Research Bulletin No. 10

NATURAL REGENERATION *on* STAGGERED SETTINGS

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ABSTRACT

In recent years much of the logging in the Douglas fir region has been by the staggered setting system. Consequently, the effects of this system upon natural coniferous regeneration have become increasingly important. This study was designed to analyze the effects of setting size and environmental factors upon natural regeneration of Douglas fir (*Pseudotsuga taxifolia,* Poir) and associated coniferous species.

A number of settings in western Oregon were examined in 1953 and 1954. The following data were recorded for each mil-acre plot studied: number, age, and species of coniferous reproduction; distance from seed source; intensity of burn; intensity and type of plant cover; amount of slash; seedbed condition; and exposure.

The effect of each of these factors was evaluated by statistical analysis of the field data. The results of the analysis indicated that:

1. There was no correlation between setting size and distance from seed source; there was little correlation between distance from seed source and occurrence of coniferous reproduction; therefore, no correlation exists between size of a staggered setting and speed of restocking.
2. For a given mil-acre plot the following environmental factors are favorable to the establishment of coniferous reproduction: no burn, northerly exposures, light slash cover, light herbaceous cover.
3. For a given mil-acre plot the following environmental factors are not favorable to the establishment of coniferous reproduction: any degree of burn, southerly exposures, medium or heavy slash, and heavy herbaceous cover or woody plant cover.

INTRODUCTION

Foresters in the Pacific Northwest have long realized that an adequate seed source is one of the essentials for natural reforestation of cut-over and burned-over lands. Just what constitutes an adequate seed source in the Douglas fir region, however, has been a moot question for years. Bever (4) made a thorough review of the literature pertinent to the subject of natural seed source in the Douglas fir region and, therefore, no attempt to duplicate his review will be made in this paper.

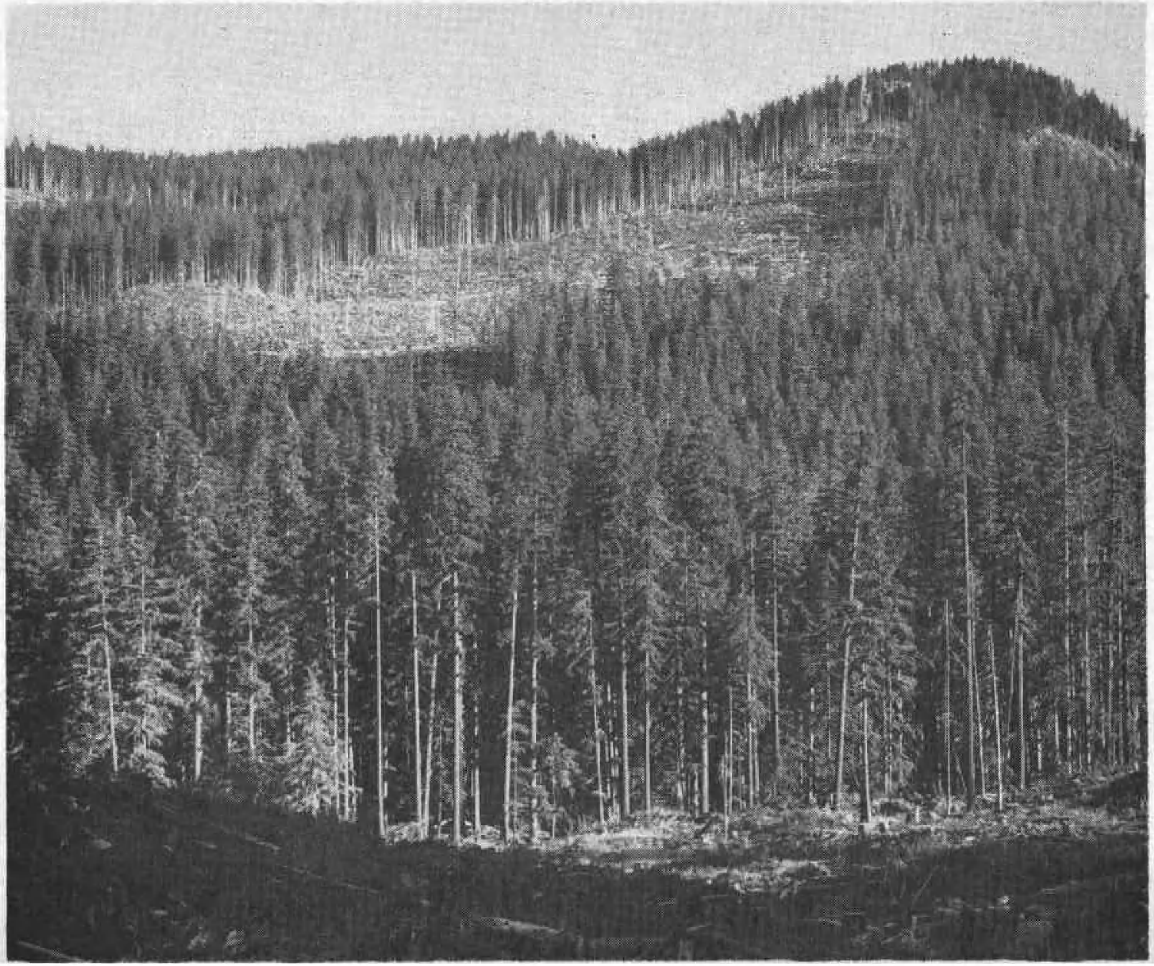
One of the problems of determining the optimum size for a single clear-cut area, where timber is being harvested by the staggered setting method, is the evaluation of the effect of the size of the setting on the amount and the species of restocking and the rapidity of restocking.

The purpose of this study was to determine, for the Douglas fir forest type of western Oregon, what relationship exists between size of the staggered setting and each of the following:

1. Amount of coniferous reproduction.
2. Composition of coniferous reproduction.

The first section of the report outlines field survey methods and compilation and analysis of the data. This was prepared by Denis P. Lavender, Oregon State Board of Forestry, and Morris H. Bergman, Willamette Valley Lumber Company, Dallas, Oregon.

The section on Statistical Analysis by Dr. Lyle D. Calvin, Statistician for the Oregon State Agricultural Experiment Station, Corvallis, Oregon, discusses the statistical methods and formulae employed in developing the analysis. In addition, a tabular summary of the results of the analysis is presented.



