Douglas-fir, Grand Fir and Plant Community Regeneration in Three Silvicultural Systems in Western Oregon

Masters Thesis

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Douglas-fir and grand fir seedling establishment and plant community regeneration were examined in a western Oregon forest following harvest in three different silvicultural systems: clearcut, two-story and patchcut. The two-story system consisted of removing all but 10 to 12 trees per acre. The patchcut system consisted of harvesting 1/2 acre patches in a grid like manner resulting in the removal of approximately 1/3 of the trees within a stand. The response of Douglas-fir and grand fir seedling growth to four vegetation control treatments nested within each silvicultural system was evaluated. The four treatments were: no-treatment, herbicide treatment, intensive treatment (herbicide treatment in addition to scalping of competing vegetation and browse protection (vexar tubing) and manual treatment (surrounding each seedling with paper mulch and slashing near-by shrub growth). Plant community regeneration in the three silvicultural systems and the effect of the no-treatment and herbicide treatment on plant growth habits and life forms was evaluated and compared to control stands that were not harvested.

Successful artificial regeneration occurred in all three silvicultural systems. However, Douglas-fir had significantly greater height to diameter ratios in patchcuts than either two-stories or clearcuts. Similar trends were observed for grand fir. This

suggests that future growth rates in patchcuts of both Douglas-fir and grand fir may be reduced relative to two-stories and clearcuts. Stocking of natural seedlings was satisfactory in two-story stands but was poor in both clearcuts and patchcuts. A lack of seed source is probably responsible for the low stocking in clearcuts. Restocking of patchcuts was low even though the potential for seedfall was high. Low levels of soil disturbance in patchcuts likely limited the amount of successful natural regeneration in this system.

The intensive control of competition was the only treatment which resulted in significantly greater Douglas-fir growth than no control of competition. All active vegetation control treatments resulted in greater grand fir growth than the no treatment. However, no differences in the effectiveness of these treatments in increasing grand fir growth were observed. These findings suggest that grand fir has a lower minimum competition response threshold than Douglas-fir. That is, greater levels of vegetation management are needed to get a positive growth response with Douglas-fir than grand fir. Over all, the best seedling growth of both species can be expected when planting stock is large and overtopping is kept to a minimum. Deer showed a marked browse preference for Douglas-fir versus grand fir. However, browsing was not a significant factor in reducing overall growth of Douglas-fir seedlings in this study.

Vegetation response to silvicultural system did not differ significantly. The herbicide treatment significantly reduced the vegetation volume. Operational restraints imposed by the different systems resulted in less effective vegetation control in patchcuts than in either the two-story or clearcut systems.

Total herb cover increased following harvest and annual herb cover increased more than perennial herb cover. In the absence of vegetation control, total herb cover, annual herb cover, and perennial herb cover are not affected by silvicultural system. However, with the herbicide treatment, a general increase in these three cover parameters from clearcut to two-story to patchcut was observed. Shrub cover is not influenced by silvicultural system in no-treatment plots although in herbicide treated plots a loose relationship resulting in less shrub cover in harvested sites is evident. Over all, vegetation treatment results in no significant reductions in shrub cover.

Douglas-fir, Grand Fir and Plant Community Regeneration in Three Silvicultural Systems in Western Oregon

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APPROVED:

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

J. Scott Ketchum

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Introduction

In Oregon's coastal forest the traditional mode of timber management is clearcutting and subsequent regeneration of conifers. Typically after harvest, the site is prepared for planting by using herbicides, mechanical scarification or burning, or a combination of these techniques to insure an adequate environment for planted Douglas-fir seedlings. This method of harvest and regeneration is quite efficient, but there is growing concern over whether it is truly the best in terms of its effects on biodiversity and other forest management objectives.

It can be hypothesized that plants and animals in coastal forests have adapted to natural disturbance regimes. These adaptations are expressed in the reproductive habits and tolerances to different environmental extremes, and utimately insure the continual presence of these species in Oregon Coastal forests. For example, *Gaultheria shallon,* a common shrub species found in mature forests of the Oregon Coast Range, survives coarse scale disturbances such as fire through resprouting from rhizomes deep within the soil (Huffman 1992). This same species is able to tolerate extreme shade and can subsist for several years in very dense stands; thus, persisting until canopy self-thinning occurs and increased light levels allow for expansion of the shrub.

Using management practices that mimic natural disturbance may have the least amount of impact on indigenous species. If the artificial disturbance that results from the harvest of trees mimics natural disturbance in terms of intensity and post-disturbance conditions, then species which have adapted reproductive habits to similar natural disturbances will likely survive harvest disturbance. Clearcuts may mimic some charcteristics of natural disturbances such as fire. With both fire and clearcutting, the overstory is removed and the understory species are disturbed to varying degrees. However, historical fire occurrence was infrequent compared to the present rate of clearcutting (Agee 1991). The stands that develop following natural fire disturbance tend to have greater numbers of overstory species and increased structural diversity, than do the even-aged stands which result from clearcut harvest and subsequent artificial regeneration.

Stand-replacing fire is not the only significant disturbance that occurs in coastal Douglas-fir forests. Other natural disturbances are competition, disease, insects, slope failures and wind throw none of which is generally stand replacing (Spies and Franklin 1988). Disturbance from these agents occurs at a variety of frequencies, intensities and spatial scales. As hypothesized earlier, it is likely that associated forest plant species have adapted in a manner to survive and possibly take advantage of these disturbances. Thus, develping silvicultural techniques which closely resemble small scale disturbance may insure the continual survival of native plant and animal species in harvested areas.

Plant Community Response to Harvesting

With the BLM's goal of maintaining biodiversity in managed forests, it is important to understand how plant species respond to stand treatments and to the vegetation control used to establish regeneration. Species such as *Acer circinatum*, *Corylus cornuta*, *Gaultheria shallon*, *Rubus parviflorus*, *Symphoricarpos albus*, and *Pteridium aquilinium*, all sprout after disturbance and are likely to persist and expand following harvest.

Effects of stand treatments and vegetation control on perennial herbaceous species, such as *Adenocaulon bicolor*, *Achlys triphylla*, and *Vancouveria hexandra* are unknown (Loucks and Harrington 1991). These species are all considered to be associated with old-growth forest (Thomas et al. FEMAT 1993, Thomas et al. SAT 1993). Their response to disturbance by logging has not been determined; however, there is an indication that because of their below-ground buds, some of these species withstand severe disturbance (Antos and Zobel 1984). There is evidence that residual perennials survive clearcutting and remain part of the post-harvest plant community (Dyrness 1973). However, the effect of alternative silvicultural systems on these herbs is unknown. No studies to date have examined the effect of alternative silvicultural systems such as group selection or shelterwood harvest on these herb species. For example, perennials may be favored by shade provided by the larger trees in shelterwood cuts and uncut portions of the stand in patch cuts. They also may be favored by soil disturbance and increased light. However, they may not survive if dense covers of tall shrubs develop and over-top them. An even more important effect may be competition from annual and biennial herbs and grasses, which tend to dominate recently clearcut sites (Dyrness 1973, Yerkes 1958, Brown 1963 and Malavasi 1978). Some of these species are *Cirsium arvense*, *Crespis setosa*, *Epilobium angustifolium* and a variety of invasive grass species.

The potential interplay of growth habits and life form types of early secondary successional species is of special interest to this study. Plant communities can be broken down into four categories of growth habit and life form types: herbs, shrubs, perennial herbs, and annual herbs. The relative importance of these growth forms will likely be affected by the type of silvicultural treatment applied. The use of herbicides will also influence the resultant communities. Operational aspects of this study introduce another source of variation in community composition among silvicultural treatments. For example, a clearcut can easily be broadcast sprayed with herbicide, while a group selection must be backpack sprayed. Other operational features of installing the silviculture treatments such as extent of disturbance due to harvesting will additionally influence the response of the resultant plant communities.

Regeneration of Conifers

Regeneration is a major part of any silvicultural system. Trees that are harvested must be replaced. Also, regeneration in partially cut stands is important for developing multi-story structures as stands are managed to produce old-growth characteristics (Tappeiner et al. 1992). This means that foresters must adapt regeneration techniques used in clearcuts for regeneration in the understory or in small openings. This will probably involve use of shade tolerant species such as grand fir as well as less shade tolerant species like Douglas-fir. To date, no direct comparison of the suitability of these two species, in terms of regeneration potential on harvested sites has been made.

A key part of regeneration in clearcuts has been controlling herbs, shrubs, and hardwoods (Hobbs et al. 1992, Walstad and Kurch 1987). To what extent is this practice needed in other silviculture systems? Current vegetation control technology reduces the need for protection from animal browsing on young planted seedlings in clearcuts (Osman and Sharrow 1993). Vigorous seedlings growing under reduced competition are able to "outgrow" the effects of browsing. How will potentially reduced seedling growth in the relatively shady environments provided by overstory and surrounding trees plus possible increased browsing pressure affect seedling establishment and growth?

Natural regeneration might be enhanced by environments provided by partial cutting. Will natural Douglas-fir and grand fir regenerate and grow in these shady environments? For example, Isaac (1956) found that establishment of natural Douglas-fir in partially cut stands was highly unpredictable. This and other concerns led him to recommend clearcutting and even-aged management. However, Williamson (1973) found that the shelterwood method could be used to regenerate Douglas-fir stands provided that there was adequate site preparation and control of herbs and shrubs. These studies were based on surveys rather than on controlled experiments.

Objectives

Most research concerning harvesting in Oregon's coastal forest has centered on clearcuts and even-aged stand management systems (Loucks and Harrington 1991); little work has been done on alternative silvicultural management systems. This study compares the effects of two alternative silvicultural systems in Douglas-fir forests on artificial regeneration and the plant community response; two story stands and patchcuts compared to conventional clearcutting.

Two story stands in this study are a form of shelterwood cut in which approximately 2/3 of the trees are removed leaving the remaining 1/3 on the site to possibly ameliorate harsh site conditions and to provide structure as well as add to canopy species diversity to the next stand. This system may mimic disturbance such as wind throw and light fire, after which some trees survive. Not all the characteristics associated with wind throw and light fire will be mimiced by two story stands. For example, tip up mounds and a great abundance of coarse woody debris will not result from the the two story silvicultural technique.

In the group selection system 1/2 acre openings are cut on a grid, resulting in the removal of approximately 1/3 of the trees in the stand and opening up 1/3 of the area of the stand. This mimics root disease, insect related mortality, or small scale wind throw. Again, this silvicultural system will not produce all the characteristics associated with these natuaral disturbances.

I have studied early plant community responses and regeneration success in the two story, group selection, and clearcut systems with emphasis on the two objectives listed below:

1.) Determine how shrub and herb composition and cover vary by silvicultural and vegetation control treatments in clearcuts, two-story cuts, patch cuts, and undisturbed controls.

2.) Compare survival and growth of planted and natural seedlings of Douglas fir and grand fir over a three year period in two story cuts, patchcuts and clearcuts.

Methods

Study Area

Two separate studies, each designed to address one of the previously stated objectives, have been installed in three areas (Lewisburg, Peavy and Dunn) of Oregon State University's McDonald-Dunn research forest. Both studies share the same study areas and basic experimental design. McDonald-Dunn forest is located at an abrupt transition zone from the generally flat Willamette Valley floor to the Coast Range. Two plant association types have been recognized within this zone: a.) *Pseudotsuga menziesii/Corylus cornuta califonica/Bromus vulgaris* and b.) *Pseudotsuga menziesii/Acer circinatum/Gaultheria shallon* (Franklin and Dyrness 1973). Both associations are found on sites in this study. The forests in study sites prior to treatment consisted of stands of a variety of ages ranging from 55 to155 year-old Douglas-fir. The Dunn area tended to consist of younger stands (55-100 years old), than the Lewisburg and Peavy areas, which were 90-155 years old. Elevations in McDonald-Dunn forest range from 140 to 470 meters above sea level. The study sites are located over this entire range of elevations, on nearly all cardinal aspects as well as on a variety of slopes. Precipitation averages 1,000 millimeters per year and occurs primarily from November to May. Summers tend to be hot and dry with mean June to August temperatures of 27.1 ^{o}C and a total of 47 mm of precipitation. King's site index ranges from 92 to 130 over the study area (King 1966).

Experimental Design

The study was conducted on three blocks of McDonald-Dunn forest over four years from 1989 to 1992. Each stand used in the study consisted of a minimum of 20 acres and was installed as follows: Lewisburg harvested 1989-90 and planted spring 1990, Peavy harvested in 1991 and planted in spring of 1992, and Dunn harvested in 1991-92 and planted in spring of 1992. The three silvicultural systems were each applied to one stand and an additional stand was identified as a control in each block (Table 1). Three one acre vegetation treatment replicates were randomly located along the edge of each system in every block, resulting in a total of nine vegetation treatment replicates in each system, across all blocks. Each replicate was divided equally into four regions, each being randomly assigned one of four vegetation treatments. Fifteen Douglas-fir and ten grand fir were planted in each of the four regions within each one acre replicate. No trees were planted in the control stands and no vegetation treatments were applied. However, three untreated plots were chosen at random in each control stand on which understory species presence and abundance was measured. Thus, there were three replications of each silvicultural system across all blocks and within each system nine replications of each vegetation management treatment on which to measure understory species response and Douglas-fir and grand fir regeneration survival and growth.

Silvicultural Systems

Three silvicultural systems were examined in this study (Table 1). The first is a traditional clearcut or even-aged silvicultural system. This system consists of harvesting all but one to two trees per acre to act as wildlife snags. Slash was piled using tractors and burned. The sites were then planted with 1-1 or P-1 Douglas-fir seedlings. The second system, two-story, had all of the overstory removed with the exception of 10 to 12 trees per acre. The trees left on the site were a combination of large, clear bole, highly marketable trees as well as some trees exhibiting characteristics that may promote

Table 1 Experimental design, silvicultural systems and vegetation treatments. Abbreviations following system and treatment types will be used in the remainder of the text.

Block	Silvicultural System (20 acre stands)	Vegetation Treatment
Lewisburg (established 1989-90 planted spring 1990)	Clearcut (CC) (all but 1-2 wildlife trees/acre harvested)	*Herbicide (HT) (application of a variety of herbicides)
Peavy (established 1990-91 planted spring 1992)	Two Story (TS) (thinned to 10-12 trees/acre, trees uniformly distributed)	Manual (MT) (mulch paper laid down around seedlings, manual slashing of competing shrub vegetation)
Dunn (established 1991-92 planted spring 1992	Patch Cut (PC) (1/2 acre cuts systematically spaced over 1/3 of the area)	Intensive (IT) (application of "herbicide" treatment plus the scalping of vegetation from around seedlings and browse protection)
	Control Stand (CS) (not harvested)	*No treatment (NT) (no vegetation control applied)
Total of 3 blocks	1 of each system/block for a total of 3 replications	3 replications of each treatment/ system/block for a total of 36 NT replications and 27 each of S, M and I treatments; ST, MT and IT were not used in CS system

* Understory presence and abundance was sampled only on these treatments.

wildlife habitat. The goal was to promote multiple canopy levels, increase wildlife habitat and provide a more sheltered environment for young seedlings to establish. Following harvest, slash was piled and burned where needed to aid in planting of 1-1 or P-1 Douglas fir seedlings. The final system was a group selection method termed "patchcut" in this study. This method consisted of harvesting 1/2 acre groups of overstory trees in a checkerboard manner, resulting in 1/3 of the stand being harvested

(Figure 1). Again the slash was piled and burned when needed, only in a few patchcuts in the Peavy block, to aid in the planting of 1-1 or P-1 Douglas fir seedlings.

Vegetation Treatments

Four vegetation control treatments were implemented within each replication of the study (Table 1):

- No treatment (NT) consisted of allowing the vegetation on the site to grow naturally with no attempt to promote seedling growth through vegetation competition control.
- Manual (MT) consisted of surrounding each planted seedling with paper mulch to control herb growth. Additionally, all above ground shrub growth was slashed within the treatment area each year in late spring (Appendix D).
- Herbicide (HT) consisted of a series of different herbicide treatments to control herb and shrub growth. Herbicide was applied by hand around each seedling in the TS and PC systems and aerially in the CC. This treatment was the normal vegetation treatment applied to all other cut areas which were not part of this study (Appendix D).
- Intensive (IT), was treated with the same herbicides as the herbicide treatment, but in addition all vegetation within a one meter radius was scalped away from the seedlings. The seedlings were also protected from browsing by vexar tubing (Appendix D).

Figure 1 Aerial photograph of the Peavy block, depicting examples of patchcuts, two-story stands and clearcuts.

Vegetation Survey Methods

Vegetation sampling was performed across each block by silvicultural system, including the control stands, and for all HT and NT replications. The sampling took place during the late spring and early summer of 1992, two years following harvest in Lewisburg, one year in the Peavy and six to nine months in the Dunn block. The MT and IT treatments were not studied; these vegetation control treatments were applied over areas too small to accurately sample. Three replications of both vegetation treatments within each silvicultural system and three replications of no treatment in the control stands in each block were sampled. A replication consisted of an area of approximately 1/2 acre, half of which received the herbicide treatment and the other half no treatment. The location of each replication was chosen randomly along the edge of the CC and TS systems such that the NT half could be protected from aerial application of herbicides. The PC replications were located within the cut areas and chosen at random from all PC's installed while the CS replications were chosen at random within the stand. The control stand data are used as a bench mark to contrast vegetation changes following harvest.

The sampling procedure consisted of establishing a 40 meter transect traveling South to North within each treatment area such that the entire transect would be contained within a single treatment area. In establishing the sampling transect, an effort was made to sample what apppeared be representative vegetation. Thus, the location of each transect within each sample area was not always truly random, but was selected subjectively in terms of what I percieved as representative of the area to be sampled. Initially, at eight meter intervals along this transect starting at one, two distances along a line perpendicular to the transect were chosen randomly by tossing a stake over a shoulder. These distances were used as plot centers for a two square meter framed quadrat to be laid over the vegetation. After sampling 12 such transects in the Dunn patch cuts, a species area curve was constructed to determine the optimum number of quadrats per transect needed to effectively capture the majority of the plant species in the sampled area. From this curve it was determined that 15 quadrats would better capture the true number of species and relative covers in a sampled area than would 10. The sampling protocol was changed to establishing two quadrats every five meters along the transect and at the last 5m interval along the 40 meter transect, only one plot was installed. Thus, 15 plots were sampled for each replication except the Dunn patchcuts, where ten plots where sampled. The Dunn patch cuts were not resampled using the new protocol due to time constraints.

Over the three blocks, 63 transects and a total of 915 plots were sampled. The following data were collected for each $2m^2$ plot:

- Percent ground cover, an estimate of the percent of ground area occupied by vegetation, the inverse of open growing space that new plants can invade.
- Average height is an estimate of the average modal height of all vegetation within the plot.
- Number of species
- Cover of individual plant species using Braun-Blanquet cover classes

Class	Cover percent	Middle point
1	up to 5	2.5
2	6 to 25	15
3	26 to 50	37.5
4	51 to 75	62.5
5	75 to 100	87.5

Vegetation Survey Data Analysis

Plant Community Cover

The following plant community cover categories were calculated:

- Summed percent cover = sum of cover (midpoint values of cover classes were used) for all species within a plot. It was decided that summed cover of a plot would more closely represent the total biomass found on each plot than did the single estimate of percent ground cover. The overlapping of leaves and the different heights in which plants grow within the herb layer are all taken into account by summed cover (which can total greater than 100%), whereas percent ground cover measures only the amount of ground covered by vegetation, without considering overlapping layers.
- Vegetation volume index was calculated by multiplying summed percent cover by modal height for each plot. Vegetation volume index is an estimate of the total three dimensional space occupied by plants on the plot and is positively correlated with plant biomass (Byrne and Wentworth 1988).

Plant Growth and Life Forms

Average cover values were calculated for:

- Total herb cover, which is the sum of cover (midpoint values were used) for all herb species. This value includes grass cover in addition to herb cover.
- Annual herb cover, which is the sum of cover (midpoint values were used) for annual herbs and grasses found within plots.
- Perennial herb cover, which is the sum of cover (midpoint values were used) for perennial herbs and grasses found within the plots.

•Total shrub cover, which is the sum of cover (midpoint values were used) for the shrub species found within the plots.

Species Diversity

Two measures of community diversity at the transect-level were used to estimate system and treatment effects: Shannon diversity index and species richness. The first, Shannon's diversity index, is a relative diversity value falling between zero and four, which is calculated as follows:

•Shannon Diversity Index[1] = -sum of ($p_i \ln p_i$)

where p_i = the proportional abundance of the ith species = (n_i/N)

The Shannon diversity number takes richness and evenness into account and combines the two into one number representing diversity. Species richness is the total number of species found within the transect sampled.

•Species Richness = (Total number of species per transect)

Statistical Analysis

Means for the above plant community parameters were calculated for each transect. The data were checked for normality and appropriate transformations were made where needed. The initial analysis used a split-plot design to perform an ANOVA of transect means among silvicultural systems. This design partitioned variation into

[1]Both Shannon diversity index and species richness are very sensitive to sample size. Transects in the Dunn patchcut herbicide treatment, had only ten measured quadrats per transect versus 15 in all other transects.

two types: (i) main effects (i.e., silvicultural system) and (ii) split-plot effects (i.e., vegetation treatment). The control stand means were not included in the initial analysis because the herbicide treatment was not applied to the control stand. Inclusion of this split-plot effect would have resulted in an unbalanced design.

Because each block was harvested at a different time prior to the vegetation sampling, it was hypothesized and supported by initial analyses that a system by block interaction would occur. Because of this interaction, analyses were performed independently for each block. Additionally, because ANOVA procedures require balanced experimental designs, the lack of a herbicide treatment replication located in the control stands results in an unbalanced design. Therefore, herbicide treatment replicates and no treatment replicates were analyzed for silvicultural differences separately. In both analyses, means from the same control stands were used. The result is a simple randomized design. The data was examined to insure reasonable normality and residuals were checked to insure a minimal of heteroscedasdicity and appropriate transformations were performed when needed.

Tests for significant differences among vegetation treatments across all blocks and including all systems except the control stands were performed using an ANOVA procedure. No significant block*treatment interactions were identified; however, the test indicated that system*treatment interactions were occurring. Due to the occurrence of significant system*treatment interactions in the full model, independent analyses testing for treatment difference were made for each system across all blocks of the study. Furthermore, similar analyses were performed for each block independently. The data were examined to insure reasonable normality and residuals were checked to insure a minimum of heteroscadasdicity and appropriate transformations were performed when needed.

For all statistical analyses performed, a least significant difference means test (LSD) was used to test the null hypotheses, at the 95 % significance level, that there were no differences in: percent ground cover, average height, summed percent cover, vegetation volume index, total herb cover, total shrub cover, annual herb cover, perennial herb cover, species diversity and species richness among the silvicultural systems and the vegetation treatments.

