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An exercise in community ecology

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AN EXERCISE IN COMMUNITY ECOLOGY

by

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I N D E X

INTRODUCTION.

1.1. THE CONCEPT OF COMMUNITY

The term "community" must be one of the most used and abused terms in Ecology. Its exact significance in the general matrix of ecological theory still remains to be determined.

Various attempts have been made to define a community e.g. McFadyen (1963) lists seven. These range between two extremes, one implying no organisation but merely a coincidence of range in time and space e.g. Clarke (1946) (from McFadyen), the other viewing the community as a "superorganism," with properties of organisation over and above those of its components. Mobius (1877) (from McFadyen) proposed the term "Biocoenose" for a "community whose total of species is mutually linked and selected under the influence of the average conditions of life." Acceptance of this latter view implies that communities exist as units and as such can be delimited, albeit imprecisely. Acceptance of the former view need not necessarily exclude the existence of separate communities as units, if species had similar ranges of tolerance to environmental differences and these ranges of tolerance tended to coincide. (Greig Smith, 1964). The general finding that a community (however it has been defined and delimited) tends to have a "normal" composition does seem to imply organisation of some kind. Although populations of plants and animals do fluctuate, their numbers tend to oscillate about a mean level which itself is related to variables in the physical environment and to the means of other populations.

Essentially, a community consists of both plants and animals, i.e. it is the living component of the term "ecosystem." But, due to the historical specialisation,

which seems to be an imposed part of most biologists' training, "animal communities" and "plant communities" tend to be considered separately. In many cases this separation, apart from simplifying the processing of data, is perfectly legitimate since many animal communities are connected with the decomposition of material. Also, animals move, whereas plants do not, so a given animal can be a member of more than one plant community. From now on, only the animal component of the pond ecosystem will be dealt with, and will be referred to as an animal community.

In practice, animal communities, however defined, have proven extremely resistant to delimitation. Various attempts have been made in terms of discontinuities in the physical environment or on the basis of discontinuities in the vegetation. But, discontinuities do not always exist in an obvious form, slow gradiation being all too apparent. Even when some sort of discontinuity does seem to be present, there is often no evidence that it applies as such to animals in the vicinity. (One only has to think of the many different types of animals which pass across the edge of a pond, a rather obvious discontinuity). A more "natural" way (if any man-made delimitation can be considered "natural") to delimit animal communities is in terms of the animals themselves. Fager's concept of recurrent groups (Fager, 1957) is an attempt at just this. Much thought and work still remains to be done in this field.

Without defining precise boundaries between them, two associations of animals can be seen to differ if they can be described in a significantly different manner by the same statistic or coefficient. Characteristics which can be used

to establish such differences are many and various. They include coefficients of similarity based on species composition, indices of diversity and measures of organisation. If the two associations are indeed significantly different, whether or not they are accorded the status of separate communities is entirely a subjective choice.

1.2 DESCRIPTION OF STUDY AREAS

The Brasside ponds lie about three kilometres north-east
of Durham City (map reference NZ45/290452). They lie in a
depression of approximately 0.8 hectares, about three metres
below the surrounding ground level. The area was an old
brick workings, abandoned in the 1930s. In the depression
there are about eight relatively permanent ponds and several
less permanent ones. Even in summer most of the ground in
the depression is extremely marshy. Fig.1 shows a map of
the area.

The ponds which were sampled are labelled A, B, C and D.
Pond A has a surface area of approximately 133 square metres and
an average depth of approximately 92 cm. Pond B has a surface
area of approximately 292 square metres and an average depth of
approximately 40 cm. Pond C has a surface area of approximately
434 square metres and an average depth of approximately 53 c.m.
Pond D has a surface area of approximately 233 square metres and
an average depth of approximately 22 c.m. (This pond at the
beginning of sampling was about 36 c.m. deeper, the outflow
being unblocked, and the level of the water sinking, about half
way during sampling.) In all four ponds the dominant vegetation
was Potamageton natans with Juncus conglomeratus around the
edges where they became shallow.

Page Bank pond is situated about eight miles south west of
Durham, just outside the village of Willsden. The pond, originally
old gravel workings is several times larger than any of the

Brasside ponds and showed evidence of being considerably
dried up; in wet weather the pond must be even larger. The
pond was choked with vegetation especially Ceratophyllum emersum
and Myriophyllum spicatum.

Fig 1 Map of Brasside Pond Complex.
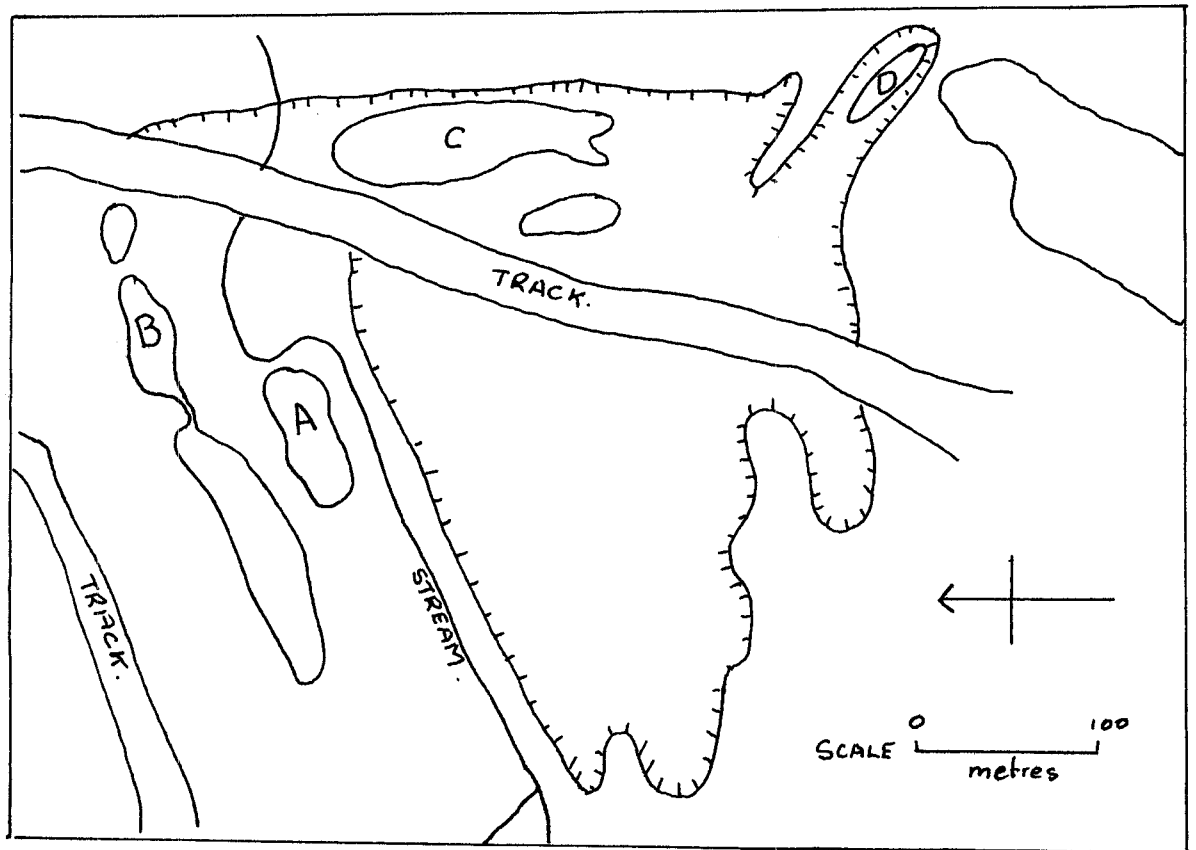
Ponds sampled were A - D

Modified from McEwen (1967)

1.3. AIMS

The close proximity and apparent similarity of the Brasside ponds present an interesting opportunity to study the relationship of these ponds to each within the framework of the ecological concept of community.

In introductory textbooks of ecology e.g. Odum (1963) a pond is presented as a relatively clear cut example of a community. But, in the case of the Brasside ponds, should each pond be considered a separate community or does it form a part of a larger community, the pond complex.

As measurements of degrees of similarity can be assessed only in relation to dissimilarity, another pond some distance away at Page Bank was used as a reference point for these studies.

The project was considered to have a twofold function, firstly to try to solve the problem stated above, and, secondly, as an exercise in community methodology.

1.4. THEORETICAL BACKGROUND

1.4.1. SPECIES ABUNDANCE RELATIONS

Most ecological communities contain many species of organisms, which vary greatly in their abundance. A widespread similarity exists between communities in the patterns of abundance of different species: there is a tendency for the numerically common species to be few in number by comparison with a large number of numerically scarce species.

To explain this generality two main hypotheses have been put forward. Both assume a random distribution of individuals in space. Fisher, Corbett and Williams (1943) fitted the observed distribution by a logarithmic series whereas Preston (1948) used the log normal distribution. Whereas the logarithmic series postulates that singleton species (i.e. those species containing only one individual) will be the most common, the lognormal distribution postulates that there will be more fairly common species than either very rare or very abundant species (see Fig. 2). Field data can be found to fit both these models.

Log Series   The species-abundance curve is fitted by a curve of the type

$$S = \alpha \ln \left(1 + \frac{N}{\alpha} \right)$$

where S = number of species

N = total number of individuals

α = a constant expressing the diversity of species in relation to the total number of individuals.

Lognormal distribution. This distribution is given by the formula

$$S_r = S_o e - (ar)^2$$

where S_o = number of species in modal octave

S_r = number of species r octaves from mode

a = a constant calculated from the data

Hairston and Byers (1954) attempted the analysis of extensive data on soil anthropods by both the logarithmic series and the lognormal method and concluded that both models were useful descriptive tools in certain cases.

The logarithmic series is a special case of the negative binomial where k is assumed to be equal to zero. The negative binomial is applicable to populations which are contagious (i.e. show clumped dispersion patterns) and is described by two parameters, the mean and the exponent k, which is a measure of the amount of clumping and is often referred to as the dispersion parameter (Southwood, 1966). The value of k is not a constant for a population but often increases with the mean. (This may explain why Hairston and Byers found that the index of diversity given by the logarithmic series also varies with sample size - see "Species Diversity" later in Section l.4.4.).

These three models: the logarithmic series, the lognormal distribution, and the negative binomial distribution are descriptive tools. Whether or not a series of samples conforms statistically with all or any of them is purely a matter of subjective curve fitting. Their usefulness lies in the fact that if a set of samples conforms to any of the models, that series of examples can be described by mathematical para-

meters, peculiar to that distribution.

Odum (1960) suggest that the reason for species abundance data tending to conform to some sort of logarithmic distribution is because directly or indirectly each rare species requires or is required by a definite number of the more common species for their survival. As long as the rarer species are related to the commoner ones by constant percentage ratios, the relationship of species to individuals is by definition logarithmic. But, it would be surprising if all species abundance data, taken from different communities, conformed to specific distributions, since these distributions are based on randomness, whereas communities exhibit some degree of organisation.

MacArthur (1957) put forward three models for the structure of a community, based on a comparison of the number of individuals to the number of species.

(1) Assumes the community to consist of a fixed number of non-overlapping, i.e. contiguous niches (not Eltonian niches). This has been referred to as "the broken stick model." Here, the total number of individuals of all species is relatively constant, so that the abundance of one will affect the abundance of another.

(2) Assumes niches overlap, i.e. the abundance of the various species is truly independent.

(3) Assumes independent abundance but based on separate, discrete, non contagious niches.

MacArthur provided mathematical formulations for each of the three models, the formulation for the first being

$$\pi_r = \frac{1}{S} \sum_{i=1}^{r} 1/(S - i + 1)$$

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above π_r is the theoretical proportion of individuals

in the rth most abundant species (r = 1, 2.....S)

When tested in the field, only (1) was found to have any validity and then only in a very few cases, usually for groups of animals of similar size and feeding preference. However, in most cases, the species abundance data does not conform to the MacArthur broken stick model, as the rare species are too rare and the common ones too common.

Hairston (1969) points out that conformity to the model is a function of sample size rather than of any ecological properties of the system being sampled. Also, that depending on sample size, deviations from the model can be in both directions.

It is now apparent that the MacArthur broken stick model is not generally applicable in the field, and furthermore, is based on untenable biological assumptions. But, because it is a model based on random allocation of individuals to inches, i.e. on minimal organisation, it still provides a useful standard against which to measure community organisation provided that its multiple limitations are fully realised.

Fig 2   Species   Abundance   Curves.
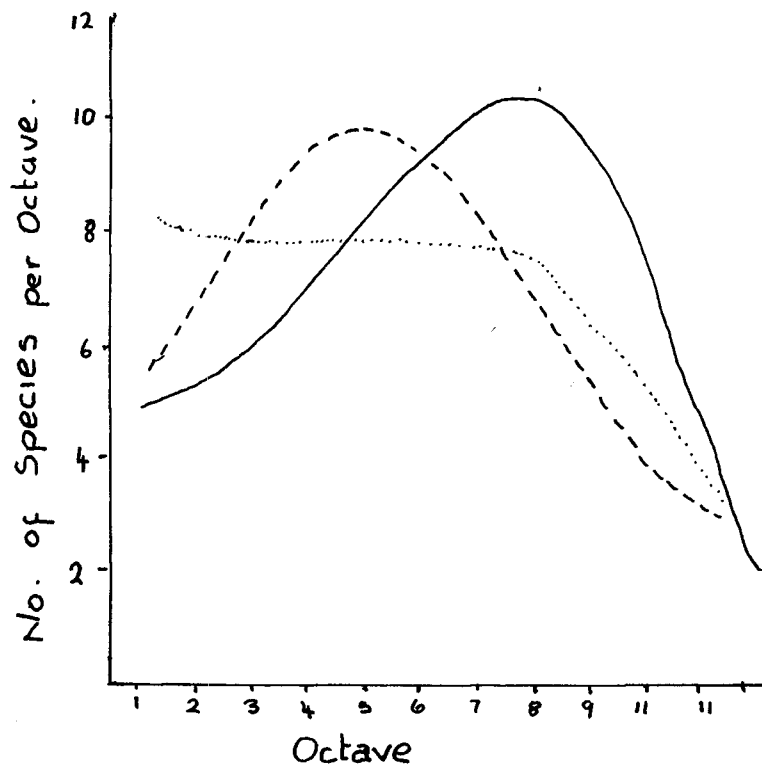
Three   theoretical   species-abundance   curves.
   Solid   line : negative   binomial.
   Dashed   line :   lognormal   distribution.
   Dotted   line :   logarithmic   series.
Curves   fitted   to   single   set   of   data.

