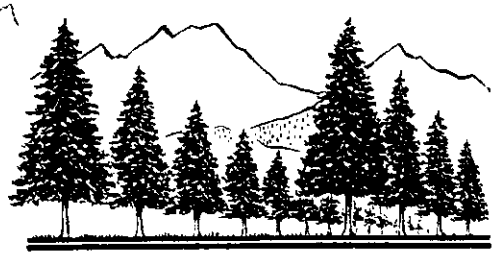

research notes

· · BRITISH COLUMBIA FOREST SERVICE · ·

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An Analysis of the Difference in Gross Merchantable Cubic-foot Volumes of the Upper Fraser Uneven-aged Spruce-Balsam Type When Computed by 2-, 4-, 6-, and 8-inch D.B.H. Classes

PART I

By

R. M. Malcolm

PART II

By

J. L. Alexander

RESEARCH DIVISION

R. H. Spilsbury, Forester

FOREWORD

Part I of the following research note is a condensation by R. M. Malcolm of a thesis he submitted in partial fulfillment of the requirements for registration in the Association of British Columbia Foresters and is reproduced with their kind permission.

Part II of the note, by J. L. Alexander, is a further development from the same basic data of some important considerations in problems of application which were beyond the scope of Mr. Malcolm's original thesis. Owing to the untimely death* of Mr. Alexander an anticipated, co-author publication was impossible. In fairness to the author no attempt was made to revise his draft manuscript and the reader is requested to overlook occasional repetition in Parts I and II.

R. H. Spilsbury.

*April 3, 1951.

Spruce-Balsam Type in the Bowron River Valley

PART I

by R. M. MALCOLM

INTRODUCTION

At a time when a forest inventory of British Columbia is urgently required for consideration of long-term management and sustained yield, it is essential that the detail and degree of accuracy in field work shall not exceed that required in the answer of volume estimation.

For decades some commercial cruisers on the Coast of British Columbia have been using the equivalent of 5- to 10-inch diameter classes, and thus reducing time in field work and compilation compared with the use of 2-inch classes.

No reference to an analysis of the difference in volumes resulting from the use of different ranges in diameter classes could be found for the Spruce, Picea glauca (Moench.) Voss, --Balsam, Abies lasiocarpa (Hook.) Nutt, type.

While cruising in the uneven-aged Spruce-Balsam type of the Prince George Region, it was felt that it would be possible to increase the speed of field work by cruising in larger diameter-groupings than the conventional 2-inch classes. Larger d.b.h. classes would result in fewer classes and there would be fewer borderline trees between the classes. This would achieve savings in time, both in cruising and in the compiling of volumes and checking.

These savings in time would lower the cost of forest inventory.

OBJECT

The object of this study is to determine the difference in volume estimates in cruises of the uneven-aged Spruce-Balsam type, when compiled in 4-, 6-, and 8-inch d.b.h. classes as compared with 2-inch classes.

It is hoped to justify the use of a larger diameter-grouping than 2-inch d.b.h. classes in tallying.

METHOD OF STUDY

No selection or rejection of basic data was made. All the one-acre tallies made by the author in two large areas of the Spruce-Balsam type in the 1948 field season were used. These areas are shown on the Location Map.

Eleven tallies from the area west of the Bowron River between the Fraser River and Bowron Lake, and thirty-three tallies from the area between Eaglet Lake and the Fraser River were used. These tallies gave considerable variation in volume per acre and diameter spread.

