RESTORING WHITEBARK PINE ECOSYSTEMS:
EFFECTS OF DAYLIGHTING, THINNING, AND PRESCRIBED BURNING TREATMENTS
(THE DAYLITE STUDY)

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ABSTRACT

Whitebark pine has been rapidly declining on many National Forests in the northwestern United States over the last three decades because of blister rust infections and mountain pine beetle outbreaks, which have been exacerbated by recent warmer climates. Great care should be taken to preserve, protect, and conserve the remaining whitebark pine because their populations are so low that future disturbances, especially those facilitated by climate change, could cause local extinctions of this valuable keystone species that provides food to hundreds of wildlife species. Silvicultural cuttings and prescribed burning have been used to successfully restore declining whitebark pine stands. However, these techniques are costly and are somewhat tricky to implement making them difficult to operationally implement on National Forests with limited budgets and expertise. New cheaper techniques need to be developed that are just as effective as the cutting and burning treatments. Daylighting treatments (cutting competing trees in a circular area around a target tree) have had success in other five-needle pine ecosystems, and many managers are now using daylighting for whitebark pine restoration because they can't afford to thin entire stands. No research study has documented the effects of daylighting treatments on whitebark pine survival, vigor, and cone production. In this study, we investigate the effects of daylighting treatments, implemented with other silvicultural and prescribed burning treatments, on wildland fuels, tree survival and mortality, and understory vegetation. We will implement this study on at least three sites: Prospect Mountain (Lolo National Forest), Grouse Mountain (Bridger-Teton National Forest), and Mink Peak (Lolo National Forest). We will put 10 plots in each unit in each study area, including a control unit where no treatments are implemented. This study will measure fuels, trees, and vegetation at several intervals: pre-treatment, post-treatment, 5 years post-treatment, 10-years post treatment, and 15 years-post-treatment.

INTRODUCTION

Whitebark pine (*Pinus albicaulis*) forests are declining across most of their range in North America because of the combined effects of three factors (Arno 1986, Kendall and Keane 2001). First, there have been several major mountain pine beetle (*Dendroctonus ponderosae*) epidemics that have killed many cone-bearing whitebark pine trees over 15 cm in diameter at breast height (Arno 1986, Waring and Six 2005) (Figure 1). The effects of an extensive and successful fire exclusion management policy have also reduced the area burned in whitebark pine forests resulting in a decrease of suitable conditions for whitebark pine regeneration (Keane and Arno 1993, Kendall and Keane 2001). And, the introduction of the exotic fungus white pine blister rust (*Cronarium ribicola*) to the western US circa 1910 has killed many five-needle pine treess and whitebark pine is one of the most susceptible to the disease (Hoff et al. 1980, Keane and Arno 1993, Murray et al. 1995, Kendall and Keane 2001a, Kendall and Keane 2001). The cumulative effects of these three agents over the last several decades have resulted in a rapid decrease in mature whitebark pine, especially in the more mesic parts of its range (Keane and Arno 1993). What's more, predicted changes in northern Rocky Mountain climate brought about by global warming could further exacerbate whitebark pine decline by increasing the frequency and duration of beetles epidemics, blister rust infections, and severe wildfires (Logan and Powell 2001, Blaustein and Dobson 2006, Running 2006)

The loss of whitebark pine could have serious consequences for upper subalpine ecosystems of the northern Rocky Mountains and Cascades of the US because it is considered a keystone species (Mills et al. 1993, Tomback et al. 2001). Whitebark pine forests cover a major portion (approximately 10-15 percent) of the northern Rocky Mountain forested landscape (Keane 2000, Tomback et al. 2001). This “stone” pine produces large, wingless seeds that are an important food source for over 110 animal species (Kendall and Arno 1990, Hutchins 1994). In the Yellowstone ecosystem, the endangered grizzly bear (*Ursus arctos horribilis)* depends on whitebark pine seeds as a major food source (Mattson and Reinhart 1990, Mattson et al. 1991, Mattson and Reinhart 1997), which it raids from red squirrel (*Tamiasciurus hudsonicus*) middens (Ferner 1974). Native American tribes used whitebark pine seed as an important food source in late summer (Munger 1993). Whitebark pine inhabits severe high elevation environments where it is the only tree species that can exist; thereby protecting snowpack and delaying snowmelt, which reduces the potential for flooding and provides high quality water into the summer (Hann 1990). While whitebark pine is not highly valued as a timber species because of its diminutive size, its twisted growth form, and its remote locations (Chew 1990, Eggers 1990), the species has great value as a recreational resource because of its pleasing aesthetic qualities such as gnarled growth forms and open, park-like forests (Cole 1990). Therefore, the restoration of the dwindling whitebark pine is critically important to high elevation ecosystems and the numerous species that depend on it for existence (Tomback et al. 2001, Aubry et al. 2008).

Whitebark pine has been rapidly declining on the National Forests (NF) in the northern Rockies over the last three decades. While whitebark pine is not overly abundant on forests of the Lolo NF and in the northern portions of its range, the remaining living whitebark pine are vital for sustaining viable populations because (1) these trees have survived the blister rust for over 20 years and can be assumed to be somewhat putatively rust resistant, (2) they have outlived the series of mountain pine beetle epidemics that occurred over the last 30 years, and (3) they could be lost in future unplanned wildfires. The trees are also important because most whitebark pine populations are on high, isolated ridges and represent the last vestiges of viable seed sources for populating the high country of northern Rocky Mountain upper subalpine areas, such as the Great Burn proposed wilderness and nearby areas. Great care should be taken to preserve, protect, and conserve the remaining whitebark pine on the NFs because their populations are so low that future disturbances, especially those facilitated by climate change, could cause local extinctions of this valuable keystone species that provides food to hundreds of wildlife species.

Silvicultural cuttings and prescribed burning have been used to successfully restore declining whitebark pine stands (Keane and Parsons 2010a, 2010b). However, these techniques are costly and are somewhat complicated to design for high mountain ecosystems making them difficult to operationally implement on National Forests with limited budgets and expertise. New techniques need to be developed that are cheaper than but just as effective as the cutting and burning treatments. Daylighting treatments (cutting competing trees in a circular area around a target tree) have had success in other pine ecosystems, and many managers are now using daylighting for whitebark pine restoration. No research study has documented the effects of daylighting treatments on whitebark pine survival, vigor, and cone production.

PROJECT OBJECTIVES AND SUMMARY

The project has two primary objectives:

- Explore the effects of daylighting, thinning, and prescribed burning treatments on the regeneration and survival of trees in the whitebark pine forest, the response of the undergrowth species, and the changes in fuel loadings. The effects of novel treatments such as daylighting, must be documented so that managers can plan their design and implementation.
- Evaluate the effects of these treatments on the vigor of the daylighted whitebark pine trees. Our assumption is that increases in vigor, as measured from diameter growth rings, will correlate with increases in the (1) potential for larger cone crops, (2) survival of trees from beetle and rust, and (3) tree survival over long time periods.

There are also some other secondary objectives that may be evaluated from this study:

- Study the effect of the daylighting treatment on the survival of daylighted trees from unplanned wildfires. This may be opportunistically studied in the future by assessing the effect of fuel removal from the immediate vicinity of individual trees on their survival during wildfire.
- Determine if the selected trees have the ability to release after treatment. This is critically important because many stunted whitebark pine advanced regeneration are found in declining forests and treatments to release these survivors may preclude the need for planting.

The audience for this effort is land managers and researchers interested in restoring whitebark pine, especially in isolated ridges and remote locations where the high elevation five needle white pine forests are severely declining. This research may lead to new methods of restoring these valuable ecosystems.

MATERIALS AND METHODS

Study Areas

Study sites will be selected in an opportunistic fashion where USFS National Forests or Districts will request RMRS scientists to study daylighting effects on their upper subalpine lands. Site visits by these scientists and NF personnel will be used to evaluate if the proposed sites are suitable for research based on the following factors:

- Is there sufficient area (>15 acres) that is homogeneous with respect to vegetation, site, and fuels, to establish 10 plots that are a tenth acre in size?
- Is there sufficient area (>15 acres) nearby to establish a control unit?
- Are there other areas similar to the daylighting treatment area where other treatments can be implemented?

Each study site is mutually agreed upon by the scientist and NF personnel. Currently, there are three study sites selected for this study, but we are actively seeking other sites to include for evaluation.

Prospect Mountain

The Prospect Mountain study area is on the Superior RD on the Lolo NF approximately 11 miles south of Superior Montana (Figure 3). The study area is on slopes between 20-50 percent on northwesterly aspects with elevations ranging from 5900 to 7000 feet MSL. Habitat types are mostly Abla lasiocarpa/menziezia (ABLA/MEFE) and Abla lasiocarpa/Luzula hitchcockii (ABLA/LUHI). These upper subalpine stands are comprised of mixed species dominated by lodgepole pine (PICO) in the overstory with highly variable amounts of subalpine fir (ABLA) and mountain hemlock (TSME) in both the overstory and understory. There are scattered whitebark pine (PIAL) trees throughout the area ranging from10-15 per acre in mature stands to 100-300 per acre in sapling-size stands, but most whitebark pine trees are shorter than the lodgepole/fir overstory canopy. There are also minor amounts of Douglas-fir (PSME), western larch (LAOC), and western white pine (PIMO).

Most of the whitebark pine trees in this area, especially the sapling and pole trees, appear to be relatively blister rust-free which can be indicative of three things. First, the smaller whitebark pine trees may have escaped rust infection, which seems highly unlikely considering the great rust mortality in surrounding stands, but possible. Second, these trees may be somewhat rust-resistant because they came from seed produced by trees that had survived major blister rust infection periods. Third, these trees may be rust-resistant but not the progeny of rust-resistant trees. There are abundant whitebark pine snags in the area that appeared to have died as a result of blister rust infections several decades ago indicating that rust has been present in this area for a considerable period. We believe that these surviving whitebark pine trees are putatively rust resistant and therefore we assume that these trees will not be killed by blister rust in the future.

This study area is at the bottom of the elevational range of whitebark pine in this region and this may not be optimum for restoration considering climate warming might drive whitebark pine’s elevational range up the mountain rendering our restoration efforts ineffective. However, we feel that these low elevation whitebark pine trees will provide the best seed for future whitebark pine forests because the trees are already reproducing and growing at lower elevations and might be adapted to warmer, drier conditions. By protecting and facilitating cone crops in these trees, we feel that these low elevation sites can provide the seed for planting rust-resistant seedlings on sites higher up the mountain.