Conifer Seedling Regeneration Methods

Artificial Regeneration

Each of the three replications within each system in each block was divided into four regions each receiving one of the four vegetation treatments. Fifteen Douglas-fir and 10 grand fir trees were planted along two perpendicular transects within each of the four areas treated. Seedlings were planted in the winter through early spring following harvest in each block. This resulted in the Lewisburg block being planted one year prior to the Peavy and Dunn blocks. Base line height, diameter at 10 cm and number of buds on the terminal leader were measured for each of the trees in each region sampled immediately following planting. These measurements, in addition to an indication of browse occurrence, were repeated every year after each growing season from November to January. Measurements were made through the winter of 1993-94 resulting in the Lewisburg block being measured over a three year period while the Peavy and Dunn blocks were measured over two years. During the final seedling measurement period, additional measurements were made to characterize the competing vegetation within a 1m radius of each tree:

- Herb cover
- Shrub cover
- Total cover
- Overtopping shrub cover

•Overtopping herb cover

In all cases cover was measured using Braun-Blanquet classifications:

Class	Cover percent	Middle point
1	up to 5	2.5
2	6 to 25	15
3	26 to 50	37.5
4	51 to 75	62.5
5	75 to 100	87.5

Overtopping cover was measured by projecting an imaginary 90^0 cone upward from the second to the top whorl of a seedling and then occularly estimating the percentage of the cone which is occluded by overhead vegetation (Howard and Newton 1984).

Natural Regeneration

In the spring of 1994, ten 11 meter transects were established in each of the silvicultural systems in all blocks of the study in areas receiving the herbicide vegetation treatment. Patchcuts were sampled by establishing two transects in each of five patchcut openings selected randomly from 10 pre-selected openings. Starting points for each transect were selected at random from 20 potential points located on maps for each clearcut and two story system sampled and from four potential points in each patchcut. The direction of the each transect was selected at random from one of the four cardinal directions. All natural Douglas-fir seedlings located within one meter of the transect were counted.

In an effort to estimate any differences in the amount of seed fall in differing silvicultural systems, eight seed traps were randomly placed in areas of each of the three silvicultural systems (only in openings in the patchcut) in both the Lewisburg and Peavy blocks of the study. The traps consisted of a square frame covered by a seed permeable hardware cloth and a seed impermeable screen bottom. The traps were of two different sizes, the smallest being 0.25 m^2 and the larger being 0.75 m^2. An effort was made to place the same number of small and large traps in each system, but because of unequal numbers of large and small traps, some systems were more intensively sampled than others (greater numbers of large traps were used). The traps were set out in the early fall of 1991 prior to seed fall and seed was collected four times through the spring of 1992. From personal observations and comparisons to other seed collections (Williamson 1983) it was determined that 1991-92 was a moderate to good seed year.

Conifer Seedling Regeneration Data Analysis

Artificial Regeneration

Stem volume index, an estimate of seedling growth, was calculated by multiplying seedling height by the square of seedling diameter.

•Stem Volume Index (SVI)= $(\text{Diameter cm})^2 * (\text{Height cm})$

The ratio of seedling height to diameter, a measure of stress, was calculated.

•Height-Diameter Ratio (HDR) = (Height cm)/(Diameter cm)

The percent mortality as well as the percent browse per treatment was calculated for each replication.

•Percent Mortality = ((number of seedlings dead)/(number of seedlings per plot))*100

•Percent Browse= ((number of seedling browsed)/(number of seedlings per plot))*100

Overtopping shrub cover and over-topping herb cover were summed to yield a new parameter "overtopping cover".

•Overtopping cover= overtopping shrub cover + overtopping herb cover

An analysis of covariance test (ANCOVA) was used to test the null hypotheses that there were no significant differences in height, diameter, SVI and HDR among silvicultural systems and vegetation treatments in 1993-94 data. Initial seedling volume was used as a covariate. I used a nested split-plot design to perform the ANCOVA procedure. The design partitioned variation into (i) main effects (i.e., block and silvicultural system) and (ii) split-plot effects (i.e., vegetation treatment). Furthermore, each replication of four treatments was independent and was nested within system. The following is the model form used in this design:

Source	df	
Total	108	
Block	2	
Syst	2	Silvicultural system (main effect)
Block*Syst	4	Interaction term
Rep(syst)	8	replication nested within silvicultural system
Block*Rep(syst)	10	Main effect error term (replication nested within system)
Trmt	3	Vegetation treatment (split-plot effect)
Syst*Trmt	6	Interaction term

Block*Syst*Trmt*Rep(syst)	72	Split-plot error term
Vol-0	1	Covariate initial stem volume

Mean squares for Block*Syst and Rep(syst) were very close to the mean square of Block*Rep(syst) and thus were illiminated from the model. The final model is as shown below.

Source	df	
Total	108	
Block	2	
Syst	2	Silvicultural system (main effect)
Block*Rep(syst)	22	Main effect error term (replication nested within system)
Trmt	3	Vegetation treatment (split-plot effect)
Syst*Trmt	6	Interaction term
Block*Syst*Trmt*Rep(syst)	72	Split-plot error term
Vol-0	1	Covariate initial stem volume

Concerns were raised that the current model used psuedoreplication. That is, each replicate within a single silvicultural system within a block was not independent from the other replicates in that particular silvicultural system and block. This concern was unfounded. The means square for both Block* Syst and Rep(syst) were not appreciably different from the main effect error term, which indicates that the variability found between replications within an individual silvicultural system was equal to the variability found between the same silvicultural systems in different blocks. Thus, although each replication is in actuality a subsample of the same stand, they are located far enough appart that each replication is independent from one another and therefore the different replications are like nine different installations of the silvicultural system in question.

The data were checked for normality and residuals examined for heteroscedasdicity and appropriate transformations were made when needed. This analysis was performed on all the experimental blocks combined as well as on each individual block. A least significant difference (LSD) means test was performed to identify significant differences between the silvicultural systems and the vegetation treatments ($p<0.05$).

A correlation analysis was performed to determine the degree of correlation between stem volume index and initial stem volume, total cover, herb cover, shrub cover and overtopping cover, to determine which of these factors were related to seedling stem volume at the 95% significance level. In addition, a stepwise regression analysis with stem volume index as the dependent variable and those parameters which were significant in the above correlation analysis as independent variables was conducted.

Natural Regeneration

Percent stocking was calculated as the total number of transects in which natural seedlings were found divided by the total number of transects sampled in each system. By extrapolating from the number of seedlings found per plot,an estimate of the total number of seedlings found per hectare was made. Similar estimates were made for total number of seeds that fell during the year in which seeds were trapped.

An analysis of variance test (ANOVA), was used to test the null hypotheses that there were no significant differences in number of seedlings per hectare and the number of seeds produced among silvicultural systems. The experimental design used was a randomized block. The data were checked for normality and residuals examined for heteroscedisidicity and appropriate transformations were made when needed. A least significant difference (LSD) means test was performed to identify significant differences between the silvicultural systems ($p<0.05$).

Vegetation Survey Results

Vegetation Volume Index

Vegetation volume differed within blocks in the no treatment (NT) plots among silvicultural systems (Table 2). For example, at Dunn vegetation volume index in the NT plots was significantly less in the control stand (CS) (6.0) than the clearcut (CC) (12.1) and two story (TS) (13.1), while in Peavy the CS (13.2) was significantly less from the TS (31.8) but not the CC (26.1). In NT plots in Lewisburg neither the CC (11.5) or the TS (13.3) were significantly different from the CS (12.1). Vegetation volume index in the NT plots at Peavy ranged from 13.8 in CS to 26.1 in CC, while at Lewisburg volume indices ranged from 11.6 in CC to 19.9 in PC's and in Dunn ranged from 6.0 in the CS to 13.1 in the TS (Table 2, Figure 2).

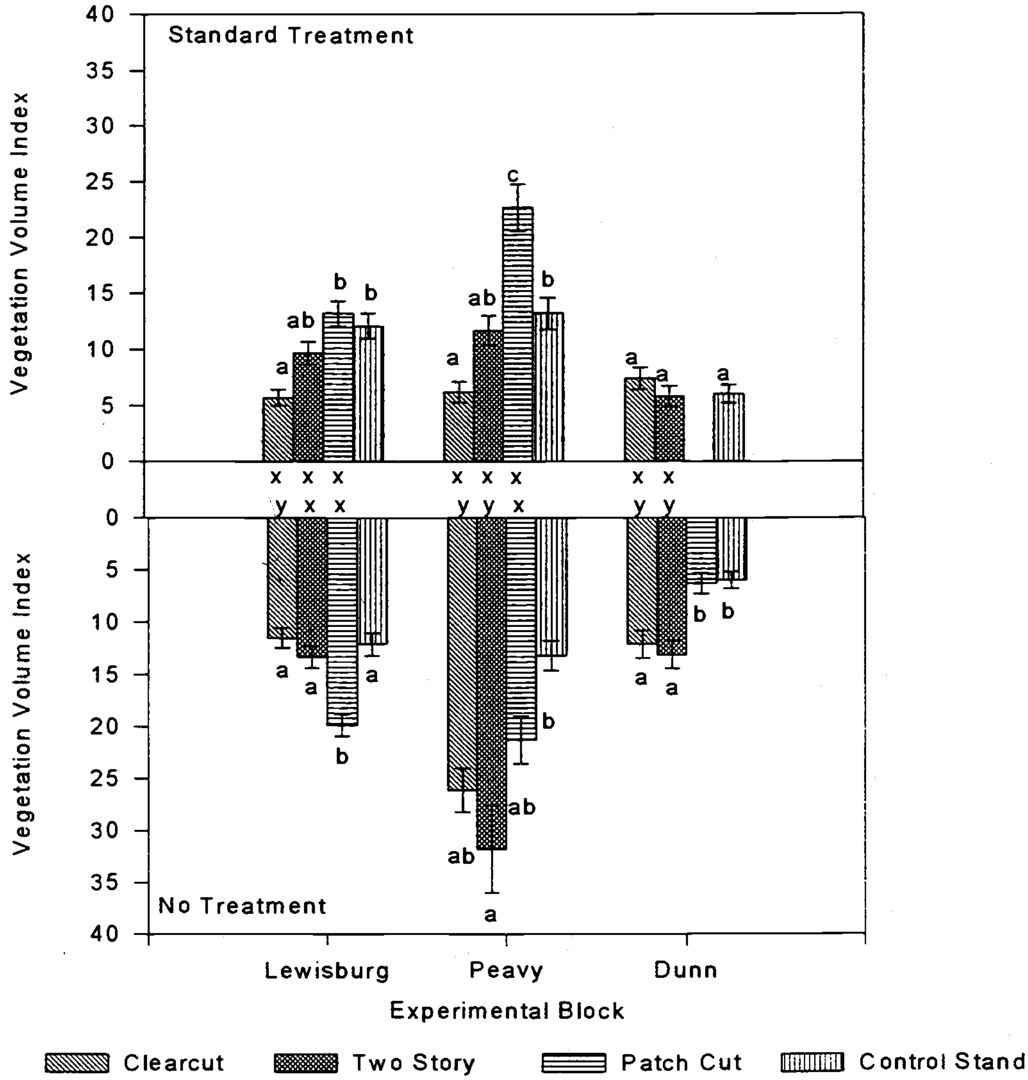
Excluding the CS's, vegetation volume in NT plots differed significantly among cutting regimes in the Lewisburg and Dunn block, although trends within each were different. For example in Lewisburg the PC (19.9) was significantly greater than the CC (11.6) and TS (13.3), while in Dunn the PC (6.3) was significantly less than the CC (12.1) and TS (11.7). No significant differences among systems were apparent in the NT plots in Peavy.

Following the herbicide treatment (HT) there was generally less vegetation volume in CC's and TS's than in PC's and CS's. In all three blocks, there were no significant differences in volume between CC's and TS's. On HT plots at Lewisburg, there was significantly less volume in the CC (5.7) than in the PC (13.2) or the CS (12.1), which were not significantly different. Similarly in Peavy, there was significantly less volume in the CC (6.2) than in the PC (22.7) and CS (13.2). Unlike Lewisburg, at Peavy the TS (11.7) and PC (22.7) did differ significantly.

Table 2. Plant community vegetation cover descriptors (summed percent cover, percent ground cover,average height, and vegetation volume index) are presented by silvicultural system. Values are means across three transects. Values followed by different letters (a,b, or c) within a column are significantly different ($p<0.05$) .

Silvicultural system	Lewisburg				Peavy				Dunn			
	No Treatment	SE (n=3)	Herbicide Treatment	SE (n=3)	No Treatment	SE (n=3)	Herbicide Treatment	SE (n=3)	No Treatment	SE (n=3)	Herbicide Treatment	SE (n=3)
Summed Percent Cover (percent)												
Clearcut	161.5a	6.4	129.6ab	4.8	275.2b	9.8	159.2a	6.7	195.6c	8.2	137.3a	6.5
Two-Story	172.8a	7.7	115.6a	7.7	278.5b	14.3	182.9a	8.4	186.3c	10.5	124.8a	9.9
Patch	189.7a	6.7	160.8b	7.3	260.3b	10.1	251.7b	11.0	147.6b	11.1	129.1a	10.4
Control	166.8a	8.6	166.8b	8.6	156.1a	8.4	156.1a	8.4	95.7a	6.8	95.8a	6.8
Percent Ground Cover (percent)												
Clearcut	97.3a	1.2	95.5b	1.8	96.3a	1.7	93.6a	2.2	89.4a	2.6	79.5ab	3.2
Two-Story	93.2a	2.2	80.2ba	3.6	89.3a	2.8	83.2a	3.1	84.5a	3.6	65.0a	4.7
Patch	98.6a	1.1	95.3b	1.7	96.3a	1.3	96.5a	1.5	88.6a	3.5	81.6b	3.2
Control	97.3a	1.4	97.3b	1.4	87.8a	2.8	87.7a	2.8	75.8a	3.9	75.8ab	3.9
Average Height (cm)												
Clearcut	71.0a	4.8	40.6a	4.3	89.1a	5.0	34.5a	3.1	57.3ab	4.1	50.5a	6.4
Two-Story	73.5a	4.2	77.2b	5.8	101.2a	7.0	57.5b	4.3	64.88b	4.8	42.0a	4.8
Patch	104.8b	4.9	80.2b	4.9	74.7a	5.2	82.6c	5.1	42.13a	5.4	not-est	
Control	69.4a	4.9	69.4b	3.1	77.2a	6.2	77.2c	6.2	56.44ab	5.2	56.4a	5.2
Vegetation Volume Index												
Clearcut	11.6a	0.97	5.7a	0.7	26.1ab	2.1	6.2a	0.9	12.1a	1.3	7.4a	1.0
Two-Story	13.3a	1.04	9.7ab	1.0	31.8b	4.2	11.7ab	1.3	13.1a	1.3	5.8a	0.9
Patch	19.9b	1.05	13.2b	1.1	21.3ab	2.3	22.7c	2.1	6.3b	1.0	not-est	
Control	12.1a	1.1	12.1b	1.1	13.2a	1.4	13.2b	1.4	6.0b	0.8	6.0a	0.8

Figure 2. Average vegetation volume index by silvicultural system for the herbicide and no treatment. Volume values are not given for the Dunn Patch cut herbicide treatment, due to missing values. For comparing system means within a block, bars with the same letter (a,b or c) are not significantly different ($p < 0.05$). For comparing treatment effects within blocks, bars with the same letter (x or y) are not significantly different ($p < 0.05$). Error bars represent standard errors for comparisons among silvicultural systems within individual blocks.

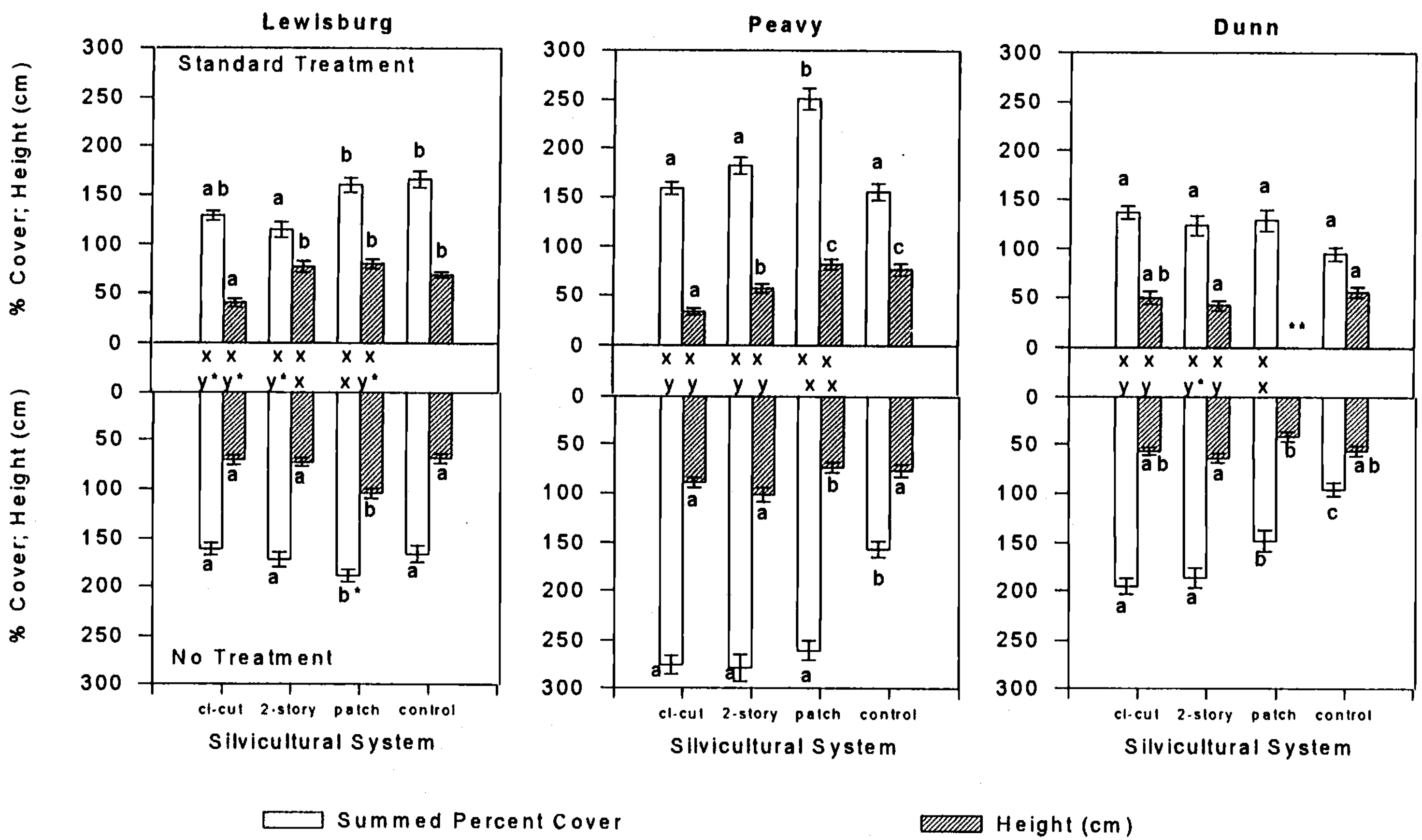


The vegetation volume index after the HT was significantly less ($p= 0.05$) than the volume index in the NT plots in CC's across all blocks and in the TS at Peavy and Dunn, but not at Lewisburg (Figure 2). However for PC's, there were no significant differences in volume index between HT and NT at Lewisburg or Peavy. For example, the volumes in the HT plots in the CC and TS at Peavy (6.2 and 11.7 respectively) were significantly less than in the NT plots (26.1 and 31.8). In the PC at Peavy, however, the volumes in the HT plots (22.7) and NT plots (21.3) were nearly identical.

Cover and Height

Results for summed percent cover and average height in both the HT and NT plots closely followed those for volume (Table 2 and Figure 3). For example, in NT plots consistent trends were not observed for system differences across blocks. However, in HT plots in the CC and the TS systems at Lewisburg and Peavy, summed percent cover was significantly smaller than the PC, with the exception of the CC at Lewisburg which although reduced was not significantly different. Similarly, vegetation heights in the CC at Peavy and Lewisburg are significantly smaller than in any other system (40.6 cm and 34.5 cm respectively). In both blocks the PC had the greatest height (82.6 cm in Peavy and 80.2 cm in Lewisburg), significantly greater than the TS height in Peavy (57.5 cm) but not in Lewisburg (77.2 cm). Additionally, heights in the CS were not significantly different from the PC in either block.

Figure 3 Summed percent cover and average height. Cover values are averages of the sum of shrub and herb cover per plot in each transect. For comparing system means within a block, bars with the same letter (a,b or c) are not significantly different (p<0.05). For comparisons between treatments within blocks, bars with the same letter (x or y) are not significantly different (p<0.05). Error bars represent standard errors for comparisons among silvicultural systems.



* Significantly different (p<0.1)
** Missing data

Growth Habit and Life Form

I examined how different plant growth habits and life forms were affected by silvicultural system and vegetation treatment. In addition, I tried to examine how individual species were affected by system and treatment and concluded that the data collected in this study were not robust enough to make conclusions about how cover for species varied by system and treatment. The experimental design limited vegetation sampling to 1/2 acre areas. Individual plant species over an entire landscape are seldom arranged in a random manner, rather they tend to be clumped as a result of chance, environmental differences, or reproductive strategies. Species that were sampled in one replication were often not found in others and it is impossible to conclude if the absence of a species is a result of experimental factors or a consequence of the clumped nature in which plant populations occur over a landscape. Therefore, only general statements about how individual species respond to experimental factors can be made.

Annual Herbs

Several weedy annuals and biennials thrive in harvested sites that were either not present prior to harvest or represented only a low percent of the total cover on undisturbed sites. For example, *Cirsium arvense, Cirsium vulgare, Senecio sylvaticus, Epilobium paniculatum* and *Galium trifidum* occurred across all blocks of the study and made up a significant proportion of the vegetation cover, except in CS's. An exception was *Galium trifidum,* which occurred in control stands in all blocks of the study but apparently greatly expanded its cover following harvest.

Annual herb cover was significantly greater on the NT plots than on CS plots in all silvicultural systems and ranged from 26.7% to 69.7% compared to the CS's that ranged from 0.5% to 13.2% cover (Table 3, Figure 4). Only the NT plots in CC at

Lewisburg (26.7%) were not significantly different ($p<0.05$) from the CS (13.2%) (Table 3). On the HT plots, annual herb cover ranged from 13.1% to 69.5%, significantly more than in the CS's in all systems except the CC at Peavy and the TS at Dunn. At Lewisburg on the HT plots, there were not significant differences among CC, TS, PC and the CS.

No significant block by treatment effects were found in annual herb cover across blocks. Therefore, statistical analysis procedures can be used to test treatment differences in annual herb cover among silvicultural systems for all blocks combined. Annual herb cover

in CC's was significantly reduced across all blocks in the HT plots versus the NT plots (from 45.0% to 17.2%) while the difference between HT and NT was nearly significant ($P<0.1$) in the TS (from 42.6% to 21.3%) and no significant difference between HT and NT was observed in the PC (NT=37.1% and HT=31.7%) (Table 4, Figure 5).