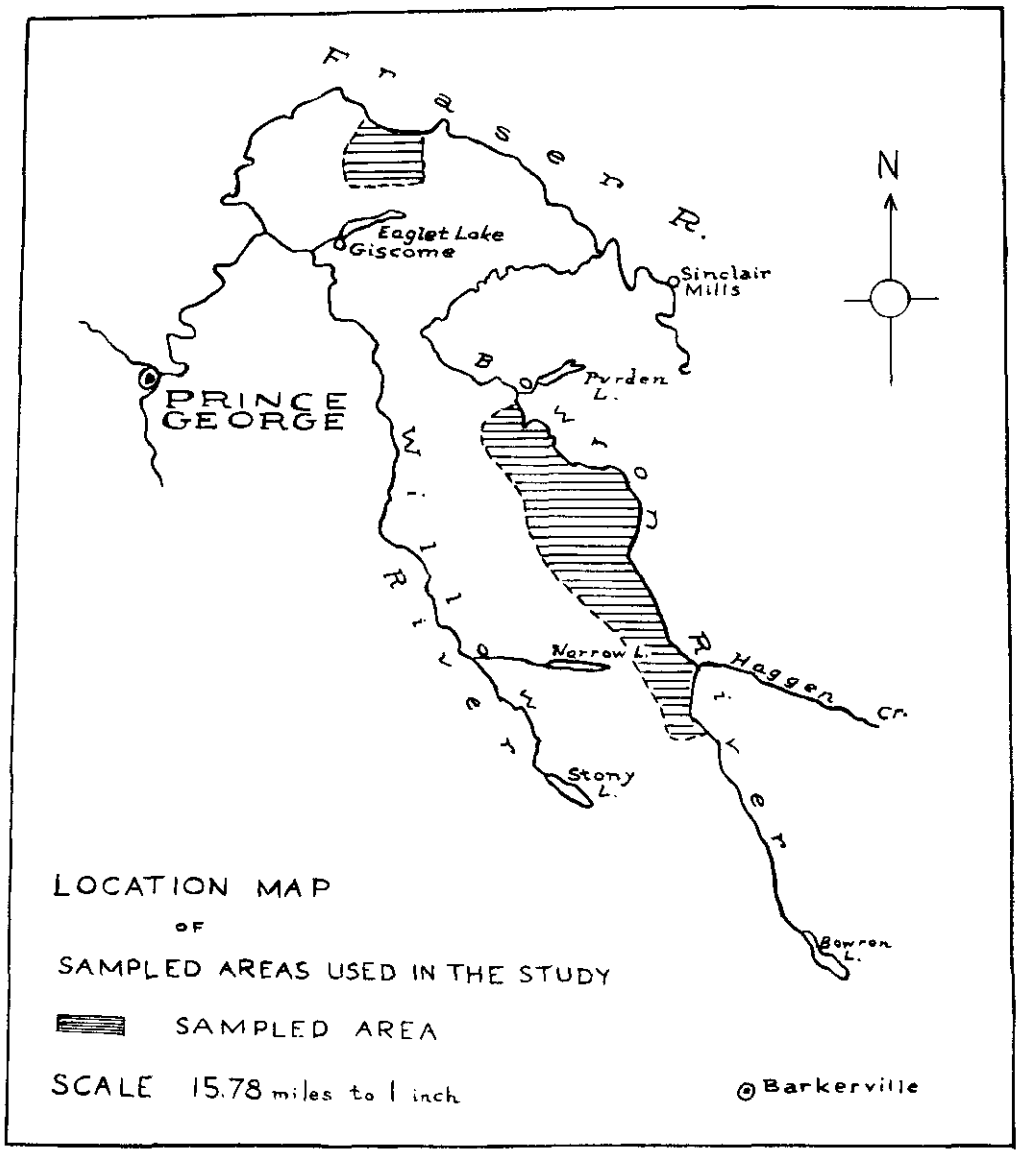


Fig. 1.

The initial cruise and volume compilation was by 2-inch diameter classes. For the purposes of this study the trees above 7.0 inches at d.b.h. in each tally were re-allocated from 2-inch classes to 4-, 6-, and 8-inch classes.

