NATURAL REPRODUCTION IN DOUGLAS FIR STANDS AS AFFECTED BY THE SIZE OF OPENING

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CHARLES MAURICE LORD

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Redacted for privacy

Head of Department of Forestry

In Charge of Major

Redacted for privacy

Chairman of School Graduate Committee

Redacted for privacy

Chairman of State College Graduate Council

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TABLE OF CONTENTS

NATURAL REPRODUCTION IN DOUGLAS FIR STANDS AS AFFECTED BY THE SIZE OF OPENING

INTRODUCTION

Early logging in the Douglas fir region of western Oregon was with bull teams or horses, and as a result was selective in nature in some areas, as only the best trees were taken out. With the coming of the donkey engine and the railroad, all this was changed. Large areas were clear cut, with all the trees that were believed to be merchantable taken out. In this power logging, most of the smaller unmerchantable trees were destroyed in removing the large trees. Broadcast slash burning to reduce the high fire hazard usually followed logging. These fires proved fatal to many of the remaining trees, and this was especially true of the thinner barked companion species of the fir, such as western red cedar and western hemlock.

Reseeding after such a fire came from: (a) seed surviving the fire, either in the duff or in the trees; (b) scattered seed trees that survived the fire; or (c) seed blown into areas from nearby uncut timber. The results varied from very good to very poor, depending on conditions as they existed on each individual area. In general, however, the condition which existed for regeneration after the fire was one of an abundance of light and considerable exposed mineral soil. These conditions were at least as

favorable, or more favorable, for the Douglas fir as for the competing species.

During the last ten years, however, we have seen the development of new mobile equipment which appears likely to supplant the donkey engine over much of the region about as completely as donkeys did the bull teams a generation ago. This equipment, Diesel cats and motor trucks, has now been so perfected that it can handle the large timber found here efficiently, and in many areas more economically than the donkey engine and railroad. It adapts itself to comparatively small tracts of timber. Therefore, once more selective logging becomes a factor in the region.

The forester is principally interested in selective logging from two different viewpoints. The first of these has to do with its economic feasibility, and the second with its silvicultural aspects.

Brandstrom and Kirkland (9), who have made the most complete studies from the standpoint of costs and returns, have been able to show rather conclusively that for many stands, such a system gives much larger returns than clear cutting, for only high grade trees which cut out a large per cent of clear lumber are taken, while smaller trees are left for a later cutting, putting on an increased increment of high grade material after their release. The system they advocate is one of mixed individual tree and group

selection, with clear cut spots amounting to one half of one per cent per year. They touch rather lightly on the silvicultural aspects, though they do state, "Long observation in the forests of this region leads the authors to believe that the clear cut spots will regenerate densely to the desired mixed conifer forest."

Besides selective cutting of this type, we shall undoubtedly see increasing numbers of small opening in the forests, where single trees or small groups of trees of certain species are removed for special uses, such as pulp or piling. Certain practices, such as broadcast burning, used in clear cutting can have little place in selective logging, so the conditions for regeneration will be vastly different.

All this leads up to the fact that we must have considerable research on the problem of regeneration of Douglas fir under selective cutting before we can blindly accept it as the one and only way. It would be folly to accept a little larger present profit for stands of inferior trees or brush patches in the future.

Commenting on silvicultural research in connection with selective logging, Isaac (6) writes:

"Thus far, studies have been confined chiefly to clear cut areas. Suddenly, with the advent of the truck and tractor, there is a pronounced movement toward partial cutting in

the type, and foresters are faced with a brand new set of problems. Knowing that Douglas fir is an intolerant tree and will not reproduce in its own shade, it is at once evident if the species is to be maintained in the type, at least half the crown will have to be removed or the cutting will have to be done in clear-cut spots. Preliminary studies indicate that there are stands in the region where either of these methods or a combination of them may be used, but there are other stands where partial cutting will not work. On moist sites or exposed places windfall is heavy if the crown is opened up. In rough topography and dense stands it is all but impossible to remove part of the trees without serious injury to the reserve stand. Some stands may be highly defective or do not have the range of age and diameter classes necessary for partial cutting. On the other hand, there are suitable stands on sufficiently favorable ground to permit partial cutting and opening of crowns sufficiently to allow Douglas fir reproduction to come in. However, it behooves the forester to analyze his stands and apply partial cutting system with caution lest he find himself with depleted stands made up of defective trees and inferior species."

It is with the hope of adding some information on the subject of Douglas fir regeneration where a system of partial cutting has been practiced that this study has been

made. The study concerns itself with the regeneration that has occurred in existing small openings. These openings are the result of various causes, though nearly all of them have resulted from cuttings made for various products. Restrictions of time and finances have confined the study to the foothills of the coast range bordering on the Willamette valley. This has, however, had the advantage of keeping it in a fairly uniform type with Douglas fir (Pseudotsuga taxifolia) and lowland white fir (Abies grandis) being the dominant timber species. Abies grandis is, however, comparable in tolerance to western hemlock and western red cedar, so the conclusions of the study may be applied to these other types, though of course not as accurately.

The principal questions which this study attempts to answer are: (a) the minimum size of opening necessary for the establishment of vigorous Douglas fir reproduction; (b) the species composition of the reproduction that will form the dominant canopy of the new stand; (c) the density and distribution of the reproduction, with observation of the factors that have the greatest effect on their determination.

It is clearly realized that any conclusions drawn from this study will apply only to a stand where a form of group selection is practiced, and not to one where individual

trees are removed, more or less evenly, all over the stand. No attempt is made to arrive at any percentage of timber to remove for the stand as a whole.

