AMOUNTS AND DISTRIBUTION OF NATURAL REGENERATION IN THREE DOUGLAS FIR PLANTATIONS ON VANCOUVER ISLAND[1]

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ABSTRACT

Considerable differences in the species composition, density, and pattern of natural regeneration were encountered within and between 16- to 18-year-old Douglas fir plantations as small as and smaller than one acre. The findings suggest that evidence on which to forecast the structure and composition of the mature forest is more likely to accrue from successive total enumerations than from sampling.

INTRODUCTION

Plantation assessments carried out to date in British Columbia have been concerned with initial stocking and thus have placed emphasis on the number of trees present one to three years after planting. These data may be useful in establishing possible overplanting requirements but are unlikely to be sufficient for forecasting the structure and composition of the mature forest; numerous changes may take place after the third year necessitating examinations of older plantations. There is no information at hand, however, to indicate the intensity or frequency of examinations required in older plantations before trends in species composition or pattern[3] may be satisfactorily determined. Obviously a great deal of further study is required.

The present report is based on examination of the density, species composition, and spatial arrangement of natural regeneration in 16- to 18-year-old Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) plantations on Vancouver Island, British Columbia. The objectives have been to examine the extent to which different populations agree in respect to these characteristics and to provide information which may be helpful should more intensive examinations be contemplated.

LOCATION AND METHOD OF STUDY

Studies were carried out in selected areas of the Robertson, Campbell, and Tsable River valleys on Vancouver Island during 1957, 1958, and 1959, respectively. A total of 20.25 ac was examined.

All of the selected areas had supported mature coniferous forests of mixed species composition prior to planting. No components of the original stand were present within the selected areas at date of examination, nor is it likely,

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[3] Pattern is used here as a term synonymous with the spatial or geographical arrangement of individuals within a specified area.

in view of previous fire histories, that they were present at dates of planting. Isolated groups and in some cases extensive stands of mature trees occurred, however, in areas adjacent to those selected and were within the range of natural seed fall.

The species, height, and condition of every tree 1 ft or more in height was noted and its position mapped. A total of 15,156 trees was examined in this manner. Douglas fir was the only tree species planted but fir and other species were present as natural regeneration. There was no practical basis for differentiating all of the naturally-seeded from planted fir. Although ages could have been determined or estimated by counting branch whorls, this method was considered impractical for general application in the areas studied. A partial segregation was attempted by recognizing two classes of fir, understory trees, trees less than 4.5 ft. in height, and overstory trees, trees equal to or more than 4.5 in height. There was little doubt that most of the understory trees were naturally seeded and that most of the dominant trees were planted. Trees of intermediate height, however, were of variable age; stem analyses of six and eight-ft fir carried out in areas immediately adjacent to those intensively studied, for example, showed that ages varied from 8 to 18 years. In this report, natural regeneration refers to species other than Douglas fir, and understory fir refers to a size class including an undetermined proportion of the natural reproduction of this species.

Appraisals of spatial pattern were based on techniques utilizing the distances between randomly selected points and the closest tree to each point (Pielou 1959). Techniques based on the analysis of quadrat-derived data were rejected on the grounds that these data may fail to detect non-randomness unless an appropriate quadrat size is employed. Tests were carried out within the 1-ac block nearest to the geographical center of each area studied and were confined to species having a density of at least 10 trees per ac within the study block. Values of an index of non-randomness derived from the data were compared with tabular values of the numerical range consistent with randomness (Pielou 1959). Values below this range were related to regular, and beyond this range to aggregated patterns. A random pattern is defined as one in which all trees have the same chance of occurring at any point within an area, all points have the same chance of receiving a tree, and the position of each tree is unaffected by the presence of other trees at other points (Clark and Evans 1954). Non-random patterns, on the other hand, arise when tree positions are determined by factors other than chance and many different models may arise. A regular pattern implies that there is a tendency for trees to be located at fixed intervals of spacing and that the presence of one tree at a point reduces the probability of occurrence of another tree at any other point within this interval. An aggregated pattern implies that there is a tendency for trees to occur in clusters; the presence of one tree at a point increases the probability of occurrence of another tree in close proximity. It is apparent that these later definitions refer to general and not specific population patterns.

Results

Stand densities ranged from 750 to 1,307 trees per ac with natural regeneration, as previously defined, comprising 1.5 to 35.8% of this density in the different areas examined. Western red cedar (*Thuja plicata* Donn) and western hemlock *(Tsuga heterophylla* (Raf.) Sarg.) were the predominant species of natural regeneration (Table 1). Western white pine (*Pinus monticola* Dougl.), western yew (*Taxus brevifolia* Nutt.), and several other species were recorded but generally in small numbers. In most areas understory Douglas fir comprised only a small part of the total population. Considerable variation occurred in the total number of naturally regenerated trees per ac. Western red cedar was the most highly variable species in this regard, its density ranging from 0 to 243 trees per ac.