EXAMINATION OF STUDY AREAS

Selection of Areas

Since it was impracticable to log areas and then study them for a period of years, it was decided to examine representative areas which had been previously logged. The original study plan specified a survey of approximately 30 settings varying in age from 4 years to 11 years (oldest staggered settings in western Oregon). However, the authors were able to locate only 13 suitable settings in this age group which had not been planted. These settings are located in the Oregon Cascades and Coast Range between 1500 and 4000 feet elevation. Three thousand two hundred and forty-one (3,241) one mil-acre plots were examined intensively in these settings.

For the purpose of this study a staggered setting (see Plate 1) was defined as a cut-over area less than 160 acres in extent and completely surrounded by timber. All areas studied met these requirements.

Sampling Methods

Stocking surveys were made on the areas selected in the manner described by Bever (2). Four mil-acre circular plots, each subdivided into one mil-acre quadrants, were spaced two chains apart on lines parallel to and perpendicular to the long axis of each study area. Each line was located 10 chains from adjacent parallel lines (Figure 1).

DATA RECORDED FOR EACH MIL-ACRE PLOT

The data recorded on each plot are described hereunder.

*Cover Class

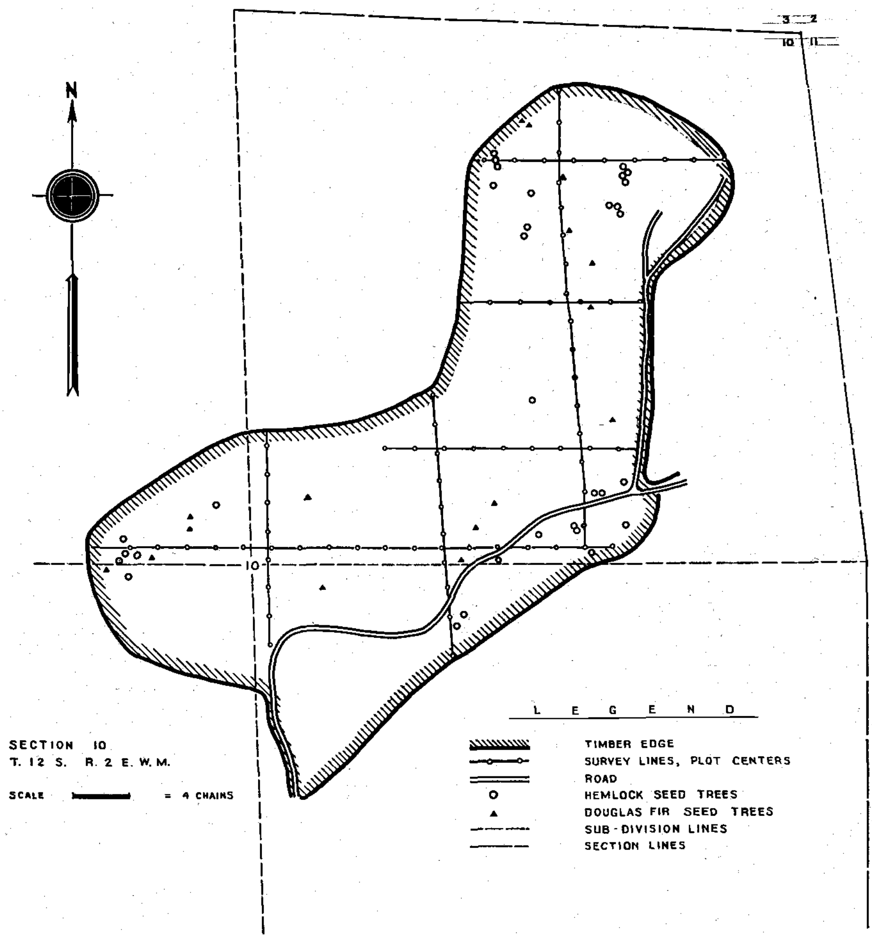
No cover

0-33% herbaceous cover	0-33% woody cover
33-66% herbaceous cover	33-66% woody cover
More than 66% herbaceous cover	More than 66% woody cover

Most of the one mil-acre plots supported a mixed cover of herbaceous and woody vegetation. When this condition occurred the extent of all plant cover was estimated and recorded as being entirely composed of the predominant class (See Plates 2-5). In all cases the estimation of the extent of plant cover was made in the following manner:

1. The percentage of the one mil-acre plot which was covered

* See Appendix for table of plant species noted on experimental plots.



A TYPICAL STAGGERED SETTING

FIGURE I.

with sufficient slash to prevent the establishment of coniferous seedlings was noted and excluded from the estimate.

2. The percentage of the remaining area which was masked by living plant cover was noted and recorded (i.e., if a mil-acre plot was 25% covered with slash and supported a living plant cover on 50% of the remaining area, it was recorded as 50% plant cover).

Plate 2. Close-up of a portion of the staggered setting shown in Plate 1. Foresters classed the slash burn on this setting as "hard" or "heavy". Even so, approximately 50 per cent of the mil-acre plots examined on this setting were classed as "light" burn or "no" burn. The average classification of the area photographed is "medium". Both "heavy" burn and "no" burn plots were tallied. Slash cover varies from 0 to 75 per cent, with an average of approximately 25 per cent. Plant cover also varies from 0 to 75 per cent, with a mean of 25 per cent.

Slash Class

As used in this report "slash" is defined as any debris resulting from logging operations.

No slash
0-25% slash
25-50% slash
50-75% slash
75-100% slash
100% slash

The extent of slash cover for each one mil-acre plot was based on the percentage of the area on which germination and survival of coniferous reproduction were prevented by mechanical hindrance of slash in contact with soil (See Plates 2-4 and 6-8). Logs and other forms of slash which were suspended above the soil were not included in the estimates of slash cover.

Burn Class

The four classes below refer to the intensity of the slash burn on each one mil-acre plot.

No burn
Very light or light burn
Medium burn
Heavy burn

The estimates of degree of burn were based on evidence which was difficult to evaluate and which was nebulous on the older plots. However, the per cent of plots in each burn classification agrees closely with the data presented by Tarrant (9). The degree of burn was assessed by examining the stumps and logs for fire scars (See Plates 2-4). Where the bark was entirely burnt and the wood badly charred, the plot was classed as a heavy burn. Where no evidence of fire could be noted on the slash, a "no burn" classification was given.

Seed Bed Conditions

Seed bed conditions in most (3,103) of the mil-acre plots examined were considered to be favorable for germination and survival of coniferous seedlings. The ground in the remaining plots (138) was classified as "unfavorable" for seedling establishment for the following reasons:

1. Excessive rotten wood (13 plots)
2. Sloughing soil (29 plots)
3. Solid rock (28 plots)
4. Excessive moisture (57 plots)
5. Excessive broken rock (11 plots)

Plate 3. This plot was classed as having a heavy burn, approximately 25% slash and a "medium" woody plant cover.

