VEGETATION MANAGEMENT PLAN FOR LOST CREEK AND CRAGS CAMPGROUNDS
LASSEN VOLCANIC NATIONAL PARK

INTRODUCTION

Lost Creek and Crags Campgrounds are very popular campgrounds in Lassen Volcanic National Park that have very serious forest health problems. The old growth mixed conifer Forest — mostly Jeffrey pine (*Pinus jeffreyi)*, ponderosa pine (*Pinus ponderosa*), and white fir (*Abies concolor*) — that grows in the 40 acre campground complex has been altered by fire suppression, development, and insect and disease epidemics. A 2002 USDA-FS biological evaluation concluded that armillaria root disease (*Armillaria* sp.) and annosus root disease (*Heterobasidion annosum)* are abundant in the campground and are killing trees, almost exclusively firs. During the pine bark beetle epidemic of the mid-1990s, large Jeffrey and ponderosa pines in the area suffered heavy mortality and pine recruitment has been insufficient. Dense pole size thickets of white fir have developed in the absence of frequent surface fires. Historic stand composition and structure was marked by a much higher percentage of pine (Jeffrey, ponderosa, and sugar) than is present today, and the stands were older and more open.

A large number of trees, mainly large firs, have needed to be removed from the campgrounds during the past several years when they became hazards to camper safety. In earlier years, removal of live trees without treatment of stumps with an antifungal agent may have increased the spread of naturally occurring annosus root disease. Lack of delineated campsite areas may have contributed to lack of tree regeneration due to trampling.

The number of hazardous trees requiring removal in the campgrounds has continued to increase. There was a root disease-caused green tree failure in the Lost Creek Campground in early 2002. The campgrounds were kept closed during all of 2002 to protect campers, facilitate a major tree removal and to allow evaluation by USFS Specialists and park staff. The USFS biological evaluation included areas near the campgrounds that were being considered as possible locations for relocating the campgrounds, but these areas were found to also have root disease problems or were otherwise unacceptable. Based on the evaluation, a decision was made to aggressively pursue reducing or eliminating annosus root disease by removal of infected trees and by thinning of firs, with retention and regeneration of pines as the annosus seems to be mostly the type that does not infect pine. The goal of the project is to restore forest health in the campground, making it safe for campers and restoring the forest to a condition that can be sustainably managed.

PROJECT AREA

The project area involves approximately 40 acres encompassing two campgrounds. Lost Creek is a group reservation campground containing nine sites, and Crags contains 45 sites. The campgrounds are open from late June to late September. Terrain is essentially flat with a slight northeast aspect. Elevation ranges from 5590 to 5615. Climate is characterized by cool, wet winters and warm, dry summers. Precipitation averages approximately 38 inches and falls mainly as snow between October and March. Vegetation is characterized by coniferous forests made up of Jeffrey pine, ponderosa pine, white fir, with a minor component of sugar pine.

FOREST DEVELOPMENT HISTORY

Forests in the project area have been altered during the last century by fire suppression, campground development, and insect and disease epidemics. Frequent, low-intensity surface fires historically common in the project area favored pines over fir and maintained open forest structures by periodically reducing understory thickets of fir (Taylor, 1998). During the last century, absence of fire has caused fir thickets to develop resulting in conditions unfavorable to the recruitment and retention of pine. Historic fires also played critical ecosystem roles in nutrient cycling, pH balance, and the control of occurrence and distribution of native pathogens, particularly dwarf mistletoe and root disease. During the past several decades of hazardous tree management in the campgrounds, incidence of annosus root disease has probably increased because stumps were not treated with antifungal agents.

Old growth pines have suffered heavy mortality in recent decades and are not regenerating in sufficient numbers to maintain their presence in the overstory. Examination of historic aerial photographs, age structures, and pine stumps provides abundant evidence that large old pines were much more plentiful in the project area than they are now. An overall shift in forest composition and structure from an open, old growth pine-dominated forest to a dense, young white fir forest is occurring rapidly.

PROJECT GOALS

The goal of the project is to restore forest health in the campground, making it safe for campers and restoring the forest to a condition that can be sustainably managed. The project objectives are to:

1. Improve vigor and survivorship of pine and fir
2. Promote the establishment of pine in the overstory of future forest stands
3. Reduce the occurrence and spread of root disease.
4. Reduce the occurrence of hazardous trees.

PROJECT STRATEGY

The project will focus on 1) reducing tree densities and stocking levels to reduce competition for site resources and, 2) creating opportunities for pine recruitment. This strategy is based on the principle that stocking level is directly related to stand vigor and that successful pine recruitment requires disturbed microsites in openings.

Selectively reducing tree densities and stocking levels through careful thinning has been shown to improve tree growth and vigor, increase live crown ratios, reduce insect and disease mortality, and promote understory shrub development (Cochran, 1998a, Fiddler, et al., 1989). Forestry studies on dry mixed conifer sites indicate that vigor is highest and mortality lowest as percentage of maximum stocking is decreased (Cochran, 1998a). A typical thinning target would be to project maximum stocking 20 years after treatment to account for increased growth of residual trees.

Successful natural recruitment of Jeffrey and ponderosa pine is dependent on several factors occurring simultaneously: seed availability, suitable microsites, suitable seedbeds (bare mineral soil), climate, competition, and low predation (Helms and Tappeiner 1996). Current conditions for Jeffrey and ponderosa pine establishment and growth are poor. For successful establishment, Jeffrey and ponderosa pines require open stands with prolonged direct sunlight and disturbed or burned seedbeds with limited competition. Seedlings that grow near the edge of an opening do not perform as well as seedlings in the center (Helms and Tappeiner, 1996, Fowells, 1965). Openings at least ¼ acre in size are required to encourage natural regeneration (Rich Coakley, pers. comm.).

FOREST CHARACTERISTICS

The following section provides a quantitative description of forest characteristics in the campgrounds. It is intended as a baseline inventory of current forest structure and composition, and as a basis for formulating and evaluating management prescriptions.

Systematic sampling methods were used to inventory campground forests. Forty nested plots were established in a grid over the campgrounds (figure 1). Within this framework, eight variable plots were established 3 chains apart on each of five grid lines. Grid lines were located 2 chains apart. At each plot center a 30 basal area factor cruising prism was used to derive plot basal area using standard forestry techniques (Dilworth, 1982). In addition. 0.02 acre circular plots were established at each plot center to tally small trees not counted during prism surveys. Diameter at breast height (dbh) and species determinations were recorded for each tree counted. Trees less than 4.5 feet tall were counted as saplings/seedlings.

Stand tables were generated from field data. Weighted average stand age was calculated from a sample of 4 site trees in the 7-12" dbh class, 2 site trees in the 13-18" dbh class, and 3 site trees in the 19-24" class. Average stand age was found to be 75 years, with a resulting site index of 60 (Dunning and Reineke, 1933). Stand carrying capacity was determined by using standard mixed conifer ("sierra desired") yield tables.

Stand table data were used to calculate basal area, density, quadratic mean diameter (QMD), and stand density index (SDI). Because of the large variation in forest structure, particularly tree density, the project area was stratified into four individual stands so that stand parameters would be representative (figure 1).

SPECIES COMPOSITION

The forest within the project area falls within Taylor's (1998) Jeffrey pine-White fir forest type. Overstory consists of a mixture of Jeffrey pine, ponderosa pine, and white fir. A minor component of sugar pine is present. Outside the campground loops (stands 1 and 3) 94% of the trees ≤ 30" dbh and 59% of the trees > 30" dbh are white fir. Inside the loops (stands 2 and 4) species composition is 100% white fir for trees ≤ 30" dbh, and 49% white fir for trees > 30" dbh.

