Contributed Papers

SESSION I: Chairman: Dr. R. K. Dell

The Distribution of Stream Bottom Faunas

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Very few animals are continuously distributed through their environment, and this is, in fact, only possible for sessile forms which can both feed and reproduce without moving from one spot. The great majority need room to move about for these purposes and therefore there must be, on the average, considerable spaces between individuals. It is the existence of these spaces which make it possible for each individual to occupy any of a number of positions, and thus for the population as a whole to be distributed in a great variety of ways. Considerable attention has already been given to the distributional patterns found in animal populations, particularly by the application of statistical techniques. These methods make it possible to test whether or not a population is randomly distributed; that is, whether the distribution is one which could reasonably occur if each individual was equally likely to be found at every point within the environment. Departures from randomness can be in one of two directions; either the animals are too evenly spaced out, that is, they are under-dispersed; or they tend to be aggregated, or gathered together in clusters—they are over-dispersed. Many actual distributions which have been studied have been found to depart markedly from randomness generally in the direction of aggregation.

Where a population is randomly distributed there is no need to postulate other than chance effects but if it is aggregated then some factors must be influencing the position occupied by each individual. These factors may be of two kinds; they may be derived either from the behaviour of the animals, or from features of the environment. Factors derived from behaviour exist if the position taken up by each animal is influenced by the presence of other individuals. If there is a tendency to avoid other individuals under-dispersion or excessively even distribution will develop, but if the tendency is to move towards a nearby individual the tendency will be t o w a r d s aggregation. Where behavioural factors such as these operate, non-random distributions can occur however uniform the environment may be. If, however, the environment varies from point to point in factors which affect its suitability as a habitat for the species under study, then these variations may affect the distributional pattern of the animal. If the environmental factors are non-randomly distributed then a similar tendency will appear in the distribution of the animal even if its behaviour does not cause tendencies towards either scattering or aggregation.

In considering the uniformity or otherwise of an environment the question of the scale of any irregularities is vitally important. After all, any environment becomes irregular and discontinuous if it is examined closely enough; even if we have to get down to atomic structure to detect it. If the distribution of any particular type of animal is to be affected, it is essential that the scale of the irregularities in the environment should be appropriately related to the size and habits of the particular animal. A level stretch of sand on the sea floor might provide an environment which, for a polychaete worm, was uniform over a substantial area, but for a protozoon living between the sand grains it would be highly irregular.

A second effect of scale, although less fundamental, is often important on account of the techniques commonly used in the study of distributional problems. Particularly with the smaller animals, it is rare to be able to observe and record the position of each individual in the undisturbed environment. We are often forced to study the problem by taking a series of samples of the environment, complete with its fauna, and comparing the numbers of individuals in the various samples. If environmental irregularities are to affect features of animal distribution found in this way then, obviously, the scale of the irregularities must be sufficiently large in relation to sample size to enable differences to exist between the samples in the essential features. The smaller the sample area or volume the finer will be the scale of the environmental irregularities which can be detected.

In New Zealand, stream-beds are most commonly composed of alluvial gravels in which the largest stones are generally in about the 3 to 30 cm. range; their faunas consist of insect larvae, molluscs, crustacea and so on, which are mostly in the 0.2 to 2.0 cm. range. Thus although an alluvial stream bed when looked at from a distance may convey an impression of uniformity, when considered in relation to its fauna it complies with the first requirement mentioned above. It contains irregularities which are large in scale in relation to the size of the individual animals. Stream-beds of this kind are most conveniently studied by taking samples of constant area. These samples are usually 1 sq. ft. (930 sq. cm.) or smaller, and thus they comply with the second condition mentioned; their scale is not great in relation to that of the irregularities of the environment.

We can therefore expect that irregularities of the environment may well affect the distributional pattern of the stream bottom fauna as shown by the usual sampling methods. Close examination of any patch of stream-bed at once shows that even within a small area there are very great differences from point to point in the type of environment. Within a radius of a few cm. there may be smooth stone surfaces fully exposed to light and current, crevices within and between stones offering shelter from both, smooth under-surfaces providing shelter combined with freedom of movement, patches of sand, and many other environmental features. In each of a series of samples the various environmental types will occur in a different arrangement and to some extent at least in different proportions.