These data were recorded in the field to provide assurance that a disproportionate number of "unfavorable" plots did not fall in any of the condition classes studied. A preliminary analysis of the data indicated that the distribution of these plots was random throughout. Consequently the "seed bed" classification was eliminated from the study.

Number and Species of Coniferous Reproduction

The number and species of coniferous seedlings were tallied for each one mil-acre plot. In addition, the estimated age of the oldest seedling of each species was recorded. Occasionally seedlings were pulled up and dissected to check accuracy of the age estimate.

The field data were recorded on standard forms which provided a place to map terrain and seed sources.

Plate 4. The upper half of this plot received a 0-25% slash classification; the lower half, 25-50% slash. The upper left quadrant has "heavy" woody cover; the lower right, "light" woody; and the remaining quadrants, "medium" woody cover. The entire plot was classed as "light" burn.

Plate 5. Heavy cover of mixed herbaceous and woody cover. This photo taken in the coast range. In the Cascades seed bearing plants replace much of the bracken.

Distance from Seed Source

Maps of the settings were obtained from the companies which had logged them. The field data obtained were plotted on these maps (see Figure 1). When plotting was completed, the distances to the nearest uncut timber edge and to seed trees were scaled and recorded for each plot.

AUTOMATIC MACHINE COMPILATION

Field data were coded and transferred to punch cards. All the tables presented, except Tables 16, 16a, 16b and 23, were compiled from summations of data prepared by automatic machines.

Plate 6. Slash covers less than 25% of the area.

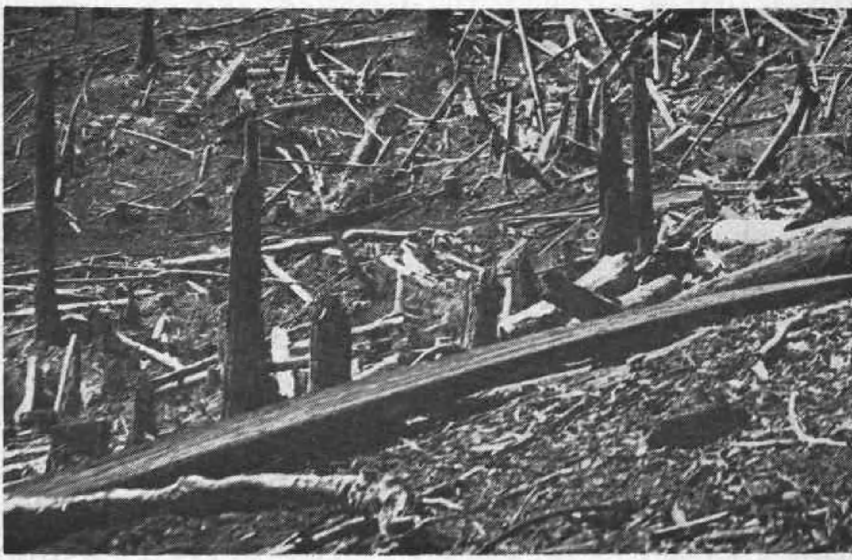


Plate 7. Slash covers 25 to 75% of the area.

Plate 8. Slash cover 50-100%.

RESULTS

Field data and results presented pertain directly to those forest land areas which fulfilled the following conditions:

Size: Less than 160 acres.

Distance from adjacent timber: Less than 15 chains.

Years since logging or slash burning: 4 to 11.

Elevation and Location: 1500 to 4000 feet in the east slope of the Oregon Coast Range or the west slope of the Oregon Cascades north of Oakridge.

The following tables present the field data for each physical condition studied. These tables reflect the relationship of coniferous stocking to each environmental condition studied as determined by the field survey. The data presented in these tables are raw and are not adjusted for the other factors as was done in the statistical analysis (page 26).

The data in the columns headed "Estimated Per Cent Stocked (4 mil-acre)" were obtained by converting the corresponding figures in the columns headed "Per Cent Stocked (mil-acre)" by means of the graphs prepared by Bever and Lavender (3).

Composition of Coniferous Reproduction by Species

On all study areas the predominant coniferous reproduction was Douglas fir. This dominance occurs even where west coast hemlock *(Tsuga heterophylla)* is a considerable portion of the adjacent timber. Noble fir *(Abies procera)*, western red cedar *(Thuja plicata)*, and incense cedar *(Libocedrus decurrens)* were only sparsely represented.

Stocking at Various Distances from Seed Source

An examination of the raw field data and the statistical analysis indicate that the rate of restocking of an area is reduced only slightly with increase in distance from seed source. A corollary to this observation is that stocking was reduced only slightly with increases in the size of settings. In fact, setting size may be varied several fold by increasing the length of the long axis of the setting without increasing the distance to a seed source for any point in the setting.

TABLE I

TOTAL CONIFEROUS STOCKING BY CHAINS FROM NEAREST SEED SOURCE

Chains from Seed Source	Stocked Plots	Non-Stocked Plots	No. of Seed-lings	Per Cent Stocked (Mil-acre)	Estimated Per Cent Stocked (4 Mil-acre)	Seed-lings per Mil-acre Plot
1	168	147	661	53	89	2.10
2	156	165	499	49	83	1.55
3	200	211	735	49	83	1.79
4	164	208	460	44	76	1.24
5	260	387	738	40	70	1.14
6	131	169	357	44	76	1.19
7	119	154	365	44	76	1.34
8	84	132	276	39	70	1.28
9	77	104	186	43	74	1.02
10	35	65	151	35	64	1.51
11	21	36	77	37	67	1.35
12	6	22	6	21	45	0.21
13	5	3	12	62	<95	1.50
14	3	5	4	37	68	0.50
15	1	3	1	25	50	0.25
TOTAL	1,430	1,811	4,528	MEAN 44	76	1.40

