Randy Wilson, September 10, 2013

Please find a draft of the Moonlight Fire Restoration Strategy, the document that will help direct how the Forest Service will spend the fire restoration funds. It is a large document, so I'll suggest where to focus:

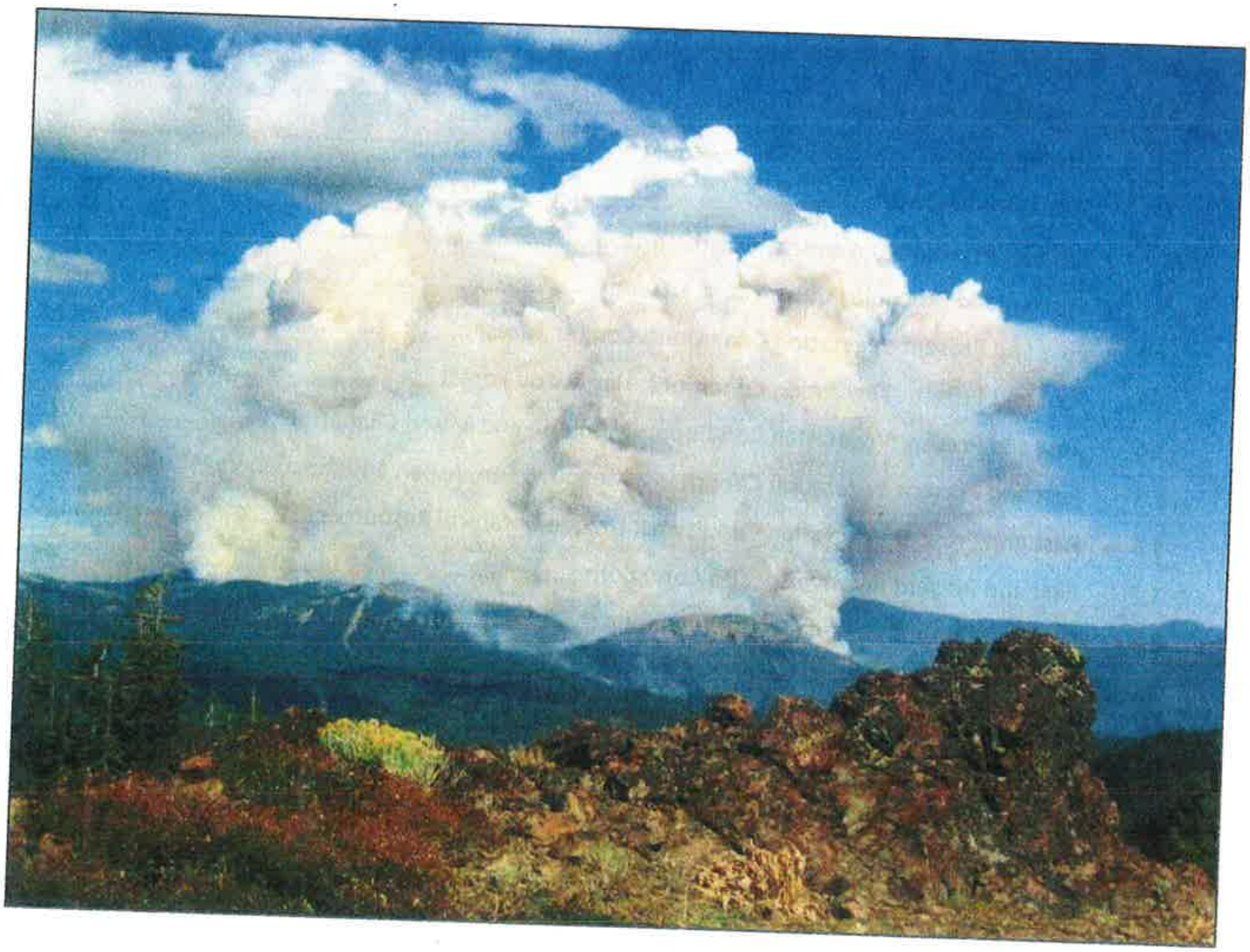
- Sections 1-4 is describe background conditions.
- Sections 5 and 6 provide an idea of what the goals and objectives are for each resource, with some suggested project types. This is a good place to look, by discipline, for what type of restoration is being proposed.
- Appendix A is a proposed summary of projects for Fiscal Year 2014, based on sections 5 & 6.

This is a draft document that will still receive edits. Your comments are welcome, though we are on a tight timeline. Our regional office will not allow us to expend additional funds until this plan is approved. If we could hear from you by September 13th, that would be idea. Your comments are welcome at any time, however.

Thanks,

Mike Donald

Moonlight Fire Restoration Strategy



USDA Forest Service
Plumas National Forest

Version 1.0
September 9, 2013

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LOCATION MAP

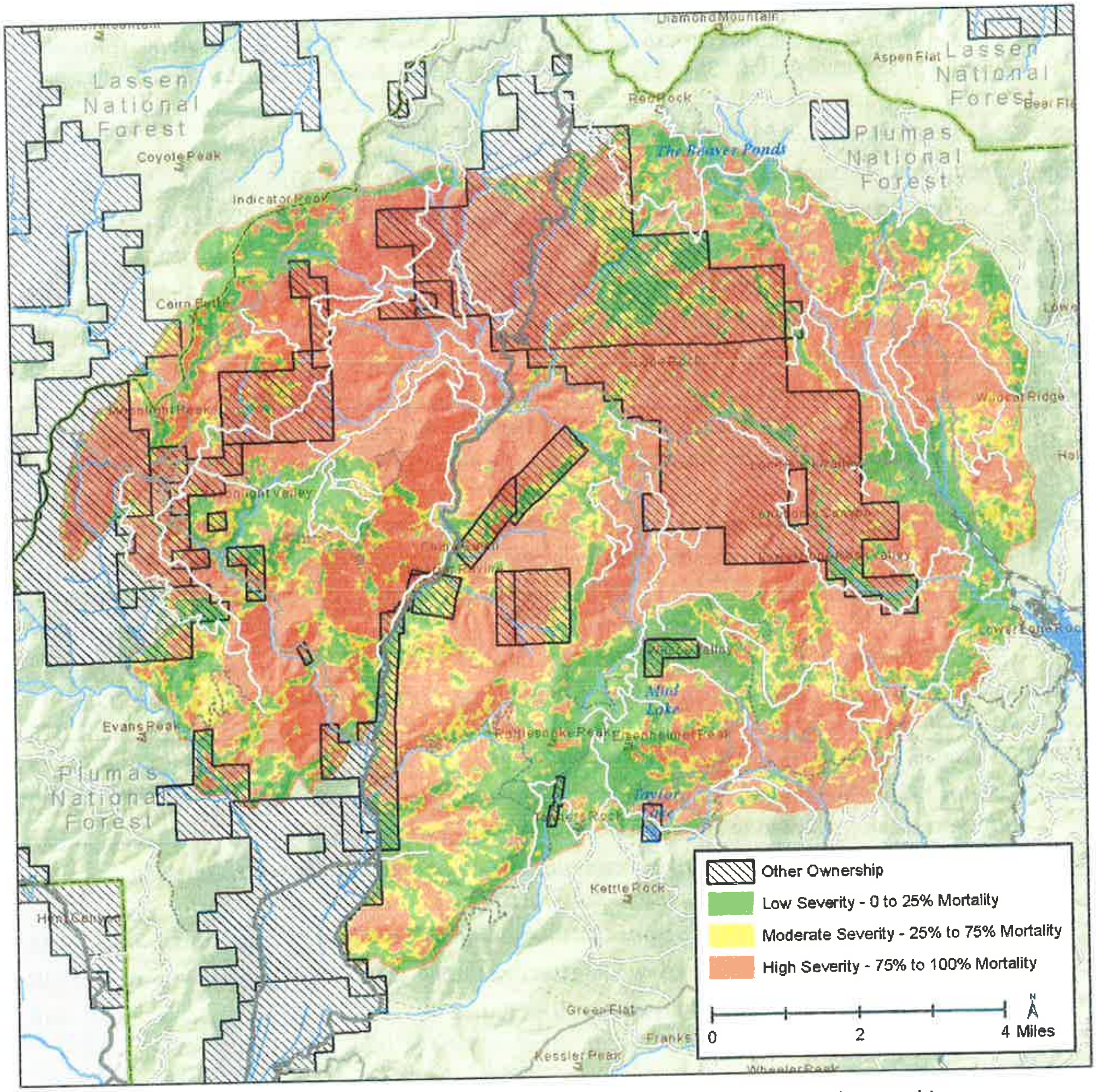


Figure 1. Map of the 2007 Moonlight Fire showing burn severity and land ownership.

1.0 Introduction

The Moonlight Fire ignited on September 3, 2007 in the northeastern portion of the Plumas National Forest (NF), just east of the main crest of the Sierra Nevada (Figure 2). Before it was contained on September 15, 2007 the fire burned approximately 65,000 acres of Sierra mixed conifer and true fir forest, hardwood stands, shrublands, meadows, and riparian areas; it also impacted roads, trails, cultural sites, rangeland infrastructure, and recreation sites. The watersheds affected by the Moonlight Fire, which range in elevation from 3,520 feet in Indian Valley to 7,820 feet at Kettle Rock, are drained by two main perennial streams, Lights Creek and Indian Creek; both eventually flow into the East Branch of the North Fork of the Feather River, an important water source for California.

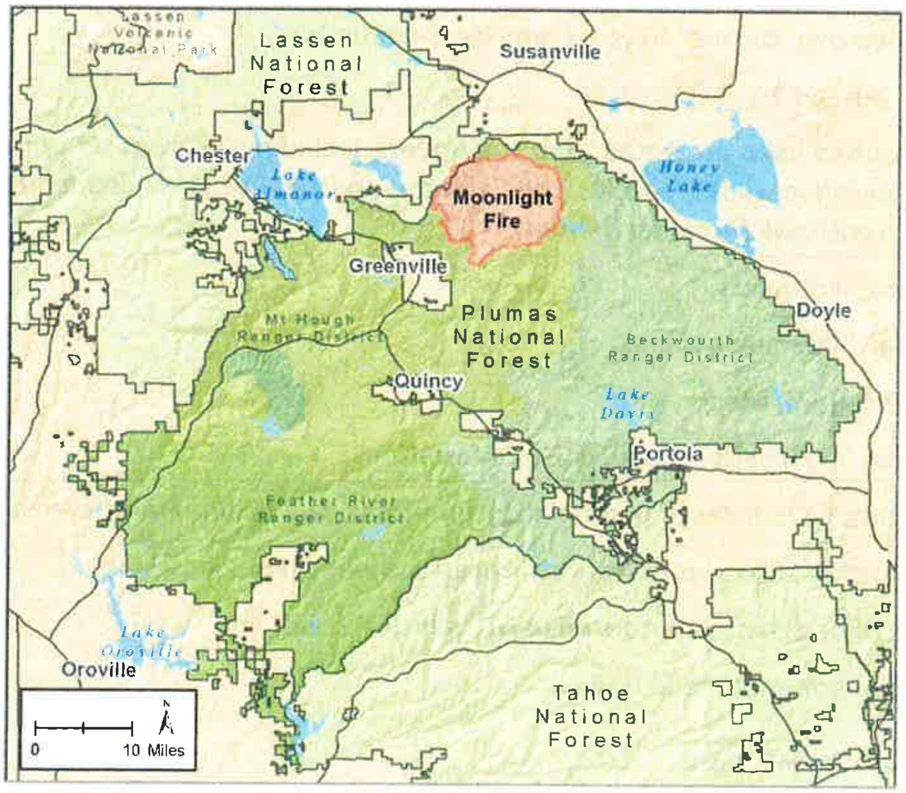


Figure 2. General vicinity map showing the location of the 2007 Moonlight Fire.

The Moonlight Fire burned through a mosaic of land ownerships, which included approximately 45,514 acres on the Plumas NF and 562 acres on the Lassen NF; it also burned large parcels of private timber land in the northeastern part of the fire and up to the Wildland Urban Interface (WUI) surrounding Indian Valley (Table 1, Figure 1). The Moonlight Fire burned over 80 percent of the Mud Lake Research Natural Area (RNA), which was established to maintain the rare fire-adapted conifer, Baker cypress (*Hesperocyparis bakeri*). The Antelope Lake Recreation Area, a popular destination for forest visitors, is situated directly adjacent to and east of the fire perimeter.

Table 1. Ownership of lands burned in the 2007 Moonlight Fire.

Land ownership	Approximate acreage	Percentage of total area burned
Plumas NF (Mt Hough Ranger District)	45,514	70%
Mud Lake Research Natural Area	*300*	
Lassen NF (Eagle Lake Ranger District)	562	1%
Private	18,920	29%

Prior to the fire, the Moonlight area landscape encompassed:

- previously treated areas, such as hazardous fuel reduction zones, plantations established over the last 40 years, and clear-cut units;
- recently burned areas (Figure 3)
- areas that had been protected from treatments, including 25 areas set aside as habitat for two sensitive wildlife species, the California spotted owl (*Strix occidentalis*) and Northern goshawk (*Accipiter gentilis*);
- six grazing allotments;
- more than 500 mining claims;
- over 100 cultural sites;
- more than 300 invasive plant species infestations;
- an estimated 475 miles of perennial, intermittent, and ephemeral streams;
- approximately 160 miles of National Forest System (NFS) roads;
- 25 miles of designated motorized (4WD vehicles) trails; and
- 18 miles of non-motorized trails.

1.1 Landscape Condition

The landscape burned by the Moonlight Fire was historically a mosaic of yellow pine forest, Sierra mixed conifer stands, true fir forest, oak woodlands, shrublands, meadows, aspen stands, and riparian corridors. Prior to European American settlement of the area in the mid-1800s, vegetation patterns and successional stages were created and maintained by historic disturbance processes, such as fire, insect and disease outbreaks, and drought. Historic fire regimes varied in response to topography and vegetation type, but were generally characterized by frequent, low to moderate intensity fires. Larger fires exhibited spatial heterogeneity in both fire intensity and patch size (Skinner and Chang 1996).

By the time the Moonlight Fire occurred in 2007, the effects of over a century of management were evident on the landscape. Past timber harvest activities, fire suppression, mining, and historic livestock grazing created areas with dense forest stands dominated by shade-tolerant species, large accumulations of fuels, degraded meadows and riparian areas, and invasive species. Heavy fuel loads and dense forest conditions, combined with high wind speeds, dry conditions, and steep terrain, increased both the size and severity of the Moonlight Fire (Daley et al. 2008). By the time it was contained, the Moonlight Fire burned almost 38,000 acres at high severity, or 58 percent of the fire area (Figure 1, Table 2). Patches of high severity in the Moonlight Fire were uncharacteristically large compared to most historic fires, with many patches exceeding 2,500 acres (Collins and Stephens 2012). Riparian areas and protected activity centers (PACs) for spotted owl had some of the greatest percentage of high severity fire effects of any area within the fire perimeter, probably as a result of the lack of fuel treatments in these areas (Dailey et al. 2008, North, Collins, and Stephens 2012). Approximately 16,034 acres (25 percent) experienced low severity fire or were left unburned (Table 2).

Table 2. Acres and percentage of vegetation burn severity within the 2007 Moonlight Fire; calculated from the USDA Rapid Assessment of Vegetation Condition after Wildfire (RAVG) data

Severity	Definition	Acres	Percentage
Unburned	0% basal area mortality	6,206	10%
Low	0% < basal area mortality < 25%	9,828	15%
Moderate	25% ≤ basal area mortality < 75%	10,969	17%
High	basal area mortality ≥ 75%	37,970	58%

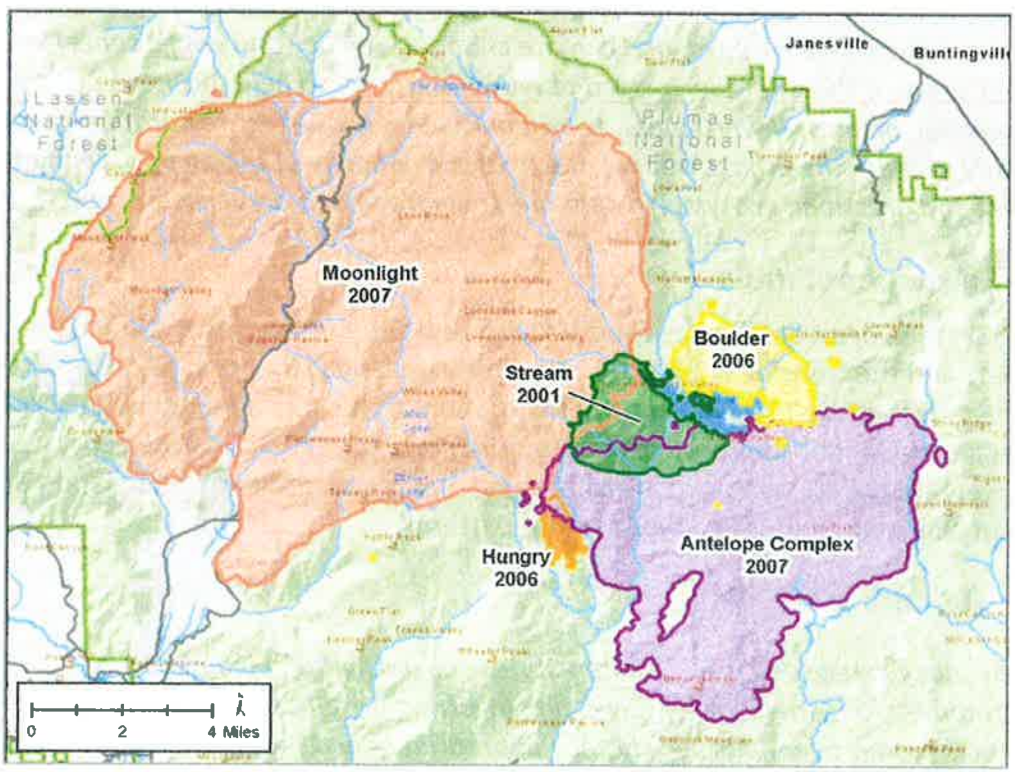


Figure 3. Large recent fires adjacent to and overlapping the 2007 Moonlight Fire

2.0 Restoration Strategy Framework

2.1 Ecological Restoration: Guiding Principles

Ecological restoration is defined by the Forest Service as:

> *"The process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed. Restoration focuses on establishing the composition, structure, pattern, and ecological processes necessary to make terrestrial and aquatic ecosystems sustainable, resilient, and healthy under current and future conditions" (Day et al. 2006, USDA 2013).*

In the Pacific Southwest Region, as stated in the Ecological Restoration Regional Leadership Intent (USDA 2011a), the Forest Service's fundamental goal is to "retain and restore ecological resilience of the National Forest lands to achieve sustainable ecosystems that provide a broad range of services to humans and other organisms." According to the Leadership Intent, "from this point forward, ecological restoration will be the central driver of wildland and forest stewardship in the Pacific Southwest Region" (USDA 2011a).

The Forest Service's Ecosystem Restoration Framework (Day et al. 2006) noted that:

> *"The nation's forests and grasslands face serious threats to their long term health, productivity, and diversity. Foremost are non-native invasive species, altered disturbance regimes, and climate change... Agency and public concern about some of these threats has led to (various efforts) to help facilitate restoration actions. Nevertheless, the magnitude of ecosystem restoration needs greatly exceeds the organizational and financial capacity of the agency. Many forest and grassland ecosystems continue to degrade at a preventable rate."*

2.2 Fire Settlement Funds

In July of 2012, the Forest Service received a settlement that included the collective sum of 55 million dollars and the transfer of 22,500 acres of private land (Mueller 2012). Fire settlement funds received by the Forest Service for the restoration of the area affected by the Moonlight Fire provide a unique opportunity to reverse ecosystem degradation, restore ecosystem health and resilience, rehabilitate damaged infrastructure, and prepare the impacted landscape for the effects of changing climates and human use patterns.

According to US Code 16 USC 579c:

> *" Any moneys received by the United States...as a result of a judgment, compromise, or settlement of any claim, involving present or potential damage to lands or improvements...are hereby appropriated and made available until expended to cover the cost to the United States of any improvement, protection, or rehabilitation work on lands under the administration of the Forest Service*

rendered necessary by the action which led to the forfeiture, judgment, compromise, or settlement."

Settlement funds spent under this Restoration Strategy must meet three key criteria from 16 USC 579c. Funds may be used:

1. To conduct improvement, protection, or rehabilitation work,
2. On lands administered by the Forest Service,
3. For purposes rendered necessary by the Moonlight Fire.

2.3 Strategy Goals and Objectives

The purpose of this strategy is to provide a framework for restoration of natural resources, ecological processes, and human values affected by the Moonlight Fire. The overarching goal of restoration in the Moonlight Fire area is to maintain, create, and promote healthy and resilient systems, which may resemble the past, but are also better prepared for changing climates and human use patterns. Specific restoration goals and objectives are provided for individual resources in sections 2.4 and 4.0 of this strategy.

This strategy does not initiate, authorize, or implement any site-specific project activities. All restoration activities that are implemented as a result of this strategy will be designed to protect National Forest resources and will comply with all applicable laws, regulations, and directives.

Restoration work carried out under the Moonlight Fire Restoration Strategy will:

- Assist the recovery of ecosystems that were degraded, damaged or destroyed by the Moonlight Fire;
- Result in more sustainable, resilient, and healthy ecosystems, with a focus on probable future conditions and climates in the restoration area;
- Adopt an interdisciplinary landscape approach to accelerate the scale and pace of ecosystem restoration;
- Engage local communities to increase awareness and understanding of ecological restoration and fire-adapted ecosystems;
- Ensure the strategy and any subsequent proposed actions are linked to the restoration objectives laid out in the Plumas NF Land and Resource Management Plan (USDA 1988a), Sierra Nevada Forest Plan Amendment (USDA 2004), and other amendments;
- Ensure alignment of the strategy and proposed actions with the Forest Service Ecological Restoration Framework, the Region 5 Ecological Restoration Leadership Intent (USDA 2011a), and Forest Service Handbook (FSH) Chapter 2020 (Ecological Restoration, in prep.);

- Utilize current scientific knowledge for landscape restoration, including – where appropriate – information synthesized in PSW-GTR-220, *An Ecosystem Strategy for Mixed Conifer Forests* (North et al. 2009), and PSW-GTR-237, *Managing Sierra Nevada Forests* (North et al. 2012);
- Coordinate with the Lassen NF, which was also affected by the Moonlight Fire, to develop landscape-scale restoration activities;
- Monitor the success of restoration efforts in the Moonlight Fire landscape and adapt the strategy when appropriate.

2.4 Strategy Framework

The following framework was used to develop restoration strategies for resources affected by the Moonlight Fire. First, PAST AND PRESENT CONDITIONS were analyzed for each resource (sections 3.0 and 4.0). The analysis of past and present conditions drew heavily from past planning documents, such as the *Moonlight and Wheeler Fires Recovery and Restoration Project Final Environmental Impact Statement* (USDA 2008); *Diamond Vegetation Management Project Draft Environmental Impact Statement* (USDA 2006a); Moonlight Fire incident reports; Burned Area Emergency Response (BAER) reports; litigation and settlement documents; GIS datasets; and monitoring reports.

For most resources, it was necessary to consider fire impacts in the context of the broader landscape. For example, the impact of the Moonlight Fire on hydrologic resources, wildlife habitat connectivity, recreation opportunities, and forest vegetation extended to an area larger than the fire perimeter. In all of these cases, rationale was provided to make a clear link between the resource, the Moonlight Fire event, and the area analyzed for restoration opportunities.

Second, DESIRED CONDITIONS (sections 5.0 and 6.0) were developed based on: analyses of past and present conditions; Forest Service guidance documents, such as the *Sierra Nevada Framework* (USDA 2004) and the *Plumas National Forest Land and Resource Management Plan* (USDA 1988); and evaluations of historic and reference ecosystems. The discrepancy between current and desired conditions was then used to identify restoration needs and to provide a target for management GOALS AND OBJECTIVES (sections 5.0 and 6.0). Resource-specific goals were developed to provide a general strategy for achieving the desired conditions, whereas objectives were developed to define measurable statements of intent. Whenever possible, restoration projects were identified and described as objectives. Additional restoration projects will be developed as data are gathered and analyzed, resource specialists become more familiar with the Moonlight Fire landscape, management guidance shifts, and conditions on the ground change. In all of these cases, future restoration projects will link to the desired conditions, goals, and objectives provided in this strategy. Specific project proposals for fiscal year 2014 are described in detail in Appendix B.

Finally, MONITORING ACTIVITIES AND OPPORTUNITIES were identified. The purpose of monitoring resources within the Moonlight Fire is to determine if restoration desired conditions, goals, and objectives are being achieved; if they are not being met, managers will use monitoring data to determine the appropriate course of action to restore or maintain conditions. Monitoring data will also be used to evaluate post-fire impacts, establish baseline conditions, and identify changes and trends over time.

3.0 Past and Present Ecological Conditions

3.1 Current and Probable Future Climate Trends

Changes in climate and climate-driven processes present new challenges for long-term restoration of any landscape, including the Moonlight Fire area. Climate models predict that future climates will likely be characterized by shifting weather patterns, increasing mean temperatures, changing precipitation patterns, and increasing incidence of extreme climatic events (Hayhoe et al. 2004, Harris et al. 2006, Safford et al. 2012). Studies of Sierra Nevada ecosystems have also shown that species ranges and ecological processes are already responding to recent climate shifts (e.g. Moritz et al. 2008, Forister et al. 2010, Miller et al. 2009).

This strategy includes discussions of past resource conditions that may provide one target for planning and implementation of restoration projects in the Moonlight Fire area; however it is also important to consider future climatic and biophysical conditions when defining desired conditions, setting restoration goals and objectives, and selecting reference systems. The following section summarizes current and probable future trends in climate and climate-driven processes across the northeastern climate region, which encompasses the area affected by the Moonlight Fire. Climate regions were developed for California by Abatzoglou et al. (2009), with each region encompassing weather stations that experience similar large-scale weather and climate patterns. Much of the following information was taken from a climate change trend summary, prepared by the Regional Ecology Program (Merriam and Safford 2011), which analyzed weather station data and spatial climate grid (Parameter-elevation Regressions on Independent Slopes Model-PRISM) data to identify regional and local climate trends.

3.1.1 Temperature

Across the northeast climate region, there have been significant increases in temperature over the last century, with mean annual temperatures increasing by approximately 1.7 degrees Fahrenheit (Figure 4). This trend is influenced by significant increases in mean minimum (nighttime) and mean maximum (daytime) temperatures. At the local scale, changes in temperature are much more variable, most likely as a result of complex weather patterns driven by topography and geography. This variability is evident in the Moonlight Fire area, where changes in temperature since the 1930s have ranged from negative to positive (Figure 5). Areas where these trends have been negative could provide important future refugia for climate-sensitive species.

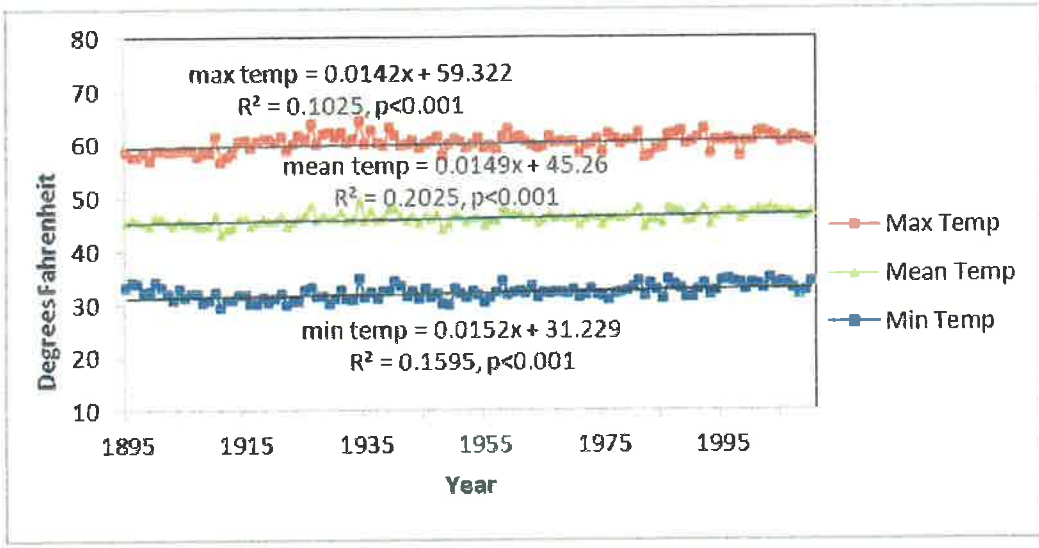


Figure 4. Trends in maximum, mean, and minimum temperatures recorded at weather stations across the northeast climate region between 1895 and 2010. Trend lines fit with simple linear regression, no transformations employed. Data from Western Regional Climate Center (WRCC 2010); figure reproduced from Merriam and Safford (2011).

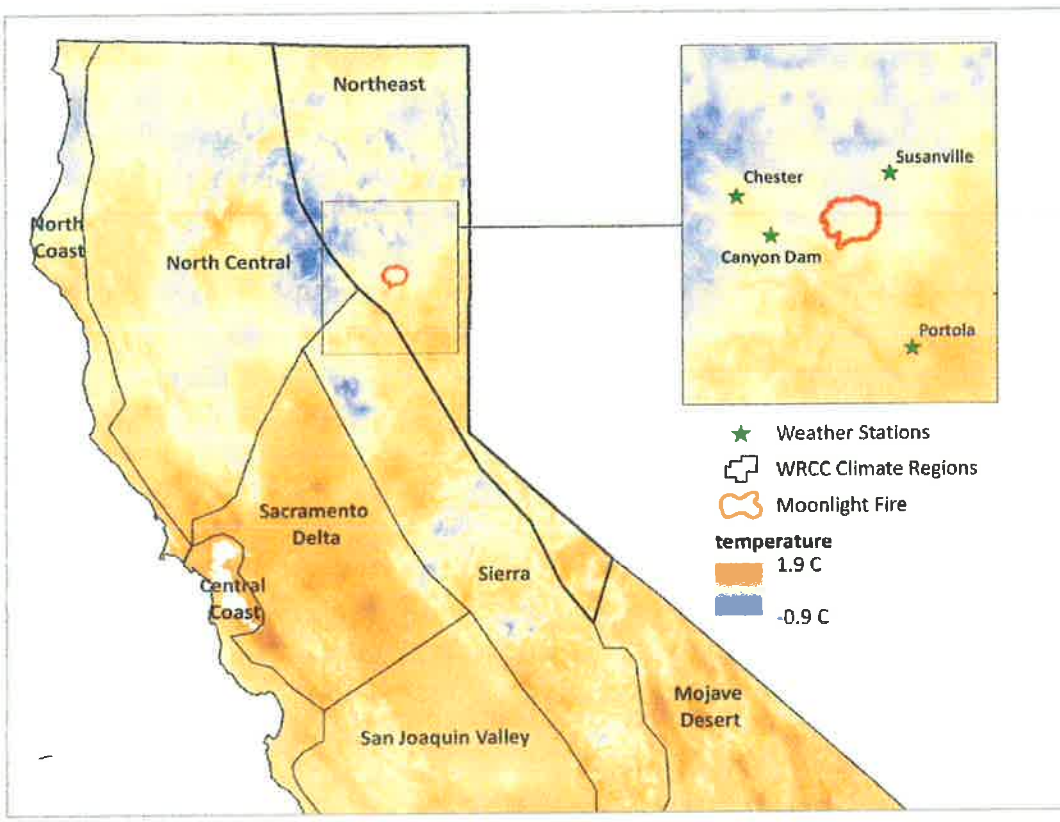


Figure 5. Mean annual temperature change between the 1930's and 2000's in central and northern California,, including the northeast climate region and the Moonlight Fire area, as derived from the PRISM climate model. Blue areas have experienced decreased mean temperatures, orange and red areas have experienced increased mean temperatures.

3.1.2 Precipitation

Regional precipitation trends have varied widely, ranging from negative to positive, even between neighboring weather stations (WRCC 2010). As a result, there has been no significant change in precipitation across the northeast climate region over the past century (Merriam and Safford 2011). The Moonlight Fire area shows similar variability in precipitation trends; however the PRISM models and data from local weather stations also suggest a general pattern of increasing precipitation in the western portion of the fire and decreasing precipitation in the eastern portion of the fire (Figure 6). Of the five weather stations evaluated in the northeast climate region, the Susanville weather station, located northwest of the Moonlight Fire, was the only station to report a significant trend in precipitation. Total annual rainfall at the Susanville station has decreased by almost nine inches since 1893 (Figure 7).