DENSITY AND SIZE CLASS DISTRIBUTION

Tree density is highly variable from stand to stand and in each campground. As a rule densities were high outside the campground loops and low inside the campground loops. In Lost Creek campground, density ranged from 879 trees per acre (tpa) in stand 1 (area outside the loop), to 325 tpa in stand 2 (area inside the loop), and averaged 677 tpa over the entire campground. Tree densities exceeding 300 tpa are generally considered very high. In Crags campground, density ranged from 265 tpa in stand 3 (area outside the loop) to 26 tpa in stand 4 (area inside the loop.) Figures 2 through 5 show size class distribution of white fir and pine species in the campgrounds. White fir densities are heavily skewed toward the smaller size classes and are as much as 60 times more numerous than pine.

BASAL AREA STOCKING

Basal area is a measure of stand stocking that describes the proportion of a given area occupied by tree boles. Basal area is more meaningful than tree density because even though there are fewer of them large trees contribute considerably more to stocking (and use more resources) than small trees. Basal area was averaged within each stand using the following formula:

Basal Area = ∑(0.005454d^2)/P

where,

d = diameter at breast height
P = number of plots

The "normal" or "maximum stocked" basal area is a threshold value used to represent complete occupancy of a site. Values that exceed this value are considered above sustainable carrying capacity. Maximum stocking level depends upon the age of the stand and the site quality. Based on a mixed conifer site index (SI) of 60 and a stand age of 75, Stand 1 at 270 ft^2/acre is 30% above the recommended stocking level of 189 ft^2/acre. Stand 3 is 20% above this level. Basal area measurements >300 ft^2/acre were recorded at 7 of 16 plots in stand 1, and at 3 of 9 plots in stand 3. Measurements >450 ft^2/acre were recorded at 3 plots in stand 1. Immediately inside the campground loops (stands 2 and 4) basal area was found to be well below recommended stocking levels. These "understocked" areas will be the focus of revegetation efforts.

Figures 2 through 5 shows the relationship between basal area and tree density across size classes. Most of the white fir basal area in all stands is concentrated at size classes below 36" dbh, whereas in pine it is concentrated at size classes above 36" dbh. Although the vast majority of white fir are ≤6" dbh, almost all of the white fir basal area is contained in trees >6" dbh which illustrates the relative importance of larger trees to stocking levels. This has important implications for reducing stocking. For example removing all white fir in the campground ≤6" dbh would reduce total tree density by 73%, but only reduce stocking by 8%. Figures 6 and 7 contains cumulative basal area curves for fir and pine. These curves were used to determine cutting thresholds required for achieving target basal area.

STAND DENSITY INDEX

Stand Density Index (SDI) is another measure of stocking that is based on the relative relationship between tree density (tpa) and quadratic mean diameter (QMD). See Reineke (1933). SDI differs from basal area because it is independent of site quality and stand age. It is useful in young stands with lower basal areas. It is calculated using the following formula:

SDI = (TPA)(QMD/10)^1.73

Where:

QMD = quadratic mean diameter
TPA = trees per acre
1.73 a constant (see Cochran, 1998b)

Maximum recommended SDI values represent thresholds beyond which growth and vigor are decreased and mortality and susceptibility to insects and diseases are greatly increased. Maximum recommended SDIs for Jeffrey and ponderosa pine dominated forests in this area is 365 (Oliver, 1996). The SDI for Stand 1 averages 481 (132% of maximum), and in Stand 3 the SDI averages

364 (100% of maximum). Individual pocket of trees within these two stands greatly exceeds maximum SDI. Both stands have high risk of mortality due to overstocking.

INSECTS AND PATHOGENS

The most significant pathogens occurring in the campgrounds are the root disease fungi *Heterobasidion annosum* and *Armillaria* species. Root diseases typically weaken trees and predispose them to attack by insects and other pathogens (Scharpf, 1993), or cause them to fail outright due to root failure. An evaluation by USFS Forest Health Protection scientists in 2002 found that these pathogens are working individually or in combination to cause root disease in fir, but not pine in the project area. The two pathogens act together to develop a “disease complex” which appears to be infecting firs of all ages (Woodruff, 2002). With overstocked conditions existing in many areas of the project area even young fir trees which are infected cannot grow at sufficient rates to counterbalance root decay. Annosus root disease is of special concern because it spreads through spores that can readily infect freshly cut stumps. Once a tree is killed the fungus enters a saprophytic stage and can live in dead roots for up to 50 years, eventually infecting the roots of other trees when they come into contact. No known treatment of these so-called “infection centers” exists, but changes in species compositions and stand density can help reduce their spread and abundance (Scharpf, 1993).

Dendroctonus bark beetle populations (*Dendroctonus jeffreyi*, *D. ponderosae*, *D. brevicomis*) , although at endemic levels during the late 1990s, are starting to increase in abundance following a period of dry years and have killed several large pines within the campground loops in the past two years. Fir engraver beetles (*Scolytus ventralis*) have also become active during this same period, and have killed white firs in the project area. According to Ferrell (1996) an “insect/disease complex” involving annosus root disease and fir engraver beetle tends to become prominent as fir stands increase to carrying capacity.

Incidental amounts of dwarf mistletoe (*Arceuthobium abietum*, *A. campylopodum*), elytroderma disease (*Elytroderma deformans*), and Cytospora (*Cytospora abietis*) canker have individually or in combination caused crown reduction and reduction of vigor in pines and firs. White pine blister rust (*Cronartium ribicola*) has been observed in a sugar pine sapling (Woodruff, 2002). Indian paint fungus (*Echinodontium tinctorium*), an important stem decay organism, has been observed in mature fir throughout the project area and has important implications to hazardous tree management.

MANAGEMENT ACTIONS

The management prescriptions can be grouped into three functional phases. The first phase involves the removal of understory trees around old-growth pine to reduce stress and competition and increase vigor. The same approach will be applied to young pine to reduce competition and encourage their growth and recruitment into the overstory. The second phase involves reducing overall stocking in some stands by removing thickets of white fir trees to achieve more sustainable stocking levels. The third phase will initiate natural and artificial regeneration of ponderosa and Jeffrey pine.

MANAGEMENT PRESCRIPTION AND GUIDELINES:

PHASE I – DRIP LINE RADIUS CUT AND JEFFREY PINE RELEASE

1. Remove all trees <18" dbh that are within five feet of the canopy drip line of all dominant and co-dominant pine (>20" dbh).
2. Remove white fir within three feet of the canopy dripline of all healthy pine <20" dbh. Sapling pine will have mistletoe rating (based on Hawksworth 1972) of 1, or 2 if the infestation is restricted to the lower crown. Otherwise pine saplings will be removed.
3. All stumps ≤10" in diameter will be flush cut and all stumps >10" in diameter will be ground and buried. Stumps will be ground within 24 hrs to reduce the attraction of red turpentine beetle to pine stumps and residual stands. Care will be taken when grinding large stumps beneath mature pine not to damage the roots or boles.
4. All stumps > 8" in diameter will be treated with Sporax within four hours of cutting. Ground stumps will be treated with Sporax after grinding.
5. All slash and unmerchantable material will be disposed of offsite. Pine slash will not remain on site for longer than 30 days.
6. Prune young pine that contain mistletoe in the lower crown. This will be done in the late fall.