Whatever system of cutting proves to be the most profitable will be the one which will be practiced on private lands. Thus it is the silviculturalist that must be able to advocate methods that are adaptable to the conditions set up. This fact should never be overlooked.

PREVIOUS WORK AND OBSERVATIONAL OPINIONS

Though selective logging in Douglas fir is a very recent development, and as yet little data has been gathered on regeneration under these conditions, there has, however, been considerable work done of the ecology of Douglas fir. Much of this is of value in understanding its behavior under this type of management. In addition to this, various foresters have made observations of the conditions as they found them where partial cuttings have been made in the past. These men have given their views as to desirable practices that will favor regeneration, and probable results to be expected.

The first necessity for regeneration is an adequate seed source. Under selective logging conditions, plenty of seed will be present. Isaac (7) found by trapping that 8,000 seeds per acre fell at 900 feet from the edge of the timber. Near the timber, the distribution was even heavier. If regeneration fails in small openings, it will not be because seed has not been distributed plentifully over the area. There are several qualities of Douglas fir trees and seed, which may be of importance in influencing the amount of successful reproduction obtained on an area. These have to do with the occurrence of seed years, and the life of seed on the forest floor. Isaac (6) states:

"Douglas fir is an average seed producer; a twenty-eight year record kept by the Forest Service in this region indicates that bumper crops occur from 3 to 7 years apart. During the intervening years light or medium crops may occur or there may be a complete crop failure. Douglas fir seed is particularly attractive to birds and rodents. It is estimated that practically all of the seed is consumed during years of light and medium crops, and most of the good stands of reproduction spring from the surplus of seed that occurs during the years of heavy crops."

Hofmann (5), who was one of the pioneers in the study of the regeneration of Douglas fir, believed that considerable regeneration following cutting came from seed stored in the duff. Isaac (8) made later studies which showed that this was a mistaken viewpoint. He carried on a series of tests, each one of which extended over a period of four years. Seed was stored in the duff in rodent-proof wire cages. A check was also run with wire cages buried in open ground. Each spring, part of the seed was dug up and tested for germination in a nursery bed. Good germination was secured the first spring from all seed, but thereafter there was no germination.

From this information on seed years and life of seed on the forest floor, we can draw some conclusions. One is that unless cutting came before the summer following a

seed year, reproduction from seed stored in the duff could not be expected. Another is that in those cuttings that were made several years before a seed year, competing vegetation would get a head start over the Douglas fir seedlings.

Isaac (6) and others, in studies made at Wind River Experimental Forest, found that from sixty-six to ninety-five per cent of the annual seedling crop is lost from various causes. He lists the principal causes, in approximate order, as: Heat injury to the stem (sun scald), drouth, rodents, frost, insect injury, and competition from other vegetation. He states, "Some losses may come from a combination of above causes, and in some years, any one of the above may be responsible for the loss of a major portion of the season's seedling crop." It can be seen that some of these factors, and especially competition, would cause continued losses in later years. The first year is, however, by far the most critical for Douglas fir seedlings.

Various investigators have found Douglas fir seedlings susceptible to damage by heat. Bates and Roeser (2) tested Douglas fir, ponderosa pine, Engelmann spruce, and lodgepole pine in an electric oven, where the roots were protected and thus only heat damage to the tops was possible. They found Douglas fir the most sensitive species in these tests. Roeser (12) made other studies of Douglas fir and its

competing species in the southern Rocky Mountains. He came to the following conclusions:

"Douglas fir is similar to western yellow pine in early deep-rooting habits, but in its case, this character appears to have been sixed, not by the physiological necessity of tapping available soil moisture sources sufficient to enable it to meet excessive transpiration demands, but by the need of reaching enough moisture to sustain life under adverse seed-bed conditions, such as are found in the presence of heavy accumulation of rapidly desiccating leaf litter and humus. It has not adjusted itself to meet the requirements of excessive and injurious heat exposure, either by morphological or physiological adaptation. In this respect, the evidence indicated, it must be rated below its contemporaries in the Rocky Mountains." He found that spruce and Douglas fir proved more efficient than the pines in their use of water, only when in extremely quiescent condition, induced by low temperatures and high humidity. This corresponds to their natural habitat in this region.

While the tree species with which Douglas fir competes in western Oregon are probably as subject to heat injury as it is, nevertheless these studies made in another region where climatic conditions are more sever indicate its susceptibility to heat injury and check with results obtained

here. Isaac (6) states that for very young seedlings, injury may take place if surface temperature exceeds 123° Fahrenheit, though older seedlings may survive temperatures of 150° F. Temperatures as high as the latter have been recorded on exposed sites in this region.

Drouth is also a factor on more exposed sites. Measurements by Isaac (6) showed less moisture in the top six inches in the open than under mature Douglas fir or brush cover. Undoubtedly, during our long, dry summers, the upper soil may approach the wilting coefficient, and even before this point is reached, many seedlings die because they are unable to take in enough water from the soil to balance rapid transpiration. Shade is thus seen to be a factor in regeneration, and probably has its effect through the temperature and soil moisture. The effect from the standpoint of heat would usually be favorable to the seedling, but it may or may not favorably affect soil moisture conditions. Isaac states:

"Dead shade, i.e., the shade of logs, stumps, and debris is more favorable to seedling growth than the shade of weeds and brush because it provides the same protection against evaporation, sun, and frost but does not compete with the seedling for moisture and plant food.

Dor the first few years of a seedling's life, vegetative cover (if not too dense) is helpful because of the

indirect benefits resulting from its shade. After the cover is well established, however, the presence of this competing vegetation appreciably retards seedling growth and also prevents new seedlings from coming in."