TABLE 2

TOTAL DOUGLAS FIR STOCKING BY CHAINS FROM NEAREST SEED SOURCE

Chains from Seed Source	Stocked Plots	Non-Stocked Plots	No. of Seed-lings	Per Cent Stocked (Mil-acre)	Estimated Per Cent Stocked (4 Mil-acre)	Seed-lings per Mil-acre Plot
1	126	189	310	40	71	0.98
2	98	223	176	30	58	0.55
3	162	249	351	39	70	0.85
4	120	252	216	32	61	0.58
5	210	437	435	32	61	0.67
6	101	199	196	34	63	0.65
7	85	188	156	31	59	0.57
8	65	151	117	30	58	0.54
9	61	120	98	34	63	0.54
10	28	72	66	28	54	0.66
11	18	39	36	32	60	0.63
12	5	23	5	18	38	0.18
13	5	3	9	62	<95	1.12
14	3	5	3	37	68	0.37
15	1	3	1	25	50	0.25
TOTAL	1,088	2,153	2,175	MEAN 34	64	0.67

TABLE 3

TOTAL WEST COAST HEMLOCK STOCKING BY CHAINS FROM NEAREST SEED SOURCE

Chains from Seed Source	Stocked Plots	Non-Stocked Plots	No. of Seed-lings	Per Cent Stocked (Mil-acre)	Estimated Per Cent Stocked (4 Mil-acre)	Seed-lings per Mil-acre Plot
1	93	222	290	30	57	0.92
2	99	222	273	31	59	0.85
3	99	312	271	24	48	0.66
4	74	298	195	20	42	0.52
5	107	540	249	17	37	0.38
6	64	236	124	21	43	0.41
7	66	207	187	24	48	0.68
8	45	171	160	21	44	0.74
9	38	143	86	21	44	0.48
10	16	84	53	16	36	0.53
11	10	47	37	18	38	0.64
12	1	27	1	4	20	0.04
13	1	7	1	6	22	0.12
14	1	7	1	6	22	0.12
15	0	4	0	0	—	0.00
TOTAL	714	2,527	1,928	MEAN 22	45	0.59

Stocking on Various Cover Classes

Tables 4 to 6 present the relationship between coniferous reproduction and living plant cover. The data clearly indicate that the coniferous reproduction associated with other woody plants is much less abundant than that occurring in a predominantly herbaceous cover type, and that this difference in cover type is much more important to establishment of coniferous reproduction than are differences in density of cover. These data are in disagreement with Bever (4) and with Smith (7), who found that the density of cover had a greater effect on the establishment of seedlings than did the composition. However, this disagreement may be caused by differences among the authors in the grouping of data by cover types rather than by real differences in the relationship of coniferous stocking to competing vegetation.

TABLE 4

TOTAL CONIFEROUS STOCKING BY LIVING PLANT COVER CLASS

Cover Class	Stocked Plots	Non-Stocked Plots	No. of Seedlings	Per Cent Stocked (Mil-acre)	Estimated Per Cent Stocked (4 Mil-acre)	Seedlings per Mil-acre Plot
No Plant Cover	38	47	61	45	77	0.72
Herbaceous						
0-33%	215	170	813	56	93	2.11
33-66%	351	260	1,261	57	95	2.06
66-100%	165	177	548	48	83	1.60
Woody						
0-33%	113	175	374	39	70	1.30
33-66%	242	432	701	36	66	1.04
66-100%	307	549	771	36	66	0.90
Total Herbaceous	731	607	2,622	Mean 55	92	1.96
Total Woody	662	1,156	1,846	Mean 36	67	1.02
Total Herbaceous and Woody				Mean		
0-33%	328	345	1,187	49	83	1.76
33-66%	593	692	1,962	46	79	1.53
66-100%	472	726	1,319	39	70	1.10

TABLE 5

TOTAL DOUGLAS FIR STOCKING BY LIVING PLANT COVER CLASS

Cover Class	Stocked Plots	Non-Stocked Plots	No. of Seed-lings	Per Cent Stocked (Mil-acre)	Estimated Per Cent Stocked (4 Mil-acre)	Seed-lings per Mil-acre Plot
No plant Cover	32	53	43	38	68	0.51
Herbaceous						
0-33%	168	217	399	44	76	1.03
33-66%	270	341	576	44	76	0.95
66-100%	110	232	210	32	60	0.61
Woody						
0-33%	99	189	288	34	64	1.00
33-66%	189	485	370	28	55	0.55
66-100%	218	638	361	26	52	0.42
Total Herbaceous	548	790	1,185	Mean 41	72	0.89
Total Woody	506	1,312	947	Mean 28	54	0.52
Total Herbaceous and Woody				Mean		
0-33%	267	406	687	40	71	1.02
33-66%	459	826	948	36	65	0.74
66-100%	328	870	571	38	68	0.48

TABLE 6

TOTAL WEST COAST HEMLOCK STOCKING BY LIVING PLANT COVER CLASS

Cover Class	Stocked Plots	Non-Stocked Plots	No. of Seed-lings	Per Cent Stocked (Mil-acre)	Estimated Per Cent Stocked (4 Mil-acre)	Seed-lings per Mil-acre Plot
No plant Cover	9	76	14	11	27	0.16
Herbaceous						
0-33%	117	268	325	30	58	0.84
33-66%	183	428	563	30	58	0.92
66-100%	114	228	296	33	62	0.87
Woody						
0-33%	47	241	119	16	35	0.41
33-66%	114	560	281	17	36	0.42
66-100%	130	726	330	15	33	0.39
Total Herbaceous	414	924	1,179	Mean 31	59	0.88
Total Woody	291	1,527	730	Mean 16	35	0.40
Total Herbaceous and Woody				Mean		
0-33%	164	509	444	24	48	0.66
33-66%	297	988	844	23	47	0.66
66-100%	244	954	626	19	40	0.52

Stocking on Various Exposures

The data in Tables 7 to 9 confirm the work of previous investigators in this field and substantiates the observation of experienced woodsmen in that northerly slopes are relatively favorable and southerly exposures are relatively unfavorable to coniferous reproduction.