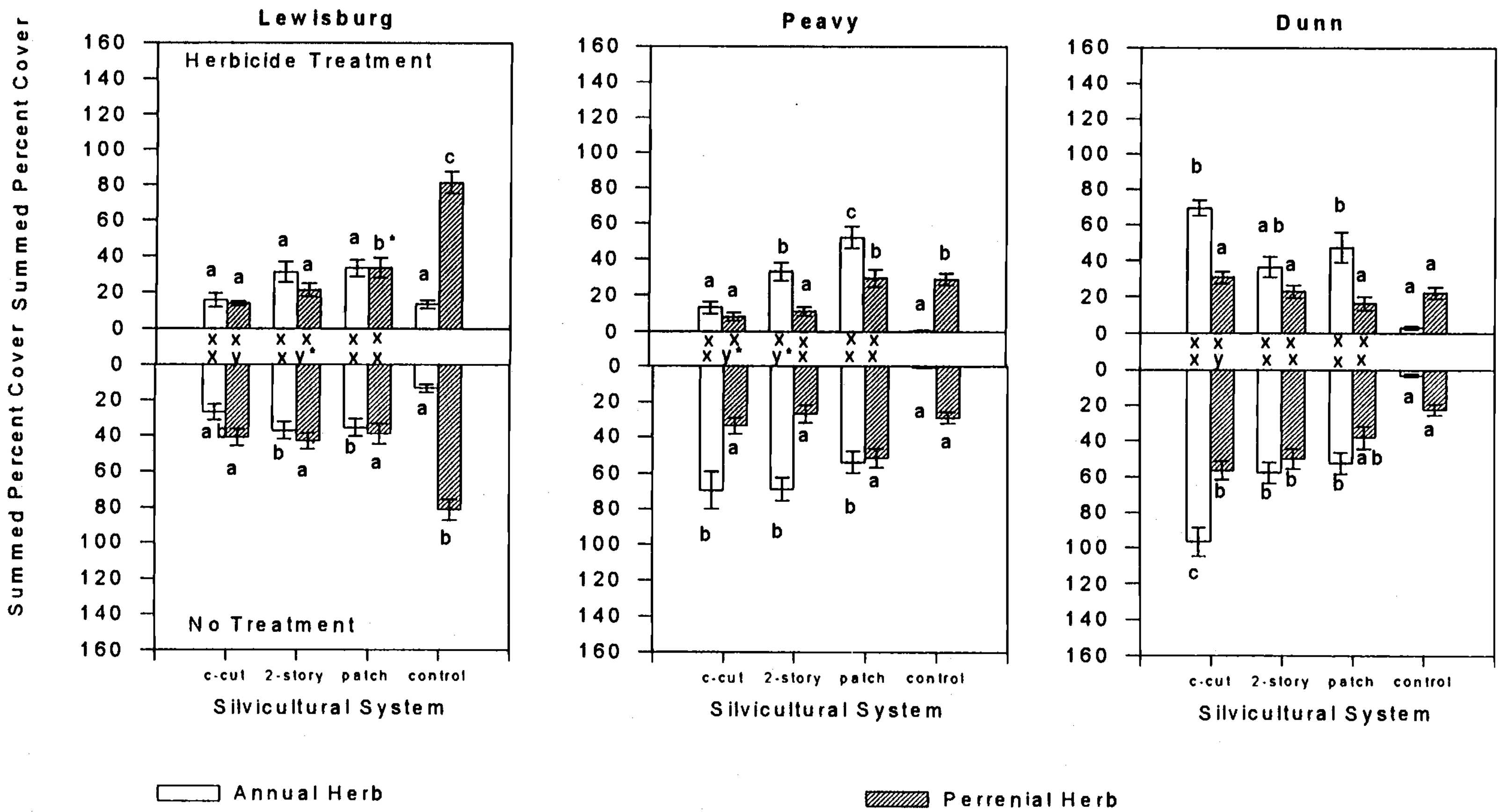
Perennial Herbs

Vancouveria hexandra, Achlys triphylla, Trientalis latifolia, Adenocaulon bicolor, Smilacina stellata, Trillium ovatum and *Viola glabella* are all herbs associated with mature forest (Spies 1991, Thomas et al. FEMAT1993, Thomas et al. SAT 1993). All of these species occurred in CS's in all blocks of the study and persisted on the sites following harvest in all three silvicultural systems. However, *Adenocaulon bicolor, Achlys triphylla,Vancouveria hexandra* , *Smilacina stellata* and *Viola glabella* generally had lower cover in harvested sites than in CS's, while cover of *Trientalis latifolia* and *Trillium ovatum* was the same in CS's as in harvested stands. All species were missing from several combinations of block and system, preventing any statistical analyses of individual species' occurrence across systems.

Table 3 Comparison of summed herb, shrub, annual herb, and perennial herb covers. Data are means of the average summed cover of herbs and shrubs for each sampled transect. Values followed by different letters (a,b, or c) within a column are significantly different ($p<0.05$).

	Herb (no treatment)	SE (n=3)	Herb (herbicide treatment)	SE (n=3)	Shrub (no treatment)	SE (n=3)	Shrub (herbicide treatment)	SE (n=3)	Annual Herb (no treatment)	SE (n=3)	Annual Herb (herbicide treatment)	SE (n=3)	Perennial Herb (no treatment)	SE (n=3)	Perennial Herb (herbicide treatment)	SE (n=3)
Lewisburg																
Clearcut	67.8a	6.5	28.9a	4.3	90.9a	6.7	97.9a	4.5	26.7ab	4.4	15.4a	3.9	41.1a	4.8	13.5a	1.3
2-story	80.2a	6.6	52.1ab	7.5	89.6a	6.8	59.1a	6.1	37.1b	5.0	31.0a	5.6	43.1a	4.4	21.1a	3.5
Patch	74.8a	4.8	66.6ab	6.9	110.4a	6.2	88.1a	8.8	35.6b	4.9	33.2a	4.7	39.2a	5.8	33.3a	5.4
Control	94.5a	6.8	94.5b	6.8	70.9a	7.8	70.8a	7.8	13.2a	2.3	13.2a	2.3	81.3b	6.0	81.3b	6.0
Peavy																
Clearcut	103.2b	11.3	21.3a	4.5	75.1a	7.6	101.8b	4.6	69.5b	10.5	13.1a	3.4	33.6a	4.5	8.2a	2.2
2-story	95.3b	7.8	44.4a	5.9	73.7a	5.7	79.1a	5.0	68.6b	6.5	33.1b	5.1	26.7a	5.0	11.2a	2.3
Patch	105.5b	5.6	81.8b	7.1	76.3a	6.8	81.6ab	5.4	53.8b	6.0	52.3c	6.1	51.6b	5.1	29.5b	4.8
Control	29.3a	3.3	29.3a	3.3	126.7b	9.1	126.8c	9.1	0.5a	0.3	0.5a	0.3	28.8a	3.3	28.8b	3.3
Dunn																
Clearcut	153.1c	8.8	100.2b	5.7	25.4a	4.0	23.8a	3.4	96.7c	8.0	69.5b	4.4	56.4b	5.0	30.7a	3.2
2-story	107.7b	7.3	59.3ab	7.7	59.5a	5.5	56.8b	5.5	57.7b	5.6	36.4ab	5.7	50.1b	5.5	22.9a	3.4
Patch	90.7b	9.7	63.9ab	9.5	46.8a	8.3	57.2b	5.8	52.5b	5.9	47.5b	8.3	38.2ab	6.4	16.4a	3.7
Control	25.2a	3.2	25.2a	3.2	70.5a	6.6	70.5b	6.6	3.1a	0.8	3.1a	0.8	22.2a	3.1	22.2a	3.1

Figure 4 Annual and perennial herb cover. Cover values are the averages of the sum of annual and perennial herb cover per plots in each transect. For comparing system means within a block, bars with the same letter (a,b, or c) are not significantly different (p<0.05). For comparing treatment effect within blocks, the same letter (x or y) are not significantly different (p<0.05). Error bars represent standard errors for comparisons among silvicultural systems.



* Significantly different (p<0.1)

Perennial herb cover in the NT plots ranged from 22.6% to 81.3% across blocks and did not differ significantly among CC, TS and PC, (Table 3, Figure 4). In Lewisburg cover in the CC (41.1%), TS (43.1%) and PC (39.2%) were significantly less than the CS (81.3%). Conversely in Dunn, cover in the CC (56.4%) and TS (50.1%) was significantly larger than the CS (22.2%), while no differences where observed among systems in Peavy.

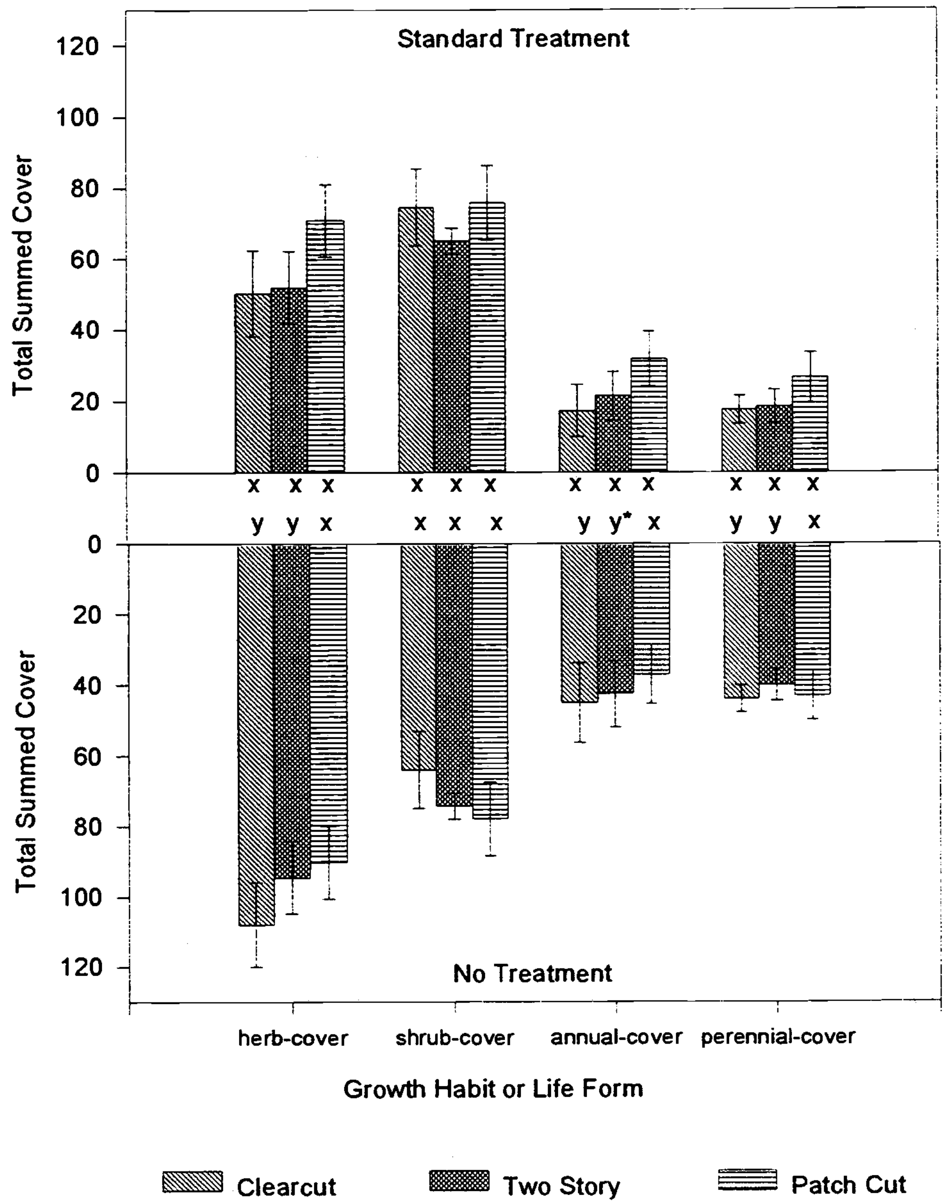
On the HT plots in the CC (13.5%) and TS (21.1%) at Lewisburg and Peavy (8.2% and 11.2% for CC and TS, respectively), perennial herb cover was significantly less than in the CS. In Dunn, perennial herb cover in HT plots in CC's and TS's ranged from 30.7% and 22.9% respectively, greater than the CS's, but not significantly different among treatments

No significant block by treatment effects were found in perennial herb cover across blocks. Therefore, statistical analysis procedures can be used to test treatment differences in perennial herb cover among silvicultural systems for all blocks combined. Perennial herb cover was significantly lower in the HT plots in the CC (from 43.7% to 17.5%) and TS (from 40.0% to 18.4% for NT and HT, respectively), but not in the PC system (NT=43.0% and HT=26.4%) (Table 4, Figure 5).

Total Herbs

In NT plots in Peavy and Dunn, total herb cover was significantly greater in CC's, TS's and PC's than in CS's, while no differences among systems and the CS were found in Lewisburg (Table 3, Figure 5). However, the CS in Lewisburg (94.5%) had much greater herb cover than in either the CS in Peavy(29.3%) or Dunn (25.2%). Significant differences in herb cover among CC's, TS's and PC's were only observed in Dunn with the CC (153.1%) having significantly greater cover than TS (107.7%) or PC (90.7%), which were not significantly different.

Figure 5 Total vegetation cover (summed across lifeform). Cover values are the sums of the average covers for each parameter across all three experimental blocks of the study. Comparisons across systems cannot be made due to block by system interactions. Only comparisons between the two treatment levels can be made when data for all blocks are combined. For comparing treatment effect within blocks, the same letter (x or y) are not significantly different ($p<0.05$). Error bars represent standard errors for comparisons between vegetation treatments.



*Significantly different ($p<0.1$).

No consistent trends in HT plots were observed in herb cover among silvicultural systems in the three blocks of this study. For example, the CC (28.9%) plots in the HT at Lewisburg, had significantly less herb cover than the CS (94.5%), while the TS (52.1%) and PC (66.6%) were not significantly different from any other systems. Conversely, at Dunn the CS (25.2%) had significantly less cover than the CC (100.2%), and the TS (59.3%) and PC (90.7%) were not significantly different from any other system. Furthermore, at Peavy herb cover in the PC HT plots was significantly greater than in the CS, CC and TS, which were not significantly different from each other.

No significant block by treatment effects were found in herb cover across blocks. Therefore, statistical analysis procedures can be used to test treatment differences in herb cover among silvicultural systems for all blocks combined. Across all blocks the HT significantly reduced total herb cover in the CC (from 108.1% to 50.2% for NT and HT, respectively) and in the TS (from 94.5% to 51.9% for NT and HT, respectively), while no difference was measured in the PC (NT=90.3 and HT=70.8) (Table 4, Figure 5).

Total Shrubs

There was a mixed response of shrub species to harvesting disturbance and vegetation treatments. For example, *Corylus cornuta* and *Polysticum munitum* tended to have less cover in harvested plots than CS plots, while *Symphoricarpos albus, Rosa gymnocarpa* and *Rubus ursinus* tended to have greater cover. Other species such as *Pteridium aquilinum* and *Rubus parviflorus* exhibited no distinct trends, having less cover in harvested plots than in CS plots in some instances, while having more cover in others. Similarly, species such as *Rosa gymnocarpa, Rubus parviflorus* and *Symphoricarpos albus* generally exhibited less cover in HT plots than NT plots, while

Table 4 Comparison of cover by growth habit and life form by silvicultural system and vegetation treatment. Values are averages of the sum of the individaul parameter's cover per plot in each transect across all three blocks of the study. Unlike letters read across the two treatments within a single silvicultural system denote statistically different means (p<0.05).

Growth Habit Life Form	Silvicultural System			
	No Treatment	SE n=9	Standard Treatment	SE n=9
	Clearcut			
Total Herb Cover	108.1a	12.1	50.2b	12.1
Total Shrub Cover	63.8a	10.9	74.5a	10.9
Annual Herb Cover	45.0a	11.3	17.2b	7.16
Perennial Herb Cover	43.7a	3.85	17.5b	3.85
	Two Story			
Total Herb Cover	94.5a	10.2	51.9b	10.2
Total Shrub Cover	74.3a	3.72	65.0a	3.72
Annual Herb Cover	72.6a	9.31	21.3a	6.74
Perennial Herb Cover	40.0a	4.6	18.4b	4.6
	Patch Cut			
Total Herb Cover	90.3a	10.2	70.8a	10.2
Total Shrub Cover	77.9a	10.5	75.7a	10.5
Annual Herb Cover	37.1a	8.4	31.7a	7.8
Perennial Herb Cover	43.0a	7	26.4a	7

Polysticum munitum and *Rubus ursinus* either had greater cover in HT plots or did not differ from NT plots.

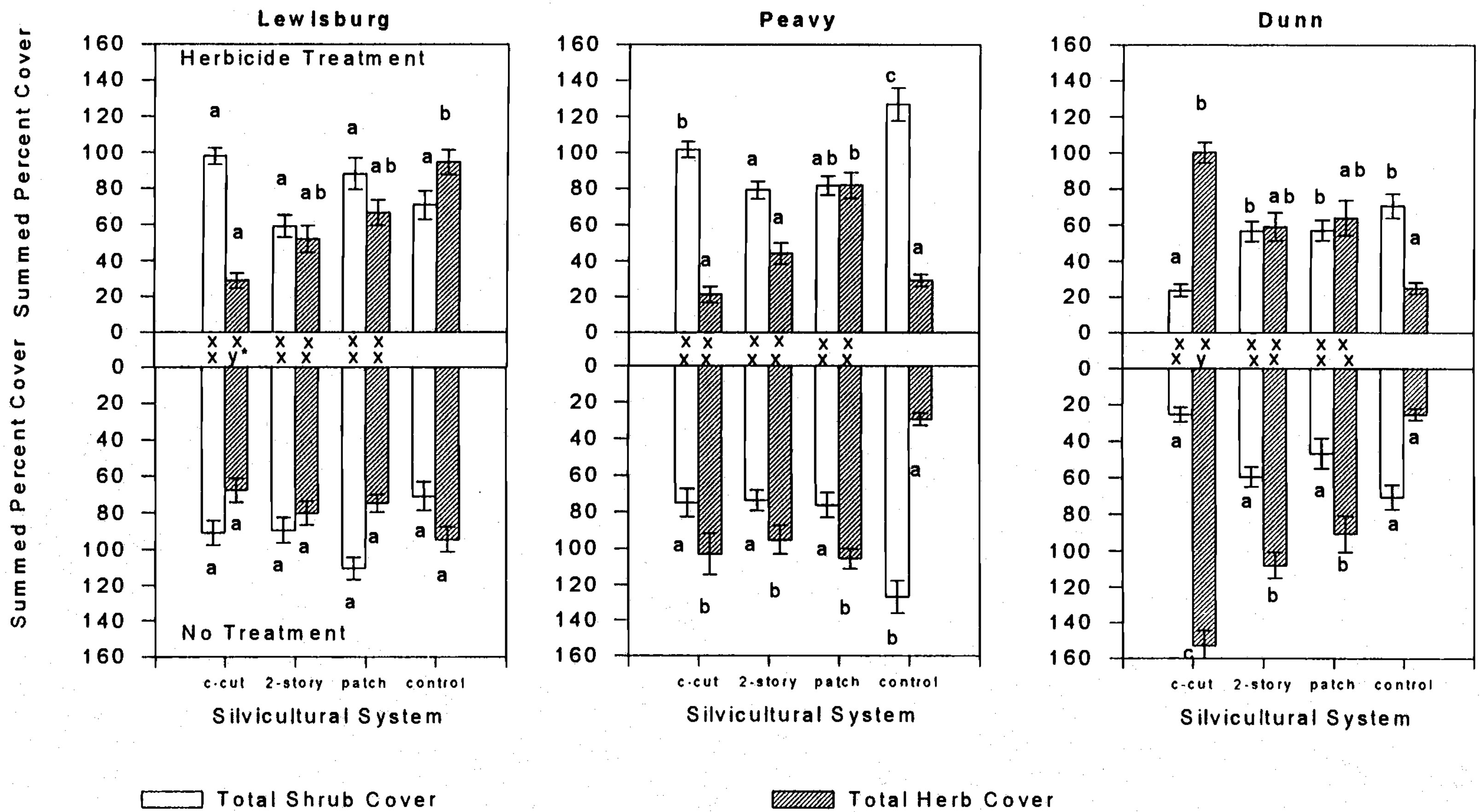
In the NT plots, shrub cover ranged from 25.4% to 110.4% on all sites and was significantly different from the CS's only in Peavy, and it was not significantly different among systems in any of the blocks (Table 3, Figure 6). In contrast in the HT plots, shrub cover was significantly less in the TS at Peavy (79.1%) than the CC (101.8%). The PC (81.6%) was not significantly different from either and all three were significantly less than the CS (126.7%). At Dunn, the TS (56.8%), PC (57.2%), and CS (70.5%) had significantly greater shrub cover than the CC (23.8%) and were not significantly different from each other. Finally, at Lewisburg shrub cover ranged from 59.1% in the TS to 97.9% in the CC with no significant differences occurring among any of the systems or with the CS. No significant block by treatment effects were found in shrub cover across blocks. Therefore, statistical analysis procedures can be used to test treatment differences in shrub cover among silvicultural systems for all blocks combined. Across all blocks for each silvicultural system, vegetation treatment did not have a detectable effect on shrub cover (Table 4, Figure 5).

Species Richness and Diversity

There was no clear pattern of species richness among the systems on the NT plots. For example at Lewisburg there were no significant differences among systems, while at Peavy and Dunn there were significantly more species in the CC and TS than in the CS (Table 5). On plots receiving the HT, species richness ranged from 15.6 on the CC site at Peavy to 31.0 in the TS at Lewisburg. Over all, there were significantly fewer species on the HT plots than on the NT plots. However, at Peavy richness in the TS and PC systems were both significantly greater than in the CS.

As for species richness, there was no clear trend in Shannon's diversity index among different systems. For example, the highest index at Dunn was 2.86 in the HT plots located in the TS, which was significantly higher than the CS (2.23), but not the CC (2.6) (Table 5). The PC's were not significantly different from the control. At Peavy the CS had significantly higher diversity than the other systems in both the HT and no NT plots, while at Lewisburg the diversity in the CS was significantly greater than PC, but not the TS.

Figure 6 Total shrub and herb cover. Cover values are means for the sum of the shrub and herb cover for each plot within each transect. For comparing system means within a block, bars with the same letter (a,b, or c) are not significantly different (p>0.05). For comparing treatment effect within blocks, the same letter (x or Y) are not significantly different (p<0.05). Error bars represent standard errors for comparisons among silvicultural systems.



