3.15) Red Fir Regeneration and Fire

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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 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. 3.15-1** and **Fig. 3.15-2**). 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.

RATIONALE AND SIGNIFICANCE

Red fir forest dynamics are still poorly understood and any additional knowledge will be beneficial for both applied and theoretical reasons. Fire suppression over the last 100 years in most Western states has increased fuel load and stand densities, resulting in forests more susceptible to insect and disease outbreaks and catastrophic fires (Parsons and Debenedetti 1979). Restoration of fire within forested ecosystems has become an increasingly important tool for land managers. However, many questions remain unanswered regarding the regeneration processes that result in the presence of fire events.

Ecological studies in forested ecosystems, such as red fir forests, that experience fires with moderate frequency (mean fire return interval 25-100 yrs) and high variation of intensity are lacking compared to ecosystems with infrequent high-severity fires (Heinselman 1981) or frequent low-severity fires (Kilgore 1981). Furthermore, patch dynamic models have experienced limited success since models have frequently imposed artificial boundaries to multiple species systems which tend to follow gradients between patches rather than clearly demarcated borders. The red fir forest are dominated by one species (95-99 %) and the intense clumping of smaller-sized trees reduces these two errors and thus lends itself to testing many of the theoretical ideas of patch dynamics.

Applied applications for the study results will also have benefits for forest management being carried on outside the park. On non-park lands, timber harvesting has been treated as a surrogate for fire in creating canopy gaps. The proposed study will determine the natural range of gap sizes and help to determine optimal cutting units for harvesting operations on these lands. This is important since regeneration was delayed by more than a decade in clearcuts, presumably due to high moisture stress on seedlings in open areas (Gordon 1970).

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..

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

Study Site

The study is being conducted at Sequoia National Park in the Mineral King watershed. This study takes advantage of the concurrent Mineral King Risk Reduction Project (MKRRP) with its associated ecological research relating to fire history, fire behavior modeling, fire effects monitoring of vegetation, and fuel load. MKRRP is one of the first landscape-scale prescribed burn projects within Park Service units and has outlined a plan to burn 10,000 to 20,000 ha over the next five years.

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. Five plots were established during 1997 (**Fig. 3.11-6** and **Table 3.15-1**)

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

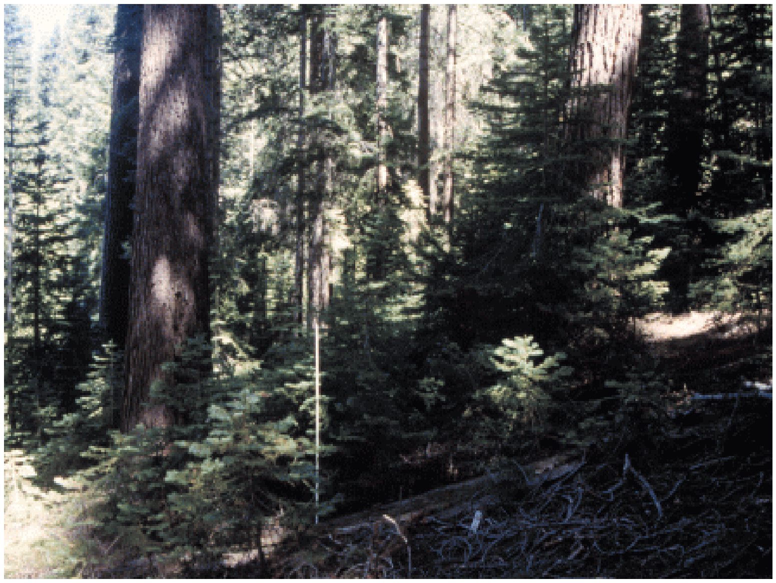

Figure 3.15-1. Preburn view of red fir plot 3.

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

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 other data sources were also made available by the Sequoia National Park, Resources Management Division and the USGS/National Biological Service. The Global Change Vegetation Monitoring project has four one-hectare red fir plots, located in Yosemite and Sequoia National Parks, which have stem maps for all trees taller than breast height. Several mapped plots of red fir surveyed in 1978 within the Mineral King study area will provide information on fire history and help to calculate a dbh versus crown area regression curve (Pitcher 1987).

