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The Sampling, Pattern, and Survival of the Higher Elevation Beech in the Great Smoky Mountains

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To the Graduate Council:

I am submitting herewith a dissertation written by Kye Chil Oh entitled "The Sampling, Pattern, and Survival of the Higher Elevation Beech in the Great Smoky Mountains." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Botany.

Jerry Olsen, Major Professor

We have read this dissertation and recommend its acceptance:

Edward E. C. Clebsch, M. E. Springer, L. F. Seatz

Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

June 19, 1964

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Jerry S. Olson
Major Professor

We have read this dissertation
and recommend its acceptance:

Edward E.C. Clebsch

Leroy F. Seitz

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M. E. Springer

Accepted for the Council:

Hilton A. Smith
Dean of the Graduate School

THE SAMPLING, PATTERN, AND SURVIVAL OF THE HIGHER ELEVATION BEECH IN THE GREAT SMOKY MOUNTAINS

A Dissertation
Presented to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

by
Kye Chil Oh
August 1964

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ABSTRACT

Six "beech gap" forests in the Great Smoky Mountains between Tennessee and North Carolina were sampled for pattern of stem distribution and for stem size and survivorship of Fagus grandifolia. Several methods for approximating the adequacy of number of plots for stem count were compared in terms of relative efficiency. Stem count and basal area of all species were similar between north-facing and south-facing stands, and between more east-facing and west-facing sides of the same stand. Mean density of live beech ranged from 3705 to 7835 trees per hectare, and basal area ranged from 16.1 to 33.0 m^2 per hectare. For living and dead stems of all species the mean density ranged from 6200 to 8515 stems per hectare, but the basal area ranged from 39.6 to only 40.0 m^2 per hectare. Ten randomly placed quadrats in each side of the stand provided measures of variance for stand data on sizes of live and dead stems and inferred survivorship. The distribution pattern of stems was also studied in mapped transects 5 by 100 meters in each stand.

The distribution of size classes of dead beech stems reveals a primary unstable size group (0.1 to 6.0 cm) and primary stable, secondary stable, and unstable size groups. The general features of the distribution curve are similar to those with constant mortality rates.

The implications of the high mortality of small stems (0-6 cm diameters) and the high density and low density patches for release and competition are discussed. The mosaic pattern of beech distribution is thought to be the result of cyclic regeneration.

The proportion of dead beech is not different significantly between north- and south-facing slopes, but it is significantly different among stands and between aspects within stand. No directional trend can be demonstrated for aspect differences. The proportion of non-beech species was significantly different between north- and south-facing slopes (21% vs. 11%), among sites, and between aspects within sites. These differences when added to characteristics of the survivorship curves and the distribution of spruce in the stands suggest that the south-facing stands are under environmental stress.

The distribution of stems was studied by analysis of variance and by Morisita's (1959) index of dispersion analysis. From the analysis of variance, several sizes of primary patches and mosaics were detected in all stands. The regular distribution pattern of individual stems and clumps of stems was revealed, as was some random distribution and several scales of aggregated pattern. North-facing sites had more randomly distributed stems among all trees and among all beech. No random distribution was found in the subareas nearest the ridge crests in the south-facing sites. Living beech was more randomly distributed than were all trees or all beech. Morisita's index reveals similar patterns, but it showed more regularity of pattern. Greig-Smith's (1964) method was more convenient for detecting and interpreting the mosaic pattern and for determining average size of clump and single clump area.

The complicated structure and dynamics of these stands are very strongly controlled by the root suckering of the sole dominant, beech. The dynamics of the stands are revealed by inferred survivorship and mosaic pattern in different size classes to be strongly controlled by changes in micro-environmental pattern and competition during growth of clumps. Maintenance of these deciduous island communities in the boreal conifer forests is possible largely because of rapid and cyclic regeneration in a complicated mosaic.

I. INTRODUCTION

Beech stands occupy some of the concave slopes and the cols or saddles of the ridges above 1372m (4500 feet) in the range of spruce-fir forest (Picea rubens - Abies Fraseri) in the Great Smoky Mountains. These "beech gap" stands are strongly dominated by one deciduous species, Fagus grandifolia. Here gray beech populations (Camp 1940, 1950, 1951) differ from the segregate populations of red and white beech of lower elevations by being smaller in stature, by reproducing mostly by sprouting, and in floristic composition of stands (Whittaker 1956).

The gray beech forests are restricted to habitats which are similar in elevation, topography, and climate. The vegetational history and degree of disturbance of the forests have been inferred by Russell (1953) and Whittaker (1956) to be relatively similar to each other. The one species dominance and the spreading form of the larger trees (designated "beech orchard" by local people) suggest a vegetation which is under environmental stress. The beech gap forests are localized and commonly sharply demarcated from neighboring spruce-fir stands. These forest areas are unglaciated and there is no record of any cutting. These characteristics of the stands provide an excellent opportunity for quantitative ecological studies on the following topics:

1. Measurement of diameters and numbers of trees per unit area provides data which are prerequisite for estimates of tree biomass and chemical composition. Computer analyses of the sampling variability indicate the number and size of plots required to obtain these estimates within specified confidence limits. An analysis of variance also tests whether there are significant differences between and within the six beech stands selected for intensive study.

2. Further interpretation of the variance in numbers of living and dead trees of various diameters provides quantitative measures of the non-random distributions which seem typical of beech gap stands. These stands provide interesting areas for testing those methods of Greig-Smith (1961a, 1961b, 1964), Kershaw (1957, 1958) and others which indicate the scale of aggregation by comparing variances of progressively larger blocks of plots with mean for the same block. Some causes of pattern are suggested and may help future workers to relate these patterns to environmental factors or stand history. These local data also have more general interest for comparison of methods of expressing by Morisita's index of dispersion (1959).

3. A step toward interpreting regeneration and survival of beech trees is provided by detailed analysis of the size distribution of living and dead stems. These results, and other studies of forest mass (Shanks and Clebsch, 1962), decay (Shanks and Olson, 1961) and productivity (Whittaker, Cohen and Olson 1963) in the same vicinity are parts of a long-range effort to

understand the processes which maintain natural vegetation.

II. SITE DESCRIPTION AND SAMPLING

A. Climate

The mountain climate around 1524m (5000 feet) at Newfound Gap is near the border of the super humid climate of the Thornthwaite (1931) classification. Mean annual precipitation values are greater than 2032mm (80 inches). Precipitation exceeds evapo-transpiration around the year except in rare drought years. Mean monthly precipitation values range from approximately 127mm (5 inches) to 330mm (13 inches) with the minimum in September and the maximum in December and January. Mean annual air temperature values range from 7.2°C (45°F) to 9.5°C (49°F). The temperature averages 12.2°C to 9.4°C (10° to 15°F) cooler than at the base of the mountains during the growing season (Shanks 1954). Snow depths approach 1 m in some years but typical depths observed in three sites around Newfound Gap in December 1962 were: 20-23 cm on the north slope of site 4, uniform 7 cm at site 1, and a patchy 3-4 cm at site 2 on the south slope. The extreme variability of the weather during winter, occasional late frost (May in 1961) and complexity of topography in the area are noteworthy.

B. Substrate

Most of the rocks of the study area are referred to the Ocoee series and were deposited in pre-Cambrian time. They are clastic metamorphic sedimentary rocks, predominantly of feldspathic sandstones, dark siltstones and conglomerate (Stose 1949, King et al. 1958).

Soils in this area have been broadly classified in the Ramsey series. Ramsey soils are azonal and belong to Lithosol great soil group (U. S. Department of Agriculture 1956). Special studies (McCracken, Shanks and Clebsch 1962) in the research area have identified beech gap soils as Sol Brun Acide. They are similar in many respects to the Sol Brun Acide under spruce-fir. Differences are principally in composition of the humus layer and free iron content. The Sol Brun Acide of the beech gaps is characterized by duff mull surficial soil material, a relatively thick and granular A_1 horizon and a B horizon differentiated by color but not by relative accumulations of layer silicate clay or iron. The soil is highly acid and extremely weathered, as indicated by extreme alteration of the feldspars and chlorite of the parent materials to vermiculite, intergradational vermiculite-chlorite with some kaolinite and a small amount of gibbsite, but without clay or iron translocation-accumulation. The soil is very low in base status (McCracken, Shanks and Clebsch 1962).

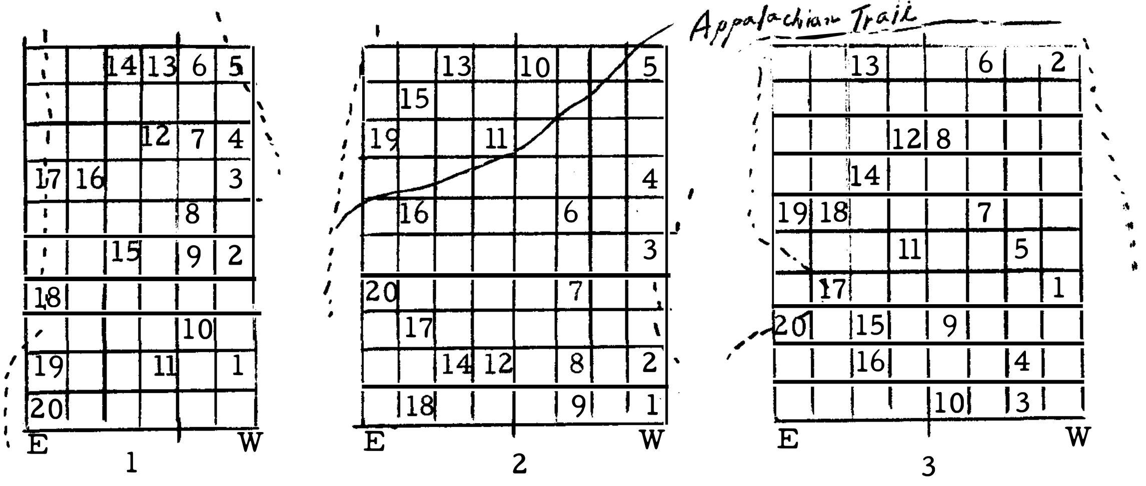
C. Field Procedure

Random sampling was used for determining adequate size and number of plots and comparing the efficiency of several different sampling methods. For the study of horizontal distribution patterns of individuals or stems, systematic sampling was also used. Data obtained through random sampling were also analyzed for the study of horizontal distribution, survivorship and other aspects of the vegetation.

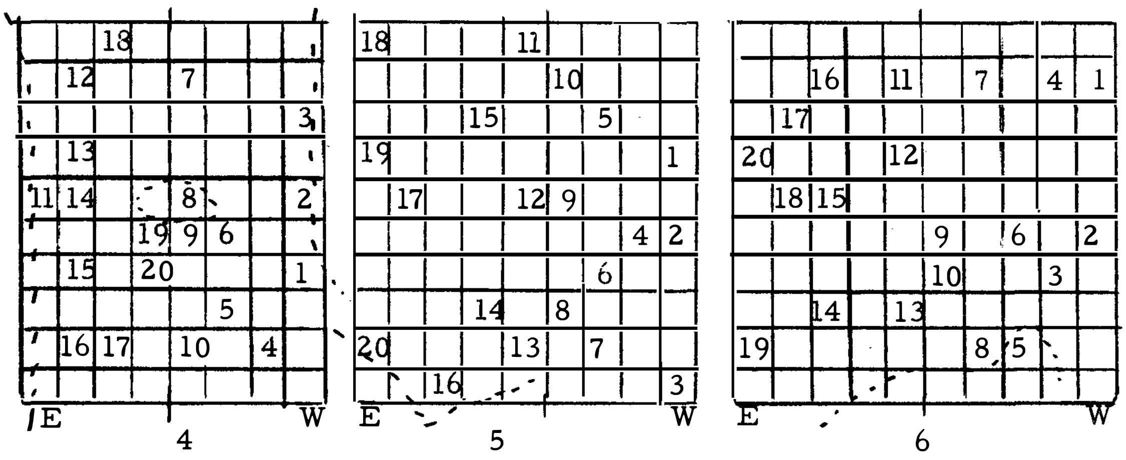
In the center of each stand a ground line of 100 meters length was marked with one-meter intervals from the foot toward the ridge. By using a pair of random numbers to establish grid coordinates (Fisher and Yates 1943) ten imaginary grid units in both the east and west parts of the stand were determined randomly on paper in advance of sampling from a total of 40 to 100 imaginary grid units. Each sampling position was determined by pacing from the ground line (Fig. 1).

A "collapsible" quadrat of 100 square meters (divided into four subplots of 25 square meters each) proved very convenient for sampling this kind of vegetation. A ten-meter pegged string with a center mark constituted one axis of the plot. The other consisted of two 2.5 meter sticks marked at 0.1 m intervals. The arrangement is shown in Figure 2.

Within the subplot each tree and shrub taller than 1.37 m (4. 5 feet) was counted, the diameter at breast height 1.37 m or 4.5 feet (hereafter



South facing sites



North facing sites

---- Border of spruce stand

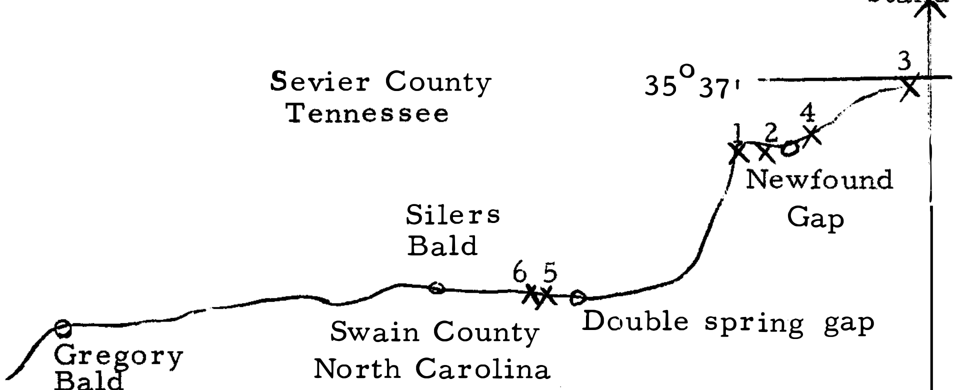


Fig. 1. Map of beech stands and quadrat locations (Arabic numbers) within stands (1-6).

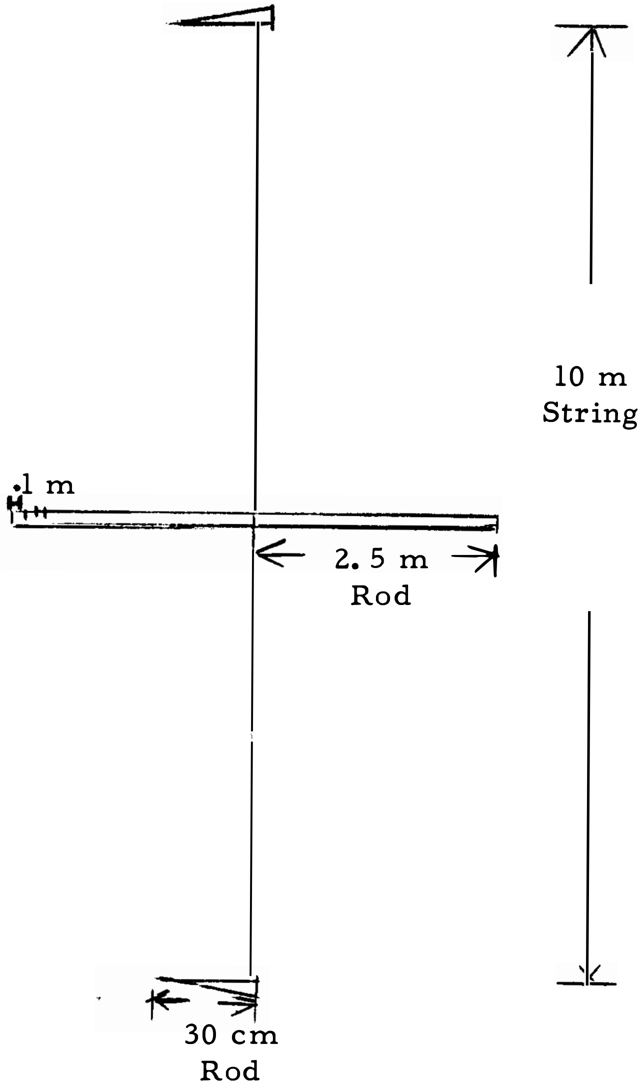


Fig. 2. Structure of the collapsible quadrat.
(Parallel location of the 2 quadrats makes one 10 by 10 m plot)

called dbh) was measured, and species was marked as to whether live or dead. These observations were recorded separately for each of the four 5 x 5 m subplots.

The belt transect with the size of five-meters width and 100-meters length was established along the ground line mentioned before. By holding and moving the five-meter stick along the ground line, the position of each live or dead tree was determined and the dbh was recorded on the graph paper. The position of trees and shrubs taller than 1.37 m (4.5 feet) was also recorded on the graph paper with the scale of one hundredth. The position of ground line was marked for possible future reference or relocation with paint, by white adhesive tape and through blaze mark cuts on the bark.

Vegetation was sampled at six locations along the slope near the ridge crests of the high elevation of the Great Smoky Mountains near the state border of Tennessee and North Carolina (Fig. 1)

D. Stand Locations

Beech Stand 1.

The stand lies about 0.5 km (0.3 miles) west of Newfound Gap at 83° 26' 07'' W, 35° 36' 38'' N. The elevation ranges from approximately 1600 m (5250 feet) to 1700 m (5500 feet). The slope (30°) faces to the southwest (197°).

Beech Stand 2.

This stand lies about 1 km (0.7 miles) at 83° 26' 19'' W, 35° 36' 39'' N west of Newfound Gap. The elevation range is similar to that in Stand 1. The slope (31°) faces southeast (143°).

Beech Stand 3.

This stand lies in about 4 km (2.5 miles) north-northeast from Newfound Gap at 83° 23' 37'' W, 35° 37' 30'' N. The elevation ranges about from 1753 m (5750 feet) to 1829 m (6000 feet). The slope faces due south. The average slopes are 21°, 19°, 13°, 10° and 14° in 20 m sections from the lower part of the slope to the ridge crest. The outline of the slope is curved inward, but is not concave.

Beech Stand 4.

This stand lies about 0.3 km (0.2 miles) northeast of Newfound Gap at 83° 25' 23'' W, 35° 36' 41''N. The elevation ranges from 1524 m (5000 feet) to 1600 m (5250 feet). The slope faces northwest at 315° within the range of the elevation mentioned. The slope ranges from 26° 40' to 28° 30' from the foot of the slope to the top. There is a slight depression between the east and west sides of the stand.

Beech Stand 5.

This stand lies about 1 km (0.7 miles) west of Double Spring Gap at 83° 33' 03" W, 35° 33' 48"N. Here the elevation ranges from 1600 m (5250 feet) to 1661 m (5450 feet) in the sampled area. The slope faces due north. The average slopes of sections are 12°, 16°, 15°, and 8° from the lower part of the slope to the ridge, with the intervals of 0 - 15 m, 15 m - 40 m, 40 m - 70 m, and 70 m - 100 m respectively. There is no noticeable change in slope aspect from west to east. This beech stand is fairly extensive and is bordered by spruce-fir stands on the lower edge.

Beech Stand 6.

This stand lies about 1.3 km (0.8 miles) west of Double Spring Gap at 83° 33' 12" W, 35° 33' 50" N. The average slopes are 18°, 21°, 16°, and 12° from the lower part of the slope to ridge for the intervals of 0 - 20 m, 20 m - 40 m, 40 m - 80 m, and 80 m - 100 m respectively. The east and west aspects are flat. This beech stand is contiguous with the west side of the former stand, and is larger than beech stands 1 to 4. It is bordered by spruce-fir stands below. To the west, this beech stand is bordered by a relatively mature buckeye stand.

III. STAND COMPOSITION AND BASAL AREA

The six stands, chosen subjectively to represent typical variations of the high-elevation Appalachian beech forests, illustrate their general uniformity in several respects. They also illustrate real differences that do exist between stands and within stands. The design of this sampling of the present study provides the first opportunity for systematic statistical analysis of means and variances for counts of trees and basal areas. The same data provide a basis for judging the efficiency of sampling methods applied here, and sampling strategies that might be used in the future in this or similar vegetation (Chapter VIII).

A. General Stand Characteristics

One similarity of all stands (Table 1A) is the unusually high density of individuals [(averaging 6618 per hectare, or 2679 per acre, including live and dead stems at the level of 137 cm (4.5' height)]. A few per cent of these are double stems from the same individual at ground level, or dead stems which are treated separately below. A second similarity, the high percentage of beech stems (72 to 95 per cent), illustrates the degree of prevalence of this single species typically found in many similar high-elevation deciduous stands. Here the trees associated with beech consistently include relatively few species, but their density (Table IA) and basal area (Table IB) vary considerably among sample stands and between other stands of the region (Whittaker 1956). Depending on the basal area of these associated species, the beech varies more than two-fold in counts (3705-7838 per hectare) and basal area (16.79 to 35.13 m^2/hectare). The basal area of all species, however, is relatively uniform (31.5 to 40 m^2/hectare, or 339.1 to 430.6 feet per acre).

The statistical significance of the differences in Table I is shown by Duncan's multiple range test (from LeClerg 1957). For beech stem counts (Table IA) and basal area (Table IB) those values which are underlined by the same line are not significantly different from one another. The possibility of a general difference between sites 1-3 on south slopes and sites 4-6 on north slopes will be tested, along with other sources of variation, in the following section on analysis of variance.

The differences between the east and west sides of each stand are indicated for both density and basal area of beech in Table II . Variability between randomly selected quadrats on each side is reflected in the width of the confidence interval which has a 95 per cent probability of covering the true mean for each side of each stand. The comparatively small numbers of beech greater than 5 cm (2"), and greater than 10 cm (4") of course reflect the large number of small stems. These

Table I. Comparison of Stem Counts and Basal Area for Six Beech stands in the Great Smoky Mountains.

Species	Stand or Site Number					
	A. Density (Stem counts/hectare)+, ranked in order for all species++					
	4	6	2	3	1	5
All stems	6200	5735	5450	6790	7020	8515
	ab	ab	b	ab	a +++	
Beech(all)	3705	4890	5180	5445	6575	7835
Beech(live)	3475	3995	4640	4825	5610	6860
Birch	345	130	15	10	5	45
Buckeye	5	235	75	0	25	155
Spruce	440	215	55	35	145	220
	B. Basal area (m^2/hectare, dm^2/100 m^2 plot, or cm^2/m^2) for stands ranked in the order for beech					
	4	2	6	5	3	1
All stems	39.600	31.540	38.920	34.730	37.740	40.040
Beech(all)	16.790	25.310	27.120	26.290	31.120	35.132
		b	ab	b	ab	a
Beech(live)	16.102	24.240	24.430	24.661	29.897	33.034
Birch(all)	13.733	.002	3.360	.105	.524	.116
Buckeye(all)	.000	3.250	5.265	5.278	0.818	2.511
Spruce(all)	6.592	3.750	1.429	2.165	0.946	1.366

+Multiply by 0.4 for stems/acre.

++Differences not significant for numbers included in same underlining tested by Duncan's multiple range test (LeClerg 1957).

+++Values with the same letter not significantly different.

Table II. Mean density and basal area for beech size classes.

		Density, stems/hectare				Basal area (m^2/hectare) (m^2/ha) = (cm^2/m^2)			
	Size	East side		West side		East side		West side	
	(dbh)		95%		95%		95%		95%
Aspect	cm	Mean	Limit	Mean	Limit	Mean	Limit	Mean	Limit
South									
1	all	6280	±1034	6870	±1122	29.24	±4.22	38.43	±10.39
	>5	1190	189	840	187	27.13	4.17	35.70	10.61
	>10	860	161	580	099	25.56	4.06	34.84	10.65
2	all	5920	± 948	4440	± 967	27.77	±6.01	22.86	± 5.78
	>5	850	273	800	150	24.32	5.93	21.01	5.56
	>10	620	204	630	153	23.46	5.86	20.28	5.55
3	all	5260	± 796	5630	± 829	33.86	±4.57	30.38	± 7.15
	>5	1650	177	1710	527	29.56	3.97	26.90	7.03
	>10	900	153	1050	335	26.86	4.72	24.13	6.92
North									
4	all	4940	±1587	2470	± 843	18.07	±6.78	15.52	± 6.44
	>5	560	169	490	216	16.23	6.38	14.40	6.53
	>10	470	132	370	179	15.84	6.38	13.93	6.45
5	all	8340	±1721	7330	± 872	24.30	±3.68	27.90	± 3.44
	>5	1470	301	1390	267	19.91	4.09	24.60	2.92
	>10	540	137	820	159	16.88	4.65	22.57	2.85
6	all	5840	± 574	3940	±1132	27.80	±4.17	26.44	± 7.78
	>5	1340	321	1320	533	25.10	4.66	20.77	6.64
	>10	720	108	510	191	22.74	4.37	17.86	6.08

are mostly assumed to be of sprout origin.

Table II confirms that small stems and saplings provide a small fraction of the basal area, as expected. Beech greater than 25 cm (10") are few enough that they also contribute little to total basal area. The largest individuals of some species are a 93 cm yellow birch (*Betula alleghaniensis*) in stand 4,a 38 cm red maple (*Acer rubrum*) in stand 6, a 50 cm buckeye (*Aesculus octandra*) in stand 1, a 54 cm red spruce (*Picea rubens*) in stand 4, and a 59 cm silverbell (*Halesia carolina*) in stand 2. However, the numbers of these associated species are not sufficient to contribute a large fraction of the basal area (Table I) except for yellow birch on site 4 (13.7 m^2/hectare).

B. Homogeneity of Variance Among Stands

In the sections following, the analysis of variance will be used to examine whether differences between the means of counts and basal areas are greater than would be expected among random samples drawn from the same population. The probability statements of those tests depend on the assumption that the variances around the means are the same for the populations whose means are being compared. Bartlett's test (Snedecor 1956) was therefore applied first to test whether there are differences among the six stands in their variances.

Differences in sample variance for counts of all trees, all beech and live beech were not sufficiently great to indicate significant differences in the variances. However, counts of dead beech considered separately were more highly variable in some stands than in others.

Variances in basal area for total beech and live beech appeared to be homogeneous, but there were significant differences in variance for basal area of all species on 10 x 10 m quadrats and on one set of 5 x 5 m subquadrats. This presumably reflects unequal local distribution of large trees of species other than beech (Appendix A).

C. Analysis of Variance of 10 x 10 m Plots

The variances for untransformed variables of counts and of basal areas were partitioned into several sources given by the so-called fixed model (Type 1) analysis of variance. Comparisons are intended for contrasts between the specific factors of north versus south aspect, among the three selected stands within each aspect, and between east and west sides of each stand. Random sampling was made within each of the sides with ten quadrats on either side of the center line for each stand, as shown in Figure 1.

The chance variable X_{ijmn} (either counts or basal area) is assumed to represent the summation of a grand mean $\overline{x}$ ....plus or minus deviations due to three factors -- N-S aspect ($i = 1, 2$), individual stand traits ($j = 1, 2, 3$), E-W side ($m = 1, 2$) -- and individual quadrat variations ($n = 1, 2, \ldots, 10$) for each combination of these three factors. Table IIIA gives the means for each combination of factors, while Table IIIB gives the analysis of variance to test the significance of differences between these means. For the Type 1 analysis of variance, the variances (or mean squares, M. S. in Table IIIB) are compared with the variance among plots to see whether their ratios (F) are significantly larger than the value of 1 which would be expected if there were no difference between N-S aspects, stands or E-W sub-aspects.

For counts of all stems, neither the north-south comparison nor the east-west comparison had a significant effect, but there was a highly significant difference among stands which was not accounted for by the N-S contrast, confirming results of the multiple range test (Table 1). For basal area of all stems, the F ratios of variances for all factors divided by variance among plots were less than one. As anticipated, this could be due partly to heterogeneity of variance among samples from six stands. Nevertheless, the test in Table IIIB tends to confirm the impression from Table IIIA that mean basal area (for all species taken together) is remarkably constant for the stands chosen. Because these six stands were not randomly sampled, the statistical analysis cannot be generalized as representing all high elevation beech stands in the Great Smokies or other Southern Appalachian mountains. On the other hand, it is quite

Table III. Analysis of counts and basal area for all stems.

