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The Application of the Logarithmic Series and the Index of Diversity to Bird Population Statistics.

By D. G. TUCKER, D.Sc.

PREAMBLE.

A NUMBER of years ago the author read a paper (Tucker 1947b) to the Society, discussing several applications of statistical methods to Natural History (and particularly ornithological) research. Among these methods was the 'logarithmic series' and its parameter, the 'Index of Diversity', and it was attempted to show various ways in which this method could be useful in ecological studies. One of the main uses seems to be (as demonstrated in the previous paper) to enable comparisons to be made between habitats and survey areas of very different sizes. But it was also pointed out that no extensive and critical test of whether the basic relationships of the method did really apply to bird populations had been made, although superficially it seemed satisfactory.

The present paper attempts to make this test. It is necessarily almost entirely numerical and possibly, therefore, rather dull. But it does review a large amount of data of bird populations, and does raise some interesting speculations. Moreover it does not entirely prove the validity of the logarithmic series, although the Index of Diversity should still be very useful. Much further research will be necessary, and this is being carried on by the Ecological Section of the Society at Bookham Common; no doubt a further report will be published.

1. *Introduction*

The logarithmic series, first proposed by R. A. Fisher (1943), has by now become well-known through the papers by C. B. Williams (1943-7) who has shown that it can represent, with fair accuracy, the distribution of units in groups in biology. It is not, therefore, proposed to discuss the theory and mathematics of the series in the present paper. However, there has been, in the published work on the subject, a notable lack of discussion of the application of the series to bird populations, and this is no doubt due to a lack of suitable data. It has been the present author's aim, over the last few years, to obtain suitable data, and this paper presents the analysis of these data from the one point of view of the logarithmic series.

The logarithmic series gives the number of groups represented by one, two, three, etc., units in a natural population. In the present case we shall consider only the number of bird species represented by one, two, three, etc., individuals in samples of bird populations. The series is

$$n_1, \frac{n_1 x}{2}, \frac{n_1 x^2}{3}, \frac{n_1 x^3}{4}, \text{ etc.}$$

where n_1 is the number of species represented by one individual, and x is a factor dependent on the sample itself, but always less than unity. If N is the total number of individuals and S is the total number of species in the sample, then

$$\frac{N}{S} = \frac{x}{(1-x)(-\log_e[1-x])}$$

which defines x.

If we define a parameter α as n_1/x, the series becomes

$$\alpha x, \frac{\alpha x^2}{2}, \frac{\alpha x^3}{3}, \frac{\alpha x^4}{4}, \text{ etc.}$$

and it can be shown that α is a constant for any population, irrespective of the size of the sample taken, and it is known as the Index of Diversity,

It can now be seen that if we can show that the logarithmic series applies to bird populations, then the Index of Diversity can be used as a parameter, or characteristic property, of the bird population of any particular habitat. Its use in ecology might then become quite important.

The data analyzed in this paper are of two types:

(a) sample counts of several different populations; for each population a number of similar counts were made over the same route at different times, and the average results are taken; the majority of the counts have been made by the author,

and (b) sample counts of several different woodland habitat types, published by Lack and Venables (1939); in each individual habitat only one count was made,* but the distribution of species and individuals has been averaged (by the present author) over all the counts of each habitat *type*.

*Actually there were many habitats in which several counts were made, but the results of these were represented in a combined form which was useless for the present purpose. Consequently only those cases where single counts were published have been utilized here.

The first set of data is therefore strictly suitable for testing the logarithmic series, but the second set is not, since the various counts which are averaged are not of the same population, but of different populations in the same habitat type—the various counts are, moreover, of samples of varying size. It is thought that these effects will probably have little influence on the results, as the variations are averaged out; and certainly this seems justified by the results, which are very similar to those obtained from the first set of data.

Particulars of the habitats, and dates and duration of counts, are given for the first set of data in Table 1, and references are given to any published accounts of the habitats and other work on their bird populations. The details of individual counts (i.e. names of species and numbers of birds in each) are not given in this paper as the space required would be so large, but they can be obtained on request from the author.

