4) Project Year 1999

4.1) Vegetation

4.11) Mineral King Landscape Assessment (MKLA)

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1999 field crew: *Kurt Menning, Will Hopkins, Bob Fahey, Allison Tokunaga, and Rob York.*

Tony Caprio, John Battles and *Nate Stephenson* also assisted in the field during the first days of formulating the sugar pine mortality study.

Project objectives and background

As in many western forests, the suppression of wildfires over the last century has altered forests in Mineral King. It is believed that the lack of fire directly has 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. Many park managers and scientists believe we should restore these forests to within a range of historic conditions at the same time catastrophic fire risks are reduced. To examine the effects of restoring forests with the direct application of 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 first, what historic forests were like when these forests were experiencing more frequent fire; second, how these forests have changed up to the present with the suppression of fire; and third, 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 (see figure below). Historic data are necessary to establish a baseline from the past to present and to act as targets for restoration through prescribed burning. Current conditions 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

- 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,

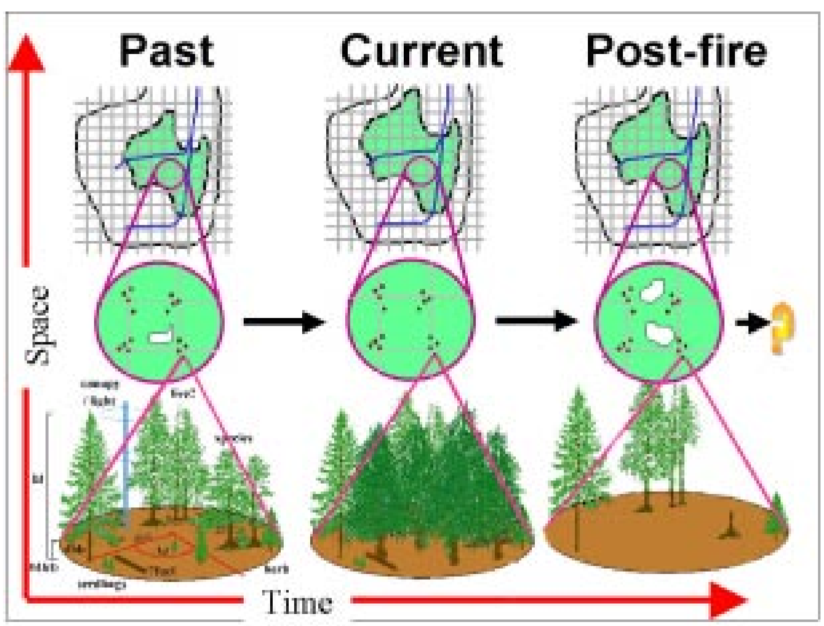
- When and where prescribed fire can be used as a restoration tool

In 1996 and 1997, over two hundred forest plots were established throughout the watershed. We hoped to inventory plots directly before the reintroduction of fire and immediately after. Unfortunately for this particular study, the schedule of burning has not matched the schedule of inventory. Over the last three years only nine plots out of 209 have 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 landscape-level effects of re-introducing fire. We are hoping that this summer we may add 10 to 24 plots to the "burned" category after the Winter 1999-2000 burns.

Due to the small spatial extent of burning in the mixed conifer portion of the watershed, we have turned our short-term attention to a more robust examination of the current (pre-fire) conditions in the area. These analyses are described below.

Project Methods

Data on current conditions have been collected both within forests using an extensive forest inventory approach, and from the air in 1997, using aerial photography. 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. These are located precisely using a precision global positioning system (GPS) unit. Within each plot, relatively complete inventories have already been completed: trees were identified by species, measured and mapped; fuel conditions have been recorded; brush and plant cover were described; slope and aspect have been recorded; and light penetrating through the forest canopy was measured.