Aspect	Stems /100 m^2 Side			Basal area dm^2/hectare Side		
A. Means for 10 x 10 m plots						
South	E	W	Mean	E	W	Mean
1	66.0	74.4	70.2	32.03	44.40	38.21
2	61.6	47.4	54.5	30.92	32.17	31.54
3	70.2	65.6	67.9	36.71	38.77	37.74
Mean			64.2			35.83
North						
4	65.3	58.7	62.0	43.52	35.67	39.60
5	88.4	81.9	85.15	34.53	34.89	34.71
6	68.6	46.1	57.35	35.77	42.07	38.92
Mean			68.16			37.74
Grand mean			66.18			36.79

B. Analysis of variance

Source of variation	Counts				Basal Area		
	d.f.	S.S.	M.S.	F	S.S.	M.S.	F
Between N-S sites	1	472.0	472.03	1.04	109.3000	109.3000	< 1
Among stands within aspect N-S	4	11744.8	2936.20	6.46**	834.7800	208.6900	<1
Between E-W	6	4427.1	737.85	1.63	1301.4600	216.9100	<1
Among plots	108	49122.0	454.83		25614.8000	237.1700	
Total		65765.9			27860.3400		

** 1% level of significance

consistent with the general impression of similarity of many stands based on inspection by other botanists and foresters.

Table IVA summarizes the means for live beech. The variance ratio F in a complete analysis of variance like that of Table IIIB again showed significant differences among stands within north and south slope groups. In Table IVB (and IVC which is similar) the degree of freedom for N-S slope, 4 degrees of freedom between stands within slopes, and the corresponding sums of squares, have been combined to give a single improved estimate of variance among all six stands. For all live beech (as for all trees in Table III) there was no significant difference between the east and west sides (or sub-aspects) within each stand, for either counts or basal areas. For total beech, live plus dead, the analysis in Table IVC shows no significant difference between sides for basal area. The difference is significant for counts -- presumably due to some differences in distribution of beech (especially dead beech) between east and west sides of sites 4 and 6 (see also Table II).

For counts and basal area of live beech and total beech and counts of all trees, differences among stands were significant at the one per cent level, even though differences in basal area for total tree species had not been significant (cf. Table IIIB). These tests thus summarize differences that were shown separately by tests of means in Table I.

Table IV. Analysis of counts and basal area for beech.

	Stems/100 m^2			Basal area, dm^2/100 m^2 (cm^2/m^2 = m^2/hectare		
	Side			Side		
A. Means of live beech for 10 x 10 m plots.						
South	E	W	Mean	E	W	Mean
1	54	58	56	28.63	37.43	33.03
2	50	42	46	26.23	22.25	24.24
3	48	48	48	31.32	28.47	27.90
Mean			50			29.06
North						
4	46	23	34	17.22	14.98	16.10
5	70	66	68	22.65	26.67	24.66
6	45	34	39	26.74	22.12	24.43
Mean			48			21.73
Grand Mean			49			25.39

B. Analysis of variance for live beech.

Source of variation	d.f.	S.S.	M.S.	F	S. S.	M.S.	F
Among stands	5	14537.1	2907.4	8.41**	3356.0300	6712060	5.45**
Among plots within stand	114	39409.8	345.7		14019.7990	1229807	

C. Analysis of variance for total beech (see Table II for means).

Source of variation	d.f.	S.S.	M.S.	F	S.S.	M.S.	F
Among stands	5	20482.4	4096.5	9.33**	3611.8800	722.3760	5.66**
Between aspect within stand	6	6703.2	1117.2	2.78*	710.4560	118.4000	0.98
Among plots	108	43328.0	401.2		13845.7000	128.2000	
Among plots within stands	114	50031.2	438.9		14556.1560	127.6855	

* 5% level of significance
** 1% level of significance

D. Analysis of Variance for 5 x 5 Meter Subplot Clusters

A further separation of the plot variance was made possible by treating separately the data for the four quarters of each 10 x 10 m quadrat (Table V). The variance among "subplots" in Table V refers to deviations of the values for each quarter of a plot around the mean of the four subplots; the variance among "plots" refers to deviations of the plot means around the mean for the east and west sides for each stand. Some data on stem counts are given in Appendix B.

The results of Table V are quite different for basal area and for stem counts. For basal area, there is no significant difference for the variance among subplots, among plots or between sides of the same stand. The only significant heterogeneity is among stands, as shown already in Table IVB.

By contrast, there is significantly greater variance in stem counts among plots than between subplots of the same plot. In other words, if some subplots of a plot tend to have numerous stems, others tend to also, as might be expected if there is any biological or environmental clustering of the types discussed in Chapters V-VII. These chapters give further attention to the magnitude of such clustering and its spatial pattern within the beech stands.

On the other hand, a high basal area (*e. g.*, due to large trees) in

Table V. Analysis of variance for quarter plots (5 x 5)m for live beech.

Source of variation	d.f.	S. S.	M. S.	M. S. symbol	F
Stems / 25 m^2					
Among stands	5	3634.28	726.85	S_s^2	S_s^2/S_c^2 = 8.82**
Between aspects within stand	6	957.89	159.64	S_a^2	S_a^2/S_c^2 = 1.93
Among plots	108	8894.57	82.36	S_c^2	S_c^2/S^2 = 2.94**
Among subplots within plots	360	10061.00	27.94	S^2	
Total		23,547.74			
Basal area (cm^2/25 m^2)					
Among stands	5	8391680	1678336	S_s^2	S_s^2/S_c^2 = 5.45**
Between aspects within stand	6	1797790	299630	S_a^2	S_a^2/S_c^2 = 0.97
Among plots	108	33251900	307880	S_c^2	S_c^2/S^2 = 0.92
Among subplots within plots	360	120890000	335811	S^2	
Total		164331370			

** 1% level of significance

one subplot does not imply a high basal area in other subplots. Even if there is some tendency for trees to cluster, there can be a tendency for large trees in one subplot to decrease the chance for large trees (and hence high basal areas) in other subplots of the same plot. Because of the importance of distributions of large and smaller trees, these are tabulated separately in Appendix A.

E. Chi-square Tests of Live and Dead Beech and Other Species

Tests for independence of observed variables on position were made using 2 by 2 tables for between side (east vs. west, live vs. dead) for each stand, and row x column tables for comparison among stands (Snedecor 1956). The null hypothesis is that the per cent of difference of dead beech between east and west side is independent of either type of positional effect. The null hypothesis is rejected with a one per cent risk of committing a type 1 error (false rejection) in sites 2, 3, 5, and 6. As shown in Table VI, the east side represents a very significantly higher percentage of dead beech than west side does in stands 2, 5, and 6 while the west side shows a very significantly high percentage of dead beech than the east side in site 3. The inference is restricted to within sites since the sites were not selected randomly.(Table VI).

Table VI. Chi-square analysis showing observed number of dead and live beech.

(Stand) Site		Live beech	Dead beech	Fraction of dead	Chi-square	$S_{\bar{p}}$[a]
A.	2 x 2 tables between east (E) and west (W) side within each stand					
1	E	544	84	.134	1.62	.0136
	W	578	109	.158		.0139
2	E	508	84	.142	20.96**	.0143
	W	420	24	.054		.0107
3	E	482	44	.083	9.20**	.0121
	W	483	80	.142		.0147
4	E	463	31	.062	.01	.0109
	W	232	15	.061		.0152
5	E	706	128	.153	13.79**	.0125
	W	666	67	.091		.0106
6	E	456	128	.219	12.67**	.0171
	W	343	51	.129		.0169
B.	A row by column table of among sites or stands					
1		1122	193	.147	44.46**	
2		928	108	.104		
3		965	124	.114		
4		695	46	.062		
5		1372	195	.124		
6		799	179	.183		
C.	A 2 x 2 table between north-(N) and south- (S) facing sites or stands					
	S	3015	425	.123	.26	
	N	2866	420	.128		

a. Standard error of the proportion of dead beech

** 1% level of sig.

The standard error of the proportion of dead beech was given by

$$S_{\bar{p}} = \sqrt{\frac{p \cdot (1 - p)}{\sum y_i - 1}}$$

where: $p = \dfrac{\sum x_i}{\sum y_i}$ $\sum y_i$ = total beech $\sum x_i$ = total dead beech

The standard error of the proportion of dead beech ranges from 1 to 1.5 per cent per site. This may provide enough basis for drawing inference from the analysis for within site Chi-square test. The percentage of dead beech is 12. 3 and 12. 8 for south and north facing sites respectively, and the Chi-square value is 0. 26, which is far smaller than the 5 per cent level figure of 3. 84 with 1 degree of freedom.

The Chi-square value from the row x column table for comparing all six stands is highly significant, that is, the null hypothesis that the percentage of dead beech is independent of stand is rejected. The range of the percentage of dead beech is from 6 per cent at site 4 to 18 per cent at site 6.

Chi-square analysis was also applied for testing the null hypothesis that percentage of non-beech is independent of difference of stand and aspect. The Chi-square was too great to accept the null hypothesis for sites 1, 3, 4, and 5. Particularly in the last three sites the probability of committing false rejection was far less than one per cent. In general west sides contain more non-beech than east sides.

except in stand 3 (Table VII).

The percentage of non-beech is 11 per cent and 21 per cent for south and north-facing sites respectively, and the chi-square is too large to accept the null hypothesis that percentage of non-beech is independent of the difference between north and south facing sites. This result is different from the similar analysis for dead beech. These facts indicate that the north-facing stands are under less extreme environmental conditions than south stands. The number and basal area for all trees on north-facing sites are larger than those from south-facing sites. It should be noted that the number and basal area for all beech and live beech are greater in south-facing stands than in north-facing stands, although the differences in number are not significant: only 5 for dead beech and 149 for live beech, in favor of the south-facing slope. The results from the survivorship study also substantiate the hypothesis that "the beech gap is under a condition of stress" by the indication of a more favorable survival rate for beech in north-facing sites. If a south-facing site is a more favorable habitat for beech, the survival status in that site should be more favorable too. In short if emigration of species other than beech from north-facing sites is inhibited, the south-facing site should show a higher basal area for beech.

Table VII. Chi-square analysis showing observed number of non-beech and beech.

(Stand) Site		Beech	Non-beech	Fraction of non-beech	Chi-square
A. 2 x 2 tables between east (E) and west (W) side within each stand					
1	E	544	32	0.05	4.80*
	W	578	56	0.09	
2	E	508	24	0.04	1.0
	W	420	27	0.06	
3	E	482	150	0.24	16.82**
	W	483	81	0.14	
4	E	463	151	0.24	12.95**
	W	232	312	0.57	
5	E	706	49	0.06	10.27**
	W	666	84	0.11	
6	E	456	97	0.17	0.41
	W	343	65	0.15	
B. A row by column table of among sites or stands					
1		1122	88	0.07	166.04***
2		928	51	0.05	
3		965	231	0.19	
4		695	463	0.39	
5		1372	133	0.08	
6		799	162	0.17	
C. A 2 x 2 table between north-(N) and south-(S) facing sites or stands					
	S	3015	370	0.11	129.6***
	N	2866	758	0.21	

IV. SIZE AND SURVIVORSHIP OF BEECH

Of the many small beech, very few mature. Dead trees provide preliminary information on how big they grow before dying, and how the over-all size distribution of surviving trees is controlled by mortality. Population structure of this dominant species will also turn out to be important for interpreting the structure or pattern of the community, as discussed in the following chapters.

A. Numbers of Live and Dead Beech by Size Classes

Table II and Appendix A summarize the abrupt decrease in numbers for diameter classes above 0-5 cm: e. g., from only 4 to 27 per cent as many in the 5-10 cm range as in the 0-5 cm range. Helping to account logically for this decrease, there is a large number of dead stems in the 0-5 cm class (averaging about 1/6 of the number of live stems in that class, in spite of the relatively prompt breakage and disappearance of standing stems of such small size).

Some stands (3, 5, and 6) still have well over 100 stems in the 5-10 cm class, on twenty 10 x 10 m plots (Apendix A3, A5, and A6). However, with this exception, there is relatively little difference between size classes and stands. Numbers decrease fairly gradually from 56 to 29 in stand 1, from the 5-10 cm to the >25 cm class; from

40 to 25 respectively for stand 2. There is slight secondary mode of 30 individuals in the 20-25 cm class in stand 4; of 36 in stand 6. Stand 5 has a more prominent secondary mode of 58 individuals, in the 15-20 cm class. Stand 3 has no secondary mode, but is unusual in showing a fairly large number of individuals in all classes from 5-10 to 20-25 cm: 141, 76, 54, and 47 respectively, as compared with 19 in the >25 cm class.

Studies in the Great Smoky Mountains National Park have not involved sufficient tree cutting, or even increment borings, as yet to permit translating these tree diameters to tree ages. Permanent plots were made in 1959 by Larry Tillman for recording mortality directly, but there has not been enough time to provide a good estimate of mortality, or of probable duration before falling of dead trees of different sizes. Hence, even indirect evidence of the trends of mortality with size (and eventually age) is still of value for tentatively interpreting the ecology of beech stands and for guiding further investigation. Accordingly, the size relations of dead trees summarized in Appendix A for 5 cm diameter classes have also been shown for 1 cm classes in the cumulative curves of Figs. 3, 4, and 5. These cumulative curves illustrate striking trends and suggest comparison with the usual cumulative curves of mortality with respect to age, which are commonly treated in population studies (*e. g.*, Pearl and Miner 1935; Odum 1959).

B. Graphic Analysis of Dead Trees

For present purposes, it will be satisfactory to express the number n of dead trees of diameter x as a fraction of the sum of all dead trees observed: $d_x = \frac{n_x}{\sum_x n_x}$. This notation is analogous with that for life tables where mortalities and ages are known. (Such tables adopt the further convention of expressing these numbers as a fraction of 1000 individuals originally introduced in the population.) The d_{x_i} were successively added up for all diameter classes i from the largest class to 0.0 - 1 cm, providing a cumulative curve designated as ℓ_x. Pursuing the life table analogy to cumulative curves, Figs. 3, 4, and 5 give for any diameter x the fraction of all dead trees having diameter x or larger. By comparison (e. g., Odum 1959, p. 166-169), survivorship curves in population ecology express deaths as a fraction of a total number of deaths or births which will occur at a given age or older: i. e., the survivors up to age x (expressed in numbers out of an initial population of 1000). If the stand as a whole is to remain in a balanced condition, the number surviving up to the beginning of each diameter interval should be balanced by either mortality or growth into the next larger interval. Some surprising approximations to this condition can be found in Appendix A, along with discrepancies which remain to be accounted for.

This analogy with survivorship curves, and closer scrutiny of the numbers of live and dead beech in Appendix A, both show striking

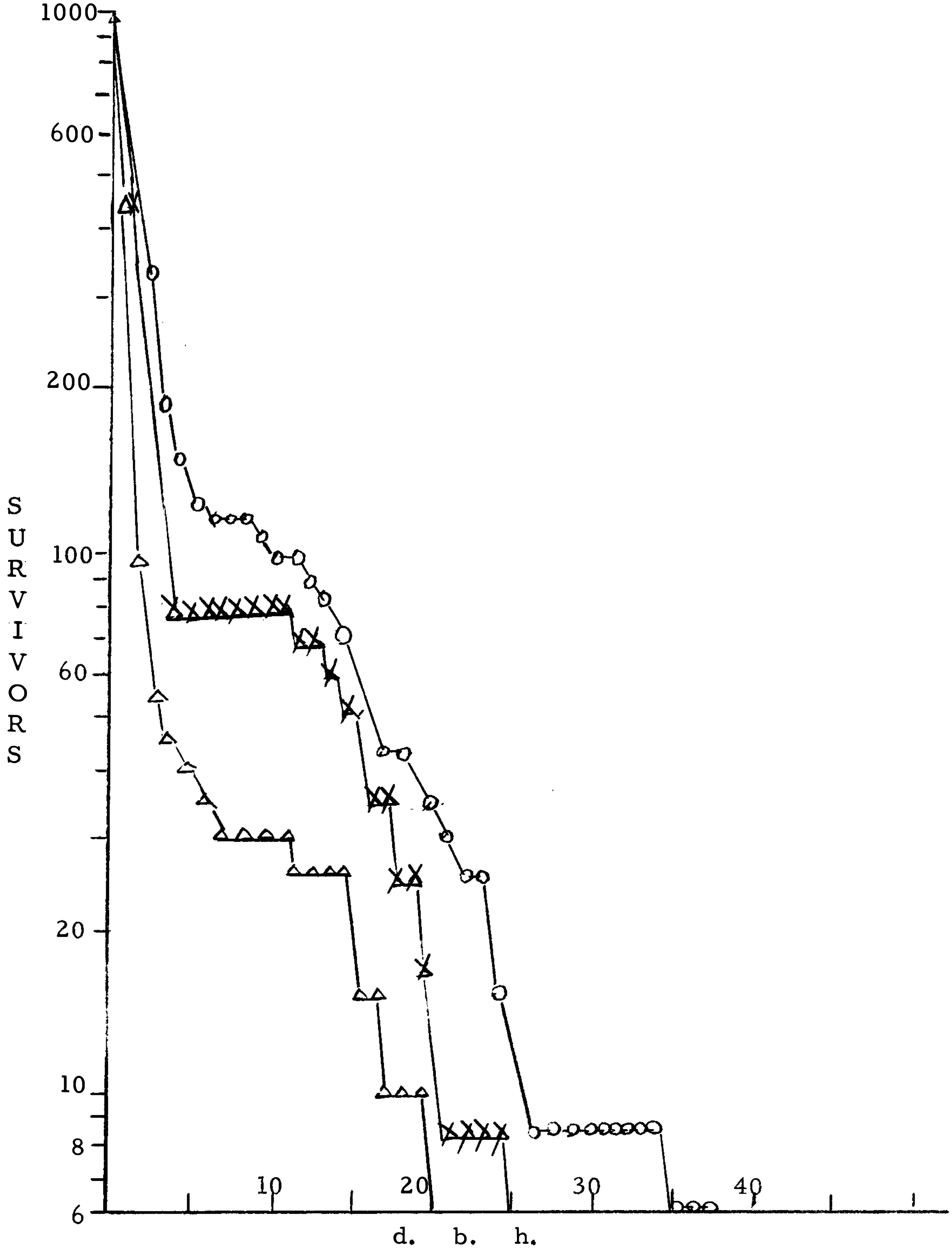


Fig. 3. Survivorship (ℓ_x) curve of the beech from site 1 (▲), 2(x), and 3(o) with 1 cm dbh intervals.

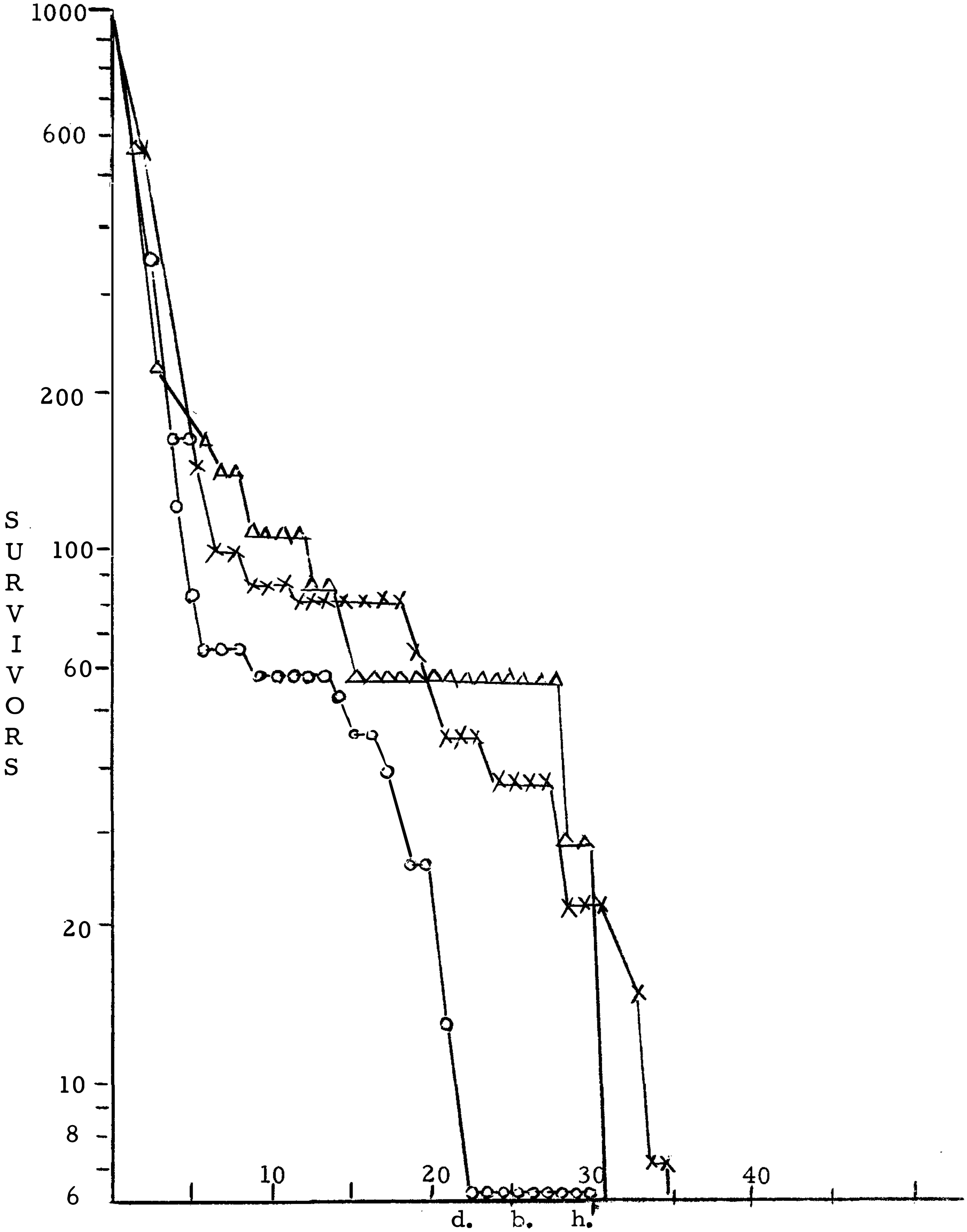


Fig. 4. Survivorship (l_x) curve of the beech from site 4 (▲), 5(x) and 6 (o) with 1 cm dbh intervals.

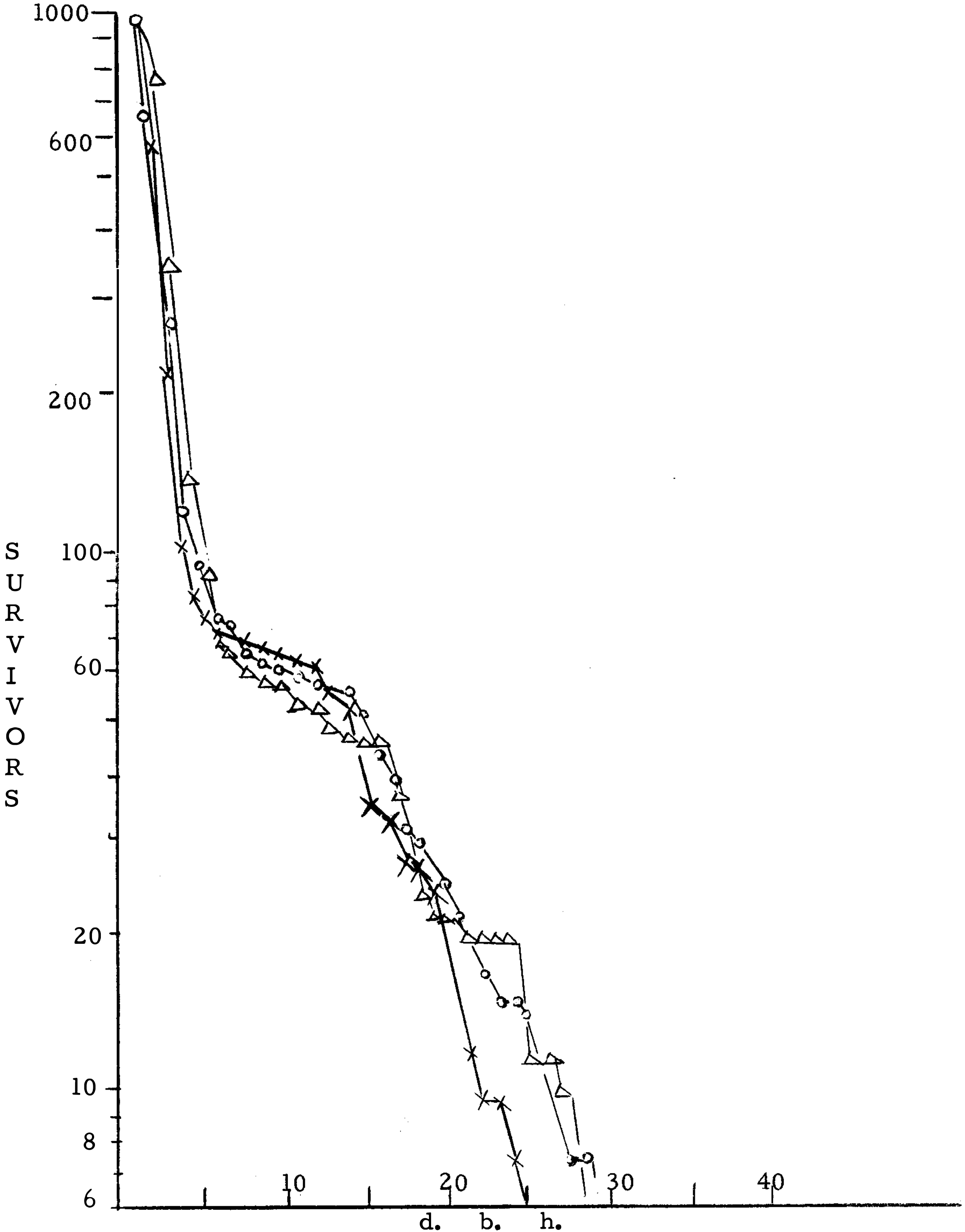


Fig. 5. Survivorship (ℓ_x) curve for north-facing sites (△), south-facing sites (x) and all sites (o) with 1 cm dbh intervals.

features besides the obviously high mortality in the 0.1-5 cm class. There is generally a diameter range somewhere between 5 and 15 cm in which few or no dead trees are found, as represented by nearly horizontal steps in Figs. 3 and 4.

The cumulative curve for stand 1 (Fig. 3) shows a nearly stable middle size group with dbh of 8 cm to 15 cm and again high mortality for the larger than 15 cm dbh group. In stand 2 a primary stable size group and perhaps a secondary stable size group are suggested for diameters of 5 to 12 cm and 22 to 27 cm respectively (Fig. 3). In stand 3, the primary stable age group is not so obvious as the secondary high mortality.

In stand 4 the curve shows a narrower and less definite primary stable size group and a more definite secondary group, perhaps representing a distinct age class (Fig. 4, Appendix A4). The curve for stand 5 is characterized by the primary stable size group 8-17 cm, leading up to the major size class (15-20) which is subject to further mortality. The curve for stand 6 is quite similar to that of stand 2.

The common primary high mortality group, which is represented by a sharp decline in numbers of living beech on the ℓ_x curve, indicates the high vulnerability among young beech. The initial part of the ℓ_x curve is quite similar to the Type III survivorship curve of Pearl and Miner (1935), which is characterized by an upward concavity or positive skew.

The presence of primary stable age groups separating two major periods of mortality is very interesting. Above some miminal size, some curves are similar to survivorship curves expected for constant percentage mortality, or steady decline on a logarithmic scale, i. e., a Type II of Pearl and Miner (1935). The Type I curve is an upwardly convex, sometimes nearly rectangular curve. There is thus a similarity to Type II in the middle size group and a closeness to Type I in the old age group. Except in the emphasis on high mortality of small trees, other details do not agree with Odum's (1959) conjecture that "most plant populations probably would plot out rather nearer the oyster type curve" for survivorship (Type III).