There are four stands within the study area (Figure 3):

1) *Oldgrowth stand.* A stand with scattered 150+ year old whitebark pine at the top of the study area (this stand was inventoried in 1982 showing that the oldest lodgepole pine were 118 and mature whitebark pine were 5-13 inches DBH with about 30 trees/acre that were heavily infected by rust and pine less than 5 inches were 150 trees/acre and had heavy mortality),
2) *1979 Stand*. A stand that was burned in a 1979 wildfire with lodgepole pine around 15-25 feet tall and varying sizes of smaller whitebark pine,
3) *MPB stand.* A stand where the lodgepole pine/whitebark pine overstory was killed by mountain pine beetles in 1930-1940, but it was also partially burned by the 1979 wildfire with a mix of lodgepole pine, subalpine fir, mountain hemlock, and whitebark pine that are 20-30 feet tall and 3-7 inch DBH, and
4) *1889 Stand.* A stand that originated from the 1889 wildfire that has a lodgepole pine overstory, scattered whitebark pine, and a fir/hemlock understory.

Grouse Mountain

This study area is on the Buffalo Ranger District of the Bridger-Teton National Forest and is composed of a mosaic of disparate stands that range from sapling lodgepole clearcuts to late seral whitebark pine stands, mid-seral whitebark pine stands, ribbon whitebark pine beetle killed forests, subalpine timber atolls meadow complex, and open grassy meadows (Figure 4). The entire site is above 8200 ft MSL and well within the potential elevational range of whitebark pine for that region. There is heavy mountain pine beetle mortality throughout the area but the heaviest is on the steep sides of Grouse Mountain.

There are basically three or four types of treatment areas. Late seral whitebark pine (Units 1, 2, 3) stands consist of mostly old growth ABLA, PIEN, PICO, and PIAL, and most PIAL in the overstory are dead. The understory consists of dense ABLA seedling and sapling regeneration along with scattered PIAL suppressed regeneration. A daylighting treatment is probably not optimal here in that there are few pole-sized or large trees to release with daylighting and the removal of the overstory will probably damage many of the understory PIAL seedlings. Mid-seral whitebark pine (Units 4, 6) stands are much younger than the late seral and are composed of dead and dying PIAL mixed with ABLA, PICO that are also dying. However, there may be few living PIAL pole or young trees that could be daylighted successfully. There are some stands that were clearcut in the 1970s and planted to PICO that are now 9-25 feet tall, but within these clearcuts are some thrifty volunteer PIAL saplings scattered throughout that is perfect for implementing daylighting for all PIAL saplings. Subalpine meadows comprise the slopes of Grouse Mountain and they are littered with dead and dying whitebark pine with a small mix of ABLA. It will be difficult to mechanically cut these stands because they are steep, unstable, and contain few whitebark pine trees, and it will also be problematic to prescribe burn these stands without considerable risk in cost and fire danger because there are few years when these sites are dry enough to burn and when they are dry enough, the surrounding stands are drier still. It is suggested that these dying stands be planted to rust-resistant PIAL as the only treatment.

Mink Peak

The stands at Mink Peak are mostly young thrifty whitebark pine trees that are mixed with ABLA, PICO, and TSME (mountain hemlock) that became established in an 1889 burn (Figure 5). Most of the trees are PICO but the entire site has scattered PIAL at about 20-25 per acre that are approximately 70 years old and most are producing cones. We observed many nutcrackers in the area and at least two family groups were harvesting the un-ripe whitebark pine cones. The site is mostly northerly facing with gentle slopes that get steeper near Mink Lake.

Treatment Implementation

Each treatment will be designed to be implemented by Forest Service Ranger District personnel in an operationally feasible manner. No special cutting or burning methods that are unknown to District personnel are specified to realize treatment objectives. It is vitally important that treatment implementation be easily accomplished by district crews or contractors. If feasible, merchantable material cut on the study area that is not needed for fuel enhancement can be harvested using low impact techniques.

Three types of treatments will be investigated in this study. The primary treatment is **daylighting** and it is defined as removing all competing trees around a target tree (whitebark pine) in a circular area of a predetermined size. This study will use a daylighting size that is both easy to implement and effective at reducing competing vegetation; it will probably be at least 15 feet in radius. We will remove ALL non-whitebark pine trees within 15 feet and leave any whitebark pine tree.

Another treatment is **prescribed fire** implemented at one or more of three intensity levels to mimic three types of fire severity in areas that are at least 10 acres in size. A *high intensity* prescribed fire can mimic stand-replacement fire where more than 90 percent of the overstory is targeted to be killed by fire, while the *moderate intensity* prescribed fire simulates effects from a mixed severity fire (Figure 2). 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 emulates a *low intensity* prescribed fire (Figure 2). Prescribed fire intensity levels are achieved through the combination desired wind speed, fuel moisture, and fuel loadings. Most prescribed burns are ignited using strip headfires of about 10 to 20 ft wide, but a heli-torch can be used to simulate stand-replacement fire.

Tree cuttings will be implemented at various intensities and design to achieve several objectives. Cutting treatments called *nutcracker openings*, where all trees except for whitebark pine trees were cut within near-circular areas of 1 to 5 ac, can be used to entice the nutcrackers to cache seeds there. Openings can be designed to mimic the effect of patchy mixed severity burns and some stand-replacement burns. Norment (1991) found that nutcrackers were most abundant in 1 to 40 acre (0.1 to 15 ha) disturbed or non-forest patches. *Thinning treatments* can be used to emulate the effect of non-lethal surface fires where all subalpine fir and spruce trees below a threshold diameter are cut. *Selection cuttings* can be also implemented where all fir and spruce trees greater than a threshold diameter (5 inches or 13 cm in most cases) are cut to mimic effects of passive crown fires in mixed severity fire regimes. Lastly, we wish to use a cutting treatment called *fuel enhancement cuttings* where small to large subalpine fir and spruce trees are cut and dropped within the treatment unit to enhance the fuel bed so prescribed fire could visit a greater portion of the stand to increase burn coverage. Fuel enhancement cuttings widen the short burning window in high-elevation environments by providing abundant dry fine fuels during the late summer and early fall (Keane and Parsons 2010a).

Some additional actions can be implemented on treatment units in this study after the cutting or burning treatments. We may pile and burn slash. We may also plant whitebark pine trees on a couple of sites, but planting is not included as a major factor in this study. This study will mainly evaluate whitebark pine natural regeneration.

Prospect Mountain

The primary purpose of the treatments is to release and weed whitebark pine saplings and poles to encourage growth, survival, and development to cone-producing age by removing competition (primarily subalpine fir) and reducing risk of stand-replacing wildfire. Two stands are being treated and they are identified in the Cedar Thom EIS as units 920 and 955 (Figure 3). Each will have 1) control, 2) daylight/lop/scatter, and 3) daylight/underburn. The objectives of the underburn are to: (1) reduce loadings of surface fuels under 3” diameter by at least 50 percent on more than 70 percent of the area, (2) limit complete duff reduction (mineral soil exposure) to less than 15 percent of the area, (3) limit mortality of daylighted whitebark pine saplings (described below) to less than 40 percent, although up to 80 percent mortality is acceptable if that is the only way to implement the prescribed burn in a timely and effective manner, and (4) provide caching habitat for nutcrackers to facilitate regeneration of whitebark pine. Slash should be allowed to cure for two seasons prior to burning to reduce flashiness.

Unit	Estimated Acres
920 control	7
920 daylight/lop/scatter	10
920 daylight/underburn	19
955 control	6
955 daylight/lop/scatter	21
955 daylight/underburn	12

Detailed descriptions of the four treatments are as follows (Figure 3):

- **1A – Control**: Nothing will be done in this area. It will be used to monitor changes without disturbance.
- **2A -- Daylight/lop/scatter**. Cut conifers of all species except whitebark pine from within 15 feet of whitebark pine trees that are over 5 feet tall, have a live top, and have a generally good growth form (vertical, relatively straight stem, low amount of blister rust) in Unit 950 and over 2 feet tall with live top and generally good form (vertical, relatively straight stem, low amount of blister rust) on unit 920. Many of these trees will be identified by RMRS scientists on various site visits. No whitebark pine tree, regardless

of size, will be slashed. This activity will result in some areas that are completely converted to whitebark pine and other areas where the whitebark pine trees will have a 15 foot clearing between them but the daylighted openings will be intermixed with thick patches of other species (955) or well-stocked lodgepole pine (unit 920). Where possible, we will drop trees away from the selected whitebark pine trees to reduce fuel buildup immediately below the daylighted trees. Slashing will be done in August and September to allow slashed material to dry to discourage producing damaging populations of *Ips* beetles. All slash will be lopped and scattered where limbs will be cut to reduce fuel depth to less than 2 feet and buck stems to less than 6 feet long to encourage drying to reduce *Ips* beetle habitat.

- **2B -- Daylight/ lop/scatter/underburn**. Cut conifers of all species except whitebark pine from within 15 feet of whitebark pine trees that are over 5 feet tall with live top and generally good form (vertical, relatively straight stem, low amount of blister rust) in Unit 950 and over 2 feet tall with live top and generally good form (vertical, relatively straight stem, low amount of blister rust) on unit 920. Many of these trees will be identified by RMRS scientists. No whitebark pine tree, regardless of size will be slashed. This activity will result in some areas that are completely converted to whitebark pine and other areas where the whitebark pine trees will have a 15 foot clearing between them and thick patches of other species (950, 955) or well-stocked lodgepole pine (unit 920). Where possible, drop trees away from the selected whitebark pine trees to reduce fuel buildup immediately below them. Slashing should be done in August and September to allow slashed material to dry to discourage producing damaging populations of *Ips* beetles. Slashing should occur AFTER the underburning in adjacent test areas. All slash will be lopped and scattered where limbs will be cut to reduce fuel depth to less than 2 feet and buck stems to less than 6 feet long to encourage drying to reduce *Ips* beetle habitat. We will construct a handline around the perimeter of the area to be underburned and the combined unit 920/955 underburn on Prospect Mountain.