Living shade is not always harmful. This seems to vary with the species casting the shade. On exposed south slopes of the Willamette valley, it has frequently been noted that Douglas fir comes in readily in the shade of the oak trees, while it is unable to survive on adjacent grass-covered areas. In a study made several years ago, the writer found temperatures and moisture conditions in the upper six inches of soil under the oak at the end of a dry summer much more favorable than in the open. There was also a much higher moisture content under the oak than at the same depths in a nearby Douglas fir forest. The type of root system of different species is undoubtedly a factor in determining how much competition they will give the seedlings for soil moisture. So far, this is practically an unexplored field. In discussing the relationship of oak and Douglas fir, Tiedemann (13) suggests that the oak leaves are very important in bringing about conditions favoring the fir seedlings.

Live shade may frequently become competitive, rather than beneficial. Competition of this character comes from lower plants, such as shrubs and herbs, other tree

seedlings, or from trees which form an overhead canopy. Discussing the first group, Hofmann (5) writes:

"The long list of shrubs, trees, and non-woody plants that compete with Douglas fir seedlings emphasizes the need of getting a stand of young trees started immediately after the forest is removed. Nearly all these competitors can endure more shade than Douglas fir seedlings, and consequently are able to crowd them out when the rapid height growth of Douglas fir, their greatest advantage when competing with this ground cover, does not give them a lead."

Tiedemann (13) thinks that bracken fern, if not too dense, favors the fir reproduction.

Douglas fir has to compete in most stands with the seedlings of other tree species. Hofmann (5) states: "Western white pine is the only tree of the Pacific Northwest that requires more light than Douglas fir. The Douglas fir will grow in about one-fourth of the full light in adjoining open areas, although under these conditions its development is retarded, and more shade-enduring species, such as western red cedar, western hemlock, and Sitka spruce have the advantage. The inability of Douglas fir to thrive in diffused light makes it incapable of forming an understory. This characteristic is a disadvantage to the tree in retaining its position in the forest, for the more shade-enduring species crowd out the

Douglas fir, and often completely replace it in the stand."

He found that on favorable sites, where soil was rich and moisture abundant, Douglas fir seedlings were able to endure more shade than on poorer sites. However, the competitive species were equally favored. On drier sites, the deeper initial root system favors Douglas fir over cedar, hemlock, spruce, and true firs.

Though Hofmann (5) considers Douglas fir to be faster growing than its competitive species, he says that even it is slow at first. He found in one study that it was only one and nine-tenths feet tall at five years, six and three-tenths feet tall at ten years, but at eighteen years it averaged twenty-four and eight-tenths feet. Other writers, including Kirkland and Brandstrom (9) have mentioned the great desirability of additional studies on the growth rate of Douglas fir and its competitors.

The lack of Douglas fir reproduction in unopened stands of this species is not due to lack of germination. Tiedemann (13) studied this on the McDonald Forest, and writes that his study reveals that "under a dense forest canopy, there is unlimited germination, but the severity of competition eliminates practically the entire crop the first year." Studying the trenched quadrats established by Professor Starker, where root competition from canopy trees has been eliminated, he found that many more seed-

lings were able to survive the summer. Thus, he felt that lack of light was probably not the most important factor in preventing survival under the canopy. This is in line with the newer conception of tolerance. He ran transects under different degrees of cover, varying from canopies of nine and seven-tenths density to small openings, and found that only where there was an opening were seedlings of three years or over present. He also noted that a moss floor seemed to favor establishment, and thought that the presence of moss might indicate more favorable conditions.

So far, controlled studies of Douglas fir reproduction under different methods of cutting have not been made in this region. However, in the southern Rocky Mountains, such a study was made and reported by Roeser (11). This study was made at the Fremont Experiment Station in Colorado, and the Douglas fir was of course the native blue variety. Four plots two hundred by two hundred feet were laid out, and on each one a different procedure was followed. The first one was clear cut; on the second plot the original condition was kept, with one thousand, one hundred forty-five trees of Douglas fir, Engelmann spruce, limber pine, ponderosa pine, aspen and willow; on the third all but eighty-three of the thriftiest Douglas fir were cut, in a shelterwood cutting; a selection system was used on the fourth plot, leaving two hundred seventy-one Douglas firs,

varying from four and one-half inches to mature trees. On all plots, small reproduction was removed, so as not to interfere in later counts.

Though total counts of all seedlings were made, the count of seedlings three or more years old was considered most valuable. The result obtained was as follows:

ESTABLISHED OR THREE YEAR OLD SEEDLINGS

Date	Clear cut	Control	Shelterwood	Selection
1919	287	238	811	480
1920	213	233	1,127	550
1921	881	2,271	5,094	3,985
1922	900	1,430	6,436	4,592
1923	1,005	1,237	6,391	4,638

SPECIES OF THE SURVIVING SEEDLINGS

Species	Clear cut	Control	Shelterwood	Selection
D. F.	62%	57%	80%	85%
E. S.	20%	36.5%	19.2%	12.7%
L. P.	18%	6.5%	0.4%	2.1%
P. P.	0	0	0.1%	0.2%

Legend: D.F.--Douglas fir L. P.--limber pine
E.S.--Engelmann spruce F.P.--ponderosa pine

Moisture conditions were found to be more favorable under shelterwood and selection. Clear cut areas dry out most rapidly in the spring, but in unopened stands, seedlings which have a plentiful amount of moisture early in

the season find the driest condition later, due to competition from old trees. A seedling has a better chance when once developed in the openings where moisture content does not go so low. In this study, it was found that eighty-five per cent of the fir had come up under the immediate protection offered by logs, stumps, juniper, grass, twigs, and small litter. Protected fir seedlings were found to be uniformly taller than the unprotected. It was found that only where humus was shallow enough that roots were able to grow through it, and into the mineral soil, so that the seedling has a plentiful supply of moisture during the first season of drouth can it survive. For the fir, it was found that one and one-half to one and three-quarters inches under protection, and one to one and one-quarter in the open was in the open was about the maximum depth at which seedlings could be expected to survive. There was little effect from humus depth after the third year.

