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Initial Vegetative Response to Alternative Thinning Treatments in Second Growth Douglas-fir Stands of the Central Oregon Cascades

Sean A. Bohac, Michael D. Lattig & Gabriel F. Tucker

The Evergreen State College, Olympia, WA 98502

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Abstract

The Young Stand Thinning and Diversity Study was initiated to examine ecosystem level effects of alternative silvicultural systems on forest health and productivity. Typical "commercial thin", "heavy thin", and "light thin with gaps" treatments were implemented with uncut control in four 30-50 year old "second growth" Douglas-fir stands in central Oregon. Our objective was to determine immediate vegetative response to these thinning regimes.

In the first year following treatment, several aspects of stand character were evaluated. Differences in overall plant community structure were observed; results are comparable to other research following disturbance (Crouch 1985, Dyrness 1973). Herb, low shrub and tall shrub cover was highest in control plots with several significant differences between treatments. Bryophyte cover was strongly affected with a nearly linear decline in relation to overstory cover reductions. Tree regeneration was approximately uniform throughout the treatments, except in the smallest classes of hardwood seedlings. Species diversity imitated trends from other disturbances, e.g. fire (Franklin and Dyrness 1973) and clearcutting (Crouch 1985, Dyrness 1973). Colonizing weeds were present in thinned sites yielding a slightly higher value of species richness.

Natural cycles of disturbance and succession produce the diversity of late-successional forests necessary for many plant and animal habitats (Ruggiero et al. 1991). Stand thinning is comparable to natural disturbance in many ways. Our long-term goal is to determine which and to what extent these management strategies will resemble natural forest disturbance and succession, accelerating the return of old growth characteristics in younger managed stands.

Introduction

The Young Stand Thinning and Diversity Study (YST&DS) is a long-term ecological research project designed to study the effects of alternative silviculture techniques on young stands in the central Oregon Cascades. In response to the decline in late-successional or "old growth" habitat in this region, land managers, foresters, and scientists have entered into a cooperative effort to research some of the questions arising from current and past forestry practices and to probe future options. Response variables include tree growth and regeneration, nutrient cycling, plant community diversity and vigor, habitat preservation, and harvest economics.

Stand age, large snags, abundant amounts of downed wood, diverse plant and animal communities, multi-layered canopies and variation in stand densities are key characteristics of late succession habitats (Nyberg et al. 1987, Franklin and Spies 1991, McComb et al. 1993). Variation in age and canopy structure, levels of residual dead wood, and understory plant communities within young stands can be affected by the implementation of alternative management strategies such as those investigated in this study. The YST&DS includes these and other characteristics within its area of attention.

Matching silvicultural strategies to natural cycles of disturbance and succession may assist in preservation of late-seral forest habitat (Guldin 1996, Spies and Franklin 1991, Hansen et al. 1991, Nyberg et al. 1987 , Means 1982). These same authors recognize a lack of data and direct comparisons of thinning treatments with controls of similar aged stands in similar conditions. The YST&DS is one of the first studies to investigate silvicultural thinning treatments on the ecosystem level in Douglas-fir forests of the Pacific Northwest. The "light thin with gaps" treatment serves to open forest canopies in a manner similar to low intensity fires or pathogenic mortality such as root rot. This treatment fosters "gap phase" regeneration, characteristic of late-mature and old-growth stage successional dynamics, as described by Guldin (1996). The "heavy thin" is nearly equal to the "light thin with gaps" treatment in overall number of trees remaining, but leaves an even distribution throughout the stand. Openings, such as those created by our treatments, allow space for regeneration and stand age complexity, multi-layered canopies, and increased richness and diversity of plant communities (Hansen et al. 1995, McComb et al. 1993). The "light thin", the same as a "commercial thin", is commonly implemented in second growth forests in the Pacific Northwest. There is great diversity in the habitat needs of individual species; no one silvicultural treatment can be capable of preserving all these diverse habitats (Guldin 1996, Nyberg et al 1987). Providing forest managers with an arsenal of silvicultural regimes will best conserve habitat in managed lands.

Baseline data for the treatment areas were recorded in 1993. Harvests began in November of 1995 and will continue through summer, 1997. 75% of the treatment areas had been harvested and were surveyed for first year post-treatment results in Summer 1996. The information presented here pertains to data collected in 1996 for botanical components of the study.

The YST&DS data collection will continue over the next twenty years. Wildlife pre-treatment data have been collected, and post-treatment study will begin this summer (1997). Residual woody debris data were collected with botanical data but have not yet been analyzed.

First-year results cannot replace a full-term data set; however, insights about how thinning harvests affect understory plants, tree regeneration (seedlings per acre), overstory cover estimates before the forest reacts to the treatment etc., are valuable pieces of information in understanding the transformation of these forests over time.

The Study Area

The study sites are located in the Willamette National Forest OR, USA within the Blue River, McKenzie and Oakridge Ranger Districts. This region is located in the *Tsuga heterophylla* vegetation zone (Franklin and Dyrness 1973) on the western slope of the Cascade Range (approx. 45 miles East-Southeast of Eugene, OR). This region receives approx. 2000 mm of rainfall annually with only 5% falling between July and August. The average yearly temperature is 10.1C, 1.6C in January and 18.9C in July. Soils are generally well developed on a tertiary volcanic substrate (Zobel et al. 1975).

Treatment areas were selected for stand characteristic homogeneity of age, stand index, soil class, treatment size, dominant plant community type, slope and elevation (Table 1). The pre-treatment stand compositions were "typically 90% Douglas-fir, with western hemlock, western redcedar, incense cedar, red alder, bigleaf maple, chinkapin and Pacific yew present in varying amounts. Before treatment, the stands averaged 45 years old, 250 trees per acre, 80 feet tall, and 10-12 inches in diameter. Most sites were starting to incur mortality from competition." (Hunter 1993).