Grouse Mountain

We propose the following treatments in the diverse area that lies in the Grouse Mountain boundaries (Figure 4):

- **Treatment 1A -** Nutcracker Openings (Unit 1): This stand consists of old ABLA, PIEN, PICO, and PIAL. Most PIAL in overstory are dead but there are some living PIAL in overstory. The understory consists of dense ABLA seedling and sapling regeneration along with scattered PIAL suppressed trees (400-800 t/a). A daylighting treatment is probably inappropriate here in that there are very few pole-sized or large trees to release with daylighting and the removal of the overstory will probably damage many of the understory PIAL seedlings and saplings. These sites should receive a treatment called "Nutcracker openings" which are basically the removal of all trees except whitebark pine in 1-5 acre patches. This district is encourage to cut as many fir and spruce trees in this area as possible, even in the understory, and pile and burn the slash. Lodgepole can be left in the overstory but can also be cut if desired.
- **Treatment 2A -** Mid-Seral Daylighting (Unit 3): These stands can be younger than the late seral and are composed of PIAL mixed with ABLA, PICO that are dying or dead. However, the few

living PIAL poles or young trees could be daylighted successfully. A daylighting treatment involves cutting all trees around a target PIAL tree (except for whitebark pine).

- **Treatment 2B -** Clearcut daylighting (Unit A): Clearcuts in the 1970s have sapling PICO trees ranging from 9-25 feet tall. These clearcuts were planted to PICO but there are some thrifty volunteer PIAL saplings that are scattered throughout. We propose daylighting around these PIAL saplings where we will cut all trees within 30 feet of the target PIAL tree to remove competition and reduce fire hazard.
- **Treatment 3A** – Prescribed burning (Unit 2). This unit will be burned using strip headfires to remove subalpine fir and spruce and enhance whitebark pine. It is suggested but not critical, that a slashing treatment be implemented before the burn to increase surface fuels, widen the prescribed burning window, and increase connectivity of surface fuels.
- **Treatment 4A -** Subalpine meadow planting (Unit 11): The slopes of Grouse Mtn are littered with dead/dying whitebark pine with a small mix of ABLA. It will be difficult to mechanically cut or Rx burn these stands without considerable risk in cost and fire danger. These dying stands should be planted to rust-resistant PIAL as a treatment.
- **Treatment 5A -** Control (Unit 6). These stands will not be treated and will be monitored for unplanned effects.

While it is not formally part of the study (except for Treatment 4A), planning putative rust resistant PIAL seedlings is strongly suggested if the monitoring of whitebark pine regeneration proves that little regeneration is being established.

Mink Peak

Again, treatment objectives are to release and to weed whitebark pine saplings to encourage growth, survival, and development to cone-producing age by removing competition and reducing risk of stand-replacing wildfire. One stand is being treated and it is identified in the Cedar Thom EIS as unit 950 (Figure 5). Objectives of the underburn is to: (1) in the daylighted area, reduce surface fuels under 3" diameter tonnage by at least 50 percent on more than 70 percent of the area well distributed across the area, (2) in the underburn-only area, reduce subalpine fir and other conifer competition to the whitebark pine (3) in both areas, limit complete duff reduction (mineral soil exposure) to less than 15 percent of the area, (4) limit mortality of selected whitebark pine saplings (described above) to less than 40 percent, although up to 80 percent mortality is acceptable if that is the only way to get the burn done in a timely and effective manner, and (5) provide habitat for regeneration of whitebark by nutcrackers.

Unit	Estimated Acres
950 control	23
950 daylight/lop/scatter	27
950 daylight/underburn	17
950 underburn	16

Treatments are (Figure 5):

- **1A – control**: Nothing will be done in this area. It will be used to monitor changes without disturbance.

- **2A -- Daylight/lop/scatter**. Cut and slash conifers of all species except whitebark pine from within 15 feet of whitebark pine trees that are over 5 feet tall with live top and generally good form (vertical, relatively straight stem, low amount of blister rust) in Unit 950. Many of these trees will be identified by RMRS scientists. No whitebark pine tree, regardless of size will be slashed. This activity will result in some areas that are completely converted to whitebark pine and other areas where the whitebark pine trees will have a 15 foot clearing between them and thick patches of other species. Where possible, drop trees away from the selected whitebark pine trees to reduce fuel buildup immediately below them. Slashing should be done in August and September to allow slashed material to dry to discourage producing damaging populations of *Ips* beetles. Slashing should occur AFTER the underburning in adjacent test areas. All slash will be lopped and scattered where limbs will be cut to reduce fuel depth to less than 2 feet and buck stems to less than 6 feet long to encourage drying to reduce *Ips* beetle habitat.
- **2B -- Daylight/ lop/scatter/underburn**. Cut and slash conifers of all species except whitebark pine from within 15 feet of whitebark pine trees that are over 5 feet tall with live top and generally good form (vertical, relatively straight stem, low amount of blister rust). Many of these trees will be identified by RMRS scientists. No whitebark pine tree, regardless of size will be slashed. This activity will result in some areas that are completely converted to whitebark pine and other areas where the whitebark pine trees will have a 15 foot clearing between them and thick patches of other species. Where possible, drop trees away from the selected whitebark pine trees to reduce fuel buildup immediately below them. Slashing should be done in August and September to allow slashed material to dry to discourage producing damaging populations of *Ips* beetles. Slashing should occur AFTER the underburning in adjacent test areas. All slash will be lopped and scattered where limbs will be cut to reduce fuel depth to less than 2 feet and buck stems to less than 6 feet long to encourage drying to reduce *Ips* beetle habitat. We will construct a handline around the perimeter of the area to be underburned.
- **3B Underburn**. We will underburn this unit with a light prescribed burn with the primary emphasis on torching competing conifers and a secondary emphasis on reducing natural surface fuels. No cutting will be done in this unit.

Field Methods

The field methods used in this study are mostly the same as those used for the RWPE study that are documented in detail in Keane and Parsons (2010a, 2010b) so results can be compared across studies. Insufficient area and heterogeneous stand conditions preclude the use of replicate block study designs (i.e., ANOVA approaches). So, a "case study" or “demonstration” approach will be initiated using a design that compares treatment area differences from many sampled macroplots with nested microplots using regression analysis. Treatment implementation by study area is detailed below.

We will install 10 plots within each treatment unit to describe changes in ecological conditions within each unit. We will systematically establish these plots across the treatment units based on fixed distances and compass bearings. We will not randomly locate plots because of the highly variable treatment unit shapes, diverse fuel conditions, and concerns for finding and relocating plots, so we will establish plots using a systematic design with a random start. All plots will be mapped using compass bearings and distances from benchmarks (flagged or blazed trees) and the UTM coordinates and zone will be recorded for each plot using a GPS. A list of all equipment is presented in Appendix A.

Plots will be circular in shape and 0.1 acre (0.04 ha) in size and they will be permanently located using 3 ft (1 m) rebar driven 2 ft (0.7 m) into the ground (Figure 6). A metal tag will be wired to the rebar identifying the treatment unit and plot number. All trees greater than 4.5 inches (12 cm) DBH (Diameter Breast Height) will be 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 will measure species, DBH, tree height, height to crown base, and health (live, sick, dying, or dead) for each tree and then record the percent crown volume killed by blister rust for all whitebark pine trees. The same characteristics will be measured for all live trees less than 4.5 inches DBH and higher than 4.5 ft tall (1.37 m) with DBH will be estimated to 1 inch (2.5 cm) diameter classes. Tree seedlings (trees less than 4.5 ft) will be counted by 1 ft (0.3 m) height classes on a 1/300 ac circular plot in the middle of the 1/10 ac plot using the same plot center.

Surface fuels will be measured on two 50 ft (15.2 m) transects that originate at the plot center rebar and extend in opposite directions (Figure 6). The two transects (A and B) will be oriented north and south for plots 1, 4, 7, and 10, and then at the azimuths 60 and 240 degrees for plots 2, 5, and 8 and azimuths 120 and 300 degrees for plots 3, 6, and 9 within a unit (Brown 1974). The end of the transects (50 ft mark) will be permanently established using a 10-inch nail driven into the ground so only the nail head will be visible. Another 10-inch nail will be driven into the ground at 37.2 ft to aid in transect relocation and to identify the outside of the macroplot. We tie wire flags and orange flagging around the nails to help in relocation. Fine woody fuels (1 hr = <0.25 inches diameter and 10 hr = 0.25-1.0 inches diameter) intersects will be counted along the first 6 ft (2 meters) of the A and B transects; small branchwood (100 hr = 1 to 3 inches diameter) intersects will be counted along the first 10 ft (3 meters); and logs (1000 hr = greater than 3 in or 7.6 cm diameter) diameters and decay classes will be measured for any log that intersect the entire 50 ft (15.2 meters). Duff and litter depths will be measured at the zero, 37.2, and 50 ft distances along each of the two transects. Log diameters will be always measured in order from the zero end of the tape (plot center) to the 50 ft mark so we can track any newly fallen log material.

We will visually estimate 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 (Figure 6) using 12 cover classes defined by the following ranges in percent: <1, 1 to 5, 5 to 15, 15 to 25, up to 95-100 (see FIREMON for details in Lutes and others 2006). We will also record the heights and two crown widths of all shrubs greater than 3.3 ft (1 m) tall. Ground cover for rock, bare soil, wood, duff+litter, and moss will be also recorded for each microplot using the same cover classes (Lutes and others 2006). Microplots will be permanently established by driving 8-inch stainless steel nails into the ground until only the nail head will be visible at the microplot corners shown in Figure 6. We will paint the nail heads orange and tie flagging around the nails to aid in relocation. Nails will be relocated during future measurements using a metal detector and re-flagged after each measurement.

We will take 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 will receive two or more treatments (cutting and prescribed burn, for example) and on these we will measure all characteristics detailed above after each treatment will be implemented. We also estimate the percent of the plot burned by the prescribed fire and documented any other disturbances observed at the plot (mountain pine beetles, *Ips* beetles, for example). We will take photographs of the plot looking north and east from plot center at each of the measurement times. Lastly, we will indirectly measure LAI (leaf area index) on each plot using the LiCor LAI-2000 instrument (Welles and Norman 1991).

