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# ASSESSMENT OF WHITEBARK PINE SEEDLING SURVIVAL FOR ROCKY MOUNTAIN PLANTINGS

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By

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Assessment of whitebark pine seedling survival for Rocky Mountain plantings

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Whitebark pine (WBP) is a keystone species of Rocky Mountain alpine and subalpine areas. A pervasive non-native fungal disease (white pine blister rust), mountain pine beetle infestation, and successional replacement by shade-tolerant competitors following decades of fire exclusion have severely reduced whitebark pine and threaten these high-elevation ecosystems. Land managers are attempting to reverse whitebark pine's decline by increasing regeneration of rust-resistant trees while restoring successional processes. Restoration efforts include the planting of whitebark pine seedlings and over 200,000 seedlings have been planted on National Forest, BLM and National Park service lands. In this Rocky Mountain (RM) study, select whitebark pine plantations were surveyed and seedling survival rates and ecological data collected. The purpose of this initial study was to determine overall survival rates for planted whitebark pine seedlings and to identify environmental conditions that have promoted high seedling survival. Data were analyzed at the site, plot and tree level. Microsites created by stumps, rocks and downed logs in close proximity to WBP seedlings greatly enhanced survival, seedling height and seedling growth during the first year after planting. Potential direct solar radiation was inversely related to WBP survival. Wet planting sites were detrimental to seedling survival. Results as to the effect of fire on seedling survival were inconclusive. However for 1st year seedlings it does appear that moderate, mixed or severe burning did result in much higher survival than unburned. To further understand the environmental conditions that affect seedling survival, an experimental planting was designed and monitored using the knowledge gained from the RM study. Seedling survival in this planting was statistically significantly associated with the presence of a microsite. And increased health of seedlings was associated with the presence of beneficial mycorrhizal associates. Only seedling located in burned or unburned whitebark pine communities were colonized with native fungi and colonization was higher for burned than for unburned sites. Whitebark pine seedlings are successfully being planted and it is possible to discern how different environmental conditions are affecting the survival, height, growth and health of planted seedlings.

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# TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

# CHAPTER 1

# WHITEBARK PINE OVERVIEW

## LITERATURE REVIEW

<u>Introduction to Whitebark Pine</u>

Whitebark pine (*Pinus albicaulis*) is classified in the family *Pinaceae*, genus *Pinus,* subgenus *Strobus* (haploxylon pines), and subsection *Cembrae.* Whitebark pine is one of five stone pines found worldwide and has a distribution limited to the high mountains of western North America (McCaughey and Schmidt 2001). It is the only North American pine of the pine subsection *Cembrae*, a taxon characterized by large wingless seeds and cones that do not open when ripe, and is specialized for dispersal by the Clark's nutcracker (Tomback 2001). Isolation of whitebark pine during Pleistocene glaciations resulted in reduced genetic diversity in the species, as is still apparent in populations today (Jorgensen and Hamrick 1997; Perkins 2004).

Whitebark pine is a keystone species of high elevation ecosystems of western North America, and in Montana, Idaho and western Wyoming, whitebark pine communities historically accounted for ten to fifteen percent of the total forest cover (McCaughey and Schmidt 1990). Through seed dispersal by the Clark's nutcracker (*Nucifraga columbiana*), whitebark pine pioneers after fire or other disturbance, and forms climax stands on dry, windswept sites throughout the subalpine zone up to tree line (Arno and Hoff 1990). The presence of whitebark pine at higher elevations slows the progression of snowmelt resulting in delayed melting; higher stream flows in summer months, and reduced spring flooding at lower elevations (Tomback et. al. 2001). As a pioneering species after disturbance, whitebark pine ameliorates the environment for other forest and understory species thus facilitating community development (Tomback et al. 2001). Whitebark pine is also an important food source for a diverse number of small birds and mammals and bears (Tomback and Kendall 2001).

Threats to Whitebark Pine

The combined effects of white pine blister rust (*Cronartium ribicola*), fire exclusion and mountain pine beetle (*Dendroctonus ponderosae*) have produced a dramatic decline in whitebark pine populations. The invasive fungus, white pine blister rust, is a stem rust fungus native to Eurasia and affects only five-needle white pines. Blister rust initially enters white pines through needle stomata, grows into the branches and stems, and erupts as spore-producing cankers that kill the branches – thus ending cone production – and finally kills most trees (Tomback et. al. 2001; Hoff et. al. 2001; Kendall et al. 1996). Blister rust has caused severe mortality (reaching nearly 100 percent) in many stands of whitebark pine north of 45 degrees latitude, and is slowly moving south through the range of whitebark pine (Hoff et. al. 2001, personal observation). Where whitebark pine is fire-dependent, the loss of fire has retarded whitebark pine community renewal and resulted in a greater abundance of late successional forest (Keane 2001; Keane and Arno 1993). Long lived and slow-growing, whitebark pine can be outcompeted for growing space by more shade-tolerant and fire-intolerant tree species (Arno 2001). Fire suppression also reduces the number of openings suitable for nutcracker seed caching significantly reducing regeneration opportunities (Tomback 2001). Northern rocky mountain landscapes are currently experiencing a mountain pine beetle epidemic. These beetles preferentially attack large, mature, trees. For whitebark, these large trees are the major cone producers. In some areas the few remaining mature whitebark pine that show resistance to white pine blister rust are being attacked by beetles, thus accelerating the loss of key cone bearing trees (Scott and McCaughey 2005; M. Jenkins, W. Paulson, Personal communication).

Whitebark Pine Restoration

An estimated 98 percent of whitebark pine's range is located on public land with close to 50 percent occurring in wilderness and roadless areas (Keane and Arno 2001). And, public land managers are coordinating the vast majority of restoration efforts. To date, these land managers have directed restoration focus toward identifying rust resistant trees, propagating rust-resistant seedlings for out-planting (Burr et al. 2001) and developing techniques for testing the natural rust-resistance of greenhouse grown seedlings (Hoff et al. 2001, McDonald and Hoff 2001). Prescribed fire and managed wildland fire are also being used to increase habitat for natural regeneration (Scott and McCaughey 2006) and to prepare sites for planting whitebark pine seedlings (personal observation). Although there has been limited research on planting whitebark pine, knowledge about whitebark's physiological and ecological characteristics are being used to inform those involved with the planting process. The natural conditions under which whitebark pine grows, where it naturally regenerates, and under what conditions seedlings establish provide important information for guiding planting efforts (Scott and McCaughey 2005; Weaver 2001).

More than 200,000 whitebark pine seedlings have been planted on National Forest (FS), Bureau of Land Management (BLM) and National Park (NP) service lands. On these public lands, whitebark pine seedlings have been planted over a wide range of sites and ecological conditions. Seed sources are local and regional to planting sites and seedlings have been grown in district or park greenhouses and by commercial nurseries. Whitebark pine seedlings have been planted in small experimental plots and in large plantations, on lands burned by wildfires and in areas previously managed for timber production. Unfortunately, to date, there has been little interagency communication on restoration efforts. Understanding the ecological conditions and managerial efforts which have promoted high seedling survival will insure that future restoration projects succeed.

<u>Influence of Clark's Nutcracker's: Whitebark's Population Structure</u>

Whitebark pine is an obligate or nearly obligate mutualist of the Clark's nutcracker depending on nutcrackers almost exclusively for seed dispersal (Tomback 2001). A single nutcracker is estimated to cache between 32,000 (Tomback 2001) to 98,000 (Hutchins and Lanner 1982) whitebark pine seeds in good seed crop years. Ordinarily nutcrackers cache 1 to 15 seeds per cache and seeds are buried from 1 to 3 centimeters deep in substrate (Tomback 2001). Seeds are stored throughout nearby terrain and as far away as 30 kilometers from seed sources (Lorenz 2007). Nutcrackers are attracted to closed-canopy forests, steep slopes, forest openings (Lorenz 2007), open-canopied forests, open terrain, and recent burns (Tomback 2001). Nutcrackers will also cache seeds in communal storage areas located on steep, windswept slopes which accumulate little snow and experience rapid snowmelt (Tomback 2001). The presence of whitebark pine seedlings and saplings on a broad range of aspects and slopes (Hansen-Bristow et al. 1990), and beneath tree canopies and (Tomback 2001, personal observation), suggests that nutcrackers will cache over a broad range of sites.

Population genetic structure, tree growth form, and elevational and site specific distribution of whitebark pine are all impacted by seed dispersal by the Clark's nutcracker (Tomback 2001; Perkins 2004). Whitebark pine trees commonly grow as clusters of trunks, often with their bases fused. Many of these clusters are composed of different genotypes; a direct consequence of nutcrackers placing more than one seed in a cache (Tomback 2001). Genetic analysis indicates that individuals within tree clusters tend to be close relatives, half siblings to full siblings to selfed, (Kendall and Keane 2001; Perkins 2004) and are more genetically related to one another than to individuals in neighboring tree clusters (Dekker-Robertson and Bruederle 2001). As well, individuals from populations many miles apart may be as similar to each other as two individuals from the same population (Dekker-Robertson and Bruederle 2001). Whitebark's natural spatial distribution may have implications for restoration planting, implying that seeds taken from a defined geographic region may be planted anywhere within that region without altering population structure (Dekker-Robertson and Bruederle 2001; Burr et. al. 2001; Kendall and Keane 2001). As well, whitebark pine seedlings appear to phenotypically adapt to individual sites. In seedling transplant experiments, Howard (1999), found differences in above and below ground growth rates and water-use efficiency among seedlings from different source populations, but seedling morphology and performance was not correlated with source population; phenotypic responses occurred on all sites (Howard 1999). Phenotypic adaptation may broaden the acceptable range for restoration transplanting of rust-resistant seedlings.

Microsite

Nutcrackers cache in a variety of microsites. Studies have shown that on level terrain they most frequently cache around the base of trees or under tree canopies (Tomback 2001). Elsewhere, nutcrackers cache in open terrain; in sites next to rocks; among tree roots; next to fallen trees or large branches; in cracks and holes; under bark on trees and among plants (Tomback 2001, Lorenz 2007). Seedling survival may be influenced by microsite factors. Vegetation and nearby objects may provide shade, modify moisture and temperature relations, affect soil stability and provide physical protection for young seedlings. Environmental features including fallen tree branches, wood pieces, rocks, snags, or stumps occurred within 15 centimeters of 85% of all whitebark pine regeneration surveyed in the Sleeping Child burn in the Sapphire Range, Montana, twenty-six years after fire (McCaughey and Tomback 2001). Tomback (2007) conducted a study of krummholtz on Lee Ridge in Glacier NP and found that whitebark pine seedlings first established on the leeward side of rocks and that over time krummholz 'stringers' developed leeward of these pioneering seedlings. No formal studies to date have addressed the relationship between the presence of a microsite and survival for planted whitebark pine seedlings.

Whitebark Pine Habitat

Heavy snowfall, strong winds, and a short growing season are characteristic of whitebark pine habitats (McCaughey and Schmidt 1990). Over eighty-five percent of precipitation comes in the form of snow between October and May (Weaver 1994) although snow can occur any month in higher elevation stands (personal observation). Whitebark pine ecosystems rarely experience soil drought (Weaver 1994); soils are saturated in spring and rates of summer precipitation generally exceed those of evaporation (Weaver 2001). Subsoils remain moist all summer in higher and lower parts of the whitebark pine zone although drying of surface soils possibly causes tree water stress at especially windy or sunny sites and at the lower elevational range of whitebark pine. (Weaver 1994; Weaver 2001). Whitebarks' active growing season extends from the end of May into early September and growing season length appears to be the primary control for whitebark pine production (Weaver 2001).

Successional floristics are relatively simple in whitebark pine ecosystems. Plant species that are present prior to disturbance events generally populate the site after disturbance (Keane 2001; Renkin personal communication 2007) and consideration of long term interspecies plant competition due to habitat type is important for restoration planning. Whitebark pine is relatively slow growing and is typically outcompeted for growing space by lodgepole pine, more shade-tolerant tree species, and robust forbs such as bear grass (Arno 2001; Weaver 2001). If lodgepole pine are present in the overstory or there are abundant lodgepole pines with semi-serotinous cones surrounding a burn, then it is likely that lodgepole pine will dominate after disturbance (Keane 2001; Renkin, personal communication). And, although whitebark pine colonizes severely burned sites better that subalpine fir, mixed severity burns create patchy landscapes that can be colonized by a mixture of the two species (Keane 2001). Whitebark pine seedlings and saplings were disproportionately associated with Grouse whortleberry (Vaccinium scoparium), Wood Rush (Luzula hitchcockii) (Perkins 2004), Elk sedge (Carex geyeri) and Ross's sedge (Carex rossii) (personal observation) relative to plant frequency and rarely associated with Beargrass (Xerophyllum tenax) (McCaughey and Tomback 2001; personal observation).

Mycorrhizal Associates

Whitebark pine is also associated with a particular set of ectomycorrhizal (EM) fungi (Mohatt et al. 2008). In natural environments, all species of the genera Pinus are dependent on ectomycorrhizal associates for normal growth and survival (Read 1998). Ectomycorrhizal fungi increase plant acquisition of nitrogen and/or phosphorus, and various species offer protection from pathogens, drought, heavy metals, and /or root grazers (Cairney and Meharg 2003). Stone pines host a particular subset of the potential 6,000 species of known EM fungi. These species include generalists as well as those uncommon or unknown on other hosts (Mohatt et al. 2008). In the Greater Yellowstone Ecosystem, 43% of 47 species of native ectomycorrhizal fungi found with whitebark pine are not known to associate with spruce, fir or other ectomycorrhizal plants in the vicinity (Mohatt et al. 2008). In studies by Mohatt (2008), *Cenococcum geophilum*, was the most frequently encountered and abundant EM species found on whitebark pine seedling roots and for many seedlings this was the only EM fungus present. *Cenococcum geophilum* has a global distribution, and forms associations with a variety of genera, including *Pinus, Picea*, and *Betula*. This fungus is frequently found in harsh, disturbed, or drought prone sites such as the subalpine (Kernaghan 2001). Perkins (2004) attempted to determine if ericoid mycorrhizal fungi were shared by whitebark pine and *Vaccinium scoparium* suggesting that species in the genus *Vaccinium* were potential sources for beneficial mycorrhizal inoculants. The results of this study were inconclusive. Ericoid mycorrhizal fungi primarily associate with *Vaccinium* species (Nilsson et al. 2005; Cairney and Meharg 2003, Read et al. 2004; Wurzburger et al. 2001). The presence of beneficial mycorrhizal associates at planting sites could strongly influence the ability of whitebark pine seedlings to establish (Mohatt 2006). Many native fungi found in whitebark pine habitat are in the EM Suilloid group (Rhizopogon and Suillus) (Mohatt 2006); fungal spores from this group might be found in soil spore banks, brought in by small mammals or in the case of Suillus dispersed through the air (Mohatt et al. 2008). Currently, how seedling mycorrhization is affected by distance from mature forests and other abiotic factors is unknown but could be potentially important for understanding whitebark pine seedling survival.

Fire

Whitebark pine seedlings may benefit either directly or indirectly from fire. Charcoal, produced during fire events, has properties that improve soil physical and biochemical conditions including increased soil-water holding capacity and reduced soil bulk density (Deluca and Alpet 2008). Recently formed charcoal adsorbs organic compounds that might otherwise be inhibitory to plants or microorganisms and charcoal gives soil its dark color, which influences the warming of soils (Deluca and Alpet 2008). Stand-replacing fires and severe surface fires that remove all vegetation, destroy the organic soil layer, and change soil water relations, have been proposed to favor whitebark pine regeneration (Arno and Hoff 1990; Tomback et. al. 2001; Weaver 2001). And, whitebark pine recruitment and growth are probably indirectly benefited by fire through lengthening of the growing season and due to effects on soil temperature (Perkins 2004). An increase in growing season length as the primary control for whitebark pine production (Weaver 2001) may result in recently burned and severely burned sites being preferable for restoration planting of whitebark pine seedlings. As well, disturbances such as fire can also alter the composition of the mycorrhizal community (Trusty and Cripps 2007, Warnock et al. 2007). Warnock et al. (2007) researched the potential effects of biomass-derived black carbon (biochar) on mycorrhizal associations and experimental evidence suggests that the presence of biochar is beneficial to mycorrhizae. Biochar appeared to improve the ability of Ectomycorrhizal (EMC) and Ericoid Mycorrhizal (ERM) fungi to colonize host plant seedlings, and effects seedling growth rates.

# CHAPTER 2

## ROCKY MOUNTAIN PLANTINGS 1989 - 2005

## RESEARCH OBJECTIVES

The primary purpose of this research effort, hereafter call the Rocky Mountain (RM) study, is to evaluate the biotic and abiotic factors that affect survival of planted whitebark pine seedlings. Specifically this study is designed to determine survival rates for planted whitebark pine over time and over a wide range of geographic locations, and assess the biotic and abiotic ecological conditions that had resulted in high survival for these planted trees.

The individual objectives are to 1) collect and compile all possible information on whitebark pine that had been planted on public lands in the Rocky Mountains of Idaho, Montana and Wyoming; 2) select and survey a representative sub-set of these plantations; 3) determine the relationship between whitebark pine seedling survival, and fire severity, aspect, slope, season of planting, habitat type, moisture regime, and presence of microsite; and 4) determine the effect of microsite direction, distance and type on seedling height and growth.

## METHODS

### Data Acquisition

During the winter of 2006, planting and monitoring data were collected and compiled from federal agencies who had planted whitebark pine seedlings on National Forest, National Park or BLM land. Efforts were made to contact all National Forests and National Parks within the Northern Rocky Mountain distribution area for whitebark pine. The Beaverhead-Deerlodge, Bitterroot, Caribou-Targhee, Clearwater, Flathead, Gallatin, Idaho Panhandle, Kootenai, Lewis & Clark, Lolo, Nez Perce, Sawtooth, and Shoshone National Forests, Glacier and Yellowstone National Parks and the Cottonwood, Idaho office of the BLM had all planted whitebark pine seedlings (Appendix B). For planting sites found on these federal lands, all available data were acquired and data relevant to this study were compiled into a preliminary database.

Historical Data Summary

Documentation was found for one hundred and twenty (Appendix B) whitebark pine planting sites in Idaho, Montana and Wyoming. At these planting sites, a total of 210,723 whitebark pine seedlings were planted by federal agencies between 1989 and 2005. The following preliminary data assessment is based on planting records, monitoring reports, and personal communications with National Forest, National Park and Bureau of Land Management staff.