Pielou   (1969)

1.4.2. INDICES OF SIMILARITY IN COMMUNITY COMPARISON AND DELIMITATION

Without defining precise boundaries between two or more communities *one way* (or of deciding whether the different areas are indeed different enough to constitute different communities), is to base this judgment on the degree of similarity or dissimilarity of their faunas.

Towards this end, various indices, collectively referred to as coefficients of community, have been proposed (see Southwood, 1966, page 332). All these indices are based on the assumption that the proportion of the number of species (S) to the number of individuals (N), is a characteristic parameter of the fauna of a habitat.

Often this index is based on presence or absence alone e.g. Sørensen's "quotient of similarity," which is expressed mathematically as:-

$$QS = 2j/a + b$$

where a and b are the numbers of species found in

habitats A and B respectively

and j is the number of species found in both

habitats

Another index based on presence or absence alone is Mountford's "index of similarity," for which an approximate formula (Southwood, 1966) is:-

$$I = \frac{2j}{2ab - (a + b)j}$$

(the symbols being the same as for the Sørensen formula)

But, as Greig Smith (1964) states, "The comparison of stands only in terms of the species present, without any reference to the abundance of species in the several stands

is a crude and insensitive mode of characterisation." He
is speaking in this case about stands of vegetation, but
the same is also quite obviously true for samples of animals.

Indices based on presence and absence alone tend to stress
the importance of the rarer species as opposed to the more
abundant or dominant ones by giving equal consideration to all
species. On the other hand, indices which take into account
abundance tend to emphasise the more dominant species. As An
example of an index based on relative abundance of species
within the samples is the "percentage similarity index"

$$\%S \quad = \sum \min (a, b, \dots x)$$

where a, b... x are the occurrence of each species as a

percentage of the total number of individuals in each

sample

The relationship between two or more habitats in terms
of these indices can then be presented in a variety of ways.
An index such as Sørensen's can be used in the construction
of a field's diagram or association table (see Southwood, 1966)
(Greig Smith, 1964). The species are so arranged that the
highest values of the similarity index fall on the diagonal
of a grid pattern. Groupings of species with high indices of
similarity can then be recognised (for further details see
Greig Smith, (1964). This form of presentation has its
greatest use in the comparison of a large number of sites
bearing some sort of spatial relationship with each other,
e.g. in studies of vegetation (Williams and Lambert, 1962).
This form of presentation has little relevance when dealing
with many random samples taken from a few ponds (except for
comparisons between ponds).

Another way of presenting indices of similarity is as a dendrogram, showing graphically the relative similarity between sites. Such a dendrogram can be constructed from the values of the Mountford similarity index. (For method see Southwood, 1966 page 342).

Once any of these indices have been calculated for a number of pairs of sites, the decision as to whether different sites contain different communities can be made on a statistical basis. But, in the final analysis, the decision is subjective as the level of significance of any differences must be chosen by the investigator.

1.4.3. RECURRENT GROUPS

An alternative way of looking at animal assemblages, avoiding the problems of community definition and delimitation, is the "recurrent group" concept of Fager (1957). This is based entirely on faunistic composition and seeks to identify a group of species which form a very frequent part of each others environment. Fager has defined a recurrent group as one that satisfies the following conditions which are to be taken in order.

"(1) The evidence for affinity is significant and the 0.S. level for all pairs of species within the group.

(2) The group includes the greatest possible number of species.

(3) If several groups with the same number of members are possible, those are selected which will give the greatest number of groups without members in common.

(4) If two or more groups with the same number of species and with members in common are possible, the one which occurs as a unit in the greatest number of examples is chosen."

This procedure selects the largest most frequently separable units. Fager goes on to state that the concept of recurrent groups makes it possible to compare groups found in different habitats, or at different times or localities. Due to differences in sampling methods and level of probability, the groups are abstractions. But, if standardised, concordance shows them to be natural assemblages, artificially delimited.

but nonetheless real.

In this study of types of association exhibited by fungus dwelling species of insects and spiders, Pielou and Pielou (1968) state that "Association may be of two kinds: non segregative in which the species, although mutually independent, are apparently crowded into fewer brackets than ~~one~~ are present; and segregative, in which recurrent groups of species are formed owing to differences among the species in their reactions to the different brackets or to one another."

Non segregative association will occur when either all the sampling units are not the same but every species responds in the same way to the differences. Thus the species behave independently and will not form recurrent groups. Segregative association will occur when the various species react differently to differences among the sampling units or, alternatively, when the species affect one another (by repelling each other or attracting each other) in which case recurrent groups will be formed.

1.4.4. SPECIES DIVERSITY

"Species diversity" is a way of expressing, in a single statistic, the joint effect of the number of different species present in a community and their relative abundances. A collection is said to have a high diversity if it has many species and their abundances are fairly similar. Conversely, diversity is low when species are few and their abundances differ widely.

Indices of diversity can be derived from both the logarithmic and the lognormal distributions which are convenient mathematical approximations to the species abundance relations observed in the wild. Hairston and Byers (1954) attempted the analysis of extensive data on soil Arthropods by using both the logarithmic and lognormal methods. They concluded that both indices of diversity were related to sample size, a feature which renders impossible the comparison of different communities. The reason suggested to explain the dependance on sample size was the clumped distribution of rare species, so that with repeated samples there is more likelihood of encountering a new, rare species than adding specimens of species already found (Hairston, 1959).

To be of wide applicability, an index of species diversity should be independent of any underlying mathematical species abundance distribution. Margalef (1957) has devised such an index based on the Shannon-Weiner function derived from information theory, and also from considerations of the logarithmic nature of many species abundance relationships.

$$I = -\sum_{i=1}^{s} - p_i \ln p_i$$

where p_i is the number of individuals in sp 1, 2....s/total number of individuals.

(Before this index can be applied to the comparison of different communities, a similar sampling procedure must have been used throughout).

In general, I will increase with an increase in the number of species, but it is also influenced by the evenness with which the total number of individuals in the sample are distributed among the species present. For a given number of species, I reaches its maximum only if all the species are equally abundant. In practice this never occurs. However, equality of abundance can be used as a criterion with which to compare the natural situation. Another useful criterion for comparative purposes is the Shannon-Weiner function as applied to the MacArthur broken stick model of species abundance, the formula for which is given by:-

$$I = -\sum_{r=1}^{s} \pi_r \log_2 \pi_r$$

where
$$\pi_r = \frac{1}{s} \sum_{i=1}^{r} 1/(s - i + 1)$$

π_r being the theoretical proportion of individuals in the rth most abundant species (r = 1. 2.....s) each theoretical proportion itself being arrived at by summing over r terms (i = 1, 2.... r).

Lloyd and Ghelardi (1964)

It is found in practice that the index usually falls in the range $0.0-4.4$. Where the index lies between 0.0 and 2.0, the environment may be considered as adverse for the community, between 2.0 and 3.0, normal and between 3.0 and 4.4 benign. (D. Jones personal communication). This is experimentally based, benign environments having a much greater species diversity than harsh ones. As once obtained, this index of diversity is comparable even between diverse communities, it has obvious practical application in the prediction of relative stability succession etc. (Margaleg, 1957).

As Lloyd and Ghelardi (1964) point out, it is desirable to separate the two components of diversity, i.e. the number of species and the evenness with which the individuals are divided between the species. (Lloyd and Ghelardi propose and use the term "equitability" instead of evenness, as a completely even distribution is not to be expected.) They note that whereas the number of species depends primarily on the structural diversity of the habitat equitability is more sensitive to the stability of physical conditions. They go on to provide a formula, based on the Shannon-Weiner function for calculating equitability. For use when the number of species is large, they also provide a formula for computing the index of diversity $H(s)$ based on the Shannon-Weiner function.

$$H(s) = C \left\{ \log_{10} N - \frac{1}{N} \sum_{r=1}^{S} n_r \log_{10} n_r \right\}$$

where n are the numbers found in the rth species
N^r is the total number of individuals
S is the total number of species
C is the conversion factor to change the base of logarithms from 10 to 2 i.e. C = 3.321928.

H(s) is then compared, by means of a table provided in the paper, with $M(s^1)$ which is the equivalent number of "equitable distributed" species based on the MacArthur broken stick method. The equitability E is then given by

$$E = s^1/s$$

Southwood (1966) proposes an alternative measure of equitability which, unlike E of Lloyd and Ghelardi, is unrelated to any particular model. This measure is the slope of the graph of abundance, plotted on a logarithmic scale, against rank.

1.4.5. COMMUNITY ORGANISATION

The extent to which "organisation" exists within and between communities, remains a bone of contention among Ecologists, as does the problem of how to measure it.

As the MacArthur "broken stick" model (MacArthur, 1957) implies minimal organisation within a community, one way of measuring the degree of organisation within a community, is by comparing the division of individuals between species in that community with the hypothetical distribution as predicted by the MacArthur model. Hairston (1959) proposed that the comparison should be between the observed variance of the number of individuals per species and the expected variance a la MacArthur. Working on the a-priori assumption of organisation within a community, Hairston proposed that the larger the ratio of observed to expected variance, the greater was the organisation within that community. In contrast, MacArthur originally suggested that departure from the model represented the inclusion of heterogenous data. Hairston then demonstrated the validity of his approach by comparing the effect on the variance ratio of (I) the inclusion of samples from other habitats with (II) the effect of further samples from the same area. The latter caused the ratio to increase linearly, but samples from other habitats, which increased the heterogeneity of the sample, reduced the ratio i.e. reduced the variance towards that expected on the MacArthur model. The practical application of this approach to community organisation, requires that within the same community (and between communities) similar sampling methods are used and similar taxonomic groups considered.

That some sort of organisation now exists within a community is now generally recognised. This is based partly on the relative stability of numbers of individuals per species taken over a relatively long (but not historically long) period of time. Organisation can also be implied from the predictive nature of many of the "coefficients of community," e.g. species diversity indices. This organisation is considered to result from the pattern of the trophic web within the community, including vertical predator - prey relationships and horizontal relationships leading to feeding specialisations. It is also thought to result from the spatial distribution of animals within a community, based ultimately on patterns in the vegetation and physical environment but obscured by the animals' mobility and behavioural patterns.

The fact and degree of organisation existing within a community may in itself have predictive power. Elton (1966) implies organisation is implicated in increasing stability. However, MacArthur (1955) in postulating complexity as responsible for stability, seems to ignore the fact that, in this context, mere complexity without organisation is meaningless.

METHODS.

2.1 SAMPLING PROCEDURE

As pointed out by McEwan(1967), there are three broad categories of sampling methods available for use in ponds:-

(a) quadrat methods

(b) a variety of grabs and samplers

(c) net methods

The water was considered too deep, many of the animals too mobile and the vegetation too thick for quadrat sampling to be used in this exercise. Grabs and samplers undoubtedly give the most accurate results (if appropriate instruments are used) but they are too destructive of the habitat to be used in a small area. Hence, for this study net sampling was considered to be most appropriate. Net methods can be used for comparisons between pond faunas provided that the general conditions in the pond are similar especially with regard to the amount and type of vegetation present which constitutes an impedance to the net. Comparable samples should be obtainable from repeated sweeps if the net is drawn through the water at a similar velocity for either similar distances or similar time periods. In view of the difficulty of marking and a precise area in the water, it was decided to move the net forwards for five seconds just under the surface of the water and then back through the same area for five seconds but at a lower level, just above the surface of the mud at the bottom. This procedure was repeated for each sample with a towing speed as constant as possible.

The Brasside ponds were sampled in rotation, usually two samples being taken each day. The position of each sample was determined as follows. The surface of each pond was

arbitarily divided into ten approximately equal areas. The
position of the first sample was then chosen randomly, and
a second sample was taken in that area furthest removed from
the first, to minimise the effects of disturbance.

The decision to sample at Page Bank, for comparative
purposes, was taken only in July. Therefore, as time was
short, only ten samples were obtained. The positions of
these samples were once again chosen randomly.

Once a sample had been taken, the animals in the net were
raised into large glass jars, together with any plant frag-
ments. The material was then brought back to the laboratory
for sorting, identification and counting.

Although it was expected that this procedure would give
results which could be compared validly, it was not expected
that the samples would give a complete picture of the
faunistic composition of the ponds. For example, animals
which were small enough or fast enough could escape capture,
as also could those which burrow into the bottom mud or cling
tightly to fixed vegetation. Furthermore, animals in the
size range of Daphnia, Cyclops etc. were not counted even if
found in the sample as there was good reason to believe that
they had not been sampled quantitatively.

2.2 PHYSICAL FACTOR DETERMINATION

The p.H of each pond was measured in the field by means of a Direct Reading p.H meter. Water samples were collected from ponds A-D in glass jars and brought back to the laboratory where the concentrations of Calcium and Magnesium were determined. Calcium concentrations were determined by titration against E.D.T.A. using Erichrome blue black as the indicator. Magnesium was determined on the Eel Atomic Absorbor Spectrophotometer using a magnesium oxide standard to give the calibration curve.

RESULTS.

3.1 FAUNAL LISTS FOR THE TWO SITES

Table 1

LIST OF FAUNA — BRASSIDE PONDS

Phylum Arthropoda
Class Arachnida
Order Acarina   Hydrachnellae

Class Crustacea
Order Amphipoda   Gammarus
Order Isopoda   Asellus

Class Insecta
Order Coleoptera   Dytiscidae   Dytiscus
                                                   Agabus
                                                   Platambus

                               Gyrinidae
                               Haliplidae
                               Hydrophilidae
Order Diptera   Chaoborinae
                               Chironomidae
                               Dixinae
Order Ephemeroptera   Baetidae
                               Caenidae
Order Hemiptera   Corixidae
                               Gerris
                               Illyocoris
                               Notonecta   immature
                               Notonecta   mature
Order Lepidoptera
Order Odonata   Aeschnidae
                               Coenogariidae
                               Lestidae
Order Trichoptera   Limnephilidae
                               Philopotamidae
                               Triaenodes

Phylum Mollusca
Class Gastropoda   Limnaedae   Limnaea stagnatis
                               Planorbidae

Class Lamellibranchiata Sphaeridae

For the sake of uniformity, generally, Generic names are used.
(It was not possible to identify all individuals down to the species level.)
Unless stated otherwise, each "Genera" contains only one species.