TABLE 7
TOTAL CONIFEROUS STOCKING BY EXPOSURE

Exposure	Stocked Plots	Non-Stocked Plots	No. of Seed-lings	Per Cent Stocked (Mil-acre)	Estimated Per Cent Stocked (4 Mil-acre)	Seedlings per Mil-acre Plot
Flat	218	272	614	45	77	1.25
North	392	242	1,519	62	<95	2.40
N. E.	189	95	727	67	<95	2.56
East	63	121	135	34	64	0.73
S. E.	17	63	30	21	43	0.37
South	43	283	67	13	30	0.21
S. W.	53	215	81	20	42	0.30
West	155	297	445	34	64	0.98
N. W.	300	223	910	57	95	1.74
TOTAL	1,430	1,811	4,528	MEAN 44	76	1.40

TABLE 8
TOTAL DOUGLAS FIR STOCKING BY EXPOSURE

Exposure	Plots Stocked	Plots Non-Stocked	No. of Seed-lings	Per Cent Stocked (Mil-acre)	Estimated Per Cent Stocked (4 Mil-acre)	Seedlings per Mil-acre Plot
Flat	167	323	307	34	64	0.63
North	295	339	650	47	80	1.02
N. E.	139	145	335	49	84	1.18
East	56	128	98	30	59	0.53
S. E.	16	64	18	20	42	0.22
South	44	282	63	13	31	0.19
S. W.	42	226	53	16	34	0.20
West	120	332	222	27	53	0.49
N. W.	209	314	429	40	71	0.82
TOTAL	1,088	2,153	2,175	MEAN 34	63	0.67

TABLE 9

TOTAL WEST COAST HEMLOCK STOCKING BY EXPOSURES

Exposure	Stocked Plots	Plots Non-Stocked	No. of Seed-lings	Per Cent Stocked (Mil-acre)	Estimated Per Cent Stocked (4 Mil-acre)	Seedlings per Mil-acre Plot
Flat	88	402	202	18	39	0.41
North	230	404	727	36	66	1.15
N. E.	110	174	341	39	70	1.20
East	16	168	35	9	28	0.19
S. E.	2	78	4	2	17	0.05
South	5	321	6	2	17	0.02
S. W.	9	259	11	3	18	0.04
West	80	372	205	18	39	0.45
N. W.	174	349	397	33	62	0.76
TOTAL	714	2,527	1,928	MEAN 22	45	0.59

Stocking on Various Slash Classes

Tables 10 to 12 indicate that a slash cover of less than 25 per cent of the plot area is most favorable to coniferous reproduction and that increasing quantities of slash create increasingly unfavorable seed beds. These results are substantially in agreement with the data reported by Bever (4) and by Smith (7).

The data also indicate that plots which had no measurable slash were less favorable to coniferous reproduction than any slash class less than 75 per cent. This situation is substantiated by the statistical analysis of the data (see Table 16). The authors are unable to explain this apparent anomaly but suspect it reflects the dearth of knowledge of the ecology of coniferous seedlings.

TABLE 10

TOTAL CONIFEROUS STOCKING BY SLASH CLASSES

Slash Per Cent	Stocked Plots	Non-Stocked Plots	No. of Seed-lings	Per Cent Stocked (Mil-acre)	Estimated Per Cent Stocked (4 Mil-acre)	Seedlings per Mil-acre Plot
0	64	125	298	34	63	1.58
0-25	829	935	2,700	47	81	1.53
25-50	327	416	935	44	77	1.26
50-75	147	211	450	41	73	1.26
75-100	63	115	145	35	65	0.81
100	0	9	0	00	00	0.00
TOTAL	1,430	1,811	4,528	MEAN 44	76	1.40

TABLE 11

TOTAL DOUGLAS FIR STOCKING BY SLASH CLASSES

Slash Per Cent	Stocked Plots	Non-Stocked Plots	No. of Seed-lings	Per Cent Stocked (Mil-acre)	Estimated Per Cent Stocked (4 Mil-acre)	Seedlings per Mil-acre Plot
0	60	129	166	32	61	0.88
0-25	665	1,099	1,411	38	68	0.80
25-50	231	512	399	31	60	0.54
50-75	90	268	144	25	50	0.40
75-100	42	136	55	24	48	0.31
100	0	9	0	0	0	0.00
TOTAL	1,088	2,153	2,175	MEAN 34	64	0.67

TABLE 12

TOTAL WEST COAST HEMLOCK STOCKING BY SLASH CLASSES

Slash Per Cent	Stocked Plots	Non-Stocked Plots	No. of Seed-lings	Per Cent Stocked (Mil-acre)	Estimated Per Cent Stocked (4 Mil-acre)	Seedlings per Mil-acre Plot
0	28	161	88	15	33	0.47
0-25	372	1,392	1,026	21	44	0.58
25-50	184	559	457	25	51	0.62
50-75	99	259	281	28	54	0.78
75-100	31	147	76	17	38	0.43
100	0	9	0	0	0	0.00
TOTAL	714	2,527	1,928	MEAN 22	45	0.59

Stocking on Various Burn Classes

Data presented in Tables 13 to 15 demonstrate that any degree of burn is deleterious to coniferous reproduction—the heavier the burn class, the less the resultant reproduction. These results are in agreement with data reported by Isaac and Meagher (5), and by Munger and Matthews (6). This condition is true for both Douglas fir and west coast hemlock. Smith (7) found burned areas slightly more favorable, while Bever (4) reported that burned areas were more favorable to coniferous reproduction and that this difference was statistically significant. However, the burn classes referred to by Bever were assigned by 4 mil-acre plots. The present authors believe that such an area is too large to permit proper evaluation of the effects of slash fire on the establishment of individual seedlings. Seedlings might very well grow in the portion of the 4 mil-acre plot unaffected by fire, although the whole plot was classified as "burned". Reduction of the plot size to 1 mil-acre increases the accuracy of classification as it pertains to individual seedlings.

TABLE 13

TOTAL CONIFEROUS STOCKING BY DEGREE OF BURN

Burn Class	Stocked Plots	Non-Stocked Plots	No. of Seed-lings	Per Cent Stocked (Mil-acre)	Estimated Per Cent Stocked (4 Mil-acre)	Seedlings per Mil-acre Plot
No burn	948	787	3,222	55	92	1.86
Light	161	283	354	36	66	0.80
Medium	277	555	874	33	62	1.05
Heavy	44	186	78	19	41	0.34
TOTAL	1,430	1,811	4,528	MEAN 44	76	1.40

TABLE 14

TOTAL DOUGLAS FIR STOCKING BY DEGREE OF BURN

Burn Class	Stocked Plots	Non-Stocked Plots	No. of Seed-lings	Per Cent Stocked (Mil-acre)	Estimated Per Cent Stocked (4 Mil-acre)	Seedlings per Mil-acre Plot
No burn	695	1,040	1,540	40	72	0.89
Light	129	315	199	29	56	0.45
Medium	234	598	399	28	54	0.48
Heavy	30	200	37	13	31	0.16
TOTAL	1,088	2,153	2,175	MEAN 34	63	0.67