2. *Fitting the logarithmic series to the data.*

For each series of counts, as set out in Table 1, and for those published by Lack and Venables, as indicated in Table 5, average results of the distribution of individuals in species were obtained by the following method. The total number of occurrences of species represented by only one individual was determined and divided by the number of counts in the series; this then gave the average number of species represented by one individual. The average numbers of species represented by two, three, etc., individuals were determined in a similar way. The results are shown in Table 2, in the columns headed "O" (i.e. "observed"). The logarithmic series corresponding to these results is determined from the average number (N_{AV}) of individuals per count and the average number (S_{AV}) of species per count, in a manner described in Williams' papers; the factor x and the parameter α (Index of Diversity) have to be calculated in order to do this, and are shown for each count in Table 2. The calculated series are shown in the columns headed "C" in Table 2, and it is simple to see by inspection what similarity exists between the observed and calculated series. It must be agreed that the similarity is good. The series of counts designated C1-3 are represented graphically in Fig. 1 to help in the appreciation of the results and the measure of agreement. In many cases the number of birds observed has been insufficient to give a smooth series of observed values, and so some grouping has been done. Generally speaking, the number of species represented by one or two individuals is in tolerable agreement with that calculated.

Table 3 shows the percentage error of the observed numbers over the calculated for the first four rows of Table 2 for those counts which are considered reliable. It is immediately obvious that there is a consistent trend in these errors. The average error over the whole 99 counts has been worked out and is shown also in Table 3. The number of species represented by one or three individuals is below the calculated

figure, and the number represented by two or four is above the calculated figure. A possible conclusion from this result is that birds tend to go about in pairs. In this connection it is important to emphasize that the counts are all of samples and not of whole populations. The effect is just as marked in winter as in summer.

It is also worthy of note that the result of Table 3 suggests that the first few terms of the observed series are better fitted by a hyperbolic series (n_1, $\frac{n_1}{2}$, $\frac{n_1}{3}$, etc.) than by the logarithmic series!

The counts designated F2 and F3 were made in very limited habitats, and the number of birds involved is very small. It is therefore a very good sign that even in these cases a tolerable resemblance between observed and calculated results exists. It is, on the other hand, rather surprising that better agreement is not obtained in the series H1, which involves over 150,000 birds and over 100 hours' observation.

The variable factor of conspicuousness has been ignored in this work; it will affect the results only if it is related to rarity.

3. *The Index of Diversity.*

To enable the significance of the values of the Index of Diversity to be better appreciated, Tables 4 and 5 have been prepared, and it can be seen at once that in all cases where a comparison can be made of the index in winter and in the breeding season, it is considerably higher in the latter. The influence of migration on this comparison would be expected to give a considerably smaller difference than this, and a more likely explanation is that, as a first approximation, for each bird seen on a count in the breeding season, there is another bird on the nest. To test this hypothesis, we can double the average number of individuals, while leaving the number of species unchanged. Ignoring the fact that the logarithmic series no longer properly applies, we can estimate the index of diversity from $2N_{AV}$ and S_{AV}, and these results are shown in brackets in Tables 4 and 5. The agreement now existing between winter and the breeding season (especially in Table 4, where the same individual habitat is involved in both winter and breeding season) is very much closer. This forces us to the conclusion that the basic assumptions on which the theory of the logarithmic series is based, namely, that the sample is randomized by units (or individuals in our case), are not always valid in the case of a bird population, and the randomization may be sometimes in pairs, or divided between units and pairs.

As far as the actual calculated values of index of diversity are related to habitat, it is evident that they are higher in the more mixed habitats. For instance, in mixed woodland and grassland (series A1-4, B1-2, G1-2) the diversity is greater than in simple habitats (series C1-3, D1, F2-3). This result has been predicted in previous papers from theoretical considerations.

But the general consistency of the figures is rather surprising, covering no greater range than 1.6 to 7.5 overall;* although it must be admitted that extreme types of habitat may not have been considered. It would be interesting to know the results for habitats such as mudflats, rocky islands, mountains, the open sea, etc.

4. *Variation from Count to Count and from One Observer to Another.*

Almost all the results discussed so far are averages over a number of counts, and in each series only one observer is concerned. The question naturally arises, to what extent do counts in the same habitat vary among themselves, and to what extent do the results obtained depend on the particular observer? No complete study of these problems has been made, but sample (and, it is thought, typical) results are given in Tables 6-8 and in Fig. 2.

Table 6 shows the actual recorded data of counts made by different observers in the area of series B. These counts were made especially for the comparison now under discussion. In each of the three sets of results the counts were made over exactly the same route at exactly the same time, and with the same duration. In the first and third sets, the author walked in the opposite direction to the other observer(s) so that there should be no mutual influence. In the second set the two observers walked only about 20-30 yards apart and tried not to be influenced by each other. The agreement is in this case as good as might be expected, but in the other cases is rather disappointingly poor. Table 7 shows the distribution of individuals in species for these counts, and it will be seen that the agreement is poor.