There was no correlation between the numbers of naturally-regenerated and overstory trees per acre; factors other than stand density thus appeared to be operative in determining the amount of natural regeneration. Although the areas differed to some extent in site and exposure, distance to seed source was considered to be the most important single factor related to the density and composition of the reproduction.

TABLE 1

NUMBER OF LIVING TREES PER ACRE RECORDED IN SELECTED DOUGLAS FIR PLANTATIONS ON VANCOUVER ISLAND

Species	Number of living trees per acre					
	Robertson River	Campbell River		Tsable River		Average (Weighted by area)
		Block I	Block II	Block I	Block II	
	(9.00 ac)	(4.80 ac)	(2.40 ac)	(2.88 ac)	(1.44 ac)	
Western red cedar	11.8	0.0	4.2	236.8	243.0	89.3
Western Hemlock	122.0	59.0	8.3	169.7	128.5	116.9
Western white pine	10.0	2.7	2.9	14.9	4.2	8.9
Other	1.5	0.8	1.3	1.4	4.2	1.7
Total	145·3	62.5	16.7	422.2	379.9	216.8
Douglas fir understory	106.6	29.2	26.2	81.6	141.6	88.3
Douglas fir overstory	498.1	748.9	1,091.7	676.4	785.4	650.3
Total	145.3	62.5	16.7	422.2	379.9	216.8
All species	750·0	840.6	1,134.6	1,180.2	1,306.9	955.4

Mortality in the different species varied considerably between areas and was most severe within the understory Douglas fir and in western white pine (Table 2). Most of the fir mortality was ascribed to Armillaria root rot and all of that in white pine to Cronartium blister rust. Most of the living pine was infected by rust and very few trees are likely to survive to maturity. No detailed examinations were made to determine the causes of death in the other species. It is known, however, that prolonged periods of summer drought may severely damage and kill western hemlock, particularly on dry sites (Molnar 1959, Weir 1960), and it is possible that some of the mortality recorded in this species may have resulted from previous periods of moisture deficiency.

Forked stems, generally arising within the first 18 in. above ground, were observed in a number of cases. Of 2,073 hemlock examined, 291 trees or

TABLE 2

MORTALITY IN NATURAL REGENERATION OCCURRING IN SELECTED DOUGLAS FIR PLANTATIONS ON VANCOUVER ISLAND

Species	Percentage of trees dead				
	Robertson River	Campbell River		Tsable River	
		Block I	Block II	Block I	Block II
Douglas fir (understory)	0.2	9.7	10.0	11.6	19.0
Western red cedar	0.0	—	0.0	0.4	0.8
Western hemlock	3.2	0.7	0.0	3.6	2.6
Western white pine	34.1	13.3	12.5	18.9	68.4

14.0% were affected, 265 having double, 21 triple, and 5 quadruple leaders. Other species were less frequently damaged; the average percentages of affected pine, understory fir, and red cedar were 3.2, 0.2, and 1.0, respectively. The cause of the condition was not determined.

TABLE 3

SPATIAL ARRANGEMENT OF NATURAL REGENERATION IN SELECTED DOUGLAS FIR PLANTATIONS ON VANCOUVER ISLAND

Species	Index of Non-randomness[1]				
	Robertson River	Campbell River		Tsable River	
		Block I	Block II	Block I	Block II
Western red cedar	1.03^c(150)	—	—	1.45^c(100)	1.33^c(274)
Western hemlock	.93^b(200)	1.43^c(100)	1.02^b(100)	1.11^b(100)	1.11^b(264)
Western white pine	.91^b(150)	.69^a(150)	.50^a(100)	.64^a(200)	.52^a(150)

[1] Interpretations based on confidence intervals presented by Pielou (1959) for $P_{.05}$ and indicated sample sizes (numbers in parentheses). Symbols: a = regular, b = random, c = aggregated pattern.

Analyses of spatial pattern demonstrated (Table 3) that western white pine conformed to regular and random patterns, and that red cedar and western hemlock conformed to random and aggregated patterns in the different areas examined. In a further analysis of the Tsable River Block II population the central study area was partitioned into three sub-blocks. Analyses demonstrated (Table 4) that western hemlock was randomly arranged in all sub-blocks, and the red cedar was randomly arranged in one and aggregated in the third. The results demonstrate that there is no uniform pattern of arrangement of natural regeneration either between or within areas as small as or smaller than 1 ac.