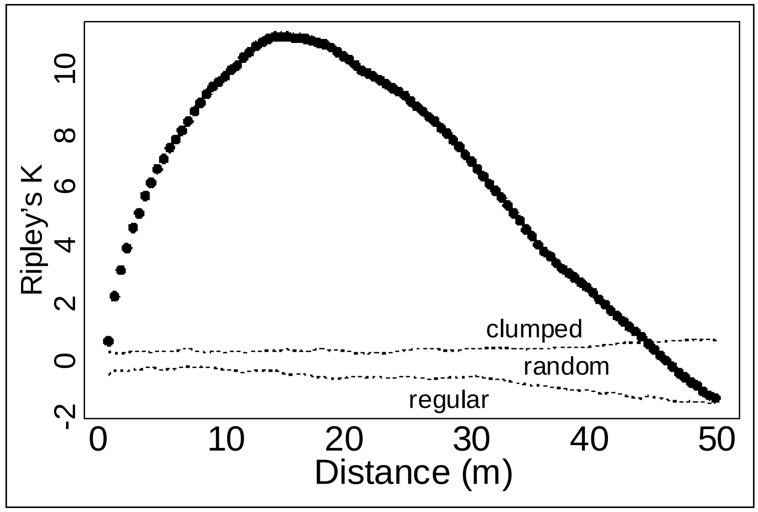

Figure 3.15-3. Clumping pattern at 10-40 m scale from Ripley's K statistic which tests observed data (red fir saplings) for deviation from complete spatial randomness.

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

Plot	UTM East	UTM North
1	352500	4033700
2	351700	4032900
3	350600	4032500
4	351300	4032800
5	353300	4033700

Table 3.15-1. UTM coordinates of plots.

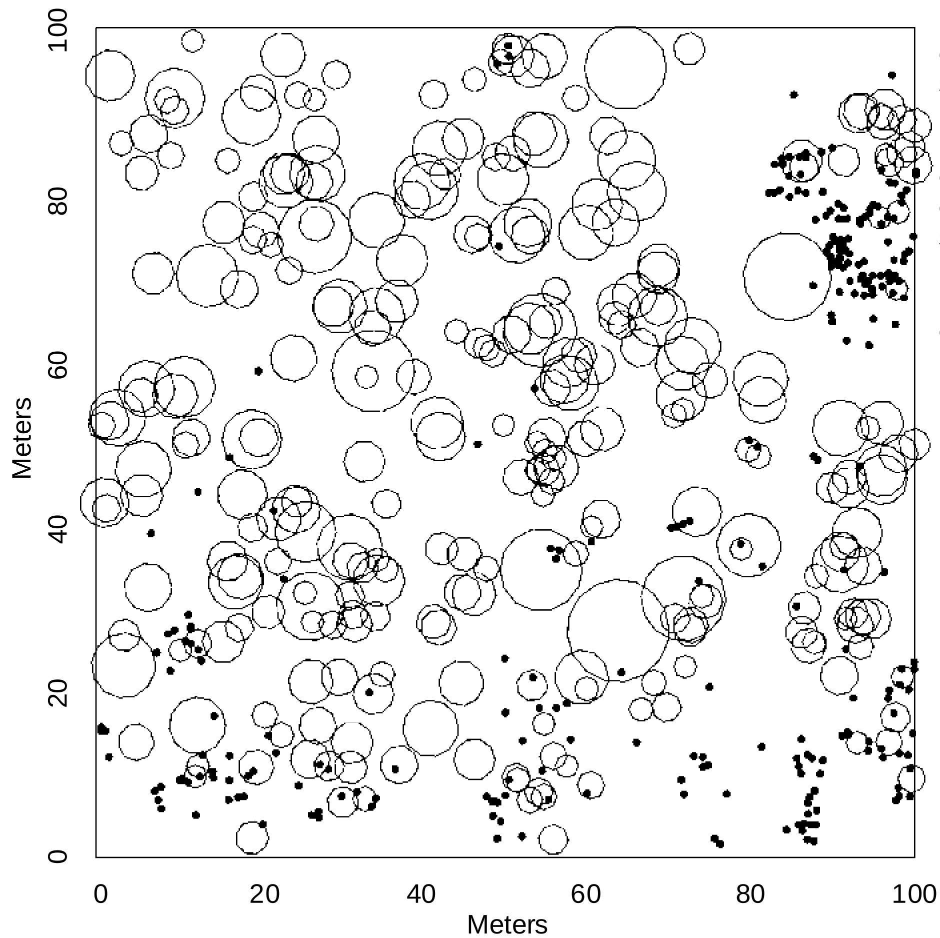

Figure 3.15-4. Spatial clumping of red fir seedlings at Panther Gap. Open circles show locations of the canopies of large overstory trees and small solid dots show locations of saplings (data from BRD global change plot).