TABLE I--TALLY VOLUMES BY 2-, 4-, 6-, and 8-INCH D.B.H. CLASSES

Strip No.	Tally No.	Volume on one acre--Gross Cubic Feet				Difference--Cubic Feet		
		2-inch Diameter Classes	4-inch Diameter Classes	6-inch Diameter Classes	8-inch Diameter Classes	4"-2"	6"-2"	8"-2"
270	1	5500	5600	5640	5970	+100	+140	+470
	2	4650	4690	4600	4930	+ 40	- 50	+280
	3	8340	8380	8430	8500	+ 40	+ 90	+160
	4	5060	5090	5090	5310	+ 30	+ 30	+250
272	1	5500	5630	5500	5890	+130	0	+390
	2	5010	5090	5010	5190	+ 80	0	+180
273	1	2030	2160	2090	2380	+130	+ 60	+350
276	1	4000	3980	4010	3920	- 20	+ 10	- 80
	2	6530	6640	6530	6540	+110	0	+ 10
	3	5300	5560	5030	5690	+260	-270	+390
	4	5440	5600	5810	5570	+160	+370	+130
	5	8640	8720	8870	8730	+ 80	+230	+ 90
279	1	6010	6120	6190	6170	+110	+180	+160
	2	5730	5920	5570	6120	+190	-160	+390
	3	6070	6160	5960	6460	+ 90	-110	+390
	4	5250	5250	5240	5380	0	- 10	+130
	5	6220	6250	6220	6210	+ 30	0	- 10
	6	6060	6250	6030	6520	+190	- 30	+460
300	1	4440	4390	4370	5010	- 50	- 70	+570
	2	3510	3660	3440	4050	+150	- 70	+540
	3	6660	6690	6430	6760	+ 30	-230	+100
	4	4740	4840	4720	4880	+100	- 20	+140
302	1	5290	5370	5250	5540	+ 80	- 40	+250
	3	4650	4740	4730	4750	+ 90	+ 80	+100
	4	3940	3940	3970	3900	0	+ 30	- 40
	5	4090	4240	4160	4540	+150	+ 70	+450
306	1	2920	2960	2920	2990	+ 40	0	+ 70
	2	5340	5430	5410	5840	+ 90	+ 70	+500
	3	4440	4510	4410	4610	+ 70	- 30	+170
	4	4840	5100	5020	5270	+260	+180	+430
	5	3880	4070	3990	4390	+190	+110	+510
	6	6580	6850	6810	7420	+270	+230	+840
307	3	5690	5750	5720	5960	+ 60	+ 30	+270
336	1	6020	6070	6220	6050	+ 50	+200	+ 30
337	1	7010	7190	7210	7430	+180	+200	+420
364	1	1520	1560	1650	1770	+ 40	+130	+250
365	1	3950	4030	4100	4250	+ 80	+150	+300
440	1	4080	4170	4110	4380	+ 90	+ 30	+300
441	1	3460	3510	3540	3640	+ 50	+ 80	+180
442	1	5370	5400	5420	5630	+ 30	+ 50	+260
443	1	4670	4730	4900	4840	+ 60	+230	+170
	2	4150	4240	4260	4560	+ 90	+110	+410
444	4	4710	4870	4850	5380	+160	+140	+670
445	1	3370	3450	3480	3450	+ 80	+110	+ 80
Total		220660	224850	222910	232770	+4190	+2250	+12110
Mean		5015	5110	5066	5290	+95	+51	+275
Percentage Difference from 2-inch class						+1.9	+1.0	+5.5

The gross cubic-foot volume of each tally was compiled, using the volume of the mid-diameter and number of trees in the d.b.h. class, for the 2-, 4-, 6-, and 8-inch classes.

RESULTS

The table on page 3 shows details of tally volumes, differences in volume, and the means of these values for each diameter-class grouping, for the 44 tallies, totalling 44.0 acres.

The standard error of the mean differences in volume caused by the various compilation classes was calculated by "Students" method and are summarized in Table II.

TABLE II--TEST OF VOLUME DIFFERENCES BY 2-, 4-, 6-, AND 8-INCH D.B.H. CLASSES

D.B.H. Grouping	No. of one-acre tallies	Total Volume cubic feet	Average Volume per acre cubic feet	Difference per acre from 2-inch Grouping		Standard Deviation of Difference cubic feet per acre	S.E. of Mean Difference of 44 samples cubic feet
				per cent	cubic feet		
2-inch	44	220660	5015				
4-inch	44	224850	5110	+1.9	**+95	± 72.6	± 10.9
6-inch	44	222910	5066	+1.0	**+51	±123.9	± 18.7
8-inch	44	232770	5290	+5.5	**+275	±199.1	± 30.0

