Management Guide to Ecosystem Restoration Treatments:

Whitebark Pine Forests of the Northern Rocky Mountains, U.S.A.

Robert E. Keane
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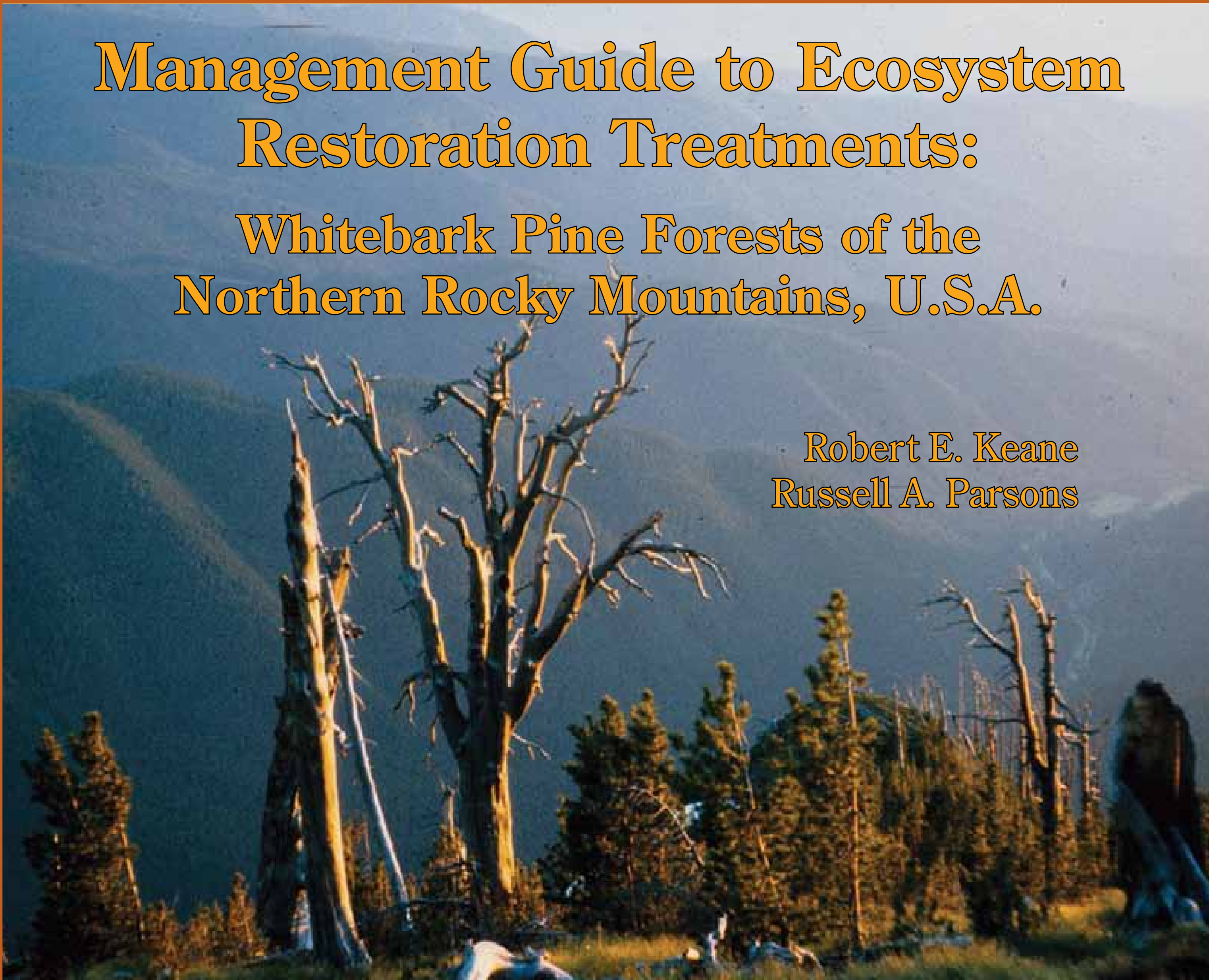

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ABSTRACT

Whitebark pine is declining across much of its range in North America because of the combined effects of mountain pine beetle epidemics, fire exclusion policies, and widespread exotic blister rust infections. This management guide summarizes the extensive data collected at whitebark pine treatment sites for three periods: (1) pre-treatment, (2) 1 year post-treatment, and (3) 5 years post-treatment (one site has a 10 year post-treatment measurement). Study results are organized here so that managers can identify possible effects of a treatment at their own site by matching it to the most similar treatment unit in this study, based on vegetation conditions, fire regime, and geographical area. This guide is based on the Restoring Whitebark Pine Ecosystems study, which was initiated in 1993 to investigate the effects of various restoration treatments on tree mortality, regeneration, and vascular plant response on five sites in the northern Rocky Mountains. The objective was to enhance whitebark pine regeneration and cone production using treatments that emulate the native fire regime. Since data summaries are for individual treatment units, there are no analyses of differences across treatment units or across sites.

Keywords: whitebark pine, ecosystem restoration, prescribed burning, fuel sampling, fire regime

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Research Summary

Whitebark pine (*Pinus albicaulis*) forests are declining across most of their range in North America because of the combined effects of three factors: (1) several major mountain pine beetle epidemics that occurred over the last 70 years, (2) an extensive and successful fire exclusion management policy, and (3) extensive infections of the exotic white pine blister rust fungus (*Cronartium ribicola*). The loss of whitebark pine is serious for upper subalpine ecosystems because it is considered a keystone species across most of its range, producing large seeds that are an important food source for more than 110 animal species.

This report details the results of an extensive, long-term study, named Restoring Whitebark Pine Ecosystems (RWPE), where the effects of several ecosystem restoration treatments were evaluated on five high-elevation sites in the northern Rocky Mountains. These treatments included prescribed fire, thinning, selection cuttings, and fuel enhancement cuttings. We evaluated fuel consumption, tree mortality, and undergrowth vegetation response measured at three time periods: (1) prior to the treatment, (2) 1 year post-treatment(s), and (3) 5 years post-treatment (10 year post-treatment measurement is available for one site).

Results show that the treatments provided desirable caching habitat for the seed dispersal vector—the Clark's nutcracker (*Nucifraga columbiana*)—but the measured whitebark pine regeneration rates were quite low due to the:

- nutcrackers reclaiming many cached seeds,
- lack of seed sources in nearby high rust-mortality stands,
- severity of the site (high snow levels, erosive soils, and cold environments),
- lack of plant cover, and
- relatively short time since disturbance.

This guide presents statistical summaries, treatment descriptions, and photographs by treatment unit at each time interval. **This guide is intended as a reference to identify possible impacts of a restoration treatment at a fine scale by matching a proposed treatment for a stand to the most similar treatment unit presented in this report based on vegetation conditions, fire regime, and geographical area.** Since data summaries are for individual treatment units, there are no analyses of differences across treatment units or across research sites.

The Management Guide Series

This report is the first of a series of publications that detail restoration, fuel reduction, and silvicultural treatment effects on ecosystems. This guide differs from most other reports in that it presents results at the treatment unit level to be more useful to land management. Recognizing that ecosystem characteristics are highly variable across many scales, any treatment replication may tend to incorporate additional biophysical variability that may mask local effects. Therefore, this management guide series summarizes collected data and results at the treatment level so that managers can match their proposed treatments to the treatments presented in this guide based on geographical area, vegetation type, or topographical setting. This guide helps with planning and designing ecosystem restoration treatments by informing managers of possible effects of treatments on trees, fuels, and undergrowth plants.

How to Use This Management Guide

To use this guide, the manager simply matches the conditions of the treatment and site to similar stratifications within this guide. First, match the proposed treatment to the fire severity regime (see Stand-Replacement Fires, Mixed-Severity Fires, and Non-Lethal Fires) it is supposed to mimic. Next, match the site to the most similar site within the chosen fire severity regime. The manager can then reference the effects of the treatments detailed in this guide and use these effects to craft cutting and prescribed burning prescriptions to achieve management objectives. The following is a set of steps that provide an example of how this guide can be used for whitebark pine restoration:

Step 1—Select site. Select a site or area for possible ecosystem restoration treatment.

Step 2—Identify the characteristics. Estimate the dominate fire regime (non-lethal surface fire, mixed-severity fire, or stand-replacement fire), topographic setting (aspect, slope, and elevation), geographic area, habitat type, and dominant vegetation.

Step 3—Develop a proposed treatment. Choose a fire regime to emulate and use it to craft specifics.

Step 4—Match site and proposed treatment to treatment study unit within this guide. Within the chosen fire regime (stand-replacement, mixed-severity, or non-lethal—pp. 13, 37, and 97, respectively), select the most similar treatment unit described, using geographic area and habitat type as criteria to narrow the selection. More than one site and treatment unit may match.

Step 5—Match pre-treatment conditions to treatment unit within this guide. Narrow the treatment unit selection from Step 4 by identifying which unit most closely resembles the proposed treatment area based on pre-treatment tree populations, fuel loadings, and vegetation conditions.

Step 6—Use the treatment unit effects described in this guide to direct management. Data from post-treatment monitoring help:

- estimate effects of proposed treatment for planning and National Environmental Policy Act (NEPA) analysis;
- design cutting and burning prescriptions to meet management objectives;
- prioritize areas for treatments; and
- fine-tune proposed treatments to achieve desired effects.

Contents

Introduction

Whitebark pine (*Pinus albicaulis*) forests are declining across most of the their range in North America because of the combined effects of three factors: (1) several major mountain pine beetle epidemics that occurred over the last 70 years, (2) fire exclusion management policies, and (3) extensive infections of the exotic white pine blister rust fungus (*Cronartium ribicola*) (Keane and Arno 1993; Murray and others 1995; Kendall and Keane 2001). The cumulative effects of these three agents are quite diverse across the range of whitebark pine, but, in general, the greatest mortality is found in the more mesic parts of its range (northern and western) where the upper subalpine forests experience a more maritime climate (Keane and Arno 1993). It also appears that changes in high-elevation climate brought about by global warming could accelerate the reduction of this important tree species (Blaustein and Dobson 2006). The loss of whitebark pine would be serious for upper subalpine ecosystems because it is considered a keystone species across most of its range, producing large seeds that are an important food source for more than 110 animal species (Forcella and Weaver 1980; Hutchins 1994).

This report details the results of an extensive, long-term study, named Restoring Whitebark Pine Ecosystems (RWPE), in which the effects of several ecosystem restoration treatments were investigated on five high-elevation sites in the northern Rocky Mountains, U.S.A. These treatments primarily included prescribed fire and thinning, selection cuttings, and fuel enhancement cuttings. We evaluated fuel consumption, tree mortality, and undergrowth vegetation response quantified from fuel loadings, tree size distributions, and plant species cover that were measured prior to the treatment, 1 year post-treatment(s), and 5 years post-treatment(s). This guide presents pictorial, anecdotal, and statistical summaries of these measurements and other observations for each treatment unit at each time interval. This guide does not provide a statistical analysis of differences across treatments or sites because it is presented in Keane and others (in press) and it tends to mask local effects due to unique biophysical conditions. One must understand the unique ecology of this high-mountain ecosystem to get the most out of this guide.

Whitebark Pine Ecology

Whitebark pine is a long-lived, seral tree with moderate shade tolerance (Minore 1979). It can live well over 400 years (one tree is more than 1300 years old), but, in the absence of fire, it is eventually replaced on many sites by the shade-tolerant subalpine fir (*Abies lasiocarpa*) and the Engelmann spruce (*Picea engelmannii*) and mountain hemlock (*Tsuga mertensiana*) in the mesic parts of its range (Arno and Hoff 1990; Keane 2001). Whitebark pine also competes with lodgepole pine (*Pinus contorta*) during early successional stages in the lower portions of its elevational range (Arno and others 1993; McCaughey and Schmidt 1990; Mattson and Reinhart 1990; Weaver and Dale 1974). It can take approximately 50 to 250 years for subalpine fir to replace whitebark pine in the overstory, depending on the local environment and previous fire history (Arno and Hoff 1990; Keane 2001).

Whitebark pine forests are found in two types of high-mountain settings. Most common are upper subalpine sites where whitebark pine is the major seral species that is successionally replaced by shade-tolerant fir, spruce, or hemlock, depending on geographic region. These sites support upright, closed-canopy forests and occur at the lower transition to timberline, just above or overlapping with the elevational limit of lodgepole pine (Arno and Weaver 1990; Arno and Hoff 1990; Pfister and others 1977). Sites where whitebark pine is the only tree species able to successfully reproduce and mature (the indicated climax) are found at lower timberline on relatively dry, cold slopes where trees often occur in elfin forests, clusters, groves, or tree islands (Arno 1986; Arno and Weaver 1990; McCaughey and Schmidt 1990; Steele and others 1983). Subalpine fir can occur on these sites, but as scattered individuals with truncated growth forms (Arno and Hoff 1990; Arno and Weaver 1990; Cooper and others 1991; Pfister and others 1977). Whitebark pine can also exist as krummholz on alpine sites (Arno and Hoff 1990; Tomback 1989) and as a minor seral in lower subalpine sites (Cooper and others 1991; Pfister and others 1977), though these sites were not included in this study.

Whitebark pine comprises about 10 to 15 percent of the forested landscape in the upper subalpine zone of the northern Rocky Mountains (Arno and Hoff 1990; Tomback and others 2001). Although it has limited use as a commercial timber species because of its diminutive stature, gnarled growth form, and remote setting, it produces seeds that are prized for food by many wildlife species, including the threatened grizzly bear (*Ursus arctos horribilis*) (Mattson and others 1991), red squirrel (*Tamiasciurus hudsonicus*) (Ferner 1974), and, most importantly, the Clark's nutcracker (*Nucifraga columbiana*) (Tomback 1989). The nutcracker plays a critical role in the whitebark pine regeneration process in that it is essentially the only vector for dispersing the heavy, wingless seed (Lorenz and others 2008; Tomback 1989; Tomback 1998). Whitebark pine also protects snowpack in high-elevation watersheds and delays snowmelt, providing high quality water to valleys below into the summer (Arno and Hoff 1990; Hann 1990; Tomback and others 2001).

Three types of fires define the diverse array of fire regimes found in whitebark pine forests (Arno and Hoff 1990; Morgan and others 1994). Some high, dry whitebark pine stands experience non-lethal surface fires (underburns) that kill the smallest trees and the most susceptible large trees because of sparse fuel loadings. These non-lethal surface fires are mostly confined to dry ridgetop settings and areas in the southern parts of the species range in the Rocky Mountains and burn only a small portion of existing whitebark pine forests (less than 10 percent) (Morgan and others 1994; Tomback and others 2001). Most of these areas have low blister rust infection rates and are within the historical fire rotation because of the inhospitable conditions for the rust infection and the long fire-return intervals (80 to 300+ years). The more common, mixed-severity fire regime is characterized by fires of different severities in space and time, which creates complex patterns of tree survival and mortality on the landscape. Mixed-severity fires can occur at 60- to 300-year intervals (Arno and Hoff 1990; Keane and others 1994; Morgan and others 1994). Individual fires can be non-lethal surface fires with differential mortality, stand-replacement fires, or, most often, fires that contain elements of both (Morgan and others 1994). Severities increase if fires enter areas with high fuel loads or if fires enter into tree crowns due to increasing winds and ladder fuels, thereby creating patches of high fire mortality (Lasko 1990). Burned patches are often 1 to 125 acres (.1 to 50 ha) in size, depending on topography and fuels, and these openings provide important nutcracker caching habitat (Norment 1991; Tomback and others 1990). Many whitebark pine forests in northwestern Montana, northern Idaho, and the Cascades originated from large, stand-replacement fires that occurred at long intervals (greater than 250 years) (Arno 1986; Keane and others 1994; Morgan and others 1994). Stand-replacement fires also occurred within mixed-severity fire regimes, but as infrequent events. These fires were usually wind-driven and often originated in lower, forested stands (Murray and others 1998).

Whitebark pine benefits from wildland fire because it is more capable of surviving and regenerating after fire than its associated shade-tolerant trees because it has somewhat thicker bark, thinner crowns, and deeper roots (Arno and Hoff 1990). It readily recolonizes after large, stand-replacement burns because nutcrackers transport its seeds great distances. Nutcrackers can disperse whitebark pine seeds up to 100 times farther (over 10 km) than wind can disperse subalpine fir and spruce seeds (McCaughey and others 1985; Tomback and others 1990; Tomback and others 1993). Essentially all whitebark pine regeneration comes from unclaimed nutcracker caches, where seeds eventually germinate and grow into seedlings (Keane and others 1990). Nutcrackers prefer open sites with many visual cues for seed caching, which are most often found in burned stands after a mixed or stand-replacement fire (McCaughey and Weaver 1990; Sund and others 1991; Tomback 1989; Tomback and others 1990; Tomback 1998). It is on these open sites that whitebark pine can successfully grow and mature to healthy cone-producing trees in the absence of competition.

Methods

Study Description

The RWPE study was started in 1993 to explore the use of prescribed fire, mechanical cuttings, and planting treatments to restore whitebark pine forests by enhancing regeneration success and prolonging whitebark pine cone production (Keane and Arno 1996). The need for restoration was first identified by Arno (1986) and later emphasized during a comprehensive symposium on whitebark pine held in Bozeman, Montana (Schmidt and MacDonald 1990). We know of no other formal restoration studies in this declining ecosystem.

The primary assumption in the RWPE study is that whitebark pine ecosystems can be restored from the damaging effects of blister rust, mountain pine beetles, and fire exclusion by mimicking historical fire regimes in stands to increase regeneration potential and to improve the vigor of surviving whitebark pine to promote future cone crops (Hoff and others 2001). We assume that the living, cone-producing whitebark pine at or near the restoration sites possess some degree of rust resistance because they have already survived decades of rust infection (Keane and Arno 1996). These apparently rust-resistant whitebark pine trees would provide the seed for the nutcrackers to plant in the treated units, and we assume this subsequent regeneration will be somewhat resistant to the rust (Hoff and others 2001). If surrounding whitebark pine seed sources are low, then planting seedlings grown from seed collected in high rust-mortality stands should be the primary vehicle to enhance the conservation of the species.

Study Sites

We implemented the RWPE study on five sites in the northern Rocky Mountains (fig. 1). Three sites are on the Bitterroot National Forest (two on the Stevensville Ranger District and one on the Darby Ranger District), one is on the Salmon-Challis National Forest, and the largest study site is on the Clearwater National Forest (table 1). Whitebark pine is declining on all sites except for the Blackbird Mountain site on the Salmon-Challis National Forest where there were few rust infections and no observed mortality. These sites were selected because they were close to a road or trail and the Ranger Districts supported our planned treatments. All sites are in the ABLA/LUHI habitat type with most in the VASC phase, but some are in the MEFE phase (Pfister and others 1977) (table 1). Some of the sites have minor elements of the PIAL-ABLA and ABLA-PIAL habitat types.

We divided each site into treatments and each treatment was further divided into treatment units. The treatment is described by the major treatment type implemented within the area while the treatment unit describes the secondary or minor treatment implemented within the same area (see Guide Organization in the Results section for a complete description of each treatment). For example, the treatment might be a prescribed non-lethal surface fire and the two treatment units might be with and without fuel enhancement cuttings, respectively. We tried to replicate treatment units within a site to satisfy requirements of a comprehensive analysis of variance, but we found it was nearly impossible due to the limited extent of the sites (most were confined by ridgetop settings) and the diversity of biophysical characteristics within the site (for example, aspect, slope, water drainage, and species composition). We also attempted to

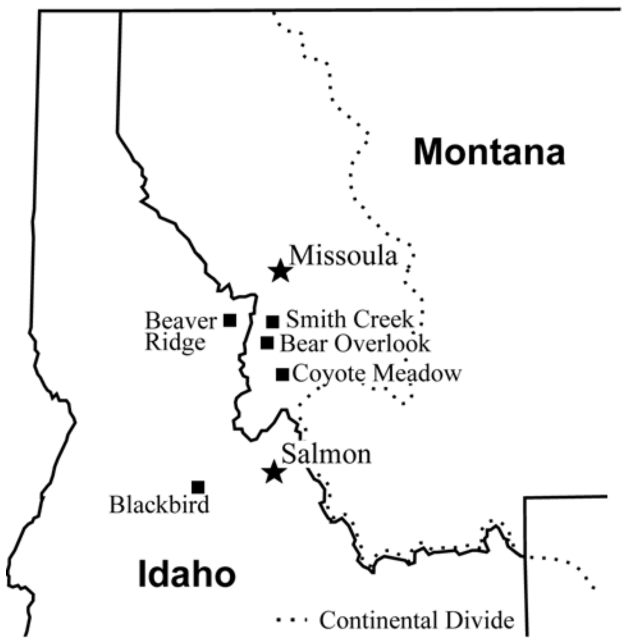


Figure 1. Study sites of the Restoring Whitebark Pine Ecosystems study.

Table 1. Description of the five sites included in the Restoring Whitebark Pine Ecosystems study.

Study Site	Smith Creek	Bear Overlook	Coyote Meadows	Blackbird Mountain	Beaver Ridge
National Forest	Bitterroot	Bitterroot	Bitterroot	Salmon	Clearwater
Elevation (ft above MSL)	7100-7600	7000-7600	7900-8200	8400-8600	6800-7600
Aspect	Southeast	Southeast	Northwest	South	South
Habitat type[1]	ABLA/LUHI	ABLA/LUHI	ABLA/LUHI ABLA/MEFE	ABLA/LUHI	ABLA/LUHI
Cover type[2]	WP/LP	WP/LP	WP/SF	WP/SF	WP/LP
Rust infection (%)	85	70	90	<1	51
Rust mortality (%)	95	93	91	<1	88
Number of treatment units[3]	3	2	6	2	8
Pre-treatment measurement year	1995	1996	1993	1997	1997
Year of prescribed burns	1996	1999	2000	1999	1999, 2000, 2002

[1] Habitat type is taken from Pfister and others (1977). ABLA is *Abies lasiocarpa*, LUHI is *Luzula hitchcockii*, and MEFE is *Menziesia ferruginea*.
[2] Cover type acronyms are WP-whitebark pine, SF-subalpine fir, and LP-lodgepole pine.
[3] Number of treatment units does NOT include control units.

make each site its own replicate, but replication of treatments across sites is difficult because of the different stand conditions within the five sites in this study. As a result, we took a "demonstration" approach to designing this study in which we implemented feasible, operational restoration treatments crafted to restore whitebark pine across large areas, and then designed treatment sampling schemes around the treated area to investigate the treatment effects. The design included a control and at least one treatment with two treatment units.

Smith Creek study site. The Smith Creek site was the first to be treated. It was composed of three treatment units (low intensity prescribed fire and nutcracker openings with and without prescribed burning) and a control (1A, 2A, and 2B, respectively, in fig. 2a). This study site was sandwiched between the 1988 Glen Lake burn and a 1967 clearcut of

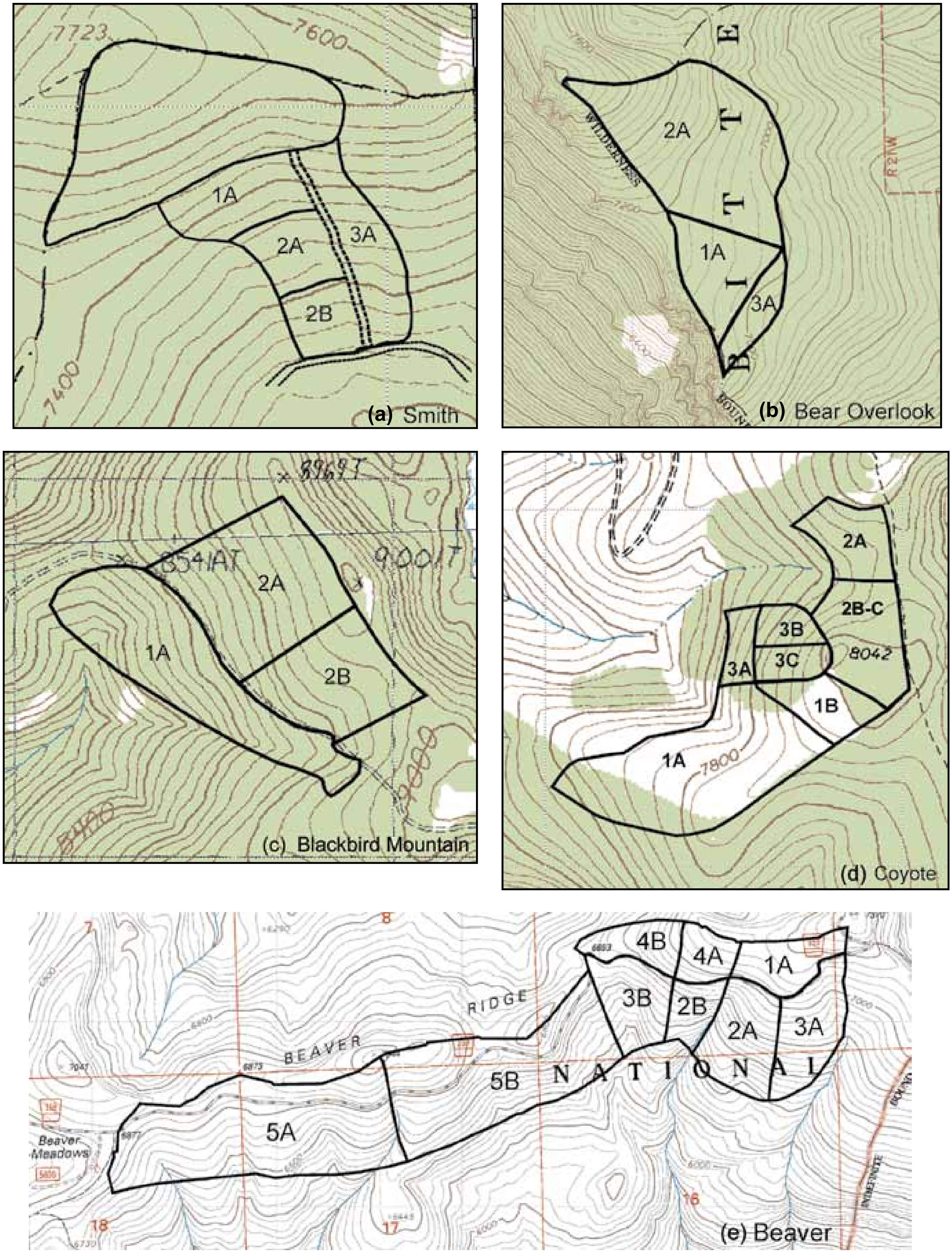


Figure 2. Treatment unit design for each site in this study: (a) Smith Creek, (b) Bear Overlook, (c) Blackbird Mountain, (d) Coyote Meadows, and (e) Beaver Ridge. See tables 1 and 3 for more information about these sites.

about 80 acres. Prior to treatment, the overstory consisted of 200- to 400-year-old overstory whitebark pine and lodgepole pine, and some younger subalpine fir and scattered large Engelmann spruce (table 1). The understory was mostly composed of seedling and sapling subalpine fir with occasional stagnated whitebark pine saplings. Grouse whortleberry (*Vaccinium scoparium)* and beargrass (*Xerophyllum tenax*) were the primary plant species dominating the undergrowth. At an elevation around 7000 ft above mean sea level (MSL), this site faced mostly southeast with slopes ranging from 10 to 50 percent. A large dozer line created during the 1988 Glen Lake fire ran up the northern boundary of the treatment areas (between the control and treatment areas). Small seeps that form the headwaters of Smith Creek delineate the boundaries of the southern portion of the study area.

Bear Overlook study site. This site was similar in stand structure and composition to the Smith Creek site. Large, old whitebark pine, subalpine fir, and scattered Engelmann spruce comprised the overstory, and the understory was dominated by subalpine fir seedlings and saplings. This site included about 0.3 miles of one of the most popular hiking trails and scenic overlooks on the Bitterroot National Forest (fig. 2b). A carpet of grouse whortleberry was the primary understory with scattered patches of mountain heath (*Phyllodoce empetritriforus)*, especially in the burn, no fuel enhancement unit (2A). The treatment area was more than 200 acres in size, but we installed plots only within the lower 20 acres of the study site, which is approximately 7200 ft MSL on flat slopes (<10 percent) that face southeast. Only two treatments were implemented on this site: moderate intensity prescribed burning treatments with and without fuel enhancement (2A, 1A) and a control (3A). We established a third treatment unit that was supposed to be a silvicultural cutting with no burn treatment, but the Ranger District was unable to implement the treatment due to lack of funds.

Blackbird Mountain study site. This site had two high intensity prescribed burning treatments (with and without fuel enhancement) and a control (2A, 2B, 1A, respectively) (table 1, fig. 2c). It was the only study site with no detectable blister rust infections on any of the sampled whitebark pine trees, although we did find one blister rust canker on a tree just above the study area. This site is at 9000 ft elevation, and faces mostly southwest with slopes from 10 to 20 percent. The site was in the late seral stages of development—it was primarily composed of old (200- to 300-year-old) whitebark pine in the overstory with significant amounts of younger subalpine fir in patches around senescing and dying whitebark pine. Sapling and seedling subalpine fir dominated the understory but the distribution was very patchy. The treated area was adjacent to a climax whitebark pine site—an open stand dominated by grasses and sedges in the understory. The Thunder Mountain Trail, created circa 1902, ran through the treatment area and there was also a major trail system that supported the lookout on Blackbird Mountain during the 1940s and 1950s. Because of these archeological relics, we had to protect those blazed whitebark pine trees and snags with fire shelters.

Coyote Meadows study site. This study site was composed of a mature stand of 300+ year-old whitebark pine surrounded by a 1963 clearcut unit. We designed treatments of low intensity prescribed fire with and without fuel enhancement in the mature stand (3B and 3C), and treatments in the cutting unit were designed to have high intensity prescribed fire with and without fuel enhancement (2B, 2C, and 1B) (fig. 2d). Fire scars sampled onsite revealed a rich history of fire, with burns in 1933, 1780, and approximately 1590. This was the first site in the RWPE study—plots were installed in the summer of 1993 and the fuel enhancement treatment was implemented in the fall of that year. Most of the site was burned in a high intensity wildfire during the Bitterroot Fires of 2000 before the prescribed burn could be implemented. The site has a westerly aspect with variable slopes ranging from 10 to 30 percent on the cutover units and greater than 30 percent in the old growth unit. The top of the unit is at approximately 8000 ft MSL and it forms the western boundary of a proposed wilderness area. There is a popular trail on the ridge that is the main route for climbing Kent Peak in the Sapphire Mountain Range. Ample seed sources were available along a high-elevation ridge northeast of the study site prior to the 2000 wildfires. Vegetation was highly variable across the units in this area. Most of the flat areas are poorly drained and contain seeps and swales with mesic, high-elevation vegetation, such as *Juncus drumundii* and *Dechampsia ceosnoposium*. Sites that are well drained usually contain common vegetation assemblages found in this ABLA/LUHI, VASC habitat type, such as grouse whortleberry, beargrass, and woodrush (*Luzula hitchcockii)*. The overstory contained old, dying whitebark pine mixed with a younger, thrifty element of subalpine fir. The understory consisted mostly of subalpine fir.

Beaver Ridge study site. This area is an extensive ridgetop system just northwest of the Selway Bitterroot Wilderness Area where there is an isolated population of rust-infected, dying whitebark pine along about 2 to 3 miles of ridge above 6800 ft elevation MSL. There is extensive whitebark pine mortality along most of this ridge caused by recent blister rust infections, the 1930 mountain pine beetle epidemic, and the historic fires (table 1). The site has many 100+ year-old snags created by the 1910 and 1889 wildfires in addition to the many living trees with fire scars from these events. Historical fire regimes were mostly mixed-severity with occasional stand-replacement fires. Beaver Ridge is experiencing a pulse of subalpine fir regeneration and rapid growth due to the high whitebark pine mortality and favorable climate conditions. The 660-acre study site is mostly south-facing with slopes ranging from 10 to 50 percent on decomposed granitic soils (mostly gneiss and schist). The entire study area is one habitat type (ABLA/LUHI, VASC; table 1) with the undergrowth dominated by beargrass and grouse whortleberry and an overstory consisting of dying whitebark pine, encroaching subalpine fir, and scattered large Engelmann spruce. There are also large patches originating from the 1910 fire that are dominated by lodgepole pine, especially on the western end of the ridge. The Beaver Ridge site had the most complex treatment design of all five sites (fig. 2e). We included low intensity prescribed fire treatments with and without fuel enhancement (4A and 4B, respectively), high intensity prescribed fire with and without fuel enhancement (5A and 5B, respectively), nutcracker openings with and without prescribed burning and with and without pile burning (2A, 2B, 3A, and 3B, respectively) (fig. 2e).

Sampling Methods

We installed 10 plots within each treatment unit to describe changes in ecological conditions within each unit. We systematically located these plots across the treatment units based on fixed distances and compass bearings. We could not randomly establish the plots because of the highly variable treatment unit shapes, diverse fuel conditions, and concerns for relocating plots, so we established the plots using a systematic design with a random start. All plots were mapped using compass bearings and distances from benchmarks (flagged or blazed trees), and the UTM coordinates and zone were recorded for each plot using a GPS.

Plots were circular in shape and 0.1 acre (0.04 ha) in size, and they were permanently located using 3-ft (1-m) rebar driven 2 ft (0.7 m) into the ground (fig. 3). A metal tag was wired to the rebar identifying the treatment unit and plot number. All trees greater than 4.5 inches (12 cm) DBH (Diameter Breast Height) were tagged using numbered aluminum (no-burn units only) or stainless steel casket (burn units) tags nailed in the center of the tree bole at DBH facing plot center. We measured species, DBH, tree height, height to crown base, and health (live, sick, dying, or dead) for each tree and then recorded the percent crown volume killed by blister rust for all whitebark pine trees. The same characteristics were measured for all live trees less than 4.5 inches DBH and higher than 4.5 ft tall (1.37 m) with DBH estimated to 1 inch (2.5 cm) diameter classes. Tree seedlings (trees less than 4.5 ft tall) were counted by 1-ft (0.3-m) height classes on a 1/300 ac circular plot in the middle of the 1/10 acre plot using the same plot center.

Surface fuels were measured on two 50-ft (15.2-m) transects that originated at the plot center rebar and extended in opposite directions (fig. 3). The two transects (A and B) were oriented north and south for plots 1, 4, 7, and 10; at the azimuths 60 and 240 degrees for plots 2, 5, and 8; azimuths 120 and 300 degrees for plots 3, 6, and 9 within a unit (Brown 1974). The end of the transects (50 ft mark) was permanently established using a 10-inch nail driven into the ground so only the nail head was visible. Another 10-inch nail was driven into the ground at 37.2 ft to aid in transect relocation and to identify the outside of the macroplot. We tied wire flags and orange flagging around the nails to help in relocation. Fine woody fuels (1 hr = less than 0.25 inches diameter and 10 hr = 0.25 to 1.0 inch diameter) intersects were counted along the first 6 ft (2 meters) of the A and B transects; small branchwood (100 hr = 1 to 3 inches diameter) intersects were counted along the first 10 ft (3 meters); and log (1000 hr = greater than 3 inches or 7.6 cm diameter) diameters and decay classes were measured for any log that intersected the entire 50 ft (15.2 meters). Duff and litter depths were measured at the zero, 37.2-ft, and 50-ft

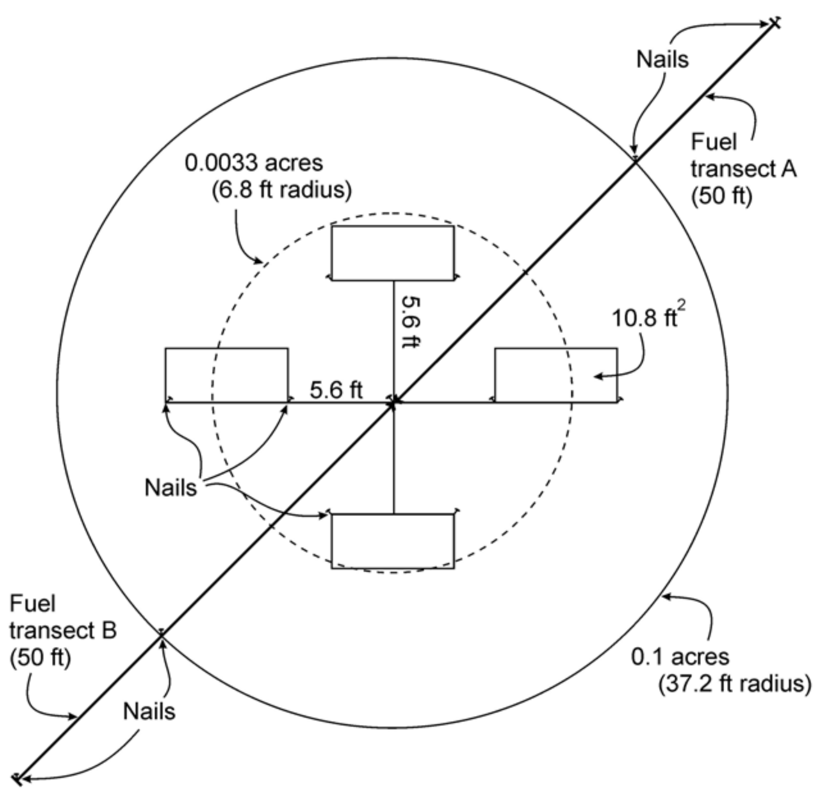


Figure 3. Diagram of the sampling design for plots used in the study.

distances along each of the two transects. Log diameters were always measured in order from the zero end of the tape (plot center) to the 50 ft mark so we could track any newly fallen log material.

We visually estimated the vertically projected foliar cover of each vascular plant species within each of four 10.8-ft^2 (1-m^2 or a frame 1.41 m by 0.71 m) microplots at each plot (fig. 3) using 12 cover classes defined by the following ranges in percent: less than 1, 1 to 5, 5 to 15, 15 to 25, and up to 95 to 100 (see FIREMON for details in Lutes and others 2006). We also recorded the heights and two crown widths of all shrubs taller than 3.3 ft (1 m). Ground cover for rock, bare soil, wood, duff/litter, and moss was also recorded for each microplot using the same cover classes (Lutes and others 2006). Microplots were permanently established by driving 8-inch stainless steel nails into the ground until only the nail head was visible at the microplot corners shown in fig. 3. We painted the nail heads orange and tied flagging around the nails to aid in relocation. Nails were relocated during future measurements using a metal detector and re-flagged after each measurement.

We took the tree, fuel, and plant species measurements described above prior to the treatment (pre-treatment), 1 year post-treatment, and 5 years post-treatment. Some units received two or more treatments (cutting and prescribed burn, for example) and we measured all characteristics detailed above after each treatment was implemented. This report only summarizes the measurements after the last treatment was implemented. We also estimated the percent of the plot burned by the prescribed fire and documented any other disturbances observed at the plot (mountain pine beetles, and *Ips* spp. beetles, for example). We took photographs of the plot looking north and east from plot center at each of the measurement times. Lastly, we indirectly measured the leaf area index (LAI) on each plot using the LiCor LAI-2000 instrument (Welles and Norman 1991).

Fuel moisture samples were collected for each fuel component (1, 10, 100, and 1000 hr; shrub; and herbaceous) at the start of the prescribed burn just outside each plot. We sampled each fine downed woody fuel size class (1, 10, and 100 hr) by collecting at least 10 twigs about 4 inches long on each plot and storing them in tightly sealed sampling bottles. Live shrub (mostly grouse whortleberry) and live herbaceous (mostly beargrass and elk sedge (*Carex geyeri*)) fuels were cut and stored in sealable plastic bags. Logs (1000 hr) were sampled by cutting a 2-inch thick "cookie," or cross-section, from the center of two to three logs per plot with a chainsaw and storing them in large, plastic sealable bags. All samples were labeled with plot number, date, sample type, and study site. Samples were placed in burlap bags, transported back to the laboratory in a cooler, then immediately weighed to the nearest 0.01 gram. After weighing, the samples were placed into aluminum pie pans and dried for 48 to 72 hrs at 80 °C, then weighed again to determine moisture content.

Treatment Summary

Three types of treatments were investigated in this study (table 2). The primary treatment investigated was prescribed fire and it was implemented at three intensity levels to mimic the three types of fire severity. A *high intensity* prescribed fire was used to mimic stand-replacement fire where more than 90 percent of the overstory is killed by fire (fig. 4c), while the *moderate intensity* prescribed fire simulated effects from a mixed-severity fire (fig. 4b). A mixed-severity fire has patches of stand-replacement fire mixed with varying severities of non-lethal surface fires (10 to 90 percent overstory mortality). The non-lethal surface fire was emulated with a *low intensity* prescribed fire (fig. 4a). Prescribed fire intensity levels were achieved through the combination of desired wind speed, fuel moisture, and fuel loadings. None of the National Forest fire staff involved in this study had extensive experience in burning high-elevation ecosystems, so most were overly cautious in implementing the burn. Consequently, the implementation of prescribed burns was at the lower end of the intensity level. Most prescribed burns

Table 2. General summary of treatments and their combinations used in the study.

Cutting treatments	Prescribed fire treatments	Slash treatments	Planting treatments
None	None	None	None
Nutcracker Openings—cut small 0.5-5 acre clearcuts leaving all healthy whitebark pine trees	*Low intensity*—light fire to consume fuels and kill understory competition	*Piled*—slash was collected by hand and put into piles	*Planted*—areas planted with rust-resistant whitebark pine
Slashing—cut subalpine fir and Engelmann spruce to enhance fuel bed	*Moderate intensity*—moderate fire to consume slash and kill subalpine fir regeneration	*Fuel enhancement*—slash was scattered by hand making fuelbed more contiguous	
Thinning—cut subalpine fir and Engelmann spruce to remove competition	*High intensity*—A fire to kill more than 90% of all trees		

Figure 4. Three types of prescribed fire implemented in this study: (a) stand-replacement fire emulated using a high intensity prescribed fire, (b) mixed-severity fire mimicked by a moderate intensity prescribed fire, and (c) non-lethal surface fire replicated by a low intensity prescribed fire.

were ignited using strip head fires about 10 to 20 ft wide, but a heli-torch was used on two sites to simulate stand-replacement fire, and a terra-torch (flame thrower mounted on a truck) was used at the Beaver Ridge site to initiate stand-replacement fire (fig. 5).

Tree cuttings were implemented at various intensities and sizes to achieve several objectives. We created cutting treatments called *nutcracker openings* where all trees except for whitebark pine trees were cut within near-circular areas of 1 to 5 acres to entice the nutcrackers to cache seeds there (fig. 6). Openings were designed to mimic the effects of patchy mixed-severity burns and some stand-replacement burns (fig. 4c). Norment (1991) found that nutcrackers were most abundant in 1- to 40-acre (0.1- to 15-ha) disturbed or non-forest patches. We also designed *thinning treatments* to emulate the effect of non-lethal surface fires where all subalpine fir and spruce trees below a threshold diameter were cut. *Selection cuttings* were also implemented where all fir and spruce trees greater than a threshold diameter (5 inches or 13 cm in most cases) were cut to mimic effects of passive crown fires in mixed-severity fire regimes. Lastly, we used a cutting treatment called *fuel enhancement cuttings* where small to large subalpine fir and spruce trees were cut and positioned within the treatment unit to enhance the fuelbed so prescribed fire could visit a greater portion of the stand to increase burn coverage (fig. 7). Fuel enhancement cuttings also widened the short burning window in high-elevation environments by providing abundant dry fine fuels during the late summer and early fall.

Some additional actions were implemented on treatment units in this study after the cutting or burning treatments. We piled and burned the slash at one Beaver Ridge treatment unit. We also planted whitebark pine trees on a couple of sites, but planting was not included as a major factor in this report.

Figure 5. Terra-torch used to ignite the high intensity, stand-replacement prescribed fire at the Beaver Ridge study site.

Figure 6. Nutcracker openings at the Beaver Ridge study site.