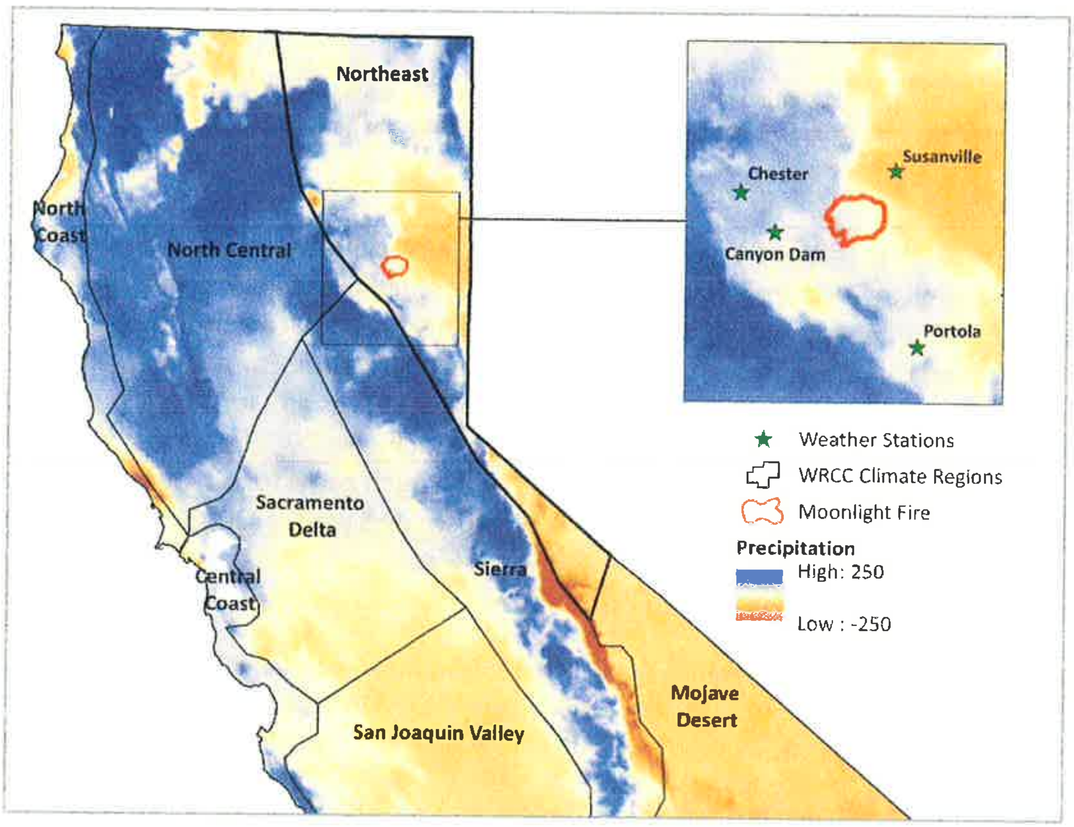


Figure 6. Mean annual precipitation change between the 1930's and 2000's for the Moonlight Fire, as derived from the PRISM climate model. Blue areas have experienced increased precipitation, orange and red areas have experienced decreased precipitation.

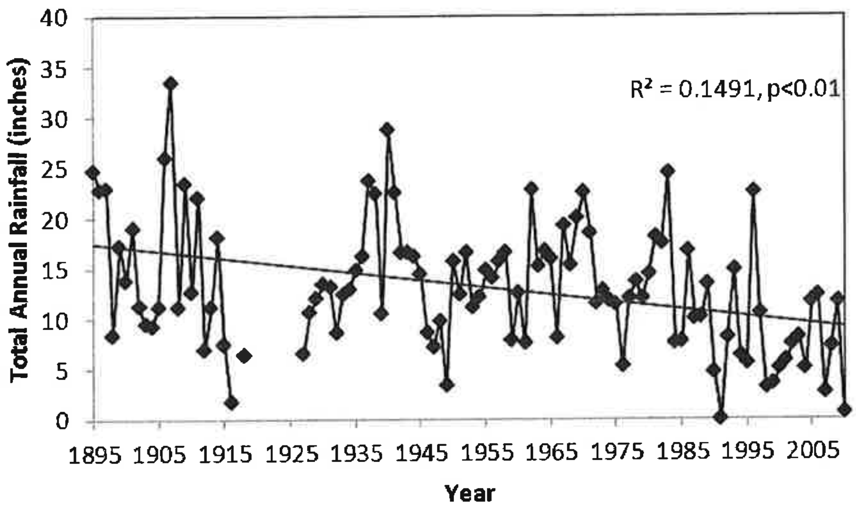


Figure 7. Total annual rainfall has significantly declined at the Susanville station, 1893-2010. Trend lines fit with simple linear regression. Data from WRCC (2010); figure from Merriam and Safford (2011).

3.1.3 Snowfall

Four of the five weather stations evaluated in the northeast climate region, including the two closest to the Moonlight Fire area, have documented significant declines in snowfall over the past century (Table 3). At several of the stations, the relationship between snowfall and year is much stronger than that observed for temperature or precipitation. For example, at the Susanville station over 40 percent of the variation in snowfall was a result of year and total annual snowfall declined from 66 inches in 1894 to four inches in 2009 (Merriam et al 2012). At the regional scale, spring snowpack has decreased by as much as 70 to 120 percent across most of the northern Sierra Nevada (Safford et al. 2012). Moser and others (2005) also reported decreases in early spring (April 1) snowpack and snow-water equivalents between 1950 and 1997 for most of the stations they surveyed in northeastern California.

Table 3. Direction and magnitude of significant shifts in total annual snowfall recorded at individual weather stations across the northeast climate region. Numerical values indicate the difference between the earliest and most recent years of each station's total annual snowfall in inches, as calculated using regression equation. Statistical significance of trends indicated as follows: 'NS' = not significant, '*' = p<0.05, '**' = p<0.01, '***' = p<0.001. Regression coefficients are also presented to indicate the strength of the relationship between snowfall and year.

Station	Total Annual Snowfall (inches)
Alturas	NS
Cedarville	-48***, R^2=0.42
Hat Creek	-38***, R^2=0.26
Susanville	-62***, R^2=0.41
Portola	-31*, R^2=0.08

3.1.4 Observed Trends

3.1.4.1 Hydrologic

As a result of decreasing snow packs, most of the western United States is experiencing a decline in total runoff occurring in the spring (Moser et al. 2009). Over the past 100 years, the fraction of annual runoff that occurs between April and July has decreased by 23 percent in the Sacramento basin and by 19 percent in the San Joaquin basin in California (Moser et al. 2009). Stewart and others (2005) showed that the onset of spring thaw in most major streams in the Sierra Nevada occurred 5 to 30 days earlier in 2002 than in 1948, and peak streamflow (measured as the center of mass annual flow) occurred 5 to 15 days earlier. In northeastern California, the timing of spring snowmelt driven streamflow is now about 10 to 15 days earlier than in the mid-1900s (Baldwin et al. 2003).

3.1.4.2 Wildfires

Wildfire frequency, size, and severity have increased across northern California over the past few hundred years (Miller et al. 2009). Westerling and others (2006) showed that the increased frequency of large fires (> 1000 acres) across the western United States since the 1980's is strongly linked to increasing temperatures and earlier spring snowmelt. Northern California, which includes the Moonlight Fire area, was one of two geographic areas with especially increased fire activity, which Westerling and others (2006) ascribed to an interaction between climate and increased fuels due to fire suppression. The authors identified northern California as being one of the geographic regions most likely to see further increases in fire activity due to projected future shifts in temperature. Northern California forests have already had substantially increased wildfire activity, with most wildfires occurring in years with early springs (Westerling et al. 2006).

Miller and others (2009) showed that mean and maximum fire size and total burned area across the Sierra Nevada, significantly increased between the early 1980's and 2007. Although climatic variables explained very little of the pattern in fire size and area in the early 20th century, 35 to 50 percent of the pattern could be explained by spring climate variables (e.g. spring precipitation and minimum temperature) in the last 25 years. The mean size of fires that escaped suppression efforts in the Sierra Nevada was about 750 acres until the late 1970's; the most recent ten-year average has climbed to about 1100 acres. Miller and others (2009) also showed that forest fire severity (a measure of the effect of fire on vegetation) rose strongly during the period between 1984 and 2007, with the pattern most evident in middle elevation conifer forests. Fires at the beginning of the record burned at an average of about 17 percent high severity, while the average for the last ten-year period was 30 percent. Approximately 58 percent of the Moonlight Fire burned at high severity. Miller and others (2009) suggest that both climate change and increasing forest fuels may explain this pattern of increasing fire severity.

3.1.4.3 Forest Structure and Composition

The role of climate in observed changes in forest structure over the past century is confounded by land use practices such as fire suppression and timber harvest, particularly in low and mid-elevation forests where these activities have been prevalent. However, a number of trends in forest structure and composition can be attributed, at least in part, to changes in climate. Regional trends that have most likely occurred in the Moonlight Fire area include: (a) increased tree regeneration and recruitment in response to increases in both temperature and precipitation (Bouldin 1999); (b) increased tree mortality associated with regional climate warming and drought stress (Bouldin 1999, Van Mantgem et al. 2009); and (c) increased frequency and severity of insect outbreaks, such as the mountain pine beetle (Mitton and Ferrenberg 2012). Comparisons of vegetation inventory data from the 1930s (Wieslander 1935) with modern vegetation maps and inventories show large changes in the distribution of many Sierra Nevada vegetation types over the last 70-80 years (Bouldin 1999, Moser et al. 2009). Two of these large-scale changes have been documented in the Moonlight Fire landscape: (a) the loss of yellow pine dominated forest and (b) the increase in the area of forest dominated by shade-tolerant conifers (especially fir species). These trends, which have been attributed more to human management choices than changes in climate, are described in Section 3.2 (Past and Present Vegetation Conditions: Conifer Forest).

3.1.4.4 Wildlife

A changing climate could have direct and indirect effects on the distribution and abundance of wildlife in the Moonlight Fire area. Recent work comparing historic (1914-1920) and contemporary small mammal surveys in Yosemite National Park (Moritz et al. 2008) documented range contractions in several high elevation species, as well as upward geographic range shifts in several lower elevation species. Similar patterns have also been observed for butterfly (Forister et al. 2010) and bird species (Tingley et al. 2009) in the Sierra Nevada. These studies suggest that wildlife species are moving in response to changing climates in order to maintain the environmental conditions to which they are adapted. Species with a high degree of habitat specialization and a smaller natural thermal range are more sensitive to changes in climate and may be under more pressure to move as climates warm (Gardali et al. 2012; Jiguet et al. 2006). As species shift their range, they will encounter new competition and predation pressures (Stralberg et al. 2009).

One major indirect impact of climate change on wildlife populations is the loss of synchrony between reproductive or migratory phenology and resource availability (Seavy et al. 2009, MacMyonowski and Root 2007). For example, the breeding dates of birds like tree swallows have advanced during the last century (Dunn and Winkler 1999), which may lead to a mismatch in timing of egg laying and the availability of food. In other areas, decreasing songbird diversity and abundance has been indirectly attributed to decreasing snowfall patterns (Martin and Maron 2012). Climate-related changes in parasitism, disease, and disturbance processes can also indirectly impact wildlife species.

3.1.5 Projected Future Trends

A review of projected future trends in climate by Safford et al. (2012) described that over the next century, average temperatures across the Sierra Nevada are predicted to increase by as much as 2-4 °F in the winter and 4-8 °F in the summer. Although future changes in precipitation are more difficult to predict, most models are in agreement that summers will be drier than they are currently, primarily as a result of declining snow pack, regardless of annual precipitation levels. Snowpack across the Sierra Nevada has also been projected to decrease by 20 to 90 percent. Increased temperatures and lower snowpack in the Moonlight Fire area could result in (a) substantial increases in flood risk due to higher peak runoff; (b) increased wildfire size and extent; (c) increased drought stress; (d) expansion of invasive species; (e) higher frequency of insect and disease outbreaks; and (f) range contraction of wildlife species.

3.1.6 Considering Climate in Restoration

Future changes in climate will have direct and indirect impacts on plant and animal populations, forest structure, hydrologic processes, and disturbance regimes both within the Moonlight Fire area and in the surrounding landscape. To address climate change, restoration strategies in the Moonlight Fire area will incorporate management strategies that focus on resistance, resilience, response, and realignment by:

- Enhancing resilience and sustainability by removing or reducing non-climatic stressors; examples may include decreasing the density of forested stands, reducing fuel loads, restoring hydrologic systems, enhancing riparian vegetation, and protecting wildlife corridors to reduce fragmentation.
- Focusing on promoting heterogeneity in ecological structure, function, and composition. Homogeneous conditions promote low resilience to disturbances and projected changes in climate. Altering forest conditions so that disturbance processes can act to increase rather than reduce forest heterogeneity will provide ecosystems with the ecological flexibility (Holling 1973) to withstand and persist through future changes in climate and climate-related processes (Safford et al. 2012).

3.2 Past and Present Vegetation Conditions: Conifer Forest

Vegetation and fire and fuels are inherently linked because vegetation type, structure, and development have a profound effect on fuel accumulations and fire behavior, and conversely, fuel accumulations and fire behavior can have a profound effect on vegetation establishment, development, and structure.

In July 2007, the Antelope Complex Fire burned approximately 23,000 acres, over 13,000 acres of which burned with high fire severity. Two months later in September of 2007, the Moonlight Fire burned into the Antelope Complex Fire resulting in an additional 65,000 acres burned in the watershed, with over 37,000 acres burning under high severity. Consequently, the direct, indirect, and cumulative effects of these fires, including size, severity, and adjacency converted a landscape previously characterized by extensively forested stands into a landscape now characterized by vast areas of standing dead trees and montane chaparral (USDA 2009).

For the purpose of this restoration strategy, the ten watersheds containing the Moonlight Fire and the Antelope Complex Fire were used as the analysis area for conifer forest vegetation (Figure 8); this area was selected because:

1) It utilizes the watershed boundaries, which are a widely recognized ecological unit for analyzing forest vegetation on the landscape scale;
2) It considers the spatial and temporal relationship of fires on the landscape, which provides the ecological context and scale appropriate to assess the direct, indirect, and cumulative effects of the Moonlight Fire on loss of conifer forest vegetation.
    a. Spatial Effects: Limiting the scope of the analysis to the Moonlight fire watersheds substantially underestimates the loss of mid and late seral forest vegetation across the landscape. In 2007, the Moonlight Fire burned into the 2007 Antelope Complex fire, spatially connecting large areas of deforested conditions and expanding the loss of conifer forest vegetation by a factor of three (Figure 8, Figure 11, Figure 16). The analysis area accounts for the cumulative effects to conifer forest vegetation from the Moonlight Fire which fundamentally altered the spatial occurrence and distribution of mid to late seral conifer forest vegetation on the landscape (Figure 16);
    b. Temporal Effects: As described above, the Moonlight Fire resulted in large scale loss of mid to late seral conifer forest (Figure 16). Development of mid to later seral forest types will take a century, if not more (Figure 17). During this time, conifer forests will remain highly susceptible to future fires (including re-burns) and changing climatic conditions – which further hinder the establishment and development of conifer forest vegetation and increase the risk of long term loss of conifer forest due to vegetation type conversion. Consequently, an effective restoration strategy must include efforts to protect existing mid and late seral stands from stand replacing fire in the interim century. Limiting the analysis to the Moonlight Fire watersheds would not address the temporal loss of mid to late seral forests and the uncertainty associated with their development. The ten watershed analysis area provides the appropriate context and scale for the long term restoration of the temporal occurrence and distribution of mid to late seral conifer forests on the landscape.
3) Allows for a landscape level analysis of both on site and off site restoration opportunities as part of a comprehensive long term restoration strategy for conifer forest vegetation affected by the Moonlight Fire.

These ten watersheds include lower Lights Creek, middle Lights Creek, upper Lights Creek, Mountain Meadows, Cooks Creek, Antelope Creek, Antelope Lake, Clarks Creek, lower Last Chance Creek, and Genesee Valley.

Figure 8 shows the affected watersheds and the spatial relationship of fire severities of the 2007 Moonlight Fire, the 2007 Antelope Complex Fire, the 2006 Boulder Fire, and the 2001 Stream Fire, all of which contributed to cumulative effects to forest vegetation on the landscape level. It is widely recognized that the size and scale of these fires on the landscape may be within the ecological range of natural variation; however the primary issue of concern in the Moonlight Fire is that uncharacteristically large patches of high severity fire have had an effect on landscape-level vegetation within a relatively short time period (2001-2007), and increase the long term risk of widespread type conversion of conifer forest vegetation to montane chaparral.

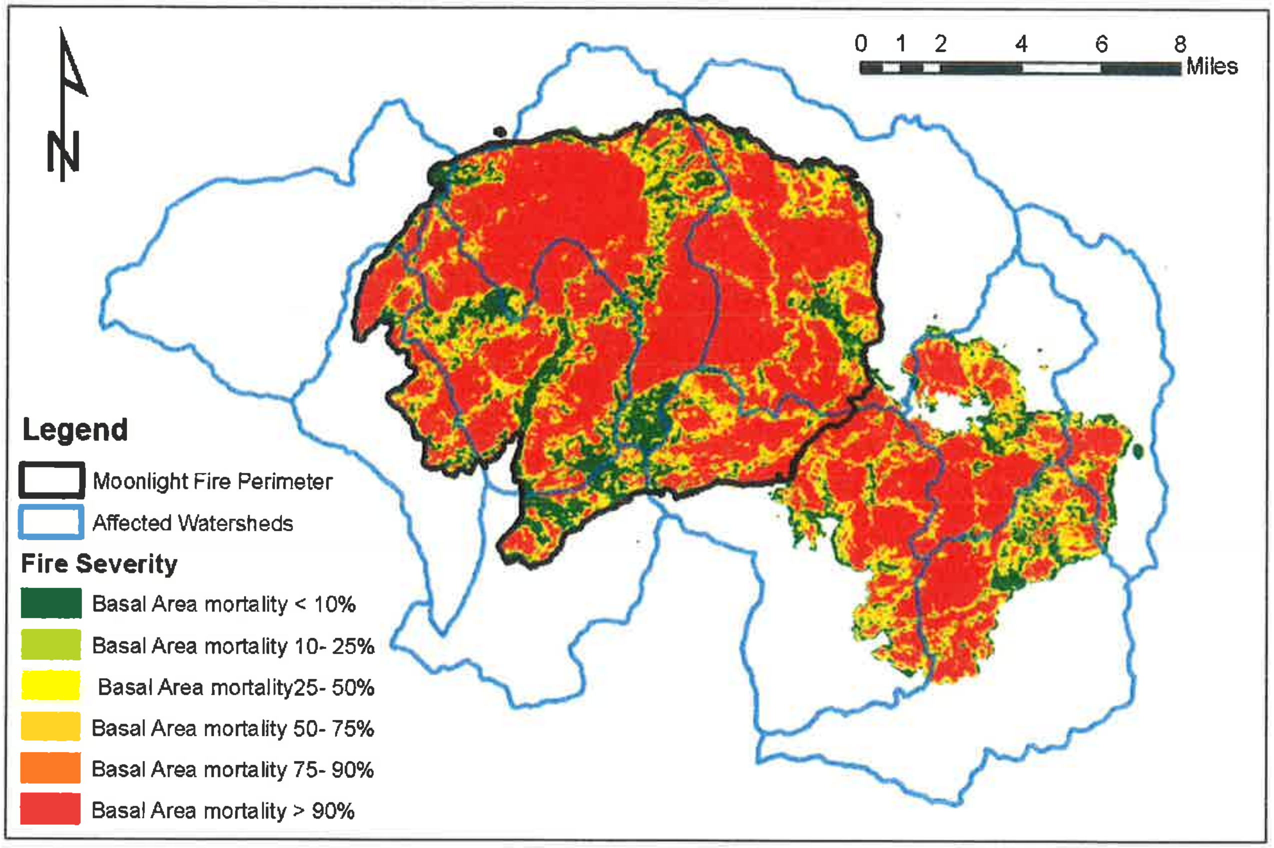


Figure 8. Area analyzed for conifer forest conditions; map displays the affected watersheds and the spatial relationship and severity of the 2007 Moonlight Fire and adjacent wildfires.

Table 4 displays the individual watersheds, the percent of the watershed that burned, and the percent of the watershed that was changed to a deforested vegetation condition as a result of high fire severity. Upper Lights Creek, Middle Lights Creek, Antelope Creek, Antelope Lake, and Genesee Valley all have uncharacteristically high amounts of high severity fire resulting in large proportions of deforested conditions.

Table 4. Affected Watersheds, percent of the watershed burned, and percent of the landscape in a "Deforested Condition"

Watershed Name	Acres[1]	Percent burned	Percent in a Deforested Condition
Antelope Creek	13,220	61%	43%
Antelope Lake	32,389	53%	41%
Clarks Creek	11,730	17%	11%
Cooks Creek	13,488	31%	21%
Genesee Valley	27,110	58%	42%
Lower Last Chance Creek	23,585	33%	21%
Lower Lights Creek	14,522	20%	7%
Middle Lights Creek	16,694	97%	66%
Mountain Meadows (Lassen NF)	20,490	3%	1%
Upper Lights Creek	22,813	83%	62%
TOTAL	**196,041**	**48%**	**34%**

[1] Reported acres and percentages include private land within the affected watersheds.

These forests within the eastside of the Sierra Nevada tend to be drier and occur on less productive sites characterized by less developed soils. The Forest Survey Site Class (FSSC) in the Moonlight and Antelope Complex fire ranges from five to seven, based on an index where FSSC seven represents the least productive site class (USDA 2006a). Consequently the relative lower site quality conditions exacerbate the temporal recovery of "deforested conditions" in terms of delaying establishment, growth, and development of forest vegetation within the affected watersheds.

3.2.1 Historic Conditions

Historic vegetation data is somewhat scant for this area as it was not included in Lieberg's (1902) survey of forest conditions in the Northern Sierra, or the recently digitized 1930s Wieslander Maps (Thorne et al. 2008). However, both historical sources do describe vegetative conditions in the Downieville and Sierraville quadrants just south of the Moonlight Fire area. We used these data, along with general patterns of precipitation across the region, to develop general inferences about forest vegetation types within the analysis area. This approach, using variables such as annual precipitation, evapotranspiration, and available water budget, is frequently used to classify ecological zones and describe ranges of dominant species types (Stephenson 1998, Van Wagtendonk and Fites-Kaufman 2006, Safford 2013).

The nearest Wieslander vegetation map completed in the 1930's lies between three and 20 miles south of the affected watersheds (Figure 9). Wieslander's map indicates that yellow pine forests generally dominate landscapes that receive less than 1000 mm of annual precipitation; this is congruent with descriptions of yellow pine and dry yellow pine dominated mixed conifer, also known as dry mixed conifer forests (Safford 2013). This trend also roughly corresponds with elevation, though it should be noted that within the affected watersheds, yellow pine forests range much higher in elevation due to lower annual precipitation levels and the proximity to the eastern escarpment of the Sierra. Van Wagtendonk and Fites-Kaufman (2006) also describe the eastside pine dominated forest type as being more than 20 miles wide along the eastern edge of the Sierra- particularly in the area north of Lake Tahoe where the affected watersheds are located.

Consequently, it is a reasonable assumption that much of the area affected by the fire was historically yellow pine dominated forest along with dry mixed conifer forest (Moody 2002, Taylor 2008). While transition to the more mesic Sierra Mixed conifer forest likely occurred in areas with higher annual precipitation, this was likely restricted to the very western portion of the affected watersheds, and true fir forests were likely limited to the highest of elevations and mesic northern aspects.

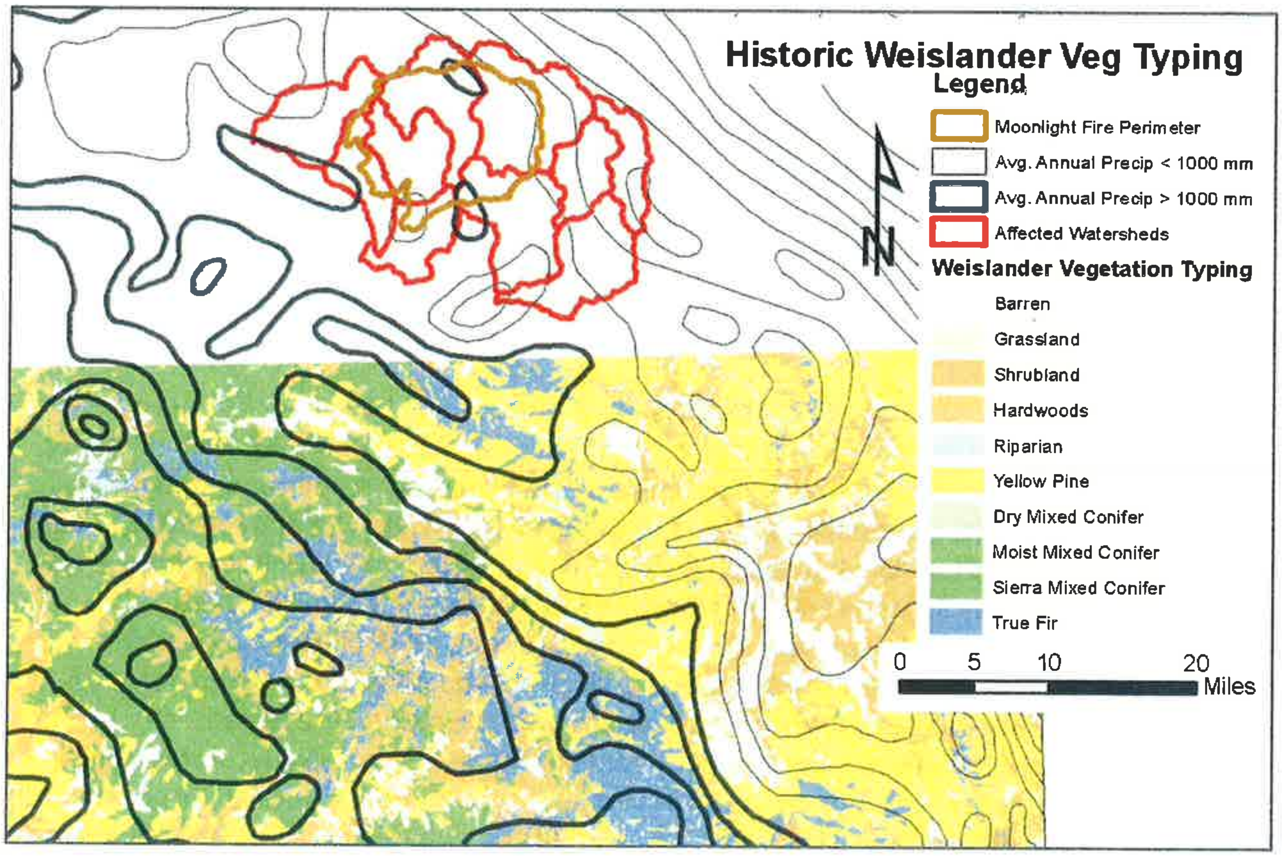


Figure 9. Historic 1930's Wieslander Vegetation Typing and Average Annual Precipitation.

Modeling by Safford (2013) indicates that for yellow pine, dry mixed conifer, and moist mixed conifer forest types, as much as 45 to 50 percent of these forest types would be in a later seral stage under a natural fire disturbance regime (Figure 10). The modeling also suggests that for yellow pine and dry mixed conifer forest types, the majority of both the mid and later seral stages would have open canopy structure, which is characteristic of a more active fire regime typified by frequent, low to mixed severity fire. Both the 1945 California Timberlands Map and the 1941 aerial photos (Figure 10) of the analysis area confirm the same trends indicated by Safford (2013) that a majority of the area was dominated by later seral stand conditions.

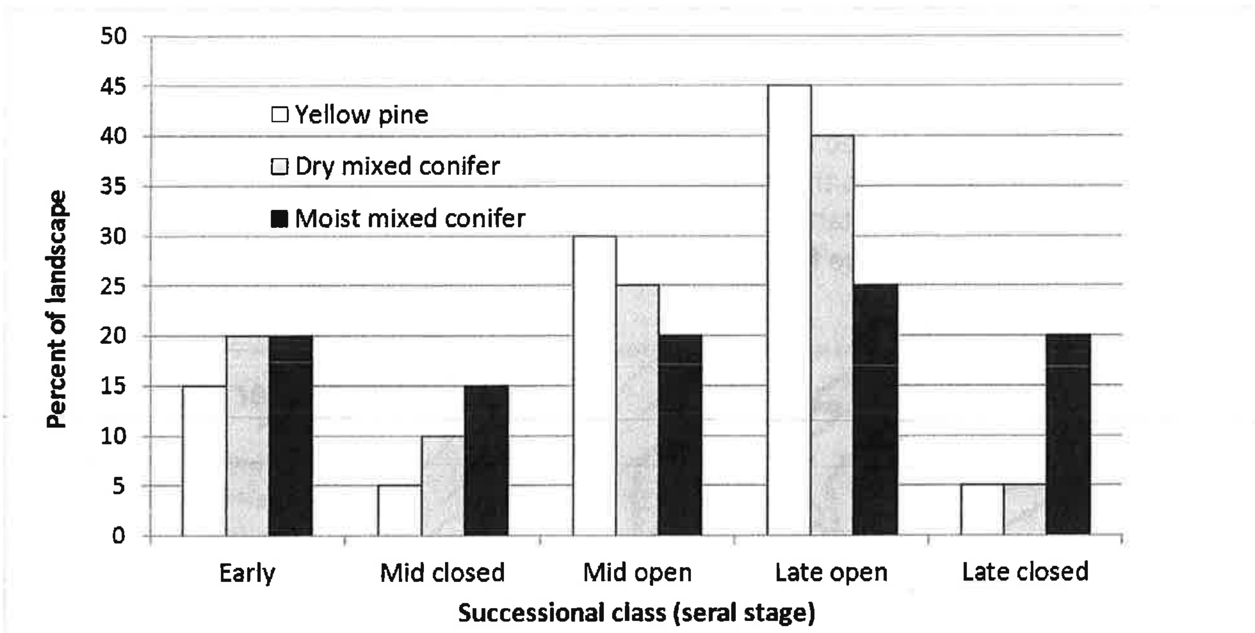


Figure 10. Seral Stage Distribution by Forest Type as modeled by Safford (2013)

Figure 11 displays a comparison of aerial photographs of the lower Lone Rock Valley and the upper reach of the Cold Stream drainage from 1941 (Photo A), 1998 (Photo B), 2005 (Photo C), and 2009 (Photo D). These photos show departure from historic landscape conditions, as well as the cumulative spatial and temporal effects of the 2007 Moonlight Fire and the 2001 Stream Fire. In the historic 1941 aerial photograph (Figure 11A), fire suppression policies had been in effect for approximately 30 years and there was little infrastructure or active forest management evident on the landscape. Considering this, these 1941 photos may depict the closest representation of a forest condition that is likely not too far departed from historical reference conditions – namely a forest that developed under a natural fire regime. Of particular note, the 1941 photo shows forest conditions dominated by later seral stages with landscape heterogeneity in canopy structure driven by aspect; more specifically the prevalence of open canopy conditions along drier south and west facing slopes, and more mesic closed canopy conditions on north-northeast facing aspects. These patterns reflect restoration framework objectives currently being employed across the Sierra Nevada (North et al. 2009 and North 2012).