Table 1. Treatment Area Stand Characteristics

TAC	Ranger District	Location	Thinning Treatment	Area acre	Stand Age	Site Index(2)	Soil Type(1)	Dominant Plant Assoc.	Elev. m	Slope %	Data includ.
1	Blue River	Cougar Res.	Control	74	40	107	23	Tshe/Gash	804	18.8	*
2	Blue River	Cougar Res.	Heavy	48	40	105	235 & 231	Tshe/Bene	792	24	*
3	Blue River	Cougar Res.	Light	92	38	107	235 & 253	Tshe/Bene	609	17.1	*
4	Blue River	Cougar Res.	Lt. w/ Gaps	36	40	105	235 & 231	Tshe/Bene	792	16	*
5	McKenzie	Mill Ck.	Control	130	42	105	23 & 236	Tshe/Bene	902	21.1	*
6	McKenzie	Mill Ck.	Heavy	86	42	105	142	Tshe/Bene	658	22.9	*
7	McKenzie	Mill Ck.	Light	92	43	105	14 & 63	Tshe/Bene	524	20	*
8	McKenzie	Mill Ck.	Lt. w/ Gaps	49	42	106	15	Tshe/Bene	438	8.9	
9	Oak Ridge	Christy Flats	Control	76	39	117	14	Tshe/Bene	877	6.2	*
10	Oak Ridge	Christy Flats	Heavy	50	36	120	14	Tshe/Bene	905	0	
11	Oak Ridge	Christy Flats	Light	79	39	117	14	Tshe/Bene	902	5.3	
12	Oak Ridge	Christy Flats	Lt. w/ Gaps	96	40	118	14	Tshe/Bene	905	5.3	*
13	Oak Ridge	Sidewalk Ck.	Control	126	37	114	132	Tshe/Rhma-Gash	634	11.4	
14	Oak Ridge	Sidewalk Ck.	Heavy	47	35	115	132	Tshe/Rhma-Gash	652	16	*
15	Oak Ridge	Sidewalk Ck.	Light	55	33	122	132	Tshe/Rhma-Gash	646	21.8	*
16	Oak Ridge	Sidewalk Ck.	Lt. w/ Gaps	75	39	111	132	Tshe/Rhma-Gash	670	14.5	*

1. See Willamette National Forest, Soil Resource Inventory Guide
2. Dominant tree height at 50 years, King's Site Index Tables

The study consists of 4 thinning treatments; "heavy thin" (target 50-55 residual trees per acrea [tpa]), "light thin" (target 100-120 residual tpa), "light thin with gaps"- same as the light thin with about 20% of the stand consisting of 0.5 acre openings, and the control (no treatment). Each of the four stand treatments were implemented in close proximity to one another in four blocks. Treatment areas (TACs) contained between 15-30 plots and averaged 75 acres in size. Sample plots represent 5-10% of the total treatment area. Following harvest, heavy and light thin w/gap treatments will be underplanted with coniferous species. Variation between blocks, and in some cases treatment areas of the same block, include aspect, dominant understory plant association, slope and harvest method. Ground based skidding, cable and mechanized (harvester-forwarder) harvest systems were used in these stands. 75% of all tratment areas had been sampled by 9-96 (TACs 1-7,9,12,14-16), three areas from each treatment type.

A comparison of observed stand density and targeted stand density is displayed in Appendix A1. Stand density averages in the control treatments have an inherent variation, as great as 18%, from the average of the three treatment areas. Other treatment types show a large variation in density compared to the the prescribed thin. Block 2 (Mill Thin) consistently has the largest variation from the target of all blocks (differing up to +47%). The differences are a result of

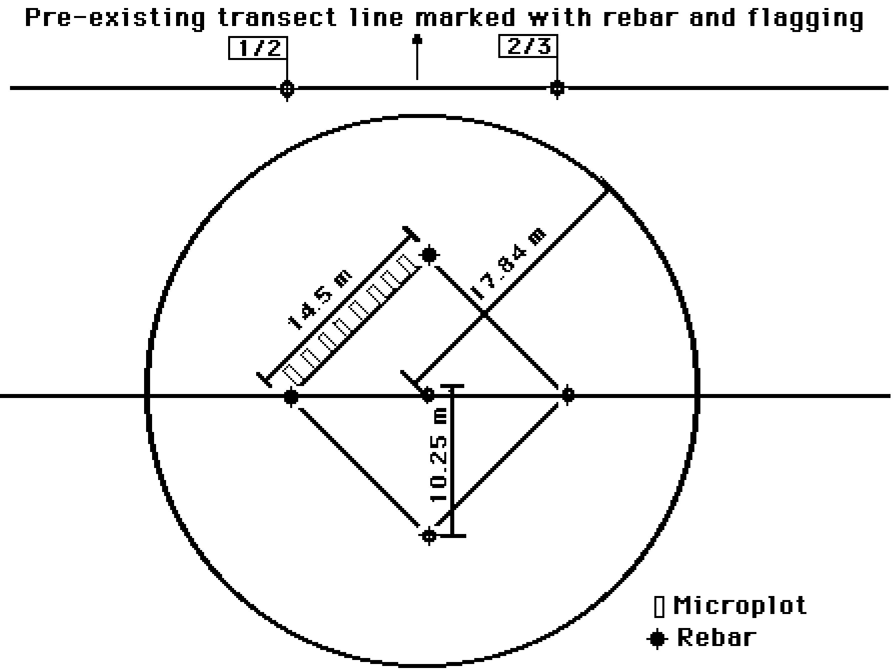


Figure 1. Plot design and layout

natural variation in stand density across the landscape and inconsistency in timber marking. Though we feel it important to note,we have made no attempt to correct the data analysis to account for this inconsistency.