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Table 2

LIST OF FAUNA - PAGE BANK

Phylum Arthropoda
<u>Class Arachnida</u>
Order Acarina   Hydrachnellae

<u>Class Insecta</u>
Order Coleoptera   Dytiscidae   Agabus
                                                         Platambus

                                 Haliplidae
                                 Hydrophilidae
Order Diptera   Chironomidae
Order Ephemeroptera   Baetidae
Order Hemiptera   Corixidae
                                 Gerris
                                 Illyocoris
                                 Notorecta   immature
                                 Notorecta   mature
Order Odonata   Coenogariidae
Order Trichoptera   Philopotamidae

<u>Phylum Mollusca</u>
<u>Class Gastropoda</u>   Hydrobidae
                                 Limnaeidae   Limnaea pereger

<u>Class Lamellibranchiata</u> Sphaeridae

TABLE 3

INDIVIDUALS PER SAMPLE   POND A

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL
Hydrachnellae	8	2	1	1	2		2	2	4	3	4	3	4	3	2	6	3	4	3	4	59
Asellus	9	10	7	15	12	12	7	7	43	22	16	18	21	23	14	22	23	16	19	21	337
Dytiscus									1			1						1		1	4
Agabus	4	3	4	2	2	1	1	1	7	3	4	1	4	3	2	1	3	1	4	4	74
Platambus				1	4	3			1	5		1	1	1	1	1	5	3	7	1	9
Hydrophilidae	16	9		8	2	2	1	9	7	8	6	8	2	6	6	11	5	1	7	4	152
Chaeborinae		2	17		6	19	17	4	7	3		3	9	1		1		3	1	1	13
Coleopt. larvae		1	1	1					1	5		1	4		2		5	3	2		10
Chironomidae	4	46	28	15	21	38	11	17	33	56	51	18	32	35	20	25	24	14	28	19	52
Dixinae	83																				594
Beetidae																					8
Corixidae	2	2	1	1	2	1	2	1	2	4	1	2	6	4	4	3	5	2	5	3	46
Illocoris	16	8	21	9	17	8	9	10	6	8	14	8	38	13	4	3	8	6	9	7	1107
Notonecta (1)	32	33	61	25	76	74	12	29	120	67	44	62	38	101	44	62	58	30	67	72	111
Coenagridae			1	2	10				5	6	7	9	1	1	1			1	2	1	11
Lestidae	15	15				7	8	10			1	2	2		1	1		2	5		188
Limnephilidae	1			1	2	1	1	1	1	1	1	2	2	1	1	1	1		2	1	8
Trichnodes							2													1	46
Nymphula								1	1				2	1	1	1	1		2		16
Gerris	1	1		2		1						2	2	1	1			1	1	1	8
Philopotamidae						1				1		2	1		1	1		1	1	1	1
Limnaeidae		2		1		1			1										1		7
Sphaeridae																					12

Total number of species 23
Total number of individuals 2995.

TABLE 4

INDIVIDUALS PER SAMPLE   POND B

	SAMPLE																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL
Hydrachnellae	6	4	3	7	4	5	4	6	3	4	7	4	5	9	15	3	10	3	7	8	117
Asellus	186	31	21	16	18	47	33	12	6	3	8	12	19	9	7	9	16	12	14	8	487
Dytiscus	11	17	39	18	6	12	16	14	18	6	20	21	27	19	15	14	22	18	12	11	336
Agabus				1		4	6	1	3	2	4	6	3	7	1	5	1	4	3	6	54
Haliplidae		3		2								1						1			2
Hydrophilidae	8	15	7	19	16	7	10	9	23	19	18	11	9	7	14	19	27	9	17	16	293
Coleopt. larvae			1	1					1		1							1	1	1	6
Chaoborinae	4	5	6	18	8	4	6	1	15	14	19	6	8	10	8	12	7	16	9	15	168
Chironomidae				1					1	1	1	1					1	1	1		5
Dixinae	16	14	4	10	6	12	14	8	23	19	18	4	7	2	14	5	1	1	1	6	141
Baetidae	3				1			1	1	1	1			6	2	2	4	8	17	6	17
Corixidae									1					1							4
Gerris	2				1	1			1			2	5	1	2	3	3		1	1	16
Illyocoris			1			1	1		1	1				1							4
Notonecta (1)	1	2	11		2	3	2	1	3	2		1	2		3		2		3	1	34
Notonecta (a)				3	1	3	2		1	1		2	1		6	1	4	3	4	2	32
Nymphula	1		1														1				8
Coenagriidae	96	47	53	22	38	41	68	71	14	22	36	28	63	43	38	32	58	61	54	23	906
Lestidae	1	2	6	3		1	2		1			1									22
Limnophilidae	9		3	1		1	1	1	2	1			1	1				1			111
Triaenodes	2		2			1											2	3			9
Planorbidae	20	14	5	3	16	19	12	9	2	1		4	6	3	7	2		1		4	130
Sphaeridae		1				3	1				1			1	1					1	15

Total number of species 23.
Total number of individuals 2877.

TABLE 5
INDIVIDUALS PER SAMPLE POND C.

								SAMPLE													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL
Hydrachnellae	2	8	4	3	7	2	2	4	2	4	6	4	2	3	5	4	2	1	2	1	64
Asellus	3	2	12	6	5	4	2	7	4	2	10	4	6	3	7	8	4	7	7	7	115
Dytiscus		1	1	1		1							1	1		1	1	1		1	10
Agabus	10		4	6	3	7	4	6	4	11	6	2	10	10	8	4	4	4	10	4	122
Coleopt. larvae												1									2
Gammarus	3	3	14	2	9	4	6	6	7	11	5	9	4	2	9	7	14	11	7		155
Chaoborinae	11	6	1	7	3	4	4	3	5	4	5		6	4	3	6	7	3	7		60
Chironomidae	48	71	48	32	28	19	35	14	10	16	6	12	18	18	12	16	15	13	12	7	448
Baetidae	2	1				1															3
Coenidae		1		1	1	1									1	1	1			1	8
Corixidae																1	2				6
Gerris	7		5	4		9			7	6	4	9	5	3	6	7	8	4	11	9	7
Illyocoris		2	1	1	1						1			1	1	1	1	1	1	1	119
Notonecta (1)		1			1																3
Notonecta (m)	22	12	57	71	68	39	47	38	57	107	77	40	55	57	72	49	56	19	17	47	1087
Coenagriidae	33	61	13	12	12	9	7	21	7	9	1	2	3	1	5	2	2	3	2	3	208
Lestidae	4	3	1	2	1			2	1	9	1	1	1	1	1	1	2	19			21
Nymphula																				1	5
Lymnephilidae	11	14			6	9	4	3	3	1	2	1	2	1	2	1	4	1	3	2	59
Triaenodes	1		1		1	1	1			1	1	1	1	1	1	1	1	1	1	1	19
Limnaeidae	19	27	146	176	89	57	61	54	8	29	24	29	21	15	22	25	31	19	25	35	892
Planorbidae		2	4	3	8	2	1	7		12	14	1	2	2	4	5	6	1	1	4	79

Total number of "species" 23
Total number of individuals 3498.

TABLE 6
INDIVIDUALS PER SAMPLE POND D.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL
Hydrachnellae	4	6	3	2	7	4	8	6	2	5	5	5	8	7	4	5	4	6	9	2	102
Asellus	9	18	14	17	28	19	23	27	11	6	5	30	32	19	14	31	28	24	10	22	387
Dytiscus		2				1		1			1					1		1			8
Agabus	4	9	11	6	7	9	9	6	12	6	5	6	6	7	11	9	7	8	9	9	156
Platambus				1	3	3		7				1									7
Gyrinidae		5			2	2										1	1				13
Haliplidae	4						9	8	12	12	5		8	7	4		4				83
Hydrophilidae				6		12	9		9	3	2		4	4	5	3		2	3	9	
Coleopt. larvae				1	2	4	1	1		1								1			5
Chaoborinae		3			4	6	2														15
Chironomidae	6	4	6	5	6	4	2		9	7	4		4	3	5	5	4	7	3	6	104
Dixinae													1	1							2
Beetidae	24	56	38	14	10	17	21	14	11	1	2	1	2	5	3	11	4	8	9	11	262
Corixidae		1	1		1							1									4
Gerris			2	1	1		3	1	1				1					1			10
Ilyocoris				1	1		1	1	1	1	2		1	1		1	1	1	1		14
Notonecta (l)	2			8															2		10
Notonecta (m)					1		1	7						1							6
Nymphula	1	1	2	4	2	2			1				1							2	16
Aeschnidae						1															3
Coenagridae	72	87	100	128	72	89	61	59	49	51	69	57	46	52	63	71	48	67	54	63	1358
Lestidae			3					1													4
Limnephilidae	4	2	2	3	2	4	1	9	6	2	2	2	1	2	4	3	4	1	5	3	9
Trichenodes	4	2		9	8	11	6	9	6	7	8	6	10	8	2	8	7	4	7	3	44
Limnaeidae	10	7	7	9	8	11	6	9	6	7	8	6	10	8	2	8	7	4	6	9	142
Planorbidae	31	26	14	11	6	28	17	19	3	7	11	7	5	7	8	14	19	10	6	9	258
Sphaeridae	20	12	32	7	5	9	6	8	13	2	4	7	6	5	6	6	7	12	14	9	190

Total number of "species" 27
Total number of individuals 3228.

TABLE 7

INDIVIDUALS PER SAMPLE POND P

	1	2	3	4	5	6	7	8	9	10	Total
Hydrachnellae	8	8	10	11	17	7	8	7	9	13	98
Agabus		2									7
Platambus	3	5	5	1	2	2	2	1	2	3	32
Haliplidae			5	6	2	2	3		2	3	7
Hydrophilidae		1		2	2	3	3		1		18
Chironomidae	2				2		4		1		4
Baetidae	9	8	4	6	4	3	13	7	7	9	70
Corixidae	1		2	5			1		1	1	11
Gerris		1						4	2	1	4
Illyocoris	1	1	1	1			1		1	1	14
Notonecta (i.)	1		2	1		1	1		1	1	7
Notonecta (m)	1		1			1	2		2		8
Coenagriidae	5	14	11	9	13	13	5	8	11	12	101
Philopotamidae		2						1	3		3
Hydrobidae	31	47	28	69	82	57	62	48	76	59	559
Limnaeidae	9	9	6	8	2	2	2	2	3	8	44
Sphaeridae		1	2		1		2		2	1	7

Total number of "species" 17

Total number of individuals 991

3.2 TREATMENT OF RESULTS

3.2.1 SPECIES ABUNDANCE RELATIONS

The species abundance data for each pond was plotted as a simple histogram of number of individuals per species against number of species containing this number of individuals e.g. Figs.2-5. To simplify the presentation, the numbers of individuals per species were grouped into class intervals of five. (Note also that the higher ranges of the horizontal axes are discontinuous). A similar graph was drawn for the combined data of ponds A-D, Fig.6.

In order to show the relationship of the data to the MacArthur "broken stick" model, the species were ranked according to the number of individuals of each and a graph drawn of the number of individuals (as a proportion of the total) against the log of the species rank (see Table 1 and Fig.7). The distribution as required by the MacArthur "broken stick" model was then added to Fig.7 for comparative purposes.