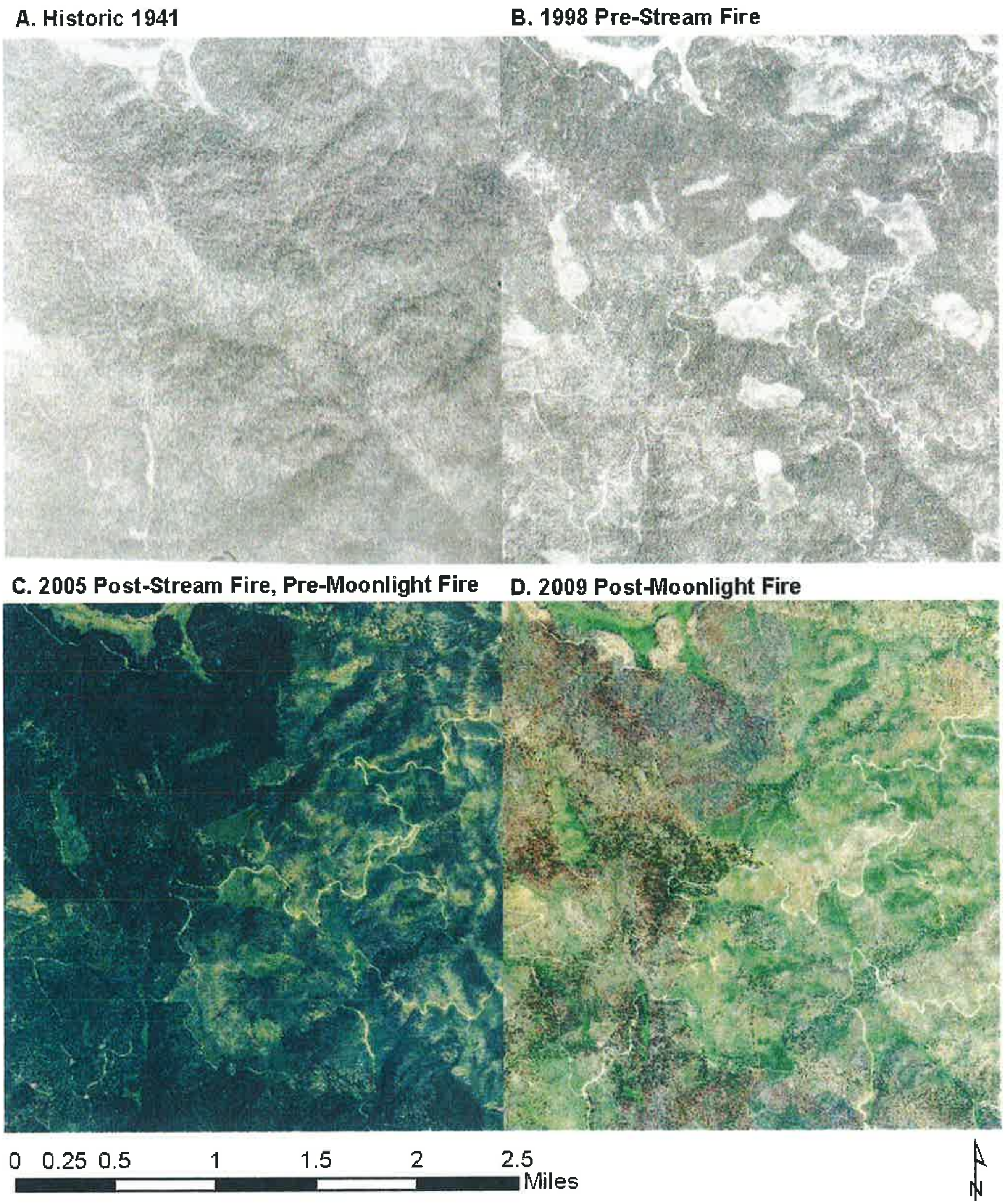


Figure 11. Comparison of Aerial Photographs of the Lower Lone Rock Valley and upper reach of the Cold Stream Drainage from 1941, 1998, 2005, and 2009. (T 27N. R 12E. Section 20 is the approximate center of the photos)

By 1998 (Figure 11B) and 2005 (Figure 11C), the effect of past management practices is evident on the landscape, including the construction of logging road infrastructure, the fragmentation from clear-cutting, the preferential removal of large diameter overstory trees, and the increasing stand densities of mid seral closed canopy stands.

The 2005 photo (Figure 11C) also shows the effect of the Stream Fire that burned approximately 3,000 acres in July of 2001. Finally, the 2009 photo (Figure 11D) shows the cumulative effects of the 2007 Moonlight Fire on mid and later seral stands and the large scale type conversion within this landscape from forested conditions to one dominated by snags and montane chaparral (USDA 2009).

3.2.2 Contemporary Pre-fire conditions

Prior to the Moonlight and Antelope Complex fires, the landscape in the analysis area consisted primarily of pine-dominated Sierra mixed conifer forests, true fir forests at the highest elevations, and plantations established over the last 40 years in burned areas and clear-cut units.

Past harvest activities resulted in: 1) the reduction of large dominant and codominant overstory trees; 2) the retention and ingrowth of smaller diameter trees; and 3) a shift in species composition from shade-intolerant pine dominated stands to shade-tolerant, white fir dominated stands. In addition, a near absence of landscape level, low-intensity surface fires contributed to increased stand densities in smaller diameter classes and large accumulations of ground fuels, ladder fuels, and canopy fuels which increase the potential for stand-replacing, high-severity fire events (Skinner and Chang 1996, Weatherspoon and Skinner 1996). These high-density stands are also more susceptible to density-dependent mortality, driven by drought and insect and disease infestations (Ferrell 1996, Cochran 1998, Guarin and Taylor 2005, Macomber and Woodcock 1994). The Moonlight landscape was affected by extensive drought in the late 1980s and early 1990s, which resulted in extensive tree mortality. Much of this material has become dead and down fuel further contributing to surface fuel loads and stand replacing fire risk in remaining mid to late seral forests. All of these factors largely decreased landscape level forest heterogeneity (McKelvey and Johnston 1992).

Because such stand structure has increased vulnerability to high-severity fires, insect outbreaks, and landscape level drought-induced mortality, a homogenous occurrence of this seral stage across the landscape is unstable and more susceptible to large-scale high severity fire events such as the Moonlight and Antelope Complex fires (McKelvey and Johnston 1992, Millar et al. 2007). The result was an uncharacteristically rapid and large shift in forest vegetation types across the landscape (Figure 12). Conifer forests (yellow pine, Sierra mixed conifer, and true fir forests) dominated by long lived conifer tree species and characterized by frequent low severity fire regimes were converted to shrublands dominated by montane chaparral species (i.e. relatively short lived Ceanothus and Arctostaphylous species) with infrequent high severity fire regimes.

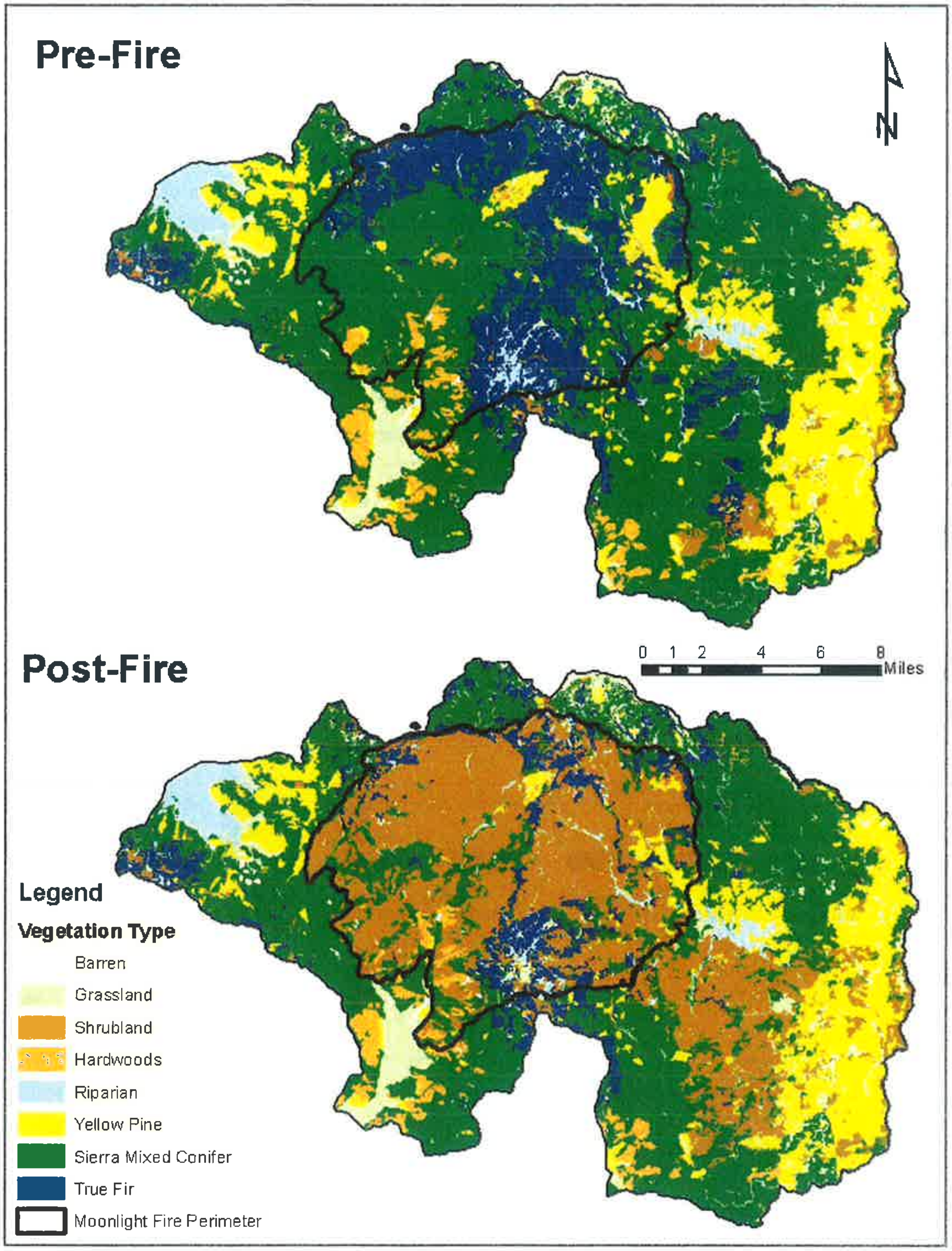
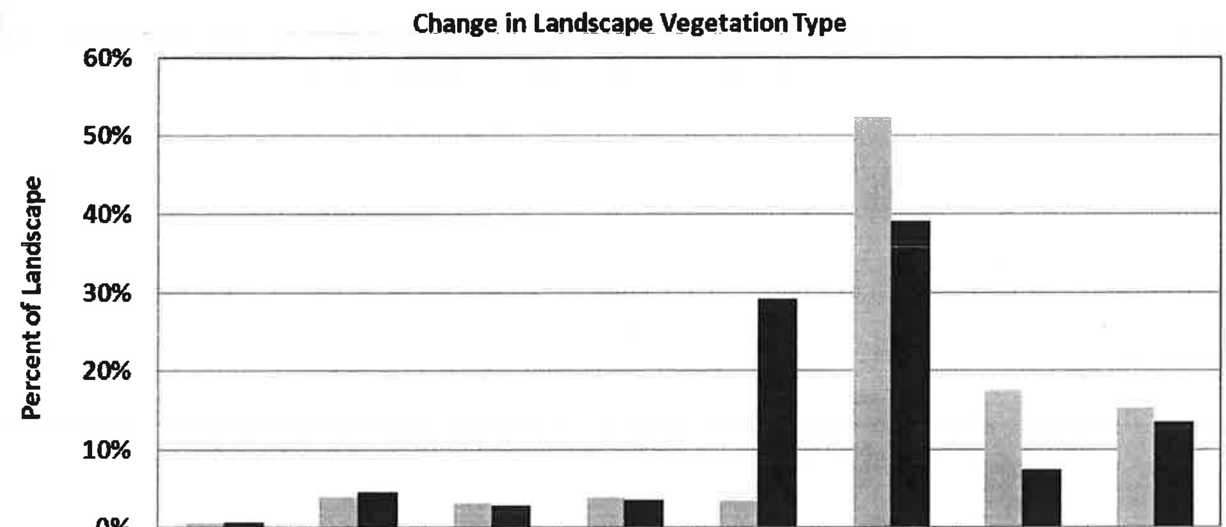


Figure 12. Pre and post-fire vegetation types across the landscape

3.2.3 Post-fire conditions

Between 2001 and 2007 approximately 48 percent of the landscape in the analysis area burned. In these fires, 70 percent of the area burned at high severity, resulting in uncharacteristically vast areas of standing dead trees, which are now dominated by shrubs. These large areas may adversely affect and/or delay the regeneration, establishment, and growth of conifer forest types due to factors such as reduced seed sources, increased distances to seed sources, the effect of competing vegetation, etc. Montane chaparral is an ecologically important early seral stage in conifer forest; however, the large patch size, and homogenous distribution of these areas across the landscape effectively increases the risk of vegetation type conversion from forest to shrubland for decades if not permanently while reducing vegetation diversity on a landscape scaleThis presents a concern for the long term viability of forest vegetation within the affected watersheds (USDA 2009, USDA 1988a). Figure 12 displays the spatial changes in vegetation types across the landscape and Figure 13 displays the changes in vegetation types by percent of the landscape both prior to and after the fires.

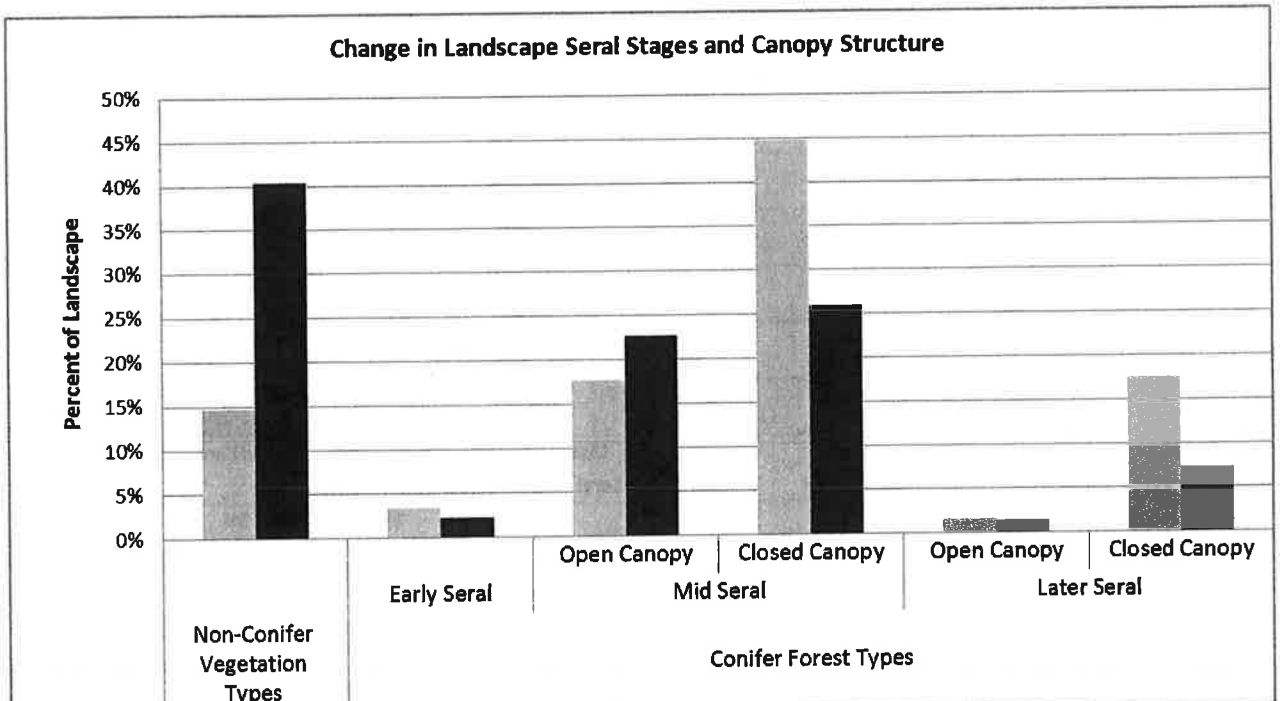


	Barren	Grassland	Montane Hardwood	Riparian	Shrubland	Sierra Mixed Conifer	True Fir	Yellow Pine
Pre-Fire	1%	4%	3%	4%	3%	52%	18%	15%
Post-Fire	1%	4%	3%	3%	29%	39%	7%	13%

Figure 13. Post-fire change in Vegetation types across the affected watersheds

Additional environmental stressors such as climate change, increase the risk of high severity fire and the potential for "re-burns" within these watersheds, which could further delay or alter the recovery of forest vegetation (Westerling and Bryant 2008, Thompson et al. 2007). The 2008 BTU Complex fires and the 2012 Chips Fire, both of which started within the footprint of the 2000 Storrie Fire, serve as a recent, local, and apropos example of this potential. In addition, the Moonlight fire burned several plantations which had been established in earlier fires further hindering the recovery of forest vegetation.

These trends highlight the importance of maintaining existing mid and late seral conifer forest on the landscape. The remaining unburned stands in the affected watersheds are also vulnerable to future high severity fire events; this increases the risk of losing values such as later seral forest habitat, desired seed sources, biological legacy structure, and landscape heterogeneity. Consequently, restoration efforts to improve existing mid and late seral conifer forest and enhance their resistance to stand replacing fire should be a high restoration priority.



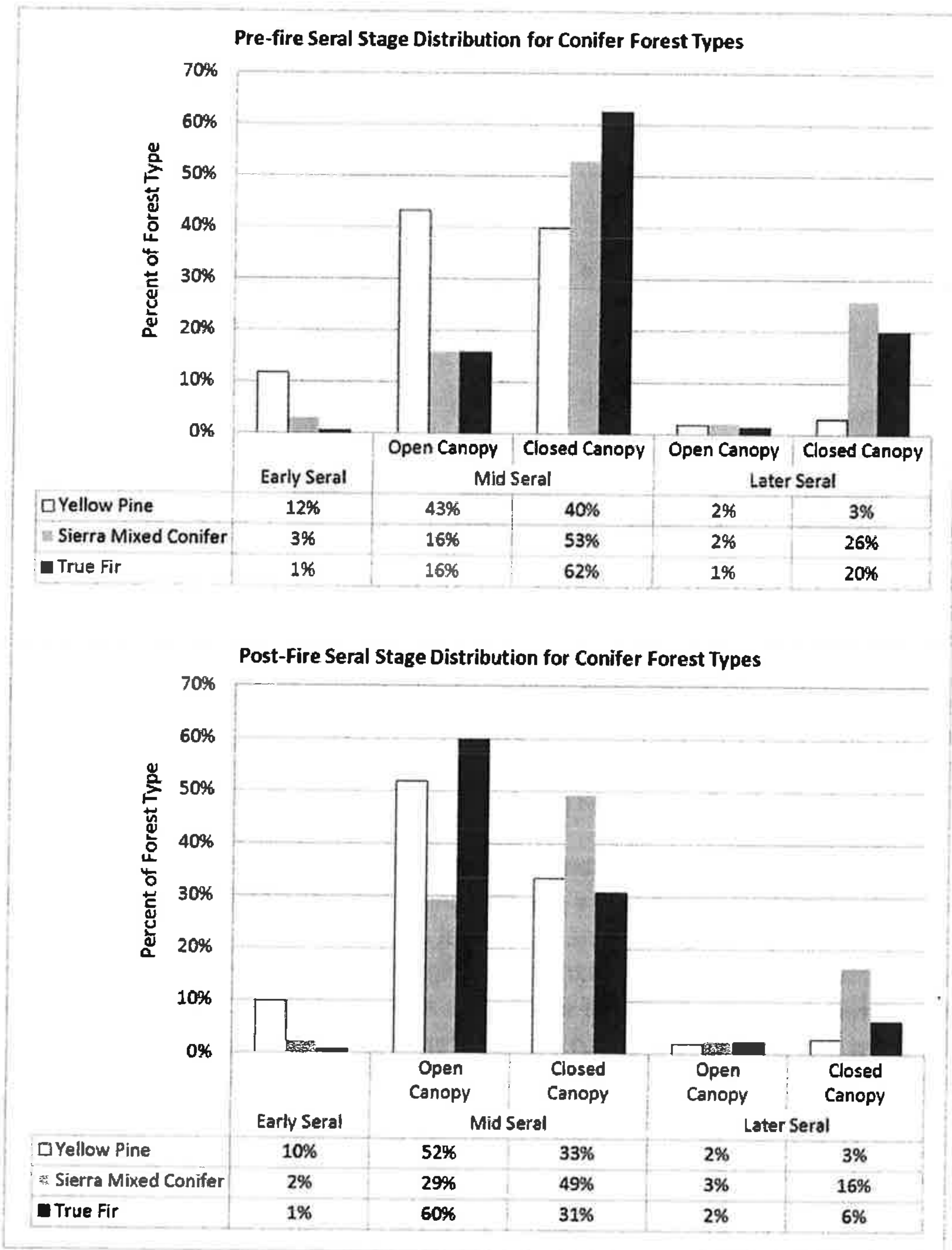
	Non-Conifer Vegetation Types	Early Seral	Mid Seral Open Canopy	Mid Seral Closed Canopy	Later Seral Open Canopy	Later Seral Closed Canopy
Pre-Fire	15%	3%	18%	45%	2%	18%
Post-Fire	40%	2%	23%	26%	1%	7%

Figure 14. Changes in Landscape Seral Stages and Canopy Structure[1]

Figure 14 displays the changes in landscape distribution of seral stages and canopy structure for vegetation types. Over 60 percent of the pre-fire landscape was dominated by closed canopy mid and later seral stands- the homogeneous spatial distribution of which makes the landscape particularly unstable and vulnerable to large scale high severity disturbance events such as those that occurred during the 2007 fire season. As a result, many mid and later seral closed canopy conifer forests were converted to non-conifer forest vegetation due to high fire severities caused by high concentrations and continuity of surface, ladder, and canopy fuels. These large homogenous and expansive areas of closed canopy forests experienced the largest

[1] Note: Conifer forest types that burned with high fire severity and experienced stand replacement were considered to be in a "Deforested Condition" per Region 5 post-fire assessment guidelines and were categorized as non-conifer forest vegetation. Conifer stands with certified establishment and stocking were classified as early seral conifer forest types.

vegetation type conversion. Figure 14 also illustrates that the relative amount of open canopy forest did not notably change. In general, many of the open canopy stands were more resilient to fire effects and had lower fire severities due to the relative lack of ladder fuels and continuity of surface, ladder, and canopy fuels. The increase in mid-seral open canopy stands post-fire is the result of low to moderate severity fire in closed canopy stands.



	Early Seral	Mid Seral – Open Canopy	Mid Seral – Closed Canopy	Later Seral – Open Canopy	Later Seral – Closed Canopy
Yellow Pine	12%	43%	40%	2%	3%
Sierra Mixed Conifer	3%	16%	53%	2%	26%
True Fir	1%	16%	62%	1%	20%

	Early Seral	Mid Seral – Open Canopy	Mid Seral – Closed Canopy	Later Seral – Open Canopy	Later Seral – Closed Canopy
Yellow Pine	10%	52%	33%	2%	3%
Sierra Mixed Conifer	2%	29%	49%	3%	16%
True Fir	1%	60%	31%	2%	6%

Figure 15. Pre (top) and post-fire (bottom) seral stage distribution for conifer forest types.

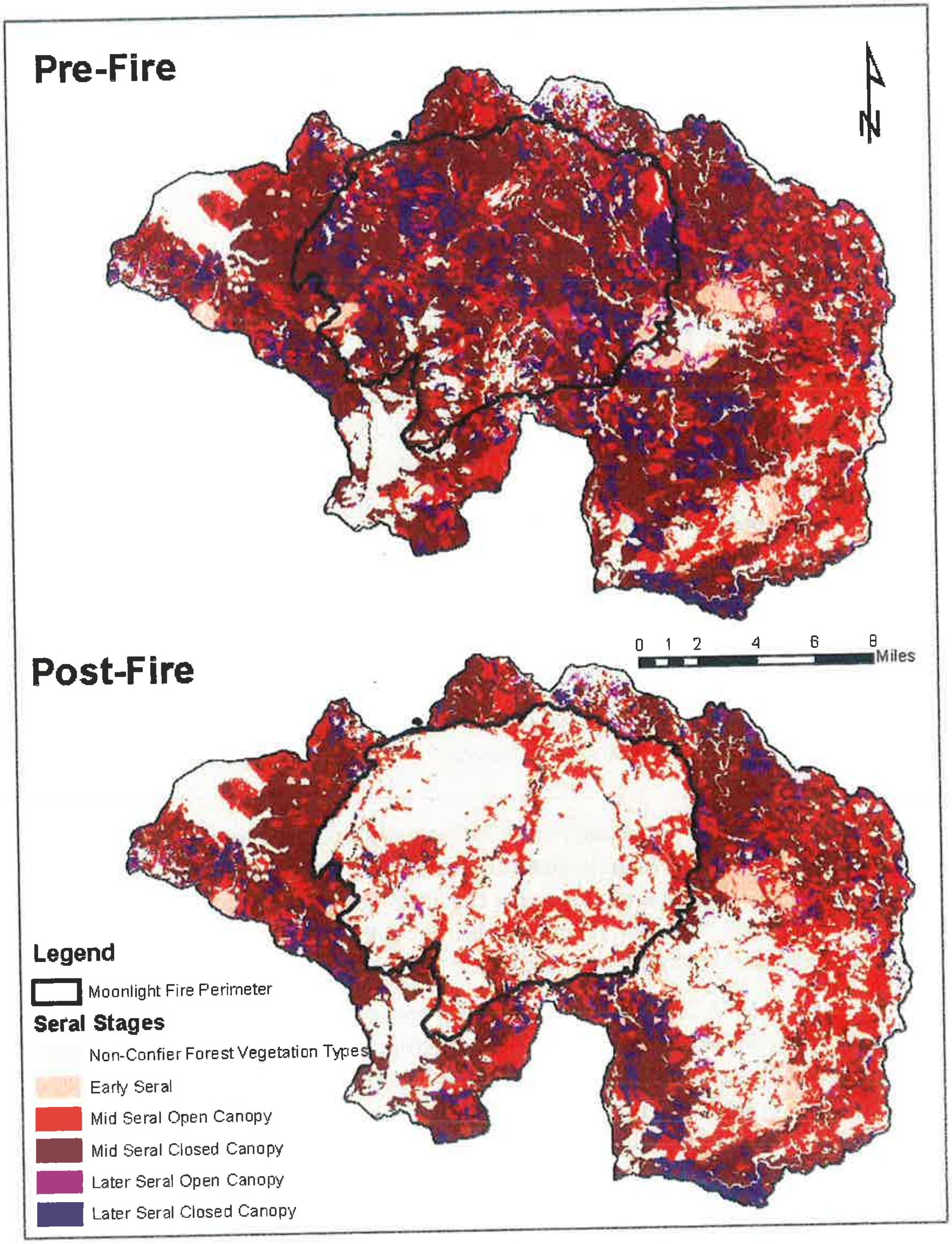


Figure 16. Pre and post-fire spatial distribution of conifer forest seral stages

Figure 15 displays the pre and post-fire distribution of seral stages for yellow pine, Sierra mixed conifer and true fir forest types. The direct and cumulative effect of the Moonlight fire converted closed canopy mid and later seral stands to non-forest chaparral vegetation types due to high severity fire. Figure 16 shows that large contiguous patches of closed canopy mid to later seral conifer forest still exist within the affected watersheds. These remaining green stands still have homogenous conditions with heavy accumulations of surface, ladder, and canopy fuels, which are susceptible to future high severity fire. Such potential fire events would only compound the adverse cumulative effects to mid and later seral forest stands within the affected watersheds.

3.2.4 Post-fire development of forest vegetation: observations from past fires within the affected landscape

Post-fire landscapes are dynamic, and temporal development of forest vegetation may vary depending on factors such as soils, topography, site quality, past management, existing seed sources, etc.. Observations from past fires on the Plumas NF serve as a useful reference for understanding potential trajectories of vegetation development over time. The conversion from conifer forest type to montane chaparral (shrub dominated non-forest vegetation), the longevity of these effects, and the development rates of forest vegetation in planted and naturally regenerated areas are evident from observations of past fires on the Plumas NF[2].

- The Morton Creek Fire in the Lights Creek drainage of the Moonlight Fire originally burned in 1959. Fifty years after the fire, plantations were characterized by early seral pole-sized stands (CWHR 3) with small areas of trees greater than 11 inches diameter at breast height (DBH) in favorable microsites. Within these small areas, the dominant trees in the plantation had reached capacity to produce a limited cone crop, but a substantial portion of this plantation was lost in the Moonlight Fire and was converted to montane chaparral.
- The Cooks fire of 1964 was planted in 1965 and prior to the Moonlight Fire was characterized by early seral pole-sized stands (CWHR 3) with a dense component of shrubs. A portion of this area burned in the 1996 Cooks Fire and converted back to montane chaparral. The remaining area burned with high severity in the 2007 Moonlight Fire and subsequently converted back to montane chaparral.
- The Big Burn of 1966 burned in the northeast corner of the Moonlight Fire. The area was planted circa 1967. Forty four years after planting, pine plantations were best characterized by early seral pole-sized stands (CWHR 3) with prolific shrub component. Hotter and drier sites had noticeably reduced tree growth and denser shrub cover. A substantial portion of this plantation re-burned in the Moonlight fire and was converted to montane chaparral.

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[2] It should be noted that plantations established within the affected landscape prior to circa 1990 likely had herbicide treatments implemented to reduce shrub competition and enhance tree survival and growth. Plantations established without the use of herbicide would likely have lower survival rates and longer developmental periods due to the effect of competing vegetation on tree survival and growth.

- The Elephant Fire burned in 1981 in the lower Last Chance Creek watershed of the 2007 Antelope Complex fire. Thirty years after the fire, areas that were left to naturally regenerate were dominated by shrub species. Pine plantations established circa 1983 and 1984 were early seral pole-sized stands (CWHR 3) with a dense component of shrubs. Substantial portions of this fire re-burned in the 2007 Antelope Complex, which converted pine plantation back to shrub dominated areas.

The effects of these fires likely varied in response to site productivity, fire severity, and subsequent post-fire salvage, site prep, and reforestation treatments. Nevertheless, observations indicate common trends in post-fire development of forest vegetation, including:

- Areas of high severity fire that are left to naturally regenerate within the Moonlight Fire will likely be dominated by shrub species for decades and, as is the case in the oldest fire observations, may persist for 85 years or more.
- Pine plantations established in past fires were typically established through intensive site preparation, planting, and follow-up herbicide treatments designed to maximize the growth of planted trees. The majority of these pine plantations have not yet matured past the pole-sized stage (CWHR 3) after 40 to 50 years of growth; however, small areas on more productive sites have developed trees greater than 11 inches DBH and have reached maturity where they could produce a limited cone crop.
- All the previously established plantations re-burned further setting back restoration of mid and late seral forests. These early seral pole-sized forest types will remain highly vulnerable to potential re-burns for decades as observed in the Cooks, Morton Creek, Big Burn, and Storrie fires and described by Thompson et al. (2007), particularly with climate-driven changes in fire regimes (Westerling and Bryant 2008).

Past fire trends indicate that these landscapes will likely be dominated by shrubs for decades. They also indicate that large areas of high severity fire, low site quality, poor soils, hot and dry microclimates on south facing slopes, or areas that experience multiple re-burns will likely experience a delay in the return to forested conditions. Those areas left to regenerate naturally are often dominated by shrubs that are susceptible to re-burn, for decades. These conditions exist on NFS lands within the Moonlight Fire area.

Natural Conifer Regeneration. Post-fire natural regeneration is highly variable due to fire severity, patch size, local seed source, competing vegetation, and site quality (Tappenier 2007, USDA 2009). Table 5 displays summarized results from 186 natural regeneration plots measured within the Moonlight Fire area (Welch 2012). Post-fire natural regeneration surveys in indicate that 33 to 37 percent of plots sampled within areas that burned under higher fire severity (fire severity codes 4 and 5) had natural regeneration. Of the 92 plots located in high fire severity, 38 percent had no visible seed source, which presents a concern for regeneration in large patches of high fire severity.

Table 5. Seedling density by fire severity[1]

Fire Severity	total # of plots	# plots w regen	% plots w regen	density conifer seedling per plot		density of conifer seedlings per acre	
				mean	s.d.	mean	s.d.
0	10	6	60	3.4	5.4	238.0	380.8
1	29	11	38	1.8	3.8	127.9	269.2
2	22	8	36	2.7	4.9	190.9	345.8
3	14	6	43	1.8	2.9	125.0	202.1
4	18	6	33	1.0	1.8	70.0	129.3
5	92	34	37	1.5	5.5	102.0	382.3

[1] Seedling Density by Fire Severity is a summary of Kevin Welch's 2012 study and annual report. Kevin Welch's summary uses the National Park Service Fire Monitoring Handbook protocol to categorize and report by Fire severity. For reference, Fire severity 3 is approximate to 50-75% BA mortality, Fire severity code 4 is approximate to 75-100% BA mortality where trees retain dead needles, and Fire severity 5 is approximate to 100% BA mortality with full consumption of crowns and needles.