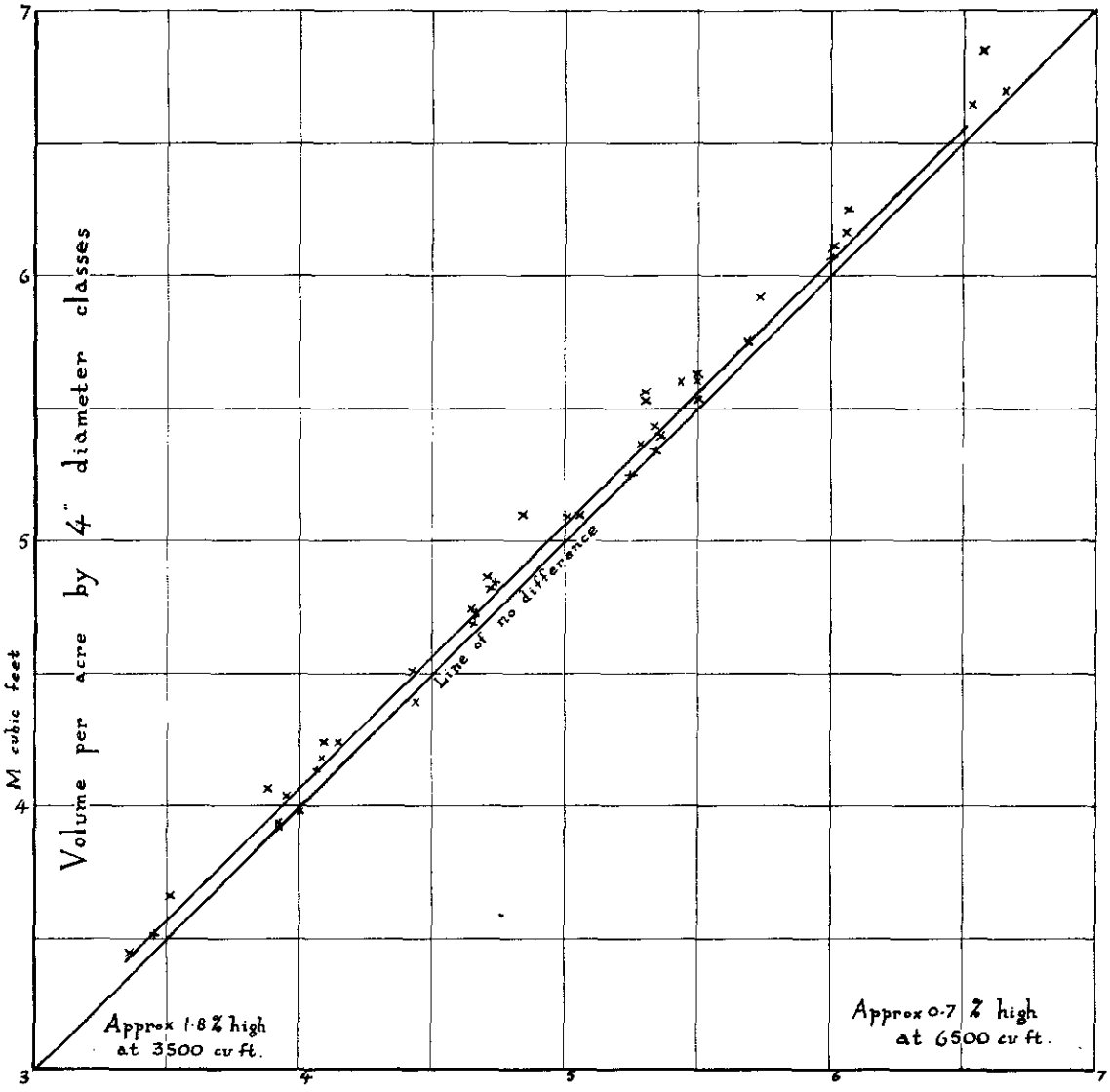
**Highly significant differences.

These results show that the mean differences in estimate caused by the three new methods of diameter grouping are all highly significant.

From the table it can be seen that the mean difference for the 6-inch grouping is less than for those of the 4-inch and 8-inch groupings. This is accounted for by the fact that, in the 6-inch grouping, the ratio standard deviation to mean difference is higher than in the 4- or 8-inch groupings. In other words, there is a comparatively wide spread of differences between the tally volumes by 6- and 2-inch d.b.h. classes, while the mean difference is small.