Table 8 shows the variations in numbers of individuals and species and in the index of diversity calculated from these numbers for the C series of counts. The variations are considerable. It will be noticed that, in all three sets of results, the average value of the index of diversity obtained this way is higher than that obtained by working out the average distribution as in Table 2. This appears to be a universal result, occurring in all the cases tested, including, for instance, the large series of counts designated H1, where the average index of diversity is 6.02 (maximum value 7.5, minimum 5.1) as compared with 5.90 obtained from the average count. This discrepancy must be due mainly to the logarithmic relationship of the index of diversity to the numbers of individuals and species. The method based on the average count (as used in Table 2) appears to be the correct one.

Figure 2 shows graphically the distribution of values of number of species over the 19 counts of series C. It can clearly be seen that for each number of individuals the number of species varies widely over the series of counts, and no great confidence can be felt in the averages obtained. The smooth curves shown in the figure are the calculated results from Table 2.

*This can be interpreted in terms of the number of species in a given number of individuals thus :—In a sample of 100 birds there would be expected between 6 and 20 species, and in a sample of 1000 birds there would be expected between 10 and 36 species approximately.

What appears to be needed to assess the reliability of the averaged results given in this paper is some means of calculating confidence limits (on a statistical basis of say 95% or 99% reliability) for the index of diversity, and a test of significance to determine whether the difference between the indices of diversity for different series of counts is significant or merely due to random causes.

5. *Conclusions.*

It may be concluded that the logarithmic series does fit observed results for sample counts of bird populations reasonably well, but it is possible that a hyperbolic series might fit better. There is evidence of pairing in the results examined, and, probably mainly on this account, the index of diversity for a given habitat is apparently much greater in the breeding season than in winter.* The basis of use of the index (and of the logarithmic series) for sample counts is thus slightly confused, and the effect of pairing requires further investigation.

For ordinary types of British habitat, the index of diversity appears to lie within the range 1.6 to 7.5

Although the variable factor of conspicuousness has not been taken into account, there is no evidence that it seriously affects the results obtained.

The reliability of the results quoted is open to some doubt on account of the great variation in results from one count to another in the same series, and from one observer to another, but in the absence of any suitable statistical test, it is thought the work done at least gives a good general picture of the position, and shows the range with which the index of diversity is likely to fall for ordinary British habitat types.

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TABLE 1. Index to Main Series of Counts.

