	PETR	REME
chamise, complete consumption, few rocks (1996 TN* = 94; 1997 TN = 84; 1998 TN = 96)	0.021 0.036 0.260					0 0.036 0.500		0 0 0.104
chamise, complete consumption, very rocky (1996 TN = 63; 1997 TN = 70; 1998 TN = 80)	0.175 0.271 0.550		0 0 0.012	0.032 0.114 0	0.079 0 0	0 0 0.075	0 0.014 0.150	0 0 0.012
chamise, poor consumption of stems (1996 TN = 38; 1997 TN = 35; 1998 TN = 40)	0.132 0.200 0.550				0.026 0 0	0.053 0.057 0.225	0.026 0 0	
foothill riparian, high consumption (1996 TN* = 38; 1997 TN = 35; 1998 TN = 40)	0.026 0.314 0.125	0 0 0.025			0.026 0 0	0 0 0.350		0 0.057 0.125
blue oak woodland, consumption good (1996 TN* = 36; 1997 TN = 56; 1998 TN = 64)	0.083 0.196 0.109		0.028 0 0	0.194 0.036 0.031	0.111 0.018 0	0.056 0.036 0.075		

CHCA = *Chaetodipus californicus*, MILO = *Microtus longicaudus*, NEFU = *Neotoma fuscipes*, PEBO = *Peromyscus boylii*, PECA = *Peromyscus californicus*, PEMA = *Peromyscus maniculatus*, PETR = *Peromyscus truei*, REME = *Reithrodontomys megalotus*, TN = trapnight

ACKNOWLEDGMENTS

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3.3 - Watershed Studies

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Projects

Stream Chemistry and Hydrology Study: Lead: Claudette Moore, Jon Keeley; crew: Andi Heard and Ann Huber

Aquatic Macroinvertebrate Study: Lead: Ian Chan, Don Erman, and Nancy Erman; crew: Ann Huber and Claudette Moore

Executive Summary

Watershed monitoring was initiated in the East Fork Kaweah River drainage as part of the Mineral King Risk Reduction Project (**Fig. 3.3-1**). The study was designed to assess the effects of watershed-scale prescribed burning on stream chemistry, discharge and aquatic macroinvertebrate communities. Two separate projects were initiated in 1995 to address these issues; the stream chemistry and hydrology project, and the aquatic macroinvertebrate project. The first project follows similar protocol used in the Log Meadow watershed pilot study, in which stream chemistry and discharge were compared in paired watersheds before and after fire.

In 1998, we concentrated on 1) fine tuning stream discharge rating curves for Trauger's and Deadwood Creeks, 2) developing monthly and annual volume-weighted mean concentrations for solutes in the study streams, 3) developing preliminary mass balance yields for Deadwood Creek using NADP wet deposition data and precipitation data from Atwell Mill, 4) collecting storm samples from Trauger's Creek to improve accuracy of wet season stream chemistry concentrations, 5) analyzing macroinvertebrate data and, 6) preparing the final aquatic

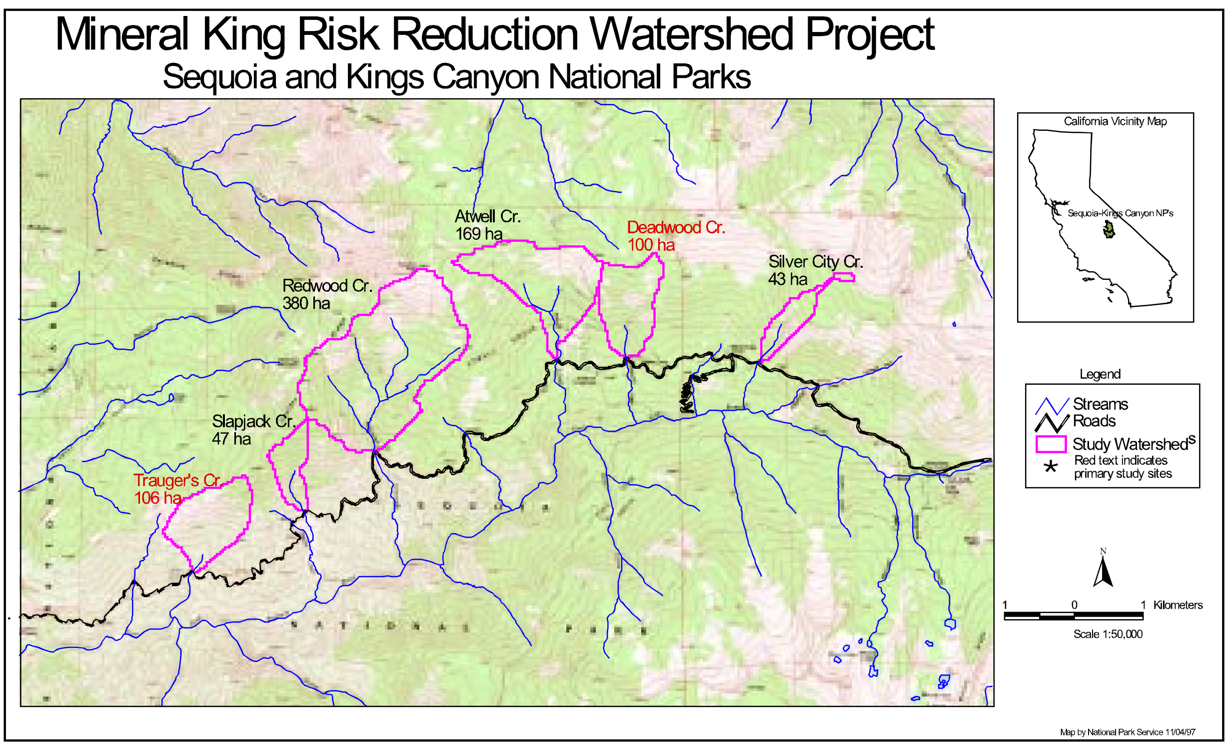

Figure 3.3-1. Tributaries of the East Fork used in the watershed studies.

macroinvertebrate report.

Stream discharge rating curves were developed based on two years of staff/discharge relationship measurements. To increase the accuracy of the rating curves, high and low flow data points obtained from other means were included in the regression analysis. The final rating curves were reviewed by UC Santa Barbara researchers and found to be derived under reasonable assumptions.

Solute concentrations varied seasonally within each catchment. While flux patterns for like solutes were similar, concentrations varied widely by catchment, a likely function of differences in vegetation cover, precipitation type and frequency, and underlying geomorphology. Base cations, and alkalinity were negatively correlated with discharge, as they were the result of mineral weathering. Hydrogen-ion was more variable, but overall, was positively correlated with discharge, and appeared sensitive to precipitation events. Sulfate was negatively correlated with discharge in East Fork and Deadwood, and positively correlated with discharge in Trauger's Creek. Sulfate concentrations in East Fork were five times greater than those observed in the smaller catchments. Mineral springs are found throughout the upper East Fork catchment and appear to influence sulfate concentration many river miles downstream. Trauger's Creek had high sodium and chloride concentrations when compared with other Mineral King study sites, and other Sierran watersheds.