Figure 7. Fuel enhancement cutting at the Beaver Ridge study site.

Analysis Methods

The ten plots within each treatment unit were used for observations in the tree mortality calculations. We used the 40 microplots (four at each plot) within each treatment unit as observations in the calculation of plant response in terms of canopy cover. Loading estimates for each of the 20 transects (two at each plot) were used as observations to detect differences in woody fuels, and 60 estimates of duff and litter depth (three measurements per transect) were used to detect differences in duff and litter loading. Pictures of selected plots are included for visual illustration of treatment effects. Within each treatment unit, we statistically compared pre-treatment conditions against each post-treatment condition (1, 5, and 10 years post-treatment) using a standard t-test. No comparisons were made among treatments or among sites.

Tree mortality was computed as a percent killed by species for three size classes: (1) seedlings (less than 4.5 ft in height), (2) saplings (less than 4.5 inches DBH), and (3) overstory (greater than 4.5 inches DBH). We also included an analysis of snags, which are trees greater than 4.5 inches DBH, that were dead at the time of measurement. Fuel loadings were computed from the planar intercept counts using the computations described by Brown (1974). Plant volume estimates were calculated by multiplying the proportion canopy cover (cover divided by 100 percent) by the area of the microplots (10.8 ft^2 or 1 m^2) and the plant height.

Results

Guide Organization

This section is the heart of the Management Guide because it contains a comprehensive summary of the measured effects of the treatment(s) for each treatment unit in the study across all sites (see table 3 for treatment summary). Each treatment unit summary has a static format that includes photographs, treatment summaries, and bar charts; tabular results that are presented in approximately the same position for each treatment unit. When possible, the photographs were taken in the same direction for the same plot for each of the re-measurement intervals, but some photographs were not always in the same direction because of trees, rain, snow, and other unforeseen problems (a fire at the Missoula Fire Sciences Laboratory destroyed slides taken for some of the study sites). Discussions of treatment details for each treatment unit may be somewhat redundant because many treatments were repeated across the sites. Tabular summaries of the tree, fuel, and plant species measurements are included for each of the three intervals. Canopy cover changes for only the ten most common vascular plant species are presented because most species occurred at less than trace levels and there were only 5 to 15 species common on all microplots (greater than 5 percent cover) in any treatment unit. Lastly, a brief discussion of study findings and management recommendations for each treatment unit is presented.

The treatment unit description section is organized by wildland fire regimes. Three fire severity types—stand-replacement fires, mixed-severity fires, and non-lethal surface fires—are discussed in this guide and are referenced by low, moderate and high intensity prescribed burns, respectively. Within each fire regime, this guide is organized by geographical area and treatment type. Each treatment type refers to a treatment unit from a site in this study. This management guide is organized in this fashion so that managers can match conditions within a proposed treatment site (prescribed fire intensity, geographical area, pre-treatment conditions, and habitat type) to a treatment unit in this study to approximate potential effects of the proposed treatment.

Graphical and tabular data are presented in a consistent manner for each treatment unit. Each summary consists of five sections with each page designed to illustrate the changes that occurred over time as a result of the treatment. The first page describes the treatment unit and the treatment(s) implemented at that unit. The second page shows photos taken in the field at the three measurement times (pre-treatment, 1 year, and 5 years post-treatment). The third page presents graphs of tree data (tree density by species and whitebark pine mortality). The fourth page presents graphs describing the fuelbed characteristics and undergrowth composition (surface fuel loads, ground cover and understory vegetation cover). The fifth page presents a table that summarizes the data presented in the graphs. All pages except the last are organized into three rows, labeled at the left margin. Row 1 is labeled “PRE” and represents conditions prior to the treatment, while “POST-1” and “POST-5” represent rows summarizing data corresponding to conditions after the treatment at 1 year and 5 years, respectively. These margin labels and the header label at the top of the page are color coded by fire severity class for convenience. Red represents stand-replacement fires (high intensity prescribed burns), orange signifies mixed-severity (moderate intensity prescribed burns), and yellow represents non-lethal surface fires emulated by low intensity prescribed burns.

Table 3. Detailed summary of the treatments and combinations applied to each treatment unit and site. The second column is the planned treatment and the third column details its final implementation. Some units were not burned at the planned fire severity.

Treatment unit	Description	Treatment details and implementation
		Smith Creek
1A	Underburn with no fuel enhancement	Low intensity prescribed burn
2A	Nutcracker opening and burn	Moderate intensity broadcast burn small clearcuts (0.1-0.2 acre) with whitebark pine retention
2B	Nutcracker opening without burn	Small clearcuts (0.1-0.2 acre) with whitebark pine retention
3A	Control for entire study site	No treatment
4A	Thin existing 1965 clearcut	Not included in this study
		Bear Overlook
1A	Underburn only	Low intensity prescribed burn
2A	Underburn with fuel enhancement	Low intensity prescribed burn with trees cut to enhance fuelbed
3A	Control for entire study site	No treatment
		Coyote Meadows
1A	Control for 1B	No treatment
1B	Burn with no fuel enhancement	Low intensity wildfire burn in 1963 clearcut
2A	Control for 2B and 2C	No treatment
2B	Burn with fuel enhancement	High intensity wildfire burn in 1963 clearcut with saplings cut to enhance fuelbed
2C	Burn with no fuel enhancement	High intensity wildfire burn in 1963 clearcut
3A	Control for 3B and 3C	No treatment
3B	Burn with no fuel enhancement	Low intensity wildfire burn in mature stand
3C	Burn with fuel enhancement	Low intensity wildfire burn with saplings cut to enhance fuelbed
		Blackbird Mountain
1A	Control for entire study site	No treatment
2A	Burn with no fuel enhancement	High intensity prescribed burn
2B	Burn with fuel enhancement	High intensity prescribed burn with fuel enhancement
		Beaver Ridge
1A	Control for entire study site	No treatment
2A	Nutcracker opening with no burn	Small clearcuts (1-2 acre) with whitebark pine retention
2B	Nutcracker opening with burn	Moderate intensity broadcast burn small clearcuts (1-2 acres) with whitebark pine retention nutcracker opening with burn
3A	Nutcracker opening with no burn and with planting	Same as 2A but planted with WP seedlings
3B	Nutcracker opening with burn and planting	Same as 2B but planted with WP seedlings
4A	Underburn with no fuel enhancement	Low intensity prescribed burn
4B	Underburn with fuel enhancement	Low intensity prescribed burn with trees cut to enhance the fuelbed
5A	Stand-replacement fire with no fuel enhancement	Moderate intensity prescribed burn
5B	Stand-replacement fire with fuel enhancement	Moderate intensity prescribed burn with trees cut to make fuelbed contiguous

The photo page shows treatment effects and how conditions changed over the course of the study. Photos were selected from all ten plots in the treatment unit and thus are not always repeated views of the same locations over time. Repeated photo-points were not always available for three reasons:

- some photos were burned in a 2004 fire at the Missoula Fire Sciences Laboratory;
- some photos were of poor quality;
- photos were not taken at exactly the right photo-point and in the right direction; and
- photos failed to provide an adequate photo sequence because trees, rocks, or logs obstructed the view.

However, we did use photos from one plot in the treatment unit when adequate pictures were available for all three time periods. We also included two views of the treatment unit for each time period.

The tree data page (second section) has two figures for each point in time. The left figure contains bar graphs depicting tree density in trees per acre, stratified by the following species:

- WP = Whitebark pine (red), and
- SF = Subalpine fir (green),

and by the following size classes:

- SEED = trees less than 4.5 ft tall,
- SAP = trees greater than 4.5 ft tall and less than 4.5 inches DBH, and
- OVST= overstory trees with greater than 4.5 inches DBH.

The right figures contain bar graphs depicting whitebark pine mortality, in percent, stratified by size class. Seedling summaries are light green in color, sapling results are forest green, and overstory results are dark green.

The fuelbed composition section (section 3) has three figures for each point in time. The figures to the left consist of bar graphs depicting surface fuel loadings for litter, fine, and coarse woody dead fuels. Litter depth (yellow) is measured in inches and includes both litter and duff layers. The fine woody fuels (1 and 10 hr, 0 to 1 inch diameter) and small branchwood (100 hr, 1 to 3 inches diameter) downed dead woody fuels are measured in tons per acre and are noted in bright (1 hr) to dark red (100 hr). Surface fuel loads of logs (1000 hr, greater than 3 inches diameter) are measured in tons per acre and are noted in brick red. Each of the three bar graphs has its own scale because the higher values for the heavy fuels tend to overwhelm the data range of the smaller fuels.

The center figure on the fuelbed composition page shows a single bar graph describing the ground cover (percent) for five different components: woody material (brown), rock (gray), soil (yellow), duff and litter (olive green), and moss (bright green). The right figure has two bar graphs describing the understory vegetation by vegetation cover (percent). The tables contain data for the 10 most common species found. To facilitate quick visual comparison between different points in time, the species are listed in the same order in all figures and each species has a unique color described in table 4.

The last section presents a tabular statistical summary of the data collected for each treatment unit for each of the time periods. Two additional tree species are includced: Engelmann spruce (ES) and Lodgepole pine (LP). The number in parentheses after each entry indicates the percent increase or decrease from the pre-treatment condition for all time periods. These percents are **bold** if they are statistically significant from the pre-treatment condition ($p < 0.05$) using the two-tailed t-test. Graphs will appear empty if data are not available.

Table 4. The ten vascular plant species presented in the fourth section of the treatment unit summaries.

Abbreviation	Scientific name Common name	Color
VASC	*Vaccinium scoparium* Grouse whortleberry	Charcoal
VAGL	*Vaccinium globulare* Blue Huckleberry	Brown
PHEM	*Phyllodoce emperitriforus* Mountain heath	Brick red
MEFE	*Menziesia ferruginea* Skunk bush	Red
XETE	*Xerophyllum tenax* Beargrass	Dark green
CAGE	*Carex geyerii* Elk sedge	Forest green
CARO	*Carex rossii* Sedge	Bright green
CARU	*Calamagrostis rubescens* Pinegrass	Dark blue
CACO	*Carex concinnoides* Sedge	Navy blue
LUHI	*Luzula hitchcockii* Woodrush	Bright blue

Stand-Replacement Fires

Study Site: Blackbird Mountain, Salmon-Challis National Forest, Central Idaho

Treatment: High intensity prescribed burn with fuel enhancement (Unit 2B)

Management Planning: This treatment was proposed in March of 1997 with a burn plan written in the summer of 1997 and the NEPA work done under a categorical exclusion for research in the winter of 1997 and 1998. Public comment was solicited during public meetings held during the fall of 1997 and winter of 1998.

Treatment Description: We used a fuel enhancement tree cutting treatment to increase loading and contagion of fuels on the treatment unit to foster an extensive, high intensity burn. The Cobalt Ranger District assigned a timber saw crew to cut subalpine fir trees and directionally fell them so the tree biomass would increase the amount and distribution of fuels on the forest floor. There were no diameter or height cutting guidelines; crews were directed to cut trees that would improve the burning of the fuelbed. This treatment was accomplished in summer of 1998 and the slash was allowed to cure for more than 1 year.

A high intensity prescribed burn was implemented on September 11, 1999, to mimic stand-replacement fires that were historically common. Fire lines surrounding the burn were widened using strip head fires that were 1 to 10 ft in width. A heli-torch was then used to ignite the center of the unit to achieve high intensities. Three, 50- to 100-ft strips were lit by the helicopter crew over an hour. However, a heli-torch malfunction required the fire crews to finish the ignition using wide strip head fires of variable length.

Fuels were moderately dry at the start of the burn with measured moistures as follows: 1 hr woody = 11 percent, 10 hr = 9 percent, 100 hr = 8 percent, 1000 hr sound = 21 percent, 1000 hr rotten = 22 percent, live shrub = 76 percent, and live herbaceous = 49 percent. A hard frost (24 °F) occurred two days prior to the burn so live fuels were dry enough to carry the fire in many areas. At ignition time, around 1130, the temperature was 50 °F with a relative humidity of 39 percent. During the burn, temperatures increased to 52 to 55 °F and relative humidity decreased to 18 to 23 percent. The temperature was 54 °F and relative humidity was 18 percent at the termination of ignition, around 1715. Weather was sunny, clear, and mostly calm, with 3 to 5 mph winds from the north and northeast. Antecedent weather for the three days prior to the burn was mostly sunny and cool with high temperatures in the 50s and relative humidity ranging from 20 to 50 percent. No significant rainfall had occurred for six days.

The high intensity prescribed fire had surface flame lengths averaging 3 to 10 ft with some slash jackpots creating flames reaching 10 to 15 ft. Strip widths and ignition rates were designed to maximize intensity and safety. Passive crown fire behavior was observed in many areas of the unit with most subalpine fir tree crowns torching in over 80-ft flames. The burn consumed nearly all fine fuels and duff, and covered more than 95 percent of the unit. Many embers were driven aloft by the fire, especially after the passive crown fire activity, and some ignited areas outside the boundary and burned portions of the control plots in this study. The fire smoldered for a couple of days after the burn, but was monitored by District personnel.

This site was burned again by the Dry Fork Fire that occurred in August of 2001. This wildfire burned under dry, summer conditions estimated at 90 ^{o}F and less than 20 percent relative humidity. However, the wildfire burned only a small portion of this unit (less than 5 percent) because of the lack of fine fuels that were consumed by the 1999 prescribed burn. All control plots were burned or partially burned by this fire, which killed most trees and consumed all fine fuels and most coarse woody debris.

Management Recommendations: Nutcrackers harvested seed from still-smoldering cones on trees within the fire boundary during the 24 hrs following the burn. We observed extensive caching by nutcrackers throughout the unit, especially during the post-fire measurement time. However, whitebark pine tree regeneration was marginal, indicating that 5 years may not be enough time for successful establishment of whitebark pine seedlings. We recommend planting these sites with rust-resistant whitebark pine seedlings to both ensure the species continued dominance and to shorten the lag time to achieve full whitebark pine stocking. Fuel enhancement cutting is recommended because it gave the fire crew a wider ignition window and it generated higher intensities even though the severities were quite similar across the two Blackbird Mountain units (2A, 2B), probably because of the drier burning conditions and heli-torch ignition method.

Site: Blackbird Mountain, Salmon-Challis National Forest, Central Idaho
Treatment: High intensity prescribed burn
with fuel enhancement (Unit 2B)

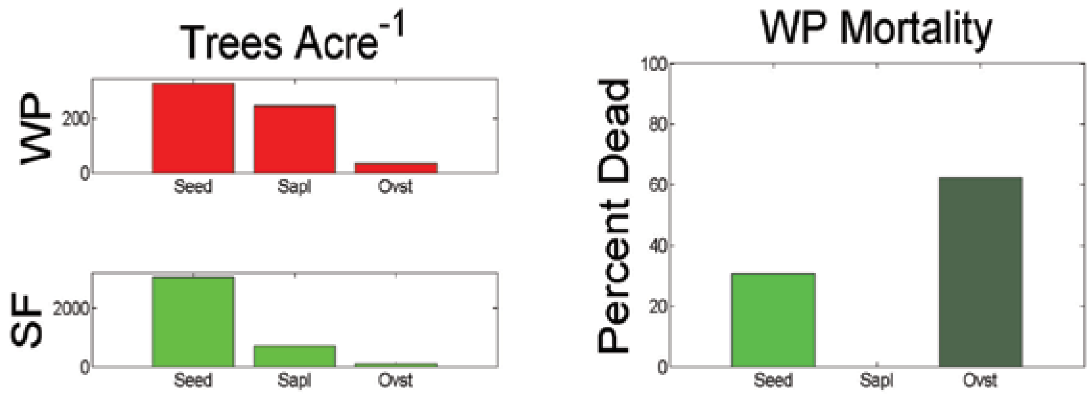
PRE

POST-1

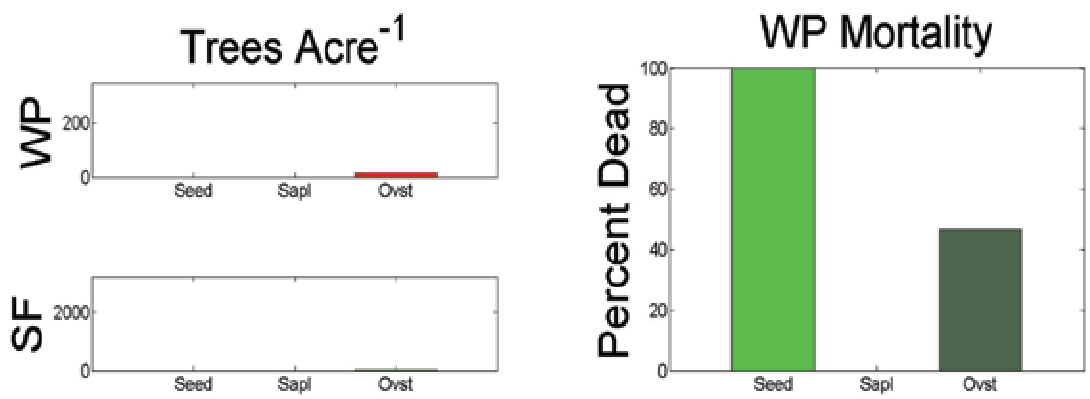
POST-5

Site: Blackbird Mountain, Salmon-Challis National Forest, Central Idaho
Treatment: High intensity prescribed burn
with fuel enhancement (Unit 2B)

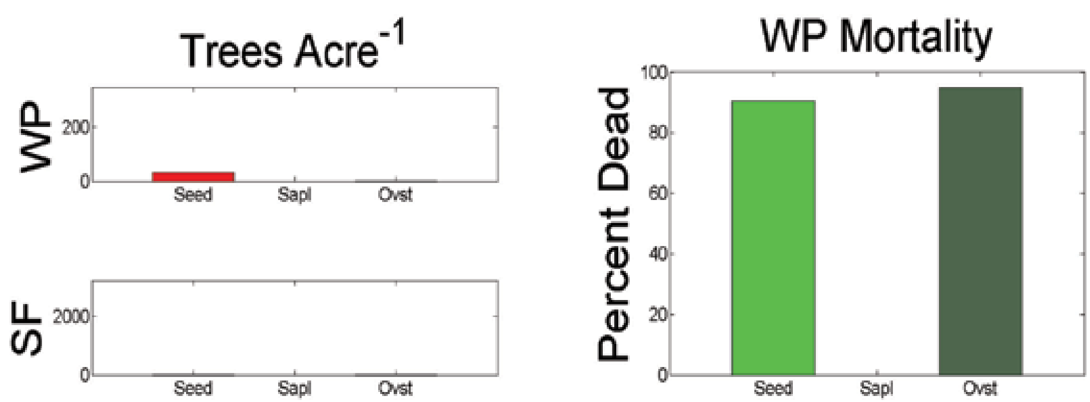
PRE



POST-1

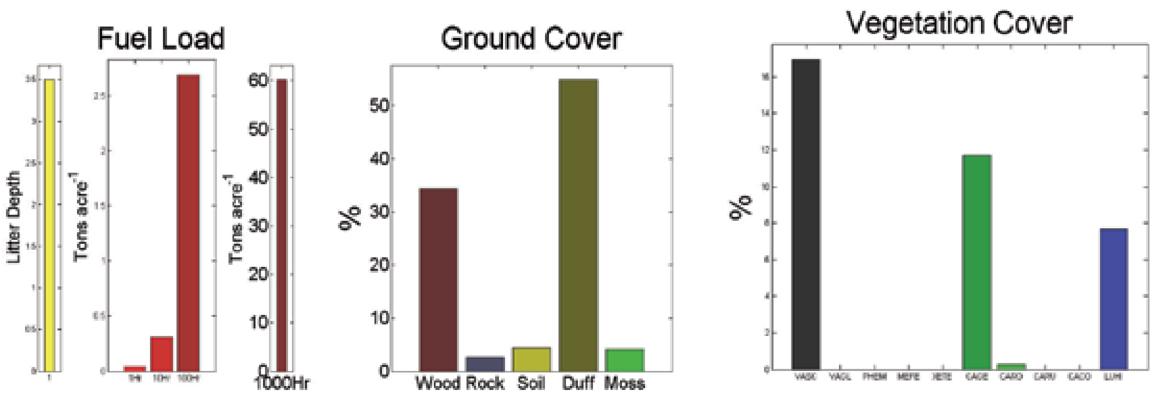


POST-5

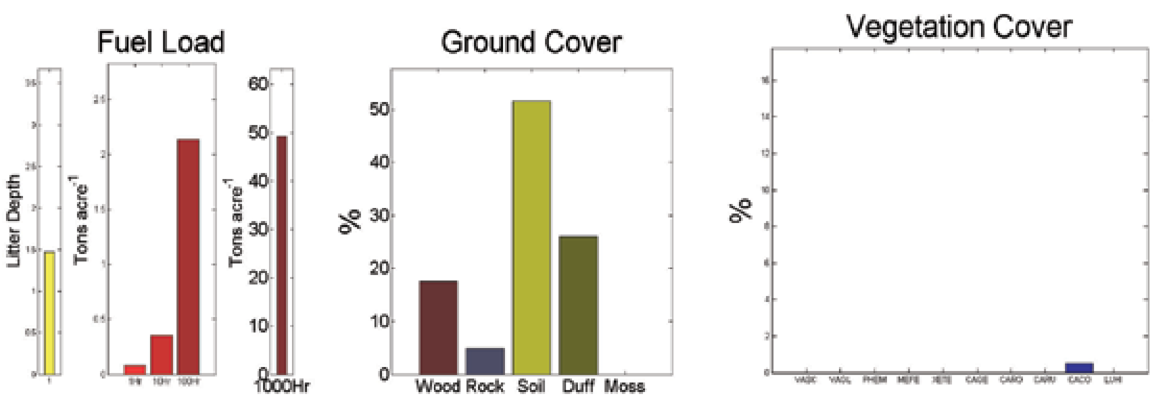


Site: Blackbird Mountain, Salmon-Challis National Forest, Central Idaho
Treatment: High intensity prescribed burn
with fuel enhancement (Unit 2B)

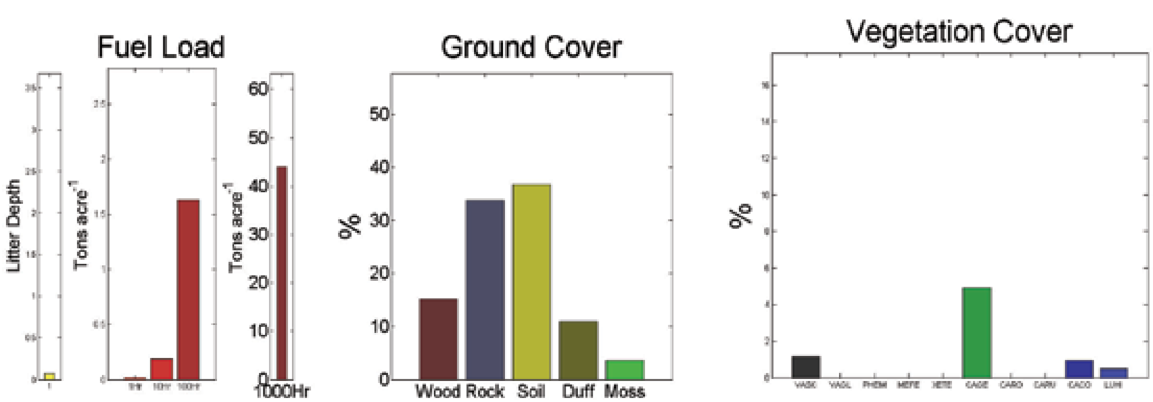
PRE



POST-1



POST-5



Site: Blackbird Mountain, ID. Salmon-Challis NF High intensity prescribed burn with fuel enhancement (Unit 2B)			
	PRE	**POST 1 Yr**	**POST 5 Yr**
TREE DENSITY (trees acre-1)			
WP seedling	331	0.00 (**-100.00**)	31.00 (**-90.63**)
SF seedling	3090	0.00 (**-100.00**)	1.00 (**-99.97**)
ES seedling	0	0.00 (NA)	0.00 (NA)
LP seedling	120	0.00 (-100.00)	0.00 (-100.00)
WP sapling	247	0.00 (**-100.00**)	0.00 (**-100.00**)
SF sapling	713	0.00 (**-100.00**)	0.00 (**-100.00**)
ES sapling	0	0.00 (NA)	0.00 (NA)
LP sapling	14	0.00 (-100.00)	0.00 (-100.00)
WP overstory	33	16.00 (-51.52)	2.00 (**-93.94**)
SF overstory	112	45.00 (**-59.82**)	12.00 (**-89.29**)
ES overstory	0	0.00 (NA)	0.00 (NA)
LP overstory	10	5.00 (-50.00)	0.00 (-100.00)
SURFACE FUELS			
Litter depth (inches)	3.5	1.47 (**-57.93**)	0.07 (**-97.95**)
1 hour fuel load (tons acre-1)	0.04	0.08 (80.19)	0.02 (-53.28)
10 hour fuel load (tons acre-1)	0.31	0.36 (16.14)	0.19 (-38.09)
100 hour fuel load (tons acre-1)	2.69	2.13 (-20.66)	1.63 (-39.24)
1000 hour fuel load (tons acre-1)	60.23	49.21 (-18.30)	44.08 (-26.82)
GROUND COVER (%)			
Wood	34.42	17.50 (**-16.92**)	15.23 (**-19.20**)
Rock	2.58	4.92 (**2.35**)	33.75 (**31.18**)
Soil	4.4	51.50 (**47.10**)	36.75 (**32.35**)
Duff	54.9	25.95 (**-28.95**)	11.00 (**-43.90**)
Moss	4.1	0.00 (**-4.10**)	3.70 (-0.40)
VEGETATION COVER (%)			
VASC	16.94	0.00 (**-16.94**)	1.16 (**-15.78**)
VAGL	0	0.00 (0.00)	0.00 (0.00)
PHEM	0	0.00 (0.00)	0.00 (0.00)
MEFE	0	0.00 (0.00)	0.00 (0.00)
XETE	0	0.00 (0.00)	0.00 (0.00)
CAGE	11.68	0.00 (**-11.68**)	4.92 (**-6.76**)
CARO	0.25	0.00 (-0.25)	0.00 (-0.25)
CARU	0	0.00 (0.00)	0.00 (0.00)
CACO	0	0.50 (0.50)	0.95 (**0.95**)
LUHI	7.67	0.00 (**-7.67**)	0.50 (**-7.17**)

Study Site: Blackbird Mountain, Salmon-Challis National Forest, Central Idaho

Treatment: High intensity prescribed burn with NO fuel enhancement (Unit 2A)

Management Planning: This treatment was proposed in March of 1997 with a burn plan written in the summer of 1997 and the NEPA work done under a categorical exclusion for research in the winter of 1997 and 1998. Public comment was solicited during public meetings held during the fall of 1997 and winter of 1998.

Treatment Description: We implemented a high intensity prescribed burn September 11, 1999 to mimic stand-replacement fires that were common on the historical landscapes in this area. Fire lines surrounding the burn were widened using strip head fires 1 to 10 ft in width. A heli-torch was used to ignite the center of the proposed burn at high intensities. Three 50- to 100-ft strips were lit by the helicopter crew over an hour. However, a heli-torch malfunction required the fire crews to finish the ignition using wide strip head fires of variable length.

Fuels were moderately dry at the start of the burn with measured moistures as follows: 1 hr woody = 11 percent, 10 hr = 9 percent, 100 hr = 8 percent, 1000 hr sound = 21 percent, 1000 hr rotten = 22 percent, live shrub = 76 percent, and live herbaceous = 49 percent. A hard frost (24 ^{o}F) had occurred two days prior to burn so live fuels were dry enough to actually carry the fire in many areas. When ignition was started around 1130 to widen fire lines, the temperature was 50 ^{o}F with relative humidity at 39 percent. During the burn, temperatures increased to 52 to 55 ^{o}F and relative humidity decreased to 18 to 23 percent. At the end of the burn (1715), the temperature was 54 ^{o}F and relative humidity was 18 percent. Weather was sunny, clear, and mostly calm, with 3 to 5 mph winds from the north and northeast. Antecedent weather for the three days prior to the burn was mostly sunny and cool with high temperatures in the 50s and relative humidity ranging from 20 to 50 percent. No significant rainfall had occurred for six days.

The high intensity fire achieved the prescribed surface flame lengths averaging 3 to 10 ft in this unit. Strip widths and ignition rates were designed to maximize intensity and safety. We observed passive crown fire behavior in many areas of the unit with most subalpine fir tree crowns torching in more than 80 ft flames. The burn consumed nearly all fine fuels and duff, and covered more than 95 percent of the unit. Many embers were driven aloft by the fire, especially after the passive crown fires, and some ignited areas outside the boundary and burned portions of the control plots in this study. The fire smoldered for a couple of days after the burn, but was monitored by District personnel.

This site was burned again by the Dry Fork Fire that occurred in August of 2001. The wildfire burned under dry, summer conditions estimated at 90 ^{o}F and less than 20 percent relative humidity. However, the fire only burned small portions of this unit (less than 5 percent) because of the lack of fine fuels that had been consumed by the 1999 prescribed burn. Nearly all control plots were burned or scorched by this wildfire, which killed most trees and consumed most fine fuels and coarse woody debris.

Management Recommendations: We observed extensive nutcracker caching of whitebark pine seeds throughout the unit, especially during the 5 years post-fire. However, whitebark pine tree regeneration was marginal indicating that 5 years may not be enough time for seedlings to successfully establish. We recommended planting these sites with rust-resistant whitebark pine seedlings both to ensure its continued dominance and to shorten the lag time to achieve full stocking. The high intensity and severity achieved with this burn without fuel enhancement demonstrates that high intensity prescribed burns are possible in natural fuels, but the conditions (temperature, humidity, and wind) must be conducive for this treatment. It may be that these conducive conditions are too dry and windy to safely contain the prescribed fire without extensive control measures (for example, wide fire lines, widespread hose lays, and fuel-free geographical features). However, this burn showed it can be done successfully without extensive control. Log loadings increased dramatically following the fire because whitebark pine snags fell as their bases were consumed by the fire.

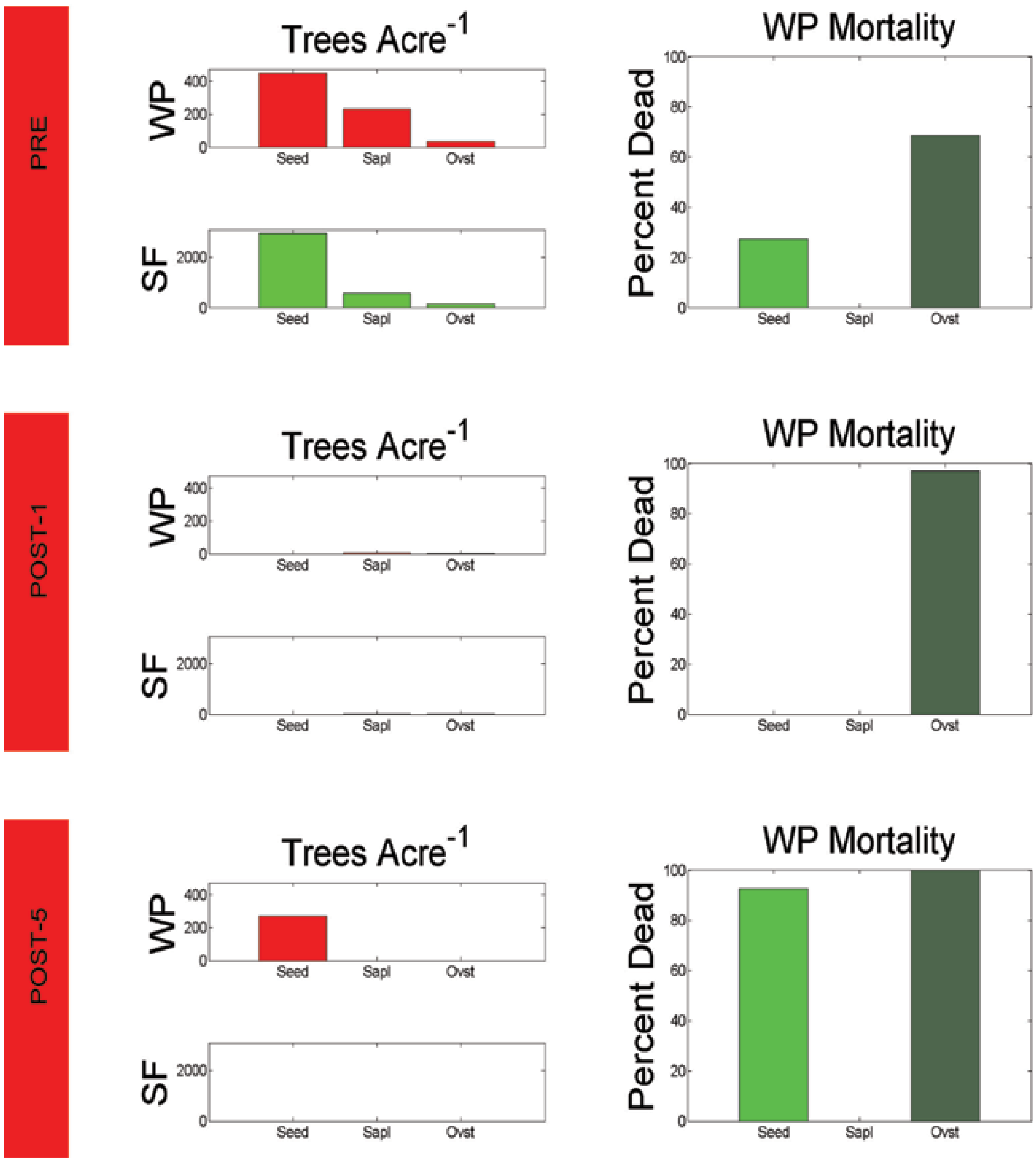
Site: Blackbird Mountain, Salmon-Challis National Forest, Central Idaho
Treatment: High intensity prescribed burn
with NO fuel enhancement (Unit 2A)

PRE

POST-1

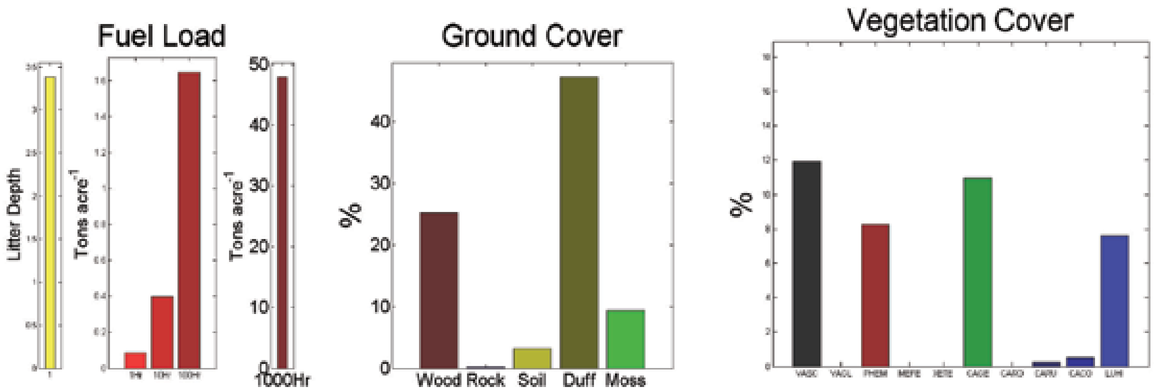
POST-5

Site: Blackbird Mountain, Salmon-Challis National Forest, Central Idaho
Treatment: High intensity prescribed burn
with NO fuel enhancement (Unit 2A)

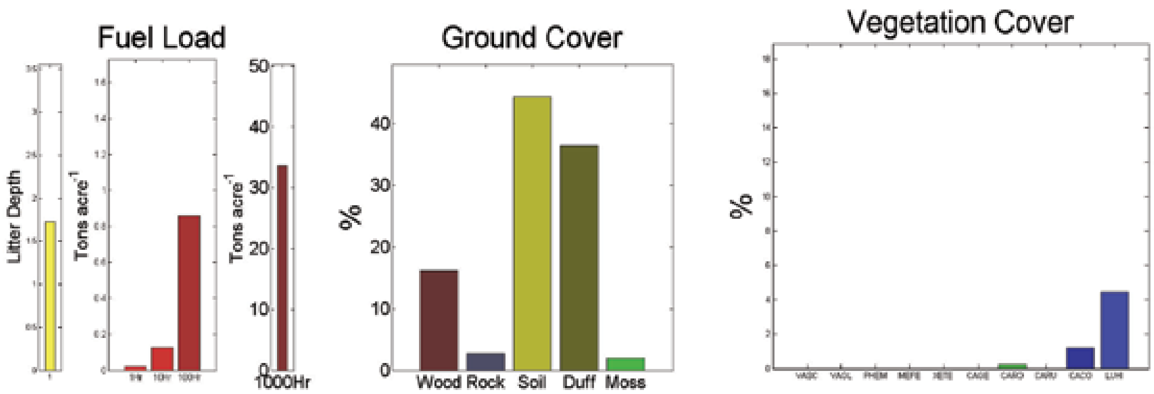


Site: Blackbird Mountain, Salmon-Challis National Forest, Central Idaho
Treatment: High intensity prescribed burn
with NO fuel enhancement (Unit 2A)

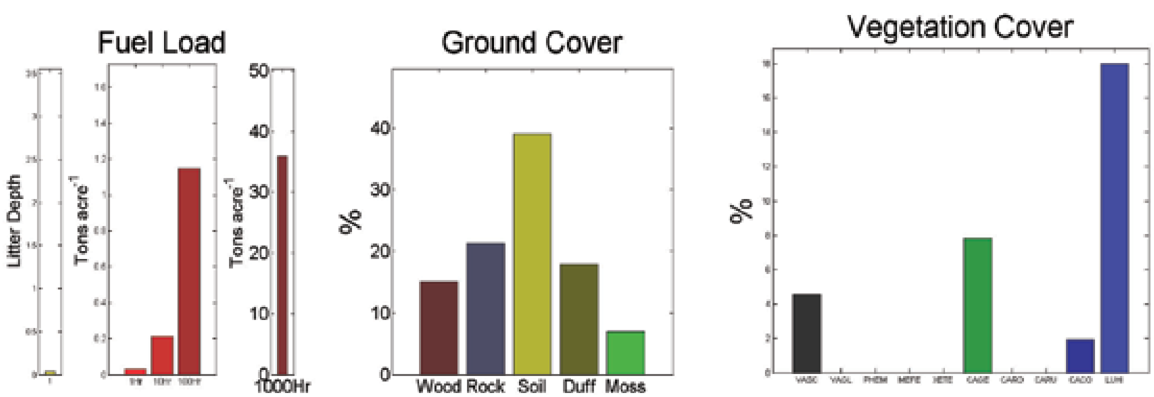
PRE



POST-1



POST-5



Site: Blackbird Mountain, ID. Salmon-Challis NF High intensity prescribed burn with NO fuel enhancement (Unit 2A)			
	PRE	POST 1 Yr	POST 5 Yr
TREE DENSITY (trees acre-1)			
WP seedling	450	0.00 (**-100.00**)	270.00 (-40.00)
SF seedling	2950	0.00 (**-100.00**)	0.00 (**-100.00**)
ES seedling	0	0.00 (NA)	0.00 (NA)
LP seedling	0	0.00 (NA)	30.00 (NA)
WP sapling	232	5.00 (**-97.84**)	0.00 (**-100.00**)
SF sapling	581	4.00 (**-99.31**)	0.00 (**-100.00**)
ES sapling	1	0.00 (-100.00)	0.00 (-100.00)
LP sapling	2	0.00 (-100.00)	0.00 (-100.00)
WP overstory	37	1.00 (**-97.30**)	0.00 (**-100.00**)
SF overstory	146	4.00 (**-97.26**)	0.00 (**-100.00**)
ES overstory	2	0.00 (-100.00)	0.00 (-100.00)
LP overstory	1	0.00 (-100.00)	0.00 (-100.00)
SURFACE FUELS			
Litter depth (inches)	3.38	1.73 (**-48.99**)	0.04 (**-98.87**)
1 hour fuel load (tons acre-1)	0.09	0.02 (**-77.66**)	0.03 (**-65.04**)
10 hour fuel load (tons acre-1)	0.4	0.13 (-68.10)	0.21 (-46.66)
100 hour fuel load (tons acre-1)	1.65	0.86 (-47.76)	1.15 (-30.26)
1000 hour fuel load (tons acre-1)	47.9	33.62 (-29.81)	35.93 (-25.00)
GROUND COVER (%)			
Wood	25.16	16.18 (-8.98)	15.20 (-9.96)
Rock	0.23	2.65 (**2.42**)	21.38 (**21.15**)
Soil	3.15	44.35 (**41.20**)	39.08 (**35.93**)
Duff	47.27	36.40 (**-10.87**)	17.93 (**-29.35**)
Moss	9.32	2.08 (**-7.24**)	6.95 (-2.37)
VEGETATION COVER (%)			
VASC	11.94	0.00 (**-11.94**)	4.57 (**-7.37**)
VAGL	0	0.00 (0.00)	0.00 (0.00)
PHEM	8.25	0.00 (-8.25)	0.00 (-8.25)
MEFE	0	0.00 (0.00)	0.00 (0.00)
XETE	0	0.00 (0.00)	0.00 (0.00)
CAGE	10.95	0.00 (**-10.95**)	7.85 (-3.10)
CARO	0	0.25 (0.25)	0.00 (0.00)
CARU	0.25	0.00 (-0.25)	0.00 (-0.25)
CACO	0.5	1.19 (0.69)	1.94 (1.44)
LUHI	7.64	4.45 (**-3.19**)	18.00 (10.36)

Study Site: Coyote Meadows, Bitterroot National Forest, Western-Central Montana

Treatment: High intensity prescribed burn with fuel enhancement in cutover unit (Unit 2C)

Management Planning: This treatment was proposed in the summer of 1992 and burn plans were developed during the winter of 1993. This unit was encompassed by a much larger area where the Darby Ranger District had already completed the NEPA work. The District also pruned all rust-infected branches on whitebark pine trees to reduce infection potential in 160 acres surrounding this unit.

Treatment Description: This unit was an unburned 1963 clearcut that contained many residual subalpine fir saplings and poles and some whitebark pine trees. The purpose of the treatment was to create post-fire conditions that mimicked a stand-replacement fire to facilitate abundant nutcracker caching. The research crew completed the fuel enhancement in this unit in late summer of 1993. We cut as many subalpine firs as necessary to make a contiguous fuelbed across the unit. Parts of the unit were bare or rock, so we directionally felled trees to allow fire to burn in these areas through the slash. The only cutting requirement for the fuel enhancement treatment was that the cut trees had to be subalpine fir or Engelmann spruce. We treated the entire unit in fewer than three days with only two people for about $10 to $30 per acre.

Fuel and weather conditions were never favorable for the prescribed burn treatment for the first 7 years of the study. The entire site finally burned during the Bitterroot Fires of 2000. Because we were unable to visit the site during the wildfire, no data are available documenting fire weather, fuel moistures, and fire behavior, but all post-fire visual evidence indicates that a moderate to high intensity fire burned through the understory and slashed fuels. Weather conditions at the time of the fire were hot and dry with temperatures in the low 90s and relative humidity around 20 percent. The burn was patchy because of the variable drainage and fuel loadings in the unit. Some trees, mostly subalpine fir, crowned during the fire. This burn was somewhat intense with more than 50 percent burn coverage.

Management Recommendations: The fuel enhancement cuttings appeared to modify wildfire behavior within the treatment unit compared to adjacent units that did not receive fuel enhancement. Burn coverage, tree mortality, and undergrowth plant cover reduction levels appeared higher in this unit. Fuel enhancement is clearly beneficial on this moist, poorly drained site because it provided dry fuel on top of the green mesic vegetation. We did not observe extensive nutcracker caching in the study site until the following year because of road closures. Whitebark pine tree regeneration was marginal, indicating that 5 years may not be enough time for the successful seedling establishment. The high levels of rust- and fire-caused tree mortality in the surrounding seed source might have also prevented extensive nutcracker caching. Though this wildfire burned at higher than the prescribed intensity, we feel that wildfire or wildland fire use can be effective for restoring whitebark pine. The observed fire effects seem well within the historical range for this site. We recommend that burned areas with high levels of blister rust mortality be planted with rust-resistant whitebark pine seeds or seedlings to ensure future dominance of this species.