Methods

Parallel North-South or East-West transect lines were established in each treatment area, >66 feet apart, in conjunction with pretreatment sampling (see Fig. 1). Tagged rebar markers were established every 66 feet (1 chain) along each transect. The area between rebar stakes constituted one plot. Plots were randomly chosen to obtain a 5-10% sample of each treatment area. Permanent plots were then installed consisting of square plot skeletons (47.6 ft [14.5m] per side) nested within 0.247 acre (0.1 ha) circular macroplots centered on transect line. To avoid plot overlap, adjacent plots were disallowed.

The plot layout for the "light thin with gaps" treatment was unique. In order to sample from each part of the treatment individually e.g. 0.5 acre gaps, gap edges, and light thin interior, plots where randomly selected in each of these portions of the treatment. In all gap thin treatments there were 30 total plots, 10 from the matrix (interior), 10 centered on the edge of the gap, and 10 centered in the gap itself.

In each plot several variables were measured. Overstory canopy density was assessed with a densitometer device, the "moosehorn"(Cook et al. 1995) at each of five plot rebar points (N,S,E,W, and C). Tall shrubs and overstory species < 2"(5cm) dbh were not included in estimates.

Understory tree (<2 in [5cm] dbh) and tall shrub cover was determined by line intercept sampling (sample size= 93.5 ft/plot). Randomly generated transect pairs, (NE/SW or NW/SE) designated plot sides on which transect lines were established (two per plot). Individual species line intercepts were determined by visually projecting a vertical line from the first intersection of shrub foliage to the last intersection (excluding gaps of < 5cm). Individuals of the same species that overlapped or gapped < 5 cm were counted within the same intercept points (start/stop pair). (Bonham, 1991).

Understory vegetation cover (herbs and low shrubs) was examined using 0.66 x 1.64 ft (0.2 x 0.5m) Daubenmire frames along the same transect lines that tall shrub data was collected. Microplots were placed at intervals of 5.25 ft (1.6 m) (see figure 1). Eight microplots on each 47.6 ft transect line were sampled; thus individual plots contained 16 microplots (17.3 total ft^2/plot), in which cover percentages for herb, low shrub, and bryophytes were estimated.

All herbs and low shrubs were identified to genus or species; Bryophytes were included in a generic category. Determination of growth habit, i.e. "tall shrub", "low shrub", or "herb" followed "Species Codes and Growth Form Assignments: Draft List for Umpqua National Forest" (prepared by Don Minore and Dan Luoma). Ferns were included in the low shrub category for our analysis.

Species presence was recorded within the 0.247 acre circular plots. This list included herbs, shrubs, and trees present but not recognized by other sampling methods. The whole plot species list was implemented for a more accurate sample of species richness.

Seedling and sapling tallies were recorded inside 47.6 x 4.92 ft(14.5 x 1.5m) strip quadrats (486 ft^2/plot). One edge of each strip plot was delineated by the vegetation transects used earlier. Tallies of all seedlings and saplings rooted within the strip quadrats were recorded. Furthermore, broadleaf and conifer seedlings and saplings were subdivided into six size classes: **Class 1** - 3.94 - 7.87" (10-20cm), **2** - 7.87 - 19.69" (20-50cm), **3** - 19.69 - 39.37" (0.5-1.0m), **4** - 39.37 - 78.74" (1.0-2.0m), **5** - 78.74 - 118.1" (2.0-3.0m), **6** - > 118.1" (>3.0m).

Results

The most direct and obvious result of stand thinning is canopy opening. In the control plots the overstory cover (see Figure 2) was consistent with the pre-treatment estimates (data not shown) of 82% (+/-10.3%, n=71). The light thin treatment average was 57% (+/-18.4%, n=54). The averages for the heavy thin and light thin with gaps were similar, 34% (+/-19.7%, n=42) and 31% (+/-24.5% n=68) respectively. ANOVA analysis results define three groups: Control, light thin, and heavy thin & "gap" thin treatments. In the gap treatment, overstory cover had an unexpected distribution (see Figure 3). Gap clearings had cover values near zero as expected, however, the interior and matrix plots