Figs 3+4 Graphs of No. of Individuals per Species.
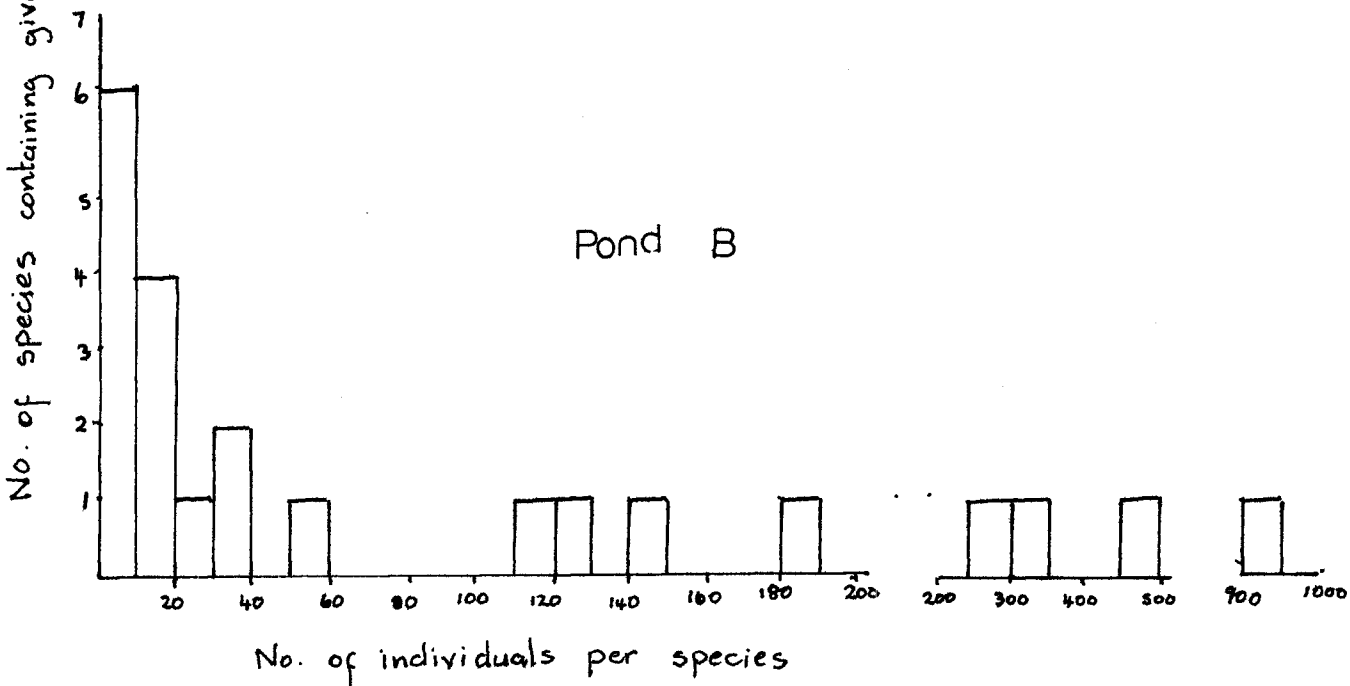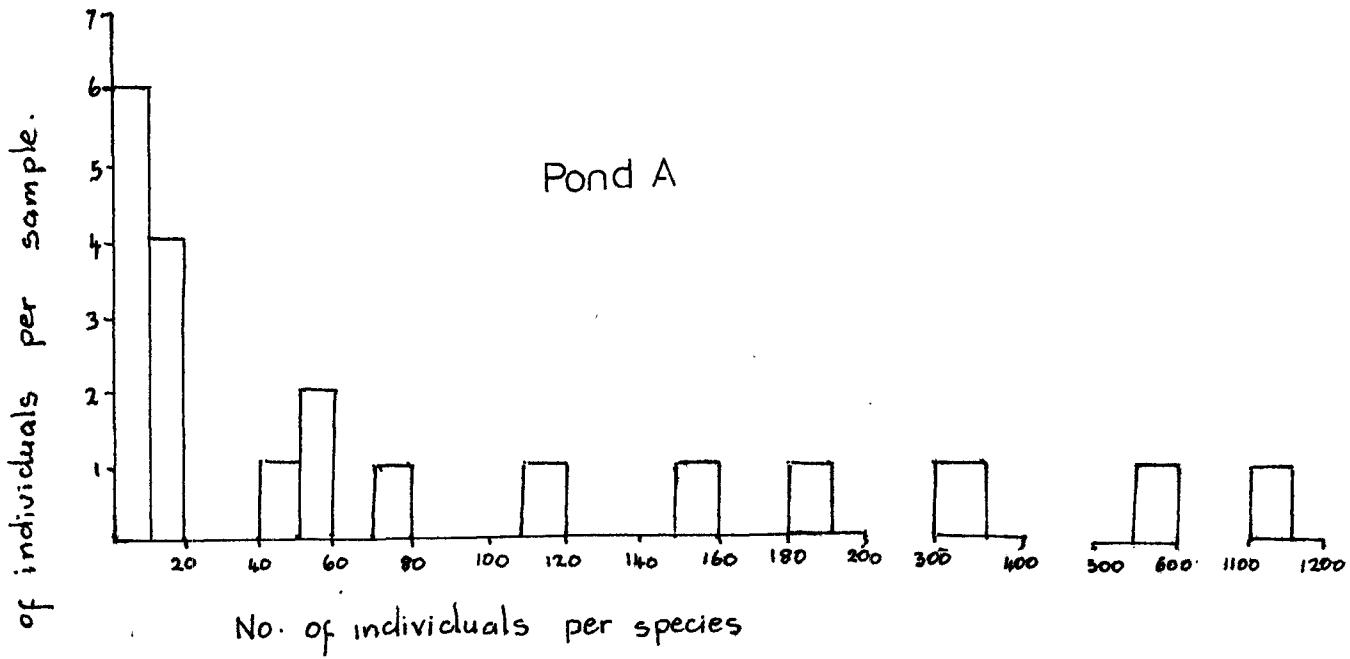
Pond A

No. of individuals per species

Pond B

No. of individuals per species

Fig 5 Graphs of No. of Individuals per Species.

Pond C

No of individuals per species.

Pond D
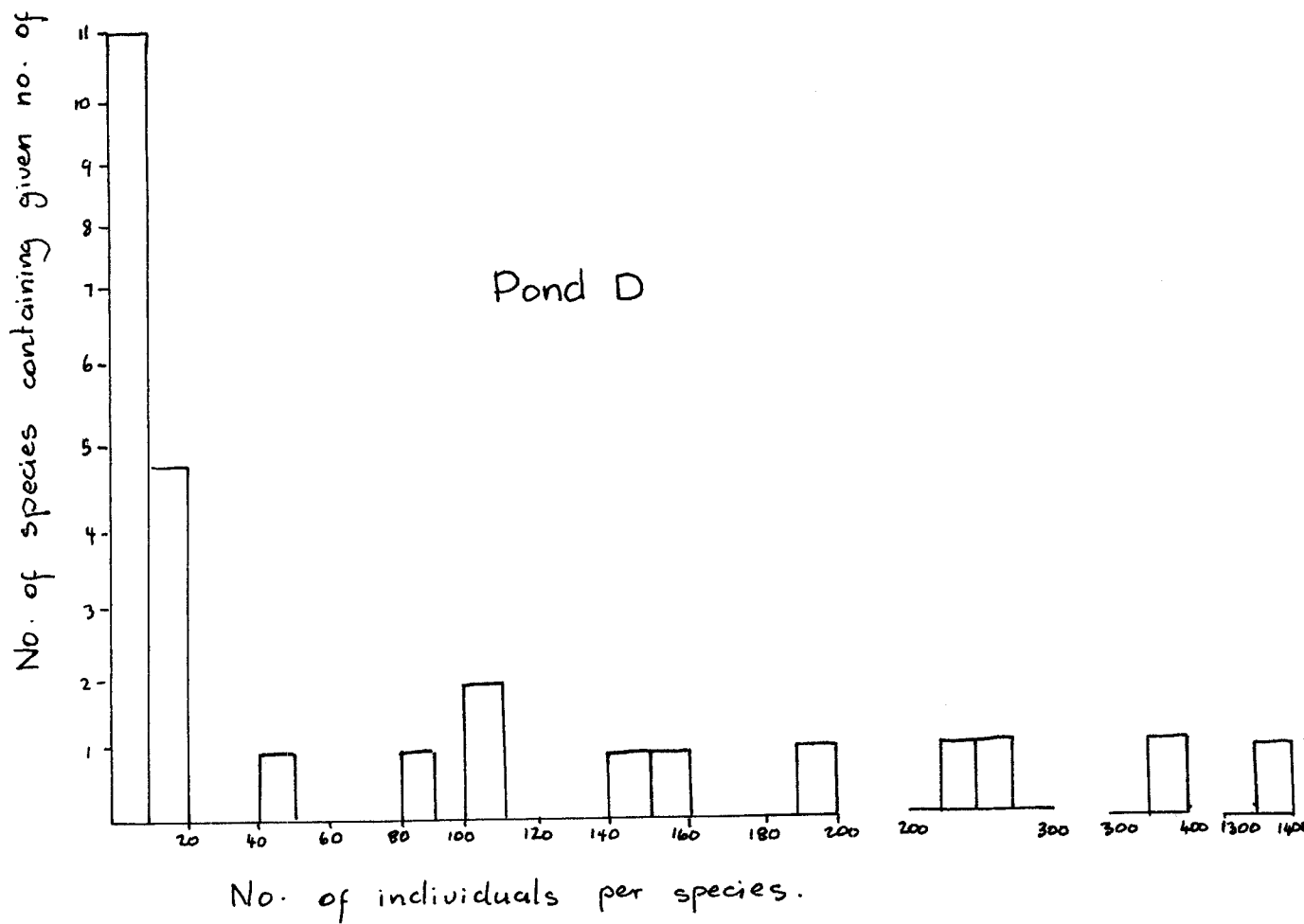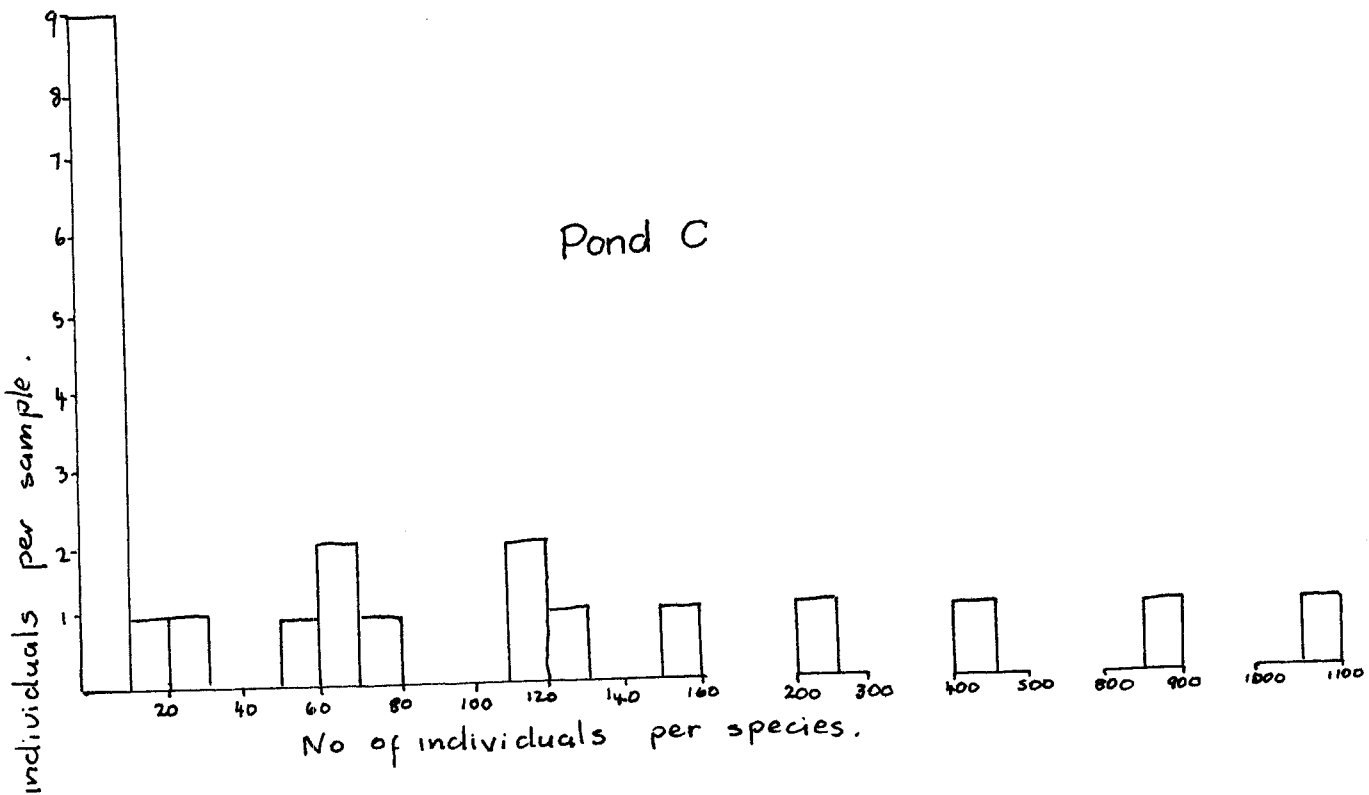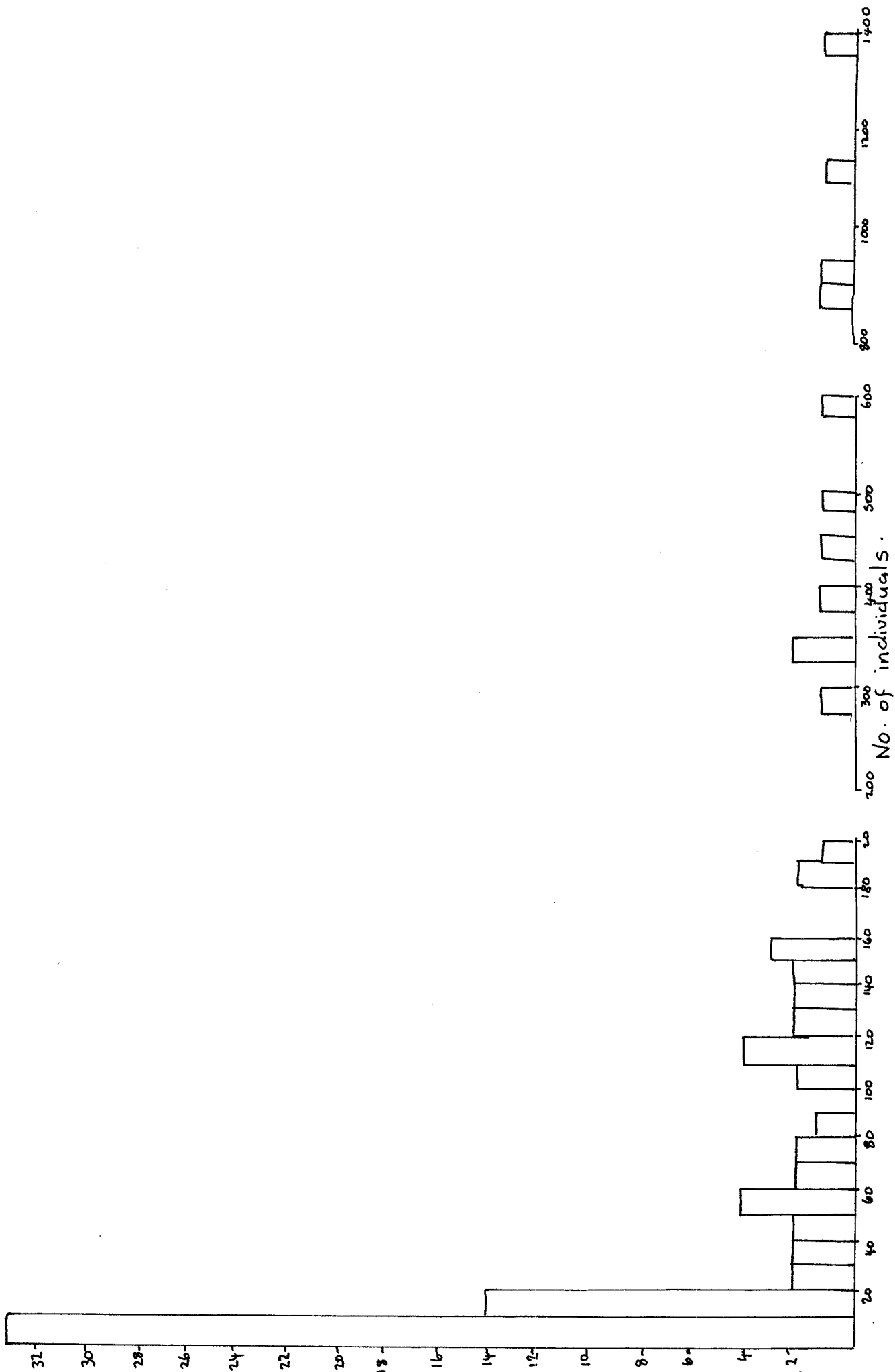
No. of individuals per species.