While natural regeneration is occurring, particularly within the lower fire severities, one large concern is the composition of regenerating species. Natural regeneration in the lower fire severities was skewed toward shade tolerant species such as white fir, Douglas-fir, and incense cedar. While the higher fire severities had larger proportions of shade intolerant natural regeneration in Welch's (2012) study, larger patch sizes of high severity fire with farther distances to remnant seed trees may be a limiting factor in meeting desired stocking levels, particularly with pine species as suggested by Collins and Roller (2013).

3.2.5 Post-fire development of forest vegetation: site quality and projected development of forest vegetation

Site Quality is used to describe the relative productivity of a site and is usually measured in terms of the capacity for forest or tree growth. Site classifications and site indices provide useful metrics in measuring the potential growth and development of forest vegetation on differing sites (Helms 1998) as well as quantifying the timeframes it would take to restore mid to late seral forest vegetation.

The Forest Survey Site Class for the Moonlight Fire area is classified as site classes 5, 6, and 7; these are the least productive of the site classes This indicates that site quality in the Moonlight Fire area has relatively low potential in terms of forest growth and production. Forest Survey Site Classes 5, 6, and 7 are equivalent to the Region 5 site classes 3, 4, and 5.

Stand exam information collected in the Moonlight Fire area measured tree heights and tree ages for mid to late seral stands. Stand exam data[3] from the Moonlight Fire area indicate that

[3] Pre-fire stand exam information (collected in the Moonlight Fire area before the fire) measured tree heights and tree age in mid to late seral stands in the fire area. In addition post-fire stand exam information collected within

mid to late seral stands had maximum tree heights that ranged from approximately 70 to over 175 feet in height for predominant, dominant, and codominant trees; on average, maximum stand height of trees within these stands was approximately 125 feet.

As shown in Figure 17, Region 5 site index tables for site class 3 indicate that it could take over 300 years for 125 foot tall trees to develop on these sites. However, favorable microsites such as drainages and valley bottoms may be better represented by Region 5 site class 2, which suggests that it would require 180 years for a 125 foot tall tree to develop. Site trees sampled for age and height indicate that trees greater than 125 feet tall ranged in age from 145 to 400 years old and were approximately 330 years old on average. These data in conjunction with observations of development on past fires indicate that it could take nearly two to three centuries for late seral conditions to develop on the majority of the landscape.

	Site Class (Field 10)					
Age	0	1	2	3	4	5
40	95	81	66	49	43	35
50	106	90	75	56	49	39
60	115	98	82	63	53	43
70	122	105	88	68	58	45
80	129	111	93	73	61	48
90	135	116	98	77	64	50
100	140	121	102	81	67	54
110	145	125	106	84	70	54
120	149	129	109	87	72	55
130	153	133	112	90	74	57
140	157	136	115	93	76	58
150	160	139	118	95	78	60
160	163	142	120	98	80	61
170	166	144	123	100	81	62
180	169	147	125	102	83	63
190	172	149	127	104	84	64
200	175	152	129	106	86	65
220	179	156	133	109	88	67
240	184	160	136	112	90	68
260	188	163	139	115	93	70
280	191	166	142	117	95	71
300	195	169	145	120	96	73
320	198	172	147	122	98	74
340	201	175	150	124	100	75
360	204	177	152	126	101	76
380	206	180	154	128	103	77
400	209	182	156	130	104	78

Figure 17. Region 5 Site Classes show height by age and site class. The Region five site classes are based on ponderosa pine, Jeffrey pine, sugar pine, Douglas-fir, red fir, and white fir. Note: the yellow highlighted data

mid to late seral stands that burned with high and moderately high severity (>50 percent basal area mortality) in the Moonlight Fire measured tree heights in the fire area.

displays that: For Site Class 2, it would take approx.180 years for the development of a 125 ft. tall tree. For Site Class 3, it would take approx. 340 years for the development of a 124 ft. tall tree.

3.2.6 Post-fire Salvage and Reforestation Treatments on National Forest System Lands

Within the Moonlight Fire, post-fire harvest treatments were primarily focused on roadside hazard tree removal and post-fire salvage treatments to recover the value of fire-killed trees. Post-fire reforestation efforts were implemented annually between 2008 and 2011, with an emphasis on establishing a future seed source of desired species across the landscape, particularly in large areas of high severity fire where local seed sources were killed.

Roadside Hazard Tree Removal. Fire-killed and fire-injured trees were harvested within 150 feet of the road prisms along all the Level 2-5 roads (open NF System roads) within the Moonlight Fire perimeter (approximately 4,389 acres). Treatment units were determined by road location and included a variation of CWHR vegetation types, size classes, and densities. It is important to note that within this strip along the roads, only fire-killed or fire-injured trees capable of hitting the road were removed. Consequently, there was variable retention of dead and live forest cover depending on site specific local variables such as fire severity, mortality or damage to trees, and assessment of hazard/target proximity. All trees greater than 10 inches DBH were removed if the tree posed a hazard to the road.

Fire Salvage Harvest. Fire-killed trees were harvested across approximately 5,158 acres of conifer forest that burned with high fire severity. The salvage harvest was focused on conifer stands best characterized by CWHR size classes 4 and 5 of moderate (M) to dense (D) canopy cover. The majority of this occurred within ground based logging units; however, some skyline and helicopter harvest did occur on the Cairn Sale centered on the Lower Lights Creek drainage and Moonlight Valley. In all of these treatments, only larger merchantable trees were removed leaving approximately 275 to 400 trees less than 16 inches in diameter per acre on site. Approximately 1,720 acres were harvested using helicopter logging; due to the nature of helicopter logging, only large diameter high quality trees were harvested, and harvest did not occur on every acre, which maintained higher amounts of snags.

Reforestation. Between 2008 and 2011, approximately 13,000 acres of conifer forest that burned with high fire severity were planted. Approximately 100 to 210 trees per acre were planted in a wide-spaced cluster design to emulate the heterogeneity of a naturally occurring forest while allowing space for natural regeneration where available. Of these 13,000 acres, only eight percent or 2,000 acres received follow-up tree release and weed treatments, primarily due to safety concerns. Of the 2,000 acres that received release treatments, approximately half were in units that had been salvaged logged where snag hazards had been abated, and the other half were within the carbon demonstration plantation in the Pierce Creek Drainage. While release treatments increased plantation survival, overall, tree survival in plantations was highly variable and averaged approximately 33 percent due to: aggressive colonization of the site by shrub species; a two to three year delay in planting on some sites;

poor site quality and/or droughty decomposed granitic soils; and competition for resources with competing vegetation.

3.2.7 Post-fire Salvage and Reforestation Treatments on Private Lands

Post-fire treatments on private lands within the Moonlight Fire included salvage harvest, herbicide applications, and plantation reforestation. These treatments were initiated rapidly. Salvage operations were intensive and extensive, covering all lands capable of timber production, and reforestation treatments were focused on establishing conifer plantations and maximizing growth and yield through elimination of competing vegetation. It is a reasonable assumption that these lands will be intensively managed as conventionally spaced conifer plantations.

3.3 Past and Present Vegetation Conditions: Hardwood Forest

The effects of the Moonlight Fire on hardwood forest vegetation were evaluated using the conifer forest vegetation analysis area, encompassing the ten watersheds containing the Moonlight and Antelope Complex fires (Figure 8). Based on this evaluation, described below, the Moonlight Fire shifted the age class distribution of hardwoods across the landscape to sprouts and seedlings. Restoration efforts to protect this new cohort of hardwoods within the fire perimeter should be the first priority. However, additional efforts to protect and restore existing mature hardwood stands may also be important to maintain hardwoods on the landscape until the new cohort of hardwoods within the fire perimeter have matured.

Hardwoods addressed in this strategy include widespread lower montane species such as California black oak *(Quercus kelloggii)* and canyon live oak (*Quercus chrysolepis*). Hardwood species associated with riparian areas, including aspen, are addressed in Section 3.5 (Past and Present Vegetation Conditions: Meadow, Fen, Aspen and Riparian Vegetation).

Hardwood species have a number of adaptations that allow them to tolerate fire. Most species can sprout from epicormic buds following disturbances that kill the above ground stems (McDonald and Tappeiner 1996). Sprouting can be vigorous, with up to 100 sprouts observed emerging from a single stump. The growth rate of sprouts is high, allowing hardwood species to quickly reoccupy sites after fires.

Fire and other disturbances are critical to maintaining hardwood species in lower montane forests. California black oak, for example, is very well adapted to early seral conditions, requiring light for rapid growth in both the seedling and sapling stages (McDonald and Tappeiner 1996). Fire reduces canopy cover, creating openings for California black oak seedling establishment, growth and development, while also killing fire intolerant, late successional conifers (Plumb 1979). The absence of disturbance, such as fire, will eventually eliminate California black oak in lower montane forests by allowing it to be replaced by conifer forests.

Hardwood vegetation occupied approximately three percent of the analysis area both prior to and after the Moonlight Fire (Figure 13). However, the fire changed the structure of these stands by decreasing the number of acres of hardwood vegetation classified as closed stands (of 40 percent or greater canopy closure) by almost 23 percent. The extent of hardwood vegetation classified as open stands (with less than 25 percent canopy closure), increased by over ten percent. The Moonlight Fire also shifted the size class distribution of hardwoods, causing a 16 percent decline in the extent of hardwoods over 11 inches DBH. There were no hardwoods in the seedling stage prior to the fire; almost 1,000 acres were mapped as hardwood seedlings after the fire. These data suggest the Moonlight Fire promoted sprouting of hardwoods and improved hardwood stand conditions by creating more open canopies and increasing light availability.

3.4 Past and Present Vegetation Conditions: Montane and Mixed Chaparral

The effects of the Moonlight Fire on montane and mixed chaparral vegetation were evaluated using the conifer forest vegetation analysis area, encompassing the ten watersheds containing the Moonlight and Antelope Complex fires (Figure 8). Based on this evaluation, described below, the Moonlight Fire did not appear to negatively affect chaparral vegetation in areas outside the fire perimeter, making potential restoration projects for montane and mixed chaparral within the Moonlight Fire perimeter the highest priority for restoration.

Montane and mixed chaparral in the analysis area can support a number of different shrub species, but often includes white-thorn (*Ceanothus cordulatus*), tobacco brush (*Ceanothus velutinus*), and green-leaf manzanita (*Arctostaphylos patula*).

Montane and mixed chaparral shrubs are fire adapted and establish rapidly after fire, either by sprouting or by germinating from a soil seed bank. For example, *Ceanothus* seeds can survive for over 200 years in the soil, allowing it to persist during long fire-free periods. Fire suppression has reduced the extent of montane and mixed chaparral as a result of succession to conifer dominated forests (Nagel and Taylor 2005). The fuel structure of montane and mixed chaparral often results in high severity crown fire, and chaparral is often more abundant on south facing upper slope positions where topography favors higher fire severity (Weatherspoon and Skinner 1995, Beaty and Taylor 2008). Large patches of montane and mixed chaparral may alter fire regimes by promoting longer fire return intervals and higher fire severity, which can effectively preclude the reestablishment of tree dominated vegetation.

The extent of montane and mixed chaparral vegetation in the analysis area increased dramatically after the Moonlight Fire (Figure 12). Shrubs occupied approximately three percent of the analysis area prior to the fire, and 29 percent of the analysis area after the fire (Figure 13). This 26 percent increase in the extent of montane and mixed chaparral as a result of the Moonlight Fire was associated with a 26 percent decrease in the extent of Sierra mixed conifer, true fir, and yellow pine forest types, as described in Section 3.2 (Past and Present Vegetation Conditions: Conifer Forest). Mature and decadent shrubs were entirely replaced by shrub seedlings as a result of the Moonlight Fire (Figure 18).

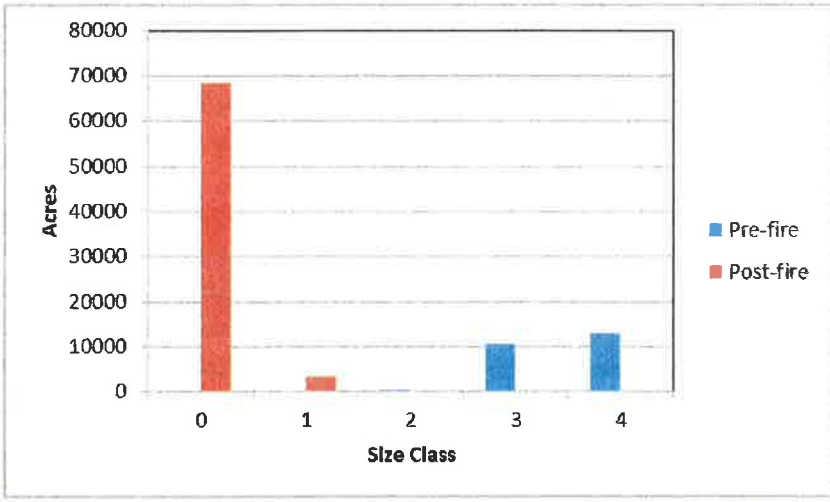

Figure 18. Size class distribution of montane and mixed chaparral prior to and after the Moonlight Fire. Size classes are: 1=Seedling Shrub, 2=Young Shrub, 3=Mature Shrub, and 4=Decadent Shrub. Data from USDA (2011b).

Prior to the Moonlight Fire, the mean patch size of montane and mixed chaparral was approximately 20 acres, ranging from less than one to over 1,000 acres in size. After the fire, patch sizes of montane and mixed chaparral ranged from 2,500 to 6,200 acres (Collins and Stephens 2012). This shift towards larger patch sizes is consistent with the large proportion of high severity fire effects resulting from Moonlight Fire (Figure 19).

Figure 19. Montane chaparral established in a former white fir stand after the Moonlight Fire.

3.5 Past and Present Vegetation Conditions: Meadow, Fen, Aspen and Riparian Vegetation

The analysis area used for other vegetation types, including hardwoods and conifers, encompassing the ten watersheds containing the Moonlight and Antelope Complex fires (Figure

8), was used to evaluate the effect of the Moonlight Fire on meadows, fens, and aspen. To evaluate the effect of the Moonlight Fire on riparian vegetation, the area used to assess hydrologic resources, which includes the six hydrologic unit code (HUC) level six (approximately 20,000 acre) watersheds that contain the Moonlight Fire, was used (Figure 50).

Based on these evaluations, described below, the Moonlight Fire may have shifted the age class distribution of aspen across the landscape to sprouts and seedlings. Projects to protect this new cohort of aspen within the fire perimeter should be the first priority for restoration. However, additional efforts to protect and restore existing mature aspen stands both within and outside the fire perimeter may also be important to maintain aspen on the landscape until the new cohort of aspen within the fire perimeter has matured.

The Moonlight Fire resulted in shifts in livestock use as a result of altered forage availability and the closure of several grazing allotments within the fire perimeter. As a result, the Moonlight Fire led to degraded conditions in some of the fens and meadows outside of the fire perimeter, as described below. Therefore, projects to protect and restore meadows and fens both within and outside the fire perimeter will be necessary to reverse the negative effects of the Moonlight Fire.

The Moonlight Fire resulted in significant losses of riparian vegetation within the fire perimeter. Projects to restore these lost riparian resources should be the first priority for restoration. However, additional efforts to protect and restore existing riparian vegetation both within and outside the fire perimeter may also be important to maintain riparian resources on the landscape until riparian vegetation within the fire perimeter has been reestablished.

This analysis is based primarily on GIS data and a limited set of monitoring data available for the analysis area. No systematic surveys of meadows, aspen, or riparian vegetation have been conducted. Previous assessments of portions of the analysis area were also consulted for this analysis.

3.5.1 Past and present conditions

3.5.1.1 Meadows and Fens

There are 98 meadows mapped in the analysis area, occupying 1,775 acres (Fryjoff-Hung and Viers 2012). This is likely a conservative estimate; aerial photos show many stringer meadows that were not included in the GIS data used for this analysis. In addition to meadows, a complex of five fen wetlands occurs in the analysis area at Lowe Flat meadow (Figure 20). Fens are unique wetland ecosystems that support many rare and endemic plant and animal species. They depend on the presence of peat-forming vegetation, which can accumulate over thousands of years and serve as important carbon sinks. The 2004 Sierra Nevada Framework Plan Amendment (SNFPA) identified fen ecosystems as a key indicator habitat type. The five sloping, spring-fed fens at Lowe Flat are surrounded by mixed conifer forest along the north and west sides of Boulder Creek. The complex is entirely within the Antelope Grazing Allotment and is subject to livestock use.

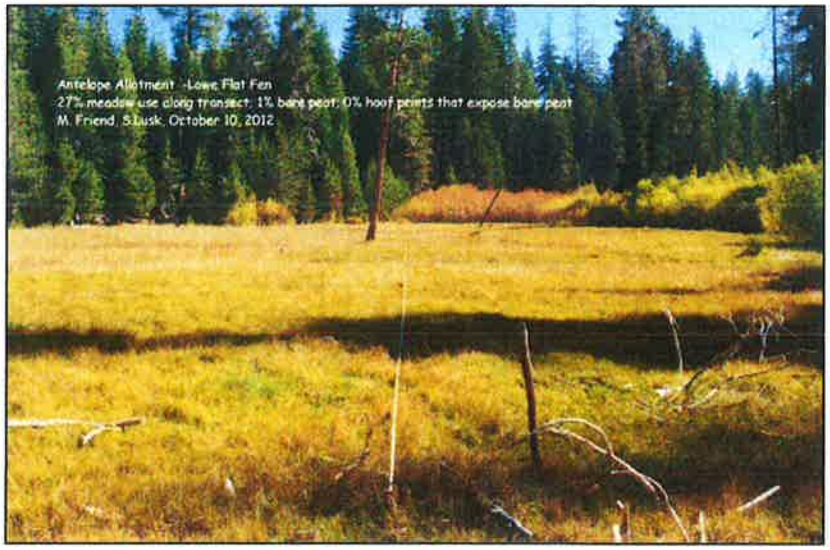

Figure 20. Lowe Flat meadow containing a fen wetland.

Although the fens in Lowe Flat meadow were not directly affected by the Moonlight Fire, assessments indicate that they are at risk from dewatering, conifer encroachment, invasive species, and livestock use (Aitken et al. 2009). Grazing utilization standards established by the Sierra Nevada Forest Plan Amendment (USDA 2004), including less than 20 percent utilization of riparian shrubs and aspen, less than 20 percent altered banks, and less than 40 percent utilization of meadows, were exceeded in 2010 and 2012 at the Lowe Flat meadow (Lusk and Johnson 2012, Lusk et al. 2010). Previous efforts to restore the hydrology of one fen in the Lowe Flat complex included the construction of small wooden check dams; however channelization of this wetland area is still evident (Figure 21).

Figure 21. Channel incision in Lowe Flat meadow (2010).

Monitoring completed by the Region 5 Range Monitoring Program includes three meadows within the analysis area. A comparison of data collected in 2002 and 2003 with data collected five years later indicated that two of the meadows had experienced a downward trend in condition and did not meet desired conditions (see Table 6). Only one site was evaluated after the Moonlight Fire.

Table 6. Region 5 Range Monitoring data for three sites within the Moonlight Fire vegetation analysis area. Only one monitoring date occurred after the Moonlight Fire (*). Data from D. Weixelman, Regional Range Ecologist.

Meadow (type)	Date	Root depth (cm)	Bare soil (%)	Early seral plants (%)	Late seral plants (%)	Mid seral plants (%)	Condition
Lowe Flat (moist meadow)	7/4/2002	32	7	15	44	41	Upper moderate, meets desired condition
	8/22/2007	13	3	34	14	52	Moderate, does not meet desired condition
Wheeler Sheep Camp (moist meadow)	7/5/2002	27	10	34	40	26	Upper Moderate, meets desired condition
	8/22/2007	14	9	44	12	44	Moderate, does not meet desired condition
Little Antelope Creek (wet meadow)	7/29/2003	27	0	2	89	9	High, meets desired condition
	8/7/2008*	25	0	5	77	28	High, meets desired condition

Proper functioning condition assessments in grazing allotments have found that some areas are functional at risk with a downward trend and are in need of restoration. For example, Lone Rock Creek was found to be functional at risk with a downward trend due to cut banks, excessive sediment deposition, and dewatering due to a culvert (Cleland et al. 2006). Six locations were identified in the Diamond Project area with headcuts, excessive channel and bank erosion, and bank instability (USDA 2006a). Where headcut erosion has occurred in meadows, the meadow may no longer function as a floodplain during high flow events, and the water table of the meadow may be lowered, resulting in soil drying and loss of meadow vegetation.

Meadows and fens are characterized by moist soil conditions, which limit the spread of fire. The Lowe Flat fen complex and 80 percent of meadows found in the analysis area did not burn in the Moonlight Fire. However, of the 376 acres of meadows that did burn, 80 percent experienced moderate to high fire severity (i.e. greater than 25 percent loss of vegetation). There are two range monitoring areas within the perimeter of the Moonlight Fire. One monitoring area is in the Lone Rock Creek grazing allotment, which burned with relatively high severity (Figure 22). This allotment was rested from grazing after the fire in 2008 and appeared to support dense vegetation the following year (Figure 22). The second range monitoring area in the Moonlight Fire perimeter is in the Lights Creek allotment. This area burned very lightly and was not rested from grazing after the fire (Figure 23).

Figure 22. Lone Rock Creek range monitoring area (from left to right): prior to the Moonlight Fire (2006), one month after the Moonlight Fire (2007), and one year after the Moonlight Fire (2008).

Figure 23 Lights Creek range monitoring area immediately after the Moonlight Fire (2007).

Fire can benefit meadows by killing encroaching conifers and upland shrubs species. Fire can also stimulate the production of herbaceous biomass in meadows in subsequent years (Wright and Chambers 2002). On the other hand, fire can negatively affect meadows. High severity fires that eliminate meadow vegetation and expose soil can increase rates of erosion, soil drying, and bank instability. The Moonlight Fire BAER report (USDA 2007a) identified numerous small meadows in the fire perimeter that had channel headcuts. Increased peak flows from the Moonlight Fire could have caused the headcuts to migrate at a faster rate, resulting in loss of meadow vegetation and increased sedimentation rates.

The Moonlight Fire may have affected livestock use in several ways. Immediately after the fire, areas that burned with moderate to high severity likely had reduced amounts of forage, which may have caused livestock to move to unburned areas to graze. In the year following the fire, burned areas probably supported higher amounts of forage as a result of resprouting, which may have concentrated livestock in these areas. Only two allotments, Lone Rock and Antelope Lake, were rested from grazing in 2008; livestock numbers, season of use, and livestock distribution were not adjusted in the remaining seven active allotments within the fire perimeter (USDA 2008). The impact associated with grazing after the fire was described in the Moonlight and Wheeler Fire Recovery and Restoration Project FEIS (2008), which stated:

> *"It is expected that first year flush of grasses/forbs and riparian species would occur along wetter sights (stream courses, meadows) and this would attract livestock, leading to concentrated use along these sensitive areas. This would probably have a short-term effect on recovery of riparian vegetation, including willow, aspen, and wet meadow. Concentrated livestock use in these areas would delay and possibly impede stream bank recovery and increase compaction around wet sites. Thus it is anticipated that some short-term delay in recovery of riparian habitat would occur."*

3.5.1.2 Aspen Stands

Geospatial data indicate that there are 568 aspen stands, totaling 1,962 acres, in the analysis area. Many of these are associated with riparian vegetation or meadows, primarily in the southern and eastern portions of the analysis area. Prior to the Moonlight Fire, many aspen stands had been identified as being suppressed by encroaching conifers (USDA 2006a).

Although no comprehensive inventory of current aspen stand conditions have been made, fire generally promotes aspen sprouting. It is likely that the Moonlight Fire may have benefitted aspen. High severity fire, in particular, may have maintained aspen stands during pre-settlement times (Sheppard et al. 2006). Photo monitoring indicates that aspen stands have responded favorably to other fires in the analysis area, such as the Stream Fire in 2001 (Figure 24).

Figure 24. Aspen stand in the Stream Fire (from left to right): immediately after the fire (September 2001), one year after the fire (September 2002); and five years after the Stream Fire (September 2006).

Fire can benefit aspen by promoting sprouting and killing competing conifers that can suppress aspen growth. However, aspen sprouts are very vulnerable to browsing by cattle or native ungulates until they are able to grow above the browse line. Repeated grazing of aspen suckers can cause aspen to grow in a bushy, multi-stemmed form that is more susceptible to browsing. Repeated browsing will eventually eliminate aspen by exhausting the underground resources of the stand (Kay 1997).

3.5.1.3 Riparian areas

Prior to the Moonlight Fire, riparian vegetation occupied approximately four percent of the analysis area; after the fire, riparian vegetation was reduced to approximately three percent of the analysis area. Although a reduction in the extent of riparian areas may have been an artifact of mapping error, it may also be attributed to loss of riparian vegetation as a result of high severity fire effects. Of the riparian vegetation within the Moonlight Fire perimeter, over 60 percent burned at moderate to high severity (i.e. greater than 25 percent basal area mortality).

As discussed in Section 3.13 (Past and Present Hydrological Conditions), mining and grazing had large impacts on riparian environments in the analysis area beginning in the late 19th century. For example, large-scale placer mining in Lights Creek likely wiped out large areas of riparian floodplain in the area downstream of the confluence of the East and West Branches (K. Roby, personal communication, 2013).

Riparian areas in the analysis area may be detrimentally affected by roads. Within the analysis area, there is approximately one mile of road in each square mile of riparian habitat conservation area, with approximately 10 stream crossings per square mile (USDA 2005). As mentioned in Section 3.13 (Past and Present Hydrological Conditions), streams such as Lone Rock Creek, Boulder Creek, and others in the Upper Antelope watershed exhibit both elevated sediment loads and headcuts.

Many headwater stream channels experienced very high severity fire effects in the Moonlight Fire, which eliminated much of the existing riparian vegetation (USDA 2007a) (Figure 25). The Moonlight and Wheeler Fire Recovery and Restoration Project FEIS (USDA 2008) noted that the post-fire condition for the drainages evaluated was moderate to poor due to loss of riparian vegetation. The amount of shade present in riparian areas was rated as poor and the amount of sediment in pool tail fines was high enough to rate as poor to very poor (USDA 2008). The authors also concluded that current and historic grazing in the area may have contributed to high sedimentation, low shade, and unstable banks within the drainages evaluated.

Figure 25. High severity fire effects in a riparian area in the Moonlight Fire

3.6 Past and Present Vegetation Conditions: Unique Botanical Resources

3.6.1 Rare plant species

The analysis area used to assess the condition of rare plants in the Moonlight Fire area includes the six HUC6 watersheds that contain the Moonlight Fire (Figure 50). This area was chosen to capture all rare plants that: (a) occur within the fire footprint; (b) were impacted by fire suppression activities adjacent to the fire footprint (Figure 26); or (c) have suitable habitat within the fire as well as a "source" (potential for seed dispersal) population located within close proximity.

In comparison to many other areas on the Plumas NF, relatively few rare plant species occur within the area affected by the Moonlight Fire (Table 7). Two notable exceptions to this generalization are: (a) the extensive stands (about 160 acres) of Baker cypress (*Hesperocyparis bakeri*) within the Mud Lake RNA and (b) the rocky ridges and outcrops within the analysis area, which support the rare adobe lomatium (*Lomatium roseanum*), Susanville beardtongue (*Penstemon sudans*), and Janish's beardtongue (*Penstemon janishiae*). Although most of the rocky ridges and outcrops were minimally impacted by the fire itself, some sites were directly impacted by bulldozer-constructed fire line as well as subsequent post-fire rehabilitation efforts (Figure 26).

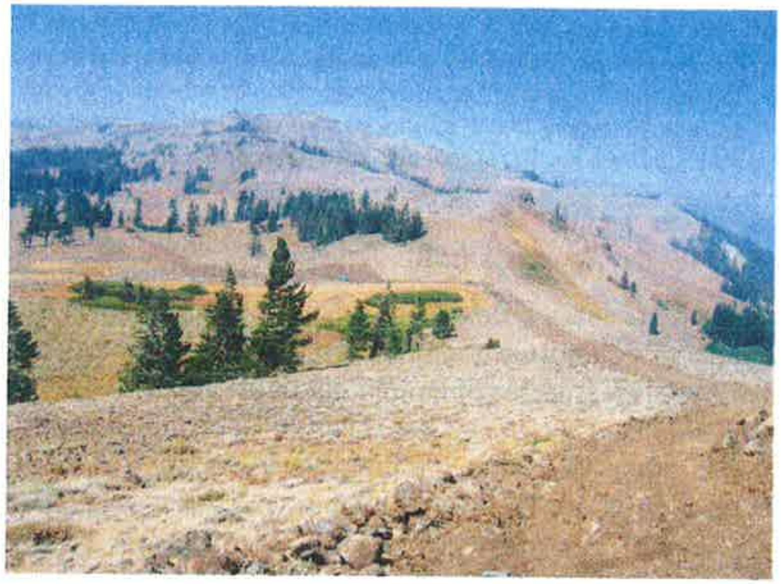

Figure 26. Photo of Diamond Mountain dozer line going through populations of *Lomatium roseanum* and *Penstemon janishiae*.

Historical trends for many of the rare species that occur within the Moonlight Fire area are unknown because they have only been documented and tracked by the Forest Service for about 15 to 20 years.

Table 7. Occurrences of Forest Service Sensitive and Plumas NF Special Interest species known within the Moonlight analysis area.

Species	Common Name	Listing Status[1]	# of Occurrences		Notes
			Within the fire	Outside fire	
Antennaria umbrinella	brown everlasting	Category 1		1	Occurrence within 200 m of fire
Astragalus pulsiferae var. pulsiferae	Suksdorf's milkvetch	Sensitive		3	Greater than 4.5 miles from fire
Carex inops ssp. inops	long-stoloned sedge	Category 2	1		
Carex pentasta	Liddon's sedge	Category 1		1	Occurrence within 250 m of fire
Carex sheldonii	Sheldon's sedge	Category 2	2	7	Outside occurrences range from 300 m to > 4 miles from fire
Cupressus bakeri	Baker cypress	Category 1	1	1	
Lomatium roseanum	Adobe lomatium	Sensitive		1	1.7 miles from fire; BUT directly impacted by suppression activities
Penstemon janishiae	Janish's beardtongue	Category 2		1	1.7 miles from fire; BUT directly impacted by suppression activities
Penstemon sudans	Susanville beardtongue	Sensitive	2	1	0.6 mile from fire
Rhamnus alnifolia	alderleaf buckthorn	Proposed		1	0.7 mile from fire boundary
Trichodon cylindricus	trichodon moss	Category 2	1		

[1] Listing Status: "Sensitive": Forest Service Region 5 Sensitive Species; "Proposed": proposed for Sensitive Species designation; "Category 1": PNF special interest species that are globally rare enough to be considered for sensitive status but have been excluded because there is not enough information to determine the species' status or the taxonomy of the species is unclear. "Category 2" PNF special interest species that are not globally rare enough to be considered for sensitive status but are locally rare, of public interest, or are a range extension of a more widespread species.

3.6.2 Baker cypress (Hesperocyparis bakeri)

Baker cypress (*Hesperocyparis bakeri*) is a rare fire-adapted conifer known from only 11 widely scattered locations in northern California and southern Oregon. Baker cypress is a California Native Plant Society list 4 species (species of limited distribution) and a Special Target Element in Region 5 of the Forest Service. This species bears closed (serotinous) cones that depend on fire for seed dispersal and require post-fire conditions, such as bare mineral soil and direct sunlight, to germinate (Vogl et al. 1977). Fire has been successfully excluded from most Baker cypress populations for almost a century. Cypress groves at many sites are densely crowded with shade-tolerant species and adult cypresses are dying with almost no evidence of regeneration. The Moonlight Fire triggered regeneration of the Baker cypress population on the Plumas NF, creating a unique opportunity to protect a young population of a species that is otherwise characterized primarily by old and decadent stands.

The analysis area for Baker cypress in this restoration strategy is the Mud Lake Research Natural Area (MLRNA), established in 1989 to preserve the two populations of Baker cypress found on the Plumas NF (Figure 27). The MLRNA is comprised of two separate units, the Wheeler Peak unit occupying 73 acres, and the Mud Lake unit, which is 307 acres in size.