Most streams appear, even superficially, to consist of a series of areas offering quite different kinds of conditions; there will be pools with deep water flowing very slowly over a sandy or muddy bed, flats where water of moderate depth flows quietly but steadily over coarse gravel, and rapids where the water races turbulently over boulders, and so on. Conditions in each of these major habitat types are so obviously different that they may well be treated separately when considering the distribution of the fauna. A more promising approach to the fundamental problems is provided by the study of the distribution over superficially more homogeneous areas, although it raises greater technical problems in analysing the essential features of the environment.

Pycnocentrodes	45	53	45	135
Parnidae	66	392	37	0
Total	157	543	195	181
Pycnocentrodes	33	41	49	278
Parnidae	140	80	4	8
Total	239	186	95	421
Pycnocentrodes	28	87	41	83
Parnidae	67	234	7	3
Total	153	381	118	157
Pycnocentrodes	41	55	161	219
Parnidae	104	38	4	60
Total	201	206	249	289

TABLE 1.—*Part of the results of a series of sixteen 1 sq. ft. samples arranged in an evenly-spaced grid. The direction of flow was from the top downwards.*

Table 1 presents some of the results obtained from a series of 1 sq. ft. samples taken in a regular grid over a fairly uniform flat. It shows the numbers of each of two main types of animal, the caddis larva, *Pycnocentrodes,* and beetle larvae of the family Parnidae as well as the total number of animals in each sample. Comparison of the numbers of the two main forms shows a marked change across the stream. Near the right bank parnids are always more numerous than *Pycnocentrodes* although the opposite is true near the left bank. Observation in the field showed that near the left bank the current was slightly faster and the bed contained rather larger stones and less sand than near the other bank. Thus, within this superficially uniform area, there were evidently environmental differences of sufficient magnitude to influence the distribution of the fauna.

Observations of this kind emphasise the need for more precise identification and measurement

SAMPLE	A	B	C	D	E	F	G	H
Chironomidae	1741	1204	1442	1150	1367	1314	813	583
Parnidae	257	350	274	69	70	93	78	17
Potamopyrgus	284	135	89	47	39	22	17	3
Total	2419	1846	1897	1315	1524	1456	943	652
Max. current (f.p.s.)	1.0	1.2	1.8	1.3	1.0	1.8	1.7	1.7
Total area (sq. in.)	273	229	274	332	293	276	340	302
Largest stone (kg.)	1.50	0.77	0.83	1.72	1.34	2.17	2.88	1.41

TABLE 2.—*Some of the results of eight 1 sq. ft. samples taken in randomised positions in an area showing a limited amount of variation in current and nature of bed.*

of important environmental features. Velocity of flow is obviously significant and an instrument has been devised which enables the current to be measured in a zone about one inch wide and about one inch from the bottom. This provides a much better approximation to the actual flow over the stream bed where the animals live than is given by a measurement near the water surface. It also enables the variation of flow within the sample area to be explored to some extent and it is commonly found that the ratio of maximum to minimum current is about two to one.

To study the actual structure of the streambed a technique has ben developed for observing and photographing the sample area in an undisturbed state. The stones of the surface layer are then removed and the area of exposed surface on each is measured, thus providing an estimate of the total surface on which animals would have lived. This area is generally found to be about 1½ to 2½ times the flat area of the sample. The observations and photographs provide an estimate also of the nature and amount of the finer deposits lying between the large stones.

Table 2 shows the results of a small series taken in carefully randomised positions over an area showing some obvious variation but all lying within the same general type of conditions. The three types of animals listed have obviously all varied in about the same way between the samples which have been arranged in a common descending order of abundance. In this series unlike the previous one there were no species present in any numbers which showed a reverse ecological trend. The table also shows three of the main environmental features which were measured. The only one of these which shows any sign of correlation with the fauna is the maximum current; in this series the fauna tends to decrease with increasing current but the correlation is much below the significant level. This however is the same relation which, in the previous series, appeared to occur for the only animals common to both, the Parnidae. Neither the total surface area available to the animals or the size of the largest stones show any correlation with abundance of the fauna.