Site: Coyote Meadows, Bitterroot National Forest, Western-Central Montana
Treatment: High intensity prescribed burn
with fuel enhancement in cutover unit (Unit 2C)

PRE

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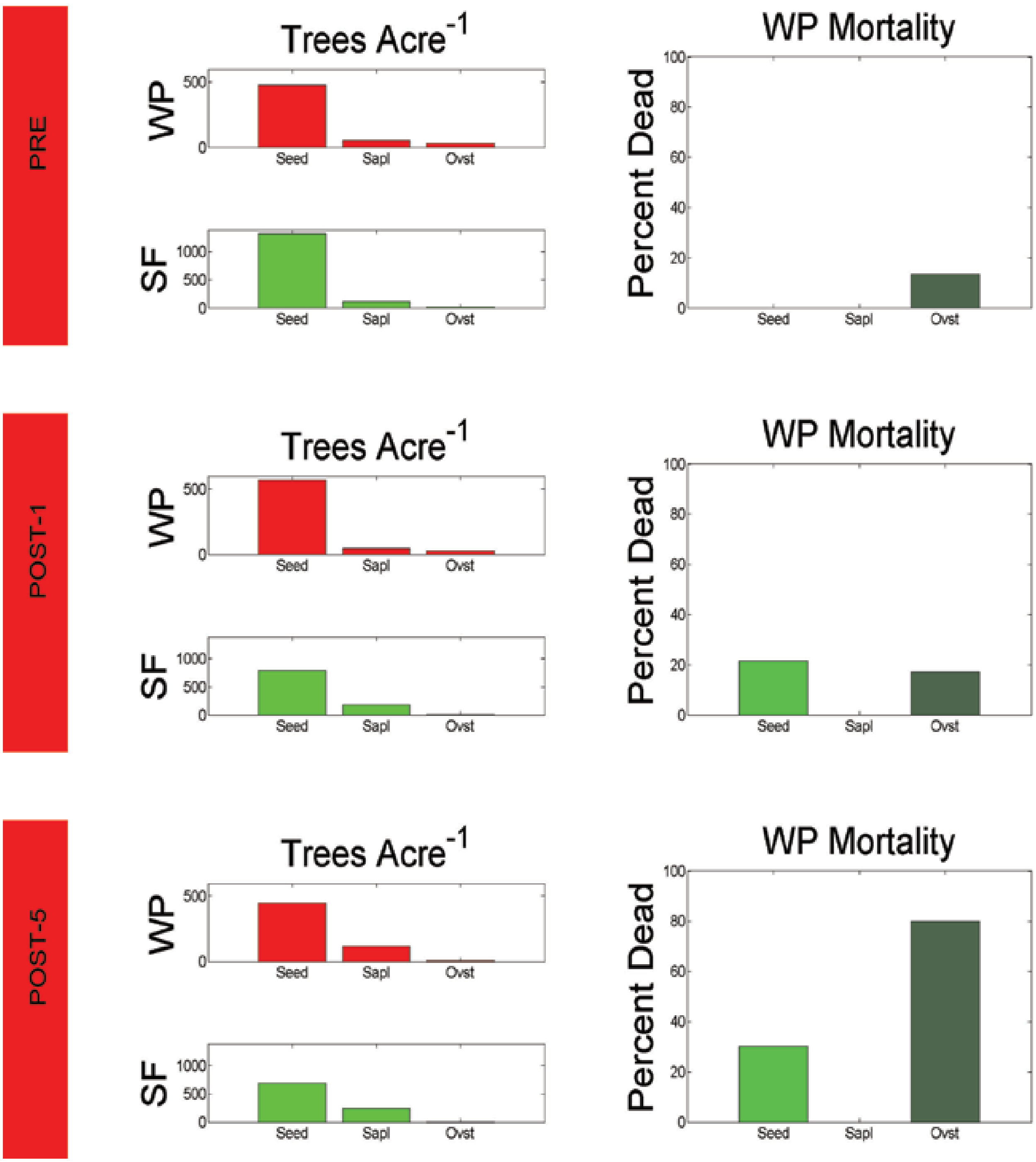
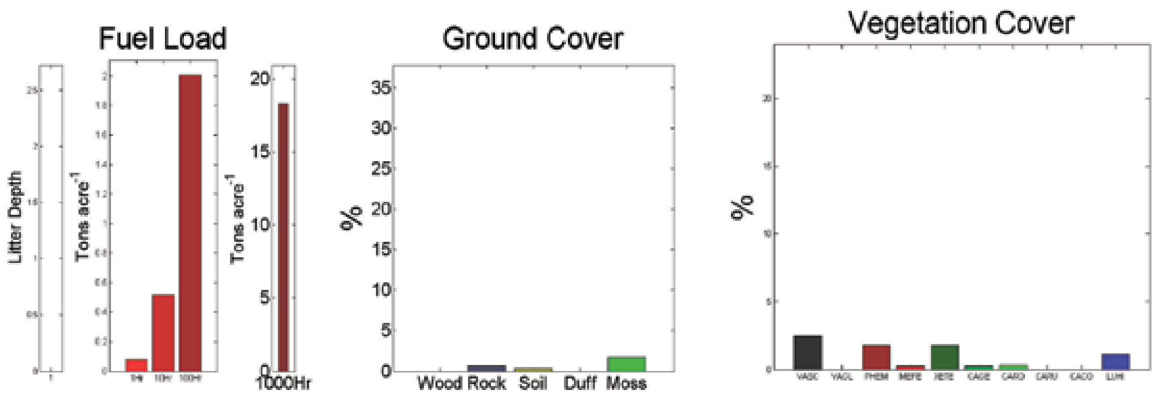
POST-5

Site: Coyote Meadows, Bitterroot National Forest, Western-Central Montana
Treatment: High intensity prescribed burn
with fuel enhancement in cutover unit (Unit 2C)

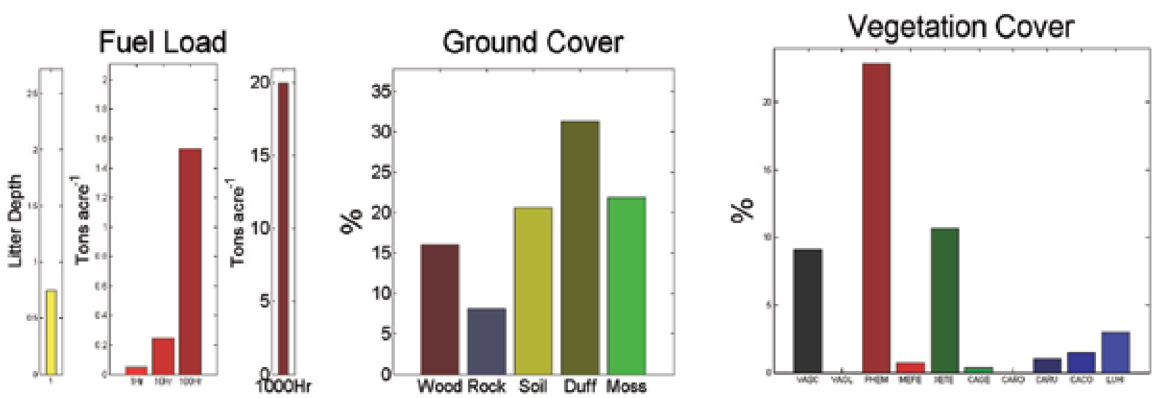


Site: Coyote Meadows, Bitterroot National Forest, Western-Central Montana
Treatment: High intensity prescribed burn
with fuel enhancement in cutover unit (Unit 2C)

PRE



POST-1



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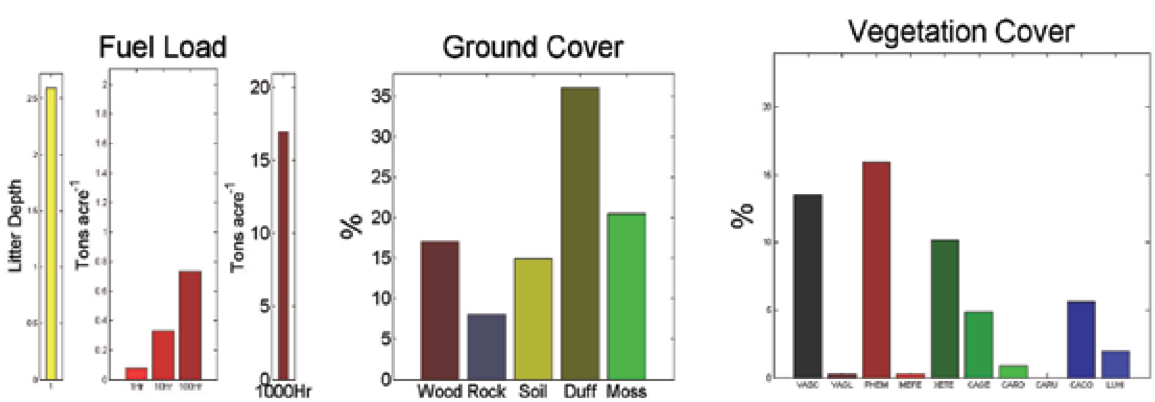


Site: Coyote Meadows, MT. Bitterroot NF High intensity prescribed burn with fuel enhancement in cutover unit (Unit 2C)			
	PRE	**POST 1 Yr**	**POST 5 Yr**
TREE DENSITY (trees acre-1)			
WP seedling	480	571.00 (18.96)	450.00 (-6.25)
SF seedling	1320	791.00 (-40.08)	691.00 (-47.65)
ES seedling	180	120.00 (-33.33)	211.00 (17.22)
LP seedling	30	30.00 (0.00)	0.00 (-100.00)
WP sapling	54	46.00 (-14.81)	117.00 (116.67)
SF sapling	118	178.00 (50.85)	250.00 (111.86)
ES sapling	4	23.00 (475.00)	52.00 (**1200.00**)
LP sapling	0	5.00 (NA)	17.00 (NA)
WP overstory	32	29.00 (-9.38)	7.00 (-78.13)
SF overstory	19	2.00 (**-89.47**)	8.00 (-57.89)
ES overstory	7	1.00 (-85.71)	1.00 (-85.71)
LP overstory	1	1.00 (0.00)	1.00 (0.00)
SURFACE FUELS			
Litter depth (inches)	0	0.75 (NA)	2.60 (NA)
1 hour fuel load (tons acre-1)	0.08	0.05 (-40.48)	0.08 (0.85)
10 hour fuel load (tons acre-1)	0.51	0.25 (**-52.22**)	0.33 (-36.08)
100 hour fuel load (tons acre-1)	2.01	1.53 (-23.93)	0.73 (**-63.55**)
1000 hour fuel load (tons acre-1)	18.34	19.96 (8.83)	16.97 (-7.45)
GROUND COVER (%)			
Wood	0	16.07 (**16.07**)	17.02 (**17.02**)
Rock	0.67	8.07 (7.40)	7.97 (7.31)
Soil	0.31	20.60 (**20.29**)	14.93 (**14.62**)
Duff	0	31.30 (**31.30**)	35.98 (**35.98**)
Moss	1.71	21.86 (**20.16**)	20.48 (**18.77**)
VEGETATION COVER (%)			
VASC	2.44	9.09 (**6.65**)	13.50 (**11.06**)
VAGL	0	0.00 (0.00)	0.25 (0.25)
PHEM	1.75	22.88 (21.13)	15.92 (14.17)
MEFE	0.25	0.75 (0.50)	0.25 (0.00)
XETE	1.75	10.65 (8.90)	10.18 (8.43)
CAGE	0.25	0.38 (0.13)	4.88 (4.63)
CARO	0.29	0.00 (**-0.29**)	0.88 (0.58)
CARU	0	1.00 (1.00)	0.00 (0.00)
CACO	0	1.47 (**1.47**)	5.58 (**5.58**)
LUHI	1.11	2.97 (**1.86**)	1.93 (**0.82**)

Study Site: Coyote Meadows, Bitterroot National Forest, Western-Central Montana

Treatment: High intensity prescribed burn with NO fuel enhancement in cutover unit (Unit 2B)

Management Planning: This treatment was proposed in the summer of 1992 and burn plans were developed during the winter of 1993. The unit was encompassed by larger area where the Darby Ranger District had already completed the NEPA work. The District pruned rust-infected branches on whitebark pine trees to reduce infection potential on 160 acres surround this unit.

Treatment Description: This unit was an unburned 1963 clearcut that contained many residual subalpine fir saplings and poles and some whitebark pine trees. The purpose of this treatment was to create post-fire conditions that mimicked a stand-replacement fire to facilitate abundant nutcracker caching. Fuel and weather conditions were unfavorable for implementing the prescribed burn on this unit over the first 7 years of the study. The entire site finally burned during the Bitterroot Fires of 2000. Because we were unable to visit the site during the wildfire, no data are available documenting fire weather, fuel moistures, and fire behavior, but all post-fire visual evidence supports a moderate to high intensity fire burning through natural fuels. Weather conditions at the time of the fire were hot and dry with temperatures in the low 90s and relative humidity around 20 percent. The burn was patchy because of variable fuel moisture (water drainage) and loadings in this unit. Some trees, mostly subalpine fir, crowned during the fire. This burn covered about 30 percent of the ground area. The wildfire burned this treatment unit at much lower severities than the fuel enhancement unit.

Management Recommendations: Burn coverage, tree mortality, and undergrowth plant cover reduction levels appeared lower than those observed in the fuel enhancement unit (2C). Fuel enhancement was clearly beneficial on this moist, poorly drained site because it provided dry fuel on top of mesic vegetation that stays green throughout much of the summer. We did not observe nutcracker caching in the study site until 2001 because of road restrictions. Whitebark pine tree regeneration for this unit was marginal, indicating that 5 years may not be enough time for the successful seedling establishment. High levels of rust in the surrounding seed source could have prevented extensive caching. Though this wildfire burned at higher than the prescribed intensity, we feel that wildfire or wildland fire use can be effective for restoring whitebark pine. The observed effects seem well within the historical range for this site. We recommend that burned areas with high levels of blister rust mortality be planted with rust-resistant whitebark pine seeds or seedlings to ensure future dominance of this species.

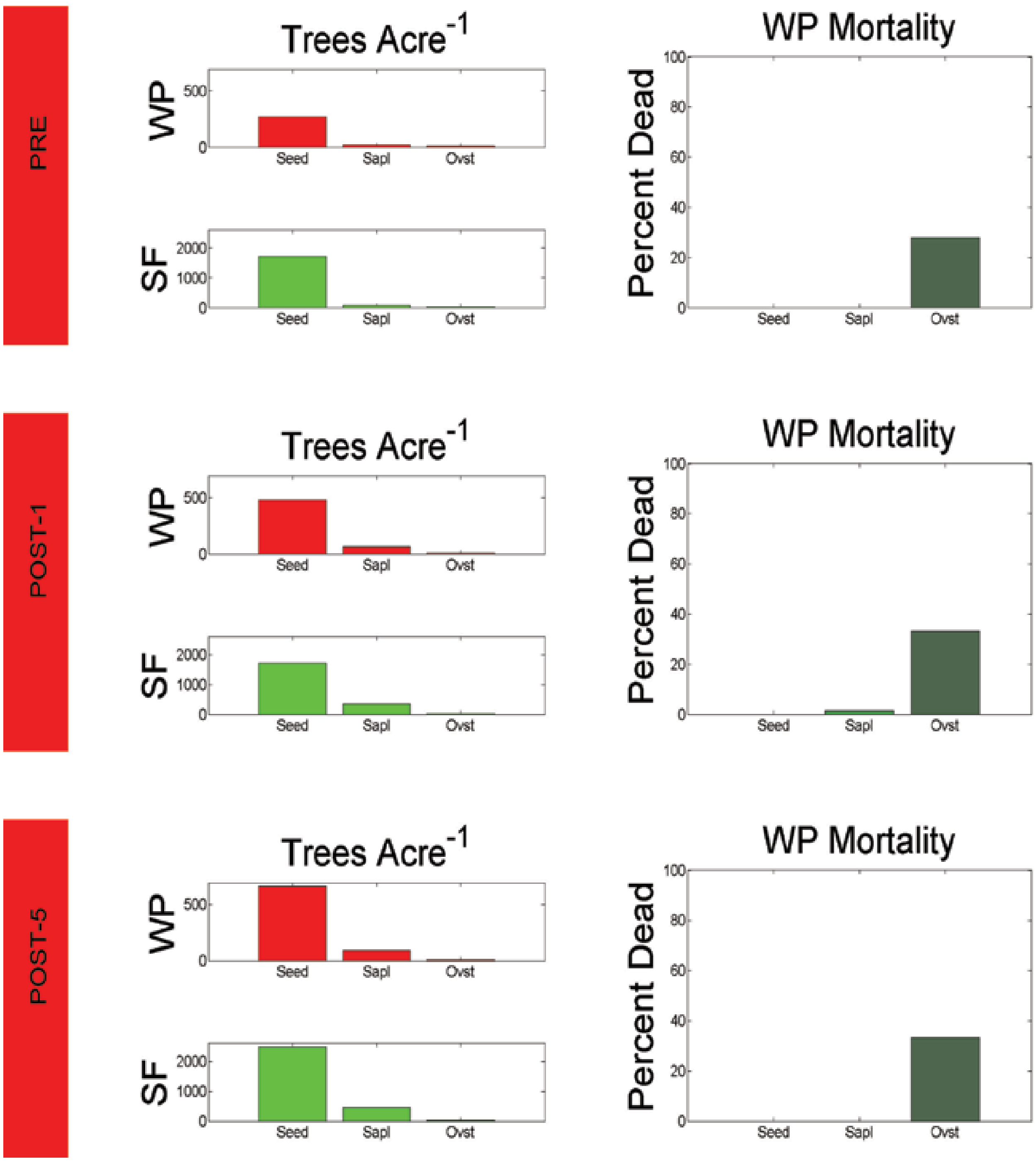
Site: Coyote Meadows, Bitterroot National Forest, Western-Central Montana
Treatment: High intensity prescribed burn
with NO fuel enhancement in cutover unit (Unit 2B)

PRE

POST-1

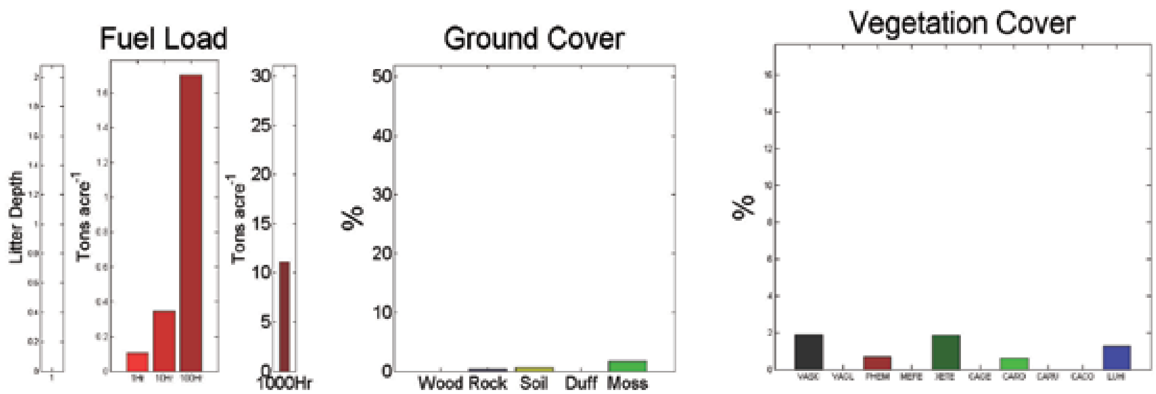
POST-5

Site: Coyote Meadows, Bitterroot National Forest, Western-Central Montana
Treatment: High intensity prescribed burn
with NO fuel enhancement in cutover unit (Unit 2B)



Site: Coyote Meadows, Bitterroot National Forest, Western-Central Montana
Treatment: High intensity prescribed burn
with NO fuel enhancement in cutover unit (Unit 2B)

PRE



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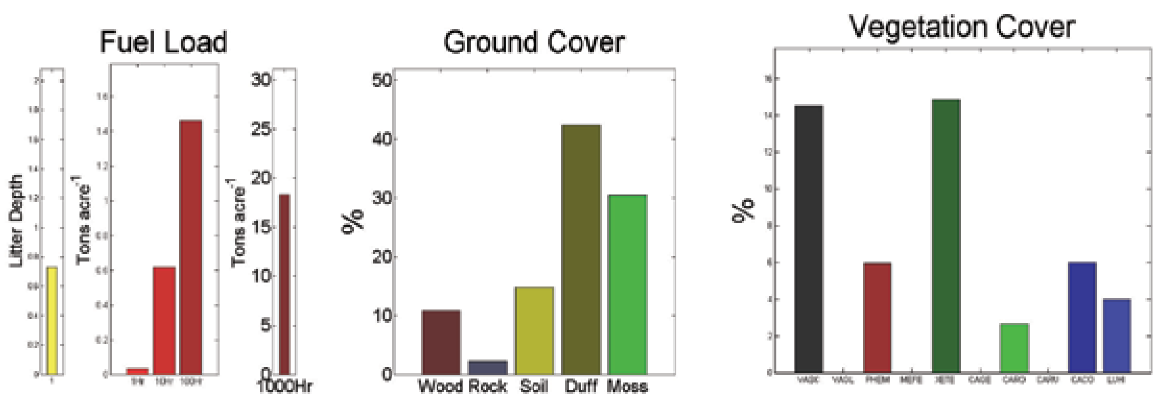

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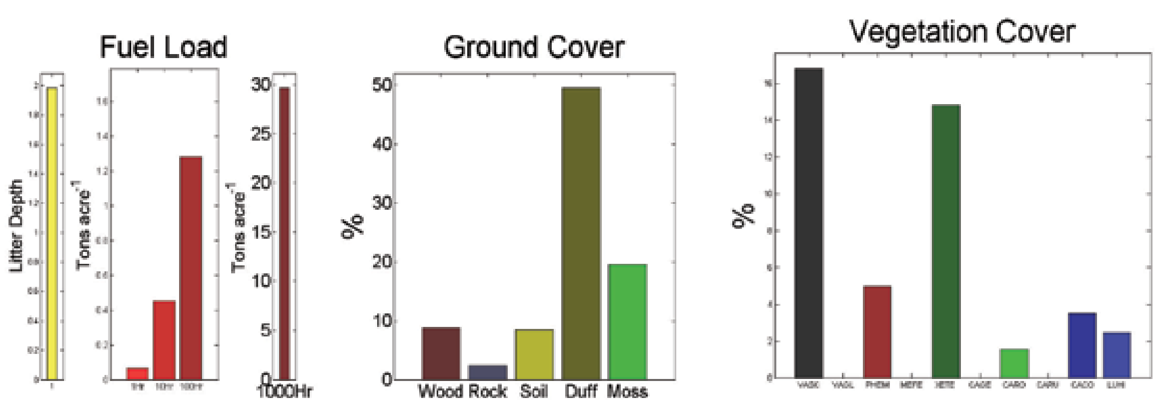


Site: Coyote Meadows, MT. Bitterroot NF High intensity prescribed burn with NO fuel enhancement in cutover unit (Unit 2B)			
	PRE	POST 1 Yr	POST 5 Yr
TREE DENSITY (trees acre-1)			
WP seedling	270	482.00 (78.52)	660.00 (144.44)
SF seedling	1710	1713.00 (0.18)	2491.00 (45.67)
ES seedling	120	301.00 (150.83)	271.00 (125.83)
LP seedling	0	0.00 (NA)	0.00 (NA)
WP sapling	22	64.00 (**190.91**)	93.00 (**322.73**)
SF sapling	94	356.00 (**278.72**)	457.00 (**386.17**)
ES sapling	4	19.00 (**375.00**)	23.00 (**475.00**)
LP sapling	4	10.00 (150.00)	20.00 (400.00)
WP overstory	13	8.00 (-38.46)	10.00 (-23.08)
SF overstory	19	19.00 (0.00)	25.00 (31.58)
ES overstory	7	8.00 (14.29)	5.00 (-28.57)
LP overstory	0	0.00 (NA)	2.00 (NA)
SURFACE FUELS			
Litter depth (inches)	0	0.73 (NA)	1.98 (NA)
1 hour fuel load (tons acre-1)	0.11	0.03 (-69.24)	0.07 (-38.53)
10 hour fuel load (tons acre-1)	0.34	0.62 (79.27)	0.45 (30.76)
100 hour fuel load (tons acre-1)	1.7	1.46 (-14.21)	1.28 (-24.93)
1000 hour fuel load (tons acre-1)	11.09	18.29 (64.87)	29.63 (167.09)
GROUND COVER (%)			
Wood	0	10.80 (**10.80**)	8.82 (**8.82**)
Rock	0.3	2.23 (1.93)	2.33 (2.03)
Soil	0.65	14.82 (**14.17**)	8.40 (7.75)
Duff	0	42.42 (**42.42**)	49.52 (**49.52**)
Moss	1.68	30.50 (**28.82**)	19.65 (17.97)
VEGETATION COVER (%)			
VASC	1.88	14.50 (**12.63**)	16.82 (14.95)
VAGL	0	0.00 (0.00)	0.00 (0.00)
PHEM	0.67	5.94 (5.27)	5.00 (4.33)
MEFE	0	0.00 (0.00)	0.00 (0.00)
XETE	1.85	14.85 (13.00)	14.80 (12.95)
CAGE	0	0.00 (0.00)	0.00 (0.00)
CARO	0.61	2.63 (2.01)	1.53 (0.92)
CARU	0	0.00 (0.00)	0.00 (0.00)
CACO	0	6.00 (6.00)	3.50 (3.50)
LUHI	1.27	3.97 (**2.70**)	2.45 (**1.18**)

Mixed-Severity Fires

Study Site: Beaver Ridge, Clearwater National Forest, Central Idaho

Treatment: Nutcracker openings with no burn and no planting (Unit 2A)

Management Planning: The Powell Ranger District created a comprehensive "District-Wide whitebark pine restoration integrated analysis" in May of 1997 identifying the need for restoration research. In the fall of 1997 it selected two areas for treatment: the Blacklead Mountain site and Beaver Ridge site. Public comment was solicited through mail in May of 1997 and the NEPA analysis for the Categorical Exclusion was finished that September. The cutting treatments were implemented in the summers of 1998 and 1999. District personnel successfully obtained diverse funding (more than $30,000) for this project from multiple sources, including the Nez Perce Tribe, Rocky Mountain Elk Foundation, National Fish and Wildlife Foundation, Forest Service Research, and hazardous fuel reduction monies.

Treatment Description: We created 1- to 3-acre nutcracker openings within this treatment unit by cutting all trees except healthy whitebark pine within circular areas that were evenly dispersed across the unit. We cut all subalpine fir and Engelmann spruce trees and left all whitebark pine and lodgepole pine between nutcracker openings. The trees were limbed where they fell and the resultant slash was scattered across the unit, especially in the nutcracker openings. Limbed logs were arranged to provide stability to the slope. Cut logs were not taken from the site because it was not economically feasible. From July 1998 to October 1998, the District fire crew performed the majority of the tree cutting and slash piling for this study. The District estimated it spent about $66,000 on three units (71 acres) with cutting estimated at $704 per acre.

The Beaver Lake wildfire burned some of the plots established within the unit in the summer of 2000. No data are available on the weather and fuel moisture conditions during fire. The lower, southwest corner of the unit was also burned in 1999 because the prescribed burn in the adjacent unit (2B) jumped the fire line and spread into this unit (2A).

Management Recommendations: This treatment, though effective at creating openings in the canopy allowing the nutcracker access to the ground, is not recommended for multiple reasons. First, the slash prevented nutcrackers from caching seed in most of the unit, so we believe few seeds were actually planted. Next, the slash and slash piles in adjacent units fostered an increase in *Ips* spp. beetle populations that eventually attacked nearly all healthy whitebark pine trees near the slash. Last, the slash, as we experienced with the Beaver Lake wildfire, posed a fire hazard and could burn at undesirable high severities under wildfire conditions. Instead, we recommend piling and burning the slash or broadcast burning the entire unit. Though slash probably caused the lack of observed whitebark pine tree regeneration on this unit, it could also be from other factors. The high rust-caused whitebark pine mortality on this isolated ridge caused a dramatic decrease in seed crops that probably resulted in less nutcracker caching. Droughty soils on southern aspects may have fostered an environment too severe for tree regeneration. We recommend that cut areas with high levels of blister rust mortality be planted with rust-resistant whitebark pine seeds or seedlings to ensure future dominance of this species. The collection of the seed from phenotypic rust-resistant whitebark pine trees will increase the chance that the planted stock or seed will survive the exotic disease infection.

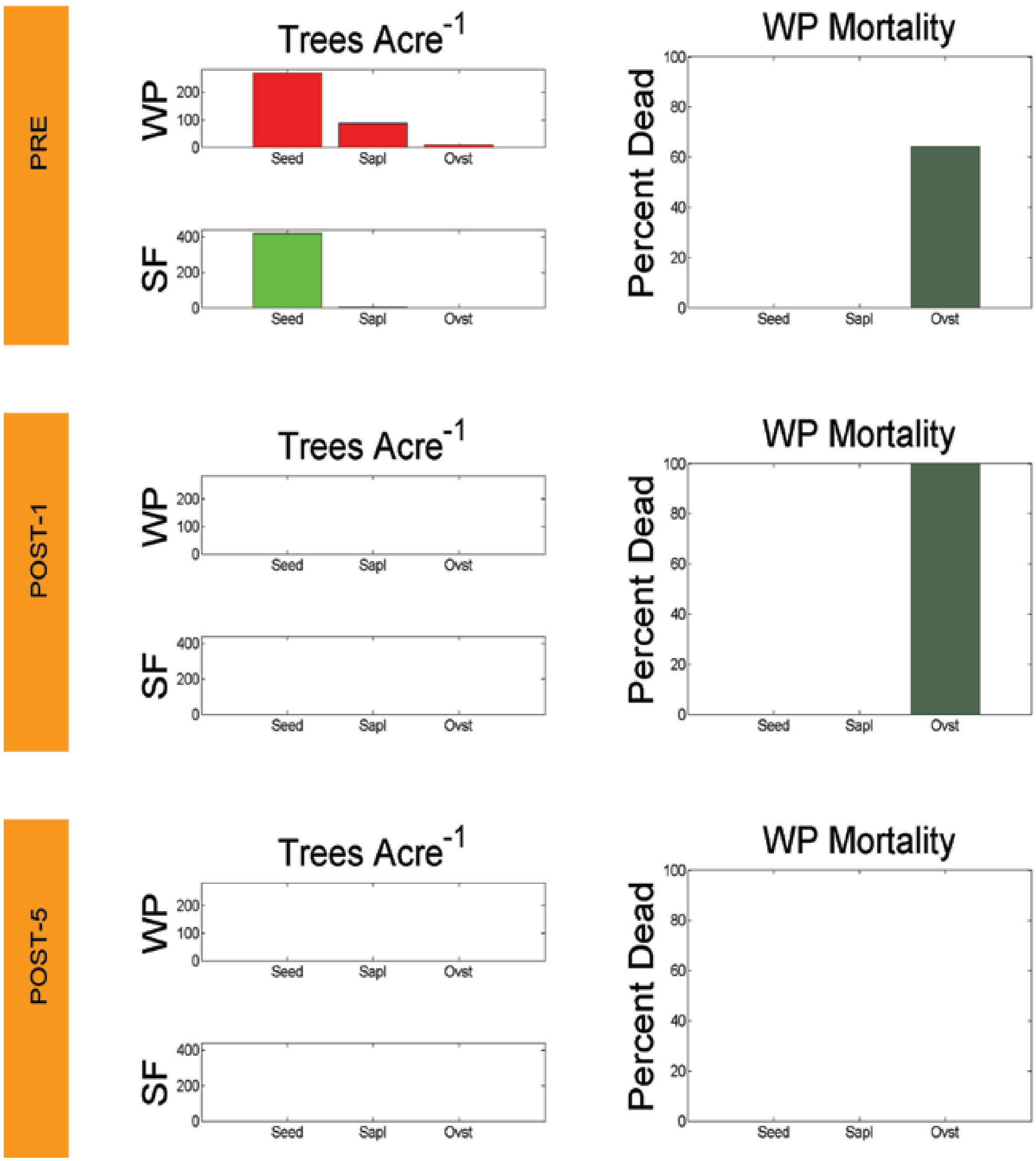
Site: Beaver Ridge, Clearwater National Forest, Central Idaho
Treatment: Nutcracker openings
with no burn and no planting (Unit 2A)

PRE

POST-1

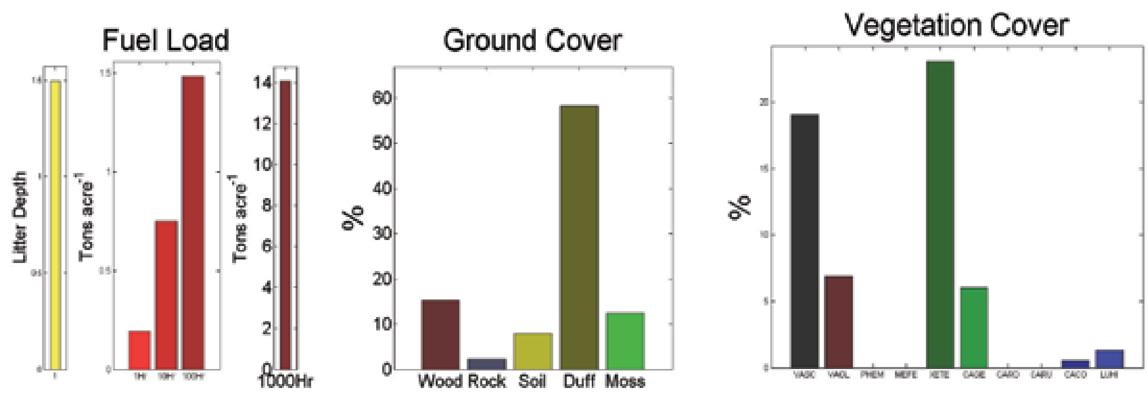
POST-5

Site: Beaver Ridge, Clearwater National Forest, Central Idaho
Treatment: Nutcracker openings
with no burn and no planting (Unit 2A)



Site: Beaver Ridge, Clearwater National Forest, Central Idaho
Treatment: Nutcracker openings
with no burn and no planting (Unit 2A)

PRE



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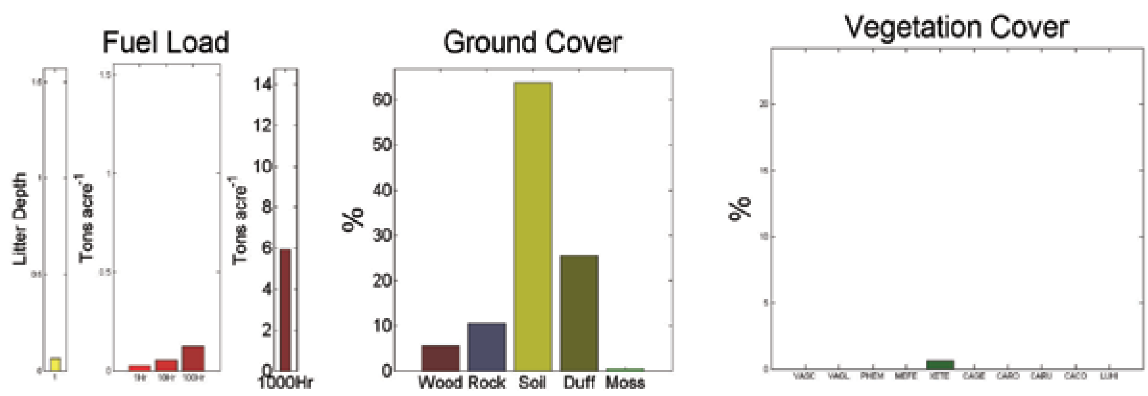

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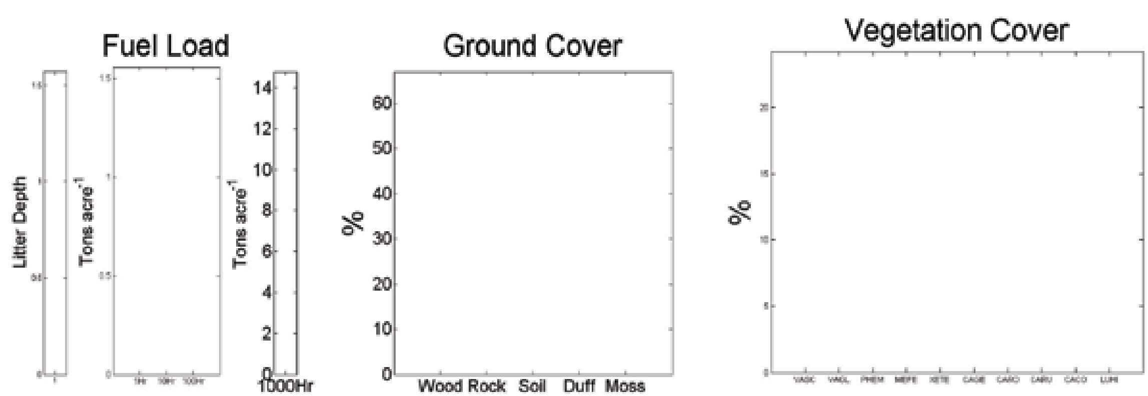


Site: Beaver Ridge, ID. Clearwater NF Nutcracker openings with no burn and no planting (Unit 2A)			
	PRE	**POST 1 Yr**	**POST 5 Yr**
TREE DENSITY (trees acre-1)			
WP seedling	270	0.00 (**-100.00**)	0.00 (**-100.00**)
SF seedling	420	0.00 (**-100.00**)	0.00 (**-100.00**)
ES seedling	90	0.00 (-100.00)	0.00 (-100.00)
LP seedling	241	0.00 (-100.00)	0.00 (-100.00)
WP sapling	88	0.00 (**-100.00**)	0.00 (**-100.00**)
SF sapling	1	0.00 (-100.00)	0.00 (-100.00)
ES sapling	0	0.00 (NA)	0.00 (NA)
LP sapling	114	0.00 (**-100.00**)	0.00 (**-100.00**)
WP overstory	10	0.00 (**-100.00**)	0.00 (**-100.00**)
SF overstory	0	0.00 (NA)	0.00 (NA)
ES overstory	0	0.00 (NA)	0.00 (NA)
LP overstory	72	0.00 (**-100.00**)	0.00 (**-100.00**)
SURFACE FUELS			
Litter depth (inches)	1.49	0.07 (**-95.65**)	0.00 (-100.00)
1 hour fuel load (tons acre-1)	0.19	0.03 (**-86.21**)	0.00 (-100.00)
10 hour fuel load (tons acre-1)	0.75	0.05 (**-92.73**)	0.00 (-100.00)
100 hour fuel load (tons acre-1)	1.48	0.13 (**-91.53**)	0.00 (-100.00)
1000 hour fuel load (tons acre-1)	14.07	5.92 (**-57.92**)	0.00 (-100.00)
GROUND COVER (%)			
Wood	15.35	5.55 (**-9.80**)	0.00 (**-15.35**)
Rock	2.27	10.50 (**8.22**)	0.00 (**-2.27**)
Soil	7.9	63.75 (**55.85**)	0.00 (**-7.90**)
Duff	58.25	25.45 (**-32.80**)	0.00 (**-58.25**)
Moss	12.31	0.38 (**-11.93**)	0.00 (**-12.31**)
VEGETATION COVER (%)			
VASC	19.07	0.00 (**-19.07**)	0.00 (**-19.07**)
VAGL	6.88	0.00 (-6.88)	0.00 (-6.88)
PHEM	0	0.00 (0.00)	0.00 (0.00)
MEFE	0	0.00 (0.00)	0.00 (0.00)
XETE	23.1	0.63 (**-22.48**)	0.00 (**-23.10**)
CAGE	6	0.00 (**-6.00**)	0.00 (**-6.00**)
CARO	0	0.00 (0.00)	0.00 (0.00)
CARU	0	0.00 (0.00)	0.00 (0.00)
CACO	0.5	0.00 (-0.50)	0.00 (-0.50)
LUHI	1.31	0.00 (**-1.31**)	0.00 (**-1.31**)

Study Site: Beaver Ridge, Clearwater National Forest, Central Idaho

Treatment: Moderate intensity prescribed burn with nutcracker openings and no planting (Unit 2B)

Management Planning: The Powell Ranger District created a comprehensive "District-Wide whitebark pine restoration integrated analysis" in May of 1997 identifying the need for restoration research. In the fall of 1997 it selected two areas for treatment: the Blacklead Mountain site and Beaver Ridge site. Public comment was solicited through mail in May of 1997 and the NEPA analysis for the Categorical Exclusion was finished that September. The cutting treatments were implemented in the summers of 1998 and 1999. District personnel successfully obtained diverse funding (more than $30,000) for this project from multiple sources, including the Nez Perce Tribe, Rocky Mountain Elk Foundation, National Fish and Wildlife Foundation, Forest Service Research, and hazardous fuel reduction monies.

Treatment Description: We created 1- to 3-acre nutcracker openings within this treatment unit by cutting all trees except healthy whitebark pine within circular areas that were evenly dispersed across the unit. We cut all subalpine fir and Engelmann spruce trees and left all whitebark pine and lodgepole pine between nutcracker openings. The trees were limbed where they fell and the resultant slash was scattered across the unit, especially in the nutcracker openings. Limbed logs were arranged to provide stability to the slope. Cut logs were not taken from the site because it was not economically feasible. From July 1998 to October 1998, the District fire crew performed the majority of the tree cutting and slash piling for this study. The District estimated it spent about $66,000 on three units (71 acres) with cutting estimated at $704 per acre.

District fire crews burned this unit September 11, 1999, using strip head fires varying in width from 10 to 30 ft. Fuels were mostly dry with measured fuel moistures as follows: 1 hr = 12 percent, 10 hr = 8 percent, 100 hr = 10 percent, sound 1000 hr = 27 percent, rotten 1000 hr = 34 percent, live herbaceous = 55 percent, and live shrubs = 53 percent. Weather conditions at the time of the fires were partly cloudy, cool, and moist. The temperature at the start of the burn (1415) was 57 ^{o}F and relative humidity was 49 percent. By mid-burn (1500), the temperature was 59 ^{o}F and humidity was 47 percent. At the end of the burn (1730), the temperature was 53 ^{o}F and humidity was its lowest at 43 percent. Winds were calm for most of the burn with occasional gusts of 3 to 7 mph from the southwest. Antecedent weather was typical of autumn with cool days and cold nights. More than 4 inches of snow (0.04 inches of water) fell four days prior to the burn. Both this unit and 3B were burned the same day.

Flame lengths on this unit varied from 2 to 8 ft. The fire killed many trees, even in the matrix between nutcracker openings, and most subalpine fir trees crowned. This burn met nearly all burn plan prescriptions. The burn covered most of the unit (greater than 80 percent) and consumed many fine fuels. The prescribed burning cost an estimated $225 per acre for 71 acres (2B, 3B, and 4B).