PHASE II – REDUCE STOCKING LEVEL TO WITHIN CARRYING CAPACITY AND REDUCE LADDER FUELS.

1. Apply a diameter limit cut of understory white fir ≤12" dbh in stands 1 and 3 to reduce stocking. In stand 2, apply a diameter cut of understory white fir ≤10" dbh only in the small thicket on the west side of the campground. Stand 4 does not require this measure. *Note: this action will reduce the overall basal area in Stand 1 from 270 ft2/ac to 189 ft2/ac (75% of maximum), and in Stand 3 from 231 ft2/ac to 189 ft2/ac (75% of maximum). SDI will be reduced to 75% of maximum in stand 1, and 74% of maximum in stand 3. QMD will increase from 8" to 22" in stand 1, and from 12" to 25" in stand 3. In cut stands, growth of residual trees would increase rapidly and normal stocking would be achieved within 20 years.*
2. All stumps ≤10" in diameter will be flush cut and all stumps >10" in diameter will be ground and buried. Stumps will be ground within 24 hrs to reduce the attraction of red turpentine beetle to pine stumps and residual stands. Care will be taken when grinding large stumps beneath mature pine not to damage the roots or boles.
3. All stumps > 8" in diameter will be treated with Sporax within four hours of cutting. Ground stumps will be treated with Sporax after grinding.
4. All slash and unmerchantable material will be disposed of offsite. Pine slash will not remain on site for longer than 30 days to prevent buildup of *Ips* bark beetles.
5. Hazardous trees identified during risk rating examinations for signs, symptoms, and indicators of root disease and other major defects will be removed.

Phases I and II will be done under contract in fall 2006 immediately after the campground is closed for the season, preferably in early October. All trees scheduled for removal during Phase I will be marked with blue paint no later than 1 week before the contractor begins work. Pines scheduled for dwarf mistletoe treatment will be flagged with yellow ribbon, marked with a numbered aluminum tag, and mapped. All trees scheduled for removal during Phase II will not be marked since a "designation by description" clause in the contract will clearly state which trees are to be removed, except identified hazardous trees which will be marked with blue paint. Trees will be manually felled by chain saw. Logs will be skidded by rubber tired skidder to designated log decks (Fig 8). Damage to residual stands will be minimized by specifying in the contract that negligent damage will be paid for by the contractor as liquidated damage at the current rate established by the International Society of Arboriculture for landscape trees, in addition to amounts payable as stumpage. The project area will be defined on one boundary side by the edge of the paved park road. The other three boundary sides will generally follow existing prescribed fire handlines established around the perimeter of the campgrounds in the early 1990s, some 200 feet from the outside edge of the campground. A smooth transition from treated stands to untreated areas is desired, therefore to the extent possible natural openings will be used when deciding project boundaries. In some cases a thin strip of trees may need to be marked with blue paint to establish the inside edge of the project boundary. Upon completion of trees felling, site rehab will be accomplished by hand raking all tire tracks and skid trails. Site preparation will be accomplished in areas targeted for regeneration (Fig 8). Areas used for log decks will be decompacted. Campground infrastructure (picnic tables, fire grates, barricade logs and posts, etc.) removed during tree removal will be replaced.

PHASE III – ARTIFICIAL AND NATURAL REGENERATION OF JEFFREY AND PONDEROSA PINE

1. Artificial regeneration: Most of the existing large openings in the campground (Stands 2 and 4) will be targeted for planting (Fig 8). Additional openings targeted for artificial regeneration will need to be at least 1/8 acre. In fir pockets infected with root disease (e.g. Site 9 in Lost Creek Campground and the Host Campsite in Crags Campground) openings will be created for planting. Jeffrey and ponderosa pine seedlings will be planted in aggregations to mimic natural patterns of seedling recruitment, with spacing of 6-10 feet. Planting sites will be prepared with tractor and disc to mitigate compacted soils.

2. Natural regeneration: Openings will be as large as possible given restrictions for screening, but will be at least at least ¼ acre. Openings for natural regeneration will be located near healthy, cone-bearing Jeffrey and ponderosa pine (fig 8). Upon completion of Phases I and II other sites may become suitable for natural regeneration and will thus be targeted for this prescription on a case by case basis. In the areas established for natural regeneration, site preparation will be accomplished with a tractor and disc and will result in a bare mineral soil seedbed. No residual trees will be left in the interior of openings, especially pine infested with mistletoe.

3. Seedling Protection: At planting sites within the campground loops where foot traffic is excessive and impacts from soil compaction and trampling is likely, exclosures consisting of 2' tall 4"x4" posts spaced at 10' intervals supporting 1.5" diameter manila or nylon rope will be constructed around seedling aggregations. This measure is not needed at most planting sites outside the loops. Mesh screens will be placed on all seedlings for protection from browsing animals. At planting areas outside the loops, this measure alone (placing mesh screens around seedlings) will probably offer the needed protection against trampling from visitors.

4. Interpretive signs will be posted at all artificial and natural regeneration sites.

Phase III will be done under contract in fall 2007, preferably during late October. Fall planting is the season of choice (vice spring) because low water holding capacity of local soils would cause spring-planted seedlings to become severely water stressed (Rich Coakley, pers. comm.). A total of 4000 ponderosa pine and Jeffrey pine seedlings (2000 each) will be grown at the USFS nursery in Placerville from seeds collected on the Lassen National Forest and stored in USFS seed banks. To ensure genetic integrity seeds will come from trees located either: 1) within 5 miles and 500' of elevation from the project area and within the Lost Creek sub-watershed, or 2) within 10 miles and 500' of elevation from the project area and within the Hat Creek watershed.

Location of planting site for each seedling will be marked with pin flags no later than one week before the contractor begins work. Seedlings will be planted using a soil auger to mitigate soil compaction and to allow fast root development. Location of underground water lines will be flagged prior to selecting planting locations.

MONITORING

Information acquired through monitoring provides and important gauge of the effectiveness of management prescriptions in meeting management goals. This information is critical for refining future management prescriptions and allows the comparison of different prescriptions.

Photo Monitoring: At each of the 40 plots used to inventory the campgrounds, permanent photopoints will be established. Points will be designated by a tagged 3/8" rebar marking plot center. During each monitoring period, photographs will be taken in cardinal directions (N,S,E,W) with a tripod mounted 35mm SLR camera fitted with a 50mm lens. Camera height will be standardized and photo direction will be established using a declination adjusted compass and/or by viewing earlier photographs. Photographs will be taken in summer 2004 before Phase 1 and 2 treatment begins, and immediately after treatment in the fall of 2004. Subsequent photography will take place at the photopoints every 10 years.

Basal Area, Species Composition, and SDI: Parameters to be measured at each of the 40 plots within one year post-treatment and every 5 years thereafter to establish overall trends in forest growth and survivorship/mortality. The cause of death (or causal factors of death) of any tree within the plot should be noted (insects, diseases, abiotic, etc.). This will allow the testing and validations of growth and successional projection models used to develop the thinning prescriptions.

Individual Tree Survival and Growth Characteristics: All trees undergoing drip line radius cut treatments will be tagged and mapped with a GPS. Various assessments including live crown ratio, mean annual increment calculations, and DBH and height measurements will be taken at 10-year intervals beginning in 2014. Initial measurements of live crown ratio will be taken immediately following treatment in Fall 2004 on all tagged trees (both drip line radius cut treatments and pruning treatments) Mortality checks will be done on tagged trees every 2 years beginning in 2005.

Regeneration: Growth (height, caliper, vigor), survival, and animal damage of artificial and natural regeneration will be monitored every year.

