Post-fire Regeneration of Riparian Vegetation in the Duncan Creek Watershed

Sara Hanna

Abstract Wildfires are an important factor in forested ecosystems as they have the potential to alter the composition and structure of the forest. Most of the studies conducted thus far in the Sierra Nevada have focused on how fire affects the mixed-conifer forest, failing to address what impact the fire has on riparian vegetation. The objectives of this study were to determine how wildfires' effects on riparian vegetation and regeneration are related to the distribution of vegetation along a gradient up from the water table, with particular attention to the sprouting responses of various hardwood species. *Ceanothus* ssp. and *Quercu*s ssp. showed the greatest regeneration potential, followed by *Salix* ssp., *Cornus* ssp., and *Alnus* ssp. By measuring vegetation along various terraces and slopes, observations were made as to the relationship between regeneration and proximity to the stream and water table. Plants that were closer to the water table had more shoot resprouting than those further away. There was no correlation between the fire severity in an area and the percentage of plants that were resprouting. However, hardwoods growing in areas of higher fire severity showed more reproductive success in the form of shoot sprouting. The information obtained from this study can be useful in determining whether or not fire should be excluded from riparian zones. Management decisions concerning riparian zones are exceedingly important as they have an impact on stream water quality.

Introduction

California's mixed-conifer forests contain heavy fuel loads and an unhealthy forest composition, resulting from the first establishment of national parks in the Sierra Nevada in 1890 which encouraged fire exclusion from forested lands (Parsons and van Wagtendonk 1996). A policy of fire suppression was due in part to the public opinion that all wildland fires were harmful (Biswell 1989). Almost one century later, the negative view towards fires shifted as resource management professionals started to understand how fires play an integral role in forest composition (Leopold et al. 1963). This shift in opinion has resulted in a new era of prescribed burning in national parks and forests to simulate natural fire processes that have been excluded from these areas for years. Although research has been conducted on how fires affect mixed-conifer forests, there have been very few studies on how fires affect riparian vegetation. One study conducted by W.H. Russell (2001) found that a fire's importance as a determining factor on forest composition reduces as it approaches the riparian region. L.M. Ellis (2001) observed that although fire frequency and severity have increased in riparian vegetation in the southwestern United States in the past few years, the role fire plays in riparian ecosystems is not clearly understood.

Forested water catchment areas are extremely important, as they are the headwaters for the river systems from which we get our water. Therefore, understanding how riparian zones function is vital, including how they respond to disturbances such as fire. Previous studies have shown that aquatic ecosystems are at risk of damage after a large fire event (USFS 2002). When riparian forests burn, the result is increased solar radiation which elevates stream temperatures. Additionally, there is an increase in surface erosion and gullies during heavy storm events for the following few years, due to the existence of fire-induced water repellency (DeBano 1981). All of these aforementioned changes resulting from fire have an effect on the quality of the water. Despite the several studies based on stream ecosystem responses to fire (Rinne 1996, Minshall et al. 1997, Gerla et al 1998, Minshall et al. 2001), there are very few studies focusing specifically on how fires affect riparian vegetation.

When studying post-fire effects on riparian vegetation, it is important to ascertain how vegetative composition changed in response to the fire, including which plants had greater mortality after burning and which plants had greater regeneration. Different species of plants have different post-fire reproductive strategies. For example, hardwoods sprout after they are burned, either from the stem or from the root, with reproductive success varying from species to species (Gom 1999). Vegetative responses also vary with fire severity and intensity. The amount of organic debris present before the fire effects the fire severity, indicating that heavy pre-fire fuel loads result in fires of higher severity (Ellis 2001). Often fires will burn in patches as they approach riparian areas. This patchy effect is characterized by areas with high-intensity canopy fires, less intense surface fires, and unburned areas; and results from differing vegetative cover, slope, soil, and other factors (Minshall et al. 1989). It is therefore important to look at the system as a whole including various plant species, vegetation density, slopes of riparian zones, fire severity, and location of the species in relation to surface water.

Study Site This study took place in a section of the Duncan Creek watershed in the Tahoe National Forest. Data was collected on the creek and three of its tributaries. The study site was located next to French Meadows Reservoir, approximately 20 miles northeast of Foresthill, CA. The average elevation of the creeks studied was 5,300 feet.