Management Recommendations: The combination of cutting and burning was highly successful at reducing subalpine fir and spruce tree competition for whitebark pine. However, many healthy whitebark pine and lodgepole pine also died from fire-related factors, which demonstrates that, given the high fuel moistures and relative humidity at the time of burning, it is difficult to craft a prescription for this site that kills most fir but allows most whitebark pine to live. We assumed that local whitebark pine populations would provide seed sources for regenerating this unit, but we may have been wrong. The marginal whitebark pine tree regeneration on this site probably resulted from many factors. First, the high whitebark pine mortality on this isolated ridge produced little seed for nutcracker caching. Second, the nutcrackers probably reclaimed seed from many of their caches. Next, the high snowfall, steep slopes, lack of plant cover, and highly erosive soils may have influenced the success of seed germination and seedling establishment. Last, the droughty soils on southern aspect created severe environments for seedlings, especially when plant cover was low. We recommend that burned areas with high levels of blister rust mortality be planted with rust-resistant whitebark pine seeds or seedlings to ensure future dominance of this species. The collection of the seed from phenotypic rust-resistant whitebark pine trees will increase the chance that the planted stock or seed will survive the exotic disease infection. We also feel an evaluation of the success of natural regeneration must be made at least a decade after burning.

Site: Beaver Ridge, Clearwater National Forest, Central Idaho
Treatment: Moderate intensity prescribed burn
with nutcracker openings and no planting (Unit 2B)

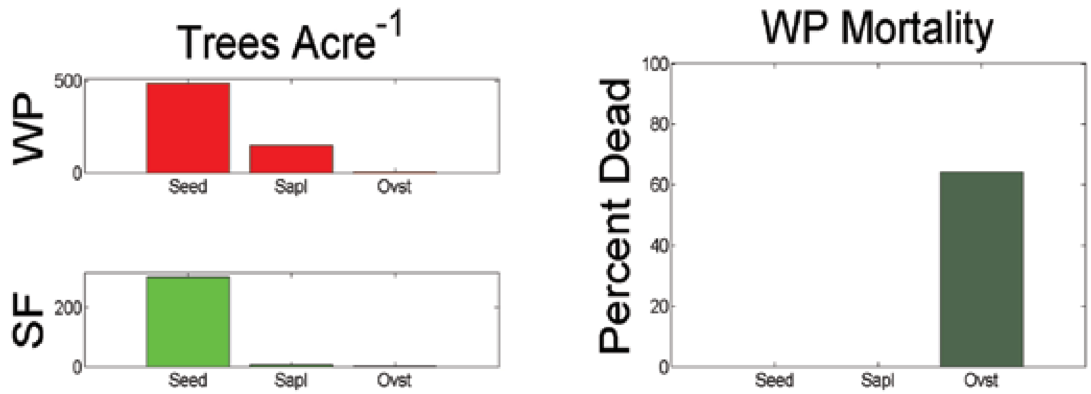
PRE

POST-1

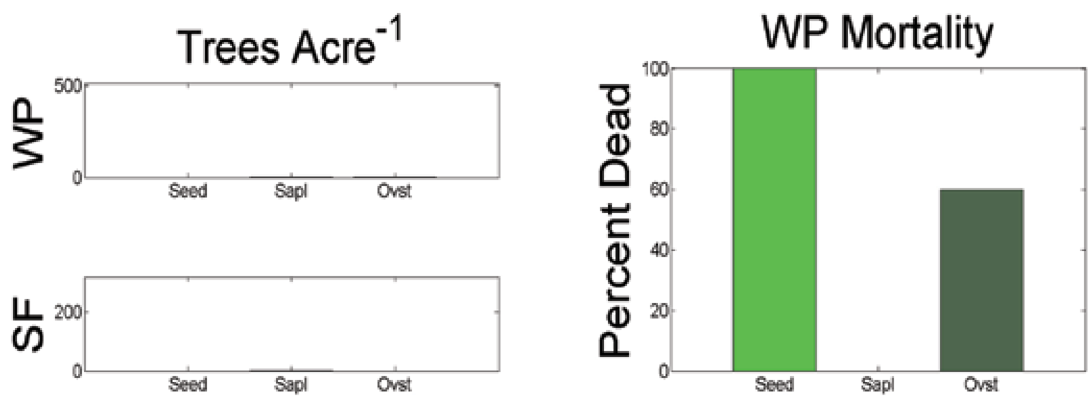
POST-5

Site: Beaver Ridge, Clearwater National Forest, Central Idaho
Treatment: Moderate intensity prescribed burn
with nutcracker openings and no planting (Unit 2B)

PRE



POST-1



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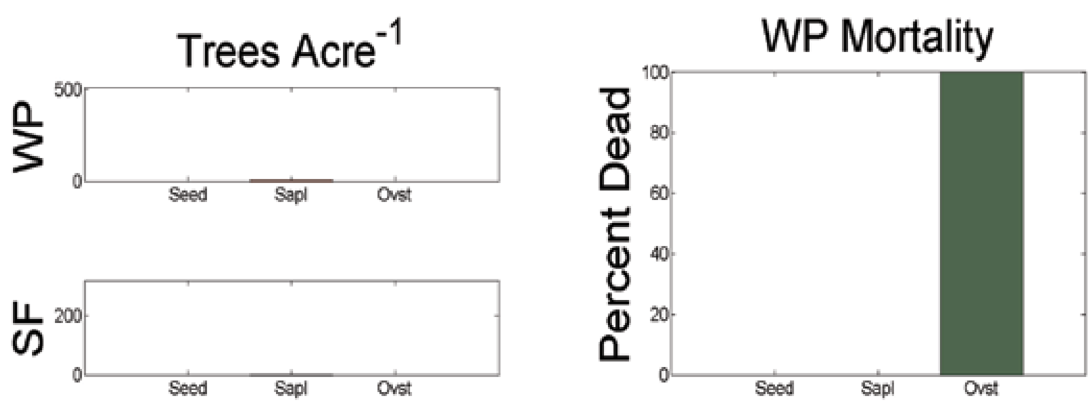
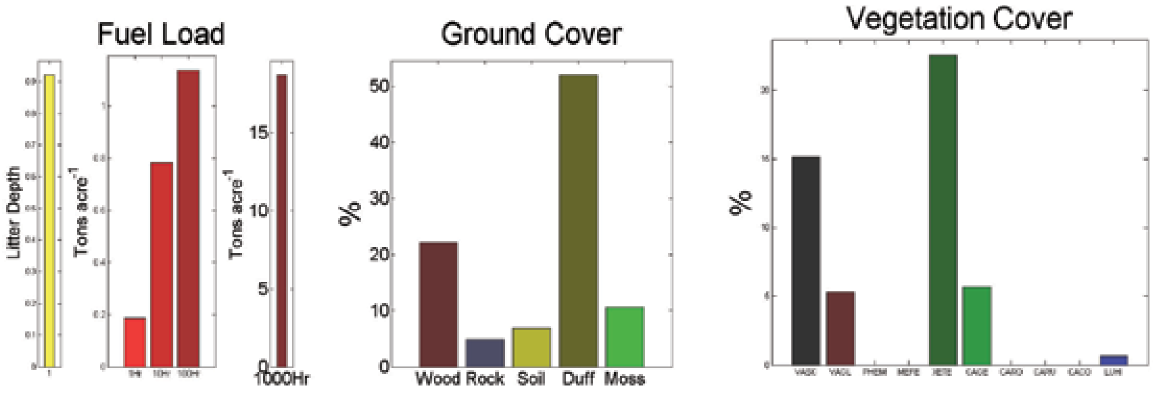


Site: Beaver Ridge, Clearwater National Forest, Central Idaho
Treatment: Moderate intensity prescribed burn
with nutcracker openings and no planting (Unit 2B)

PRE



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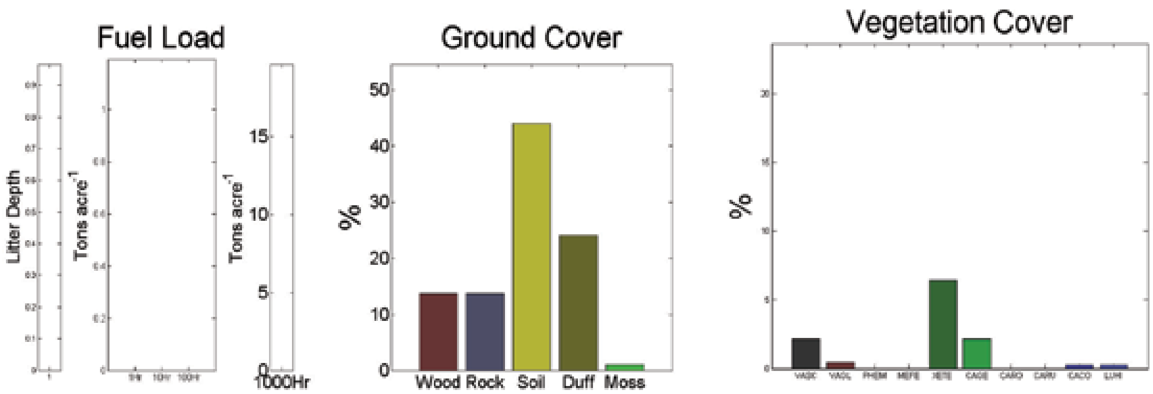

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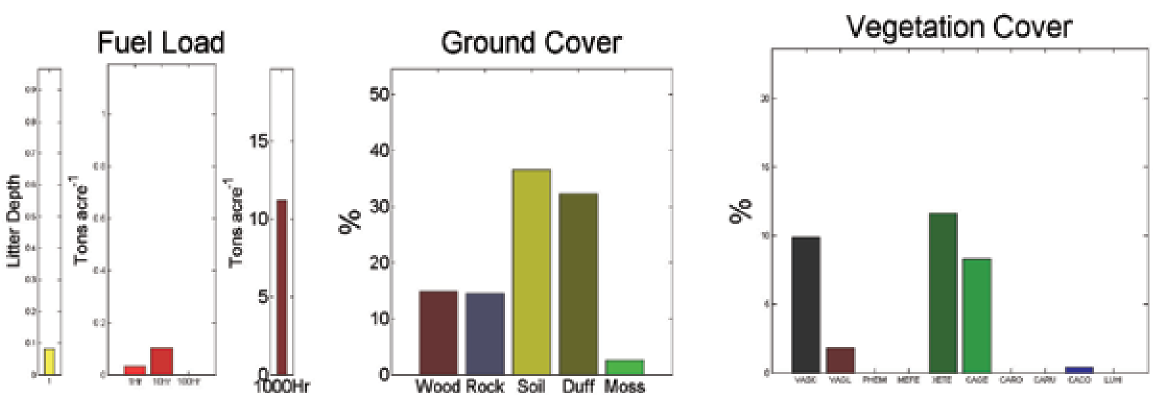


Site: Beaver Ridge, ID. Clearwater NF Moderate intensity prescribed burn with nutcracker openings and no planting (Unit 2B)			
	PRE	**POST 1 Yr**	**POST 5 Yr**
TREE DENSITY (trees acre-1)			
WP seedling	489	0.00 (**-100.00**)	0.00 (**-100.00**)
SF seedling	303	0.00 (**-100.00**)	0.00 (**-100.00**)
ES seedling	0	0.00 (NA)	0.00 (NA)
LP seedling	220	0.00 (**-100.00**)	300.00 (36.36)
WP sapling	149	1.00 (**-99.33**)	4.00 (**-97.32**)
SF sapling	6	1.00 (-83.33)	1.00 (-83.33)
ES sapling	0	0.00 (NA)	0.00 (NA)
LP sapling	147	9.00 (**-93.88**)	8.00 (**-94.56**)
WP overstory	5	2.00 (-60.00)	0.00 (**-100.00**)
SF overstory	1	0.00 (-100.00)	0.00 (-100.00)
ES overstory	0	0.00 (NA)	0.00 (NA)
LP overstory	47	23.00 (-51.06)	8.00 (**-82.98**)
SURFACE FUELS			
Litter depth (inches)	0.92	NA	0.08 (**-91.31**)
1 hour fuel load (tons acre-1)	0.19	NA	0.03 (**-81.83**)
10 hour fuel load (tons acre-1)	0.78	NA	0.10 (**-86.83**)
100 hour fuel load (tons acre-1)	1.14	NA	-0.18 (**-115.46**)
1000 hour fuel load (tons acre-1)	18.68	NA	11.19 (-40.13)
GROUND COVER (%)			
Wood	22.13	13.70 (**-8.43**)	14.93 (-7.20)
Rock	4.83	13.73 (**8.90**)	14.55 (**9.73**)
Soil	6.88	44.08 (**37.20**)	36.65 (**29.77**)
Duff	52	24.07 (**-27.93**)	32.33 (**-19.67**)
Moss	10.6	1.02 (**-9.57**)	2.52 (**-8.07**)
VEGETATION COVER (%)			
VASC	15.13	2.17 (**-12.96**)	9.86 (**-5.26**)
VAGL	5.28	0.42 (**-4.86**)	1.82 (-3.46)
PHEM	0	0.00 (0.00)	0.00 (0.00)
MEFE	0	0.00 (0.00)	0.00 (0.00)
XETE	22.55	6.42 (**-16.13**)	11.65 (-10.90)
CAGE	5.65	2.14 (**-3.51**)	8.31 (2.66)
CARO	0	0.00 (0.00)	0.00 (0.00)
CARU	0	0.00 (0.00)	0.00 (0.00)
CACO	0	0.25 (0.25)	0.38 (0.38)
LUHI	0.63	0.25 (-0.38)	0.00 (-0.63)

Study Site: Beaver Ridge, Clearwater National Forest, Central Idaho

Treatment: Nutcracker openings with planting and no burning (Unit 3A)

Management Planning: The Powell Ranger District created a comprehensive "District-Wide whitebark pine restoration integrated analysis" in May of 1997 identifying the need for restoration research. In the fall of 1997 it selected two areas for treatment: the Blacklead Mountain site and Beaver Ridge site. Public comment was solicited through mail in May of 1997 and the NEPA analysis for the Categorical Exclusion was finished that September. The cutting treatments were implemented in the summers of 1998 and 1999. District personnel successfully obtained diverse funding (more than $30,000) for this project from multiple sources, including the Nez Perce Tribe, Rocky Mountain Elk Foundation, National Fish and Wildlife Foundation, Forest Service Research, and hazardous fuel reduction monies.

Treatment Description: We created 1- to 3-acre nutcracker openings within this treatment unit by cutting all trees except healthy whitebark pine within circular areas that were evenly dispersed across the unit. We cut all subalpine fir and Engelmann spruce trees and left all whitebark pine and lodgepole pine between nutcracker openings. The trees were limbed where they fell and the resultant slash was scattered across the unit, especially in the nutcracker openings. Limbed logs were arranged to provide stability to the slope. Cut logs were not taken from the site because it was not economically feasible. From July 1998 to October 1998, District fire crew performed the majority of the tree cutting and slash piling for this study. The District estimated it spent about $66,000 on three units (71 acres) with cutting estimated at $704 per acre.

After cutting, the Powell RD planted 30 acres of this unit with 2-year-old whitebark pine seedlings grown in a nursery in Lewiston, Idaho. The seedlings were planted with approximately 10- by 10-ft spacing and were purposefully planted near logs, stumps, or other cover to improve survival. The crew planted mostly inside the nutcracker openings.

In the summer of 2000, the Beaver Lake wildfire burned a portion of this unit. No data are available documenting the weather and fuel moisture conditions during the fire. Many planted whitebark pine seedlings died from the fire or from the severe site conditions experienced during the summer of planting.

Management Recommendations: This treatment, though effective at creating nutcracker openings, is not recommended for a number of reasons. First, the slash prevented nutcrackers from caching seed in a majority of the unit so we believe very few seeds were actually planted. Second, the slash and slash piles in adjacent units fostered an increase in *Ips* spp. beetle populations that eventually attacked nearly all the healthy whitebark pine trees near the slash. Last, the slash, as we experienced with the Beaver Lake wildfire, poses a fire hazard and will burn at undesirable high severities in wildfire conditions. Instead, we recommend piling and burning the slash, or broadcast burning the entire unit. The slash probably caused the lack of observed whitebark pine tree regeneration on this unit, but it could also be from other factors. The high whitebark pine mortality on this isolated ridge caused a dramatic decrease in seed crops that may have resulted in very little nutcracker caching. The droughty soils and southern aspect may be too severe for rapid tree regeneration while plant cover is low.

We recommend that cut areas with high levels of blister rust mortality be planted with rust-resistant whitebark pine seeds or seedlings to ensure future dominance of this species. The collection of the seed from phenotypic rust-resistant whitebark pine trees will increase the chance that the planted stock or seed will survive the exotic disease infection. Planting whitebark pine seedlings on this site was marginally successful with less than 30 percent survival over 5 years; seedlings are now about 1 ft tall and robust. This survival rate could be improved now that there are planting guidelines for whitebark pine seedling stock (McCaughey and others 2009; McCaughey and Scott 2006). We recommend that burned areas with high levels of blister rust mortality be planted with whitebark pine seeds or seedlings to ensure future dominance of this species. We also feel that the cutting treatment could have been economically feasible as a merchantable harvest given the right market conditions.

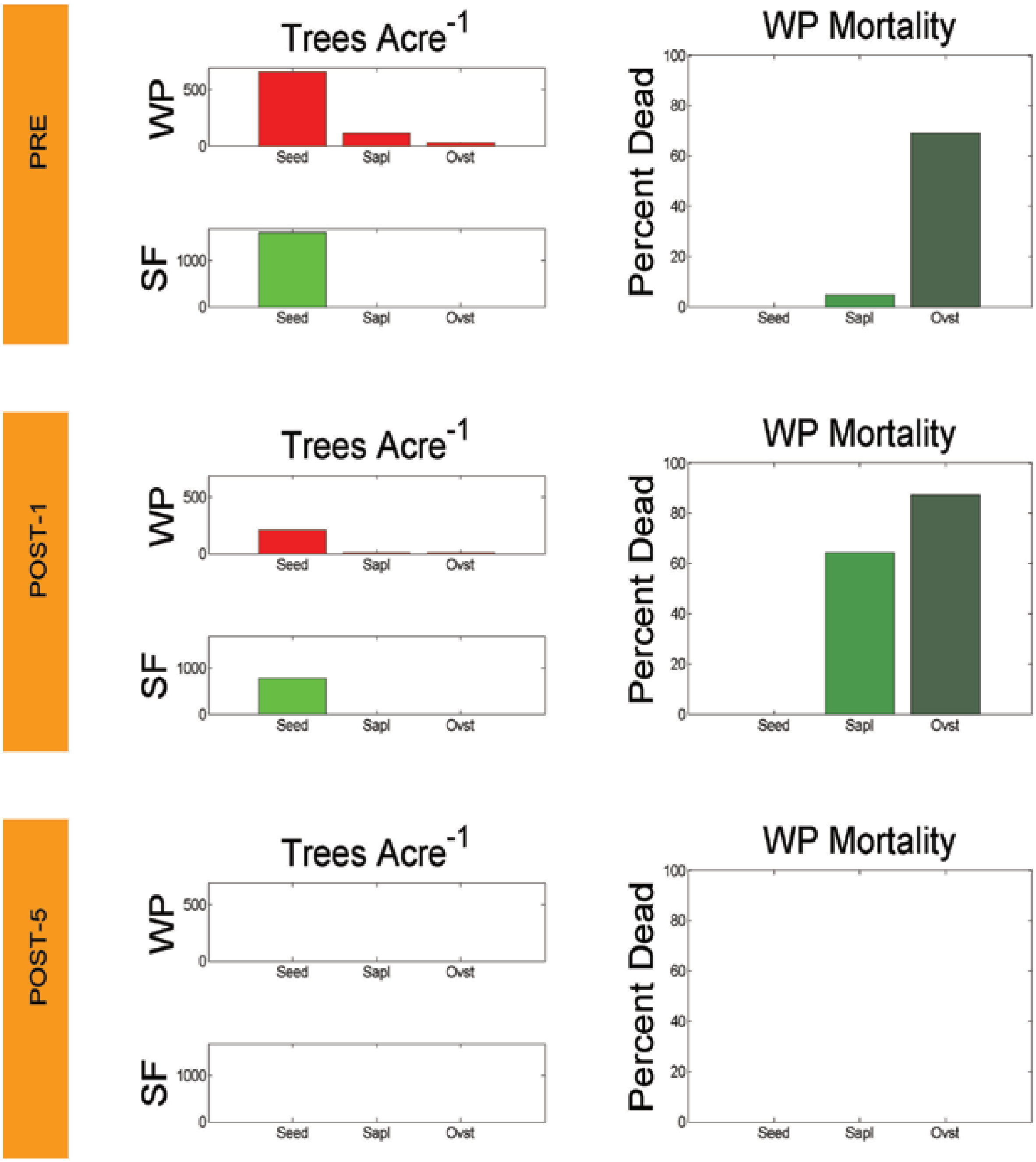
Site: Beaver Ridge, Clearwater National Forest, Central Idaho
Treatment: Nutcracker openings
with planting and no burning (Unit 3A)

PRE

POST-1

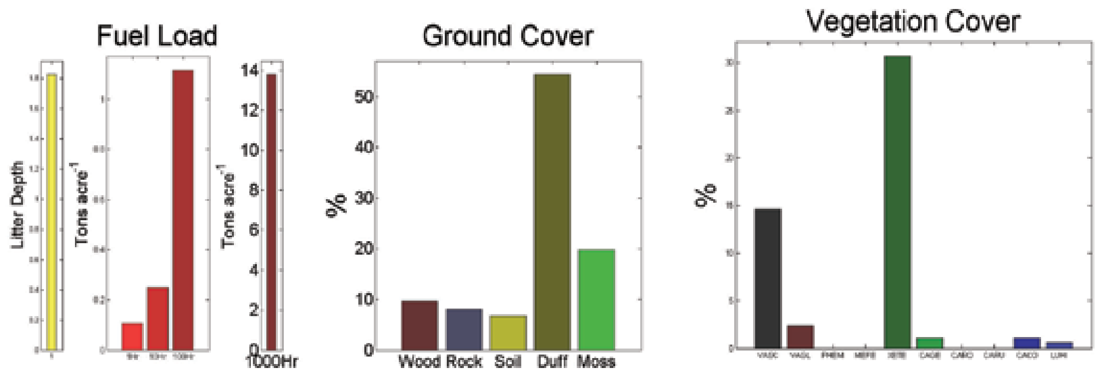
POST-5

Site: Beaver Ridge, Clearwater National Forest, Central Idaho
Treatment: Nutcracker openings
with planting and no burning (Unit 3A)

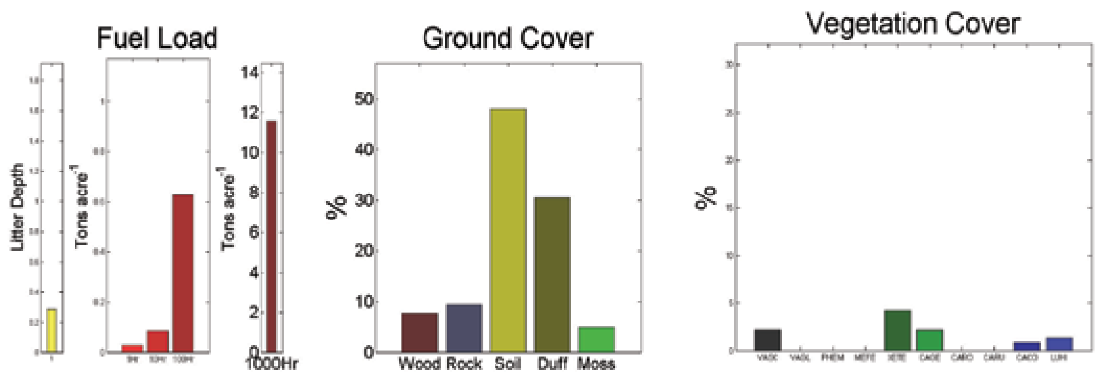


Site: Beaver Ridge, Clearwater National Forest, Central Idaho
Treatment: Nutcracker openings
with planting and no burning (Unit 3A)

PRE



POST-1



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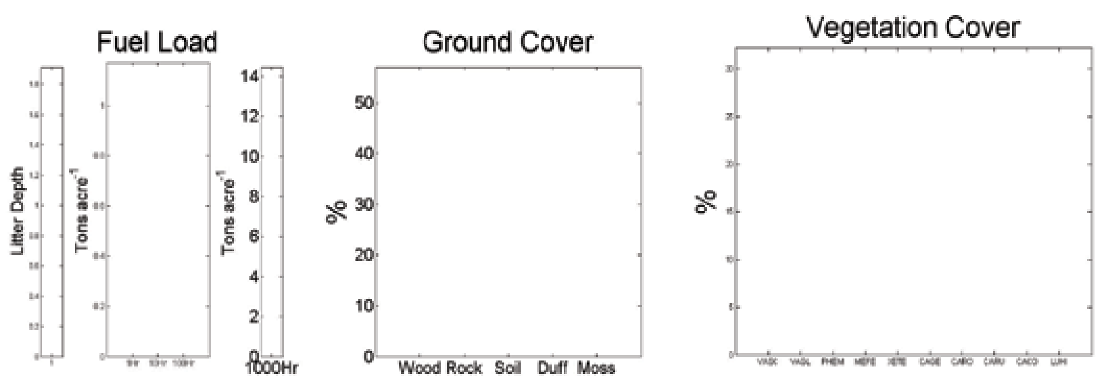


Site: Beaver Ridge, ID. Clearwater NF Nutcracker openings with planting and no burning (Unit 3A)			
	PRE	**POST 1 Yr**	**POST 5 Yr**
TREE DENSITY (trees acre-1)			
WP seedling	663	210.00 (-68.33)	0.00 (**-100.00**)
SF seedling	1614	780.00 (-51.67)	0.00 (**-100.00**)
ES seedling	120	0.00 (-100.00)	0.00 (-100.00)
LP seedling	30	60.00 (100.00)	0.00 (-100.00)
WP sapling	111	10.00 (**-90.99**)	0.00 (**-100.00**)
SF sapling	0	0.00 (NA)	0.00 (NA)
ES sapling	0	0.00 (NA)	0.00 (NA)
LP sapling	1	2.00 (100.00)	0.00 (-100.00)
WP overstory	26	7.00 (**-73.08**)	0.00 (**-100.00**)
SF overstory	0	0.00 (NA)	0.00 (NA)
ES overstory	0	0.00 (NA)	0.00 (NA)
LP overstory	0	0.00 (NA)	0.00 (NA)
SURFACE FUELS			
Litter depth (inches)	1.82	0.29 (**-84.27**)	0.00 (-100.00)
1 hour fuel load (tons acre-1)	0.11	0.03 (-72.42)	0.00 (-100.00)
10 hour fuel load (tons acre-1)	0.25	0.09 (**-65.43**)	0.00 (-100.00)
100 hour fuel load (tons acre-1)	1.12	0.63 (-43.60)	0.00 (-100.00)
1000 hour fuel load (tons acre-1)	13.78	11.59 (-15.88)	0.00 (-100.00)
GROUND COVER (%)			
Wood	9.72	7.83 (-1.90)	0.00 (**-9.72**)
Rock	8.1	9.43 (1.33)	0.00 (**-8.10**)
Soil	6.78	48.08 (**41.30**)	0.00 (**-6.78**)
Duff	54.33	30.52 (**-23.80**)	0.00 (**-54.33**)
Moss	19.73	4.92 (**-14.80**)	0.00 (**-19.73**)
VEGETATION COVER (%)			
VASC	14.63	2.17 (**-12.46**)	0.00 (**-14.63**)
VAGL	2.38	0.00 (-2.38)	0.00 (-2.38)
PHEM	0	0.00 (0.00)	0.00 (0.00)
MEFE	0	0.00 (0.00)	0.00 (0.00)
XETE	30.73	4.25 (**-26.48**)	0.00 (**-30.73**)
CAGE	1.1	2.17 (1.07)	0.00 (**-1.10**)
CARO	0	0.00 (0.00)	0.00 (0.00)
CARU	0	0.00 (0.00)	0.00 (0.00)
CACO	1.09	0.88 (-0.22)	0.00 (**-1.09**)
LUHI	0.58	1.38 (0.79)	0.00 (**-0.58**)

Study Site: Beaver Ridge, Clearwater National Forest, Central Idaho

Treatment: Moderate intensity prescribed burn with nutcracker openings and planting (Unit 3B)

Management Planning: The Powell Ranger District created a comprehensive "District-Wide whitebark pine restoration integrated analysis" in May of 1997 identifying the need for restoration research. In the fall of 1997 it selected two areas for treatment: the Blacklead Mountain site and Beaver Ridge site. Public comment was solicited through mail in May of 1997 and the NEPA analysis for the Categorical Exclusion was finished that September. The cutting treatments were implemented in the summers of 1998 and 1999. District personnel successfully obtained diverse funding (more than $30,000) for this project from multiple sources, including the Nez Perce Tribe, Rocky Mountain Elk Foundation, National Fish and Wildlife Foundation, Forest Service Research, and hazardous fuel reduction monies.

Treatment Description: We created 1- to 3-acre nutcracker openings within this treatment unit by cutting all trees except healthy whitebark pine within circular areas that were evenly dispersed across the unit. We cut all subalpine fir and Engelmann spruce trees and left all whitebark pine and lodgepole pine between nutcracker openings. The trees were limbed where they fell and the resultant slash was scattered across the unit, especially in the nutcracker openings. Limbed logs were arranged to provide stability to the slope. Cut logs were not taken from the site because it was not economically feasible. From July 1998 to October 1998, the District fire crew performed the majority of the tree cutting and slash piling for this study. The District estimated it spent about $66,000 on three units (71 acres) with cutting estimated at $704 per acre.

District fire crews burned this unit September 11, 1999, (same day as 2B) using strip head fires varying in width from 10 to 30 ft. Fuels were mostly dry with measured fuel moistures as follows: 1 hr = 12 percent, 10 hr = 9 percent, 100 hr = 13 percent, sound 1000 hr = 27 percent, rotten 1000 hr = 34 percent, live herbaceous = 55 percent, and live shrubs = 57 percent. Weather conditions at the time of the fire were partly cloudy, cool, and moist. The temperature at the start of the burn (1415) was 57 °F and relative humidity was at 49 percent. By mid-burn (1500), the temperature was 59 °F and humidity was at 47 percent. At the end of the burn (1730), the temperature was 53 °F and humidity was its lowest at 43 percent. Winds were calm for most of the burn with occasional gusts of 3 to 7 mph from the southwest. Antecedent weather was typical of autumn with cool days and cold nights. More than 4 inches of snow (0.04 inches of water) fell four days prior to the burn.

Flame lengths on this unit varied from 3 to 8 ft. The fire killed many trees, even in the matrix between nutcracker openings, and most subalpine fir trees crowned. This burn met nearly all burn plan prescriptions. The burn covered most of the unit (greater than 80 percent) and consumed many fine fuels. The prescribed burning cost an estimated $225 per acre for 71 acres (2B, 3B, and 4B).

After cutting, the District planted 30 acres of this unit with 2-year-old whitebark pine seedlings grown in a nursery in Lewiston, Idaho. The seedlings were planted with approximately 10- by 10-ft spacing and were purposefully planted near logs, stumps, or other cover to improve survival. The crew planted mostly inside the nutcracker openings.

Management Recommendations: The combination of cutting and burning was highly successful at reducing subalpine fir and spruce tree competition for whitebark pine. However, many healthy whitebark pine and lodgepole pine also died from fire-related factors, which demonstrates that, given the high fuel moistures and relative humidity at the time of burning, it is difficult to craft a prescription for this site that kills most fir but allows most whitebark pine to live. We assumed that local whitebark pine populations would provide seed sources for regenerating this unit, but we may have been wrong. The marginal whitebark pine tree regeneration on this site probably resulted from many factors. First, the high whitebark pine mortality on this isolated ridge produced little seed for nutcracker caching. Second, the nutcrackers probably reclaimed seed from many of their caches. Next, the high snowfall, steep slopes, lack of plant cover, and highly erosive soils may have influenced the success of seed germination and seedling establishment. Last, the droughty soils on southern aspect created severe environments for seedlings, especially when plant cover was low.

Planting whitebark pine seedlings on this site was marginally successful with less than 30 percent survival over 5 years; seedlings are now about 1 ft tall and robust. This survival rate could be improved now that there are planting guidelines for whitebark pine seedling stock (McCaughey and others 2009; McCaughey and Scott 2006). We recommend that burned areas with high levels of blister rust mortality be planted with whitebark pine seeds or seedlings to ensure future dominance of this species. The collection of the seed from phenotypic rust-resistant whitebark pine trees will increase the chance that the planted stock or seed will survive the exotic disease infection. We also feel an evaluation of the success of natural regeneration must be made at least a decade after burning. We also feel that the cutting treatment could have been economically feasible as a merchantable harvest given the right market conditions.

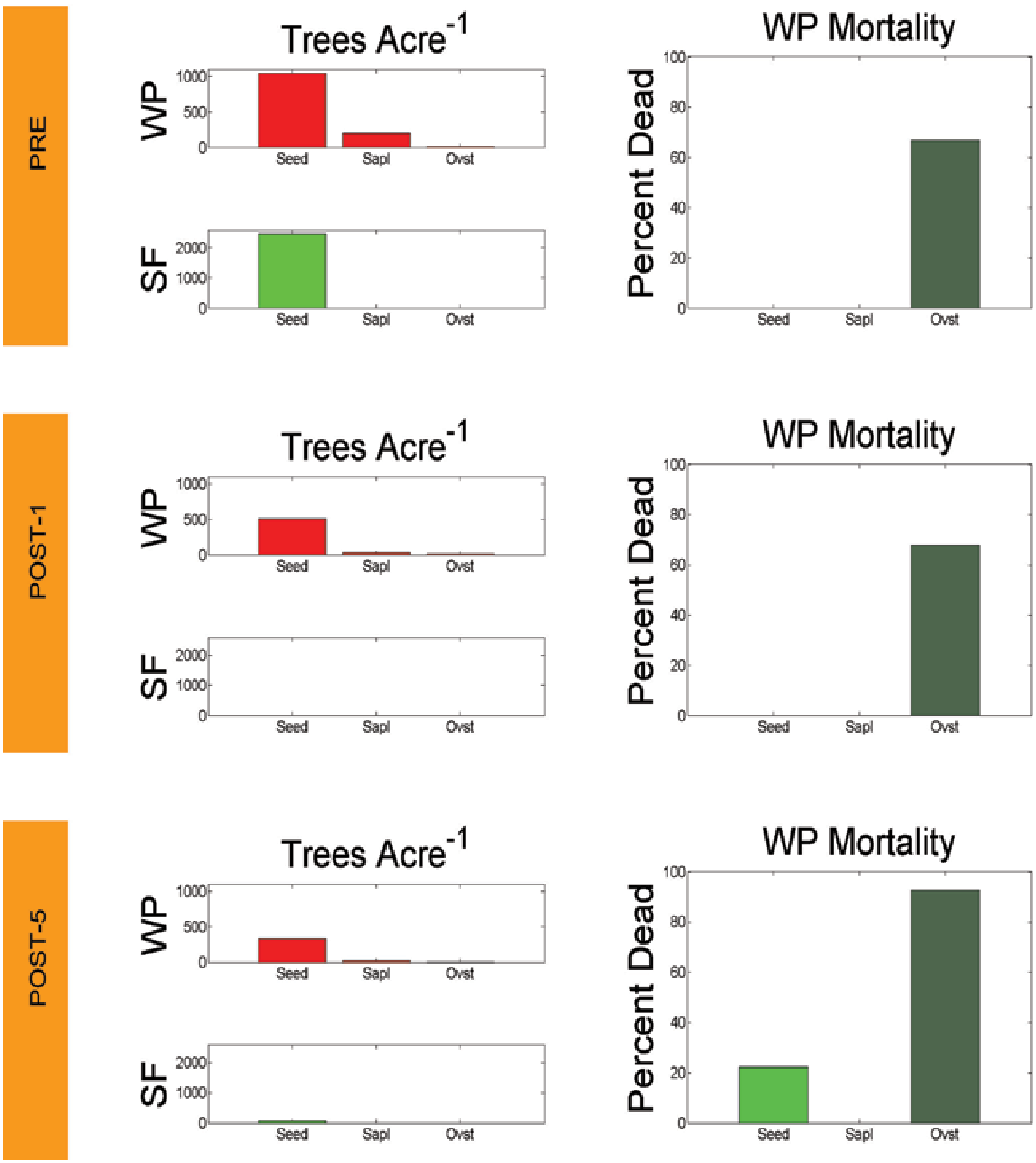
Site: Beaver Ridge, Clearwater National Forest, Central Idaho
Treatment: Moderate intensity prescribed burn
with nutcracker openings and planting (Unit 3B)

PRE

POST-1

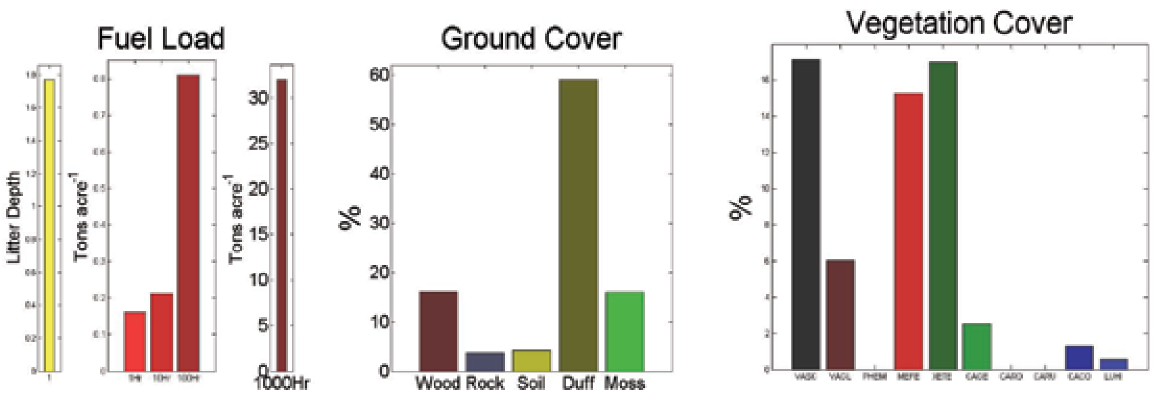
POST-5

Site: Beaver Ridge, Clearwater National Forest, Central Idaho
Treatment: Moderate intensity prescribed burn
with nutcracker openings and planting (Unit 3B)

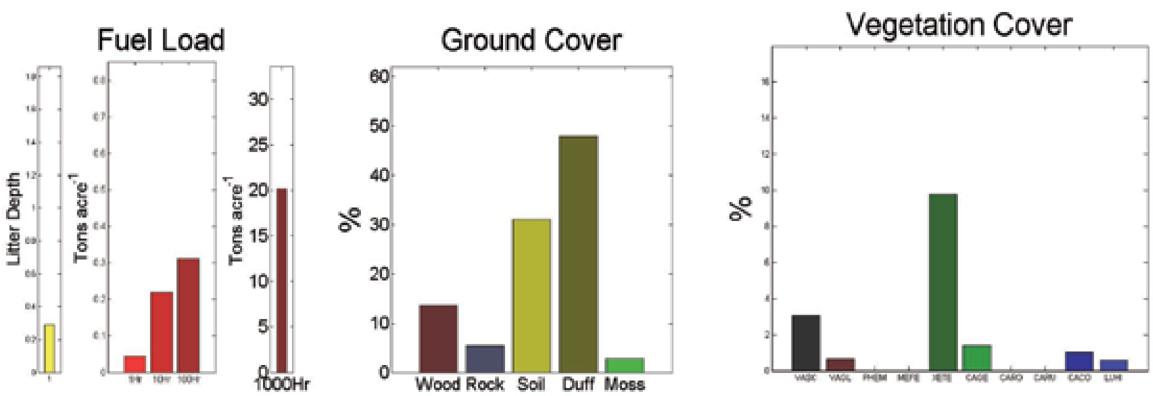


Site: Beaver Ridge, Clearwater National Forest, Central Idaho
Treatment: Moderate intensity prescribed burn
with nutcracker openings and planting (Unit 3B)

PRE



POST-1



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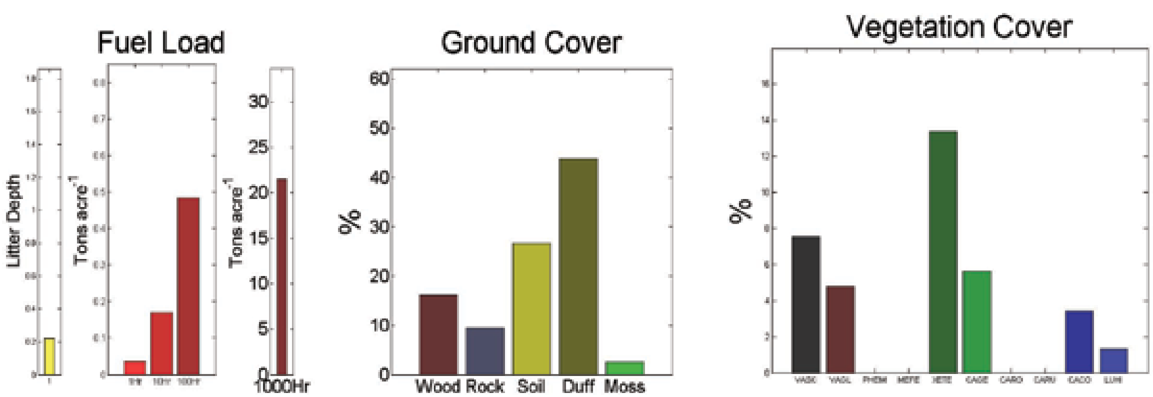


Site: Beaver Ridge, ID. Clearwater NF Moderate intensity prescribed burn with nutcracker openings and planting (Unit 3B)			
	PRE	**POST 1 Yr**	**POST 5 Yr**
TREE DENSITY (trees acre-1)			
WP seedling	1051	510.00 (-51.47)	330.00 (-68.60)
SF seedling	2460	0.00 (-100.00)	60.00 (-97.56)
ES seedling	120	0.00 (-100.00)	60.00 (-50.00)
LP seedling	540	120.00 (-77.78)	150.00 (-72.22)
WP sapling	201	27.00 (**-86.57**)	22.00 (**-89.05**)
SF sapling	0	0.00 (NA)	0.00 (NA)
ES sapling	0	0.00 (NA)	0.00 (NA)
LP sapling	22	6.00 (-72.73)	4.00 (-81.82)
WP overstory	12	8.00 (-33.33)	2.00 (-83.33)
SF overstory	0	0.00 (NA)	0.00 (NA)
ES overstory	0	0.00 (NA)	0.00 (NA)
LP overstory	1	0.00 (-100.00)	0.00 (-100.00)
SURFACE FUELS			
Litter depth (inches)	1.77	0.29 (**-83.80**)	0.22 (**-87.66**)
1 hour fuel load (tons acre-1)	0.16	0.04 (**-72.48**)	0.04 (**-77.19**)
10 hour fuel load (tons acre-1)	0.21	0.22 (3.13)	0.17 (-20.50)
100 hour fuel load (tons acre-1)	0.81	0.31 (**-61.65**)	0.48 (-40.29)
1000 hour fuel load (tons acre-1)	32.02	20.19 (**-36.94**)	21.48 (-32.91)
GROUND COVER (%)			
Wood	16.13	13.55 (-2.57)	16.05 (-0.07)
Rock	3.65	5.35 (1.70)	9.53 (**5.88**)
Soil	4.17	30.98 (**26.80**)	26.64 (**22.46**)
Duff	59	47.83 (-11.17)	43.88 (**-15.13**)
Moss	16	2.75 (**-13.25**)	2.60 (**-13.40**)
VEGETATION COVER (%)			
VASC	17.13	3.03 (**-14.09**)	7.53 (**-9.60**)
VAGL	6.03	0.67 (**-5.36**)	4.79 (-1.24)
PHEM	0	0.00 (0.00)	0.00 (0.00)
MEFE	15.25	0.00 (-15.25)	0.00 (-15.25)
XETE	16.98	9.75 (**-7.23**)	13.35 (-3.63)
CAGE	2.5	1.38 (-1.13)	5.64 (**3.14**)
CARO	0	0.00 (0.00)	0.00 (0.00)
CARU	0	0.00 (0.00)	0.00 (0.00)
CACO	1.29	1.00 (-0.29)	3.42 (**2.13**)
LUHI	0.55	0.56 (0.01)	1.33 (0.78)

Study Site: Beaver Ridge, Clearwater National Forest, Central Idaho

Treatment: Moderate intensity prescribed burn with fuel enhancement (Unit 5A)

Management Planning: The Powell Ranger District created a comprehensive "District-Wide whitebark pine restoration integrated analysis" in May of 1997 identifying the need for restoration research. In the fall of 1997 it selected two areas for treatment: the Blacklead Mountain site and Beaver Ridge site. Public comment was solicited through mail in May of 1997 and the NEPA analysis for the Categorical Exclusion was finished that September. The cutting treatments were implemented in the summers of 1998 and 1999. District personnel successfully obtained diverse funding (more than $30,000) for this project from multiple sources, including the Nez Perce Tribe, Rocky Mountain Elk Foundation, National Fish and Wildlife Foundation, Forest Service Research, and hazardous fuel reduction monies.