Fuel moisture samples will be collected for each fuel component (1, 10, 100, and 1000 hr, shrub and herbaceous) at the start of any prescribed burn just outside each plot (see Appendix C). We will sample 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) fuels will be cut and stored in sealable plastic bags. Logs (1000 hr) will be 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 will be labeled with plot number, date, sample type, and study site. Samples will be 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 will be placed into aluminum pie pans and dried for 48 to 72 hrs at 80^{o}C, then weighed again to determine moisture content. During the prescribed burn we will take hourly measurements of temperature, relative humidity, wind speed and direction, and percent cloudiness.

All data will be recorded on Rite-in-the-rain paper forms that are presented in Appendix B.

Analysis

Field data will be entered into the computer in spreadsheets with the data management format presented in Appendix D. These data will be entered, then checked for errors by re-entry of the data or checking the data from the last entered to the first entered. All data will be checked for anomalous values and a complete metadata form will be completed using Metavist prior to data entry.

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

Tree mortality will be computed as a percent killed by species for three size classes: (1) seedlings (less than 4.5 ft in height), saplings (less than 4.5 inches DBH), and overstory (greater than 4.5 inches DBH). We will also include an analysis of snags which are trees greater than 4.5 inches DBH that will be dead at the time of measurement. Fuel loadings will be computed from the planar intercept counts using the computations described by Brown (1974). Plant volume estimates will be 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.

SAFETY

The field portion of this project may be somewhat dangerous for field crews. We plan to conduct daily safety sessions to remind crews of dangers in sampling surface fuels and trees. The crews will be given extensive training and the state-of-the-art safety equipment to complete their tasks. Windy days when the crowns are swaying will also pose a significant risk to the crews because of potential snag fall, so sampling may be curtailed during these days. This is especially true during thunderstorms when wind AND lightning are problems. Crews will be informed of the proper procedures to report accidents and we will train some crew members in first aid in case of an accident. This project will also require endless hours of driving to field sites on unimproved roads under poor driving conditions so the proper precautions will be taken to ensure no automobile accidents including defensive driving.

Three areas of concern are evident:
(1) Driving hazards. Prospect Mtn and Mink Peak study sites are about 65 miles west of Missoula and Grouse Mountain is over 6 hours from Missoula, MT. Seat belts are to be worn when the vehicle is operating. Defensive driving must be emphasized including reducing driver fatigue. Constant concern for other vehicular traffic must be exercised on single-lane roads. Other study areas are nearer to Missoula and same precautions will be taken.
(2) On-Site safety. These sites will have considerable slash and debris on the ground; also, live or dead branches reach the ground. Sturdy boots, hard hats and safety eyewear will reduce the possibility of injury from these hazards. Special care will be used to identify possible snag hazards and minimize the risk of snag injury by positioning sampling outside snag fall zone if possible.
(3) Fire hazards -- All personnel working during prescribed burns will be required to have a red card.

PROJECT SCHEDULE

This study will take over 15 years to finish. We will start sampling in 2011 and continue sampling until all plots have received a 15 year post-burn measurement. We would like to treat all sites by winter of 2013 and burn all sites by 2014. All fieldwork will be done during July and August of the following years. There will be an additional six months of analyses, report writing, manuscript preparation, and review.

PERSONNEL

Dr. Robert Keane has extensive experience in ecological modeling and conducting large ecological field studies, specializing in whitebark pine ecosystems. Dr. Keane will support the project through his expertise in whitebark pine ecology, ecological restoration, fuels sampling, and botanical identification. His is primarily responsible for the field sampling design and analysis of the ecological measurements. He will also write the various programs specified in this study plan.

BUDGET

The budget for this project is impossible to estimate because the study will last well over 15 years. However, the table below specifies some resources that will be needed for each year of the study.

ITEM	PER YEAR
Keane salary	4 PP
Technician*	12 PP
Field equipment	$1000
Travel	$2000
Publications	$100

* Technician is pay periods needed for a crew of four to perform field measurements

DELIVERABLES

This project will result in several products that will be useful to managers in any agency with responsibility for fire management in upper elevation conifer forests. Excepting the normal publication delays, all deliverables will be available at the conclusion of the study.

- A journal article describing the results of this study published in Ecological Restoration.
- A USDA Forest Service GTR that describes the treatments and their effects.

TECHNOLOGY TRANSFER

These demonstration studies will produce publications describing both research findings and applications for ecosystem management. It will also be used to demonstrate management that can benefit some high-elevation ecosystems where timber production is not a management objective. Information gathered from this study will aid in restoring these valuable high mountain ecosystems. Research results will also be used to parameterize and initialize simulation models to further investigate the effects of anthropomorphic disturbance on whitebark pine ecosystems.

Technology transfer will include:

- The teaching of the study results to forest managers.
- The USFS General Technical Report describing the treatment effects
- Publication of journal article

REFERENCES

Agee, J. K. and L. Smith. 1984. Subalpine tree reestablishment after fire in the Olympic Mountains, Washington. Ecology **65**:810-819.

Arno, S., Elizabeth Reinhardt, and J. Scott. 1993. Forest structure and landscape patterns in the subalpine lodgepole pine type: A procedure for quantifying past and present conditions. USDA Forest Service Intermountain Research Station General Technical Report INT-294. 88 pages.

Arno, S. F. 1986. Whitebark pine cone crops a diminishing source of wildlife food. Western Journal of Applied Forestry. **9**:92-94.

Arno, S. F. and R. Hoff. 1990. *Pinus albicaulis* Engelm. Whitebark Pine. Pages 268-279 In: Silvics of North America. Vol. I. Conifers. Agr. Handbook. USDA For. Service.

Arno, S. F., D. J. Parsons, and R. E. Keane. 2000. Mixed-severity fire regimes in the northern Rocky Mountains: consequences of fire exclusion and options for the future. Pages 225-232 In: Wilderness science in a time of change conference, Volume 5: wilderness ecosystems, threat, and management, Missoula, Montana, May 23-27, 1999. U.S. Dept. of Agriculture Forest Service Rocky Mountain Research Station General Technical Report RMRS-P-15-VOL-3. Ft Collins CO.

.Arno, S. F., D. F. Tomback, and R. E. Keane. 2001. Whitebark pine restoration: a model for wildland communities. Pages 416-419 In: D.F. Tomback, S.F. Arno, and R.E. Keane (editors): Whitebark pine communities: ecology and restoration. Island Press, Washington D.C.

Arno, S. F. and T. Weaver. 1990. Whitebark pine community types and their patterns on the landscape. Pages 118-130 In: Schmidt W.C. and K. MacDonald (Compilers) Proceedings -- Symposium on Whitebark Pine Ecosystems: Ecology and management of a high mountain resource. USDA Forest Service Intermountain Research Station General Technical Report INT-270. Bozeman, MT., USA. Ogden, UT.

Aubry, C., D. Goheen, R. Shoal, T. Ohlson, T. Lorenz, A. Bower, C. Mehmel, and R. A. Sniezko. 2008. Whitebark pine restoration strategy for the Pacific Northwest 2009-2013. Region 6 Report, U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Portland, OR.

Baker, K. M. and D. L. Six. 2001. Restoring whitebark pine (Pinus albicaulis) ecosystems: a look at endemic bark beetle distribution. Pages 501-502 *in* Society of American Foresters 2000 National Convention. Society of American Foresters, Bethesda, Maryland, Washington DC USA.

Blaustein, A. R. and A. Dobson. 2006. Extinctions: A message from the frogs. Nature **439**:143-144.

Brown, J. K. 1974. Handbook for inventorying downed woody material. USDA Forest Service, Intermountain Forest and Range Experiment Station General Technical Report GTR-INT-16. Ogden, UT, USA. 28 pages.

Brown, J. K. 1981. Bulk densities of non-uniform surface fuels and their application to fire modeling. Forest Science **27**:667-683.

Brown, J. K. and P. J. Roussopoulos. 1974. Eliminating biases in the planar intersect method for estimating volumes of small fuels. Forest Science **20**:350-356.

Chew, J. D. 1990. Timber management and target stands in the whitebark pine zone. Pages 211-223 In: Schmidt W.C. and K. MacDonald (Compilers) Proceedings -- Symposium on

Whitebark Pine Ecosystems: Ecology and management of a high mountain resource. USDA Forest Service Intermountain Research Station General Technical Report INT-270. Ogden, Utah, USA.
Cole, D. N. 1990. Recreation in whitebark pine ecosystesm: demand, problems, and management strategies. Pages 305-310 *in* Proceedings--Symposium on whitebark pine ecosystems: Ecology and management of a high-mountain resource. USDA Forest Service, Intermountain Research Station, Bozeman, MT USA.
Day, R. J. 1967. Whitebark pine in the Rocky Mountains of Alberta. Forestry Chronicle **43**:278-282.
Eggers, D. E. 1990. Silvicultural management alternatives for whitebark pine. Pages 324-328 *in* Symposium on whitebark pine ecosystems: Ecology and management of a high-mountain resource. USDA Forest Service Intermountain Research Station General Technical Report INT-270. Ogden, Utah, USA.
Ferner, J. W. 1974. Habitat relationships of *Tamiasciurus hudsonicus* and *Sciurus aberti* in the Rocky Mountains. Southwest Naturalist. **18**:470-473.
Hann, W. J. 1990. Landscape and ecosystem-level management in whitebark pine ecosystems. Pages 290-299 In: Schmidt W.C. and K. MacDonald (Compilers) Proceedings --Symposium on Whitebark Pine Ecosystems: Ecology and management of a high mountain resource. USDA Forest Service Intermountain Research Station General Technical Report INT-270. Ogden, UT.
Hoff, R., R. T. Bingham, and G. I. McDonald. 1980. Relative blister rust resistance of white pines. Eur. J. For. Path. **10**:307-316.
Hoff, R. J., D. E. Ferguson, G. I. McDonald, and R. E. Keane. 2001. Strategies for managing whitebark pine in the presence of white pine blister rust. Pages 346-366 In: D.F. Tomback, S.F. Arno, and R.E. Keane (editors): Whitebark pine communities: ecology and restoration. Washington D.C: Island Press c2001.
Hurlbert, S. H. 1984. Pseudoreplication and the design of ecological field experiements. Ecological Monographs **54**:187-211.
Hutchins, H. E. 1994. Role of various animals in dispersal and establishment of whitebark pine in the Rocky Mountains, U.S.A. General Technical Report INT-GTR-309, U.S. Department of Agriculture, Forest Service, Intermountain Research Station Ogden,UT., USA, St. Moritz, Switzerland.
Hutchins, H. E. and R. M. Lanner. 1982. The central role of Clark's nutcrackers in the dispersal and establishment of whitebark pine. Oecologia **55**:192-201.
Keane, R. E. 2000. The importance of wilderness to whitebark pine research and management. Pages 84-93 *in* Proceedings of the symposium: Wilderness Science: In a time for change. Volume 3: Wilderness as a Place for Scientific Inquiry. USDA Forest Service General Technical Report RMRS-P-15-VOL-3, Missoula, MT USA.
Keane, R. E. 2001. Successional dynamics: modeling an anthropogenic threat. Pages 159-192. *in* D. Tomback, S. Arno, and R. Keane, editors. Whitebark pine communities: ecology and restoration. Island Press, Washington DC, USA.
Keane, R. E. and S. F. Arno. 1993. Rapid decline of whitebark pine in Western Montana: Evidence from 20-year remeasurements. Western Journal of Applied Forestry **8**:44-47.
Keane, R. E. and S. F. Arno. 1996. Whitebark pine (Pinus albicaulis) ecosystem restoration in western Montana. Pages 51-54 *in* The use of fire in forest restoration-- a general session

at the annual meeting of the Society of Ecosystem Restoration "Taking a broader view". USDA Forest Service General Technical Report INT-GTR-341, Seattle, WA USA.