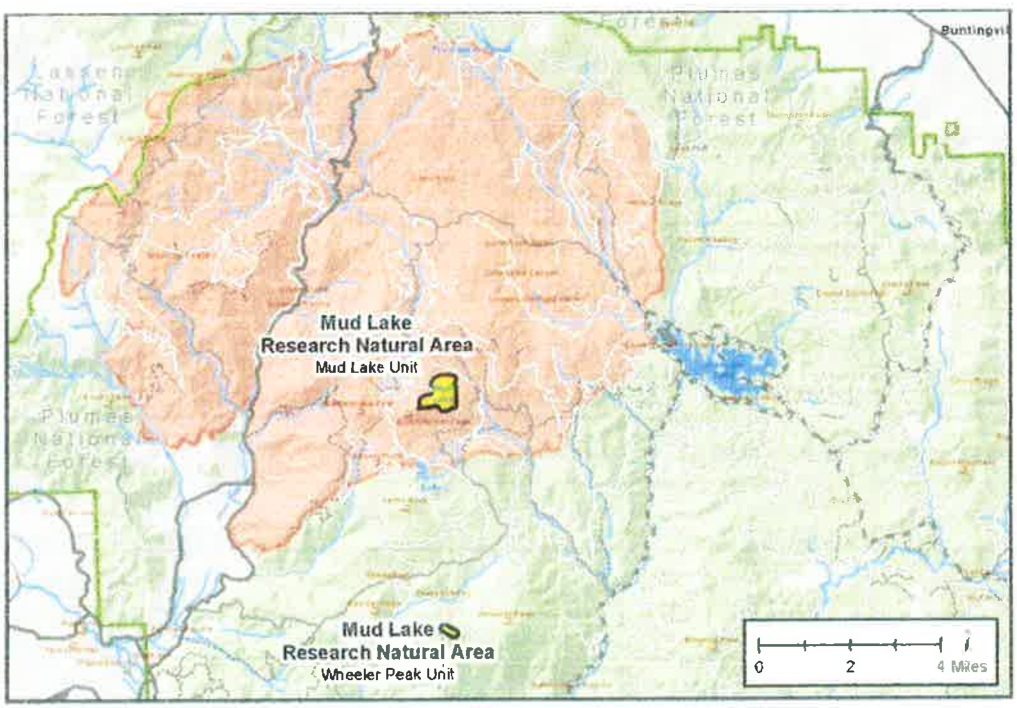

Figure 27. The Mud Lake and Wheeler Peak units of the MLRNA, the analysis area for Baker cypress.

Baker cypress stands are widely scattered throughout the two units of the MLRNA, representing the highest elevation, and furthest inland, occurrences of this species; no other cypress species in California has been documented above 6,000 feet in elevation and further than 150 miles inland from the Pacific Ocean (Keeler-Wolf 1989). As a result, the two populations of Baker cypress within the MLRNA are likely subjected to lower temperatures and more snowfall than any other population of cypress in California or the world (Peattie 1953).

The effect of the Moonlight Fire on Baker cypress, as described below, included stimulating cypress regeneration at the Mud Lake Unit. Baker cypress in the Wheeler Peak unit now represent the only reproductively mature population in this portion of the species range. Projects to protect this new cohort of cypress within the fire perimeter should be the first priority for restoration. However, additional efforts to protect and restore the existing mature Baker cypress stands at the Wheeler Peak Unit are also important to maintain this rare species on the landscape until the new cohort of cypress within the fire perimeter has matured.

This analysis is based primarily on data collected during a three-year study to evaluate Baker cypress across its range. The results of this larger study are described in Rentz and Merriam (2011a, 2011b) and Frame (2011).

3.6.2.1 Past and present conditions

Wheeler Peak Unit

The Wheeler Peak unit contains the world's largest Baker cypress, with a DBH of 56 inches and a height of 71 feet. In addition to this champion tree, several other Baker cypress trees within the Wheeler Peak unit are over 36 inches DBH (Figure 28). These large trees occur on a largely unvegetated, rocky ridgetop. The Wheeler Peak population of Baker cypress is younger than the Mud Lake population. The average age of trees in our plots at Wheeler Peak was 95 years, with a range of between 46 and 158 years. Keeler-Wolf (1985) suggested that this unit is in an earlier successional stage than the Mud Lake population.

The Wheeler Peak population is relatively healthy compared to other populations of Baker cypress across the species range. Average crown condition of trees at Wheeler Peak was less than 50 percent dead or dying, just slightly over the range-wide average of 44 percent. Baker cypress trees at the Wheeler Peak unit were among the largest in DBH across the range of the species, averaging 9.8 inches. Much of the unit is characterized by small, dense groves of Baker cypress isolated from one another by open, rocky soil. However, there are some areas where competition from white fir may threaten Baker cypress trees, particularly on the lower slopes of the unit where there is evidence of suppression by conifers. Overtopping conifers can reduce Baker cypress cone production, tree health, and eventually cause tree mortality (Rentz and Merriam 2011a, 2011b). No seedlings were observed at the Wheeler Peak unit.

Figure 28. Baker cypress champion tree (left) and another larger Baker cypress (right) in the Wheeler Peak unit.

Mud Lake Unit

Prior to the 2007 Moonlight Fire, no fires had been recorded in either the Wheeler Peak or the Mud Lake unit of the MLRNA since 1910. Baker cypress averaged 135 years of age, ranging in age from 101 to 167 years. No seedlings were found in any of the study plots prior to the Moonlight Fire, and the Baker cypress stand was very unhealthy (Figure 29). Cypress trees were 87 percent dead or dying and represented only 28 percent of total stand density. Fire suppression at the MLRNA had allowed dense thickets of shade-tolerant white fir to dominate the stand, resulting in high levels of cypress mortality (Wagener and Quick 1963, Keeler-Wolf 1985). Other species averaged nine feet taller than Baker cypress in our plots. This competition for light produced some of the tallest known Baker cypress, measuring up to 100 feet in height. The decline of Baker cypress at the Mud Lake unit due to competition was first noted by Wagener and Quick (1963) and had been recognized repeatedly since that time (Keeler-Wolf 1985). Prior to the 2007 Moonlight Fire, there was concern that without immediate action to reintroduce fire to this population, it would be extirpated.

Figure 29. Dead and dying cypress in the Mud Lake unit prior to the Moonlight Fire.

After the 2007 Moonlight Fire, substantial Baker cypress regeneration was observed at the Mud Lake unit (Figure 30). Despite low densities of living mature cypress in the stand prior to the fire, these residual trees had sufficient canopy seed storage to produce numerous seedlings. Seedling densities of up to 85 seedlings/m2 occurred in plots with only three living cypress prior to the fire. Pre-fire data indicated that even plots with only three Baker cypress adult trees prior to the fire could have dispersed an average of 15,000 viable seeds after the fire. Fire severity was the strongest predictor of post-fire seedling density. Plots with higher scorch and char heights, and more percent crown scorch volume, had greater numbers of seedlings. Plots with higher soil burn severity also had significantly higher seedling density. The high severity fire effects caused by the Moonlight Fire were very beneficial to this population of Baker cypress.

Currently there is a high density of snags throughout most of the stand, and potential fire hazard may increase over time as these snags decay. The population in the Mud Lake unit is currently at significant risk of extirpation until the population can produce cones and accumulate sufficient seeds to regenerate the population after a fire. Cypress trees do not begin producing cones until around 15 years of age, and our research suggests that it takes a population between 35 and 50 years to accumulate enough cones in the canopy to regenerate the population after a fire. This range of fire return intervals is typical of the mixed fir forests where Baker cypress occurs.

Figure 30. Cypress seedling densities were high after the Moonlight Fire.

3.7 Past and Present Invasive Species Conditions

Invasive plant species pose a serious threat to biological diversity because of their ability to displace native species, alter nutrient and fire cycles, decrease the availability of forage for wildlife, and degrade soil structure (Bossard, Randall and Hoshovsky 2000). Disturbance, whether it is natural (such as the Moonlight Fire) or associated with management activities, often creates ideal conditions for the introduction and establishment of invasive species. Colonization into disturbed sites is often facilitated by the removal of natural barriers that frequently keep invasive species in check, such as unsuitable light, soil, or moisture conditions (Parendes and Jones 2000). Wildfires can expose soil surfaces, reduce shade, decrease competition from native species, and flush the soil of nutrients; all of these factors can create conditions favorable to invasion (Turner 1997, Sheley 2002). See section 3.10, Past and Present Aquatic Conditions and Aquatic Invasive Species, for details on aquatic invasive species.

In order to assess the risk of invasive plant introduction, establishment, and spread within the Moonlight Fire area, a geographic area was selected for analysis based on the watershed boundaries (Figure 31). This area encompasses the Moonlight Fire, as well as the primary access roads, adjacent high-use recreation sites, and areas used during the fire suppression effort; these areas represent potential seed sources or vectors for invasive plant introduction and spread.

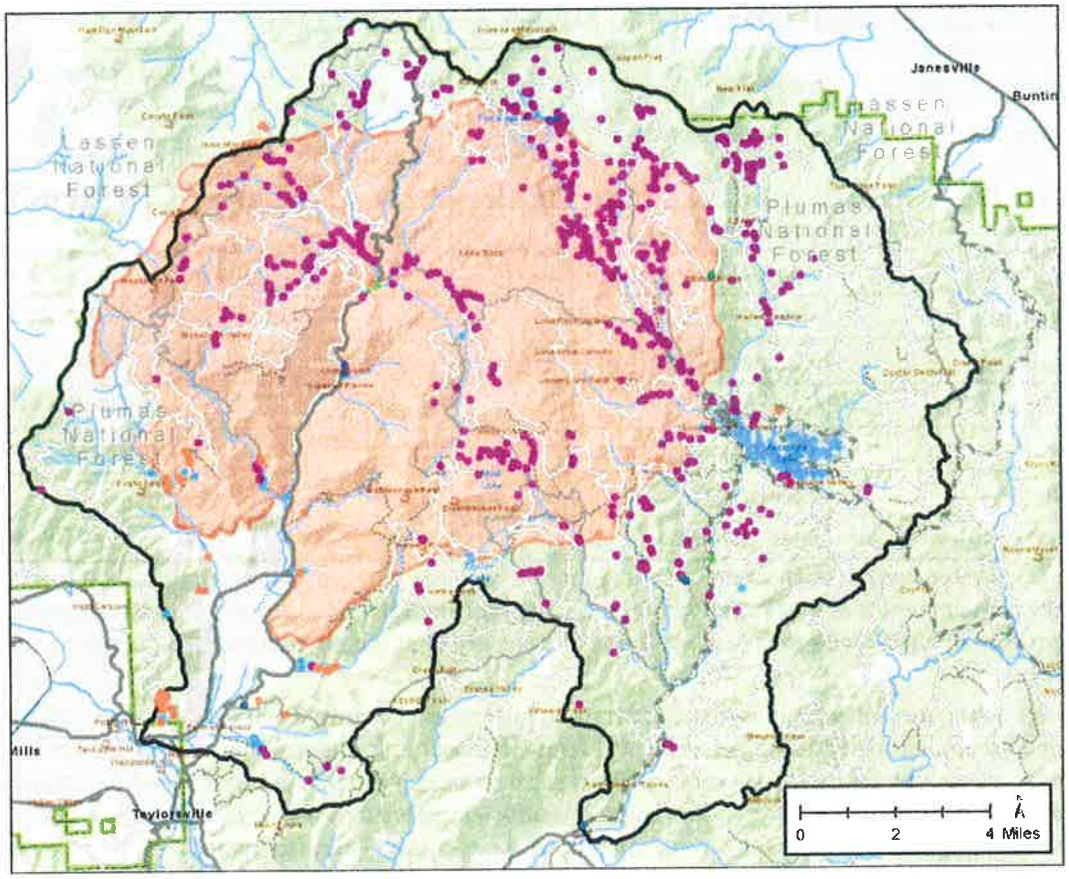

Figure 31. The area analyzed for invasive plant species. Dots indicate infestations of barbed goatgrass (brown), spotted knapweed (green), yellow starthistle (light blue), Canada thistle (purple), Scotch broom (dark blue), dyer's woad (yellow), Russian thistle (teal), medusahead (pink)

3.7.1 Moonlight Invasive Species

Eight priority invasive plant species have been documented within the analysis area (Table 8). These species are known from 756 locations and about 240 acres; just over half (444 sites, 125 acres) occur within the Moonlight Fire boundary (Table 8). At present, most infestations are small, with 73 percent of the known locations occupying less than 0.1 acre. Approximately 74 percent of infestations occur within 500 feet of roads or trails. These infested areas can act as source populations for introduction and spread into less-invaded portions of the Moonlight Fire area. The highest concentration of invasive plants is presently in the northern portion of the Moonlight Fire, in the Lone Rock Creek-Indian Creek and Upper Lights Creek watersheds (Table 9).

Table 8. Invasive species documented in the Moonlight Fire analysis area

Species	Common Name	CDFA rating[1]	Cal-IPC rating[2]	Number of infestations (approximate acreage)	
				Within fire footprint	Within analysis area; outside fire
Aegilops triuncialis	barb goatgrass	B	High		1(0.7 ac)
Centaurea maculosa	spotted knapweed	A	High	6 (0.03 ac)	1 (< 0.1 ac)
Centaurea solstitialis	yellow starthistle	C	High	14 (9.4 ac)	38 (38.5 ac)
Cirsium arvense	Canada thistle	B	Moderate	400 (110 ac)	243 (36.4 ac)
Cytisus scoparius	Scotch broom	C	High	3 (1.6 ac)	4 (0.4 ac)
Isatis tinctoria	dyer's woad	B	Moderate	2 (3.7 ac)	
Salsola tragus	Russian thistle	C	Limited	2 (0.07 ac)	
Taeniatherum caput-medusae	medusahead	C	High	17 (0.3 ac)	25 (38.7 ac)

[1] CDFA ratings - A listed weeds: eradication or containment is required at the state or county level; B-listed weeds: eradication or containment is at the discretion of the County Agricultural Commissioner; C-listed weeds: eradication or containment required only when found in a nursery or at the discretion of the County Agricultural Commissioner.

[2] CalIPC ratings- High: attributes conducive to moderate to high rates of dispersal and establishment; usually widely distributed among and within ecosystems. Moderate: impacts substantial and apparent, but not severe; attributes conducive to moderate to high rates of dispersal; distribution may range from limited to widespread. Limited : ecological impacts are minor or information is insufficient to justify a higher rating, although they may cause significant problems in specific regions or habitats; attributes result in low to moderate rates of invasion; distribution generally limited, but may be locally persistent and problematic.

Table 9. Number of invasive plant locations (with approximate acreage in parentheses) within the botany analysis area HUC12 watersheds.

	barbed goatgrass	Canada thistle	Dyer's woad	medusahead	Russian thistle	Scotch broom	spotted knapweed	yellow starthistle
Antelope Creek	1 (0.7)	6 (0.9)		1 (0.7)				
Boulder Creek		70 (22)						
Cold Stream-Indian Creek		38 (1.5)		1 (< 0.01)		3 (0.3)	1 (< 0.01)	1 (< 0.01)
Cooks Creek		4 (0.02)	1 (3.6)	12 (3.3)				11 (8.3)
Hungry Creek		77 (15.1)						
Lone Rock Creek-Indian Creek		260 (76.6)			2 (0.07)		3 (< 0.01)	1 (0.02)
Lower Lights Creek		14 (1.9)		25 (34.9)		1 (0.1)		33 (39.4)

	barbed goatgrass	Canada thistle	Dyer's woad	medusahead	Russian thistle	Scotch broom	spotted knapweed	yellow starthistle
Middle Lights Creek		23 (0.6)		3 (0.01)		3 (1.6)	2 (0.03)	5 (0.1)
Upper Lights Creek		151 (27.5)	1 (0.09)				1 (< 0.01)	1 (< 0.01)
Grand Total	**1 (0.7)**	**643 (146)**	**2 (3.7)**	**42 (38.9)**	**2 (0.07)**	**7 (2)**	**7 (0.03)**	**52 (47.8)**

The most prevalent invasive species in the analysis area is Canada thistle (*Cirsium arvense*). This perennial thistle is most abundant in moist, riparian habitats within the fire, but is also found in drier sites such as old landings, skid trails, and roadsides. Canada thistle spreads rapidly either by seed or vegetatively (Bossard et al. 2000); documented rates of spread range from less than two feet to over 40 feet per year (Donald 1990, Nuzzo 1997, Bond and Turner 2004, USGS 2005). Like many of the invasive species in the Moonlight Fire, Canada thistle is considered particularly difficult to eradicate.

3.7.2 Effect of the Moonlight Fire on invasive species

About 72 percent (550 locations) of the infestations within the analysis area were discovered prior to the Moonlight Fire. Many of these were documented during project-level field surveys that were conducted on approximately 60,628 acres within the analysis area between 2000 and 2007. The remainder of the area had not been recently surveyed before the fire; therefore it is highly possible that a number of weed infestations were present in the un-surveyed areas prior to the fire and suppression activities.

Post-fire monitoring activities and surveys within the analysis area have documented 206 infestations that are either new or have expanded in size since the Moonlight Fire. It is often difficult to determine whether these new infestations became established after the fire because accurate pre-fire information is generally lacking; however there are some situations where inferences can be made. In 2008, weed detection surveys were conducted on approximately 20 miles of fire line and 122 miles of NFS roads within the fire perimeter (USDA 2008). These areas were identified in the 2007 BAER report as important potential corridors for noxious weed dispersal, introduction, and spread (USDA 2007b). As a result of this effort, 35 new infestations were documented. Of these, 13 were discovered within previously surveyed areas and a large majority of the remaining infestations were found along NFS roads where they would likely have been visible and documented prior to the fire (USDA 2008). These findings suggest that some of these infestations were introduced after, and possibly as a result of, the Moonlight Fire.

Figure 32. New infestation of Dyer's woad discovered during post-fire BAER monitoring

Fire suppression activities during the Moonlight Fire likely increased the number of invasive species both within and adjacent to the fire. Dozer lines, drop points, and safety zones can all serve as invasive plant dispersal areas or corridors and suppression equipment can act as vectors for spread. Movement of fire suppression and rehab equipment can also facilitate the spread of invasive plants to and from areas within the fire. To prevent the introduction of noxious weeds into the burned area during suppression activities, Forest Service policy requires washing of all equipment mobilizing onto wildfires; however, the Moonlight Fire increased in size rapidly during the first several days due to extreme fire behavior, and some vehicles and equipment were not washed during mobilization (USDA 2007b). In addition, equipment such as tankers, engines, dozers, and excavators were not washed, inspected, or cleaned for dirt/plant parts on the way into the fire during suppression and rehabilitation efforts (USDA 2007b).

One infestation of spotted knapweed was disturbed by heavy equipment during the fire. The site was plowed for use as a safety zone and it is likely that fire suppression vehicles either parked in the site or passed through (USDA 2007b). Although post-fire monitoring did not detect an increase in knapweed individuals at the site (USDA 2008), future monitoring may detect new infestations within the fire footprint.

The effect of the Moonlight Fire on the existing invasive plant infestations was highly variable and was largely dependent on the species' ecology, location of the infestation relative to suppression activities, fire severity, and the effectiveness of pre-fire weed control efforts (USDA 2008). In 2008, 59 previously known weed infestations were re-visited and evaluated to determine the impact of the fire and suppression activities (USDA 2008). Of these, three previously known infestations of Canada thistle were encountered that had significantly increased in size (USDA 2008). General observations also noted that some lower priority invasive species, primarily cheat grass (*Bromus tectorum*) and bull thistle (*Cirsium vulgare*), were more abundant in some of the fire lines compared to the surrounding area (C. Rowe personal observation 2008). In 2012, eight Canada thistle locations within the Moonlight Fire were revisited; although the estimated acreage of these infestations decreased slightly, the density of stems five years after the fire had tripled compared to the density two years prior to the fire (J. Belsher-Howe, personal communication).

3.7.3 Weed control efforts

Weed control efforts within the analysis area have been conducted on an annual basis since 2002. The total acreage treated each year is less than five percent of the total present due to a lack of funding and completed environmental analysis for herbicide treatment. Although treatments have been limited in scope, they have been successful in eradicating a few small populations and reducing the size or preventing the spread of several others. In contrast, some infestations continue to spread despite dedicated treatment efforts. Many of the infestations documented prior to the Moonlight Fire were proposed for treatment under the Diamond Project DEIS (USDA 2006a), which was never implemented. Approximately 100 locations of Canada thistle have also been proposed for treatment under the proposed Wildcat Project.

3.7.4 Risk to the Moonlight Landscape

The location, severity, and management of the Moonlight and adjacent fires have created a high risk for invasive plant introduction and spread within the analysis area watersheds. Fire suppression activities, combined with large areas of high burn severity, resulted in considerable ground disturbance and the creation of favorable conditions for invasion. This level of past disturbance, combined with the large number of invasive species concentrated along roads where the risk of spread is high, greatly increases the vulnerability of the Moonlight Fire landscape.

Invasive plants migrate, establish, and spread rapidly and unpredictably. New infestations have been discovered within the analysis area every year since the Moonlight Fire. Without effective and timely treatment, invasive plants may spread rapidly within the watersheds affected by the Moonlight Fire.

3.8 Past and Present Fire and Fuels Conditions

Fire continues to be a major management challenge for National Forests of the Sierra Nevada. More and more frequently, fire suppression forces are overwhelmed by extreme fire behavior largely driven by past forest management practices and century of fire suppression (see Past and Present Vegetation Conditions: Conifer Forest above). Fire suppression has always been applied with the greatest intentions, however; it has also resulted in a number of unintended consequences including high fuel load accumulations and high tree stem densities particularly in small diameter shade tolerant trees (Beaty and Taylor 2001, Taylor and Skinner 2003, Beaty and Taylor 2007). In the most general terms, past management strategies have shifted systems from frequent low severity fire to infrequent high severity fire.

For analysis purposes a landscape approach has been adopted to help quantify impacts and trends within the Central Fire Management Zone of the Plumas NF (Figure 34). Both historically and currently, fire acts on a scale from 10's to 100's of thousands of acres moving wherever there are consumable fuels (Norman and Taylor 2003). Adding a temporal component of at least a century, only large landscapes can provide any insight into ecosystem trends and resource management goals and objective. Within these landscapes it will be important to balance and sustain resources such as timber and wildlife habitat for current and future generations.

3.8.1 Pre-Suppression Fire < 1900

Prior to European settlement, these landscapes experienced frequent and predictable fire cycles that functioned as a fundamental ecosystem process. Pre-suppression era fires were not only primarily frequent, low to moderate-intensity fires, but were also quite large, frequently covering 10's to 100's of thousands of acres (Norman and Taylor 2003). Landscapes with active fire regimes included open park-like multi-aged stands as well as relatively dense even-aged stands and shrub patches. Past fire cycles created complex mosaics of vegetation and successional stages capable of supporting old forest species such as the California Spotted Owl as well as disturbance dependent species such as the Black Backed Woodpecker. Effective fire suppression over the past century has considerably altered these ecosystems. Prior to European settlement, frequent fire dominated this analysis area as well as the Moonlight Fire footprint (Figure 33 and Figure 34). Based on fire return interval departure data compiled by Safford and others (2011), there is very little difference in fire regimes on the District compared to the Moonlight Fire area with 90 and 96 percent of these areas respectively dominated by fire return intervals in the range of 10 to 20 years.

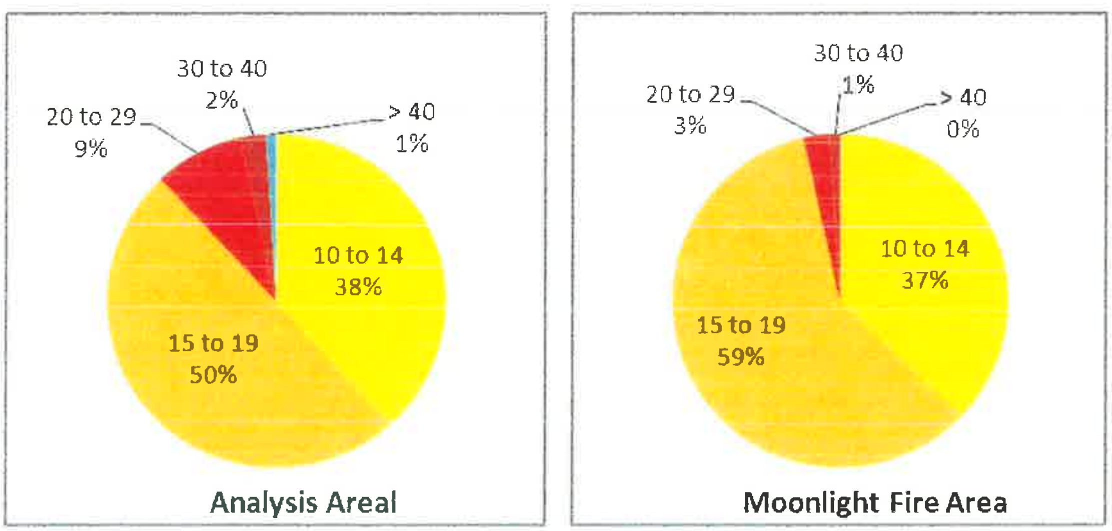

Figure 33. Graph showing the percent within Pre European mean fire return intervals within the analysis area and the Moonlight Fire area. Based on fire return interval departure data compile by Safford and Van De Water (2011).

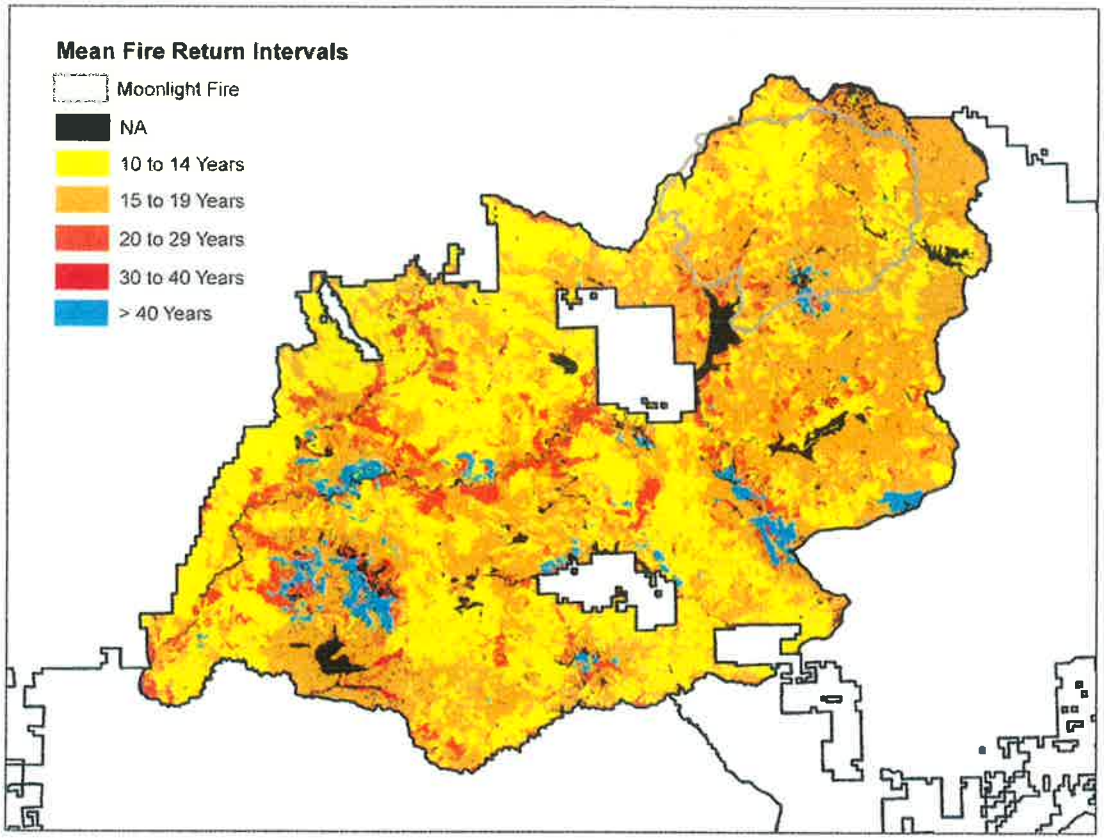

Figure 34. Map showing the distribution of Pre European mean fire return intervals on the Mt. Hough Ranger District and within the Moonlight Fire area (Safford and Van De Water 2011).

3.8.2 Fire Starts

Within the analysis area, the annual average number of fire starts recorded was 66 from 1970 to 2009 (Figure 35). The majority of recorded fire starts, 67 percent, are from lightning strikes. On average, the analysis area receives 427 lightning strikes per year with a general trend of fewer strikes in the west, with gradually increasing strike density as you move to the east (Table 10).

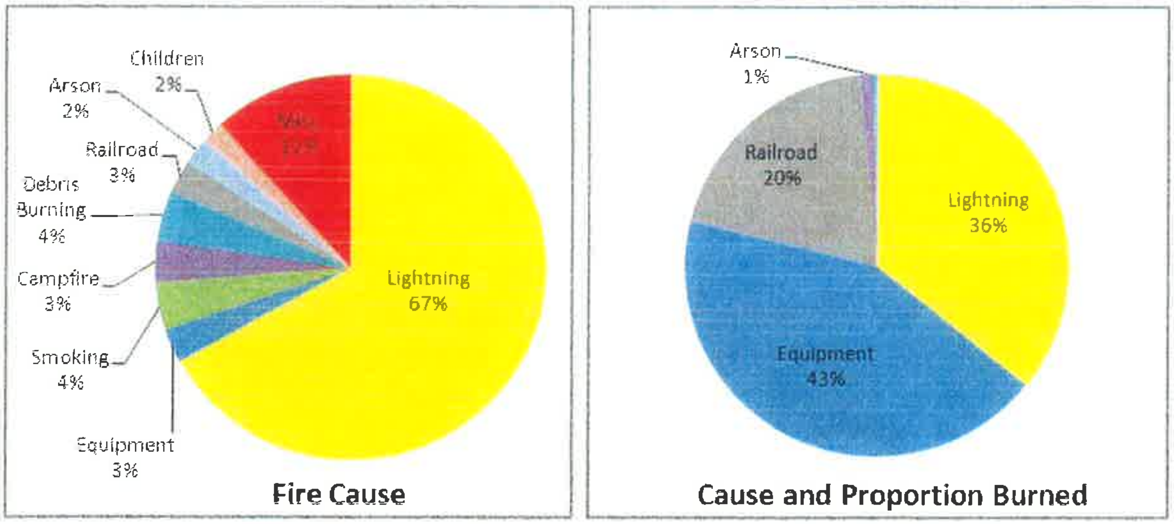

Figure 35. Left: historic fire starts from 1970 to 2009. Right: Proportion of area burned and their associated cause for large fires (>100 acres) from 1980 to 2011

Table 10. Average annual lightning strikes by Ranger District from 1995 through 2009.

Ranger District	Annual Strikes	Annual Strikes per Mile
Feather River	208	0.340
Mt. Hough	427	0.499
Beckwourth	624	0.813

Seasonally, the distribution of lightning strikes is in close alignment with the fire season (Figure 36). The arrival of spring weather systems triggers a sharp increase in lighting activity in May and June. The spring and summer months, from May through August, accounted for 81 percent of the lightning strikes throughout the year. Although lightning strikes account for the majority of fire starts, human caused fire has accounted for the majority of the area burned in recent decades. Fires associated with the railroad and equipment combined account for only six percent of the fire starts, however they are responsible for nearly two thirds of the area burned in recent large fires. It is unclear why this disparity exists. One of the largest contributing factors was the Moonlight Fire itself, which started as the result of heavy equipment use. Another contributing factor may be that in recent years the Forest Service has become exceedingly efficient at hunting down lightning strike fires with the ability to precisely map strike locations almost in real time as weather systems are moving through an area. This combined with aerial scouting has resulted in a 98 percent success rate in keeping lightning fires less than 10 acres in size.