No 1

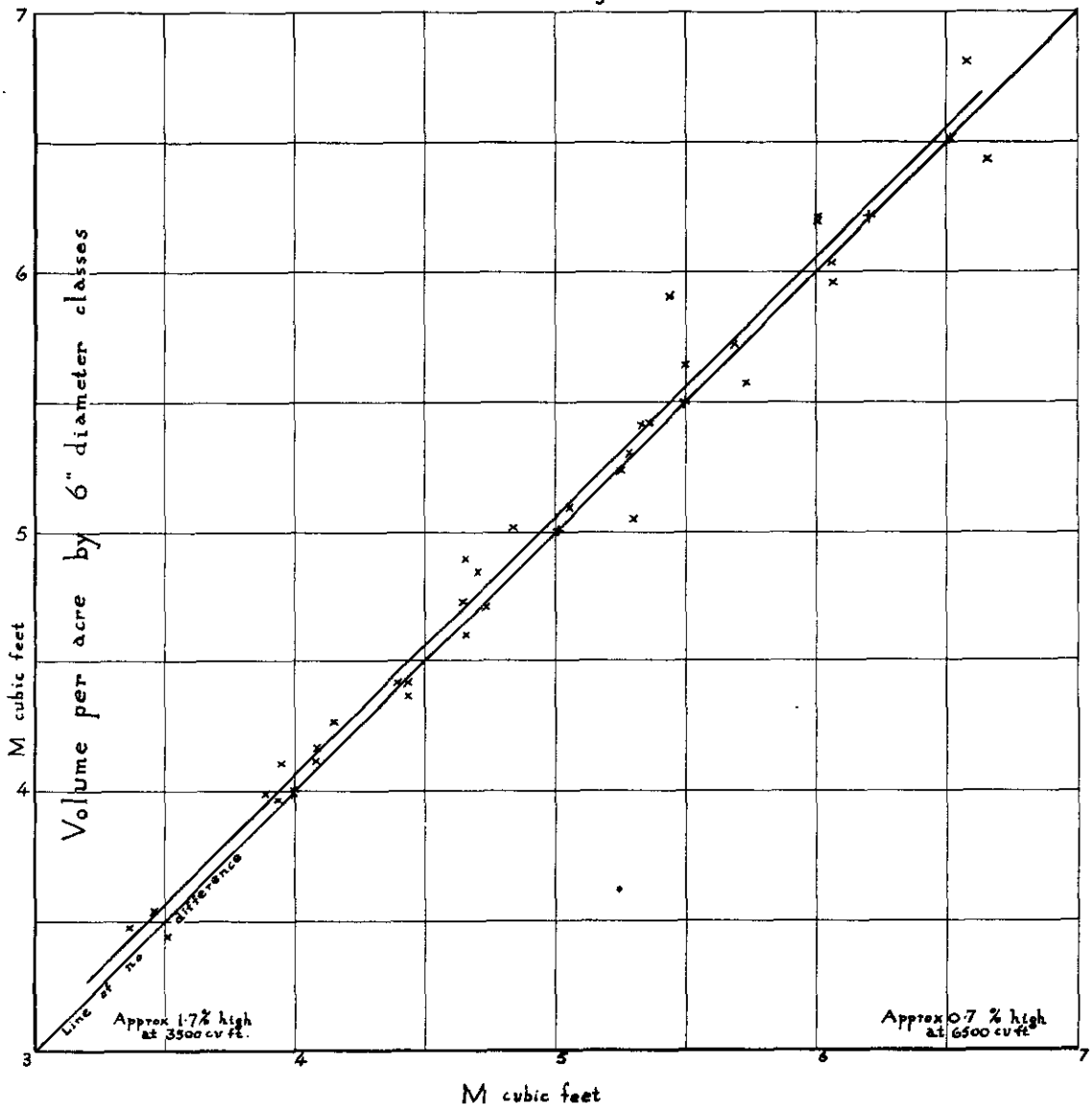
GRAPH of VOLUME PER ACRE by 2" and 4" DIAMETER CLASSES



· Volume per acre by 2" diameter classes

No 2

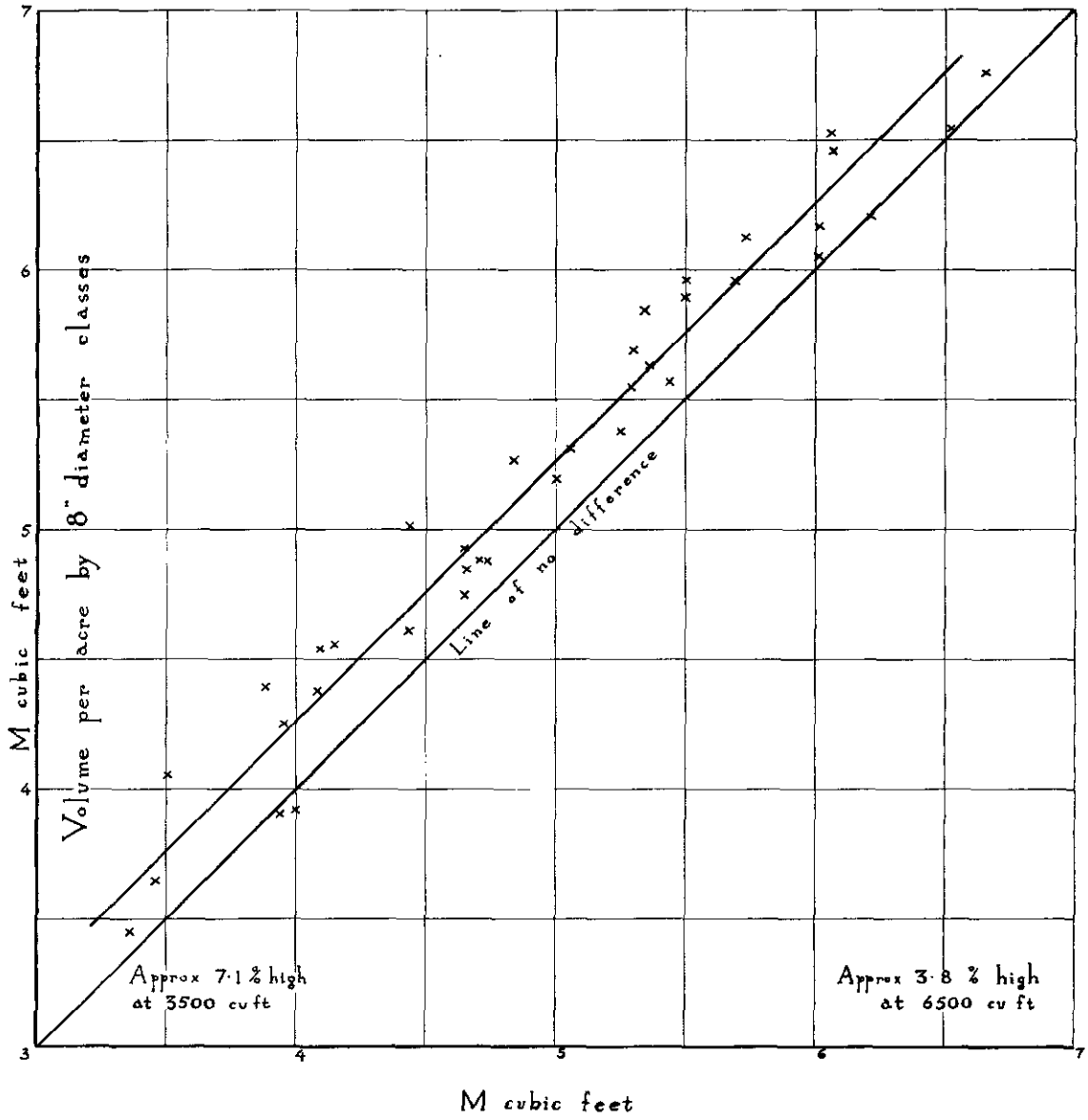
GRAPH of VOLUME PER ACRE by 2" and 6" DIAMETER CLASSES