Series designation.	Particulars of Habitat.	Particulars of Counts.
A1-4	Highams Park, part of Epping Forest, Essex. Mixed habitat, 18 acres oak-hornbeam wood, 6 acres grass, 6 acres lake. See Tucker (1947a). All counts about 45 mins. duration.	A1. 7 counts in winter under quiet conditions (i.e. less than 20 human beings in area). Dates and times:—11/1/46, 11.30 a.m.; 20/1/46, 8.50 a.m.; 24/1/46, 8 a.m.; 4/2/46, 12.30 p.m.; 16/3/46, 11.40 a.m.; 18/3/46, 10.40 a.m.; 28/3/46, 9 a.m. A2. 11 counts in winter under busy conditions (i.e. more than 20 human beings in area). Dates and times:—25/12/45, 11.15 a.m.; 26/12/45, noon; 6/1/46, noon; 6/1/46, 3 p.m.; 12/1/46, 2.45 p.m.; 13/1/46, noon; 13/1/46, 3 p.m.; 19/1/46, 3 p.m.; 10/3/46, 10.30 a.m.; 24/3/46, 11.30 a.m.; 28/3/46, 2.20 p.m. A3. 3 counts in spring under quiet conditions. Dates and times:—2/5/46, 7 a.m.; 19/5/46, 10.20 a.m.; 7/6/46, 8.30 a.m. A4. 7 counts in spring under busy conditions. Dates and times:—7/4/46, 11 a.m.; 7/4/46, 3 p.m.; 14/4/46, 10.30 a.m.; 5/5/46, 11.45 a.m.; 19/5/46, 2.30 p.m.; 11/6/46, 2.20 p.m.; 23/6/46, 10.30 a.m.
B1-2	Ludgate Plain (Epping Forest, Essex). Mixed habitat, about 20 acres oak-hornbeam wood with beech, holly, rose and blackthorn, and about 3 acres marshy grass. See Epping Forest Survey (1948). All counts about 50 mins. duration.	B1. 10 counts made by Mr. A. C. Wheeler. Dates and times:—28/4/46, 10.40 a.m.; 30/6/46, 9.30 a.m.; 28/7/46, 9.30 a.m.; 28/7/46, 10.20 a.m.; 2/8/46, 8.45 a.m.; 4/8/46, 7.15 a.m.; 12/8/46, 8.10 a.m.; 8/9/46, 9 a.m.; 27/9/46, 8.30 a.m.; 29/9/46, 9 a.m. B2. 5 counts made by author. Dates and times:—28/4/46, 9.40 a.m.; 28/4/46, 10.40 a.m.; 26/5/46, 9.40 a.m.; 2/6/46, 11 a.m.; 30/6/46, 9.30 a.m.
C1-3	Bicker (Parts of Holland, Lincs). Agricultural land, mainly arable, with a few small grass-fields and a few farmhouses and cottages; hedgerows along the roads, and a few large trees. See Tucker (1948). Counts about 25 mins. duration.	C1. 9 counts in summer along a public road. Dates and times:—7/6/46 3.30 p.m.; 7/6/46, 4 p.m.; 8/6/46, 9 a.m.; 8/6/46, 9.30 a.m.; 11/6/46, 9 a.m.; 11/6/46, 9.30 a.m.; 6/8/46, 9 a.m.; 6/8/46, 9.30 a.m.; 8/8/46, 9 a.m. C2. 4 counts in winter along the same route. Dates and times:—24/12/46, 10.40 a.m.; 25/12/46, 11 a.m.; 25/3/47, 9.50 a.m.; 25/3/47, 10.15 a.m. C3. 6 counts in summer along a route entirely in fields, no houses or trees, some hedgerows. Dates and times:—12/6/46, 9 a.m.; 4/8/46, 12.30 p.m.; 5/8/46, 8.15 a.m.; 9/8/46, 8 a.m.; 29/5/47, 10.15 a.m.; 30/5/47, 10.15 a.m.
D1	River Welland saltings (Lincs.). Entirely salt-marsh except for one small cottage. Count 30 mins. duration.	D1. 1 count on 6/8/46, 5.30 p.m.
E1	Burnham-on-Crouch (Essex). Walk along river-wall, mainly pasture and marsh on land side. Count 45 mins. duration.	E1. 1 count on 17/6/46, 1 p.m.
F1-3	Amersham (Bucks.). Mainly arable land, some grass, small mixed woods and hedgerows. Duration of counts, 15 mins. for F1, 10 mins. for F2-3.	F1. 7 counts in wood and along a hedgerow. F2. 7 counts in a large field, no hedges (soil ploughed). F3. 7 counts along a tall, thick hedge. One count of each type done on 15/2/48, noon; 21/2/48, 3 p.m.; 28/2/48, 3.30 p.m.; 7/3/48, 11 a.m.; 26/3/48, 10.30 a.m.; 27/3/48, 11.20 a.m.; 4/4/48, 11.40 a.m.
G1-2	Limpsfield Common (Surrey). Dry, heathy land at 500 ft. elevation, with bracken, grass, heather, etc, and some woodland. See Limpsfield Common Survey (1938-1942).	G1. Complete winter census, 4/12/38, 10.30 a.m.-4 p.m. See Currie (1939). G. Complete winter census, 3/12/39, 10.45 a.m.-1 p.m. See Parmenter (1940).
H1	Mitcham Common (Surrey). Open land, route including Beddington Sewage Farm. Total mileage of route, 3½ miles. All counts about 3½ hours duration, and made by Mr. L. Parmenter.	H1. 30 counts in winter, all between about 9 a.m. and 1 p.m. Dates:—15/2/31, 1/3/31, 8/3/31, 15/3/31, 18/10/31, 1/11/31, 22/11/31, 20/12/31, 25/12/31, 17/1/32, 14/2/32, 20/3/32, 2/10/32, 6/11/32, 4/12/32, 15/1/33, 29/1/33, 5/3/33, 19/11/33, 21/1/34, 4/3/34, 4/11/34, 20/1/35, 3/2/35, 3/3/35, 10/3/35, 13/10/35, 4/10/36, 29/11/36, 17/1/37.

TABLE 2. Distribution of Individuals in Species.