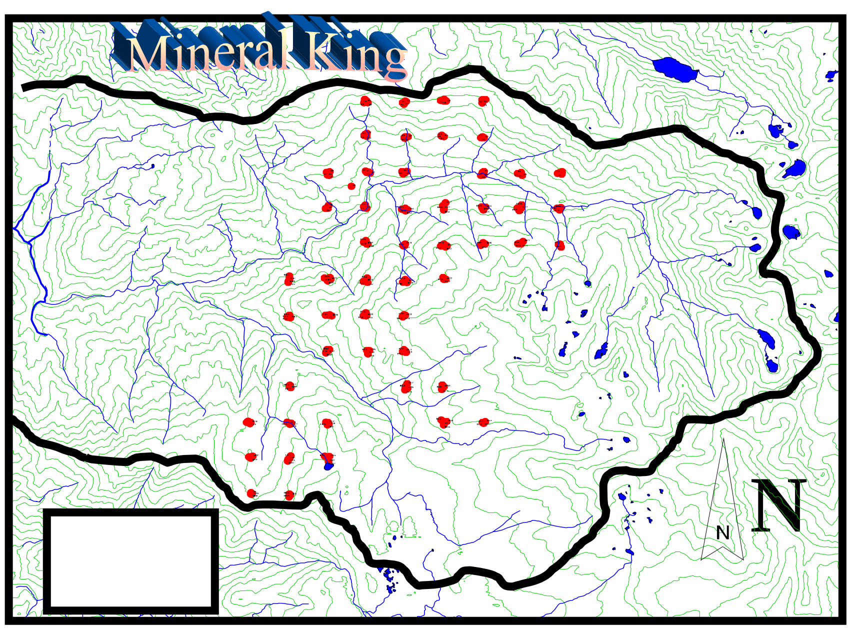


Collection of the remote imagery data involved a more elaborate process. High resolution, digital photographs were collected during an over-flight in the summer of 1997. The digital photographs, with a resolution of about one meter, are actually four simultaneous pictures in different bands of light—blue, 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. Unfortunately, Digital Orthorectified Quadrangle (DOQ) maps were not immediately available. When these became available in 1998 they allowed us to begin the orthorectification process.

Fieldwork completed in 1999

In the summer of 1999, despite the lack of burning in the mixed conifer forest in the autumn and winter of 1998, we set out to collect additional data from existing plots. We wished to better understand factors that create forest heterogeneity throughout the watershed. We believe that soil moisture holding capacity, forest canopy architecture[1], relative decomposition rates and other factors contributing to microclimatic variation between sites could be very important factors in affecting the variability in mixed conifer structure and composition. This variability, in turn, could greatly affect both the way in which fire burns through the forest and the patterns of severity that result.

In two and a half months, we revisited 160 of the plots previously established to collect these data. The only area with many plots we did not revisit was the Cahoon Creek watershed due to logistical constraints and heavy field equipment. *Soil depths* up to 1m deep were determined using a tile probe and slide hammer at three sites in each plot. Previous data on soil depth using hand-pushed rods had proved to be too dependent on the measurer to be reliable. *Hemispherical photographs* of the canopy of each plot were taken from these same three known points. In addition to the hemispherical photographs taken for the MKLA project, Will Hopkins took additional photos in the white fir-red fir interface zone to support his master's thesis study on factors affecting regeneration and species composition in this zone.[2] *Forest litter samples*—twigs, needles, cones and bark flakes—were collected from inside each plot for a study on bulk density of litter. In order to study the rates of ground fuel (litter and duff) *decomposition rates* we strung wooden popsicle sticks on fishing line and hid these beneath the litter layer. These will be recollected in several years if they survive or avoid fire.



In addition, we began a new piece of research on sugar pine (*Pinus lambertiana*) mortality. This study was designed in reaction to the views of many managers and scientists who believe that re-introducing fire directly can lead to increased mortality of large pines. During fieldwork in Mineral King we had observed another trend that complicated the argument that burning around

[1] Using hemispherical crown photographs of each plot to create a permanent record of canopy architecture at each site. These photos provide an excellent baseline for examining changes caused by fire.
[2] In John Battles' Forest Community Ecology Laboratory, University of California, Berkeley.

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 tree 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 competition from fire suppression.

We selectively cored and geo-referenced large living and dead sugar pines. Our goal is 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.

Our attempts to collect cores were somewhat complicated by the rate at which the outside layers of sugar pines decay. Attaining good cores was difficult and our sample size was relatively small. We hope to be able to cross-date these cores this spring.

Current status of MKLA research

Hemispherical photography

Analysis of the hemispherical photos is divided between two different projects. First, hemispherical photographs support the MKLA assessment of forest structure, especially forest canopies. We anticipate that these data also will be very helpful in our efforts to understand the water and energy balance in the watershed that is affecting forest structural development. The soil depth measurements taken will provide additional support for these analyses. These photos, approximately 400 in number, still are being scanned and processed using hemispherical light interpretation software; results are not yet available.

Second, Will Hopkins is examining light conditions within the permanent MKLA plots using a different series of hemispherical photographs. For this analysis we measured saplings of white fir and red fir (0.2 – 2.2 m height) to determine relative growth rate, an index for overall growth performance. The saplings were categorized as growing under a white fir dominated canopy, a red fir dominated canopy, or a mixed red fir – white fir ecotone canopy. We hypothesized that growth rates across the ecotone and between species would conform to the plant strategy theory of interspecific competition. Specifically, white fir, the lower elevation species, is presumably a better competitor than red fir on the higher quality sites, while red fir is presumably the better tolerator and able to out tolerate white fir in the harsh conditions of the upper elevation sites. Consequently, we would expect the white fir to perform better in the white fir zone than in the ecotone and for red fir to perform better in the ecotone than in the red fir zone.