Fig 6 No. of Individuals per Species. Ponds A - D

3.2.2. INDICES OF SIMILARITY IN COMMUNITY COMPARISON AND DELIMITATION

Three indices of similarity were used in an attempt to determine the relative similarity of the ponds in terms of their species composition. Sørensen's and Mountford's indices are based on presence or absence alone, thus placing relatively greater emphasis on rare species. The third, an index of percentage similarity, takes into account also the numbers of each species, and thus tending to emphasise the more dominant species. Formulae for the calculation of these indices are to be found in the introduction (1.4.2). Each index was determined for every combination of the five ponds (compared two at a time). The results are given in Table 8.

The relationship between the various ponds, based on indices of similarity, can be represented diagrammatically in various ways. To illustrate the range of presentations which are possible, the three indices have been represented in different ways. Thus the values for Sørensen's index are presented in a trellis diagram (Fig.8), the percentage similarity index graphically (Fig.9) and Mountford's index of similarity by means of a dendrogram (Fig.10). (The method for constructing a dendrogram is given in the appendix). All three methods show quite clearly the relatively close relationship of ponds A-D compared with the distant relationship of pond P with any of A-D.

Table 8   Indices   of   Similarity.

Pond Combination	Sorensen's Index.	Mountford's Index	Percentage Similarity.
A + B	0.91	0.46	69.5
A + C	0.82	0.21	68.3
A + D	0.90	0.37	68.2
B + C	0.87	0.29	61.4
B + D	0.90	0.37	70.5
C + D	0.82	0.23	64.0
P + A	0.55	0.06	25.1
P + B	0.55	0.06	27.0
P + C	0.50	0.05	25.4
P + D	0.55	0.06	27.1

Table 9   Indices   of   Similarity   Ranked.

Index.	Rank.									
	1	2	3	4	5	6	7	8	9	10
Sørensen's.	A + B	A + D	B + D	B + C	C + D	A + C	D + P	B + P	A + P	C + P
Mountfords.	A + B	A + D	B + D	B + C	C + D	A + C	D + P	B + P	A + P	C + P
Percentage Similarity.	B + D	A + B	A + C	A + D	C + D	B + C	D + P	B + P	C + P	A + P

Sorensens Index of Similarity in Trellis-Diagram Form

Fig. 8.

	A	B	D	C	P
A					
B	0.91				
D	0.90	0.90			
C	0.82	0.87	0.82		
P	0.55	0.55	0.55	0.50	

Crosshatching = Similarity greater than 0.80

Fig 9   Graphic Representation of the Percentage Similarity Index.
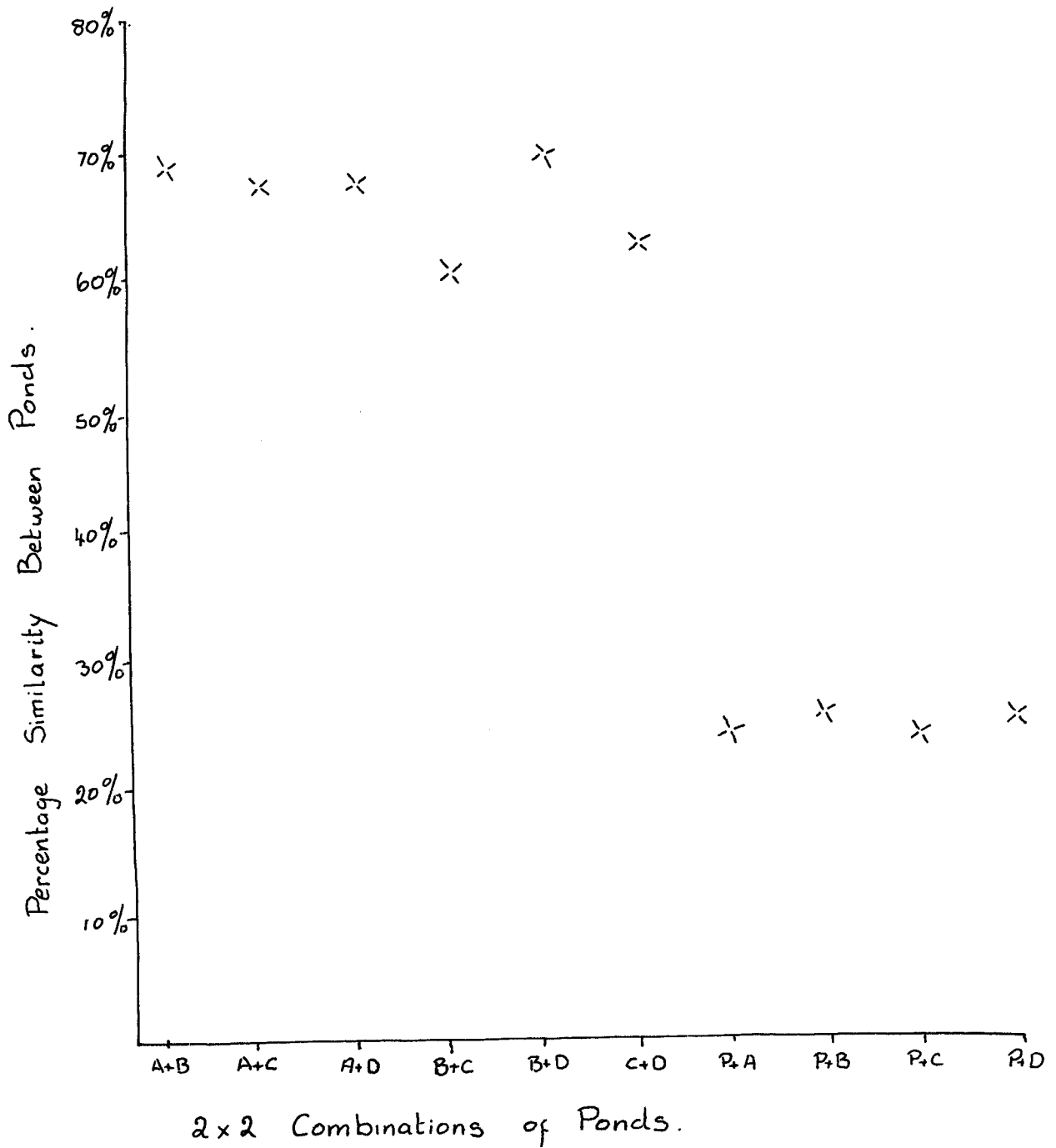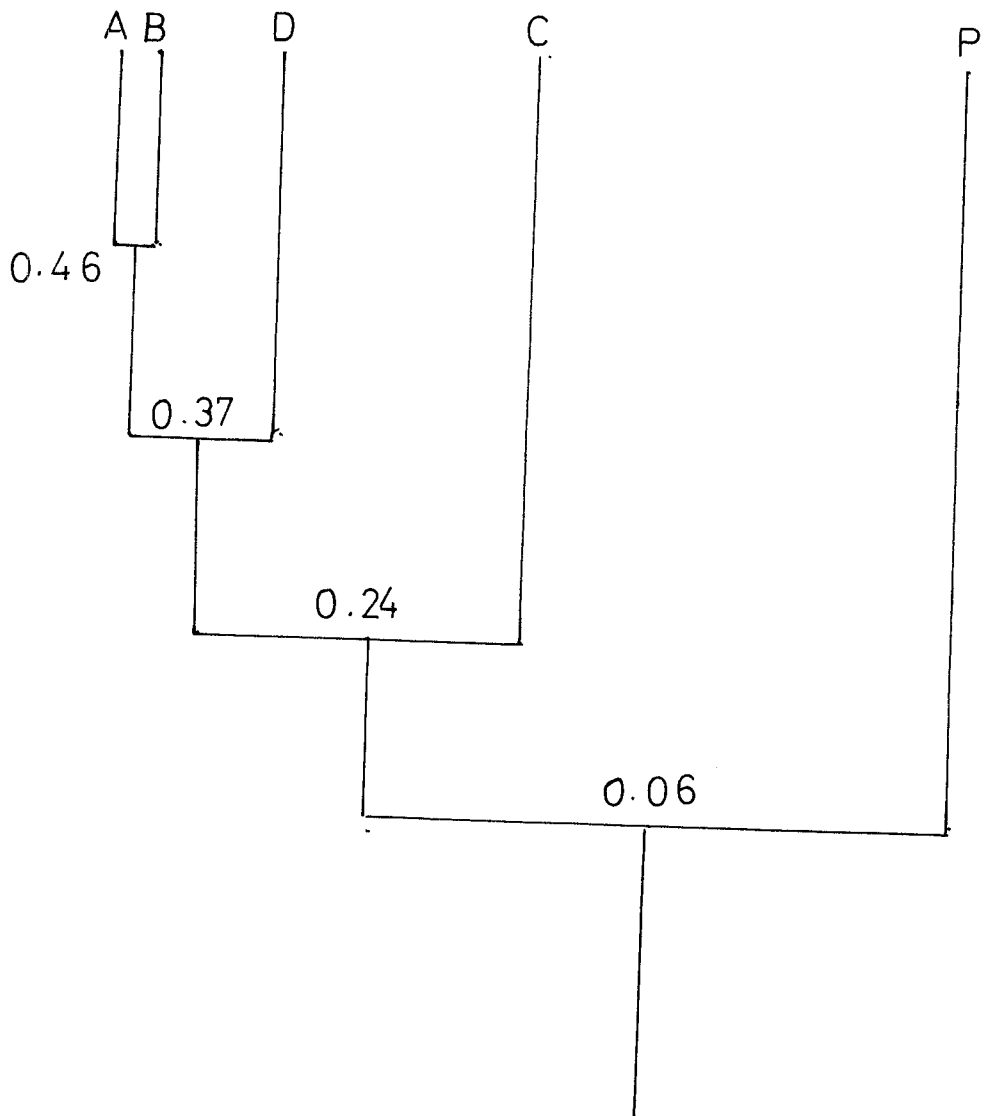
2 x 2 Combinations of Ponds.

Fig. 10 Dendrogram Based on Mountfords Index of Similarity Between The Five Ponds.

3.2.3 RECURRENT GROUPS

In their paper of 1967, Pielou and Pielou propose a test
as to whether species are associated in a segregative manner
(with the formation of recurrent groups) or in a non-
segregative manner. The test for segregative association is
based on the null hypothesis that all species have been
assigned independently and at random to the sampling units.
The number of combinations of species occurring in the
different samples are counted, and these numbers are compared
with the number of combinations expected if the species were
assigned to each sample at random. Definition of a combination:
For each sample, arrange names of all species in one order,
at each address in that list write 1 or 0 for whether the
species is present or absent in that sample. Reading in one
direction, the list of 1s and 0s can be considered as a number.
Do this for each sample. Then, one combination of species is
the same as another if the corresponding numbers are exactly
equal. If not, it is a different combination. This is
precisely how the numbers of combinations are counted in both
the programme for counting the number of observed combinations,
and also in the Monte Carlo programme for generating expected
combinations. If recurrent groups are present, the observed
number of combinations will fall short of expectation.

To determine the expected number of combinations by direct
mathematical argument is not feasible. It is therefore
necessary to obtain an estimate of the expected number of
combinations by Monte Carlo methods. A computer programme
was therefore devised to do this. For each pond, the expected
results are each based on ten sets of one hundred runs, each

set having a different base for generating the pseudo-random numbers. The computer programme will be found in the appendix. The results are given in Table 11.

When the species data for each pond were analysed by the procedure proposed by Fager (1957) for his "Determination and Analysis of Recurrent Groups," certain groupings of species resulted, and these are set out in Table 10.

TABLE 10

RECURRENT GROUPS

MAIN RECURRENT GROUP

	POND				
	A	B	C	D	P
Hydrachnellae	Hydrachnellae	Hydrachnellae	Hydrachnellae	Hydrachnellae	Hydrachnellae
Asellus	Asellus	Asellus	Asellus	Asellus	Asellus
Agabus	Agabus	Agabus	Agabus	Agabus	Agabus
Chaoborinae	Chaoborinae	Chaoborinae	Chaoborinae		
Chironomidae	Chironomidae	Chironomidae	Chironomidae	Chironomidae	
Baetidae	Baetidae	Baetidae	Baetidae	Baetidae	Baetidae
Notonecta (i)	Notonecta (i)	Notonecta (i)	Notonecta (i)	Notonecta (i)	Notonecta (i)
Nymphula	Nymphula				
Coenogariidae	Coenogariidae	Coenogariidae	Coenogariidae	Coenogariidae	Coenogariidae
Lestidae	Lestidae		Lestidae		
Triaenocles	Triaenocles			Triaenocles	
Hydrophilidae		Hydrophilidae		Hydrophilidae	
Notonecta (m)		Notonecta (m)			Notonecta (m)
Planorbidae		Planorbidae	Planorbidae	Planorbidae	
Sphaeridae		Sphaeridae	Sphaeridae	Sphaeridae	
L. Stagnalis				L. Stagnalis	
L. pereger					L. pereger
Hydrobia					Hydrobia

49.

TABLE 10 (Cont.)

RECURRENT GROUPS

	A	B	C	D	P
ASSOCIATED SPECIES	Corixidae	Corixidae	L. Stagnalis	Notonecta (m)	Corixid
	Coleopt. larvae	Coleopt. larvae	Gerris	Chaoborinae	Sphaeridae
	Hydrophilidae	Illyocoris	Triconocles	Haliplidae	Chironomidae
	Limnephilidae	Limnephilidae	Nymphula	Gyrinidae	Haliplidae
	Dixinae	Triaenocles		Platambus	
	Nymphula	Lestidae		Illyocoris	
		Nymphula		Aeschnidae	
				Gerris	
				Dytiscus	
OTHERS	Illyocoris		Corixidae		
	Gerris		Dytiscus		
	Sphaerium				

POND

Species not mentioned were not abundant enough to be included in analysis.