Treatment Description: We implemented a fuel enhancement treatment in September 1998 by cutting subalpine fir or Engelmann spruce tree to increase fuel loadings and improve continuity of the fuelbed. We directionally felled the trees to fill in gaps of bare soil within the fuelbed, but, in many parts of the stand, there were insufficient subalpine fir trees to optimally augment the fuelbed. The District fire crew did some of the saw work but most was accomplished through an experienced contract crew. The District estimated it spent from $20 to $40 per acre on slashing.

This unit was burned September 28, 2002, by District fire crews using strip head fires varying in width from 20 to 60 ft. Fuels were mostly dry with measured moisture contents as follows: 1 hr = 10 percent, 14 hr = 3 percent, 100 hr=15 percent, sound 1000 hr = 19 percent, rotten 1000 hr = 18 percent, live shrubs = 52 percent, and live herbaceous at 25 percent. Weather conditions at the time of the fire were sunny and warm (50 to 60 ^{o}F), with 3 to 7 mph winds and relative humidity around 30 to 40 percent. Antecedent weather was typical for autumn with cool days and cold nights. No significant rain had fallen four days prior to the burn. A terra-torch was used to widen the fire line where the unit meets the road.

This prescribed burn was originally designed to mimic a stand-replacement fire using a high intensity prescription, but logistical concerns and insufficient fuels, even with fuel enhancement, necessitated a less intense fire, so we implemented a mixed-severity burn at the high end of the mixed-severity category. Flame lengths varied from 1 to 9 ft with passive crown fire behavior observed throughout the burning period, especially in mature subalpine fir trees. Many trees were killed, especially in those areas with dense subalpine fir regeneration, but the pattern of mortality was highly variable. Young lodgepole patches experienced mostly non-lethal surface fire, whereas dense fir and spruce thickets experienced high mortality because of high intensities. This burn was cooler than planned because of the moist conditions but still met many burn plan objectives. The burn covered most of the unit (greater than 70 percent) and consumed many fine fuels. The prescribed burning cost an estimated $200 per acre. Areas around the research plots burned at lower intensities than the rest of the burn.

Management Recommendations: Though this burn was successful, a more continuous and heavier fine fuel component would have achieved higher fir mortality under less than optimal moisture contents. This burn was successful because a hard frost (less than 25 ^{o}F) occurred on the site two weeks prior to the burn and killed most shrub and herbaceous foliage, which allowed plants to dry below 50 percent moisture contents.

We observed abundant nutcracker harvesting but very little caching in this unit. Whitebark pine tree regeneration was marginal on this site probably because of the lack of nutcracker caching, high burn severity, and severity of site (doughty soils, south-facing slopes, and heavy snow loads). We recommend that burned areas with high levels of blister rust mortality be planted with rust-resistant whitebark pine seeds or seedlings to ensure future dominance of this species. The collection of the seed from phenotypic rust-resistant whitebark pine trees will increase the chance that the planted stock or seed will survive the exotic disease infection. We also feel an evaluation of the success of natural regeneration must be made at least a decade after burning.

Site: Beaver Ridge, Clearwater National Forest, Central Idaho
Treatment: Moderate intensity prescribed burn
with fuel enhancement (Unit 5A)

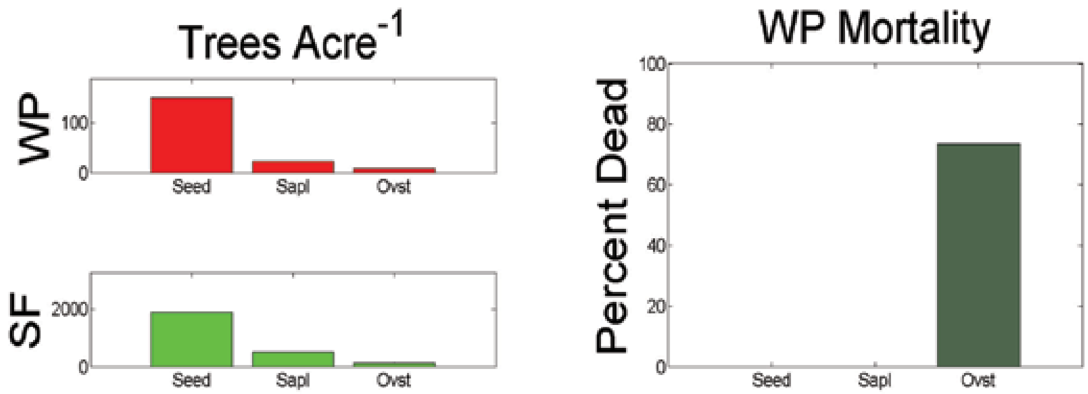
PRE

POST-1

POST-5

Site: Beaver Ridge, Clearwater National Forest, Central Idaho
Treatment: Moderate intensity prescribed burn
with fuel enhancement (Unit 5A)

PRE



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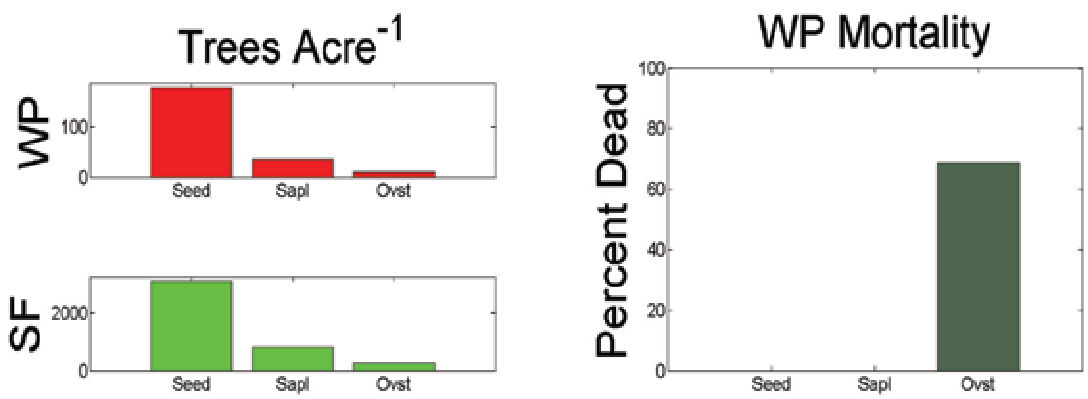

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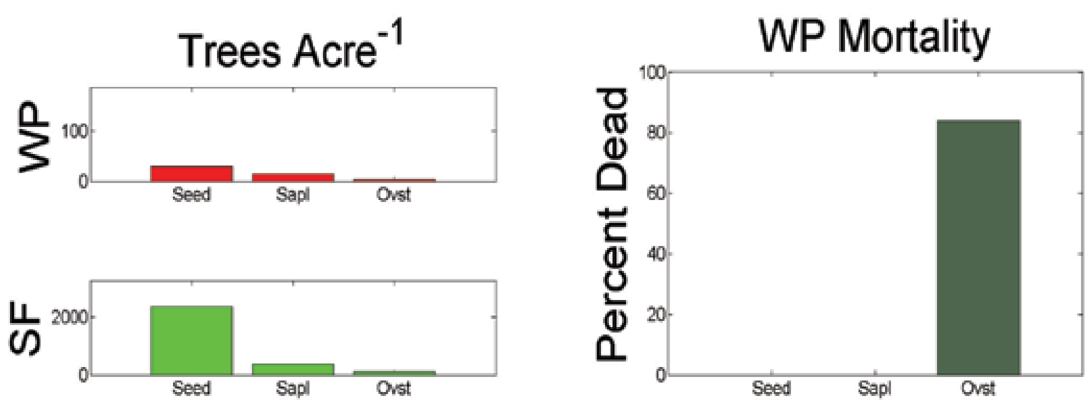
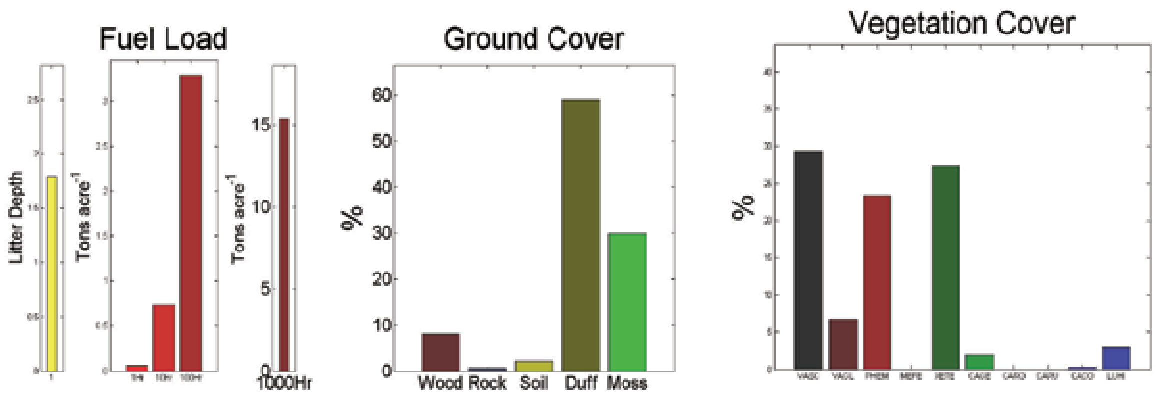
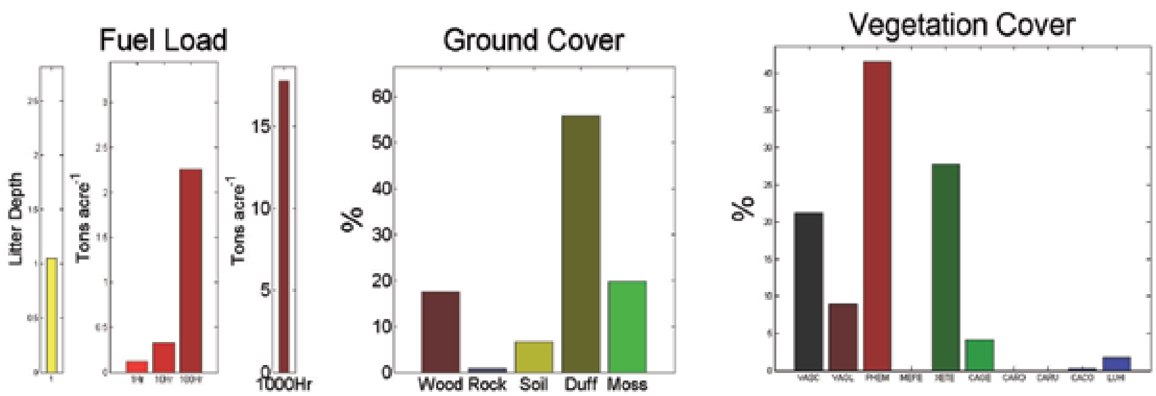


Site: Beaver Ridge, Clearwater National Forest, Central Idaho
Treatment: Moderate intensity prescribed burn with fuel enhancement (Unit 5A)

PRE



POST-1



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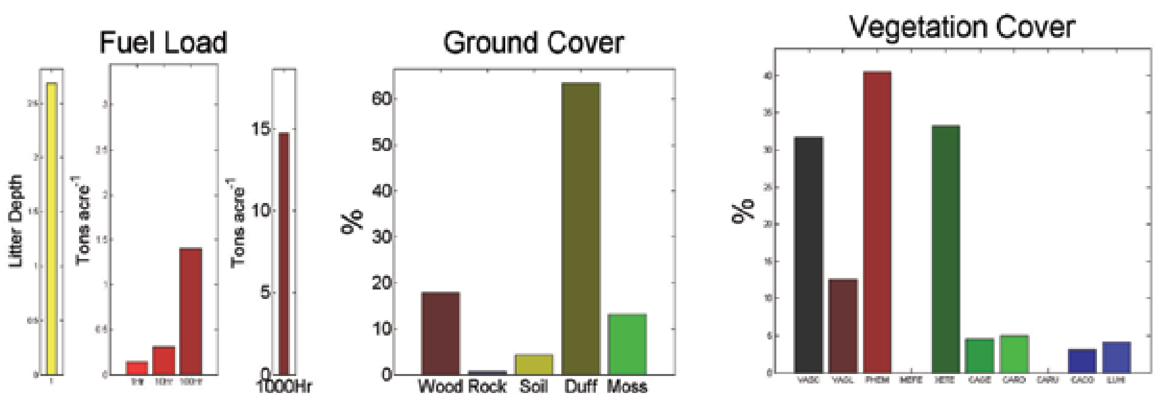


Site: Beaver Ridge, ID. Clearwater NF Moderate intensity prescribed burn with fuel enhancement (Unit 5A)			
	PRE	**POST 1 Yr**	**POST 5 Yr**
TREE DENSITY (trees acre-1)			
WP seedling	151	180.00 (19.21)	30.00 (-80.13)
SF seedling	1891	3122.00 (65.10)	2371.00 (25.38)
ES seedling	120	0.00 (-100.00)	60.00 (-50.00)
LP seedling	150	300.00 (100.00)	90.00 (-40.00)
WP sapling	22	36.00 (63.64)	15.00 (-31.82)
SF sapling	516	830.00 (60.85)	366.00 (-29.07)
ES sapling	62	74.00 (19.35)	47.00 (-24.19)
LP sapling	50	66.00 (32.00)	40.00 (-20.00)
WP overstory	9	10.00 (11.11)	4.00 (-55.56)
SF overstory	130	238.00 (83.08)	99.00 (-23.85)
ES overstory	22	4.00 (-81.82)	11.00 (-50.00)
LP overstory	45	42.00 (-6.67)	36.00 (-20.00)
SURFACE FUELS			
Litter depth (inches)	1.79	1.05 (-41.26)	2.68 (49.67)
1 hour fuel load (tons acre-1)	0.06	0.12 (**105.57**)	0.14 (**135.81**)
10 hour fuel load (tons acre-1)	0.73	0.33 (-55.31)	0.31 (-58.29)
100 hour fuel load (tons acre-1)	3.29	2.26 (-31.25)	1.40 (-57.46)
1000 hour fuel load (tons acre-1)	15.39	17.76 (15.42)	14.73 (-4.30)
GROUND COVER (%)			
Wood	7.95	17.55 (**9.60**)	17.85 (**9.90**)
Rock	0.6	0.85 (0.25)	0.70 (0.10)
Soil	2.15	6.63 (4.47)	4.30 (2.15)
Duff	59	55.75 (-3.25)	63.30 (4.30)
Moss	29.82	19.65 (**-10.18**)	13.13 (**-16.70**)
VEGETATION COVER (%)			
VASC	29.3	21.22 (**-8.08**)	31.75 (2.45)
VAGL	6.67	8.92 (2.25)	12.58 (5.92)
PHEM	23.31	41.63 (18.31)	40.50 (17.19)
MEFE	0	0.00 (0.00)	0.00 (0.00)
XETE	27.35	27.75 (0.40)	33.23 (5.88)
CAGE	1.91	4.14 (2.24)	4.54 (2.64)
CARO	0	0.00 (0.00)	5.00 (5.00)
CARU	0	0.00 (0.00)	0.00 (0.00)
CACO	0.25	0.25 (0.00)	3.08 (2.83)
LUHI	2.97	1.75 (-1.22)	4.14 (1.17)

Study Site: Beaver Ridge, Clearwater National Forest, Central Idaho

Treatment: Moderate intensity prescribed burn with NO fuel enhancement (Unit 5B)

Management Planning: The Powell Ranger District created a comprehensive "District-Wide whitebark pine restoration integrated analysis" in May of 1997 identifying the need for restoration research. In the fall of 1997 it selected two areas for treatment: the Blacklead Mountain site and Beaver Ridge site. Public comment was solicited through mail in May of 1997 and the NEPA analysis for the Categorical Exclusion was finished that September. The cutting treatments were implemented in the summers of 1998 and 1999. District personnel successfully obtained diverse funding (more than $30,000) for this project from multiple sources, including the Nez Perce Tribe, Rocky Mountain Elk Foundation, National Fish and Wildlife Foundation, Forest Service Research, and hazardous fuel reduction monies.

Treatment Description: This unit was burned September 28, 2002, by District fire crews using strip head fires varying in width from 20 to 60 ft. Fuels were mostly dry with measured moisture contents as follows: 1 hr = 10 percent, 14 hr = 3 percent, 100 hr = 15 percent, sound 1000 hr = 19 percent, rotten 1000 hr = 18 percent, live shrubs = 52 percent, and live herbaceous at 25 percent. Weather conditions at the time of the fire were sunny and warm (50 to 60 °F), with 3 to 7 mph winds and relative humidity around 30 to 40 percent. Antecedent weather was typical for autumn with cool days and cold nights. No significant rain had fallen four days prior to the burn. A terra-torch was used to widen the fire line where the unit meets the road.

This prescribed burn was originally designed to mimic a stand-replacement fire using a high intensity prescription, but logistical concerns and insufficient fuels, even with fuel enhancement, necessitated a less intense fire, so we implemented a mixed-severity burn at the high end of the mixed-severity category. Flame lengths varied from 1 to 9 ft with passive crown fire behavior observed throughout the burning period, especially in mature subalpine fir trees. Many trees were killed, especially in those areas with dense subalpine fir regeneration, but the pattern of mortality was highly variable. Young lodgepole patches experienced mostly non-lethal surface fire, whereas dense fir and spruce thickets experienced high mortality because of high intensities. This burn was cooler than planned because of the moist conditions but still met many burn plan objectives. The burn covered most of the unit (greater than 70 percent) and consumed many fine fuels. The prescribed burning cost an estimated $200 per acre. Areas around the research plots burned at lower intensities than the rest of the burn.

Management Recommendations: Though this burn was successful, a more continuous and heavier fine fuel component would have achieved higher fir mortality under less than optimal moisture contents. This burn was successful because a hard frost (less than 25 °F) occurred on the site two weeks prior to the burn and killed most shrub and herbaceous foliage which allowed plants to dry below 50 percent moisture contents.

We observed abundant nutcracker harvesting but very little caching in this unit. Whitebark pine tree regeneration was marginal on this site probably because of the lack of nutcracker caching, high burn severity, and severity of site (doughty soils, south-facing slopes, and heavy snow loads). We recommend that burned areas with high levels of blister rust mortality be planted with rust-resistant whitebark pine seeds or seedlings to ensure future dominance of this species. The collection of the seed from phenotypic rust-resistant whitebark pine trees will increase the chance that the planted stock or seed will survive the exotic disease infection. We also feel an evaluation of the success of natural regeneration must be made at least a decade after burning.

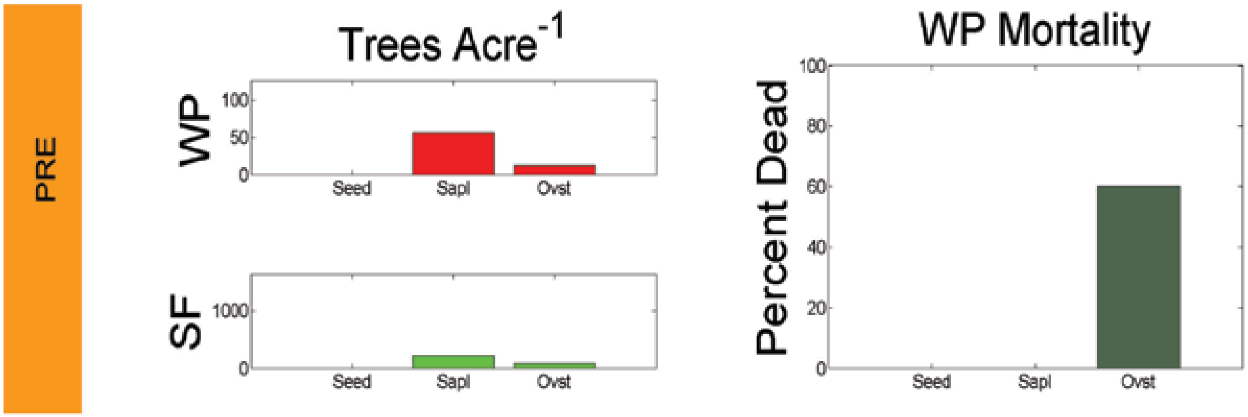
Site: Beaver Ridge, Clearwater National Forest, Central Idaho
Treatment: Moderate intensity prescribed burn
with NO fuel enhancement (Unit 5B)

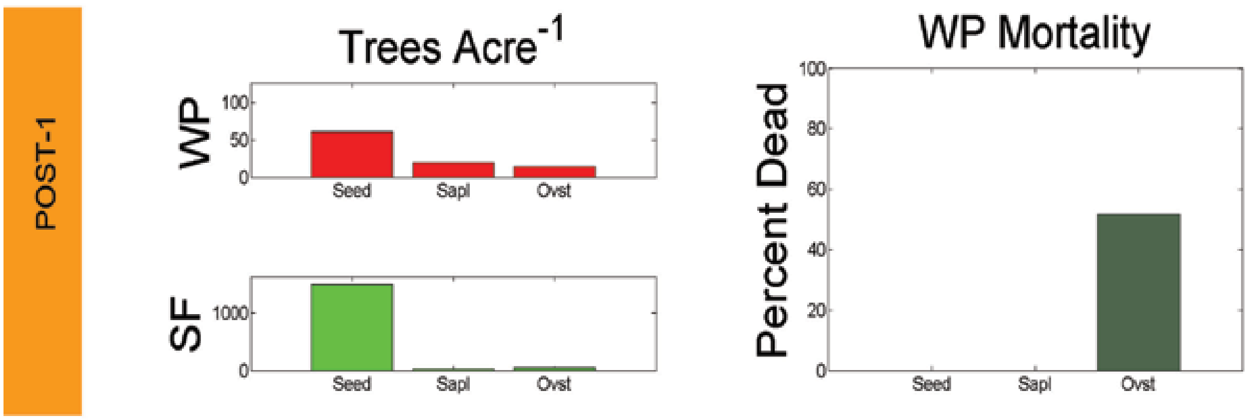
PRE

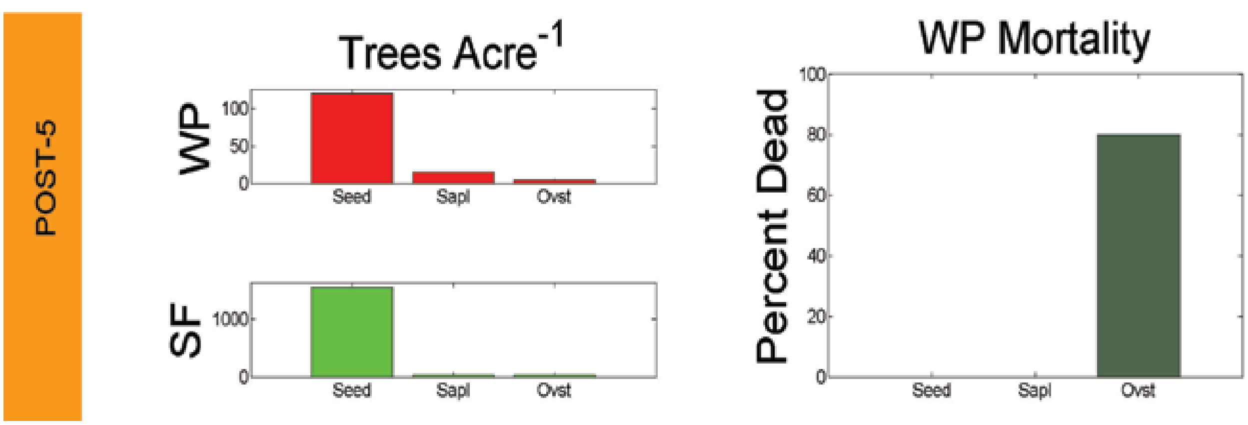
POST-1

POST-5

Site: Beaver Ridge, Clearwater National Forest, Central Idaho
Treatment: Moderate intensity prescribed burn
with NO fuel enhancement (Unit 5B)

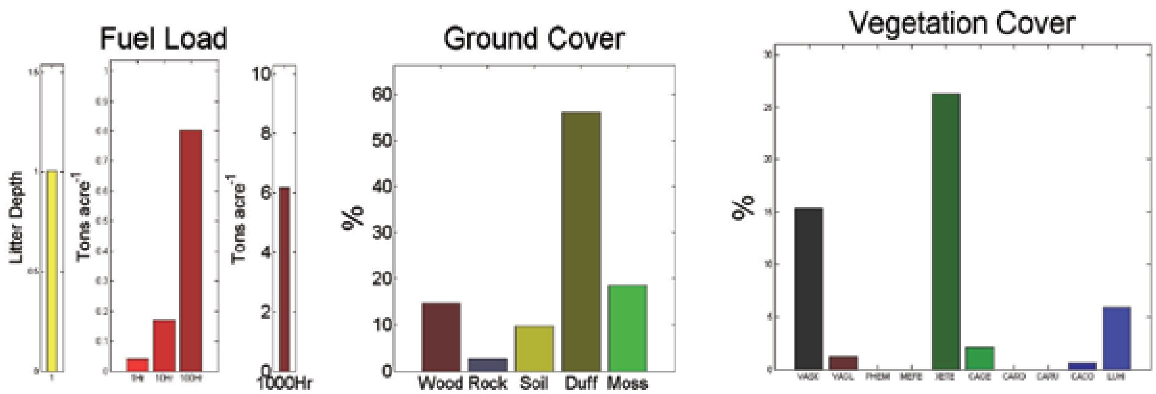




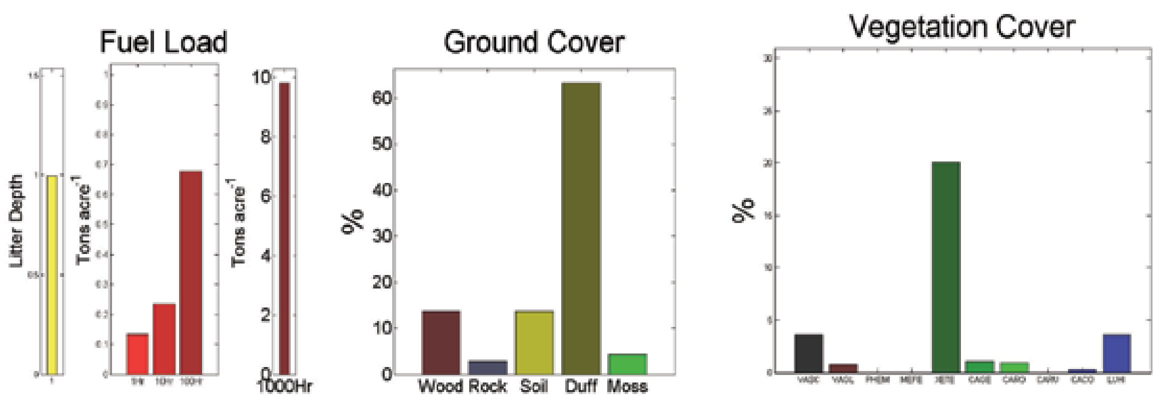


Site: Beaver Ridge, Clearwater National Forest, Central Idaho
Treatment: Moderate intensity prescribed burn
with NO fuel enhancement (Unit 5B)

PRE



POST-1



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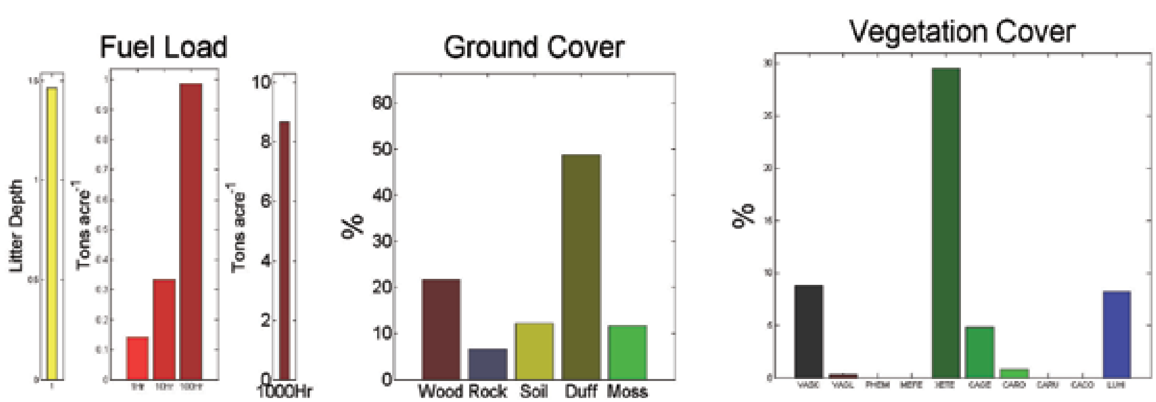


Site: Beaver Ridge, ID. Clearwater NF Moderate intensity prescribed burn with NO fuel enhancement (Unit 5B)			
	PRE	POST 1 Yr	POST 5 Yr
TREE DENSITY (trees acre-1)			
WP seedling	0	61.00 (NA)	120.00 (NA)
SF seedling	0	1504.00 (NA)	1561.00 (NA)
ES seedling	0	0.00 (NA)	0.00 (NA)
LP seedling	390	273.00 (-30.00)	360.00 (-7.69)
WP sapling	56	20.00 (**-64.29**)	15.00 (**-73.21**)
SF sapling	222	31.00 (**-86.04**)	25.00 (**-88.74**)
ES sapling	2	2.00 (0.00)	2.00 (0.00)
LP sapling	142	54.00 (**-61.97**)	38.00 (**-73.24**)
WP overstory	12	14.00 (16.67)	4.00 (-66.67)
SF overstory	84	48.00 (**-42.86**)	31.00 (**-63.10**)
ES overstory	0	0.00 (NA)	0.00 (NA)
LP overstory	64	55.00 (-14.06)	44.00 (-31.25)
SURFACE FUELS			
Litter depth (inches)	1	1.00 (-1.00)	1.46 (45.44)
1 hour fuel load (tons acre-1)	0.04	0.13 (223.02)	0.14 (**244.65**)
10 hour fuel load (tons acre-1)	0.17	0.23 (38.35)	0.33 (**97.47**)
100 hour fuel load (tons acre-1)	0.8	0.68 (-15.50)	0.99 (23.12)
1000 hour fuel load (tons acre-1)	6.17	9.80 (58.82)	8.66 (40.34)
GROUND COVER (%)			
Wood	14.65	13.68 (-0.97)	21.75 (7.10)
Rock	2.67	2.90 (0.23)	6.65 (**3.98**)
Soil	9.72	13.73 (4.00)	12.30 (2.58)
Duff	56.15	63.25 (7.10)	48.77 (-7.38)
Moss	18.6	4.28 (**-14.33**)	11.68 (**-6.93**)
VEGETATION COVER (%)			
VASC	15.38	3.60 (**-11.78**)	8.82 (**-6.55**)
VAGL	1.17	0.75 (-0.42)	0.25 (-0.92)
PHEM	0	0.00 (0.00)	0.00 (0.00)
MEFE	0	0.00 (0.00)	0.00 (0.00)
XETE	26.27	20.07 (-6.20)	29.52 (3.25)
CAGE	2.1	1.06 (-1.04)	4.81 (2.71)
CARO	0	0.92 (**0.92**)	0.80 (**0.80**)
CARU	0	0.00 (0.00)	0.00 (0.00)
CACO	0.56	0.25 (-0.31)	0.00 (**-0.56**)
LUHI	5.92	3.60 (-2.32)	8.21 (2.29)

Study Site: Coyote Meadows, Bitterroot National Forest, Western-Central Montana

Treatment: Moderate intensity prescribed burn with fuel enhancement (Unit 3C)

Management Planning: This treatment was proposed in the summer of 1992 and burn plans were developed during the winter of 1993. This unit was encompassed by a much larger area where the Darby Ranger District had already completed the NEPA work. The District also pruned all rust-infected branches on whitebark pine trees to reduce infection potential in 160 acres surrounding this unit.

Treatment Description: The research crew completed the fuel enhancement in this unit in late summer of 1993. We cut as many subalpine firs as necessary to make a contiguous fuelbed across the unit. Parts of the unit were bare or rock, so we directionally felled trees to allow fire to burn in these areas through the slash. The only cutting requirement for the fuel enhancement treatment was that the cut trees had to be subalpine fir or Engelmann spruce. We treated the entire unit in one day with only two people for about $10 to $35 per acre.

Fuel and weather conditions were never favorable for the prescribed burn treatment for the first 7 years of the study. The entire site finally burned during the Bitterroot Fires of 2000. Because we were unable to visit the site during the wildfire, no data are available documenting fire weather, fuel moistures, and fire behavior, but all post-fire visual evidence indicates that a moderate to high intensity fire burned through the understory and slashed fuels. Weather conditions at the time of the fire were hot and dry with temperatures in the low 90s and relative humidity around 20 percent. However, this burn was quite intense and ended up killing nearly all trees on the site. Burn coverage was nearly complete with more than 90 percent of the area burned. The wildfire burned at a severity much higher than that targeted by the prescribed burn plan. Although the wildfire appeared to burn as a surface fire, it killed most trees and consumed all fine and most coarse woody fuels.

Management Recommendations: The fuel enhancement cuttings appeared not to modify wildfire behavior within the treatment unit compared to adjacent units that did not receive fuel enhancement. Burn coverage, tree mortality, and undergrowth plant cover reduction levels seemed the same across 3A and 3B. Fuel enhancement is clearly beneficial on this moist, poorly drained site because it provided dry fuel on top of the green mesic vegetation.

We did not observe extensive nutcracker caching in the study site until the following year because of road closures. Whitebark pine tree regeneration was marginal, indicating that 5 years may not be enough time for successful seedling establishment. The high levels of rust- and fire-caused tree mortality in the surrounding seed source might have also prevented extensive nutcracker caching. Though this wildfire burned at higher than the prescribed intensity, we feel that wildfire or wildland fire use can be effective for restoring whitebark pine. The observed fire effects seem well within the historical range for this site. We recommend that burned areas with high levels of blister rust mortality be planted with rust-resistant whitebark pine seeds or seedlings to ensure future dominance of this species. Log loadings increased dramatically following the fire because whitebark pine snags fell as their bases were consumed by the fire.

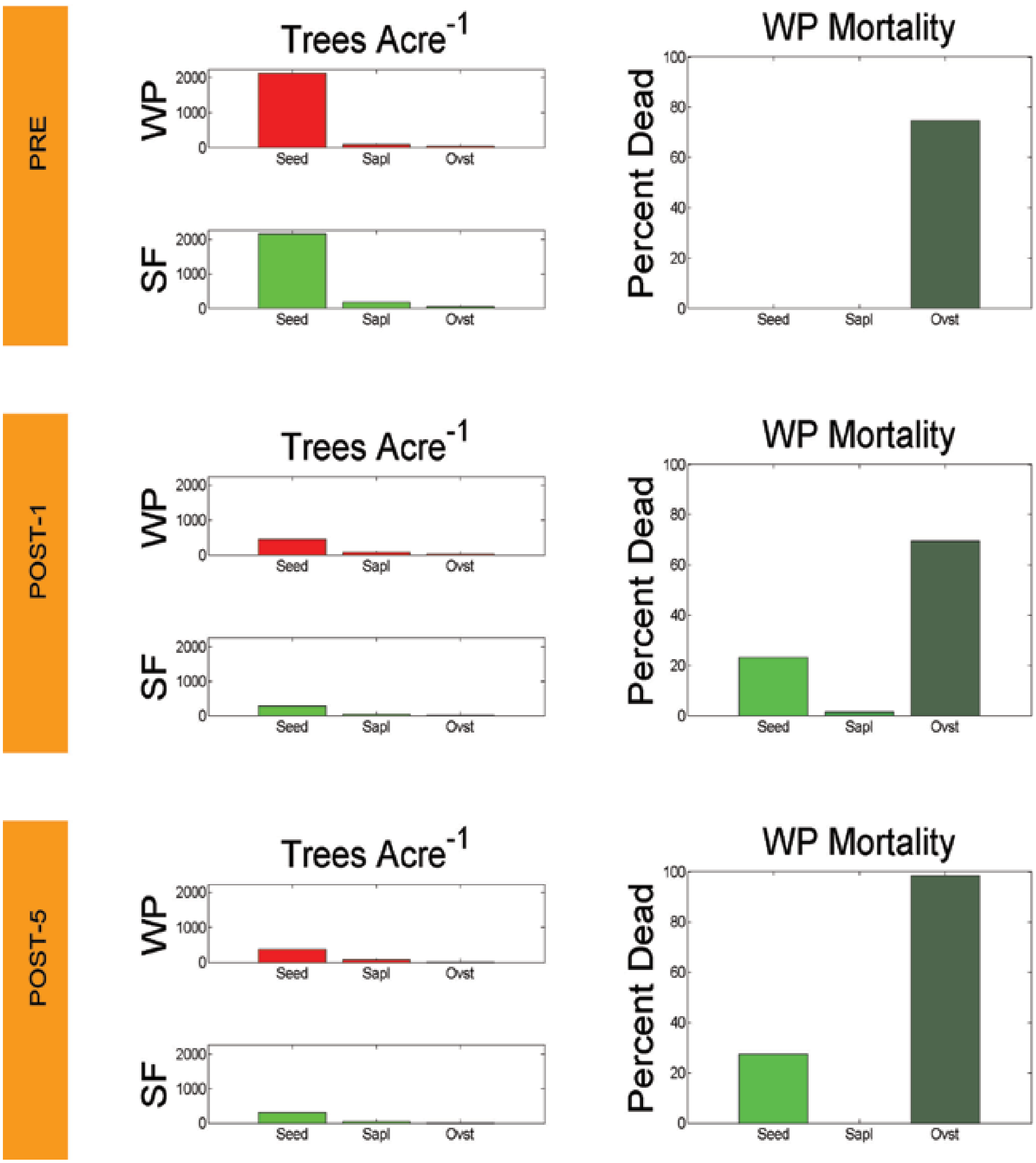
Site: Coyote Meadows, Bitterroot National Forest, Western-Central Montana
Treatment: Moderate intensity prescribed burn
with fuel enhancement (Unit 3C)

PRE

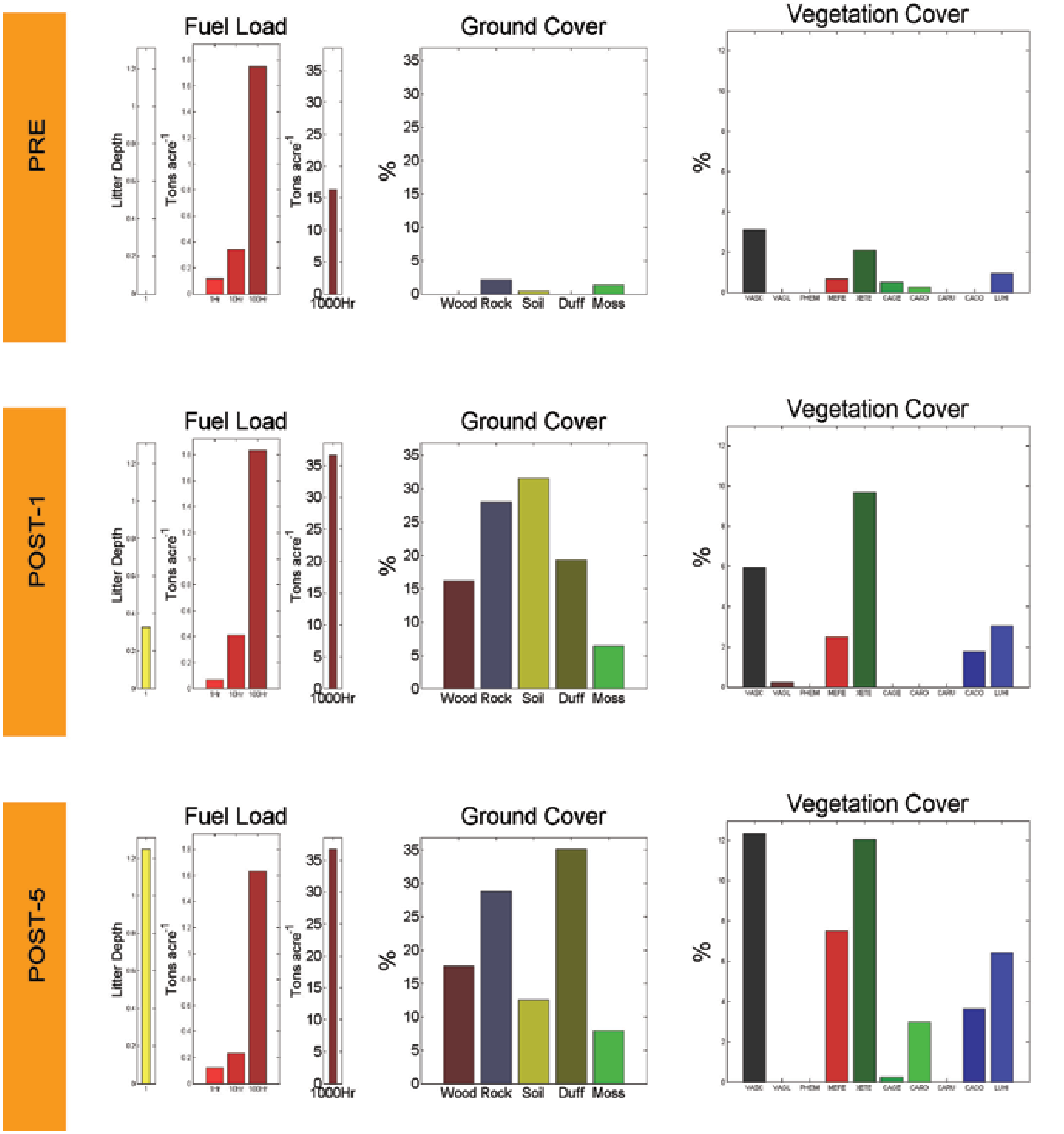
POST-1

POST-5

Site: Coyote Meadows, Bitterroot National Forest, Western-Central Montana
Treatment: Moderate intensity prescribed burn
with fuel enhancement (Unit 3C)



Site: Coyote Meadows, Bitterroot National Forest, Western-Central Montana
Treatment: Moderate intensity prescribed burn
with fuel enhancement (Unit 3C)



Site: Coyote Meadows, MT. Bitterroot NF Moderate intensity prescribed burn with fuel enhancement (Unit 3C)			
	PRE	POST 1 Yr	POST 5 Yr
TREE DENSITY (trees acre-1)			
WP seedling	2131	451.00 (**-78.84**)	361.00 (**-83.06**)
SF seedling	2161	271.00 (**-87.46**)	300.00 (**-86.12**)
ES seedling	120	1.00 (-99.17)	0.00 (-100.00)
LP seedling	0	0.00 (NA)	0.00 (NA)
WP sapling	86	69.00 (-19.77)	72.00 (-16.28)
SF sapling	170	44.00 (**-74.12**)	42.00 (**-75.29**)
ES sapling	3	4.00 (33.33)	2.00 (-33.33)
LP sapling	0	0.00 (NA)	0.00 (NA)
WP overstory	34	18.00 (-47.06)	1.00 (**-97.06**)
SF overstory	39	3.00 (**-92.31**)	1.00 (**-97.44**)
ES overstory	15	9.00 (-40.00)	2.00 (**-86.67**)
LP overstory	1	0.00 (-100.00)	0.00 (-100.00)
SURFACE FUELS			
Litter depth (inches)	0	0.33 (NA)	1.25 (NA)
1 hour fuel load (tons acre-1)	0.12	0.07 (-42.13)	0.12 (6.74)
10 hour fuel load (tons acre-1)	0.34	0.41 (19.52)	0.24 (-31.55)
100 hour fuel load (tons acre-1)	1.75	1.83 (4.71)	1.64 (-6.58)
1000 hour fuel load (tons acre-1)	16.31	36.64 (**124.62**)	36.72 (**125.13**)
GROUND COVER (%)			
Wood	0	16.14 (**16.14**)	17.55 (**17.55**)
Rock	2.13	27.95 (25.83)	28.73 (26.60)
Soil	0.36	31.43 (**31.07**)	12.53 (**12.16**)
Duff	0	19.27 (**19.27**)	35.08 (**35.08**)
Moss	1.35	6.39 (5.04)	7.88 (6.53)
VEGETATION COVER (%)			
VASC	3.1	5.94 (**2.84**)	12.35 (**9.25**)
VAGL	0	0.25 (0.25)	0.00 (0.00)
PHEM	0	0.00 (0.00)	0.00 (0.00)
MEFE	0.67	2.50 (1.83)	7.50 (6.83)
XETE	2.1	9.66 (**7.56**)	12.05 (**9.95**)
CAGE	0.5	0.00 (-0.50)	0.25 (-0.25)
CARO	0.25	0.00 (-0.25)	2.96 (**2.71**)
CARU	0	0.00 (0.00)	0.00 (0.00)
CACO	0	1.75 (**1.75**)	3.63 (**3.63**)
LUHI	0.95	3.05 (2.10)	6.42 (5.47)

Study Site: Coyote Meadows, Bitterroot National Forest, Western-Central Montana

Treatment: Moderate intensity prescribed burn with NO fuel enhancement (Unit 3B)

Management Planning: This treatment was proposed in the summer of 1992 and burn plans were developed during the winter of 1993. This unit was encompassed by a much larger area where the Darby Ranger District had already completed the NEPA work. The District also pruned all rust-infected branches on whitebark pine trees to reduce infection potential in 160 acres surrounding this unit.