Whitebark pine seed sources are local and regional to planting sites. In the northern regions, where whitebark pine populations have been heavily infected by blister rust, agencies most often collect seeds from local potentially rust-resistant trees. Seed transfer boundaries based on mountain ranges, are also used to create zones for seed collection. Seeds collected within a zone are used to produce seedlings for planting on forests throughout that zone.

Seedlings for plantings have generally come from the forest services' Coeur d'Alene Nursery and a private nursery in Idaho, Western Forests Systems, although some seedlings have been grown locally in district or park greenhouses and by Bitterroot Nurseries. Bare root and container seedlings are typically planted operationally at 1½- to 2-years of age. These small, container seedlings are not inoculated for white pine blister rust, although, seedlings grown from seeds collected in high blister rust infection areas are potentially rust-resistant. In 2005, 1,849 six-year old bareroot whitebark pine seedlings were planted by the Bitterroot, Clearwater, Flathead, Gallatin, Idaho Panhandle, Lewis & Clark, Lolo, and Nez Perce National Forests. These more mature seedlings, from a blister rust screening study conducted at the Coeur D'Alene nursery, were sent out to forests within seed zones. Some seedlings were inoculated and some served as controls and were not inoculated. Seedlings were examined for active cankers and trees were eliminated if active cankers were found. Trees ranged in height from 3 or 4 inches to over 12 inches and average seedling height varied by seed zone (Foushee personal communication).

Whitebark pine has been planted in small experimental plantings with as few as 30 seedlings and large commercial plantations of more than 10,000 trees (Figure 2.1).

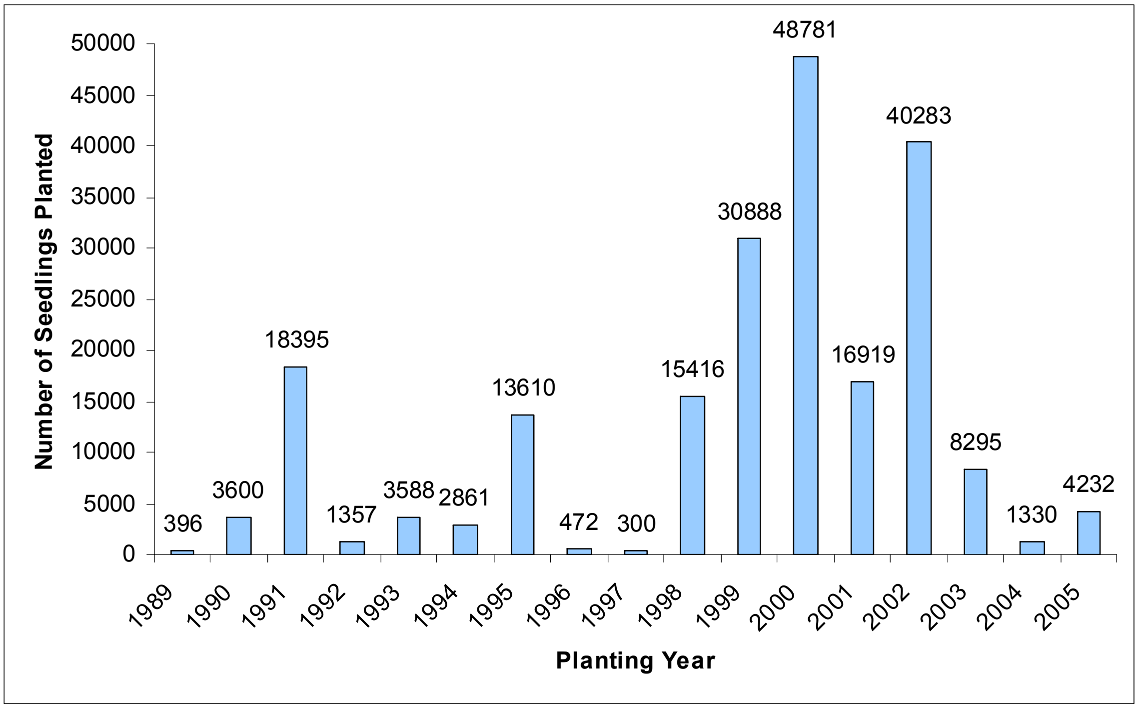


**Figure 2.1. Number of seedlings planted categorized by planting year for the 120 planting sites found during the RM study.**

Older whitebark pine plantations in the Gallatin and Clearwater National Forests were often mixed plantings with lodgepole pine (*Pinus contorta*), Douglas-fir (*Pseudotsuga menziesii*), western larch (*Larix occidentalis*), Engelmann spruce (*Picea engelmannii*) and/or subalpine fir (*Abies lasiocarpa*). On the Beaverhead-Deerlodge and Sawtooth national forests and on private and state land whitebark pine has been used in the restoration planting of mining sites and has been planted on road cuts for mitigation purposes in Yellowstone National Park. Planting crews vary between and within plantations and agencies. Most whitebark pine seedlings were planted on National Forest land by professional contract crews. Other planting sites, on National Forest, Park Service, state and private land, have been planted by re-vegetation crews, private and agency researchers, force account, fire crews, the Montana Conservation Corps and volunteers.

The vast majority of whitebark pine has been planted for restoration purposes on public lands burned by wildfire. Seedlings have been planted in severe, mixed and moderate burns, and in unburned areas. In previously unburned sites, prescribed fire was frequently used to prepare sites for planting. Stand histories include no previous management action, logging operations before fire and salvage logging after fire. The length of time after wildfire that seedlings were planted varies by site.

Initial monitoring surveys of plantations were generally, but not in all cases, implemented at the end of the season in which seedlings were planted or the following summer. Some plantations, chosen to be included in the RM study, have never been monitored.

Choice of Survey Sites

Data were sufficient at sixty-one of the one hundred and twenty-five documented planting sites to calculate seedling survival as well as to allow for re-location of individual sites. Forty-eight of these sites, representing the widest range of environmental conditions and management actions possible, were then chosen to be surveyed (Figures 2.2 - 2.9). Two sites on the Lolo National Forest (monitoring year 1) and two sites located on the Gallatin NF (monitoring year 15) were monitored for survival in 2006 but no ecological data were taken. At these four sites, permanent monitoring plots allowed for exact seedling survival counts and these counts have been used in the calculation of overall seedling survival.  The remaining 44 sites were field located in the summer of 2006 and *Site* level and *Plot* level data were collected including photos of each site. Complete data collection was accomplished for only thirty-three sites and assessment of ecological conditions supporting whitebark pine seedling survival is based on data collected from these sites.


Figure 2.2. Shoshone NF, Wind River RD


Figure 2.3. Gallatin NF, Livingston RD

Figure 2.4. Gallatin NF, Gardiner RD

Figure 2.5. Gallatin NF, Livingston RD

Figure 2.6. BLM, Marshall Mountain


Figure 2.7. Caribou-Targhee NF

Figure 2.8. Yellowstone NP

Figure 2.9. Flathead NF, Swan Valley RD

Study Area

Study area sites were located throughout the Rocky Mountains (Figure 2.10, Table 2.1). The northern most survey site was located in Glacier National Park (Latitude 48.824°) with sites dispersed throughout Rocky Mountain alpine regions south to the Shoshone National Forest (Latitude 42.644°) in Wyoming's Wind River Range, west to Marshall Mountain (Longitude -115.868°) in central Idaho, and as far east as the Gallatin National Forest near Cook City, Montana (Longitude -109.893°). Planting sites were found at the highest elevations (9,500 feet) on the Shoshone National Forest and, in accordance with expected latitudinal controls on whitebark pine's elevational range, at the lowest elevations (5,045 feet) on the Idaho Panhandle National Forest.

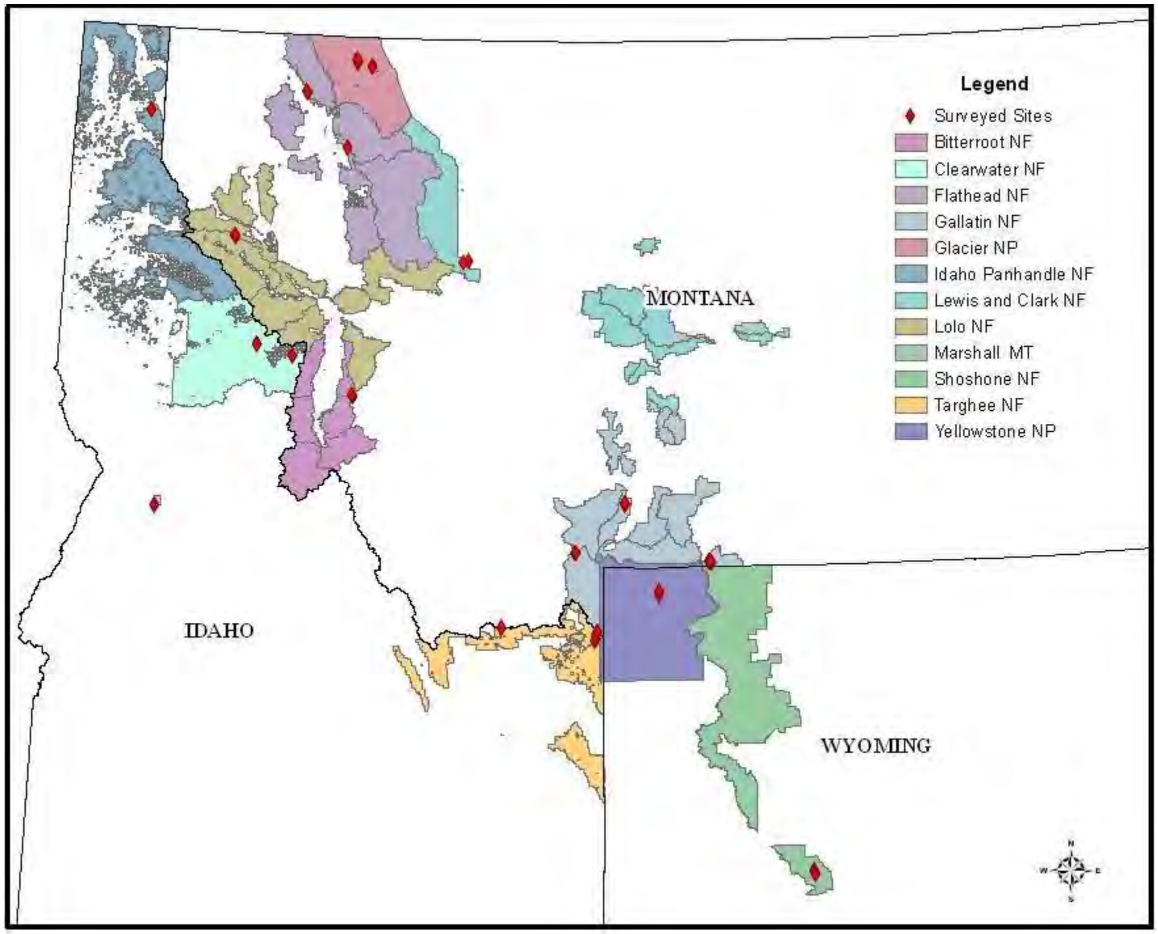


**Figure 2.10. Map of surveyed WBP plantations shown by national forest or park. Red diamonds represent survey sites.**

Elevation is the primary determiner of weather for whitebark pine planting sites used in this study. The mountainous terrain that whitebark pine occupies can receive two to three times the annual precipitation of surrounding valleys and plains (Pfister et al. 1977). Landforms where planting sites were located included ridge tops, mountain slopes, high mountain valleys, moraines, and benches. Planting site slopes ranged from zero to fifty degrees (Table 2.1). Due to the steep-slope landscape positions most planting sites occupied, erosion of various forms was the predominant surficial process. At these locations, soils were generally minimally developed and highly influenced by underlying parent material (Hansen-Bristow et al. 1990).

For most study sites, microclimate was influenced by topographic features and survey sites were found on all aspects (Table 2.1). The aspect or azimuth that a slope faces strongly influences snow accumulation and soil development (Pfister et al. 1977), potential direct incident radiation and temperature (McCune and Keon 2002). As well, topographic constrictions, typical of mountain environments, potentially affected some planting site conditions through the formation of frost pockets in cold air drains (Pfister et al. 1977).

Historical habitat type designations, provided by the USFS and National Park Service, were universally based on Pfister's Forest Habitat Types of Montana (Table 2.1). Whitebark pine plantations were located in a variety of habitat types within the subalpine fir, whitebark pine and lodgepole pine climax series. For plantings included in this study, all habitat types corresponded to the natural range of whitebark pine. As well, naturally occurring whitebark pine was a minor to major component of all planting sites although seedling proximity to naturally occurring whitebark pine stands and individual trees within sites was variable.

**Table 2.1. Locations and site descriptions for 37 sites, listed by planting date, where ecological and survival data was collected and used for site and plot level data analyses.**

| *Site Location* | *Date Planted* | *Lat* | *Long* | *Elevation in Feet* | *Aspect* | *Slope in Degrees* | *Burn Severity* | *Habitat Type* |
|---|---|---|---|---|---|---|---|---|
| Gallatin NF Gardiner RD | Aug-91 | 45 | -110 | 8100 | 225 | 15 | Severe | ABLA/VAGL |
| Gallatin NF Gardiner RD | Aug-91 | 45 | -110 | 8100 | 225 | 15 | Severe | ABLA/VAGL |
| Gallatin NF Gardiner RD | Aug-91 | 45 | -110 | 8700 | 135 | 10 | Moderate | ABLA/ARCO |
| Gallatin NF Gardiner RD | Aug-91 | 45 | -109 | 9300 | 135 | 10 | Mixed | ABLA/GATR |
| Gallatin NF Gardiner RD | Aug-91 | 45 | -109 | 8400 | 90 | 15 | Mixed | ABLA/VASC |
| Lewis & Clark NF Rocky MT RD | Sep-91 | 47 | -113 | 5600 | 360 | 35 | Mixed | ABLA/VAGL |
| Gallatin NF Hebgen Lake RD | Sep-92 | 45 | -111 | 8100 | 315 | 5 | Mixed | ABLA/VASC-VASC |
| Lewis & Clark NF Rocky MT RD | Sep-94 | 47 | -113 | 5800 | 45 | 30 | Mixed | PICO/CARU |
| Coeur d'Alene District BLM | Oct-95 | 45 | -116 | 7795 | 225 | 5 | Severe | PIAL/ABLA |
| Caribou-Targhee NF Island Park RD | Sep-98 | 44 | -111 | 7500 | 225 | 30 | Severe | ABLA/VASC |
| Caribou-Targhee NF Island Park RD | Jul-99 | 44 | -111 | 8100 | 135 | 30 | Severe | ABLA/VASC |
| Gallatin NF Gardiner RD | Jul-99 | 45 | -110 | 8800 | 90 | 20 | Severe | ABLA/VASC |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Gallatin NF<br>Hebgen Lake RD | Jun-00 | 45 | -111 | 8700 | 180 | 10 | Unburned | ABLA/ARCO |
| Clearwater NF<br>Powell RD | Jul-00 | 47 | -114 | 8100 | 225 | 35 | Severe | ABLA/XETE-VASC |
| Glacier NP<br>Grinnell Point | Sep-00 | 49 | -114 | 7500 | 180 | 45 | Severe | PIAL/ABLA |
| Caribou-Targhee NF<br>Dubois RD | May-01 | 45 | -112 | 8000 | 225 | 30 | Unburned | ABLA/VASC-VASC |
| Glacier NP<br>Flattop MT | Jul-01 | 49 | -114 | 6300 | 90 | 20 | Mixed | ABLA/LUHI |
| Glacier NP<br>Flattop MT | Sep-01 | 49 | -114 | 6800 | 135 | 20 | Mixed | ABLA/LUHI |
| Caribou-Targhee NF<br>Island Park RD | Oct-01 | 44 | -111 | 7800 | 225 | 45 | Severe | PIAL |
| Caribou-Targhee NF<br>Island Park RD | Jun-02 | 44 | -111 | 8000 | 315 | 20 | Severe | PIAL |
| Shoshone NF<br>Wind River RD | Jun-02 | 43 | -109 | 9500 | 90 | 10 | Severe | PIAL |
| Shoshone NF<br>Wind River RD | Jun-02 | 43 | -109 | 9200 | 180 | 0 | Severe | PIAL |
| Flathead NF<br>Swan Valley RD | Jul-02 | 48 | -114 | 5500 | 225 | 45 | Moderate | ABLA/XETE-VAGL |
| Gallatin NF<br>Livingston RD | Jul-02 | 45 | -111 | 8400 | 360 | 50 | Severe | PIAL/ABLA |
| Glacier NP<br>Flattop MT | Sep-02 | 49 | -114 | 6750 | 90 | 20 | Severe | ABLA/LUHI |
| Clearwater NF<br>Powell RD | Sep-02 | 47 | -115 | 6600 | 180 | 20 | Severe | ABLA/XETE-VASC |
| Gallatin NF<br>Livingston RD | Jun-03 | 45 | -111 | 8000 | 315 | 45 | Severe | PIAL/ABLA |
| Yellowstone NP<br>Dunraven Pass | Sep-03 | 45 | -110 | 8900 | VAR | 20 | Mixed | PINALB |
| Clearwater NF<br>Powell RD | Oct-03 | 47 | -115 | 7185 | 225 | 35 | Severe | ABLA/XETE-VASC |
| Flathead NF<br>Glacier View RD | Jun-05 | 49 | -114 | 6320 | 225 | 30 | Severe | ABLA/XETE |
| Flathead NF<br>Glacier View RD | Jun-05 | 49 | -114 | 6700 | 45 | 20 | Severe | ABLA/LUHI |
| Flathead NF<br>Glacier View RD | Jun-05 | 49 | -114 | 6544 | 270 | 15 | Severe | ABLA/XETE |
| Lolo NF<br>Plains RD | Jun-05 | 47 | -115 | 6000 | VAR | 20 | Severe | ABLA/LUHI-VASC |
| Lolo NF<br>Plains RD | Jun-05 | 47 | -114 | 6671 | VAR | VAR | Severe | ABLA/XETE |
| Lolo NF<br>Plains RD | Jun-05 | 47 | -115 | 6412 | VAR | VAR | Severe | ABLA/LUHI |
| Bitterroot NF<br>Darby RD | Jun-05 | 46 | -114 | 7600 | 180 | 10 | Severe | ABLA/XETE |
| Idaho Panhandle NF<br>Sandpoint RD | Jun-05 | 48 | -116 | 5045 | 90 | 25 | Mixed | ABLA/XETE-VAGL |

Site-Level Data Collection

Planting sites were field located and planting boundaries determined. During the initial ‘walk through’ of each planting area, *Site* data were collected. *Site* data included: location, elevation in feet, slope in degrees, aspect, landform and a general description of vegetation: dominant tree and understory species. Along with the historical data collected from participating federal agencies, these data represent the first dataset comprised of 36 sites, i.e. *site-level*.