ACKNOWLEDGEMENTS

Special thanks to Rich Coakley (District Siliviculturist, HCRD Lassen National Forest), Calvin Farris (former Plant Ecologist, Lassen Volcanic National Park), and Lauren Payne (District Silviculturist, ARD Lassen National Forest) for assistance with inventory design, data interpretation, and silvicultural prescriptions.

Figure 1. Area map showing arrangement of permanent plots within four stands in Lost Creek and Crags Campgrounds, Lassen Volcanic National Park.

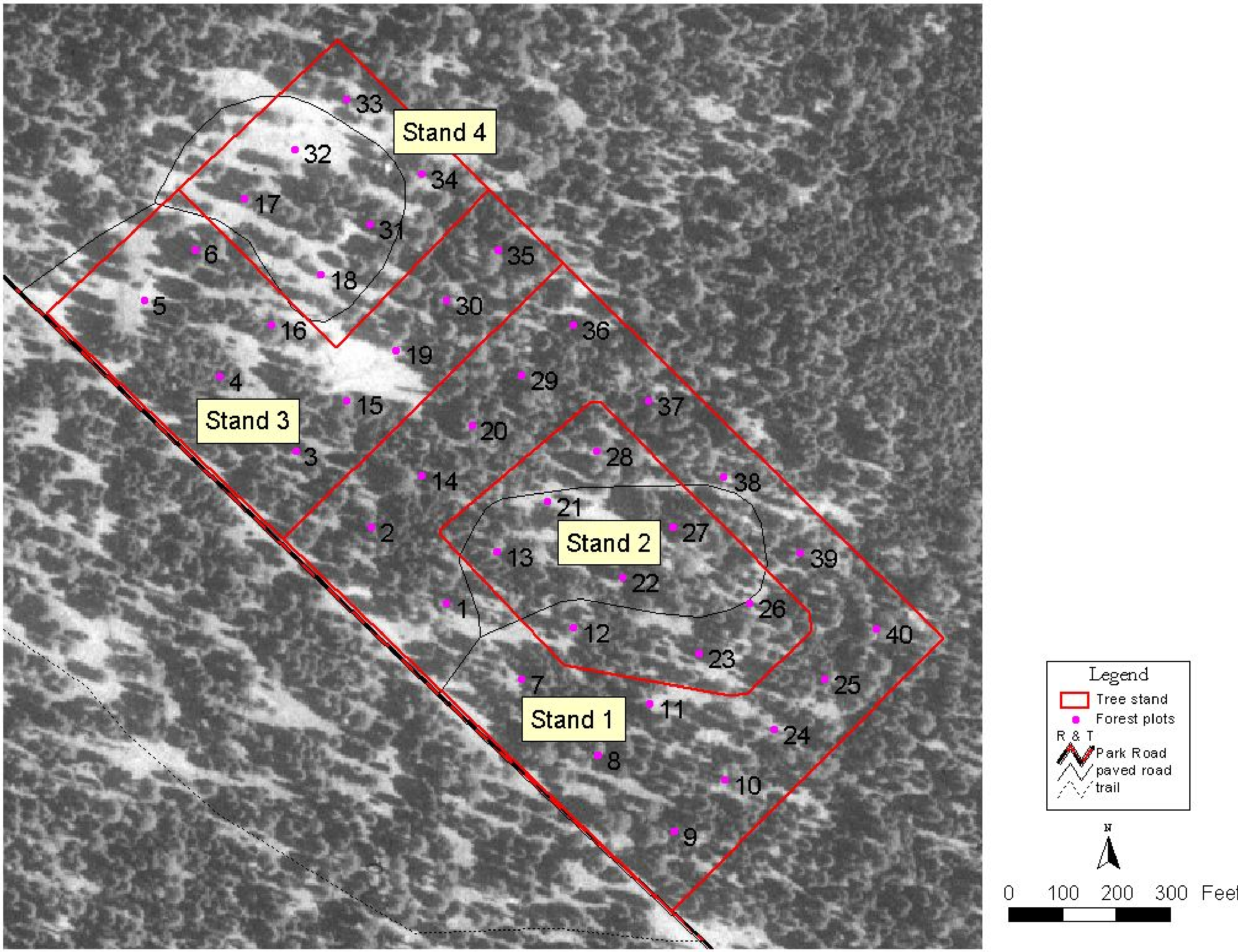
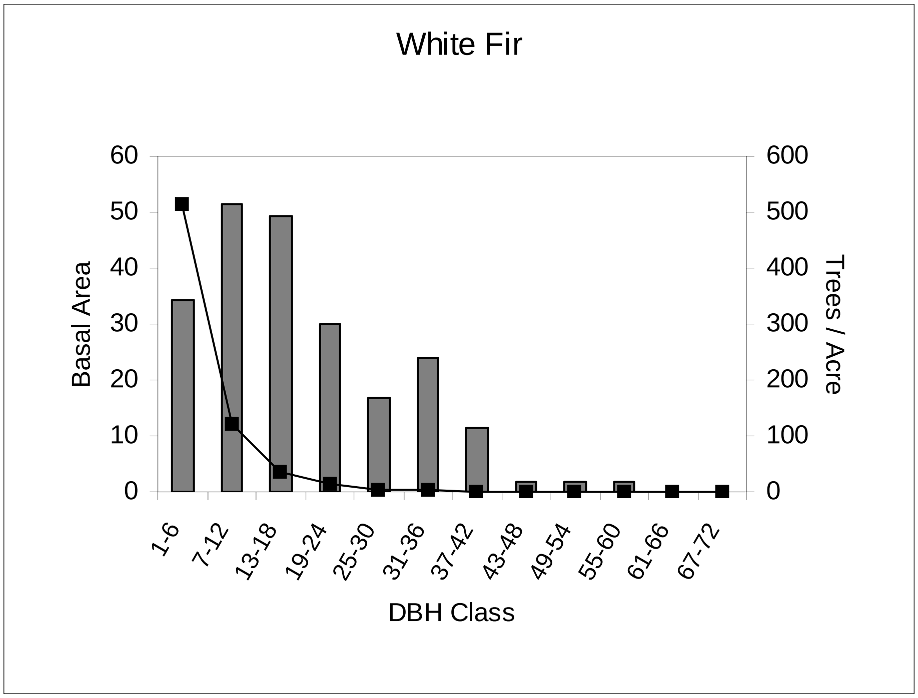


Figure 2. Relationship between basal area composition tree size in Stand 1. The bars represent the amount of basal area in a given size class and the lines represent the corresponding tree density.