Considering north-facing stands and the south-facing stands together, the curve for trees above 15 cm provides a surprisingly close match to the Type II class (Fig. 5). The common Type III curves for early age groups (diameters 0. 0 to 6 cm) are also similar. The flat-topped Type I curves for larger than 6 cm diameters deserve further attention. The chances of survival are good after arriving at some diameter above 6 cm.

V. INDICES OF DISPERSION

Indices of dispersion measure the degree of departure from "randomness" *i.e.*, from the hypothesis that individuals are located independently of one another, over an essentially uniform environment. Without being based on a particular alternative hypothesis of contagious -"clumped"- distribution, such indices may nevertheless suggest clump size and sometimes the nature of distribution within clumps.

A. Variance/Mean Ratio

Suppose N trees from a large population are distributed in q sample plots, with n_i individuals (i = 1, 2, . . . q) in each quadrat. The sample variance is estimated by

$$s^2 = \frac{\sum_{i=1}^{q} n_i^2 - N^2/q}{q - 1} \quad . \qquad (1)$$

This should vary only within moderate limits above or below the mean m under the null hypothesis of truly random distribution of individuals with respect to quadrats. This follows because the frequency distribution of number of quadrats with 1, 2, . . . trees per quadrat should be given by a Poisson distribution, with a mean m and a true variance σ^2 which theoretically should be equal to the mean (Feller, 1957). The ratio of sample variance to the true variance or to the mean, s^2/σ^2 or s^2/m should vary around an expected value of 1 within limits given by the distribution of Chi-square divided by the degrees of freedom of the sample variance, i.e. $\chi^2_{q-1}(\alpha)/(q-1)$. If we accept a risk α_1 of only 0.01 for concluding that there is a significant clumping where none actually exists, and a risk α_2 of 0.01 also for falsely concluding there is an excessively regular distribution (type I errors of statistical inference), then we make no claim for departure from randomness unless s^2/m lies above $\chi^2_{q-1}(0.99)/(q-1)$ or below $\chi^2_{q-1}(0.01)/(q-1)$ respectively.

Such low risks of type I error carry with them a high risk of type II error -- of failing to detect departures from randomness which are real. Avoiding this error often leads to accepting higher risks of falsely claiming a non-random distribution (e.g., $\alpha_1 = \alpha_2 = 0.05$, or total risk of 10 per cent). Only when numbers of quadrats are very large is it possible to keep both risks of error low. A practical compromise is to accept the hypothesis of random distribution if the variance/mean ratio varies between limits of $\chi^2_{q-1}(0.975)/(q-1)$ and $\chi^2_{q-1}(0.025)/(q-1)$, which are those tabulated by Thompson (1958) and Greig-Smith (1961a). This procedure accepts 1 chance in 40 of falsely claiming clumping, and 1 chance in 40 of falsely claiming regularity, when none actually exists. The upper limit is equivalent to using a variance ratio of $s^2/m = F_{\infty}^{q-1}$ (0.025) as a test for clumping, but the usual F tables used in analysis of variance do not include values of F less than 1, which would be needed for testing for regularity in spatial distribution. To show the commonest features of dispersion, some general results from all quadrats and then all transects will first be considered together. Comparison between sites and subareas will also show some differences in distribution, as well as tree numbers and sizes, discussed previously. Chapter VI will consider certain details of clump sizes and mosaic units by paying special attention to blocks of adjacent quadrats.

B. Morisita's Index of Dispersion

In addition to the common index of dispersion already provided by the ratio of variance over mean, s^2/m, Morisita (1959) has advocated another index I_δ , which equals q times a measure δ of diversity:

$$\delta = \frac{\sum_{i=1}^{q} n_i(n_i - 1)}{N(N-1)} = \frac{\sum_{i-1}^{q} n_i^2 - N}{N^2 - N} \qquad (2)$$

Simpson (1949) has shown how δ serves to estimate his measure of diversity, the measure of concentration of the population in certain quadrats. Like s^2/m, the index I_δ has an expected value of 1 for a random distribution and this is not affected by quadrat size (trend A in Fig. 6). When individuals are distributed uniformly in an area, the I values are less than 1, but tend to increase and approach 1 as the quadrat

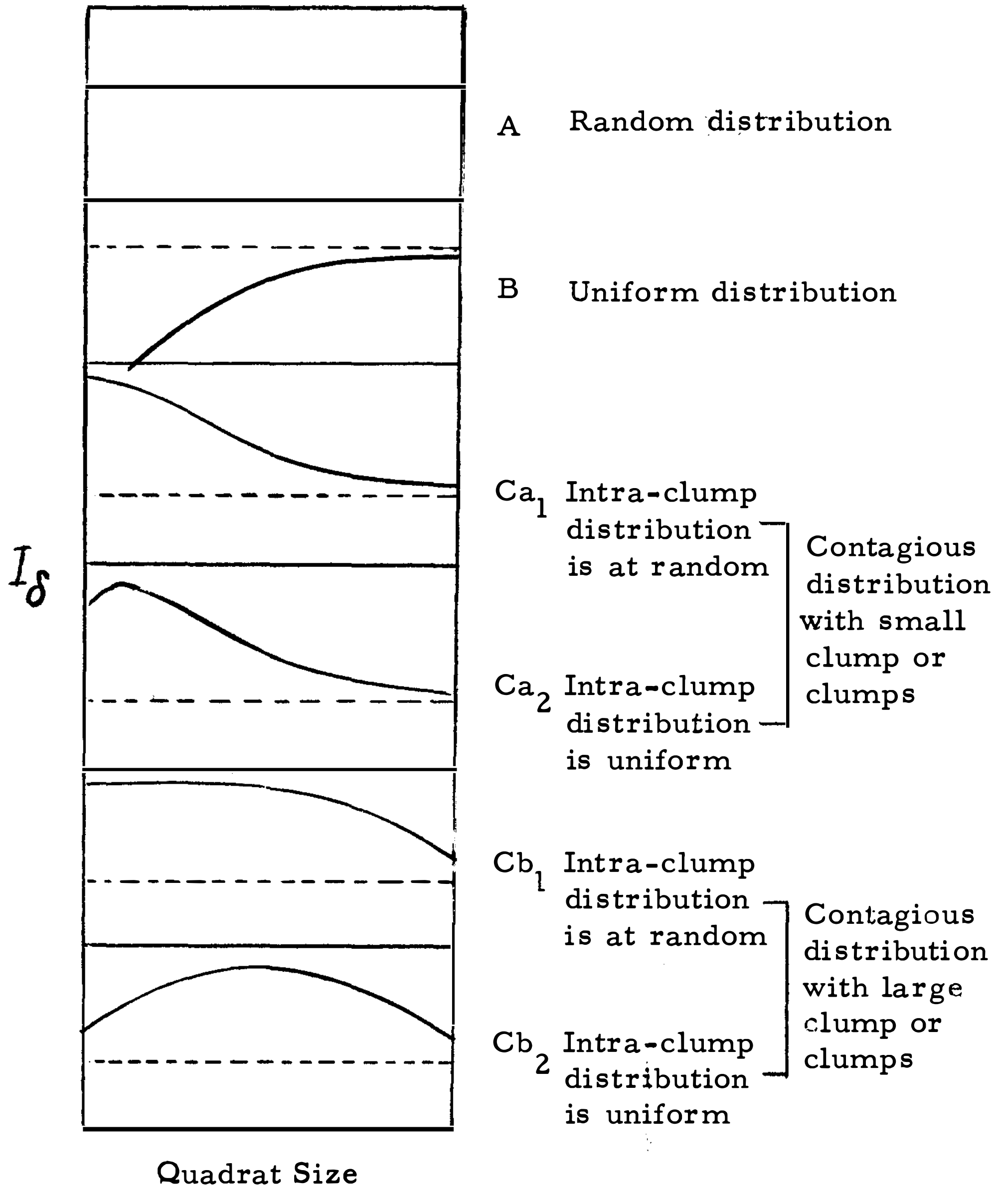


Fig. 6. Schematic representations of I_δ-quadrat size relations for various distributional patterns of populations. The broken lines indicate the value of unity. (From Morisita's Fig. 1, 1959).

size becomes larger (trend B in Fig. 6). For clumped populations, I_δ tends to be greater than 1, but decreases toward 1 as quadrat size increases. Morisita (1959) classified contagious distributions into four sub-types shown in Fig. 6. Contagious distributions with small clumps included class Ca_1 if individuals are randomly distributed within clumps, and Ca_2 if they tend to be regularly distributed within clumps. Similarly, contagious distributions with large clumps include class Cb_1 if individuals are randomly distributed, and Cb_2 if regularly distributed within clumps.

Information about the size of clumps is suggested by dividing the index I_δ (s) for a given quadrat size by I_δ (2s) for a quadrat just twice as large. When this ratio is plotted against plot size (of 2s), the maximum value should appear at the value of plot size which is related to the natural clump size. Since actual clump sizes and shapes vary, of course, this value is merely an index of an "effective" size of clumps.

C. Quadrat Data

Indices of dispersion were derived from both the quadrat and transects. For quadrat data, the basic units are the 5 x 5 m subplots, which were combined to give 5 x 10 and 10 x 10 m plots. Basic data are included in Appendix B for live beech.

The analysis of variance for Table V already provides measures of variance for different levels of sampling. The variance among sub-plots of the same plot (27.94) divided by the mean number of live beech per sub-plot (14.02) gives a ratio $s^2/m = 2.225$, which already suggests either clumping or heterogeneity. The larger variances among plots in a given stand of course give a higher ratio, as a result of additional variation between different parts of the same stand. Variance among plots of the same stand divided by the mean was about 6.6.

Morisita's index of dispersion likewise exceeds 1 and suggests a clumped distribution for beech stems less than 5 cm in diameter and because the small sizes predominate, also for total beech stems and other stems (Table VIII). By contrast, the largest beech (>25 cm) show either random or uniform distributions. The intermediate diameter classes show intermediate results -- a mixture of cases of random or clumped distributions. A steady decline in the index as sub-plots are grouped into whole plots tends to fit Morisita's Ca_1 trend of contagious distribution: distribution within clumps may be approximately random. A few cases with lower index for subplots than for grouped plots are suggestive of a tendency toward uniform distribution within clumps of 15-25 cm pole trees, before trees have grown to a size that tends to show over-all uniformity of distribution. Those few cases will be further considered in the ensuing chapter on pattern.

Species other than beech consistently show clumped patterns of distribution (Table VIII), wherever there are enough individuals for making

Table VIII. Patterns Suggested by Morisita's Index of Dispersion for Quadrats.

SPECIES Size	STANDS					
	South-facing			North-facing		
	1	2	3	4	5	6
Fagus grandifolia						
<5 cm	Ca_1	Ca_1	Ca_1	Ca_1	Ca_1	Ca_1
5.0-14.9 cm	A	Ca_1	A	Ca_1	Ca_1	Ca_1
15.0-24.9 cm	A	Ca_2	Ca_1	A	Ca_2	Ca_1
>25 cm	B	B	A	A	B	A
Picea rubens	Ca_1			Ca_1	Ca_1	Ca_1
Viburnum alnifolium	Ca_2			Ca_1		
Acer spicatum			Ca_1	Ca_1		
Betula alleghaniensis				Ca_1		
Ilex montana				Ca_1		
Aesculus octandra					Ca_1	Ca_2

an analysis.

To allow a greater range of plot size classes, the transect data were arranged for convenient grouping of 0.5 x 0.5 m basic units, into groups of plots 2, 4, 8, 16, 32 and 64 units (together constituting 4 x 4 meter squares), and these in turn were even grouped into strips of 4 x 8 m along the transects. In addition, the lower (0-32 m = A), middle (32-64 m = B), and upper (64-96 m = C) thirds of the transect were considered separately in parts of the analysis, to detect differences related to lower and upper slopes. Graphs of Morisita's dispersion index and clump index ratio for total trees and total beech are shown in Fig. 7, for whole stands. Tabular values are provided for different size classes for the divided transects in Table IX.

D. Total Transect Analysis

In stands 1 and 2 all trees, ± B (all beech) + B (live beech), + B $>$5 cm diameter, + B $>$15 cm diameter and + B $<$5 cm diameter consistently show a Ca_1 type of distribution, with a clump size of 1 by 0.5 m (Fig. 7). In stand 2, the -B (dead beech) represents the Ca_2 type pattern, which is characterized by uniform distribution within the small clumps, but all other variables are also type Ca_1. In stand 4, dead beech is also type Ca_2, but all other variables are type B.

In stand 3, the distribution of all trees, ± B, + B and + B $<$ 5.0 cm

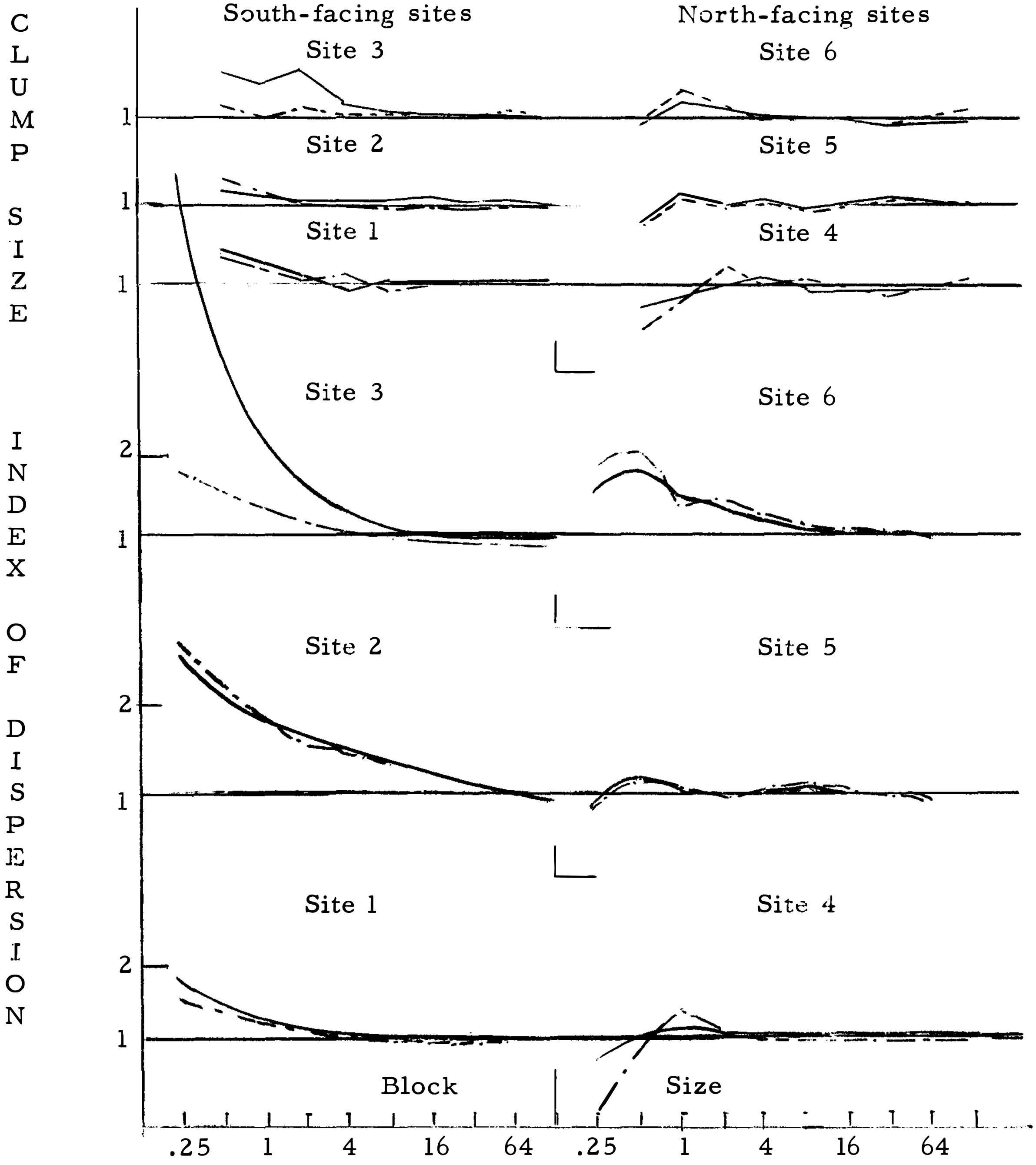


Fig. 7. Analysis of dispersion and clump size of all trees (——) and all beech (—·—) from total transects.

Table IX. Index of dispersion and clump size for different diameter classes of live and dead beech (I_δ of Morisita).

			<5.0 cm		≥5.0 cm		≥15.0 cm	
Stand No.	Sub-area	Block size sq. m	Index of dispersion	Clump size index	Index of dispersion	Clump size index	Index of dispersion	Clump size index
1	A	0.25	**4.04	0.00	**6.56	0.00	0.00	0.00
		.5	2.02	2.00	3.28	2.00	0.00	0.00
		1	*2.52	.80	1.64	2.00	0.00	0.00
		2	1.26	2.00	2.46	.66	*4.26	0.00
		4	1.01	1.24	1.64	1.50	4.26	1.00
		8	1.01	1.00	.82	1.99	2.13	2.00
		16	.98	1.03	1.02	.80	2.13	1.00
		32	1.05	.92	1.12	.90	*2.66	.80
		64	1.05	1.00	1.23	.91	1.33	2.00
	B							
		0.25	1.23	0.00	0.00	0.00	0.00	0.00
		.5	.98	1.24	0.00	0.00	0.00	0.00
		1	1.10	.88	0.00	0.00	0.00	0.00
		2	1.07	1.02	.83	0.00	2.32	0.00
		4	1.13	.94	.62	1.33	1.16	2.00
		8	1.12	1.01	1.15	.54	.58	1.99
		16	1.09	1.02	1.41	.81	1.16	.50
		32	1.06	1.02	1.17	1.20	.80	1.45
		64	1.05	1.00	1.05	1.11	.90	.88
	C	0.25	**2.44	0.00	**6.64	0.00	**18.61	0.00
		.5	**1.66	1.47	**3.32	2.00	**9.30	1.99
		1	1.22	1.35	*2.77	1.20	**9.30	1.00
		2	1.24	.98	**3.04	.90	**8.14	1.14
		4	1.14	1.08	1.52	2.00	**4.07	2.00
		8	**1.28	.89	**1.93	.78	**3.49	1.16
		16	**1.21	1.05	1.17	1.64	*1.89	1.84
		32	*1.08	1.12	1.03	1.13	.94	1.99
		64	1.02	1.05	1.09	.95	.98	.96
2	A	0.25	1.49	0.00	**24.38	0.00	**51.20	0.00
		.5	1.34	1.11	**12.19	2.00	**25.60	2.00

Table IX. (Continuted).

Stand No.	Sub-area	Block size sq. m	< 5.0 cm Index of dispersion	< 5.0 cm Clump size index	≥5.0 cm Index of dispersion	≥5.0 cm Clump size index	≥15.0 cm Index of dispersion	≥15.0 cm Clump size index
2	A	1	**1.72	.78	*6.09	2.00	**12.80	2.00
(cont.)		2	*1.38	1.24	3.04	2.00	*6.40	2.00
		4	1.15	1.19	3.04	1.00	3.20	2.00
		8	1.15	1.00	2.28	1.33	1.60	2.00
		16	*1.12	1.03	1.14	2.00	.80	2.00
		32	.99	1.12	.95	1.19	.80	1.00
		64	1.03	.96	1.04	.90	.80	1.00
	B	0.25	**4.01	0.00	**9.30	0.00	**24.38	0.00
		.5	**2.40	1.66	*4.65	2.00	**12.19	2.00
		1	1.30	1.84	**6.98	.66	**12.19	1.00
		2	1.35	.96	**5.81	1.19	**12.19	1.00
		4	*1.33	1.01	**4.07	1.42	**9.14	1.33
		8	1.14	1.16	**3.78	1.07	**11.42	.80
		16	*1.22	.93	**2.47	1.52	**5.71	1.99
		32	1.03	1.17	1.23	2.00	**2.85	2.00
		64	1.04	.99	*1.34	.91	**1.42	2.00
	C	0.25	2.51	0.00	**5.62	0.00	24.38	0.00
		.5	**2.65	.94	**2.81	2.00	**12.19	2.00
		1	*1.60	1.65	**5.62	.50	**6.09	2.00
		2	*1.36	1.17	**8.43	.66	**9.14	.66
		4	*1.24	1.09	**4.21	2.00	**6.09	1.50
		8	**1.29	.95	**3.16	1.33	**3.04	2.00
		16	**1.28	1.00	1.75	1.80	1.52	2.00
		32	**1.32	.96	1.14	1.53	.95	1.59
		64	*1.06	1.25	1.12	1.01	1.04	.90
3	A	0.25	*1.72	0.00	1.57	0.00	0.00	0.00
		.5	1.55	1.11	1.57	1.00	0.00	0.00
		1	*1.63	.94	1.18	1.33	0.00	0.00
		2	1.16	1.40	.59	1.99	0.00	0.00

Table IX. (Continued).

Stand No.	Sub-area	Block size sq.m	< 5.0 cm Index of dispersion	< 5.0 cm Clump size index	≥5.0 cm Index of dispersion	≥5.0 cm Clump size index	≥15.0 cm Index of dispersion	≥15.0 cm Clump size index
3	A	4	1.07	1.08	.59	1.00	.96	0.00
(cont.)		8	.87	1.23	.88	.66	1.21	.80
		16	.95	.91	.76	1.16	.84	1.42
		32	.97	.98	.89	.84	.90	.93
		64	.98	.98	.96	.92	.93	.96
	B	0.25	**2.61	0.00	0.00	0.00	0.00	0.00
		.5	**2.17	1.19	0.00	0.00	0.00	0.00
		1	1.41	1.53	0.00	0.00	0.00	0.00
		2	1.08	1.30	1.64	0.00	4.26	0.00
		4	*1.33	.81	1.23	1.33	4.26	1.00
		8	1.08	1.22	*1.64	.75	2.13	2.00
		16	*1.03	1.05	*1.64	1.00	*3.20	.66
		32	.96	1.07	*1.58	1.03	*2.66	1.20
		64	.98	.97	1.07	1.47	1.33	2.00
	C	0.25	**2.58	0.00	**5.38	0.00	**9.30	0.00
		.5	1.72	1.50	2.69	2.00	*4.65	2.00
		1	*1.93	.88	**4.04	.66	*4.65	1.00
		2	1.39	1.38	**3.70	1.09	**5.81	.79
		4	1.39	1.00	**3.87	.95	*2.90	2.00
		8	*1.34	1.03	**3.28	1.17	**2.90	1.00
		16	*1.25	1.07	**2.10	1.56	**2.18	1.33
		32	1.09	1.14	**1.62	1.29	**1.96	1.11
		64	1.01	1.08	**1.46	1.10	**2.00	.98
4	A	0.25	0.00	0.00	0.00	0.00	0.00	0.00
		.5	0.00	0.00	0.00	0.00	0.00	0.00
		1	.42	0.00	0.00	0.00	0.00	0.00
		2	.85	.49	0.00	0.00	0.00	0.00
		4	.74	1.14	0.00	0.00	0.00	0.00

Table IX. (Continued).

Stand No.	Sub-area	Block size sq. m	<5.0 cm		≥5.0 cm		≥15.0 cm	
			Index of dispersion	Clump size index	Index of dispersion	Clump size index	Index of dispersion	Clump size index
4 (cont.)	A	8	1.12	.66	0.00	0.00	0.00	0.00
		16	1.06	1.05	.76	0.00	0.00	0.00
		32	1.18	.89	.95	.80	1.33	0.00
		64	1.09	1.08	.85	1.11	2.00	.66
	B	0.25	**6.56	0.00	**14.22	0.00	0.00	0.00
		.5	3.28	2.00	**7.11	1.99	0.00	0.00
		1	1.64	2.00	3.55	2.00	0.00	0.00
		2	**4.10	.39	1.77	2.00	0.00	0.00
		4	**3.28	1.25	.88	1.99	0.00	0.00
		8	1.64	2.00	.88	1.00	0.00	0.00
		16	1.33	1.23	.88	1.00	0.00	0.00
		32	1.12	1.18	1.11	.80	.66	0.00
		64	.97	1.15	1.22	.90	1.00	.66
	C	0.25	1.26	0.00	0.00	0.00	0.00	0.00
		.5	1.57	.80	0.00	0.00	0.00	0.00
		1	.94	1.66	2.32	0.00	0.00	0.00
		2	.94	1.00	1.16	2.00	0.00	0.00
		4	1.10	.85	.58	1.99	0.00	0.00
		8	1.26	.87	1.16	.50	2.66	0.00
		16	*1.35	.92	1.01	1.14	1.33	2.00
		32	**1.39	.97	1.23	.82	.66	1.99
		64	*1.11	1.25	.98	1.25	.66	1.00
5	A	0.25	.73	0.00	0.00	0.00	0.00	0.00
		.5	1.10	.66	1.49	0.00	0.00	0.00
		1	.73	1.49	.74	1.99	0.00	0.00
		2	1.03	.71	.74	1.00	3.04	0.00
		4	.92	1.12	.56	1.33	3.04	1.00
		8	1.05	.87	.74	.74	2.28	1.33
		16	1.08	.97	.79	.94	1.14	2.00

Table IX. (Continued).

			< 5.0 cm		≥5.0 cm		≥15.0 cm	
Stand No.	Sub-area	Block size sq. m	Index of dispersion	Clump size index	Index of dispersion	Clump size index	Index of dispersion	Clump size index
5 (cont.)	A	32	.98	1.10	.98	.80	.57	1.99
		64	1.00	.98	1.08	.90	.85	.66
	B	0.25	.92	0.00	**3.78	0.00	**24.38	0.00
		.5	.81	1.14	*2.52	1.50	**12.19	2.00
		1	.75	1.07	**2.52	1.00	*6.09	2.00
		2	.92	.81	*1.73	1.45	3.04	2.00
		4	1.12	.82	**1.89	.91	1.52	2.00
		8	**1.23	.91	**1.65	1.14	1.52	1.00
		16	*1.15	1.07	1.28	1.29	1.52	1.00
		32	.96	1.19	1.05	1.21	1.33	1.14
		64	.98	.97	1.06	.99	.85	1.55
	C	0.25	**1.90	0.00	**4.04	0.00	0.00	0.00
		.5	1.43	1.33	2.02	2.00	0.00	0.00
		1	*1.55	.92	1.51	1.33	3.55	0.00
		2	*1.37	1.13	1.26	1.19	1.77	2.00
		4	**1.52	.90	1.39	.90	.88	1.99
		8	**1.27	1.19	1.64	.84	.44	2.00
		16	1.10	1.15	1.16	1.40	1.11	.40
		32	1.03	1.06	*1.28	.91	1.33	.83
		64	.99	1.04	1.11	1.14	.88	1.49
6	A	0.25	0.00	0.00	0.00	0.00	0.00	0.00
		.5	1.10	0.00	0.00	0.00	0.00	0.00
		1	.55	1.99	2.84	0.00	0.00	0.00
		2	.68	.79	2.84	1.00	0.00	0.00
		4	.82	.83	1.42	2.00	0.00	0.00
		8	.89	.92	.71	1.99	0.00	0.00
		16	.98	.91	1.06	.66	.80	0.00
		32	.98	1.00	.71	1.49	.80	1.00
		64	.99	.98	.93	.76	1.20	.66

Table IX. (Continued).

Stand No.	Sub-area	Block size sq. m	≤5.0 cm Index of dispersion	≤5.0 cm Clump size index	≥5.0 cm Index of dispersion	≥5.0 cm Clump size index	≥15.0 cm Index of dispersion	≥15.0 cm Clump size index
6	B	0.25	**4.14	0.00	**6.56	0.00	0.00	0.00
		.5	**4.14	1.00	3.28	2.00	0.00	0.00
		1	**2.41	1.71	1.64	2.00	**12.80	0.00
		2	*2.33	1.03	2.46	.66	**19.20	.66
		4	*1.55	1.50	**2.87	.85	**9.60	2.00
		8	*1.29	1.20	**2.66	1.07	**4.80	1.00
		16	1.10	1.17	*1.64	1.62	**4.80	2.00
		32	*1.16	.94	**1.89	.86	*4.00	1.20
		64	**1.21	.95	1.23	1.54	2.00	2.00
	C	0.25	*2.52	0.00	1.45	0.00	**28.44	0.00
		.5	1.89	1.33	.72	1.99	**14.22	2.00
		1	1.57	1.20	.72	1.00	**21.33	.66
		2	1.41	1.11	.72	1.00	**26.66	.80
		4	*1.73	.81	1.18	.61	**13.33	2.00
		8	**1.65	1.04	1.23	.96	**6.66	1.99
		16	1.06	1.55	1.09	1.12	**3.55	1.87
		32	1.08	.98	1.07	1.02	**2.44	1.45
		64	*1.11	.97	.97	1.09	**2.00	1.22

* 5% level of significance
** 1% level of significance

again shows the Ca_1 type with relatively consistent clumps of 1 by 0.5 m, 1 by 2 m and 2 by 4 m, while the patterns of + B ≥ 5.0 and + B ≥ 15.0 are uniform but with consistent remnant 4 x 4 m clumps (Type B). The dead beech also shows a generally uniform pattern except in the 1 by 2 m blocks.