Preliminary solute yields were calculated for the Deadwood catchment. As in other Sierran watershed systems, base cations are exported. Acid anions were exported during the dry season and retained during the wet season. The exception was sulfate, which was predominately exported. This may be the result of naturally high sulfate in the catchment, or underestimated deposition values.

Results of the preliminary aquatic macroinvertebrate study indicated that the 1995 prescribed fire in the Atwell segment did result in some change in Atwell and Redwood Creeks. Decreases in aquatic benthic invertebrate diversity were observed in 1996, despite more intensive sampling. Further study is needed to determine if this is a short-term change in species composition. The fire also resulted in increased large woody debris (LWD) per unit stream length, and an increase in fine sediments in the treated streams. Canopy cover and insolation were not affected by the fire in the treated catchments.

Aquatic invertebrate diversity generally increased with an increase in elevation, and taxa richness was consistently higher in fall samples. The Shannon Diversity Index and Evenness scores were the best indicators of invertebrate differences among sites. The commonly used EPT/D (Ephemeroptera, Plecoptera, Trichoptera/Diptera) ratio was not a useful indicator among sites.

INTRODUCTION

This work was initiated to evaluate the effects of fire on watersheds at two scales: small ($\approx$ 100 ha) and large ($\approx$ 20,000 ha). The literature is lacking in carefully designed studies to evaluate the effects of fire on watershed processes. Generally, watershed studies are initiated after fire has already moved through a watershed, making it difficult to assess the resulting changes due to the lack of pre-burn data. Much of what we know about fire effects on Sierran watersheds is derived from a 1990 pilot watershed study conducted in Log Meadow (Giant Forest), in which biogeochemical processes were compared in paired watersheds before and after fire. The Tharp's watershed (13.1 ha) was burned and the Log watershed (49.8 ha) served as the control site.

The striking chemical response of the pilot experimental watershed in Giant Forest to a fire led to incorporation of further watershed studies on streams feeding the East Fork of the Kaweah River as an element of the "Mineral King Risk Reduction Project." This experimental effort to reduce fuels and restore more typical ecological function to an entire landscape provides a valuable opportunity to measure the physical, chemical, and biotic effects of landscape-scale burning on streams, and on the river systems they feed. For example, fire-induced changes in stream chemistry and sediment loading can have significant effects on fisheries and reservoirs, respectively. Alterations in forest structure result in changes in hydrodynamics that can significantly affect the efficiency of water-storage and release systems. As the Departments of Agriculture and Interior have recently ordered substantial increases in the area of wildland burned each year; the research in Sequoia and Kings Canyon National Parks will provide for more sound implementation of ecosystem management throughout the semi-arid West. Continued monitoring in the East Fork will allow us to evaluate recovery rates of affected parameters such as nitrogen and sulfur constituents, pH, and alkalinity. Additionally, results from the aquatic biota survey will enhance our understanding of the impacts of prescribed fire on the structure of macro-invertebrate communities in the Sierra. While pre-fire surveys of aquatic invertebrate communities provide a baseline for monitoring and developing a catalog of information on the parks' biological resources, post-fire long-term research will track the response and recovery time of communities to fire, while further enriching our understanding of biological diversity along structural and temporal axes.

SITE DESCRIPTIONS

The East Fork Kaweah is a diverse 20,000 ha basin comprised of first to third order subcatchments ranging from chaparral and hardwood forests at the lower elevations, to mixed-conifer and Sequoia forests at mid elevations. Alpine vegetation is found above 3,100 m. Six subcatchments within the basin are monitored as part of the watershed studies. Trauger's Creek and Deadwood Creek are the primary focus for the stream chemistry and hydrology study. Both tributaries are first order perennial streams. They are separated by an elevation difference of approximately 600 meters.

Four additional streams were monitored through 1997 as part of the aquatic macroinvertebrate study: Slapjack, Redwood, Atwell and Silver City Creeks. Limited baseline stream chemistry samples were collected from these streams in 1996.

METHODS

Watershed research in the East Fork has three primary areas of study: 1) stream hydrochemistry, 2) stream discharge, and 3) aquatic macro-invertebrates. The aquatic macro-invertebrates was conducted by UC Davis graduate student Ian Chan under the direction of co-principal investigators Don Erman, and Nancy Erman.

Stream Chemistry

The three study sites were sampled weekly throughout much of the water year. Grab samples were collected, with alternate replicates each month. This year, efforts were made to collect storm samples from Trauger's Cr. and the East Fork, and runoff samples during the snowmelt period at Deadwood Cr. Samples were filtered and processed at the Southern Sierra Laboratory within six hours of collection. On site analysis included pH (Beckman pH meter), alkalinity (Gran titration), conductivity (YSI 1.0 cm-1 cell), ammonium, phosphate and silica (colorimetric analysis). Additional base cation and acid anion analyses were conducted at the Rocky Mountain Station Water Analysis Laboratory in Fort Collins, CO.

Stream Hydrology

Continuous flow and stream temperature measurements have been collected at Trauger's and Deadwood Creeks using Omnidata 800 series data loggers since 1996. Each site is equipped with two pressure transducers, which enable us to monitor the sensors for drift over time, and provide continued coverage in the event that one sensor malfunctions. A thermistor records hourly stream temperature.

Data were downloaded and error-checked weekly. Flow data were calculated from October 1995 through February 1996 using weekly staff readings and precipitation records from Atwell Mill and Lookout Point. This time accounted for the period of WY 1996 prior to installing the data loggers.

Constant Injection Salt Dilution (Kilpatrick and Cobb 1985) measurements were conducted in Trauger's and Deadwood Creeks between spring 1996 and spring 1998 to capture the range of staff gauge/flow fluctuations. Replicate measurements were taken, and a rating curve was developed in July 1998. Slight changes in protocol were made in summer 199, and greatly improved the accuracy of our techniques. The rating curve was reviewed in Nov. 1998 by UC Santa Barbara researchers.

Aquatic Macroinvertebrates

The macroinvertebrate study focused on three areas of data collection: 1) benthic macroinvertebrates, 2) adult-stage insects, and 3) physical stream characteristics. Data collection commenced in the fall of 1995. Extensive sampling was conducted in the spring and fall of 1996. Adult-stage insects were collected through the fall of 1997.

Benthic Macroinvertebrates
Benthic macroinvertebrates samples were collected from three different habitat types: pools, riffles, and bedrock outcrops. Three different pools, riffles and bedrock outcrops were sampled. Analysis was based on a composite of four samples collected during each sample event between fall 1995 and fall 1996.

All invertebrate samples were preserved in 80% ethyl alcohol, and stained in a solution of rose Bengal dye to facilitate separation of invertebrates from collection debris. All of the 1995 samples and the 1996 bedrock samples were picked through, separated and identified in their entirety. Due to the large volume of debris in the 1996 riffle and pool samples, these samples were subsampled before identification was made.

To validate the lab subsampling and field composite samples, tests were carried out on all split fractions from three Trauger's Creek riffle samples collected on 21 September 1996. Several species richness and statistical tests were conducted to determine whether the subsampling and compositing methods accurately and adequately represented species richness and number of individuals. Results from these analyses showed no significant difference between subsamples from the sample riffle. Error from splitting samples was <5% for the total number of individuals.