A study made as to height growth of seedlings showed that from best to poorest the ranking was shelterwood, clear cut, selection, and uncut. This held for all ages of seedlings that had developed during this study. In summing up, Roeser states:

"This study of reproduction under the various cutting methods has brought out the desirability of the shelterwood

system, as particularly adapted to Douglas fir stand. It has not proved slash scattering, employed mainly to furnish shade for seedlings and help conserve soil moisture, has any decided silvicultural advantage over piling and burning save that it is the less expensive and therefore more desirable method. This is more or less a question to be decided on the ground. The natural debris resulting from logging operations should ordinarily furnish all the protection the seedlings will need."

A fairly heavy, but not complete cutting, is thus seen to be the most favorable for Douglas fir in the Rocky Mountain region. It seems logical to believe that one at least as heavy would be necessary in the Pacific Coast region, where the seedlings receive less light and the growth of competitive vegetation is more vigorous.

The advocates of selective logging in the Douglas fir region have expressed their opinions as to probable silvicultural results. Ames (1) in one of the early articles states that he considers that selective logging would be more favorable to regeneration, due to less fire danger and increased seed source, but does not discuss it further.

Kirkland and Brandstrom (9) in their publication express certain opinions. They admit that single tree selection will not be favorable and therefore suggest a combination of this with larger group selection. They

write:

"To insure that there will be sufficient recruits of high quality to the small timber class in the Douglas fir region, considerable dependence must be placed on the clear cut spots resulting from the cutting of groups of trees."

In addition to group selection, they believe that due to various reasons, principally topographic, there would be areas, mostly from two to ten acres in size, that would be clear cut. Speaking of these, they comment:

"These areas would as a rule restock in quick order. It is the authors' opinion, based on many years of observation in this region, that the best results in regeneration, from the standpoint of density of stocking and of desirable mixture of Douglas fir and tolerant species, will be obtained on areas of two to five acres. It is suggested that one-half of one per cent of the total area in the management unit be cut yearly by group selection or in these open spots. On such clear cut spots, they suggest that burning of the slash, impossible in individual tree selection, would be desirable. Along this line, one idea brought forward seems to be of especial merit. This is to fall slash into existing brush-filled blank areas, and burn this, creating an exposed seed bed, and at the same time lessening competition to the establishment of seedlings. They consider that the selective type of cutting

will result in a mixed type, but feel that perpetuation of a mixed forest may be better fitted to meet the needs of the region than a preponderance of Douglas fir. These mixed stands are likely to be dense, and a mixture with tolerant species helps to bring about natural pruning. They suggest that once the desired natural pruning has been obtained it might be desirable to take out these other species, or part of them, in thinnings. This is possible, if there is a market for pulp species. Many pure Douglas fir stands have little value, due to the fact that they grew in a very scattered condition.

They also suggest that where resulting reproduction is of species like hemlock or white fir, it might be desirable to plant widely spaced Douglas fir, Port Orford cedar, or other valuable species to supplement the natural reproduction.

Their principal viewpoint, silviculturally, is that as the operations go on, they will serve as the source of information necessary to determine just how the cutting methods should be modified, to obtain regeneration of desired density and composition. While this is true, it does not lessen the desirability of obtaining information sooner by controlled cutting studies, and by examination of existing areas where various degrees of cutting have been practiced in the past. It is here that studies like the present one

find their justification.

SEEDLING HEIGHT GROWTH STUDY

As a supplement to the main investigation , a special study of the growth rate of seedling Douglas fir and white fir was made. This was really in the nature of a project report, for the study was originally set up by Delbert Turner, now deceased, as his silviculture project while an undergraduate at Oregon State College. The original stand was probably about eighty per cent Douglas fir, twenty per cent white fir. About eighty per cent of the stand was removed, but the remaining timber varies from scattered individuals to groups of trees that were too small for cutting at the time of the removal of the rest. The study was made of seedlings that have come in since the cutting. Throughout this study, the term seedling refers to origin rather than size, and may include young trees more than three feet tall.

The method used was to select pairs of seedlings, one Douglas fir and one white fir, which were growing close together, and of as nearly as possible the same height. We thus have similar sizes of seedlings growing under very similar environmental conditions. Measurement of the seedlings showed the following results: (see accompanying tables on Douglas fir-white fir height growth study and analysis of height growth data.)