Since the goal of this study was to represent each planting *Site* as accurately as possible, consideration was given to establishing monitoring plots that were representative of the variation in burn severity, slope, aspect, and vegetation density encountered on non-uniform sites. Where plantation conditions were relatively uniform, monitoring plots were placed at random locations within the site.

The majority of plots were selected according to the following protocol: the initial monitoring plot was located as near to the center of the planting site as possible or if a “stake row” (a row of seedlings marked with wooden stakes to be used for 1$^{st}$ and 3$^{rd}$ year monitoring by the USFS) was found, a stake was chosen to be the center of the initial plot. For selection of each additional monitoring plot an azimuth was chosen at random by one of the two field technicians, and an arbitrary distance, in meters, was chosen by the other field worker. An azimuth was established using a hand-held compass, the distance paced off and the center of the new plot placed in the resultant location. This selection process was repeated (using the previous plot as the starting point) for each additional monitoring plot within that site.

Plot-Level Data Collection

A minimum of three monitoring plots were placed at each planting site with more plots placed in larger plantations. For smaller plantations the whole planted area was treated as one monitoring plot. Stake rows or individual stakes were sometimes found within planting sites, but, stakes were often missing and specific information for most stake rows was not available. With the exception of sites on the Bitterroot and Lewis & Clark National Forests, stake rows were not used to determine seedling survival rates. For planting sites on the Lolo and Flathead National Forests and in Yellowstone and Glacier

National Parks pre-established monitoring plots were located and exact tree counts were made.

Plot radii ranged from seven to twenty meters. Plots with larger radii were used for seedlings planted at a larger spacing. The center of each plot was established, marked with a flag and UTM coordinates collected using a *Garmin etrex Legend* GPS. A meter tape was then used to establish a seven to twenty meter radius circular plot. A systematic search by field technicians was then completed and each seedling found within the monitoring area was flagged.

Aspect and slope was recorded in degrees (± 5 degrees) using a hand held compass. If the site was disturbed, the presence and type of disturbance was noted. The presence of soil movement or flow, based on visual observation, was recorded as stable or unstable. The structure of vegetative cover was assessed: ocular estimates for each plot's absolute percent cover (± 5 percent) for emergent trees, tree canopy, tree subcanopy, standing dead trees, tall shrubs (2 – 5 meters), medium shrubs (0.5 – 2 meters), short shrubs (< 0.5 meters), and herbaceous plants were recorded. Percent cover (± 5 percent) was also recorded for each plant species present and ground cover (± 5 percent) recorded for plants, bare ground, organic matter, rock, wood, and moss. As well, photos were taken of each monitoring plot. This constituted the second data set comprised of 106 plots, i.e. plot-level.

Seedling-Level Data Collection

Data were collected for each individual seedling found within a monitoring plot. For each of these seedlings height and the length of new apical growth for the dominant growing shoot were recorded in centimeters (±0.2 cm). The presence or absence of a microsite (MS) for each planted seedling was noted and for each microsited seedling, the type, orientation and distance of the MS were recorded. Categories for microsites were: downed logs, stumps, large rocks, snags and live trees and shrubs. MS orientation from each seedling was recorded as a slope direction (up, down, side), flat or in some cases all directions. MS distance was recorded in centimeters. This constituted the third data set comprised of 1106 trees, i.e. *tree-level*.

In summary there are three data sets, each nested within the other and containing more detail.

Original and Supplemental Data Organization and Generation

Site level latitude and longitude were calculated using field collected NAD 1983 UTM coordinates as base data. When site aspects were obtained from agencies in nominal notation, aspects were translated into decimal degrees. Site habitat type designations were used to predict estimated yield capabilities (Yield Capacity) of East-side and West-side Montana habitat types based on site index data and stockability factors (Pfister et al. 1977). Site habitat type, burn severity, and planting season were all numerically coded for data analysis (Appendix A).

Three plots within the plot-level data set were trimmed; survival rates were changed from 1.07 (Caribou-Targhee NF), 1.05 (Idaho Panhandle NF), and 1.00 (Lolo NF) to 0.99 in order to facilitate data analysis. Plot Level moisture regime, as indicated by associate plant species, was determined using the *Vegetation Classification of Waterton-Glacier International Peace Park* (Reid et al. 2004) and given numerical codes. Plot-level topology, burn severity and soil stability were all given numerical codes (Appendix A).

For data collected at the individual seedling level, microsite direction and microsite type were assigned numerical codes (Appendix A) and seedling heath designations were categorized.

The following equation was used to estimate potential annual direct incident radiation (RAD):

RAD = 0.339+0.808*COS(L)*COS(S) -0.196*SIN(L)*SIN(S)-
0.482*COS(A)*SIN(S) (McCune and Keon 2002).

Where L = latitude in degrees * π/180,
S = ATAN(slope in degrees * π/180), and
A = folded aspect = (180 - ABS(aspect in degrees - 180)) * π/180.

For this equation aspect was ‘folded’ about the north-south line, rescaling 0-360 degrees to 0 -180, degrees such that NE = NW, E = W, etc.

Percent survival was calculated. For each site, the number of acres planted was converted to square meters (acres x 4046.84) and divided by the total number of seedlings planted; this number represented the number of square meters expected to be occupied by a single seedling. Radii of monitoring plots were then converted to area ($\pi r^2$) in square meters. The total expected seedlings per plot was then calculated ((area in square meters)/(calculated meters per seedling)). To calculate the estimated proportion survival for each plot, the actual number of seedlings found in a given plot was divided by the calculated number of seedlings expected to be found in that plot. Estimated proportion survival at the site level was obtained by dividing the number of seedlings found in all plots at that site by the number of seedlings expected to be found in all plots at that site. Survival data were subset according to monitoring year and results for first year survival (monitoring year one) analyzed separately. Outliers were removed (proportion survival over 1.0) for site and plot level data analysis. At the plot level the calculated proportion of seedling survival was transformed for statistical analyses.

<u>Statistical Analyses</u>

Graphical displays in the form of scatter diagrams and boxplots were constructed using seedling survival and seedling height growth as dependent variables (Y-axis) and all other variables, either discrete or continuous, as independent variables (X-axis) to identify trends. Seedling survival was summarized by site, plot, and presence of microsite and year of planting. Regression analyses were conducted to predict 1-year height growth at the tree-level as a function of various site variables and logistic regression was employed at the site-level to predict seedling survival as a function of various site variables such as burn severity, habitat yield capacity, potential direct solar radiation, number of years planted, etc. Two-sample t-tests were conducted to investigate whether there was a significant difference between combined 2$^{nd}$ and 3$^{rd}$ year and combined 4$^{th}$ and 5$^{th}$ year seedling growth and height. Chi-square tests were performed to determine whether there was dependence between survival and presence/absence of microsite for 1-yr RM seedlings at the site-level and Dunraven Pass data set. S-N-K pairwise multiple comparisons were run after 1-way ANOVAs on height and growth as related to microsite type

# RESULTS

<u>Seedling Survival</u>

Thirty-six planting sites (outlier removed), representing 114,677 seedlings were used to calculate average seedling survival. The average survival for these sites was 42 percent. Survival for seedlings planted in 2005 ($1^{st}$ year monitoring in 2006) was significantly different from survival for monitoring years three through fifteen and, survival data were subset and the results for first year survival analyzed separately (Figure 2.11).

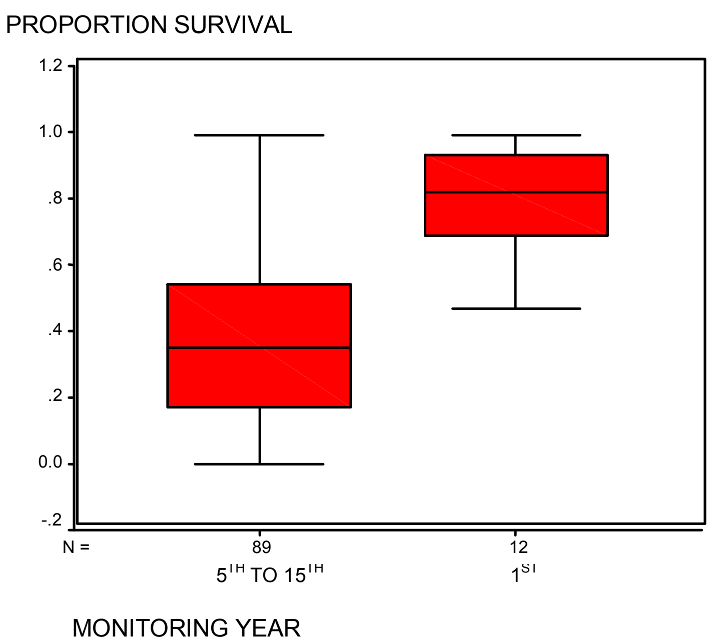


**Figure 2.11. Plot-level boxplots of WBP seedling survival distribution by $1^{st}$ monitoring year and $3^{rd}$ through $15^{th}$ monitoring years. Median proportion survival for $1^{st}$ monitoring year seedlings was 0.78 and for $3^{rd}$ through $15^{th}$ monitoring years was 0.35.**

The average 1st-year seedling survival was 74 percent (Table 2.2). Survival ranged from a minimum of 59 percent to a maximum of 92 percent and was consistent with historical first year monitoring data for sites included in this study. Historical $1^{st}$-year survival data for thirteen additional survey sites showed an average of 78 percent survival. For these thirteen plantings $1^{st}$-year survival ranged from a minimum of 44 percent to a maximum of 100 percent.

**Table 2.2. 1st-year survival rates by site for rust resistant seedlings planted at 9 RM sites.**

| *Forest* | *Date Planted* | *Monitoring Year* | *Seedlings Planted* | *Survival 2006* |
|---|---|---|---|---|
| Bitterroot NF - Darby RD | Jun-05 | 1 | 130 | 78% |
| Flathead/Glacier View RD | Jun-05 | 1 | 10 | 63% |
| Flathead/Glacier View RD | Jun-05 | 1 | 35 | 92% |
| Flathead/Glacier View RD | Jun-05 | 1 | 13 | 85% |
| Idaho Panhandle NF - Sandpoint RD | Jun-05 | 1 | 300 | 75% |
| Lolo NF - Plains/Thompson Falls RD | Jun-05 | 1 | 95 | 85% |
| Lolo NF - Plains/Thompson Falls RD | Jun-05 | 1 | 86 | 74% |
| Lolo NF - Plains/Thompson Falls RD | Jun-05 | 1 | 64 | 56% |
| **Total Seedlings Planted** | | | **733** | |
| **Average Survival** | | | | **74%** |

The average survival for monitoring years three through fifteen was 38 percent with one outlier removed (Table 2.3). This outlier site (survival 187 percent), located on the Caribou-Targhee NF, will not be considered for the remainder of this study. Survival rates over 100 percent were potentially a result of survey bias, the presence of natural regeneration and/or incorrect baseline data. Survey bias and imprecise baseline data could have lead to underestimation as well, although this was not factored into data analysis.

For the 28 remaining sites used for subsequent data analysis, survival ranged from a minimum of 10 percent (monitoring year six) to a maximum of 81 percent (monitoring year fifteen).

**Table 2.3: Seedling survival rates by site for monitoring years 3 through 15.**

| *Site Location* | *Date Planted* | *Monitoring Year* | *Seedlings Planted* | *Survival 2006* |
|---|---|---|---|---|
| Gallatin NF - Livingston RD | Jun-03 | 3 | 4500 | 31% |
| Yellowstone NP - Dunraven Pass | Sep-03 | 3 | 30 | 47% |
| Clearwater NF - Powell RD | Oct-03 | 3 | 3765 | 38% |
| Caribou-Targhee NF - Island Park RD | Jun-02 | 4 | 10000 | 35% |
| Shoshone NF - Wind River RD | Jun-02 | 4 | 436 | 10% |
| Shoshone NF - Wind River RD | Jun-02 | 4 | 1962 | 49% |
| Flathead - Swan Valley RD | Jul-02 | 4 | 3000 | 20% |
| Glacier NP - Flattop MT | Sep-02 | 4 | 2222 | 48% |
| Clearwater NF - Powell RD | Sep-02 | 4 | 6245 | 78% |
| Caribou-Targhee NF - Dubois RD | May-01 | 5 | 5400 | 19% |
| Glacier NP - Flattop MT | Jul-01 | 5 | 1500 | 29% |
| Glacier NP - Flattop MT | Sep-01 | 5 | 1438 | 29% |
| Caribou-Targhee NF - Island Park RD | Oct-01 | 5 | 2800 | 32% |
| Gallatin NF - Livingston RD | Jul-02 | 5 | 16380 | 42% |

| | | | | |
|---|---|---|---|---|
| Gallatin NF - Livingston RD | Jun-00 | 6 | 5000 | 22% |
| Clearwater NF - Powell RD | Jul-00 | 6 | 6720 | 62% |
| Glacier NP - Grinnell Point | Sep-00 | 6 | 96 | 41% |
| Caribou-Targhee NF - Island Park RD | Jul-99 | 7 | 5000 | 76% |
| Gallatin NF - Gardiner RD | Jul-99 | 7 | 10724 | 52% |
| Caribou-Targhee NF - Island Park RD | Sep-98 | 8 | 1100 | 187%* |
| Coeur d'Alene BLM District | Oct-95 | 11 | 10000 | 12% |
| Lewis & Clark NF - Rocky MT RD | Sep-94 | 12 | 661 | 58% |
| Gallatin NF - Hebgen Lake RD | Sep-92 | 14 | 960 | 21% |
| Gallatin NF - Gardiner RD | Aug-91 | 15 | 3110 | 17% |
| Gallatin NF - Gardiner RD | Aug-91 | 15 | 1000 | 26% |
| Gallatin NF - Gardiner RD | Aug-91 | 15 | 5310 | 45% |
| Gallatin NF - Gardiner RD | Aug-91 | 15 | 1050 | 40% |
| Gallatin NF - Gardiner RD | Aug-91 | 15 | 3870 | 81% |
| Lewis & Clark NF - Rocky MT RD | Sep-91 | 15 | 765 | 79% |
| **Total Seedlings** | | | **113944** | |
| **Average Survival** | | | | **38%** |

* Outlier removed

## Burn Severity

For monitoring years 3 through 15 mean survival was highest in mixed severity burns (0.52) less for severe burns (0.41) and moderate burns (0.29) and lowest for unburned (0.21) sites (Figure 2.12). Planting sites with mixed severity burns were mosaics of severe and moderate burns and unburned areas.

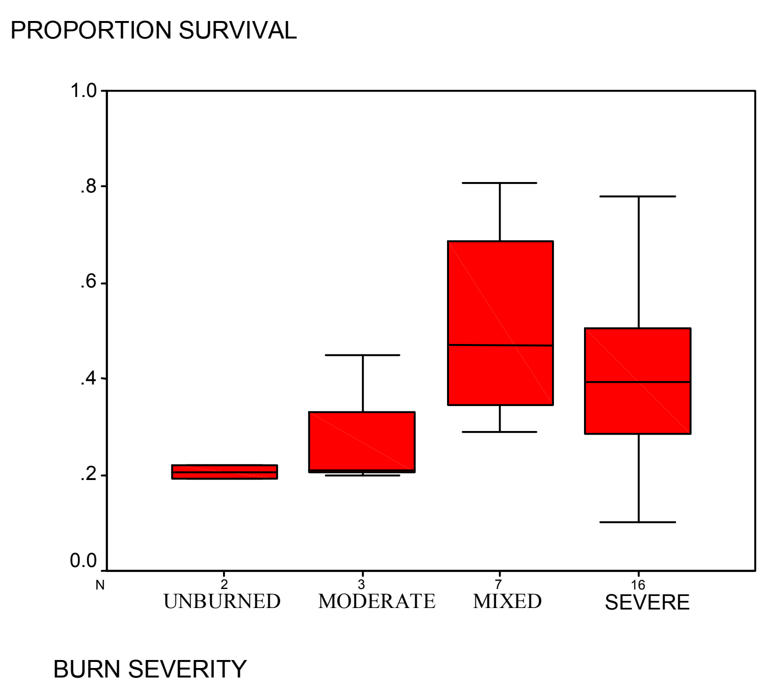

**Figure 2.12. Boxplot of seedling survival distribution for unburned, moderate, mixed, and severe burns.**

Potential direct solar radiation

Potential direct solar radiation (RAD) was inversely related to whitebark pine survival (Figure 2.13).

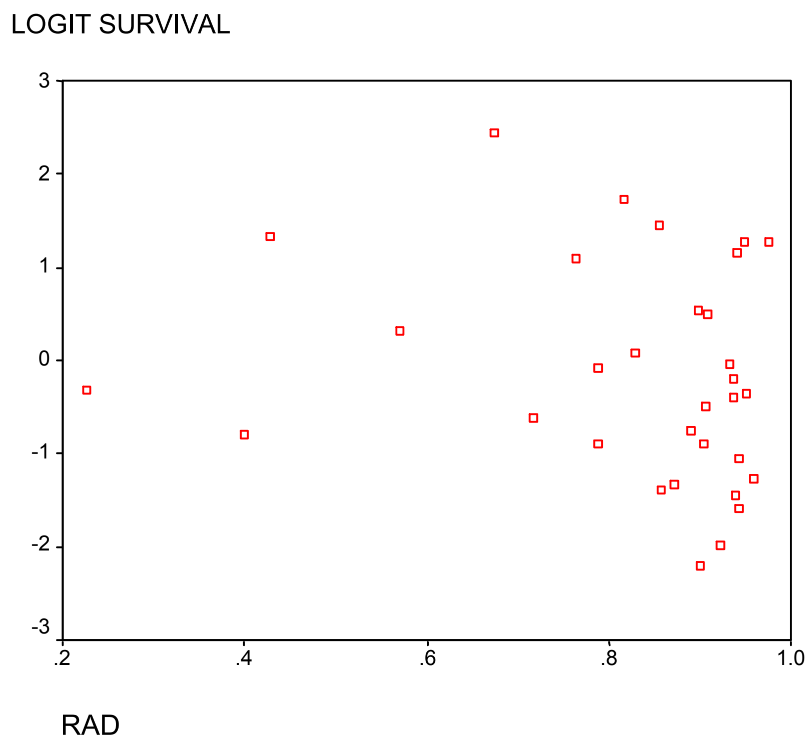


**Figure 2.13. Scatterdiagram of LOGIT (Survival) plotted against potential solar radiation (RAD).**

A logistic regression of seedling survival as a function of potential direct solar radiation, habitat type yield capacity, burn severity and number of years since planting yielded an $R^2 = 0.56$ and SEE = 0.81. The order of importance of independent variables on the Logit (survival) is: Yield Capacity, Monitoring Year, Burn Severity and finally RAD. Positive effects on survival resulted from yield capacity, 1st monitoring year seedlings, and increased burn severity. On the other hand, increased potential direct solar radiation (RAD) was negatively related to whitebark pine survival.