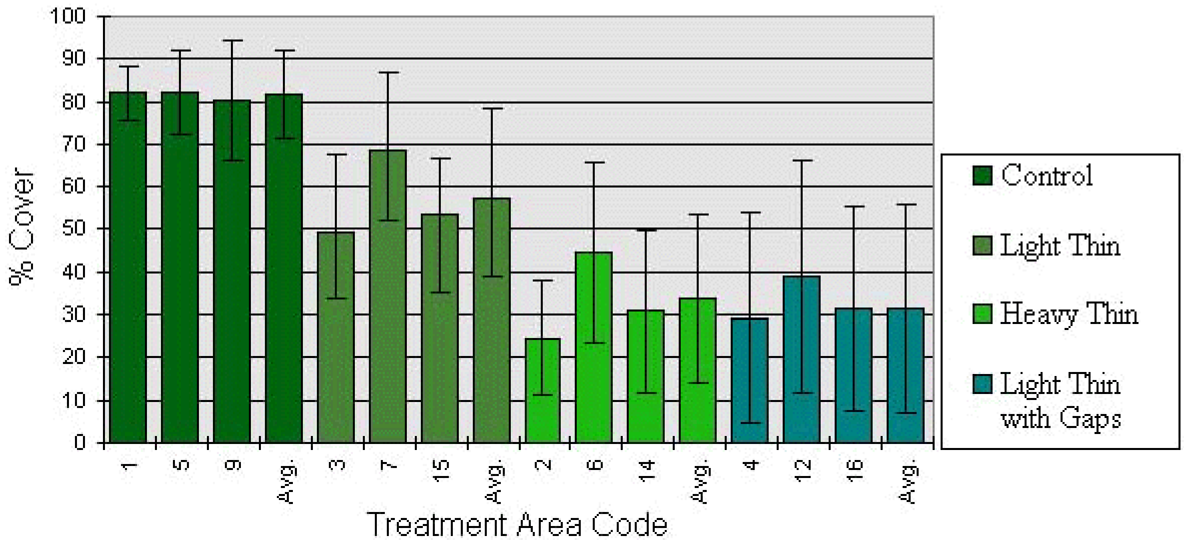


Figure 2 Overstory cover percentages, with standard deviations, are displayed by treatments area. Treatment areas (TAC) are grouped by treatment type, the last bar in each series is a weighted average of plots. ANOVA analysis differentiated three groups:a- Control, b- Light Thin, c- Light Thin with Gaps and Heavy thin, (alpha = .05).

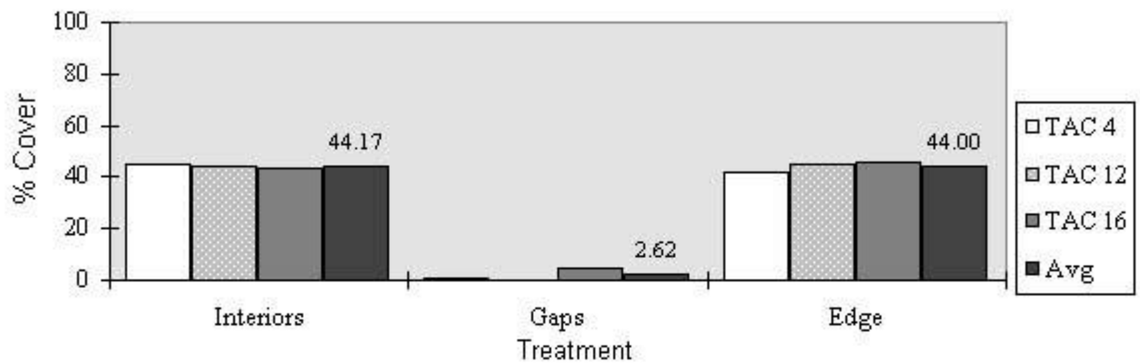


Figure 3 The Gap treatment overstory cover distribution differed from expectation. The light thin interior values were 13.4% lower than the light thin treatment averages. The gap edge values were similar to interior values even though at least one data point out of five in each plot was zero. Early increases in canopy density on gap edges may be a result of increased light penetration to sub-canopy levels.

had a nearly identical mean cover. The matrix interior values were 13.3% lower than the values for the light thin treatments.

Treatment type strongly affected bryophyte cover (see Figure 4). The moss cover values were significantly less than control in all treatments (alpha = .05), light thin averages were significantly higher than the group composed of gap and heavy thin treatments. Moss cover averages had a positive linear relationship with overstory canopy cover (Figure 5).

Cover averages for other growth forms also varied, though with less correlation to canopy cover. Understory canopy structure and species composition varied over the four treatments as well.

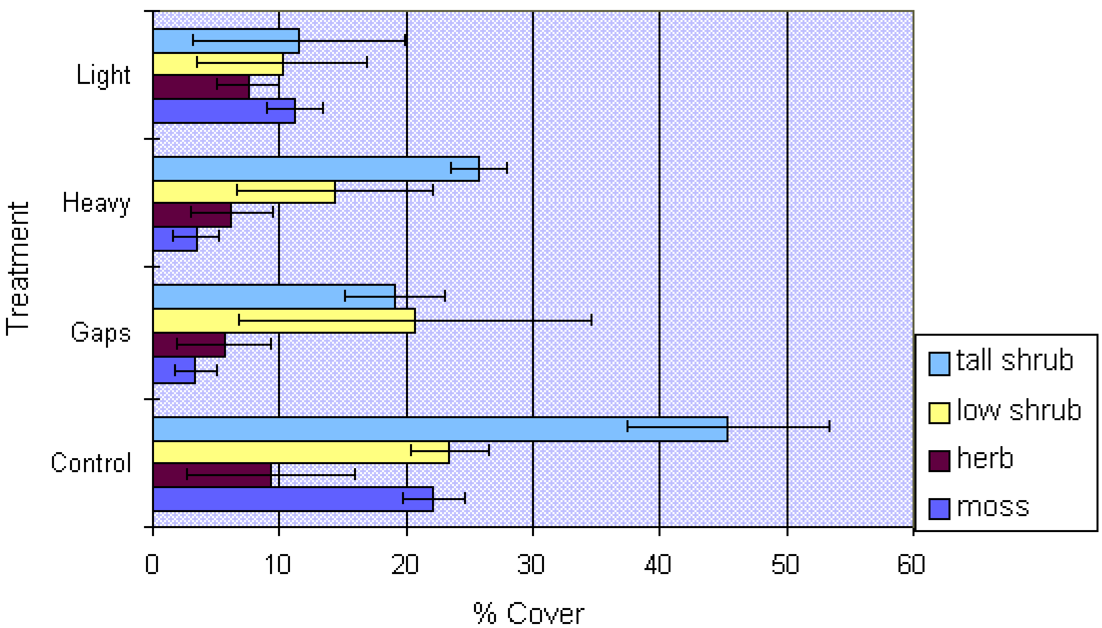


Figure 4 Understory cover estimates are displayed by growth habit in descending order of canopy height. Standard deviation error bars are derived from treatment area averages. Small sample plot size increased standard deviations. See Table 2 for ANOVA analysis results.