DOUGLAS FIR--WHITE FIR HEIGHT GROWTH STUDY

No.	Douglas fir			White fir		
	Dec. 3 1933	May 15 1937	Increase	Dec. 3 1933	May 15 1937	Increase
1.	.35	.55	.20	.35	.53	.18
2.	2.80	3.83	1.03	2.80	4.42	1.62
3.	9.70	12.10	2.40	9.70	12.44	2.74
4.	5.10	7.38	2.28	5.10	7.89	2.79
5.	.45	.22	-.23	.45	.73	.28
6.	.60	.81	.21	.60	1.22	.62
7.	1.20	2.11	.91	1.20	2.15	.95
8.	1.30	2.44	1.14	1.35	2.57	1.22
9.	.55	1.25	.75	.52	.93	.41
10.	1.55	2.60	1.05	1.55	2.05	.50
11.	1.40	2.68	1.28	1.37	1.72	.35
12.	.96	2.19	1.23	.95	1.57	.62
13.	.62	1.39	.77	.65	.73	.08
14.	1.31	2.16	.85	1.35	1.92	.57
15.	2.60	4.17	1.57	2.10	2.98	.88
16.	.80	1.62	.82	.80	Dead	
17.	1.45	2.08	.63	1.45	2.13	.68
18.	1.24	2.41	1.17	1.24	1.81	.57
19.	1.98	2.90	.92	1.92	2.36	.54
20.	1.64	2.59	.95	1.52	1.77	.25
21.	.29	.55	.26	.31	.45	.14
22.	3.35	5.17	1.82	3.37	4.56	1.19
23.	.78	1.31	.53	.80	Dead	
24.	4.75	5.49	.74	4.78	6.02	1.24
25.	3.80	5.40	1.60	3.70	4.66	.96
26.	1.52	2.36	.84	1.75	2.92	1.17
27.	6.90	9.54	2.64	6.82	8.33	1.51
28.	.20	.44	.24	.30	Dead	
29.	8.00	9.77	1.77	8.20	10.27	2.07
30.	10.50	14.27	3.77	9.70	12.89	3.19
31.	4.00	4.72	.72	4.00	4.85	.85
32.	4.35	5.41	1.06	4.35	5.17	.82
33.	5.90	6.87	.97	6.00	7.32	1.32
34.	1.10	1.75	.65	1.00	1.45	.45
35.	1.50	2.67	1.17	1.43	1.98	.55
36.	.90	1.25	.35	.95	1.39	.44
37.	.42	1.02	.60	.40	.72	.32
38.	2.90	4.75	1.85	2.78	3.92	1.14
39.	1.10	1.84	.74	1.10	1.23	.13
40.	.47	1.03	.56	.50	Dead	
41.	.52	.94	.42	.55	.75	.20

Table continued:

No.	Dec. 3 1933	May 15 1937	Increase	Dec. 3 1933	May 15 1937	Increase
42.	.72	1.11	.39	.68	1.08	.40
43.	.60	1.21	.61	.68	1.47	.79
44.	.58	1.63	1.05	.70	1.00	.30
45.	1.90	3.85	1.95	1.80	3.50	1.70
46.	.98	2.08	1.10	.90	1.43	.53
47.	1.05	2.20	1.15	1.12	1.82	.70
48.	1.16	1.67	.51	1.10	1.56	.46
49.	1.98	3.65	1.67	2.00	3.02	1.02
50.	1.10	2.25	1.15	1.10	2.62	1.52
51.	1.30	2.62	1.32	1.50	2.27	.77

Heights are given in feet.

ANALYSIS OF HEIGHT GROWTH DATA

Height class Feet	No. of pairs in which each species leads		Av. Height Growth	
	Douglas fir	White fir	Douglas fir	White fir
0-.99	13#	5	.55	.37##
1-1.99	14	5	1.06	.74
2-3.99	4	1	1.57	1.16
4-5.99	1	4	1.15	1.40
6	2	2	2.65	2.38
	34	17		

#There are four pairs in the 0-.99 foot class where the white fir has died. In such cases the Douglas fir is counted as ahead.

##Due to the four dead trees the average growth of the white fir is based on the fourteen living samples.

The tolerant white fir will not be shaded out by the Douglas fir, and the problem is, therefore, whether or not the Douglas fir growth is fast enough to keep it ahead of the white fir. Though this study does not cover a large enough number of samples to be findal, it does rather definitely indicate that in the younger age classes the Douglas fir is more than able to hold its own for height growth.

It should thus be able to maintain itself in the final stand whenever it gets an even start with the white fir. The higher mortality of the smaller white fir may be a purely local condition, or characteristic for the species. This height growth advantage of Douglas fir would, of course, only hold where the canopy had been opened up quite heavily.

PROCEDURE OF PRINCIPAL STUDY

As the most important problem of this study is the approximate determination of the minimum size of opening in which successful, vigorous Douglas fir reproduction will become established, it was decided that the maximum size of area taken should be held between one-half acre and one acre. Time available for study was also a factor. The method used in studying these openings was felt to apply better to areas of this size than to larger ones. Previous general observations had convinced the author that examples of vigorous Douglas fir reproduction were to be found on areas as small as one-half acre.

In the field, the following observations were made:

I. Date of observation

II. Location and physical features
    1. Location
    2. Area
    3. North and south extension
    4. East and west extension
    5. Aspect
    6. Slope
    7. Soil
    8. Site

III. History
    1. Date of occurrence of opening

2. Treatment by man, stock, and fire

IV. Present conditions

1. Surrounding timber

a. Type and species

b. Average height

c. Average D. B. H.

d. Average age--estimate

2. Brush and ground cover

3. Reproduction

a. Reproduction count: area, species, and number

b. Age of reproduction--estimate

c. Condition of reproduction

V. General observations and remarks

Some of the items in the above outline are self-explanatory, but others need clarification. The method of taking data in the field was to set up a staff compass by estimation at the point in the area where transects of maximum length, running in north and south and east to west directions would cross. This exact point was not always selected, but for most openings it was closely approximated. From this point, a transect, consisting of a consecutive series of milacre quadrats, was run north to the edge of the unopened canopy. The number of seedling occurring on each quadrat was recorded. After this, a similar transect was run south to the edge of the timber. In a like

manner, east and west transects were run. The first quadrat on the east and west lines commenced three and three-tenths feet from the center point.