A much smaller range of variation between samples occurs when a series is taken at places selected by eye to be as similar as possible. Table 3 shows such a series; the range of variation is obviously very much less than in gridded or randomised samples. The coefficient of variation (standard deviation as a proportion of the mean) in a series of samples selected for uniformity is generally found to be about 0.2 while in gridded or randomised series within a fairly uniform area it is about 0.4 to 0.5. This increased variability is clearly due to environmental features. How far these contribute to the variability among selected samples is not yet clear, and much more needs to be done in identifying and measuring possible environmental factors. Current appears to be important but more detailed study of its actual distribution close to the bottom is desirable. Stone size and total surface area in the crude form in which they have so far been expressed have little or no effect within the limits yet examined, but exploration over a wider range of environments may be fruitful. The development of techniques for the study of the nature of, and conditions in, the spaces actually under

	A	B	C	D	E	F
Parnidae	146	153	156	99	134	86
Chironomidae	127	79	86	84	50	33
Total	460	447	380	370	313	264
Max. current (f.p.s.)	2.0	2.0	1.6	1.8	1.8	1.7
Total area (sq. in.)	285	254	227	262	252	248
Largest stone (kg.)	2.50	0.89	0.80	0.71	0.42	1.13

TABLE 3.—*Some of the results of six 1 sq. ft. samples taken in places selected by eye as being as similar as possible.*

and between the stones is obviously desirable. Direct observation shows that a very high proportion of the individuals of many species are normally living below the stones where they are hidden from view. For *Potamopyrgus*, for example, about one per cent. of the individuals are visible at any one time; the rest are hidden beneath the stones. Even more extreme are the parnid larvae; not a single specimen of these has been seen under natural conditions during this work although areas containing in the aggregate several thousand specimens have been watched.

Another factor which may sometimes be of importance in the distribution of the fauna is the previous history of the area. Disturbance of the bed prior to the time of observation by floods and other causes may have greatly reduced the fauna. In June 1958 a sharp rise of about one foot in the Horokiwi stream disturbed much of the bed in the centre where the current was most rapid but had little effect near the banks. A series of samples was taken about a week later. In one subseries close to the bank in undisturbed conditions the total number of animals ranged from 1,374 to 2,115, but in the other subseries near midstream the range was from 31 to 105. Such marked variations are normally only temporary and, if stable conditions follow, a return to the more usual degree of variation soon takes place.

Finally, it should be noted that, the degree of variation among selected similar samples is much too great to be due purely to random effects and if it is not due to unidentified environmental factors the behaviour of the animals must be involved. A purely random distribution would tend to follow a Poisson series and its variance would be about equal to its mean. In the series so far studied the variance has always been very much greater, often 20 to 40 times the mean.

The Sampling Problem in Benthic Ecology

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The importance of the role of benthic invertebrates in the bionomics of demersal fisheries is very considerable for it is almost entirely through their agency that the demersal fish are able to utilise as food the organic material in the deposits of the continental shelves (Longhurst, 1958a). Yet quantitative ecology of the benthos lags far behind that of the plankton, in a ratio that seems disparate with the bionomic—and certainly with the economic—importance of the two subjects; it is fairly clear that the reason for this relative neglect lies in the nature of the material and the difficulties inherent in an assessment even of an instantaneous standing crop. The benthic fauna is buried in, or attached to, a substratum of varying consistency into which the gear must make uniform bites; the individual organisms are arranged patchily, both on a large and on a small scale; they may be extremely divergent in size and so sparsely distributed that much time will be expended in obtaining sufficient numbers for statistical treatment. The comparisons between this and a plankton sample with quantitative gear are so obvious as to need no enumeration.

To overcome these difficulties a great variety of grabs and dredges have been designed since Petersen (1911) introduced the first quantitative gear; none appears to be entirely satisfactory, but the later modifications of the Petersen grab, such as those designed by van Veen (Thamdrup, 1933) or Smith and MacIntyre (1954) are probably the best instruments available for quantitative work—in time they will doubtless be replaced by a corer of some sort, but a satisfactory type has yet to be designed and proved at sea. With proper design of the bucket and with adequate weight good results may be had with a grab provided its shortcomings are recognised and the validity of the samples analysed.

Unfortunately, the sampling characteristics of grabs are not yet satisfactorily understood, nor have there been adequate comparative trials at sea between one grab and another, though Ursin (1954), Thamdrup, Smith & MacIntyre, and Birkett (1958) have produced preliminary data; Holme (1953) and Jones (1957) have recorded data on the cumulative curves for recruitment of species to samples using scoop samplers and van Veen grabs respectively.