No. of Individuals in Species	A1		A2		A3		A4		B1		B2		C1		C2		C3	
	O	C	O	C	O	C	O	C	O	C	O	C	O	C	O	C	O	C
1	2.7	3.57	2.45	3.16	4.7	5.76	3.86	4.09	4.3	6.6	5.4	5.1	4.11	4.0	3.0	3.15	2.5	3.5
2	1.7	1.73	1.55	1.52	2.3	2.59	2.28	1.90	3.4	2.9	2.6	2.32	2.33	1.84	1.25	1.51	2.0	1.58
3	1.57	1.12	0.64	0.97	1.3	1.55	0.86	1.18	2.4	1.7	1.4	1.40	1.11	1.14	1.0	0.96	0.83	0.95
4	1.14	0.81	0.55	0.70	1.3	1.05	0.86	0.82	1.5	1.12	0.8	0.96	1.11	0.79	1.5	0.55	0.83	0.64
5	0.29	0.63	1.1	0.54	1.7	0.75	0.43	0.61	1.3	0.79	0.2	0.70	1.11	0.58	1.25		0.67	
6	0.29	0.50	0.55	0.43	0.3	0.57	0.57	0.47	0.6	0.58	0.2	0.53	0.33	0.45	0.75		0.5	
7	0.14	0.42	0.45	0.36	0.6	0.44	0.57	0.38	0.4	0.44	0.4	0.41	0.11	0.36	0		0.33	
8	0.29	0.37	0.55	0.30	0	0.34	0.43	0.31	0.5	0.34	0.4	0.33	0	0.29	0.25		0	
9					0.6	0.28	0.57	0.25	0.1	0.26	0.4	0.26	0.11	0.24	0		0.17	
10					0	0.22	0	0.21	0.3	0.21	0.2	0.21	0	0.20	0	0.21	0.17	0.14
1 and 2							6.14	5.99										
3 and 4																		
1,2 and 3	6.0	6.42							10.1	11.2	9.4	8.8	7.55	6.98	5.25	5.62		
N_{AV}	107.6		79.4		57		59.6		55.1		56.6		53.5		71		36.8	
S_{AV}	12.71		10.64		14.7		11.9		15.5		13.2		11.67		10.5		8.83	
x	0.967		0.960		0.90		0.93		0.88		0.909		0.926		0.955		0.904	
α	3.7		3.3		6.4		4.4		7.5		5.6		4.3		3.3		3.9	

O=observed. C=calculated log series. N_{AV} =average no. of individuals per count. S_{AV} =do. species. α=index of diversity. Numbers in all columns except first are the average numbers of species represented by the given number of individuals.

TABLE 2 (*continued*).

No. of Individuals in Species	D1		E1		F1		F2		F3		G1		G2		H1	
	O	C	O	C	O	C	O	C	O	C	O	C	O	C	O	C
1	2	4.28	10	6.25	4.0	3.45	1.0	1.29	1.0	1.82	6	6.77	6	6.9	4.7	5.90
2	3	2.08	1	2.91	2.0	1.46	1.0	0.51	1.57	0.64	4	3.32	1	3.35	3.93	2.95
3	1	1.36	2	1.81	0.14	0.82	0.28	0.27	0.43	0.30	2	2.17	1	2.2	2.07	1.97
4	2	0.48	2	1.26	0.43	0.52	0.14		0.14	0.15	0	1.60	4	1.6	2.3	1.47
5	0	0.76	1	0.94	0.14	0.35	0		0		0	1.26	2	1.25	1.17	1.18
6	2	0.62	0		0.14	0.25	0		0		1	1.03	0		1.7	0.98
7	0	0.51	1		0.28	0.18	0		0		1	0.87	0		1.07	0.84
8	0	0.44	0		0		0		0		0	0.74	0		1.17	0.74
9	0	0.38	0		0		0		0		1	0.65	4		0.83	0.66
10	0	0.33	0		0.14		0		0		0	0.57	0		1.4	0.59
1and 2	5	6.36	11	9.16			2.0	1.80	2.57	2.46	10	10.09			8.63	8.85
3and 4	3	2.34														
1,2and 3					6.14	5.73									10.70	10.82
N_{AV}	156		92		22.4		6.14		6.0		385		328		5729	
S_{AV}	16		18		7.56		2.57		3.14		28		27		40.77	
x	0.972		0.932		0.845		0.79		0.70		0.982		0.980		0.99897	
α	4.4		6.7		4.1		1.63		2.6		6.9		7.0		5.9	

TABLE 2 (*continued*).