The mapping of the area was done to a predetermined scale on cross-section paper. When the end of a transect was reached, this point was located on the cross-section paper, and the edge of the canopy was drawn in after the same general method that is used in mapping in contours for forest survey work. This edge was taken as the average extent of the limbs on any particular tree, thus smoothing out small irregularities. For larger openings, pacing out at right angles to the transect lines at certain intervals was resorted to as a check of the accuracy of drawing in the boundary. The area of the opening was then easily obtained by counting the squares.

In counting the seedlings, the record was kept by species. In this study, all reproduction that has come in since creation of the opening is referred to as seedlings, even though, for some areas, many individuals exceed the three-foot size limit usually selected for seedlings. Origin, rather than size, is the determining factor. Counts of the seedlings of only those species that will form the upper canopy of the mature forest are included. Only Douglas fir and white fir were considered in this class on the areas studied. Yew and hardwood seedlings were not counted,

but are mentioned under discussion of the brush cover. Their effect on the fir seedlings is considered to be quite similar. The maximum number of seedlings recorded for any milacre was twenty-five, as numbers above this would be meaningless. On most areas, a majority of the seedlings were over three years of age, and in no case was any seedling recorded that had not survived its first summer. It is of course realized that three-year-old seedlings are much surer of surviving than those one year old, but where a large number of one-year-old seedlings is present, many of them are sure to survive. The age of the seedlings is discussed for each area.

In a few cases, the exact date of occurrence was obtainable, but in determining the date, borings with an increment borer were of greatest use. The trees around the opening show increased growth due to release from competition. The age of opening indicated by the increased growth was checked by the condition of the stumps and slash, and by age counts made on the oldest reproduction. The borings also proved of use in determining the age of the surrounding stand, and coupled with height measurements, were used in making site determinations. Height measurements were made with an Abney hand level, which was also used for checking slope.

The determination of the treatment the area had received

since cutting was made by careful observational study of the opening itself. This of course was necessary, for factors such as burning of slash and grazing greatly alter conditions and may or may not favor regeneration. The age, height, and species composition of surrounding timber are all important in such a study. The species composition determines what the source of seed will be, and thus what species of seed will be present for germination, though of course it does not control the amount of seed that will germinate, or the survival by species under the conditions that exist in the opening. Age is a factor in the amount of seed produced and its viability. The height of the stand determines, to a considerable extent, the portion of the opening that will be exposed to direct sunlight, uninterrupted by any overhead canopy.

In discussing brush cover, the species present, as well as the density, was considered. It was felt that different species might have a different effect on reproduction, though of the same density. Trees left on the area at time of cutting are discussed along with brush cover. In this discussion, the common names of the plants are used. In order to indicate just which species these names refer to, a list of species mentioned, with their scientific names, follows this description of methods used. This list is mainly trees and shrubs, for in general, species of grasses

and other herbs and mosses are not differentiated.

The number, species, and distribution of seedlings was obtained from the counts made on the quadrats. It is realized that the method used does not give an exactly accurate picture, when the total number of seedlings is calculated, for in terms of the area they represent, the quadrats nearer the center are over-weighted, and those near the edge under-weighted. Any loss of accuracy here, however, seems to be more than offset by the value of the study in distribution that this method gives. On the basis of total area of opening, the smaller areas have a larger percentage of sampling than the larger ones, but that is a desirable feature.

In recording the species on the map, the small letter "d" following the number indicates the Douglas firs on the quadrat, while the number followed by a small "w" indicates the white fir. The small circle on the map indicates the point from which the transects were started. On quadrats of the north and south transect, the number of white fir follows the Douglas fir, with a dash between; on quadrats of the east and west transects, the white fir is recorded below the Douglas fir. Because of the fact that typewriter spacing is constant on the map, and for a given quadrat the seedlings varied from "0" to those that took three spaces, such as "15d", the relationship of the last quadrat record

to the map boundary varies. In some cases, where the reproduction was heavy, the last two or three quadrat records fall outside the map boundary, but in all cases, the last quadrat recorded fell just inside the boundary of the opening in the field.

The scale used on the maps in the report is one-fourth inch to six and six-tenths feet. This scale was taken as checking with the milacre-quadrat sampling of the reproduction. The scale is not shown on individual maps, but the dimensions of each area in the cardinal directions are given for comparison. Direction is not given on the maps, but the standard for maps, with north at the top of the sheet, is used. The sheets are crowded enough without any directional arrows.

To assist in emphasizing the density of distribution of Douglas fir seedlings, a system of underlining was used for all stocked quadrats. Unstocked quadrats are self-evident. Three groupings were made, as follows: one or two seedlings per quadrat was considered as low, and underlined in black; from three to five seedlings was considered as medium and underlined in green; over five seedlings was considered heavy stocking, and underlined in red. It is believed that this system is of considerable aid when comparing areas or in visualizing the distribution on any one area.

In those openings where a logging road had materially disturbed or exposed the mineral soil, the quadrats that fell in the road are indicated by the letter "R".

There may be some question as to the advisability of using the milacre quadrat as the unit of sampling the reproduction. Lowdermilk and Haig (4) first used the milacre as their unit for determining stocking, but later adopted a thirteen and two-tenths foot quadrat. This was taken as approximately the area each tree seven inches or over would occupy at rotation age. Haig admits that seedlings at more frequent intervals might be desirable for quality production and to more thoroughly protect the site from deterioration.