The vegetation type surrounding the study site is mixed-conifer forest, characterized by several defining species including *Abies concolor* (white fir), *Calocedrus decurrens* (incense-cedar), *Pseudotsuga menziesii* (Douglas fir), *Pinus jeffreyi* (Jeffrey pine), *Pinus lambertiana* (sugar pine), *Pinus ponderosa* (ponderosa pine), and *Quercus kelloggii* (black oak), while the riparian species bordering the creek and its tributaries was comprised mostly of *Alnus incana* (mountain allder), *Alnus rhombifolia* (white alder), *Arctostaphylos* ssp. (manzanita), *Ceanothus* ssp. (California-lilac), *Cornus nuttallii* (mountain dogwood), *Cornus sericea* (red osier), *Populus balsamifera* (black cottonwood), *Quercus* ssp. (oaks), and *Salix* ssp.(willows),

The Star Fire originated on August 25, 2001 and was contained on September 13, 2001. This fire burned almost 17,500 acres in the Tahoe and El Dorado National Forests. Riparian areas that burned include the Middle Fork American River and its tributaries, including Duncan Canyon Creek. Within the above-mentioned 17,500 acres, 4,309 acres are within the Duncan Canyon Inventoried Roadless Area. The burned areas contained old-growth forest which provided prime habitat for spotted owls and goshawks, as well as many perennial and ephemeral streambeds bordered by riparian zones. The fire burned through the area's characteristically steep canyons which had heavy fuel loads with extremely low fuel moisture levels. Burning of the riparian areas varied in severity, and each of these severities was sampled in this study.

Figure 1: Map of the Star Fire (El Dorado and Tahoe National Forests, USFS 2001)

This study examined post-fire responses of riparian vegetation along Duncan Creek and its tributaries in the Tahoe National Forest, one year after the Star Fire occurred. The questions addressed in this study include the following:

1. Will plants growing closer to the water table have a higher likelihood of resprouting than those growing further away?
2. Will certain species have better resprouting success than others?
3. Will a higher fire severity result in less resprouting of the total vegetation?
4. Will the length of the riparian zone have an effect on the fire severity?

Developing an understanding of how fires affect these specific riparian zones is essential for creating future management and policy initiatives pertaining to prescribed burning and fire suppression in riparian zones.

Methods

This study took place in June 2002, almost one year after the Star Fire ignition on August 25, 2001. Data was collected in the Tahoe National Forest, along burned and unburned sections of Duncan Creek and three of its tributaries. Thirty quadrats were measured, 15 on Duncan Creek and 15 on the tributaries, each located at 30 meter intervals. The quadrats were 10 feet in width and extended upslope from the stream edge to a few feet beyond the boundary of the riparian zone. This boundary determination assured that the variability in the size of the riparian zone was captured. Riparian zone boundaries were determined visually, based on the occurrence of characteristic riparian vegetation species and indications of floodplain terraces. Descriptions of surrounding vegetation were used to analyze potential seed sources for regeneration on the riparian quadrats. Analysis of the fire's effects on vegetation did not include non-riparian segments of the quadrats.

The lengths of the gravel bars, escarpments, and terraces were measured from the creek edges to the end of the quadrat. Riparian profile features, such as gravel bars, terraces and their escarpments, and slopes, were measured for length and elevation above the water surface. Slopes were measured using a compass clinometer and heights of steps between terraces were measured using a standard measuring tape.

The quadrats were mapped on 10 to the inch graph paper to illustrate the boundary between the riparian and non-riparian vegetation, the extent of the burn zone, the location of all burned vegetation and new seedlings, and the boundaries of the various topographic positions (Kobziar, L.N. and J.R. McBride, in review). All vegetation was recorded and identified using Trees and Shrubs of California (Stuart and Sawyer 2001); unidentified species were brought back to the lab for further identification. Sprouting was recorded as either basal or stem. Species that occur in clumps were mapped as one plant.

Burn characteristics were estimated for each transect individually. A subjective evaluation of the degree of damage to vegetation within the quadrat was used, including the amount of charring on standing trees and shrubs, evidence of crown fire, or the level of surface litter combustion (Wells, 1979). Fire severity was defined as the degree to which a quadrat is altered by the fire (McPherson et al., 1990) and was categorized as: 0) no fire in riparian zone, 1) low-severity understory fire, 2) understory fire with areas of high-severity, 3) spotty crown fire, mixed severity understory burn, and 4) crown fire, mixed-severity understory burn. Patterns of charring were observed in the quadrats and across the creeks in order to determine the direction and extent of the fire.

Results

A total of 30 quadrats was recorded, 15 on Duncan Creek and 15 on its tributaries. Every identifiable plant on each transect was recorded and categorized as to its reproductive success. Certain species showed signs of resprouting while others had survived the fire but not shown visible signs of regeneration. Ceanothus ssp. and Quercus ssp. showed the most regeneration with 100% and 80% of the plants resprouting respectively. 66% of the Ceanothus resprouted from its roots while 33% of resprouting occurred from the shoots. In the Quercus ssp., all of the resprouting observed occurred from the roots. The other species that showed resprouting were Salix ssp., Cornus ssp., and Alnus ssp. which showed 19%, 26%, and 5% resprouting respectively. These results are graphed in Figure 2.