Specimens were generally keyed to genus. Benthic samples were compared on the basis of diversity, evenness similarity, taxa richness, and number of individuals. Three indexes were used to determine the above: 1) the Shannon Index of Diversity, 2) the Jaccard Coefficient of Similarity, and 3) comparisons between Ephemeroptera, Plecoptera, and Trichoptera (EPT) and Diptera abundance. Samples were analyzed by habitat and season (spring and fall).

Adult-stage Aquatic Insects

Adult stage aquatic insects were collected using 1 m^2 pyramidal emergence traps. The traps were placed over pool habitats in the six study streams, and maintained from early April through late October during 1996 and 1997. Samples were collected weekly or biweekly. Collections were standardized into two week periods to allow comparison of samples collected on slightly different dates. Within standardized periods, adult insect emergence was described by average number of individuals collected per week/m^2 by insect order.

Physical Stream Characteristic

Stream order, elevation, slope and aspect were estimated from USGS 7.5 minute topographic maps. Watershed area was estimated using GIS (Resources Management, Sequoia NP). Discharge measurements from Trauger's and Deadwood Creeks were obtained from the USGS/BRD staff. Discharge for ungauged streams was estimated from the relationship between drainage area and mean annual discharge for streams in the Tulare Lake Basin (US Geological Survey). Solar insolation was calculated from three randomly selected sites for each stream.

The substrate surface layer was sampled using the random pebble count method (Wolman, 1954, Leopold 1970). Sub-surface bed sediments were collected using a modified excavated core (EC) sampler after McNeil and Ahnell (1964). Three cores were collected from three different pools. Large woody debris (LWD) surveys were conducted in each stream. Wetted width and bankful measurements were also collected.

RESULTS TO DATE

Due to the delayed turn around time in chemistry analysis, the following discussion is based on data from water years (WY) 1996 and 1997.

Stream Hydrology

Stream rating curves were developed based on two years of Constant Injection Salt Dilution measurements made at Trauger's Creek and Deadwood Creek. Preliminary rating curves were developed using data from the salt dilution measurements, which represented low to moderate flows in both streams. The lack of high flow data points in the rating curve is a limitation that is faced by many and was difficult to overcome. Based on the continuous flow data, each stream only has one significant spike in staff height each winter, lasting only a few hours. In Trauger's Cr., this usually occurs during a large rain event in February or March. In Deadwood Cr., this occurs during peak snow melt, which is hard to predict. To account for this deficiency in the data, maximum discharge values were determined using engineering histograms for flow through a culvert. These data points enabled us to determine how well the rating curves predicted high flows. In addition, since salt dilutions are known to over predict flows by as much as 30% (Melack et al. 1998), flow measurements were made using a 3.5 gal. bucket and a stop watch for the lowest observed staff heights.

The preliminary rating curve for Deadwood Cr. under predicted peak flow by 8% and over predicted the lowest flow by 44%. To improve the accuracy of the rating curve, it was recalculated using the peak and low flow points derived from alternative sources. This improved the accuracy of the rating curve for both the upper and lower ends of the curve (r^2 0.95 and 0.85 with and without additional measurements, respectively).

The preliminary rating curve for Trauger's Cr. over predicted peak and low flows by 53% and 160%, respectively. Although salt dilution results have been shown to over predict flow, something else was apparently influencing the measurements. Recent analysis of solutes revealed high concentrations of both sodium and chloride in Trauger's Cr, which were likely influencing the outcome of our measurements. To account for this naturally high concentration of sodium, the flow values were adjusted by 65%. This adjustment resulted in a rating curve that under predicted peak flow by 10% and over predicted low flow by 80%. The final rating curve was developed based on 65% of the original flow values, and included peak and low flow values derived from alternative means. This rating curve produced the best overall flow values for both high and low flow conditions.

These rating curves were reviewed by UC Santa Barbara researchers and found to be derived under reasonable assumptions. The inclusion of the high and low flow values makes the rating curves more robust and reduces error in over predicting low flows, which can persist for several months during late summer and early fall. High flow estimates will also be more accurate.

The relationship between precipitation and discharge is as one would expect. Trauger's, a rain-dominated catchment, reaches maximum discharge rates during the month with the greatest precipitation (usually Feb. or March), and drops of steeply throughout the spring. In years with low to normal precipitation, late summer and fall discharge rates fall below 1 cfs. Deadwood and East Fork are snow-dominated systems, thus, maximum discharge rates correspond to snow melt runoff in these catchments. Discharge peaks in April or May in Deadwood. The flood event in Jan. 1997 resulted in anomalous spikes in discharge in both catchments, and produced a second peak in discharge for East Fork in water year 1997 (**Fig. 3.3-2a and 3.3-2b**). Maximum discharge in East Fork occurred in June for water years 1996 and 1997. The onset of peak discharge in East Fork most likely occurs during June in years of low to normal precipitation. Black (1994) found that East Fork headwater lake systems peaked in June during a 1993 study, and historic data (USGS, 1973) also shows peak discharge in June.

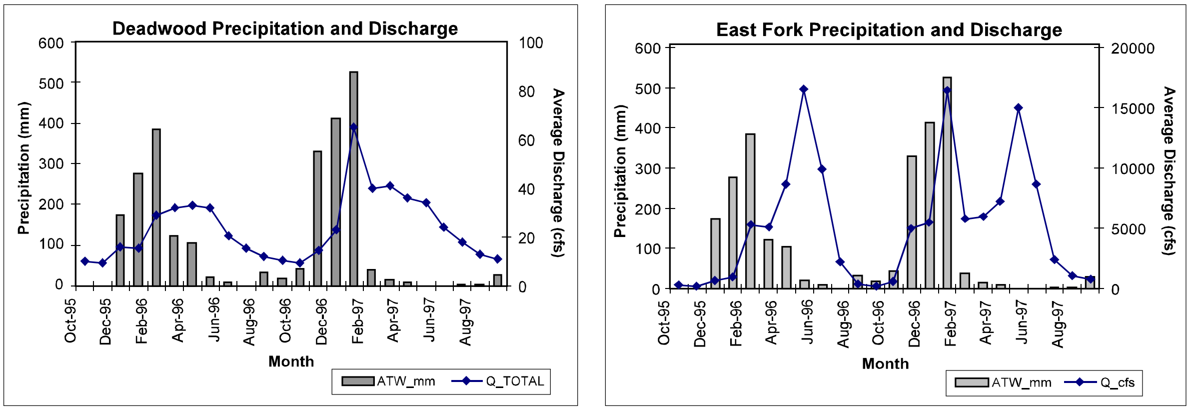

Figure 3.3-2a and 3.3-2b. Relationship between discharge and precipitation in East Fork Kaweah. The Jan. 1997 flood resulted in peak discharge for WY 1997, overshadowing the peak associated with snowmelt runoff in both catchments.

Stream Chemistry

Solute concentrations varied seasonally within each catchment. While flux patterns for like solutes were similar, concentrations varied widely by catchment, a likely function of differences in vegetation cover, precipitation type and frequency, and underlying geomorphology. The discussion below is based on volume-weighted mean (VWM) concentrations.