Cowlin (3) also used this same thirteen and two-tenths unit in sampling Douglas fir reproduction in the timber survey of the Douglas fir region. On the survey, they considered a quadrat stocked if they found one seedling on it, and did not look for any more. However, they did check on several thousand quadrats, and found that for stocked quadrats, the average number of seedlings present was five and three-tenths. These extra seedlings were not recorded in the larger study, but were considered sufficient to take care of losses. He defines his degrees of stocking as follows:

	Quadrats stocked	Number of trees
Non-stocked	0 to 10%	0 to 132
Poor stocking	10 to 40%	133 to 529
Medium stocking	40 to 70%	530 to 927
Good stocking	70 to 100%	928 to 1325

I do not think that one seedling per four milacre quadrat is sufficient for a degree of stocking that will insure timber of high quality on a rotation possible for second growth. McArdle and Meyer (10) found that a fully stocked acre at thirty years of age had from two thousand seven hundred trees for site index eighty, to three hundred on site index two hundred ten, and on site index one hundred forty, an average site, there are eight hundred sixty-five trees at this age. Certainly it would be desirable to have stands that would close much earlier than thirty years, if the best quality of timber is to be produced. Fully stocked acres on site index one hundred forty do not drop to two hundred fifty trees, one every thirteen and two-tenths foot quadrat, until between the ages of seventy and eighty years. Far too many of our second growth Douglas fir stands are practically worthless from having been open grown. Douglas fir is a notoriously slow self-pruner, the dead limbs of any size often clinging to the tree for twenty or more years after dying. Because of the above, the milacre was selected as the unit of sampling.

Its size also checks quite well with the spacings, six or eight feet, which have been found most desirable in artificial regeneration by planting for most species.

One more point seems to need some discussion. That is the one of isolation of openings. As nearly as possible, areas taken were those surrounded for a considerable distance by an unbroken stand. However, in some cases, some light came in under the surrounding trees from other openings. It is very hard to find many openings where at least a little extra light does not come from this source, and such openings would not occur very frequently under a system of selective logging. Thus it was felt that a little extra light from other openings at a little distance did not greatly harm the value of the study. It is also true that study of the trenched quadrats previously mentioned, and of others in different forest types have done much to discount overemphasis on the importance of the quantity of light. Root competition for water is now considered much more important.

LIST OF PLANT SPECIES MENTIONED

I. Trees

Douglas fir--Pseudotsuga taxifolia

Lowland white fir--Abies grandis

Vine maple--Acer circinatum

Yew--Taxus brevifolia

Bigleaf maple--Acer macrophyllum

Oak--Quercus garryana

Cherry--Prunus emarginata

Dogwood--Cornus nuttallii

Chittum--Rhamnus purshiana

Madrone--Arbutus menziesii

Indian peach--Osmaronia cerasiformis

II. Shrubs

Hazel--Corlyus californica

Snowberry--Symphoricarpos albus

Oregon grape--Berberis aquifolium

Sweetbriar rose--Rosa rubiginosa

Thimbleberry--Rubus parviflorus

Trailing blackberry--Rubus ursinus

Flowering currant--Ribes sanguineum

Blue elderberry--Sambucus glauca

Ocean spray--Holodiscus discolor

Black cap--Rubus leucodermis

Wild rose--Rosa gymnocarpa or Rosa nutkana

Poison oak--Rhus diversiloba

Evergreen blackberry--Rubus laciniatus

Salal--Gaultheria shallon

Red huckleberry--Vaccinum parvifolium

Honeysuckle--Lonicera ciliosa

III. Herbs

Peavine--Lathyrus spp.

Strawberry-Fragaria spp.

Iris--Iris tenax

Fireweed--Epilobium agustifolium

Canada thistle--Carduus arvensis

Bull thistle--Carduus lenceolatus

Goatweed--Hypericum perforatum

Bed straw--Gallium spp.