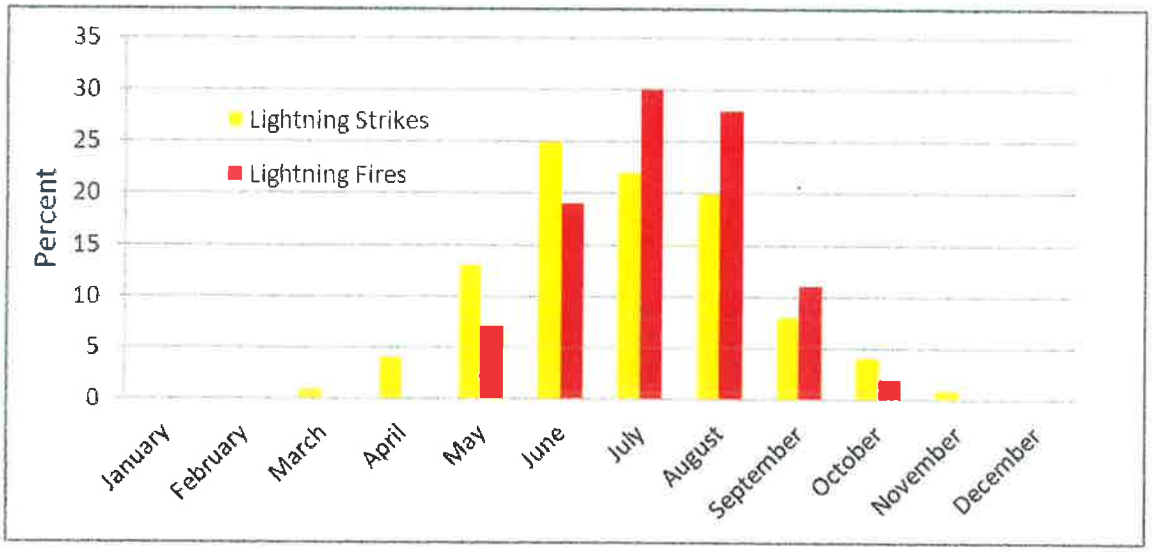

Figure 36. Seasonal distribution of lightning strikes and lightning fires on the Plumas NF from 1995 through 2009

It is unknown if these trends in fire starts and resulting burned areas will continue. However, it is clear that the Moonlight Fire area will be susceptible to reburning due to both lighting and human caused fires in the future.

3.8.3 Historic Fire 1910 to Present

Excluding the large fire complexes of 2007 including the Moonlight Fire, very little fire was historically seen in the vicinity of the Moonlight Fire. Some recent increases in fire activity were seen to the south east with the 2001 Stream Fire (3,524 acres) and 2006 Boulder Fire (2,919 acres). Taken together, these fires generally coincide with the increases in fire activity of the 2000s, with the strongest concentrations in the North Fork of the Feather River Canyon and to a lesser degree the Middle Fork of the Feather River near Lake Oroville Forest wide.

Prior to the Moonlight Fire, the Moonlight Fire footprint had 15 recorded fires from 1917 to 2001 covering a total area of 7,216 acres. Most of these fires were relatively small with an average size of 481 acres. The largest historic fire occurred in 1966 and burned 2,181 acres. Overall, this level of fire activity represents a major departure from pre-settlement fire regimes with 89 percent of the area experiencing no recorded fire for about 100 years prior to the Moonlight Fire.

Although historic fire area data prior to about 1950 may be questionable (Lorrie Peltz-Lewis personal communication 2012), fire size and cumulative area burned has clearly been increasing in recent decades (Figure 37 and Figure 38). In the past decade the analysis area experienced the greatest number of acres burned in recorded history dating back to about 1910, with a cumulative total of 193,914 acres or about 35 percent of the area within the administrative boundary. As large as this number seems, it is important to put it in perspective with what would be expected to burn within a decade prior to fire suppression. This equates to about 366,900 acres burned per decade. This disparity between what would be expected to burn and what has burned creates a vast fire deficit. In the dry forest types of the Sierra Nevada, decomposition via fungus and bacteria is frequently out paced by biomass production. Frequent, low severity fire was the primary ecological process that historically balanced out this equation.

Exacerbating this problem is the fact that by default, management dominated by fire suppression actively manages for high severity wildfire. It is only under the worst case scenarios, when fuels, weather, and topography come into alignment, that fire escapes initial attack. Shoulder season fires, and those occurring in better topography or fuel conditions, may provide ecological benefits, however by the same token they are more easily suppressed. In addition, notable increases in fire activity are predicted for California, driven largely by projected increases in temperature, decreases in snow pack, and to a lesser extent, increased fuel production from CO_2 "fertilization" (Flannigan et al. 2000, Lenihan et al. 2003, Lenihan et al. 2008, Westerling et al. 2011).

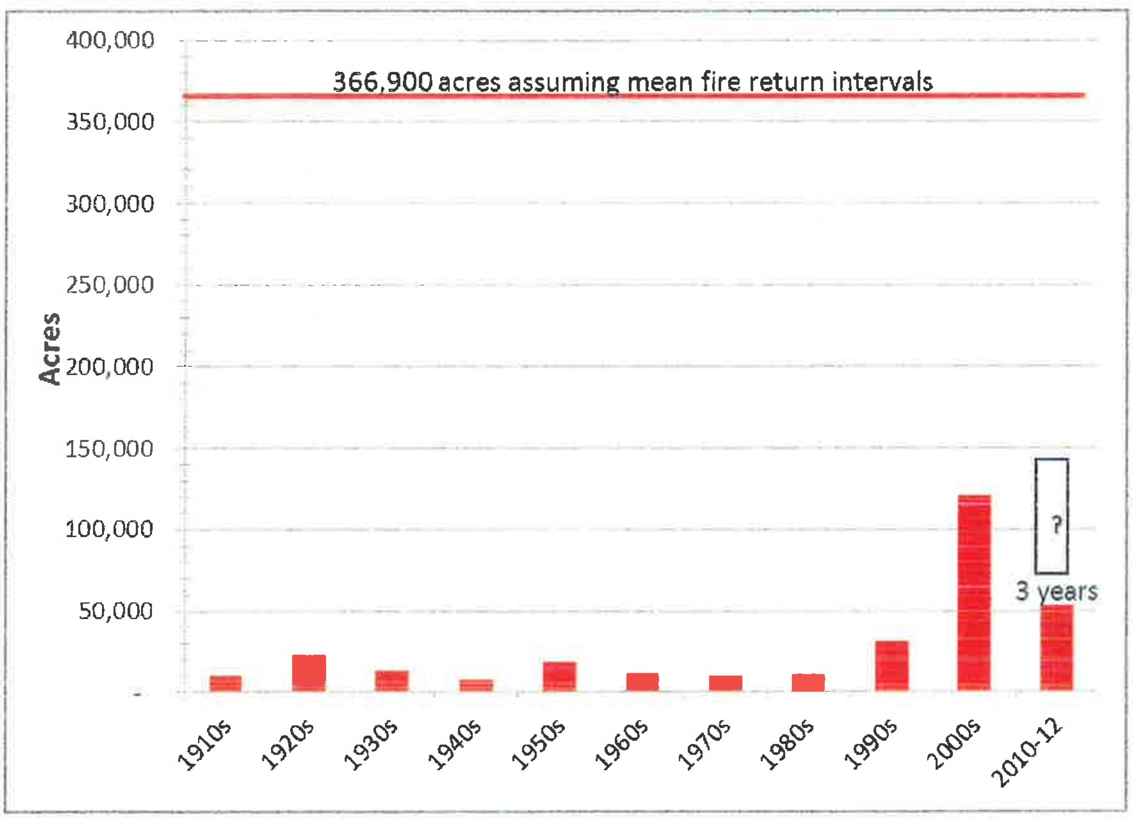

Figure 37. Cumulative acres burned by decade. Last bar only includes the past 3 years and is largely represented by the 2012 Chips fire with question mark above representing the uncertainty about cumulative fire over the rest of the current decade. Line above represents the number of acres that would be expected to burn prior to fire suppression.

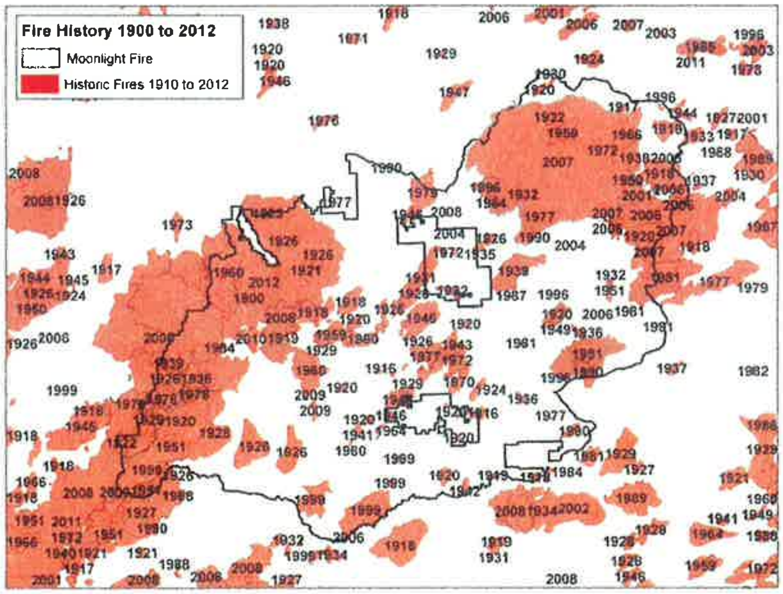

Figure 38. Fire history from 1910 to 2012

3.8.4 Trends and Impacts of Fire Severity

As mentioned above, fire size is not the major concern as we are only now beginning to approach fire areas that are within the pre-settlement natural range of variability (Collins and Stephens, 2010; Collins and Stephens, 2012). The patch size of high severity wildfire is the major concern as this has had a major impact on values such as timber and wildlife habitat (Skinner and Chang, 1996; Scholl and Taylor, 2010). The Moonlight Fire was dominated by large patches of high severity wildfire. Collins and Stephens (2012) found high severity patch sizes ranging from 2,500 to 6200 acres. In addition, when compared to other recent large fires in the analysis area, the Moonlight Fire was particularly severe with an unprecedented 62 percent of the fire area considered high severity (Table 11).

Table 11. Basal Area (BA) mortality for recent high severity wildfires within the analysis area.

Fire	BA Mortality Acres (Percent)				Total Acres
	<25%	25-50%	50-75%	>75%	
Storrie [2000]	8,466 (34%)	2,475 (10%)	2,125 (9%)	11,605 (47%)	24,670
Moonlight-Antelope [2007]	15,609 (19%)	7,509 (9%)	7,117 (9%)	50,301 (62%)	80,537
Chips [2012]	19,984 (39%)	11,969 (23%)	6,434 (12%)	13,102 (25%)	51,488

For an overview of severity trends, data from the Monitoring Trends in Burn Severity Project (http://www.mtbs.gov) was combined with severity data for the recent 2012 Chips Fire. Large fires from 1990 to 2012 were analyzed. Where fires overlap, the highest severity polygons trumped or were "floated to the top" such that no acres were double counted. The resulting dataset shows the greatest impacts of recent fires on the landscape (Figure 39 and Table 12).

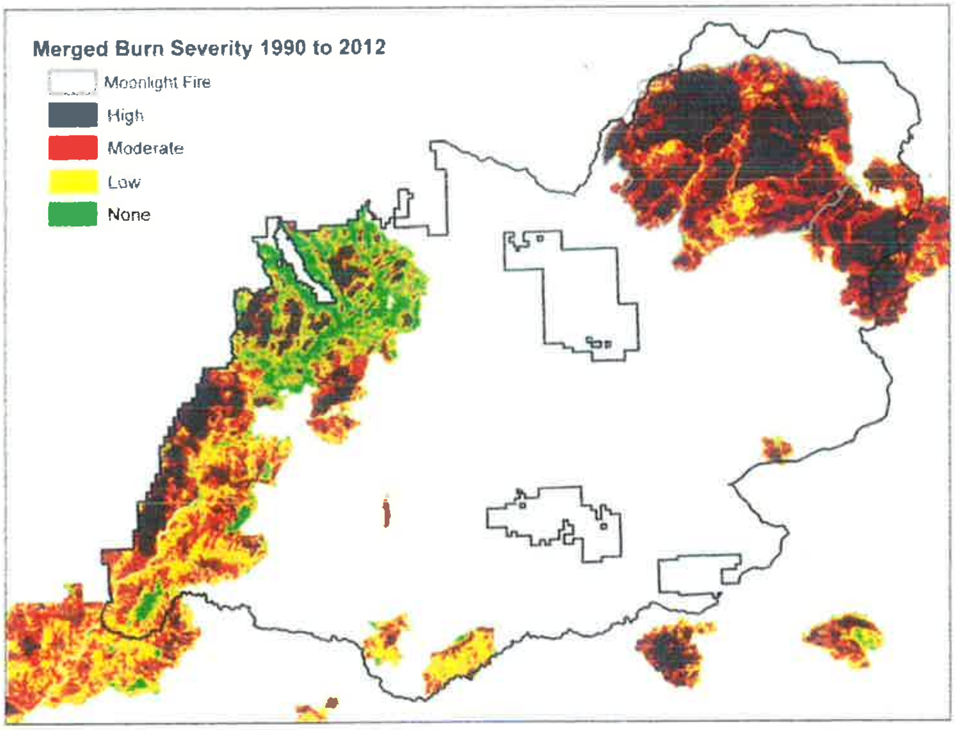

Figure 39. Merged fire severity for fires from 1990 to 2012

Table 12. Merged fire severity from 1990 to 2012; where fires overlapped in area, higher severity trumped.

Ranger District	High	Moderate	Low	No Impact	Total
Beckwourth	26,959	25,581	12,739	3,497	68,776
Feather River	10,110	20,802	36,474	4,706	72,091
Mt. Hough	76,048	45,358	41,122	21,739	184,267
Total	**113,116**	**91,741**	**90,335**	**29,942**	**325,134**

Intersecting this severity data set with other resource allocations also yields interesting results. For example, when intersected with Old Forest Emphasis areas, about 57,685 acres of this land allocation has been lost or degraded by wildfire on the Mt. Hough Ranger District. This represents nearly one third of this land designation and a significant decline in habitat for old forest dependent species such as the pine marten, California Spotted Owl, and the Northern Goshawk.

3.8.5 Current Fire Risk

In addition to the impact of recent fires, wildfire danger and the risk of future damage to resources remains high, especially in unburned areas outside of the Moonlight Fire footprint (Figure 40 and Figure 41). FlamMap 5 was used to predict fire behavior and movement across the landscape under high fire danger conditions. Model inputs included fuel model and topography data from Land Fire Refresh 2008. District Fire Management Staff also provided expert opinions on fire weather and fuel moisture content parameters (Table 13). Overall, fire danger within the District remains extremely high, with 52 percent of the area susceptible to flame lengths greater than 12 feet high. Under these conditions crowning, spotting and major fire runs are probable and control efforts are largely ineffective (Table 14).

Table 13. High fire danger FlamMap 5.0 inputs

1hr	10hr	100hr	Herbaceous	Woody	20 foot wind speed (MPH)	Direction (degrees)
2%	3%	6%	30%	70%	15	225

Table 14. Fire Behavior Hauling Chart; tactical interpretation for flame length

Flame Length	Interpretation	
Less than 4 feet		Fires can generally be attacked at the head or flanks by firefighters using hand tools. Handline should hold fire.
4 to 8 feet		Fires are too intense for direct attack on the head with hand tools. Handline cannot be relied on to hold the fire. Dozers, tractors-plows, engines and retardant drops can be effective.
8 to 11 feet		Fires may present serious control problems: torching, crowning, and spotting. Control efforts at the head will probably be ineffective.
Over 11 feet		Crowning, spotting, and major fire runs are probable. Control efforts at the head of the fire are ineffective.

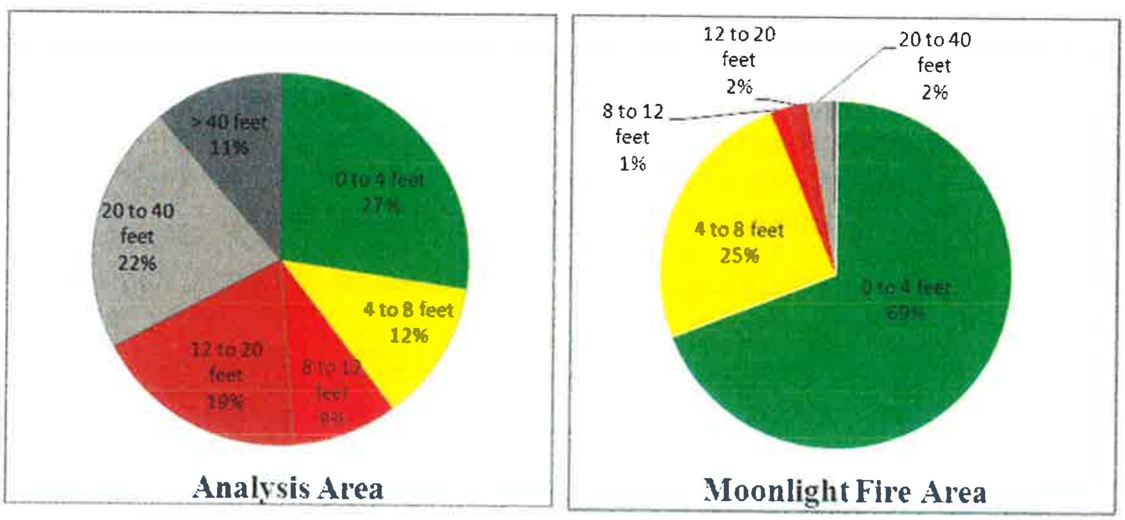

Figure 40. Graph showing FlamMap 5.0 predicted flame lengths under high fire danger conditions

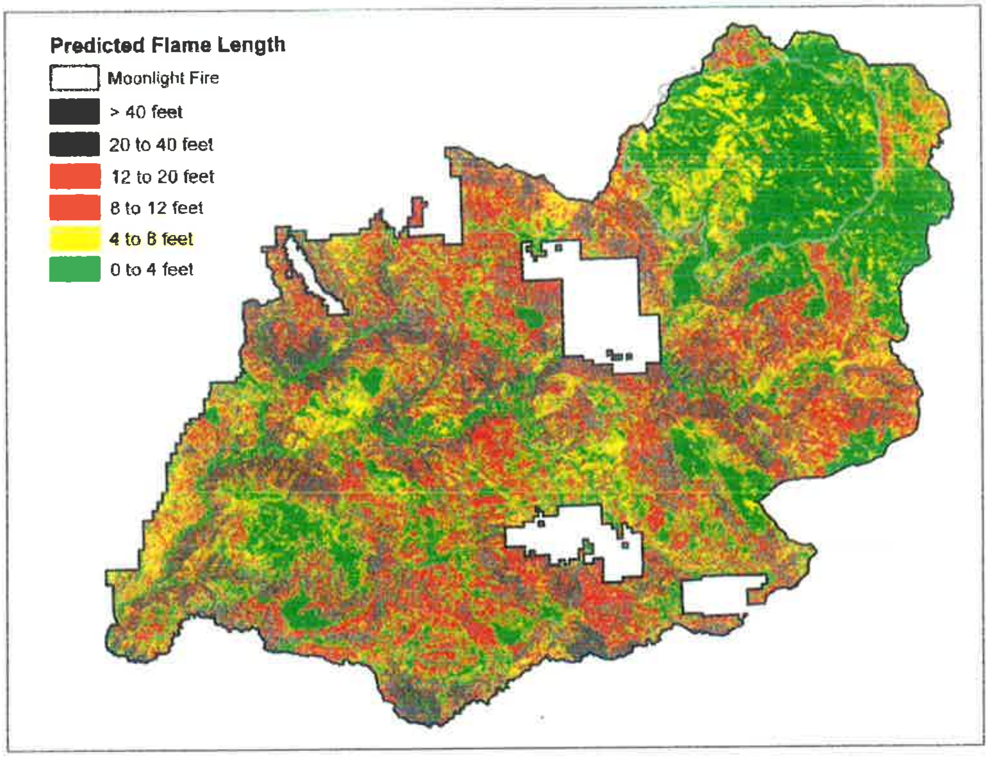

Figure 41. Map showing FlamMap 5.0 predicted flame lengths under high fire danger conditions

In contrast, fire danger within the Moonlight Fire footprint is considerably reduced (Figure 41). This result may be misleading as Land Fire Data used was only one year post-fire. In terms of the risk of re-burning, some lessons may be learned by looking at the overlap between the 2000 Storrie Fire and the 2012 Chips Fire (Table 15). Even though these fires were only 12 years apart, the proportion of high severity within this overlap was still relatively high at 32 percent. In fact, many remnant conifer stands that persisted after the Storrie Fire were subsequently lost in the Chips Fire, widening forest gaps and eliminating conifer seed sources.

Table 15. 2012 Chips Fire Basal Area mortality within the overlap of the 2000 Storrie Fire.

BA Mortality Acres (Percent)				Total Acres
<25%	25-50%	50-75%	>75%	
12,767 (52%)	1,898 (8%)	1,864 (8%)	7,812 (32%)	24,340

In part, some of the re-burn severity in Chips may be a result of the large accumulation of surface fuels and woody debris that resulted from the first fire event. In many high severity areas 12 years after the Storrie Fire, fuel loads were represented by high snag densities, thick shrubs as high as 5 feet tall, and a complex arrangement of fallen trees, broken tops and branches intermixed and suspended within a heavy shrub component (Figure 42). It is estimated that overall fuel loading could be as high as 200 tons per acre (Powers et al. 2013).

These elevated fuel loads and associated risk may persist for more than half a century (Figure 43). Currently, no fuel model exists to describe this complex arrangement of fuels and this condition is becoming ever more common as the size and severity of fires continues to increase within the region.

Figure 42. Left: Post 2000 Storrie Fire conditions captured 12 years after the fire. Right: Same frame taken 22 days after the Chips Fire passed through this site on August 1st 2012

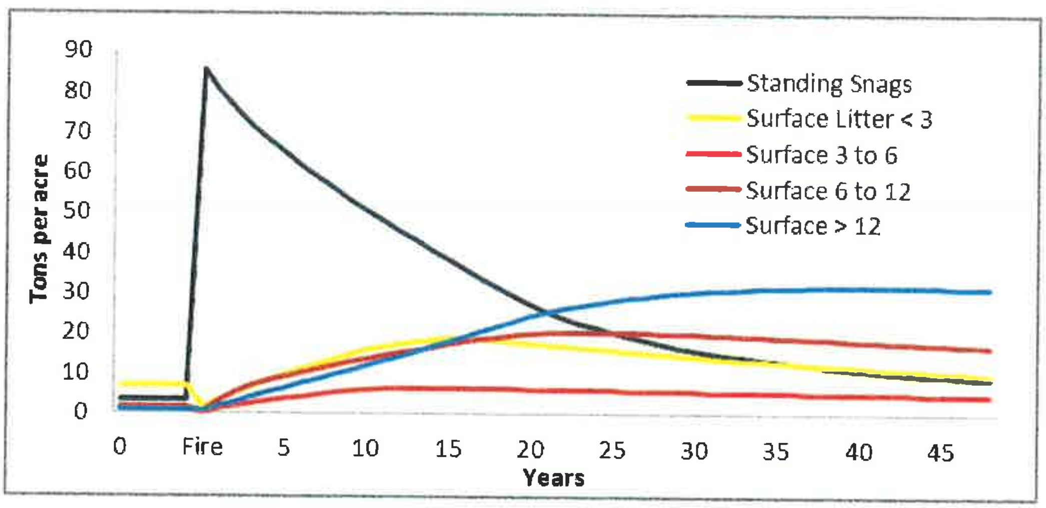

Figure 43. Fuel loading over time after stand replacing wildfire with no treatment. Representative mixed conifer stand chosen for Forest Vegetation Simulation was well to over stocked with a dense understory. Trees per acre = 450, basal area = 275, merchantable board feet = 30,000, quadratic mean diameter = 10.5

Much of the Moonlight Fire area may be susceptible to similar secondary fire events particularly in areas where no salvage or fuels work has been implemented. About 10,300 acres (16 percent) of the Moonlight Fire area was salvaged and these salvaged areas typically left logging slash and smaller snags 12 to 14 inches in diameter.

3.9 Past and Present Wildlife Habitat Conditions

The wildlife section of this restoration strategy is both a compilation of existing information, as well as some new analysis. Much of the following information was taken from a report written by Rotta (2011) titled *Assessment of Impacts of the Moonlight Fire on Sensitive Wildlife Species Habitat*. In addition, data and narratives were borrowed from: the *Diamond Landscape Assessment* (USDA 2005), the *Biological Evaluation for the Moonlight-Salvage FEIS* (Collins 2009a), and the *Management Indicator Species report for the Moonlight-Salvage FEIS* (Collins 2009b).

The Moonlight Restoration Strategy wildlife analysis area used includes the Moonlight Fire and the adjacent Wheeler Fire area and all of the HUC 12 watershed boundaries that overlap with the fire perimeters (Figure 44), but excludes the overlap with the Lassen NF in a different watershed. In many cases, information borrowed from existing reports used either the Moonlight Fire footprint (Rotta 2011) or the Moonlight and Antelope Complex fire footprints combined (Collins 2009a, Collins 2009b, Keane et al. 2011). When these different analysis areas are used, they are noted.

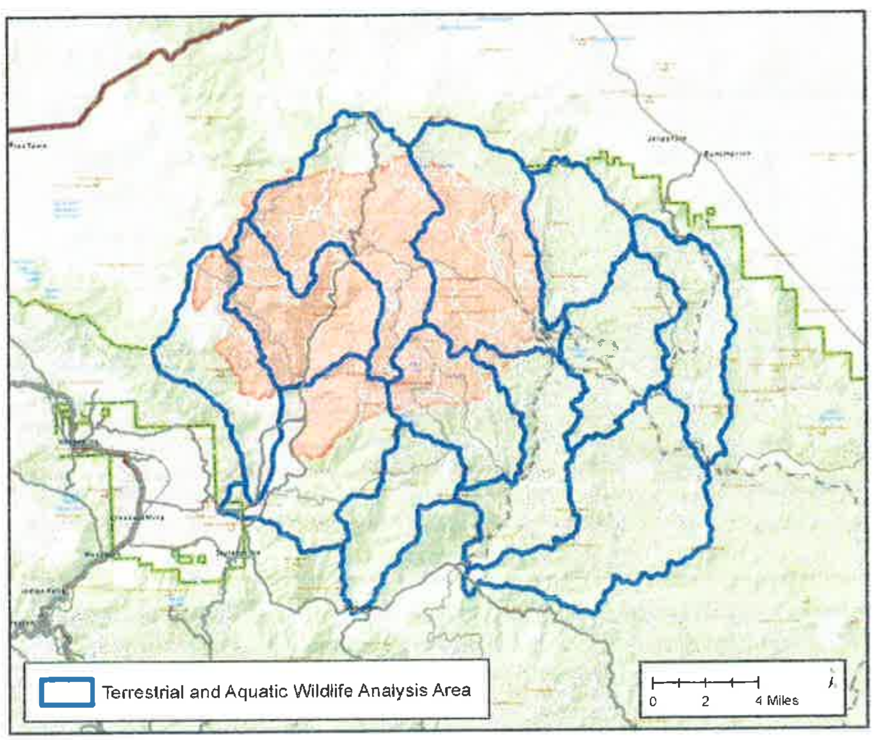

Figure 44. Analysis area for wildlife habitat restoration; maps displays the affected watersheds (analysis area) and the spatial relationship and severity of the 2007 Moonlight Fire and adjacent wildfires.

Although historic vegetation data from the analysis area is limited, vegetative conditions for adjacent areas are available (varying between 3-20 miles from the analysis area; see section 3.2.1 for details). Based on the congruence of historical vegetation data, precipitation patterns, and prior modeling efforts, we assume that much of the area affected by the fire was historically yellow pine dominated forest along with dry mixed conifer forest (Moody 2002, Taylor 2008, see section 3.2.1 for details). Yellow pine forest in the analysis area likely transitioned to Sierra mixed conifer forest in areas with higher annual precipitation (i.e. in the western portion of the analysis area), and true fir forests likely occurred at higher elevations and along more mesic northern aspects. Under a natural fire regime, it is estimated that roughly half of forests in the analysis area would have been in relatively later seral stages (Figure 10, see section 3.2.1 for details). Modeling efforts also predicted that both mid and late seral stages also would have had an open canopy structure (Figure 10, Safford 2013).

Prior to the Moonlight and Antelope Complex fires, the analysis area consisted primarily of pine-dominated Sierra mixed conifer forests, true fir forests at higher elevations, and plantations (less than 50 years old). Forest management during the preceding century decreased landscape level forest heterogeneity compared to historic levels by reducing dominant and codominant overstory trees, retaining smaller diameter trees (via selective harvest and fir suppression), and a resultant shift in forest species composition to a greater representation of shade tolerant species (i.e., white fir). Compared to historic conditions, pre-fire forests within the analysis area contained denser stands of smaller diameter trees (primarily Sierra mixed conifer rather than historic yellow pine forests) and copious amounts of ground and ladder fuels (see section 3.2.1 for details).

The Moonlight and Antelope Complex fires resulted in a rapid shift in forest vegetation types within the analysis area. Conifer forests dominated by long lived tree species and characterized by frequent low severity fire regimes were converted to shrublands dominated by montane chaparral species (relatively short lived) with infrequent high severity fire regimes (Figure 12). Although montane chaparral is an ecologically important early seral habitat type in this area; wildlife that previously utilized mid and late seral conifer forest habitat (Sierra mixed conifer, true fir, yellow pine) in the area experienced considerable habitat loss (Figure 13). Further, the level of fuels that exist within conifer forests that were not converted to shrublands post-fire (i.e., forests that did not burn at high severity, approximately 30 percent of the area that burned), coupled with the high-severity fire regime associated with shrublands increases the risk of high severity fire returning to the analysis area and further reducing conifer forest habitat for wildlife species (Westerling and Bryant 2008, Thompson et al. 2007). Thus, remaining conifer forest stands in the analysis area are vulnerable to future high severity fire events. Aside from additional reductions to wildlife habitat for mid and late seral forest species, further loss of conifer forest to fire would reduce seed source availability near shrublands (limiting forest regeneration) and reduce forest heterogeneity and increase mid and late seral habitat fragmentation. Although high severity fire (basal area mortality greater than 50 percent) reduced habitat availability for wildlife associated with mid and late seral conifer forests, low to moderate severity fire (basal area mortality less than 50 percent) also modified these forest types by the increasing snag recruitment over time (which in the future would lead to more downed logs) and encouraging understory growth (a key habitat component for many species) by opening up overly dense forest stands.

The availability of snags and large down woody debris on the landscape is critical for numerous wildlife species (i.e., availability of cavity and den sites). The average tonnage of woody debris within the analysis area will fluctuate over time as trees killed in the Moonlight Fire perimeter fall over. Further, live green trees isolated by the fire could also be more susceptible to wind throw. The rate of snag fall varies with DBH and species and the rate of downed log decay varies with size species (Lyon 1977, Raphael and Morrison 1987, Cluck and Smith 2007). Snag fall rates are highest the first ten years within the smaller diameter classes, while larger snags persist for relatively longer time periods (Cluck and Smith 2007). The majority of snags resulting from the Moonlight and Antelope Complex fires are expected to fall within approximately 20 years post-fire. Additional snag recruitment would be expected through delayed mortality from live trees that initially survived the fire.

Due to habitat changes as a result of the fire, wildlife occupying habitat that was lost during fires was displaced into adjacent areas that may be of lower quality habitat or currently occupied. This may cause stress to the individuals occupying the current areas and the individuals being displaced. Competition for available resources may lead to the death of individuals, reduction in the health of individuals, and/or reduction in reproductive success of individuals. Such displacement effects may have already occurred and continue to occur within the analysis area.

3.9.1 Late Seral Forests and Associated Species

Large scale, high severity wildfire, exhibited in the Moonlight and Antelope Complex fires resulted in long-term harmful effects to late seral forest species as forest stands containing large trees and multiple canopy layers that were lost to fire will not be replaced for over a century (i.e., California spotted owl, *Strix occidentalis*; northern goshawk, *Accipiter gentilis*; American marten, *Martes americana*).

3.9.1.1 California Spotted Owl

The California spotted owl occurs in mixed-conifer and hardwood forests throughout the Sierra Nevada and the mountain ranges of Southern California (Verner et al. 1992). Spotted owls nest in tree cavities, generally in conifer and mixed conifer-hardwood forests with dominant and co-dominant trees in the canopy averaging at least 24 inches in DBH with at least 70 percent total canopy cover, higher than average levels of very large old trees, and higher than average levels of snags and downed woody material, provides habitat for California spotted owl nesting, and roosting, in the Sierra Nevada (USDA 2001). Definitions of suitable habitat are derived from those listed in Verner et al (1992), SNFPA (USDA 2004), and 70 Federal Register, June 21, 2005.