*Significantly different (p<0.1)

Table 5 Species diversity (Shannon's Index) and species richness by silivicultural system and control stand for each experimental block as well as vegetation treatment. Data are means of three transects within each system within individual blocks. Unlike letters read down silvicultural treatments within an individual block denote statistically different means ($p<0.05$)

Silvicultural System	Experimental Block											
	Lewisburg				Peavy				Dunn			
	No treatment	SE n=3	Herbicide treatment	SE n=3	No treatment	SE n=3	Herbicide treatment	SE n=3	No treatment	SE n=3	Herbicide treatment	SE n=3
Shannon Diversity												
Clearcut	2.4ab	1.01	1.79a	0.29	1.77a	0.11	1.28a	0.20	2.61ab	0.13	2.6a	0.17
Two Story	2.76b	0.15	2.74b	0.13	1.96a	0.07	1.97b	0.04	2.86b	0.04	2.53a	0.17
Patch Cut	2.15a	0.25	2.06a	0.05	1.88a	0.15	1.88b	0.06	2.37a	0.03	2.01a	0.28
Control	2.78b	0.11	2.78b	0.11	2.92b	0.19	2.92c	0.19	2.22a	0.22	2.23a	2.22
Species Richness												
Clearcut	25.3ab·	7.8	20.67a	2.4	30.66b	3.8	15.66a	2.6	33.66c	1.2	30.33b	1.3
Two Story	34.33b	4.3	31.0b	2.5	31.33b	1.3	28.66c	1.8	41.0b	1.0	29.33b	3.7
Patch Cut	22.67a	2.8	19.0a	2.0	26.67ab	1.5	28.33c	0.7	24.33a	1.2	20.66a	3.2
Control	29.0ab	2.9	29.0b	2.9	22.33a	2.4	22.33b	2.4	21.66a	1.7	21.66a	1.7

Vegetation Survey Discussion

Silvicultural System Effect on Plant Community Cover

The data suggest that, in the absence of the herbicide treatment: **A.**) Vegetation on the study sites was less affected by silvicultural system than by site characteristics. **B.**) In an operational sense, if the herbicide treatment in this study is applied with the goals of reducing vegetation biomass on sites within McDonald Dunn Forest, it can be expected to be most effective on clearcuts, next on two-story stands, and least effective in patch cuts. This difference is not a direct result of the silvicultural system employed, but rather an operational constraint imposed by the different systems on how vegetation is treated.

A.) Many of the variations observed from block to block are influenced by site variables such as slope, aspect and soils. Site differences between blocks are especially evident when vegetation volume indices for the different silvicultural systems are compared in the Lewisburg and Peavy blocks in the NT plots (Figure 2). Volume index is lower across all systems in Lewisburg than Peavy. Several authors have shown that biomass tends to continually increase for the first four years following harvest (Malavasi 1978, Brown 1963, Yerkes 1958). Lewisburg was harvested three years prior to measurement, one year prior than Peavy, and would therefore be expected, with all environmental factors being equal, to have higher vegetation volume indices. The fact that Peavy has larger volume index values associated with it than Lewisburg, lends strong evidence to site differences being the most important factor in determining vegetation volume in NT plots.

The majority of study sites in the Peavy block are located on gentle southerly slopes, providing excellent conditions for vegetative growth. In contrast, Lewisburg sites are generally on steeper northerly slopes which tend to be cooler and receive less direct radiation. Although conditions such as in the Lewisburg block may be more favorable in harsh environments, sites in the MacDonald forest clime receive adequate moisture and generally are not considered to be harsh sites. It is possible that environmental differences such as slope, aspect, soil depth and fertility associated with the different blocks (Peavy and Lewisburg) accounts for much of the variation observed between the two blocks.

B.) The herbicide treatment strongly influences the system effects that are observed. These effects are best illustrated by vegetative volume index which represents a three dimensional estimate of plant cover. There is a clear trend in sites receiving the HT, in the Lewisburg and Peavy blocks, of vegetation volume index being lowest in the CC and highest in PC, while the TS in Lewisburg is intermediate and not significantly different from either (Figure 2). However, the TS is significantly less than the PC in Peavy and not different from the CC. These results suggest that HT is more effective in controlling vegetation in CC's than PC's and has an intermediate effect on vegetation in TS.

Comparing the observed difference between HT and NT plots for each silvicultural system furthers the above argument. Application of the HT in CC's in all blocks of the study, significantly reduced vegetation volume, while in PC's, the HT had no significant effect of vegetation volume. Furthermore, in the TS in Peavy and Dunn vegetation volume was significantly reduced by the HT treatment, however, in Lewisburg the HT had no significant effect.

The operational constraints imposed by the different systems are likely the cause for volume differences across systems. The herbicides were applied differently depending on the system. Clearcutting allows for the aerial application of herbicide. This form of application results in a continuous, even coverage of the chemicals used. In contrast, herbicide is applied by back pack sprayer in the PC's, which results in herbicide only being applied to the vegetation adjacent to planted seedlings. In TS's, herbicides were applied both aerially and by back pack sprayer. Thus, there is a gradient in coverage of herbicide with CC's receiving the greatest amount of coverage, TS's an intermediate coverage, and finally the PC's receiving the least. As would be expected, this gradient is inverse to the observed vegetation volume index gradient across the different systems.

The above conclusions have been made primarily using data from only the Lewisburg and Peavy blocks. Patterns seen in the Peavy and Lewisburg blocks in vegetation volume index, summed percent cover, and height are not always evident in Dunn. The likely reason that similar trends were not observed in the Dunn block is that it was harvested just prior to vegetation sampling. The amount of vegetative cover found on a site is influenced by the time since harvest. Additionally, at Dunn the survey was performed in mid spring, a short time into the growing season. While data were being collected, vegetation on sites in the Dunn block was undergoing the initial vegetative expansion associated with harvesting disturbance. For example, at the time of sampling most residual shrubs had just started to resprout and many herbaceous species were developing their first true leaves. The lack of any height measurements for the HT PC's in Dunn makes comparisons in vegetation volume among silvicultural systems across all three blocks impossible. The end result is that trends in vegetation volume index, summed percent cover and height seen in the Lewisburg and Peavy blocks are not as evident or impossible to determine in the Dunn block.

Silvicultural System Effect on Growth Habit and Life Cycle

The data suggest that on the study sites: **A.)** Total herb cover increases following harvest and annual herb cover more so than perennial herb cover. **B.)** In the absence of vegetation control, total herb cover, annual herb cover, and perennial herb cover are not affected by the type of silvicultural system (Figures 4 and 6). However, with the herbicide treatment, trends similar to those associated with the influence of silvicultural system on vegetation volume occur (Figure 3), which is a general increase in cover from CC to TS to PC (except at Dunn). **C.)** Shrub cover is not influenced by silvicultural system in NT plots although in HT plots a loose relationship resulting in less shrub cover in harvested sites is evident. Over all, vegetation treatment results in no significant reductions in shrub cover.

A.) Total herb cover is greater in the CC, TS and PC than CS following harvest in all but the Lewisburg block (Figure 4). The CS has equal or greater herb cover than any other system in Lewisburg. It is likely that this is a result of the CS not being representative of the block prior to harvest. Lewisburg CS plots have a large constituent of perennial grass cover, with the native grass, *Bromus vulgaris* and exotic *Brachypodium sylvaticum* making up a large portions of the total herb cover (Appendix B). Both grasses can be found ubiquitously the Lewisburg block, although generally not at the levels associated with the CS. The CS is located on or near the top of a east to west orientated ridge and has primarily a southern exposure. The topographic characteristics of the CS appear to largely favor the cover of the two grass species mentioned. In addition, several other grasses occur in these stands which also exhibit greater cover than is generally associated with mature forests in the Lewisburg block. In the CS's located in Peavy and Dunn, these grasses are either absent or constitute only a small part of the total cover. It is likely that the high cover value introduced by these grasses is a localized phenomenon and endemic to the stand used as a CS in the Lewisburg block. Thus, the total herb cover associated with the Lewisburg CS may not be representative of conditions in the cut areas prior to harvest.

The most striking effect that harvesting had on the understory plant community is the dramatic differences observed in annual herb cover between harvested sites and the CS's. Similar observations have been made by Dyrness (1973) who found that the cover for invading herb species was greater than for residual herbs for the first few years following harvest on clearcuts in the western Oregon Cascades. Schoonmaker and McKee (1988) found an initial decrease in residual herbs and an increase of invading herbs in the first few years following disturbance in the western Cascades of Oregon. The disturbance associated with logging provides an excellent habitat for weedy annual herb species to colonize. Harvest disturbance eliminates most canopy cover, reduces shrub cover and provides for abundant areas of freshly disturbed mineral soil. All of these factors strongly promote the establishment of annual and biennial weedy species.

Exotic weedy species such as *Senecio sylvaticus* and *Cirsium arvense*, as well as native plants such as *Crepis setosa* and *Epilobium paniculatum* all produce large numbers of highly mobile seeds and are therefore capable of taking quick advantage of the germination sites provided by logging. In addition, annual weedy seeds make up a large proportion of the seeds located in forest seedbanks (Kellman 1970, Olmsted and Curtis 1947).

Many plant species associated with mature forests such as *Smilacina stellata* and *Achlys triphylla* "maintain extensive rhizome systems with short and long shoots This growth form allows these species flexibility in exploiting the forest environment" (Antos and Zobel 1984). It follows that rhizomes allow these herbs to take advantage of increased light as a result of harvesting and thus they are effective competitors with weedy annuals for available growing space. However, overall mature forest perennials tended to have less cover in harvested sites than CS's (Appendix B). This suggests that these perennial species may be slow to respond to the new growing space and increased light provided by harvest disturbance.

The data suggest that following harvest, perennial herbs tend to dominate roughly the same amount of cover as in unharvested sites, while annuals occupy significantly greater cover percentages in harvested sites than unharvested. This possibly reflects the superior ability of annuals to invade freshly opened sites through wind disseminated and thus widely distributed propugules. Furthermore, large quantities of annual seeds located in seed banks could also be greatly responsible for the quick invasion of annuals versus perennials on harvested areas. It is likely that seeds from mature forest perennials are also located in the local seed banks, but through casual observations very few new germinants of these species were observed. Residual forest perennial species, must first overcome the shock that disturbance likely imposes on them in the form of broken stems and disrupted rhizome connections as well as greatly increased light levels before they can invade new areas. Invasive perennials such as *Hypericum perforatum*, *Hypochaeris radicata*, *Sanicula bipinnatifida* and several grass species are largely responsible for the increases observed in perennial herb cover (Appendix B).

B.) The three silvicultural systems used in this study do not appear to affect the cover by various plant growth habits or life forms in the absence of any vegetation control treatments. When the herbicide treatment is applied, a trend of increasing total herb cover, from CC's to TS' to PC's tends to occur. This trend is similar to that witnessed for vegetation volume and the reasons for it are likely the same. That is, differences occur due to the operational manner in which the three systems receive the herbicide treatment.

C.) When separate analyses for each individual silvicultural system are performed, no differences in shrub cover between the NT and HT plots in any of the systems are evident. These findings hold for analyses performed by individual blocks (Figure 5) as well as for all blocks combined (Figure 6), suggesting that shrub cover is not significantly affected by the HT.

Total shrub cover in NT plots does not differ significantly among silvicultural systems with the exception of significantly greater shrub cover in the CS at Peavy than the CC, TS or PC. This suggests that the three cutting regimes do not affect shrub cover in NT plots disparately. In addition, shrub cover levels may be less on harvested sites than un-harvested, although this is likely only a temporary phenomenon and likely related to pre-harvest cover and time since disturbance. For example, if there is a large amount of shrub cover prior to harvest it may take several seasons for it to grow back to pre-harvest levels (Yerkes 1958, Malavasi 1978, Schoonmaker and McKee 1988).

Shrub cover in both the Peavy and Dunn blocks in HT plots, is greater in the CS which received no HT than the CC. In addition, in Peavy the CC and CS have greater shrub cover than the TS and PC. However, no significant differences are evident among systems in Lewisburg HT plots. This suggests a loose relationship between shrub cover on HT plots and silvicultural system, with the CC system tending to have less shrub cover than CS's. Additionally, shrub cover may be more influenced by factors such as block differences and microsite variability than by silvicultural system and vegetation treatment interaction.

Species Richness and Diversity

The data suggest that in study sites: **A.)** Species diversity (Shannon's index) in CC's, TS's and PC's tended to be either the same or is less than the CS (Table 5). This trend is most evident in those plots which received the herbicide treatment. Conversely, species richness in CC's, TS's and PC's tended to be greater than CS's, most noticeable in those plots receiving no treatment. **B.)** Of the three silvicultural systems measured the TS tended to exhibit the greatest species diversity and richness.

A.) No other studies have examined species diversity and richness as a result of two story or patch cuts, although several studies have examined diversity trends in clearcut systems. Following clearcut harvesting, species richness typically increases for the first few years (Shaffi and Yarranton 1972, Long 1977, Schoonmaker and McKee 1988). In contrast to my study, Long (1977) and Schoonmaker and McKee (1988) both noticed significant increases in diversity following harvest. It should be noted that Long (1977) was using the Brillouin's diversity index and not the Shannon index, although the Brillouin index tends to give similar relative estimates for diversity as Shannon's (Magurran 1988). Shaffi and Yarranton (1972), noticed little change in diversity although their study was performed in a boreal forest system in Ontario Canada, while the other studies were in Douglas fir forests of the western Cascades of Washington and Oregon respectively.

The Shannon diversity index is a measure of both species richness and evenness (Magurran 1988). The likely reason that diversity goes down and richness goes up following harvest in sites in this study is the domination of harvested sites by only a few species. Early annual invaders such as *Crespis setosis, Cirsium vulgare* and *Galium trifidum* make up much of the cover observed following harvest (Appendix B). Thus, the sites are dominated by a few species even though more species are present on the sites than there were prior to harvest. This domination results in a decrease in evenness and a subsequent decline in Shannon diversity index. Richness increases because most species, although not all, that were present prior to harvest are present after harvest. In addition, invasive sun loving weedy species not found in uncut sites are generally found in newly harvested locals, thus increasing the richness of harvested sites.

B.) Another species diversity trend following harvest is for TS stands to exhibit greater diversity as well as richness than CC's and PC's, although not necessarily significantly. This pattern holds across all blocks and generally persists even if the site received the HT. An exception was in the Dunn HT plots in which the CC had the greatest diversity and richness. A combination of amelioration of harsh conditions by the residual TS overstory and high light penetration may be responsible for increased numbers of species in TS's. Another noticeable trend, was for diversity in HT plots to be less in CC's than in either TS's or in PC's with the exception of the Dunn block. This suggests that the HT is more effective in CC's than in the TS's or the PC's. As discussed previously, this is again probably a result of how the herbicide treatment was applied due to the operational constraints imposed by the different systems. However, similar relationships were not evident in the Dunn block indicating that other unknown causal agents may also be influencing diversity within the silvicultural systems.

Vegetation Treatment Effects

The data suggest that in sites in this study: **A.)** The effect of the herbicide treatment on vegetation volume is less in TS's than CC's and has little if any effect in PC's. **B.)** The herbicide treatment is more effective in reducing herb cover than shrub cover and is equally effective in reducing perennial and annual herbs.

A.) As mentioned previously, the system differences that were observed in the effectiveness of the HT may result from how the herbicides were applied. That is, CC's receiving aerial application, TS's a combination of aerial and back pack application and PC's receiving only back pack spraying results in different intensities and distributions of herbicidal agents and thus different degrees of effectiveness of these agents. This statement is best supported by the lack of similar trends for vegetation volume in the HT and NT plots (Figure 2). For example, in Peavy NT plots, significant differences among systems are not observed in vegetation volume. However, plots receiving the HT had significantly less vegetation volume than NT plots in the CC and TS but not the PC. Similarly, in Lewisburg the CC in the HT plots was significantly less than in the NT plots, while no difference was observed in PC. This all suggests that vegetation treatment is largely responsible for the similar vegetation volume trends observed in the HT plots among blocks.

B.) The herbicide treatment reduced the herb component of the plant community more so than the shrub component (Table 4). This suggests that the reduction in vegetative volume found on treated plots was more a result of decreases in herb than shrub cover. It is likely that the deep-rooted, well established shrubs were able to tolerate low levels of herbicides better than were herbs, of which many are newly established annuals.

Conifer Seedling Regeneration Results

Artificial Regeneration

Douglas-fir

There were significant block differences in percent mortality, stem volume and height-diameter ratios, but no significant block*system, block*treatment or system*treatment interactions. Thus, block and system effects on mortality, stem volume and height-diameter ratio do not affect treatment trends.

Seedling Mortality

Average mortality was significantly less in CC's (7.3%) than in TS (19.7%) and PC's (14.7%) (Table 6, Figure 7). When data from all systems were combined, there was significantly less mortality in the intensive (IT) (14.9%) and manual treatment (MT) (12.8%) than the herbicide (HT) (23.0%) and no treatment (NT) (19.0%) (Tables 7 and 8 and Figure 7).

There were not consistent trends in mortality by vegetation treatment are not evident among the three silvicultural systems. In TS and PC the NT had significantly greater mortality than all other treatments, while in the CC NT mortality did not vary significantly from the others. IT, MT and HT were not significantly different from one another in all systems except the CC, where HT was significantly greater than MT but not IT (Figure 7).

Table 6 Douglas-fir and Grand fir stem volume, height diameter ratio, percent mortality and percent browse grouped by silvicultural system across all blocks. Means presented are adjusted for missing values. For comparing among different systems in the same row of the table, values followed by the same letter (x, y or z) are not significantly different (p<0.05).

	Clearcut	SE n=9	Two story	SE n=9	Patch cut	SE n=9
Stem Volume (cm^3)						
DF	87.4xy*	10.1	94.6y	11.0	73.7x*	8.6
GF	64.1x	7.4	75.2x	7.1	64.7x	6.8
Height / Diameter Ratio						
DF	54.1x	1.0	58.0y	1.2	61.6z	1.2
GF	55.6x	1.15	57.4x	1.0	60.8y	1.0
Percent Mortality						
DF	7.3x	3.5	19.7y	5.1	14.7xy	4.5
GF	18.8xy	3.5	11.6x	2.9	22.2y	3.9
Percent Browse						
DF	31.6y	2.8	25.2x*	2.6	28.9xy*	2.8
GF	1.2x	0.1	2.0x	0.1	3.0x	0.1

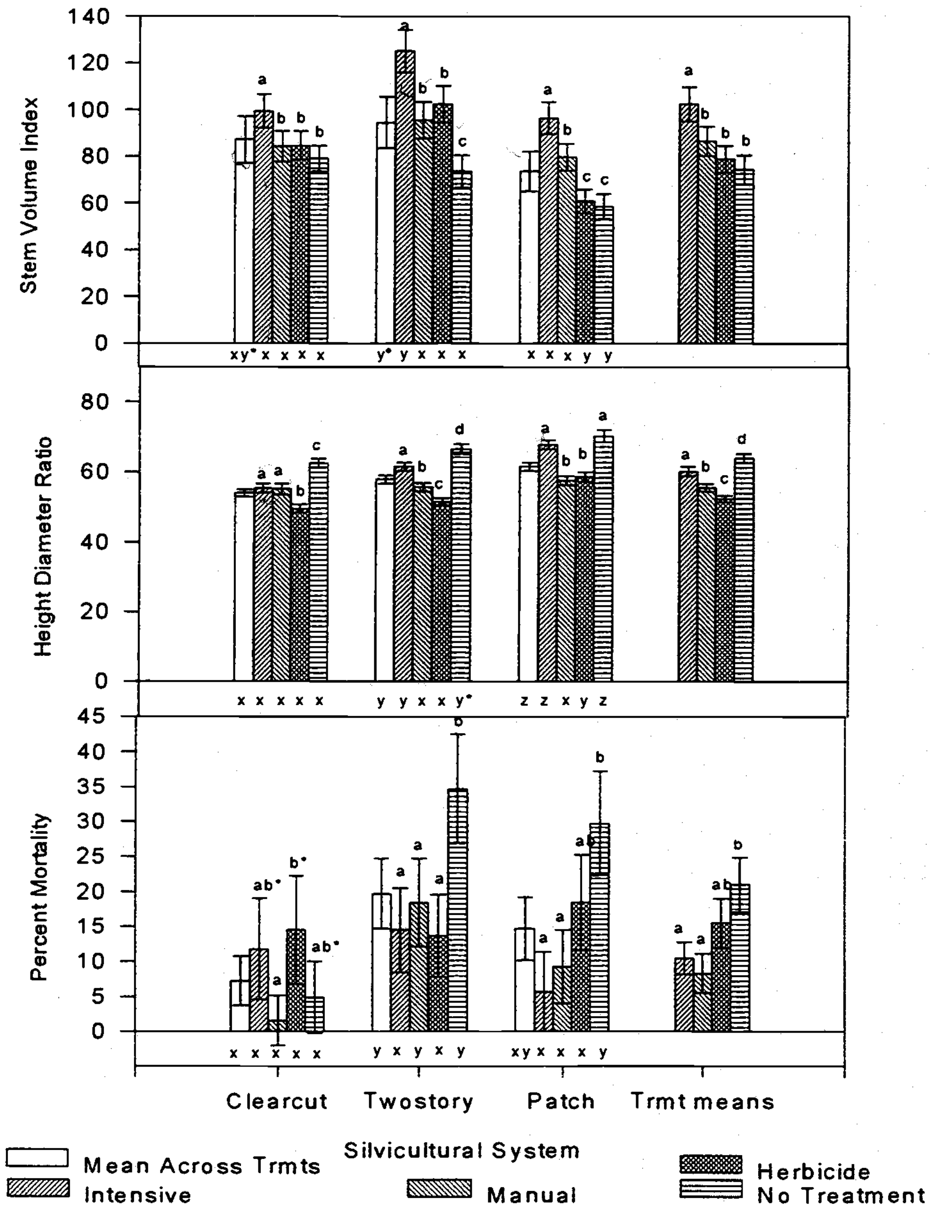
*Significantly different (p<0.1)

Seedling Stem Volume

Stem volume in IT plots was significantly greater than all other treatments in all systems (Table 8). The NT plots had significantly less stem volume than all other treatments in the TS system and less stem volume than the IT and MT in the PC system (Table 8, Figure 7). In the CC system, there were no significant differences in NT, MT and HT. Finally, significant differences among the MT and HT were observed in only the PC (79.8 cm^3 and 60.9 cm^3).

There were no significant differences in mean stem volume among systems, ranging from a high of 94.6 cm^3 in TS's to a low of 73.7 cm^3 in PC's (Table 7, Figure 7).

Figure 7 Douglas-fir stem volume index, height diameter ratio and percent mortality among systems and among treatments. For comparing treatments within individual systems, bars with the same letter (a,b,c and d) are not significantly different ($p < 0.05$). For comparing treatment effect among different systems, bars with the same letter at the base (x,y and z) are not significantly different ($p<0.05$). Error bars represent standard errors for comparisons among vegetation treatments within individual silvicultural systems.



* Significantly different ($p<0.1$)

Table 7 Ranking of the effects of the vegetation treatments within each silvicultural system. Ranking of 1 indicates highest stem volume or lowest height-diameter ratio, 4 the lowest stem volume and highest height-diameter ratio. Only significantly different ($p<0.05$) values are ranked separately. Two values (i.e. 1,2) within the same block of the table indicate no significant differences.

	Douglas-fir				Grand fir			
	Intensive treatment	Manual treatment	Herbicide treatment	No-treatment	Intensive treatment	Manual treatment	Herbicide treatment	No-treatment
	Stem Volume Index							
Clearcut	1	2,3,4	2,3,4	2,3,4	2,3	1	2,3	4
Two-story	1	2,3	2,3	4	1,2,3	1,2,3	1,2,3	4
Patchcut	1	2	3,4	3,4	2,3	1,2	1,2,3	4
	Height diameter ratio							
Clearcut	2,3	2,3	1	4	1,2,3	1,2,3	1,2,3	4
Two-story	3	2	1	4	3	1,2	1,2	4
Patchcut	3,4	1,2	1,2	3,4	3	1,2	1,2	4

However, when all systems are combined total stem volume is significantly greater than all other treatments in the IT (102.5 cm^3), while MT, HT and NT are not significantly different (86.5 cm^3, 79.0 cm^3 74.4 cm^3 respectively).