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.

EXTREMELY PRELIMINARY RESULTS

Spatial clumped patterning were detected in smaller-sized (0-10 cm dbh) red fir trees using Ripley's K statistic ($p< 10^{-6}$)(**Fig. 3.15-3**). The size of red fir regeneration patches was 10 m to 40 m, roughly the size of one to several canopy tree crowns. The distribution of smaller-sized (0-10 cm) trees appears to be associated with canopy openings, but quantitative measures have not been applied to date (**Fig. 3.15-4**).

Fuel measurements between patch (gap) areas and random fuel plots in non-patch (understory) areas differed significantly (**Fig. 3.15-5**). The amount of fine fuels in non-patch fuel transects (0-1/4", ¼-1", and 1-3" size classes) are roughly doubled when compared to patch fuel transects. Heavy fuel levels in the sound category are approximately 50% greater in non-patch areas whereas rotten heavy fuels are roughly even under both conditions. Furthermore, average duff depth was 60% greater in non-patch areas versus patch areas.

Moisture levels were compared for both branchlets and duff samples (**Table 3.15-2**). The six

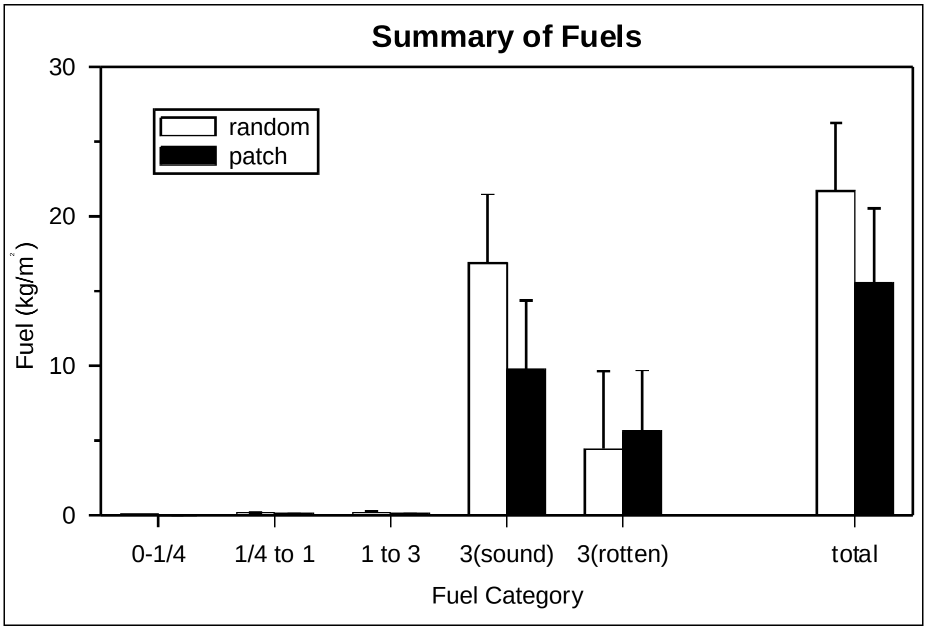

Figure 3.15-5. Comparison of fuel loads between patch areas (areas with high sapling densities) and random non-patch areas.

treatments include the combinations of size (seedling vs. sapling) and density (very sparse, sparse, dense).

While differences between some treatments were statistically significant (t-test), the slight variation in moisture levels probably do not have large implications for higher survival rates of regenerating trees in different size classes or density.

DISCUSSION

Detailed understanding of the role regeneration patches in red fir forest dynamics requires the results from post-fire analysis. Nevertheless, the preliminary results have been promising by demonstrating that the majority of red fir regeneration is found in patches associated with canopy gaps. The patch areas have lower fuel conditions since canopy gaps containing patches have fewer canopy trees contributing to fuel buildup. Post-fire analysis will show whether lower fuel conditions in patches can contribute to their increased survival rates after fire events and may indicate their relative importance in forming later successional seres.

Table 3.15-2. Moisture content of red fir branchlets and ground surface duff during August 1997 at three density levels and two height levels.

Density	Dense		Sparse		Understory	
Size	Sap	Seed	Sap	Seed	Sap	Seed
Branchlets						
Moisture %	61.3	62.2	60.0	64.7	61.3	61.7
S.D.	3.2	5.1	1.9	1.9	2.1	1.6
Duff						
Moisture %	11.5	9.4	9.1	9.0	10.7	9.4
S.D.	1.8	1.9	1.7	2.1	1.8	1.7