No. of Individuals in Species.	L1W O	L1W C	L1B O	L1B C	L2W O	L2W C	L2B O	L2B C	L3W O	L3W C	L3B O	L3B C	L4W O	L4W C	L4B O	L4B C	L5W O	L5W C	L5B O	L5B C
1	3.72	4.47	4.08	5.17	2.43	2.32	5.43	5.84	2.25	2.50	3.0	3.19	2.4	2.26	4.55	4.52	1.16	1.56	3.54	3.66
2	2.48	2.08	3.28	2.32	1.57	1.12	2.86	2.54	1.0	1.20	1.89	1.42	1.4	1.04	1.64	1.99	0.5	0.76	1.38	1.65
3	1.32	1.29	1.44	1.39	0.29	0.73	1.14	1.47	0.75	0.76	0.77	0.84	0.65	0.63	1.27	1.17	0.5	0.50	0.85	0.98
4	0.96	0.91	1.44	0.43	0.71	0.52	1.57	0.96	0.25	0.54	0.55	0.57	0.65	0.44	0.91	0.77	1.0	0.36	1.08	0.66
5	0.76	0.68	0.68	0.67	0.29	0.40	0.57	0.67	0.75	0.42	0.22	0.40	0.25	0.32	0.64	0.55	0.17	0.28	0.62	0.48
6	0.44	0.52	0.64	0.50	0.57	0.32	0.43	0.49	0.25	0.33	0.33	0.30	0.1	0.24	0.36	0.40	0.17	0.23	0.39	0.36
7	0.76	0.42	0.64	0.38	0.86	0.27	0.43	0.36	0.75	0.27	0.22	0.23	0.1	0.195	0.27	0.30	0	0.20	0.15	0.27
8	0.36	0.34	0.16	0.30	0.14	0.23	0.29	0.27	0.25	0.23	0	0.18	0.05	0.15	0.18	0.23	0.33	0.17	0.23	0.22
9	0.08	0.28																		
10	0.12	0.24																		
1 and 2	6.20	6.55	7.36	7.49	4.29	4.17	8.29	8.38	3.25	3.7	4.89	4.61	3.8	3.3	6.19	6.51	1.66	2.32	4.92	5.31
3 and 4																				
1,2 and 3																				
N_{AV}	65		50.2		67.9		44.9		57.25		29.8		26.95		38.3		66.7		35.9	
S_{AV}	12.64		13.12		8.14		13.4		8.25		7.88		6.15		10.8		6.0		9.23	
x	0.932		0.897		0.966		0.87		0.956		0.893		0.916		0.882		0.977		0.898	
α	4.8		5.77		2.4		6.71		2.62		3.57		2.47		5.13		1.6		4.08	

TABLE 3.

Percentage Errors between Calculated and Observed Numbers of Species.

Series	No. of Counts	% error for 1, 2, 3 or 4 individuals per species			
		1	2	3	4
A1	7	-24	0	+40	+40
A2	11	-22	0	-30	-21
A3	3	-18	-11	-16	+24
A4	7	-5	+20	-27	+5
B1	10	-35	+17	+41	+34
B2	5	+6	+12	0	-17
C1	9	+3	+26	-3	+40
C2	4	-5	-17	+4	+180
C3	6	-28	+26	-12	+29
F1	7	+16	+37	-82	-17
H1	30	-20	+33	+5	+56
AVERAGE ERROR FOR 99 COUNTS		-15.8	+19.3	-3.8	+32.6

TABLE 4.

Index of Diversity for Main Series of Counts.

Locality	Series	Date	No. of Counts	Index of Diversity
Highams Park,	Winter, Quiet	1945-6	7	3.7
(Epping Forest)	Winter, Busy	1945-6	11	3.3
	Spring, Quiet	1946	3	6.4 (4.5)*
	Spring, Busy	1946	7	4.4 (3.3)*
Ludgate Plain	Counts by A.C.W.	1946	10	7.5
(Epping Forest)	Counts by D.G.T.	1946	5	5.6
Bicker,	Road, Summer	1946	9	4.3 (3.3)*
(Holland, Lincs.)	Road, Winter	1946-7	4	3.3
	Fields, Summer	1946,7	6	3.9
River Welland	Saltings	Aug. 1946	1	4.4
Burnham-on-Crouch	River bank	June 1946	1	6.7
Amersham (Bucks.)	Wood + hedges	Winter 1948	7	4.1
	Fields	"	7	1.6
	Hedgerow	"	7	2.6
Limpsfield Common	Winter Censuses	1938	1	6.9
(Surrey)		1939	1	7.0
Mitcham Common	Winter Counts	1931-7	30	5.9

*Values obtained when average no. of birds in count is doubled, but average no. of species is unchanged.

TABLE 5.

Index of Diversity from Published Counts.

Design-ation	Habitat	Winter or Breeding Season	No. of Counts	Index of Diversity
L1	Oakwoods	W	25	4.8
		B	25	5.8 (4.1)*
L2	Beechwoods (with secondary growth)	W	7	2.4
		B	7	6.7 (4.4)*
L3	Beechwoods (no secondary growth)	W	4	2.6
		B	9	3.6 (2.45)*
L4	Scots Pine (England)	W	20	2.5
		B	11	5.1 (3.4)*
L5	Scots Pine (Scotland)	W	6	1.6
		B	13	4.1 (2.8)*

*Values obtained when average no. of birds in count is doubled, but average no. of species is unchanged.