Table 11 Monte - Carlo Results.

Pond	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A																			4	96
B																		1	4	95
C																	1	7	38	54
D																			6	94

SPECIES DIVERSITY

A computer programme was devised to determine the value of H(s) in the Shannon-Weiner function for each pond. H(s) is a valid empirical measure of species diversity.

The "equitability" of Lloyd and Ghelardi (1964) for the species abundance distribution in each pond is determined by comparing the observed value for H(s) with the M(s'), the equivalent number of "equitably distributed" species, based on the Mac Arthur "brocken stick" model. This comparison is made by using a table provided in the paper by Lloyd and Ghelardi (1964). The equitability E is then given by

$$E = \frac{s'}{s}$$

Table 12 Indices of Species Diversity.

Pond	H(s) Maximum	H(s) Observed	Equitability ε
A	4.52	2.97	0.47
B	4.52	3.12	0.52
C	4.52	2.99	0.47
D	4.75	3.03	0.44
P	4.09	2.38	0.41

3.2.5 COMMUNITY ORGANISATION

In 1959, Hairston proposed a method for measuring community organisation by comparison with the MacArthur "broken stick" model which postulates random "organisation." Hairston's method is based on the ratio of the observed variance of samples (in terms of numbers of individuals per species) to the variance expected on the basis of the MacArthur model. He also states that if the observed variance is divided by the square of the mean number of individuals per species in the sample, virtually the same ratio results. (The second method of calculation is easier than the first).

Variances were calculated for each of the twenty samples from each pond by means of a computer programme (see appendix). The variances of the pooled data were calculated by hand. Since the sampling was at random, the decision as to which samples to use was made arbitarily; where five samples were required, samples 4, 8, 12, 16, 20 were used, when ten were required, 2, 6, 10, 14, 18 were also used. The decision to take pond A as the standard was made by a random method as was the decision also to use pond C.

Fig.11 shows the change in the variance/mean^2 ratio with increase in number of samples pooled. Fig.12 shows a comparison of the ratio between ponds A, C and P and the ratios obtained from pooling data from ponds A and C and A and P. Fig.13 is a copy of the figure that appears in Hairston's paper (1959) for comparative purposes.

Table 12, "Observed Variance / Square of Mean", for single Samples.

Pond	Samples	Obs. variance mean²	Average.
A	4 8 12 16 20	1.3 1.0 2.2 2.6 3.5	2.1
C	4 8 12 16 20	4.3 2.2 1.8 2.1 2.5	2.6
P	4 8 12 16 20	2.4 2.9 2.9 2.1 3.3	2.7

Table 14   Observed Variance Square of Mean for Combined
Samples.

Pond (s)	No. of samples combined.	$\dfrac{Obs.\ Variance}{Mean^2.}$
A_1	5	3.3
A_2	5	3.3
B	5	2.3
C	5	3.7
D	5	4.8
P	5	5.1
$A_1 + A_2$	10	3.4
A + C	10	3.4
A + P	10	3.2
$A_{Total.}$	20	3.6

Fig 11 Variance/Mean² Ratio for Pond A.

Variance/Mean²

No. of samples pooled.
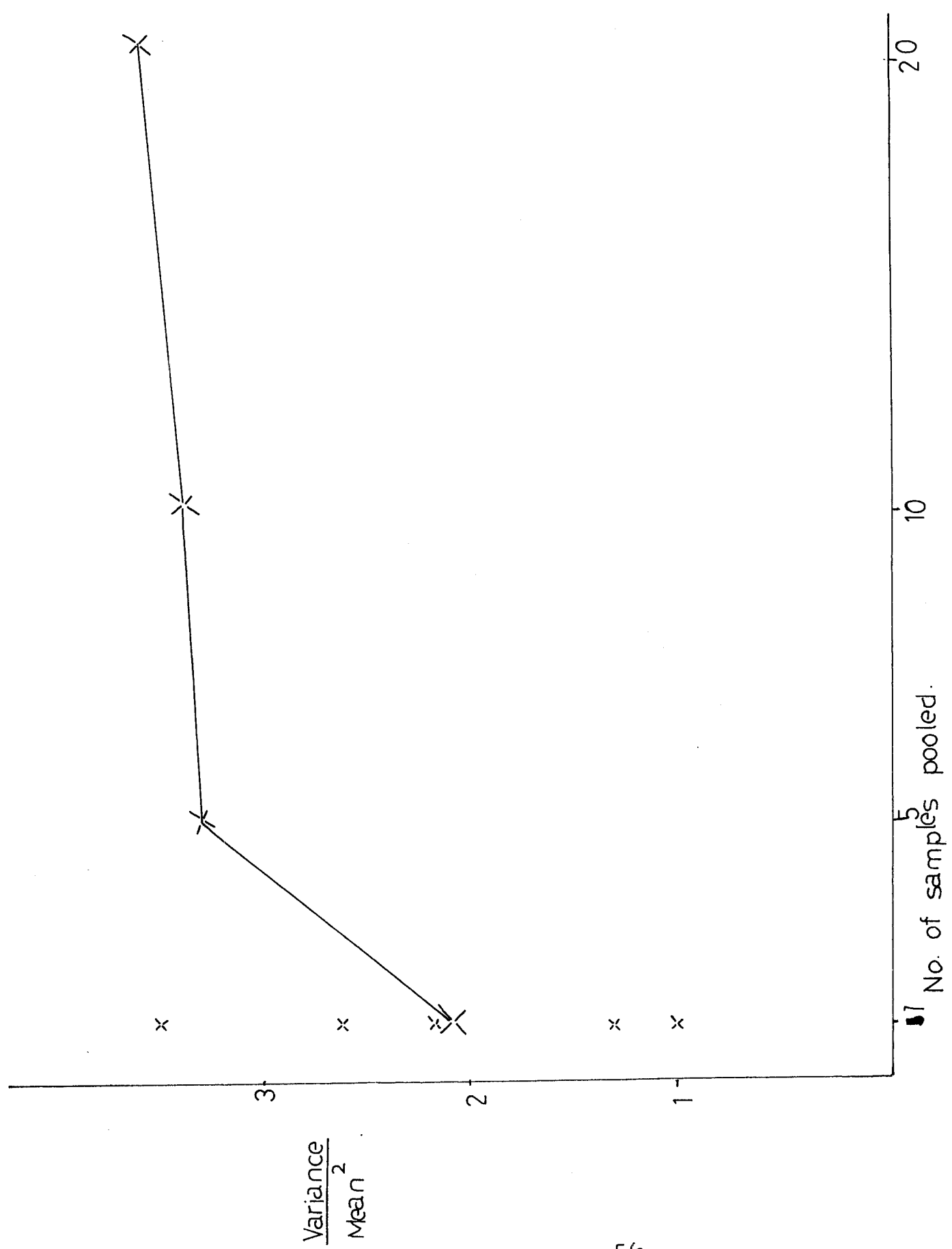
Fig 12 Variance / Mean² Ratio for Pooled Samples.

Variance / Mean²

No of samples pooled.

57
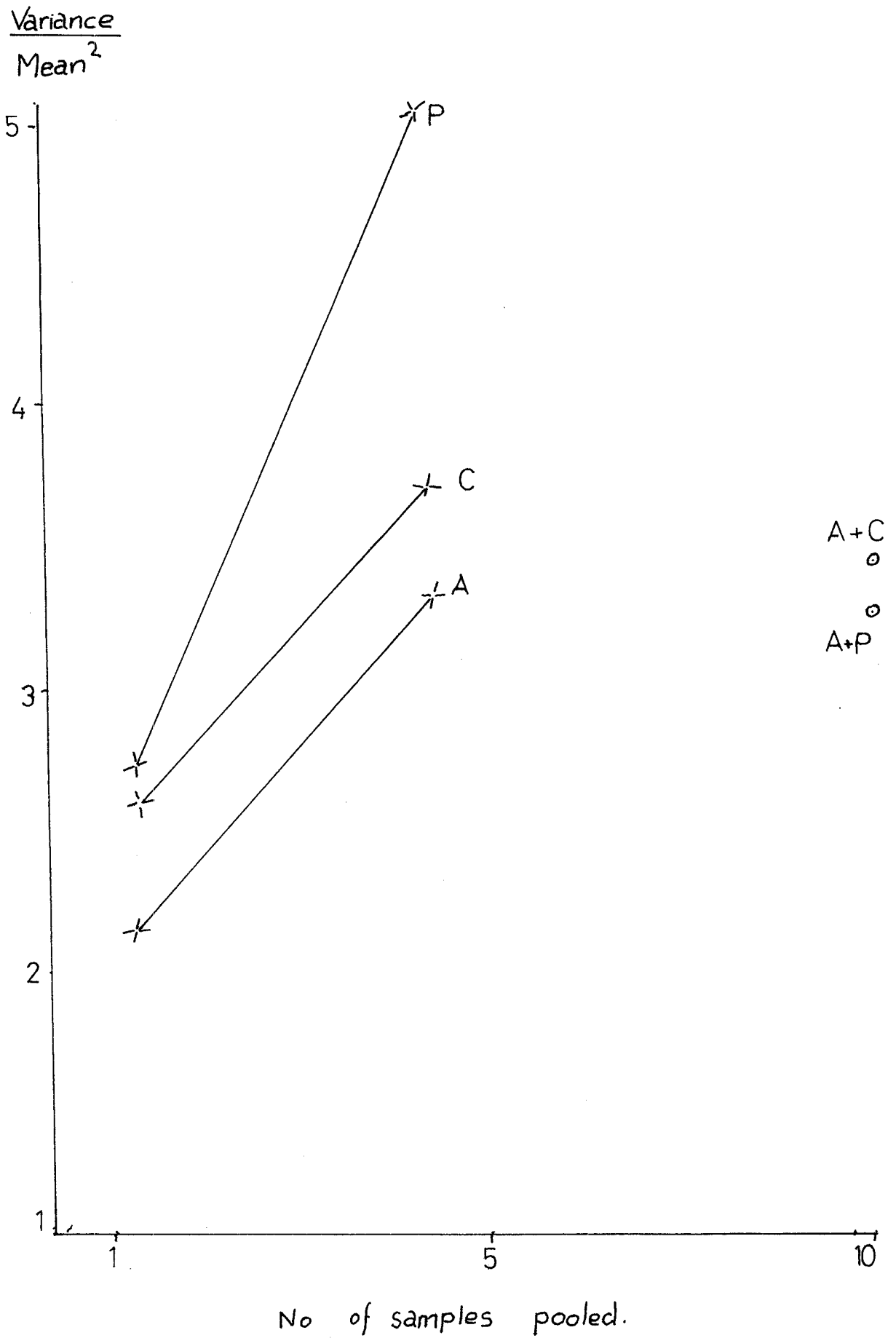
Table of Physical Factors.

p.H.

Pond.	Readings.						Average
A	6.9	6.8	6.8	7.0	6.9	7.0	6.9
B	7.0	7.0	7.1	7.1	7.2	7.1	7.1
C	7.5	7.5	7.3	7.6	7.4	7.4	7.5
D	6.8	7.0	7.0	6.8	7.0	6.9	6.9

$[Ca^{++}]$ p.p.m

Pond	Results			Average
A	75.4	73.7	73.7	73.9
B	115.4	117.0	114.0	115.5
C	84.2	81.8	85.0	83.7
D	67.3	68.1	67.3	67.6

$[Mg^{++}]$ ppm.

Pond	Result
A	24.0
B	52.5
C	49.0
D	23.0

Page Bank

$[Ca^{++}]$ p.p.m	74.
$[Mg^{++}]$ p.p.m	31
p.H.	9.6.

DISCUSSION.

4.1 SPECIES ABUNDANCE RELATIONS

From Figs. 2-6, where the number of species containing a given number of individuals per sample are plotted against the number of individuals found in that pond, it can be seen that the rare species are relatively numerous compared with the more dominant ones. This concurs with the results which are generally obtained when species abundance data is plotted in a similar nature.

Whether or not the species abundance data corresponds with one or more of the more specific distributions i.e. logarithmic series, lognormal distribution or the negative bionomial distribution, could only be determined by curve fitting. Due to the biased nature of the data (see 2.1 Sampling Procedure) this was not attempted. But, it was found that with a few exceptions, these species with very low abundances, the species present showed a contagious, i.e. clumped distribution. (A species can be said to be clumped between samples when the variance of the number of individuals of that species per sample is considerably greater than the mean. To find the variance to mean ratio, a computer programme was used (see appendix). Thus, any statistic appropriate to the negative bionomial distribution could be used legitimately).

When the data for all four ponds A-D is compared with the hypothetical distribution based on the MacArthur "broken stick" model, once again the rare species are too rare, the common ones too common (Fig.7). Whereas the MacArthur distribution gives a straight plot, the observed distribution

gives a curved plot. This form of non concurrence with the
MacArthur model is what is generally found from field data.
As Hairston (1969) points out: "Conformity to the MacArthur
model is a function of sample size rather than any ecological
properties of the community being sampled. A good fit to the
broken stick model can be obtained by choosing the correct
sample size which will vary with the material. The greater
the variance in species abundance, the smaller the collection
that should provide a fit." The model is though a useful
yardstick with which to compare natural distributions.

4.2 INDICES OF SIMILARITY IN COMMUNITY COMPARISON AND DELIMITATION

From Table 8 it can be seen that, when each pond is compared with each other pond in twos, by means of Sørensen's and Mountford's indices of similarity and an index of percentage similarity, there is a relatively high similarity between each pair of ponds A-D, and also a relatively high similarity between pond P and any of ponds A-D. Between the former and the latter groups of results though, there is a difference, which, in the case of Sørensen's and Mountford's indices, can be tested statistically using a modification of the t test for comparing the means of two samples. (This test cannot be applied to percentage data). When this test is applied, the difference between the two groups (i.e. ponds A-D and pond P with ponds A-D) is significant at the 0.001 level with 8 degrees of freedom. (t in the case of the Sørensen index is 17.99 and in the case of Mountford's index is 6.74). Thus, by inference, ponds A-D are highly similar to each other but very dissimilar from pond P.