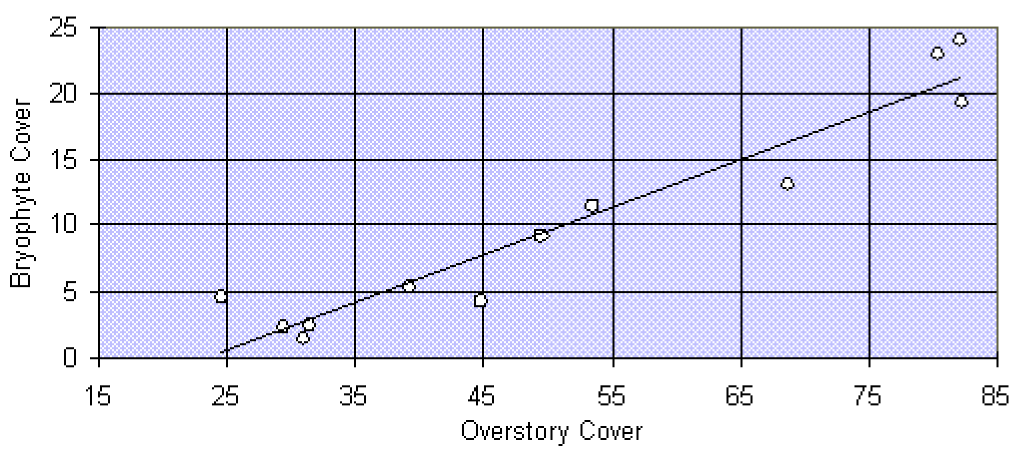


Figure 5 Cover for the "moss" growth habit showed highest dependance on treatment type. Above scatter plot of average bryophyte cover vs. average overstory canopy cover reveals a linear relation (between ca. 30 & 80% overstory cover), correlation coefficient = 0.96.

Thinned sites exhibited an increase in species richness. This increase is largely due to additional pioneering herbaceous species present. *Epilobium* spp, *Senecio sylvaticus*, *Collomia heterophylla*, *Gnaphalium* spp. and *Cirsium* spp. were rarely encountered in controls, but formed a significant presence in thinned sites. The more heavily thinned treatments, gap and heavy thin, consistently had higher frequency values than the light thin for these species.

Table 2 Changes in Species Cover and Frequency

Average cover and frequency values were tabulated for some key ecosystem species and invader species. In several cases frequency increased as cover decreased, most likely due to plant sizes and colonization. Several invader species appeared or increased presence in thinned plots. Causality of differences are obscured by incomplete block data collection.

Species	Control		Heavy		Light		Light w/Gaps	
	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.
Tall Shrubs								
Acer circinatum	37.8	70.4	8.5	92.6	5.6	72.2	10.7	91.3
Rhododendron macrophyllum	2.3	23.9	4.5	48.2	0.9	29.6	2.8	55.4
Vaccinium parvifolium	0.8	56.3	0.7	89.4	0.1	85.2	1.0	77.1
Low Shrubs								
Berberis nervosa	11.6	62.0	7.0	100	4.3	88.9	6.5	97.2
Chimaphila menziesii	*	43.7	*	24.2	*	33.3	*	10.3
Chimaphila umbellata	*	25.4	*	16.7	*	7.4	*	24.7
Gaultheria shallon	5.0	59.2	4.1	96.8	2.5	90.7	7.3	88.1
Linnaea borealis	2.5	56.3	0.9	84.1	0.6	68.5	1.4	67.8
Rubus nivalis	0.3	33.8	*	9.5	*	3.7	0.1	18.0
Rubus ursinus	2.8	62.0	1.8	100	1.8	92.6	3.9	97.2
Whipplea modesta	0.9	46.5	0.3	63.8	0.3	40.7	0.7	74.8
Ferns								
Polystichum munitum	5.1	56.3	2.3	89.6	3.6	96.3	3.5	88.6
Pteridium aquilinum	1.4	46.5	1.4	86.4	1.9	72.2	1.1	66.0
Herbs								
Cirsium vulgare	*	1.4	*	39.9	*	1.9	*	38.1
Collomia heterophylla	-	0	0.1	37.7	*	38.9	0.1	25.0
Epilobium paniculatum	-	0	*	17.9	-	0	*	56.5
Epilobium watsonii	-	0	*	61.4	*	20.4	*	34.5
Gallium triflorum	*	23.9	0.2	81.1	0.2	70.4	0.3	82.7
Trillium ovatum	*	54.9	*	70.7	*	35.2	*	31.7
Senecio sylvaticus	*	1.4	0.1	77.1	*	44.4	0.3	84.0
Vancouveria hexandra	*	35.2	0.1	53.7	*	31.5	0.1	51.3
Viola sempervirens	0.6	56.3	0.2	86.4	0.2	68.5	0.1	69.4

* Value less than 0.05

\- No presence detected

Several species important in vegetation zone classification decreased in thinned areas compared to control: *Berberis nervosa*, *Acer circinatum*, *Polystichum munitum*, *Chimaphila menziesii*, *Achlys triphylla*, *Adendocaulon bicolor* and *Viola sempervirens*. *Vancouveria hexandra*, *Trillium ovatum*, *Rubus ursinus*, and *Whipplea modesta*, common species in the *Tsuga heterophylla* zone, showed no significant change in cover percentages between treatments and control. Frequency and percent cover of selected species are presented in Table 2.