DISCUSSION

Because the present data are based on observations of Douglas fir plantations at only one stage in their development, they cannot be used to forecast

TABLE 4

SPATIAL ARRANGEMENT OF NATURAL REGENERATION WITHIN SUB-AREAS OF TSABLE RIVER BLOCK II POPULATION

Species	Index of Non-randomness[1]		
	Block A	Block B	Block C
Western red cedar	1.24^{c}(87)	$.82^{b}$(107)	1.78^{c}(80)
Western hemlock	1.08^{b}(87)	1.11^{b}(102)	1.11^{b}(75)

[1] Interpretations based on confidence intervals presented by Pielou (1959) for $P_{.05}$ and indicated sample sizes (numbers in parentheses). Symbols: b = random, c = aggregated pattern.

changes in pattern or species composition which may take place in the future. They may, however, be helpful in examining some of the problems likely to be encountered should periodic observations be undertaken with this objective.

Natural regeneration was highly variable in respect to species composition, density, and spatial arrangement between and within areas as small as 1 ac. This finding suggests that appraisals of trends may have to be based on the examination of every tree in a given area rather than on data gained through sampling; unless intensive sampling is undertaken in an area the necessary precisions in estimating population values may not be achieved, and lacking this precision there may be no way to determine if differences between successive observations represent sampling variation or valid evidence of change. To estimate[4] the population mean density of western hemlock in the Tsable River Block II population with a precision of 5%, for example, it would be necessary to sample 567 quadrats (each 10 x 10 ft square) or 49% of the total population of quadrats of this size. The sampling intensity required with this precision would be somewhat smaller if larger quadrats were used and would be reduced to 19% if only 10% precision were required with the 10 x 10 ft quadrat, but in the latter case the population mean could be estimated only within the approximate limits of 140 and 172 trees.

The occurrence of different patterns of natural regeneration between different species in one area and within one species in different areas shows that the spatial arrangement of a tree species may be determined by a number of factors operating simultaneously. It is doubtful, under these circumstances, that a single model would describe the range of circumstances likely to be encountered in Douglas fir plantations. On the assumption that no two populations are precisely the same, it is possible that an extended, even infinite, series of models would be required. Should this be the case it would be difficult or impossible to assess changes by comparing one population with another at a different stage in its development; periodic observations within a single population would be necessary.

It is not possible with the present data to determine the extent to which replications would be necessary in different populations. It does not necessarily follow, however, that the presence of an infinite series of models would require an infinite series of replications. With reference to Pielou's index of

[4] With a confidence of .68 and assuming a normal distribution of values.

non-randomness, for example, values[5] within the limits of 0 and .810 indicate regularity, values from .811 to 1.203 indicate randomness, and values above 1.203 indicate aggregation; thus, only two changes in pattern are possible, towards regularity or aggregation. A regular pattern yielding an index of, say, .70, could only remain static, become more regular, or change in the direction of aggregation. The rate and extent to which a population changed would vary according to the population affected and with the extent to which factors responsible for change exerted their influence. Two natural factors capable of transforming patterns have been recognized (Foster and Johnson 1963) in Douglas fir plantations; competition, which may not effect a change towards regularity, and mortality caused by root rot, which may introduce elements of aggregation to the pattern of surviving trees. In general, the time required for the natural transformation of one pattern to another should vary with the extent to which the two patterns differ initially. Studies to establish transformation rates are required.

Knowledge of future trends in the number of trees per ac may not in itself provide sufficient information on which to forecast future productivity; different areas of the same site, species composition and density of trees per ac might provide substantially different yields depending on the pattern in which the trees are arranged. In general, the highest yields should be obtained if trees are arranged in a regular pattern and the yield should decrease with increasing tendency to aggregation. In a strongly aggregated pattern, for example, most of the trees could occur in one or several isolated groups and very few trees might attain a desired size class owing to severe root and crown competition arising from over-crowding. This concept suggests that it may be of considerable importance in plantations and in natural stands to determine spatial patterns and trends in their transformation. It may be impractical or impossible to reverse undesirable trends but it should be possible to obtain more accurate estimates of future yield if forecasts of the future population patterns are available.

Plantation assessments require simultaneous observations of natural regeneration and planted trees. Previous studies of the latter component (Foster and Johnson 1963) have indicated that important changes in the density and pattern of planted trees may take place at an early age. It may be necessary, therefore, to initiate periodic observations from the date of planting, or prior to planting, if the extent of these changes are to be fully appreciated.

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[5] Based on a sample size of 100 trees and with $P = .05$.