If the values for the indices are ranked (as in Table 9) Sørensen's and Mountford's indices give identical results. The percentage similarity index gives a slightly different ranking order, due to the lower emphasis on rare species. Thus, it would seem that although there is a high similarity between ponds A-D in terms of the species present, those species vary in their relative abundance between the ponds.

The diagrams Figs. 8, 9 and 10 illustrate in three different ways the similarity of ponds A-D when compared with pond P.

4.3 RECURRENT GROUPS

Pielou and Pielou (1968) state that if recurrent groups are present, the observed number of samples having a different combination of species in them will fall short of the expected number of combinations. As can be seen from Table 11, in no case does this occur. In ponds A, B and D, twenty is by far the most likely number of combinations expected (expected in ninety-six times out of one hundred for pond A, ninety-five times for pond B and ninety-four times for pond D). For pond C, twenty is still the most likely number of expected combinations but the frequency is reduced to fifty-four out of one hundred while nineteen different combinations would be expected thirty-eight times out of one hundred.

The number of observed combinations in all cases was twenty. Therefore in no case does the observed number of combinations differ significantly from the expected frequency as generated by Monte-Carlo methods.

This technique for the detection of recurrent groups was inappropriate for two reasons. Firstly, whereas Pielou and Pielou (1968) found that most of their species only occurred in one or two samples (brackets in their case) in this exercise, for all the ponds, many of the species occurred in all twenty samples, and many of the other species occurred in a large number of samples. As it is laborious and wasteful of computer time, to assign the larger numbers at random, where the species occurred in ten or more samples, the number of absences rather than the number of presences were counted. Still, a lot of the species occurred in seven, eight or nine samples. Pielou and Pielou (1968) give a graph showing that

the number of expected combinations has a peak as the ratio
of average number of filled samples to total number of samples
increases; it then declines. To illustrate this point, another
programme was run with the same number of samples containing
the same species, but changing the parameter N sam., the total
number of species over a range of fifteen to thirty. (As it
is only of academic interest only the results of two of these
runs are given.)

The second reason why this technique could be considered
inappropriate is the dissimilarity of the sampling units in
this exercise when compared with those of Pielou and Pielou
(1968). Whereas the sampling units of Pielou and Pielou,
brackets, were spatially discrete, the samples in the pond
were random samples from a larger heterogeneous assemblage,
in no way could the samples be considered as discrete.

Two reasons have been given for the inappropriateness of
this technique, and, these were realised before it was
attempted. But, as this project was partly an exercise in
ecological techniques, this particular technique was considered
as interesting and therefore worthy of inclusion. The
inappropriateness of the technique had yet to be proved.

As Pielou and Pielou (1968) state, "Recurrent groups will
result if pairwise interspecific association, either positive
or negative is a common phenomenon." But, in order for these
to become apparent in the method of analysis used by Fager
(1957) the segregation must occur in space or time i.e. the
species must be segregated between samples.

In this study of ponds, clear cut recurrent groups would
hardly be expected since only the "free swimming phase" of the
pond fauna was sampled. Furthermore, this phase is relativel·

homogenous, although most of the species show a contagious
pattern of distribution, the "clumps" do not seem to occur
in any but a random manner. This expectation is borne out by
the results. In no case can groups be separated which have
any significant distinction from any other groups. In all
cases analysed, there is one major group, consisting of the
more abundant or numerically dominant species, and a group
of associates - species of less numerous occurrence.

If the Sørensen index of similarity is calculated for
each combination of pairs of recurrent groups, see Table 10a,
it will be seen that ponds A-D have a higher similarity
between themselves than any of them have with pond P. This
result based on recurrent groups confirms that ponds A-D are
significantly different from pond P.

The Sørensen index of similarity between the total fauna
of each pond takes into account all species and yet has higher
similarity indices than the same index applied to the
recurrent groups. This suggests that in the present investi-
gation, that the concept of a recurrent group is an abstrac-
tion with little ecological significance. This is borne out
by the Monte-Carlo a la Pielou and Pielou (1968).

4.4   SPECIES DIVERSITY

Accepting H(s) as a valid empirical measure of species diversity, (Lloyd and Ghelardi, 1964), from Table 12 the species diversity of the five ponds can be seen to vary between 2.38 (pond P) and 3.12 (pond B).

For each pond, if all species contained the same number of individuals, M(s) would be at a maximum depending only on the number of species present. This maximum is given in Table 12. In any natural situation though, the number of individuals in each species varies considerably and this is reflected in a decrease in the value of H(s) away from the maximum as can be seen from comparing the observed H(s) for each pond with the maximum H(s).

Theoretically, one would expect an increase in H(s) as the number of species increases. Thus, the lowest value of H(s) observed (that of pond P) corresponding with the lowest number of species, is quite expected. On this basis alone, the highest value for H(s) observed should be for pond P with 27 species (ponds A, B and C having 23 species each). But, H(s) is also affected by the evenness with which the individuals are distributed between the species. Thus, it is not so anomalous that pond B has a higher value for H(s) observed than pond D.

Because in any natural situation the number of individuals per species does vary, it is theoretically impractical to compare the observed H(s) with the maximum value of H(s). A much better way is to compare the observed H(s) with H(s[1]), the expected value assuming an underlying species abundance distribution based on the MacArthur "broken stick" model,

which itself assumes that the individuals are apportioned among the species in about an even a nature as could ever be expected in nature. Experience suggests that this value of $M(s^1)$ represents at least approximately the "ecological maximum." By comparing $M(s)$ with $M(s^1)$ in this manner, one is measuring the evenness with which the individuals are distributed among the species or, as Lloyd and Ghelardi call it, the "equitability" of the distribution.

From Table 12 it can be seen that the equitability of each pond carries between 0.41 (pond P) and 0.52 (pond B). Thus, owing to "inequitability in the distribution of individuals among the species, these ponds have species diversity "appropriate" to communities with from only 41%-52% as many species as actually occur.

The concept of information theory in Ecology is relatively novel. It was used by Margaleg in 1957, MacArthur and MacArthur in 1961, and Watt in 1964. They use the Shannon-Weiner function as the information content of the community or ecosystem. They point out that the greater the amount of information contained within the system, the greater will be that communities stability and probable permanence. Accepting $H(s)$ as also a valid measure of species diversity, the greater the diversity of a system, the greater will be the number of alternative paths for energy flow; this tends towards stability.

4.5 COMMUNITY ORGANISATION

As can be seen from Figs.11 and 12, Hairston's (1959) general hypothesis (that the greater the homogeneity or organisation within the community, the greater the ratio of observed variance/mean^2) seems generally to fit my data. Hairston found that the average of the ratios for five separate samples from one community, was always less than the ratio for the five samples pooled. He also found that when five and then ten samples were pooled from the same community, the ratio increased in a linear fashion (Fig.13). In terms of the a priori assumptions that Hairston makes (namely, that community organisation is a definite property of a community) this sort of result would be expected; as long as all the samples come from the one community, the more samples that are taken into consideration, the greater the degree of community structure that will be revealed, in terms of homogeneity and organisation.

From Fig.11, dealing with pond A, it is obvious that the average ratio for the five samples taken singly (2.1) is considerably below that for the five samples pooled, thus showing increased homogeneity and organisation with increasing number of samples up to five. But, when more than five samples are pooled, the ratio does not increase linearly (as found by Hairston) although there is a slight upward trend. Obviously, the larger and more complex a community, the greater will be the potential for revealing increased organisation as more samples are pooled. Pond A is a relatively small, relatively homogeneously dispersed community (when considered as such an entity). Perhaps, therefore, the maximum organisation of the community is nearly completely revealed by pooling only five

samples, further data adding little more to the picture.

When data from different ponds are compared, Fig.12, in all cases a larger ratio is obtained from five samples pooled than from the mean of the ratios of each of the five samples separately. Again from Fig.12 it can be seen that the ratios for pond C show similar values and trends as those of pond A, when plotted in the same manner. This contrasts with the behaviour of the ratios for pond P. (Ponds A and C come from the same pond complex whereas pond P is quite separate). The higher ratios obtained from pond P probably result from its lower content of species and individuals.

When five samples from pond A are pooled with five samples from pond C, there is a slight decrease in the variance/mean^2 ratio when compared with the ratio for pond C, but a slight increase when compared with the ratio for pond A. Such a situation would result if the ponds were very similar in species composition and organisation. When five samples from pond A are pooled with five samples from pond P, the variance/mean^2 ratio is much lower than that from pond A. Such a result would be expected if the ponds contained different species with a different basis of organisation. (If sampling data from a pond even further separated were pooled with these from pond A, an even greater reduction in the ratio would be expected.)

4.6 VARIATION BETWEEN PONDS IN RELATION TO PHYSICAL FACTORS

The Brasside ponds, being relatively close to each other, all within the same drainage system, subject to intermingling at times of heavy rainfall, and approximately the same surface area and depth, would be expected to have a strong similarity in terms of water chemistry. They all have similar vegetation which, while leading slight support to this theory also tends towards increasing the similarity. The fact that roughly similar conditions also occur at Page Bank does not deny the similarity of the Brasside ponds but does not supply any means of gauging this similarity.

Between the Brasside ponds, when compared to the pond at Page Bank, there is a high degree of similarity of faunistic structure as borne out by such indices as those of similarity, diversity and organisation. This fact alone does not deny the basic similarity of the ponds in terms of chemical factors. As Fager showed in his article, similar structures, in his case beach logs, can have very different faunas, the final faunistic composition of each log depending mainly on the vagaries of invasion and colonisation. From this Fager concluded that in general species were not inexpendible in terms of the functional role they played within the community. Also, that once a community or even a successional pattern had been established, new species, potentially new members for that community had not only to be adapted with respect to the physical conditions pertaining, but also had to be able to associate with those species already present. Thus, even given similar initial conditions, convergence to a similar pattern of faunistic composition was not bound to happen.

Macan (1966) stated:" Attempts to explain the distribution of species in terms of chemical differences have not had much success except where conditions are extreme." As the conditions at neither the Brasside pond complex or the Page Bank site could be said to be extreme, also considering the paucity of the data on physical conditions, no attempt has been made to correlate differences in species presence and abundance between the ponds with any or a combination of physical factors.

CONCLUSIONS.

CONCLUSIONS

Animal communities have been classified and delimited
on the basis of various characteristics, including the
abiotic environment and the vegetation. Surely, the best
method is one based on the animals present and their
relationships with each other. With this fact in mind,
various measures of the species composition and organisation
were determined for the four Brasside ponds and the Page
Bank pond. On the basis of the results obtained, the four
Brasside ponds showed great similarity with each other when
compared to the Page Bank pond.

Whether or not an assemblage of animals warrant the
status of "Community" is a subjective judgment which, apart
from purely academic considerations, is primarily a matter
of convenience. If the term "community" had to be applied
in some way to the Brasside pond area, in view of the faunal
similarity of the ponds, it would be better to apply the term
to the whole pond complex rather than to each individual pond.

ACKNOWLEDGMENTS

7. SUMMARY.

6. SUMMARY

Twenty samples from each of four ponds at Brasside, and ten samples from a pond at Page Bank were taken by means of a net. The animals within each sample were then sorted, identified and counted. For each of the ponds, pH was measured in the field while the calcium and magnesium concentrations for each pond were determined back in the laboratory.

The results of the faunal analysis of each pond was then discussed within the general framework of "the concept of community." Special attention was paid to species abundance relations, indices of similarity in community definition and delimitation, recurrent groups, species diversity and community organisation. The fauna of the Brasside ponds was also discussed in relation to certain physical parameters namely p.H., calcium concentration and magnesium concentration. The aim of the exercise was to determine whether each of the Brasside ponds could be considered as a separate community in itself or, whether they constituted together part of the Brasside pond-complex community.