For all growth forms the control plots had the highest cover estimates and a ratio of 5:2.5:1 - tall shrub: low shrub: herb cover. The overall architecture of the understory remained mostly the same (albeit lower cover values) in the heavy thin treatments (4.1:2.3:1 ratio). Low shrubs in the light thin had the greatest difference from the control of all treatments, 57% lower, decreasing from 23.5% to 10.2% cover. The heavy thin showed no significant difference from any of the groups for low shrubs. Tall shrub cover was reduced greatly in all treatments. The light thin showed the greatest reduction at 25% of the control value. Gap and heavy thin treatments were reduced by 58% & 43% respectively. Though there was a reduction in herb foliage cover in the treatments (range- 9.3% in control, 5.6% in gaps), significant herb layer changes did not occur according to ANOVA analysis, alpha = .05 (see Table 3). The gap thin had a canopy component ratio of 3.4:3.7:1 and the light thin- 1.5:1.4:1, nearly even coverage for all growth forms.

Table 3 ANOVA Results for Understory Cover

ANOVA tests were performed using TAC averages(n=3). Particularly large differences existed in Moss and Tall Shrub cover. Canopy opening most likely contributed to the Moss cover averages(see Fig 6). Tall Shrub and Low Shrub values are less likely to be dependent on canopy cover than harvest practice (which varied among treatment areas) so soon after treatment.

Growth Habit	Treatment	Mean Cover %	n	group
Moss	Control	22.13	3	a
	Light Thin	11.27	3	b
	Heavy Thin	3.40	3	c
	Light Thin w/ Gaps	3.35	3	c
Herbs	Control	9.32	3	a
	Light Thin	7.51	3	a
	Heavy Thin	6.23	3	a
	Light Thin w/ Gaps	5.64	3	a
Low Shrubs	Control	23.45	3	a
	Light Thin	10.20	3	b
	Heavy Thin	14.37	3	ab
	Light Thin w/ Gaps	20.63	3	a
Tall Shrubs	Control	45.37	3	a
	Light Thin	11.50	3	c
	Heavy Thin	25.67	3	b
	Light Thin w/ Gaps	19.09	3	bc

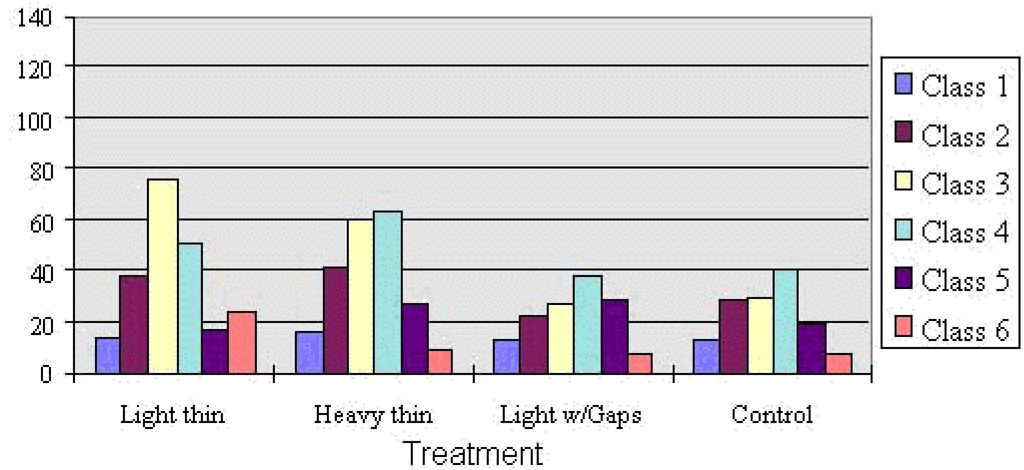


Figure 6a Conifer seedling regeneration (mostly *Tsuga heterophylla & Thuja plicata*) shows normal distribution in all treatments. These results are pre- *Pseudotsuga menziesii* stocking in heavy and light/gaps treatments.

Canopy tree regeneration ratios are displayed in Figure 6a & b. There is little deviation from values in the control plots for coniferous species and a slight rise in stems per acre for broadleaf species. One block of the study had inflated values for the youngest hardwood seedlings in the light thin and heavy thin treatment areas. Coniferous species are evenly distributed amongst the size classes with the largest values in classes 2, 3, and 4 (Fig. 6a). The Control exhibited the greatest density for conifer seedlings/saplings with an average of 219 stems per acre. Number of stems per acre varied little by treatment type. Shade tolerant western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*) and Pacific yew (*Taxus brevifolia*) represent the majority of the coniferous seedling/sapling population within the treatment areas . Shade tolerant species accounted for 94% of species recorded in the light thin, 89% in the control, 87% in the heavy thin, and 66% in the light thin with gaps. Douglas-fir (*Pseudotsuga menziesii*) were most plentiful in "gap" and heavy thin treatments, 34% and 14% respectively.