Base Cations

Base cation concentrations were inversely related to discharge rates, and were therefore highest during low flow periods when surface waters contain the highest percent of ground water sources. East Fork solutes show the greatest seasonal flux of volume-weighted means, though not necessarily the highest concentrations. The dominant cation order was Ca>Na>Mg>K in Deadwood and East Fork, which is typical of Sierran systems in metamorphic terrain (Melack et al. 1985). Sodium and calcium were reversed in Trauger's, with sodium concentrations of 280-580 μEq (**Fig. 3.3-3**). Calcium had the largest magnitude in seasonal flux (278 uEq to 702 uEq) in the East Fork. In the late summer and early fall when calcium is high, the East Fork receives up to 50% of is volume from headwater lake systems with large calcareous inputs (Black 1994). In water year 1996, potassium concentrations fluctuated widely in the East Fork, however, the same pattern was not observed in WY 1997.

Alkalinity and pH

Buffering or acid neutralizing capacity (ANC) is a function of bicarbonate concentrations present in surface waters. In the Sierra Nevada, buffering capacity is derived from weathering processes, and is also negatively correlated with stream discharge. Peak concentrations are reached during the late summer and early fall and begin to decline as snow melt and other surface flow enters the streams. Trauger's Creek ANC recovered earlier than Deadwood and East Fork since the catchment did not receive snow melt runoff. Again, East Fork hd the greatest flux in ANC concentrations. Trauger's ANC had the lowest seasonal flux generally remaining between 0.47 and 0.75 mEq. Seasonal differences in East Fork and Deadwood ranged from 0.30 to 0.95 mEq and 0.38 to 0.74 mEq, respectively. These differences probably reflect differences in the amount of snow melt runoff received by each catchment, and the corresponding recovery time of ANC.

Hydrogen-ion concentrations tended to be positively correlated with discharge, and were more

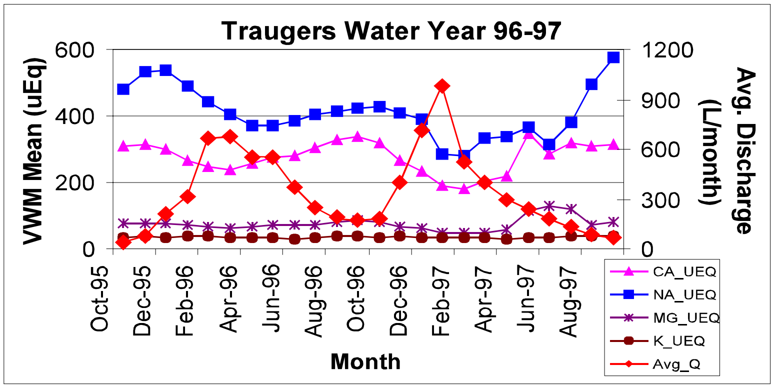

Figure 3.3-3. Base cations are negatively correlated to discharge in Trauger's Creek. In contrast to other Sierran systems, sodium VWM exceeds calcium VWM.

varied than ANC concentrations. In WY 1996, there was less fluctuation as weather patterns were more typical of normal. In WY 1997, the East Fork had two small peaks in H^+ (0.25 and 0.28 uEq) in the fall and Jan 1997 flood, and reached maximum peak (0.45 uEq) in June during peak discharge. Both Trauger's and Deadwood H^+ peaked (0.25 and 0.37 uEq, respectively) during the Jan 1997 flood event, which fell as rain in both catchments. Another smaller peak was observed in June, which was likely associated with rain events received during that month.

Changes in stream hydrogen-ion concentrations appeared to be highly sensitive to precipitation events and snow melt. pH values for summer precipitation events in the Middle Fork measured between 4.45 and 4.89 during WY 1996 and 1997. Summer rain events in Emerald Lake Basin have also resulted in short-term elevated H^+ concentrations (Melack et al. 1998).

Acid Anions

Sulfate was negatively correlated with discharge in East Fork and Deadwood, and positively correlated with discharge in Trauger's Creek. In Trauger's, peak concentrations averaged 14 uEq, and minimum concentrations averaged 6 uEq. These values were slightly higher than averages observed in Deadwood (5 uEq and 11 uEq, respectively). Sulfate concentrations in East Fork were on average five times greater (28 uEq and 77 uEq) than those seen in Trauger's and Deadwood Creeks (**Fig. 3.3-4**). Mineral weathering is the most likely source of sulfate in these basins (Melack et al. 1998).

In snow-dominated Sierran systems, sulfate is negatively correlated with discharge due to the dilution effect of snow melt runoff. However, since solute data from rain-dominated catchments in the Sierra is lacking, it's unknown whether sulfate is often positively correlated with flow in these catchments. This correlation may reflect the direct input of dry deposition into the stream following a precipitation event.

High sulfate concentrations in East Fork are likely due to the presence of mineral springs that are present throughout the upper East Fork catchment. Sulfate concentrations were found to range between 12 and 240 uEq L^{-1} in the headwater lakes and springs of the East Fork (Black 1994). Sulfate obviously remains elevated many river miles down stream of its source.

Nitrate concentrations were also elevated in East Fork during high flows, whereas it has been undetectable in Deadwood and Trauger's for much of the study.

Nutrients

As in most Sierran systems, the East Fork catchments are nitrogen limited. Ammonium was undetectable throughout much of the year in Trauger's and Deadwood. Maximum concentrations averaged 0.37 uEq in both catchments. Maximum concentrations were positively correlated with flow, and tend to drop to below detection level during the growing season.

Phosphate was highest in Deadwood and lowest in the East Fork. There was no apparent seasonal pattern and did not appear to be strongly correlated positively or negatively with discharge. Phosphate was generally detectable throughout the growing season, and was, on average, 5.5 times greater in concentration than ammonium in Deadwood and Trauger's Creeks, and two times greater in East Fork.

Deadwood Creek Yields

Preliminary monthly solute yields were calculated for Deadwood Creek using NADP wet deposition chemistry data collected in Giant Forest, and Atwell Mill precipitation data. The NADP data were collected at a similar elevation from the next major drainage north. Deposition rates were slightly under estimated due to loss of sample during successional major winter events, and unaccounted deposition during summer events, which were very localized. Other sources of error included the lack of dry deposition data, and stream chemistry data from storm events. These limitations in the data set resulted in underestimated yields. However, trends in yields are still useful as a baseline to evaluate how fire may affect these trends. As expected, base cations were exported in concentrations relative to their dominant order. Sulfate and chloride were predominately exported throughout the year. Retention was observed during some wet months, which may reflect under sampling high flows. Hydrogen-ion, ammonium, and nitrate were retained during the wet months and exported during the dry months. However, exported concentrations were very low suggesting that Deadwood is primarily a sink for these solutes. This is a trend generally observed in other Sierran watersheds.

Annual solute yields for Tharp's and Log catchments in Giant Forest followed the same trends during a ten year study from 1984-1993 (Williams and Melack 1997). Cations were exported from these catchments, whereas anions tended toward negative yields. Sulfate and chloride also tended toward negative yields. However, sulfate and chloride were exported for a period of years following the 1990 fire in the Tharp's catchment. These solutes were also exported from Log during wet years.