Keane, R. E. and S. F. Arno. 2000. Restoration of whitebark pine ecosystems in western Montana and central Idaho. Pages 324-330 In: Proceedings of the Society of American Foresters 1999 national convention, Portland, Oregon, September 11-15, 1999. Bethesda MD: Society of American Foresters c2000.

Keane, R. E. and S. F. Arno. 2001. Restoration concepts and techniques. Pages 367-400 In: Tomback, D.F., Arno, S.F. and Keane, R.E. (Editors): Whitebark pine communities : ecology and restoration. Washington D.C: Island Press c2001.

Keane, R. E., S. F. Arno, and C. A. Stewart. 2000. Ecosystem-based management in the whitebark pine zone. Pages 36-40 *in* The Bitterroot Ecosystem Management Research Project : what we have learned : symposium proceedings, Missoula, Montana, May 18-20, 1999. Fort Collins CO: U.S. Dept. of Agriculture Forest Service Rocky Mountain Research Station 2000.

Keane, R. E., K. L. Gray, and L. J. Dickinson. 2007. Whitebark pine diameter growth response to removal of competition. U.S. Department of Agriculture, Forest Service Rocky Mountain Research Station Research Note RMRS-RN-32. Ogden, UT.

Keane, R. E., P. Morgan, and J. P. Menakis. 1994. Landscape assessment of the decline of whitebark pine (Pinus albicaulis) in the Bob Marshall Wilderness Complex, Montana, USA. Northwest Science **68**:213-229.

Keane, R. E. and R. Parsons. 2010a. Restoring whitebark pine forests of the northern Rocky Mountains, USA Ecological Restoration 28:56-70.

Keane, R. E. and R. A. Parsons. 2010b. A management guide to ecosystem restoration treatments: the whitebark pine forests of the Northern Rocky Mountains. General Technical Report RMRS-GTR-232, USDA Forest Service Rocky Mountain Research Station, Fort Collins, CO.

Keane, R. E., S.F. Arno, and C. Stewart. 1996. Restoration of upper subalpine whitebark pine ecosystems in western Montana. Pages 31-26 *in* Proceedings of the 43 annual Western International Forest Disease Work Conference. Society of American Foresters, Bethesda, MD, USA., Whitefish, Montana, USA.

Kendall, K. and R. E. Keane. 2001a. The decline of whitebark pine. Pages 123-145 *in* D. Tomback, S. F. Arno, and R. E. Keane, editors. Whitebark pine communities: Ecology and Restoration. Island Press, Washington DC, USA.

Kendall, K. C. and S. F. Arno. 1990. Whitebark pine: an important but endangered wildlife resource. Pages 29-36 In: Schmidt W.C. and K. MacDonald (Compilers) Proceedings -- Symposium on Whitebark Pine Ecosystems: Ecology and management of a high mountain resource. USDA Forest Service Intermountain Research Station General Technical Report INT-270. Ogden, UT.

Kendall, K. C. and R. E. Keane. 2001b. Whitebark pine decline: infection, mortality, and population trends. Pages 221-242 In: Tomback, D.F., Arno, S.F. and Keane, R.E. (Editors): Whitebark pine communities : ecology and restoration. Washington D.C: Island Press c2001.

Lanner, R. M. 1996. Made for each other: A symbiosis of birds and pines. Oxford University Press, New York, New York, USA.

Logan, J. A. and J. A. Powell. 2001. Ghost forests, global warming, and the mountain pine beetle (*Coleoptera: Scolytidae*). American Entomologist **47**:160-173.

Lorenz, T. J., C. Aubry, and R. Shoal. 2008. A review of the literature on seed fate in whitebark pine and the life history traits of Clark's Nutcracker and pine squirrels. USDA Forest Service Pacific Northwest Research Station General Technical Report PNW-GTR-742. Portland, OR.

Lutes, D. C., R. E. Keane, J. F. Caratti, C. H. Key, N. C. Benson, S. Sutherland, and L. J. Gangi. 2006. FIREMON: Fire effects monitoring and inventory system. USDA Forest Service Rocky Mountain Research Station General Technical Report RMRS-GTR-164-CD. Fort Collins, CO USA.

Mattson, D. J., B. M. Blanchard, and R. R. Knight. 1991. Food habits of Yellowstone grizzly bears, 1977-1987. Can. J. Zool. **69**:1619-1629.

Mattson, D. J. and D. P. Reinhart. 1990. Whitebark pine on the Mount Washburn Massif, Yellowstone National Park. Pages 106-117 *in* Schmidt W.C. and K. MacDonald (Compilers) Proceedings -- Symposium on Whitebark Pine Ecosystems: Ecology and management of a high mountain resource. USDA Forest Service Intermountain Research Station General Technical Report INT-270. Ogden, UT

Mattson, D. J. and D. P. Reinhart. 1997. Excavation of red squirrel middens by grizzly bears in the whitebark pine zone. Journal of Applied Ecology **34**:926-940.

McCaughey, W. W., W. C. Schmidt, and R. C. Shearer. 1985. Seed-dispersal characteristics of conifers in the inland mountain west.*in* Proceedings from the Conifer Tree Seed in the Inland Mountain West Symposium, Missoula, MT.

McCaughey, W. W. and T. Weaver. 1990. Biotic and microsite factors affecting whitebark pine establishment. Pages 319-324 In: Schmidt W.C. and K. MacDonald (Compilers) Proceedings -- Symposium on Whitebark Pine Ecosystems: Ecology and management of a high mountain resource. USDA Forest Service Intermountain Research Station General Technical Report INT-270. Ogden, UT

McKinney, S. T. and D. F. Tomback. 2007. The influence of white pine blister rust on seed dispersal in whitebark pine. Canadian Journal of Forest Research **37**:1044-1057.

Mills, L. S., M.E. Soule, and D. F. Doak. 1993. The keystone-species concept in ecology and conservation. Bioscience **43**:219-224.

Minore, D. 1979. Comparative autecological characteristics of northwestern tree species: a literature review. General Technical Report PNW-87, U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, OR., USA.

Morgan, P. and S. C. Bunting. 1989. Whitebark pine: Fire ecology and management. Women in Natural Resources **11**:52.

Morgan, P. and S. C. Bunting. 1990. Fire effects in whitebark pine forests. Pages 319-324 In: Schmidt W.C. and K. MacDonald (Compilers) Proceedings -- Symposium on Whitebark Pine Ecosystems: Ecology and management of a high mountain resource. USDA Forest Service Intermountain Research Station General Technical Report INT-270. Ogden, UT

Morgan, P., S.C. Bunting, Robert E. Keane, and S. F. Arno. 1994. Fire ecology of whitebark pine (Pinus albicaulis) forests in the Rocky Mountains, USA. Pages 136-142 *in* Proceedings of the international symposium Subalpine stone pines and their environment: The status of our knowledge, St. Moritz, Switzerland.

Munger, B. S. 1993. High country archaeology in the Bitterroot Mountains. Archaeology in Montana **34**:1-6.

Murray, M. P. 1996. Landscape dynamics of an island range: Interrelationships of fire and whitebark pine (Pinus albicaulis). Ph.D. Dissertation. University of Idaho, Moscow, ID., USA.

Murray, M. P. 2008. Fires in the high Cascades: new findings for managing whitebark pine. Fire Management Today **68**:26-29.

Murray, M. P., S. C. Bunting, and P. Morgan. 1998. Fire history of an isolated subalpine mountain range of the intermountain region, United States. Journal of Biogeography **25**:1071-1080.

Murray, M. P., S.C. Bunting, and P. Morgan. 1995. Whitebark pine and fire suppression in small wilderness areas. General Technical Report INT-GTR-320, U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Ogden, UT., USA, Missoula, MT., USA.

Norment, C. J. 1991. Bird use of forest patches in the subalpine forest-alpine tundra ecotone of the Beartooth Mountains, Wyoming. Northwest Science **65**:2-9.

Pfister, R. D., B. L. Kovalchik, S. F. Arno, and R. C. Presby. 1977. Forest habitat types of Montana. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station General Technical Report INT-34. Ogden, UT., USA.

Reinhardt, E. D. and K. C. Ryan. 1988. How to estimate tree mortality resulting from underburning. Fire Management Notes **49**:30-36.

Running, S. W. 2006. Is global warming causing more, larger wildfires. Science **313**:927-928.

Ryan, K. C. and E. D. Reinhardt. 1988. Predicting postfire mortality of seven western conifers. Canadian Journal of Forest Research **18**:1291-1297.

Scott, G. L. and W. W. McCaughey. 2006. Whitebark pine guidelines for planting prescriptions. Pages 84-90 *in* National proceedings: Forest and Conservation Nursery Associations--2005. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Tomback, D. F., S. F. Arno, and R. E. Keane. 2001. Whitebark pine communities: Ecology and Restoration. Island Press, Washington DC, USA.

Tomback, D. F. 1982. Dispersal of whitebark pine seeds by Clark's nutcracker: a mutualism hypothesis. J. of Animal Ecol. **51**:451-467.