When the data are analyzed independently by treatment among the three silvicultural systems, seedlings in the HT (61.0 cm^3, y[2]) and NT (58.6 cm^3 , y) plots in PC's have significantly less stem volume than in CC's (84.8 cm^3, x and 79.1 cm^3, x) and TS's (102.5 cm^3, x and 73.7 cm^3, x^*) (Figure 7). Additionally, mean stem volume in the TS intensive plots was 125.2 cm^3, significantly greater than either the CC (99.5 cm^3) or PC (58.6 cm^3) plots.

Seedling Height Diameter Ratio

Height-diameter ratio can be thought of as an indirect measure of stress. Seedlings with high height-diameter ratios are allocating greater resources to height growth than to diameter growth, which is a common response to crowding or overtopping (Hughes et al. 1990, Cole and Newton 1986).

For all treatments combined, mean height-diameter ratio varied significantly among silvicultural systems, lowest in CC's (54.1), next in TS (58.0) and greatest in PC (61.6) (Table 6, Figure 7). When all systems are combined, total mean height-diameter ratio varied significantly among all vegetation treatments, with a value of 64.1 in the NT plots being the greatest, decreasing to 60.3 in IT and 55.7 in MT with the lowest value in the HT of 52.5 (Table 8, Figure 7). The IT height-diameter ratio was expected to be smaller than all others, because it had the greatest amount of vegetation control and the

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[2]Refer to Figure 6. For comparing treatment affect among different systems, bars with the same letter at the base (x, y and z) are not significantly different ($p<0.05$).

Table 8 Douglas-fir and Grand fir stem volume, height diameter ratio, percent mortality and percent browse grouped by vegetation control treatment. Values presented are means across all silvicultural systems and blocks and adjusted for missing values. For comparing among different systems in the same row of the table, values followed by the same letter (a, b, or c) are not significantly different ($p<0.05$).

	Intensive	SE n=27	Manual	SE n=27	Herbicide	SE n=27	No treatment	SE n=27
	Stem Volume							
DF	102.5b	7.4	86.5a	6.3	79.0a	5.8	74.4a	6.2
GF	71.5b	5.2	86.5b	8.1	75.2b	5.4	45.6a	3.8
	Height / Diameter Ratio							
DF	60.3c	1.3	55.7b	1.1	52.5a	1	64.1d	1.3
GF	57.0a	1.3	54.4a	1.5	54.7a	1.3	65.6b	1.4
	Percent Mortality							
DF	10.5a	2.3	8.3a	2.8	15.5ab	3.5	21.0b	3.9
GF	14.9ab	3.4	12.8a	3.24	19.0ab	3.7	23.0b	3.4
	Percent Browse							
DF	5.2a	2.2	33.0b	5	47.5c	4	36.2b	4.2
GF	0.6a	1.6	3.2b	1.2	3.3b	1.2	1.7ab	0.8

seedlings from browse. The tubing is secured with two stakes, thus supporting the seedling and probably reducing the need for diameter growth; the reduced diameter growth results in greater height-diameter ratios.

Height-diameter ratios in IT and NT varied significantly among systems, both were lowest in the CC (55.5, x[3] and 62.6, x respectively) intermediate in the TS (61.6, y and 66.1, y*) and greatest in the PC (67.9, z and 70.4, z) (Table 7, Figure 7). The HT (58.7, y) is significantly greater in the PC than in both the TS (51.5, x) and CC (49.6, x), while in the MT it was not significantly different among any of the silvicultural systems.

Height-diameter ratio varied from a low of 49.6 in the HT in the CC to a high of 70.4 in the NT in the PC. The NT is significantly larger than all other treatments in all systems with the exception of the PC where IT and NT are similar (Table 7). Likewise, this ratio is significantly smaller in the HT in all systems except the PC, where it is not significantly different from the MT. Finally, in all systems except the CC both HT and MT are different from the IT.

Grand fir:

There were significant block differences in percent mortality, stem volume and height-diameter ratios, but no significant block*system, block*treatment or system*treatment interactions. Thus, block and system effects on mortality, stem volume and height-diameter ratio do not affect treatment trends.

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[3]Refer to Figure 6. For comparing treatment affect among different systems, bars with the same letter at the base (x, y and z) are not significantly different ($p<0.05$).

Mortality

Mortality was significantly greater in the PC (22.2%) than in the TS (11.6%), while the CC (18.8%) did not differ significantly from either system. For all systems combined mortality in MT was lowest and significantly less than NT; it was not significantly different from the IT or HT (Figure 8).

Percent mortality ranged from a low of 9.3% in the MT in the TS to a high in PC of 31.9% in the NT. There were no significant differences in mortality as a result of different treatments when data for the three systems are combined (Table 8, Figure 8). However, when analyzed by system, percent mortality was significantly greater in the NT than IT in all systems except the TS. Furthermore, there were no significant differences between HT and MT in any of the systems with both being intermediate and not significantly different from either IT or NT.

Stem Volume

Stem volume ranged from 64.1 cm^3 in CC's to 75.2 cm^3 in TS's and did not vary significantly among any of the silvicultural systems (Table 6, Figure 8). However, significant differences were observed among vegetation treatments with volume ranging from a high in MT of 86.5 cm^3 to a low in NT of 45.6 cm^3. There were no significant differences among IT, MT and HT, but volumes in all were significantly greater than in the NT when analyzed across all systems (Table 8).

When the data are analyzed by treatment among the three silvicultural systems, stem volume in MT and NT does not differ significantly from volume in the IT and HT. However, IT is significantly greater in TS (84.8 cm^3, x[4]) than in either CC (65.4 cm^3, y)

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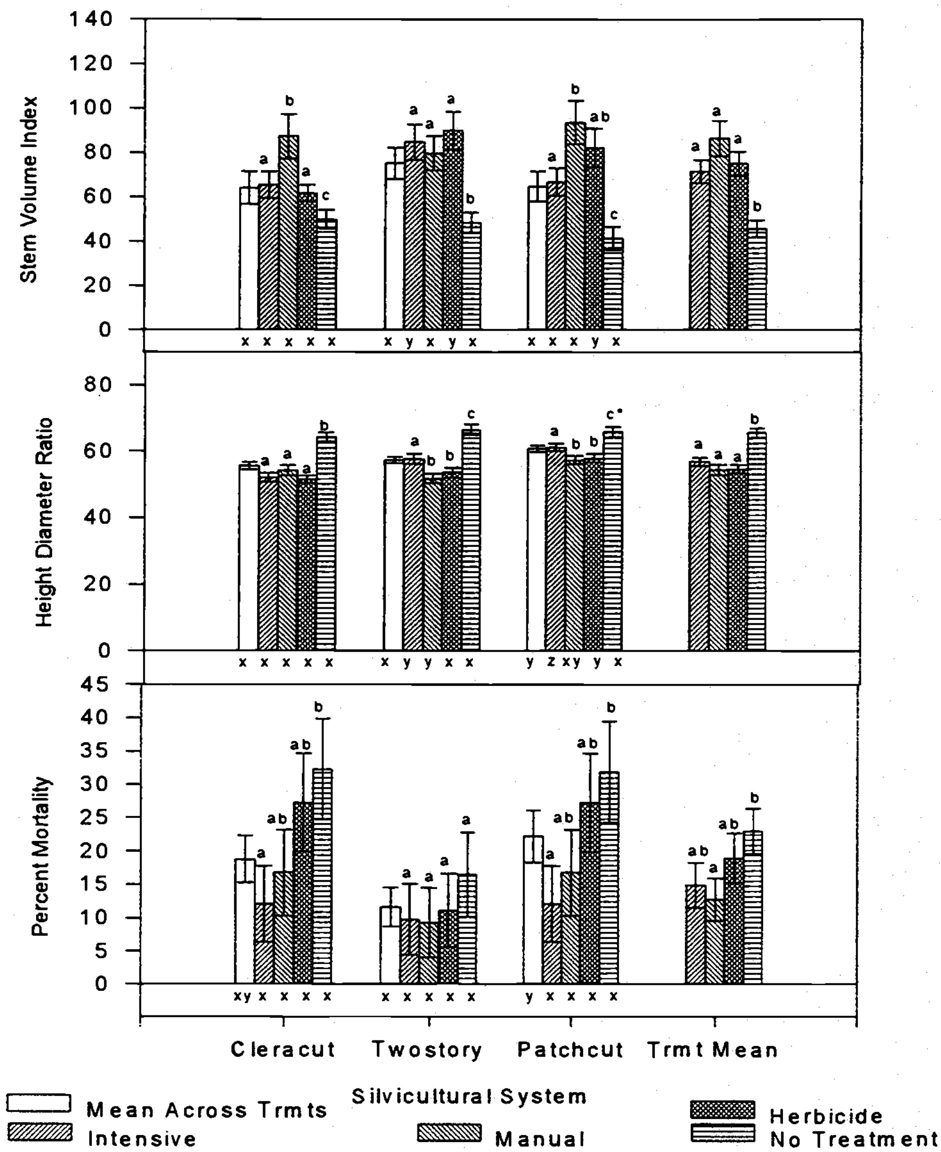
[4]Refer to Figure 7. For comparing treatment affect among different systems, bars with the same letter at the base (x, y and z) are not significantly different ($p<0.05$)

Figure 8 Grand fir stem volume index, height diameter ratio and percent mortality among systems and among treatments. For comparing treatments within individual systems, bars with the same letter (a,b,c and d) are not significantly different ($p < 0.05$). For comparing treatment effect among different systems, bars with the same letter at the base (x,y and z) are not significantly different ($p<0.05$). Error bars represent standard errors for comparisons among vegetation treatments within individual silvicultural systmes.



* Significantly different ($p<0.1$)

or PC (66.7 cm^3, y), while HT is significantly greater in TS (90.0 cm^3, y) and PC (82.3 cm^3, y) than in CC (61.6 cm^3, x*) (Table 7, Figure 8).

In all systems stem volume in NT is significantly less than in the rest of the treatments, and volume in IT and HT are not significantly different from each other (Table
7). Stem volume in MT is significantly greater than IT in all but the TS system and significantly greater than HT only in the CC.

Height-Diameter Ratio

Mean height-diameter ratios for all vegetation treatments combined were significantly greater in PC's (60.8), than in CC (55.5) and TS (57.4) (Table 6, Figure 8). Total mean height diameter ratio across all systems was greater in the NT (65.2) than in IT (56.9), MT (54.4) or HT (54.7), which were not significantly different from each other.

Height-diameter ratio varied significantly for IT plots among the silvicultural systems, with CC being lowest at 52.1 (x), TS intermediate at 57.7 (y) and PC greatest at 61.2 (z) (Table 7, Figure 8). No differences in height-diameter ratio were observed in NT among the systems, while HT was significantly greater in PC (58.1) than in either CC (51.6) or TS (53.6). Additionally, MT in the TS (51.8) had a significantly smaller height-diameter ratio than in the CC (54.3), although neither was different from the PC (57.4).

Height-diameter ratio in the NT was significantly greater than in other treatments in all systems, although only significant different at $p<0.1$ from the others in the PC (Table 7, Figure 8). The HT and MT treatments were not significantly different from each other in any of the systems. Ratios in IT were significantly greater than HT and MT in the TS and PC but not in the CC.

Browse

Percent browse did not vary significantly among silvicultural systems for either Douglas fir or grand fir (Table 6, Figure 9). Additionally, percent browse was significantly less in the IT from all other treatments because of the vexar tubing. There was a marked differences in the amount of browse on Douglas-fir (ranging from 25.2% in TS to 31.6% in CC) and grand fir (ranging from 1% in CC to 3% in PC), indicating a strong preference for Douglas fir versus grand fir by deer.

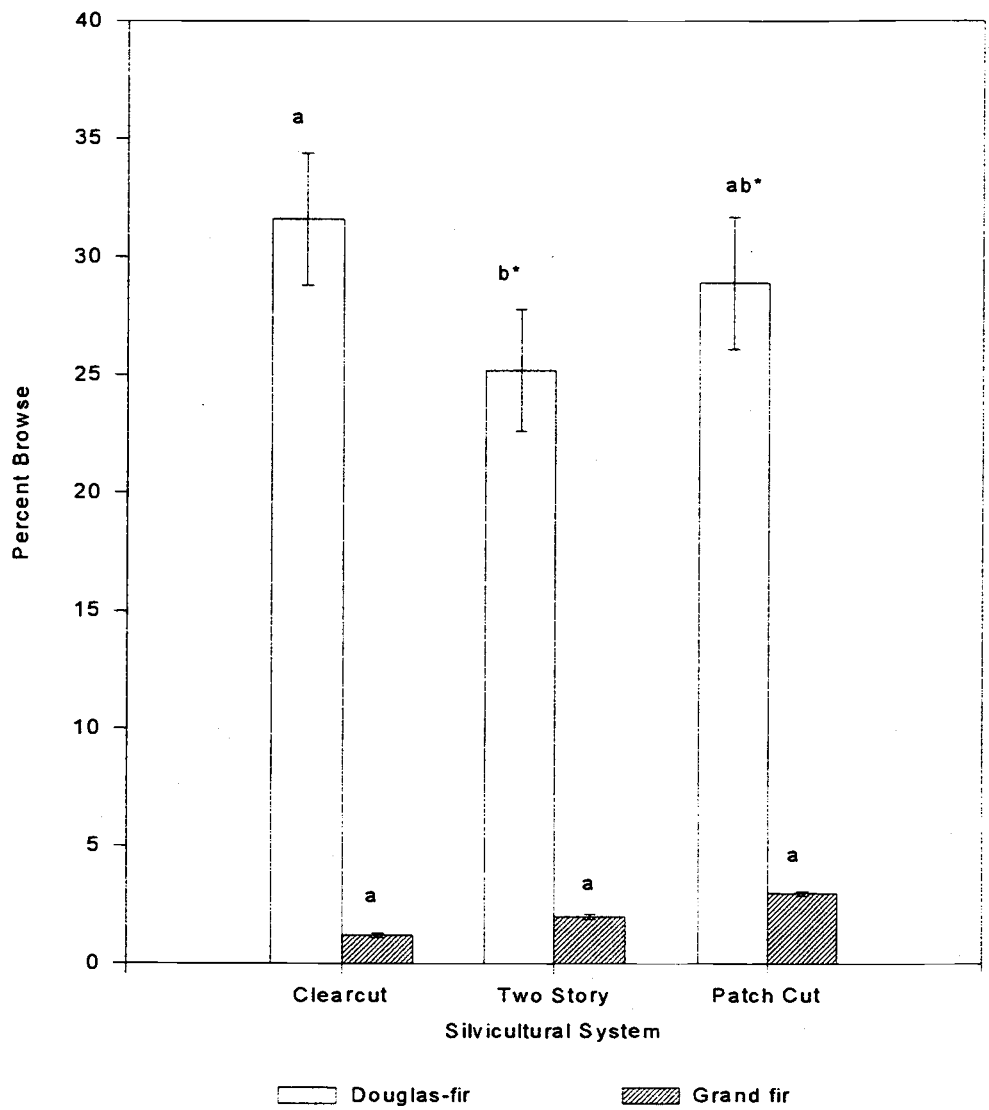
Important Seedling Growth Predictors

Thus far, the analysis has focused on silvicultural and vegetation treatment differences. The following section was an attempt to determine which biotic factors were the most important in determining the success of an individual seedling. Applying different silvicultural prescriptions ultimately results in manipulating the biotic factors which determine the success of any one seedling. Thus, by understanding how biotic factors affect seedlings and how silvicultural prescriptions affect biotic factors we can understand the mechanisms in which silvicultural prescriptions are going to affect seedling success.

Initial seedling stem volume and seedling age for both Douglas-fir and grand fir were significantly and positively correlated with final stem volume. Pearson correlation coefficients between stem volume and initial stem volume and seedling age for Douglas-fir

respectively were 0.52 and 0.49 and for grand fir were 0.45 and 0.41 (Table 9). Conversely, herbaceous cover (Douglas-fir r = -0.14), shrub cover (Douglas-fir r = -0.1, grand fir r =- 0.12), percent ground cover (grand fir r = -0.18), and percent overtopping (Douglas-fir r=-0.22, grand fir r = -0.3) were all significantly but negatively correlated

Figure 9 Douglas-fir and grand fir percent browse. For comparing among different systems, bars with the same letter (a and b) are not significantly different (P<0.05). Error bars are standard errors.



* Significantly different (p<0.1)

Table 9 Adjusted R^2 and p-values for the final model determined by stepwise regression. In addition Pearson correlation coefficients are given with their associated p-values. In both cases natural log of seedling stem volume was the dependent variable.

	Adjusted R2	P> F	Correlation R	P>|R|
	Douglas-fir Ln Stem Volume (n=1235)			
Initial volume	0.275	0.0001	0.523	0.0001
Seedling Age	0.088	0.0001	0.49	0.0001
Overtopping cover	0.022	0.0001	-0.22	0.0001
Percent browse	0.004	0.0053	0.005	0.852
Percent herbaceous cover	0.003	0.0098	-0.14	0.0001
Percent Shrub cover	0.002	0.0405	-0.1	0.0001
Total R2	0.39			
	Grand fir Ln Stem Volume (n=721)			
Initial Volume	0.201	0.0001	0.45	0.0001
Overtopping cover	0.0733	0.0001	-0.31	0.0001
Seedling age	0.0621	0.0001	0.41	0.0001
Percent browse	0.0097	0.0011	-0.15	0.667
Percent ground cover	0.0033	0.058	-0.18	0.0001
Shrub cover	0.0023	0.108	-0.123	0.0001
Total R2	0.35			

with seedling stem volume. Browse, slope, aspect and Cos(Slope*Aspect) were not significantly correlated with stem volume.

Stepwise regression of those factors that were significantly correlated with stem volume yielded a model containing the following parameters: initial volume, seedling age, percent overtopping vegetation, percent browse, herbaceous cover (only for Douglas-fir), shrub cover and percent ground cover (only for grand fir). For both species, initial stem volume accounted for the greatest amount of the variability (Douglas-fir 28%, grand fir 20.1%) with overtopping cover accounting for 2.2% in Douglas-fir and 7.3% in grand fir, while seedling age accounted for 8.8% in Douglas-fir and 6.2% in grand fir. Over all, the regression model accounted for 39% of the variability in Douglas-fir seedling stem volume and 35% in grand fir.

Natural Regeneration

Seed Fall

Douglas-fir seed fall differed significantly among silvicultural systems. The CC (76,000 seeds per hectare) had significantly less seed fall than the TS (187,00 seeds per hectare) and PC (250,000 seeds per hectare) which were not significantly different (Table 10). Douglas-fir seed fall differed significantly by block. Across all silvicultural systems the Lewisburg block had 290,000 seeds per hectare and the Peavy block 56,000 seeds per hectare.

Seeds from three tree species were found in traps: Douglas-fir, grand fir and big leaf maple. No significant differences were observed in the amount of grand fir or maple seed trapped among silvicultural systems. However, grand fir seed trapped across all silvicultural systems in Lewisburg (44,000 seeds per hectare), differed significantly from grand fir seed trapped in Peavy (10,000 seeds per hectare). No significant differences between blocks in trapped big leaf maple seed were observed, at Lewisburg and Peavy (600 and 4,400 trapped seeds/ha respectively). Variability observed in grand fir and big leaf maple seed fall is probably due to spotty distribution of seed trees.

Table 10 Seed-fall for Douglas-fir, grand fir and big leaf maple. Seed fall per hectare is extrapolated from means of the number of seeds that were collected per m^2 via seed traps. Values followed by different letters (a or b) within a row are significantly different ($p<0.05$).

	Clearcut	Two Story	Patch Cut
	Seed-Fall per Hectare (thousands)	Seed-Fall per Hectare (thousands)	Seed-Fall per Hectare (thousands)
	Lewisburg		
Douglas-fir	123	309	504
Grand fir	32	50	51
Big leaf Maple	2.5	0	2.2
	Peavy		
Douglas-fir	28	65	69
Grand fir	8	19	4
Big leaf Maple	2	2	13
	Blocks Combined		
Douglas-fir	76a (se=26, n=6)	187b (se=39, n=6)	287b (se=53, n=6)
Grand fir	18a (se=7, n=6)	33a (se=9, n=6)	23a (se=9, n=6)
Big leaf Maple	2a (se=3, n=6)	0.5a (se=2, n=6)	4a (se=4, n=6)

Natural Seedling Survey

Like seed fall the number of natural seedlings within each sampling unit varied significantly among silvicultural systems; however most natural seedlings occurred in TS. The TS had on average 1045 natural seedlings per hectare, significantly greater than either

the CC (227 seedlings/ha) or PC (227 seedlings/ha), which were not significantly different (Table 11).

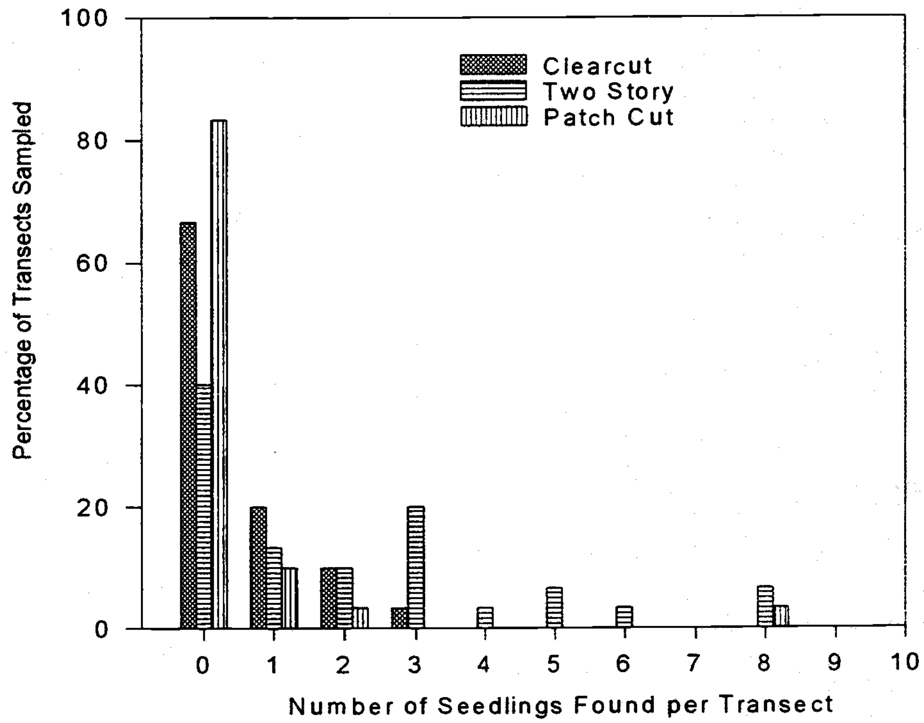
Stocking varied greatly among blocks. For example, the TS was 90% stocked in Lewisburg, 60% in Peavy and 40% in Dunn. Similarly, the CC was 80% stocked in

Lewisburg and10% in Peavy and Dunn, while, the PC was only 40% stocked in Lewisburg, 10% in Peavy and no natural regeneration was found in the Dunn PC's. Across all blocks, Douglas fir stocking was low, with the lowest stocking occurring in the PC (16%) next in the CC (33%) and highest in the TS (60%) (Table 11, Figure 10).