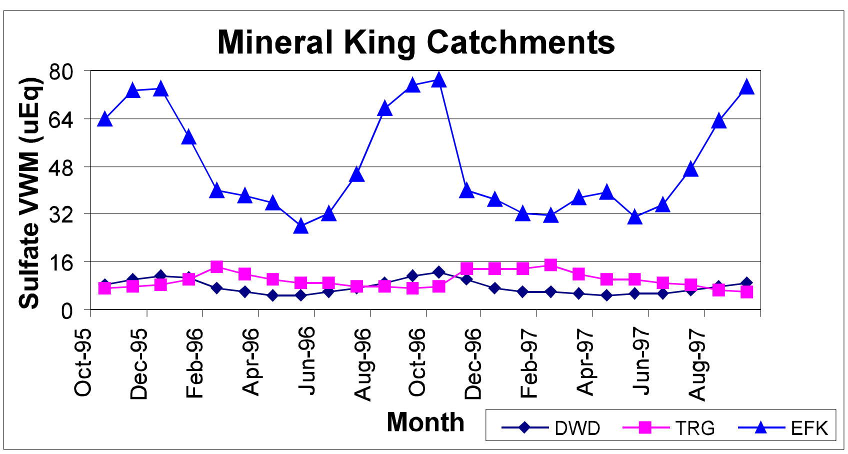

Figure 3.3-4. Sulfate VWM is significantly higher in East Fork due to the presence of mineral springs in the upper basin. Sulfate is positively correlate with discharge in Trauger's Cr., possibly due to the direct input of dry deposition, which is flushed into the stream during rain events.

Aquatic Macroinvertebrates

Results of the aquatic macroinvertebrate study provide valuable baseline data for understanding invertebrate diversity, abundance and evenness in small, steep headwater catchments in mixed-conifer forests.

Benthic Macroinvertebrates
A total of 136 taxa were identified from 109 benthic samples collected during 1995 and 1996. The Shannon Index of Diversity was expected to be higher in 1996 due to more intensive sampling. However, Atwell and Redwood Creeks, which were burned following limited 1995 sampling, decreased in diversity by 14% and 10%, respectively in pool habitats. In contrast, pool habitats in adjacent unburned streams increased by 23-40% for the same period (F**ig. 3.3-5**).

As expected, increased sampling in 1996 resulted in an increase in taxa richness. Unburned streams had the highest increases ranging from 75% to 150%. Redwood Creek had the smallest increase in richness, only 25%. Increases varied with habitat type. Pools showed the most consistent increases, and were the best indicators of taxa richness (**Fig. 3.3-6**).

Differences in the Shannon Index of Evenness were evident in burned versus unburned streams. Burned streams generally had a lower index of evenness. Slight differences in community similarity were also detected between burned and unburned streams. Burned-to unburned comparisons averaged lower similarity than unburned-to-unburned comparisons. Pool habitats were once again the best indicator of these differences. In same stream comparisons by season (spring and fall), unburned streams were more similar overall than burned streams, ranging from 45-64% to 34-40%, respectively.

Based on number of individuals, members of the dipteran family Chironomidae frequently dominated samples from all habitat types. *Baetis* spp. mayflies, the cased caddisfly, and freshwater mites (Hydracarina) were also present in large numbers. Riffle habitats were dominated by nemourid (Zapada spp.), and chloropelid stoneflies. Pool habitats were most abundant in lepidostomatid caddisflies (*Lepidostoma* spp.), ostracods, and small clams

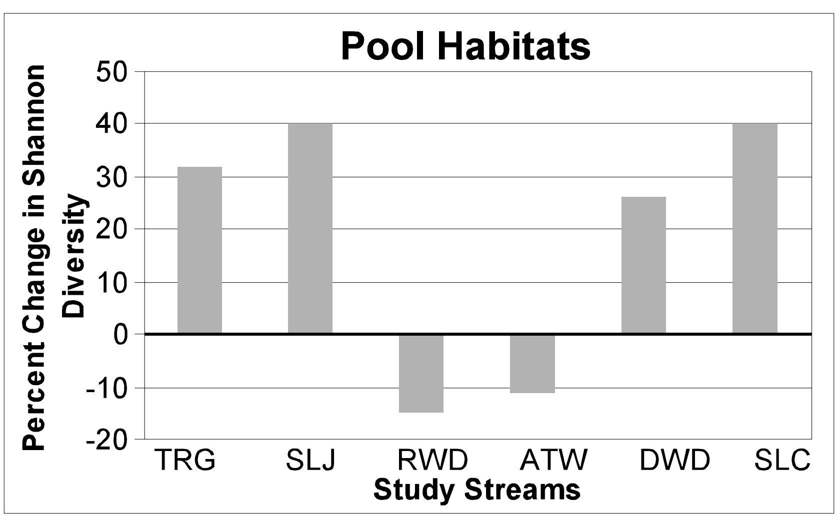

Figure 3.3-5. The Shannon Index of Diversity and Evenness decreased for Atwell and Redwood Creeks between fall 1995 and fall 1996 samples despite increased sampling efforts in 1996.

(Pelecypoda). Bedrock outcrops were abundant in blackfly larvae (Simuliidae), heptageniid mayflies (*Ironodes* and *Rithrogena*), and rhyacophilid caddisflies (*Rhyacophila* spp.).

Some endemic and unusual species were identified within the study area. The caddisfly *Yphria califonica* was frequently collected in pools at elevations above 1700 m (Redwood Cr. and above). Known only from the Sierra Nevada, Siskyous, and Cascades, *Yphria califonica* is possibly the most primitive living species of the tube-case-making caddisfly in the world (Wiggins 1962, and Anderson 1976). The unusual caddisfly genus *Cryptochia* was also found in pools throughout the study area. Symbiotic associations of *Cricotopus* midges and *Nostoc* cyanobacteria were commonly found in bedrock outcrops.

Overlap of taxa between habitat types, especially riffles and pools ranged between 23% to 43%. This pattern held true for both ubiquitous and less common taxa. This may be due in part to poorly defined riffle and pool habitats in these small streams.

Adult Insects
Data from adult collections revealed no distinct trends between burned and unburned streams. In general, Atwell and Redwoods Creeks had higher average emergence rates for all taxa. This may be a function of catchment size, as these were to two largest catchments in the study.

True flies (Diptera) were collected in most abundance. This finding is consistent with other work on small streams in the Sierra (Erman and Erman 1990). Peaks in emergence for stone flies (Plecoptera, mayflies (Ephemeroptera) and caddisflies (Trichoptera) also occurred in most streams. The total average number of invertebrates collected per week/m^2 (from all orders combined) increased consistently with stream size during 1997.

Fire Effects on Streams

Erosion of fine sediments from fire-treated hillslopes resulted in increased sedimentation of aquatic habitats, particularly in depositional areas such as pools. Large deposited of fine sediments were observed behind debris jams, on stream banks, along margins of the bankful channels, and in pool habitat in Redwood and Atwell Creeks in 1996. Median particle size (D_{50}) was smallest in the two burned streams, despite the fact that they were the largest steams in the study area. Plots of sediment size versus watershed area for the study streams illustrate that smaller particle size would not be predicted on the basis of underlying watershed characteristics.