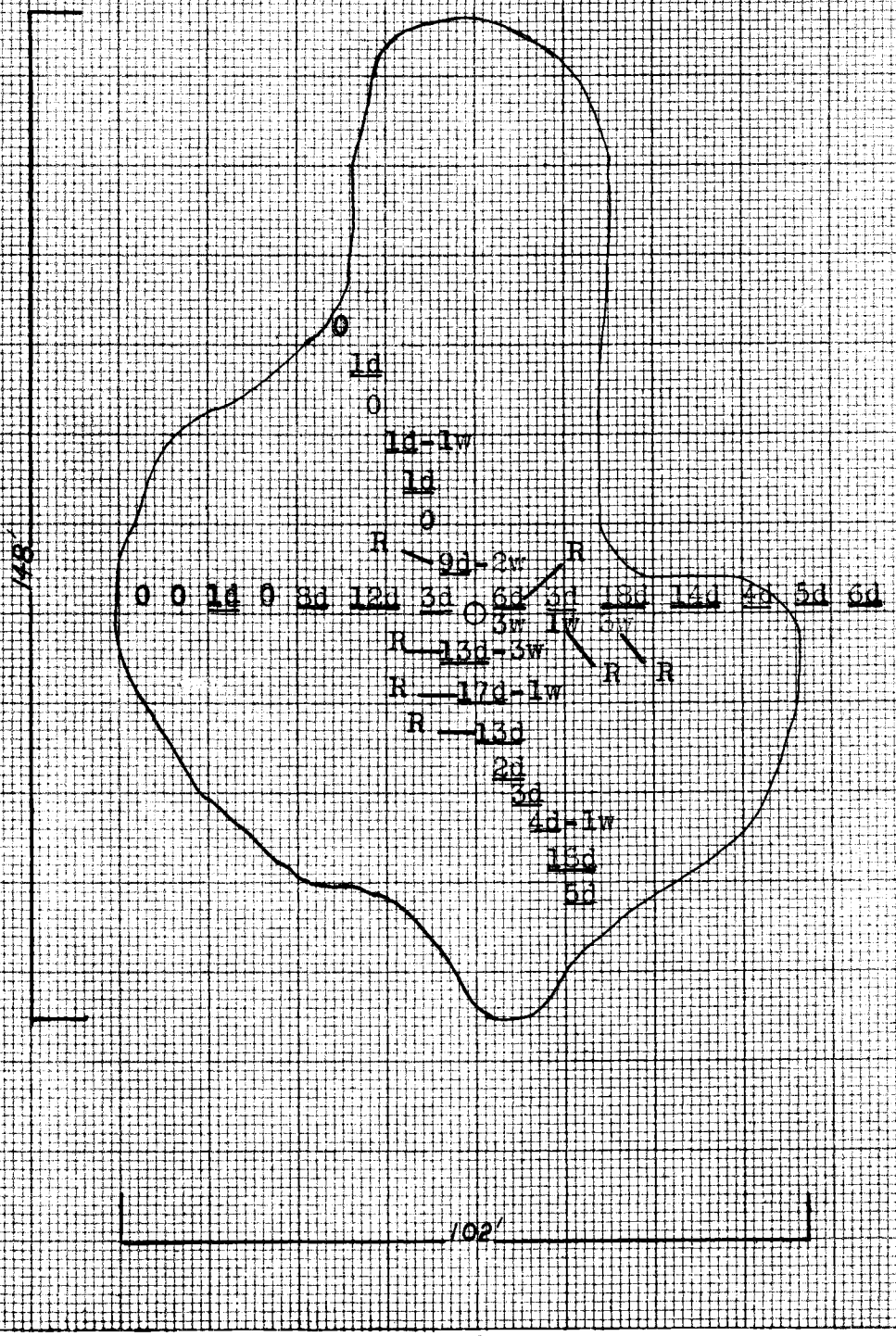
Bracken fern--Pteridium aquilinum

Sword fern--Polystichum munitum

AREA No. I

Area-6,500 sq. ft. or .195 A.
Seedlings per acre
Douglas fir-6,600
All species-7,167

Quadrats stocked
Douglas fir-80%
All species-80%
Vigor-good



AREA No. I

I. Date of observation: March 2, 1937

II. Location and physical features

1. Location: N.E.¼, Sec. 2, T. 11 S., R. 5 W., W.M.
2. Area: 8,500 square feet or .195 acres
3. North and south extension: 148 feet
4. East and west extension: 102 feet
5. Aspect: east
6. Slope: varies from 0 to 10%
7. Soil: Olympic clay loam
8. Site: III

III. History

1. Date of occurrence: This opening occurred sometime during the years 1929 to 1931, probably being nearer the latter, as shown by ring borings from surrounding trees. It was made by taking out a group of white fir for pulpwood, leaving the surrounding Douglas fir.
2. Treatment by man, stock, and fire: The slash on this area was burned soon after the cutting, but a clean burn was not obtained, and several slash piles are still present. The road used for taking white fir out of this general area runs through this opening, with a log landing in one corner. To avoid following this road, and thus

getting a false picture of the reproduction present, on the north and south line, the transects running in these directions were changed slightly. Milacres in the road are designated with an "R". The area has been subject to some grazing by sheep and goats, but it is apparent that this was never heavy.

IV. Present conditions

1. Surrounding timber: It is now a pure Douglas fir type, due to the removal of all white fir over sixteen inches in diameter. Before cutting took place, white fir may have exceeded twenty per cent of the stand, occurring generally in groups like the one removed here. A few white fir of less than sixteen inches are found widely scattered in the stand. Two age classes of Douglas fir are present in this stand. Most of the trees are second growth, averaging eighty years of age, one hundred fifteen feet tall, and twenty inches in diameter, but varying from twelve to twenty-four inches. Two old growth trees, about three feet in diameter and one hundred fifty feet tall, are in the surrounding stand. A small amount of light besides that from overhead comes in below the canopy from another opening to the east.

2. Brush and ground cover: The brush cover in this opening varies considerably as to density. Over about one-fifth of the area, the thimbleberry brush is heavy, but on the rest of the area brush is scattered, with open spaces between the clumps. Apparently, prior to cutting on this area, little brush was present, so that the reproduction was able to gain a start at the same time that the brush was coming in. Brush in the surrounding unopened timber is scattered. Besides thimbleberry, other shrubs that are well represented are trailing blackberry, flowering currant, black caps, and snowberry. Grass is well developed between the clumps of brush, and bracken and sword fern are both present, as well as a number of small herbs. Besides the herb and brush layers, one Douglas fir tree and several broadleaf maples were present on the area and not cut at the time of logging. From two maples that were cut, thrifty clumps of sprouts have developed.
3. Reproduction: The area, species, and number are shown in the accompanying map. From examination of seedlings, all the Douglas fir present appear to date from the 1932 seed year, though there may be a few slightly older or younger seedlings.

This reproduction is in a very thrifty condition. It varies from six to twenty-four inches in height; the average is about sixteen inches, with a leader growth of over six inches not unusual.

V. General observations and remarks: This area is one on a medium site, where conditions were favorable to reproduction. The brush layer was light in this stand before it was opened up, and the opening was made just shortly before a seed year. As a result, seedlings were able to start at the same time as the brush. Of special not is the excellent reproduction occurring on those milacres which fall in and near the road, where the mineral soil was exposed and disturbed.