The summary statistics are: $n = 32$, $R^2 = 0.52$, $SEE = 0.86$, $F_{4, 27} = 7.32$***

As untransformed equation is:

$$\text{Survival} = 1 / (1 + e^{-B})$$

$$\text{where } B = -0.877 + 0.381 \text{ (Burn Severity)} + 0.0238 \text{ (Yield Capacity)} - 1.729 \text{ (RAD)} + 1.263 \text{ (Monitoring year)}$$

Natural Regeneration

The presence or absence of whitebark pine natural regeneration was recorded for 33 sites (Table 2.4). Regeneration was found in 88 percent of sites within the Greater Yellowstone Ecosystem in contrast to only 35 percent of sites in northwest Montana and northern Idaho.

**Table 2.4. Presence and absence of natural whitebark pine regeneration by site.**

| *Location* | *Number of Sites* | *Present* | *Absent* | *Percent sites with Natural Regeneration* |
|---|---|---|---|---|
| Northwest Montana & Northern Idaho | 17 | 6 | 11 | 35% |
| Greater Yellowstone Ecosystem | 16 | 14 | 2 | 88% |
| **All sites** | **33** | **20** | **13** | **61%** |

Moisture regime

At the plot level (n = 101), the Pearson Correlation analysis was used to examine the effect of moisture regime, aspect, slope, topology, fire severity, percent organic, percent plant on survival. And, a significant relationship between survival and moisture regime (.244) was observed. Mean survival was greater for plots placed in mesic (0.458) and dry (0.483) sites than for wet site plots (0.253) (Figure 2.14).

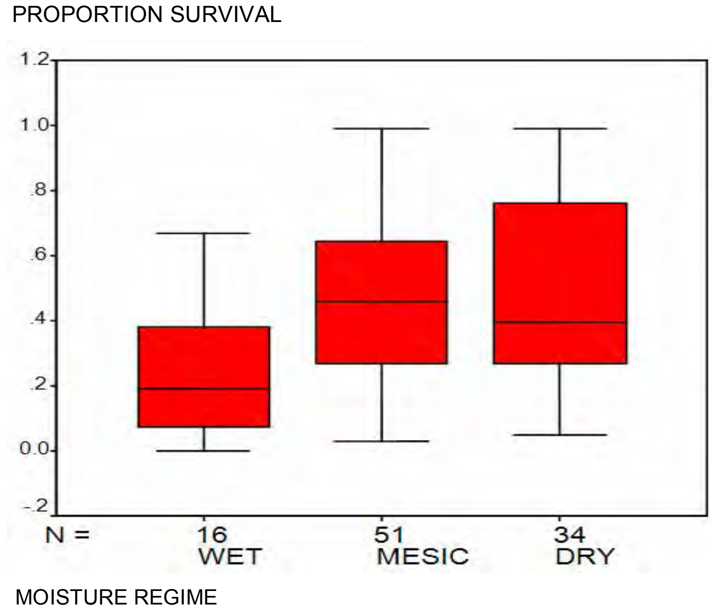


**Figure 2.14. Boxplots of seedlings survival distributions by wet, mesic and dry moisture regimes.**

Microsite presence

The relationship between the presence/absence of a microsite and seedling survival, seedling growth and seedling height were analyzed. 77 percent of all 1105 surviving seedlings were found growing next to a microsite.

**Table 2.5. Percent of surviving seedlings with and without microsites for all years**

| **Monitoring Year** | ***Seedlings With Microsite*** | ***Seedlings No Microsite*** | ***Total Seedlings*** | ***% Seedlings With Microsite*** | ***% Seedlings No Microsite*** |
|---|---|---|---|---|---|
| ***1*** | 124 | 15 | 139 | 89% | 11% |
| ***3 to 15*** | 725 | 241 | 966 | 75% | 25% |
| ***All Years*** | 849 | 256 | 1105 | 77% | 23% |

The presence of a microsite significantly increased mean seedling height and mean seedling apical growth for monitoring years 1, 3 and 4 (Table 2.6). For monitoring years 5 to 15, no significant difference in seedling height or growth, due to MS, was observed (Table 2.7, Figure 2.15).

**Table 2.6. Summary statistics for seedling height for monitoring years 1 through 15 by absence / presence of microsite**

| | No Microsite | | | Microsite Present | | |
|---|---|---|---|---|---|---|
| **Monitoring Year** | **n** | **mean** | **std dev** | **n** | **mean** | **std dev** |
| 1 | 15 | 16.13 | 4.138 | 124 | 19.81 | 8.267 |
| 3 | 12 | 9.50 | 3.631 | 56 | 12.32 | 4.922 |
| 4 | 36 | 13.93 | 6.493 | 159 | 22.32 | 8.719 |
| 5 | 53 | 22.81 | 8.012 | 85 | 22.45 | 7.405 |
| 6 | 30 | 38.08 | 14.525 | 166 | 36.73 | 20.313 |
| 7 | 28 | 28.21 | 13.731 | 111 | 34.41 | 14.153 |
| 11 | 19 | 50.05 | 20.652 | 13 | 54.23 | 25.515 |
| 14 | 8 | 47.00 | 27.867 | 20 | 53.45 | 22.698 |
| 15 | 55 | 56.29 | 36.615 | 115 | 56.85 | 30.811 |

**Table 2.7. Summary statistics for apical growth for monitoring years 1 through 15 by absence/ presence of microsite.**

| | No Microsite | | | Microsite Present | | |
|---|---|---|---|---|---|---|
| **Monitoring Year** | **n** | **mean** | **std dev** | **n** | **mean** | **std dev** |
| 1 | 15 | 1.340 | 0.880 | 124 | 2.487 | 2.174 |
| 3 | 12 | 1.333 | 1.851 | 56 | 4.041 | 2.811 |
| 4 | 36 | 4.394 | 2.937 | 159 | 7.263 | 3.841 |
| 5 | 53 | 5.532 | 2.931 | 85 | 6.807 | 3.240 |
| 6 | 30 | 8.427 | 3.952 | 166 | 8.567 | 4.448 |
| 7 | 28 | 6.946 | 3.609 | 111 | 9.360 | 1.428 |
| 11 | 19 | 8.342 | 3.834 | 13 | 9.077 | 4.800 |
| 14 | 8 | 11.250 | 5.471 | 20 | 9.000 | 4.117 |
| 15 | 55 | 9.944 | 7.602 | 115 | 9.474 | 6.368 |

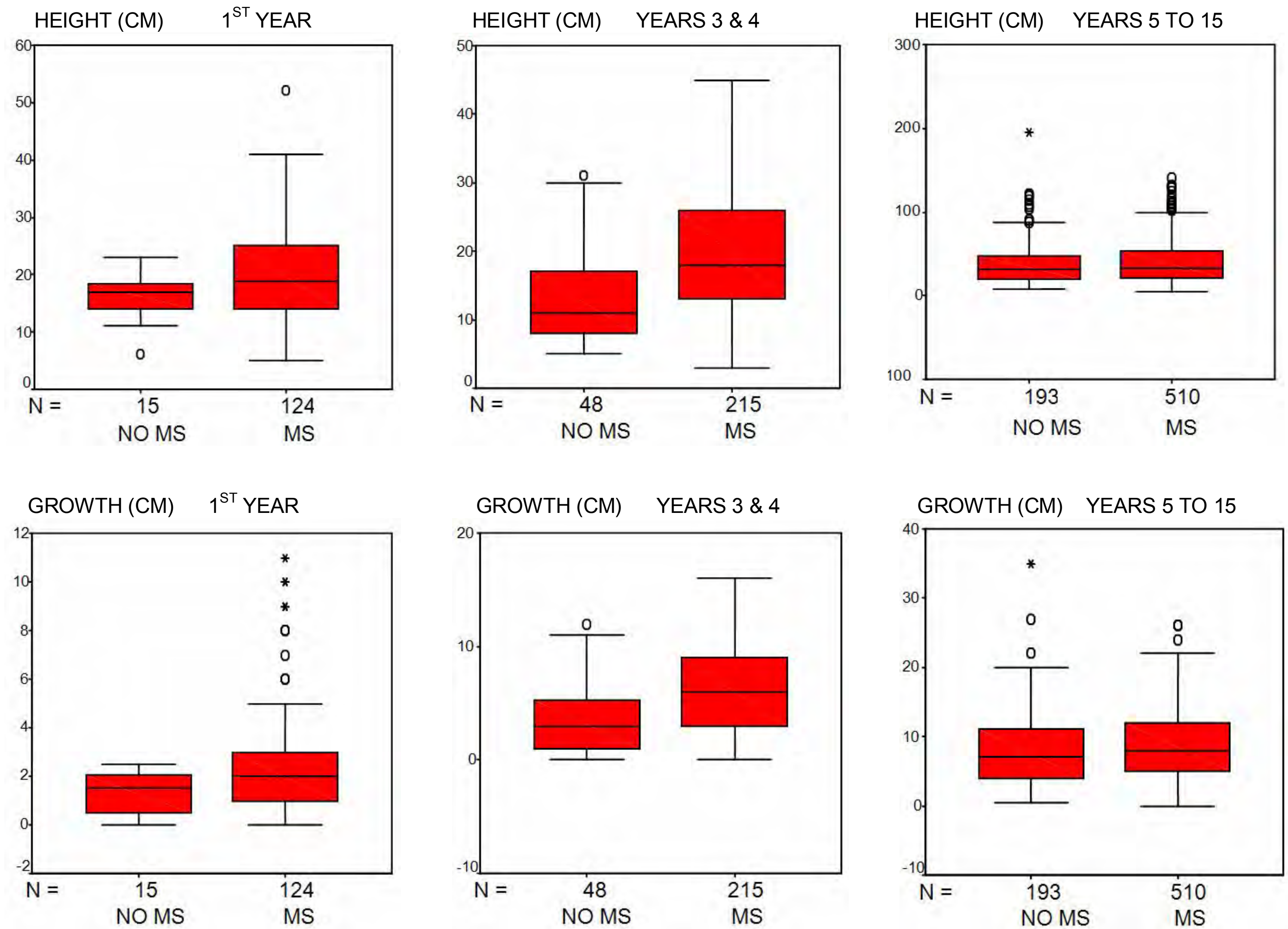


**Figure 2.15. Seedling height and growth distributions by presence & absence of microsite for 1$^{st}$ yr, combined 3$^{rd}$ and 4$^{th}$ yrs and 5 to 15 yrs combined.**

For 1st-monitoring-year seedlings planted on the Bitterroot, Flathead and Lolo National Forests the exact location of all live and dead seedlings was known and the presence or absence of a microsite could be accounted for (Table 2.8). A total of 100 seedlings (dead and live) from these three national forests were used to examine the relationship between microsite and survival.

**Table 2.8. Percent of RMS live and dead seedlings with and without microsites present.**

| | *Microsited Seedlings* | *Seedlings No Microsite* | *Total Seedlings* | *% Microsited Seedlings* | *% Seedlings No Microsite* |
|---|---|---|---|---|---|
| ***Dead Seedlings*** | 13 | 7 | 20 | 65% | 35% |
| ***Live Seedlings*** | 78 | 2 | 80 | 97.5% | 2.5% |
| ***Total Seedlings*** | 91 | 9 | 100 | | |
| ***% Total Seedlings*** | | | | 91% | 9% |

A Chi-square test was conducted and the null hypothesis that seedling survival is independent of microsite was rejected ($P < .001$) implying that there is a dependency between survival and presence of a microsite. For these 1st-yr seedlings Chi-square = 16.857 with df = 1 (adjusted Pearson Chi-square test value).

Microsite direction

The mean height and growth for monitoring-year-one seedlings was found to be statistically significantly different (2-sample t-test) with respect to microsite direction. Seedling mean height (29.56cm) and mean growth (2.76cm) were greater when microsites were located up-slope or to the side of seedlings on a slope. Mean height (17.57cm) and growth (1.67cm) was less for seedlings with microsites located down-slope or on flat ground (for height ($T_C = 2.20$, $P < 0.05$, $\bar{h}_{2+3} = 17.57$, $n_{2+3} = 31$, $\bar{h}_{4+5} = 20.56$, $n_{4+5} = 93$) and for growth ($T_C = 3.16$, $P < 0.01$, $\bar{g}_{2+3} = 1.67$, $\bar{g}_{4+5} = 2.76$))

Microsite distance

There is an inverse linear trend between first year seedling height and LN (distance to object creating microsite) (Figure 2.16).

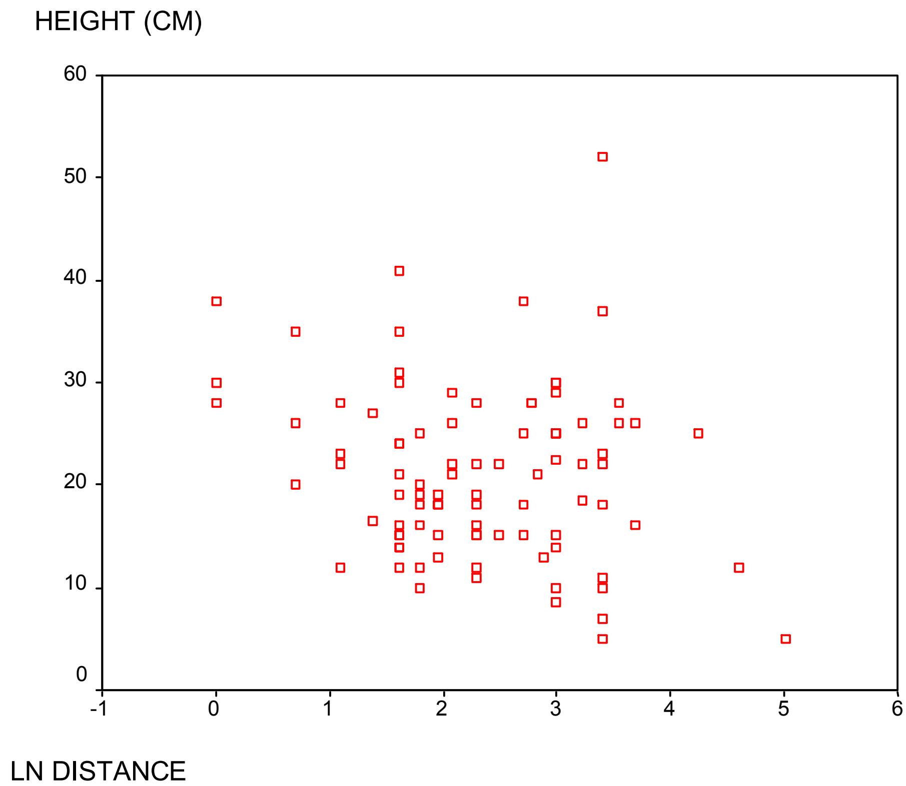


**Figure 2.16. Scatterdiagram of height in centimeters versus Ln (distance cm) of microsite objects for 1st yr seedlings.**

Microsite Type

S-N-K pairwise multiple comparisons were run, after 1-way ANOVAs on height and growth as related to microsite type were performed, and showed that population mean seedling heights and growths were significantly different from each other due to microsite type for $p < .001$. An effect of microsite type on mean height of seedlings was observed but we were unable to discern the nature of those differences. For all microsited seedlings for all monitoring years, an effect of microsite type (Table 2.9, Figure 2.17) on seedling growth was found. Highest mean growth was seen for seedlings microsited with logs (7.658 cm) and rocks (7.310 cm) which were statistically different from the lowest apical growth rates (4.207) which were observed when live trees and shrubs were used as microsites.

**Table 2.9. Distribution of MS types for all microsited seedlings in all monitoring years.**

| *Microsite type* | *Frequency* | *% of Microsites* | *Mean Height cm* | *Mean Growth cm* |
|---|---|---|---|---|
| Log | 500 | 59% | 34.83 | 7.658 |
| Snag | 61 | 7% | 24.07 | 5.926 |
| Live Trees and Scrubs | 15 | 2% | 23.40 | 4.207 |
| Stump | 137 | 16% | 27.93 | 6.343 |
| Rock | 136 | 16% | 27.75 | 7.310 |
| Total Microsited Seedlings | 849 | | | |

**Figure 2.17. Logs and rocks proved to be more effective when used as microsites than stumps.**

## DISCUSSION

Whitebark pine seedlings are successfully being planted and my results indicate that biotic and abiotic environmental conditions are affecting the survival, height, and apical growth of planted seedlings. Microsite presence, type, distance and direction was shown to affect individual seedling survival, height, and apical growth. Data analysis at the site and plot levels indicated that seedling survival was related to moisture regime, burn severity and potential direct solar radiation. Habitat type was investigated at the site level and likely affects seedlings survival although no formal assertions can be made. And, for these studies, there was no significant difference in survival for seedlings planted in the spring or fall.

Seedling Survival

First monitoring year survival rates were similar for all RM plantings. And, the age of seedlings at the time of planting did not seem to affect survival. Historical first year survival rates for seedlings planted at two years old were not significantly different than survival rates for the older (3 to six years old) Coeur d'Alene seedlings evaluated in this study. Similar first year survival rates are potentially due to the comparatively large root systems of greenhouse grown seedlings and I believe that 2-year-old seedlings are truly ready to survive in a natural habitat. Although the trajectory for survival is presently unknown, based on my data, seedling survival rates appear to decline in the first 3 years after planting and stabilize afterward.

The Effect of Microsite

Monitored seedlings in the RM study were significantly associated with microsites and 77 percent of all seedlings found in field surveys were located next to a substantial microsite. Results indicated that, the presence or absence of a microsite (MS) affected first, third and fourth monitoring year seedlings survival, height and growth. The effect of MS appeared to be greatest for first year seedlings, and, a dependency of seedlings on MS for survival was observed for 1$^{st}$ year seedlings in the RM study at the $P < .001$ level. Height and growth of 5$^{th}$ through 15$^{th}$ monitoring year seedlings did not appear to be significantly affected by the presence of a microsite.