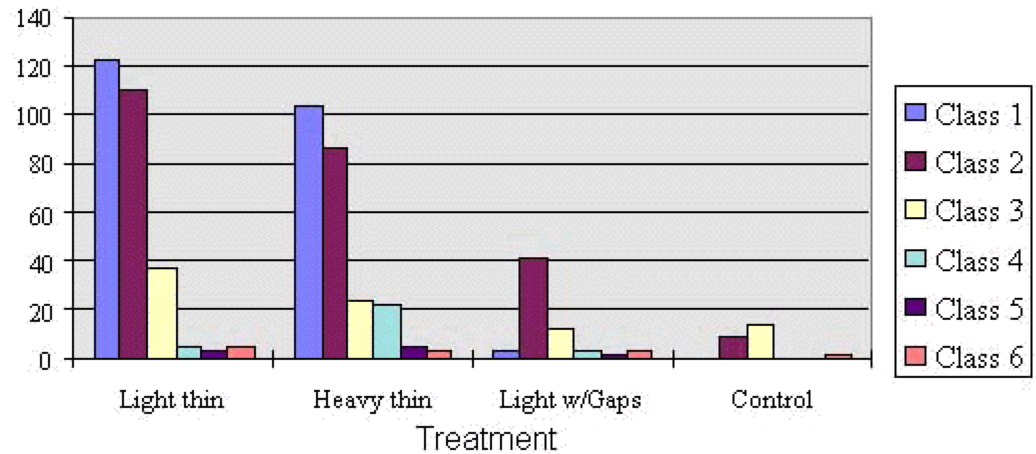


Figure 6b Average size class distribution of broadleaf regeneration. Size class 1 & 2 in the light and heavy thin are skewed by outlying results from block 2, TACs 6 and 7. Excluding these areas results in a normal distribution in each treatment type.

Broadleaf distribution deviated from that of coniferous species. Hardwood species in the light thin and heavy thin had very large values in classes 1 and 2 and high densities compared to the other size classes (Fig. 6b). These values are affected by block two values (McKenzie sites) that heavily skewed the data set. Though we chose to include these values in this report, if block two is disregarded, a normal size class distribution occurs in all four treatment types. "Gap" and control stands have fewer broadleaf species per acre and less variance in the size classes. The most common broadleaf species recorded were bigleaf maple (*A. macrophyllum*), golden chinkapin (*Castinopsis chrysophylla*), cascara buckthorn (*Rhamnus purshiana*), and bitter cherry (*Prunus emarginata*), with occasional presence of black cottonwood (*Populus trichocarpa*), and dogwood (*Cornus nutalii*).

Distribution of overstory trees among diameter classes for density and basal area (ft^2/acre) were calculated as a measure of overall stand structure (data displayed in Appendix A2). The average diameter for all trees recorded in the study was 10.8 in.with 95% of the population falling within $^+/_-$ 5.4 in. of the mean. Medium size Douglas-fir, diameter 10-20 in., account for the majority of basal area in all stands, with a small(<10%) component of hardwoods and other conifer species. Sub-dominant non-Douglas-fir conifers have been reduced greatly in all treatments compared to the control. These shade tolerant conifers and the hardwood species are still present in high numbers in the smaller size classes (dia. 2-6 in.) together comprising >60% of these stems in number and area.

Discussion

Two factors influence stand characteristics following thinning treatments: Increased light intensity reaching sub-canopy levels and logging destruction. As the understory equilibrates with ambient conditions (increased light, lower humidity etc.) changes from logging destruction will have a smaller impact than stand conditions. In work presented by Dyrness (1973), vegetation following clearcut and slash-burning regained some pre-disturbance character after 5 - 6 years. As these data become available, causal relationships for our observations will be more evident.

Important differences between the treatments and the control plots were observed in three areas: Overstory cover, species diversity, and understory characteristics. Thinning generally leads to canopy opening; our plots follow this trend (Figure 2). In the gap treatment there was an unexpected trend in overstory cover of the sub-treatment types (Figure 3). The gap edge values were significantly higher than would be expected since at least one of the five data points for each plot was zero. The high gap edge plot values may be a result of edge effect canopy thickening, though it is unlikely after so brief a period (1-12 months). Alternately, quantitative basal area and stem density results for these plots may show deviation from thinning treatment prescription. Changes in levels of light penetrating the canopy has both constructive and destructive effects on the understory.

Species richness was increased in thinned plots over the control (data not shown). Several colonizing species appeared, utilizing increased sunlight levels and soil disturbance in thinning treatments, similar trends were observed by Franklin & Dyrness (1973). Most herbacious species and several low shrubs typically have small canopies making quantitative analysis difficult. For these species, the presence/absence differences are more descriptive of stand character. Table 2 shows distinct increases in presence of *Epilobium* and *Senecio* species. Invading species typically peak and decline 2-10 years after disturbance (Dyrness 1973). Key species in the *T. heterophylla* zone were variously affected. Trends in species composition through the treatments show little commonality.

Sub-canopy architecture varied by treatment type. As shown in Figure 5 bryophyte cover averages declined linearly with overstory cover. This phenomenon appears to be directly related to dehydration mortality. As seen in Figure 4 the control plot shows a trend of decreasing cover with canopy height. In the heavy thin, this trend is preserved albeit with lower cover percentages.

The gap treatment showed similar values in all growth habits except tall shrubs, which was decreased. The light thin was most divergent in canopy architecture from the control plots, in that all four growth form cover averages were nearly equal.

Conclusion

Vegetative response following clearcutting is well documented (Crouch 1985, Dyrness 1973, Franklin and Dyrness 1973). Interest in ecosystem level management has drawn attention to the lack of understanding of alternative thinning treatments. Here, three alternative treatments designed to promote late-successional stand characteristics were compared. One year following harvest, minor changes in understory structure of herbs and low shrubs were observed. Tall shrub and moss growth habits were impacted the greatest among all subcanopy constituents examined. Bryophytes were particularly sensitive to canopy openings resulting in a dramatic reduction in cover. Species richness increased as a result of thinning treatments. Invading herbs accounted for the majority of new species arriving in the recently disturbed sites. Some species decreased in frequency and cover while others appeared to benefit from increased light levels and soil disturbance. Moreover, the thinning techniques did not result in species eradication, all species encountered in the control were recorded within treatment areas. Though some effects were noted, subsequent data collection and analysis is necessary before reaching a solid ecological understanding of these thinning treatments.