Table 11 Douglas-fir stocking and seedling density. Stocking percentage was calculated as the percent of 0.0022 hectare plots in which natural regeneration was found. Seedling density per hectare was extrapolated from the average number of seedlings found within the same 0.0022 hectare plots.

	Clearcut		Two Story		Patch Cut	
	Stocking percentage (n=10)	Seedlings/ hectare (n=10)	Stocking percentage (n=10)	Seedlings/ hectare (n=10)	Stocking percentage (n=10)	Seedlings/ hectare (n=10)
Lewisburg	80%	590	90%	1545	40%	545
Peavy	10%	45	60%	1136	10%	45
Dunn	10%	45	40%	227	0%	0
All blocks Combined	33% (n=30)	227 (n=30)	60% (n=30)	1045 (n=30)	16% (n=30)	227 (n=30)

Figure 10 Douglas-fir stocking percentage per 0.00022 ha plots. The number of times different numbers of seedlings were observed within a plot are indicated by the vertical bars. Bars with different fills represent different silvicultural systems.



Conifer Seedling Regeneration Discussion

Silvicultural System Effect

The data suggest for sites in this study, that on the basis of height diameter ratio, clearcuts provide the best environment for seedlings to grow, followed next by TS and last PC. Additionally, future growth in PC's will tend to be reduced and generally more spindly than in TS's or CC's.

Cole and Newton (1986) found that in five year old plantations, increases in the height diameter ratio were associated with encroaching vegetation, overtopping and possibly tree vigor. These authors suggested that the height diameter ratio represents the manner in which resources are allocated within the seedling. That is, for high ratios more resources are being allocated to height growth than diameter growth. Height diameter ratios above

70 were associated with decreases in height growth, while maximum height growth occurred at ratios of 65 to 70 and finally, ratios above 100 were associated with impending mortality.

Height-diameter ratios for Douglas-fir ranged from 54.1 in CC's to 61.6 in PC's and were significantly different in each silvicultural system. Height- diameter ratio increased similarly for grand fir. Ratios for both species closely follow the amount of canopy overtopping associated with each of the different systems (Appendix C). In addition, these ratios follow the increasing vegetation volume trend from CC's to PC's observed in HT plots in Study 1. A combination of overstory trees and competitive vegetation are likely responsible for the differences in height diameter ratio observed. For example, CC's have the least residual overstory and tend with the HT to have the least amount of competing vegetation, thus lower height diameter ratios. Likewise, PC's have the greatest amount of residual canopy and with the HT have the greatest amount of competing vegetation, while TS's are intermediate. The integration of residual canopy and understory vegetation results in a gradient of increasing competition for seedlings and thus increasing height-diameter ratios. However, it should be noted that in all silvicultural systems to date, the height diameter ratio was far less than the value proposed by Cole and Newton (1986) of 70 to 100 as a number indicating probable decreased height growth or poor vigor. Thus, even though greater competitive stress is being faced by seedlings in the PC's than the CC's the danger of initial regeneration failure is low.

Growing conditions have been adequate thus far and stem volume has not differed among silvicultural systems. However, as seedlings become larger their demands for light and water increase. Relatively higher height-diameter ratios in PC's and NT plots suggest that the seedlings acheived their stem volume with somewhat more height growth in relation to diameter growth. Presently the height-diameter ratios within PC's and NT plots are still within an acceptable range. Results of other work (Huges 1990) suggests that continued competition may result in higher height-diameter ratios and consequently spindly trees. However, if the seedlings can achieve sufficient height growth to overtop the surrounding vegetation then normal growth and height-diameter ratios will return.

The difference between my study and others, is that there are two levels of competition taking place in PC's. The first level is the shrub and herbaceous competition and the second is the surrounding large trees. The seedlings in PC's will likely overtop the shrub and hebaceous plants, but cannot overtop the surrounding trees. It is probable, due to overtopping from surrounding trees in PC's, that the seedlings will begin to grow at a reduced rate and in a spindly manner relative to trees in CC's or TS's. The same argument can be applied to the overstory in the TS's. However, 10 to 12 overstory trees per acre is probably not enough to significantly impact seedling growth in TS's.

Whereas height-diameter ratio can be viewed as a measure of seedling stress or seedling potential, stem volume is a measure of past seedling success. That is, if a seedling has a relatively large stem volume it has grown in a satisfatory operational environment with minimal impacts from browsing, adequate light, water etc.. When stem volume is compared across the three silvicultural systems no significant trends are evident for either Douglas-fir or grand fir.

Height-diameter ratio differs significantly among silvicultural systems. If height diameter ratio is a measure of seedling potential, it is reasonable to assume that differences in height diameter ratio would be expressed by stem volume. I suspect that the differences in height-diameter ratio that were observed, although measurable and statistically different, are not biologically significant to the extent to be expressed by seedling stem volume. That is, seedling stem volume is determined by a number of highly variable environmental and genetic factors and the variability imposed by these factors results in small differences in height-diameter ratio not being expressed by stem volume.

Treatment effect

The data suggest for sites in this study, that vegetation control treatments resulted in conditions which promoted Douglas-fir and grand fir seedling success. However, Douglas-fir and grand fir greatly differed in their response to the vegetation treatments, with grand fir requiring much less intense vegetation control to achieve maximum growth than Douglas-fir. Additionally, Douglas-fir was much more preferred as browse by deer than grand fir.

Douglas-fir stem volume was greater only in sites receiving the IT than the NT, while for grand fir all treatments resulted in greater stem volume than NT. Vegetation control results in increased water availability and consequently greater stem volume

(Newton and Preest 1988). Seedlings which are overtopped by neighboring vegetation are generally smaller and grow slower than seedlings not overtopped (Howard and Newton 1984, Chan and Walstad 1987). The removal of overtopping vegetation and greater water availability is probably responsible for the increases observed in stem volume among the different vegetation treatments. The lack of significant increases in Douglas-fir stem volume in the HT and MT are likely due to less tolerance of Douglas-fir to competing vegetation than grand fir.

Douglas-fir and grand fir differ in their response to the different vegetation treatments, suggesting that the two species have different minimum competition response thresholds. The minimum competition response threshold is defined as the "level of vegetation abundance that must be reached before additional control measures will yield an appreciable increase in tree performance" (Wagner et al. 1989).

Grand fir stem volume is greater in all vegetation control treatments than in the NT, while Douglas-fir has greater stem volume than the NT only in the IT. A gradient of increasing vegetation control exists from the HT to the MT to the IT, a subsequent increase in grand fir and Douglas-fir stem volume should also be evident along this gradient. However, grand fir stem volume is not different in any of the vegetation control treatments and Douglas-fir stem volume differs from all other treatments only in the IT. This suggests that with the application of the HT the minimum competitive threshold is reached for grand fir, while this threshold is not reached until the IT is applied for Douglas-fir. From a management perspective, less rigorous vegetation treatments may be needed to insure adequate grand fir regeneration relative to Douglas-fir.

Grand fir is a shade tolerant species while Douglas-fir is considered intermediate (Burns and Honkala 1990). Therefore, grand fir would be expected to exhibit less of a response to the increased shading associated with the PC than Douglas-fir. Additionally, because of the lower minimum competitive response threshold exhibited by grand fir versus Douglas-fir the HT may be effective enough in promoting better growing conditions for grand fir even though Douglas-fir can not realize these benefits.

Many studies have examined the competitive effect of secondary successional species on the growth of planted seedlings following clearcutting (Chan and Walstad 1987, Cole and Newton 1986, Howard and Newton 1984, Huges et al. 1990, Newton and Preest 1988, Tesch and Hobbs 1989 and Wagner and Radosevich 1991). A general conclusion from these studies is that increased competition results in decreased seedling growth. My results closely follow these previous studies. Vegetation control resulted in increased seedling stem volume, decreased height diameter ratios and reduced mortality.

The IT and MT treatment result in the removal of all vegetation from a one meter radius around each seedling. Both treatments appear to be effective means of increasing seedling survival percentages. These findings are similar to those of Tung et. al. (1986) and Harrington and Radosevich (1986). Tung observed an increase in Douglas-fir seedling survivorship from 14% to 80% with the application of paper mulch around seedlings in an Oregon Coastal plantation. Similarly, Harrington and Radosevich found significantly greater survival in sites receiving complete removal of vegetation via repeated herbicide applications than for less rigorous single herbicide treatments. Similar to my study, both of these studies were performed in locations in which drought was not considered to be a limiting factor but rather competition for available growing space the most important factor in determining regeneration success.

System and Treatment Response

No significant system*treatment interactions were indicated by the ANCOVA statistical procedure. However, from a management perspective there is one combination of system and treatment which results in significantly smaller stem volumes.

Douglas-fir in PC's receiving the HT have significantly less stem volume than in CC's and TS's receiving the HT. Less stem volume in the HT is probably the result of a combination of reduced light levels in PC's along with the HT being less effective in reducing vegetation volume in PC's (Figure 2). In addition, the height diameter ratio in PC HT was significantly higher than the HT in the TS and CC, possibly indicating reduced vigor of Douglas-fir seedlings in the PC. The end result is that relatively poor growth of Douglas-fir seedlings can be expected in PC's unless intensive vegetation control measures are employed. Grand fir does not exhibit this same response, and no difference in stem volume between PC HT and NT sites occurs due to grand fir having a relatively lower minimum competitive response threshold than Douglas-fir.

Growth Predictors

The results suggest that initial seedling stem volume was the best predictor of seedling size for both Douglas-fir and grand fir. Seedling age and percent overtopping were the next most important factors. Other parameters such as the occurrence of browse, shrub cover, herb cover and percent ground cover all were significant predictors of seedling success although not as important as initial volume, seedling age and percent overtopping vegetation.

Many studies have attempted to determine what factors are most important in determining seedling success (Wagner and Radosevich 1991, Howard and Newton 1984, and Cole and Newton 1986). Howard and Newton (1984) concluded that initial size and stock type were good predictors of later seedling size. Additionally, vegetation encroachment and overtopping significantly reduced seedling size. Cole and Newton (1984) concluded that crowding and interspecific competition from alder (*Alnus rubra)* and grass largely influenced seedling growth. Wagner and Radosevich (1991) determined that seedling age interspecific competition and initial seedling height strongly influenced seedling growth. My results closely follow the findings of these studies and suggest that to ensure maximum regeneration success, large seedlings and adequate overtopping vegetation control should be used.

Natural Regeneration

The amount of seed-fall as well as stocking percentage of Douglas-fir varies greatly by silvicultural system and location. The greatest stocking and total number of seedlings per hectare occurred in the TS's.

The majority of seeds produced by Douglas-fir fall within 100m of the parent tree (Burns and Honkala 1990). It is not surprising that seed fall and stocking of Douglas-fir would be less in CC's, which generally are devoid of parenting sources and subsequently received less seed fall and reduced levels of stocking as compared to TS's. What is surprising, is that PC's had abundant seed-fall but low stocking percentages and seedling densities. McDonald (1976) found little difference in the percentage Douglas-fir stocking when comparing natural regeneration among group selection cuts, shelterwood cuts and clearcuts. However, unlike in my study, the group selection cuts in McDonald's study received intensive ground preparation following harvest.

The lack of soil disturbance in PC's is probably responsible for their relatively low stocking. PC's were installed by falling trees from inside a designated "cut area" out into the remaining stand. Only in sites where slash was a hindrance to replanting was site preparation such as piling and burning performed. Thus, only a few PC sites received any intensive soil disturbance. Douglas-fir seeds are the most successful when they germinate and establish on bare mineral soil (Burns and Honkala 1990, Minore 1986, Seidel 1979). Site preparation and overstory density are probably more important than heavy seed crops in establishment of natural regeneration (Williamson 1973). The PC's probably had less soil disturbance and thus fewer good germination sites than the

TS or CC, which through the yarding of logs and the use of machinery to pile slash had a relatively greater amount of soil disturbance. From a management perspective, if natural regeneration is important when employing PC's it would be advisable to insure that some soil disturbance occurs.

The amount of seed fall varied greatly among the different blocks. This may be due to the amount of time since harvest in which the seed trapping occurred in the Lewisburg and Dunn blocks. The Lewisburg block was harvest one year prior to Peavy. The amount of seed produced following shelterwood harvest increases (Williamson 1983). This suggests that harvest results in physiological keys in remaining trees that lead to increased seed production. Douglas-fir requires two years from the time of flower budding until seeds are dispersed to produce a new cohort of seeds (Schopmeyer 1974). It's possible that the Lewisburg block, which was harvested two years prior to the seed trapping, had sufficient time in which to produce a new seed crop following harvest and thus reap the benefits of increased seed production via a harvest stress-induced bumper crop. Peavy, harvested less than one year prior to seed trapping, would not benefit from a similar harvest-induced large seed crop. In addition, damage to existing cones in Peavy, via damage from tree felling or exposure could also have resulted in less seed fall. Finally, the variability in seed fall associated with the different blocks may be due to the temporal and spatial variability of good Douglas-fir seed crops (Williamson 1983, Burns and Honkala 1990).

The percent stocking in different blocks varied greatly. This variation is likely due to differences in seed crops and thus likely due to natural variability associated with different locals as mentioned above. Direct relationships between the number of seeds trapped and the percent of stocking cannot be made. The majority of seedlings sampled in Lewisburg were over three years of age and the seed cohort from which they germinated fell prior to when seed was trapped in Lewisburg. Although seed trapping was done in the Dunn block the number of traps used was too small to make any accurate predictions of seed fall. Only in the Peavy block can direct correlations between the stocking percentages measured and the number of seed trapped be made. However, it would be unwise to make any conclusions on the basis of such comparisons because of the lack of any replication.

Management Implications

All three silvicultural systems examined are effective means of harvesting and regenerating forests in the sites studied. However, it is likely that slower growth can be expected from seedlings in PC's versus TS's and CC's. Additionally, relying on natural regeneration to restock stands following harvest is not recommended in either the CC or PC systems as they were used in this study. Reasonable levels of restocking can be expected in the TS if seed production is moderate to good in the first few years following harvest. The amount of natural restocking in PC's may be increased by providing for more bare mineral soil during harvesting.

Increased growth can be expected for both Douglas-fir and grand fir when vegetation control is used. Because of greater levels of overtopping associated with PC's, it is recommended that intensive vegetation control be used to insure adequate growth of Douglas-fir. If the resources are not available to provide intensive vegetation control, grand fir may be a less expensive alternative to regenerating PC stands. Due to a lower minimum competition response threshold than Douglas-fir, grand fir does not require intensive vegetation control to insure regeneration success . However, even for grand fir, it is recommended that at least a minimal amount of vegetation control be used.

Overall the best seedling growth can be expected when planting stock is large and overtopping vegetation is kept to a minimum. Browsing was not a significant factor in reducing overall growth of seedlings in my experiment. However, on poorer sites where seedlings do not have adequate resources to recover from browse, the over all impact of browsing may be greater. Grand fir is a good alternative on such harsh sites, because of the lack of feeding preference by deer for foliage from this tree species.

The vegetation found on a site following harvest is less affected by the silvicultural system used than by the environmental characteristics and pre-harvest vegetation communities. However, if vegetation control measures are taken, specifically the application of herbicides similar to the HT in this study, PC's will tend to have more vegetation than CC's. The operational restrictions imposed by PC's in this study, result in herbicides being applied by back pack versus aerially in CC's. Back pack spraying resulted in less total impact on the plant community over a large area than did aerial application. From a management perspective this may provide for increased species diversity and richness in PC's versus CC's with TS's being intermediate if the HT is applied.

In sites in this study shrub cover returns to pre-harvest levels quickly, as do annual and perennial herb cover. Annual and perennial herbs tended to expand their coverage following harvest, with annual herbs expanding more so than perennials. Silvicultural treatment had little effect on the magnitude of the response of these three plant growth habit and life form categories. However, the HT in the TS and CC systems, results in decreases in both perennial and annual herb cover and had little effect on shrub cover. The HT in the PC system, results in the least amount of impact on cover for the three plant habit and life form categories discussed. From a management perspective, if a vegetation control system similar to the HT is used, then the PC may be the best harvest system to insure the continued presence of mature forest species on harvested sites. However, if spot weeding around planted seedlings was employed in CC's similar overall plant community responses to those seen for PC's could be expected.

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Appendices

APPENDIX A

List of all plant species found within sampled transects and from casual observations. Not all of these species appeared in the transects that were sampled but were noticed while traveling from one sampling area to another or were noticed within a sampling area but were not represented in any of the quadrats sampled.

Abreviation	latin name	common name	life-form
Trees			
ABGR	*Abies grandis*	grand fir	N/A
ACMA	*Acer macrophyllm*	big leaf maple	N/A
ALRU	*Alnus rubra*	red alder	N/A
ARME	*Arbutus menziesii*	madrone	N/A
CONU	*Cornus nuttallii*	dog wood	N/A
FRLA	*Fraxinus latifolia*	oregon ash	N/A
PREM	*Prunus emarginata*	cherry	N/A
PSME	*Pseudotsuga menziesii*	Douglas fir	N/A
QUGA	*Quercus garryanna*	white oak	N/A
Shrubs			
ACCI	*Acer circinatum*	vine maple	N/A
AMAL	*Amelanchier alnifolia*	service berry	N/A
BENE	*Berberis nervosa*	Oregon grape	N/A
COCO	*Corylus cornuta*	hazel	N/A
GASH	*Gaultheria shallon*	salal	N/A
HODI	*Holodiscus discolr*	ocean spray	N/A
ILAQ	*Ilex aquifoliaceae*	holly	N/A
POMU	*Polystichum munitum*	sword fern	N/A
PTAQ	*Pteridium aquilinium*	bracken fern	N/A
RHDI	*Rhus diversiloba*	poison oak	N/A
RHPU	*Rhmnus purshianna*	cascara	N/A
ROGY	*Rosa gymnocarpa*	rose	N/A
RULA	*Rubus laciniatus*	evergreen blackberry	N/A
RUPA	*Rubus parviflorus*	thimble berry	N/A
RUPR	*Rubus procerus*	Himalaya blackberry	N/A
RUUR	*Rubus ursinus*	trailing black berry	N/A
SARA	*Sambucus*	elderberry	N/A
SASC	*Salix scouleriana*	Scouler's willow	N/A
SYAL	*Symphoricarpos alnus*	snowberry	N/A
VAPA	*Vaccinium parvifolium*	red huckleberry	N/A
Herbs			
ACMI	*Achillea millefolium*	yarrow	Perennial
ACRU	*Actaea rubra*	bane berry	Perennial
ACTR	*Achlys triphylla*	vanilla-leaf	Perennial
ADBI	*Adenocaulan bicolor*	path finder	Perennial
AGCA	*Agropyron caninum*	slender wheatgrass	Perennial
AGGR	*Agroseris grandiflora*	large-flowered agroseris	Perennial
AGHA	*Agrostis hallii*	Hall's agrostis	Perennial
AICA	*Aira caryophyllea*	silver hairgrass	Annual
ANCO	*Anthemis cotula*	dog fennel	Annual
ANLY	*Anemone lyallii*	small wind flower	Perennial
ANMA	*Anaphalis margaritacea*	pearly everlasting	Perennial

Abreviation	latin name	common name	life-form
APAN	*Apocynum androsaemifolium*	dog bane	Perennial
AQFO	*Aquilegia formosa*	columbine	Perennial
ARMA	*Arenaria macrophylla*	sandwort	Perennial
ARMI	*Arctium minus*	burdock	Perennial
ASSU	*Aster subspicatus*	Douglas' aster	Perennial
AVFA	*Avena fatua*	wild oat	Annual
BAOR	*Barbarea orthoceras*	American wintercress	Perennial
BRCA	*Bromus carinatus*	California brome	Perennial
BRMO	*Bromus mollis*	soft chess	Annual
BRSY	*Brachypodium sylvaticum*	false brome	Perennial
BRVU	*Bromus vulgaris*	Columbia brome	Perennial
CAREX	*Carex spp*	sedge spp	N/A
CASC	*Campanula scouleri*	Scouler's harebell	Annual
CECY	*Centaurea cyanus*	bachelor button	Annual
CEUM	*Centaurium umbellatum*	common entaury	Annual
CHLE	*Chrysanthemum leucanthemum*	ox-eyed daisy	Annual
CIAL	*Circaea alpina*	night shade	Perennial
CIAR	*Cirsium arvense*	Canadian thistle	Annual
CIVU	*Cirsium vulgare*	bull thistle	Annual
CLVI	*Clarkia viminea*	twiggy godetia	Annual
COHE	*Collomia heterophylla*	varied leaf collomia	Annual
CRCA	*Crespis capillaris*	hawksbeard	Annual
CRSE	*Crespis setosa*	bristly hawksbeard	Annual
CYEC	*Cynosurus echinatus*	bristly dog tail	Annual
DACA	*Daucus carota*	wild carrot	Annual
DAGL	*Dactylis glomerata*	orchard grass	Perennial
DEDA	*Deschampsia danthonioides*	slender hairgrass	Annual
DEME	*Delphinium mensiesii*	field larkspur	Perennial
DIFO	*Dicentra formosa*	bleeding heart	Perennial
DISM	*Disporum smithii*	fairy lattern	Perennial
DISY	*Dipsacus sylvestris*	teasel	Annual
EPAG	*Epilobium angustifolium*	fire weed	Annual
EPMU	*Epilobium munitum*	small flowered willow herb	Annual
EPPA	*Epilobium panicultum*	tall annual wiilow herb	Annual
ERMI	*Erechtites minima*	Australian fire weed	Annual
FEOC	*Festuca occidentalis*	Western fescue	Perennial
FERU	*Festuca rubra*	red fescue	Perennial
FESU	*Festuca subuliflora*	crinkle awn fescue	Perennial
FRVE	*Fragaria vesca*	strawberry	Perennial
GATR	*Galium trifolium*	bedstraw	Annual
GEDI	*Geranium dissectum*	cut leaf geranium	Annual
GERO	*Geranium robertianum*	Roberts' geranium	Annual
GOOB	*Goodyera oblongifolia*	rattlesnake plantain	Perennial
HELA	*Heracleum lanatum*	cow parsnip	Perennial
HIAL	*Hieracium albiflorium*	hairy hawkweed	Perennial