In stand 4 uniform patterns are observed for trees in most categories. Exceptions are the Cb_2 type for + B <5.0 and the Cb_2 type for - B. The latter is characterized by uniform distribution of beech within large clumps. The last two patterns are suggestive of regenerating small beech and death, possibly due to their competition. Most of the indices decrease in the number of statistically significant values as one proceeds from all trees to ± B, to + B, and in each of these from smaller to larger dbh classes.

In stand 5, the ± B ≥ 15 shows a completely uniform pattern, but the + B and the + B <5.0 are clumped with stems within clumps uniformly distributed. The dead beech shows a uniform pattern with a remnant Cb_2 type.

In stand 6, + B > 5 cm and + B > 15 cm show uniform distributions, - B also being uniform with a remnant Cb_2 type pattern. All trees, ± B and + B represent Ca_2 type pattern while + B <5.0 is intermediate between the Ca_1 and Cb_2 types.

In general the results are similar for the divided transect analysis, with minor differences. The uniform or random distribution in north-facing slopes and contagious patterns in south-facing slopes are generally observed from this analysis.

The regular intraclump distribution for various attributes for the larger diameter classes and tree components also suggests the existence of competition between stems. There are more observations to show uniform pattern on total transect analysis than if the parts of the transect are considered separately. The size of basic units is the same for both cases but the total number of basic units is different from each other in the two analyses. This is thought to mean that when dividing a transect into three subareas, the mosaic units or clumps are divided into separate subareas, while the total transect includes them as a whole.

The cause of the Ca_1 or Ca_2 type of pattern is attributed to the establishment of the smaller regenerating beech, especially well shown in subarea A of stand 3, subarea B of stand 4 and subarea C of stands 5 and 6. For example, in stand 5 the Ca_1 type of pattern even includes + B $\geqslant$ 5.0 cm and + B 15 - 25 cm, indicating remnants of a small scale of heterogeneity as the trees become larger. Generally as young dense clumps grow up they mediate microenvironmental differences and competition develops between stems. Subarea A also shows similar features, and can be regarded as the furthest advanced in this stand. Subarea C seems to be the youngest and subarea B seems intermediate.

The patterns of subarea C for stands 5 and 6 are not the same but the general trends are toward establishment of a random pattern in beech larger than 15.0 cm and 5.0 cm.

The consistent pattern of the Ca_1 type for all variables is also well shown in subarea C of stand 1, subarea B of stand 2, and subarea B of stand 4, with common clump sizes 1 by 0.5 m, and 1 by 1 m. These relations in the transects for additional species show many similarities.

E. Distribution of Different Species

1) *Acer spicatum*

Throughout stand 3, subarea C of stand 4 and subarea A of stand 6 there is a very significant Ca_1 type pattern in mountain maple. In these subareas the clump sizes of 2 by 2 m and 4 by 4 m are consistently revealed. Subareas A and B of stand 4 show the Ca_2 type, which indicates uniform pattern for individual stems within small clumps, corresponding with the visual impression of thicket growth (Table X).

2) *Betula alleghaniensis*

In stand 4, subareas A and B of the transect showed Ca_2 type and subarea C of the stand represents Cb_2 type with the following clump sizes: 2 by 2 m, 4 by 4 m, 4 by 8 m and 4 by 16 m. In stand 6, all subareas

Table X. Examples of Morisita's dispersion index and clump size (C) for species other than beech on lower, middle and upper subareas (A, B, C) of transects.

	Plot Size Unit (m^2)								
Species	0.25	0.5	1	2	4	8	16	32	64
<u>Acer spicatum</u>									
Stand 3A	0.00	0.00	0.00	21.33	10.66^{c}	5.33	2.66	4.00	2.00^{c}
B	111.70	65.16	32.58^{c}	18.61	9.30^{c}	9.01	4.50^{c}	4.00	2.00^{c}
C	142.82	71.41	35.70^{c}	34.02	17.01^{c}	14.41	7.20^{c}	4.00	2.00^{c}
4A	0.00	17.06**	8.53*	4.26^{c}	4.26*	2.13	1.06^{c}	1.06	1.33
B	0.00	0.00	0.00	0.00	32.00	16.00	8.00	4.00	2.00
C	54.85**	27.42^{c}**	32.00**	16.00**	8.00^{c}**	6.28**	3.14^{c}**	2.28**	2.00**
6A	4.04**	4.04**	4.04**	2.52^{c}**	2.65**	2.15**	1.67^{c}**	1.72**	1.52**
<u>Betula alleghaniensis</u>									
Stand 4A	0.00	12.19**	12.19**	9.14**	4.57**	5.33*	2.66*	1.33	1.42
B	0.00	0.00	0.00	10.66	5.33	2.66^{c}	1.33	0.66	1.00
C	0.00	0.00	0.00	4.26	4.26^{c}*	6.40**	3.20^{c}*	2.66	1.33^{c}
6A	18.28**	18.28**	9.14**	9.14**	8.00^{c}**	8.57**	4.28^{c}**	3.00**	1.50^{c}*
B	18.61*	9.30**	4.65^{c}*	2.32	1.16	1.16	1.45	1.45	0.90^{c}
C	170.66**	85.33**	42.66^{c}**	21.33**	10.66**	16.00**	8.00**	4.00*	2.00^{c}
<u>Picea rubens</u>									
Stand 4B	44.37**	22.18^{c}**	25.17**	27.09**	14.50^{c}**	14.72**	7.36^{c}**	4.00**	2.00^{c}**
C	0.00	12.19**	6.09*	3.04	1.52^{c}	0.76	1.52	1.33	0.85
5A	0.00	0.00	0.00	0.00	0.00	0.00	1.33	2.00	2.00^{c}
<u>Viburnum alnifolium</u>									
Stand 4B	3.34	6.69	5.85	2.92^{c}	2.50	1.67^{c}	1.56	1.20	0.99^{c}
C	46.08	25.60^{c}**	28.58**	27.09*	13.76^{c}**	12.48**	8.00**	4.00^{c}**	2.00**

*Significant at 5% level. **Significant at 1% level indicate Ca_1 type pattern with a consistent 4 by 16 m size of clump.

3) Picea rubens

This species shows three types of distribution: random in subarea A of stand 5, Ca_2 type in subarea C of stand 4. Irrespective of their pattern all consistently show clumps with the sizes of 2 by 2 m and 4 by 16 m. Considering the patterns, clump sizes, number of stems and their diameter range together (as did for Greig-Smith's method in Chapter VI) within stand 4 subarea B the distribution seems to represent an early phase of regeneration of the species while other subareas probably are in the initial stage of establishment of it.

4) Viburnum alnifolium

The species shows both Ca_2 and Ca_1 type patterns, with inconsistent clump sizes between two subareas (B and C) in stand 4.

5) General Discussion

No single species shows complete consistency in type of pattern and size of clumps throughout study areas. However, the prevailing pattern at block size 4 by 16 m for different attributes, whether these are significant or not, warrants further consideration by the analysis of pattern in Chapter 6.

Morisita's method is convenient mainly to categorize or to describe the distribution of stems in any area into types (A, B, Ca_1, Ca_2, Cb_1, Cb_2), while Greig-Smith's method indicates the effective mean area of clumps and single clump area more directly than Morisita's method.

VI. PATTERN ANALYSIS FOR BEECH STANDS

Many investigators have used relations between grouped plots for analysis of pattern departure from randomness (Agnew 1961; Anderson 1961; Chadwick 1960; Cooper 1960; Greig-Smith 1952; 1961a; Kershaw 1958, 1959, 1960, 1963; Kershaw and Tallis 1958; Phillips 1954). The mean area of clumps, or intensity of pattern, may in some cases be related to differences of the few micro-environmental factors which vary significantly over distances having the same scale as vegetation pattern. Variations of different factors and vegetation variables are assumed to be less correlated with each other within areas bearing apparently homogeneous vegetation than they are within areas big enough to include patches of contrasting character.

For estimating the scale of non-randomness or heterogeneity in distribution of trees and shrubs on a superficially homogeneous area within each beech stand, data from transects were separated into three 32 meter sub-areas A, B and C, (e. g., 1A, 1B, 1C) with a coordinate (Y) numbered from the foot to the top of the ridge (Appendix C). Each sub-area was ultimately subdivided into basic units of 0.5 by 0.5 meters which is small enough to average much less than one clump or patch. The basic units were later grouped into blocks of 2, 4, 8, 16, etc. The numbers of trees and shrubs within each basic unit were added together to give the total number of stems of the respective block size. Comparisons of variance for each block size gave the variances attributable to changes in scale of sampling.

If a non-random population is sampled by a number of quadrats which are much smaller than the average size of a patch or clump of individuals, the variance of an observation may not be greatly different from the mean of the population, provided that the distribution of individuals within the patches is neither very aggregated nor unusually regular. This follows from the sampling variance of the Poisson distribution discussed by Feller (1957) and Greig-Smith (1964) and dealt with above at the beginning of Chapter V.

As quadrat size increases and approaches the average size of a patch (or patches) the ratio of variance to mean will increase sharply. If the patches are regularly distributed,the variance for still larger quadrats relative to mean will then decrease again, ultimately reaching or falling below the mean. In other words, when patches form a <u>recurrent pattern</u> or <u>mosaic unit</u> with both high and low density patches, within which the individuals are randomly distributed, the variance decreases sharply as the quadrat size approaches the size of the mosaic unit or recurrent pattern. If, however, the patches are distributed randomly or contagiously, the ratio of variance to mean will remain higher than unity as the quadrat size increases beyond the average individual patch area. This kind of pattern, formed by randomly or contagiously distributed clumps, is likely to be detectable by field observation while the former kind of pattern, formed by recurrent clumps, is not.

The ratios of variance/mean in Table XI will help to indicate whether any particular block size forms a unit of some larger scale of heterogeneity. In the graphs of variance against block size (Figs. 8 through 18) a peak or series of peaks represents intensity and scale of pattern in the sense of Greig-Smith (1952, 1964) and Thompson (1958).

A. General Results for All Stems

1. A Case Study: Stand 1

In subarea 1B (mid-slope) there is no statistically significant or suggestive unit of heterogeneity; distribution in this subarea fails to show departures from randomness. In subarea 1A (lower slope), the values suggest a primary scale of pattern at block size of 0. 5 by 0. 5 m but the variance/mean ratio is significant only for beech. A secondary scale of pattern is suggested but is not statistically significant. There is a significant tertiary scale of pattern at a block size of 4 by 16 m, as shown in Fig. 8. In the vegetation map (Appendix C) the general appearance of the distribution is random, but the significant unit of tertiary scale of

Table XI. Variance/mean for numbers of beech trees (for three diameter classes and lower, mid and upper slopes: A, B and C).

Stand No.	Block size sq. m	Lower Slope A			Mid Slope B			Upper Slope C		
		<5.0 cm	>5.0 cm	>15.0 cm	<5.0 cm	>5.0 cm	>15.0 cm	<5.0 cm	>5.0 cm	>15.0 cm
					South-facing Sites					
1	0.25	1.17	1.15	1.00	1.06	1.00	1.00	*1.23	*1.27	*1.36
	0.5	.91	1.15	1.00	.93	1.00	1.00	*1.25	1.09	1.00
	1	*1.43	.84	* .66	1.03	.77	* .63	.94	.90	1.18
	2	1.17	1.30	1.00	.87	1.11	1.36	1.25	*2.00	*2.27
	4	1.00	1.61	1.66	1.06	.44	1.36	* .35	.45	1.36
	8	1.08	.69	1.00	1.24	.44	* .27	1.64	*3.00	*3.00
	16	.56	.69	.33	1.46	2.00	1.90	*3.53	1.72	*3.36
	32	1.08	.38	*4.33	1.30	2.00	.45	2.71	.45	.81
	64	2.13	3.76	2.66	4.44	2.00	.09	2.51	2.90	.81
2	0.25	1.03	*1.28	*1.40	*1.31	1.18	*1.28	.96	1.14	*1.28
	0.5	.83	*1.28	*1.40	*1.43	.81	1.00	*1.49	* .71	*1.28
	1	1.30	1.28	*1.40	.96	1.18	1.00	1.22	* .42	.71
	2	1.40	1.00	1.40	1.03	1.54	*1.57	1.22	*2.71	*1.57
	4	1.00	1.28	1.40	1.58	1.18	* .14	.80	*1.85	*2.14
	8	1.27	1.85	1.40	.49	*2.63	*5.28	1.06	*3.28	2.14
	16	*2.79	1.28	1.00	*3.31	*4.09	*5.28	.34	*3.00	1.85
	32	* .01	.71	1.00	.80	.45	*5.28	*9.00	1.14	.71
	64	2.86	1.28	.20	3.31	4.45	3.57	4.73	2.57	1.28

Table XI. (Continued).

Stand No.	Block size sq. m	Lower Slope A <5.0 cm	Lower Slope A >5.0 cm	Lower Slope A >15.0 cm	Mid Slope B <5.0 cm	Mid Slope B >5.0 cm	Mid Slope B >15.0 cm	Upper Slope C <5.0 cm	Upper Slope C >5.0 cm	Upper Slope C >15.0 cm
3	0.25	1.03	1.00	1.00	1.08	1.00	1.00	1.11	*1.20	1.18
	0.5	.96	1.07	1.00	*1.28	1.00	1.00	.94	.80	1.00
	1	*1.40	1.23	1.00	1.24	.69	.66	1.28	1.10	.81
	2	1.14	1.00	.66	.63	1.15	1.00	1.00	.90	1.90
	4	1.69	.53	.83	1.73	.69	1.66	1.11	1.70	1.00
	8	.45	1.38	1.50	1.32	1.00	.33	1.40	*3.80	1.90
	16	.74	.15	.83	1.85	1.15	1.66	2.31	*3.30	1.54
	32	.67	.15	.83	.51	*4.07	*4.33	2.42	2.50	.81
	64	.16	.15	.33	.18	1.92	2.66	1.39	*9.80	*11.00
					North-Facing Sites					
4	0.25	1.00	1.00	1.00	1.15	*1.22	1.00	1.00	1.00	1.00
	0.5	.92	1.00	1.00	1.15	1.22	1.00	1.06	.81	1.00
	1	.84	1.00	1.00	* .53	1.22	1.00	1.00	1.18	1.00
	2	1.08	1.00	1.00	1.30	1.22	1.00	.86	1.18	1.00
	4	.44	1.00	1.00	*2.23	1.00	1.00	.72	.63	.50
	8	1.16	.42	1.00	1.46	1.00	1.00	.65	1.18	1.50
	16	.28	.71	.33	1.61	.55	.50	.72	.45	1.50
	32	2.12	1.28	.33	1.92	.55	.50	*5.00	2.27	1.00
	64	3.23	.14	3.00	.69	2.77	1.00	4.17	.81	0.00

Table XI. (Continued).

Stand No.		Lower Slope A <5.0 cm	Lower Slope A >5.0 cm	Lower Slope A >15.0 cm	Mid Slope B <5.0 cm	Mid Slope B >5.0 cm	Mid Slope B >15.0 cm	Upper Slope C <5.0 cm	Upper Slope C >5.0 cm	Upper Slope C >15.0 cm
5	0.25	.89	.89	1.00	1.02	1.13	*1.28	1.12	1.17	1.00
	0.5	1.21	1.10	1.00	1.02	1.00	*1.28	.93	1.08	* .77
	1	* .65	1.00	.71	.82	1.34	1.28	1.18	1.08	1.22
	2	1.26	1.10	1.00	.58	.86	1.28	.69	.91	1.22
	4	* .38	.78	1.28	.55	1.41	1.00	*2.00	.65	1.22
	8	.73	.89	1.85	1.71	*2.31	1.00	*2.36	*2.30	.33
	16	*2.84	.15	1.85	*4.10	2.58	1.28	2.15	.39	.55
	32	.38	.05	.14	.25	.86	2.42	2.42	2.82	2.77
	64	1.07	2.57	.14	.01	2.79	.14	.54	3.52	.11
6	0.25	.87	1.00	1.00	1.00	1.15	1.00	1.06	1.07	*1.44
	0.5	1.12	.77	1.00	*1.51	1.15	.60	1.06	1.00	* .55
	1	.93	1.00	1.00	1.05	.84	.60	1.06	1.00	* .33
	2	.87	1.44	1.00	*1.92	.84	*2.20	.72	.62	*4.33
	4	.87	1.44	1.00	1.61	1.15	1.00	1.13	.92	4.33
	8	.67	.77	.60	1.92	*2.53	*3.40	*3.06	1.44	4.11
	16	1.00	1.88	1.00	.38	.23	1.80	.86	1.14	3.22
	32	.80	.11	.20	* .02	*4.99	5.00	.58	2.25	2.77
	64	.80	.11	1.80	*9.25	3.76	5.00	4.17	.33	*9.00

* 5% level of significance

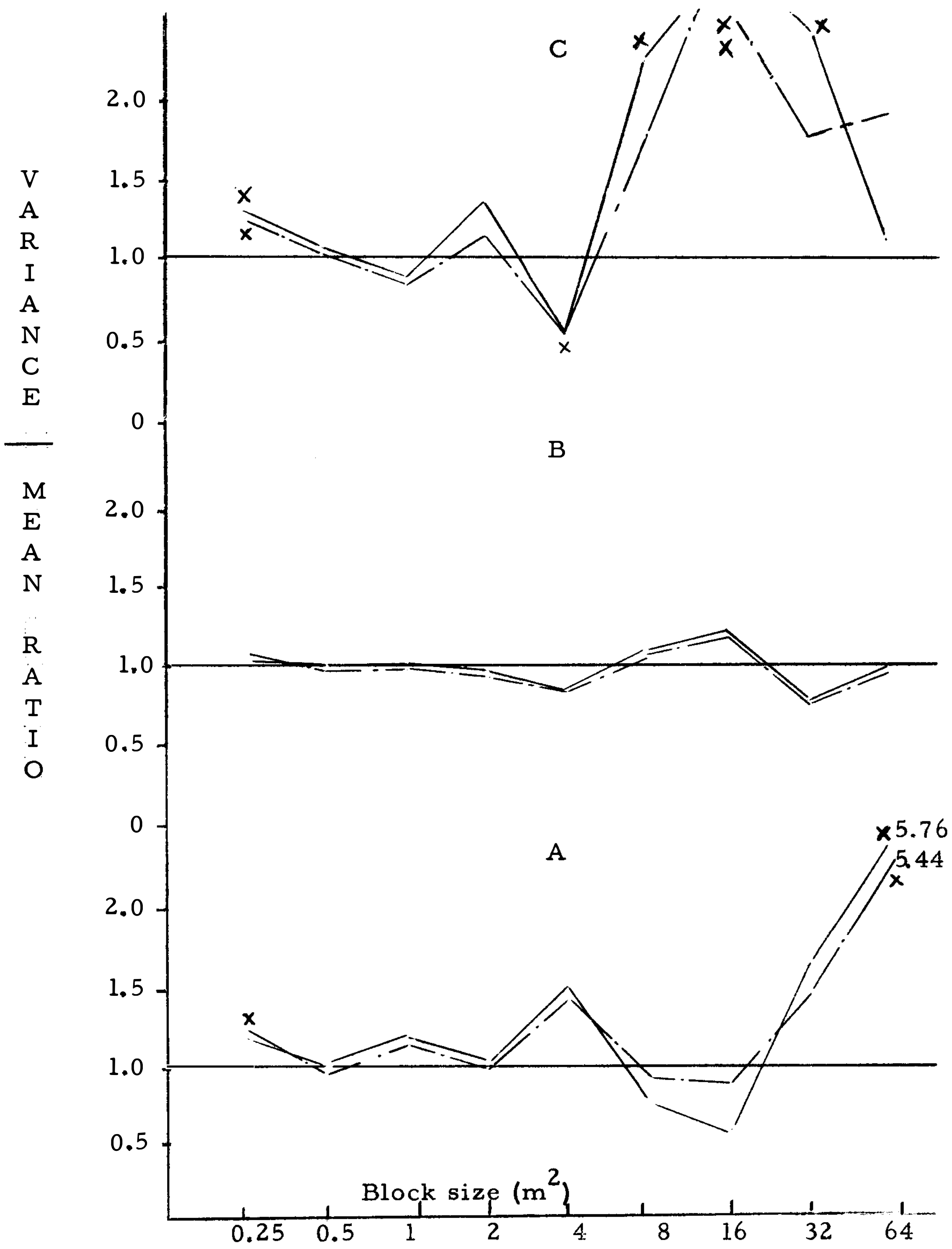


Fig. 8. Graphs of analysis of all trees(——) and live beech (—.—) count data from site 1. xSig. at 5% level
xxSig. at 1% level

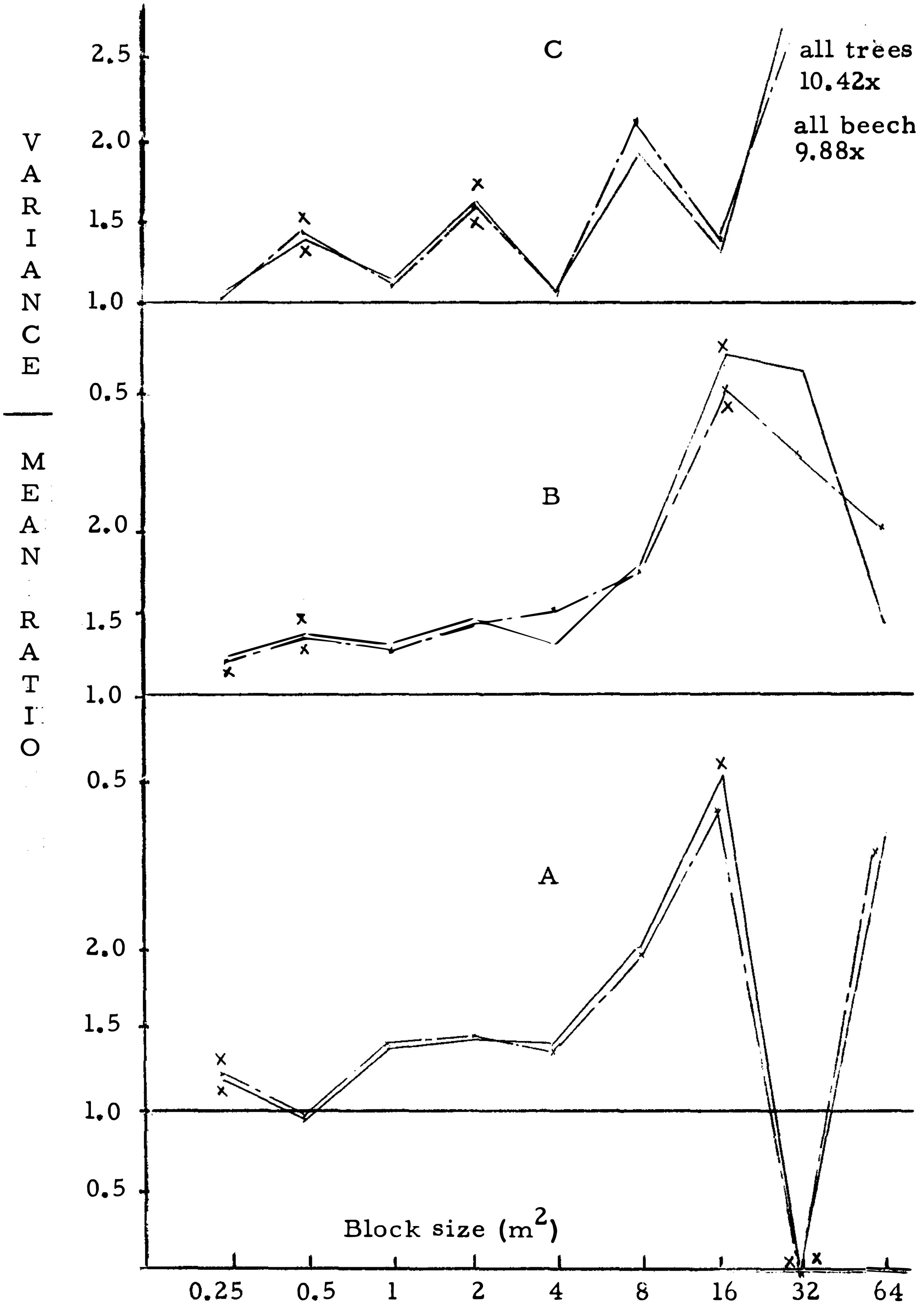


Fig. 9. Graphs of analysis of all trees (—) and all beech (—·—) count data from site 2. xSig. at 5% level
xxSig. at 1% level

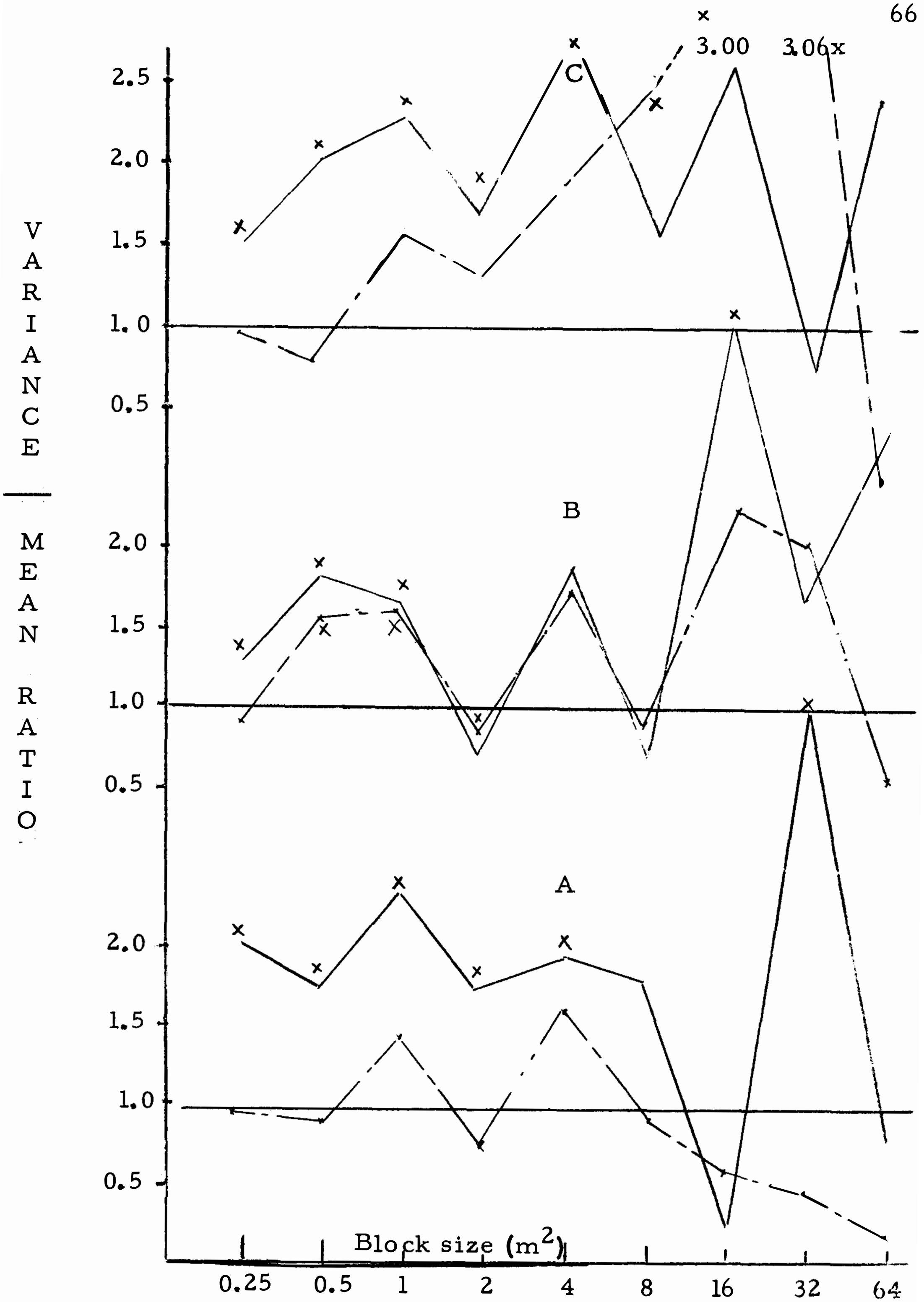


Fig. 10. Graphs of analysis of all trees (—) and all beech (–.–) count data from site 3. xSig. at 5% level
xxSig. at 1% level