TABLE 6.

Comparison of Counts by Different Observers.

Check-list Number	Name of Species	Numbers observed on dates shown by observers indicated by initials						
		28/4/46		2/6/46		30/6/46		
		DGT	ACW	DGT	GB	DGT	PR	ACW
3	Crow	3	3	1	-	11	1	1
5	Jackdaw	-	-	-	2	4	4	2
11	Jay	2	-	1	-	2	2	4
14	Starling	4	-	41	46	-	-	-
19	Greenfinch	1	2	-	-	-	-	2
41	Chaffinch	3	6	7	5	-	6	5
61	House-sparrow	-	-	-	-	-	2	2
75	Tree Pipit	-	1	-	-	-	-	-
93	Tree Creeper	-	1	-	-	-	-	-
96	Nuthatch	-	-	-	-	-	-	1
98	Great Tit	10	5	3	3	21	16	18
100	Blue Tit	1	5	8	7	3	5	4
102	Coal Tit	-	-	-	-	2	-	1
107	Marsh Tit	1	1	-	-	-	2	2
129	Chiffchaff	-	-	1	1	-	1	-
132	Willow-warbler	1	3	2	2	2	3	4
162	Blackcap	-	-	1	1	-	-	-
163	Whitethroat	3	2	2	4	-	1	-
174	Mistle-Thrush	-	-	2	2	-	-	-
175	Song-Thrush	1	1	-	-	-	3	-
184	Blackbird	4	5	6	5	9	9	7
201	Redstart	-	-	-	-	-	-	3
203	Nightingale	-	2	-	-	-	-	-
208	Robin	-	2	-	3	3	6	2
211	Hedge-sparrow	-	-	-	-	-	1	-
213	Wren	-	1	1	-	2	6	5
225	Swift	-	-	1	-	-	-	-
235	Green Woodpecker	-	-	-	-	1	1	2
237	Great Spotted Woodpecker	-	-	-	-	1	2	2
380	Woodpigeon	1	1	-	-	22	-	1
383	Turtle-Dove	-	-	-	4	-	-	-

TABLE 7.

Distributions by Different Observers.

Number of Individuals	Number of species on dates shown						
	28/4/46		2/6/46		30/6/46		
	DGT	ACW	DGT	GB	DGT	PR	ACW
1	6	6	6	2	2	5	4
2	1	4	3	3	4	4	7
3	3	2	1	2	2	2	1
4	2	0	0	2	1	1	3
5	0	3	0	2	0	1	2
6	0	1	1	0	0	3	0
7	0	0	1	1	0	0	1
8	0	0	1	0	0	0	0
Total species	13	16	14	13	13	18	19
Total Individuals	35	41	77	85	83	71	68

TABLE 8.

Variation Among Counts. Series C.

(A) Series C1.

Number of Individuals	45	53	41	53	41	59	49	57	84
Number of Species	13	13	13	12	10	13	11	10	10
Index of Diversity (α)	6.4	5.8	6.8	4.9	4.2	5.2	4.4	3.5	2.9

Average α=4.90 (α from average count=4.3).

(B) Series C2.