Seedling apical growth rates appeared to be affected by microsite type. There was a statistical difference in growth between logs and rocks; and stumps, snags and live trees and shrubs. Logs or downed trees and rocks supported the highest apical growth rates for all seedlings. Large and medium sized logs and downed trees when laid out parallel to the slope provide a large surface area to redirect soil and water flow. Logs used as microsites were observed to terrace or make steps in burned and unstable slopes and provided stable soils for seedlings to establish in. Boulders and large rocks were a good choice for microsites when seedling were located in exposed areas that had experienced severe fire or had low tree cover before fire events. Indications were that snags and stumps supported less apical growth and perhaps due to increased shade inherent to these taller microsite objects. Live trees and shrubs used as microsites supported the lowest apical growth in seedlings. These living microsites, while providing physical protection, potentially compete with seedlings for resources such as water, light and nutrients.

There was a significant difference in height and growth due to MS direction. Seedling mean height and mean growth were greatest when microsites were located up-slope or to the side of seedlings on a slope. And, mean height and growth was less for seedlings with microsites located down-slope or on flat ground. Placing a MS up-slope makes good sense. Most whitebark pine habitat is located in mountainous terrain and moderate to steep slopes are common. Soil flow and erosion of various forms were apparent in most sites especially in severe burns with low plant cover and hydrophobic ashy soils. Large stable microsites up-slope from seedlings were observed at many sites to redirect soil flow to the side of seedlings. When microsites were located down-slope of seedlings soil was 'pooled' and seedlings were partially buried, although many seedlings still survived. On steeper slopes, the effect of snow movement was evident from the numerous cases of sheared-off tops on planted seedlings. Repeatedly, seedling height was level with the top of an up-slope MS object with only new apical growth above the MS object height.

The distance microsite objects were from individual seedlings had a weak statistical significance on the height of seedlings. For first year microsited seedlings in the RM study, seedling height decreased as distance from a MS increased. Ninety-eight percent of the 849 microsited seedlings monitored in the RM study had microsites within 40cm. Seedlings planted directly beside a MS (zero to 5cm) potentially gain the greatest benefits. With close proximity to seedlings, smaller microsite materials can likely be used to greater advantage. Traditionally, temporary microsites have been placed adjacent to seedlings by tree planters to provide shade for seedlings and the need for partial shade is especially important in alpine environments where radiation is increased by elevation.

Nutcrackers place seeds in wide variety of sites, but natural whitebark pine regeneration is significantly associated with microsites (Roy Renkin personal communication; McCaughey and Tomback 2001; personal observation).

Habitat Type

All 36 survey sites used for the RM study were located within intact whitebark pine habitat; an additional 11 sites, located outside of whitebark pine habitat on the Shoshone National Forest (Appendix B, 102 - 112), were surveyed but not included for analysis in this study. These other eleven planting sites were located in limber pine (*Pinus flexilis*) forest habitat type and no whitebark pine of any age class was found in or near these sites. At these eleven sites, approximately 20,000 whitebark pine seedlings were planted in 2000 and in 2006 no planted seedlings were found. Presumably these sites experienced 100% mortality. These seedlings were part of a large batch of seedlings sent to several National Forests and seedlings planted at other sites survived. Although other environmental factors could have influenced survival, it is possible that high mortality was due to the warmer and dryer conditions and the presence of more basic soil types common to limber pine habitats on the Shoshone NF.

Moisture Regime

Within intact whitebark pine habitats, survival for RM seedlings at the individual plot level was affected by moisture regime. Associate plant species were used to determine if plots were placed in wet, mesic or dry sites. Mesic and dry survival rates were nearly equal with the wettest sites having the lowest survival. In planting sites with seasonally saturated soils surviving seedlings were generally found on hummocks or raised areas within these sites. Although, whitebark pine can survive in wet conditions, dryer, rockier, better drained planting sites should be more appropriate for whitebark pine planting.

Burn Severity

When considered as an independent variable, at the site level mixed severity burns exhibited the highest seedling survival rates. When burn severity was used as an independent variable in a logistic regression of seedling survival combined with potential direct solar radiation, number of years since planting, habitat type, and yield capacity, severe burns appeared to support the highest seedling survival. At the plot-level, a Pearson Correlation analysis showed no strong relationship between seedling survival and fire severity alone. The 101 plots used for plot level data analysis were placed within sites in such a way as to capture a singular fire regime within each plot; plots were unburned, moderately burned or severely burned. These plot designations should be the best indicator of within site conditions and no difference in survival was observed due to burn severity. For 1st year seedlings there did appear to be a difference, although not statistically because of a small sample size (n =12), in survival due to burn severity with the highest median survival for moderate burns. Due to these conflicting results, I can make no assertions about the positive or negative effects of fire on whitebark pine seedling survival.

Potential direct solar radiation

Increased potential direct solar radiation appeared to be moderately important and negatively related to whitebark pine seedling survival. According to these results, planting on northwest to southeast facing slopes should moderately improve survival.

Planting Season

Planting Season is a potential factor in seedling survival but no conclusions about the merits of spring or fall planting can be drawn from my studies. Average survival was higher for 1st year RM study seedlings (74%) planted in June of 2005, than for Dunraven Pass seedlings (68%) planted in the September of 2006. Planting season for seedlings in monitoring years 3 through 15 (RM study) were 12 spring plantings (May, June, July), and 16 fall plantings (August, September, October). For these plantings, average survival rates were spring (38%) and fall (43%). Tara Carolin (2006) found that for the three Flattop Mountain sites located in Glacier NP, there was no significant difference in survival between spring and fall plantings.

Slope

At both the site and plot level, slope did not have a statistical influence on seedling survival. Yet, personal observation leads me to believe that slope does have an influence on survival. Throughout the range of these plantings, flat sites harbored more ground dwelling mammals than sites located on a slope. These below ground grazers and well as above ground grazers have severely reduced seedling survival at some flat sites. On the Caribou Targhee NF one site, surveyed but not used for statistical analysis due to inadequate data, was located on flat ground and was still experiencing seedling mortality from underground grazers 8 years after planting. Extensive grazing and wallowing by elk at the Marshall Mountain site appeared to have severely negatively impacted planted seedlings survival. Surviving seedlings at both of these sites were robust but very few had survived. Flat sites, as well, can hold snowpack longer shorting the growing season and melt off can pool and saturate soils for longer periods than on sloped sites.

# CHAPTER 3

# DUNRAVEN PASS PLANTING, 2006

## RESEARCH OBJECTIVES

The specific aim of this study was to design and monitor an experimental whitebark pine planting for Yellowstone National Park using the knowledge gained from surveys of past planting efforts. Individual objectives were to: 1) plant and monitor whitebark pine seedlings; 2) determine the relationship between whitebark pine seedling survival and fire severity, habitat type, and presence of microsite; and 3) present new information on mycorrhizal associates.

## METHODS

### Study Area

In September 2006, Yellowstone National Park re-vegetation crews, the Montana Conservation Corps, and my field assistant and I planted 4000 two-year-old bare root seedlings along Dunraven Pass on Mount Washburn in Yellowstone NP (Table 3.1). The slopes of Mount Washburn, burned in the 1988 Yellowstone fires, are a mosaic of burned mixed conifer forest, unburned stands of large diameter whitebark pine, subalpine fir and Engelmann spruce, and subalpine meadows. Seedlings were planted in portions of the Dunraven Pass road corridor disturbed by road construction and adjacent to burned and unburned forest (Table 3.1). As well, seedlings were planted outside of the road corridor in undisturbed burned and unburned mixed conifer forests and meadows.

**Table 3.1. Dunraven Pass site level information.**

| *Date Planted* | *Seedlings Planted* | *Latitude* | *Longitude* | *Elevation in Feet* | *Aspect* | *Slope in Degrees* | *Habitat Type* |
|---|---|---|---|---|---|---|---|
| Sep-06 | 4000 | 44 | -110 | 8900 | Variable | 0 - 30 | PIAL |

Plot-Level Data Collection

Monitoring plots were installed on the day seedlings were planted and efforts were made to monitor the total range of planting conditions and locations. Plots were set up at ten locations (Plots 1 through 9 and Plot 11) and 273 seedlings monitored. Monitoring plot 10 was designed to monitor seeds sown the day of the planting and is not included in data analysis for this study. Monitoring plots were installed in the following manner. A rebar stake was first installed at each monitoring site. From this stake, using a meter tape, the distance (to the nearest centimeter) and azimuth (using a hand held compass) was recorded for each monitored seedling. For each plot, the aspect and slope were recorded using a hand held compass. Elevation was determined using a *Garmin etrex Legend* GPS. An ocular estimate of percent plant cover was recorded and the presence or absence of burn was noted. As well, the presence or absence of mature burned or unburned whitebark pine within the planting area was recorded.

Seedling-Level Data Collection

At the time of monitoring plot installation, the presence or absence of a microsite was recorded for each of the 273 monitored seedlings. Only downed logs, stumps, large rocks, snags and live whitebark pine were considered as microsites for this study.

The ten Dunraven plots were revisited in June of 2007. For each of the 273 monitored seedlings, a designation of dead or alive was assigned. The health of each seedling was also assessed using an ordinal scale of one to ten. The health designation for all seedlings was a subjective assessment based on growth, needle color, loss of needles and the presence or absence of contusion or broken limbs. A healthy seedling (apparent apical growth, moderate amounts of yellow or brown needles) received a ranking of 6 to 10. A compromised seedling (ranking of 1 to 5) had dying needles and branches, little or no apical growth and was considered to have a poor chance of surviving.

In June of 2007, Montana State University Plant Pathologist, Cathy Cripps removed planted seedlings near each Dunraven monitoring plot and assessed the percent mycorrhizal colonization for these seedlings.

# RESULTS

## Seedling Survival

After 9 months the first-year survival rate for the Dunraven Pass seedlings was 68% (Table 3.2).

**Table 3.2. Plot level ecological conditions for Dunraven Pass Planting,**

| *Plot* | *Aspect* | *Slope* | *Seedlings Monitored* | *% Live* | *% Mycorrhizal Colonization* | *Habitat Notes* |
|---|---|---|---|---|---|---|
| 1 | W | 30 | 30 | 87% | < 1% | unburned, PIAL** |
| 2 | W | FLAT | 25 | 96% | < 1%* | unburned, disturbed |
| 3 | W | 40 | 27 | 81% | < 1%* | unburned, disturbed, PIAL** |
| 4 | SE | 25 | 25 | 84% | 0% | unburned, meadow |
| 5 | SE | 15 | 17 | 59% | 0% | unburned, meadow |
| 6 | NW | 20 | 28 | 43% | < 30% | burned, PIAL** |
| 7 | NW | 30 | 30 | 100% | < 5% | burned, PIAL** |
| 8 | S | 20 | 50 | 30% | 0% | unburned, windy, exposed |
| 9 | W | 10 | 16 | 94% | < 5% | burned/unburned PIAL** |
| 11 | NW | 15 | 25 | 44% | < 1% | unburned/PIAL** |
| **Total** | | | **273** | Ave = 68% | | |

* Non-native nursery fungi
** Mature burned or unburned whitebark pine present in or adjacent to planting site

## Microsite Presence

The relationship between microsite (MS) and survival was analyzed (Table 3.3). A Chi-square test was conducted to test the null hypothesis whether seedling survival was independent of microsite. That hypothesis was soundly rejected with P < .001 implying that survival was dependent on the presence of a microsite. For these seedlings Chi-square = 73.337 with df = 1 (adjusted Pearson Chi-square test value).

**Table 3.3. Dunraven live and dead seedlings with and without microsites present.**

| | *Total Seedlings* | *Microsited Seedlings* | *Seedlings No Microsite* | *% Microsited Seedlings* | *% Seedlings No Microsite* |
|---|---|---|---|---|---|
| ***Dead Seedlings*** | 87 | 8 | 79 | 9% | 91% |
| ***Live Seedlings*** | 186 | 122 | 64 | 66% | 34% |
| ***Total Seedlings*** | 273 | 130 | 143 | 48% | 52% |

<u>Mycorrhizal Colonization</u>

The following assessment of mycorrhizal colonization of seedlings planted on Dunraven pass is based on research by Cathy Cripps (2007) and presented with her permission.

Initial mycorrhizal colonization of seedlings with native fungi (Figure 3.1) was found for all planting sites located near or adjacent to burned or unburned mature whitebark pine and mycorrhizal colonization was higher for burned sites than for unburned sites (Table 3.2). A diversity of native Suilloid fungi was found to be available at these sites and mycorrhizal colonization of healthy green seedlings had begun. Only one "compromised" seedling had some colonization. Mycorrhizal colonization levels were still low on all sites except for site 6. Only the nursery fungus E-strain was recorded for sites 2 and 3, both located in disturbed, unburned sites. No mycorrhizal colonization of seedlings had initiated at sites 4 (unburned, subalpine meadow) and 5 (unburned, disturbed, subalpine meadow) or site 8 (windy, barren, unburned).

Photo A Photo B

**Figure 3.1. A. Mycorrhiza initiating on roots of seedling planted along Dunraven Pass. B. Native ectomycorrhizal fungus covering root of whitebark pine seedling planted on Dunraven Pass (Cripps photos).**

The average health of Dunraven pass seedlings was higher in sites where mycorrhizal colonization of sampled seedlings had begun (Figure 3.2).

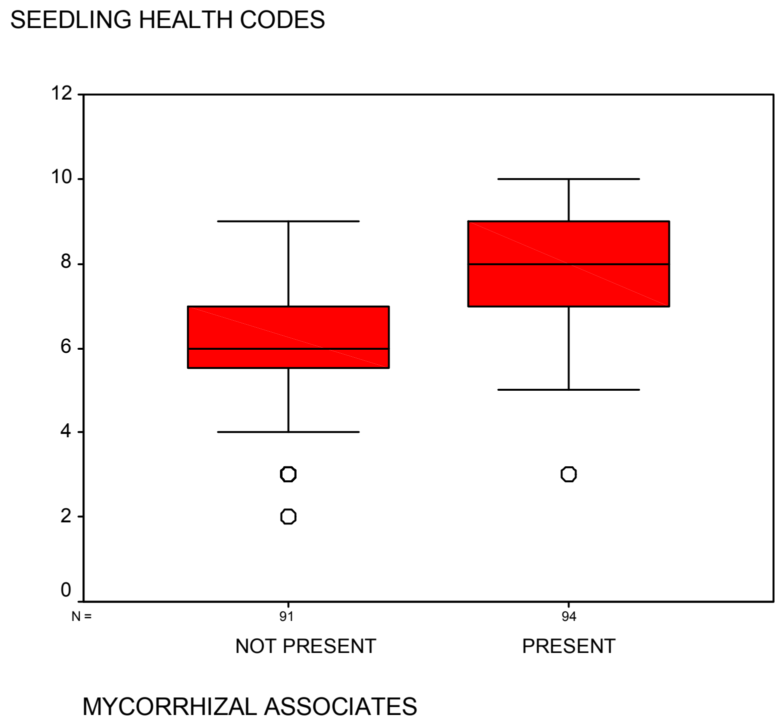


**Figure 3.2. The average health of Dunraven pass seedlings was higher in sites where mycorrhizal associates were present on the roots of sampled seedlings.**

Seedling survival rates were not improved by mycorrhizal colonization of seedlings (Figure 3.3).

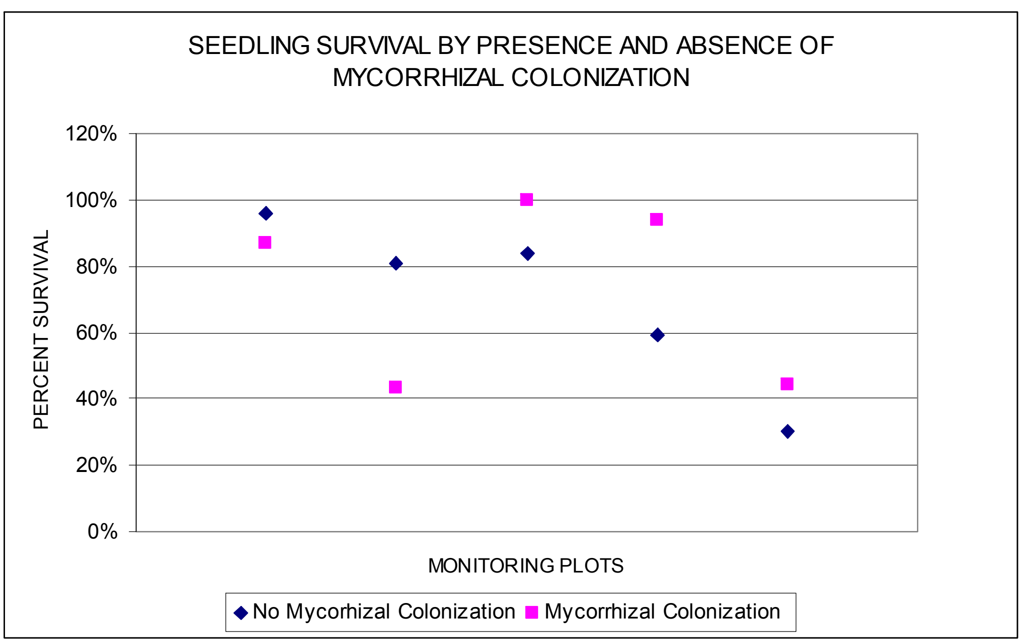

**Figure 3.3. Seedling survival plotted against mycorrhizal colonization occurring at sites. Increased survival could not be attributed to mycorrhizal colonization of seedlings.**

## DISCUSSION

The Effect of Microsite

The beneficial affects of the presence of a MS were further supported by the results of the Dunraven study. Although the percentage of seedlings on Dunraven pass with and without a MS were nearly equal (48% with MS, 52% without MS), 91% of the seedling that died during the winter of 2007 (87 seedlings) were not planted next to a MS.