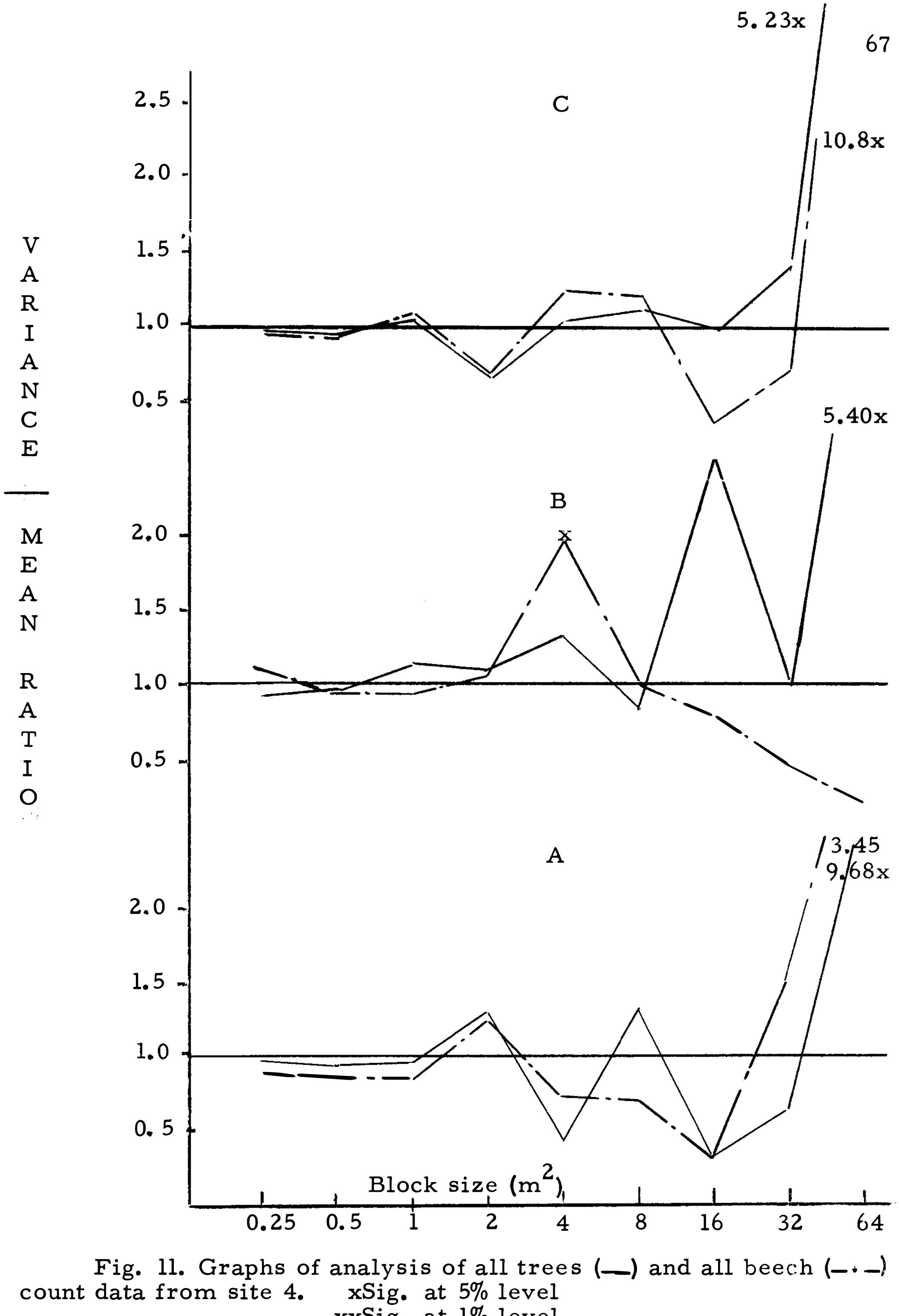


Fig. 11. Graphs of analysis of all trees (——) and all beech (—·—) count data from site 4. xSig. at 5% level
xxSig. at 1% level

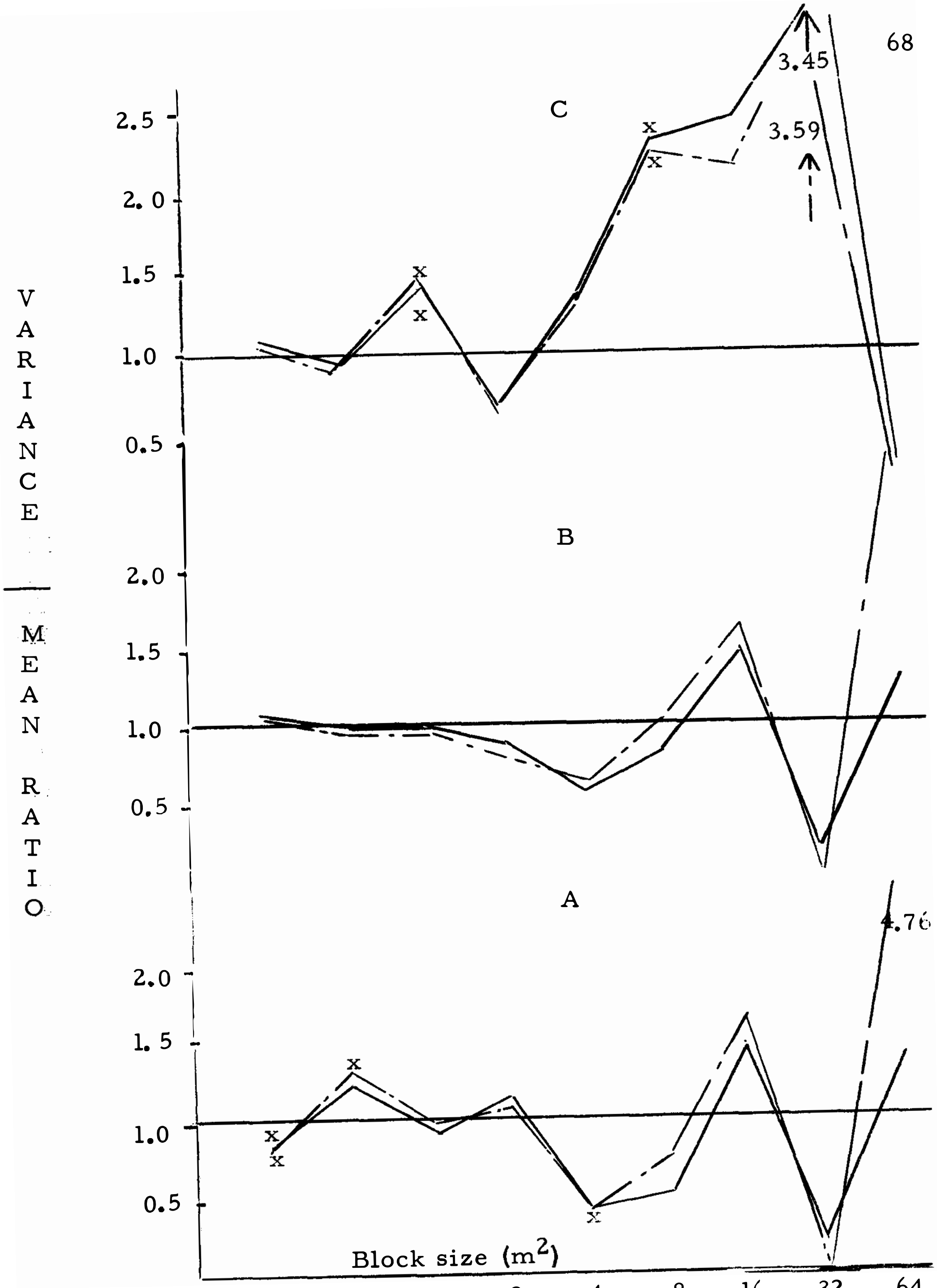


Fig. 12. Graphs of analysis of all trees (—) and all beech (—•—) count data from site 5. xSig. at 5% level
xxSig. at 1% level

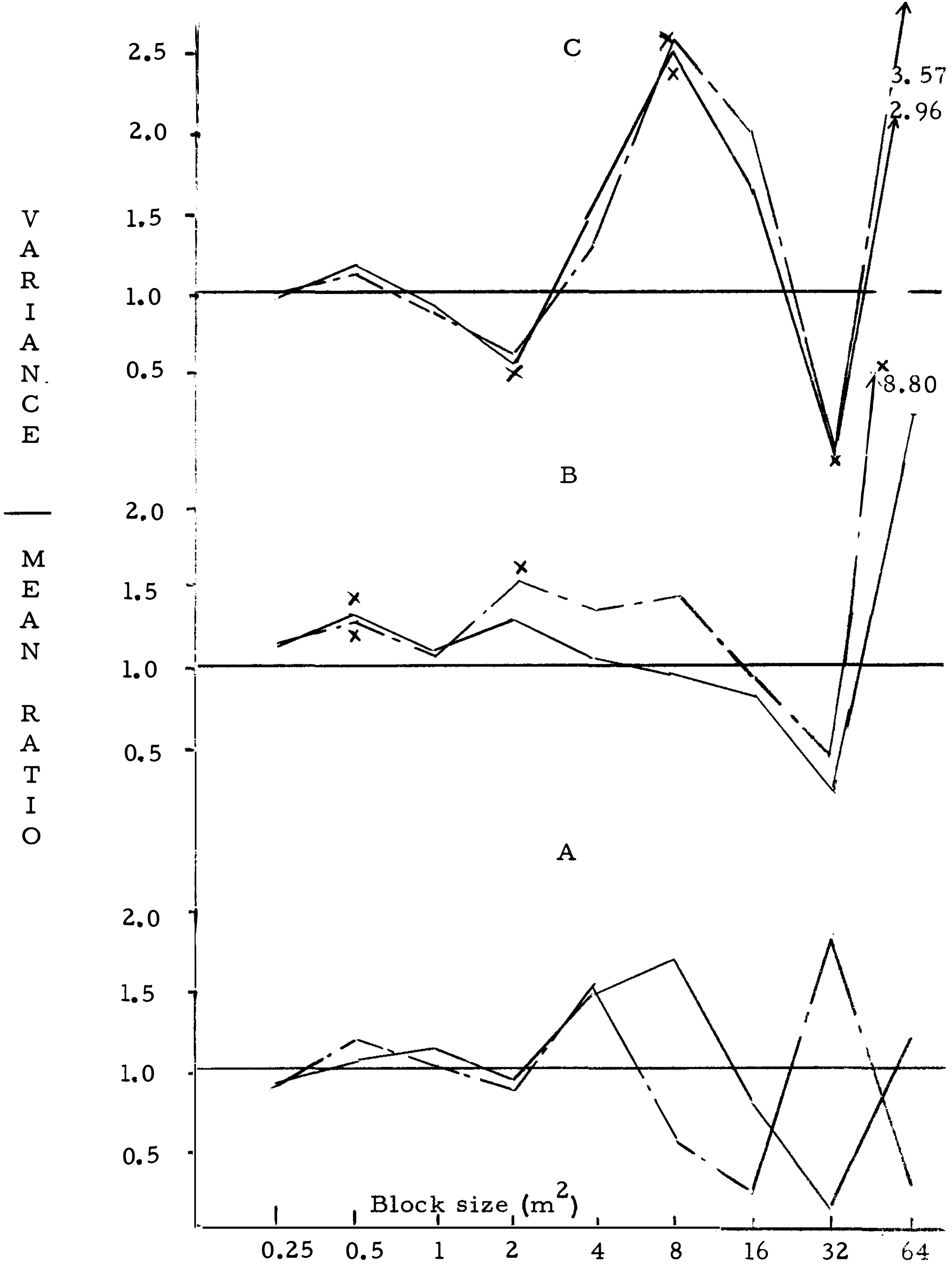


Fig. 13. Graphs of analysis of all trees (—) and all beech (–·–) count data from site 6. xSig. at 5% level
xxSig. at 1% level

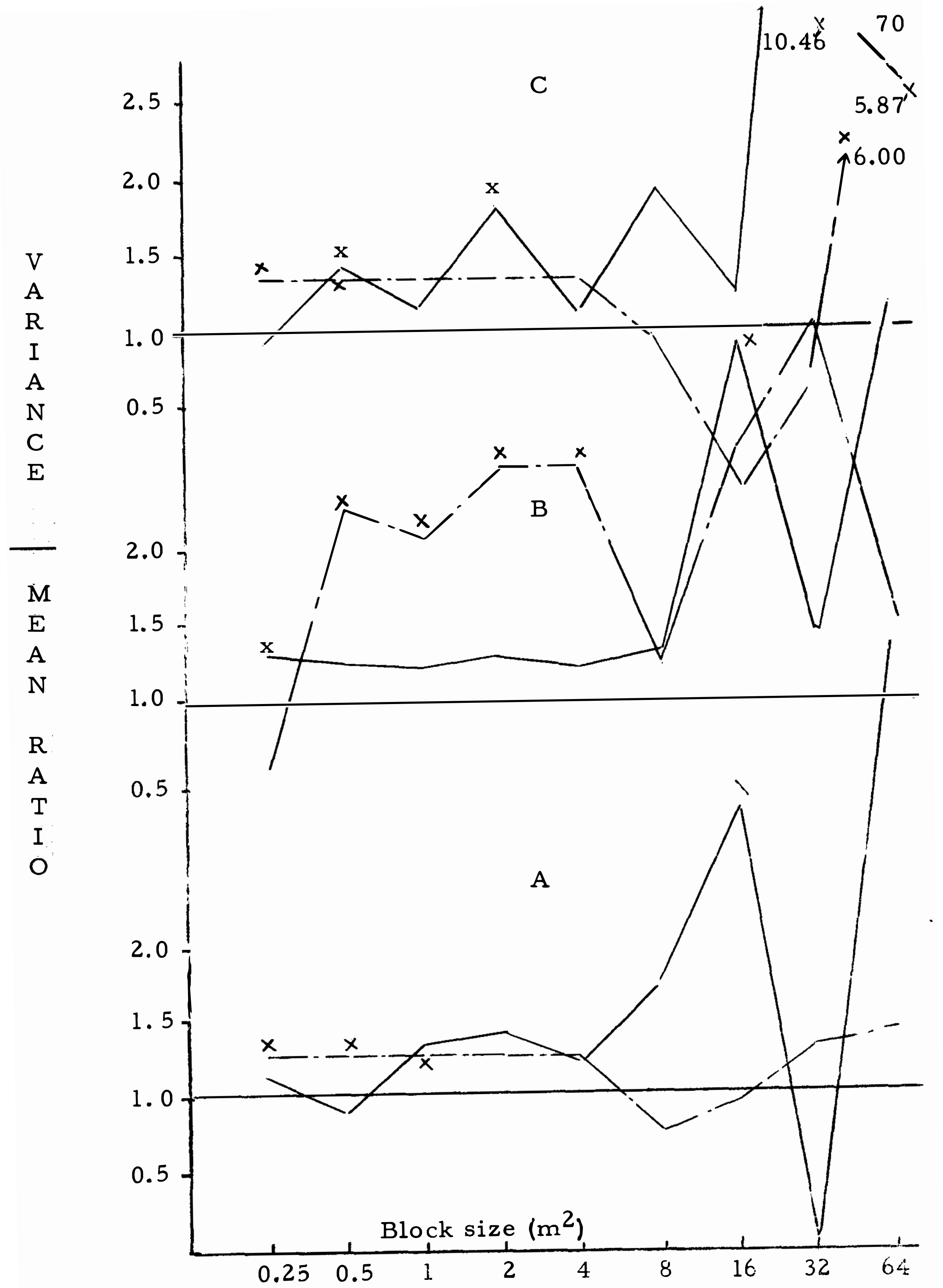


Fig. 14. Graphs of analysis of live beech (—) and dead beech (—·—) count data of site 2. x Sig. at 5% level
xx Sig. at 1% level

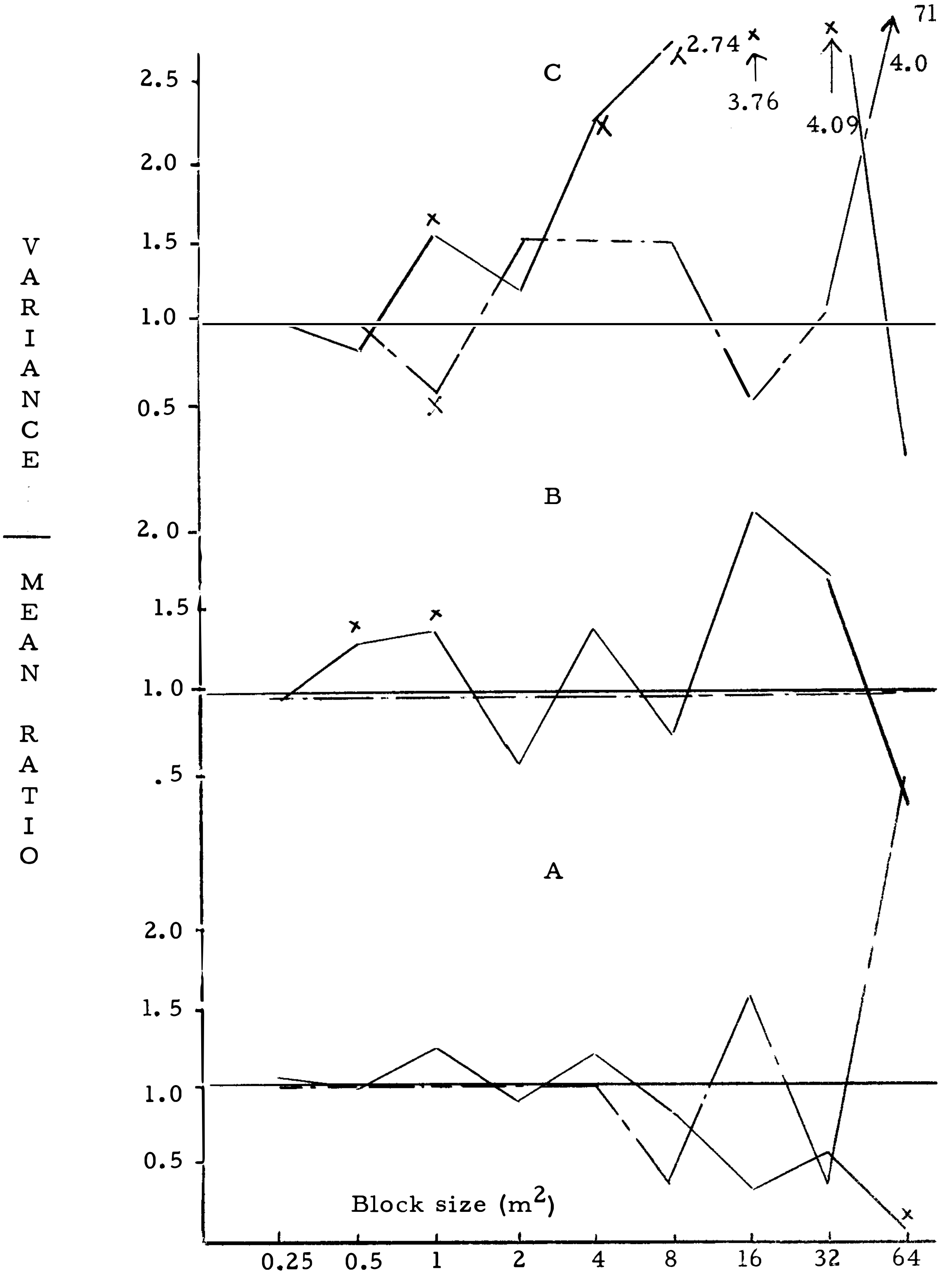


Fig. 15. Graphs of analysis of live beech (—) and dead beech (—·—) count data of site 3. x Sig. at 5% level
xx Sig. at 1% level

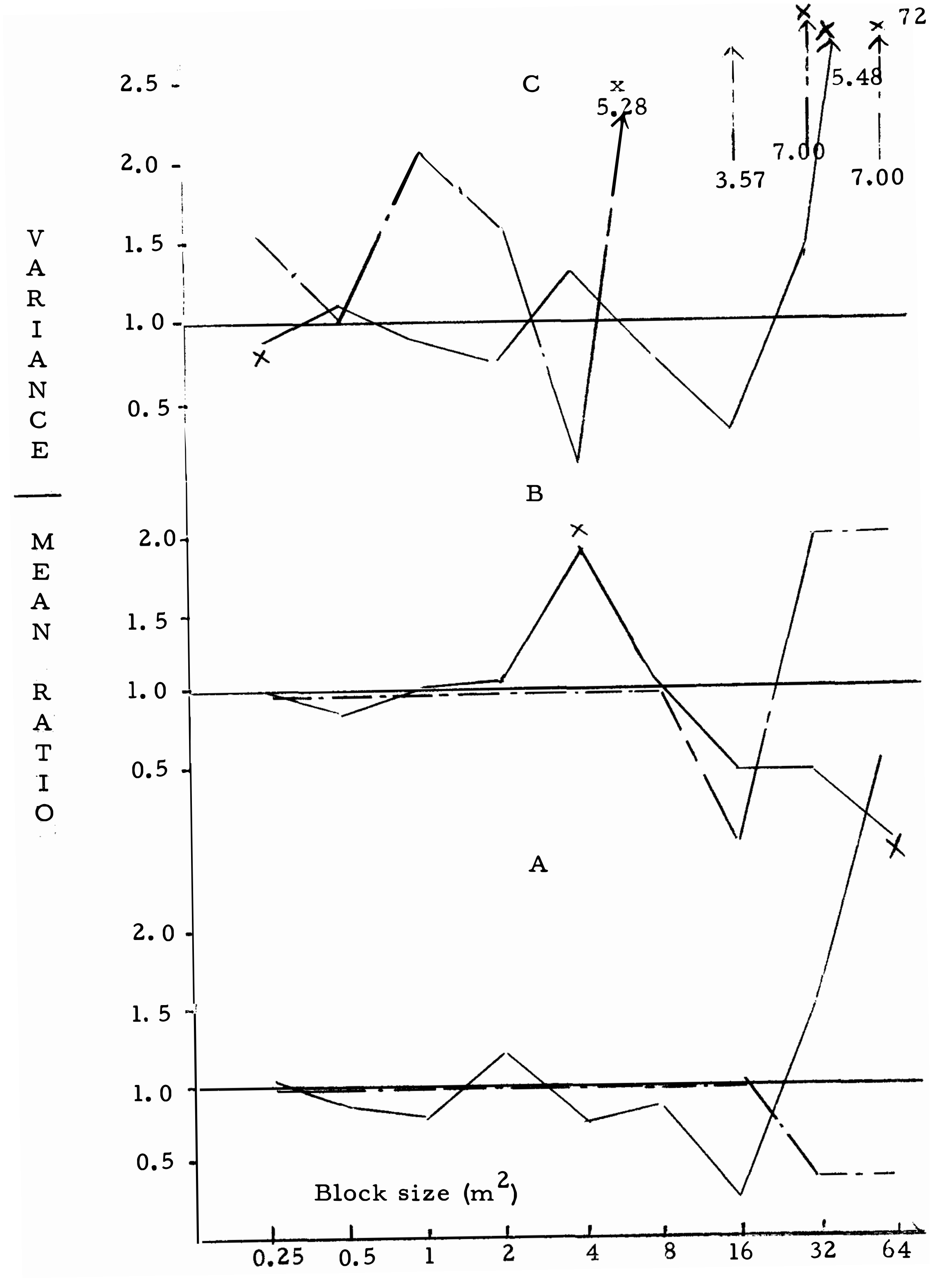


Fig. 16. Graphs of analysis of live beech (—) and dead beech (—·—) count data of site 4. xSig. at 5% level
xxSig. at 1% level

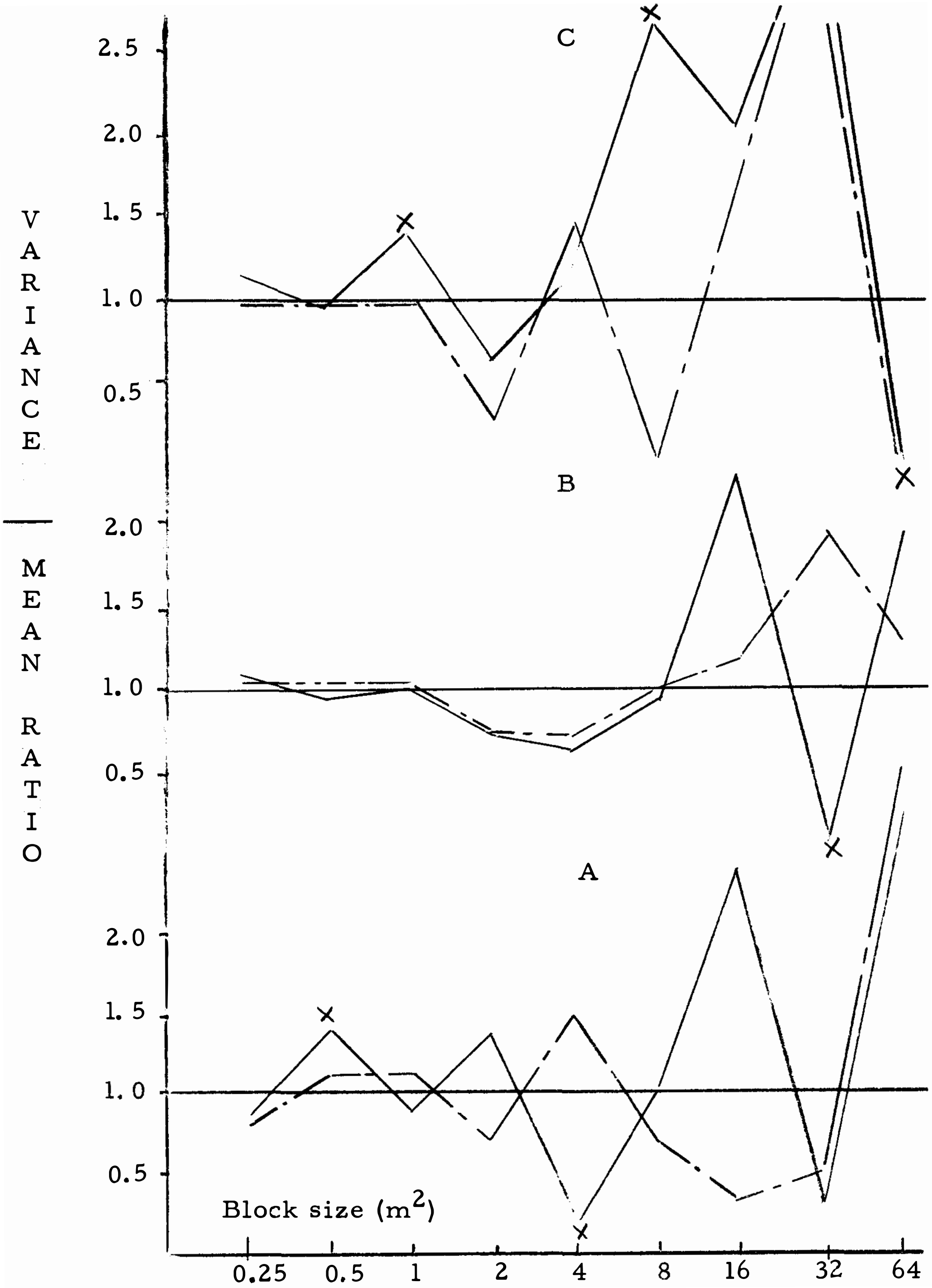


Fig. 17. Graphs of analysis of live beech (—) and dead beech (—·—) count data of site 5. xSig. at 5% level
xxSig. at 1% level