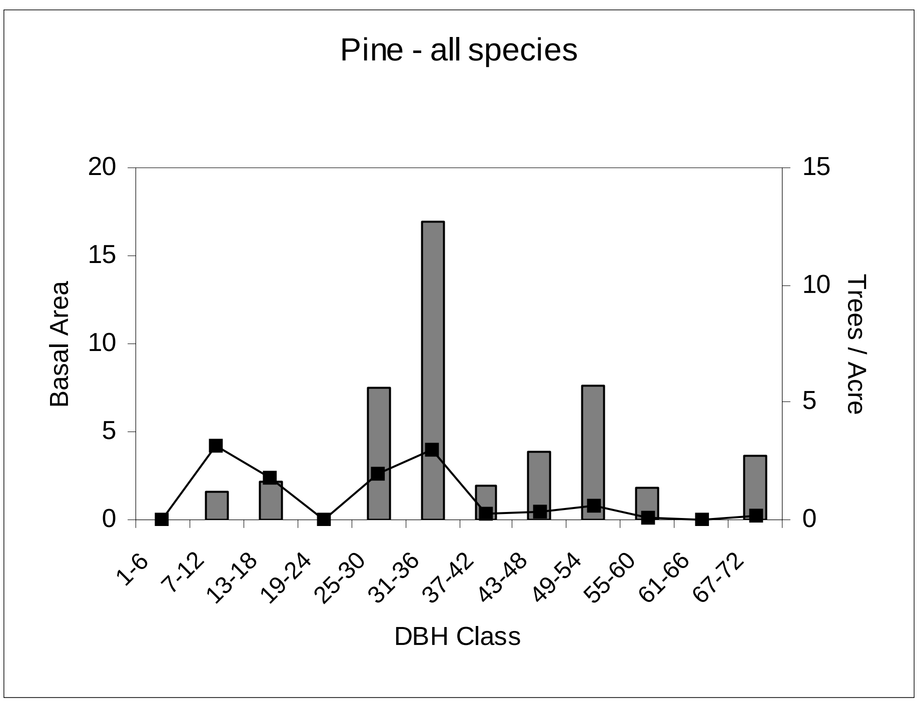
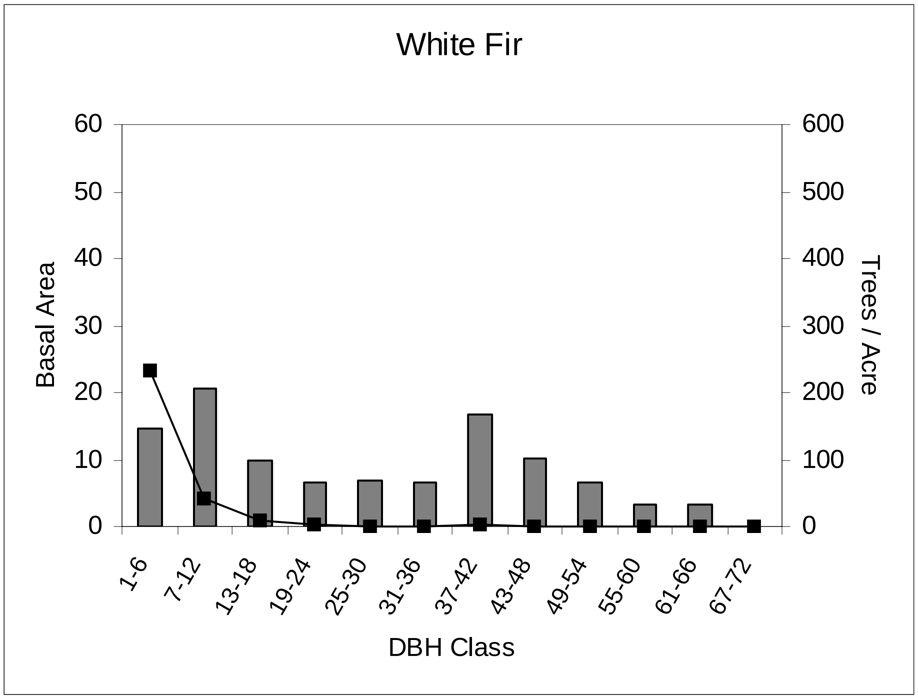


Figure 3. Relationship between basal area composition tree size in Stand 2. The bars represent the amount of basal area in a given size class and the lines represent the corresponding tree density.



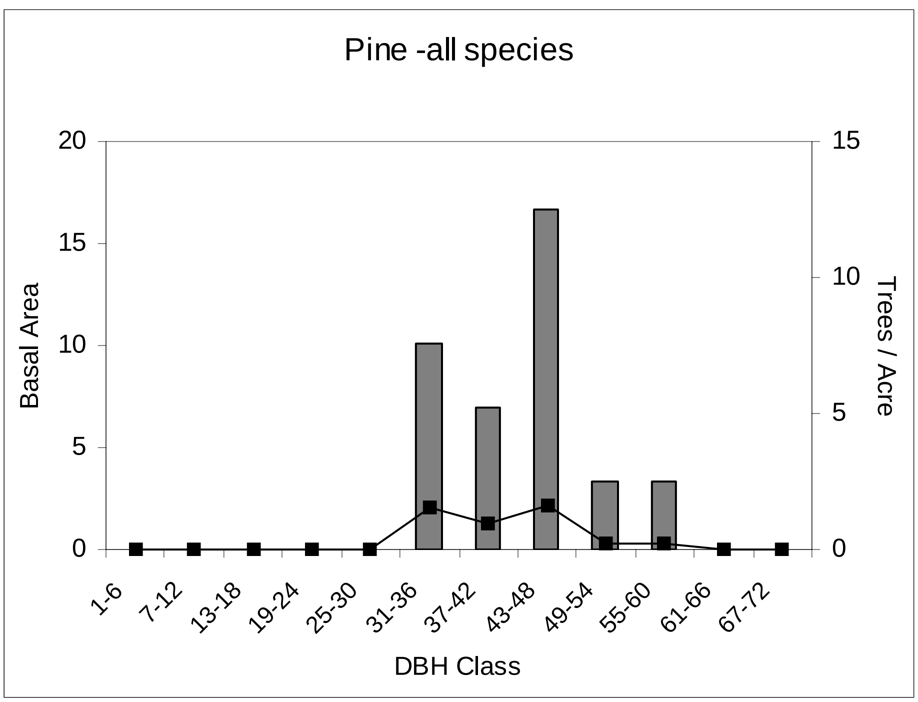
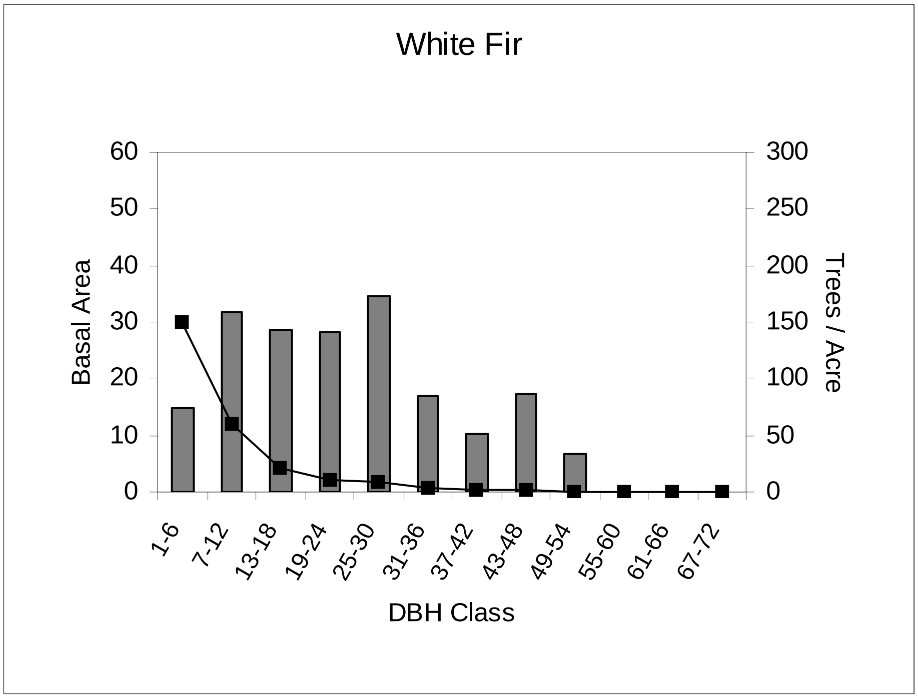


Figure 4. Relationship between basal area composition tree size in Stand 3. The bars represent the amount of basal area in a given size class and the lines represent the corresponding tree density.