Pebble counts were found to adequately document changes in sediment size in the study streams. More elaborate excavated core analysis detected similar changes, but required substantially more sampling and processing effort. Strong correlation between surface and subsurface sediment sizes in the study streams suggests that the surface layer serves as an adequate proxy for overall substrate character. Thus, surface sampling may be sufficient for detecting relative changes in channel substrate sizes.

The 1995 prescribed fire had little effect on canopy cover, insolation or stream temperature in Redwood and Atwell Creeks. Variation in solar radiation was associated with stream width. Stream temperature followed climatic trends associated with stream elevation.

Large woody debris (LWD) surveys conducted on the study streams in 1996 indicated increased debris per unit stream length in the treated streams. This was evident based on the number of LWD pieces found with recent char markings. The literature suggests LWD decreases in streams following fire due to increases in discharge velocities, which can transport large materials down stream. However, increase in peak and annual discharge may be delayed several years due to delayed mortality in large trees. Decreases in LWD were observed in Trauger's Creek in 1998. These data are still being analyzed, but suggest that the January 1997 flood removed a lot of woody debris that was previously measured in the 1996 survey.

1999 GOALS

In 1999 we will begin evaluating the relationship between precipitation and snowmelt runoff, and discharge in each of the study areas. In the smaller catchments, detailed analysis of responses to precipitation events will be conducted. Presently, raw data indicate that precipitation events in the Trauger's catchment result in short-term increases in discharge. More analysis is necessary to understand how the magnitude of the event and the antecedent conditions affect discharge response. The Deadwood catchment shows little response to early season rain events, as evidenced by the raw flow data. This lack of response needs more investigation, as changes in litter and duff levels after fire may result in increased discharge following early season rain events and snowmelt runoff.

Using historic flow data collected by USGS, Southern California Edison, and the US Army Corps of Engineers, we would like to 1) determine the contribution of the upper East Fork catchment to the East Fork water budget and, 2) determine the contribution of the East Fork Kaweah to the overall Lake Kaweah budget. This information will allow us to piece together how the burned subcatchments within the East Fork will change the overall water budget, and, in turn, how these changes affect the Lake Kaweah water budget.

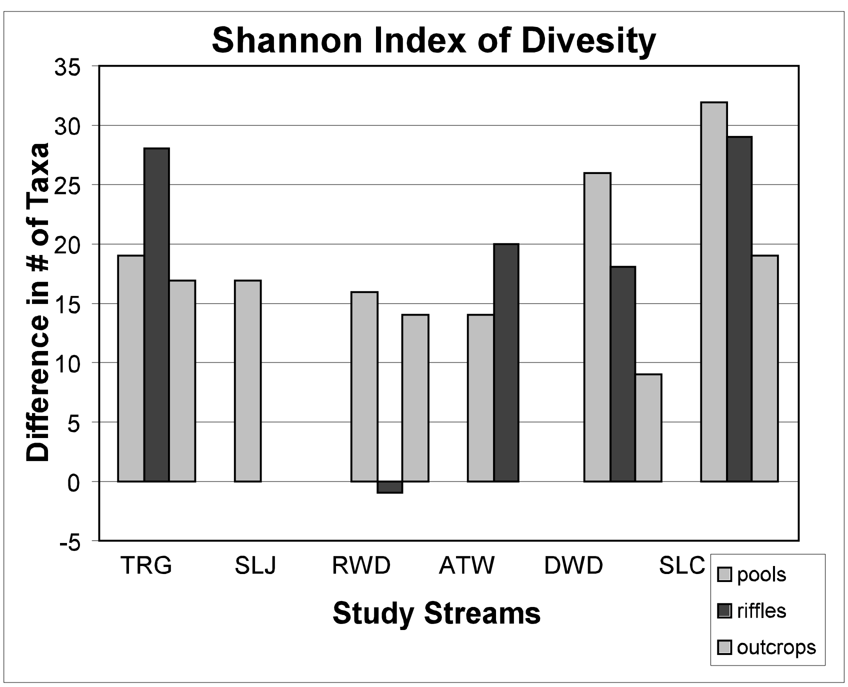

Figure 3.3-6. Overall, there was a greater increase in taxa between the fall 1995 and fall 1996 samples for all habitats in the unburned streams. Only pool habitats were sampled in Slapjack Cr.

In addition, we will work on calculating more accurate yields from the study sites by including dry deposition data collected from the NOAA station at Wolverton, and installing an Aerochemetrics collector at Lookout Point.

Due to the stable nature of most solutes during the summer base flow season, sampling will be reduced to biweekly, and possibly monthly depending on the budget. Reduced sampling during this period will free up dollars to conduct intensive sampling in the fall when Trauger's and Deadwood catchments are scheduled to burn. We will also analyze the storm samples collected in 1998 to quantify solute concentrations transported during these events. This information will increase the accuracy of our monthly and annual load calculations for the study sites.

Large woody debris surveys will be conducted and analyzed in Deadwood Creek, and analysis of the Trauger's data collected in 1998 will continue. These results are important to determine how weather patterns affect LWD distribution. Since the original measurements were made, the study area has experienced two significant weather events: the Jan.1997 flood and the 1998 El Niño.

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3.4) Cost-effectiveness Analysis of Hazard Fuel Reduction Programs

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INTRODUCTION

Assessing the cost-effectiveness of fuel treatments presents many challenges. These challenges are accentuated when the fuel treatment under consideration is prescribed fire, especially when proposed fires will be applied over a large geographic area such as a watershed. Prescribed fire may be the most cost-effective fuel treatment for an area, especially in areas managed for ecosystem sustainability or restoration of natural patterns and processes. However, there are consequences that must be considered in evaluating prescribed fire as a treatment. Threats of escape and smoke pollution are two of the more obvious consequences. While prescribed fire treatments generally are lower in cost than other fuel treatments, i.e., mechanical thinning, fire also is more variable in its effects. This variability in treatment effect is especially evident in the spatial mosaic created by large-scale fire application. On the other hand, mechanical methods may not be suitable where land management objectives call for restoring or imitating natural patterns and processes over the landscape.

In Phase 1 of this project we elucidated some of these challenges through our problem analysis and construction of a prototype simulator for the Mineral King study area in Sequoia-Kings Canyon National Parks (Omi and others 1998). The problem analysis identified anticipated conceptual difficulties while other obstacles only became apparent as we proceeded to build the prototype.

In Phase 2 of this project our intent is to continue with prototype development and consider the feasibility of incorporating benefits in addition to reduction in fire hazard. In phase 1 we focused solely on reductions in burned area, treatment and suppression costs made possible by treatments of increasing larger areas using prescribed fire. Our intent in Phase 2 is to incorporate additional criteria, such as non-market values, emission estimates, and other indicators of overall value-at-risk.

In addition, we intend to examine issues related to extending the prototype to other suitable DOI units. For example, these could include other national parks, FWS refuges, or BLM areas managed as wilderness.