The Moonlight Fire resulted in habitat loss and large scale openings that fragmented suitable nesting, foraging and dispersal habitat for spotted owls. Conversely, in some low burn severity areas that support live trees and forested canopy there likely would be a short-term increase in snag availability that could provide additional nesting structures of owls. Further, increases in forest down wood component will benefit owl prey species. Increased habitat edge, between non-burned middle to late seral forest and burned early seral habitat may provide excellent foraging opportunities for spotted owls. Although California Spotted Owls require late-seral forest habitat, owls do exploit resources on post-fire landscapes. Recent studies have reported California Spotted Owls may select forest patches that burned at high severity for foraging over adjacent green forest habitat (Bond et al. 2009), and that high severity fire may burn over 30% of suitable habitat in a spotted owl breeding site without reducing the probability of site occupancy (Lee et al. 2012). The only edge habitat available for late seral species, such as spotted owls, to exploit is on the fire perimeter where high, medium and low severity patches occur adjacent to unburned habitat outside the fire perimeter.

As a result of the high severity burn within the Moonlight Fire, late seral closed canopy habitat (spotted owl nesting habitat) decreased 96 percent from pre-fire conditions, and total available spotted owl habitat (nesting and foraging) was reduced by 91 percent (Table 16).

Table 16. Effects of Moonlight Fire on Spotted Owl Suitable Habitat within the Moonlight Fire landscape (all acres approximate and all are NF)

Habitat*	**Pre-Fire Acres**	**Post-Fire Acres**	**Reduction in Suitable Acres**	**Reduction in Suitable Habitat (%)**
Suitable Nesting Habitat (5M, 5D, 6)	13,876	501	13,375	96%
Suitable Foraging Habitat (4M, 4D)	18,029	2,517	15,512	86%
Total	31,905	2,018	28,887	91%

*CWHR tree habitat: SMC, PPN, WFR, RFR. 5M = trees >24 inch DBH, 40-59% canopy cover; 5D = trees >24 inch DBH, >60% canopy cover; 6 = size class 5 trees over a distinct layer of size class 4 or 3 trees, total tree canopy exceeds 60% closure; 4M = trees 11-24 inches DBH, 40-59% canopy cover and 4D = trees 11-24 inches DBH, >60% canopy cover.

The SNFPA Record of Decision (USDA 2004) provides direction for spotted owl management, including Protected Activity Center (PAC) and Home Range Core Area (HRCA) delineation. California spotted owl PACs are delineated surrounding each territorial owl activity center detected on NFS lands since 1986. PACs are delineated to include known and suspected nest stands and to encompass the best available 300 acres of habitat in as compact a unit as possible. Home Range Core Areas (HRCAs) are established to surround each spotted owl PAC. On the Plumas NF, each HRCA is to be 1000 acres, which includes the 300 acre PAC. These HRCAs encompass the best available owl habitat in the closest proximity to the owl activity center; HRCAs are delineated within 1.5 miles of the activity center.

All or a portion of nineteen spotted owl PACs and their associated HRCAs were located within the perimeter of the Moonlight Fire (USDA 2008). As noted earlier, recent studies have reported California Spotted Owls may select forest patches that burned at high severity for foraging over adjacent green forest habitat (Bond et al. 2009), and that high severity fire may burn over 30% of suitable habitat in a spotted owl breeding site without reducing the probability of site occupancy (Lee et al. 2012). However, 17 of the 19 spotted owl PACs affected by the Moonlight and Antelope Complex fires have been rendered unsuitable due to high severity wildfire effects and have been removed from the PNF PAC distributional network

(USDA 2008). Narrow corridors of dispersal habitat, primarily provided by riparian habitat along creeks, within the fire area may still allow for owl dispersal across the area, but the combination of the Moonlight and Antelope Complex fires may have significantly reduced owl dispersal across the landscape in northeastern Plumas County. Based on the evidence above, the Moonlight Fire resulted in long-term habitat loss and fragmentation that will impede dispersal into, use of, and occupancy of, this area by California spotted owl and creates a potential barrier to habitat connectivity.

Future risk to spotted owl habitat

To investigate the risk of wildfire impacting spotted owl habitat in the future (i.e., loss of existing habitat to future wildfires) we modeled fire within the analysis area (and Mt Hough RD) to predict potential fire behavior and movement across the landscape (see section 3.8.5, Current Fire Risk, for details).A modeled fire burning during moderate weather conditions would be expected to burn 56 percent of PACs at high severity (flame length greater than 12 feet), and 25 percent of PACs at low severity (4-8 foot flame length) (Table 17). For context, another analysis at a larger scale was conducted across the Mt Hough Ranger District; this analysis found that 77 percent of the acres within PACs would likely burn at high severity under moderate weather conditions, an additional seven percent would burn at moderate-high severity (8-12 foot flame length), and additional four percent would burn at moderate severity (Figure 45).

Table 17. Predicted burn severity of California spotted owl PACs within the wildlife analysis area. Spotted Owl PACs with less than 50 percent of the acres in low severity category are at high risk for loss during the next wildfire. Predicted burn severity was modeled using moderate fire weather conditions (see section 3.8.5, Current Fire Risk, for model details).

PAC #	% by predicted burn severity (flame length)			
	Low Severity (0 to 4 feet)	Moderate Severity (4 to 8 feet)	Mod-High Severity (8 to 12 feet)	High Severity (>12 feet)
PLU0071	89	4	2	5
PLU0072	22	11	14	53
PLU0085	14	6	20	60
PLU0107	58	8	5	29
PLU0109	33	7	4	57
PLU0130	2	2	9	86
PLU0131	6	14	21	59
PLU0167	43	14	12	32
PLU0200	5	4	12	80
PLU0210	6	1	7	86
PLU0220	56	17	10	17
PLU0230	13	14	12	60
PLU0241	7	1	3	89
PLU0258	6	6	5	84

PAC #	% by predicted burn severity (flame length)			
	Low Severity (0 to 4 feet)	**Moderate Severity (4 to 8 feet)**	**Mod-High Severity (8 to 12 feet)**	**High Severity (>12 feet)**
PLU0286	20	10	9	61
PLU0287	27	9	18	47
PLU0301	51	14	15	20
PLU0355	10	11	12	66
Grand Total	**25**	**8**	**10**	**56**

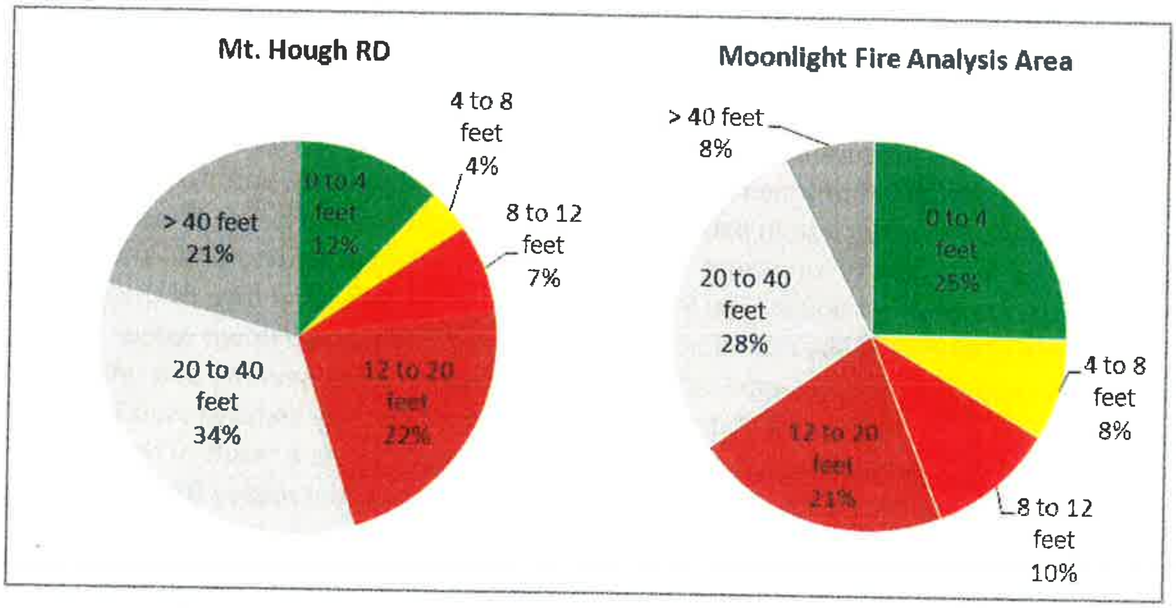

Figure 45. Predicted flame length within existing Spotted Owl PACs when wildlife was modeled across the analysis area and the entire Mt Hough Ranger District. Desired conditions are for at least 50 percent of the acreage to be in low fire severity condition (green) with no more than 25 percent of acres in moderate to high severity conditions (red and gray). See section 3.8.5, Current Fire Risk, for model details.

To provide evidence to show that this modeling effort is valid, the following information shows that actual wildfires have burned spotted owl PACs in similar severity to the results of this modeling effort. In their assessment of the Moonlight Fire Dailey et al. (2008) found that 68 percent of the total spotted owl PAC and HRCA acreage had 75-100 percent canopy cover loss (high severity). This modeling effort found that 56 percent of PAC acres in adjacent unburned watersheds would likely burn at high severity. Dailey et al. (2008) also found that PAC and HRCA acres were burned at higher burning intensity than other untreated areas. They also found that areas treated with a combination of thinning and prescribed burning showed the greatest ability to reduce burning intensity. Dailey et al. (2008) recommended treating in protected areas to enable these sites to withstand fire with lesser effects. Spotted owl PACs should be prioritized for treatment, with those with the highest percent predicted to burn at high severity ranking highest for treatment to reduce fire risk.

3.9.1.2 Northern Goshawk

The Northern goshawk requires mature conifer and deciduous forest with large trees, snags, and downed logs, dense canopy closure for nesting. Goshawks use forests with moderately open canopy and understory vegetation interspersed with meadows, brush patches, or other natural or artificial openings and riparian areas for foraging. Studies indicate that goshawks typically select for canopy closures greater than 60 percent for nesting (Hall 1984, Richter and Callas 1996, Keane 1997). Goshawks usually nests on north slopes, near water, in the densest parts of stands, but close to openings (CDFG 2006). Goshawks construct stick nests generally located in live conifer or hardwood trees, although nests are sometimes placed in snags, and these nest trees are commonly among the largest trees in a stand (USDA 2001). The following forest types, typical of the restoration area prior to the fire, provide high nesting and feeding habitat capability when composed of medium (11-24 inches DBH) and large (greater than 24 inches DBH) tree with greater than 40 percent canopy cover: Sierran mixed conifer, white fir, red fir, ponderosa pine, lodgepole pine, and eastside pine (SNFPA FEIS Vo1.3, Chap.3, part 4.4 p. 116).The Moonlight and Antelope Complex fires resulted in long-term harmful effects to goshawk habitat due to reduction in existing large tree component and dense forested stand structure, as well as a short to long-term reductions in availability of structural diversity provided by mature conifer habitat. The foraging goshawk can take advantage of the short-term increase in prey availability resulting from the increase in snag and down wood component throughout the burn, especially on edges adjacent to low severity and unburned habitat. However, wildfires the size and severity of the Moonlight Fire usually result in habitat loss and large scale openings, fragmenting suitable nesting habitat. As a result of the high severity burn within the Moonlight Fire, potential goshawk habitat decreased 91 percent from pre-fire conditions (Table 18).

Table 18. Effects of Moonlight Fire on Goshawk Habitat (all acres approximate and all are NFS lands).

Habitat	**Pre-Fire Acres**	**Post-fire Acres**	***Reduction in suitable habitat***
*Suitable Habitat (5M, 5D,4M, 4D)**	*31,905*	*3,018*	*28,887 acres* *91% reduction*

**Sierra mixed conifer, ponderosa pine, white fir, red fir, lodgepole and eastside pine forest types. 5M = trees >24 inch DBH, 40-59% canopy cover; 5D = trees >24 inch DBH, >60% canopy cover; 6 = size class 5 trees over a distinct layer of size class 4 or 3 trees, total tree canopy exceeds 60% closure; 4M = trees 11-24 inches DBH, 40-59% canopy cover and 4D = trees 11-24 inches DBH, >60% canopy cover.

The SNFPA ROD (USDA 2004) provides direction for goshawk management and Protected Activity Center (PAC) delineation. Goshawk PACs are delineated surrounding all known and newly discovered breeding territories detected on NFS lands. PACs are delineated to include known and suspected nest stands and to encompass the best available 200 acres of habitat in the largest contiguous patches possible.

All six goshawk PACs located within the Moonlight Fire were severely impacted by the Moonlight Fire. Five of six goshawk PACs burned at moderate to high severity (greater than 50 percent basal area mortality) over 60 percent of the PAC. The fire rendered most potential habitat within each PAC unsuitable with high severity burn areas converted to brush fields and lower severity burn areas experiencing a reduction in canopy closure to 25-39 percent.

Although goshawks may take advantage of the short-term increase in prey availability resulting from the increase in snag and down wood component throughout the burn (especially on edges adjacent to low severity and unburned habitat), all six PACs within the Moonlight fire were rendered unsuitable due to high severity wildfire effects and have been removed from the PNF PAC distributional network . Within the Moonlight Fire perimeter, low quality habitat suitable for nesting goshawks may not be available for 80-100 years. High quality habitat with the stand structure and tree size capable of providing goshawk habitat that was present prior to the Moonlight Fire is not expected for 150+ years.

Future risk to goshawk habitat

To investigate the risk of wildfire impacting residual goshawk PACs in the analysis area (i.e., loss of existing PACs to future wildfires, N = 7) we modeled fire within the analysis area (and Mt Hough RD) to predict potential fire behavior and movement across the landscape (see section 3.8.5, Current Fire Risk, for details). Despite not using severe fire weather conditions in these models, four of seven PACs were predicted to have had greater than 60 percent of the acreage burn at high fire severity during the next fire event (Table 19 and Figure 46).

Table 19. Predicted burn severity of northern goshawk PACs within the wildlife analysis area. Goshawk PACs with less than 50 percent of the acres in low severity category are at high risk for loss during the next wildfire. Predicted burn severity was modeled using moderate fire weather conditions (see section 3.8.5, Current Fire Risk, for model details).

Goshawk PAC #	% by predicted burn severity			
	Low Severity (0 to 4 feet)	Moderate Severity (4 to 8 feet)	Mod-High Severity (8 to 12 feet)	High Severity (> 12 feet)
T02	13	1	6	80
T05	25	5	8	63
T30	70	6	15	9
T31	3	4	12	81
T45	49	21	12	17
T47	66	14	12	8
T50	10	10	11	69

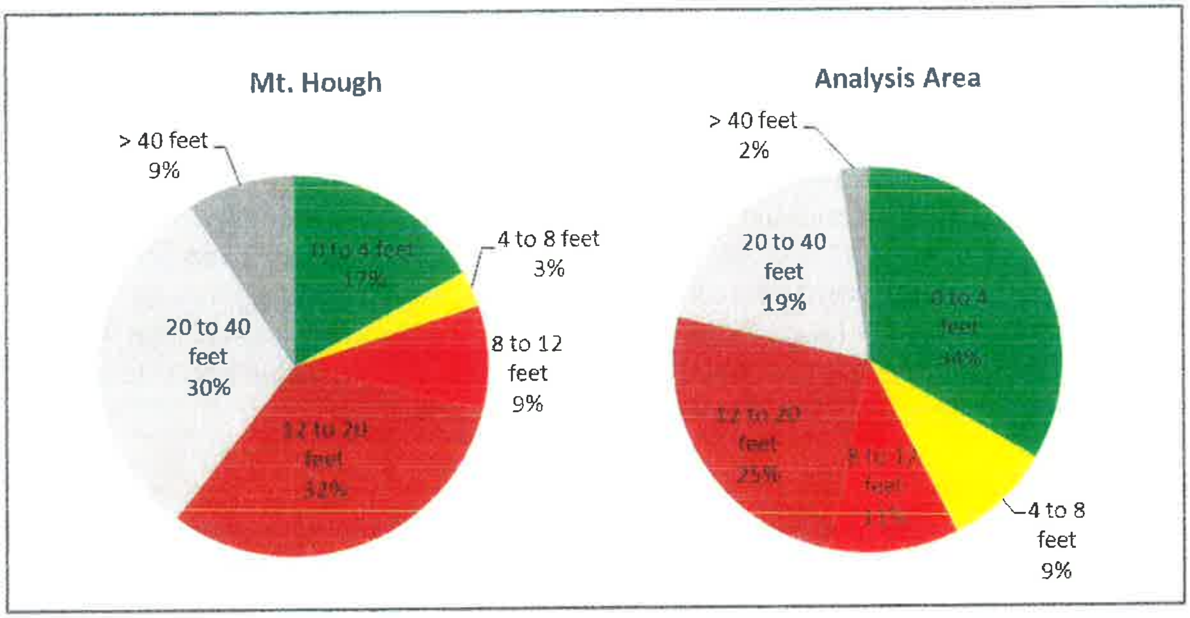

Figure 46. Predicted flame length within existing northern goshawk PACs when wildlife was modeled across the analysis area and the entire Mt Hough Ranger District. Desired conditions are for at least 50 percent of the acreage to be in low fire severity condition (green) with no more than 25 percent of acres in moderate to high severity conditions (red and gray). See section 3.8.5, Current Fire Risk, for model details.

3.9.1.3 Mesocarnivores (American Marten and Pacific Fisher)

Habitat requirements for forest carnivores can be found in California Wildlife Habitat Requirements (Zeiner et al. 1990), habitat capability models (Freel 1991) and in Ruggerio et al. (1998). Large trees, large snags, large down wood and higher than average canopy cover are important habitat attributes for fisher, and a vegetated understory and large woody debris appear to be important for their prey species. Preferred fisher forest types include: Aspen, Douglas-fir, Eastside Pine, Jeffrey Pine, Lodgepole Pine, Montane Hardwood, Montane Hardwood-Conifer, Montane Riparian, Ponderosa Pine, Red Fir, Sierran Mixed Conifer, Subalpine Conifer and White Fir. In the Sierra Nevada, marten are most often found above 7,200 feet, but the species core elevation range is from 5,500 to 10,000 feet (USDA 2001b). Martens prefer coniferous forest habitat with large diameter trees and snags, large down logs, moderate-to-high canopy cover, and in interspersion of riparian areas and meadows. Martens generally avoid habitats that lack overhead cover; they select stands with 40 percent canopy cover for both resting and foraging and usually avoid stands with less than 30 percent canopy cover. Foraging areas are generally in close proximity to both dense riparian corridors (used as travel ways), forest meadow edges, and include an interspersion of small (less than 1 acre) openings with good ground cover used for foraging. Important forest types for marten include mature mesic forests of Aspen, Douglas-fir, Eastside Pine, Jeffrey Pine, Lodgepole Pine, Montane Riparian, Ponderosa Pine, Red Fir, Sierran Mixed Conifer, Subalpine Conifer and White Fir. The red fir zone forms the core of marten occurrence in the Sierra Nevada.

Approximately 65 percent of the PNF has been systematically surveyed, by the Pacific Southwest Research Station (PSW), district biologists/wildlife technicians and contractors, to protocol for mesocarnivores using track plates and camera stations (American Marten, Fisher, Lynx and Wolverine: Survey Methods for Their Detection; Zielinski and Kucera 1995). To date, there have been no fisher observations on the PNF, but reintroduction efforts on adjacent private lands have used radio transmitters to track individuals making forays onto the forest. All confirmed sightings (photograph, tracks, hair sample, sighting by reputable biologist) of American marten on PNF occur within three areas: the Lakes Basin-Haskell Peak area, Eureka Ridge area, or around Little Grass Valley Reservoir.

Open roads and improperly closed roads adversely affect mesocarnivores by: allowing access to areas and causing disturbance to these animals from human intrusion and removal of snags and downed logs through wood gathering activities; increasing vehicle/animal encounters resulting in road-kill; and fragmenting the habitat and affecting the ability of animals to use otherwise suitable habitat on opposing sides of the road (Duncan Furbearer Interagency Workgroup 1989). There may be a threshold value for road density (miles of open road per square mile) above which the habitat cannot sustain certain wildlife species but studies specifically addressing these effects on marten or fisher have not yet been addressed (USDA 2001a,b). Early habitat models (Freel 1991) indicated that to provide high habitat capability for marten, open road densities should be less than 1mile/square mile, while 1-2 miles/square mile provided moderate habitat capability; more than 2 miles was providing low-no habitat capability. Models indicate that open road densities should be less for pacific fisher. The approximate road density within the analysis area currently ranges between 1.25 and 2.94 miles of open road per square mile (see section 3.13, Past and Present Hydrological Conditions, for additional details).

We previously discussed the extensive loss of late seral closed canopy forest, mesocarnivore habitat, within the analysis area during the Moonlight Fire. Hardwood and hardwood-conifer forest types (approximately three percent of the analysis area prior to the fire) also provided potential mesocarnivore habitat. However, the fire resulted in a reduction in the number of acres of hardwood vegetation classified as closed stands (40 percent or greater canopy closure) by almost 23 percent. Prior to the Moonlight Fire, there were no hardwoods in the seedling stage; however post fire vegetation mapping has identified nearly 1,000 acres of hardwood seedlings, suggesting the fire promoted hardwood sprouting (see section 3.3, Past and Present Conditions: Hardwood Forest).

Although no comprehensive inventory of aspen distribution and condition has been made on the forest, PNF has identified 568 aspen stands in the analysis area, approximately 1,962 acres. Fire generally promotes aspen sprouting, and photo monitoring indicates that aspen stands have responded favorably to other fires in the analysis area, such as the Stream Fire in 2001. Although the Moonlight Fire may have promoted aspen sprouting and kill competing conifers that can suppress aspen growth, aspen sprouts are very vulnerable to browsing by cattle or native ungulates until they are able to grow above the browse line. Repeated grazing of aspen suckers can cause aspen to grow in a bushy, multi-stemmed form that is more susceptible to browsing. Repeated browsing will eventually eliminate aspen by exhausting the underground resources of the stand (Kay 1997, see section 3.5.1.2, Aspen Stands).

Although the analysis area did not appear to provide habitat needed to sustain resident fisher or marten populations prior to the Moonlight and Antelope Complex fires, the presence of other late seral forest species (e.g., spotted owl and goshawk) implies that the habitat may have developed into suitable mesocarnivore habitat in the future. Further, we manage the forest to perpetuate those attributes that are important to fisher and marten to provide suitable travel corridors between resident populations and grow forest habitat to promote establishment of future populations.

Three species of bat (*Corynorhinus townsendii, Antrozous pallidus, Myotis thysanodes*) on the Regional Forester's Sensitive Species List (Region 5) occur within the analysis area in a variety of habitat types including late seral forest, grasslands, shrublands, woodlands, riparian zones, mixed conifer and true fir forests. There is scant information on the distribution of these species across the forest and within the analysis area, and information on habitat selection within the analysis area is rarer.

3.9.2 Shrubland, Early and Mid Seral and Burned Forests and Associated Species

The Black-backed Woodpecker (*Picoides arcticus*) is a Forest Service Management Indicator Species (MIS) for the ecosystem component of snags in burned forests. MIS are animal species identified in the Sierra Nevada Forests MIS Amendment Record of Decision (USDA 2007a). Guidance regarding MIS is set forth in the 1988 Plumas LRMP (USDA 1988a) as amended by the 2007 MIS Amendment (USDA 2007a) and directs Forest Service resource managers to: (1) at project scale, analyze the effects of proposed projects on the habitat of each MIS affected by such projects, and (2) at the bioregional scale, monitor populations and/or habitat trends of MIS, as identified in the 1988 LRMP, as amended. Black-backed woodpeckers are dependent on snags created by moderate and high severity fires (greater than 25 percent basal area mortality; Hutto 1995, Kotliar et al. 2002, Smucker et al. 2005, Dudley 2012). Severely burned forests provide abundant snags that benefit prey (by providing food for the specialized beetle larvae that serve as prey) and ample nesting sites (Hutto and Gallo 2006). Areas where vegetation burn severity habitat is low (i.e. less than 25 percent basal area mortality) are not considered to provide suitable Black-backed Woodpecker habitat but may contribute future snag habitat for Black-backed Woodpecker foraging and nesting near moderate and high burn severity areas (Hutto 1995).

Recent studies have confirmed and better delineated key habitat features (e.g., the importance of snag density) for Black-backed Woodpeckers (Siegel et. al 2013), and the recently developed Black-backed Woodpecker Conservation Strategy (Bond et al. 2012) provides numerous management recommendations that may be employed to benefit the species. Burned forest habitat suitability for black-backed woodpecker's declines over time as snags fall and decomposing trees gradually decline in foraging quality (Dudley and Saab 2007, Siegel et al.

2013). Over 30,000 acres of potentially suitable black-backed woodpecker habitat was created during the Moonlight and Wheeler fires(USDA XXXX moonlight FEIS). Over 50 percent of this habitat was not treated during the Moonlight and Wheeler Fires Recovery and Restoration Project and provides suitable habitat for black-backed woodpeckers (USDA XXXX moonlight FEIS).

The Fox Sparrow (*Passerella iliaca*) is the FS MIS for shrubland (chaparral) habitat on the west-slope of the Sierra Nevada, comprised of montane chaparral (MCP), mixed chaparral (MCH), and chamise-redshank chaparral (CRC) as defined by the California Wildlife Habitat Relationships System (CWHR) (CDFG 2005). In the Sierra Nevada, the Fox Sparrow is dependent on open shrub-dominated habitats for breeding (Burnett and Humple 2003, Burnett et al. 2005, Sierra Nevada Research Center 2007). The Moonlight and Antelope Complex fires resulted in a rapid shift in forest vegetation types within the analysis area. Conifer forests dominated by long lived tree species and characterized by frequent low severity fire regimes were converted to shrublands dominated by montane chaparral species (relatively short lived) with infrequent high severity fire regimes (Figure 12). Seventy percent of the area burned during these fires burned at high severity, resulting in uncharacteristically vast areas of standing dead trees, which are now dominated by shrubs. The amount of the analysis area typed as shrubland increased after the fires from three to 29 percent (Figure 13). Surveys within the footprint of three fires on the Plumas and Lassen NF (Moonlight, Storrie and Cub) and green forest survey units on the Lassen NF found avian species richness, and total bird abundance were significantly higher in green forest compared to any of the three fire areas (Burnett et al. 2009, 2010). Fox sparrows were one of several species that exhibited greater abundance within the Moonlight Fire footprint compared to green forest habitat survey units (Burnett et al. 2009, 2010).

Mountain Quail (*Oreortyx pictus*) is the FS MIS for early and mid seral confierous forests (Douglas-fir, eastside pine, Jeffrey pine, ponderosa pine, red fir, Sierran mixed conifer, and white fir), but mountain quail also may serve as a good indicator of shrubland habitat quality in the Moonlight Restoration analysis area. The Mountain Quail is routinely found on steep slopes, in open, brushy stands of conifer and deciduous forest and woodland, and chaparral; it may gather at water sources in the summer, and broods are seldom found more than 0.8 km (0.5 mi) from water (CDFG 2005). Aside from their use of shrubland habitat, mountain quail typically uses early seral coniferous forest composed primarily of seedlings (less than one inch dbh), saplings (one to 5.9 inches dbh), and pole-sized trees (6 to 10.9 inches dbh), and mid seral coniferous forest comprised primarily of small-sized trees (11 - 23.9 inches dbh). Although shrubland habitat is utilized by mountain quail, and the proportion of the analysis area supporting shrublands increased by 26 percent after the Moonlight and Antelope Complex fires (Figure 13), there were negligible differences in the amount of early seral and mid seral (open canopy) habitat available to quail within the analysis area pre and post fire (Figure 14). There was a 19 percent reduction in the amount of mid seral (closed canopy) habitat within the analysis area post fire compared to pre fire conditions (Figure 14).

The Moonlight and Antelope Complex fires created large patches of shrubland habitat (25 percent increase over pre fire acreage levels), some of which will develop into early seral conifer forest habitat. Shrublands and early seral forests provide excellent foraging opportunities for mule deer (*Odocoileus hemionus*), the FS MIS for hardwood and hardwood-conifer forests. Early seral and shrubland habitats provide forage for deer in their summer, migration and winter ranges. However, important winter thermal cover was lost when mid- and late-seral habitats burned during fires. Prior to the Moonlight and Antelope Complex fires there was a network of 13 water catchment devices (termed guzzlers) in the analysis area. Guzzlers were placed to increase water distribution for wildlife species, specifically deer, quail and grouse. Numerous other species of wildlife also took advantage of increased water availability. Monitoring of wildlife guzzlers found that deer, bear, gray fox, squirrels, songbirds, quail and striped skunks were frequent users of the additional water available. Twelve of the 13 guzzlers burned in the Moonlight (N = 9) and Antelope Complex (N = 3) fires.

3.9.3 Golden Eagle and Other Cliff Nesting Raptors

Although golden eagles (*Aquila chrysaetos*) forage in grasslands and early successional stages of forest and shrub habitats, they construct stick nests on cliff ledges and in large trees within mature conifer forest. Golden eagles were known in the fire area before the Moonlight Fire, with nest sites ringing the fire area. Most (12 of 16) historic golden eagle nest sites on the PNF were located within late seral forest with moderate (greater than 40 percent) to dense (greater than 60 percent) canopy cover; four other nests were on cliff ledges. Golden eagle home ranges vary across the landscape with nesting densities ranging from one pair per 36 square miles to one pair per 48 square miles in California (Zeiner et al. 1990). Given adequate resources (i.e. food and nesting sites), the analysis area could support two to three nesting pair of golden eagles. Two falcon species (*Falco peregrinus* and *F. mexicanus*) also have been observed in the analysis area.

The Moonlight wildfire resulted in a long-term decrease in the number of large trees available for eagle nesting, and concomitantly increased open foraging habitats. Golden eagles can take advantage of the increase in prey availability resulting from the increase in open foraging conditions throughout the burn area, but only with sufficient nesting locations. Table 20 displays the effects of the Moonlight Fire on suitable golden eagle nesting habitat on FS lands within the analysis area. Approximately 28,887 acres of suitable nesting habitat was rendered unsuitable on NFS lands as a result of the stand replacing wildfire.

Table 20. Effects of Moonlight Fire on Tree-nesting Habitat for Golden Eagles (all acres approximate and all are NFS lands).

Habitat	Pre-Fire Acres	Post-fire Acres	*Reduction in suitable habitat*
*Suitable Habitat (5M, 5D,4M, 4D)**	*31,905*	*3,018*	*28,887 acres - 91% reduction*

* * Sierra mixed conifer, ponderosa pine, white fir, red fir, lodgepole and eastside pine forest types (trees >24 inch DBH, 40-59% canopy cover; 5D = trees >24 inch DBH, >60% canopy cover; 6 = size class 5 trees over a distinct layer of size class 4 or 3 trees, total tree canopy exceeds 60% closure; 4M = trees 11-24 inches DBH, 40-59% canopy cover and 4D = trees 11-24 inches DBH, >60% canopy cover.

3.9.4 Meadow Habitat and Associated Species

Ninety eight meadows have been mapped in the analysis area (1,775 acres, Fryjoff-Hung and Viers 2012); however, this is a conservative estimate as aerial photos show many stringer meadows that have not yet been georeferenced, nor included this analysis. A complex of five fen wetlands also occurs in the analysis area (Lowe Flat meadow, Figure 20). Fens are unique wetland ecosystems that support many rare and endemic plant and animal species. Fens depend on the presence of peat-forming vegetation, which can accumulate over thousands of years and serve as important carbon sinks (see section 3.5.1.1, Meadows and Fens, for additional details). Meadows and fens are characterized by moist soil conditions, which limit the spread of fire. The Lowe Flat fen complex and 80 percent of meadows found in the analysis area did not burn in the Moonlight Fire. However, of the 376 acres of meadows that did burn, 80 percent experienced moderate to high fire severity (greater than 25 percent loss of vegetation). Fire can benefit meadows by killing encroaching conifers and upland shrubs species. Fire can also stimulate the production of herbaceous biomass in meadows in subsequent years (Wright and Chambers 2002). On the other hand, fire can negatively affect meadows. High severity fires that eliminate meadow vegetation and expose soil can increase rates of erosion, soil drying, and bank instability.