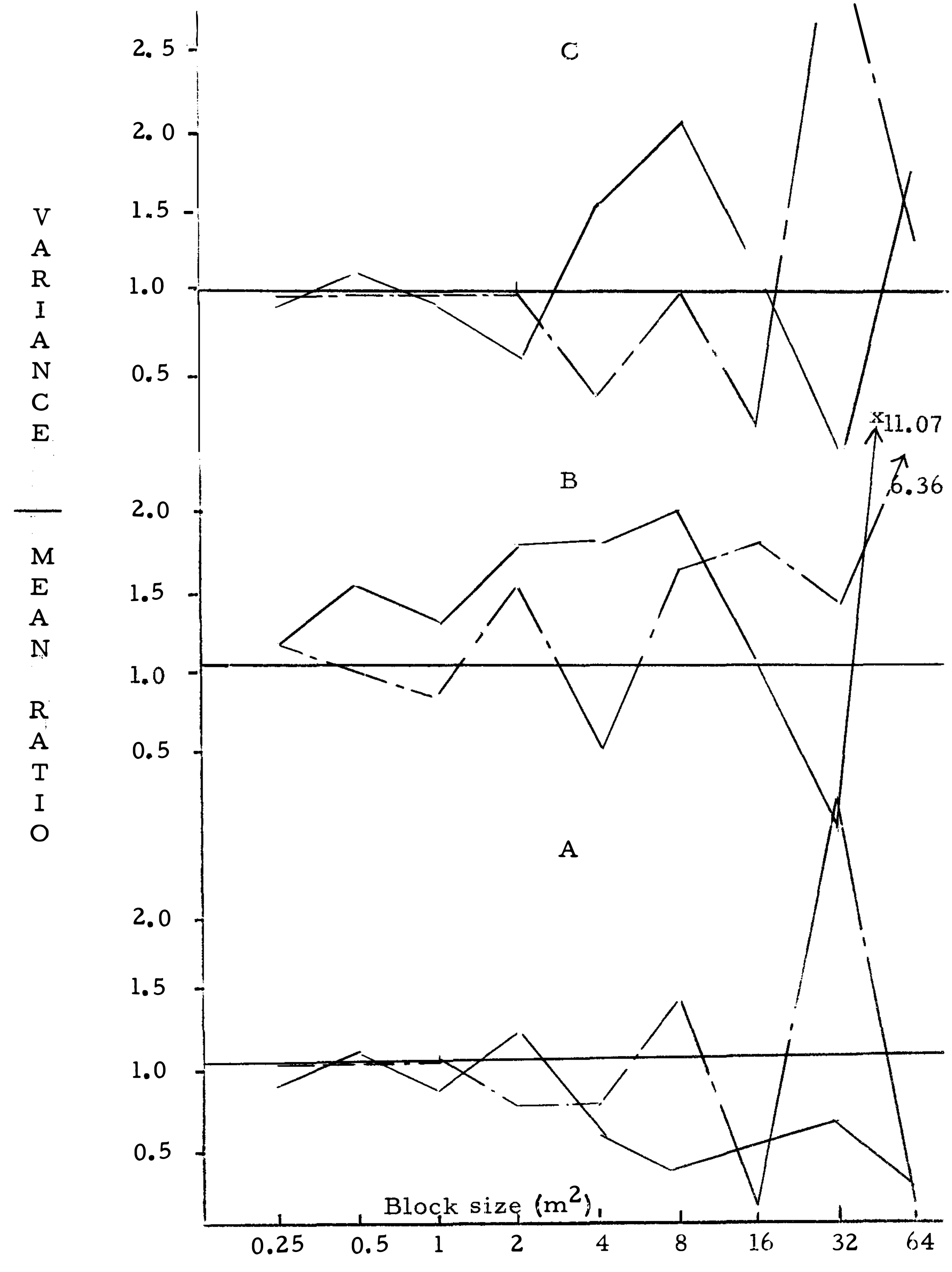


Fig. 18. Graphs of analysis of live beech (——) and dead beech (—·—) count data from site 6. xSig. at 5% level
xxSig. at 1% level

pattern reveals patches of high density (0-16 m) and low density (16-32m).

In subarea 1C (upper slope) there is a statistically significant peak related to clumps with an average size of 4 by 4 m within which primary and secondary scales of pattern are regularly distributed. The actual distribution of individuals of beech is illustrated on the map of Appendix C. The values and tests from this analysis coincide and illustrate the assertions by Greig-Smith (1952, 1964) and others that peaks show the mean area of clumps and that a sharp decrease indicates the possibility of a mosaic unit that includes alternating patches of high and low density.

2. Summary

The distribution of trees of all species in the stands was essentially random in subareas 1B, 5A and B and 6A, but no transect had the trees distributed randomly throughout the total 4 by 96 m area. The mosaic distribution in stand 4 deserves particular mention with its alternating phases of high and low density on a scale of 4 by 16 m, within which the trees are randomly distributed. Stand 6 as a whole shows almost random distribution with heterogeneity in the 0. 5 by 1 m and 2 by 4 m blocks in subareas 6B and 6C respectively. In general, the trees are more randomly distributed on north-facing slopes than on south-facing slopes. Remnant scales of clump pattern may be present. Most of the trees in those study areas are beech and other species are not so consistent in their primary scale of pattern as are the beech. The primary scales of pattern probably can be regarded mainly as the result of characteristics of beech distribution, but these in turn could be influenced by groups or large individuals of other species. Further interpretations of this will be discussed in more detail later.

The patterns can be classified as follows:

Type I. Multi-heterogeneous unit: This includes highly complicated pattern, seen in subarea 1C and 2C (Fig. 8, 9).

Type II. Single mosaic with clear clumps: This type is observed in subareas 3A (Fig. 10) and 5C (Fig. 12).

Type III. Double mosaic: This pattern is most common among other types where there is a remnant or embryonic pattern. It is illustrated on subareas 2A and 3BC for all trees (Fig. 9 and 10) and subareas 2AB, 5AB and 6BC for all beech (Fig 9, 12 and 13).

Type IV. Single large scale mosaic: This type of pattern seems advanced from type III, because the 4 by 4 m size clump has disappeared and the remnant primary scales of pattern of 1 by 1 m or 2 by 2 m are regularly distributed in subareas 4ABC and 1A for all trees (Fig. 11 and Fig. 8) and subareas 4C and 1A (Fig. 11 and 8) for all beech.

Type V. Random distribution: This represents completely random distribution of trees within subareas of 4 by 32 m, already best represented in subareas 1B, 4A and 5AB for all trees (Fig. 8, 11 and 12) and subareas 1B, 3A, 5B and 6AC (Fig. 8, 10, 12 and 13) for all beech.

B. Patterns of Distribution of Living and Dead Beech

The distribution of +B is similar to that of all living trees in stands 1 and 2. The consistency of the peaks in subareas 2B and 2A is clear. The -B distribution seems random in subarea A. In subarea 2B, -B distribution shows several more intense and significant scales of pattern in the range from 0. 5 by 0. 5 m to 2 by 2 m than from other groupings (Fig. 14).

In stand 3, subarea A, all beech and +B seem quite randomly distributed. The first three scales of pattern show consistently in all groupings of living and dead trees in block sizes of 0. 5 by 0. 5 m, 1 by 1 m, and 2 by 2 m throughout this stand. In subarea 3C the ±B and B represent a more intense and significant heterogeneity in their pattern in the 4 by 4 m blocks than do all trees. Within the primary clumps in the 1 by 1 m blocks individual beech are more regularly distributed than all trees. As a whole in stand 3, the order of beech distribution from nonrandomness to randomness is as follows: subarea C ⟶ B ⟶ A, as shown in Figure 15. This happens even though there is a reduction of heterogeneity in larger than 4 by 4 m clumps while primary scales of pattern are maintained.

In subarea 4A, patterns of all trees and beech are similar to each other particularly for the primary and tertiary scales of pattern. Since the dominant trees are beech this is not strange. The secondary scale of pattern of beech is regularly distributed while that of total trees is far more intense and shows a tendency toward clumping. Within the primary scale of pattern of beech the individuals are regularly distributed. The number of units of heterogeneity in beech is two while it is three for total trees. In subarea B beech show a different scale of pattern from that of total trees. The only significant scale of pattern in beech is in the 2 by 2 m block. Within the clumps the trees are relatively random but the clumps themselves are quite regularly distributed throughout the subarea. The number of dead beech was only two, as in subarea 3B. In subarea C the distribution of all trees and all beech is quite similar. The -B are strongly non-random in their distribution at several scales (Fig. 16).

In stand 5 as a whole the distributions of all trees, live beech, and all beech are quite similar. The tertiary scale of pattern of live beech in the 4 by 4 m and the 2 by 2 m block for subareas 5A, 5B and 5C is more intense than that of all trees and all beech. Patterns of dead beech are quite random in subarea B, but in subarea C the pattern is similar to that of live beech. In subarea 6A, none of the patterns depart significantly from randomness (Fig. 17 and Fig. 18).

In summary, the distribution of live beech in stands could not be distinguished from a random distribution in the following subareas:

subareas 1B, 3A, 4A, 5B and 6A and C. There was not a complete transect of 4 by 96 m which showed an overall random distribution.

The distribution of dead beech appears random except in stand 2 and subareas 4C, 5A, and 6C. It was, however randomly distributed in the 4 by 16 m blocks in the last two subareas. Even subareas 2A and C showed one significant randomly or regularly distributed unit of heterogeneity. While the distribution of dead beech in general cannot be distinguished from random distribution, the low density of dead beech provides low power of the significance tests, and there could be some clumping that goes undetected by these tests.

C. Distribution of Different Diameter Classes of Live and Dead Beech Stems

Because so many of the beech stems are small, the pattern of +B and ≤ 5.0 cm +B are similar to each other, but there are minor changes and shifts in the number of units of heterogeneity and their statistical significance. Examination of data in Table XI reveals that several scales of pattern appear in some subareas, with the number of units of heterogeneity varying and the block size also varying.

Larger beech show more random distribution than small beech, and hence more than all beech taken together. The small sized primary clumps are fewer than those of +B, as expected. However, some examples are opposite to these generalizations. Heterogeneity in +B may be a reflection of the characteristics unique to each subarea--environmental patterns--(Kershaw 1959, 1963) that cannot be eliminated by aging and competition within clumps, or it may reflect remnants of a pattern already established during clumped regeneration.

The only prominent clumping in beech larger than 15 cm diameter occurs in stands 1 and 2, and in general the distribution is as random as the > 5 cm +B. Examples of persistence of non-random distribution are fewer than in the case of > 5.0 ±B. Where the non-random pattern occurs, it seems to be closely related to site characteristics rather than to size of trees, with the possible exception of subarea 6C. In that subarea, the distribution of > 15 +B shows significant scales of pattern while the distribution of +B is completely random.

These larger trees are reaching considerable importance in their controlling influence in the regeneration of the stands, as will be explored in greater detail in subsequent chapters. They would seem to be the product of development of the clumps of smaller trees. Their apparently random distribution can be assessed only as being intermediate between clumped and regular, but it could be interpreted as being a stage in the process of development of older and larger, regularly distributed dominant individuals in the stand overcoming initially clumped distribution.

D, Distribution of Species

1. *Acer spicatum:* The patterns of distribution are similar to each other in subareas B and C of stand 3. There are highly significant units of heterogeneity in several block sizes. The first two units of significant clumps and the decrease of the value at 1 by 1 m blocks are quite the reverse of the pattern of beech in the subarea. This species is clumped in the 1 by 0. 5, 1 by 2, and 4 by 16 m blocks throughout this study. The species distribution does not show any clear mosaic distribution and over-all random distribution as beech did. It is in an intermediate stage of succession in those study areas. The theoretical basis for this statement will be discussed later.

2. *Betula alleghaniensis* shows units of heterogeneity in 1 by 2 and 2 by 4 m blocks except in subarea B of stand 4. The number of units of heterogeneity varies from stand to stand. This species represents various stages of establishment from an initial random stage as represented in subarea B of stand 4 to the least number of unit of heterogeneity in subarea B of stand 6 to a medium number of units of heterogeneity in subarea C of stands 4 and 6, to a maximum number of units in subarea A of stand 6. The last condition may be the maximum establishment in all of the study areas.

3. *Viburnum alnifolium:* In stand 4 three scales of pattern are

observed, but there is no consistent peak from subareas B and C to correspond to those in *Acer spicatum*.

4. *Picea rubens*: The general impression of the distribution of this species within the beech gaps is one of either discrete clumps or thin, elongate columns. Some of the columns are continuous with adjacent spruce forests, while others are isolated as spruce "islands."

This macropattern seems to be in an advancing or already established phase, but there is no evidence of degeneration. Whether the "islands" of spruce are static and confined as they appear, or are spreading is not certain. The ratio of dead to total spruce is 1/33 and 0/7 in the belt transects of stands 4 and 5 and is 13/88 and 2/44 in the quadrat data from the same stands. Of the thirteen dead spruce in stand 4, eleven were found within a quadrat near the southeast edge of the gap ranging in diameters from 0.7 cm to 7.8 cm. Among them six were larger than 2.4 cm. The number of dead beech is very small; the range of dbh distribution is from 0.5 to 47.5 cm. The frequency distribution of diameters is similar to the beech.

The analysis of pattern is of interest in considering the dynamics of spruce in the beech gaps, and the data support the hypothesis mentioned earlier that the random distribution of the species in subarea A of stand 5 indicates initial establishment within the unexacting habitat. Their diameter range of 0.5 to 11.4 cm indicates a young generation. The pattern in subarea C of stand 4 indicates a primary scale of pattern, which can be interpreted as a regenerating phase. The range of diameters is from 1.5 to 51.2 cm. The pattern in subarea B of stand 4 indicates the most complicated distributional phase among the spruce. The diameter ranges from 0.5 to 47.5 cm in the subarea. The first, second and last example may be interpreted as successive stages of establishment of spruce. The theoretical basis for this tentative conclusion will be discussed more fully in a later section.

E. Comparison among Sites and Subareas

If one examines the distribution pattern of all trees in each of the 4 by 32 4 m subareas, the pattern revealed in four of the 18 is one of apparent randomness. One of the subareas is from a south-facing slope and three are from north-facing slopes. The most heterogeneous patterns are from the top subarea among south-facing slopes.

Even in the subareas where the distribution is completely random, remnant scales of pattern may remain and the mosaic scale may be large or small. Regular distribution of clumps was not as common as random distribution of clumps of all trees and all beech, and there were only a few examples of regularly distributed clumps of live beech. These were observed from subarea A of stands 1 and 5. Apparently random distribution in the ≤5.0 cm, >5.0 cm and >15.0 cm beech was observed from 4, 8, and 8 subareas respectively. Clump and mosaic patterns which are analyzed above illustrate quantitatively a prominent characteristic of the pattern for beech irrespective of aspect differences.

A trend toward random or regular distribution may be regarded as one measure of competition and stand maturation of the beech, as discussed in the following chapter (Dice, 1952, Evans 1952, Greig-Smith 1964, Morisita 1959, Odum 1959, Pielou 1959).

VII. GENERAL DISCUSSION OF PATTERN AND STAND HISTORY

Means and variances of samples, survivorship, dispersion and pattern have been discussed separately in the foregoing chapters. This chapter relates these problems to a general and broader discussion of the ecology of beech forests.

Field observations of the beech stands confirm that they are fairly homogeneous physiognomically and floristically. The density and basal area of beech and of all species together are not consistently different between north- and south-facing slopes although they are significantly different among the sites within each slope aspect. There is no trend in density or basal area of all trees or all beech related to degree of slope and azimuth angle.

Russell (1953) stated that "The beech forests are well developed only on south slopes in the beech gaps of the Great Smoky Mountains." In view of the present study the statement does not apply to numbers of trees. The counts which included both live and dead beech showed slight differences between north (54.76/100 m^2) and south (57.33/100 m^2) slopes which were not statistically significant (25 per cent probability of occurring by chance variation alone). For live beech the mean counts in the north- and south-facing stands were 48 and 50 trees per 100 m^2

respectively. However, present data confirm the general impression of lower mean basal area of live beech on north-facing sites than on south-facing sites: 21.78 dm^2 and 29.06 dm^2 per 100 m^2 respectively (23.34 dm^2 and 30.42 dm^2 for live and dead beech taken together). Thus, beech stems have greater basal area on south-facing slopes. The mean count (68) and basal area (37.74 dm^2) of all trees on north-facing sites are slightly greater than count (64) and basal area (35.83 dm^2) on south-facing sites.

In this connection Whittaker's (1956) general statement that the number of tree stems is greater in xeric sites than in mexic sites applies to beech count data but not to all trees. Greater mean basal area and count of all trees were observed in north-facing sites of Cushetunk Mountain, New Jersey, by Cantlon (1953) with the mean count of *Cornus florida* excluded, but the mean count of beech on south-facing aspects was greater than that in north-facing aspects. The reverse was true for basal area.

Patterns of size and inferred survivorship can be related to distributional patterns of beech. Most of the sample areas contained stable primary and secondary diameter groups which showed little direct or indirect evidence of mortality. Typically there is a mosaic pattern characterized by alternating high and low density patches, within which each stem or small groups of stems are randomly or even regularly distributed. The primary stable diameter groups seem to coincide with the high density patches of 5-15 cm beech. Within these the stems are relatively small. The secondary size groups of larger stems (15 or 25 cm) is probably comprised of the individuals or stems which may control the low density patches. The unstable size group of small stems (mostly 0-5 cm) common to all stands typifies the clump size which makes the small scale of pattern, but may also be influenced by dense shade or gaps between crowns of large trees which could provide micro-environmental control of larger scales of pattern as well. Since the transect grid sample for the analysis of pattern and that for the survivorship study are not drawn from the same source, the result of the pattern analysis may not be representative of a whole stand. However, it reveals some features of pattern of the stands and of high altitude beech forests.

Controlling factors of pattern might concievably be systematic soil variation within the sites. Some soil variation is undoubtedly present, but may have been influenced by vegetational differences. The blowing of leaves and the influence of undercover vegetation are believed to favor comparatively homogeneous soil conditions, with relatively minor influuences on soil microheterogeneity. Systematic soil variation seems a less likely cause than the existence of high and low density patches in a mosaic pattern inherent in the phases of beech regeneration (Watt 1947).

Watt (1947) recognized cyclic regeneration in European beech (*Fagus sylvatica*), and he concluded that its cyclic nature was related to senescence and suppression. On the basis of the data of this study it may be speculated that high density patches made up of small trees may be suppressed by the larger trees of low density patches. The high density patches are released upon death of the larger individuals of the low density patches and these in turn lose most of their individuals through competition as the patch matures. An underlying interpretation of this scheme is that suppression is predominately due to light or soil moisture relations. One or at most a few individuals then become members of the dominating low density patches of the next cycle. This speculation could best be substantiated by extensive growth ring analysis of small plants from high density patches and large plants from low density patches.

Field observations on south-facing slopes suggest that the significant primary scale of pattern of regenerating small beech trees is centered near parent trees. This tendency is less pronounced on north-facing slopes. This coalescence among clumps or trees may tend to induce random distribution most rapidly on north-facing stands and hasten the process of leveling out clump contrasts. Among south-facing stands, the intensity of pattern is stronger in stand 3 than in stands 1 and 2. This could mean that the site of stand 3 is more favorable for forming clumps or has had less mediating of environmental differences than the two latter sites.

The cyclic phase of beech performance as postulated by Watt may well relate to the systematic mosaic at block size 4 by 8 m or 4 by 16 m related to major canopy openings, such as those due to ice storms.

The regular distribution of beech trees within the primary clumps cannot result from regular seed dispersal or complete covering of seeds or of sprouts on the ground. The most likely cause of the phenomenon seems to be vegetative spread and competition as observed, postulated, and described by various workers (Ashby 1948, Greig-Smith 1961, Thompson 1958). Kershaw's (1963) emphasis on the "possible existence of the organic connection between a group of apparently distinct individuals which can be designated as a morphological pattern" seems appropriate for beech sprouts, but the National Park was not a suitable place for digging out underground connections. The regeneration of beech by root suckers from "feeding" roots of large trees has been described by many workers (e. g., Illick and Frontz 1928, Harlow and Harrar 1941) and presumably applies in the Great Smoky Mountains as well. Another means to test the hypothesis of sprout connection besides direct observation of the root sucker system of beech is the application of radioactive tracer to beech in both high and low density patches. This test should also prove or disprove the proposed morphological pattern of patch structure and history.

According to the Greig-Smith (1952 .) and Kershaw's (1959) hypothesis on succession, from both theoretical considerations and field observation, initial woody colonization sometimes may be random. Where reproduction is from the pioneer plants, offspring form non-random groups around parents and cause small scale heterogeneity. Where groups increase in size, the non-randomness shows an increase in scale of heterogeneity which is designated "larger scale of pattern". This disappears when the groups meet and seemingly random distribution is observed. The process of disappearance of non-randomness can also be attributed to leveling out toward a homogeneous and favorable site over the whole area as development proceeds.

When invading species are unexacting ones, for which the area is well within the limits of tolerance, we may expect that plants might colonize in a nearly random manner in the area from the beginning. If, on the other hand, the habitat is a marginal one for an invading species, it may be expected to become established only locally in slightly more favorable subareas within the stand--even if the plants occur randomly within those subareas. This situation can thus show larger scale pattern at the start in the area as a whole and may well apply to the scatterd islands of spruce and other species which reach better development elsewhere than the beech gaps.

If this hypothesis is tenable, the red spruce aggregations in islands might also be explained either as a regeneration complex or as advancing or invading islands of successional change in beech stands. The red spruce aggregations are not observed in the most homogeneous subarea where mosaic in beech is best developed, but often are on the border of the beech forest or near to it. It is highly unlikely that spruce is part of the normal regeneration complex within beech stands.

The patterns of _Picea rubens_ seem to fit the above hypothesis. The random distribution in the 4 by 32 m blocks in subarea 5A suggests that the whole subarea is an unexacting one for spruce. The range of diameters of spruce in the subarea is from 0.5 to 11.4 cm. In subarea 4C, there is a large scale of pattern in the 4 by 8 m blocks, but there is also a primary scale of pattern in the 0.5 by 1 m blocks. Subarea 5A is considered to be in a more advanced stage than 4C. Here the diameter of spruce ranges from 1.5 to 51.2 cm. In the same stand, subarea B shows four significant scales of pattern with the diameter ranging from 0.5 to 47.5 cm. The patterns cited above for spruce represent the initial and intermediate stage of group development by coniferous species. The neighboring spruce stands appear to have a typical randomness in their distribution.

Considering the nature of the beech population on the basis of Greig-Smith's theoretical approach (1952b, 1964), the random distribution of individuals (_e.g._, in the north-facing slopes) does not support the view of the community as a "complex organism" (Clements 1916 and Tansley 1920). The indications of regular distribution of the larger trees which may sort out because of competition and some clumping of smaller trees also do not support the individualistic view of the community (Gleason 1926, Curtis and McIntosh 1951, Brown and Curtis 1952, Greig-Smith 1952 , and Whittaker 1956). However, a synthesis drawing on both views can be drawn from Watt's (1947) and Greig-Smith's (1952 , 1964) theoretical considerations of beech and associated populations, irrespective of just how vegetative reproduction, competition, and other mechanisms act in the population and in the development and maintenance of community structure.

VIII. CONCLUSIONS ABOUT METHOD AND SAMPLING EFFICIENCY

The aim of ecology is to understand fundamental principles controlling the structure, function, development, maintenance and distribution of ecosystems. The flow of energy and nutrients through natural ecosystems, such as the high elevation beech and spruce forests, has been a central theme of continuing studies by The University of Tennessee Botany Department. The present study was begun as a step toward understanding the sampling problems inherent in estimating the nutrient pools and structure of stands like those which received special attention from Prof. R. E. Shanks and cooperating investigators. Assessment of the variability of the beech forests was a necessary first step to generalizations about the forest type.

This chapter briefly summarizes a few of the many implications which this study will have for sampling and estimation of plant biomass, chemical inventories, and other characteristics of beech ecosystems. These implications would not all be evident without the basic study of structure, development, and maintenance of beech communities and populations which have been emphasized in the previous chapters. Efficient sampling for either plant biomass or for investigating the distribution of various kinds of stand components calls for understanding of the spatial distribution and hence the variance of beech and associated species. Treating the enormous variation in living things does not allow many simple approaches of physics and formal logic. However, recent advances in statistics do provide the mathematical techniques and logic of inference that can assess the intensity and scale of pattern in complex systems such as vegetation.

This study had investigated this problem with reference to concrete beech stands and to high elevation beech vegetation in the abstract sense. Further use of methods illustrated here will undoubtedly raise questions and provide clues for further investigation. Studies using these mathematical methods may also clarify classic questions regarding "succession", "climax", and the nature of the "community" and its structure.

A. Sampling the Finite Population of Individual Stands

In many places in previous chapters it has been convenient to express numbers and basal areas for individual plots (10 by 10 m, or sometimes 5 by 5 m or smaller subplots). The means for q of these plots are taken as representative of a finite population of Q plots, outlined in Fig. 1. The sample fraction $f = q/Q$ was of the order of 25 per cent. This portion of the total population is known with certainty; sampling error about stand totals (or totals per hectare) $\underline{Y}$ for either density or basal area arises from uncertainty about the actual value of plots which were not sampled. Standard errors $S_{\bar{Y}}$ of the estimated stand total are slightly lower than the standar errors would have been if a negligible percentage of the stand were represented in the sample-- lower by a factor 1 - f (finite population correction) :

$$S_{\bar{Y}} = \frac{Qs}{\sqrt{q}} \sqrt{1 - f} \quad .$$

The 95 per cent confidence intervals in Table II were calculated on a hectare basis with this finite population correction taken into account, as essentially equal to ± twice this standard error.

It turned out that 10 to 13 plots of 10 by 10 m were required (except in stand 4) in order to get the 10% sampling error of both plot counts and basal area for all trees and for beech. In comparing alternative strategies of sampling, an increase in numbers of quadrats q not only increases the denominator in the preceding equation, but also decreases the standard error by increasing f. If more precise documentation were desired for the sake of knowing individual stands in more detail, the extra time could be spent in recording data in more plots, without very much more time spent in laying out the general grid. To do much more intensive sampling than in the present study, however, might well have approached the point at which a complete census would have been as feasible. The extra time spent in recording additional plots would have been partially offset by the use of a given set of plot boundaries for more than one plot at a time.

B. Efficiency of Stratified and Cluster Sampling

For 10 by 10 m plots, counts of all trees showed nine per cent gain in stand 2 and 27 per cent gain in stand 6 -- gain due to stratification into east and west sides of stands (10 plots each) as against simple random sampling. For basal area of all trees it indicates 18 per cent and 1.6 per cent in stands 1 and 4 respectively. However, for other stands the efficiency gain was very minor or negative for both count and basal area. Whatever their efficiency is, there was generally no significant difference of variance between sides over that within sides for both count and basal area.

With the same plot size, stratification for beech count sampling shows its gain in efficiency as 12 per cent, 66 per cent and 26 per cent in sites 2, 4, and 6, and for the basal area sampling it showed a 12 per cent gain in site 1. Gain in the rest of the sites was negligible. The improvement in efficiency in individual cases would not warrant stratified sampling in general.

The ration of (standard error of the mean)/(mean) for plots of different size [(5 by 5 m), (5 by 10 m), 3(5 by 5 m) and (10 by 10 m)] varied with stand, side and attribute (density and basal area). In general the 5 by 5 m and 5 by 10 m plot sizes were more efficient for larger diameter classes than for small ones. A plot size of 5 by 5 m apparently was not efficient for stems smaller than 5.0 cm because of the high variance between plots which happened to include dense clusters and other plots which did not.