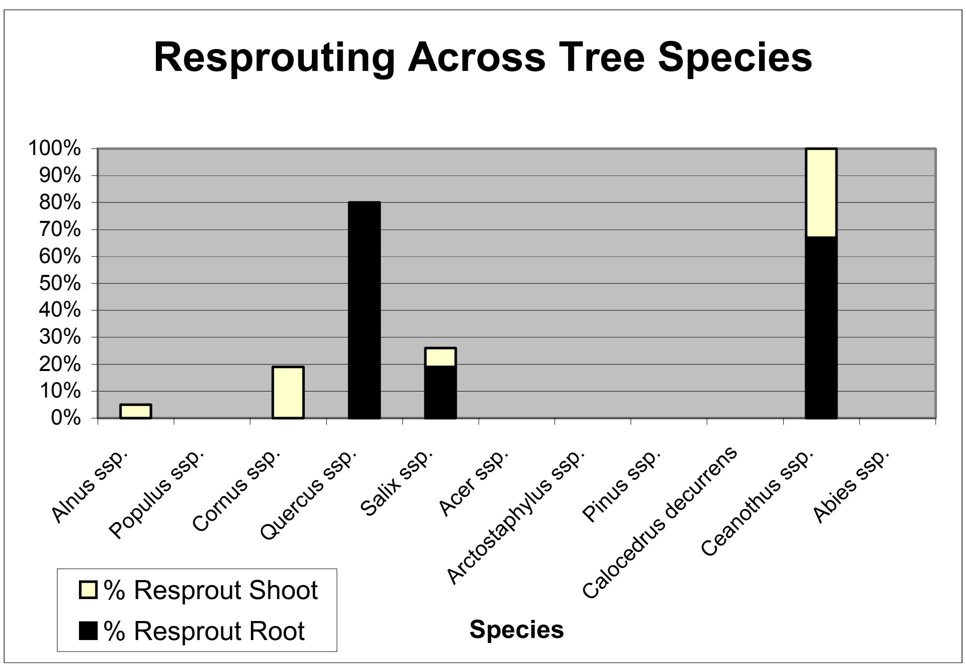

Figure 2: Species vs. the percent resprouting of the total individuals recorded from that species. Black indicates resprouting from the roots while white indicates resprouting from the shoots.

In addition to species composition, data was collected to observe a correlation between resprouting success and distance from the water's edge. Plants were assigned a number based on their reproductive success. 0 = no resprouting, 1 = resprouting from the roots, 2 = resprouting from the shoots. Shoot resprouting was more common in plants closer to the water's edge, while root resprouting was more evenly distributed throughout the quadrats. Figure 3 shows the results from this data.

Figure 3: Distance from the water table vs. resprouting.

Fire severity was measured on each quadrat according to the procedures outlined by McPherson et al. (1990). The range of severity was 0 to 4, 0 indicating no fire present on the quadrat and 4 indicating the most severely burned areas. Data on fire severity was analyzed against the percentage of resprouting plants on each quadrat and is graphed in Figure 4 below. Only quadrats with resprouting are included in the graph. The data indicates that there is no strong correlation between the fire severity and the percentage of plants that resprout (p-value = 0.654459).

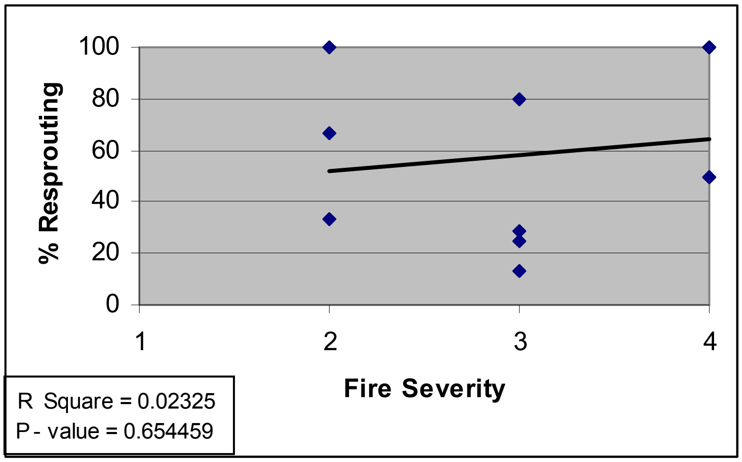

Figure 4: Graph of Fire Severity vs. Percent Resprouting

The width of each plot was standardized to 10 feet, while the length of each plot varied and was determined by how long the riparian zone was on that segment of the creek. The riparian zone was determined by characteristic riparian vegetation and topography. These lengths were recorded and analyzed with the fire severity information to observe a linear correlation between the length of the riparian zone and the severity of the fire in that area. The data was analyzed using linear regression and presented in Figure 5.