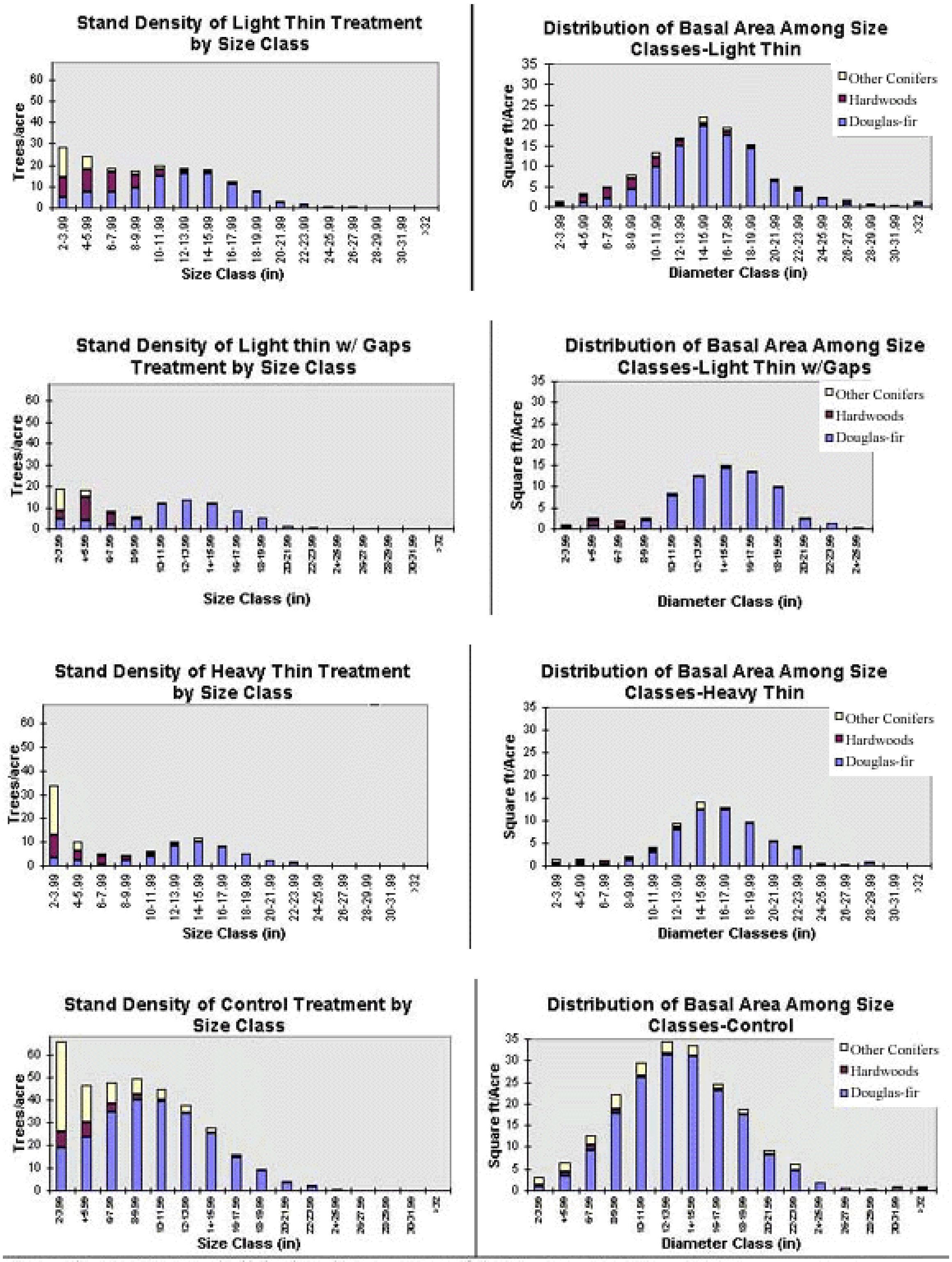
Appendix

Appendix A1 Variation in Trees per acre From Thinning Prescription

Treatment	Control			Light			Heavy			Gap		
Block	observ.	target	var	observ	target	var	observ.	target	var	observ.*	target*	var*
Cougar Res.	266	x	2%#	123	100-110	12%	51	50-55	0	77	80-88	-3%
Mill Thin	215	x	-18%#	152	100-110	38%	81	50-55	47%			
Christy Flats	308	x	18%#							76	80-88	-6%
Sidewalk Creek				100	100-110	0	46	50-55	-8%	77	80-88	-4%
mean	261	x	x	130	100-110	18%	59	50-55	7%	77	80-88	-4%

Value for control is based on variation from average

* Target for gaps is based on 80% of the Light Thin target leave trees per acre. The Light Thin with Gaps is 20% clearcut gaps by area and 80% light thinned (100-110 tpa). Observed values = (0.8 x interior plot avg/acre) + (0.2 x gap plot avg/acre).



Appendix A2 Measured Silvicultural Parameters of the Treatments Both the X & Y axis are equalized to show differences between treatments. Decreases in basal area and density follow expected pattern. Distribution of trees and basal area show patterns typical of even-aged stand.

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