Treatment Description: Fuel and weather conditions were never favorable for the prescribed burn treatment for the first 7 years of the study. The entire site finally burned during the Bitterroot Fires of 2000. Because we were unable to visit the site during the wildfire, no data are available documenting fire weather, fuel moistures, and fire behavior, but all post-fire visual evidence indicates that a moderate to high intensity fire burned through the understory and slashed fuels. Weather conditions at the time of the fire were hot and dry with temperatures in the low 90s and relative humidity around 20 percent. However, this burn was quite intense and ended up killing nearly all trees on the site. Burn coverage was nearly complete with more than 90 percent of the area burned. The wildfire burned at a severity much higher than that targeted by the prescribed burn plan. Although the wildfire appeared to burn as a surface fire, it killed most trees and consumed all fine and most coarse woody fuels. Because the 2000 wildfire burned at higher than expected intensities, effects of fuel enhancement might have been masked.

Management Recommendations: The fuel enhancement cuttings did not appear to modify wildfire behavior within the treatment unit compared to adjacent units that did not receive fuel enhancement. Burn coverage, tree mortality, and undergrowth plant cover reduction levels seemed the same across 3A and 3B. This might indicate that warmer, drier burn prescriptions may not always require fuel enhancement for success, but there will be significant increases in tree mortality. Fuel enhancement is clearly beneficial on this moist, poorly drained site because it provided dry fuel on top of the green mesic vegetation, but the high wildfire intensities confound the interpretation of this effect.

We did not observe extensive nutcracker caching in the study site until the following year because of road closures. Whitebark pine tree regeneration was marginal, indicating that 5 years may not be enough time for the successful seedling establishment. The high levels of rust- and fire-caused tree mortality in the surrounding seed source might have also prevented extensive nutcracker caching. Though this wildfire burned at higher than the prescribed intensity, we feel that wildfire or wildland fire use can be effective for restoring whitebark pine. The observed fire effects seem well within the historical range for this site. We recommend that burned areas with high levels of blister rust mortality be planted with rust-resistant whitebark pine seeds or seedlings to ensure future dominance of this species. Log loadings increased dramatically following the fire because whitebark pine snags fell as their bases were consumed by the fire.

Site: Coyote Meadows, Bitterroot National Forest, Western-Central Montana
Treatment: Moderate intensity prescribed burn
with NO fuel enhancement (Unit 3B)

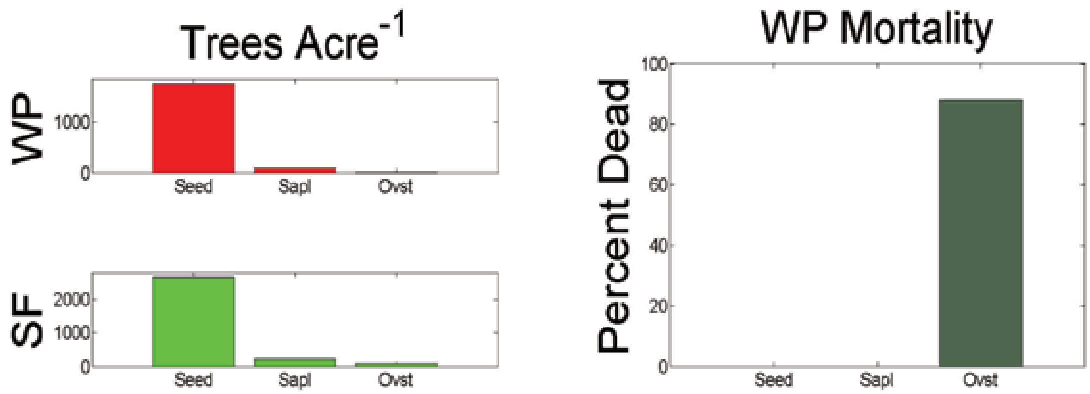
PRE

POST-1

POST-5

Site: Coyote Meadows, Bitterroot National Forest, Western-Central Montana
Treatment: Moderate intensity prescribed burn
with NO fuel enhancement (Unit 3B)

PRE



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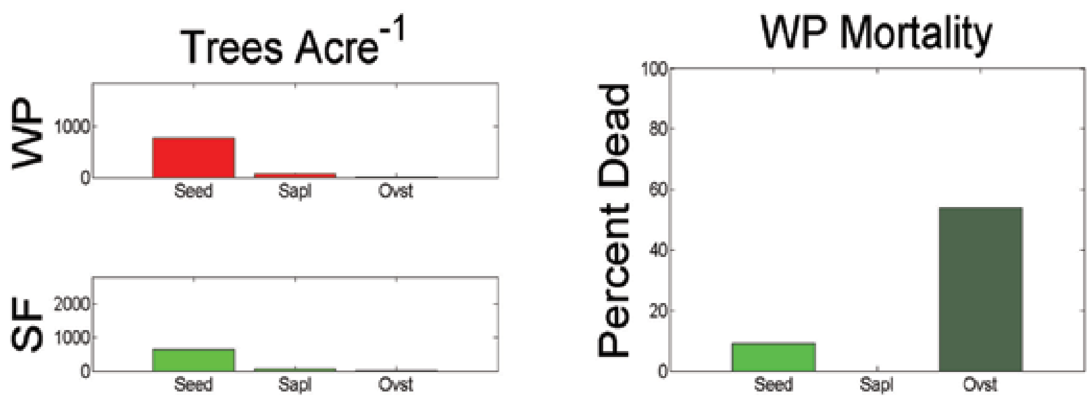
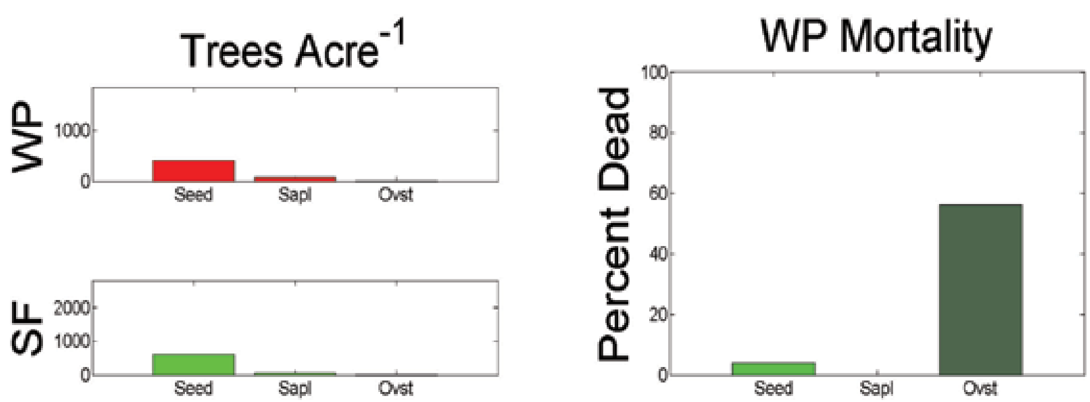
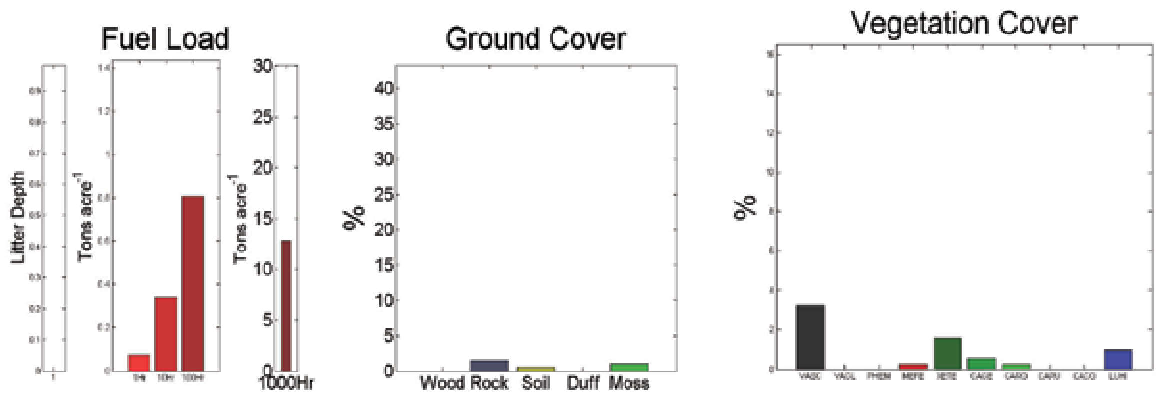


POST-5

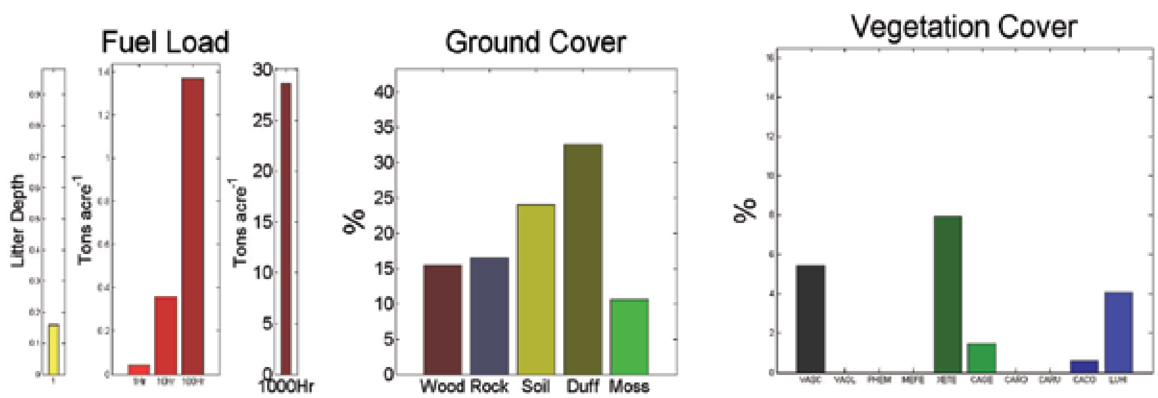


Site: Coyote Meadows, Bitterroot National Forest, Western-Central Montana
Treatment: Moderate intensity prescribed burn
with NO fuel enhancement (Unit 3B)

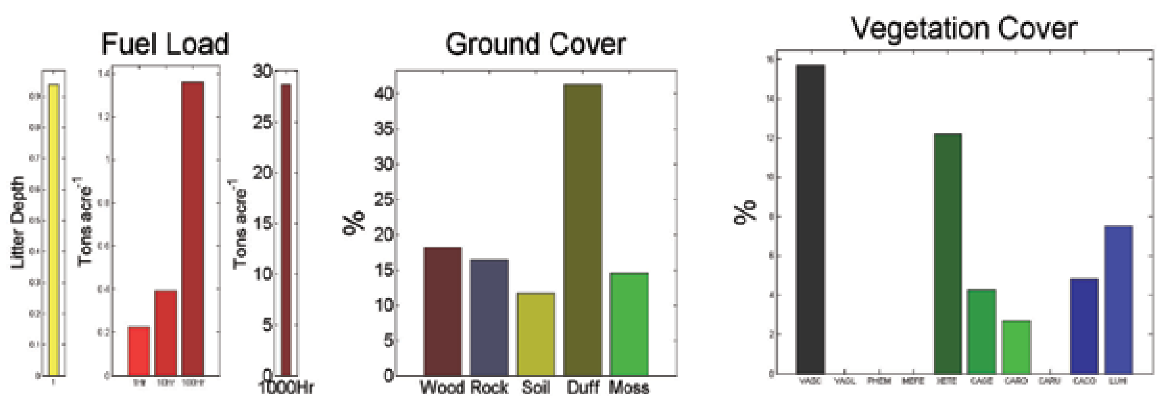
PRE



POST-1



POST-5



Site: Coyote Meadows, MT. Bitterroot NF Moderate intensity prescribed burn with NO fuel enhancement (Unit 3B)			
	PRE	**POST 1 Yr**	**POST 5 Yr**
TREE DENSITY (trees acre-1)			
WP seedling	1770	781.00 (-55.88)	405.00 (**-77.12**)
SF seedling	2671	631.00 (**-76.38**)	608.00 (**-77.24**)
ES seedling	30	60.00 (100.00)	30.00 (0.00)
LP seedling	60	0.00 (-100.00)	0.00 (-100.00)
WP sapling	107	79.00 (-26.17)	70.00 (-34.58)
SF sapling	242	73.00 (**-69.83**)	46.00 (**-80.99**)
ES sapling	0	0.00 (NA)	0.00 (NA)
LP sapling	1	0.00 (-100.00)	0.00 (-100.00)
WP overstory	13	12.00 (-7.69)	7.00 (-46.15)
SF overstory	84	9.00 (**-89.29**)	11.00 (**-86.90**)
ES overstory	15	6.00 (**-60.00**)	8.00 (-46.67)
LP overstory	0	0.00 (NA)	0.00 (NA)
SURFACE FUELS			
Litter depth (inches)	0	0.16 (NA)	0.94 (NA)
1 hour fuel load (tons acre-1)	0.07	0.04 (-43.26)	0.22 (**203.76**)
10 hour fuel load (tons acre-1)	0.34	0.36 (5.34)	0.39 (14.66)
100 hour fuel load (tons acre-1)	0.81	1.37 (69.51)	1.36 (68.32)
1000 hour fuel load (tons acre-1)	12.76	28.62 (**124.24**)	28.65 (**124.52**)
GROUND COVER (%)			
Wood	0	15.47 (**15.47**)	18.13 (**18.13**)
Rock	1.48	16.50 (15.03)	16.42 (14.94)
Soil	0.55	24.06 (**23.51**)	11.70 (**11.15**)
Duff	0	32.50 (**32.50**)	41.23 (**41.23**)
Moss	0.97	10.58 (9.61)	14.53 (**13.55**)
VEGETATION COVER (%)			
VASC	3.25	5.43 (**2.18**)	15.70 (**12.45**)
VAGL	0	0.00 (0.00)	0.00 (0.00)
PHEM	0	0.00 (0.00)	0.00 (0.00)
MEFE	0.25	0.00 (-0.25)	0.00 (-0.25)
XETE	1.58	7.92 (**6.35**)	12.20 (10.63)
CAGE	0.54	1.45 (0.91)	4.28 (3.74)
CARO	0.25	0.00 (-0.25)	2.67 (**2.42**)
CARU	0	0.00 (0.00)	0.00 (0.00)
CACO	0	0.58 (**0.58**)	4.81 (**4.81**)
LUHI	0.95	4.08 (3.13)	7.50 (6.55)

Study Site: Smith Creek, Bitterroot National Forest, Western-Central Montana

Treatment: Commercial Harvest using nutcracker openings followed by moderate intensity prescribed burn (Unit 2A)

Management Planning: The Stevensville District performed a biological evaluation for sensitive plant species in June of 1994 and the findings were that "no individual sensitive plants would be affected because none were found." The Forest Hydrologist who evaluated the treatment suggested that the riparian areas be excluded from treatment due to Montana's Streamside Management Zone rules. The treatments were planned and implemented as a demonstration research study project using standard NEPA analyses. The harvest units were cruised, marked, and traversed in the summer of 1994. A burn plan was written in the summer of 1996 and signed in September of 1996.

Treatment Description: Because the site is accessible by road, fire patches were simulated by commercially cutting all trees except for healthy, cone-bearing whitebark pine in small, 0.1- to 0.5-acre circular nutcracker openings to entice nutcrackers to cache whitebark pine seeds in the treated area. Circular units were located to maximize the distance to subalpine fir seed sources even though historical fires probably were irregularly shaped. No more than 40 percent of the entire unit was cut in nutcracker openings. A commercial thinning was done between nutcracker openings during which all subalpine fir and spruce, some lodgepole pine, and dying whitebark pine were removed from the forested areas down to approximately 50 ft^2 per acre of basal area. We did this to limit the seed rain from the wind-dispersed, shade tolerant tree species that could out-compete nutcracker-cached whitebark pine seedlings after treatment. All merchantable trees were whole tree skidded to log decks where they were limbed. The slash was piled and burned off-site. The loggers left substantial slash (approximately 20 tons per acre) on-site because of significant broken branches from skidding. We also cut and left all non-merchantable subalpine fir and spruce. Total harvest volume by species for the three treatments was as follows: lodgepole and dying whitebark pine = 26 thousand board ft (MBF), subalpine fir = 14 MBF, and Engelmann spruce = 6 MBF.

The unit was burned on October 3, 1996, using strip head fires varying in width from 10 to 15 ft. We measured the following fuel moistures at the start of the burn: 1 hr = 12 percent, 10 hr = 8 percent, 100 hr = 10 percent, 1000 hr sound = 15.7 percent, 1000 hr rotten = 18.6 percent, 10000 hr (greater than 9 inches diameter) sound = 21.4 percent, and 10000 hr rotten = 26.2 percent. At the start of the burn (1230), the temperature was 59 ^{o}F with relative humidity at 28 percent. The temperature increased to 60 ^{o}F and relative humidity decreased to 21 percent by 1500. The burn lasted until 1910 when the temperature was 56 ^{o}F and relative humidity was 29 percent. Weather was partly cloudy with 5 to 10 mph wind gusts upslope from the southwest. A total of 0.96 inches of rain had fallen on the site over the previous three weeks with no precipitation recorded three days prior to burn.

Flame lengths varied from 3 to 6 ft with flames in some slash jackpots reaching 8 to 10 ft. Strip widths and ignition rates were adjusted to keep flame lengths just under 6 ft. We observed passive crown fire behavior in some areas of the unit with most tall subalpine fir tree crowns torching in 100-ft flames. Very little of the riparian area was burned. A hard frost (23 ^{o}F) occurred four days prior to burn and killed shrub foliage. Embers were driven aloft by the fire, especially after the passive crown fires, but rarely ignited fuels outside the burn boundary. The fire smoldered for seven days but was monitored by District personnel. Prescribed burning cost an estimated $2900 for the 10 acres or $290 per acre. We estimate an additional 40 percent burn cover in the days after the prescribed burn indicating that the majority of desirable effects may take place in post-frontal combustion and smoldering.

This site was burned again by spotting from the Gash Creek Fire in August of 2006. The wildfire burned under hot, dry summer conditions estimated at 90 °F and 20 percent relative humidity. However, the fire only burned small portions of this unit (less than 10 percent) because of the lack of fine fuels that had been consumed by the 1996 prescribed fire.

Management Recommendations: The logging contractor sold approximately $10,000 of timber harvested from this unit, proving that if the treatment area is near a road, it is possible to conduct a profitable harvest in some whitebark pine forests. Slash should be removed from the site or burned using prescribed fire so that nutcrackers have full access to the ground and to prevent regeneration mortality from future unplanned fires. For example, the 2006 Gash Fire burned in and around the entire Smith Creek study site but the unit was only lightly burned (less than 10 percent burned) because of the lack of fine fuel from the 1996 prescribed burn. Whitebark pine tree regeneration was marginal, indicating that even after 10 years, the site still does not contain substantial regeneration. We observed extensive nutcracker caching in the fall of 1997 and 1998 in this unit so we are sure that seeds were planted in this site, but we don't know how many of the cached seeds were reclaimed by the nutcrackers or found by rodents. We recommend planting these sites with rust-resistant whitebark pine seedlings both to ensure its continued dominance and to shorten the lag time in achieving full stocking.

Site: Smith Creek, Bitterroot National Forest, Western Montana
Treatment: Commercial Harvest using nutcracker openings
followed by moderate intensity prescribed burn (Unit 2A)

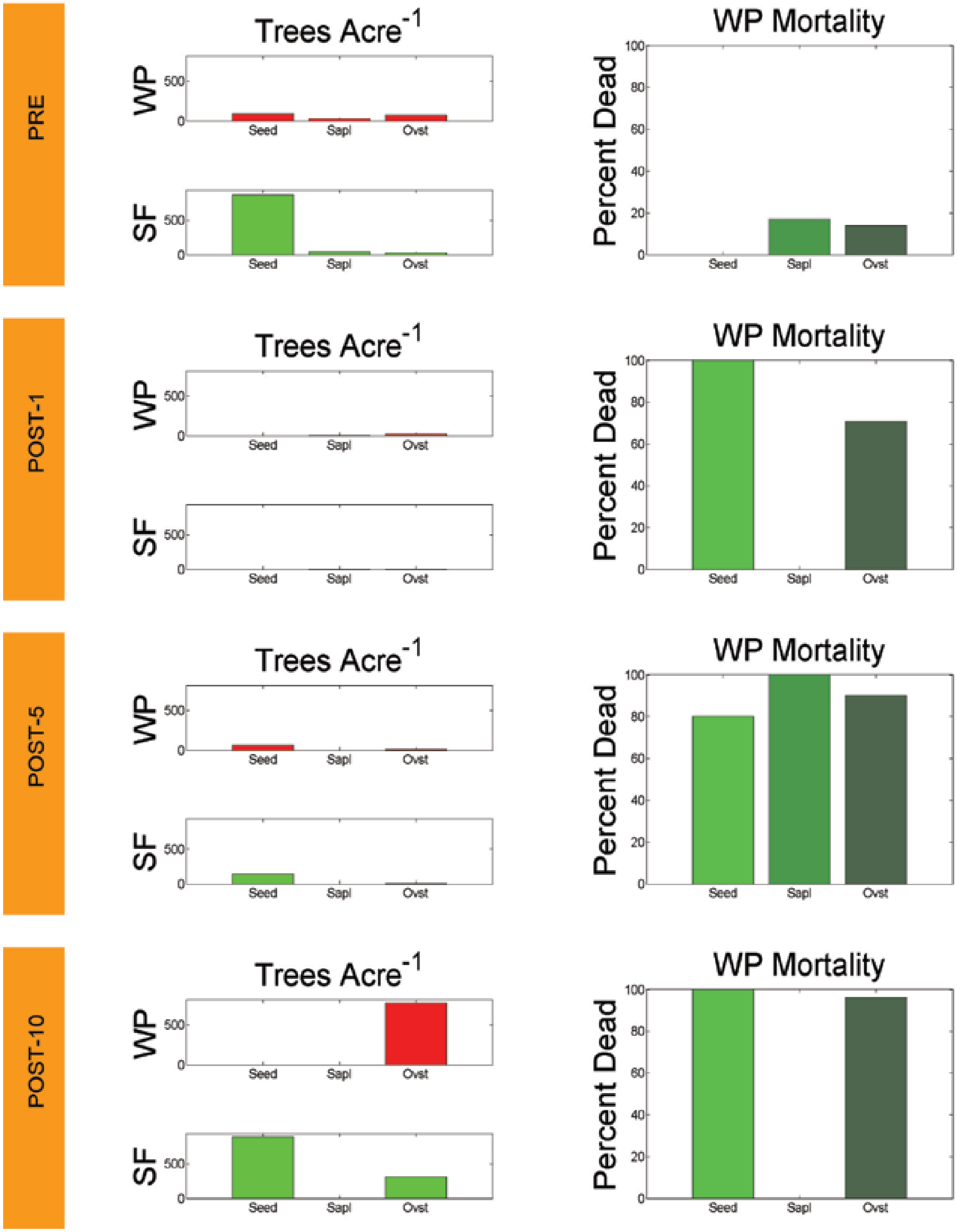
PRE

POST-1

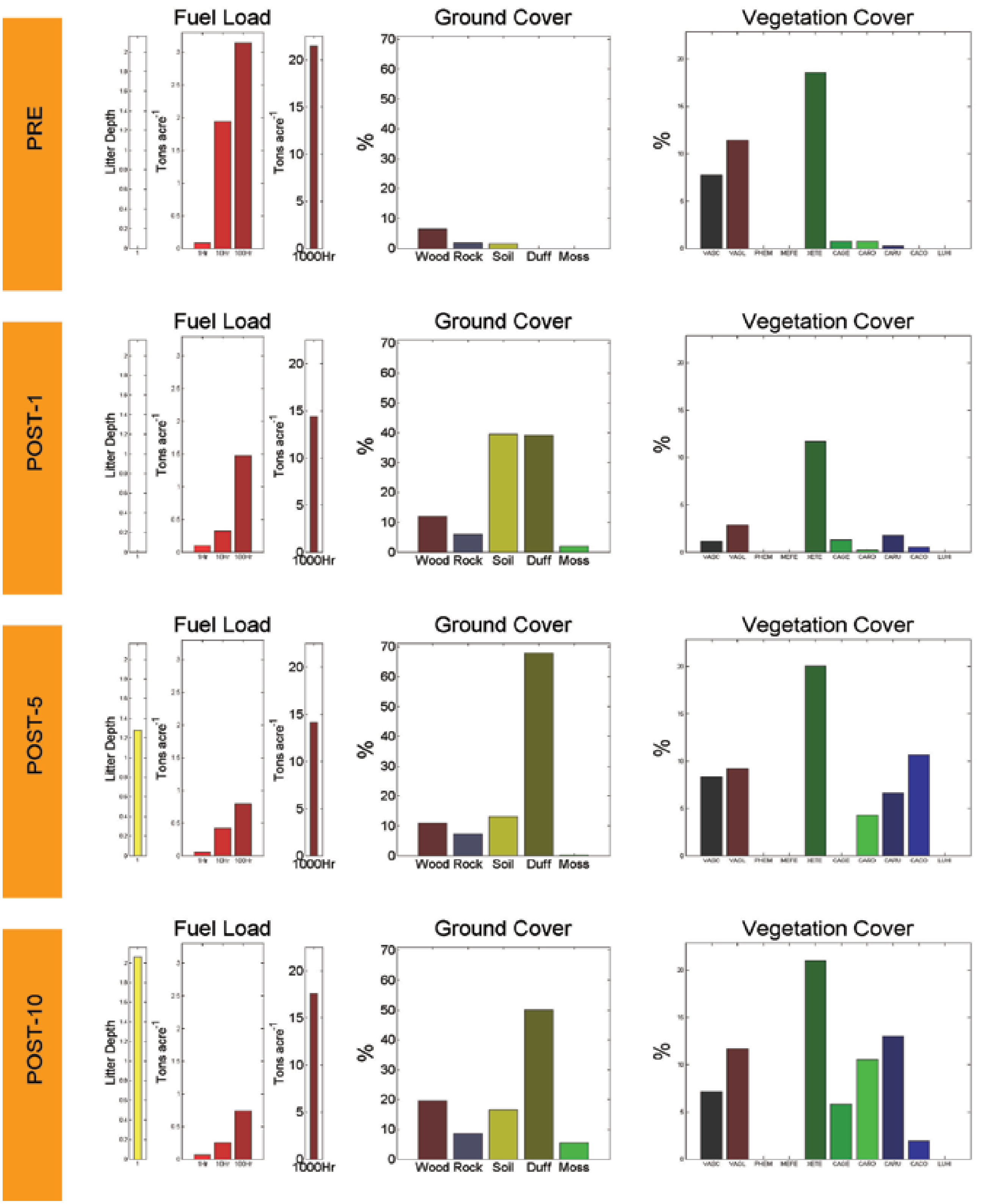
POST-5

POST-10

Site: Smith Creek, Bitterroot National Forest, Western Montana
Treatment: Commercial Harvest using nutcracker openings
followed by moderate intensity prescribed burn (Unit 2A)



Site: Smith Creek, Bitterroot National Forest, Western Montana
Treatment: Commercial Harvest using nutcracker openings
followed by moderate intensity prescribed burn (Unit 2A)



Site: Smith Creek, MT. Bitterroot NF Commercial Harvest using nutcracker openings followed by moderate intensity prescribed burn (Unit 2A)			
	PRE	**POST 1 Yr**	**POST 5 Yr**
TREE DENSITY (trees acre-1)			
WP seedling	90	0.00 (-100.00)	60.00 (-33.33)
SF seedling	870	0.00 (**-100.00**)	150.00 (-82.76)
ES seedling	0	0.00 (NA)	30.00 (NA)
LP seedling	0	0.00 (NA)	270.00 (NA)
WP sapling	34	1.00 (**-97.06**)	0.00 (**-100.00**)
SF sapling	43	3.00 (**-93.02**)	0.00 (**-100.00**)
ES sapling	11	2.00 (-81.82)	0.00 (-100.00)
LP sapling	2	0.00 (-100.00)	0.00 (-100.00)
WP overstory	74	21.00 (-71.62)	8.00 (**-89.19**)
SF overstory	29	5.00 (-82.76)	2.00 (-93.10)
ES overstory	9	4.00 (-55.56)	2.00 (-77.78)
LP overstory	17	10.00 (-41.18)	0.00 (**-100.00**)
SURFACE FUELS			
Litter depth (inches)	0	NA	1.28 (NA)
1 hour fuel load (tons acre-1)	0.08	0.10 (25.58)	0.05 (-35.95)
10 hour fuel load (tons acre-1)	1.94	0.32 (**-83.27**)	0.42 (**-78.28**)
100 hour fuel load (tons acre-1)	3.14	1.47 (**-53.12**)	0.80 (**-74.63**)
1000 hour fuel load (tons acre-1)	21.46	14.39 (**-32.96**)	14.15 (**-34.07**)
GROUND COVER (%)			
Wood	6.47	11.93 (**5.45**)	10.86 (4.39)
Rock	1.77	5.92 (**4.14**)	7.31 (**5.53**)
Soil	1.52	39.48 (**37.95**)	13.08 (**11.56**)
Duff	0	39.13 (**39.13**)	67.78 (**67.78**)
Moss	0	1.95 (**1.95**)	0.25 (**0.25**)
VEGETATION COVER (%)			
VASC	7.78	1.13 (**-6.65**)	8.39 (0.62)
VAGL	11.4	2.85 (**-8.55**)	9.19 (-2.21)
PHEM	0	0.00 (0.00)	0.00 (0.00)
MEFE	0	0.00 (0.00)	0.00 (0.00)
XETE	18.57	11.69 (-6.88)	20.06 (1.48)
CAGE	0.72	1.33 (**0.61**)	0.00 (-0.72)
CARO	0.75	0.25 (-0.50)	4.25 (3.50)
CARU	0.25	1.75 (1.50)	6.63 (**6.38**)
CACO	0	0.50 (**0.50**)	10.69 (**10.69**)
LUHI	0	0.00 (0.00)	0.00 (0.00)

Study Site: Smith Creek, Bitterroot National Forest, Western Montana

Treatment: Commercial Harvest using nutcracker openings with no prescribed fire (Unit 2B)

Management Planning: The Stevensville District performed a biological evaluation for sensitive plant species in June of 1994 and the findings were that "no individual sensitive plants would be affected because none were found." The Forest Hydrologist who evaluated the treatment suggested that the riparian areas be excluded from treatment due to Montana's Streamside Management Zone rules. The treatments were planned and implemented as a demonstration research study project using standard NEPA analyses. The harvest units were cruised, marked, and traversed in the summer of 1994. A burn plan was written in the summer of 1996 and signed in September of 1996.

Treatment Description: Because the site is accessible by road, mixed-severity fire patches were simulated by commercially cutting all trees except for healthy, cone-bearing whitebark pine in small, 0.1 to 0.5-acre circular nutcracker openings to entice nutcrackers to cache whitebark pine seeds in the treated area. Circular units were located to maximize the distance to subalpine fir seed sources even though historical fires probably were irregularly shaped. No more than 40 percent of the entire unit was cut in nutcracker openings. A commercial thinning was done between nutcracker openings, during which all subalpine fir and spruce, some lodgepole pine, and dying whitebark pine were removed from the forested areas down to approximately 50 ft^2 per acre of basal area. We did this to limit the seed rain from the wind-dispersed, shade tolerant tree species that could out-compete nutcracker-cached whitebark pine seedlings after treatment. All merchantable trees were whole tree skidded to log decks where they were limbed. The slash was piled and burned off-site. The loggers left substantial slash (approximately 20 tons per acre) on-site because of significant broken branches from skidding. We also cut and left all non-merchantable subalpine fir and spruce. Total harvest volume by species for the three treatments was as follows: lodgepole and dying whitebark pine = 26 thousand board ft (MBF), subalpine fir = 14 MBF, and Engelmann spruce = 6 MBF.

This site was burned by spotting from the Gash Creek Fire in August of 2006. The wildfire burned under hot, dry summer conditions estimated at 90 ^{o}F and 20 percent relative humidity. The fire burned intensely through the remaining slash, scorching more than 90 percent of the site and killing most regeneration.

Management Recommendations: The logging contractor sold approximately $10,000 of timber harvested from this unit, proving that if the treatment area is near a road, it is possible to conduct a profitable harvest in some whitebark pine forests. Slash should be removed from the site or burned using prescribed fire so that nutcrackers have full access to the ground and to prevent regeneration mortality from future unplanned fires. For example, the 2006 Gash Fire burned in and around the entire Smith Creek study site, but the unit was only lightly burned (less than 10 percent burned) because of the lack of fine fuel from the 1996 prescribed burn. Whitebark pine tree regeneration was marginal, indicating that even after 10 years, the site still does not contain substantial regeneration. We observed extensive nutcracker caching in the fall of 1997 and 1998 in this unit so we are sure that seeds were planted in this site, but we don't know how many of the cached seeds were reclaimed by the nutcrackers or found by rodents. We recommend planting these sites with rust-resistant whitebark pine seedlings both to ensure its continued dominance and to shorten the lag time in achieving full stocking.

Site: Smith Creek, Bitterroot National Forest, Western Montana
Treatment: Commercial Harvest using nutcracker openings
with no prescribed fire (Unit 2B)

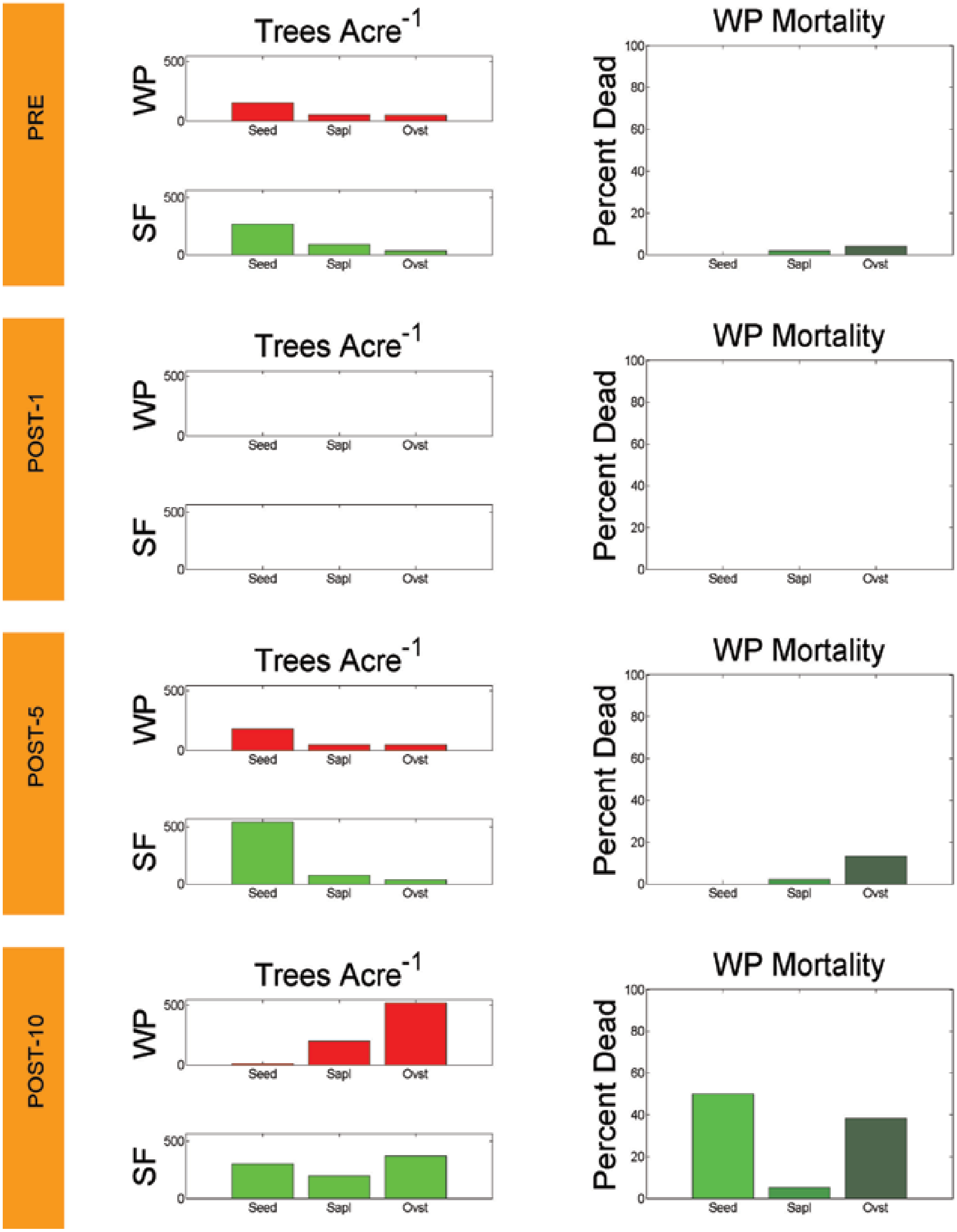
PRE

POST-1

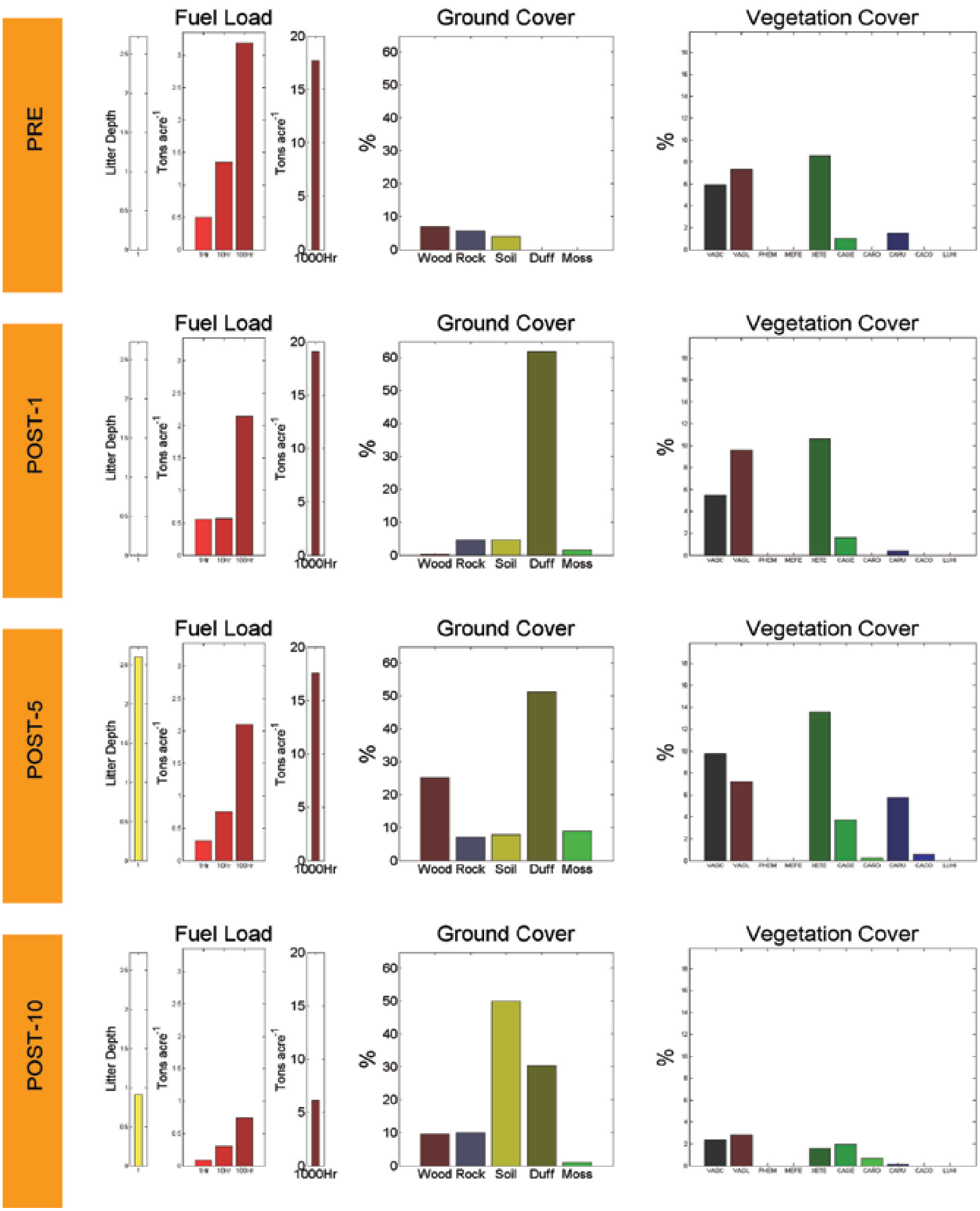
POST-5

POST-10

Site: Smith Creek, Bitterroot National Forest, Western Montana
Treatment: Commercial Harvest using nutcracker openings
with no prescribed fire (Unit 2B)



Site: Smith Creek, Bitterroot National Forest, Western Montana
Treatment: Commercial Harvest using nutcracker openings
with no prescribed fire (Unit 2B)



Site: Smith Creek, MT. Bitterroot NF Commercial Harvest using nutcracker openings with no prescribed fire (Unit 2B)			
	PRE	**POST 1 Yr**	**POST 5 Yr**
TREE DENSITY (trees acre-1)			
WP seedling	151	0.00 (-100.00)	180.00 (19.21)
SF seedling	270	0.00 (**-100.00**)	540.00 (100.00)
ES seedling	0	0.00 (NA)	0.00 (NA)
LP seedling	0	0.00 (NA)	120.00 (NA)
WP sapling	53	0.00 (**-100.00**)	47.00 (-11.32)
SF sapling	90	0.00 (-100.00)	78.00 (-13.33)
ES sapling	9	0.00 (-100.00)	9.00 (0.00)
LP sapling	2	0.00 (-100.00)	2.00 (0.00)
WP overstory	48	0.00 (**-100.00**)	46.00 (-4.17)
SF overstory	34	0.00 (-100.00)	36.00 (5.88)
ES overstory	2	0.00 (-100.00)	1.00 (-50.00)
LP overstory	34	0.00 (**-100.00**)	36.00 (5.88)
SURFACE FUELS			
Litter depth (inches)	0	NA	2.60 (NA)
1 hour fuel load (tons acre-1)	0.5	0.55 (11.08)	0.30 (-39.26)
10 hour fuel load (tons acre-1)	1.35	0.56 (**-58.28**)	0.75 (**-44.38**)
100 hour fuel load (tons acre-1)	3.19	2.15 (-32.72)	2.10 (-34.15)
1000 hour fuel load (tons acre-1)	17.71	19.07 (7.68)	17.59 (-0.68)
GROUND COVER (%)			
Wood	6.97	0.24 (**-6.73**)	25.15 (**18.17**)
Rock	5.81	4.75 (-1.06)	7.20 (1.39)
Soil	4.04	4.72 (0.69)	7.90 (**3.86**)
Duff	0	61.75 (**61.75**)	51.25 (**51.25**)
Moss	0	1.60 (1.60)	8.97 (**8.97**)
VEGETATION COVER (%)			
VASC	5.92	5.50 (-0.42)	9.78 (3.86)
VAGL	7.33	9.60 (2.27)	7.20 (-0.13)
PHEM	0	0.00 (0.00)	0.00 (0.00)
MEFE	0	0.00 (0.00)	0.00 (0.00)
XETE	8.55	10.63 (2.07)	13.57 (5.02)
CAGE	1.04	1.60 (0.56)	3.72 (**2.68**)
CARO	0	0.00 (0.00)	0.25 (0.25)
CARU	1.5	0.40 (-1.10)	5.75 (4.25)
CACO	0	0.00 (0.00)	0.60 (**0.60**)
LUHI	0	0.00 (0.00)	0.00 (0.00)

Non-Lethal Surface Fires

Study Site: Bear Overlook, Bitterroot National Forest, Western Montana

Treatment: Low intensity prescribed burn with fuel enhancement (Unit 2A)

Management Planning: This treatment was proposed in the winter of 1996 by the Stevensville District for a 200+ acre study site. The District completed the burn plan in August of 1997 and NEPA work was finished by winter of 1998. The District did not want the prescribed fire escaping into the Selway-Bitterroot Wilderness Area located near the treatment boundaries. This site was sensitive because it contained the most popular hiking trail and scenic overlook on the Bitterroot National Forest.