TABLE 15

TOTAL WEST COAST HEMLOCK STOCKING BY DEGREE OF BURN

Burn Class	Stocked Plots	Non-Stocked Plots	No. of Seed-lings	Per Cent Stocked (Mil-acre)	Estimated Per Cent Stocked (4 Mil-acre)	Seedlings per Mil-acre Plot
No burn	512	1,223	1,364	30	57	0.79
Light	59	385	123	14	32	0.28
Medium	123	709	399	15	34	0.48
Heavy	20	210	42	9	24	0.18
TOTAL	714	2,527	1,928	MEAN 22	45	0.59

It must be remembered that the above tables apply strictly to mil-acre plots. Tarrant (8) reports that on intensively examined areas of burned slash on the H. J. Andrews Experimental Forest in the Lane County Cascades, 49 per cent of the area was classified as unburned. Data presented which indicate that burned settings are more favorable to reproduction than unburned settings may, therefore, not be at variance with the findings of this study. Slash fires usually burn hardest in concentrations of slash too dense to permit coniferous reproduction. The seed bed created by the fire clearly is not optimum for coniferous seedling establishment but is, however, more suitable for seedling growth than are heavy slash concentrations. Therefore, settings which have been burned will contain unburned and burned microsites which, in sum, may be more favorable to the establishment of coniferous reproduction than are microsites with various quantities of slash on unburned settings.

In any complex ecological system the effects of the individual factors which influence the growth of any one plant species are difficult to define. The sum effect of the physical environment is obvious—if the seed is plentiful and no seedlings are found, the particular micro-environment studied is unfavorable to coniferous reproduction. It is more difficult to determine by inspection which of the various physical factors involved are responsible for the failure of coniferous reproduction. It is impossible, in most cases, to determine the degree to which any one factor makes an environment unfavorable for seedling survival.

Several tables previously presented in this report contain estimates of the effects of individual factors upon seedling establishment and survival. However, even though these tables summarize data for each environmental factor separately, they are still complicated by the effects of the distribution of associated factors; e.g., in Table 13 the heavy burn plots are shown to be much less favorable to seedling establishment than the unburned. Part of this difference may be due to the probability that the heavy burn plots were farther from a seed cource on the average than the unburned plots. It is also possible that the heavily burned plots occurred more frequently on the unfavorable southerly exposures than they did on the more favorable northerly exposures.

SEPARATE EFFECTS OF INDIVIDUAL FACTORS

Table 16 presents the relative effect of each factor taken separately as determined by statistical formulae (see Statistical Analysis, pp. 28-31). The statistical procedure employed enables evaluation of the separate effect of each factor on rate of restocking. The "base stocking factor" has no significance in itself, but is merely a reference point from which estimations of stocking percentages may be computed by adding the appropriate values listed in Table 16 according to the example on the following page.

TABLE 16

EFFECT OF PHYSICAL FACTORS UPON THE ESTABLISHMENT OF CONIFEROUS REPRODUCTION

Field Condition	*Value*
No Burn	0.0816
Burn	
Light Burn	0.0140
Medium Burn	—0.0306
Heavy Burn	—0.0650
Exposure	
Flat	0.0828
NW, N, NE	0.1604
E	—0.0314
SE, S, SW	—0.1460
W	—0.0658
No Slash	—0.2602
Slash	
0-25%	—0.0432
25-50%	—0.0864
50-75%	—0.1296
75-100%	—0.1728
No Cover	—0.0852
Cover	
Herbaceous Cover	
0-33%	—0.0582
33-66%	—0.1164
66-100%	—0.1727
Woody Cover	
0-33%	—0.0979
33-66%	—0.1958
66-100%	—0.2938
Distance (Chains from Seed Source)	—0.0127/chain
Years since Logging or Burning	0.0497/year
Base Stocking Constant	0.3404

The following example illustrates the effect of factors studied upon natural regeneration. The values presented in Table 16 are used to evaluate the rapidity of natural restocking for a given area. Assume an area with the following average conditions: medium burn, east exposure, 25-50% slash, 33-66% herbaceous cover, 3 chains from seed source, burned 7 years ago. The coniferous stocking (by mil-acres) expected would be:

	+	—
Base Stocking factor	0.3404	
Medium burn		0.0306
East Exposure		0.0314
25-50% slash		0.0864
33-66% herbaceous cover		0.1164
3 chains from seed source (3 x 0.0127)		0.0381
7 years since burning (7 x 0.0497)	0.3479	
Total	0.6883	0.3029

.6883 — .3029 = 0.3854 or 39% stocking by mil-acre

Had this same area been 13 chains from a seed source, the stocking would have been 38.5% — (10 x 0.0127) or 26%. Obviously, it would be impractical to evaluate a logged or burned area in such detail. These values do, however, indicate the relative ease with which areas with predominant burn, slash, cover types, and exposures will restock to the native coniferous species. In addition, the data indicate the small effect which distance from seed source has upon restocking when compared with that of all other factors studied.

SUMMARY AND CONCLUSIONS

The following results are evident from the analysis of the data presented in this report:

1. There is no correlation between setting size and distance from seed source; there is little correlation between distance from seed source and occurrence of coniferous reproduction; therefore, no correlation exists between size of a staggered setting and the speed of restocking.
2. The data indicate that the rate of restocking is uniform over the period of years covered by this report. This may be due to two factors:
   (a) All the years except 1949 had light to medium coniferous seed crops.
   (b) An estimate was made of the age of only the oldest seedling of each species in each plot. Therefore, any younger seedlings which may have resulted from subsequent seed crops would not be credited to these years. Thus, there may have been considerable differences in total numbers of seedlings resulting from a given seed year, even though the increase in "stocking per cent" each year remained relatively constant.
3. For a given mil-acre plot the following environmental factor classes are favorable to the establishment of coniferous reproduction: "no burn," "northerly exposures," "light slash cover," "light herbaceous cover."

4. For a given mil-acre plot the following environmental factor classes are unfavorable to the establishment of coniferous reproduction: "any degree of burn," "southerly exposures," "medium" or "heavy" slash, and "heavy herbaceous cover" or "woody cover."

DISCUSSION

An examination of the data presented in Table 16 will reveal the relative effects of the several environmental factors studied upon the abundance of coniferous reproduction. For example: assume a plot with a northerly exposure, unburned, 20% slash cover, 25% herbaceous cover, and one chain distant from seed source. Any one of the following changes in the environment of the plot would have a greater tendency to reduce the expected coniferous regeneration than would an additional 10 chains distance from seed source: "unburned" to "heavy burn;" "northerly" to "easterly" exposure; 20% "herbaceous cover" to 50% "woody cover."