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APPENDIX.

```
        £COMPILE   PAGES=25
   1               DIMENSION N(30),BIT(30)
   2               REAL N,NIND
   3         550 FORMAT(I4)
   4         551 FORMAT(F6.0)
   5               DO1 IPOND=1,5
   6               READ(5,550)NSP
   7               SUM=0.0
   8               WRITE(6,649)
   9         649 FORMAT(30X,'BRONWEN HIGGS',/30X,'------- -----',//
      6'          CALCULATION OF EQUITABILITY'///)
  10               WRITE(6,648)IPOND
  11         648 FORMAT(6X,'POND NUMBER ',I2//)
  12               WRITE(6,670)
  13         670 FORMAT(17X,'NSP',6X,'N(IR)',7X,'IR',5X,'LOG(N(IR))',14X,'SUM',
      61X,'(CUMULATIVE)'/)
  14               TOT=0.0
  15               DO74 IR=1,NSP
  16               READ(5,551)N(IR)
  17               TOT=TOT+N(IR)
  18               BIT(IR)=N(IR)*ALOG10(N(IR))
  19               SUM=SUM+BIT(IR)
  20               WRITE(6,660)NSP,N(IR),IR,ALOG10(N(IR)),BIT(IR),SUM
*EXTENSION*        IO-C
  21         660 FORMAT(15X,I5,F10.0,I8,F12.6,F15.7,F15.7)
  22          74 CONTINUE
  23               WRITE(6,271)
  24         271 FORMAT(///)
  25               READ(5,551)NIND
  26               B=ALOG10(NIND)-(SUM/NIND)
  27               HS=3.321928*B
  28               WRITE(6,661)NIND,ALOG10(NIND),B,HS
*EXTENSION*        IO-C
  29         661 FORMAT(10X,'NIND,TENLOG(NIND),B,HS...',F6.0,F15.7,F15.7,F15.7///)
  30               WRITE(6,650)HS
  31         650 FORMAT(1X,'HS = SHANNON-WEINER FUNCTION =',F9.5//)
  32               WRITE(6,646)TOT
  33         646 FORMAT(/////6X,'AS CHECK,TOT SHOULD EQUAL NIND.....TOT = ',F10.0)
  34               WRITE(6,270)
  35         270 FORMAT('1')
  36           1 CONTINUE
  37               STOP
  38               END
```

```
                 £COMPILE PAGES=100
       1         DIMENSION C(30,30)
       2         DIMENSION B(30,30)
       3         DIMENSION ICS(30)
       4         DIMENSION IP(30,30)
       5         DIMENSION ITYPE(30)
       6         DO4 IPOND=1,4
       7         DO25 KK=1,30
       8         ICS(KK)=0
       9         ITYPE(KK)=99
      10         DO25 KJ=1,30
      11         IP(KK,KJ)=6
      12         B(KK,KJ)=99.0
      13      25 CONTINUE
      14         READ(5,504)NSPEC
      15     504 FORMAT(I2)
      16         IC=0
       C IC=0 FIRST RUN HENCE VAR=VAR OVER 20 SAMPLES WITHIN A SPECIES.
      17         IF(IC.EQ.0)K=20
      18         IF(IC.EQ.0)KI=NSPEC
      19         DO6 I=1,KI
      20         READ(5,505)(B(I,J),J=1,20)
      21     505 FORMAT(20F3.0)
      22         SUM=0.0
      23         SUMSQ=0.0
      24         N=0
      25         DO7 J=1,K
      26         IF(B(I,J).EQ.0.0)IP(I,J)=0
      27         IF(B(I,J).GE.1.0)IP(I,J)=1
      28         IF(B(I,J).EQ.0.0)N=N-1
      29         SUM=SUM+B(I,J)
      30         SUMSQ=SUMSQ+(B(I,J)*B(I,J))
      31         N=N+1
      32       7 CONTINUE
      33         NJN=N
      34         IF(IC.EQ.0)N=20
      35         FMEAN=SUM/N
      36         A=(SUM*SUM)/N
      37         IF(IC.EQ.0)V=(SUMSQ-A)/(N-1)
      38         SD=V**0.5
      39         IF(IC.EQ.0)WRITE(6,654)
      40     654 FORMAT(6X,'VARIANCE IS ESTIMATED USING (N-1) ....NOT N ITSELF',/)
      41         N=NJN
      42         IF(IC.EQ.0)WRITE(6,606)IPOND,I,N,(B(I,J),J=1,20),FMEAN,V,SD
      43     606 FORMAT(10X,'POND NO.',I3/10X,'----------',/20X,'SPECIES NO.',I3,
                610X,'NO.OF SAMPLES CONTAININGIT=',I3//1X,'NO.S',20F4.0//10X,
                62X,'MEAN =',F12.6,20X,'VARIANCE =',F12.6/80X,'ST.DEV =',F12.6///)
      44       6 CONTINUE
      45         WRITE(6,270)
      46     270 FORMAT('1')
      47         WRITE(6,671)
      48     671 FORMAT(5X,'TABLE OF THE NUMBERS OF INDIVIDUALS OF EACH SPECIES',
                6' IN EACH SAMPLE.',//25X,'ROWS = SPECIES.      COLUMNS = ',
                6' SAMPLES.',/)
      49         WRITE(6,670)(J,J=1,20)
      50     670 FORMAT(/2X,20I4)
      51         DO10 I=1,NSPEC
      52         WRITE(6,660)(B(I,J),J=1,20)
      53     660 FORMAT(/2X,20F4.0)
```

```
      54      10 CONTINUE
      55         WRITE(6,270)
      56         WRITE(6,672)
      57     672 FORMAT(5X,'TABLE OF PRESENCE (1)  OR ABSENCE  (0) OF EACH ',
                6'SPECIES IN EACH SAMPLE.',//15X,'ROWS = SPECIES       ',
                6'COLUMNS = SAMPLES',/)
      58         WRITE(6,651)(J,J=1,20)
      59     651 FORMAT(20X,20I4/)
      60         DO23 I=1,NSPEC
      61         WRITE(6,651)(IP(I,J),J=1,20)
      62         DO23 J=1,20
      63         ICS(J)=ICS(J)*2+IP(I,J)
      64      23 CONTINUE
      65         IT=0
      66         WRITE(6,270)
      67         DO21 J=1,20
      68         IF(ITYPE(J).NE.99)GOTO83
      69         IT=IT+1
      70         ITYPE(J)=IT
      71      83 CONTINUE
      72         MX=J+1
      73         IF(MX.GT.20)GOTO70
      74         DO22 M=MX,20
      75         IF(ICS(J).EQ.ICS(M))ITYPE(M)=ITYPE(J)
      76      22 CONTINUE
      77      70 CONTINUE
      78         WRITE(6,650)ICS(J),J,ITYPE(J),(IP(I,J),I=1,NSPEC)
      79     650 FORMAT(2X,I12,3X,' IN THE J.TH.SAMPLE J=',I3,'...YTYPE',I3,26I1/)
      80      21 CONTINUE
      81         WRITE(6,653)IT,IPOND
      82     653 FORMAT(/5X,'NO.OF DIFFERENT COMBINATION TYPES = ',I6,'  IN ',
                6' POND NO.',I4//)
      83         IC=1
      84         WRITE(6,270)
      85         WRITE(6,655)
      86     655 FORMAT(6X,'THIS IS A TRUE OR OBSERVED VARIANCE...CALCULATED',
                6' WITH THE ACTUAL  NUMBER OF SPECIES OCCURRING IN THE SAMPLE',/
                6' (AND NEITHER THE POSSIBLE NUMBER NOR ONE LESS THAN THE ',
                6' OBSERVED) BEING USED AS THE DIVISOR OF THE SUM OF SQUARES.',//)
      87         II=IPOND
      88         DO14 J=1,20
      89         SUM=0.0
      90         SUMSQ=0.0
      91         N=0
      92         DO8 I=1,NSPEC
      93         SUM=SUM+B(I,J)
      94         SUMSQ=SUMSQ+B(I,J)*B(I,J)
      95         IF(B(I,J).EQ.0.0)N=N-1
      96         N=N+1
      97       8 CONTINUE
      98         FMEAN=SUM/N
      99         A=(SUM*SUM)/N
     100         IF(IC.EQ.1)V=(SUMSQ-A)/N
     101         SD=V**0.5
     102         IF(II.NE.4)WRITE(6,607)IPOND,J,N,FMEAN,V,SD,(B(L,J),L=1,23)
     103         IF(II.EQ.4)WRITE(6,607)IPOND,J,N,FMEAN,V,SD,(B(L,J),L=1,26)
     104      14 CONTINUE
     105     607 FORMAT(///10X,'POND NO.',I3/10X,'-------',/20X,'SAMPLE NO.',I3,
                610X,'NO.OF SPECIES CONTAINED =',I3//10X,
```

```
                62X,'MEAN =',F12.6,20X,'VARIANCE =',F12.6/80X,'ST.DEV =',F12.6/
                61X,'NUMBERS OF EACH SPECIES IN THIS SAMPLE ARE..',/1X,26F4.0)
     106       4 CONTINUE
     107         STOP
     108         END
```

```
0001          DIMENSION IFR(30,30)
0002          DIMENSION N(30),IC(30),IP(30,30),ICS(30),ITYPE(30),ICOMB(100)
0003          DIMENSION IFREQ(30),ICUMFU(30),ICUMFD(30)
      C  MAX NO OF SAMPLES OR SPECIES = 30 £OTHERWISE CHANGE DIMENSION STATEMT
0004          IX=794236173
0005          KT=0
0006          DO1 IPOND=1,4
0007          READ(5,500)NSAM,NSPEC
0008      500 FORMAT(I3,I3)
0009          READ(5,501)(N(I),I=1,NSPEC)
0010      501 FORMAT(40I2)
0011          DO24 IM=1,30
0012          DO24 IJM=1,30
0013          IFR(IM,IJM)=0
0014       24 CONTINUE
0015          WRITE(6,603)IPOND,NSAM,NSPEC
0016      603 FORMAT(///5X,'COMBINATIONS GENERATED  FOR POND NUMBER',I4,//12X,
         6'WITH NUMBER OF SAMPLES = ',I4//12X,'AND NUMBER OF SPECIES =',I5//
         612X,'AND WITH THE NUMBER OF SAMPLES HOLDING EACH SPECIES BEING'//)
0017          WRITE(6,604)(I,I=1,NSPEC)
0018      604 FORMAT(2X,'SPECIES',10X,22I4/)
0019          WRITE(6,605)(N(I),I=1,NSPEC)
0020      605 FORMAT(2X,'NO. OF SAMPLES',3X,22I4//20X,'COMBINATIONS'//)
0021          DO803 IN=1,10
0022          DO16 LJ=1,100
0023          ICOMB(LJ)=0
0024       16 CONTINUE
0025          IF(IN.EQ.2)IX=371369479
0026          IF(IN.EQ.3)IX=763741181
0027          IF(IN.EQ.4)IX=961338143
0028          IF(IN.EQ.5)IX=583172811
0029          IF(IN.EQ.6)IX=814393353
0030          IF(IN.EQ.7)IX=538271773
0031          IF(IN.EQ.9)IX=713829157
0032          WRITE(6,689)IN
0033      689 FORMAT(5X,'THIS IS THE ',I4,' TH. SET OF 100 RUNS..',//)
0034          DO9 K=1,100
0035          DO17 L=1,30
0036          ICS(L)=0
0037          ITYPE(L)=0
0038          IFREQ(L)=0
0039          ICUMFU(L)=0
0040          ICUMFD(L)=0
0041          DO17 LL=1,30
0042          IP(L,LL)=0
0043       17 CONTINUE
0044          DO2 ISPEC=1,NSPEC
0045          MD=N(ISPEC)
      C N((ISPEC)=NUMBER OF SAMPLES IN WHICH THE 'ISPEC'TH SPECIES OCCURS
0046          DO19 L=1,30
0047       19 IC(L)=248
0048          DO3 NN=1,MD
0049          MS=NSAM+1-NN
0050       84 CONTINUE
0051          CALL RANDU(IX,IY,YFL)
```

```
0052          IX=IY
0053          MK=MOD(IX,MS)+1
0054          LC=0
0055          GOTO82
0056       82 CONTINUE
0057          LC=LC+1
0058          IF(LC.EQ.3)GOTO 84
0059          DO4 J=1,NN
0060          IF(MK.GE.IC(J))MK=MK+1
0061          IF(MK.GT.NSAM)MK=MK-NSAM
0062        4 CONTINUE
0063          DO21 JJJ=1,NSAM
0064          IF(MK.EQ.IC(JJJ))GOTO 82
0065       21 CONTINUE
0066          IC(NN)=MK
0067          IP(ISPEC,MK)=1
      C               IP(I,MK)=1 IF I TH SP PLACED IN MK TH. SAMPLE
0068        3 CONTINUE
0069        2 CONTINUE
0070          IT=1
0071          ITYPE(1)=1
0072          DO5 J=1,NSAM
0073          DO6 I=1,NSPEC
0074          ICS(J)=ICS(J)*2+IP(I,J)
0075        6 CONTINUE
0076        5 CONTINUE
      C  THE COUNTER FOR THE J TH SAMPLE = THE COUNTERS FOR THE PRESENCE
      C       OR ABSENCE OF THE I TH. SPECIES IN THE J TH SAMPLE,
      C       EACH OF SUCH MINOR COUNTERS AT DIFFERENT POSITION
      C            ALONG ITS LENGTH.
0077          DO7 J=1,NSAM
0078          IF(ITYPE(J).NE.0)GOTO83
0079          IT=IT+1
0080          ITYPE(J)=IT
0081       83 CONTINUE
0082          MX=J+1
0083          IF(MX.GT.NSAM)GOTO 70
0084          DO8 M=MX,NSAM
0085          IF(ICS(J).EQ.ICS(M))ITYPE(M)=ITYPE(J)
0086        8 CONTINUE
0087       70 CONTINUE
0088        7 CONTINUE
0089          ICOMB(K)=IT
0090        9 CONTINUE
0091          DO10 J=1,76,25
0092          JJ=J+24
0093          WRITE(6,602)(ICOMB(K),K=J,JJ)
0094      602 FORMAT(/,5X,25I4/)
0095       10 CONTINUE
0096          WRITE(6,811)
0097      811 FORMAT(///)
0098          DO12 J=1,NSAM
0099          DO12 K=1,100
0100          IF(ICOMB(K).EQ.J)IFREQ(J)=IFREQ(J)+1
0101       12 CONTINUE
```

```
0102          WRITE(6,606)(J,J=1,NSAM)
0103      606 FORMAT(3X,'NO.OF COMBINATIONS',5X,20I4/)
0104          WRITE(6,607)(IFREQ(J),J=1,NSAM)
0105      607 FORMAT(3X,'FREQUENCY OCCURRING',4X,20I4/)
0106          DO14 J=1,NSAM
0107          IFR(IN,J)=IFR(IN,J)+IFREQ(J)
0108          DO14 JK=1,J
0109          ICUMFU(J)=IFREQ(JK)+ICUMFU(J)
0110       14 CONTINUE
0111          DO15 J=1,NSAM
0112          ICUMFD(J)=100-ICUMFU(J)
0113       15 CONTINUE
0114          WRITE(6,609)(ICUMFU(J),J=1,NSAM)
0115      609 FORMAT(3X,'CUMULATIVE FREQ.UPWARDS',20I4/)
0116          WRITE(6,610)(ICUMFD(J),J=1,NSAM)
0117      610 FORMAT(3X,'CUMULATIVE FREQ.DOWN',3X,20I4//)
0118      803 CONTINUE
0119          WRITE(6,270)
0120      270 FORMAT('1')
0121          WRITE(6,619)
0122      619 FORMAT(15X,'SUMMARY OF £IN£ RUNS.',///)
0123          WRITE(6,606)(J,J=1,NSAM)
0124          DO23 IN=1,10
0125          WRITE(6,607)(IFR(IN,J),J=1,NSAM)
0126       23 CONTINUE
0127          WRITE(6,270)
0128        1 CONTINUE
0129          STOP
0130          END
```

TOTAL MEMORY REQUIREMENTS 003042 BYTES

```
      C    HEREWITH THE STANDARD SUBROUTINE FOR GENERATING RANDOM NUMBERS.
      C    WE ARE GOING TO USE ONLY THE INTEGER VALUES (IY).
      C    THE REAL VALUES (YFL) ARE NOT USED AT ALL
0001          SUBROUTINE RANDU(IX,IY,YFL)
0002          IY=IX*65539
0003          IF(IY)5,6,6
0004        5 IY=IY+2147483647+1
0005        6 YFL=IY
0006          YFL=YFL*.4656613E-9
0007          RETURN
0008          END
```

TOTAL MEMORY REQUIREMENTS 000188 BYTES
EXECUTION TERMINATED