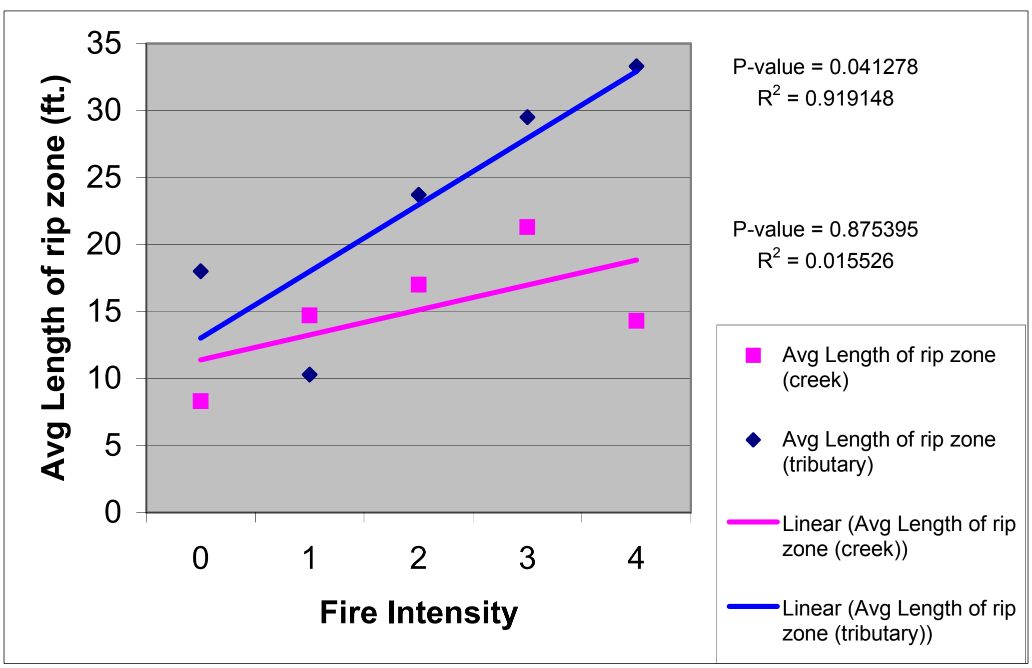

Figure 5: Fire Severity as determined by the length of the riparian zone.

The results from the data show that there is a significant correlation (p-value = 0.04) between the fire intensity and the length of the riparian zone for the tributaries studied, while the relationship between fire intensity and length of the riparian zone for the creek is not significant (p-value = 0.87).

There was so obvious correlation found between fire intensity and conifer seedling regeneration. Analysis of seedling production is of little importance in the areas studied because of the extremely high temperatures caused by the fire which resulted in hydrophobic soil. Most of the seedlings produced in the year following the fire will not survive due to lack of water.

Discussion

One year after the Star Fire, the riparian vegetation in the area was showing various regeneration responses. Five genera – Ceanothus ssp., Quercus ssp., Salix ssp., Cornus ssp., and Alnus ssp. – were already showing resprouting only one year after the fire occurred.

A positive correlation existed between the distance from the water table and the shoot resprouting of various species. This would suggest that plants with access to an underground water source are able to regenerate with more success than those further away from an underground water source. This data support the results obtained by Kobziar, L.N. and J. R. McBride (in review) which indicated that the closer a plant is to the water table, the higher the potential for regeneration after a fire event. Additionally, the data from this study supports the observation recorded by Russell, W.H. and J.R. McBride (2000) that the importance of fire as a determining influence on forest composition declines in proximity to the riparian zone.

An unexpected correlation was observed between the fire severity in an area and the percentage of plants resprouting. Ellis (2000) observed that the sprouting of native shrubs was higher at the sites with the lowest fire severity. However, the data collected in this study indicates that more resprouting occurred in areas with higher fire severity. This inconsistency could be partially explained by observer bias due to the ease of observing resprouting in burned areas as compared to densely vegetated unburned areas.