Table 23 lists nine of the thirteen settings which are 50 acres or more in extent. Yet only 1 per cent of the plots examined were in excess of 12 chains from a seed source. Apparently, therefore, within these limitations the size of a setting has only a minor effect upon natural regeneration compared to environmental factors such as cover, exposure, or burn.

Logging practices at the time most of these settings were cut resulted in leaving a few scattered seed trees. Because many of these trees would be logged today, the effect of seed trees upon resulting stocking should be considered. Since the occurrence of seed trees is random with respect to the environmental factors studied, these trees could modify only the "stocking with respect to distance from seed source" data. On 80 per cent of the areas studied, an average of approximately one Douglas fir seed tree per eight acres was noted (many of these trees were close to the timber edge). The remaining 20 per cent had a much greater number of seed trees, an average of nearly one Douglas fir per acre. However, these settings had a lower stocking percentage than did those of the same age with fewer seed trees. An analysis of the field data revealed no relationship between the incidence of Douglas fir seed trees and Douglas fir stocking. Some relationship was found between hemlock reproduction and the occurrence of hemlock seed trees. However, the great majority of these hemlock seed trees are no more than poorly formed saplings.

The data presented in this report clearly suggest a minor effect of setting size upon coniferous restocking. Staggered settings should be laid out, therefore, with less regard for area size than for: (1) windthrow, (2) erosion, (3) fire, and (4) greatest economy of road construction and logging.

STATISTICAL ANALYSIS

The objective of the study was to examine the relationships among the physical factors which could be measured and to determine the effect of each upon the stocking per cent (per cent of mil-acre plots stocked).

Before a complete analysis could be made, it was necessary to study the simple relationships between the factors and stocking per cent in order to set up a mathematical model to represent or describe the relationships. The particular information needed was the functional form of the equation relating stocking per cent to each factor: e.g., whether burn was linearly related to stocking per cent or whether a curved line represented the relationship better.

The preliminary studies indicated that:

1. Burn, as scored on a 0-4 scale, was not related to stocking per cent in any simple functional form, and, therefore, each degree of burn was considered separately.
2. Direction of exposure, being a qualitative factor, was not related in a functional form. The effects of exposures north, northwest, and northeast were similar as were south, southwest, and southeast; so that only five exposures, viz. flat, north (northwest to northeast), east, south (southwest to southeast) and west were considered in later analysis.
3. Amount of slash was linearly related to stocking per cent except the "no slash" class, which was considered as a separate effect.
4. The effect of amount of cover depended upon the type of cover. The "no cover" class did not behave linearly with the other amounts and was, therefore, considered a separate effect. Both herbaceous cover and woody cover were individually related linearly to stocking per cent.
5. Distance from seed source was linearly related to stocking per cent.
6. The number of years since logging or burning was linearly related to stocking per cent.

These preliminary studies did not attempt to estimate the quantitative effect of the factors but only the type of relationship. On the basis of these studies the following mathematical model, incorporating all the factors under study, was set up:

$$Y = M + B_i + E_j + S_k + C_l + b_d D + b_t T + e$$

Y = stocking proportion (from 0 to 1)

M = a stocking proportion constant added to all plots

B_i = change in stocking proportion resulting from the i^{th} burn condition

E_j = change in stocking proportion resulting from the j^{th} exposure conditon

S_k = change in stocking proportion resulting from the k^{th} slash condition

C_l = change in stocking proportion resulting from the l^{th} cover condition

b_d = change in stocking proportion per chain distance from seed source

b_t = change in stocking proportion per year since logging or burning

D = number of chains from plot to seed source

T = number of years since logging or burning

e = error of prediction

The slash effect is further broken as

$S_k = S_o + b_s S$

where S_o = change in stocking proportion when slash is absent (S_o = o when slash is present on the plot)

b_s = change in stocking proportion per unit slash score

S = slash score as defined previously (S = 0, 1, 2, 3, or 4)

Similarly, the cover effect is broken down as

$C_l = C_o + b_h C_h + b_w C_w$

where C_o = change in stocking proportion when cover is absent

b_h = change in stocking proportion per unit of herbaceous cover score

b_w = change in stocking proportion per unit of woody cover score

C_h = herbaceous cover score (C_h = 0, 1, 2, or 3)

C_w = woody cover score (C_w = 0, 1, 2, or 3)

If C_o is zero, indicating that cover is present on the plot, then either C_h or C_w must be a non-zero value. Because a plot is always described with either no cover or herbaceous cover, or woody cover, two of the three C values (C_o, C_h, and C_w) must be zero for each plot.

Using the least squares criterion (Anderson and Bancroft (1)) that the sum of the squares of the errors (e) shall be a minimum, the effects in the model were estimated. These estimates and their standard errors are given in Table 16-A.

TABLE 16-A

EFFECT OF SOME PHYSICAL FACTORS UPON THE ESTABLISHMENT OF CONIFEROUS REPRODUCTION

Field Condition	Symbol	Value	Standard Error ±
No Burn	B_1	0.0816**	0.014
Burn			
Light Burn	B_2	0.0140**	0.018
Medium Burn	B_3	—0.0306*	0.015
Heavy Burn	B_4	—0.0650*	0.024
Exposure			
Flat	E_1	0.0828**	0.018
NW, N, NE	E_2	0.1604**	0.014
E	E_3	—0.0314	0.027
SE, S, SW	E_4	—0.1460**	0.017
W	E_5	—0.0658	0.056
No Slash	S_0	—0.2602**	0.037
Slash			
0-25%	S_1	—0.0432**	0.009
25-50%	S_2	—0.0864**	0.018
50-75%	S_3	—0.1296**	0.027
75-100%	S_4	—0.1728**	0.036
No Cover	C_0	—0.0852	0.037
Cover			
Herbaceous Cover			
0-33%	C_{H1}	—0.0582**	0.013
33-66%	C_{H2}	—0.1164**	0.025
66-100%	C_{H3}	—0.1727**	0.038
Woody Cover			
0-33%	C_{W1}	—0.0979**	0.011
33-66%	C_{W2}	—0.1958**	0.021
66-100%	C_{W3}	—0.2938**	0.032
Distance (ch. from seed source)	b_d	—0.0127/ch.**	0.003
Years since logging or burning	b_t	0.0497/yr.**	0.0003
Base Stocking Constant	M	0.3404	0.039

* Significant at the 5% level
** Significant at the 1% level

TABLE 16-B

Example: For plots with, say

light burn, B_2
east exposure, E_3
no slash, S_o
80% herbaceous cover, C_{h3}
3 chains from seed source
6 years since logging or burning

the estimate of stocking proportion is given by inserting the appropriate values in the prediction equation and solving for Y, the stocking proportion. In this example,

$$Y = M + B_2 + E_3 + S_o + C_{h3} + b_d(3) + b_t(6)$$
$$Y = .3404 + .0140 - .0314 - .2602 - .0127(3) + .0497(6)$$
$$Y = .3229 = 32.3 \text{ per cent}$$

Approximately 32 per cent of mil-acre plots, under these conditions, would be stocked with one or more seedlings.