Tomback, D. F. 1986. Post-fire regeneration of krummholz whitebark pine: a consequence of nutcracker seed caching. Madrono **33**:100-110.

Tomback, D. F. 1998. Clark's Nutcracker.*in* A. Poole and F. Gill, editors. The Birds of North America No. 331. The Birds of North America Inc.

Tomback, D. F. 2005. The impact of seed dispersal by the Clark's Nutcracker on whitebark pine: Multi-scale perspective on a high mountain mutualism. Pages 181-201 *in* G. Broll and B. Kepline, editors. Mountain Ecosystems: Studies in treeline ecology. Springer.

Tomback, D. F., L.A. Hoffman, and S. K. Sund. 1990. Coevolution of whitebark pine and nutcrackers: Implications for forest regeneration. Pages 118-130 In: Schmidt W.C. and K. MacDonald (Compilers) Proceedings -- Symposium on Whitebark Pine Ecosystems: Ecology and management of a high mountain resource. USDA Forest Service Intermountain Research Station General Technical Report INT-270. Ogden, UT

Tomback, D. F., S.K. Sund, and L. A. Hoffman. 1993. Post-fire regeneration of Pinus albicaulis: height-age relationships, age structure, and microsite characteristics. Canadian Journal of Forest Research **23**:113-119.

Waring, K. M. and D. L. Six. 2005. Distribution of bark beetle attacks after whitebark pine restoration treatments: a case study. Western Journal of Applied Forestry **20**:110-116.

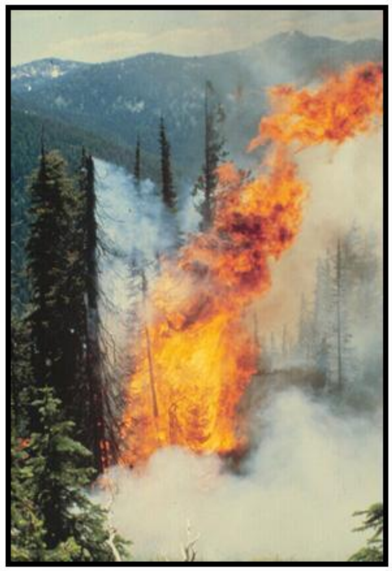
FIGURES

Figure 1. Declining whitebark pine forest on the Clearwater National Forest, Idaho

Figure 2. The three types of fire regimes often found in whitebark pine forests.

a) Non-lethal surface fire

b) Mixed severity fires



c) Stand-replacement fires

Figure 3. Prospect Mountain study site with treatment stands.

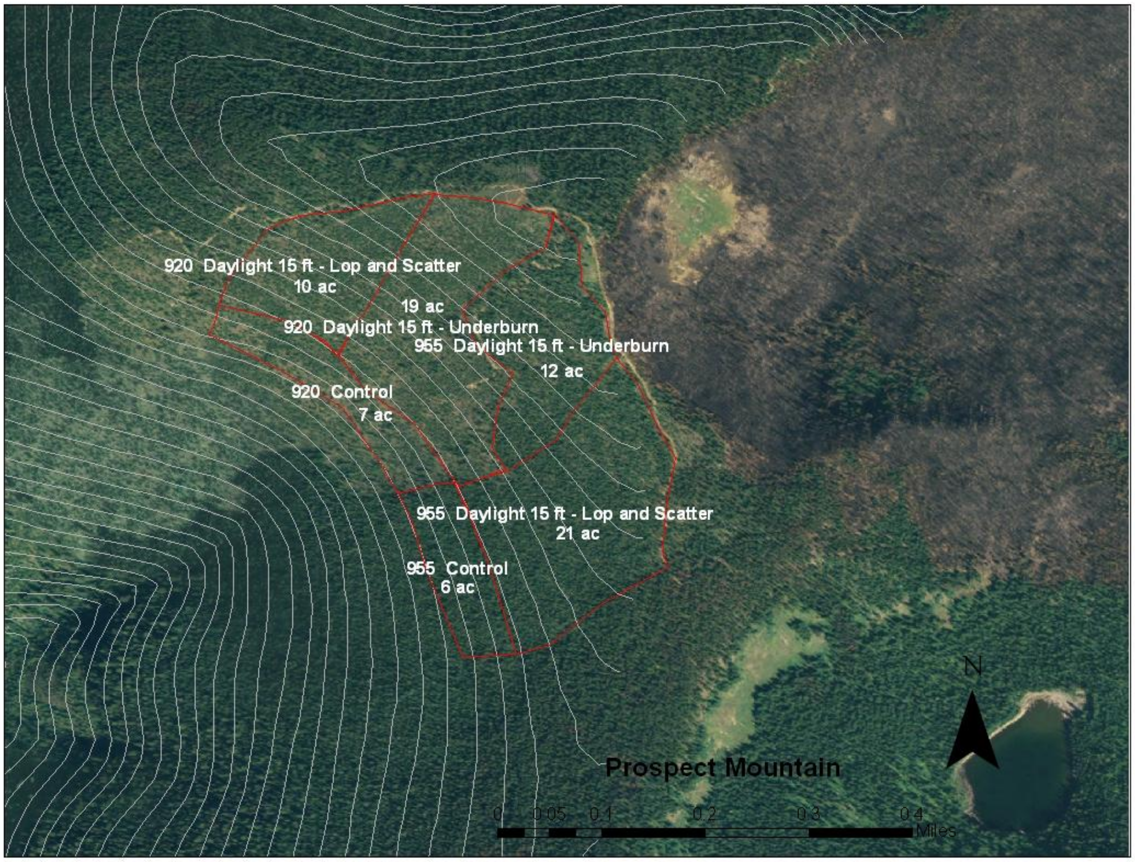


Figure 4. Grouse Mountain treatment areas.

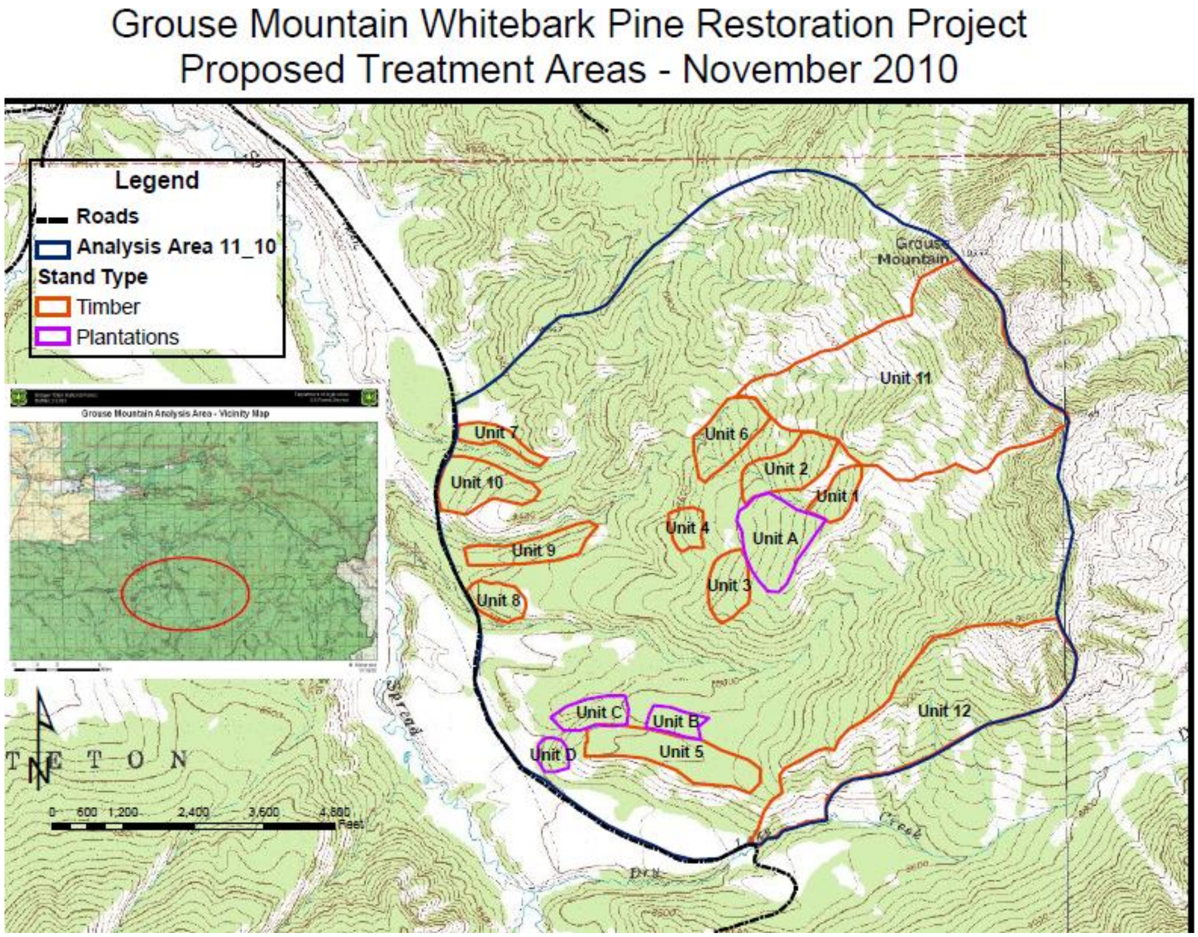


Figure 5. Mink Peak treatment areas.