There are two range monitoring areas in meadow habitat within the perimeter of the Moonlight Fire. One monitoring area is in the Lone Rock Creek grazing allotment, which burned with relatively high severity. This allotment was rested from grazing after the fire in 2008 and appeared to support dense vegetation the following year (see section 3.5.1.1, Meadows and Fens, for additional details). The second range monitoring area in the Moonlight Fire perimeter is in the Lights Creek allotment. This area burned very lightly and was not rested from grazing after the fire (Figure 23). Monitoring completed by the Region 5 Range Monitoring Program includes three meadows within the analysis area. A comparison of data collected in 2002 and 2003 with data collected five years later indicated that two of the meadows had experienced a downward trend in condition and did not meet desired conditions (see section 3.5.1.1, Meadows and Fens, for additional details). Further, proper functioning condition assessments in grazing allotments have found that some areas are functional at risk with a downward trend and are in need of restoration. For example, Lone Rock Creek was found to be functional at risk with a downward trend due to cut banks, excessive sediment deposition, and dewatering due to a culvert (Cleland et al. 2006). Six locations were identified in the Diamond Project area with headcuts, excessive channel and bank erosion, and bank instability (USDA 2006a). Where headcut erosion has occurred in meadows, the meadow may no longer function as a floodplain during high flow events, and the water table of the meadow may be lowered, resulting in soil drying and loss of meadow vegetation.

The willow flycatcher (*Empidonax trailii brewsteri*) is a neotropical migrant that breeds in riparian and mesic upland thickets in the United States and southern Canada. Willow flycatchers typically inhabit moist meadows with perennial streams and smaller spring fed or boggy areas with willow (*Salix* spp.) or alders (*Alnus* spp.) on PNF. The willow flycatcher is a FS Sensitive Species (Region 5), and has been detected at 25 distinct sites across PNF.

Approximately 600 acres of potentially suitable willow flycatcher habitat has been identified within the analysis area, ranging in size from a couple acres to over 45 acres. Two statewide surveys found most (more than 80 percent) willow flycatchers on meadows greater than 19.8 acres in size (Serena 1982, Harris et al. 1988). Although use of meadows less than 0.5 ha (1 ac) have been documented (Stafford and Valentine 1985, USDA FS 1991), more than 95 percent of Willow Flycatcher breeding meadows are greater than 10 acres, and the most successful meadows (i.e., those in which >1 territory fledged young) are greater than 15 acres (Green et al. 2003).

3.10 Past and Present Aquatic Conditions

The aquatic analysis area covers over 184,000 acres ranging in elevation between 3,520 and 7,820 feet (Figure 44). The area contains approximately 1,015 acres of lacustrine habitat, 1,963 miles of stream habitat, and six mapped springs. Antelope Lake is by far the largest lake is the restoration analysis area at approximately 948 acres. Taylor Lake (approximately 26 acres) is considerably smaller in size, but is much larger compared to the 60+ small lakes (mean = 0.7 acres, range =0.03 – 5.5 acres) scattered across the analysis area. 201 miles of stream channel in the analysis area miles are perennial streams, 432 miles are intermittent and 1,329 miles are ephemeral streams. The average slope of streams in the area is 20 percent. The number of springs reported in the analysis area is certainly an underestimate as data on the distribution of springs across the forest is limited, at best. Additional surveys are necessary to determine an accurate estimate of the number of springs in the analysis area.

3.10.1 Aquatic Habitat Condition

Managers expressed concern for the condition of streams in the Moonlight Fire area prior to the fire (USDA 2005, USDA 2008, also see section 3.13 for additional details). Several streams within the aquatic analysis area were surveyed prior to the Moonlight Fire (Stream Condition Inventory, SCI). Examination of overall stream condition (based on physical characteristics including bank full width: depth ratio, bank angle, shade, pool tail fines, particle count less than two millimeters, and unstable banks) found that less than a third of streams surveyed in the analysis area were in good condition; whereas, the remaining streams were in moderate to poor condition (see section 3.13, Past and Present Hydrological Conditions, for details). Relatively fine sediment in pool tails were found in lower gradient reaches, and historic grazing regimes were suggested as one possible cause of poor pre-fire stream condition in the area; however, two years prior to the Moonlight Fire, stream conditions were generally improving in the area (USDA 2007a).

Aside from SCI surveys, 37 additional stream miles were examined for general condition prior to the Moonlight Fire. These were relatively longer stream lengths compared to the SCI reach surveys, and they revealed that approximately 22 percent of stream lengths had noticeable bank erosion, six percent had prevalent bank erosion, and one percent had extensive bank erosion. Further, 13 headcuts were identified in the Antelope Lake HUC 6 watershed (USDA 2007a). In general, large woody debris (LWD) was rated good or fair in the area (90 percent of streams rated good). Streams with less than optimal LWD were concentrated in the Antelope Lake area.

Forest roads that are not properly maintained may have severe and catastrophic impacts to streams. Most roads surveyed in the analysis area were found to be in good condition prior to the Moonlight Fire; however, approximately six percent of roads were identified as requiring some level of reconstruction and roughly three percent of roads were causing resource damage and should likely have been decommissioned (USDA 2007a).

Prior to the fire, large cut banks and deposition resulted in classification of Lone Rock Creek as functioning-at-risk. Some of this habitat degradation was apparently due to a misaligned culvert on a NFS road. However, there has been concern with grazing impacts to stream banks along Rock Creek coupled with herbivory on willows (Salix) that have consistently resulted in the areas being rated below thresholds of concern (for more details see section 3.13- Past and Present Hydrological Conditions).

Mining activities have disturbed riparian areas and stream channels in several creeks in the area (e.g., Cooks, Moonlight, Lights and Indian Creeks), creating over-steepened and unstable stream banks at a minimum. There is little information available on mining related contaminant threats to aquatic organisms in the analysis area; however, knowledge of contaminant threats is necessary for effective aquatic restoration.

The effects of the Moonlight Fire on riparian vegetation were previously presented (section 3.5 - Past and Present Vegetation Conditions: Meadow, Fen, Aspen and Riparian Vegetation). Over 60 percent of riparian vegetation in the Moonlight fire perimeter burned at moderate to high severity (greater than 25% basal area mortality), and many first order streams experienced high severity fire (great than 75% basal area mortality; USDA 2007a). Most drainages evaluated post fire experienced significant loss of riparian vegetation, and the amount of shade present in riparian areas was rated as poor (USDA 2008).

In general, LWD was only partially consumed in larger channels; however, the Moonlight Fire burned out LWD in most first and second order streams, releasing sediment stored by LWD (USDA 2007a, USDA 2008). Reaches within meadow areas were relatively untouched, and burn severity was light on the meadow floodplain. Reaches in gorges such as Lower Lights Creek, with large areas of rock out cropping, also experience a relatively less severe burn (USDA 2007e, USDA 2008).

Post-fire surveys reported that the main channel and tributaries of Pierce and Indian Creeks (composed mostly of cobbles and boulders) appeared stable; however, intermittent and ephemeral streams in Pierce and Upper Indian Creek drainages did exhibit prevalent or extensive bank instability (USDA 2008). Sections of Pierce and Boulder Creeks also contained high sediment in pool tail fines. Historic grazing activity around both reaches may have contributed to bank instability. Further, Middle and Upper Indian Creek Drainages were found to contain inadequate amounts of LWD.

The confluence of numerous streams forms the main stem of Lights Creek (West Branch Lights Creek, upper Lights Creek, Bear Valley Creek, Morton Creek, Smith Creek, Fant Creek and East Branch Lights Creek). Channels in this area are broad and mobile with cobble/boulder dominated beds (USDA 2008). Channels upslope of the confluence with Lights Creek are steep with unstable banks. Prominent terraces have developed along Morton Creek immediately upstream of its confluence with East Branch Lights Creek. These features indicate that accelerated post-fire erosion and sedimentation are likely to increase channel instability and bank erosion in this area. The main channel of Lights Creek (braided cobble-dominated channel) also is unstable with high sediment loading for approximately one mile downstream of the confluence area. Abundant mine tailings and debris are present in the channel and on the banks of Middle Lights Creek and placer mining activities also have caused the channel to degrade (USDA 2007a).

The level of aquatic habitat fragmentation in the analysis area is unknown. There are anthropogenic barriers to aquatic organism passage (AOP) between both Lone Rock and Boulder Creeks and Antelope Lake. However, these AOP barriers likely reduce the risk that introduced fish species will negatively impact upstream Sierra Nevada yellow-legged frog (*Rana sierrae*) populations. Yellow-legged frogs also occur along Pierce Creek, but it is unknown whether there are anthropogenic or natural barriers to AOP between Antelope Lake and the creek. Additional information on AOP in the analysis area is needed.

3.10.2 Aquatic Species

Aside from both native (*Oncorhynchus mykiss, Catostomus platyrhynchus, Rhinichthys osculus*) and introduced (*Salmo trutta, Salvelinus fontinalis*) fish, salamanders (*Ambystoma macrodactylum*) and multiple species of frog (*Pseudacris regilla, Rana boylli, R. sierrae*), the Moonlight Fire restoration analysis area contains numerous semiaquatic (cranes, Gruiformes) and aquatic (herons, Ardeidae) and birds, mammals (beaver) and a reptile (western pond turtle, *Actinemys marmorata*). Prior to construction of Oroville Dam, the analysis area historically provided breeding habitat for salmon (*Oncorhynchus*). Aquatic species of concern in or near the analysis area are listed in Table 21; these include Federally Threatened, Endangered, Proposed, and USDA Management Indicator and Regional Forester's (Region 5) Sensitive Aquatic Species.

Aquatic invasive species includes both aquatic plant and aquatic animal species. Invasive aquatic plants are introduced plants that have adapted to living in, on, or next to water, and that can grow either submerged or partially submerged in water. Invasive aquatic animals require a watery habitat, but do not necessarily have to live entirely in water. There are excellent resources for aquatic invasive species management at the USDA National Invasive Species Information Center (http://www.invasivespeciesinfo.gov/aquatics/main.shtml) and California Department of Fish and Wildlife (http://www.dfg.ca.gov/invasives/) websites.

Although signal crayfish (*Pacifastacus leniusculus*) are native to the northwestern U.S., it is an introduced species in California, and currently occurs in the analysis area. The American bullfrog (*Rana catesbeiana*) is native to the eastern half of the U.S.; however, this species also was introduced in California and occupies aquatic habitats in the analysis area. There are several aquatic invasive species that have not been detected in the analysis or adjacent areas, but are quite likely being dispersed through adjacent habitats, and possibly through the analysis area (i.e., *Dreissena polymorpha, D. bugensis, Potamopyrgus antipodarium, Corbicula fluminea*). For example, recreational boaters are a vector for many aquatic invasive species and Antelope Lake attracts both anglers and water sport enthusiasts to its waters, often after previously utilizing other water bodies which may contain aquatic invasive species. Similar to aquatic invasive species that have not been detected in the analysis area, but post a serious threat to aquatic communities, whirling disease, caused by a myxozoan parasite (*Myxobolus cerebralis*) occurs within Yellow Creek on Plumas and Lassen NFs (Weber 2013). It is unknown whether whirling disease occurs within the analysis area.

In April 2013, the U.S. Fish and Wildlife Service (FWS) issued a proposed rule to list the Sierra Nevada yellow-legged frog (*Rana sierra*) as an endangered species under the Endangered Species Act (ESA) (http://www.gpo.gov/fdsys/pkg/FR-2013-04-25/pdf/2013-09600.pdf), and also proposed Critical Habitat for the species (http://www.gpo.gov/fdsys/pkg/FR-2013-04-25/pdf/2013-09598.pdf). Over 9,700 acres of habitat on Forest Service lands in the analysis area are proposed as critical habitat for the Sierra Nevada yellow-legged frog (Subunit 2A: Boulder/Lone Rock Creeks).

Potential habitat for Sierra Nevada yellow-legged frog (SNYLF) in the analysis area is along perennial and intermittent streams and water bodies above 3,500 foot elevation. SNYLF's occur in the Meadow Valley area and on the Feather River Ranger District as low 3,500 feet in elevation. Yellow-legged frogs are highly aquatic, typically utilizing only the immediate bank and emergent rocks and logs. Frogs appear to be more common in well illuminated, sloping banks of meadow streams, riverbanks, isolated pools, and lake borders with vegetation that is continuous to the water's edge (Martin 1992, Zeiner et al. 1988). Historically streams with a bank of less than 10 inches in vertical height with a moderately rocky, sparsely vegetated bank harbored the densest populations (Mullally and Cunningham 1956).

Frog space use patterns involve three main sites: overwintering, breeding and foraging. Tadpoles and adults overwinter in deep pools with undercut banks that provide cover (Martin 1992). Suitable breeding habitat is considered to be low gradient (up to four percent) perennial streams and lakes. Frogs usually lay their eggs in clusters, submerged along stream banks or on vegetation. Tadpoles require at least one year before metamorphosis to the adult stage, and some high elevation populations may require up to three years before metamorphosis (Knapp 1996).

Table 21. Threatened, Endangered, Proposed, and USDA Management Indicator and Regional Forester's (Region 5) Sensitive Aquatic Species and their habitats in the Moonlight Restoration analysis area.

Species Name	Elevation (feet)	Habitat	Potential Threats	PNF Status	Analysis Area		
					Suitable Habitat	Detection	Restoration Synopsis
Amphibians							
Rana boylii FOOTHILL YELLOW-LEGGED FROG Forest Service R5 Sensitive Federal Species of Concern	< 6,400	Breed in shallow, slow flowing water with at least some pebble and cobble substrate. Found in riffles and pools with some shading (>20%) in riparian habitats, and moderately vegetated backwaters, isolated pools, and slow moving rivers with mud substrate. Rarely found far from permanent water	Disease (chitrid fungus), Introduced exotic predators (fish stocking), contaminants, recreation, and grazing	>50 site detections on PNF	Yes	Yes	Multiple detections in one area (North Arm of Indian Valley)
Rana sierrae SIERRA NEVADA YELLOW-LEGGED FROG Federal Proposed	3,500 - 12000	Found in ponds, tarns, lakes and streams with sufficient depth and adequate refuge for over wintering. On the Plumas, most are in stream habitat	Disease (chitrid fungus), Introduced exotic predators (fish stocking), contaminants, recreation, and grazing	Greater than 50 site detections on PNF	Yes	Yes	Multiple detections at several sites
Fish							
Mylopharodon conocephalus HARDHEAD USDA Regional Forester (Region 5) Sensitive Species,	< 6,000	Widely distributed in undisturbed reaches of low to mid elevation streams from the Kern River in the south to the Pit River in the north	Population isolation, hydro-electric power, predation by smallmouth bass	Known distribution is 135 miles; suspected in 80 additional miles	No	No.	Suspected to occur downstream of analysis area (Indian Creek)

Species Name	Elevation (feet)	Habitat	Potential Threats	PNF Status	Analysis Area		
					Suitable Habitat	Detection	Restoration Synopsis
Reptiles							
Actinemys marmorata WESTERN POND TURTLE USDA Regional Forester (Region 5) Sensitive Species, Federal Species of Concern	< 4,700	Aquatic habitat in spring and summer. Adjacent upland habitat fall and winter. In rivers, needs slow flowing areas with deep underwater refugia and emergent basking sites. Migration, hibernation, and nesting occur on land up to 330 feet from riparian area	Non-native fauna, non-native turtles through competition and disease, bullfrogs and predatory fish, vehicles, timber harvest, mining, fire, grazing, water alteration and diversion	Greater than 50 detections from about 25 sites across the PNF (Butte & Plumas County)	Yes	Yes	One detection
Invertebrates							
AQUATIC MACROINVERTEBRATES USDA Management Indicator Species (Region 5) Aquatic Macroinvertebrates include: insects in their larval or nymph form, crayfish, clams, snails, and worms.	NA	Riverine and Lacustrine	Changes in: water chemistry, temperature, physical features, and flow. Increased sedimentation and changes in vegetative cover	Across PNF	Yes	Yes	throughout area

Adults primarily feed on aquatic and terrestrial invertebrates favoring terrestrial insects such as beetles, flies, ants, bees, and true bugs (Jennings and Hayes 1994). They are also known to feed on pacific treefrog (*Hyla regilla*) tadpoles (Zeiner et al. 1988). SNYLF tadpoles graze on algae and diatoms along rocky bottoms in streams, lakes and ponds. Garter snakes and introduced trout prey upon SNYLF tadpoles (Zeiner et al. 1988). As adults overwinter underwater and tadpoles exhibit an extended metamorphosis period, the species is very vulnerable to introduced fish (Knapp 1996). Female frogs can have live 13-14 years with a male maximum recorded life span of 11-12 years (Matthews and Miaud 2007).

Preliminary survey effort in the southwestern portion of the analysis area reported both foothill yellow-legged frog (*Rana boylii*, FYLF) and SNYLF in the North Arm of Indian Valley. Further survey efforts are necessary to elucidate whether these data are accurate (i.e., whether both species occur in the watershed, or misidentification may have occurred). The SNYLF is known to occupy habitat upstream of the North Arm of Indian Valley (West Branch Lights Creek), to the northwest of Antelope Lake (Boulder, Pierce, and Lone Rock Creeks), and along the eastern edge of Plumas County (Clarks Creek) in the restoration analysis area. Additional considerations may be appropriate for FYLFs if future surveys confirm that they occur (or co-occur with SNYLFs) along Cooks and Lights Creeks in the North Arm of Indian Valley.

Managers expressed concern for the condition of aquatic habitats in the Moonlight Fire area prior to the fire; and although some areas appear to be recovering quickly (e.g., Moonlight Creek), riparian zones across much of the restoration analysis area (e.g., Lone Rock, Upper Indian (and its tributaries), Boulder, and Lights Creeks) have and will continue to merit attention from land managers (USDA 2008, for additional details see Section 3.13 of this document - Past and Present Hydrological Conditions). Many streams were impacted through accelerated erosion and sedimentation post-fire, and the eastern part of the analysis area contained headcuts and monitoring results indicated less than desirable conditions both before and after the Moonlight Fire (USDA 2008). Although some areas appear to be recovering quickly (e.g., Moonlight Creek), riparian zones across much of the restoration analysis area (e.g., Lone Rock, Upper Indian (and its tributaries), Boulder, and Lights Creeks) have and will continue to merit attention from land managers (USDA 2008).

3.11 Past and Present Range Conditions

Range resources in the Moonlight restoration area include the understory vegetation in timbered areas, meadows and fens, and riparian areas, creeks, and springs. Range resources also include the permittee and the permitted livestock that graze within an allotment. An allotment is the area of land designated for livestock grazing in the Plumas NF LRMP (USDA 1988a) and is authorized under a grazing permit. Grazing permits are issued to permittees for individual allotments; some permittees are authorized to graze on two or more allotments. The grazing permit defines the number, kind, and class of livestock, season of use, standards and guidelines, allowable use, monitoring areas, pasture rotation, range improvements, and areas of concerns.

The area analyzed for range resources includes the eleven allotments that were in the 2007 Moonlight and Antelope Complex fires (Table 22). These allotments intersect the forest vegetation analysis area (see Section 3.2). The watersheds in this analysis area were historically characterized by a mosaic of open eastside pine and mixed conifer forest types and a frequent low-severity fire regime. The range resources within these watersheds have been cumulatively impacted by multiple recent fire events, which include the Moonlight Fire (2007), Antelope Complex (2007), Boulder Fire (2006), and Stream Fire (2001). The Moonlight Fire burned into the Antelope Complex, which burned a month earlier and likely limited the total area burned. Allotment boundaries were chosen for the analysis area because grazing is permitted and administered by allotment. The eleven allotments within the analysis area are listed in Table 22 (also see Figure 47). Two of the allotments, Hungry Creek and Taylor Lake, are currently vacant and were considered in this analysis for comparison and for potential restocking opportunities. Analyses of these allotments will enable the forest to meet Region 5 Range targets and make reductions in season and number and change grazing systems if need be.

Table 22. Range allotments within the analysis area

Allotment	**Total size[1]**	**Acres within analysis area (% of total)**	**Acres within Moonlight Fire (% of total)**
Antelope	24,447	24,277 (99%)	1,927 (8%)
Antelope Lake	4,401	4,401 (100%)	125 (3%)
Bass	2,155	2,155 (100%)	
Clarks Creek	17,478	17,431 (100%)	
Doyle	5,091	3,434 (67%)	
Fitch Canyon	17,911	1,255 (7%)	
Hungry Creek[2]	17,007	16,996 (100%)	2,974 (17%)
Jenkins	34,044	15,504 (46%)	
Lights Creek	29,930	29,882 (100%)	20,144 (67%)
Lone Rock	24,633	24,633 (100%)	24,288 (99%)
Taylor Lake[2]	26,922	20,014 (74%)	13,760 (51%)

[1]Acres are based on GIS information and may differ slightly from the permitted size; [2] Currently vacant allotments

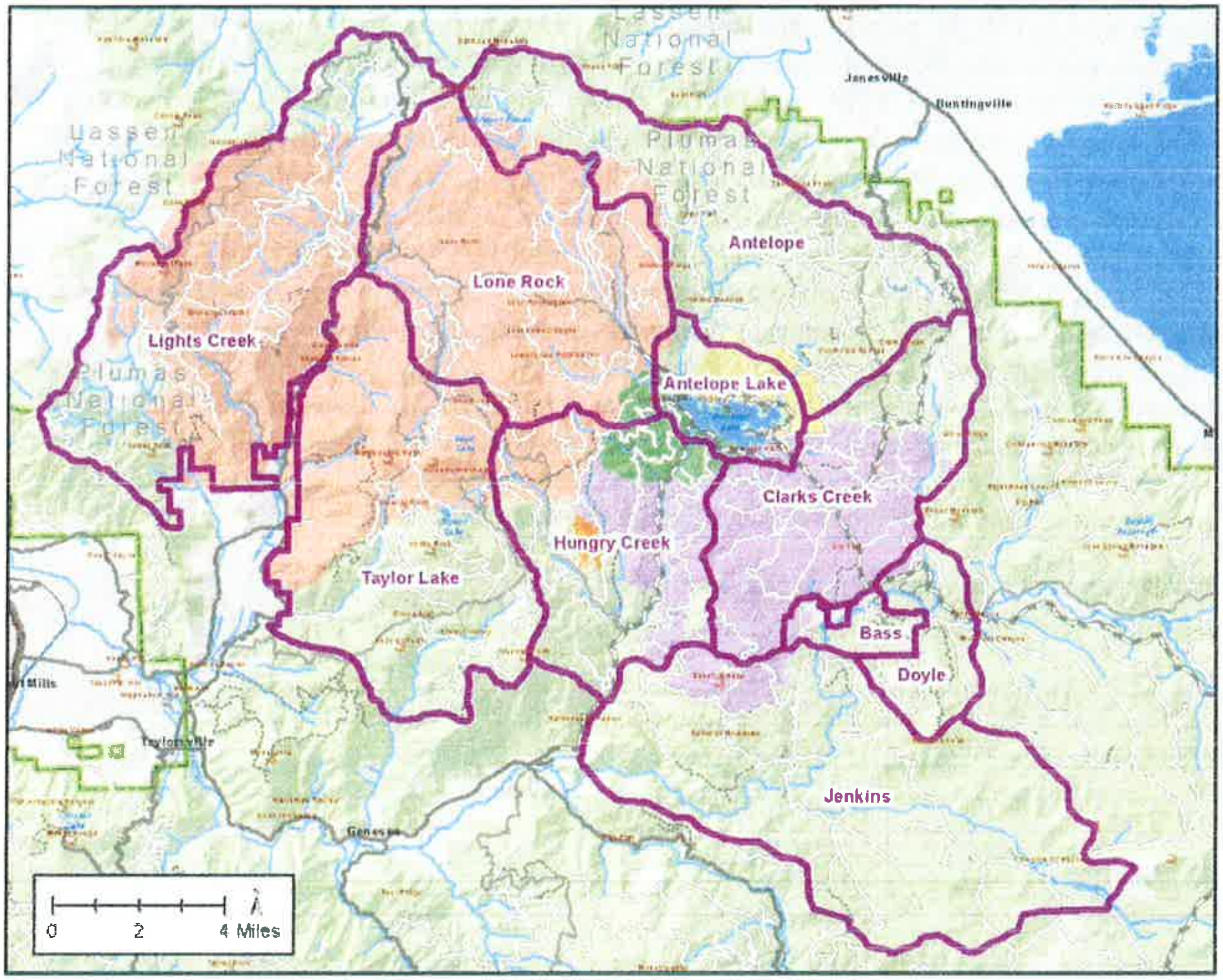

Figure 47. Area analyzed for range resources and restoration opportunities. Past fires are shown in purple (2007 Antelope Complex), yellow (2006 Boulder Complex), green (2001 Stream Fire), and orange (2006 Hungry Fire)

Livestock grazing has occurred on the Plumas NF since the mid-1800s. The early 1860s ushered in an era of intensive livestock use across the Sierra Nevada (Allen-Diaz 1991, McKelvey and Johnston 1992). Increasing human populations and market demands, combined with wide scale drought in the 1860s and 1870s, resulted in summer grazing of Sierra montane meadows where livestock could take advantage of abundant forage and water (Kosco and Bartolome 1981, Ratliff 1985). In the 1880s and early 1900's, an estimated 30,000 sheep grazed within the restoration area (S. Lusk personal communication). Grazing remained unregulated until the early 1900s, when regulations helped bring livestock numbers within reasonable bounds (Kosco and Bartolome 1981). Today, most allotments in the analysis area contain fewer than 500 calf/cow pairs (Table 23).

Table 23. Allotment management grazing strategy, numbers and season for 2013

Allotment	Permittee	Permitted Numbers and Season	Grazing Strategy
Antelope	CW Johnson	200 cattle pair; 6/15-9/15	Two pasture split herd

Antelope Lake	R.Egan	150 cattle pair; 9/3-10/2	Deferred till after Labor Day
Bass	CW Johnson	64 cattle pair; 6/1-9/30	Four pasture rotation
Clarks Creek	Five Dot	207 cattle pair; 6/1-10/1	Four pasture rotation
Doyle	J.Egan	100 cattle pair; 6/1-9/15	Four pasture rotation
Fitch Canyon	K.Wemple	317 cattle pair; 6/3-10/2	Six pasture rotation
Hungry Creek	Vacant	Vacant	Vacant
Jenkins	Five Dot	609 cattle pair; 6/14-10/13	Five pasture rotation
Lights Creek	Stroing	20 pair On, 16 pair Off; 6/1-9/1	Season long
Lone Rock	R.Egan	116 On, 180 Off; 6/16-9/15	Season long
Taylor Lake	Vacant	Vacant	Vacant

3.11.1 Fire effects on vegetation and forage

As discussed in the Vegetation sections of this strategy (sections 3.2 through 3.7), plant communities in the analysis area have been altered by past management activities, including fire suppression. Prior to European-American settlement in the mid-1800s, frequent, low intensity fires maintained a mosaic of open eastside pine and mixed conifer forest types with productive understory plant communities; however fire suppression, combined with past timber harvest, had decreased forest heterogeneity across the landscape, resulting in dense, overcrowded stands and closed forest canopies with sparse herbaceous understory. Prior to the Moonlight Fire, very little forage was available to cows in the forest understory (Fites 1993). As a result, grazing was concentrated in meadows, riparian stringers, and along roads (USDA 2007c).

As described in the discussion of montane and mixed chaparral vegetation (Section 0), the extent of shrubland in the analysis area increased dramatically after the Moonlight Fire (Figure 12); shrub types increased from approximately three percent of the analysis area prior to the fire to an estimated 29 percent after the fire (Figure 13). Increased shrub cover in post-fire landscapes can discourage the development of herbaceous vegetation, which is important foraging material for grazing animals.

In the short-term, the Moonlight Fire may have reduced forage within burned areas; however, many important forage species, such as grasses, sedges, willows, and aspen, were also likely encouraged by the fire (Figure 48). In some allotments, forage likely increased, creating transitory range. The number of cattle on allotments was not increased to optimize transitory forage created after the Moonlight or Antelope Complex fires.

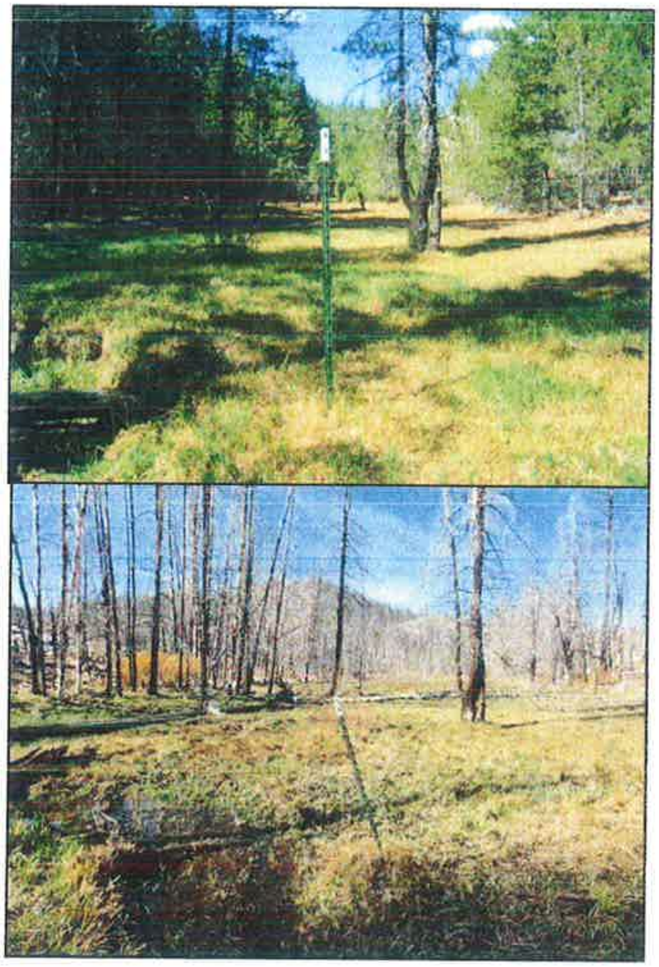

Figure 48. Three Creeks South Pasture in the Clarks Creek Allotment before the Antelope Complex Fire (top) and after fall grazing in 2012 showing sedge meadow regrowth after fire (bottom).

The majority of primary livestock range did not burn at high severity in the Moonlight Fire (USDA 2007c). This left a mosaic of burned and unburned areas (Figure 49), with many of the primary grazing areas left unburned (USDA 2007c). The primary grazing areas in the Lights Creek Allotment, which include Indicator Meadow, Flemming Sheep Camp, and Snoring Spring, were not burned (USDA 2007c). The Antelope allotment was also relatively unaffected by the Moonlight Fire (USDA 2007c). The majority of forage in the Lone Rock allotment occurs on private lands. After the Moonlight Fire, private timber lands were harvested and replanted and the Lone Rock permittee was asked to run more cattle to reduce grass competition on planted conifer seedlings (S. Lusk personal communication)

Figure 49. Lone Rock allotment in September 2007 right after the Moonlight Fire, showing a mosaic of burned and unburned patches within the meadow.

There are two range monitoring areas within the perimeter of the Moonlight Fire. One monitoring area is in the Lone Rock Creek grazing allotment, which burned with relatively high severity. This allotment was rested from grazing after the fire in 2008 and appeared to support dense vegetation the following year (Figure 22). The other range monitoring area in the Moonlight Fire perimeter is in the Lights Creek allotment. This area burned very lightly and was not rested from grazing after the fire (Figure 23). These allotments are monitored annually to determine if standards and guidelines (outlined in Table 38) have been met or exceeded. Post-fire monitoring determined that the standards and guidelines have not been exceeded since the Moonlight Fire (S. Lusk personal communication).

Monitoring completed by the Region 5 Range Monitoring Program includes three meadows within the analysis area. A comparison of data collected in 2002 and 2003 with data collected five years later suggest that two of the meadows did not meet desired conditions prior to the fire (see Table 1); the remaining site, which was the only one evaluated after the Moonlight Fire, met desired conditions. In 2004, a rapid assessment transect was also established to determine meadow species vegetation composition in each pasture in the monitoring area. This monitoring needs to be repeated to determine the effects of the fire on meadow vegetation.

In 2006, Proper Functioning Condition (PFC) assessments were conducted on some of the streams within the allotments. These pre-fire assessments rated Lone Rock Creek as Functioning at Risk with a downward trend due to active cut banks and excessive deposition of sediments and recommended the removal of the culvert (Cleland et al. 2006). PFC ratings done on Antelope and Antelope Lake Allotments were at PFC, except for Lowe Unit, which was a wet meadow due to a beaver dam and was not assessed.