APPENDIX

TABLE 17

TOTAL CONIFEROUS STOCKING BY YEARS SINCE AREA WAS LOGGED OR BURNED

Years Since Logging or Burning	Stocked Plots	Non-Stocked Plots	No. of Seedlings	Per Cent Stocked (Mil-acre)	Estimated Per Cent Stocked (4 Mil-acre)	Seedlings per Mil-acre Plot
4	68	304	89	18	37	0.24
5	280	512	580	35	65	0.73
6	272	395	645	41	72	0.97
7	92	105	302	47	81	1.53
8	53	7	293	88	<95	4.88
9	119	285	345	29	57	0.85
10	270	109	1,181	71	<95	3.11
11	276	94	1,093	74	<95	2.95
TOTAL	1,430	1,811	4,528	MEAN 44	76	1.40

TABLE 18

DOUGLAS FIR STOCKING BY YEARS SINCE AREA WAS LOGGED OR BURNED

Years Since Logging or Burning	Stocked Plots	Non-Stocked Plots	No. of Seedlings	Per Cent Stocked (Mil-acre)	Estimated Per Cent Stocked (4 Mil-acre)	Seedlings per Mil-acre Plot
4	51	321	61	14	32	0.16
5	212	580	333	27	53	0.42
6	214	453	376	32	61	0.56
7	77	120	209	39	70	1.06
8	34	26	76	57	95	1.27
9	98	306	160	24	50	0.40
10	211	168	540	56	93	1.42
11	191	179	420	52	87	1.14
TOTAL	1,088	2,153	2,175	MEAN 34	64	0.67

TABLE 19

WEST COAST HEMLOCK STOCKING BY YEARS SINCE AREA WAS LOGGED OR BURNED

Years Since Logging or Burning	Stocked Plots	Non-Stocked Plots	No. of Seedlings	Per Cent Stocked (Mil-acre)	Estimated Per Cent Stocked (4 Mil-acre)	Seedlings per Mil-acre Plot
4	16	356	17	4	20	0.05
5	96	696	178	12	28	0.22
6	81	586	186	12	28	0.28
7	32	165	57	16	35	0.29
8	50	10	207	83	<95	3.45
9	50	354	165	12	28	0.41
10	190	189	526	50	86	1.39
11	199	171	592	54	90	1.60
TOTAL	714	2,527	1,928	MEAN 22	45	0.59

TABLE 20

STAGGERED SETTINGS EXAMINED DURING 1953 AND 1954

Location	Elevation	Area	Number of Years since Logging or Burning	Stocking Per Cent 4 Mil-acre	Stocking Per Cent Mil-acre
Sec. 10 T12S R2E	3000 to 3500 ft.	88 acres 20 x 64 chs.	10 burned 11 logged	98	71
Sec. 2 T12S R2E	2500 to 3000 ft.	43 acres 14 x 28 chs.	5 burned 5 logged	88	58
Sec. 1 T12S R2E	2500 to 3000 ft.	48 acres 18 x 30 chs.	6 burned 6 logged	83	50
Sec. 35 T11S R2E	2500 to 3000 ft.	50 acres 14 x 40 chs.	11 burned 11 logged	98	83
Sec. 25 T11S R2E	2500 to 3000 ft.	18 acres 4 x 40 chs.	8 logged	100	87
Sec. 25 T11S R2E	2500 to 3000 ft.	72 acres 16 x 44 chs.	10 logged	88	74
Sec. 27 T13S R5E	2500 to 2800 ft.	125 acres 32 x 40 chs.	5 burned 6, 7 logged	59	40
Sec. 23 T13S R5E	3200 to 3800 ft.	140 acres 28 x 48 chs.	5 burned 6 logged	77	42
Sec. 23 T13S R5E	3500 to 4000 ft.	135 acres 30 x 55 chs.	4 burned 4 logged	44	18
Sec. 33 T12S R7W	2000 to 2500 ft.	140 acres 45 x 55 chs.	9 burned 10 logged	57	30
Sec. 35 T22S R3E	1500 to 2000 ft.	40 acres 20 x 24 chs.	7 burned 7 logged	50	27
Sec. 35 T22S R3E	1500 to 2000 ft.	59 acres 18 x 28 chs.	6 burned 6 logged	81	45
Sec. 35 T22S R3E	2000 to 2500 ft.	50 acres 20 x 27 chs.	6 burned 6 logged	43	22

PLANTS COMMONLY FOUND ON AREAS EXAMINED

Brush and Trees

Scientific Name	*Common Name*
Acer circinatum	Vine maple
Arctostaphylos columbiana	Hairy manzanita
Berberis aquifolium	Oregon grape
Castanopsis chrysophylla	Chinquapin
Ceanothus velutinus	Ceanothus
Corylus californica	Hazel
Gaultheria shallon	Salal
Holodiscus discolor	Ocean spray
Rhododendron californicum	Coast Rhododendron
Rubus parviflorus (Nutt.)	Thimbleberry
Rubus spectabilis (Pursh.)	Salmonberry
Salix spp.	Willow
Sambucus callicarpa	Red elderberry
Symphoricarpos albus	Snowberry
Vaccinium parvifolium	Red huckleberry
Rubus vitifolius	Trailing blackberry

Herbaceous

Achlys triphylla	Vanilla leaf
Anaphalis margaritacea var. occidentalis	Pearly everlasting
Chimaphila menziesii	Little Prince's pine
Clintonia uniflora	One-flowered clintonia
Coptis laciniata	Western goldthread
Cornus canadensis	Dwarf dogwood
Epilobium angustifolium	Fireweed
Oxalis oregana	Oxalis
Linnaea borealis var. americana	American twinflower
Smilacina racemosa	False Solomon's Seal
Streptopus amplexifolius	Large twisted stalk
Trientalis latifolia (Hook)	Broad-leaved Star flower
Viola sp.	Wood violet
Xerophyllum tenax	Bear-grass

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