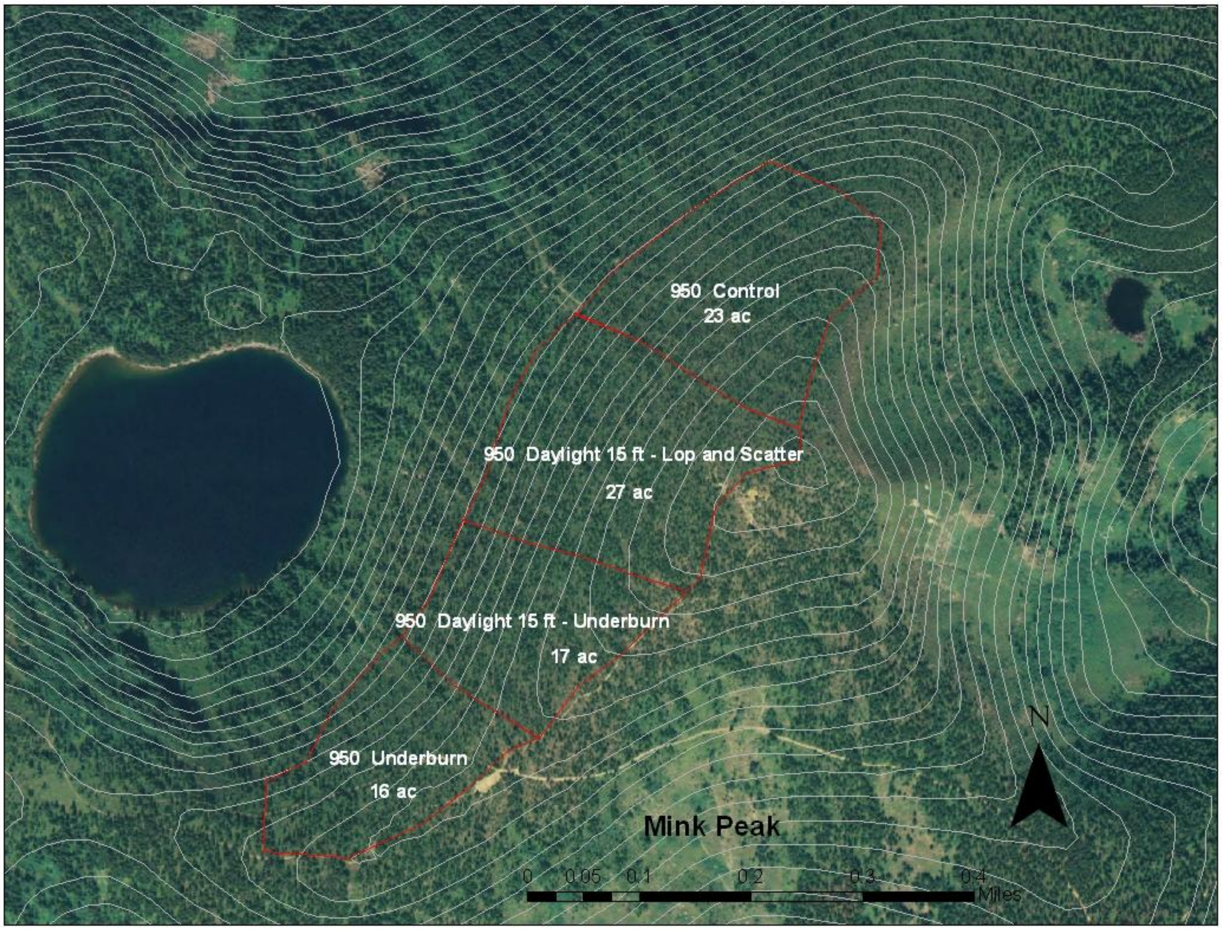
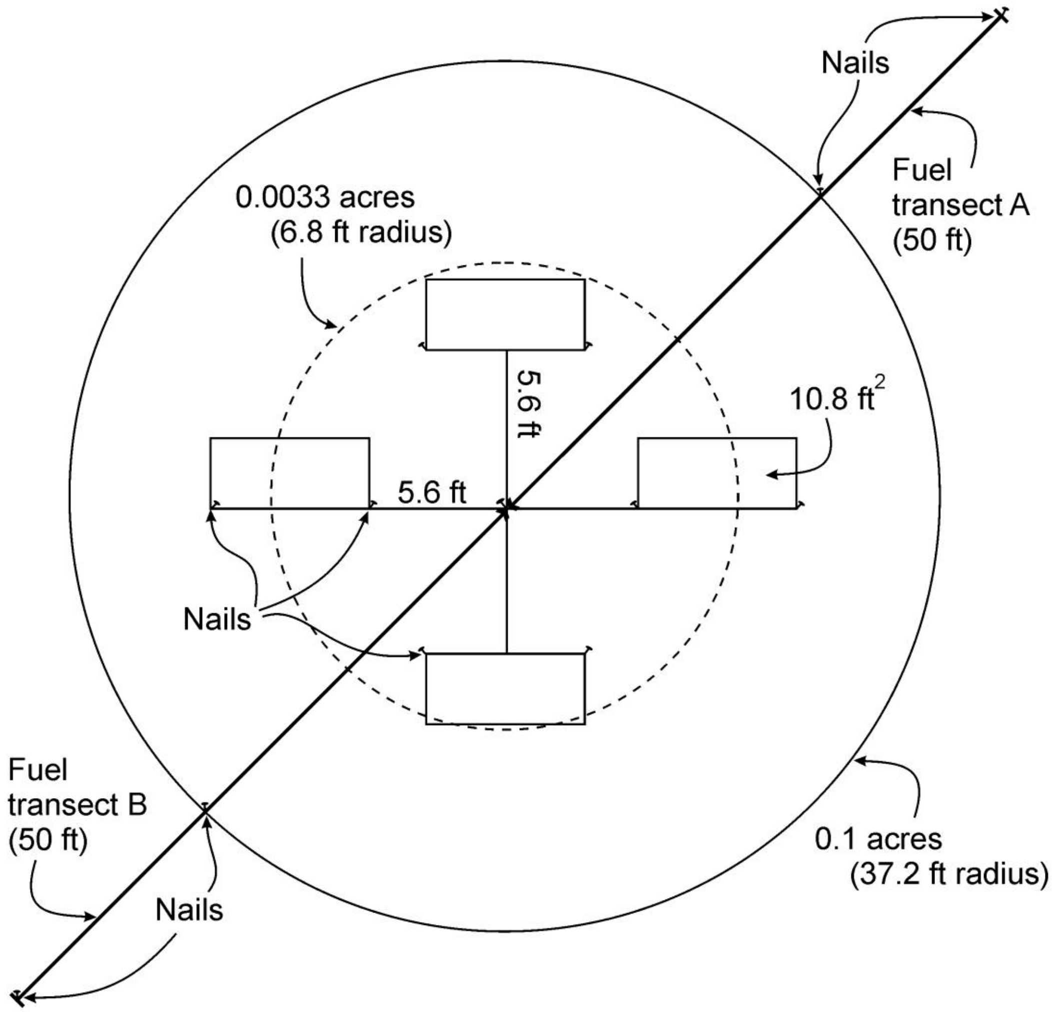


Figure 6. Plot layout for sampling trees, vascular plant cover, and fuels.



APPENDIX A
Equipment list

Plot setup

- Compass
- Clinometer
- Logger’s tape (DBH tape)
- GPS unit
- Flagging
- Pencils, field notebook
- Field sheets
- 3 foot Rebar
- Caps for rebar
- 12 inch spikes for fuel transects
- Wire flagging
- Orange flagging for nails
- Yellow flagging for plot boundaries
- Cloth tapes at least 25 meters long
- Go-no-go gauges
- Tree tags: aluminum and steel
- Tree tag nails
- Hammer, Hatchet
- 3 cloth tapes at least 75 feet long
- Microplot frame
- Duff litter measuring probe (nail)
- Clear plastic ruler
- Metal detector
- 8 in nails for veg plots
- LiCor LAI-2000

Photos

- 1 camera
- 1 range pole for center

Field Sheets

- Tree data
- Fuel Data
- LAI data
- Veg canopy cover height

Safety

- Helmets
- Sunglasses, safety glasses
- Gloves
- RX burn PPE

APPENDIX B

Plot forms
(Saved in a subfolder: ..\plot_forms

APPENDIX C

Prescribed Fire Preburn Tasks

The only research measurement that must be done just prior to ignition of a whitebark pine prescribed burn is the estimation of fuel **moistures** for 1, 10, 100, 1000 sound, 1000 hr rotten, and live shrubby fuels. Fuel moisture sampling requires the following equipment.

Pruning shears	Fuel Bottles (numbered)	Sharpie
Plot sheets	Pencil	Chainsaw
Ziplock bags (gallon size)	Cooler (with ice if possible)	Large backpack or Sacks
Camera and film	Video camera and tape	Nomex clothing
Helmet	Gloves	Lunch
Water	Safety glasses	Chainsaw chaps
Weather kit		

About 3 fuel bottles and three to five ziplock bags are needed at each plot. There are 10 plots per treatment. The following is the procedure for sampling fuels. Care must be taken to ensure moisture does not escape from bottles or ziplock bags. Also, DO NOT COLLECT FUELS FROM FUEL TRANSECTS. Transects are at 0 and 180 degrees azmith on plots 1, 4, 7, and 10; 60 and 240 degrees on plots 2, 5, and 8; 120 and 300 degrees on plots 3, 6, and 9. Be careful of snags overhead and impending ignition. Only collect fuels from burn treatments. Inform district crews as IFSL activities and personnel location.

Proceed to a plot identified by a tag on a rebar sunk in the ground painted orange. Maps of plot locations are attached for reference. Pick up a handful of 1 hour fuel which is less than 0.25 inch in diameter. Place the handful in the bottle. Gather enough 1 hour fuel to fill the bottle but make sure the fuel can be removed easily. Fuel should be about as long as the bottle. Screw the cap on the bottle and record the bottle number and plot number on the attached plot sheet labeled for the appropriate fuel type (in this case 1 hour fuels), study area, and date. Sampler should have a large backpack with enough bottles to finish all plots. Repeat this procedure for 10 hour fuels (0.25-1 inch diameter) and 100 hour fuels (1 to 3 inch diameter). Now clip enough VASC or VAGL to loosely fill a ziplock bag. Record the plot number and date on the ziplock bag and store in backpack. Next, cut a cross-section from a sound and from a rotten log on or near the plot with a chainsaw. The log should be representative of the plot in both diameter and soundness. Put each cookie in its own ziplock bag and label as to plot number, date, and soundness. Be sure to tightly close ziplock and be sure it is airtight. If unsure of which log to sample, simply take more samples from a variety of log diameters and soundness. Place samples in backpack, then proceed to next plot and repeat above. Be sure to store all sampled fuels in a cold cooler for transport to the lab for weighing and drying.

If there are problems with getting the collection done in time, then only take 10 samples of each for the six fuel types (1, 10, 100, 1000 sound, 1000 rotten, live shrub). These should be taken evenly across the study area but do NOT need to be tied to plots.