Dunraven monitoring plot 6 was located on a slope adjacent to the road and in an area that was used to dump snow in winter (Mary Hektner, personal communication). Most seedlings adjacent to the road were dead or could not be found, yet, all microsited seedlings (11) survived in this plot and all dead or missing seedlings (16) were not planted next to a microsite. Microsites appeared to serve important functions as wind breaks protecting seedlings from wind desiccation. On Dunraven pass, the plot with the lowest survival rate (30%) was located in a windy, unburned and treeless site. Fifty seedlings were monitored but only fifteen seedlings, all planted on the leeward side of two large rocks, survived. Seedlings in monitoring plot 7 achieved 100% survival. These seedlings were planted in a disturbed road cut, on a slope adjacent to a severely burned whitebark pine dominated stand. Downed logs from the burn were used for micrositing as well as large and medium sized rocks and all seedlings had been microsited. At site 7, all seedlings were healthy when monitored in June 2007.

Mycorrhizal Colonization

There was no evidence that the presence of mycorrhizal associates within individual monitoring plots increased seedling survival, but, mycorrhizal colonization did appear to increase the fitness of surviving seedlings.  Monitoring plot 6, located in a burned area adjacent to an unburned mature whitebark pine stand had the highest mycorrhizal colonization for sampled seedlings yet had a low survival rate (43%). At this site the determining factor for seedling survival appeared to be the presence or absence of microsites; all dead seedlings were not microsited.

As well, the presence of native beneficial mycorrhiza was associated exclusively with burned and unburned whitebark pine communities. No colonization with native mycorrhiza had occurred in monitoring plots located within two subalpine meadows and at a barren site. Mycorrhizal colonization was higher for burned sites than for unburned sites. And, these findings are consistent with recent research. Warnock et al. (2007) documented studies showing that in the presence of charcoal resulting from burn events, the ability of mycorrhiza to colonize seedlings is improved and, that in the presence of activated charcoal, the rate of mycorrhizal colonization of seedlings increases. The presence of charcoal in the soil of some monitoring plots could be facilitating and increasing EM colonization of seedlings at these sites. It is also possible that fungi from unburned whitebark pine communities are colonizing planted seedlings. Trusty and Cripps (2007) found high levels of mycorrhizal colonization on whitebark pine seedlings located within a severely burned whitebark pine stand adjacent to a stand of mature unburned whitebark pine. 100% of planted seedlings examined were colonized with beneficial mycorrhizal associates five years after planting. And, all natural whitebark pine regeneration in the unburned forest and planted seedlings in the burn shared native Suilloid fungi species.  It is also possible that, in burned whitebark pine habitat, beneficial mycorrhiza are still present in the soil.

# CHAPTER 4

# CONCLUSIONS

Greenhouse grown whitebark pine seedlings are surviving in plantations throughout the Rocky Mountains and it is possible to improve survival rates through good planting practices. When seedlings, on Dunraven Pass, were planted within mixed burn whitebark pine habitat, on a north facing 30 degree slope, and with a microsite located up-slope of each seedling, first year survival was 100 percent.

Seedling survival was significantly higher for microsited seedlings. When logs were used as microsites and placed adjacent to and up-slope of seedlings, mean seedling height and apical growth were the greatest. Seedling survival was higher in dry and mesic sites than in wet sites. Beneficial mycorrhizal associates were found only within whitebark pine habitat and were more abundant in burned sites. These mycorrhizal associates were associated with increased health in planted seedlings.

Although some environmental conditions investigated in this study were shown to influence seedling survival, height, health, or growth, interactions between these environmental conditions were minimally explored. In light of this lack of assessment of interaction, I was unable to rank environmental conditions in an order of importance to seedling survival; interactions between the effect of moisture regime, burn severity, habitat type, slope, presence of microsite and presence of mycorrhizal associates should be further explored. As well, the mechanics of plant facilitation and plant competition are likely very important and were not considered within this study. Long-term monitoring of planting sites is warranted to track reductions in planted seedling survival over time at specific sites and allow a determination of how reduced survival relates to changes in environmental conditions.

## Observations from the Field

- Planting whitebark pine seedlings in 'mixed plantings' (along side other conifers) is not supportive of high whitebark pine seedling survival. A number of mixed planting sites were visited during my field season and in all cases whitebark pine were being out-competed by faster growing tree species. Whitebark pine is slow growing and will not ‘release’ under any canopy cover.

- Don’t plant in burned lodgepole pine habitat. Lodgepole regeneration will rapidly replace the burned stand and over shadow any whitebark pine.
- Only 21 out of the 1105 seedlings monitored in my RM study had beargrass located within 40 centimeters of individual seedlings; no statement can be made as to the influence of beargrass from my studies. That said, beargrass is extremely hardy and competitive. Beargrass roots create large underground masses that compete with and crowd out whitebark pine seedling roots. Even in some severely burned areas, beargrass roots survive and beargrass can and will regenerate. As well, tree planters have communicated to me that it is extremely difficult to plant in areas with large populations of beargrass.
- Standing dead trees will in time fall and there have been several reports of seedlings being killed by falling trees. Although snags make good microsites downed trees make better microsites.
- Our National Forests have an abundance of wildfire burned areas and burned logging units. Many of these burns and burned logging units are within or adjacent to whitebark pine habitat and these areas would be my first choice for planting. Access on logging roads would be generally available, these areas contain more than enough micrositing materials (logs), and there would be no need to prepare sites for planting.
- In conversations with tree planters, I have come to realize that most tree planters consider the function of a microsite to be the provision of shade. Although providing shade is an important function, a microsite can be placed so that it provides many more ecosystem functions.
- Not one of the thousands of planted seedlings that I observed during my field surveys had obvious infections of white pine blister rust.
- Mountain Pine Beetles do not attack seedlings; planting blister rust resistant whitebark pine seedlings is a good choice for insuring that we have a next generation of whitebark pine.

Planting Recommendations

- Plant in intact whitebark pine habitat.
- Plant in the burned portions of mixed severity burns.
- Plant in dry and mesic sites but not in wet sites, in saturated soils, or in sites with late snow melt off.
- Plant on 10 degree to 45 degree slopes but not on flat ground.
- Plant next to microsites. Logs and downed trees make the best microsite and a single log can provide micrositing for several seedlings. In order of decreasing effectiveness, these objects also make good microsites: large rocks, stumps, and snags.
- Use microsites up-slope and in close proximity to seedlings
- Avoid planting in extremely windy sites.
- Plant slowly and carefully; seed sources are becoming increasingly scarce.

## LITERATURE CITED

Arno, S. F. 2001. Community Types and Natural Disturbance Processes. Pages 74-84 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 R. J. Hoff. 1990. *Pinus albicaulis* Engelm. Whitebark pine. Pages 268-279 in R. M. Burns and B. H. Honkala, technical coordinators. Silvics of North America. United States Department of Agriculture, Forest Service, Agriculture Handbook of 654, Washington, D.C.

Arno, S. F., and R. J. Hoff. 1989. Silvics of whitebark pine (*Pinus albicaulis*). USDA Forest Service, Intermountain Research Station, General Technical Report INT-253, Ogden Utah.

Burr, K. E., A. Eramian, and K. Eggleston. 2001. Growing whitebark pine seedlings for restoration. Pg. 325-345 in D.F. Tomback, S. F. Arno, and R. E. Keane, editors. *Whitebark pine communities: ecology and restoration*. Island Press, Washington, D.C.

Cairney, J. W. and A. A. Meharg. 2003. “Ericoid mycorrhiza: a partnership that exploits harsh edaphic conditions”. *European Journal of Soil Science.* 54: 735–740. Retrieved March 6, 2006 http://www.blackwell-synergy.com.weblib.lib.umt.edu:2048/doi/full/10.1046/j.1351-0754.2003.0555.x

Carolin, T. 2006. Whitebark and Limber Pine Restoration in Glacier National Park: Monitoring Results. Nutcracker Notes 10: 14

Cripps, C. L. and K. R. Mohatt. 2005. Preliminary results on the Ectomycorrhizal Fungi of Whitebark Pine Forests. Nutcracker Notes 7: 9-11.

Cripps, C. L. 2007. Ectomycorrhizae of Whitebark Pine. Whitebark Pine Foundation Website, Ecology, Mycorrhizae: http://www.whitebarkfound.org/Mycorrhizae.html.

Dekker-Robertson, D., and L. P. Bruederle. 2001. Management Implications of Genetic Structure Pg. 310-324 in D. F. Tomback, S. F. Arno, and R. E. Keane, editors. *Whitebark pine communities: ecology and restoration*. Island Press, Washington, D.C.

Deluca, T. H. and G. H. Aplet. 2008. Charcoal and carbon storage in forest soils of the Rocky Mountain West. Front Ecol Environ 2008; 6, doi:10.1890/070070

Hansen-Bristow, K., M. Clifford, and G. Schmid. 1990. Geology, Geomorphology, and Soils within Whitebark Pine Ecosystems. Pages 62-71 in W. C. Schmidt and K. J. McDonald, 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.

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*. Island Press, Washington, D.C.

Howard, J. 1999. Transplanted whitebark pine regeneration: The response of different populations to variation in climate in field experiments. M.S. Thesis. Division of Biological Sciences: The University of Montana, Missoula, MT.

Hutchins, H. E. and R. M. Lannar. 1982. The central role of the Clark's nutcracker in the dispersal and establishment of whitebark pine. Oecologia 55:192-201

Jorgensen, S. M., and J. L. Hamrick. 1997. Biogeography and population genetics of whitebark pine, Pinus albicaulis. Canadian Journal of Forest Research 27: 1574-1585

Keane, R. E. and S. F. Arno. 1993. Rapid Decline of Whitebark Pine in Western Montana: Evidence form 20 – Year Remeasurements. Western Journal of Applied Forestry. 8(2): 92-94.

Keane, R. E. and S. F. Arno. 2001. Restoration Concepts and Techniques. Pages 367-400 D. F. Tomback, S. F. Arno, and R. E. Keane, editors. *Whitebark pine communities: ecology and restoration*. Island Press, Washington, D.C.

Keane, R. E. 2001. Successional Dynamics: Modeling an Anthropogenic Threat. Pages 159-191 in D. F. Tomback, S. F. Arno, and R. E. Keane, editors. *Whitebark pine communities: ecology and restoration*. Island Press, Washington, D.C.

Kendall, K. D., and R. E. Keane. 2001. Whitebark Pine Decline: Infection, Mortality, and Population Trends. Pages 221-242 in D. F. Tomback, S. F. Arno, and R. E. Keane, editors. *Whitebark pine communities: ecology and restoration*. Island Press, Washington, D.C.

Kendall, K., D. Schirokauer, E. Shanahan, R. Watt, D. Reinhart, R. Renkins, S. Cain, and G. Green. 1996. Whitebark pine health in northern Rockies national park ecosystems: A preliminary report. Nutcracker Notes 7:16. http://www.mesc.usgs.gov/glacier/nutnotes.htm.

Kernaghan, G. 2001. Ectomycorrhizal fungi at tree line in the Canadian Rockies II. Identification of Ectomycorrhizae by anatomy and PCR. Mycorrhiza 10: 217-229.

Lorenz, T. J. 2007. Radio-Tagging Clark's Nutcrackers: Preliminary Data from a Study of Habitat Use in Washington State. Proceedings - Whitebark Pine: A Pacific Coast Perspective. Unpublished data.

McCaughey, W. W., and W. C. Schmidt. 1990. Autecology of Whitebark Pine. Pages 85-96 in W. C. Schmidt and K. J. McDonald, 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.

McCaughey, W. W., and W. C. Schmidt. 2001. Taxonomy, Distribution, and History. Pages 29-40 in D. F. Tomback, S. F. Arno, and R. E. Keane, editors. *Whitebark pine communities: ecology and restoration*. Island Press, Washington, D.C.

McCaughey, W. W., and D. F. Tomback. 2001. The Natural Regeneration Process. Pages 103-120 in D. F. Tomback, S. F. Arno, and R. E. Keane, editors. *Whitebark pine communities: ecology and restoration*. Island Press, Washington, D.C.

McCune, B. and D. Keon.  2002.  Equations for potential annual direct incident radiation and heat load. Jour. Veg. Science 13: 603-606.

McDonald, G. I., and R. J. Hoff. 2001. Blister Rust: An Introduced Plague. Pages 193-220 in D. F. Tomback, S. F. Arno, and R. E. Keane, editors. Whitebark pine communities: ecology and restoration. Island Press, Washington, D.C.

Mohatt, K. R. 2006. Ectomycorrhizal fungi of whitebark pine (Pinus albicaulis) in the Greater Yellowstone Ecosystem. M.S. Thesis, Montana State University.

Mohatt K. R., C. L. Cripps, and M. Lavin. 2008. Ectomycorrhizal fungi of whitebark pine (a tree in peril) revealed by sporocarps and molecular analysis of mycorrhizae from treeline forests in the Greater Yellowstone Ecosystem. Botany 56: 12 pgs (in ed.).

Nilsson L. O., R. Giesler, E. Bååth, and H. Wallander. 2005. "Growth and biomass of mycorrhizal mycelia in coniferous forests along short natural nutrient gradients". New Phytologist. 165:613–622. March 5, 2006 (www.newpytologist.com)

Perkins, J. L. 2004. Pinus albicaulis seedling regeneration after fire. Ph.D. thesis, Division of Biological Sciences, University of Montana, Missoula, MT.

Pfister, R. D., B.L. Kovalchik, S.F. Arno, and R. C. Presby. 1977. Forest Habitat Types of Montana. USDA Forest Service, Intermountain Research Station, General Technical Report INT-34, Ogden, Utah.

Read, D.J. 1998. The mycorrhizal status of *Pinus*. *In* Ecology and Biogeography of *Pinus.,* ed D.M. Richardson, Cambridge University Press, Cambridge, U.K. Pgs 324-340.

Read, D.J., J.R. Leake, and J. Perez-Moreno. 2004. "Mycorrhizal fungi as drivers of ecosystem processes in heathland and boreal forest biomes." Can. J. Bot. 82:1243–1263. Retrieved April 4, 2006 (http://canjbot.nrc.ca)

Reid, M. S., S. V. Cooper, and G. Kittel. 2004. Vegetation Classification of Waterton-Glacier International Peace Park (Final Report). USGS-NPS Vegetation Mapping Program, NatureServe, Western Regional Office, Boulder, CO. 39 pp. + Appendices [KDH1].

Renkin, R. A., and D. G. Despain. 1991. Fuel moisture, forest type, and lightning-caused fire in Yellowstone National Park. Can. J. For. Res. 22:37-45.

Scott, G. L., and W. W. McCaughey. 2006. Whitebark Pine Guidelines for Planting Prescriptions. Riley, L.E., Dumroese, R.K., Landis, T.D., tech. coords. National Proceedings: Forest and Conservation Nursery Associations - 2005. Proc. RMRS-P-43. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 84-90

Tomback, D. F. 2001. Clark's Nutcracker: Agent of Regeneration. Pages 89-104 in D. F. Tomback, S. F. Arno, and R. E. Keane, editors. *Whitebark pine communities: ecology and restoration*. Island Press, Washington, D.C.

Tomback, D. F. 2007. Blister rust in Krummholz whitebark pine. Whitebark Pine Foundation Annual Meeting, Lincoln MT. Sept., 2007 (oral presentation).

Tomback, D. F., S.F. Arno, and R.E. Keane. 2001. The Compelling Case for Management Intervention. Pages 3-25, in D. F. Tomback, S. F. Arno, and R. E. Keane, editors. *Whitebark pine communities: ecology and restoration*. Island Press, Washington, D.C.

Tomback, D. F., and K.C. Kendall. 2001. Biodiversity Losses: The Downward Spiral. Pages 243-259 in D. F. Tomback, S. F. Arno, and R. E. Keane, editors. *Whitebark pine communities: ecology and restoration*. Island Press, Washington, D.C.

Trusty, P., and C.L. Cripps. 2007. Ectomycorrhizal fungi of whitebark pine seedlings on burns in regard to restoration strategies. Mycological Society of America Annual Meeting, Baton Rouge, LA, Aug. 6-9.

Warnock, D. D., J. Lehmann, T. W. Kuyper, and M. C. Rillig. 2007. Mycorrhizal responses to biochar in soil – concepts and mechanisms. Plant Soil 300:9–20

Weaver, T., 1990. Climates of Subalpine Pine Woodlands. Pages 72-79 in W. C. Schmidt and K. J. McDonald, 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.

Weaver, T. 1994. Climates Where Stone Pines Grow, a Comparison. Pages 85-89 in W. C. Schmidt and F. Holtmeier, compilers. Proceedings – International Workshop on Subalpine Stone Pines and Their Environment: the Status of Our Knowledge. USDA Forest Service, Intermountain Research Station, General Technical Report INT-GTR-309, Ogden, Utah.

Weaver, T. 2001. Whitebark Pine and Its Environment. Pages 41-73 in D. F. Tomback, S. F. Arno, and R. E. Keane, editors. *Whitebark pine communities: ecology and restoration*. Island Press, Washington, D.C.