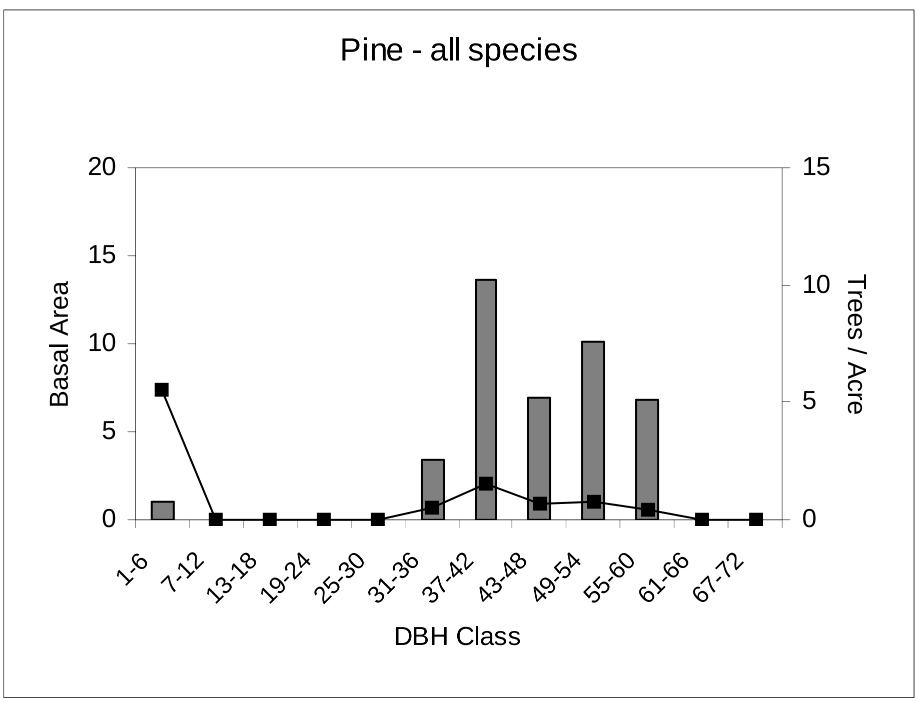
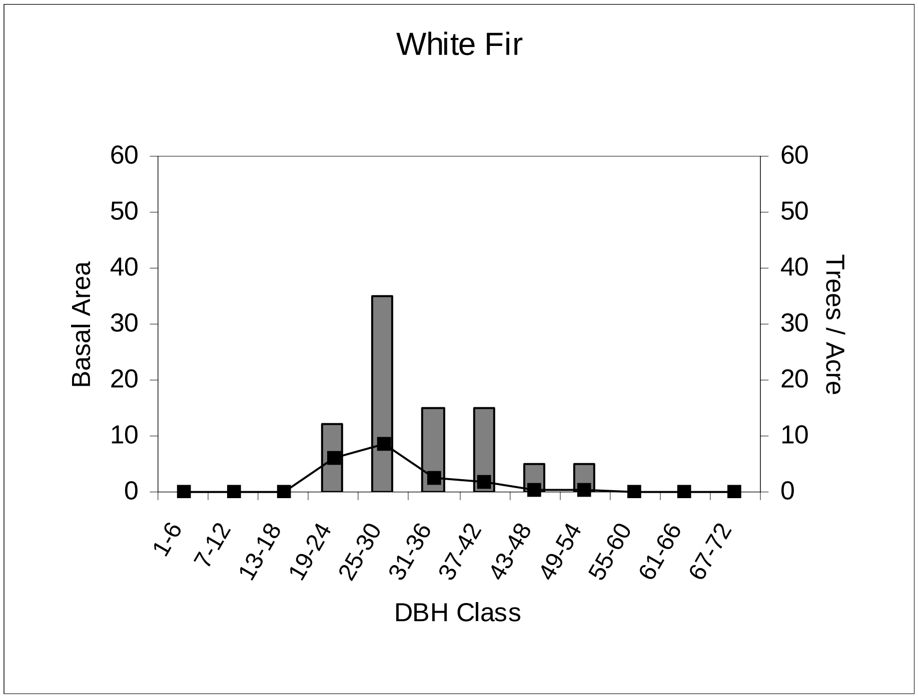


Figure 5. Relationship between basal area composition tree size in Stand 4. The bars represent the amount of basal area in a given size class and the lines represent the corresponding tree density.



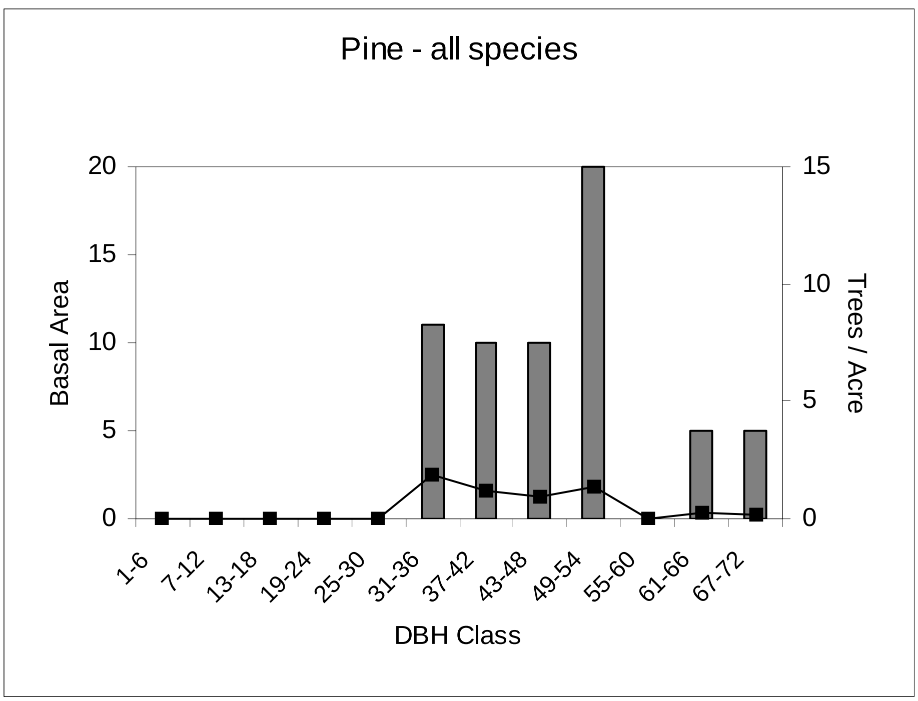


Figure 6. Cumulative basal area distribution as a function of tree size in Stand 1, Lost Creek Campground. Graph a) shows entire distribution of all trees. Graph b) only shows the distribution up to 12" dbh because trees this size or larger would not be subject to removal under current management scenarios.