Abreviation	latin name	common name	life-form
HOLA	*Holcus lanatus*	velvet grass	Perennial
HYOC	*Hydrophyllum occidentale*	water leaf	Perennial
HYPE	*Hypericum perforatum*	St. Johns' wort	Perennial
HYRA	*Hypochaeris radicata*	false dandilion	Perennial
IRTE	*Iris tenax*	purple iris	Perennial
LAMU	*Lactuca murallis*	wall letuce	Annual
LAPO	*Lathyrus polyphyllus*	oregon pea	Annual
LASA	*Lactuca saligna*	willow letuce	Annual
LASE	*Lactuca serriola*	prickly letuce	Annual
LIAP	*Ligusticum apigfolium*	celaery leved lovage	Perennial
LIBO	*Linnaea boralis*	twin flower	Perennial
LOCI	*lonicera cilisa*	trumpet honeysuckel	Perennial
LOHI	*lonicera hispidula*	hairy honeysuckel	Perennial
LOMI	*Lotus Micranthous*	slender tree foil	Annual
LOMU	*Lolium multiflorum*	annual ryegrass	Annual
LOPU	*Lotus purshiana*	spanish clover	Perennial
LOUT	*Lomatium utriculatum*	common lomatium	Perennial
LUMI	*Lupinus micranthus*	small flowered lupine	Annual
MAGR	*Madia gracilis*	tar weed	Annual
MAOR	*Marah oreganus*	Oregon bigroot (cucumber)	Perennial
MASA	*Madia sativa*	gum-seed	Annual
MOSI	*Montia sibrica*	candy flower	Annual
MOUN	*Monotropa unflora*	indian pipe	Perennial
MYDI	*Myosotis discolor*	small blue forget me not	Annual
NASQ	*Navarretia squarrosa*	skunkweed	Annual
NEPA	*Nemophilia parvifolia*	wood nemophilia	Annual
OSCH	*Osmorhiza chilensis*	common sweet cicely	Perennial
PHPR	*Phleum pratense*	Timothy	Perennial
POGR	*Potentilla gracilis*	five finger	Perennial
POPA	*Poa palustris*	fowl bluegrass	Perennial
PRVU	*Prunella vulgaris*	selfheal	Perennial
RAUN	*Ranuculus uncinatus*	woods buttercup	Perennial
SABI	*Sanicula bipinnatifida*	purple snake root	Perennial
SACA	*Sanicula crassicaulis*	snake root	Perennial
SADO	*Satureja douglesii*	herba buena	Perennial
SESY	*Senicio sylvaticus*	wood groundsel	Annual
SEVU	*Senicio vulgaris*	common groundsel	Annual
SMRA	*Smilacina racemosa*	large false solomon's seal	Perennial
SMST	*Smilacina stellata*	small false solomons seal	Perennial
SOAR	*Sonchus arvensus*	field mild thistle	Perennial
SOAS	*Sonchus asper*	prickly sow thistle	Annual
SODU	*Solanum dulcanara*	bittersweet night shade	Perennial
SOOL	*Sonchus olearaccus*	sow thistle	Annual
STME	*Stellaria media*	chickweed	Annual
SYRE	*Synthyris reniformis*	snowqueen	Perennial
TAOF	*Taraxacum officinale*	common dandlion	Perennial

Abreviation	latin name	common name	life-form
TEGR	*Tellima grandiflora*	fringe cups	Perennial
THOC	*Thallictrum occidentale*	meadow rue	Perennial
TOME	*Tolmeia menziesii*	pig a back	Perennial
TRCA	*Trisetum canescens*	tall trisetum	Perennial
TRDU	*Tragopogon dubius*	large yellow head dandilion	Annual
TRLA	*Trientalis latifolia*	star flower	Perennial
TROV	*Trillium ovatum*	wood lily	Perennial
TRPE	*Triodanis perfoliata*	Venus's-looking-glass	Annual
VAHE	*Vancouveria hexandra*	inside out flower	Perennial
VECA	*Veratrum californicum*	false white hellebore	Perennial
VIAM	*Vicia americana*	American vetch	Perennial
VIGL	*Viola glabella*	wood violet	Perennial

APPENDIX B

Average percent cover of all species identified within quadrats along the sampled transects. The cover values have been broken up by silvicultural system and vegetation treatment. If cover for a specific species is zero in all columns then that particular species did not occur in any sampled quatrats, but was noticed while traveling from one sampling area to another within a silvicultural system or was noticed within a sampling area but was not represented in any of the sampled quadrates. Refer to Appendix A for explanation of abreviations used to identify species.

Percentage of cover for all species across all blocks.

	No treatment				Herbicide treatment		
	clearcut	2-story	patchcut	control	clearcut	2-story	patchcut
Trees							
ABGR	0.04	0.06	0.65	0.96	0.22	0.28	0.04
ACMA	4.93	4.28	3.41	22.22	3.02	1.43	3.47
ARME	0.04	0.04	---	0.28	---	---	---
CONU	0.69	0.35	0.15	4.89	0.24	0.69	1.43
FRLA	---	0.11	---	0.11	---	---	---
PREM	0.06	0.96	---	0.02	0.26	0.15	0.11
PSME	0.57	1.50	0.26	0.35	0.30	1.17	0.30
QUGA	0.39	---	0.30	0.28	0.11	0.13	0.22
Shrubs							
ACCI	---	---	---	---	---	---	---
AMAL	0.52	0.24	---	0.35	---	0.11	0.31
BENE	0.11	2.81	---	0.96	---	0.35	---
COCO	6.52	9.26	4.25	17.63	5.44	8.37	6.25
GASH	---	2.50	---	---	---	0.85	---
HODI	0.94	0.15	0.24	0.69	0.11	1.67	0.13
HOLLY	---	---	0.11	---	---	0.22	---
POMU	1.91	2.31	8.94	19.19	1.46	5.20	11.85
PTAQ	5.41	4.37	2.06	5.37	6.54	2.96	2.00
RHDI	3.63	6.15	3.33	8.65	6.41	1.81	2.23
RHPU	0.26	0.85	0.84	0.54	0.33	1.67	0.06
ROGY	1.85	1.87	1.75	0.57	0.57	0.65	0.72
RULA	---	0.11	0.02	---	0.11	0.11	0.02
RUPA	2.46	4.74	4.80	6.76	1.76	3.78	2.28
RUPR	0.52	0.39	0.83	---	0.78	0.28	2.13
RUUR	28.89	29.57	37.97	19.43	47.09	29.61	43.02
SARA	0.04	0.59	0.16	0.04	0.15	---	0.02
SASC	---	---	---	---	---	---	---
SYAL	10.72	8.39	12.57	9.22	3.76	7.35	4.65
VAPA	---	---	---	---	---	---	---
Herbs							
ACMI	---	---	---	---	---	---	---
ACRU	---	---	---	0.50	---	0.13	0.11
ACTR	0.17	0.41	---	3.06	---	1.20	0.38
ADBI	1.72	2.20	2.35	5.44	0.02	1.61	1.29
AGCA	---	---	---	---	---	---	---
AGGR	---	---	---	---	---	---	---
AGHA	---	---	---	---	---	---	---
AICA	---	0.22	---	---	0.02	---	---
ANCO	---	0.11	---	---	---	---	---
ANLY	---	---	---	---	---	---	---
ANMA	0.02	0.11	0.11	---	---	---	---
APAN	---	---	0.05	---	---	---	---
AQFO	---	---	---	---	0.02	---	---
ARMA	---	0.02	---	---	---	---	---

	No treatment				Herbicide treatment		
	clearcut	2-story	patchcut	control	clearcut	2-story	patchcut
ARMI	0.11	---	---	---	---	---	---
ASSU	---	---	---	---	---	---	---
AVFA	---	---	---	---	---	---	---
BAOR	---	---	---	---	---	---	---
BRCA	0.30	---	0.33	---	0.78	0.11	0.03
BRMO	---	---	---	---	---	---	---
BRSY	3.35	2.31	8.65	2.85	1.17	0.02	5.28
BRVU	14.56	14.15	16.99	11.74	2.37	2.67	6.49
CAREX	0.26	---	0.13	0.28	0.28	0.11	0.22
CASC	---	---	---	---	---	---	---
CECY	0.13	---	---	---	---	---	---
CEUM	---	---	---	---	---	---	---
CHLE	2.48	0.17	0.11	0.11	2.20	---	---
CIAL	---	---	---	---	---	---	0.17
CIAR	0.94	0.37	1.96	---	0.52	1.06	0.48
CIVU	7.50	4.41	4.28	---	0.61	2.56	2.02
CLVI	---	---	---	---	---	---	---
COHE	0.02	0.22	---	0.02	0.13	0.06	---
CRCA	0.13	---	---	---	0.11	---	---
CRSE	3.93	1.31	0.28	---	5.50	3.19	0.54
CYEC	3.46	2.61	---	---	1.46	0.13	---
DACA	0.98	0.65	---	---	0.41	0.15	---
DAGL	0.02	---	---	0.02	1.20	---	0.02
DEDA	---	---	---	---	0.02	---	---
DEME	---	---	---	0.13	---	---	---
DIFO	0.11	---	---	---	---	---	0.17
DISM	1.35	0.37	---	0.41	0.06	0.56	1.22
DISY	---	---	---	---	---	---	---
EPAN	---	---	0.02	---	---	0.02	0.11
EPMU	0.93	1.72	2.30	---	0.02	2.72	1.57
EPPA	3.28	5.31	0.88	---	0.28	3.48	0.96
ERMI	0.04	0.09	0.19	---	0.65	0.06	0.44
FEOC	---	0.72	0.22	0.81	---	0.33	---
FERU	---	1.26	---	---	---	---	---
FESU	3.13	1.15	---	1.19	0.91	0.74	1.61
FRVE	0.26	---	---	0.48	---	---	---
GATR	19.13	20.65	25.54	4.80	15.37	9.67	26.31
GEDI	---	---	---	---	---	0.11	---
GERO	---	---	---	---	1.13	0.33	0.03
GOOB	---	---	---	0.04	---	---	---
HELA	---	---	---	---	---	---	---
HIAL	0.11	0.06	---	1.11	0.06	---	0.17
HOLA	1.43	1.41	0.50	---	1.76	---	1.35
HYOC	---	---	---	---	---	---	---
HYPE	0.61	1.65	2.69	---	1.35	1.89	3.13
HYRA	1.11	1.02	0.25	---	1.11	0.91	0.56

	No treatment				Herbicide treatment		
	clearcut	2-story	patchcut	control	clearcut	2-story	patchcut
IRTE	0.28	0.09	---	0.04	0.09	0.37	0.04
LAMU	0.11	0.19	0.74	0.48	0.37	2.28	0.36
LAPO	0.06	0.24	0.11	0.02	0.37	0.52	0.22
LASA	0.04	0.04	0.02	---	---	0.28	---
LASE	2.83	1.70	0.42	---	---	0.93	0.13
LIAP	1.39	0.91	0.96	0.33	2.11	0.85	0.77
LIBO	---	---	---	---	---	---	---
LOCI	---	---	---	---	---	---	---
LOHI	0.28	0.61	0.23	0.57	---	0.13	0.07
LOMI	0.63	0.22	---	---	0.72	0.37	---
LOMU	0.28	0.37	0.02	---	0.13	0.02	0.46
LOPU	---	---	---	---	0.28	---	---
LOUT	---	---	---	---	---	---	---
LUMI	---	---	---	---	0.22	---	---
MAGR	1.43	0.57	---	---	---	---	---
MAOR	---	---	---	0.50	---	---	---
MASA	---	---	---	---	---	---	---
MOSI	5.46	0.65	6.06	0.17	0.15	0.26	5.07
MOUN	---	---	---	---	---	---	---
MYDI	---	---	---	---	---	---	---
NASQ	---	0.11	---	---	---	---	---
NEPA	0.56	0.61	1.03	---	---	---	0.75
OSCH	1.30	0.72	3.10	1.11	1.87	2.04	1.14
PHPR	---	---	---	---	---	---	---
POGR	---	---	---	---	---	---	---
POPA	0.06	---	---	---	0.13	---	---
PRVU	0.02	---	0.02	---	---	---	---
RAUN	---	---	---	---	---	---	---
SABI	7.94	6.43	4.78	0.04	1.28	0.13	0.04
SACR	---	---	---	---	0.11	---	---
SADO	1.94	1.74	0.42	0.11	0.13	0.65	0.28
SEJA	8.52	9.96	2.55	---	2.07	3.72	4.69
SEVU	---	---	---	---	---	---	---
SMRA	---	---	---	---	---	---	---
SMST	---	0.11	0.41	3.17	0.13	0.02	0.06
SOAR	---	---	0.33	---	---	---	---
SOAS	1.33	1.96	0.08	---	0.11	1.65	0.19
SODU	---	---	---	---	---	---	---
SOOL	---	---	0.39	---	---	---	---
STME	---	---	0.33	---	---	---	---
SYRE	---	0.02	---	0.20	---	---	---
TAOF	---	---	---	---	0.02	---	---
TEGR	---	---	---	---	---	---	---
THOC	0.04	0.44	---	0.02	0.06	0.50	0.67
TOME	0.02	0.04	0.03	0.06	---	0.02	0.11
TRCA	---	---	---	---	---	---	---

	No treatment			Herbicide treatment			
	clearcut	2-story	patchcut	control	clearcut	2-story	patchcut
TRDU	---	---	---	---	---	---	---
TRLA	0.13	0.96	0.19	0.70	0.17	1.22	0.24
TROV	---	0.11	---	0.19	---	---	---
TRPE	0.15	0.02	0.03	---	0.13	---	---
VAHE	1.19	0.76	0.06	6.80	0.06	1.85	0.86
VECA	---	0.11	---	0.02	---	0.22	---
VIAM	0.02	---	---	---	---	---	---
VIGL	0.54	0.07	0.19	2.20	---	0.13	---

Percent cover of all species within the Lewisburg block

	No treatment				Herbicide treatment		
	clearcut	2-story	patchcut	control	clearcut	2-story	patchcut
Trees							
ABGR	0.06	0.06	1.94	2.56	0.33	0.44	0.06
ACMA	0.72	0.83	1.78	12.17	0.33	0.39	0.89
ARME	0.11	---	---	0.83	---	---	---
CONU	1.06	---	0.44	0.33	0.72	0.72	4.28
FRLA	---	---	---	---	---	---	---
PREM	0.11	0.06	---	0.06	0.78	0.39	---
PSME	0.72	2.06	0.06	0.39	0.67	2.44	0.22
QUGA	---	---	0.33	---	---	---	0.67
Shrubs							
ACCI	---	---	---	---	---	---	---
AMAL	---	---	---	0.67	---	---	0.94
BENE	0.33	7.22	---	---	---	1.06	---
COCO	10.72	10.39	6.28	15.72	9.72	15.39	9.06
GASH	---	7.50	---	---	---	2.56	---
HODI	2.44	0.44	0.72	0.33	0.33	1.83	---
HOLLY	---	---	0.33	---	---	---	---
POMU	0.94	1.17	5.22	2.61	0.78	1.83	8.61
PTAQ	12.78	6.33	5.44	6.94	10.28	5.28	3.67
RHDI	4.11	1.00	0.11	---	10.33	0.33	0.11
RHPU	---	---	0.39	---	0.83	---	0.06
ROGY	3.28	3.78	4.67	0.11	1.00	1.44	1.67
RULA	---	---	---	---	0.33	---	---
RUPA	6.94	13.00	13.72	8.56	5.22	10.33	3.78
RUPR	---	0.33	0.83	---	---	---	---
RUUR	31.89	27.22	50.78	29.56	57.94	15.17	57.06
SARA	---	1.56	0.33	---	---	---	---
SASC	---	---	---	---	---	---	---
SYAL	17.44	9.67	21.61	6.39	1.11	3.89	3.17
VAPA	---	---	---	---	---	---	---
Herbs							
ACMI	---	---	---	---	---	---	---
ACRU	---	---	---	0.33	---	0.39	0.33
ACTR	---	1.22	---	0.72	---	3.28	0.72
ADBI	0.06	1.94	0.39	12.50	---	0.50	0.22
AGCA	---	---	---	---	---	---	---
AGGR	---	---	---	---	---	---	---
AGHA	---	---	---	---	---	---	---
AICA	---	---	---	---	---	---	---
ANCO	---	---	---	---	---	---	---
ANLY	---	---	---	---	---	---	---
ANMA	---	---	---	---	---	---	---
APAN	---	---	---	---	---	---	---
AQFO	---	---	---	---	0.06	---	---
ARMA	---	---	---	---	---	---	---

	No treatment				Herbicide treatment		
	clearcut	2-story	patchcut	control	clearcut	2-story	patchcut
ARMI	---	---	---	---	---	---	---
ASSU	---	---	---	---	---	---	---
AVFA	---	---	---	---	---	---	---
BAOR	---	---	---	---	---	---	---
BRCA	---	---	---	---	---	---	---
BRMO	---	---	---	---	---	---	---
BRSY	7.44	0.83	25.94	8.50	3.39	---	14.61
BRVU	23.28	22.17	9.50	26.89	1.78	1.83	2.56
CAREX	0.06	---	0.39	0.83	0.83	---	0.67
CASC	---	---	---	---	---	---	---
CECY	---	---	---	---	---	---	---
CEUM	---	---	---	---	---	---	---
CHLE	0.39	0.44	---	0.33	---	---	---
CIAL	---	---	---	---	---	---	---
CIAR	1.22	---	5.39	---	0.39	3.11	1.39
CIVU	1.39	1.78	2.00	---	---	0.72	0.17
CLVI	---	---	---	---	---	---	---
COHE	---	---	---	---	---	0.11	---
CRCA	---	---	---	---	---	---	---
CRSE	7.17	1.50	0.33	---	8.50	5.44	---
CYEC	0.83	0.83	---	---	---	0.06	---
DACA	---	0.39	---	---	---	0.06	---
DAGL	---	---	---	0.06	---	---	0.06
DEDA	---	---	---	---	---	---	---
DEME	---	---	---	0.39	---	---	---
DIFO	---	---	---	---	---	---	---
DISM	0.11	1.11	---	0.33	0.17	1.67	3.67
DISY	---	---	---	---	---	---	---
EPAN	---	---	0.06	---	---	---	---
EPMU	2.00	1.33	3.33	---	---	3.50	2.17
EPPA	2.17	9.11	---	---	0.83	7.22	1.72
ERMI	---	---	---	---	---	0.11	---
FEOC	---	2.17	0.33	1.94	---	---	---
FERU	---	3.78	---	---	---	---	---
FESU	4.67	1.11	---	3.56	0.39	2.06	---
FRVE	0.78	---	---	1.11	---	---	---
GATR	9.00	17.44	22.72	11.50	5.61	5.44	18.28
GEDI	---	---	---	---	---	---	---
GERO	---	---	---	---	---	---	---
GOOB	---	---	---	---	---	---	---
HELA	---	---	---	---	---	---	---
HIAL	---	0.11	---	2.67	---	---	---
HOLA	0.33	0.11	---	---	---	---	1.67
HYOC	---	---	---	---	---	---	---
HYPE	---	---	0.89	---	---	---	4.67
HYRA	0.33	0.11	---	---	---	0.33	0.11

	No treatment				Herbicide treatment		
	clearcut	2-story	patchcut	control	clearcut	2-story	patchcut
IRTE	0.56	0.28	---	0.11	0.17	1.11	0.11
LAMU	---	0.06	---	1.39	---	0.06	0.67
LAPO	---	0.33	0.33	---	0.06	1.56	0.67
LASA	---	---	---	---	---	0.06	---
LASE	---	0.22	---	---	---	---	---
LIAP	1.67	1.94	0.39	1.00	5.94	1.44	0.67
LIBO	---	---	---	---	---	---	---
LOCI	---	---	---	---	---	---	---
LOHI	---	---	---	0.06	---	0.39	---
LOMI	---	---	---	---	---	---	---
LOMU	---	---	---	---	---	---	---
LOPU	---	---	---	---	---	---	---
LOUT	---	---	---	---	---	---	---
LUMI	---	---	---	---	---	---	---
MAGR	0.33	0.44	---	---	---	---	---
MAOR	---	---	---	1.50	---	---	---
MASA	---	---	---	---	---	---	---
MOSI	---	---	0.39	---	---	---	---
MOUN	---	---	---	---	---	---	---
MYDI	---	---	---	---	---	---	---
NASQ	---	---	---	---	---	---	---
NEPA	---	---	0.83	---	---	---	---
OSCH	---	---	---	1.00	0.44	---	---
PHPR	---	---	---	---	---	---	---
POGR	---	---	---	---	---	---	---
POPA	---	---	---	---	---	---	---
PRVU	---	---	0.06	---	---	---	---
RAUN	---	---	---	---	---	---	---
SABI	---	---	---	---	---	---	---
SACR	---	---	---	---	---	---	---
SADO	---	---	---	0.33	---	0.06	---
SEJA	2.28	3.28	0.17	---	0.06	3.50	8.17
SEVU	---	---	---	---	---	---	---
SMRA	---	---	---	---	---	---	---
SMST	---	---	1.22	0.39	---	---	---
SOAR	---	---	---	---	---	---	---
SOAS	---	---	0.06	---	---	0.06	---
SODU	---	---	---	---	---	---	---
SOOL	---	---	---	---	---	---	---
STME	---	---	---	---	---	---	---
SYRE	---	0.06	---	0.56	---	---	---
TAOF	---	---	---	---	---	---	---
TEGR	---	---	---	---	---	---	---
THOC	0.06	1.33	---	0.06	0.17	1.11	2.00
TOME	---	---	---	---	---	---	---
TRCA	---	---	---	---	---	---	---

	No treatment			Herbicide treatment			
	clearcut	2-story	patchcut	control	clearcut	2-story	patchcut
TRDU	---	---	---	---	---	---	---
TRLA	0.11	2.06	0.06	0.11	0.06	1.78	---
TROV	---	0.33	---	0.06	---	---	---
TRPE	---	---	---	---	---	---	---
VAHE	1.00	1.89	---	13.56	0.11	4.11	1.33
VECA	---	0.33	---	---	---	0.67	---
VIAM	---	---	---	---	---	---	---
VIGL	0.67	0.17	---	2.78	---	0.39	---

Percent cover for all species within the Peavy block.