The ten 10 by 10 m plots are randomly located in both east and west sides of the stand, but the four elementary units of 5 by 5 m per cluster are not independent of one another. Therefore, s^2 for the latter 40 units is not an unbiased estimate of variance from 40 simple random observations with 5 by 5 m elementary units (Sukhatme 1960). The estimated s_w^2 within clusters is compared to the variance between clusters s_c^2 (Sukhatme 1960) by the ratio F_1 in Table XII. The value of the relative efficiency is obtained and represented in Table XII.

Considering the count sampling of all trees and beech the value of the relative efficiency ranges from 0.42 to 0.77 for all trees and from 0.46 to 0.71 for beech. Although the sampling fraction or area is the same for both simple random and random cluster sampling, the latter sampling reduces the efficiency, as the figure shows. In other words, if 40 units of 5 by 5 m are randomly located , the variance may range from 0.42 and 0.77 of that from the cluster sampling for all tree count sampling.

Table XII. Variance ratio of cluster to that of units (F_1) and relative efficiency (R.E.) of clustering for counts (C) and basal area (B).

	SITE											
	1		2		3		4		5		6	
	C	B	C	B	C	B	C	B	C	B	C	B
All trees												
F_1	*2.98	0.59	*2.69	0.93	*2.12	1.55	**4.12	1.14	**4.12	1.21	1.91	**7.33
R.E.	0.52	1.50	0.52	1.06	0.77	0.73	0.42	0.90	0.46	0.86	0.64	1.28
Beech												
F_1	**3.64	0.48	**2.59	1.31	*1.90	1.28	**3.84	*1.86	**3.28	0.66	1.61	1.57
R.E.	0.46	1.81	0.53	0.82	0.64	0.83	0.49	0.62	0.48	1.37	0.71	0.72

* 5% level of significance
** 1% level of significance

The relative efficiency for basal area is different from that for count. For all tree sampling it ranges from 0.73 in stand 3 to 1.50 in stand 1. In general the values for relative efficiency for basal area sampling are higher than those for count sampling. The ten clusters with four compact elementary units (5 by 5 m) are not much less efficient than 40 random plots of 5 by 5 m. It should be noted that cluster sampling for basal area increased the efficiency 50 per cent and 28 per cent in stands 1 and 6 over that of simple random sampling. Four count sampling clustering reduced the efficiency to approximately half that of simple random sampling except in stand 3.

C. Comparison of Pattern Analysis Methods

The results of an analysis of Morisita's index of dispersion were similar to those of the Greig-Smith method of progressively nested quadrats. More examples of regular distribution were suggested by Morisita's analysis. Although it can be applied to random quadrat samples for characterizing dispersion of stems, Greig-Smith's method is more sensitive for detecting and interpreting mosaic pattern.

IX. SUMMARY

1. Six high elevation stands dominated by beech (Fagus grandifolia) in the Great Smoky Mountains (three south slopes, three north slopes) were sampled in 1962. The distributional pattern of stems of live and dead beech and associated species was studied. A complete map of all stems 1.37 m (4.5 feet) or more high in a 5 by 100 m transect running up the center of each stand was used in analyzing the pattern of stem distribution. Ten randomly placed sample plots on each side of the transect provided estimates of density, basal area, analysis of sizes, survivorship, and additional indices of dispersion.

2. Bartlett's test showed homogeneity among the variances of counts and basal area data for 10 by 10 m plots from the six stands for all beech and live beech. Analysis of variance and Duncan's multiple range test indicated significant differences among some stand means for counts and basal areas.

3. The mean count of live beech ranged from 34.7 to 68.6 per 100 square meters, mostly in the 0-5 cm size class. The mean basal area for beech ranged from 16.10 dm^2 to 33.03 dm^2 per 100 m^2 plot.

4. The Chi-square tests for independence failed to show a consistent difference in proportion of dead beech between north-and south-facing sites.

However, there were some differences among sites and between east and west sides within stands. The same test also confirmed obvious differences between beech and non-beech which are related to the greater relative importance of associated species (*e.g.*, *Betula alleghaniensis*, *Aesculus octandra*, *Picea rubens*) in some north-facing stands.

5. Size classes of live beech and inferred survivorship (based on sizes of dead stems) were studied from the random sample data. The curves are characterized by the common primary unstable diameter group (0.1 - 6.0 cm) in all stands. Individuals growing through this size appear to suffer lower inferred mortality rate until they exceed 15 cm.

6. The randomness and patterns of live and dead beech of different diameter classes and of different species studied from the census data were investigated by the ratio of variance/mean for the nested blocks of plots and also by Morisita's index of dispersion. In north-facing stands the stems were generally more randomly distributed than they were on south-facing stands. Beech distribution involves complicated clumps, expecially in subareas nearest the ridge crests in the south-facing sites. Dead beech distribution could not be distinguished from random distribution. The larger stems of all trees and of living beech appear to have less clumped distribution than the smaller ones, perhaps because the smaller, denser trees crowd one another during maturation. Several scales of

pattern and alternating mosaics of dense and sparse distribution were commonly detected, and may result from vegetative reproduction. They may also be an indirect morphological pattern related to release and competition. Species other than beech also show highly clumped patterns. The implications of the patterns are discussed, and related to the evidence for high mortality of small stems (0-6 cm diameter) and one or more stable age classes of larger diameter. The relation between distributional pattern of stems and survivorship was discussed and possible relations to cyclic regeneration were suggested.

7. The mosaic pattern of beech distribution is thought to be the result of cyclic regeneration. It could develop under homogeneous edaphic conditions, even if soil variation is not the cause of the mosaic pattern.

8. The ratio of (standard error of the mean)/(mean) for plots of different size [(5 by 5 m), (5 by 10 m), 3(5 by 5 m), and (10 by 10 m)] varied with site, aspect, and attribute (density and basal area). In general the 5 by 5 m and 5 by 10 m plot sizes were more efficient for larger diameter classes than for small ones. A plot size of 5 by 5 m apparently was not efficient for stems smaller than 5.0 cm because of the high variance between plots which happened to include dense clusters and other plots which did not.