Our third objective in Phase 2 involves revision and updating of the program RXCOST (Omi and others 1992), initially provided to the NPS in 1992. This tool identifies upper and lower limits for proposed prescribed treatment costs, based on regression equations developed for hazard fuel reduction cost requests submitted to NPS-NIFC during the period 1989 to 1992. Since that time numerous changes have occurred in prescribed fire programs throughout the nation, such as expansion of total area treated due to policy changes and improvements in expertise in using fire as a management tool. Administrative changes have occurred, such as institution of NPS prescribed fire modules. These and other changes have motivated the need for updating the original RXCOST program.

The report summarizes progress to date in completing the Phase 2 objectives described above. In addition we suggest how managers might use some of the outcomes from our research efforts and identify potentially fruitful areas of further inquiry.

SUMMARY OF PROGRESS TO DATE

Objective: Develop the prototype simulator for the Mineral King study area

The prototype simulator developed in Phase 1 relies on FARSITE™ simulations, with and without treatment, to arrive at estimates for reductions in area burned by wildfire and resultant reductions in total cost (treatment cost + wildfire suppression costs). The foundation for these estimated savings is illustrated in **Fig. 3.4-1**, which shows the reduction in area burned by wildfires (x-axis) associated with various levels of prescribed fire application (y-axis). The graphic in **Fig.3.4-1** is taken from Omi and others (1998) to illustrate how the prototype simulator was constructed in the Mineral King study area of Sequoia-Kings Canyon National Park. **Fig. 3.4-1** also indicates that treatment of segments 1,2, and 4 (Rx 1,2,4) is a less desirable alternative to treating segments 1 and 4, since a higher number of acres treated (7740) would result in a smaller reduction in burned area (4021) than with Rx1,4. In other words, Rx1,2,4 is an inferior solution as are all other unlabeled points that lie above and to the left of a line connecting Rx4, Rx2,4, Rx1,4 and Rx1,2,3,4 in the figure. Further, tradeoffs associated with treating larger areas can be evaluated by moving upward along such a line and noting the resultant reduction in burned area.

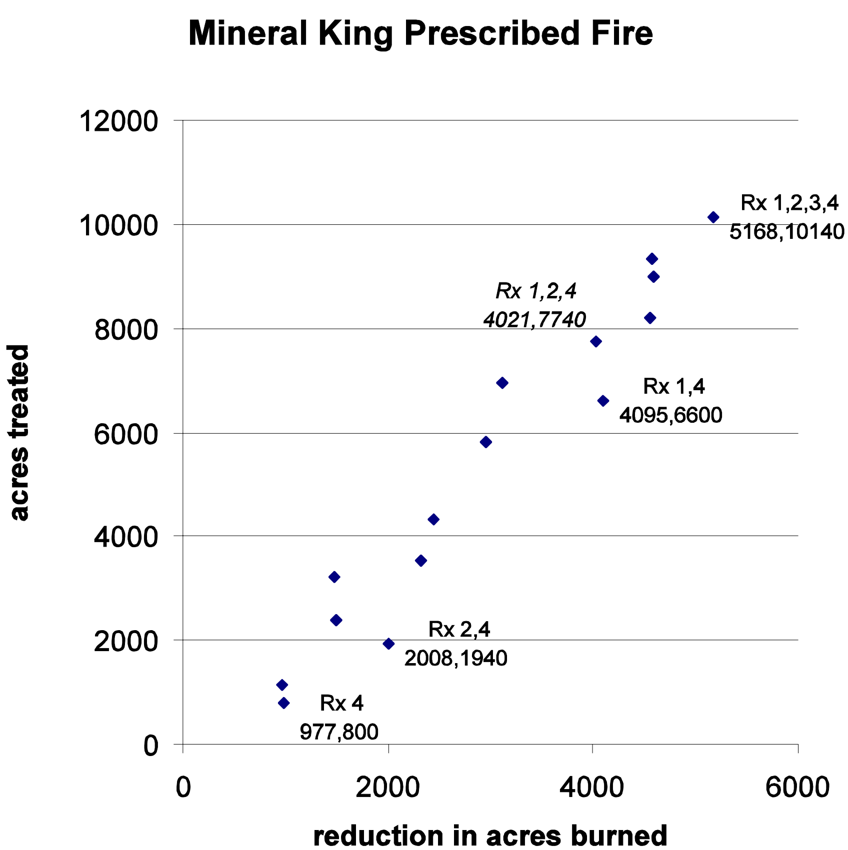

Figure 3.4-1. Reductions in burned area resulting from prescribed fire treatments based on FARSITEä simulations for the Mineral King study area. Treatment of segments 1 and 4 (Rx 1,4), a total of 6600 acres treated, result in a reduction of 4095 acres burned by wildfires. Other illustrative treatment combinations, treatment area, and burned area reductions are noted for treatment of segments 4 (Rx$), segments 2 and 4 (Rx2,4), 1,2, and 4 (Rx1,2,4), and 1,2,3,4 (Rx1,2,3,4). Other treatment combinations are graphed as unlabelled points.

Additional graphs can be produced once this fundamental relationship between treatment area and burned area is establishied. For our analysis we rely on our prior study of suppression costs from historic DI-1202 records (Omi and others 1995), and cost estimates for prescribed fire treatments from the RXCOST (Omi and others 1992) to examine cost savings from fuels treatment. For example Omi and others (1998) illustrated a variety of other graphic relationships, such as treatment cost vs. reduction in area burned (so-called cost-effectiveness frontier), and treatment cost vs. suppression cost savings.

In similar fashion, we are currently examining the feasibility of analyzing and incorporating additional contributors to values at risk, such as non-market resources (e.g., threatened and endangered species or scenic resources) as covered in Rideout and others (1997). Non-market valuation techniques under consideration include travel cost method (TCM) and contingent valuation method (CVM). As described in Rideout and others (1997) these techniques have been used for valuing both recreation and nonmarketed benefits of environmental resources (game birds, threatened and endangered resources, viewing birds, small game mammals, big game mammals, threatened and endangered mammals, water quality, fishing and other recreation, etc.).

We also are examining implications of incorporating smoke emissions from wild and prescribed fires into the analysis. The approach currently under consideration relies on emissions estimates derived for a hypothetical unit area (i.e., acre or hectare). For example, if fuel loadings (tons/ha) are estimable then fuel consumption and emission estimates can be generated for flaming and smoldering combustion in treated vs. untreated areas. The procedure relies on literature estimates for fuel consumption and emission factors during flaming and smoldering combustion (e.g. Ward and others 1993). For example, particulate emissions can be estimated as

$$E = w\ EF\ A \qquad (1)$$

where E = total emissions (g/m^2),
w = mass of fuel consumed (kg/m^2),
EF= emission factor (g/kg of fuel consumed), and
A = burned area (m^2).

Ward and others (1993) show how emissions and emission factors during flaming and smoldering can be estimated for a variety of smoke constituents. These include carbon monoxide (CO), green house gases CO_2 and CH_4), nonmethane hydrocarbons (NMHC), total particulate matter (PM), and particulate matter with diameters less than 2.5 micrometers (PM2.5). These emissions are considered important for visibility and human health standards, and can be arrayed against levels of fuel treatment as well.