	No treatment				Herbicide treatment		
	clearcut	2-story	patchcut	control	clearcut	2-story	patchcut
Trees							
ABGR	0.06	0.11	---	---	---	---	0.06
ACMA	7.44	6.06	3.44	53.00	0.94	1.17	4.94
ARME	---	---	---	---	---	---	---
CONU	---	---	---	14.33	---	0.33	---
FRLA	---	---	---	0.33	---	---	---
PREM	---	1.61	---	---	---	---	0.33
PSME	0.28	0.33	0.22	0.67	0.11	0.44	0.17
QUGA	---	---	0.06	---	0.33	---	---
Shrubs							
ACCI	---	---	---	---	---	---	---
AMAL	---	---	---	---	---	---	---
BENE	---	0.06	---	1.72	---	---	---
COCO	2.78	12.22	3.56	27.17	4.89	5.72	4.28
GASH	---	---	---	---	---	---	---
HODI	0.39	---	---	1.72	---	3.17	0.39
HOLLY	---	---	---	---	---	0.67	---
POMU	2.33	4.39	5.61	24.56	1.61	7.11	6.78
PTAQ	3.44	4.89	0.56	9.17	9.28	2.56	2.33
RHDI	0.39	6.56	7.89	4.44	1.44	3.17	4.83
RHPU	---	0.44	1.22	0.83	---	0.39	0.56
ROGY	1.72	1.39	---	1.5	0.67	0.44	0.5
RULA	---	---	0.56	---	---	---	0.56
RUPA	0.44	1.22	0.67	11.72	0.56	1	3.56
RUPR	---	0.83	1.67	---	0.33	0.83	6.39
RUUR	49.72	30.2	45.1	24.83	73.72	38.28	42.16
SARA	0.11	0.17	0.56	0.11	0.39	---	0.56
SASC	---	---	---	---	---	---	---
SYAL	13.72	11.9	10.4	19	9.44	15.72	10.8
VAPA	---	---	---	---	---	---	---
Herbs							
ACMI	---	---	---	---	---	---	---
ACRU	---	---	---	1.17	---	---	---
ACTR	---	---	---	7.72	---	---	0.33
ADBI	1.17	1.83	1.67	1.33	---	1.5	1.89
AGCA	---	---	---	---	---	---	---
AGGR	---	---	---	---	---	---	---
AGHA	---	---	---	---	---	---	---
AICA	---	---	---	---	---	---	---
ANCO	---	---	---	---	---	---	---
ANLY	---	---	---	---	---	---	---
ANMA	0.06	---	0.33	---	---	---	---
APAN	---	---	0.56	---	---	---	---
AQFO	---	---	---	---	---	---	---
ARMA	---	0.56	---	---	---	---	---

	No treatment				Herbicide treatment		
	clearcut	2-story	patchcut	control	clearcut	2-story	patchcut
ARMI	0.33	---	---	---	---	---	---
ASSU	---	---	---	---	---	---	---
AVFA	---	---	---	---	---	---	---
BAOR	---	---	---	---	---	---	---
BRCA	0.89	---	---	---	0.33	---	---
BRMO	---	---	---	---	---	---	---
BRSY	2.61	6.11	---	---	0.11	0.56	1.22
BRVU	13.22	9.22	24.9	4.00	2.56	2.67	13.16
CAREX	0.72	---	---	---	---	0.33	---
CASC	---	---	---	---	---	---	---
CECY	---	---	---	---	---	---	---
CEUM	---	---	---	---	---	---	---
CHLE	5.94	---	0.33	---	---	---	---
CIAL	---	---	---	---	---	---	---
CIAR	1.61	0.11	0.17	---	0.39	0.56	0.56
CIVU	10.5	5.56	7.17	---	0.56	4.89	3.56
CLVI	---	---	---	---	---	---	---
COHE	0.06	---	---	---	0.39	0.56	---
CRCA	0.33	---	---	---	---	---	---
CRSE	1.83	0.33	0.33	---	0.11	1.00	0.94
CYEC	---	---	---	---	---	---	---
DACA	---	---	---	---	---	---	---
DAGL	0.06	---	---	---	---	---	---
DEDA	---	---	---	---	---	---	---
DEME	---	---	---	---	---	---	---
DIFO	---	---	---	---	---	---	---
DISM	---	---	---	0.89	---	---	---
DISY	---	---	---	---	---	---	---
EPAN	---	---	---	---	---	0.56	0.33
EPMU	0.22	2.50	1.89	---	---	2.00	2.22
EPPA	3.17	3.44	2.56	---	---	2.22	1.17
ERMI	0.06	---	0.33	---	0.56	---	0.83
FEOC	---	---	0.33	---	---	---	---
FERU	---	---	---	---	---	---	---
FESU	4.72	2.33	---	---	2.33	0.17	4.83
FRVE	---	---	---	---	---	---	---
GATR	17.61	26.6	33.2	0.33	10.39	12.0	33.5
GEDI	---	---	---	---	---	---	---
GERO	---	---	---	---	---	---	---
GOOB	---	---	---	---	---	---	---
HELA	---	---	---	---	---	---	---
HIAL	---	---	---	---	---	---	---
HOLA	3.17	0.72	1.50	---	1.50	---	2.39
HYOC	---	---	---	---	---	---	---
HYPE	0.89	3.56	5.17	---	---	1.33	1.72
HYRA	1.17	---	---	---	---	1.56	0.56

	No treatment				Herbicide treatment		
	clearcut	2-story	patchcut	control	clearcut	2-story	patchcut
IRTE	---	---	---	---	0.56	---	---
LAMU	---	---	0.56	---	---	0.56	---
LAPO	0.17	0.56	---	0.56	---	---	---
LASA	---	0.11	0.56	---	---	0.44	---
LASE	6.44	3.56	1.17	---	---	2.78	0.39
LIAP	1.44	0.39	1.00	---	0.39	0.33	1.56
LIBO	---	---	---	---	---	---	---
LOCI	---	---	---	---	---	---	---
LOHI	0.06	0.67	0.11	---	---	---	0.56
LOMI	---	---	---	---	0.89	0.44	---
LOMU	0.83	1.56	0.56	---	---	0.56	0.89
LOPU	---	---	---	---	---	---	---
LOUT	---	---	---	---	---	---	---
LUMI	---	---	---	---	---	---	---
MAGR	---	---	---	---	---	---	---
MAOR	---	---	---	---	---	---	---
MASA	---	---	---	---	---	---	---
MOSI	---	0.44	1.56	0.11	---	0.44	2.72
MOUN	---	---	---	---	---	---	---
MYDI	---	---	---	---	---	---	---
NASQ	---	---	---	---	---	---	---
NEPA	---	1.5	---	---	---	---	---
OSCH	1.33	0.78	2.56	0.56	1.00	1.50	1.33
PHPR	---	---	---	---	---	---	---
POGR	---	---	---	---	---	---	---
POPA	0.17	---	---	---	---	---	---
PRVU	0.06	---	---	---	---	---	---
RAUN	---	---	---	---	---	---	---
SABI	0.78	0.56	13.3	---	0.56	0.56	0.11
SACR	---	---	---	---	---	---	---
SADO	0.44	0.67	1.17	---	---	1.56	0.67
SEJA	19.56	19.83	4.39	---	0.83	4.28	5.33
SEVU	---	---	---	---	---	---	---
SMRA	---	---	---	---	---	---	---
SMST	---	0.33	---	8.39	0.39	0.56	0.17
SOAR	---	---	---	---	---	---	---
SOAS	1.22	3.50	0.11	---	---	2.39	0.39
SODU	---	---	---	---	---	---	---
SOOL	---	---	---	---	---	---	---
STME	---	---	100	---	---	---	---
SYRE	---	---	---	---	---	---	---
TAOF	---	---	---	---	---	---	---
TEGR	---	---	---	---	---	---	---
THOC	---	---	---	---	---	0.39	---
TOME	0.06	0.11	---	0.17	---	0.56	---
TRCA	---	---	---	---	---	---	---

	No treatment			Herbicide treatment			
	clearcut	2-story	patchcut	control	clearcut	2-story	patchcut
TRDU	---	---	---	---	---	---	---
TRLA	0.28	0.39	---	0.28	0.56	0.17	0.56
TROV	---	---	---	0.50	---	---	---
TRPE	---	0.56	---	---	---	---	---
VAHE	---	---	---	0.39	---	---	---
VECA	---	---	---	0.56	---	---	---
VIAM	---	---	---	---	---	---	---
VIGL	0.06	0.56	---	3.83	---	---	---

Percent cover for all species within the Dunn block

	No treatment				Herbicide treatment		
	clearcut	2-story	patchcut	control	clearcut	2-story	patchcut
Trees							
ABGR	---	---	---	0.33	0.33	0.39	---
ACMA	6.61	5.94	5.00	1.50	7.78	2.72	4.583
ARME	---	0.11	---	---	---	---	---
CONU	1.00	1.56	---	---	---	1.00	---
FRLA	---	0.33	---	---	---	---	---
PREM	0.6	1.22	---	---	---	0.56	---
PSME	0.72	2.11	0.50	---	0.11	0.61	0.50
QUGA	1.17	---	0.50	0.83	---	0.39	---
Shrubs							
ACCI	---	---	---	---	---	---	---
AMAL	1.56	0.72	---	0.39	---	0.33	---
BENE	---	1.17	---	1.17	---	---	---
COCO	6.06	5.17	2.92	10.00	1.72	4.00	5.42
GASH	---	---	---	---	---	---	---
HODI	---	---	---	---	---	---	---
HOLLY	---	---	---	---	---	---	---
POMU	2.44	1.39	16.00	30.39	2.00	6.67	20.16
PTAQ	---	1.89	0.67	---	0.56	1.56	---
RHDI	6.39	11.39	2.00	21.5	7.44	1.94	1.75
RHPU	0.78	2.11	0.916	0.78	0.17	4.61	0.0.0083
ROGY	0.56	0.44	0.583	0.11	0.56	0.56	---
RULA	---	0.33	---	---	---	0.33	---
RUPA	---	---	---	---	---	---	---
RUPR	1.56	---	---	---	2.00	---	---
RUUR	5.0.006	31.28	18.07	3.89	9.61	35.39	29.83
SARA	---	0.06	0.08	---	0.56	---	---
SASC	---	---	---	---	---	---	---
SYAL	1.00	3.61	5.67	2.28	0.72	2.44	---
VAPA	---	---	---	---	---	---	---
Herbs							
ACMI	---	---	---	---	---	---	---
ACRU	---	---	---	---	---	---	---
ACTR	0.50	---	---	0.72	---	0.33	0.08
ADBI	3.94	2.83	5.00	2.50	0.56	2.83	1.75
AGCA	---	---	---	---	---	---	---
AGGR	---	---	---	---	---	---	---
AGHA	---	---	---	---	---	---	---
AICA	---	0.67	---	---	0.56	---	---
ANCO	---	0.33	---	---	---	---	---
ANLY	---	---	---	---	---	---	---
ANMA	---	0.33	---	---	---	---	---
APAN	---	---	0.08	---	---	---	---
AQFO	---	---	---	---	---	---	---
ARMA	---	---	---	---	---	---	---

	No treatment				Herbicide treatment		
	clearcut	2-story	patchcut	control	clearcut	2-story	patchcut
ARMI	---	---	---	---	---	---	---
ASSU	---	---	---	---	---	---	---
AVFA	---	---	---	---	---	---	---
BAOR	---	---	---	---	---	---	---
BRCA	---	---	1.00	---	2.00	0.33	0.08
BRMO	---	---	---	---	---	---	---
BRSY	---	---	---	0.56	---	---	---
BRVU	7.17	11.06	16.58	4.33	3.28	3.5	3.75
CAREX	---	---	---	---	---	---	---
CASC	---	---	---	---	---	---	---
CECY	0.39	---	---	---	---	---	---
CEUM	---	---	---	---	---	---	---
CHLE	1.11	0.06	---	---	6.61	---	---
CIAL	---	---	---	---	---	---	0.5
CIAR	---	1.00	0.33	---	0.78	---	---
CIVU	10.61	5.89	3.67	---	1.78	2.56	2.33
CLVI	---	---	---	---	---	---	---
COHE	---	0.67	---	0.56	---	---	---
CRCA	0.0	---	---	---	0.33	---	---
CRSE	2.78	2.11	0.17	---	7.89	3.11	0.67
CYEC	9.56	7.00	---	---	4.39	0.33	---
DACA	2.94	1.56	---	---	1.22	0.39	---
DAGL	---	---	---	---	3.61	---	---
DEDA	---	---	---	---	0.56	---	---
DEME	---	---	---	---	---	---	---
DIFO	0.33	---	---	---	---	---	0.50
DISM	3.94	---	---	---	---	---	---
DISY	---	---	---	---	---	---	---
EPAN	---	---	---	---	---	---	---
EPMU	0.56	1.33	1.67	---	0.56	2.67	0.33
EPPA	4.50	3.39	0.08	---	---	1.00	---
ERMI	0.06	0.28	0.25	---	1.89	0.56	0.5
FEOC	---	---	---	0.50	---	1.00	---
FERU	---	---	---	---	---	---	---
FESU	---	---	---	---	---	---	---
FRVE	---	---	---	0.33	---	---	---
GATR	30.78	17.94	20.7	2.56	30.1	11.6	27.16
GEDI	---	---	---	---	---	0.33	---
GERO	---	---	---	---	3.39	1.00	0.0
GOOB	---	---	---	0.11	---	---	---
HELA	---	---	---	---	---	---	---
HIAL	0.33	0.06	---	0.67	0.17	---	0.50
HOLA	0.78	3.39	---	---	3.78	---	---
HYOC	---	---	---	---	---	---	---
HYPE	0.94	1.89	2.00	---	4.56	4.33	3.0
HYRA	1.83	2.94	0.75	---	3.33	1.33	1.50

	No treatment				Herbicide treatment		
	clearcut	2-story	patchcut	control	clearcut	2-story	patchcut
IRTE	0.28	---	---	---	0.56	---	---
LAMU	0.33	0.50.00	2.17	0.56	1.11	6.72	0.416
LAPO	---	0.33	---	---	1.56	---	---
LASA	0.11	---	---	---	---	0.33	---
LASE	2.06	1.33	0.08	---	---	---	---
LIAP	1.06	0.39	1.50	---	---	0.78	0.08
LIBO	---	---	---	---	---	---	---
LOCI	---	---	---	---	---	---	---
LOHI	0.78	1.17	0.58	1.67	---	---	0.17
LOMI	1.89	0.67	---	---	1.28	0.67	---
LOMU	---	0.06	---	---	0.39	---	0.50
LOPU	---	---	---	---	0.83	---	---
LOUT	---	---	---	---	---	---	---
LUMI	---	---	---	---	0.67	---	---
MAGR	3.94	1.28	---	---	---	---	---
MAOR	---	---	---	---	---	---	---
MASA	---	---	---	---	---	---	---
MOSI	16.39	1.50	16.75	0.39	0.44	0.33	12.5
MOUN	---	---	---	---	---	---	---
MYDI	---	---	---	---	---	---	---
NASQ	---	0.33	---	---	---	---	---
NEPA	1.67	0.33	2.25	---	---	---	2.25
OSCH	2.56	1.39	7.25	2.28	4.17	4.61	2.08
PHPR	---	---	---	---	---	---	---
POGR	---	---	---	---	---	---	---
POPA	---	---	---	---	0.39	---	---
PRVU	---	---	---	---	---	---	---
RAUN	---	---	---	---	---	---	---
SABI	23.06	19.22	1.00	0.11	3.78	0.33	---
SACR	---	---	---	---	0.33	---	---
SADO	5.39	4.56	0.08	---	0.39	0.33	0.17
SEJA	3.72	6.78	3.08	---	5.33	3.39	0.58
SEVU	---	---	---	---	---	---	---
SMRA	---	---	---	---	---	---	---
SMST	---	---	---	0.72	---	---	---
SOAR	---	---	1.00	---	---	---	---
SOAS	2.78	2.39	0.08	---	0.33	2.50	0.17
SODU	---	---	---	---	---	---	---
SOOL	---	---	1.17	---	---	---	---
STME	---	---	---	---	---	---	---
SYRE	---	---	---	0.56	---	---	---
TAOF	---	---	---	---	0.56	---	---
TEGR	---	---	---	---	---	---	---
THOC	0.06	---	---	---	---	---	---
TOME	---	---	0.08	---	---	---	0.33
TRCA	---	---	---	---	---	---	---

	No treatement			Herbicide treatment			
	clearcut	2-story	patchcut	control	clearcut	2-story	patchcut
TRDU	---	---	---	---	---	---	---
TRLA	---	0.44	0.5	1.72	0.39	1.72	0.67
TROV	---	---	---	---	---	---	---
TRPE	0.44	---	0.08	---	0.39	---	---
VAHE	2.56	0.39	0.17	6.44	0.56	1.44	1.25
VECA	---	---	---	---	---	---	---
VIAM	0.06	---	---	---	---	---	---
VIGL	0.89	---	0.58	---	---	---	---

APPENDIX C

Light Study

It was hypothesized that incoming radiation would differ among the three silvicultural systems. This study was performed to document any light difference occuring among silvicultural systems.

Objective

Determine how silvicultural system (clearcut, two-story and patchcut) differ in the amount of incoming radiation they receive.

Methods

In-coming radiation was measured as "percent sky" using a pair of Licor 2000 Canopy Analyzers. These instruments use a fish eye lens to estimate the amount of sky (percent sky) not obscured by forest overstory. Measuring "percent sky" involves operating one of the Canopy Analyzers in the open (no canopy cover) and the other in the site to be measured. Both Canopy Analyzers record light readings via digital data loggers. Recordings from both Analyzers are compared and the difference between the two are used to calculate relative "percent sky".

Three 100 meter transects were located within the two-story (TS) and clearcut (CC) systems in the Peavy block by picking a random point 50 meters from southern edge of each system traveling north. Percent sky was sampled every 10 meters along these transects for a total of 10 measurements per transect. Patchcuts averaged only 40 meters in diameter; thus, within each patchcut a 25 meter transect bisecting the cut traveling south to north and another transect bisecting the cut from east to west was established and percent sky was measured every five meters along each transect for a total of ten measures in each patchcut.

Analysis

"Percent sky" was calculated independently for each sampling point (every ten meters in TS and CC, every five meters in PC) and averaged over each transect. An analysis of variance test ANOVA was used to test the null hypothesis that there were no significant differences in "percent sky" among the three silvicultural systems. A least significant difference means test was performed to identify significant differences between the silvicultural systems.

Results

The PC had a mean "percent sky" of 43.5 % (se=0.03), significantly ($p<0.05$) lower than both the TS (61.5% se=0.03) and the CC (95.7% se=0.03) which differed significantly from each other ($p<0.05$).

Discussion

A light gradient from a low in PC's, intermediate in TS's and greatest in CC's is clearly evident.

Appendix D

Summary of post harvest silvicultural treatments; including timing of site preparations, planting and all vegetation control treatments. Separate spreadsheets are included for each of the three experimental blocks examined in this study. Within each experimental block treatments are identified by silvicultural system.

Experimental Block and Silvicultural System	Activity	When	Comments
Lewisburg / Clearcut	Slash	10/89	By Hand
	Pile	10/89	D-6 w/rake
	Site prep spray	8/90	1.5 qt. Accord ground broadcast
	Burn Piles	10/90	
	Plant	12-2/91	DF 1-1 308 tpa GF veg. plots 2-1
	Grass/herb Spray	3/91	$ lb Atrazine + 1.5 at. 2,4-D, Aerial
	Mulch paper	4/91	Manual veg. plots 4x4 paper
	Grass/her Spray	3/92	4 lb atrazine + 1.5 qt. 2,4-D, Aerial
	Fall Release Spray	8/92	1.5 qt. Accord + 10 oz. Entry 2, Aerial
Lewisburg/ Two Story	Slash	10/89	By Hand
	Pile	10/89	D-6 w/rake
	Plant	1- 2/91	DF 1-1 352 tpa GF veg. plots 2-1
	Grass/herb Spray	4/91	20 lb Pronone 10G, Aerial
	Mulch	4/91	Manual veg. plots 4x4 paper
	Fall release Spray	8/92	Contract spot spray w/ 2% Accord + !% Entry 2
	Fall Release Spray	9/93	Contract spot spray w/ 1.5 qt. Accord + 10 oz. Entry 2
Lewisburg/ Patches	Slash	7/90	By hand
	Pile/scatter	9/90	D-6 w/rake
	Plant	12-2/91	DF 1-1 221 tpa GF veg plots 2-1
	Grass/herb Spray	4/91	Ground broadcast w/ Atrazine + 1.5 qt. 2,4-D
	Maple Foliar spray	9/91	2.5% Arsenal Contract backpack
	Grass/herb Spray	3/92	Contract Backpack 4 lb atrazine + 1.5 qt. 2,4-D
	Fall Release	8/92	ground Broadcast w/ 1qt. Accord + 10 oz Entry 2
	Grass/herb Spray	4/93	4 qt. Velpar, contract Backpack
	Fall Release	9/93	!% Accord + 3/4% Garlon 4 + 1% morAct. Backpack

Experimental Block and Silvicultural System	Activity	When	Comments
Peavy/ Clearcut	Slash	4/91	By Hand
	Pile	6/91	D-6 w/rake
	Plant	1/92	DF 1-1 311 tpa GF veg plots 2-0
	Mulch	3/92	manual plots 4x4 paper
	Grass/herb Spray	3/92	4 lb Atrizine + 1.5 qt. 2,4-D Aerial
	Fall Release Spray	3/92	1.5 qt. Accord + 10 oz. Entry 2 Aerial
	Grass/herb Spray	3/93	2.66 oz Oust Aerial
Peavy/ Two Story	Slash	4/91	by Hand
	Pile	7/91	D-6 w/rake
	Plant	1/92	DF 1-1 367 tpa GF 2-0 veg plots
	Mulch	3/92	Manual plots 4x4 paper
	Grass/herb	3/92	29 lb Pronone 10G Aerial
	Fall Release	9/92	2% Accord + 1% Entry 2 Backpack
	Maple Foliar	8/92	2.5% Arsenal, Backpack
	Grass/Herb	4/93	3.75 qt Velpar backpack
	Fall Release	9/93	1% Accord + 1% Garlon4 + 1% Moract
Peavy Patch	Slash	1-8/91	by Hand
	Plant	1/92	DF 1-1 234 GF 2-1 veg plots
	Grass/herb Spray	4/91	4 lb Atrazine + 1/5 qt. 2,4-D ground broadcast
	Pile	7/91	D-6 w/rake
	Maple foliar spray	8/91	2.5% Arsenal Backpack
	mulch	3/92	manual plots 4x4 paper
	Grass/herb Spray	3/92	4 lb Atrazine +1.5 qt. 2,4-D or 4qt Velpar Backpack
	Fall Release Spray	8/92	1.5 qt. Accord + 10 oz Entry 2 ground broadcast
	Maple foliar Spray	9/92	2.5 % Arsenal .5% Entry 2 backpack
	Grass/ herb Spray	3/93	4 qt. Valpart, spot
	Manual Release	3/93	
	Fall release	9/93	1 qt. Garlon 4 ground broadcast

Experimental Block and Silvicultural System	Activity	When	Comments
Dunn/ Clearcut	Slash	9/91	by hand
	Pile	9/91	D-6 w/rake
	Plant	1/92	DF P-1 tpa GF veg plots 2-0
	Mulch	3/92	Manual plots, 4x4 paper
	Grass/herb Spray	3/92	4 lb Atrazine + 1.5 qt 2,4-D Aerial
	Grass/herb Spray	4/93	2.66 oz Oust Aerial
	Maple foliar spray	9/93	2.5% Arsenal AC + .5% Surf. Backpack
Dunn /Two Story	Plant	1/92	DF p-1 376 tpa GF veg plots 2-0
	Mulch	3/92	manual plots 4x4 paper
	Grass/herb Spray	3/92	20 lb Pronone 10g Aerial
	Slash	4/92	by hand
	Grass/Herb Spray	4/93	3.75 qt. Velpar spot backpack
	Maple foliar Spray	9/93	2.5% Arsenal AC + .5% Surf. Backpack
Dunn Patches	Plant	1/92	DF P-1 248 tpa GF veg plots 2-0
	Mulch	3/92	manual plots 4x4 paper
	Grass/herb	3/92	4 lb Atrazine + 1.5 qt 2,4-D or 4 qt Velpar Backpack
	Fall Release	8/92	1.5 qt Accord + 10 oz Entry 2 ground broadcast
	Grass/herb Spray	4/93	4 qt Velpar backpack
	Maple foliar Spray	9/93	2.5 % Arsenal AC + .5% Surf. Backpack
	Fall Release	9/93	1qt Garlon 4 or 1% Accord + .75% Garlon 4 + 1% MorAct. ground broadcast