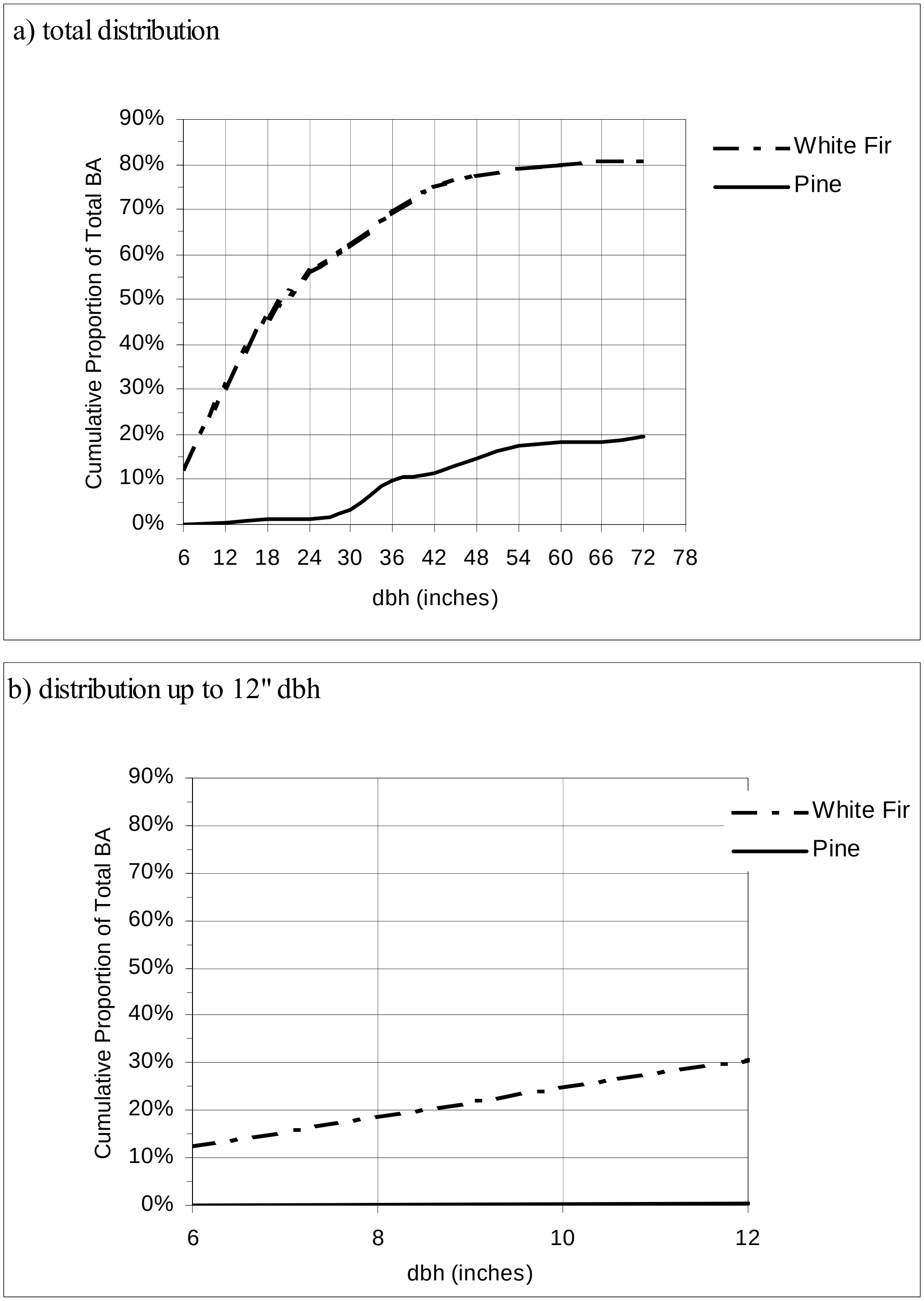
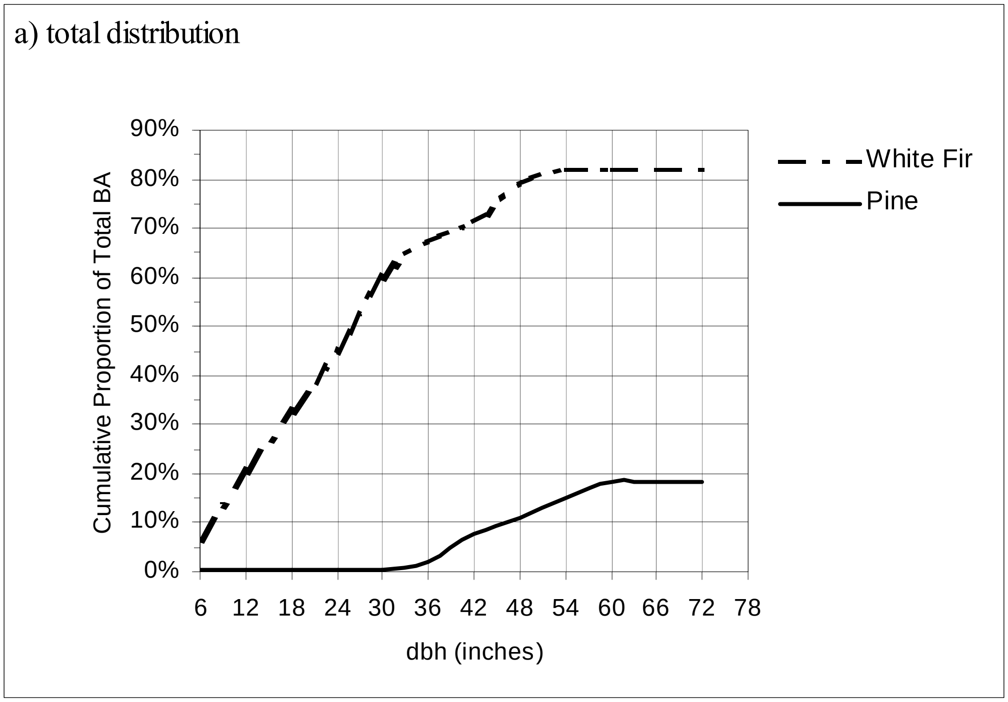


Figure 7. Cumulative basal area distribution as a function of tree size in Stand 3, Crags Campground. Graph a) shows entire distribution of all trees. Graph b) only shows the distribution up to 12" dbh because trees this size or larger would not be subject to removal under current management scenarios.