After controlling for neighborhood level variations in light regime (a light index calculated from fisheye photos), basal area (existing MKLA data), and near neighbor density (using data from the MKLA seedling and sapling counts) we found growth rate patterns that conform to expectations. White fir growth rates decreased from 4.3% in the white fir zone to 3.7% in the red fir zone while red fir growth rates decreased from 3.1% in the ecotone to 2.9% in the red fir zone. The zone was a significant predictor ($p<0.05$) of growth rate in an Analysis of Covariance that included the above-mentioned independent variables.

Dominant Species	Density g/cm^3	n	sd
Oak	0.062	2	0.023
Sequoia/ cedar	0.084	14	0.027
White fir	0.091	57	0.030
Pine	0.10	14	0.043
Red fir	0.11	30	0.055

Litter Density Analyses

Litter bulk density analyses, while still underway, already have provided interesting results. Historically, the mixed conifer forest was regularly disturbed by frequent, low-severity fires with ground and surface fuels as important vectors of fire spread. The canopy species diversity in this forest should result in a similarly variable litter base. Our earlier studies of forest structure and fire history in the area revealed that topographic factors are important determinants of both forest structure and fire history patterns. However, the specific link between variability in forest composition and in fire regimes has not been identified.

To address one possible explanation we examined the density of the forest litter mat to determine if the dominant canopy species would affect litter density and could thereby help regulate fire behavior. Dense litter mats, for example, retain more moisture and have low air flow, resulting in slow fire spread. We sorted our mixed conifer plots into those dominated by red fir (*Abies magnifica*), white fir (*A. concolor*), sequoia or incense-cedar (*Sequoiadendron giganteum* and *Calocedrus decurrens*), and pine species (*Pinus ponderosa*, *P. jeffreyi*, *P. monticola*, *P. contorta*). Red fir litter was the densest at 0.11 g/cm^3 (n = 30), followed by pine (0.10 g/cm^3, n = 14), white fir (0.09 g/cm^3, n =57), and least dense, sequoia and cedar (0.084 g/cm^3, n = 14). Significant differences in litter density were observed between red fir and white fir ($p = 0.005$), and between red fir and sequoia/cedar ($p = 0.003$). The high density of pine litter in comparison to white fir litter was unexpected. We had anticipated that pine litter, composed largely of long needles, would have the lowest density. Red fir had the highest variability (by coefficient of variation) in litter density, which may be an important result for explaining patchy fire behavior in that vegetation type.

In order to determine whether these differences in bulk litter density could play important roles in fire behavior we ran a Rothermel fire behavior model to determine rates of spread and intensity with all other factors held constant.[3] The results were striking. The rate of spread in white fir, with the measured bulk densities, would be more than double that in areas dominated by red fir. The fire-line intensity would be more than five times as great.

[3] Basic assumptions included no slope, 10 mph wind, 25% fuel moisture content, a particle density of 30 lb/ft^3, and fuel depth 0.2ft.

While these results complement the analyses presented last year on forest structure and fuels distributions they are not yet complete. Some additional resorting and processing needs to be completed before these numbers are final.

Species	**Spread rate** (ft/min)	**Intensity** (BTU/ft^2*min)
Sequoia/ cedar	0.544	17.6
White fir	0.368	7.56
Pine	0.249	3.19
Red fir	0.169	1.33

Remote sensing

Currently, remote image processing and analysis is underway on the digital multi-spectral imagery collected in the summer of 1997. A case study is being developed to link, in a small geographic area, the imagery with its embedded information on canopy structure, with the ground data provided by the field plots. We expect to expand this analysis throughout the mixed conifer zone in the watershed. With over 700 images to be processed from 1997 and more than 400 from 1996 there will be many repetitions of the same basic processing. We have hired an assistant to work 10-20 hours a week on image processing.

Summer 2000 and beyond

In winter 1999-2000, prescribed fire may have burned as many as 24 plots in the MKLA study area. Our best estimate at this time is that fire reached 16 plots. We plan to revisit and re-inventory these plots to detect changes due to fire. To accomplish this we plan to spend two to three weeks in Mineral King collecting data this summer.

Within the next year, we also plan to begin analyzing historic data. The qualities of different kinds of historic data vary. Data on the *spatial* arrangement of trees within stands, for example, are quite limited.[4] In contrast, most sources probably do have some information on forest *composition* and *structure*. Fire histories dating back centuries are available and quite reliable for many slopes, elevations and aspects in the watershed.