Volume per acre by 2" diameter classes

No 3

GRAPH of VOLUME PER ACRE by 2" and 8" DIAMETER CLASSES



Volume per acre by 2" diameter classes

Although they are highly significant, the absolute differences in volume due to grouping by the 4- and 6-inch diameter classes are only 1.9 and 1.0 per cent, respectively, and unimportant. The difference in volume due to grouping by the 8-inch diameter classes is 5.5 per cent, which is an important difference.

Graphs 1, 2, and 3 show volumes by 4-, 6-, and 8-inch diameter classes plotted over volumes by 2-inch classes. Graphs 1 and 2 show that in tallies compiled by 4- and 6-inch diameter classes there is a consistently high difference in volume estimates over the range of volumes found in the Spruce-Balsam type. The difference is small in magnitude in both cases.

From Graph 3, it is evident that computing volumes by 8-inch diameter classes gives a consistently high difference which is large enough to be important.

The reason for the consistently high difference is unknown, but it may be associated with distributions and weighting which is beyond the scope of this study. The possibility of calculating a correction factor for volume estimates, computed from 8-inch diameter classes, will, therefore, not be discussed.

SUMMARY

The conclusions of this study apply only to the uneven-aged Spruce-Balsam type of the Prince George Region, volumes compiled in cubic feet.

The sample of 44 one-acre tallies, computed by 2-, 4-, 6-, and 8-inch d.b.h. classes, gives the following differences in volume from the computations by 2-inch classes.

D.B.H. Class--Inches	Per Cent Difference in Volume from 2-inch Class
4	+1.9
6	+1.0
8	+5.5

These differences apply to the mean of 44 tallies only.

1. In the case of the estimates by 4- and 6-inch d.b.h. classes the differences are highly significant for an unknown reason; but their magnitude is consistently small over the range in volumes normally encountered in the type, and they are, therefore, considered unimportant.

2. Six-inch diameter classes appear to be the largest grouping giving volume estimates of sufficient accuracy for extensive forest survey purposes, without the application of a correction factor.

3. Tallying by 6-inch diameter classes in the Spruce-Balsam type should cause savings in time and cost of both field and subsequent office work.

A test was carried out to determine the approximate saving in time of compiling tallies by 6-inch diameter classes, instead of by 2-inch classes. The author was the compiler throughout this test.

The results were as follows.

Diameter Class Grouping inches	Number of tallies	Time to Compile --minutes	Per Cent Saving in time from 2-inch Classes
2	15	56	
6	15	33	41

This saving in time of office compiling is indicative of the faster compiling and tallying which may be expected in the field.

It would be of great value to carry out a field study to determine the saving in time and cost of tallying by 6-inch diameter classes instead of by 2-inch classes.

PART II

by J. L. ALEXANDER

INTRODUCTION

Cruisers in Eastern Canada and the United States, where the diameter-range of stands is relatively small, have used 2-inch diameter classes for tallying from the early days. On most areas in the softwood forests six classes would cover the bulk of the trees even cruising down to 4 inches d.b.h. As the forests in the West became more important,

necessitating stock-taking, government agencies and some commercial cruisers adhered to the 2-inch classes even though, for Coast timber, there might be 30 or more diameter classes in a stand. Some commercial cruisers jumped to 5-inch classes in the early days, and some old-time cruisers who recorded the volume of individual trees directly, used the equivalent of 10- to 12-inch classes in old-growth Douglas Fir and Sitka Spruce stands.