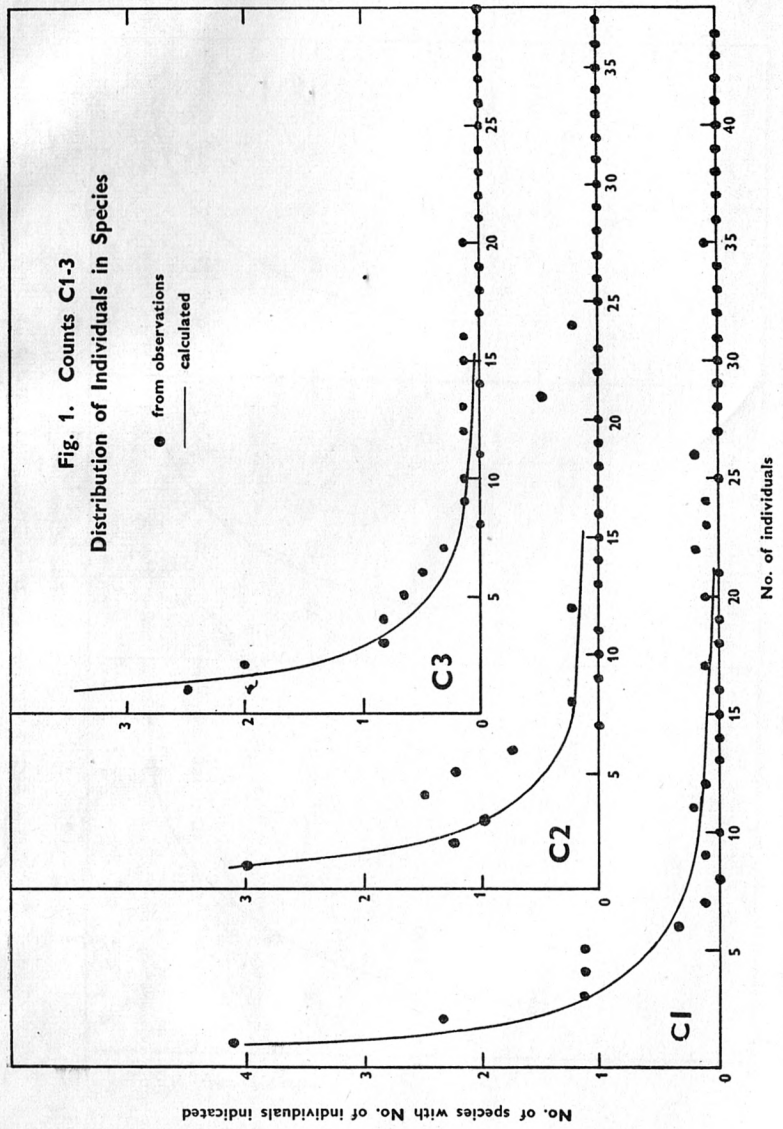
Number of Individuals	114	40	70	60
Number of Species	13	6	12	11
Index of Diversity (α)	3.7	1.9	4.2	3.9

Average α=3.43 (α from average count=3.3).

(C) Series C3.

Number of Individuals	34	28	11	73	31	44
Number of Species	10	7	6	12	9	9
Index of Diversity (α)	5.1	3.0	5.4	4.1	4.4	3.4

Average α=4.23 (α from average count=3.9).



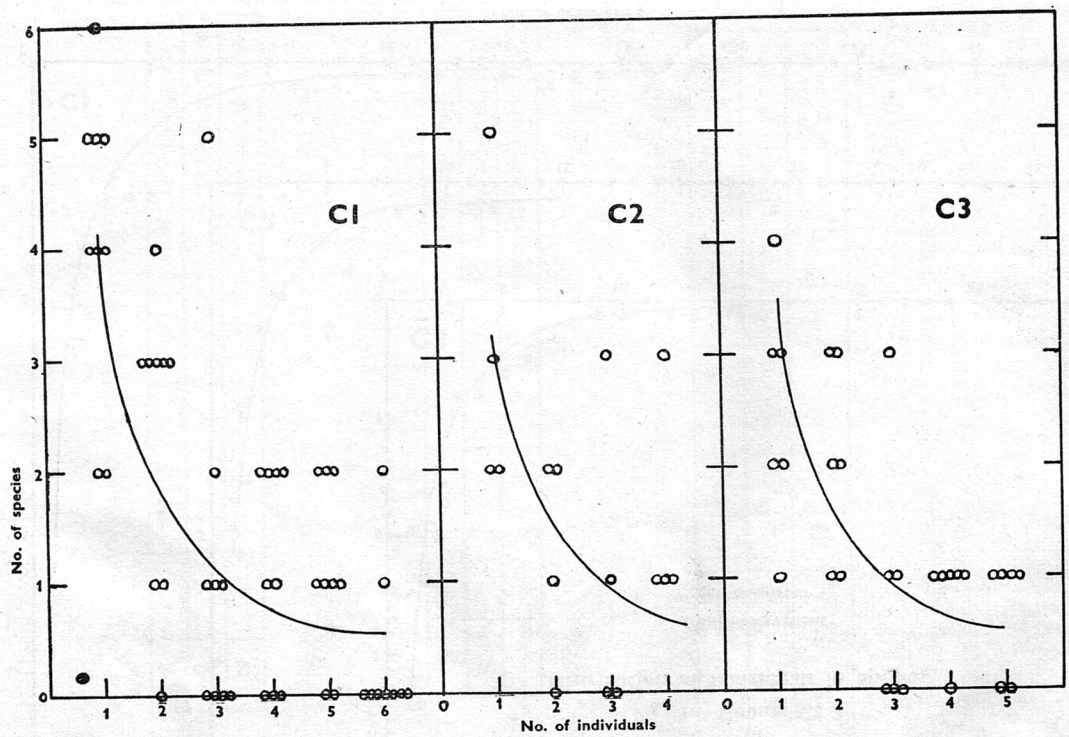


FIG. 2. Counts C1-3. Variation among Counts