Wurzburger, N., and C.S. Bledsoe. 2001. "Comparison of ericoid and ectomycorrhizal colonization and ectomycorrhizal morphotypes in mixed conifer and pygmy forests on the northern California coast" *Can. J. Bot*. 79:1202–1210. Retrieved March 5, 2006 (http://canjbot.nrc.ca)

# APPENDICES

# APPENDIX A

## DATA CODES

### SITE-LEVEL

Burn Severity
Unburned – 0
Moderate – 1
Mixed – 2
Severe – 3

Whitebark Pine Habitat
NO – 0
Minor Component – 1
Major Component – 2

Natural Regeneration
No – 0
Yes – 1

Season Planted
Spring – 1
Fall - 2

### PLOT-LEVEL

Keyed Plant Community Type
Wet – 1
Mesic – 2
Dry – 3

### TREE-LEVEL

MS Direction
More than one direction – 1 (unused)
Down – 2
Flat – 3
Side – 4
Up – 5

MS Type
Log – 1
Dead Tree/Snag – 2
Other – 3
Stump – 4
Rock – 5

# APPENDIX B

## ROCKY MOUNTAIN STUDY - SITE DATABASE

| ENTRY NO. | LOCATION | PLANTING NAME | STAND NUMBER | PLANTING DATE | SEEDLINGS PLANTED | ASPECT |
|---|---|---|---|---|---|---|
| 1 | Bitterroot NF - Darby RD | Dam Lake | 24002004 | 6/19/05 | 60 | W |
| 2 | Bitterroot NF - Darby RD | Salkaho | 24002002 | 6/14/05 | 130 | S |
| 3 | Caribou Targhee - Island Park RD | Black Canyon Rd | 213-76 | 9/17/94 | 2200 | S |
| 4 | Caribou Targhee - Island Park RD | Black Canyon Rd | 213-76 South | 9/23/96 | 320 | S |
| 5 | Caribou Targhee - Island Park RD | Black Canyon Rd | 213-085 | 9/24/98 | 1100 | SW-W |
| 6 | Caribou Targhee - Island Park RD | Fish Creek Rd | 251-620 | 7/1/99 | 5000 | SSE |
| 7 | Caribou Targhee - Island Park RD | Black Canyon Rd | 217-143 | 10/1/01 | 2800 | SW |
| 8 | Caribou Targhee - Island Park RD | Black Canyon Rd | 217-143 | 6/1/02 | 7000 | VARIED |
| 9 | Caribou Targhee NF - Dubois RD | | 294-001 | 5/1/01 | 5400 | SW |
| 10 | Clearwater NF - Powell RD | Brushy Fork | 601-03-014 | 7/14/99 | 1666 | W |
| 11 | Clearwater NF - Powell RD | Spruce Creek | 602-07-010 | 7/13/99 | 600 | N |
| 12 | Clearwater NF - Powell RD | Spruce Creek | 602-07-019 | 7/13/99 | 1600 | NW |
| 13 | Clearwater NF - Powell RD | Beaver Ridge/burned 2003 | 607-01-010 | 7/14-18/98 | 6400 | S |
| 14 | Clearwater NF - Powell RD | Beaver Ridge | 607-01-072 | 7/9/00 | 6720 | SW |
| 15 | Clearwater NF - Powell RD | Beaver Ridge/burned 2003 | 607-01-073 | 7/14-18/98 | 6800 | S |
| 16 | Clearwater NF - Powell RD | Granite Pass | 611-02-030 | 7/5/00, 6/27/01 | 852 | SW |
| 17 | Clearwater NF - Powell RD | Granite Pass | 613-06-015 | 6/26-27/01 | 86 | W |
| 18 | Clearwater NF - Powell RD | Granite Pass | 613-06-028 | 6/26-27/01 | 50 | W |

| ENTRY NO. | SLOPE | ELEVATION | HABITAT TYPE | TYPE OF PLANTING | BURN HISTORY | SEEDLING AGE | NURSERY |
|---|---|---|---|---|---|---|---|
| 1 | 5 | 7500 | 690 | WBP | Ann Burn/ 1994/severe | | Coeur d'Alene |
| 2 | 0 | 7600 | 690 | WBP | Ann Burn/ 1994/severe | | Coeur d'Alene |
| 3 | 5 | 8100 | 730 | WBP | 1988 - North Fork Fire | Containerized 1-0 | Bitterroot Growers |
| 4 | 5 | 8100 | 730 | WBP | 1988 - North Fork Fire | Containerized 3-0 | Bitterroot Growers |
| 5 | 30 | 8100 | 730 | WBP | 1988 - North Fork Fire | Containerized 2-0 | |
| 6 | 30 | 7800 | 730 | WBP | 1988 - North Fork Fire | Containerized 2-0 | |
| 7 | 45 | 8000 | 730 | WBP | 1988 - North Fork Fire | Containerized 2-0 | |
| 8 | 60 | 8000 | 730 | WBP | 1988 - North Fork Fire | Containerized 2-0 | |
| 9 | 30 | 8100 | 732 | WBP | unburned | Containerized 2-0 | |
| 10 | 35 | 6100 | 694 | MIXED | Prescribed | | Western Forest Systems |
| 11 | 15 | 6750 | 672 | MIXED | Prescribed?60% burned | | Western Forest Systems |
| 12 | 15 | 6500 | 673 | MIXED | Prescribed?35% burned 1998 | | Western Forest Systems |
| 13 | 40 | 7000 | 850 | WBP | unburned | | Western Forest Systems |
| 14 | 35 | 6600 | 692 | WBP | Eco burn 1999 | 1.5 | Western Forest Systems |
| 15 | 30 | 6800 | 694 | WBP | unburned | | Western Forest Systems |
| 16 | 15 | 6400 | 690 | MIXED | wildfire/2000/Crooked Fire | | Western Forest Systems |
| 17 | 20 | 6200 | 673 | MIXED | wildfire/2000/Crooked Fire | | Western Forest Systems |
| 18 | 25 | 6300 | 691 | MIXED | wildfire/2000/Crooked Fire | | Western Forest Systems |

| ENTRY NO. | PLANTING COMMENTS | STAND HISTORY |
|---|---|---|
| 1 | | Selected overstory removal: ABILAS, PINCON, PICENG, SOME PINALB, 1972; SALVAGE LOGGING OPERATION 1984 |
| 2 | Rocky | Selected overstory removal 1972 |
| 3 | S end not planted Groups of 10 - 15 trees | gophers killed 1st 2 yrs |
| 4 | tons of gophers, planted part missed in 1994 | |
| 5 | steep side hill | |
| 6 | steep side hill | |
| 7 | steep side hill | |
| 8 | steep side hill to creek bottom | |
| 9 | side hill | |
| 10 | 50% of area is rock, planted around rocks | logged |
| 11 | 1/2 acre snowdrift when planted, south end rock | logged~ 60% burned |
| 12 | some gopher disturbed soil | logged, 1-2 acres new blowdown |
| 13 | tough planting, beargrass, roots, rock, duff, sod | slashed, not burned |
| 14 | lots of VACSCO | cut/burned 1999 |
| 15 | tough planting, beargrass, roots, rock, duff, sod | slashed, not burned |
| 16 | soil compacted | salvaged/~ 1/2 stand burned 2000, re-planted 2001 |
| 17 | | |
| 18 | | |

| ENTRY NO. | LOCATION | PLANTING NAME | STAND NUMBER | PLANTING DATE | SEEDLINGS PLANTED | ASPECT |
|---|---|---|---|---|---|---|
| 19 | Clearwater NF - Powell RD | Granite Pass | 613-09-068 | 6/26/01 | 1295 | S |
| 20 | Clearwater NF - Powell RD | Blacklead | 643-04-109 | 10/9/05 | 2800 | |
| 21 | Clearwater NF - Powell RD | Blacklead | 643-04-106 | 9/28/02 | 6245 | S |
| 22 | Clearwater NF - Powell RD | Blacklead | 643-04-106 | 10/6/03 | 3765 | SW |
| 23 | Coeur d'Alene District BLM | Marshall Mountain | | 10/1/95 | 10000 | SW |
| 24 | Deer Lodge - Basin Creek Mine | Rock Piles | NA | 9/24-29/96 | 20 | |
| 25 | Deer Lodge - Basin Creek Mine | Paupers Peak | NA | 9/24-29/96 | 100 | |
| 26 | Deer Lodge - Basin Creek Mine | Block B | NA | 9/24-29/96 | 32 | |
| 27 | Deer Lodge - Basin Creek Mine | Upper 13 Acre | NA | 9/25-10/2/97 | 100 | |
| 28 | Deer Lodge - Basin Creek Mine | Waste Dump | NA | 9/25-10/2/97 | 100 | |
| 29 | Deer Lodge - Basin Creek Mine | Luttrell Ridge | NA | 9/25-10/2/97 | 100 | |
| 30 | Deer Lodge - Basin Creek Mine | Paupers Pit | NA | 8/28-9/2/98 | 330 | |
| 31 | Deer Lodge - Basin Creek Mine | W. of Main Intersection | NA | 8/28-9/2/98 | 63 | |
| 32 | Deer Lodge - Basin Creek Mine | Columbia Tailings | NA | 8/28-9/2/98 | 22 | |
| 33 | Deer Lodge - Basin Creek Mine | Leach Pad 1 | NA | 8/31-9/5/98 | 415 | |
| 34 | Deer Lodge - Basin Creek Mine | Leach Pad 1 | NA | 9/21-25/98 | 286 | |
| 35 | Deer Lodge - Basin Creek Mine | Leach Pad 1 | NA | 9/8-17, 10/13-18/99 | 70 | |
| 36 | Deer Lodge - Basin Creek Mine | Top Soil 1 | NA | 9/8-17, 10/12-18/99 | 178 | |

| ENTRY NO. | SLOPE | ELEVATION | HABITAT TYPE | TYPE OF PLANTING | BURN HISTORY | SEEDLING AGE | NURSERY |
|---|---|---|---|---|---|---|---|
| 19 | 10 | 6300 | 690 | MIXED | 70% burned | | Western Forest Systems |
| 20 | | | 692 | MIXED | | | Western Forest Systems |
| 21 | 25 | 6600 | 692 | WBP | prescribed burn 2001 | | Western Forest Systems |
| 22 | 20 | 7185 | 692 | WBP | wildfire 2003 | | Western Forest Systems |
| 23 | 5 | 7705 | 850 | WBP | Wildfire 1994 severe | | |
| 24 | | | | Restoration | | | |
| 25 | | | | Restoration | | | |
| 26 | | | | Restoration | | | |
| 27 | | | | Restoration | | | |
| 28 | | | | Restoration | | | |
| 29 | | | | Restoration | | | |
| 30 | | | | Restoration | | | |
| 31 | | | | Restoration | | | |
| 32 | | | | Restoration | | | |
| 33 | | | | Restoration | | | |
| 34 | | | | Restoration | | | |
| 35 | | | | Restoration | | | |
| 36 | | | | Restoration | | | |

| ENTRY NO. | PLANTING COMMENTS | STAND HISTORY |
|---|---|---|
| 19 | | salvaged/70% of area burned |
| 20 | | |
| 21 | Microsite #3 | Prescribed burn 2001, Planting 2002, Wildfire 2003 |
| 22 | transportable shade | |
| 23 | singly | Logged post-burn |
| 24 | no topsoil, not hydroseeded | Mined for gold / rehabilitation of mine site |
| 25 | rocky site, often windy, some shelter on sides from mature trees | Mined for gold / rehabilitation of mine site |
| 26 | fairly sheltered site, lots of organic debris | Mined for gold / rehabilitation of mine site |
| 27 | replant (1994), some compacted areas, mostly worked up | Mined for gold / rehabilitation of mine site |
| 28 | newly prepared site, some compaction in places | Mined for gold / rehabilitation of mine site |
| 29 | Planted 1994, replant of areas reworked by heavy machinery | Mined for gold / rehabilitation of mine site |
| 30 | some plants covered with hydromulch while planting | Mined for gold / rehabilitation of mine site |
| 31 | | Mined for gold / rehabilitation of mine site |
| 32 | | Mined for gold / rehabilitation of mine site |
| 33 | recently hydroseeded and mulched | Mined for gold / rehabilitation of mine site |
| 34 | recently hydroseeded and mulched | Mined for gold / rehabilitation of mine site |
| 35 | | Mined for gold / rehabilitation of mine site |
| 36 | very compact and hard ground | Mined for gold / rehabilitation of mine site |

| ENTRY NO. | LOCATION | PLANTING NAME | STAND NUMBER | PLANTING DATE | SEEDLINGS PLANTED | ASPECT |
|---|---|---|---|---|---|---|
| 37 | Deer Lodge - Basin Creek Mine | Top Soil 2 | NA | 9/8-17, 10/12-18/99 | 170 | |
| 38 | Deer Lodge - Basin Creek Mine | Waste Dump | NA | 9/8-17,10/12-18/99 | 190 | |
| 39 | Deer Lodge - Basin Creek Mine | Paupers Pit | NA | 9/8-17, 10/12-18/99 | 510 | |
| 40 | Deer Lodge - Basin Creek Mine | Leach Pad 1 Dyke | NA | 9/8-17,10/12-18/99 | 100 | |
| 41 | Deer Lodge - Basin Creek Mine | Process Pond Dyke | NA | 9/8-17,10/12-18/99 | 80 | |
| 42 | Deer Lodge - Basin Creek Mine | Leach Pad 3 | NA | 9/15-28/00 | 200 | |
| 43 | Deer Lodge - Basin Creek Mine | Paupers Peak/Drill Rds | NA | 9/15-28/00 | 500 | |
| 44 | Deer Lodge - Basin Creek Mine | Paupers Pit | NA | 9/15-28/00 | 50 | |
| 45 | Deer Lodge - Basin Creek Mine | Luttrell Point North | NA | 9/15-28/00 | 100 | |
| 46 | Deer Lodge - Basin Creek Mine | Malfunction Jct/P. Pit Rd | NA | 9/15-28/00 | 50 | |
| 47 | Flathead NF - Glacier View RD | Werner Peak 1 | NA | 6/1/05 | 10 | SSW |
| 48 | Flathead NF - Glacier View RD | Werner Peak 2 | NA | 6/5/05 | 35 | ENE |
| 49 | Flathead NF - Glacier View RD | Werner Peak 3 | NA | 6/5/05 | 13 | W |
| 50 | Flathead NF - Hungry Horse RD | Hornet Mountain | 710-7-018 | 7/14/00 | 1535 | |
| 51 | Flathead NF - Swan Valley RD | Jewel Basin | 115-05-901 | 7/1/02 | 2000 | SW |
| 52 | Flathead NF - Tally Lake RD | Elk Mountain | 91 -94 | 7/10/00 | 2000 | S/SE |
| 53 | Gallatin NF Livingston RD | West Pine Creek | 218-01-067 | 7/1/02 | 7735 | N |
| 54 | Gallatin NF Livingston RD | West Pine Creek | 218-01-094 | 7/1/02 | 8645 | N |

| ENTRY NO. | SLOPE | ELEVATION | HABITAT TYPE | TYPE OF PLANTING | BURN HISTORY | SEEDLING AGE | NURSERY |
|---|---|---|---|---|---|---|---|
| 37 | | | | Restoration | | | |
| 38 | | | | Restoration | | | |
| 39 | | | | Restoration | | | |
| 40 | | | | Restoration | | | |
| 41 | | | | Restoration | | | |
| 42 | | | | Restoration | | | |
| 43 | | | | Restoration | | | |
| 44 | | | | Restoration | | | |
| 45 | | | | Restoration | | | |
| 46 | | | | Restoration | | | |
| 47 | 20-40 | 6320 | 830 | WBP | Werner Fire Wildfire 2001 | Mixed ages 3+ years | Coeur d'Alene |
| 48 | 20 | 6700 | 690 | WBP | Werner Fire Wildfire 2001 | Mixed ages 3+ years | Coeur d'Alene |
| 49 | 15 | 6544 | 690 | WBP | Werner Fire Wildfire 2001 | Mixed ages 3+ years | Coeur d'Alene |
| 50 | | 6000 | 625, 670 | MIXED | broadcast burned 2000 | | Coeur d'Alene |
| 51 | 45 | 5500 | 690 | WBP | Rx Burn 2001/light-moderate | 2 | Coeur d'Alene |
| 52 | 0 | 6200 - 6600 | 670, 740, 690 | WBP | under burned fall 1999 | | |
| 53 | 20 | 8900 | 820 | WBP | Wildfire 2001 - severe | | |
| 54 | 50 | 8400 | 850 | WBP | Wildfire 2001 - severe | | |

| ENTRY NO. | PLANTING COMMENTS | STAND HISTORY |
|---|---|---|
| 37 | very compact and hard ground | Mined for gold / rehabilitation of mine site |
| 38 | good, loose soil with fresh hydroseeding, 1/2 acre erosion blanket | Mined for gold / rehabilitation of mine site |
| 39 | 1 acre erosion blanket, planted through, good loose ground | Mined for gold / rehabilitation of mine site |
| 40 | 1/2 acre new ground, rest replant into grass | Mined for gold / rehabilitation of mine site |
| 41 | replant into grass | Mined for gold / rehabilitation of mine site |
| 42 | good logs and slash for micrositing, 1/2 site had VAM applied | Mined for gold / rehabilitation of mine site |
| 43 | well sheltered, rocky, good moisture in pockets | Mined for gold / rehabilitation of mine site |
| 44 | | Mined for gold / rehabilitation of mine site |
| 45 | | Mined for gold / rehabilitation of mine site |
| 46 | | Mined for gold / rehabilitation of mine site |
| 47 | | rust resistant stock, 6 years old…see notes from Cd'A |
| 48 | | rust resistant stock, 6 years old…see notes from Cd'A |
| 49 | Deer tubes on, Natural WBP Regen present | rust resistant stock, 6 years old…see notes from Cd'A |
| 50 | Upper 5 acres seems to have been planted in a monoculture of WBP | clearcut 1999 / , PINCON, PICENG, LAROCC, ABILAS AND PINALB present before logging, abundant VACSCO, XERTEN LUZHIC |
| 51 | burn provided many planting spots | No prior management |
| 52 | | open grassy hill side with patchy ABILAS & PINCON (stunted/stagnant 25-30ft tall), XERTEN, VACSCO, JUNCOM, BALSAG, ARCUVA, CARGEY, ARNCOR |
| 53 | | |
| 54 | | |

| ENTRY NO. | LOCATION | PLANTING NAME | STAND NUMBER | PLANTING DATE | SEEDLINGS PLANTED | ASPECT |
|---|---|---|---|---|---|---|
| 55 | Gallatin NF Livingston RD | West Pine Creek | 218-01-089 | 7/1/02 | 2730 | E |
| 56 | Gallatin NF Livingston RD | West Pine Creek | 218-01-183 | 6/28/03 | 4500 | |
| 57 | Gallatin NF - Gardiner RD | Drought/ Cooke City | 311-02-087 | 7/1/99 | 10724 | E |
| 58 | Gallatin NF - Gardiner RD | High Water | 311-02-018 | Fall 1991 | 3870 | SE |
| 59 | Gallatin NF - Gardiner RD | Cooke City | 311-02-011 | Fall 1993 | 2700 | SE |
| 60 | Gallatin NF - Gardiner RD | Cooke City | 311-02-002 | Summer 1995 | 3321 | SE |
| 61 | Gallatin NF - Gardiner RD | Cooke City | 311-02-014 | 8/1/91 | 3340 | SW |
| 62 | Gallatin NF - Gardiner RD | Cooke City | 311-02-006 | 8/1/91 | 1000 | SE |
| 63 | Gallatin NF - Gardiner RD | Cooke City | 311-02-006 | 8/1/91 | 2260 | SE |
| 64 | Gallatin NF - Gardiner RD | Cooke City | 311-02-048 | 8/1/91 | 3050 | SE |
| 65 | Gallatin NF - Gardiner RD | Cooke City | 311-02-014 | 8/1/91 | 3110 | SW |
| 66 | Gallatin NF - Gardiner RD | Cooke City | 311-02-014 | 8/1/91 | 1000 | SW |
| 67 | Gallatin NF - Hebgen Lake RD | Madison Plateau | 706-01-116 | Fall 1990 | 1020 | NW |
| 68 | Gallatin NF - Hebgen Lake RD | ? | 706-01-121 | Fall 1990 | 250 | NW |
| 69 | Gallatin NF - Hebgen Lake RD | Big Game | 706-04-051 | 9/1/92 | 960 | NW |
| 70 | Gallatin NF - Hebgen Lake RD | Madison Plateau | 706-01-001 | 9/1/90 | 250 | NE |
| 71 | Gallatin NF - Hebgen Lake RD | Madison Plateau | 706-01-005 | 9/1/90 | 1000 | NE |
| 72 | Gallatin NF - Hebgen Lake RD | Madison Plateau | 706-01-038 | 9/1/90 | 1080 | N |