The 2-inch diameter classes will give the most accurate estimate but the difference between using 2-inch classes and larger classes may be unimportantly small, if based on a sufficient number of tallies.

The relative error is more closely related to the number of diameter classes recognized in a stand than the range in diameters from the smallest to the largest trees.

The range covered by each diameter class for a given precision in the volume will depend on the total range of diameters in a stand and the number of tallies making up each average. The larger the diameter classes, the greater the saving in field work and computation and for a given area tallied the less precision in the results. This necessitates balancing costs against accuracy.

OBJECT

The object of this study is to determine the maximum sizes of diameter classes which may be used in the uneven-aged Spruce-Balsam type of the Upper Fraser at a predetermined sacrifice of precision for a given number of acres tallied.

DATA

Mr. R. M. Malcolm, while cruising in the uneven-aged Spruce-Balsam type of the Upper Fraser tallied one-acre units, compiled the volumes by 2-, 4-, 6-, and 8-inch classes and made them available for this study. (See Part I.)

ANALYSIS AND RESULTS

The results from this analysis apply only to this type or similar types covering the same range in diameters. The gross merchantable volume averaged 5,000 cubic feet per acre. The loss from defect is probably about one-seventh of the gross volume. This latter factor was not taken into consideration in the analysis. The diameters ranged from 7 to 30 inches with a few larger trees, giving about 12, 6, 4, and 3 classes when compiled by 2-, 4-, 6-, and 8-inch classes, respectively.

There is high correlation between the volume of individual tallies calculated by 2-inch classes and the larger diameter classes; a low volume per acre for one class will mean a low volume per acre for each of the other classes. "Students" method which is especially adapted to this kind of data was used in the analysis of differences.

The results of the analysis are presented in Table II of Part I. The standard deviation of the differences in cubic feet per acre from the volume by 2-inch d.b.h. classes is the real meat in this table. The residual error after allowing for the significant differences is directly proportional to the standard error of the differences shown in Table II. For example, the residual error when 6-inch classes are used is $\frac{123.9}{72.6} = 1.71$ times the error for 4-inch classes and when 8-inch classes are used $\frac{191.1}{72.6}$ = 2.74 times the error for the 4-inch classes.

The significant differences of 95, 51, and 275 cubic feet were subtracted from the acre volumes for each tally computed by 4-, 6-, and 8-inch classes, respectively. Then the differences between the residual volumes computed by 4-, 6-, and 8-inch classes and by 2-inch classes were determined and, together with the uncorrected differences (see Table I), are summarized in Table III on page 9.

The average difference in per cent in Table III was calculated from the total volumes. Although the average difference based on 44 tallies for 4- and 6-inch classes are low, individual tallies had differences up to 5.5 and 6.8 per cent, respectively. The maximum difference for one acre calculated by 6-inch classes is 7 times the average for the 44 acres. Therefore, averages without reference to the number of tallies on which they are based may lead to erroneous conclusions.

Since the error to be expected when different diameter classes are used depends on the number of acre-tallies making up each average, Table IV has been prepared. It is based on the standard errors of the differences in Table II and indicates the maximum difference in cubic feet due to sampling that may be expected at a probability of 0.05 between volumes compiled by 4-, 6-, and 8-inch classes compared with volume compiled with 2-inch classes.

Table IV shows that the sampling error for the same number of tallies is greater the larger the diameter class used in compilation and that the sampling error also depends on the number of tallies. For example, the error for 20 tallies by 8-inch classes will be less than the error for 5 tallies by 4-inch classes. The number of tallies making up a type should be considered in deciding the diameter class to be used.

TABLE III--DISTRIBUTION OF ACRE TALLIES ACCORDING TO DIFFERENCES IN CUBIC FEET PER ACRE FROM VOLUMES COMPUTED BY 2-INCH D.B.H. CLASSES

Difference in Cubic Feet per Acre	Not Corrected			Corrected		
	D.B.H. Classses					
	4-inch	6-inch	8-inch	4-inch	6-inch	8-inch
	Number of Acre Tallies					
0- 50	14	16	4	20	12	8
51-100	15	9	6	19	17	3
101-150	6	8	3	2	7	13
151-200	6	5	6	3	4	8
201-250	0	4	3		0	4
251-300	3	1	5		2	4
301-350		1	1		2	1
351-400			4			2
401-450			4			0
451-500			3			0
501-550			2			0
551-600			1			1
601-650			0			
651-700			1			
701-750			0			
751-800			0			
801-850			1			
Total	44	44	44	44	44	44
Maximum Difference Cubic Feet per Acre	260	370	840	175	321	565
Maximum Difference per cent	5.5	6.8	12.8	3.3	6.1	8.9
Average Difference per Acre						
(1) Cubic Feet	95	51	275			
(2) Per cent	1.9	1.0	5.6			

Note: Numbers corresponding to average difference per acre based on 44 tallies are underlined.