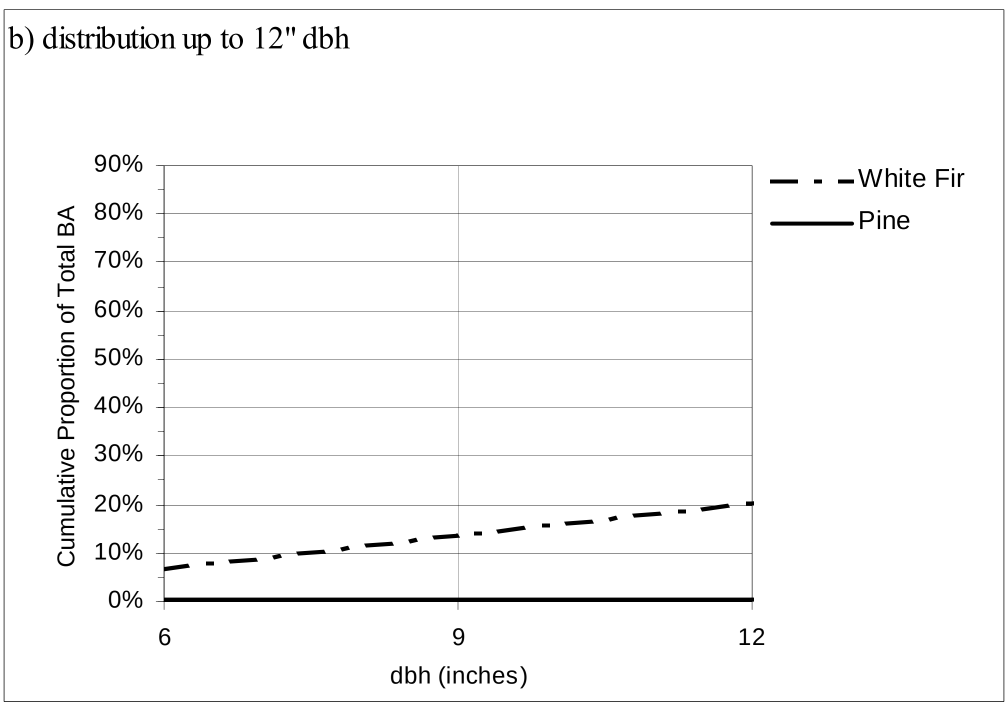
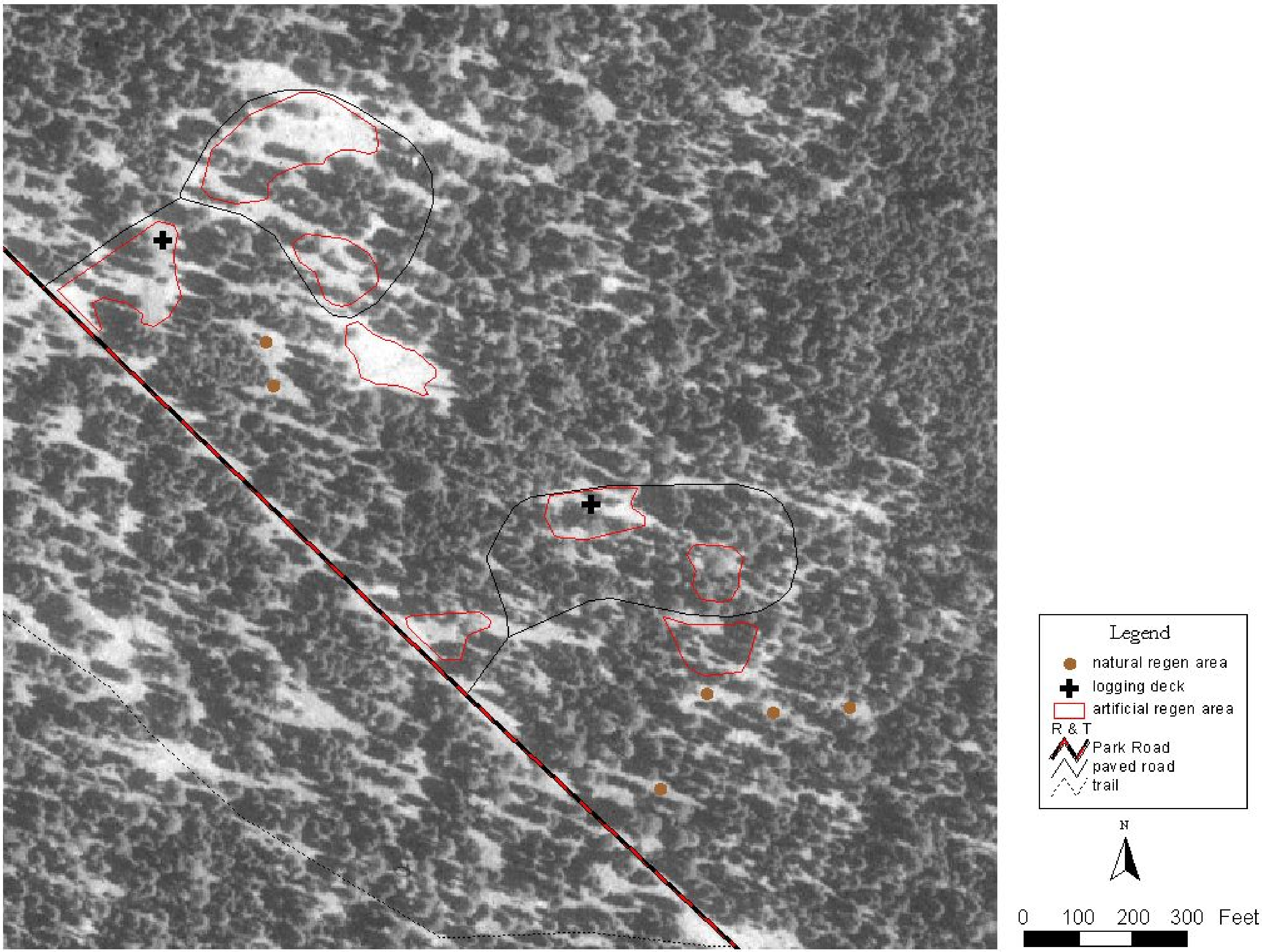


Figure 8. Locations of artificial and natural regeneration areas in Lost Creek and Crags Campgrounds, Lassen Volcanic National Park



REFERENCES

Cochran, P.H. 1998a. Thirty-five year growth of thinned and unthinned ponderosa pine in the Methow Valley of northern Washington. USDA Forest Service, Pacific Northwest Research Station. PNW-RP-502.

Cochran, P.H. 1998b. Examples of mortality and reduced annual increments of white fir induced by drought, insects, and disease at different stand densities. USDA Forest Service, Pacific Northwest Research Station. PNW-RN-525.

Dillworth, J.R. 1982. Log Scaling and Timber Cruising. O.S.U. Bookstore, Corvallis, OR.

Dunning, D. and L.H. Reineke. 1933. USDS Tech Bulletin 354.

Ferrell. G.T. 1996. The influence of pests and pathogens on Sierra Forests. *In* Sierra Nevada Ecosystem Report: Volume II, assessments and scientific basis for management options. Wildand Resources Center Report No. 37, University of California, Davis. Pgs. 1177-1192.

Fiddler, G.O., T.A. Fiddler, D. Hart. and P.M. Oliver. 1989. Thinning decreases mortality and increases growth of ponderosa pine in northeastern California. USDA Forest Service, Pacific Southwest Research Station. PSW-RP-194.

Fowells, H.A. 1965. Silvics of forest Trees of the United States. U.S. Department of Agriculture, Forest Service. Agriculture Handbook no. 271.

Hawksworth, F.G. 1972. Dwarf mistletoes of ponderosa pine. USDA

Helms, H.A. and J.C. Tappeiner. 1996. Silviculture in the Sierra. *In* Sierra Nevada Ecosystem Report: Volume II, assessments and scientific basis for management options. Wildand Resources Center Report No. 37, University of California, Davis. Pgs. 439-476.

Reineke, L.H. 1933. Perfecting a stand-density index for even-aged forests. Journal of Agricultural Research. 46(7):627-638.

Oliver, W.W. 1996. Is self-thinning in ponderosa pine ruled by *Dendroctonus* bark beetles? *In* Covington, W.W. and P.K. Wagner (eds.). Conference on adaptive ecosystem restoration and management: restoration of the Cordilleran conifer landscapes of North American. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. RM-GTR-278. Pgs 213-218. .

Scharpf, R.F. (tech. coord.). 1993. Diseases of pacific coast conifers. U.S. Department of Agriculture, Forest Service. Agricultural Handbook no. 521. Pacific Southwest Research Station, Albany, CA.

Taylor, A.H. 1998. Vegetation change and dynamics in Lassen Volcanic National Park. Unpublished report on file at Lassen Volcanic National Park.

Woodruff , W.C. 2002. Evaluation of root disease in Crags and Lost Creek Campgrounds, Lassen Volcanic National Park. USDS Forest Service, Pacific Southwest Region, Forest ealth Protection Report No. NE02-12.