Several other tasks need to be done during the burn. Temperature and relative humidity must be measured each hour and recorded in a notebook. The character of the fire must be recorded on camera film and videotape. Notes must be taken on burning method, burn characteristics, and prescribed fire problems. District crews might need help with containment. Be sure to help the District when they need it but stay out of their way when they are busy. Be sure to take copius pictures of the fire and ignition processes with both a video and film camera.

APPENDIX D

DATABASE STRUCTURE
Restoring Whitebark Pine Ecosystems: The DAYLITE Study

This describes the data format for the entry of all field data collected for the whitebark pine restoration study. Bob Keane is the principle scientist for this project and Steve Arno is an associate. There are four different databases that describe the information collected at the study sites. All files will be entered in ASCII text files. All treatments always have 10 plots. All numbers should be right justified and all alpha codes should be left justified. All alpha codes should be entered in capital letters. All data should be entered with care. It is very helpful to keep all numbers in tight columns so they can be quickly scanned for errors. Using leading zeros is often quicker that hitting the space bar. Once the data are entered they should be checked again for errors.

General Plot Data

File: PLOT.DAT

Description: Plot site and stand description is entered in this file.

Field	Symbol	Units	Description
1	SA	None	Study Area
2	DATE	None	Date of collection
3	PLOT	None	Plot ID tag
4	CT	None	Cover type of plot
5	HT	None	Habitat type of plot
6	SLOPE	Percent	Slope of plot
7	ASPECT	Azimuth	Aspect of plot
8	PIC	None	Direction of pictures (N,S,E,W)
9	LAI	m2/m2	Leaf area index of plot
10	SEL	m2/m2	Error of LAI estimate of plot

Notes:

Study area codes are as follows - G=Grouse Mountain, P=Prospect Mountain, K=Mink Peak

Collection data is entered in the international format of YYMMDD or 970721 for July 21, 1997.

Plot tags are entered without any punctuation marks, for example 1A1 or 5B10.

Cover type codes are as follows: SF=subalpine fir, WB=whitebark pine, ES=Engelmann spruce.

Habitat type codes are as follows: 1=ABLA/LUHI,VASC

Aspect and slope are taken from the tree plot sheet. LAI and SEL are taken from the field notebook. Picture directions are taken from either the fuels or tree plot sheets, and there should always be two pictures. Enter two blanks if no pictures taken.

Example of file structure:

```
B 960896 1A1 SF 1 15 340 NW 2.13 0.32
M 970809 1B2 WB 1 03 189 NW 3.24 0.97
S 950911 2B2 SF 1 23 087 SW 1.23 0.56
```

Tree Data

File: TREE.DAT

Description: Individual tree measurements collected on 0.1 acre plots (>4.5 feet tall) and 0.01 (trees > 4.5 feet tall).

Field	Symbol	Units	Description
1	SA	None	Study Area
2	DATE	None	Date of collection
3	PLOT	None	Plot ID tag
4	TNUM	None	Tree Number
5	NTREE	Trees	Number of Trees
6	STAT	None	Tree status (1-live, 0-dead, 2-stump, 3-fallen)
7	SPP	None	Species of tree
8	DBH	Inches	Tree diameter at breast height
9	LCBH	Feet	Live crown base height
10	HT	Feet	Tree height
11	COM	None	Comments

Notes:

Study area codes are as follows - G=Grouse Mountain, P=Prospect Mountain, K=Mink Peak
Collection data is entered in the international format of YYMMDD or 970721 for July 21, 1997.
Plot tags are entered without any punctuation marks, for example 1A1 or 5B10.

Tree number is the tag number attached to the tree and labeled “Tree #” in tree plot form. If no tree number is entered on form, enter the number zero in the field.

Number of trees is the number of trees having the same identical DBH, HT, LCBH, SPP attributes. These can be summarized from the plot sheet prior to entering data. This field was made for seedling data (trees<4.5 feet tall).
Tree status is identified by a zero (dead snag) or one (live tree) in the STAT field. Stumps are identified by a 2 -- See note on snags to identify a snag on the plot form. Also, if a tagged tree has fallen or disappeared then identify the status as code 3.

Species codes are as follows: WB=whitebark pine, SF=subalpine fir, DF=Douglas-fir, MH=mountain hemlock, ES=Engelmann spruce, LP=lodgepole pine. You may see AF or SA codes on plot sheets for subalpine fir and WP for whitebark pine. Be sure to use the codes above.

DBH should be entered in tenths of inches. You do not need the decimal point for whole DBH estimates.

For seedling data, enter the number zero for diameter, zero for LCBH, and the midpoint of the height class for HT (ex: 1 for 0.5 to 1.5 class). For the first height class (0-0.5 feet) enter the number zero for height. Enter the product of the number of trees (dot tally) and the number 30 in the NTREE (number of trees) field.

Snags (dead standing trees) are identified on plot forms by a dash in the LCBH column and usually (not always) a note in the comments column. Snags should be coded to zero in the STAT field and zero in the LCBH field.

Example of file structure:

```
B 960896 1A1 263 1 1 LP 8.3 28 54
B 960896 1A1   0 1 1 SF 2.0 02 09
B 960896 1A1   0 1 0 SF 3.0 00 26
B 960896 1A1 266 1 1 LP 6.5 25 42
B 960896 2A1   0 1 1 ES 1.0 03 07
B 960896 2A1   0 1 1 SF 0.0 00 03
```

File: TREEMORT.DAT

Description: Individual tree measurements of fire effects for tagged trees collected on 0.1 acre plots

Field	Symbol	Units	Description
1	SA	None	Study Area
2	DATE	None	Date of collection
3	PLOT	None	Plot ID tag
4	TNUM	None	Tree Number
5	SHT	ft	Scorch height (ft)
6	PCS	percent	Percent crown scorched (%)
7	PBS	percent	Percent diameter bole scorch (%)
8	BCHT	ft	Bole char height (ft)

Notes:

Study area codes are as follows - G=Grouse Mountain, P=Prospect Mountain, K=Mink Peak

Collection data is entered in the international format of YYMMDD or 970721 for July 21, 1997.

Plot tags are entered without any punctuation marks, for example 1A1 or 5B10.

Tree number is the tag number attached to the tree and labeled “Tree #” in tree plot form.

The number 99 was used for 100 percent crown or bark scorch

Example of file structure:

```
B 960896 1 A 1 263 15 23 12 03
B 960896 1 A 1 345 32 22 87 15
```

Vegetation Data

File: VEG.DAT

Description: Individual species cover and height measurements collected on 4, one square meter microplots per plot. Also collected was ground cover.

Field	Symbol	Units	Description
1	SA	None	Study Area
2	DATE	None	Date of collection
3	PLOT	None	Plot ID tag
4	SPP	None	Species code or ground cover code
5	COV1	Percent	Vertically projected species cover in microplot 1
6	MHT1	Feet	Average height of species in microplot 1
7	COV2	Percent	Vertically projected species cover in microplot 2
8	MHT2	Feet	Average height of species in microplot 2
9	COV3	Percent	Vertically projected species cover in microplot 3
10	MHT3	Feet	Average height of species in microplot 3
11	COV4	Percent	Vertically projected species canopy cover microplot 4
12	MHT4	Feet	Mean species height in microplot 4

Notes:

Study area codes are as follows - G=Grouse Mountain, P=Prospect Mountain, K=Mink Peak

Collection data is entered in the international format of YYMMDD or 970721 for July 21, 1997.

Plot tags are entered without any punctuation marks, for example 1A1 or 5B10.

Species codes are the 4 letter alpha codes used in past vegetation studies. You will encounter some species with six letter codes (PEDCON for Pedicularis contorta) so just condense to four letter code. Hint: it may be faster to code each species with a number and then change to alpha codes using options in the Brief editor. Ground cover codes are as follows: ROCK=rock, SOIL=gravel, soil, WOOD=woody fuel cover, DUFF=duff and litter, MOSS=moss, fungus, lichen. Enter a 00 for height for the ground cover codes.

Mean species height can be entered without the decimal but be sure to always enter the leading zero.
Species with no cover on microplot should have 00 entered for cover and 00 entered for height.

Example of file structure:

```
B 960896 1A1 VASC 40 01 60 10 40 06 70 10
B 960896 1A1 CHUM 01 04 00 00 00 00 00 00
B 960896 1A1 WOOD 10 00 40 00 10 00 10 00
B 960896 1A1 ROCK 10 00 01 00 10 00 10 00
```

Woody Fuels Data

File: FUEL.DAT

Description: Down dead wood counts and duff depths from two transects per plot.

Field	Symbol	Units	Description
1	SA	None	Study Area
2	DATE	None	Date of collection
3	PLOT	None	Plot ID tag
4	TRAN	None	Transect code (A,B)
5	SLOPE	Percent	Transect slope in percent
6	W1	Count	Down woody 1 hour fuel counts
7	W10	Count	Down woody 10 hour fuel counts
8	W100	Count	Downed woody 100 hour fuel counts
9	W1000N	Number	Number of 1000 hour logs
10	DUFFPC	cm	Duff depth at plot center
11	DUFF37	cm	Duff depth at 37.2 feet on transect
12	DUFF50	cm	Duff depth at 50 feet on transect
13	LOGD1	inches	Log 1 diameter
14	LOGC1	class	Log 1 decay class
15	LOGD2	inches	Log 2 diameter
16	LOGC2	class	Log 2 decay class
17...	LOGDN	inches	Repeat for N logs on transect

Notes:

Study area codes are as follows - G=Grouse Mountain, P=Prospect Mountain, K=Mink Peak

Collection data is entered in the international format of YYMMDD or 970721 for July 21, 1997.

Plot tags are entered without any punctuation marks, for example 1A1 or 5B10.

Be sure to count all logs and enter in the W1000N field. String the log diameters and decay class out past the duff depths. Do not worry about file width. Decay classes can be entered as single digits.

Enter duff depths in millimeters without decimal points. If some plots do not have duff depths (such as B or S), then enter blanks for that field.

Be sure you are only entering data for one transect at a time.

Example of file structure:

```
B 960896 1A1 A 01 06 00 01 03 01 10 22 16 2 08 5 04 2
B 960896 1A1 B 01 06 00 01 03          15 4 07 5 04 2
M 970896 1A1 A 17 06 07 03 05 12 14 03 21 2 12 4 09 5 14 3 13 3
```