At the landscape level, far fewer data exist. Aerial photographs prior to 1954 have not yet been located (NPS and Stephenson, personal communication). Even if earlier photos are not available, these 1954 photographs, when compared with current imagery, should provide almost fifty-year trends in mosaic pattern, gap size, and encroachment. A second source of landscape level data is historic landscape photographs taken from the ground. Many of these landscape photographs, which date from the turn of the century, are archived at Sequoia National Park headquarters. These photographs should be useful in showing large-extent landscape patterns of presence and extent of forest patches.

With the exception of the evaluation of the historical data, most of these analyses will be completed in the next year by the conclusion of Kurt Menning's dissertation.

[4] Bonnicksen and Stone present a limited analysis of spatial in-stand tree data but these have been described as underestimating forest conditions (Stephenson, personal communication).

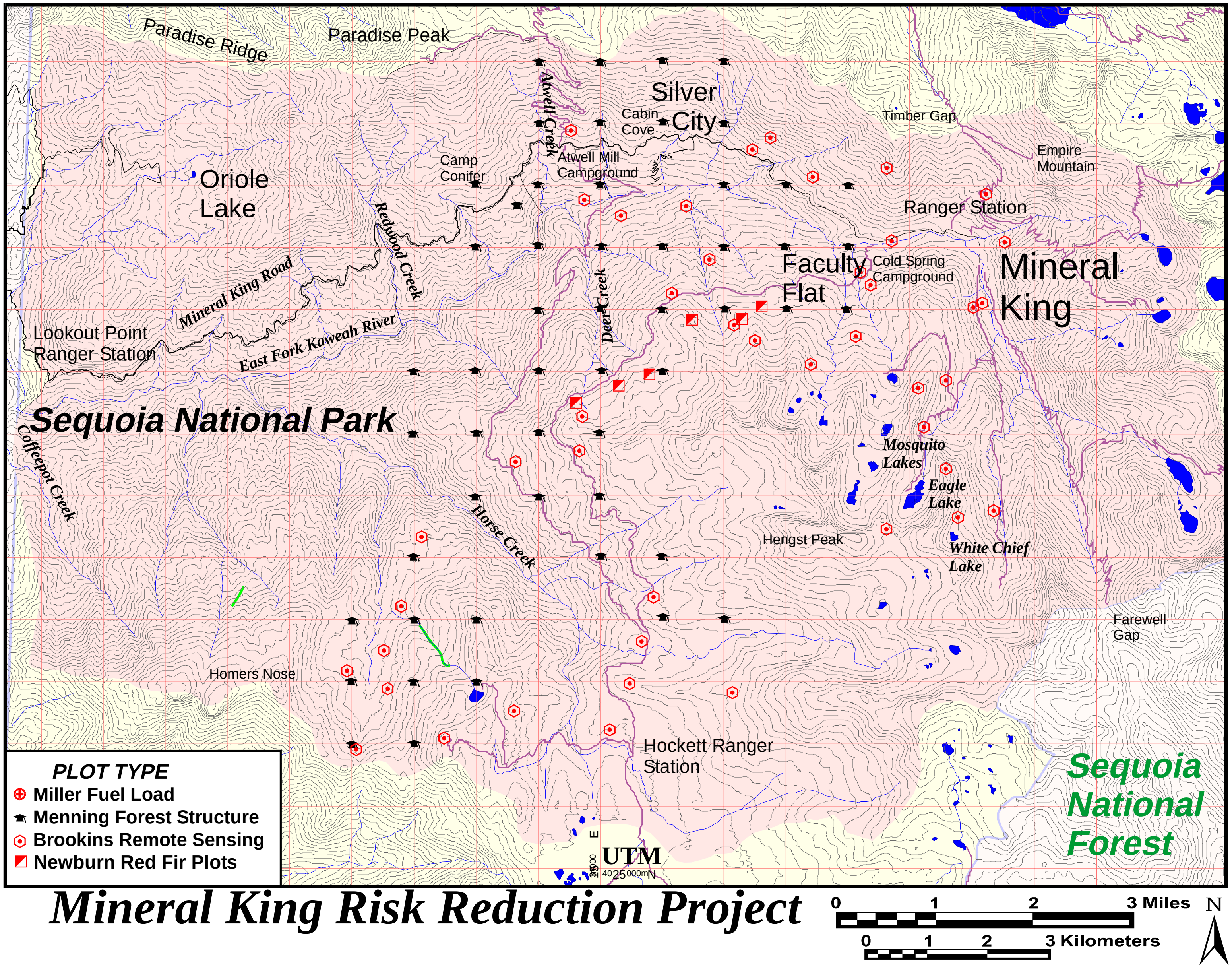


Figure 4.11-1. Location of plots by graduate students in the East Fork drainage.