Currently, we believe that equation (1) can be used to transform the x-axis in Figure 1 from reductions in area burned to reductions in total emissions by wild and prescribed fires. Using the program RXCOST, we also can transform the y-axis in Figure 1, resulting in a graph of treatment costs vs. emission reductions. This would provide a tool to managers for assessing the cost-effectiveness of fuel treatments for reducing overall emissions. We envision a similar framework can be developed for assessing treatment costs vs. effects on nonmarket resources.

Objective: Expand applicability of the prototype simulator to suitable DOI units

We anticipate that the simulator will be most applicable to areas like Sequoia-Kings Canyon NP, with actual or contemplated large-scale prescribed burn programs. Likely candidates include other national parks with high levels of fire activity (wildfire, prescribed fire, and wildland fire for resource benefit). Other candidate areas could include large refuges or wilderness areas with active fire programs.

Eventually, the prototype might prove useful for evaluating fuel management schemes for areas with extensive fuelbreak systems, especially where prescribed fire is the preferred treatment for reducing fuel hazards between fuelbreak segments. In such landscapes, fuelbreak system layout would need to be included as a GIS theme, including dates for construction and maintenance, for incorporation into the cost-effectiveness analysis.

Pending successful outcomes of phase 2, a transfer workshop or conference may be planned for disseminating results from our efforts. Other potential products include non-technical user guides for the simulator and several scientific publications.

Objective: Revise and update program RXCOST

Efforts are currently underway to update the RXCOST program, using fire records archived since construction of the original program. Efforts to date have involved data retrieval, preliminary analysis, and contemplation of the 'look and feel' of the revised system. We anticipate that the revised systems will distinguish between proposed and actual costs while featuring several different screens than the original version.

So far, we have collected all the data needed for RXCOST. We were able to collect not only project requests but also the matching actual project costs. Additional guidance will be required from NPS-NIFC regarding the impact of the new roving crews (modules) on individual fire costs. To date, we have been unable to collect the cost per field area of these roving crews.

Some preliminary regression analysis has been completed. We have not yet identified all variables and relationships impacting expected project costs. Primary impacts do appear to remain the same as previously found: acres treated, NFDRS fuel model treatment/project type, field area. The regression analysis should be finished by mid-February.

Management Implications

This project will improve the ability of DOI managers to implement cost effective prescribed fire programs, based on foundations established on previous projects, including Phase 1 of the current project. We anticipate that managers will gain improved perspectives for assessing impacts large scale prescribed fire programs, including reductions in suppression costs but also incorporating nonmarketed values and smoke impacts.

The cost-effectiveness frontier generated by the simulator enables managers to select the most effective size of the prescribed fire program subject to the available budget, as well as assessing tradeoffs between different budgetary levels. Transforming simulator inputs and outputs can assess additional tradeoffs. The improved processor also will allow agencies to be more accountable and responsive to mandates contained in GPRA.

Conclusions

Phase 2 of this project will considerably enhance decision-making capabilities for assessing DOI prescribed fire programs. Although we feel we are on the right track, progress to date has been impeded with the departure of the part-time graduate research assistant prior to summer, 1998. This situation should improve with the anticipated hire of a full-time Research Associate during January 1999.

Although this project will improve decision-making capabilities, substantial work remains in terms of assessing and evaluating DOI prescribed fire programs. A spatially-explicit tool for assessing the benefits and costs of large scale fuel treatments is an ambitious undertaking that will require periodic refinements and updates, especially in response to technological improvements and changing policy environments. Our prototype represents a first attempt aimed at incorporating economic criteria in such a tool. As such, the estimates are admittedly crude for projected burned area, suppression cost savings, or other derived estimates for emissions and impacts on values-at-risk (including nonmarket resources). Managers will be able to rely on the prototype for guidance but not leadership in making cost-effective decisions.

Areas of Future Research

The current prototype's focus on smoke emissions may require additional refinement. Smoke impacts per incident may be more important than the total emissions currently under consideration. A single episode that "smokes in" a local community may nullify years of successful prescribed burning projects in an area.

Prototype application to other DOI units will require consideration of the unique features and values at risk in each study area. Perhaps more important will be the extent to which fuels have been treated in the area. Areas in which fire has been excluded for decades will require a different perspective than areas in which fire has been restored in recent years.

Our analyses in Phase 1 and currently under refinement in Phase 2 will assist managers in justifying a cost-effective prescribed fire management program subject to alternative budgetary constraints. However, the optimal budget level for a management unit or DOI bureau is another issue that is determined elsewhere.

Additional refinements that might be contemplated in the future include extension to areas where treatments other than prescribed fire are contemplated. For example, the analysis system might be used in areas possessing an installed fuelbreak network, with fuelbreak segments serving as anchors for rotational applications of large scale prescribed fire. Alternatively, the system might be modified to facilitate comparisons between prescribed fire and mechanical thinning alternatives.

Once fire has been successfully restored in an area, additional prototype refinements might facilitate establishment of seasonally adjusted goals for prescribed fire maintenance treatments. For example, the size of annual prescribed fire treatments might need to be adjusted depending on climatic influences, fire danger variations, and area burned by wild and prescribed fires to date.

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3.5 - Other

- **Natural Resource Inventory -** No Natural Resource Inventory (NRI) plots were sampled during 1997 because no plots were burned during 1996. A few plots may be sampled during 1998 that were burned during 1997 in the Redwood Segment (segment #4). The NRI project has been carried out by staff of the Biological Resources Division of the USGS (formerly NBS). Their objectives have been to establish or revisit permanent inventory plots within the East Fork drainage. The general purpose of the NRI plots is to provide a systematic, plot-based inventory for detecting and describing the distribution of vascular plants, vertebrate animals, and soils throughout the Sequoia and Kings Canyon National Parks. Within the East Fork, the plots document the preburn floristic composition and structure of vegetation. Since 1995, 18 plots have been established as part of the MKRRP (**Fig. 3.13-1**). These supplement 32 plots that already existed in the watershed. Plots that burned during 1995 have been revisited during 1996 (seven of nine were relocated) to assess burn impacts and first year postburn vegetation responses. An effort was made to also sample locations falling within the little known, dense chaparral vegetation of the East Fork.

- **Bark-Foraging Bird Species -** Todd Dennis (graduate student University of Virginia) conducted research that focused on understanding possible mechanisms that may limit bird species distributions (his emphasis is on the bark-foraging guild - some 14 species of woodpeckers, nuthatches, etc. inhabit the west slope of the Sierra Nevada). Over 600 foraging behavior plots were sampled along with some 450 descriptive vegetation plots during 1996 and 1997. Much of his field sampling was undertaken within the East Fork watershed and has included the examination of species within a number of recent burns in the drainage. He found a number of bark-foraging species to prefer these recent burned areas: northern flicker, white-headed woodpecker, hairy woodpecker, Williamson's sapsucker, and black-backed woodpecker. The latter species was only observed in recent burns which appear to be critical habitat for its presence. His data suggests that fire creates more habitat diversity, allowing better foraging opportunities and nesting locations. Sampling through 1997 is described in the 1997 MKRRP Annual Report (Caprio 1997). No further updates on the work carried out in 1997/1998 are available.

4. Acknowledgments

Assistance in the tedious task of compiling and checking of the report was provided by Jeff Manley. I would also like to thank everyone who contributed individual project sections for this report or helped in some other capacity by providing information or assistance during the last year.