Treatment Description: Crews cut and directionally felled any sized subalpine fir or Engelmann spruce trees to cover bare areas on the ground to enhance the fuel by increasing fuel continuity and loading. The Stevensville District employed smokejumpers and its fire crew to cut the fire line and perform the fuel enhancement cuttings. The treatment doubled and sometimes tripled fine fuel loadings on some of the research plots. The cost of fuel enhancement ranged from $20 to $80 per acre depending on the density of subalpine fir trees and the skill of the saw crew. Many whitebark pine snags were cut during the fuel enhancement for safety reasons.

About 40 fire crew members from across the Bitterroot National Forest implemented the prescribed burn on October 5, 1999. The burn was intended to mimic a mixed-severity burn by killing overstory and understory subalpine fir trees (greater than 50 percent) and creating optimal caching habitat for the nutcracker. Crews ignited the burn in the upper, northwestern portion of the unit first using strip head fires and progressively burned downward to the lower, southeastern portion of the unit. Strips were hand-lit with drip-torches and widths varied from 10 to 30 ft depending on observed fire behavior. A goal was to keep flame lengths below 8 ft. We measured the following woody fuel moistures at the time of fire: 1 hr = 8 percent, 10 hr = 12 percent, 100 hr = 6 percent, sound 1000 hr = 20 percent, rotten 1000 hr = 25 percent, live herbaceous = 42 percent, live shrub = 45, and live tree seedlings = 40 percent. The top portion of the unit was ignited 30 minutes after a test fire that was started at 1300 revealed acceptable fire behavior. Weather conditions were highly variable (partly sunny) with 2 to 9 mph winds gusting up to 15 mph. At 1630, the winds became calm and a small rain squall moved through the area. The temperature was 62 ^{o}F at the start of the burn and 55 ^{o}F at the end of ignition (1800). Relative humidity was 27 to 30 percent at ignition and increased to 40 percent by the end of the burn. There was light rain shower activity in the area the three days preceding the burn.

This prescribed fire was spotty due to the variable wind and moisture conditions. It achieved the prescribed goal in areas where fuel enhancement left the greatest amount of downed slash. The fuel enhancement treatment allowed a wider burn window for the fire crew by increasing the availability and contagion of fine woody debris. However, because of a lack of subalpine fir trees, much of the stand (greater than 40 percent) did not have sufficient fuel enhancement to carry the fire, which contributed to the low burn area within the plots (less than 20 percent of plot was burned) and low burn severity. The high humidity, combined with the moist 10-hr fuels and the intermittent showers, resulted in incomplete consumption of many fine fuels and inconsistent and incomplete fire spread. The surface fire ignited some crowns of large overstory subalpine fir and spruce, causing crown flame lengths to exceed 50 ft, but most lodgepole and whitebark pine trees did not experience crown fires. Because rain showers occurred in the afternoon, the prescribed fire burned coolest in the lower portions of the unit that contained the research plots.

Management Recommendations: Fuel enhancement is an essential activity for achieving the desired goals of restoration. This treatment is best implemented after the first hard frost of the autumn (less than 25 °F). It is most effective when the fuelbed is enhanced by cutting and felling large subalpine fir trees. It is also best to wait one year after cutting to allow the woody fuels and foliage to cure. This unit should have been burned again under drier and maybe windier conditions to kill more shade-tolerant subalpine fir and to create better nutcracker caching habitat. Though additional fuel enhancement could have been implemented in some places, there appeared to be sufficient residual fine fuel in many unburned and burned areas to carry a second fire.

Site: Bear Overlook, Bitterroot National Forest, Western Montana
Treatment: Low intensity prescribed burn
with fuel enhancement (Unit 2A)

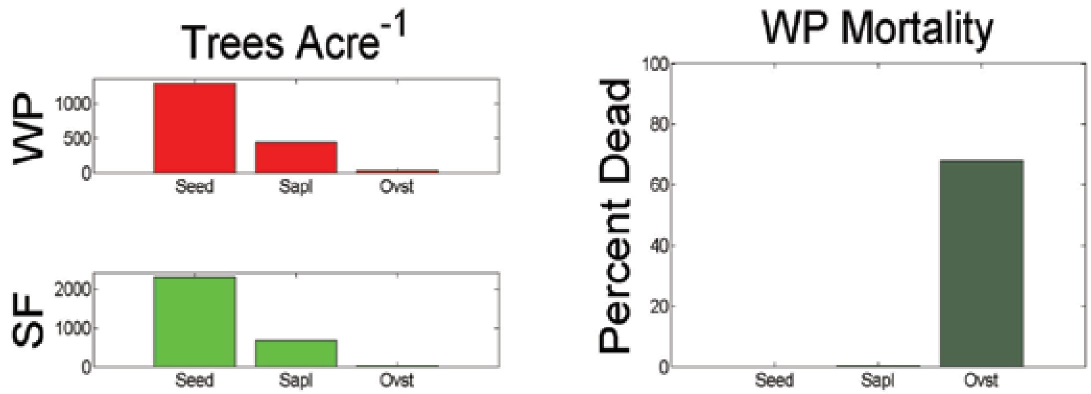
PRE

POST-1

POST-5

Site: Bear Overlook, Bitterroot National Forest, Western Montana
Treatment: Low intensity prescribed burn
with fuel enhancement (Unit 2A)

PRE



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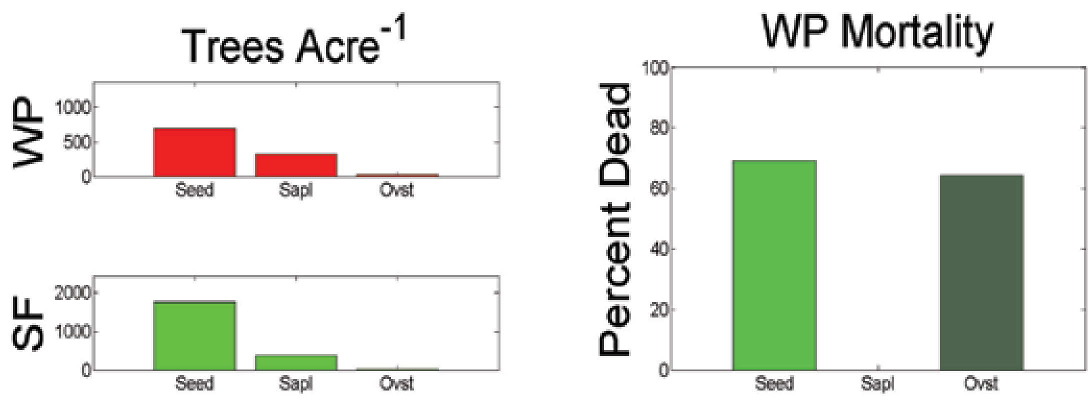

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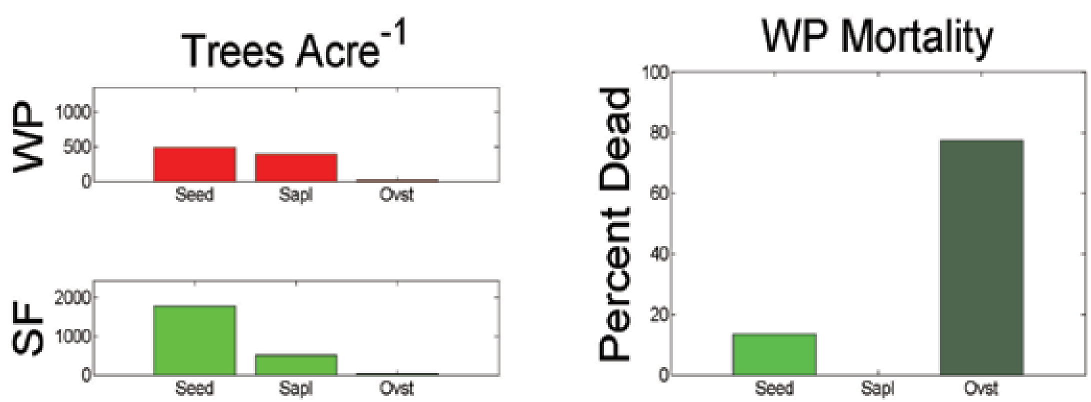
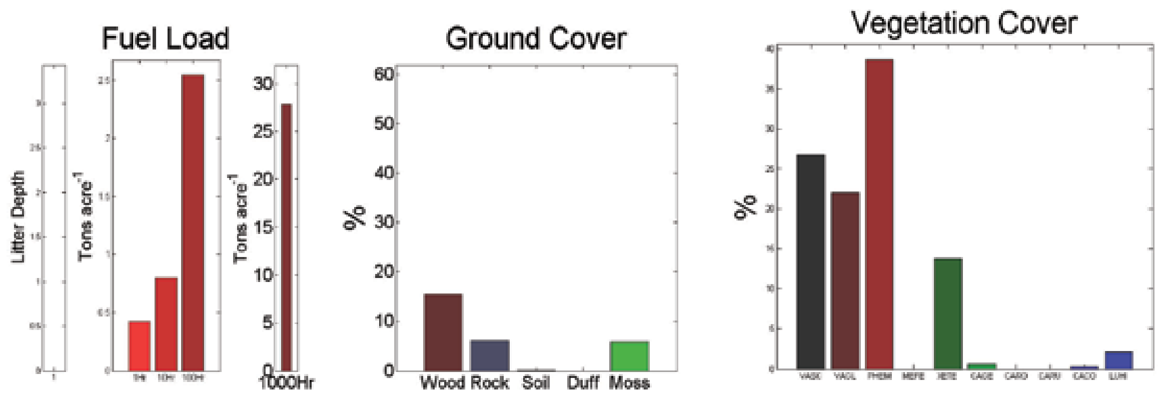


Site: Bear Overlook, Bitterroot National Forest, Western Montana
Treatment: Low intensity prescribed burn
with fuel enhancement (Unit 2A)

PRE



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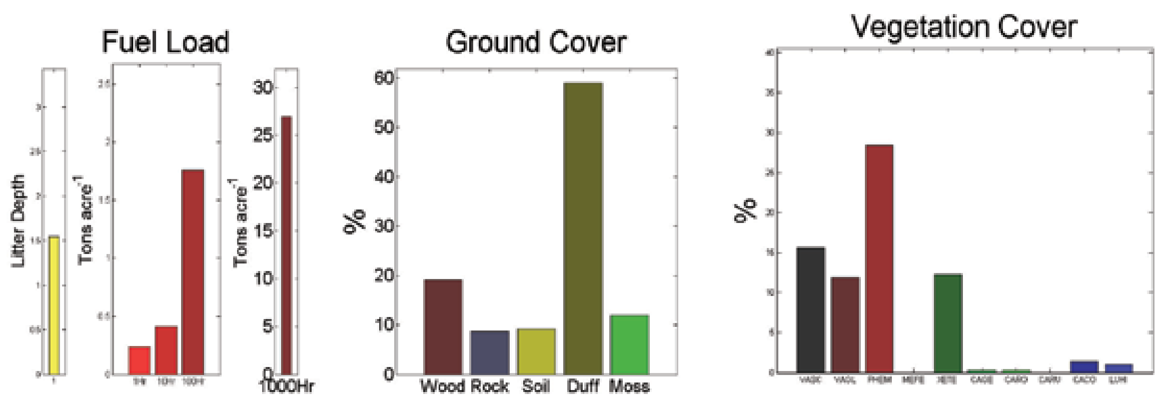

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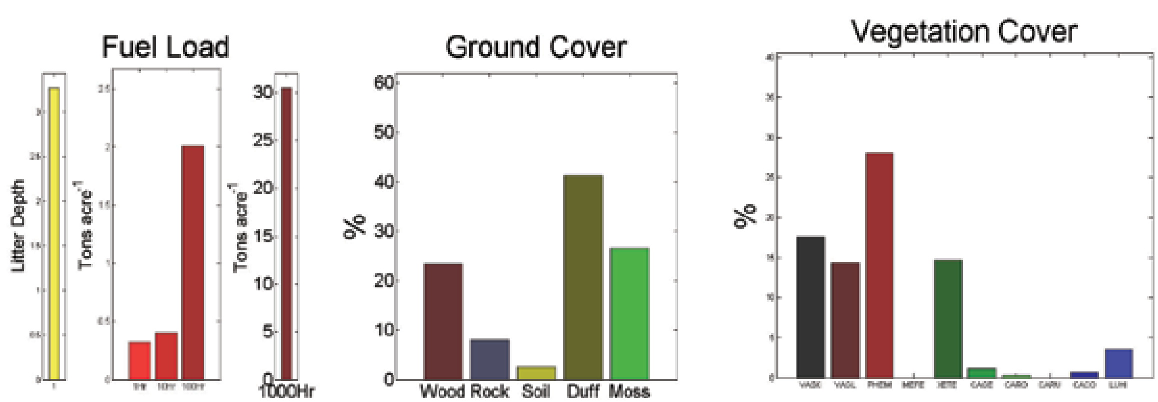


Site: Bear Overlook, MT. Bitterroot NF Low intensity prescribed burn with fuel enhancement (Unit 2A)			
	PRE	**POST 1 Yr**	**POST 5 Yr**
TREE DENSITY (trees acre-1)			
WP seedling	1290	693.00 (-46.28)	481.00 (**-62.71**)
SF seedling	2310	1745.00 (-24.46)	1771.00 (-23.33)
ES seedling	360	157.00 (-56.39)	91.00 (-74.72)
LP seedling	120	33.00 (-72.50)	271.00 (125.83)
WP sapling	435	317.00 (-27.13)	383.00 (-11.95)
SF sapling	671	382.00 (**-43.07**)	507.00 (-24.44)
ES sapling	161	118.00 (-26.71)	96.00 (-40.37)
LP sapling	80	56.00 (-30.00)	69.00 (-13.75)
WP overstory	34	26.00 (-23.53)	19.00 (**-44.12**)
SF overstory	33	35.00 (6.06)	28.00 (-15.15)
ES overstory	34	33.00 (-2.94)	29.00 (-14.71)
LP overstory	42	48.00 (14.29)	44.00 (4.76)
SURFACE FUELS			
Litter depth (inches)	0	1.54 (NA)	3.27 (NA)
1 hour fuel load (tons acre-1)	0.42	0.24 (-43.61)	0.32 (-24.25)
10 hour fuel load (tons acre-1)	0.8	0.41 (-48.60)	0.40 (-49.37)
100 hour fuel load (tons acre-1)	2.55	1.76 (-30.96)	2.01 (-21.16)
1000 hour fuel load (tons acre-1)	27.88	26.94 (-3.37)	30.42 (9.11)
GROUND COVER (%)			
Wood	15.53	19.13 (3.60)	23.38 (**7.85**)
Rock	6.13	8.64 (2.52)	7.95 (1.83)
Soil	0.1	9.08 (**8.98**)	2.58 (**2.48**)
Duff	0	58.88 (**58.88**)	41.25 (**41.25**)
Moss	5.81	11.97 (**6.16**)	26.48 (**20.66**)
VEGETATION COVER (%)			
VASC	26.8	15.57 (**-11.23**)	17.63 (**-9.18**)
VAGL	21.98	11.95 (**-10.03**)	14.38 (**-7.60**)
PHEM	38.67	28.42 (-10.25)	28.00 (-10.67)
MEFE	0	0.00 (0.00)	0.00 (0.00)
XETE	13.75	12.28 (-1.47)	14.68 (0.93)
CAGE	0.63	0.25 (-0.38)	1.17 (0.54)
CARO	0	0.25 (0.25)	0.25 (0.25)
CARU	0	0.00 (0.00)	0.00 (0.00)
CACO	0.25	1.38 (1.13)	0.69 (0.44)
LUHI	2.13	1.00 (-1.13)	3.50 (1.38)

Study Site: Bear Overlook, Bitterroot National Forest, Western Montana

Treatment: Low intensity prescribed burn with NO fuel enhancement (Unit 1A)

Management Planning: This treatment was proposed in the winter of 1996 by the Stevensville District for a 200+ acre study site. The District completed the burn plan in August of 1997 and NEPA work was finished by winter of 1998. The District did not want the prescribed fire escaping into the Selway-Bitterroot Wilderness Area located near the treatment boundaries. This site was sensitive because it contained the most popular hiking trail and scenic overlook on the Bitterroot National Forest.

Treatment Description: About 40 fire crew members from across the Bitterroot National Forest implemented the prescribed burn on October 5, 1999. The burn was intended to mimic a mixed-severity burn by killing overstory and understory subalpine fir trees (greater than 50 percent) and creating optimal caching habitat for the nutcracker. Crews ignited the burn in the upper, northwestern portion of the unit first using strip head fires and progressively burned downward to the lower, southeastern portion of the unit. Strips were hand-lit with drip-torches and widths varied from 10 to 30 ft depending on observed fire behavior. A goal was to keep flame lengths below 8 ft. We measured the following woody fuel moistures at the time of fire: 1 hr = 8 percent, 10 hr = 12 percent, 100 hr = 6 percent, sound 1000 hr = 20 percent, rotten 1000 hr = 25 percent, live herbaceous = 42 percent, live shrub = 45, and live tree seedlings = 40 percent. The top portion of the unit was ignited 30 minutes after a test fire that was started at 1300 revealed acceptable fire behavior. Weather conditions were highly variable (partly sunny) with 2 to 9 mph winds gusting up to 15 mph. At 1630, the winds became calm and a small rain squall moved through the area. The temperature was 62 ^{o}F at the start of the burn and 55 ^{o}F at the end of ignition. Relative humidity was 27 to 30 percent at ignition and increased to 40 percent by the end of the burn. There was light rain shower activity in the area the three days preceding the burn.

This prescribed fire was spotty due to the variable wind and moisture conditions. It burned the best in the lowest, southwestern part of the study site where there was dense subalpine fir sapling regeneration. The low fine fuel loadings and the high fuel moistures caused by the rain and high humidity did not allow the fire to spread to significant portions of the stand. A great part of the stand (greater than 50 percent) did not have sufficient fuels to carry the fire, which contributed to the low burn area within the plots (less than 20 percent). The surface fire ignited some crowns of large overstory subalpine fir and spruce causing high crown flame lengths, but most lodgepole and whitebark pine did not experience crown fires. The fire burned best in less dense areas with low tree cover that allowed more solar radiation to warm and dry the fuelbed. Because rain showers occurred in the late afternoon, the prescribed fire burned coolest in the parts of the unit burned last, which included nearly all research plots.

Management Recommendations: Fuel enhancement is an essential activity for achieving the desired goals of restoration—it was obvious that whitebark pine stands with low fuel loadings should be treated to increase fine fuel loadings. This treatment is best implemented after the first hard frost of the autumn (less than 25 °F). It is most effective when the fuelbed is enhanced by cutting and felling large subalpine fir trees. It is also best to wait one year after cutting to allow the woody fuels and foliage to cure. This unit should have been burned again under drier and maybe windier conditions to kill more shade-tolerant subalpine fir and to create better nutcracker caching habitat. Though fuel enhancement could have been implemented in some places, there appeared to be sufficient fine fuel in many unburned areas to carry a second fire.

Site: Bear Overlook, Bitterroot National Forest, Western Montana
Treatment: Low intensity prescribed burn
with NO fuel enhancement (Unit 1A)

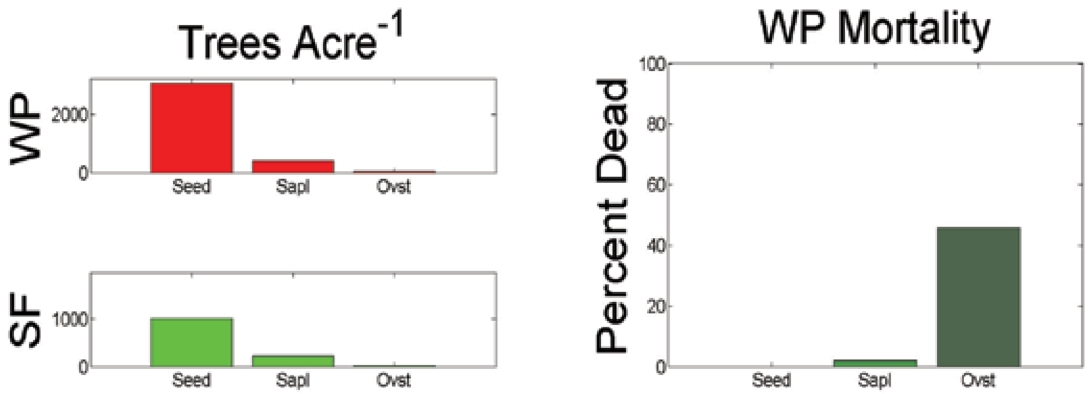
PRE


POST-1


POST-5


Site: Bear Overlook, Bitterroot National Forest, Western Montana
Treatment: Low intensity prescribed burn
with NO fuel enhancement (Unit 1A)

PRE



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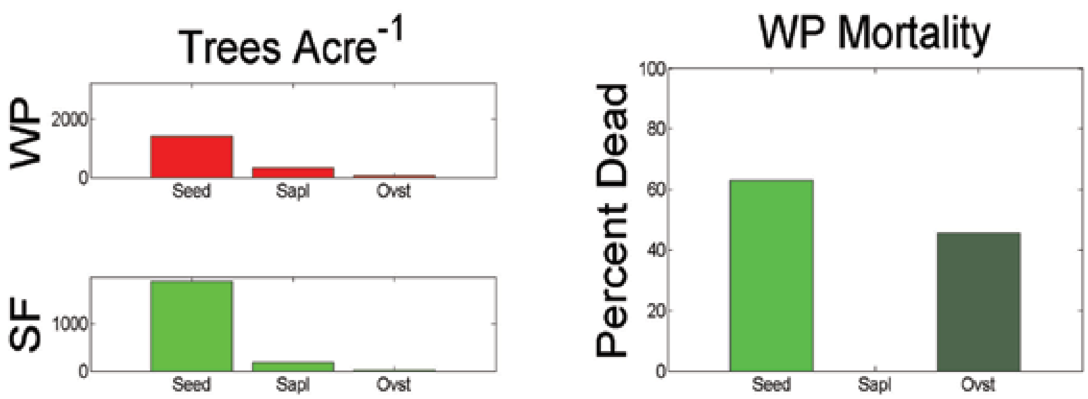

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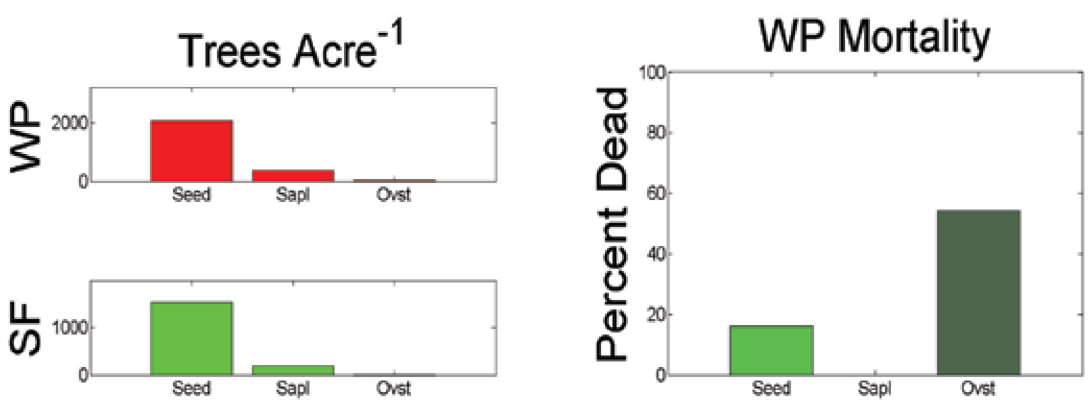
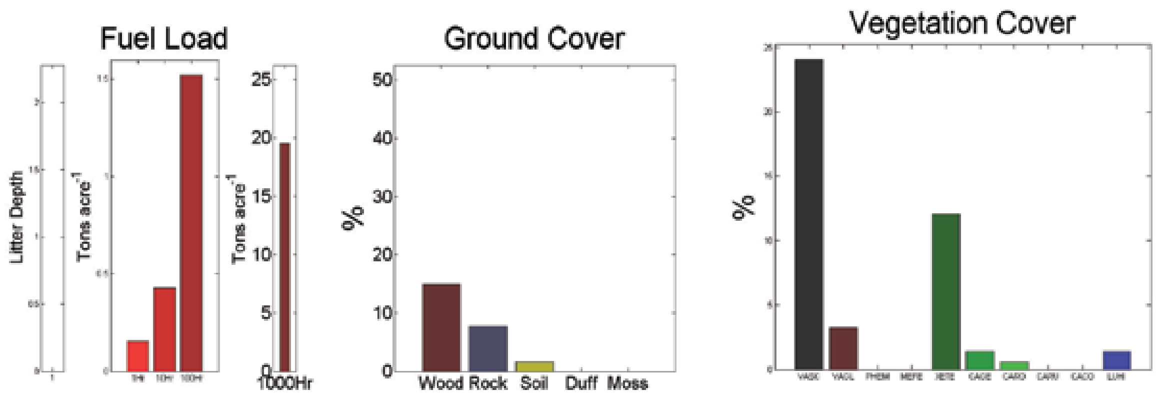


Site: Bear Overlook, Bitterroot National Forest, Western Montana
Treatment: Low intensity prescribed burn
with NO fuel enhancement (Unit 1A)

PRE



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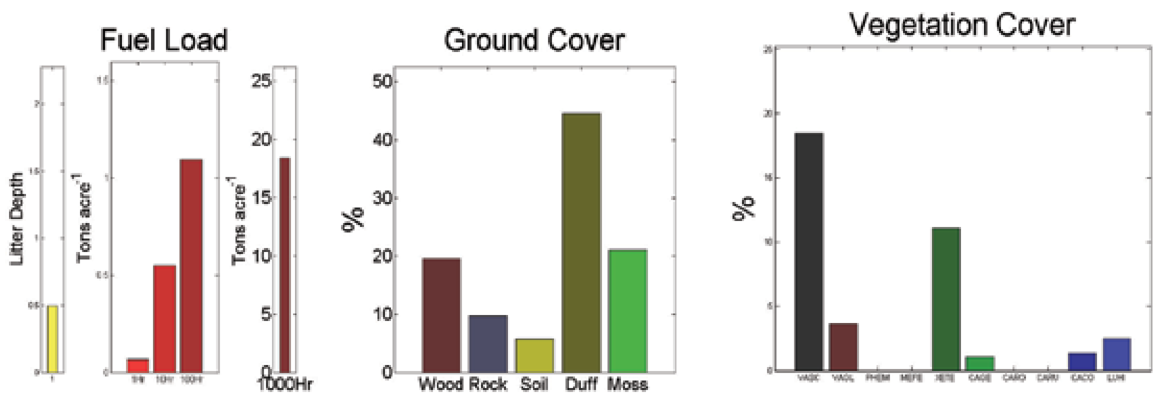

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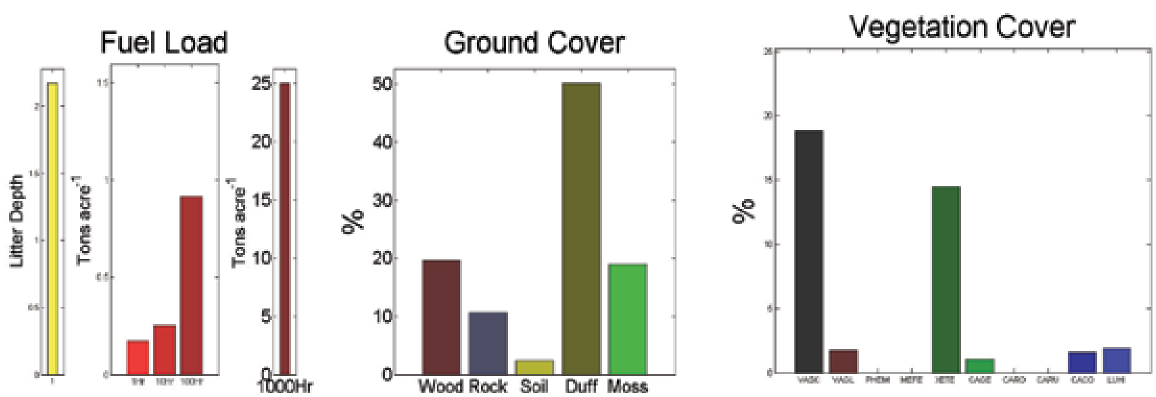


Site: Bear Overlook, MT. Bitterroot NF Low intensity prescribed burn with NO fuel enhancement (Unit 1A)			
	PRE	**POST 1 Yr**	**POST 5 Yr**
TREE DENSITY (trees acre-1)			
WP seedling	3090	1412.00 (-54.30)	2074.00 (-32.88)
SF seedling	1021	1891.00 (85.21)	1530.00 (49.85)
ES seedling	210	60.00 (-71.43)	60.00 (-71.43)
LP seedling	2220	457.00 (**-79.41**)	786.00 (-64.59)
WP sapling	411	317.00 (-22.87)	353.00 (-14.11)
SF sapling	216	178.00 (-17.59)	181.00 (-16.20)
ES sapling	41	43.00 (4.88)	37.00 (-9.76)
LP sapling	299	260.00 (-13.04)	220.00 (-26.42)
WP overstory	53	55.00 (3.77)	38.00 (-28.30)
SF overstory	17	22.00 (29.41)	7.00 (-58.82)
ES overstory	44	44.00 (0.00)	37.00 (-15.91)
LP overstory	152	151.00 (-0.66)	133.00 (-12.50)
SURFACE FUELS			
Litter depth (inches)	0	0.50 (NA)	2.17 (NA)
1 hour fuel load (tons acre-1)	0.15	0.07 (-55.93)	0.17 (12.58)
10 hour fuel load (tons acre-1)	0.43	0.55 (28.42)	0.25 (-41.15)
100 hour fuel load (tons acre-1)	1.52	1.09 (-28.02)	0.91 (-39.86)
1000 hour fuel load (tons acre-1)	19.52	18.41 (-5.67)	25.00 (28.08)
GROUND COVER (%)			
Wood	14.93	19.50 (4.57)	19.65 (4.72)
Rock	7.67	9.70 (2.02)	10.63 (2.95)
Soil	1.6	5.78 (**4.18**)	2.40 (0.80)
Duff	0	44.52 (**44.52**)	50.10 (**50.10**)
Moss	0	21.13 (**21.13**)	18.98 (**18.98**)
VEGETATION COVER (%)			
VASC	24.05	18.45 (-5.60)	18.80 (-5.25)
VAGL	3.25	3.67 (0.42)	1.75 (-1.50)
PHEM	0	0.00 (0.00)	0.00 (0.00)
MEFE	0	0.00 (0.00)	0.00 (0.00)
XETE	12.07	11.05 (-1.02)	14.48 (2.40)
CAGE	1.38	1.08 (-0.29)	1.06 (-0.31)
CARO	0.55	0.00 (**-0.55**)	0.00 (**-0.55**)
CARU	0	0.00 (0.00)	0.00 (0.00)
CACO	0	1.33 (1.33)	1.60 (**1.60**)
LUHI	1.38	2.50 (1.13)	1.92 (0.54)

Study Site: Beaver Ridge, Clearwater National Forest, Central Idaho

Treatment: Low intensity prescribed burn with NO fuel enhancement (Unit 4A)

Management Planning: The Powell Ranger District created a comprehensive "District-Wide whitebark pine restoration integrated analysis" in May of 1997 identifying the need for restoration research. In the fall of 1997 it selected two areas for treatment: the Blacklead Mountain site and Beaver Ridge site. Public comment was solicited through mail in May of 1997 and the NEPA analysis for the Categorical Exclusion was finished that September. The cutting treatments were implemented in the summers of 1998 and 1999. District personnel successfully obtained diverse funding (more than $30,000) for this project from multiple sources, including the Nez Perce Tribe, Rocky Mountain Elk Foundation, National Fish and Wildlife Foundation, Forest Service Research, and hazardous fuel reduction monies.

Treatment Description: This unit was burned September 4, 2002, by District fire crews. It was supposed to be burned the same day as 4B but time did not allow for this. We measured the following fuel moistures on the day of the burn: 1 hr = 9 percent, 10 hr = 10 percent, 100 hr = 10 percent, sound 1000 hr = 19 percent, rotten 1000 hr = 20 percent, live herb = 56 percent, and live shrubs = 54 percent. Antecedent weather for the three days prior to the burn was partly cloudy, cool (60s to 70s), and somewhat dry. The temperature at the start of the burn (1100) was 57 °F and the relative humidity was 40 percent. At the height of the burning period (1715), the temperature was 74 °F with relative humidity around 32 percent. Winds averaged 3 to 7 mph for most of the burn with occasional gusts of 7 to 12 mph from the northwest. Fire crews first burned out the fire lines surrounding the unit, then started lighting a 10- to 40-ft strip head fires from the newly created fire line at the ridgetop down to the road that delineated the bottom of the unit. The western end of the unit burned the hottest and experienced the greatest tree mortality.

The prescribed burn was very spotty and effects were highly variable. However, it appears that the burn coverage of this unit was nearly the same as that of the fuel enhanced unit (4B). Tree mortality was highly variable depending on fuel coverage, but, overall, it was much less than expected. The discontinuity of the fuelbed resulted in variable burn cover and very little fir regeneration mortality. The prescribed burning cost an estimated $250 to $300 per acre for 23 acres.

Management Recommendations: This treatment illustrates that drier burn conditions can achieve the same results as fuel enhancement cuttings, though neither was particularly effective at this site. The dry conditions needed to conduct a successful low intensity surface fire would probably be so dry that spotting and containment might be a problem. We probably should have waited until three days after the first hard frost before we burned this unit to allow the shrub and herbaceous fuels sufficient time to dry to moistures lower than 50 percent (no recent frost was recorded for this site). This unit needs at least one more prescribed burn for the restoration treatment to be effective, but this might only be possible if another fuel enhancement cutting was implemented. As with all the other study results, there was very little whitebark pine regeneration observed on these plots. We suggest additional burns if fuel enhancement is possible or if sufficient fuels are on the ground. These sites should not be planted because the seedlings might stagnate under the surviving canopy (Keane and others 2007).

Site: Beaver Ridge, Clearwater National Forest, Central Idaho
Treatment: Low intensity prescribed burn
with NO fuel enhancement (Unit 4A)

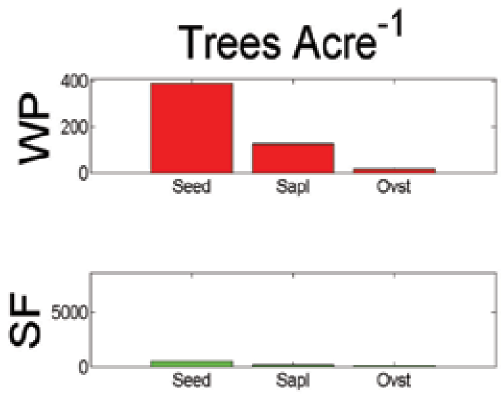
PRE

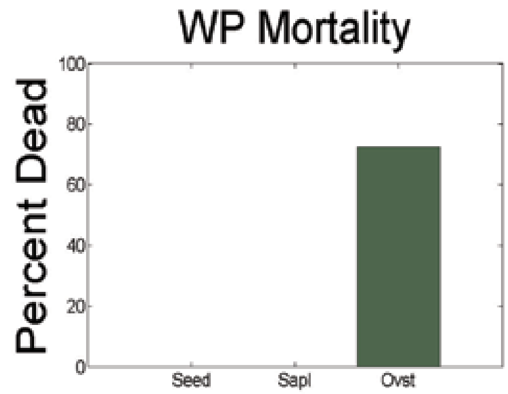
POST-1

POST-5

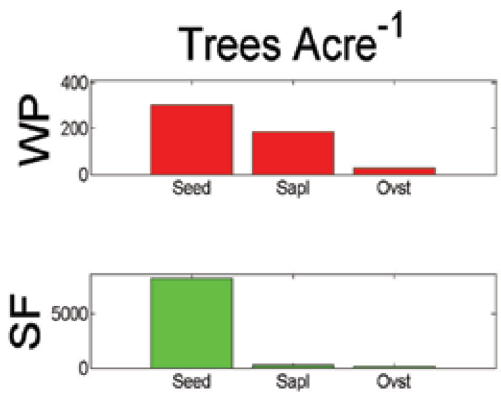
Site: Beaver Ridge, Clearwater National Forest, Central Idaho
Treatment: Low intensity prescribed burn
with NO fuel enhancement (Unit 4A)

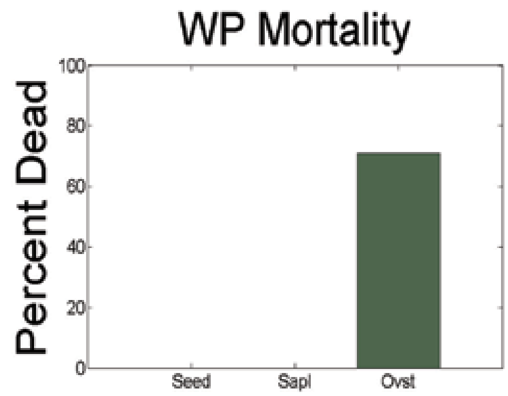
PRE





POST-1





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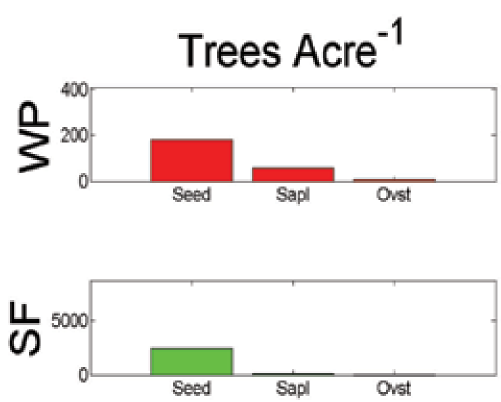
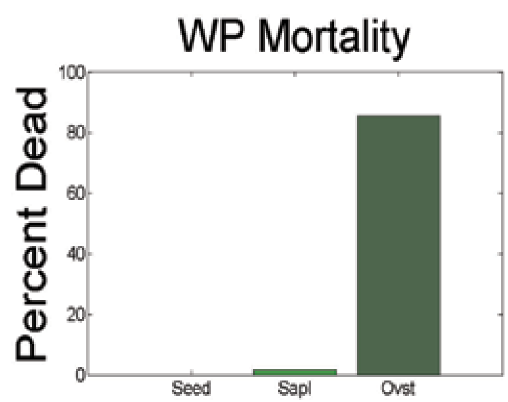
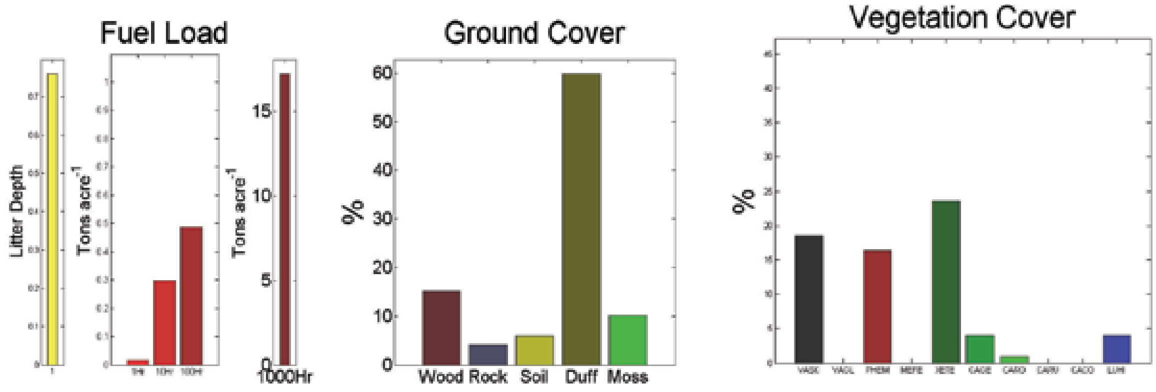




Site: Beaver Ridge, Clearwater National Forest, Central Idaho
Treatment: Low intensity prescribed burn
with NO fuel enhancement (Unit 4A)

PRE



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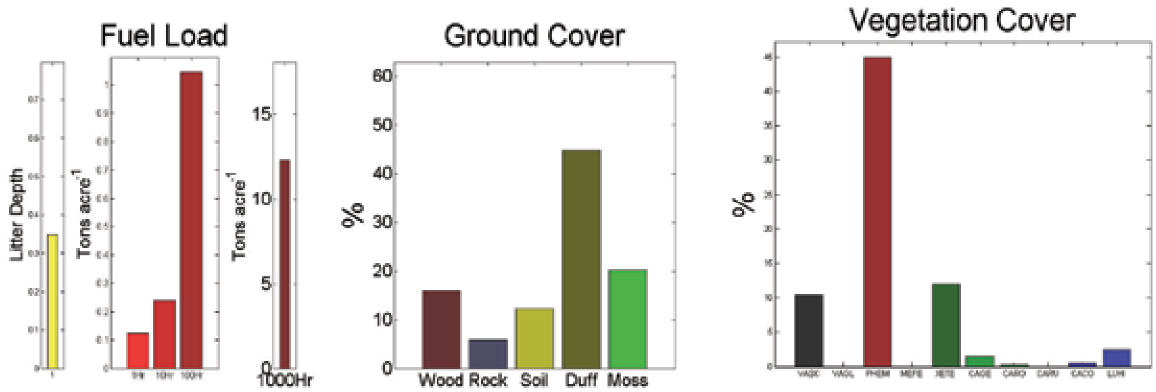

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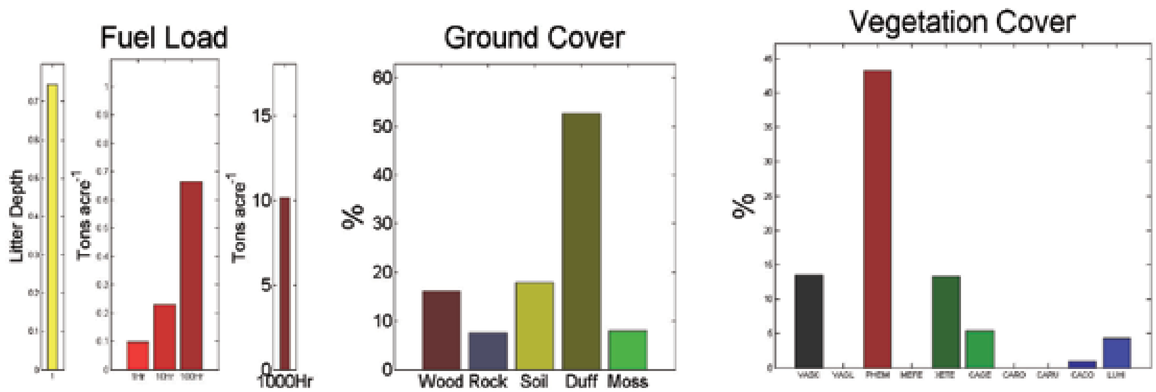


Site: Beaver Ridge, ID. Clearwater NF Low intensity prescribed burn with NO fuel enhancement (Unit 4A)			
	PRE	POST 1 Yr	POST 5 Yr
TREE DENSITY (trees acre-1)			
WP seedling	390	302.00 (-22.56)	180.00 (-53.85)
SF seedling	511	3290.00 (1522.31	2431.00 (375.73)
ES seedling	0	0.00 (NA)	0.00 (NA)
LP seedling	482	725.00 (50.41)	242.00 (-49.79)
WP sapling	125	186.00 (48.80)	58.00 (-53.60)
SF sapling	179	312.00 (74.30)	71.00 (-60.34)
ES sapling	0	4.00 (NA)	1.00 (NA)
LP sapling	90	202.00 (124.44)	54.00 (-40.00)
WP overstory	17	28.00 (64.71)	7.00 (-58.82)
SF overstory	64	150.00 (**134.37**)	47.00 (-26.56)
ES overstory	5	10.00 (100.00)	2.00 (-60.00)
LP overstory	44	82.00 (86.36)	44.00 (0.00)
SURFACE FUELS			
Litter depth (inches)	0.76	0.35 (**-54.17**)	0.74 (-2.08)
1 hour fuel load (tons acre-1)	0.02	0.12 (671.98)	0.10 (**509.58**)
10 hour fuel load (tons acre-1)	0.3	0.24 (-20.02)	0.23 (-23.62)
100 hour fuel load (tons acre-1)	0.49	1.05 (114.90)	0.67 (36.80)
1000 hour fuel load (tons acre-1)	17.21	12.29 (-28.59)	10.17 (-40.92)
GROUND COVER (%)			
Wood	15.1	15.93 (0.83)	16.07 (0.97)
Rock	4.1	5.80 (1.70)	7.60 (3.50)
Soil	5.95	12.30 (**6.35**)	17.80 (**11.85**)
Duff	59.83	44.75 (**-15.08**)	52.65 (-7.18)
Moss	10.2	20.18 (**9.98**)	8.05 (-2.15)
VEGETATION COVER (%)			
VASC	18.5	10.50 (**-8.00**)	13.48 (-5.03)
VAGL	0	0.00 (0.00)	0.00 (0.00)
PHEM	16.38	45.00 (28.63)	43.25 (26.88)
MEFE	0	0.00 (0.00)	0.00 (0.00)
XETE	23.57	11.92 (**-11.66**)	13.30 (**-10.27**)
CAGE	4	1.53 (-2.47)	5.43 (1.43)
CARO	0.88	0.25 (-0.63)	0.00 (-0.88)
CARU	0	0.00 (0.00)	0.00 (0.00)
CACO	0	0.50 (**0.50**)	1.00 (**1.00**)
LUHI	4	2.44 (-1.56)	4.25 (0.25)

Study Site: Beaver Ridge, Clearwater National Forest, Central Idaho

Treatment: Low intensity prescribed burn with fuel enhancement (Unit 4B)

Management Planning: The Powell Ranger District created a comprehensive "District-Wide whitebark pine restoration integrated analysis" in May of 1997 identifying the need for restoration research. In the fall of 1997 it selected two areas for treatment: the Blacklead Mountain site and Beaver Ridge site. Public comment was solicited through mail in May of 1997 and the NEPA analysis for the Categorical Exclusion was finished that September. The cutting treatments were implemented in the summers of 1998 and 1999. District personnel successfully obtained diverse funding (more than $30,000) for this project from multiple sources, including the Nez Perce Tribe, Rocky Mountain Elk Foundation, National Fish and Wildlife Foundation, Forest Service Research, and hazardous fuel reduction monies.