Another unexpected observation was the relationship between fire severity and the length of the riparian zone. The finding from Russell, W.H. and J.R. McBride (2000) that a fire's importance decreases as it reaches the riparian zone supports the assumption that the larger the riparian zone, the less severe the fire would be. However, the data collected suggests exactly the opposite. The average length of the riparian zone increases as fire severity increases. This data is difficult to explain and does not correspond well with the other data collected in this study. However, in areas where the forest is artificially thinned, either through prescribed burned or mechanical thinning methods, the riparian zones are denser and thus contain more fuel which could explain higher fire severities.

There were several limitations to this study that impacted the accuracy of the results. The absence of pre-fire data on the areas surveyed made it virtually impossible to compare pre- and post-fire vegetation composition in the riparian zones. Additionally, in the most severely burnt sites, plant identification was difficult and thus many plants were not included in the analyses because they could not be accurately identified. Lengths of riparian zones were determined using characteristic riparian vegetation and the presence of an upland slope, indicating greater distance to the water table making that area unsuitable for riparian vegetation. This length determination may contain some observer bias as the upland slope and the second terrace were often interchangeable.

In terms of experimental design and feasibility of replicating this experiment, it is important to realize that burned sites are not replicable. Due to the erratic nature of wildfires, the number of plants exposed to different levels of fire severity are not equal (Ellis 2000). However, the results obtained from this study do provide site-specific conclusions about how riparian vegetation responds to wildfire in the Duncan Creek Watershed. Future studies in this area should look at the composition of the riparian stands 5, 10, and 20 years after the fire and should be more comprehensive in geographic scope. Certain plant species may take more time to reproduce and thus conclusions on the post-fire composition of riparian vegetation cannot be made with data collected only one year after the fire.

Acknowledgements

I would like to thank Karen Jones from the Foresthill Ranger Station for helping me locate a study site. Collecting data was made easier by the hospitality of the French Meadows Reservoir foresters who allowed us to stay in their barracks. Professor Joe Mc Bride helped design the experimental procedure. Matt Orr and John Latto helped me narrow down a topic and were supportive throughout the whole process. Special thanks go to Karl for his help with various computer problems and to my brother John who spent long days collecting data with me last summer.

References

Biswell, H. H. 1989. Prescribed Burning in California Wildlands Vegetation Management. University of California Press. California.

DeBano, L.F. 1981. Water repellent soils: A state-of-the-art, USDA Forest Service General Technical Report PSW-46.

Ellis, L.M. 2001. Short-term response of woody plants to fire in a Rio Grande riparian forest, Central New Mexico, USA. Biological Conservation. 97(2): 159-170.

Gerla, P.J. and J.M. Galloway. 1998. Water quality of two streams near Yellowstone Park, Wyoming, following the 1988 Clover-Mist wildfire. Environmental Geology (Berlin). 36(1-2): 127-136.

Gom, L.A. 1999. Fire induces clonal sprouting of riparian cottonwoods. Canadian Journal of Botany. 77(11): 1604-1616.

Leopold, A.S., S.A. Cain, C.M. Cottam, J.M. Gabrielson, and T.L. Kimball. 1963. Wildlife management in national parks. American Forests. 69:32-35, 61-63.

Minshall, G.W., Brock, J.T., and J.D. Varley. 1989. Wildfires and Yellowstone's Stream Ecosystems: A temporal perspective shows that aquatic recovery parallels forest succession. BioScience. 39(10): 707-715.

Minshall, G.W., Robinson, C.T., and D.E. Lawrence. 1997. Postfire responses of lotic ecosystems in Yellowstone National Park, U.S.A. Canadian Journal Fisheries Aquatic Sciences. 54: 2509-2525.

Minshall, G.W., Royer, T.V., and C.T. Robinson. 2001. Response of the Cache Creek macroinvetebrates during the first ten years following disturbance by the 1998 Yellowstone wildfires. Canadian Journal Fisheries Aquatic Sciences. 58: 1077-1088.

Parsons, D.J. and J.W. van Wagtendonk. 1996. Fire research and management in the Sierra Nevada National Parks. Science and Ecosystem Management in the National Parks. University of Arizona Press, Tuscon, Arizona.

Rinne, J.N. 1996. Short-term effects of wildfires on fisheries and aquatic macroinvertebrates in the southwestern United States. North American Journal of Fisheries Management. 16(3): 653-658.

Russell, W.H. and J.R. McBride. 2001. The relative importance of fire and watercourse proximity in determining stand composition in mixed conifer riparian forests. Forest Ecology and Management. 150 (3): 259-265.

United States Forest Service. Regions 1 and 4 National Fire Plan: Defining the Effects of Stand-replacing Wildfire on Stream Ecosystems. http://www.fs.fed.us/r1/nfp/research/project4.shtml (2001)