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APPENDICES

APPENDIX A.

```
                           LOWER LIMIT OF DBH CLASS      BASAL AREA   PERCENT   FREQ.    FREQ.
A1                  TYPE   0.    5.   10.   15.   20.   25.  (LIVE-DEAD) BA. AR.   (5*5)  (10*10).
FAGUS               LIVE  923    56    39    45    31    29    67669.73    88.53   100.00   100.00
  GRANDIFOLIA       DEAD  184     3     3     2     1     0
PICEA               LIVE   16     6     1     2     3     1     2731.02     3.57    13.75    25.00
  RUBENS            DEAD    0     0     0     0     0     0
AESCULUS            LIVE    0     0     0     1     0     4     5022.15     6.57     6.25    15.00
  OCTANDRA          DEAD    0     0     0     0     0     0
AMELANCHIER         LIVE    5     0     1     0     0     0      176.07      .23     2.50     5.00
  LAEVIS            DEAD    0     0     0     0     0     0
PRUNUS              LIVE    1     0     2     1     0     0      573.29      .75     3.75    15.00
  SEROTINA          DEAD    0     0     0     0     0     0
VIBURNUM            LIVE   36     0     0     0     0     0       14.57      .02    13.75    20.00
  ALNIFOLIUM        DEAD    0     0     0     0     0     0
ABIES               LIVE    2     0     0     0     0     0        2.65      .00     2.50    10.00
  FRASERI           DEAD    1     0     0     0     0     0
ACER                LIVE    5     0     0     0     0     0       11.95      .02     3.75    10.00
  SPICATUM          DEAD    0     0     0     0     0     0
BETULA              LIVE    0     0     0     1     0     0      235.06      .31     1.25     5.00
  ALLEGHANIENSIS    DEAD    0     0     0     0     0     0
          TOTAL LIVE      988    62    43    50    34    34    76436.49
          TOTAL     DEAD  185     3     3     2     1     0
          AVERAGE LIVE   49.4   3.1   2.2   2.5   1.7   1.7     3821.82
          AVERAGE DEAD    9.3    .2    .2    .1    .1    .0

                           LOWER LIMIT OF DBH CLASS      BASAL AREA   PERCENT   FREQ.    FREQ.
A2                  TYPE   0.    5.   10.   15.   20.   25.  (LIVE-DEAD) BA. AR.   (5*5)  (10*10)
FAGUS               LIVE  763    40    35    32    33    25    50635.65    80.25   100.00   100.00
  GRANDIFOLIA       DEAD   99     0     5     2     1     1
PICEA               LIVE    6     2     0     2     0     1     1697.01     2.69     8.75    30.00
  RUBENS            DEAD    0     0     0     0     0     0
AESCULUS            LIVE    5     1     0     1     1     7     7501.99    11.89    13.75    50.00
  OCTANDRA          DEAD    0     0     0     1     0     1
AMELANCHIER         LIVE   10     1     2     1     0     0      522.68      .83     6.25    15.00
  LAEVIS            DEAD    0     0     0     0     0     0
PRUNUS              LIVE    1     0     0     0     0     0       14.65      .02     2.50    10.00
  SEROTINA          DEAD    1     0     0     0     0     0
VIBURNUM            LIVE    0     0     0     0     0     0         .00      .00      .00      .00
  ALNIFOLIUM        DEAD    0     0     0     0     0     0
ABIES               LIVE    2     0     0     0     0     0        4.98      .01     2.50    10.00
  FRASERI           DEAD    0     0     0     0     0     0
BETULA              LIVE    3     0     0     0     0     0        4.51      .01     1.25     5.00
  ALLEGHANIENSIS    DEAD    0     0     0     0     0     0
CORNUS              LIVE    4     0     0     0     0     0       10.00      .02     2.50    10.00
  ALTERNIFOLIA      DEAD    0     0     0     0     0     0
HALESIA             LIVE    0     0     0     0     0     1     2706.24     4.29     1.25     5.00
  CAROLINA          DEAD    0     0     0     0     0     0
    MONTICOLA LIVE        794    44    37    36    34    34    63097.71
      0 TOTAL       DEAD  100     0     5     3     1     2
      0 AVERAGE LIVE     39.7   2.2   1.9   1.8   1.7   1.7     3154.89
      0 AVERAGE DEAD      5.0    .0    .3    .2    .1    .1

                           LOWER LIMIT OF DBH CLASS      BASAL AREA   PERCENT   FREQ.    FREQ.
A3                  TYPE   0.    5.   10.   15.   20.   25.  (LIVE-DEAD) BA. AR.   (5*5)  (10*10)
FAGUS               LIVE  629   141    76    54    47    18    64246.88    85.11   100.00   100.00
  GRANDIFOLIA       DEAD  107     3     7     2     4     1
PICEA               LIVE    3     2     1     0     1     0     1893.06     2.51     3.75    10.00
  RUBENS            DEAD    1     0     0     0     0     1
AMELANCHIER         LIVE    7     2     0     1     0     1     1635.96     2.17     3.75    15.00
  LAEVIS            DEAD    2     0     0     0     0     0
PRUNUS              LIVE    2     1     1     0     0     0      194.94      .26     3.75    10.00
  SEROTINA          DEAD    2     1     0     0     0     0
VIBURNUM            LIVE   27     0     0     0     0     0       81.41      .11    10.00    35.00
  ALNIFOLIUM        DEAD    6     0     0     0     0     0
ABIES               LIVE   13     6     4     1     2     2     4390.71     5.82    25.00    65.00
  FRASERI           DEAD    2     1     0     0     0     1
ACER                LIVE  119    20     2     0     0     0     1871.35     2.48    36.25    50.00
  SPICATUM          DEAD   19     1     0     0     1     0
BETULA              LIVE    0     1     0     0     0     1     1048.17     1.39     1.25     5.00
  ALLEGHANIENSIS    DEAD    0     0     0     0     0     0
PYRUS (SORBUS) $    LIVE    1     0     1     0     0     0      121.40      .16     1.25     5.00
  AMERICANA         DEAD    0     0     0     0     0     0
VACCINIUM           LIVE    9     0     0     0     0     0        3.49      .00     5.00    10.00
  ERYTHROCARPON     DEAD    0     0     0     0     0     0
          TOTAL LIVE      810   173    85    56    50    22    75487.35
          TOTAL     DEAD  139     6     7     2     5     3
          AVERAGE LIVE   40.5   8.7   4.3   2.8   2.5   1.1     3774.37
          AVERAGE DEAD    7.0    .3    .4    .1    .3    .2
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A4

	TYPE	LOWER LIMIT OF DBH CLASS 0.	5.	10.	15.	20.	25.	BASAL AREA (LIVE-DEAD)	PERCENT BA. AR.	FREQ. (5*5)	FREQ. (10*10)
FAGUS	LIVE	590	21	20	15	30	19	33599.48	42.42	90.00	100.00
GRANDIFOLIA	DEAD	41	1	2	0	0	2				
PICEA	LIVE	43	26	9	4	0	6	13184.40	16.65	46.25	85.00
RUBENS	DEAD	9	2	0	1	1	0				
AESCULUS	LIVE	1	0	0	0	0	0	.07	.00	1.25	5.00
OCTANDRA	DEAD	0	0	0	0	0	0				
AMELANCHIER	LIVE	3	0	0	0	0	0	1.59	.00	3.75	15.00
LAEVIS	DEAD	0	0	0	0	0	0				
PRUNUS	LIVE	3	0	0	0	0	0	1.47	.00	2.50	10.00
CAROLINA	DEAD	0	0	0	0	0	0				
VIBURNUM	LIVE	133	0	0	[illegible]	0	1	798.83	1.01	36.25	70.00
ALNIFOLIUM	DEAD	3	0	0	0	0	0				
ACER	LIVE	83	8	3	2	0	0	1498.98	1.89	36.25	65.00
SPICATUM	DEAD	8	0	1	0	0	0				
BETULA	LIVE	39	4	7	[illegible]	3	10	27465.28	34.68	32.50	70.00
ALLEGHANIENSIS	DEAD	3	0	0	0	0	0				
CORNUS	LIVE	8	0	0	0	0	0	5.52	.01	8.75	35.00
ALTERNIFOLIA	DEAD	1	0	0	0	0	0				
ACER	LIVE	10	5	2	1	0	2	2225.39	2.81	12.50	40.00
SACCHARUM	DEAD	4	0	0	0	0	0				
FRAXINUS	LIVE	1	0	0	0	0	0	1.33	.00	1.25	5.00
AMERICANA	DEAD	0	0	0	[illegible]	0	0				
PYRUS (SORBUS)	LIVE	1	0	0	0	0	0	1.33	.00	1.25	5.00
AMERICANA	DEAD	0	0	0	0	0	0				
ACER	LIVE	10	3	1	0	0	0	266.61	.34	10.00	25.00
PENSYLVANICUM	DEAD	1	0	0	0	0	0				
ILEX	LIVE	25	0	0	0	0	0	151.43	.19	6.25	25.00
MONTANA	DEAD	1	1	0	0	0	0				
TOTAL	LIVE	950	67	42	28	33	38	79201.72			
TOTAL	DEAD	71	4	3	1	1	2				
AVERAGE	LIVE	47.5	3.4	2.1	1.4	1.7	1.9	3960.09			
AVERAGE	DEAD	3.6	.2	.2	.1	.1	.1				

A5

	TYPE	LOWER LIMIT OF DBH CLASS 0.	5.	10.	15.	20.	25.	BASAL AREA (LIVE-DEAD)	PERCENT BA. AR.	FREQ. (5*5)	FREQ. (10*10)
FAGUS	LIVE	1086	150	33	58	33	12	52198.16	75.19	100.00	100.00
GRANDIFOLIA	DEAD	185	1	2	6	0	1				
PICEA	LIVE	20	11	4	5	2	2	4330.06	6.24	28.75	45.00
RUBENS	DEAD	0	2	0	0	0	0				
AESCULUS	LIVE	4	7	6	6	0	8	10556.44	15.21	27.50	75.00
OCTANDRA	DEAD	0	0	0	0	0	1				
AMELANCHIER	LIVE	6	0	0	0	0	0	15.38	.02	6.25	25.00
LAEVIS	DEAD	0	0	0	0	0	0				
ABIES	LIVE	2	1	2	1	1	1	1803.07	2.60	6.25	20.00
FRASERI	DEAD	0	0	0	0	0	0				
ACER	LIVE	6	1	0	0	0	0	74.86	.11	1.25	5.00
SPICATUM	DEAD	0	0	0	0	0	0				
BETULA	LIVE	7	1	1	0	0	0	201.10	.29	6.25	20.00
ALLEGHANIENSIS	DEAD	0	0	0	0	0	0				
CORNUS	LIVE	13	0	1	0	0	0	206.97	.30	5.00	10.00
ALTERNIFOLIA	DEAD	0	0	0	0	0	0				
HAMAMELIS	LIVE	9	0	0	0	0	0	11.46	.02	6.25	20.00
VIRGINIANA	DEAD	0	0	0	0	0	0				
TSUGA	LIVE	2	0	0	0	0	0	13.89	.02	2.50	10.00
CANADENSIS	DEAD	0	0	0	0	0	0				
BETULA	LIVE	3	0	0	0	0	0	11.38	.02	3.75	15.00
LENTA	DEAD	0	0	0	0	0	0				
TOTAL	LIVE	1158	171	47	70	36	23	69422.76			
TOTAL	DEAD	185	3	2	6	0	2				
AVERAGE	LIVE	57.9	8.6	2.4	3.5	1.8	1.2	3471.14			
AVERAGE	DEAD	9.3	.2	.1	.3	.0	.1				

A6

	TYPE	LOWER LIMIT OF DBH CLASS 0.	5.	10.	15.	20.	25.	BASAL AREA (LIVE-DEAD)	PERCENT BA. AR.	FREQ. (5*5)	FREQ. (10*10)
FAGUS	LIVE	533	143	30	33	36	24	54248.14	69.69	97.50	100.00
GRANDIFOLIA	DEAD	165	3	0	5	1	5				
PICEA	LIVE	9	20	13	1	0	0	2849.97	3.66	28.75	50.00
RUBENS	DEAD	0	0	0	0	0	0				
AESCULUS	LIVE	15	3	7	10	6	6	10529.59	13.53	36.25	70.00
OCTANDRA	DEAD	0	1	0	0	0	1				
AMELANCHIER	LIVE	1	0	0	0	0	0	1.77	.00	1.25	5.00
LAEVIS	DEAD	0	0	0	0	0	0				
VIBURNUM	LIVE	1	0	0	0	0	0	2.02	.00	1.25	5.00
ALNIFOLIUM	DEAD	2	0	0	0	0	0				
ABIES	LIVE	3	0	0	1	0	0	314.63	.40	5.00	15.00
FRASERI	DEAD	0	0	0	0	0	0				
ACER	LIVE	17	5	0	0	0	1	1205.65	1.55	7.50	25.00
SPICATUM	DEAD	1	0	0	0	0	0				
BETULA	LIVE	21	1	1	0	0	3	6720.90	8.63	20.00	55.00
ALLEGHANIENSIS	DEAD	0	0	0	0	0	0				
CORNUS	LIVE	6	2	0	0	0	0	84.63	.11	7.50	20.00
ALTERNIFOLIA	DEAD	2	0	0	0	0	0				
HAMAMELIS	LIVE	2	0	0	0	0	0	3.09	.00	2.50	5.00
VIRGINIANA	DEAD	0	0	0	0	0	0				
TSUGA	LIVE	1	0	0	0	0	0	.20	.00	1.25	5.00
CANADENSIS	DEAD	0	0	0	0	0	0				
ACER	LIVE	3	1	0	0	0	2	1885.48	2.42	2.50	10.00
RUBRUM	DEAD	0	0	0	0	0	0				
TOTAL	LIVE	612	175	51	45	42	36	77846.06			
TOTAL	DEAD	170	4	0	5	1	6				
AVERAGE	LIVE	30.6	8.8	2.6	2.3	2.1	1.8	3892.30			
AVERAGE	DEAD	8.5	.2	.0	.3	.1	.3				

A7 SOUTH

	TYPE	LOWER LIMIT OF DBH CLASS 0.	5.	10.	15.	20.	25.	BASAL AREA (LIVE-DEAD)	PERCENT BA. AR.
FAGUS	LIVE	2315	237	150	131	111	72	182545.19	84.90
GRANDIFOLIA	DEAD	390	6	15	6	6	2		
PICEA	LIVE	25	10	2	4	4	2	6321.09	2.94
RUBENS	DEAD	1	0	0	0	0	1		
AESCULUS	LIVE	5	1	0	2	1	11	12524.14	5.82
OCTANDRA	DEAD	0	0	0	1	0	1		
AMELANCHIER	LIVE	22	3	3	2	0	1	2334.70	1.09
LAEVIS	DEAD	2	0	0	0	0	0		
PRUNUS	LIVE	4	1	3	1	0	0	782.88	.36
SEROTINA	DEAD	3	1	0	0	0	0		
VIBURNUM	LIVE	63	0	0	0	0	0	95.98	.04
ALNIFOLIUM	DEAD	6	0	0	0	0	0		
ABIES	LIVE	17	6	4	1	2	2	4398.34	2.05
FRASERI	DEAD	3	1	0	0	0	1		
ACER	LIVE	124	20	2	0	0	0	1883.30	.88
SPICATUM	DEAD	19	1	0	0	1	0		
BETULA	LIVE	3	1	0	1	0	1	1287.74	.60
ALLEGHANIENSIS	DEAD	0	0	0	0	0	0		
CORNUS	LIVE	4	0	0	0	0	0	10.00	.00
ALTERNIFOLIA	DEAD	0	0	0	0	0	0		
ACER	LIVE	0	0	0	0	0	0	.00	.00
SACCHARUM	DEAD	0	0	0	0	0	0		
FRAXINUS	LIVE	0	0	0	0	0	0	.00	.00
AMERICANA	DEAD	0	0	0	0	0	0		
PYRUS (SORBUS)	LIVE	1	0	1	0	0	0	121.40	.06
AMERICANA	DEAD	0	0	0	0	0	0		
HAMAMELIS	LIVE	0	0	0	0	0	0	.00	.00
VIRGINIANA	DEAD	0	0	0	0	0	0		
ACER	LIVE	0	0	0	0	0	0	.00	.00
PENSYLVANICUM	DEAD	0	0	0	0	0	0		
ILEX	LIVE	0	0	0	0	0	0	.00	.00
MONTANA	DEAD	0	0	0	0	0	0		
TSUGA	LIVE	0	0	0	0	0	0	.00	.00
CANADENSIS	DEAD	0	0	0	0	0	0		
BETULA	LIVE	0	0	0	0	0	0	.00	.00
LENTA	DEAD	0	0	0	0	0	0		
VACCINIUM	LIVE	9	0	0	0	0	0	3.49	.00
ERYTHROCARPON	DEAD	0	0	0	0	0	0		
ACER	LIVE	0	0	0	0	0	0	.00	.00
RUBRUM	DEAD	0	0	0	0	0	0		
HALESIA	LIVE	0	0	0	0	0	1	2706.24	1.26
CAROLINA MONTICOLA	DEAD	0	0	0	0	0	0		
TOTAL	LIVE	2592	279	165	142	118	90	215014.42	
TOTAL	DEAD	424	9	15	7	7	5		
AVERAGE	LIVE	129.6	14.0	8.3	7.1	5.9	4.5	10750.72	
AVERAGE	DEAD	21.2	.5	.8	.4	.4	.3		

A8 NORTH

	TYPE	LOWER LIMIT OF DBH CLASS 0.	5.	10.	15.	20.	25.	BASAL AREA (LIVE-DEAD)	PERCENT BA. AR.
FAGUS	LIVE	2209	314	83	106	99	55	140042.76	61.84
GRANDIFOLIA	DEAD	391	5	4	11	1	8		
PICEA	LIVE	72	57	26	10	2	8	20364.40	8.99
RUBENS	DEAD	9	4	0	1	1	0		
AESCULUS	LIVE	20	10	13	16	6	14	21086.08	9.31
OCTANDRA	DEAD	0	1	0	0	0	2		
AMELANCHIER	LIVE	10	0	0	0	0	0	18.74	.01
LAEVIS	DEAD	0	0	0	0	0	0		
PRUNUS	LIVE	3	0	0	0	0	0	1.47	.00
SEROTINA	DEAD	0	0	0	0	0	0		
VIBURNUM	LIVE	134	0	0	0	0	1	800.85	.35
ALNIFOLIUM	DEAD	5	0	0	0	0	0		
ABIES	LIVE	5	1	2	2	1	1	2117.70	.94
FRASERI	DEAD	0	0	0	0	0	0		
ACER	LIVE	106	14	3	2	0	1	2779.50	1.23
SPICATUM	DEAD	9	0	1	0	0	0		
BETULA	LIVE	67	6	9	6	3	13	34387.27	15.18
ALLEGHANIENSIS	DEAD	3	0	0	0	0	0		
CORNUS	LIVE	27	2	1	0	0	0	297.12	.13
ALTERNIFOLIA	DEAD	3	0	0	0	0	0		
ACER	LIVE	10	5	2	1	0	2	2225.39	.98
SACCHARUM	DEAD	4	0	0	0	0	0		
FRAXINUS	LIVE	1	0	0	0	0	0	1.33	.00
AMERICANA	DEAD	0	0	0	0	0	0		
PYRUS (SORBUS)	LIVE	1	0	0	0	0	0	1.33	.00
AMERICANA	DEAD	0	0	0	0	0	0		
HAMAMELIS	LIVE	11	0	0	0	0	0	14.55	.01
VIRGINIANA	DEAD	0	0	0	0	0	0		
ACER	LIVE	10	3	1	0	0	0	266.61	.12
PENSYLVANICUM	DEAD	1	0	0	0	0	0		
ILEX	LIVE	25	0	0	0	0	0	151.43	.07
MONTANA	DEAD	1	1	0	0	0	0		
TSUGA	LIVE	3	0	0	0	0	0	14.08	.01
CANADENSIS	DEAD	0	0	0	0	0	0		
BETULA	LIVE	3	0	0	0	0	0	11.38	.01
LENTA	DEAD	0	0	0	0	0	0		
VACCINIUM	LIVE	0	0	0	0	0	0	.00	.00
ERYTHROCARPON	DEAD	0	0	0	0	0	0		
ACER	LIVE	3	1	0	0	0	2	1885.48	.83
RUBRUM	DEAD	0	0	0	0	0	0		
HALESIA	LIVE	0	0	0	0	0	0	.00	.00
CAROLINA	DEAD	0	0	0	0	0	0		
MONTICOLA	LIVE	2720	413	140	143	111	97	226467.36	
TOTAL	DEAD	426	11	5	12	2	10		
AVERAGE	LIVE	136.0	20.7	7.0	7.2	5.6	4.9	11323.37	
AVERAGE	DEAD	21.3	.6	.3	.6	.1	.5		

A9 ALL

	TYPE	LOWER LIMIT OF DBH CLASS 0.	5.	10.	15.	20.	25.	BASAL AREA (LIVE-DEAD)	PERCENT BA. AR.
FAGUS GRANDIFOLIA	LIVE	4524	551	233	237	210	127	322575.15	73.07
	DEAD	781	11	19	17	7	10		
PICEA RUBENS	LIVE	97	67	28	14	6	10	26685.46	6.04
	DEAD	10	4	0	1	1	1		
AESCULUS OCTANDRA	LIVE	25	11	13	18	7	25	33610.21	7.61
	DEAD	0	1	0	1	0	3		
AMELANCHIER LAEVIS	LIVE	32	3	3	2	0	1	2353.44	.53
	DEAD	2	0	0	0	0	0		
PRUNUS SEROTINA	LIVE	7	1	3	1	0	0	784.35	.18
	DEAD	3	1	0	0	0	0		
VIBURNUM ALNIFOLIUM	LIVE	197	0	0	0	0	1	896.82	.20
	DEAD	11	0	0	0	0	0		
ABIES FRASERI	LIVE	22	7	6	3	3	3	6516.04	1.48
	DEAD	3	1	0	0	0	1		
ACER SPICATUM	LIVE	230	34	5	2	0	1	4662.79	1.06
	DEAD	28	1	1	0	1	0		
BETULA ALLEGHANIENSIS	LIVE	70	7	9	7	3	14	35675.01	8.08
	DEAD	3	0	0	0	0	0		
CORNUS ALTERNIFOLIA	LIVE	31	2	1	0	0	0	307.11	.07
	DEAD	3	0	0	0	0	0		
ACER SACCHARUM	LIVE	10	5	2	1	0	2	2225.39	.50
	DEAD	4	0	0	0	0	0		
FRAXINUS AMERICANA	LIVE	1	0	0	0	0	0	1.33	.00
	DEAD	0	0	0	0	0	0		
PYRUS (SORBUS) AMERICANA	LIVE	2	0	1	0	0	0	122.73	.03
	DEAD	0	0	0	0	0	0		
HAMAMELIS VIRGINIANA	LIVE	11	0	0	0	0	0	14.55	.00
	DEAD	0	0	0	0	0	0		
ACER PENSYLVANICUM	LIVE	10	3	1	0	0	0	266.61	.06
	DEAD	1	0	0	0	0	0		
ILEX MONTANA	LIVE	25	0	0	0	0	0	151.43	.03
	DEAD	1	1	0	0	0	0		
TSUGA CANADENSIS	LIVE	3	0	0	0	0	0	14.08	.00
	DEAD	0	0	0	0	0	0		
BETULA LENTA	LIVE	3	0	0	0	0	0	11.38	.00
	DEAD	0	0	0	0	0	0		
VACCINIUM ERYTHROCARPON	LIVE	9	0	0	0	0	0	3.49	.00
	DEAD	0	0	0	0	0	0		
ACER RUBRUM	LIVE	3	1	0	0	0	2	1885.48	.43
	DEAD	0	0	0	0	0	0		
HALESIA CAROLINA MONTICOLA	LIVE	0	0	0	0	0	1	2706.24	.61
	DEAD	0	0	0	0	0	0		
TOTAL	LIVE	5312	692	305	285	229	187	441469.03	
TOTAL	DEAD	850	20	20	19	9	15		
AVERAGE	LIVE	265.6	34.6	15.3	14.3	11.5	9.4	22073.45	
AVERAGE	DEAD	42.5	1.0	1.0	1.0	.5	.8		

APPENDIX B

BI

QUADRAT	PLOT	COUNT	BASAL AREA
1	1	8	708.7449
	2	10	320.3804
	3	10	452.7517
	4	10	1114.2704
	TOTAL	38	2596.1466
2	1	5	895.4345
	2	6	9.3698
	3	5	22.9965
	4	20	818.4810
	TOTAL	36	1746.2818
3	1	7	1672.4699
	2	8	356.3203
	3	14	668.9330
	4	17	1987.4231
	TOTAL	46	4685.1449
4	1	12	294.4936
	2	15	913.4752
	3	9	405.4470
	4	22	759.2226
	TOTAL	58	2372.6367
5	1	20	801.4928
	2	16	792.5943
	3	21	1020.9885
	4	16	756.8507
	TOTAL	73	3371.9246
6	1	22	595.4510
	2	24	720.4788
	3	21	1414.3404
	4	20	771.8361
	TOTAL	87	3502.1047
7	1	22	495.2261
	2	17	826.5785
	3	12	1354.1552
	4	0	.0000
	TOTAL	51	2675.9592
8	1	23	1117.7341
	2	14	605.5905
	3	15	1085.6861
	4	21	648.6776
	TOTAL	73	3457.6659
9	1	10	303.2901
	2	8	120.9437
	3	14	628.1708
	4	7	481.0261
	TOTAL	39	1533.4303
10	1	6	263.4232
	2	7	1073.9402
	3	13	343.6361
	4	17	1013.6293
	TOTAL	43	2694.6275
11	1	28	472.2689
	2	17	4424.6685
	3	16	65.4238
	4	18	380.9661
	TOTAL	79	5343.3261
12	1	12	1953.7531
	2	21	778.7869
	3	18	99.2353
	4	17	48.4827
	TOTAL	68	2880.2558
13	1	16	1587.6782
	2	21	688.7408
	3	4	332.5541
	4	14	374.1488
	TOTAL	55	2983.1201
14	1	16	366.1299
	2	18	1121.1113
	3	14	1447.5000
	4	22	786.2404
	TOTAL	70	3720.9800
15	1	19	464.3442
	2	13	610.0830
	3	15	291.4776
	4	11	243.1755
	TOTAL	58	1609.0788
16	1	6	250.0635
	2	3	867.7884
	3	11	27.9524
	4	15	1432.8444
	TOTAL	35	2578.6479
17	1	9	27.9995
	2	6	14.3257
	3	13	677.3132
	4	5	7268.1071
	TOTAL	33	7987.7455
18	1	10	532.9332
	2	13	462.1686
	3	18	1116.7602
	4	8	5.6706
	TOTAL	49	2117.5315
19	1	13	749.0386
	2	18	74.2988
	3	16	3475.2760
	4	19	846.4177
	TOTAL	66	5145.0312
20	1	19	443.4682
	2	12	285.2573
	3	16	902.4246
	4	18	1435.2320
	TOTAL	65	3066.3811

B2

QUADRAT	PLOT	COUNT	BASAL AREA
1	1	9	77.4483
	2	25	1456.6892
	3	19	1004.1810
	4	6	27.9759
	TOTAL	59	2566.2932
2	1	20	92.6301
	2	6	23.5777
	3	4	379.6780
	4	15	118.5640
	TOTAL	45	614.4497
3	1	5	1085.9647
	2	10	682.4812
	3	4	6.6995
	4	8	304.7745
	TOTAL	27	2079.9188
4	1	21	400.6090
	2	22	392.2759
	3	17	1273.7224
	4	17	1323.2889
	TOTAL	77	3389.8957
5	1	23	971.3670
	2	16	221.3336
	3	19	788.5651
	4	9	466.7946
	TOTAL	67	2448.0587
6	1	12	1731.6734
	2	6	171.4921
	3	6	652.2825
	4	20	1447.3507
	TOTAL	44	4002.7973
7	1	9	1141.2725
	2	12	622.6651
	3	8	1205.9816
	4	5	537.3864
	TOTAL	34	3507.3047
8	1	8	1611.2559
	2	21	90.3131
	3	14	71.3693
	4	13	395.2761
	TOTAL	56	2168.2123
9	1	11	702.9408
	2	17	788.9107
	3	10	45.3490
	4	16	93.2977
	TOTAL	54	1630.4970
10	1	6	839.6868
	2	11	1083.9540
	3	14	682.8267
	4	14	1217.8097
	TOTAL	45	3824.2760
11	1	11	156.4438
	2	19	1149.9355
	3	20	575.5254
	4	6	224.8365
	TOTAL	56	2106.7401
12	1	27	947.8521
	2	10	1006.8906
	3	16	1151.4356
	4	22	1613.4549
	TOTAL	75	4719.6319
13	1	11	1260.7162
	2	2	80.1187
	3	2	15.7473
	4	7	364.5434
	TOTAL	22	1721.1252
14	1	21	1088.9335
	2	7	12.3936
	3	9	525.6839
	4	5	129.8031
	TOTAL	42	1756.8132
15	1	13	118.5561
	2	16	567.1923
	3	11	35.4844
	4	9	405.4313
	TOTAL	49	1126.6640
16	1	19	306.1097
	2	10	1089.2712
	3	7	27.6225
	4	13	606.9414
	TOTAL	49	2029.9437
17	1	4	174.3352
	2	10	1196.3212
	3	8	721.0051
	4	9	175.9139
	TOTAL	31	2267.5746
18	1	6	541.0856
	2	4	901.7491
	3	11	572.3995
	4	7	507.4548
	TOTAL	28	2522.6881
19	1	11	1482.2696
	2	11	494.8570
	3	11	517.3194
	4	12	438.4103
	TOTAL	45	2932.8547
20	1	11	515.0260
	2	5	225.1270
	3	5	113.4746
	4	2	210.0002
	TOTAL	23	1063.6278

B3

QUADRAT	PLOT	COUNT	BASAL AREA
1	1	10	812.7555
	2	6	881.0224
	3	9	1044.4170
	4	9	670.5038
	TOTAL	34	3408.6979
2	1	12	469.2451
	2	18	1807.6843
	3	9	193.9702
	4	6	925.6567
	TOTAL	45	3396.5555
3	1	18	1124.0644
	2	15	253.9434
	3	8	173.0550
	4	9	204.6595
	TOTAL	50	1755.7208
4	1	15	869.2885
	2	14	1022.1902
	3	4	268.4340
	4	14	321.1029
	TOTAL	47	2481.0146
5	1	8	292.8600
	2	12	1129.3816
	3	3	719.0651
	4	6	853.0308
	TOTAL	29	2994.3369
6	1	24	1604.8391
	2	14	1294.0956
	3	13	517.1152
	4	2	145.6838
	TOTAL	53	3561.7327
7	1	19	920.0175
	2	13	763.2438
	3	9	331.8236
	4	7	711.4860
	TOTAL	48	2726.5702
8	1	9	1255.7210
	2	10	817.1773
	3	16	938.2467
	4	14	870.5530
	TOTAL	49	3881.6962
9	1	14	1395.9541
	2	16	941.8124
	3	20	1071.3012
	4	17	945.0875
	TOTAL	67	4354.1531
10	1	17	598.6554
	2	19	670.7394
	3	9	509.7639
	4	15	980.5954
	TOTAL	60	2759.7530
11	1	19	1873.8386
	2	14	1181.6499
	3	16	848.2398
	4	10	980.4776
	TOTAL	59	4884.2043
12	1	8	751.9420
	2	10	523.2963
	3	12	1535.8103
	4	14	1219.3648
	TOTAL	44	4030.4122
13	1	5	136.5889
	2	2	264.3499
	3	6	1638.4071
	4	9	878.7605
	TOTAL	22	2918.1062
14	1	8	351.5058
	2	16	813.9257
	3	22	912.7604
	4	16	327.9830
	TOTAL	62	2406.1729
15	1	17	684.2954
	2	19	928.4606
	3	22	1262.3576
	4	10	693.1783
	TOTAL	68	3568.2904
16	1	10	186.2262
	2	17	913.0510
	3	19	1156.8234
	4	21	1857.8714
	TOTAL	67	4113.9704
17	1	16	503.3550
	2	9	198.7062
	3	15	629.1132
	4	12	267.4365
	TOTAL	52	1598.6104
18	1	16	583.9763
	2	24	1055.5540
	3	9	521.2307
	4	7	331.1482
	TOTAL	56	2491.9083
19	1	13	488.2596
	2	6	45.1919
	3	5	360.9463
	4	4	683.5964
	TOTAL	28	1577.9941
20	1	12	760.1572
	2	8	42.8985
	3	2	51.5615
	4	3	31.3296
	TOTAL	25	885.9468

B4

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QUADRAT     PLOT      COUNT    BASAL  AREA

   1          1         10      244.9427    11          1        15      428.5142
              2          8      105.9897                2         2        4.3511
              3          2       15.8494                3         0         .0000
              4         10      122.7973                4         1        3.1416
            TOTAL       30      489.5790              TOTAL      18      436.0069

   2          1         15      815.1431    12          1         3      989.9024
              2         10      352.6132                2         0         .0000
              3          5      329.2161                3         6     1073.9166
              4          7        9.1970                4         5     1050.4174
            TOTAL       37     1506.1688              TOTAL      14     3114.2362

   3          1          3       26.3737    13          1         4      901.1522
              2         15     1846.5459                2        12     1836.7913
              3         13      371.2114                3         0         .0000
              4         20     1130.8346                4         0         .0000
            TOTAL       51     3374.9645              TOTAL      16     2737.9435

   4          1          5       28.6357    14          1         5      122.2239
              2          7       28.5100                2        13      517.9320
              3          9       53.5800                3         2        5.1051
              4          7      483.1859                4         1        3.1416
            TOTAL       28      593.9116              TOTAL      21      648.4026

   5          1          8      362.0223    15          1         2      632.9224
              2         10      789.3663                2         8       12.6371
              3         12      699.0217                3         0         .0000
              4         15      792.8142                4         0         .0000
            TOTAL       45     2643.2233              TOTAL      10      645.5595

   6          1          0         .0000    16          1         4       30.5206
              2          1       10.1788                2         0         .0000
              3          5      190.9622                3         8      246.5056
              4         10      733.9563                4        14     1214.7546
            TOTAL       16      935.0972              TOTAL      26     1491.7808

   7          1          6      536.7031    17          1         1       22.0619
              2         29      667.2366                2         0         .0000
              3         12      606.1010                3         1        6.1575
              4         10      285.7678                4         1        1.7672
            TOTAL       57     2095.8072              TOTAL       3       29.9866

   8          1          2       12.1266    18          1        22      785.8555
              2          5        9.1342                2         8      562.2364
              3          3        1.7907                3         7      670.5745
              4         13     1028.0414                4         9     1152.9435
            TOTAL       23     1051.0929              TOTAL      46     3171.6093

   9          1         34     1316.9430    19          1         9      137.4607
              2         25     1270.2823                2        10      144.9063
              3         31     1222.6478                3         6      924.3686
              4         15       24.5202                4        10      951.6142
            TOTAL      105     3834.3904              TOTAL      35     2158.3494

  10          1         26      192.8157    20          1         5       12.7078
              2          9       19.9963                2        15       34.1335
              3         16      279.2018                3        10       35.1702
              4         20      203.4971                4        13      469.1587
            TOTAL       71      695.5108              TOTAL      43      551.1701
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B5

QUADRAT	PLOT	COUNT	BASAL AREA
1	1	13	333.7714
	2	12	399.1403
	3	18	925.1697
	4	16	1037.7411
	TOTAL	59	2695.8217
2	1	14	893.2197
	2	12	526.9091
	3	18	104.3168
	4	19	336.7010
	TOTAL	63	1861.1448
3	1	5	20.4047
	2	11	1361.4986
	3	4	939.8567
	4	30	806.3780
	TOTAL	50	3128.1370
4	1	28	351.7021
	2	17	185.7392
	3	18	908.2365
	4	29	443.3269
	TOTAL	92	1889.0035
5	1	10	262.8105
	2	3	86.4647
	3	14	483.5079
	4	12	107.5291
	TOTAL	39	940.3122
6	1	28	516.3848
	2	12	1082.7131
	3	37	324.8964
	4	28	1330.1298
	TOTAL	105	3254.1210
7	1	18	606.0225
	2	11	169.5679
	3	13	1055.0749
	4	7	176.9742
	TOTAL	49	2007.6389
8	1	42	690.4922
	2	37	435.0801
	3	26	296.8997
	4	25	422.0111
	TOTAL	130	1846.4807
9	1	16	748.6904
	2	12	651.4657
	3	16	1222.2237
	4	11	380.2514
	TOTAL	55	3002.6298
10	1	15	406.5466
	2	22	268.6225
	3	15	640.3523
	4	12	714.7061
	TOTAL	64	2030.2267
11	1	29	809.3782
	2	14	971.6969
	3	13	31.1804
	4	22	501.1088
	TOTAL	78	2313.3627
12	1	24	468.2712
	2	23	744.1743
	3	6	768.7495
	4	21	349.8721
	TOTAL	74	2331.0657
13	1	21	951.0251
	2	17	498.2499
	3	12	1125.4781
	4	14	134.4448
	TOTAL	64	2709.1965
14	1	16	792.5707
	2	12	871.9746
	3	18	1287.1998
	4	13	926.6070
	TOTAL	59	3878.3507
15	1	16	975.1212
	2	16	931.0995
	3	14	556.6994
	4	13	568.4332
	TOTAL	59	3031.3517
16	1	10	644.9076
	2	10	536.9230
	3	7	958.7299
	4	11	727.5003
	TOTAL	38	2868.0599
17	1	12	673.0878
	2	13	749.5229
	3	6	331.2267
	4	15	55.9755
	TOTAL	46	1809.8117
18	1	29	592.8984
	2	27	729.4324
	3	28	164.9890
	4	19	1021.6954
	TOTAL	103	2509.0133
19	1	24	804.1160
	2	13	854.6016
	3	33	607.1927
	4	15	290.8886
	TOTAL	85	2556.7971
20	1	11	398.4805
	2	18	489.9482
	3	22	1640.0407
	4	9	131.6959
	TOTAL	60	2660.1649

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6
QUADRAT      PLOT        COUNT       BASAL  AREA

   1           1           12         354.0897     11          1           4          64.2928
               2            6         389.6998                 2           4          44.4772
               3           21        1105.5368                 3           0            .0000
               4            9         233.9078                 4           3          46.3857
             TOTAL         48        2083.2335               TOTAL        11         155.1558

   2           1           12          96.2508     12          1          11         731.9378
               2           18         923.3947                 2           5         792.0288
               3            8         430.7997                 3           6          14.1451
               4            5          78.7756                 4           9          85.1766
             TOTAL         43        1529.2202               TOTAL        31        1623.2875

   3           1           11         742.1323     13          1           2         201.2588
               2            7         503.2058                 2           2         484.2148
               3           14         437.4599                 3           1         201.0624
               4           12         658.7699                 4           3         668.0141
             TOTAL         44        2341.5669               TOTAL         8        1554.5499

   4           1           12         774.2552     14          1           8         741.5118
               2            7         124.7294                 2          15        1274.9790
               3           26         848.2320                 3           3         458.4380
               4           10          47.5010                 4           9        1685.7275
             TOTAL         55        1794.7169               TOTAL        35        4160.6557

   5           1           10         535.5800     15          1           9         472.5594
               2           12        1244.1128                 2          17         816.6196
               3           10          42.1210                 3          14        1628.0477
               4            7         453.8041                 4           9         247.5973
             TOTAL         39        2275.6171               TOTAL        49        3164.8233

   6           1           16        1155.7239     16          1           6          69.6100
               2            7          84.2263                 2           8         398.0172
               3           13         537.8262                 3           0            .0000
               4           26        1157.4753                 4          11         788.0782
             TOTAL         62        2935.2500               TOTAL        25        1255.7053

   7           1            8         854.2089     17          1          12         766.2833
               2           11         581.0310                 2           4         123.6141
               3           16        1316.8565                 3           9         735.9433
               4           17         441.8267                 4           2         318.3383
             TOTAL         52        3193.9210               TOTAL        27        1944.1789

   8           1           18        1383.9454     18          1          10        1621.7645
               2            8         544.8948                 2          16         339.5598
               3            3        1097.5336                 3          17        1196.0306
               4            3         866.2334                 4          11         102.1020
             TOTAL         32        3892.6065               TOTAL        54        3259.4547

   9           1           11         613.1539     19          1          17         109.2099
               2            9        1323.7131                 2           7         803.7077
               3            9        1045.1867                 3          29         924.9341
               4            7         793.1440                 4           5          27.6539
             TOTAL         36        3775.1971               TOTAL        58        1865.5049

  10           1            8         697.0346     20          1          11        1169.8768
               2           13         750.4340                 2          10         380.9818
               3           12         789.7590                 3           7         486.3589
               4           12         684.4761                 4          17        1097.7063
             TOTAL         45        2921.7023               TOTAL        45        3134.9226
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APPENDIX C.

Y AXIX	LOWER LIMIT OF X AXIS							
LOW LIM.	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
.5	0	0	0	0	0	0	0	0
1.0	0	0	0	0	0	0	1	1
1.5	0	0	0	0	1	0	0	0
2.0	0	0	0	1	0	1	0	0
2.5	0	0	0	0	0	0	0	0
3.0	0	0	0	0	0	0	0	0
3.5	0	2	0	0	0	0	0	0
4.0	0	0	0	0	0	0	0	0
4.5	0	0	0	0	0	0	0	0
5.0	0	0	0	0	0	0	0	0
5.5	0	0	0	0	0	0	0	0
6.0	0	0	0	0	0	0	0	0
6.5	0	0	0	0	0	1	0	0
7.0	0	0	0	0	0	0	0	0
7.5	0	0	1	0	0	1	0	0
8.0	0	0	0	0	0	0	0	0
8.5	0	0	0	0	0	0	0	0
9.0	0	0	0	0	1	1	1	0
9.5	0	0	0	0	0	0	0	0
10.0	0	0	0	1	0	0	1	0
10.5	0	0	0	0	0	0	0	0
11.0	0	0	0	0	1	0	0	0
11.5	0	0	0	0	0	0	0	0
12.0	0	0	1	0	0	0	0	0
12.5	0	0	0	0	1	0	0	0
13.0	0	1	0	0	0	0	0	0
13.5	0	1	1	0	0	0	0	0
14.0	0	0	0	0	0	0	0	0
14.5	0	0	0	0	0	1	0	0
15.0	0	0	0	0	1	0	0	0
15.5	0	0	0	0	0	0	0	0
16.0	1	0	0	1	0	0	0	0
16.5	0	0	0	0	0	0	0	0
17.0	0	0	0	0	0	0	0	0
17.5	0	0	0	0	0	0	0	0
18.0	0	0	0	2	0	0	0	0
18.5	0	0	0	0	0	0	0	0
19.0	0	0	0	0	0	0	0	1
19.5	0	0	0	0	0	0	0	0
20.0	0	0	0	0	0	1	1	0
20.5	0	1	0	0	0	0	0	0
21.0	0	0	0	0	0	0	0	0
21.5	0	0	0	0	0	0	0	0
22.0	0	1	0	0	0	0	0	0
22.5	0	0	0	0	0	0	0	0
23.0	0	0	0	0	0	0	0	0
23.5	0	0	0	0	0	0	0	0
24.0	1	0	0	0	0	0	0	0
24.5	0	0	0	0	0	0	0	0
25.0	0	0	0	0	0	0	0	0
25.5	0	0	0	0	0	0	0	0
26.0	0	0	0	0	0	0	0	0
26.5	0	0	0	0	0	0	0	0
27.0	0	0	0	0	0	0	0	0
27.5	0	0	0	0	0	0	0	0
28.0	0	0	0	0	0	0	0	0
28.5	0	0	0	0	0	0	0	0
29.0	0	0	0	0	0	0	0	0
29.5	0	0	0	0	0	0	0	0
30.0	0	0	0	0	0	0	0	1
30.5	0	0	0	0	0	0	0	0
31.0	0	0	0	0	0	0	0	0
31.5	0	0	0	0	0	2	0	0
32.0	0	0	0	0	0	0	0	0
32.5	0	0	0	0	0	0	0	0
33.0	0	0	0	0	0	0	0	0
33.5	0	0	0	0	0	0	0	0
34.0	0	0	1	0	0	0	0	0
34.5	0	0	0	0	0	0	1	0
35.0	0	1	0	1	0	0	0	0
35.5	0	1	0	0	0	0	0	0
36.0	0	1	0	0	0	0	0	0
36.5	0	0	0	0	0	1	0	1
37.0	0	0	0	0	0	0	1	0
37.5	0	0	0	0	0	0	1	0
38.0	0	0	0	0	0	0	0	0
38.5	0	0	0	0	0	0	0	0
39.0	0	0	0	2	0	1	0	0
39.5	0	0	0	0	0	0	0	1
40.0	0	0	0	1	1	0	0	0
40.5	0	0	0	0	0	0	0	0
41.0	0	0	0	0	0	0	0	0
41.5	1	0	0	0	0	2	1	1
42.0	0	0	1	0	0	0	0	0
42.5	0	0	0	0	1	1	0	0
43.0	0	0	0	0	0	1	0	0
43.5	0	0	0	0	1	1	0	0
44.0	0	0	0	0	0	0	0	0
44.5	0	0	0	1	0	0	0	0
45.0	0	0	0	0	0	0	1	0
45.5	0	0	0	1	0	1	0	0
46.0	0	0	0	0	0	0	0	0
46.5	0	0	0	0	0	0	0	0
47.0	0	0	0	0	0	1	0	0
47.5	0	0	0	0	0	0	0	0
48.0	0	0	0	0	0	0	1	0
48.5	0	0	0	0	0	0	2	0
49.0	0	0	0	0	0	0	0	0
49.5	0	0	0	0	0	0	0	0
50.0	1	0	0	0	0	0	0	0
50.5	0	0	0	0	0	0	0	1
51.0	0	0	1	0	0	0	1	0
51.5	0	0	0	0	0	0	0	1
52.0	2	0	0	0	0	1	0	0
52.5	1	0	0	0	0	0	0	0
53.0	0	1	0	0	0	0	0	0
53.5	0	0	0	0	0	0	0	0
54.0	0	0	0	0	1	0	1	0
54.5	0	0	0	0	0	0	0	2
55.0	0	1	0	1	0	0	0	0
55.5	0	0	0	0	0	0	0	0
56.0	0	0	0	0	0	0	0	0
56.5	0	1	0	0	[illegible]	0	1	0
57.0	0	0	0	0	0	0	1	1
57.5	0	0	1	0	0	0	0	0
58.0	0	0	0	1	0	1	0	0
58.5	0	0	0	0	0	0	0	0
59.0	0	0	0	0	1	0	1	1
59.5	1	0	0	0	0	0	0	0
60.0	0	0	0	2	1	0	1	1
60.5	1	0	1	0	1	0	1	0
61.0	0	1	0	0	1	0	0	0
61.5	0	0	0	0	0	0	0	0
62.0	0	1	0	1	0	0	0	1
62.5	0	0	0	0	0	0	0	0
63.0	0	0	0	0	0	1	0	0
63.5	1	0	0	0	0	0	1	0
64.0	0	1	0	0	2	0	1	0
64.5	0	0	0	0	0	1	1	0
65.0	0	1	0	1	1	0	0	0
65.5	0	0	0	0	0	0	0	0
66.0	0	0	2	1	0	0	0	0
66.5	0	0	0	0	0	0	1	0
67.0	0	0	0	0	0	0	0	0
67.5	0	0	0	0	0	0	0	0
68.0	0	0	0	0	0	0	0	0
68.5	0	0	0	1	1	0	0	0
69.0	0	0	0	1	0	0	1	0
69.5	0	0	0	0	0	0	0	0
70.0	0	0	0	0	0	0	0	0
70.5	0	1	0	0	0	0	0	0
71.0	0	0	1	0	0	0	0	0
71.5	0	0	0	0	0	0	0	0
72.0	0	0	0	0	0	0	0	0
72.5	0	0	0	2	0	0	0	0
73.0	0	1	0	1	0	0	0	0
73.5	0	0	0	1	0	0	3	0
74.0	0	0	0	0	0	0	0	0
74.5	0	1	0	0	1	0	0	0
75.0	1	1	2	0	1	0	0	2
75.5	0	0	0	1	0	0	0	1
76.0	0	0	0	0	0	0	0	0
76.5	0	0	1	1	1	0	0	0
77.0	0	1	0	0	0	0	0	0
77.5	0	1	0	0	1	0	1	1
78.0	0	1	0	0	0	0	0	0
78.5	0	0	0	0	0	0	0	0
79.0	0	0	0	0	0	0	0	0
79.5	0	0	0	0	0	0	0	0
80.0	2	1	0	0	0	0	0	0
80.5	0	0	0	0	0	1	0	0
81.0	0	0	0	2	0	1	0	0
81.5	1	0	0	0	0	1	1	0
82.0	0	0	0	2	0	0	0	1
82.5	0	2	0	0	1	0	0	0
83.0	0	0	0	0	1	1	0	1
83.5	1	0	0	0	0	1	1	0
84.0	0	0	0	0	0	1	0	0
84.5	0	1	0	0	0	0	0	0
85.0	0	0	0	0	0	0	0	2
85.5	0	0	0	0	1	0	0	0
86.0	0	0	0	0	0	0	0	1
86.5	0	0	0	0	0	0	0	0
87.0	0	0	0	1	0	0	0	1
87.5	0	0	0	0	0	0	0	0
88.0	0	0	0	0	0	0	0	0
88.5	0	0	0	0	0	0	0	0
89.0	0	0	0	0	0	0	0	0
89.5	0	0	0	0	0	0	0	0
90.0	0	0	0	2	0	0	1	0
90.5	0	0	0	0	1	0	0	0
91.0	2	0	0	1	0	0	0	1
91.5	0	0	0	0	1	1	0	0
92.0	0	0	0	0	0	1	2	0
92.5	0	0	0	0	1	0	0	0
93.0	1	1	0	0	0	0	0	0
93.5	0	0	0	1	0	0	0	0
94.0	0	0	0	0	1	0	1	1
94.5	0	1	1	1	0	0	0	0
95.0	3	0	0	1	0	0	0	0
95.5	0	0	0	0	0	0	0	0
96.0	0	0	0	0	0	0	1	2