Treatment Description: District and contract crews implemented the fuel enhancement treatment by cutting and directionally felling subalpine fir and Engelmann spruce trees to increase fuel loadings and to improve continuity of the fuelbed. The District fire crew completed some of the work but most was accomplished through an experienced contract crew. The cutting was implemented in September of 1998 and cost an estimated $40 per acre.

This unit was burned September 10, 1999, by District fire crews. We measured the following fuel moistures the day of the burn: 1 hr = 11 percent, 10 hr = 16 percent, 100 hr = 12 percent, sound 1000 hr = 17 percent, rotten 1000 hr = 23 percent, live herbs = 54 percent, and live shrubs = 50 percent. Antecedent weather for the three days prior to the burn and the day of the burn was partly cloudy, cool, and somewhat dry. The temperature at the start of the burn (1445) was 64 °F and relative humidity was 40 percent. By 1525 hours, the temperature was its highest (62 °F) and humidity was 31 percent. By 1715 (end of burn), the temperature was 61 °F and humidity was the lowest at 30 percent. Winds averaged 3 to 5 mph for most of the burn with occasional gusts of 3 to 7 mph from the southwest. More than 3 inches of snow (0.02 inches of water) fell four days prior to the burn. Fire crews first burned a fire line across the top of the unit, then ignited a10- to 40-ft strip head fires from the burned fire line to the road at the bottom of the unit. The western end of the unit burned the hottest and experienced the greatest tree mortality.

The prescribed burn was very spotty and effects were highly variable. Areas with abundant fuel enhancement experienced the highest burn coverage and highest subalpine fir mortality, contrasted to areas with low loadings that experienced very little burn coverage. Tree mortality was highly variable depending on fuel coverage, but, overall, it was much less than expected. The crews were also supposed to burn unit 4A but did not have the time. The prescribed burning cost an estimated $225 per acre for the 71 acres (3 units).

Management Recommendations: Fuel enhancement cuttings increased the fire severity in this unit by killing more subalpine fir trees and creating more desirable caching habitat. Fuel enhancement is essential on these droughty soils because of the low cover—biomass of the undergrowth vegetation provides the fuel to carry the surface fire. We observed both nutcracker harvesting and caching on this unit.

We feel that non-lethal surface fires without fuel enhancement might be difficult to implement in this forest type because the dry conditions needed to burn the unit may increase the chance that the fire would spot to adjacent areas. Unless subalpine fir trees are available to enhance the fuelbed, the site should probably not be treated. The spotty character of the fire and fuels on this site suggests that additional fire treatments might be necessary to accomplish the objectives of the treatment. We suggest implementing additional burns if fuel enhancement is possible or if sufficient surface fuels are available. These sites probably should not be planted because most whitebark pine seedlings might stagnate under the surviving canopy.

Site: Beaver Ridge, Clearwater National Forest, Central Idaho
Treatment: Low intensity prescribed burn
with fuel enhancement (Unit 4B)

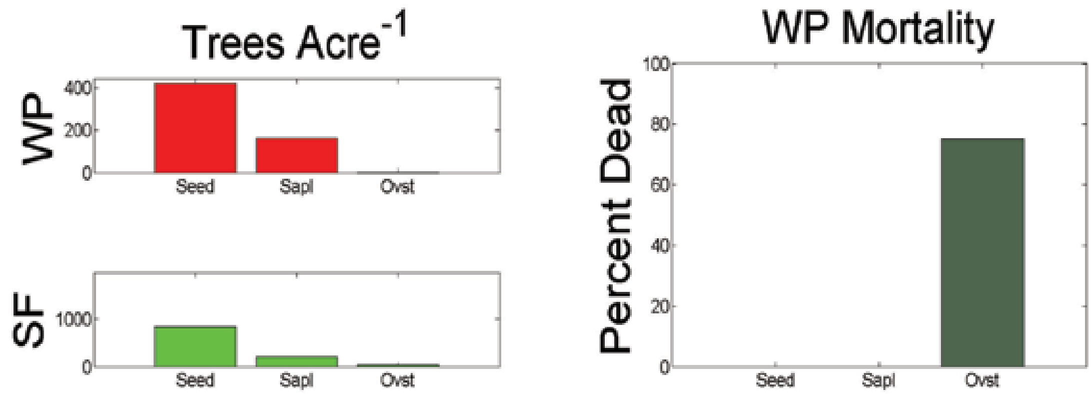
PRE

POST-1

POST-5

Site: Beaver Ridge, Clearwater National Forest, Central Idaho
Treatment: Low intensity prescribed burn
with fuel enhancement (Unit 4B)

PRE



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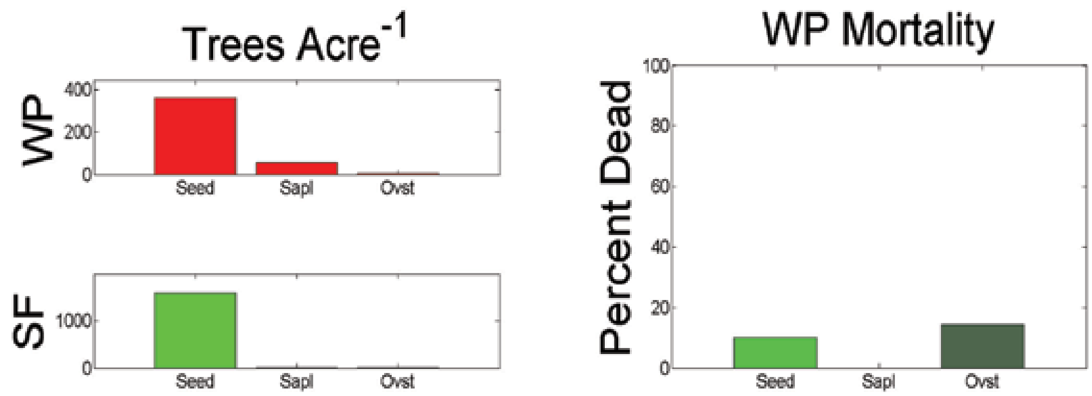

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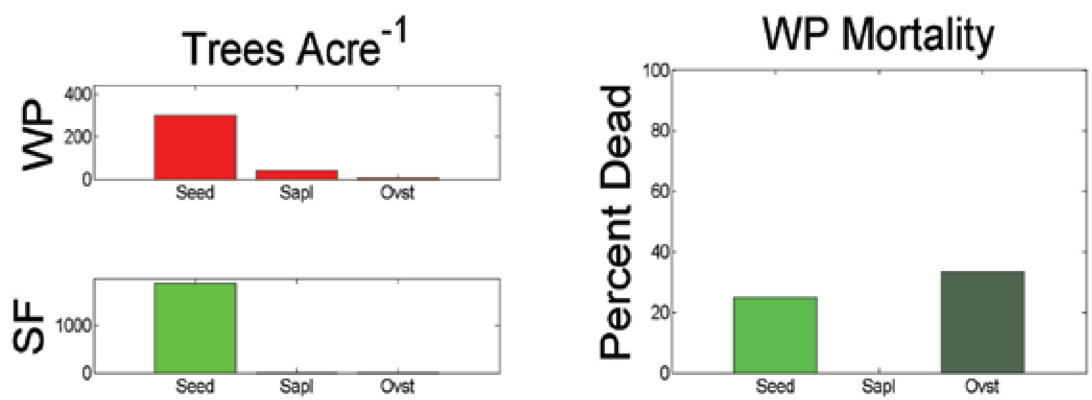
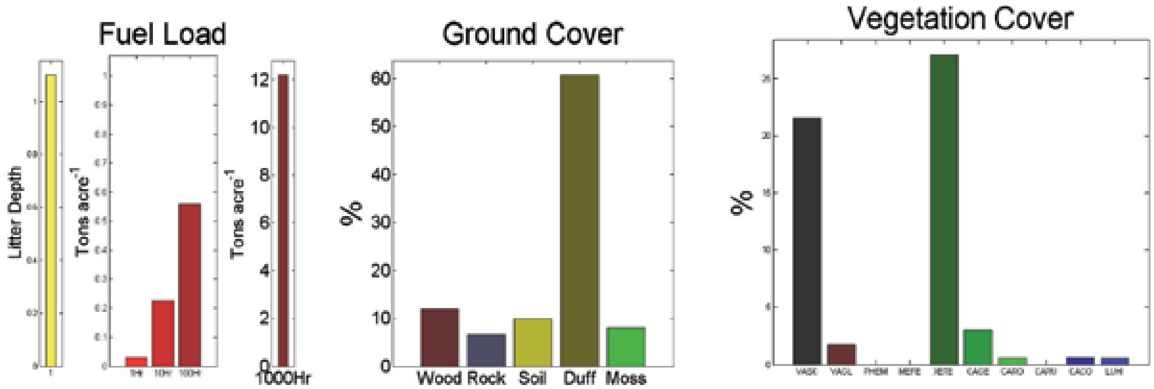


Site: Beaver Ridge, Clearwater National Forest, Central Idaho
Treatment: Low intensity prescribed burn
with fuel enhancement (Unit 4B)

PRE



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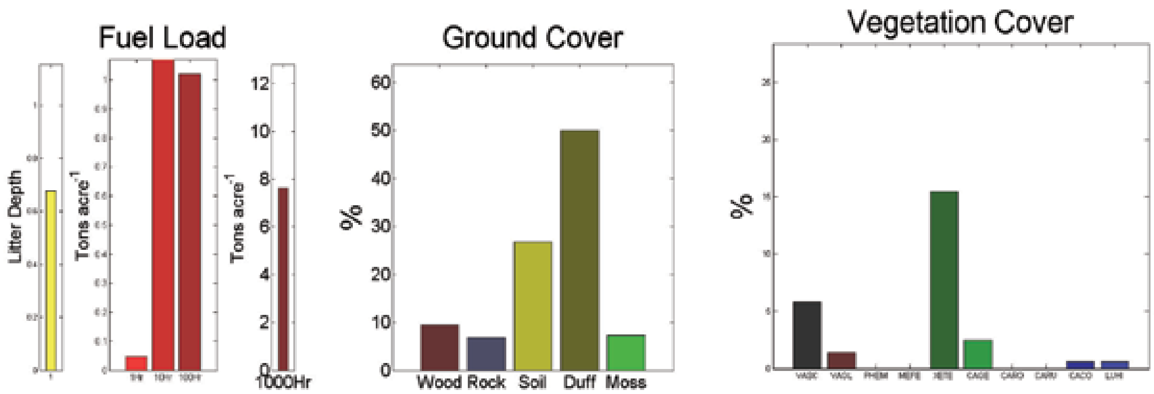

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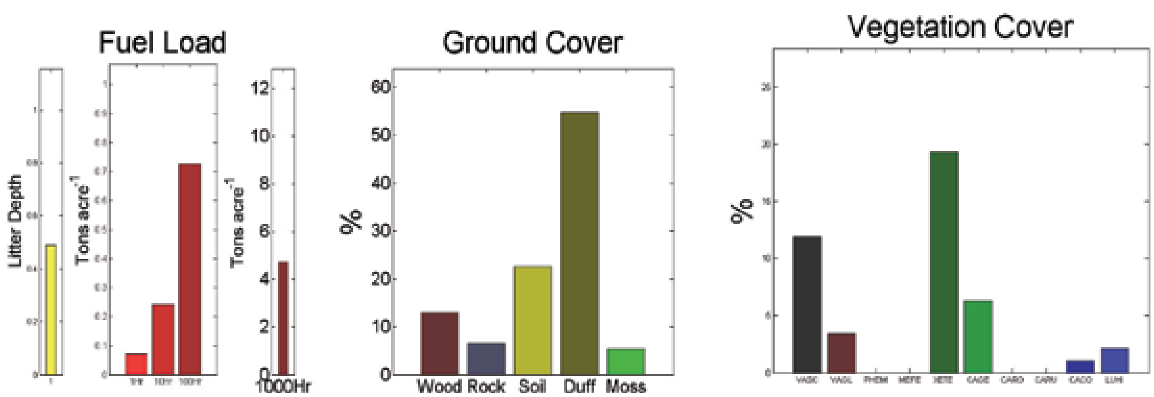


Site: Beaver Ridge, ID. Clearwater NF Low intensity prescribed burn with fuel enhancement (Unit 4B)			
	PRE	POST 1 Yr	POST 5 Yr
TREE DENSITY (trees acre-1)			
WP seedling	421	360.00 (-14.49)	300.00 (-28.74)
SF seedling	842	1590.00 (88.84)	1890.00 (124.47)
ES seedling	30	30.00 (0.00)	60.00 (100.00)
LP seedling	300	240.00 (-20.00)	300.00 (0.00)
WP sapling	163	56.00 (**-65.64**)	40.00 (**-75.46**)
SF sapling	206	8.00 (**-96.12**)	13.00 (**-93.69**)
ES sapling	7	0.00 (-100.00)	0.00 (-100.00)
LP sapling	101	34.00 (**-66.34**)	42.00 (-58.42)
WP overstory	3	6.00 (100.00)	4.00 (33.33)
SF overstory	35	14.00 (-60.00)	8.00 (**-77.14**)
ES overstory	1	1.00 (0.00)	0.00 (-100.00)
LP overstory	55	45.00 (-18.18)	43.00 (-21.82)
SURFACE FUELS			
Litter depth (inches)	1.1	0.68 (-38.48)	0.49 (-55.68)
1 hour fuel load (tons acre-1)	0.03	0.05 (59.82)	0.07 (**149.53**)
10 hour fuel load (tons acre-1)	0.22	1.11 (395.39)	0.24 (8.20)
100 hour fuel load (tons acre-1)	0.56	1.02 (82.15)	0.73 (29.69)
1000 hour fuel load (tons acre-1)	12.2	7.62 (-37.57)	4.72 (**-61.32**)
GROUND COVER (%)			
Wood	11.88	9.47 (-2.40)	12.90 (1.03)
Rock	6.63	6.90 (0.28)	6.47 (-0.15)
Soil	9.85	26.70 (**16.85**)	22.57 (**12.73**)
Duff	60.75	50.08 (**-10.67**)	54.75 (-6.00)
Moss	8.05	7.30 (-0.75)	5.33 (-2.73)
VEGETATION COVER (%)			
VASC	21.57	5.81 (**-15.77**)	11.93 (**-9.65**)
VAGL	1.69	1.38 (-0.31)	3.42 (1.73)
PHEM	0	0.00 (0.00)	0.00 (0.00)
MEFE	0	0.00 (0.00)	0.00 (0.00)
XETE	27.07	15.48 (**-11.60**)	19.38 (-7.70)
CAGE	3	2.44 (-0.56)	6.28 (**3.28**)
CARO	0.5	0.00 (-0.50)	0.00 (-0.50)
CARU	0	0.00 (0.00)	0.00 (0.00)
CACO	0.56	0.61 (0.04)	1.00 (**0.44**)
LUHI	0.54	0.60 (0.06)	2.15 (1.61)

Study Site: Smith Creek, Bitterroot National Forest, Western Montana

Treatment: Low intensity prescribed burn with NO fuel enhancement (Unit 1A)

Management Planning: The objective of this treatment was to enhance the vigor of living whitebark pine trees so that they could produce more cones. This differs from the other Smith Creek units (2A and 2B) where the objective was to encourage and enhance whitebark pine regeneration. The Stevensville District performed a biological evaluation for sensitive plant species in June of 1994 and the findings were that "no individual sensitive plants would be affected because none were found." The Forest Hydrologist who evaluated the treatment suggested that the riparian areas be excluded from treatment due to Montana's Streamside Management Zone rules. The treatments were planned and implemented as a demonstration research study project using standard NEPA analyses. The harvest units were cruised, marked, and traversed in the summer of 1994. A burn plan was written in the summer of 1996 and signed in September of 1996.

Treatment Description: The low intensity prescribed burn was implemented on October 3, 1996, using strip head fires with the strips varying from 15 to 20 ft. We used drip-torches to start the fire. We measured the following fuel moistures at the start of the burn: 1 hr = 12 percent, 10 hr = 8 percent, 100 hr = 10 percent, 1000 hr sound = 15.7 percent, 1000 hr rotten = 18.6 percent, 10000 hr sound = 21.4 percent, 10000 hr rotten = 26.2 percent. At the start of the burn (1230), the temperature was 59 ^{o}F with relative humidity at 28 percent. The temperature increased to 60 ^{o}F and relative humidity decreased to 21 percent at 1500. This unit was burned first on the Smith Creek site to provide a fire break for the other burns. The burn lasted until 1910 when the temperature was 56 ^{o}F and relative humidity was 29 percent. Weather was partly cloudy with wind gusts from 5 to 10 mph upslope from the southwest. A total of 0.96 inches of rain had fallen on the site over the previous three weeks with no precipitation recorded within three days of the burn—it was warm (upper 60s) and windy the three days prior to burn.

Flame lengths averaged 1 to 3 ft in this unit with some passive crown fire behavior observed in small areas of the unit when tall subalpine fir trees crowned (torching caused flames more than 50 ft tall). Very little of the riparian area was burned. A hard frost (24 ^{o}F) had occurred four days prior to burn so the shrub fuels were dry enough to carry the fire in many areas. However, the extensive shade on the unit from the overstory tree cover and the dense subalpine fir undergrowth prevented extensive drying on this unit, so the prescribed fire was unable to visit many parts of the stand. The areas that burned with the most desirable intensity were those that received direct sunlight during the ignition. We tried to ignite most subalpine fir crowns regardless of tree size but few were dry enough to torch. Many embers were driven aloft by the fire, especially after some passive crown fires, but they rarely ignited fuels outside the unit boundary. The fire smoldered for seven days in this unit but was monitored by District personnel. Cost of the burning was estimated at $2900 or $290 per acre for the 10 acres.

This site was burned again by spotting from the Gash Creek Fire in August of 2006. The wildfire burned under hot, dry summer conditions estimated at 90 ^{o}F and 20 percent relative humidity. However, the fire only burned small portions of this unit (less than 15 percent) because of the lack of fine fuels that had been consumed by the 1996 prescribed fire. We estimate an additional 40 percent of the unit area was burned in the days after the prescribed burn indicating that the majority of desirable effects may take place in post-frontal combustion and smoldering

Management Recommendations: This treatment, if done under the right conditions, can effectively simulate low intensity fires in whitebark pine forests. However, this is difficult to achieve. The fine fuels that carry the fire, mainly shrub, herbaceous, and litter, are rarely dry enough during the fall burning season to carry a fire. The shrub and herb foliage often need to be killed by a frost to drive moisture contents down low enough to foster fire spread. However, the antecedent weather needed to create these low moistures may dry surrounding lowland areas so extensively that fire managers might be reluctant to implement prescribed burns in the high elevation. Whitebark pine tree regeneration was marginal, indicating that even after 10 years, the site is not able to support substantial regeneration. We did not observe extensive nutcracker caching on this site, probably because the birds seem to prefer the open burned areas of the other units (2A and 2B).

Site: Smith Creek, Bitterroot National Forest, Western Montana
Treatment: Low intensity prescribed burn
with NO fuel enhancement (Unit 1A)

PRE

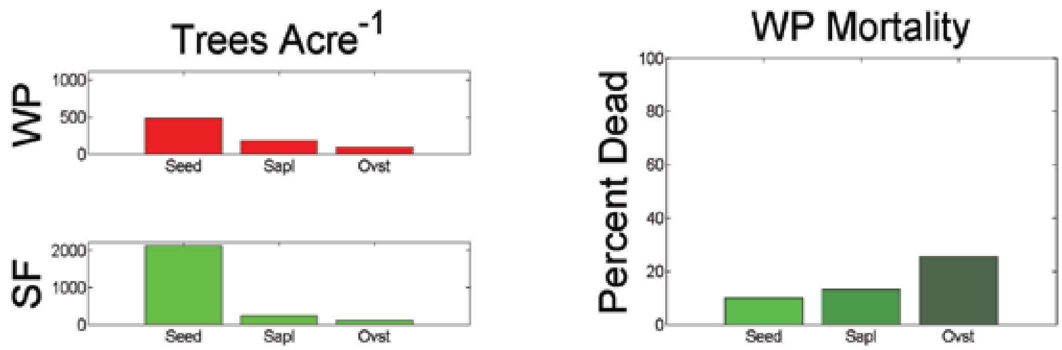
POST-1

POST-5

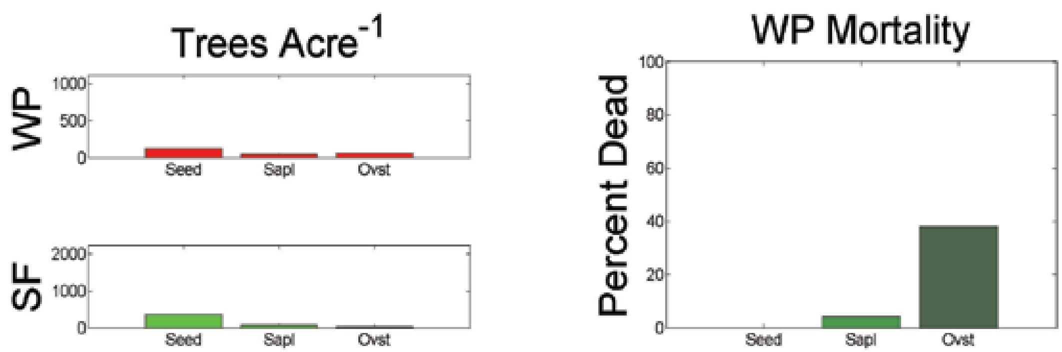
POST-10

Site: Smith Creek, Bitterroot National Forest, Western Montana
Treatment: Low intensity prescribed burn
with NO fuel enhancement (Unit 1A)

PRE



POST-1



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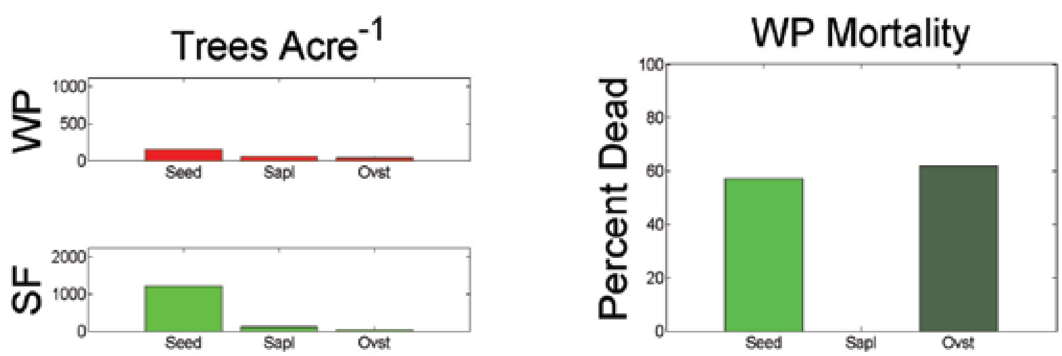
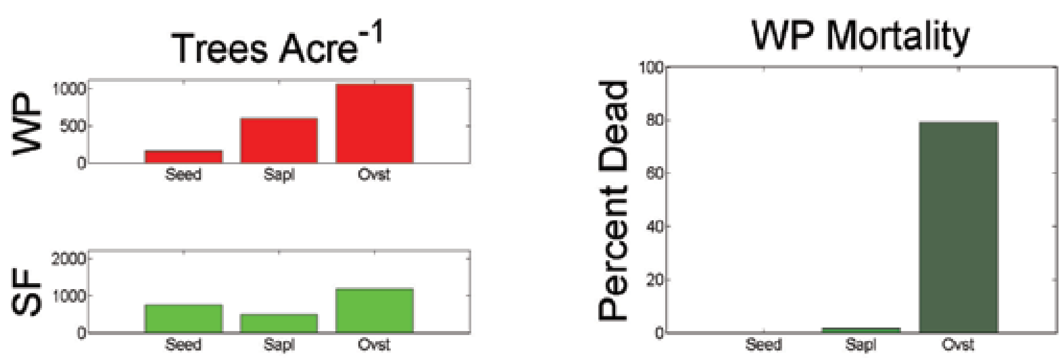
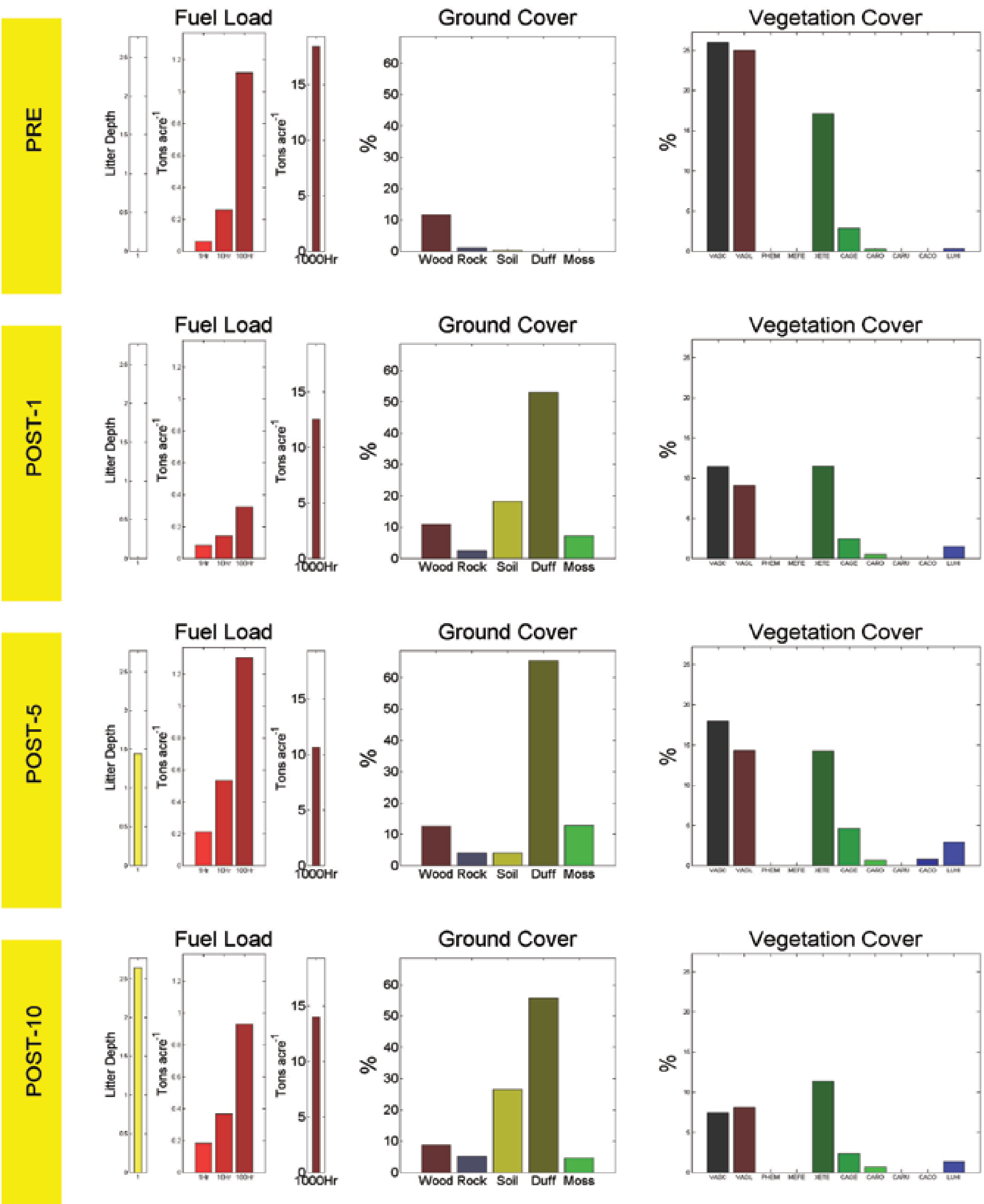


POST-10



Site: Smith Creek, Bitterroot National Forest, Western Montana
Treatment: Low intensity prescribed burn
with NO fuel enhancement (Unit 1A)



Site: Smith Creek, MT. Bitterroot NF Low intensity prescribed burn with NO fuel enhancement (Unit 1A)			
	PRE	POST 1 Yr	POST 5 Yr
TREE DENSITY (trees acre-1)			
WP seedling	480	121.00 (**-74.79**)	150.00 (-68.75)
SF seedling	2130	363.00 (**-82.96**)	1200.00 (-43.66)
ES seedling	0	0.00 (NA)	90.00 (NA)
LP seedling	0	0.00 (NA)	150.00 (NA)
WP sapling	178	45.00 (**-74.72**)	53.00 (**-70.22**)
SF sapling	243	72.00 (**-70.37**)	107.00 (**-55.97**)
ES sapling	21	4.00 (-80.95)	3.00 (**-85.71**)
LP sapling	18	5.00 (-72.22)	8.00 (-55.56)
WP overstory	90	64.00 (-28.89)	39.00 (**-56.67**)
SF overstory	114	26.00 (**-77.19**)	20.00 (**-82.46**)
ES overstory	20	11.00 (-45.00)	6.00 (-70.00)
LP overstory	108	82.00 (-24.07)	61.00 (**-43.52**)
SURFACE FUELS			
Litter depth (inches)	0	NA	1.44 (NA)
1 hour fuel load (tons acre-1)	0.06	0.08 (34.57)	0.21 (245.21)
10 hour fuel load (tons acre-1)	0.26	0.14 (**-45.24**)	0.53 (107.13)
100 hour fuel load (tons acre-1)	1.12	0.32 (-71.03)	1.30 (16.70)
1000 hour fuel load (tons acre-1)	18.41	12.50 (**-32.14**)	10.67 (**-42.07**)
GROUND COVER (%)			
Wood	11.65	10.90 (-0.75)	12.55 (0.90)
Rock	1.13	2.42 (1.30)	3.92 (**2.80**)
Soil	0.15	18.25 (**18.10**)	4.03 (**3.88**)
Duff	0	53.00 (**53.00**)	65.34 (**65.34**)
Moss	0	7.28 (**7.28**)	12.82 (**12.82**)
VEGETATION COVER (%)			
VASC	25.95	11.43 (**-14.52**)	17.95 (**-8.00**)
VAGL	24.98	9.05 (**-15.93**)	14.30 (**-10.68**)
PHEM	0	0.00 (0.00)	0.00 (0.00)
MEFE	0	0.00 (0.00)	0.00 (0.00)
XETE	17.1	11.48 (-5.63)	14.25 (-2.85)
CAGE	2.85	2.42 (-0.43)	4.63 (1.77)
CARO	0.25	0.50 (0.25)	0.67 (0.42)
CARU	0	0.00 (0.00)	0.00 (0.00)
CACO	0	0.00 (0.00)	0.81 (**0.81**)
LUHI	0.3	1.50 (1.20)	2.88 (2.58)

Discussion

Nearly all high and moderate intensity prescribed fire treatments combined with a cutting treatment effectively created desirable nutcracker caching habitat, as evidenced by the abundant nutcracker caching observed at nearly all sites. However, the whitebark pine regeneration that was expected to result from this caching has not yet materialized. Nearly all sites contain very few or no whitebark pine seedlings. This could be a result of many factors. First, we believe that many of the cached seeds have been reclaimed by the nutcrackers. We also feel that high rust mortality has reduced populations of cone-producing whitebark pine at or near our study areas so few seeds were actually available to be cached. At low levels of seed production, most seeds are consumed by the nutcrackers rather than forgotten and allowed to germinate. Next, severe site conditions could have killed many emerging seedlings. Our steep, high-mountain study sites experience deep snowpack, especially the Beaver Ridge site, which had more than 50 ft of snow in 1997. This heavy snowpack can "creep" down the slope and pull seedlings out of the ground. Moreover, most soils on our study site are highly erosive and spring snowmelts scoured the topsoil and washed away those seedlings rooted in it, especially in recently burned sites. Some researchers have identified a lag period of up to 40 years for the disturbed site to stabilize enough to allow whitebark pine to become established in upper subalpine zones (Agee and Smith 1984; Arno and Hoff 1990). Therefore, we believe that a 5-year evaluation period is too short to determine whitebark pine regeneration dynamics in these severe sites and a 10- or 20-year measurement might more accurately describe the success of our treatments. We recommend that sites where whitebark pine mortality is above 20 percent and rust infection is above 50 percent be planted with rust-resistant seedlings to shorten this long lag between disturbance and regeneration.

We lost many control plots on three study sites to wildfires. The fires that swept through the Bitterroot National Forest in 2000 burned the entire Coyote Meadows study site rendering all 30 control plots ineffective. The 2001 Dry Fork fire on the Salmon-Challis National Forest consumed 3 of 10 control plots on the Blackbird Mountain site. Embers from the prescribed burn at Blackbird Mountain started small fires in four of the control plots. The 2006 Gash Creek fire burned 5 of 10 control plots on the Smith Creek site and part of the Bear Overlook site (no control plots were burned). While a small wildfire at the Beaver Ridge site missed the control plots, it burned two cutting-only treatment units (3A and 2A; fig. 2e). The lack of sufficient control measurements makes it difficult to determine if changes measured on some of the treatment units were a result of the treatment and not of external factors such as climate. However, we found no significant difference in control plots for those sites that remained unburned (Keane and Parsons, in press).

Because of their lack of experience in burning high-elevation ecosystems, fire crews implemented prescribed burns under moister than desired conditions, thereby achieving less than desired fire intensity and severity. None of the fire crews had ever burned in the upper subalpine zone, so few wanted to risk burning in the desired dry conditions when the possibility of fire escape is high. In hindsight, as fire crews became familiar with burning in this high-elevation system, nearly all crews recognized that they could have easily achieved the higher severities. This may mean multiple treatments are needed to successfully realize burn plan objectives when experience is low or the consequences of escaped prescribed fires are severe.

Most treatments increased fuel loadings on most sites, especially the coarse woody debris (logs greater than 3 inches diameter). This was primarily because the prescribed fire burned through the bases of the abundant rust-killed whitebark pine snags within the treated stands. The newly fallen logs posed a low fuel hazard because they lacked fine fuels that contribute to increased fire spread. Their presence might actually improve the potential for whitebark pine regeneration by providing safe sites for cached whitebark pine seed (Izlar 2007). Managers should inspect the level of whitebark pine snags in potential treatment areas to evaluate if the restoration treatment could also be a fuel reduction treatment.

Planting whitebark pine seedlings on the Beaver Ridge site was marginally effective in this study (approximately 30 percent survival after 5 years) because nursery techniques and planting guidelines for whitebark pine at the time of planting were not as refined as they are today (McCaughey and others 2009). Our seedlings were small and they were planted in mid-summer, just after snowmelt, so they had to survive three hot, dry months of drought. There is now extensive reference material for growing whitebark pine in nurseries and recommendations for planting whitebark pine (Scott and McCaughey 2006; McCaughey and others 2009; Izlar 2007). Our success would have been improved using today's technology. Planting should be done in mid-autumn and seedlings should be planted near structures, such as stumps, logs, and rocks, that provide stability from snowpack damage. Recently, Perkins (2004) found that grouse whortleberry had a positive effect and elk sedge had a negative effect on the growth and survival of planted whitebark pine seedlings. But Izlar (2007) found safe sites are more important to survival than sufficient whortleberry cover.

We recommend a fuel enhancement cutting implemented at least 1 year prior to a prescribed burn to ensure that burn objectives are fully realized. Adding cured slash to discontinuous fuelbeds facilitates burn effectiveness by providing additional fine fuel to aid fire spread into all areas of the treated stand and augment quick-drying fine fuel levels so the burn can be implemented in moister conditions. Prescribed burns had greater coverages (50 percent increase in burn coverage) and severities in fuel-enhanced stands. Fuel enhancement is an easy, inexpensive, and relatively rapid treatment that can be implemented by timber crews, fire crews, or contractors. We found that shrub and herbaceous fuels were much drier after the first hard frost in late summer or early autumn. Frost kills the aboveground foliage that allows the plants to take water from the soil so the aboveground plant structure can dry sufficiently for burning.

Ignition methods were important in this study. Most prescribed fires were ignited using strip head fires whose width was increased if higher fire intensities were desired. However, some study sites were so moist at ignition that even wide strips couldn't generate our desired intensities. Using the terra-torch and heli-torch, we were able to burn large areas to achieve the high target intensities. However, because these techniques may not always be available, the drip-torch is the primary ignition technique. To be effective, these drip-torch ignitions should be done in dry conditions to generate sufficient intensities to kill undesirable tree species. If possible, multiple burns may also produce similar effects as one high intensity fire.

Summary and Conclusions

Whitebark pine will continue to decline across its range as extensive exotic blister rust infections, more frequent and severe mountain pine beetle epidemics, and fire exclusion-oriented management policies continue. An extensive and long-term, integrated research and management program is needed to maintain this valuable tree species on the high-mountain landscape in the western United States and Canada. Restoration of this precious ecosystem will depend on cost-effective, coordinated efforts to

- conduct fundamental ecological research in whitebark ecosystems,
- develop methods to harvest seed from rust-resistant trees,
- refine nursery techniques to produce high quality, inexpensive rust-resistant seedlings for planting,

- create effective guidelines for planting rust-resistant seedlings and seeds,
- develop methods to plan and prioritize those areas in greatest need of whitebark pine restoration, and
- develop innovative prescribed burning and silvicultural cutting methods for restoring the keystone whitebark pine ecosystem (Keane and others, in press).

This management guide is a first step to develop restorative burning and cutting methods. Details in this report can be used to prioritize, plan, and implement restoration treatments in declining whitebark pine stands by providing a reference for determining effects of various prescribed burning and cutting treatments. Though we have not yet observed significant whitebark pine regeneration in many of our treated areas, we feel these techniques can be combined with planting of rust-resistant seedlings to effectively return whitebark pine to the landscape.

We recognize it will be impossible to implement the treatments explored in this study on all whitebark pine lands during this period of rapid decline. But, there will be critical whitebark pine forests that will require immediate and extensive proactive restoration, and the findings of this study will provide critical information for the successful planning and implementation of restoration activities. Since most whitebark pine forests are in protected areas such as National Parks, Wilderness Areas, and proposed Wilderness Areas that prohibit many of the treatments detailed in this report (Keane 2000), we feel wildland fire use (in essence, letting lightning-ignited fires burn under allowable parameters) will be the primary vehicle for treating deteriorating whitebark pine stands. No matter the treatment type, it will be critical to extensively monitor the effects of all direct (used in this study) and indirect (wildland fire use) treatments so we can refine and modify treatment guidelines in the future to account for local conditions and changing environments (for example, climate change and rust epidemics). Though the outlook may seem bleak for whitebark pine, recent exciting advances in research and many management successes will hopefully help secure the conservation of this keystone species.

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