| ENTRY NO. | SLOPE | ELEVATION | HABITAT TYPE | TYPE OF PLANTING | BURN HISTORY | SEEDLING AGE | NURSERY |
|---|---|---|---|---|---|---|---|
| 55 | 60 | 8200 | 730 | WBP | Wildfire 2001 - severe | | |
| 56 | | | 850 | WBP | Wildfire 2001 - very severe | | |
| 57 | 20 | 8800 | 730 | WBP | Wildfire 1999 | | |
| 58 | 20 | 8800 | 630 | MIXED | Yellowstone Wildfire 1988 | | |
| 59 | 20 | 8400 | 720 | MIXED | Yellowstone Wildfire 1988 | | |
| 60 | 15 | 8200 | 730 | MIXED | Yellowstone Wildfire 1988 | | |
| 61 | 15 | 8100 | 720 | MIXED | Yellowstone Wildfire 1988 | | |
| 62 | 20 | 8400 | 720 | WBP | Yellowstone Wildfire 1988 | | |
| 63 | 20 | 8400 | 720 | WBP | Yellowstone Wildfire 1988 | | |
| 64 | 20 | 8400 | 720 | WBP | Yellowstone Wildfire 1988 | | |
| 65 | 15 | 8100 | 720 | WBP | Wildfire 1988 | | |
| 66 | 15 | 8100 | 720 | WBP | Wildfire 1988 | | |
| 67 | 10 | 7500 | 732 | MIXED | Northfork Fire 1988 | | |
| 68 | 1 | 7800 | 732 | MIXED | Northfork Fire 1988 | | |
| 69 | 5 | 8100 | 732 | WBP | Northfork Fire 1988 | | |
| 70 | 8 | 7500 | 732 | MIXED | Northfork Fire 1988 | | |
| 71 | 4 | 7600 | 732 | MIXED | Wildfire 1988 | | |
| 72 | 8 | 7700 | 730 | MIXED | Wildfire1988 | | |

| ENTRY NO. | PLANTING COMMENTS | STAND HISTORY |
|---|---|---|
| 55 | | |
| 56 | | Soil was removed by fire and wind, very rocky |
| 57 | | |
| 58 | | |
| 59 | | |
| 60 | | |
| 61 | | |
| 62 | | |
| 63 | see sketch for WBP | |
| 64 | see sketch for WBP | |
| 65 | 2 areas planted w/pure WBP see stand sketch 6 acre:3110, 3 acre:1000 | |
| 66 | 2 areas planted w/pure WBP see stand sketch 6 acre:3110, 3 acre:1000 | |
| 67 | mixed throughout | |
| 68 | mixed throughout | |
| 69 | see sketch for WBP planting | |
| 70 | | |
| 71 | | |
| 72 | | |

| ENTRY NO. | LOCATION | PLANTING NAME | STAND NUMBER | PLANTING DATE | SEEDLINGS PLANTED | ASPECT |
|---|---|---|---|---|---|---|
| 73 | Gallatin NF - Hebgen Lake RD | Beaver Creek | 715-06-011 | 6/1/01 | 4250 | S |
| 74 | Gallatin NF - Hebgen Lake RD | Buck Creek | 721-02-148 | 6/1/00 | 5000 | S |
| 75 | Glacier NP | Flattop Mountain | | 7/11/01 | 1500 | EAST |
| 76 | Glacier NP | Flattop Mountain | | 9/10/01 | 1438 | SE |
| 77 | Glacier NP | Flattop Mountain | | 9/12/02 | 2222 | VARIED |
| 78 | Glacier NP | Longfellow Peak | | 9/1/01 | 100 | |
| 79 | Glacier NP | Grinnell Point | | 9/2/00 | 96 | S |
| 80 | IPNF - Sandpoint RD | Nosebag | | 6/15/05 | 300 | |
| 81 | IPNF - St. Joe RD | Crittenden Peak North | 216-1-88 | 6/28/04 | 620 | SW |
| 82 | IPNF - St. Joe RD | Crittenden Peak South | 216-1-83 | 7/1/04 | 40 | |
| 83 | IPNF - St. Joe RD | Freezeout Ridge | NO DATA | 6/15/05 | 140 | |
| 84 | Kootenai NF - ? | | NO DATA | 6/27/05 | 200 | |
| 85 | Lewis & Clark NF - Rocky Mountain RD | Falls Cr. | 13801023 | 9/22/89 | 396 | E |
| 86 | Lewis & Clark NF - Rocky Mountain RD | Cyanide Cr. | private land | 9/12/91 | 765 | N |
| 87 | Lewis & Clark NF - Rocky Mountain RD | E. Fork Cyanide | 14205030 | 10/2/92 | 397 | N |
| 88 | Lewis & Clark NF - Rocky Mountain RD | W. Fork Cyanide | 14205023 | 9/22/93 | 888 | N |
| 89 | Lewis & Clark NF - Rocky Mountain RD | Elk Cr. | 14204019 | Fall 1994 | 661 | NE |
| 90 | Lewis & Clark NF - Rocky Mountain RD | Jackie Cr. | 14503017 | Fall 1995 | 289 | NW |

| ENTRY NO. | SLOPE | ELEVATION | HABITAT TYPE | TYPE OF PLANTING | BURN HISTORY | SEEDLING AGE | NURSERY |
|---|---|---|---|---|---|---|---|
| 73 | 30-90 | 7800 | 450 | MIXED | ?? | | |
| 74 | 20 | 8700 | 780 | WBP | ?? | | |
| 75 | FLAT - 30 | 6300 | 830 | WBP | Wildfire 1998 | | CDL and Glacier |
| 76 | FLAT - 30 | 6800 | 830 | WBP | Wildfire 1998 | | CDL and Glacier |
| 77 | FLAT - 30 | 6750 | 830 | WBP | Wildfire1998 | | CDL and Glacier |
| 78 | | | | WBP | Moose Fire 2001 | | Glacier |
| 79 | 45 | 7300-7700 | 850 | WBP | Wildfire | | |
| 80 | | | 691 | WBP | Nosebag Wildfire 2000 - mixed | Mixed ages 3+ years | Coeur d'Alene |
| 81 | | 6100 | 690 | WBP | 2003 Prescribed Burn | | Coeur d'Alene |
| 82 | | 6100 | 690 | WBP | 2003 Prescribed Burn | Mixed ages 3+ years | Coeur d'Alene |
| 83 | | | | WBP | | Mixed ages 3+ years | |
| 84 | | | | MIXED | | | |
| 85 | 60 | 4900 | | WBP | 1988 - Canyon Creek Fire | | |
| 86 | 20 | 5600 | 720 | WBP | 1988 - Canyon Creek Fire | | |
| 87 | 50 | 5600 | | WBP | 1988 - Canyon Creek Fire | | |
| 88 | 60 | 6400 | | WBP | 1988 - Canyon Creek Fire | | |
| 89 | 30 | 5800 | 950 | WBP | 1988 - Canyon Creek Fire | | |
| 90 | 48 | 5800 | | WBP | 1988 - Canyon Creek Fire | | |

| ENTRY NO. | PLANTING COMMENTS | STAND HISTORY |
|---|---|---|
| 73 | see sketch, need acres, could do | |
| 74 | | Lots of PINCON natural regen in stand, MPB activity in surrounding WBP |
| 75 | whitebark pine habitat, black islands were planted, | No management action |
| 76 | mulched with nearby light-colored duff material. | No management action |
| 77 | VACSCO, CARGEY sites selected for | No management action |
| 78 | Planted in Groups (3 to 5) | Burn - High/ mod - high for canopy. Mature canopy at 90% mortality but soil severity did not seem especially high…top layer of litter and duff burned but lower horizons unaffected. burned two to three weeks before planting |
| 79 | | |
| 80 | Trees were jelly rolled and planted | Shelterwood cut 1973; Pre-commercial thin - 1992 |
| 81 | site prep/ thick XERTEN | 1984, Few unhappy ABILAS, PSEMEN, White pine, non-forest land, generally XERTEN, some VACSCO, problems with ground squirrels |
| 82 | no site prep | Natural opening / no site prep |
| 83 | | |
| 84 | | |
| 85 | Some planted in groups | |
| 86 | Some planted in groups | |
| 87 | Some planted in groups | |
| 88 | Some planted in groups | |
| 89 | Some planted in groups | |
| 90 | Some planted in groups | |

| ENTRY NO. | LOCATION | PLANTING NAME | STAND NUMBER | PLANTING DATE | SEEDLINGS PLANTED | ASPECT |
|---|---|---|---|---|---|---|
| 91 | Lolo NF - Plains RD | Greenwood Hill | | 6/13/05 | 94 | VARIED |
| 92 | Lolo NF - Plains RD | Tepee Creek | | 6/14/05 | 86 | |
| 93 | Lolo NF - Plains RD | Siegel Creek | | 6/15/05 | 64 | |
| 94 | Nez Perce NF - Salmon RD | | | 6/27/05 | 300 | |
| 95 | Sawtooth NF | Dana Perkins | 3 sites | 6/1/00 | 1000 | |
| 96 | Shoshone NF - Clarks Fork RD | Lodgepole Creek | WB-99-1 & 2 | 1999 | 10000 | |
| 97 | Shoshone NF - Clarks Fork RD | Lodgepole Creek | WB-00-1, 2E, 2W | 2000 | NO DATA | |
| 98 | Shoshone NF - Clarks Fork RD | Sheridan Cr. 21 | 517525-0012 | 2000 | NO DATA | N |
| 99 | Shoshone NF - Clarks Fork RD | Squaw Cr. 7 | 129207-0019 | 2000 | 380 | SW |
| 100 | Shoshone NF - Clarks Fork RD | Squaw Cr. 8 | 129207-0019 | 2000 | 1050 | SW |
| 101 | Shoshone NF - Clarks Fork RD | Squaw Cr. 9 | 129207-0005 | 2000 | 3300 | SW |
| 102 | Shoshone NF - Clarks Fork RD | E. Fork Painter 10 | 121209-0008 | 2000 | 380 | E |
| 103 | Shoshone NF - Clarks Fork RD | E. Fork Painter 11 | 121209-0008 | 2000 | 1450 | W |
| 104 | Shoshone NF - Clarks Fork RD | E. Fork Painter 12 | 121209-0008 | 2000 | 760 | W |
| 105 | Shoshone NF - Clarks Fork RD | E. Fork Painter 13 | 121209-0008 | 2000 | 380 | S |
| 106 | Shoshone NF - Clarks Fork RD | Painter Gulch 14 | 121213-0002 | 2000 | 1050 | S |
| 107 | Shoshone NF - Clarks Fork RD | Painter Gulch 15 | 121213-0002 | 2000 | 1050 | S |
| 108 | Shoshone NF - Clarks Fork RD | Painter Gulch 16 | 121213-0002 | 2000 | 1050 | S |

| ENTRY NO. | SLOPE | ELEVATION | HABITAT TYPE | TYPE OF PLANTING | BURN HISTORY | SEEDLING AGE | NURSERY |
|---|---|---|---|---|---|---|---|
| 91 | 5 | 5680 -6450 | 831 | WBP | Wildfire 2003 - severe | Mixed ages 3+ years | Coeur d'Alene |
| 92 | | 6258-6585 | 830 | WBP | Wildfire 2003 - severe | Mixed ages 3+ years | Coeur d'Alene |
| 93 | | 6538-7071 | 690,691 | WBP | Wildfire 2003 - severe | Mixed ages 3+ years | Coeur d'Alene |
| 94 | | | | MIXED | | | |
| 95 | | | | WBP | | | |
| 96 | | | | WBP | Clovermist Wildfire 1988 | | |
| 97 | | | | WBP | Clovermist Wildfire 1989 | | |
| 98 | 10 | 8300 | | WBP | | | |
| 99 | 3 | 6800 | 040 | INTERPLANT | Yellowstone Wildfire 1988 | | |
| 100 | 8 | 7100 | 040 | INTERPLANT | Yellowstone Wildfire 1988 | | |
| 101 | 8 | 6800 | 040 | INTERPLANT | Yellowstone Wildfire 1988 | | |
| 102 | 30 | 6800 | 040 | WBP | Yellowstone Wildfire 1988 | | |
| 103 | 70 | 7200 | 040 | WBP | Yellowstone Wildfire 1988 | | |
| 104 | 30 | 7000 | 040 | WBP | Yellowstone Wildfire 1988 | | |
| 105 | 30 | 7600 | 040 | WBP | Yellowstone Wildfire 1988 | | |
| 106 | 20 | 7200 | 040 | WBP | Yellowstone Wildfire 1988 | | |
| 107 | 80 | 7200 | 040 | WBP | Yellowstone Wildfire 1988 | | |
| 108 | 95 | 7200 | 040 | WBP | Yellowstone Wildfire 1988 | | |

| ENTRY NO. | PLANTING COMMENTS | STAND HISTORY |
|---|---|---|
| 91 | planted in clusters in 3 wildfire areas | No management activities prior to wildfire, No post fire salvaging |
| 92 | planted in clusters in 3 wildfire areas | No management activities prior to wildfire, No post fire salvaging |
| 93 | planted in clusters in 3 wildfire areas | No management activities prior to wildfire, No post fire salvaging |
| 94 | | |
| 95 | | |
| 96 | | |
| 97 | | |
| 98 | | NOT ENOUGH DATA TO INCLUDE |
| 99 | Planted 2 / scalp | |
| 100 | Planted 2 / scalp | |
| 101 | Planted 2 / scalp | |
| 102 | Planted 2 / scalp | |
| 103 | Planted 2 / scalp | |
| 104 | Planted 2 / scalp | |
| 105 | Planted 2 / scalp | |
| 106 | Planted 2 / scalp | |
| 107 | Planted 2 / scalp | |
| 108 | Planted 2 / scalp | |

| ENTRY NO. | LOCATION | PLANTING NAME | STAND NUMBER | PLANTING DATE | SEEDLINGS PLANTED | ASPECT |
|---|---|---|---|---|---|---|
| 109 | Shoshone NF - Clarks Fork RD | Painter Gulch 17 | 121213-0002 | 2000 | 1875 | S |
| 110 | Shoshone NF - Clarks Fork RD | Painter Gulch 18 | 121213-0001 | 2000 | 1050 | S |
| 111 | Shoshone NF - Clarks Fork RD | Painter Gulch 19 | 121213-0002 | 2000 | 1875 | N |
| 112 | Shoshone NF - Clarks Fork RD | Sulphur Camp 20 | 119232-0005 | 2000 | 2275 | S |
| 113 | Shoshone NF - Wind River RD | Geyser Cr. 1 | 522504-0200 | 2000 | 3728 | N |
| 114 | Shoshone NF - Wind River RD | Geyser Cr. 2 | 522505-0003 | 2000 | 3924 | NE |
| 115 | Shoshone NF - Wind River RD | Geyser Cr. 3 | 522504-0120 | 2000 | 5101 | VARIED |
| 116 | Shoshone NF - Wind River RD | Lander Loop 4 | 318702-0017 | Jun-02 | 1962 | S |
| 117 | Shoshone NF - Wind River RD | Lander Loop 5 | 315713-0041 | Jun-02 | 1308 | E |
| 118 | Shoshone NF - Wind River RD | Lander Loop 6 | 318702-0017 | Jun-02 | 436 | E |
| 119 | Yellowstone NP | Dunraven Pass | NA | 10/4/04 | 670 | VARIED |
| 120 | Yellowstone NP | Dunraven Pass | NA | 9/1/03 | 30 | VARIED |

| ENTRY NO. | SLOPE | ELEVATION | HABITAT TYPE | TYPE OF PLANTING | BURN HISTORY | SEEDLING AGE | NURSERY |
|---|---|---|---|---|---|---|---|
| 109 | 30 | 7400 | 040 | WBP | Yellowstone Wildfire 1988 | | |
| 110 | 25 | 7600 | 040 | WBP | Yellowstone Wildfire 1988 | | |
| 111 | 85 | 7300 | 040 | WBP | Yellowstone Wildfire 1988 | | |
| 112 | 15 | 7400 | 050 | WBP | Yellowstone Wildfire 1988 | | |
| 113 | 9 | 9000 | 730 | INTERPLANT | Geyser Creek Wildfire 1975 | | |
| 114 | 10 | 9200 | 730 | WBP | Geyser Creek Wildfire 1975 | | |
| 115 | 5 | 9000 | 730 | INTERPLANT | Geyser Creek Wildfire 1975 | | |
| 116 | 9 | 9200 | 870 | WBP | broadcast burned 1999 | | |
| 117 | 8 | 9000 | 870 | WBP | broadcast burned 1999 | | |
| 118 | 10 | 9500 | 870 | WBP | broadcast burned 1999 | | |
| 119 | VARIED | 8572 -8880 | 870 | WBP | Yellowstone Wildfire 1988 | 2 | |
| 120 | VARIED | 8900 | 870 | WBP | Yellowstone Wildfire 1988 | 2 | |

| ENTRY NO. | PLANTING COMMENTS | STAND HISTORY |
|---|---|---|
| 109 | Planted 2 / scalp | |
| 110 | Planted 2 / scalp | |
| 111 | Planted 2 / scalp | |
| 112 | Planted 2 / scalp | |
| 113 | Planted 2 / scalp | salvage logged 1977 / lots of natural regen WBP and PINCON |
| 114 | Planted 2 / scalp | salvage logged 1977 / lots of natural regen WBP and PINCON |
| 115 | Planted 2 / scalp | salvage logged 1977 / lots of natural regen WBP and PINCON |
| 116 | Planted 2 / scalp | logged clearcut 1998 / almost no natural regen |
| 117 | Planted 2 / scalp | logged clearcut 1998 / almost no natural regen |
| 118 | Planted 2 / scalp | logged clearcut 1998 / almost no natural regen |
| 119 | | |
| 120 | | |