TABLE IV--MAXIMUM DIFFERENCES DUE TO SAMPLING FOR VARIOUS D.B.H. CLASSES AND NUMBERS OF TALLIES.

Number of Acre Tallies	Maximum Difference due to Sampling. Cubic Feet per Acre		
	D.B.H. Classes		
	4-inch	6-inch	8-inch
5	101	172	276
10	54	91	148
15	42	71	114
20	35	59	96
30	28	47	76
50	21	36	57
100	15	25	40
1000	5	8	12

The error due to the use of larger than 2-inch classes is a compromise against reduced costs and since the total error of a cruise is the sum of all the errors some maximum must be established. Let us assume that the saving in labour justified a one per cent allowable error due to diameter grouping. Since this type averages 5,000 gross merchantable cubic feet per acre the allowable error will be 50 cubic feet. Referring to Table IV this tolerance requires 13, 26, and 60 tallies when computed by 4-, 6-, and 8-inch classes respectively. Where 4-, 6-, and 8-inch are used in computing, the volume 91, 51, and 275 cubic feet, respectively, should be deducted from the average volume per acre to obtain the best estimate of the average type volume. This illustrates the use of Table IV.

In high-intensity surveys for the planning of logging coast timber where the logging costs $1,000 per acre, the saving in using larger diameter classes will be a very small percentage of this operating cost. However, where the logging chance is broken down only into broad volume classes such as 3,000-5,000, 6,000-10,000, and over 10,000 cubic feet per acre, large classes may frequently be used at considerable actual saving without much loss in precision.

The loss in precision in using diameter classes larger than 2-inch will depend on the range in diameters in the type and the number of tallies making up each average and these are the factors that should be considered in determining the diameter classes to be used. No one diameter class can be expected to be acceptable for all types in British

Columbia varying from the small-diameter range of Lodgepole Pine to the large range in mature coast forests on good sites. Under certain conditions large-diameter classes may be used with relatively little loss in precision and at considerable saving in labour costs.

SUMMARY

(1) This analysis is based on 44 one-acre tallies made by R. Malcolm in the uneven-aged Spruce-Balsam type of the Upper Fraser and compiled by him in 2-, 4-, 6-, and 8-inch d.b.h. classes.

(2) The gross merchantable cubic-foot volume per acre without allowance for defect averaged 5,000 cubic feet per acre with individual tallies varying from 1,520 to 8,640 cubic feet. The range in diameters was from 7 inches to 30 inches with a few larger trees.

(3) The results of this study apply only to this type or similar types having about the same average volume and diameter distribution.

(4) The aggregate difference per acre for the 44 tallies compiled by 4-, 6-, and 8-inch classes compared with 2-inch d.b.h. classes was 95, 51, and 275 cubic feet, respectively. This amounted to 1.9, 1.0, and 5.6 per cent of the gross cubic feet volume. All these differences were positive and significant.

(5) The maximum differences for individual tallies were 260, 370, and 840 cubic feet per acre for 4-, 6-, and 8-inch classes respectively. These amounted to 5.5, 6.8, and 12.8 per cent of the average volume.

(6) The standard deviation of the differences based on individual one-acre tallies were 72.6, 123.9, and 199.1 cubic feet per acre for 4-, 6-, and 8-inch classes. The error after correction for the significant differences of 95, 51, and 275 cubic feet is proportional to the standard deviations when various classes are used.

(7) The sampling error depends on the diameter class used and the number of tallied acres making up the average for the type.

(8) Assuming a maximum error of 1 per cent for the use of diameter classes larger than 2 inches, a minimum of 13, 26, and 60 tallies are required when 4-, 6-, and 8-inch classes are used.

(9) When tallies are computed by 4-, 6-, and 8-inch classes the significant differences of 95, 51, and 275, respectively, should be deducted from the average volume per acre for the type.

(10) The range in diameters and the number of tallies making up each average determine the diameter classes to be used for a given precision. Therefore, no one diameter class can be expected to be suitable for all of the types in British Columbia.

(11) The larger the diameter class the less the precision but the greater the saving in labour and costs.