An Effective Method of Diagramming Diurnal Movements of Zooplankton Organisms

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AN EFFECTIVE METHOD OF DIAGRAMMING DIURNAL MOVEMENTS OF ZOÖPLANKTON ORGANISMS [1]

Although there is a very large literature concerned with the daily vertical movements of zooplankton organisms, the significance of data contained in many of these papers has been minimized because of the fact that unsuitable tabular or graphic methods have been used. The devices most commonly employed may be conveniently classified according to the following categories:

1. Numerical tables. This is perhaps the simplest way of presenting diurnal migration data. The numbers of organisms collected at the various depths are usually indicated in a series of vertical columns which are arranged according to the time of collection (table I).
2. Several types of histograms. One of the most common diagrams of this type involves vertical series of horizontal bars, each series comprising the samples taken at a particular time, and the length of each bar corresponding to the number of organisms found in a particular sample taken at a particular depth (figure 1). A modification of this device is sometimes used where the length of each bar corresponds to the *percentage* of the total number of organisms collected in all of the samples comprising each vertical series. Sometimes, instead of bars, a vertical axis of symmetry is used for each series, with the various widths corresponding to the numbers of animals found at the particular depths.
3. Curves representing the daily movements of the *average individual* in a population (figure 2).[2]

While all of these methods are quite satisfactory for demonstrating the migrations of large populations of zoöplankters which exhibit pronounced daily vertical movements, they are not particularly suitable for showing the diurnal movements of small populations of Rotatoria, Cladocera, and Copepoda, especially those species which are characterized by slow, vertical "drifts" of relatively small amplitude. Moreover, it seems important that diurnal migration data should be presented in a manner which can be easily and quickly interpreted by the average reader interested in ecological phenomena.

Weighty tabular material is particularly unsuitable for the presentation of "drift" data, because of the fact that the large amount of numerical material necessarily used often obscures small population movements and must be examined closely by the average reader before proper interpretations can be made. Similarly, it is often difficult to interpret series of histograms, particularly when an inappropriate scale is used, when the vertical distribution is relatively homogeneous or unusually irregular, or when there are small numbers of organisms present in the collections. Curves representing the migrations of "average" individuals, on the other hand, may be actually misleading because of the fact that they do not indicate the general vertical distribution plan of the *entire* population at any one time.

The method which is here outlined, however, was devised in order to minimize some of these difficulties, so that even "drift" data could be presented in a manner readily interpreted. This method, which is well-adapted to plankton trap catches and involves the use of quartile curves, is outlined in the following paragraph.

By arranging the cumulated numbers of organisms in a vertical column for each series of samples, the quartiles may be easily established in the usual way. For the series of samples taken at noon, August 3, 1940, in Summit Lake, Colorado (see table I), for example, the cumulated numbers are as follows:

Depth, meters	Cumulated numbers of organisms
0	1
1	1
3	4
5	16
7	21
9	24
11	38
13	43
(13.6)	(48)

Although the deepest sample was taken at 13.0 meters, it is arbitrarily assumed, for the sake of completeness, that there were as many organisms actually at the bottom (13.6 meters) as there were in the deepest sample. It is easily seen that the quartiles fall between 3.0 and 5.0 meters, at 9.0 meters, and between 9.0 and 11.0 meters. By interpolation, they can be shown to lie at 4.3, 9.0, and 10.7 meters. In other words, at noon, 25 per cent of the organisms were

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[2] The method for deriving such curves is given by E. B. Worthington. 1931. Vertical movements of fresh-water macroplankton. *Int. Rev.*, **25**: 394–436. Incidentally, Worthington's equation has been misprinted; it should read:

$$\text{Average depth} = \frac{x^1d^1 + x^2d^2 + \cdots}{x^1 \quad + x^2 \quad + \cdots}.$$

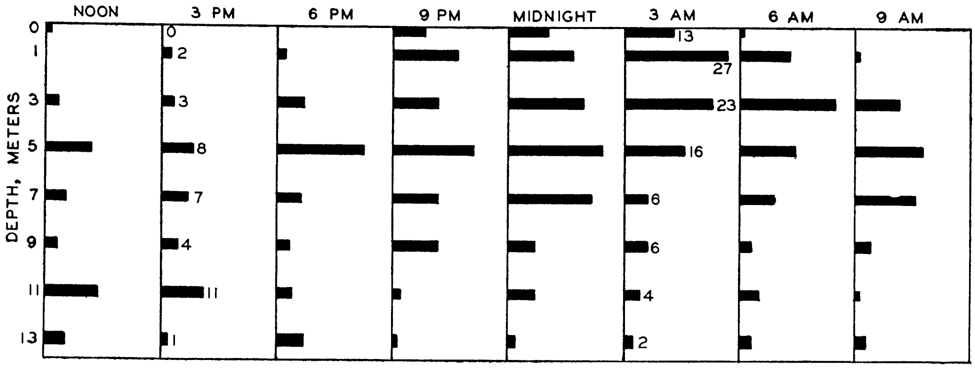

FIG. 1. Diurnal migration of *Daphnia pulex* in Summit Lake, Colorado, August 3 and 4, 1940. Actual numbers of organisms per ten-liter plankton trap sample have been inserted for 3 P.M. and 3 A.M.

between the surface and 4.3 meters, 25 per cent were between 4.3 and 9.0 meters, the third quarter between 9.0 and 10.7 meters, and the bottom quarter were between 10.7 and 13.6 meters. The three points, 4.3, 9.0, and 10.7 meters, are then indicated in the final diagram. In a similar manner the quartiles may be determined for each vertical series of samples. In the completed diagram (figure 3) the final quartile curves have been drawn in.

The use of three curves, dividing the population into equal quarters, is simply an arbitrary device. Two curves, or four or more, may be used, as desired, depending on the density of the population, the frequency of sampling, and the depth of the body of water.

Perhaps the outstanding objection to using this method of diagramming diurnal migration is the fact that considerable time is involved in manipulating and preparing the data for presentation in final form. The writer has found, however, that with a little practice, a large amount of data can be handled in a surprisingly short time. A second objection is that the final diagram does not give any idea of the *actual numbers* of organisms involved. This objection may be easily disposed of, however, by simply inserting the numbers of organisms collected per unit volume of water for one or more vertical series of zoöplankton samples. Such data have been inserted in figure 3 for the vertical series taken at 3 P.M. and 3 A.M.

Two other objections may be noted. First, the use of quartile curves does not take into account numerical irregularities in zoöplankton populations in the water between any two successive sampling depths in a vertical series. Second, this method is not particularly accurate when only small numbers of organisms are present in a body of water. Both of these objections are inherent mechanical collecting difficulties in

TABLE I. *Vertical distribution of* Daphnia pulex *in Summit Lake, Colorado, August 3 and 4, 1940. Expressed as numbers of organisms per ten liters of water*

Depth, meters	Time							
	noon	3 P.M.	6 P.M.	9 P.M.	mid-night	3 A.M.	6 A.M.	9 A.M.
0	1	0	0	8	10	13	1	0
1	0	2	2	17	17	27	13	1
3	3	3	7	12	20	23	25	12
5	12	8	23	21	25	16	15	18
7	5	7	6	12	22	6	9	16
9	3	4	3	12	7	6	3	4
11	14	11	4	2	7	4	5	1
13	5	1	7	1	2	2	3	3

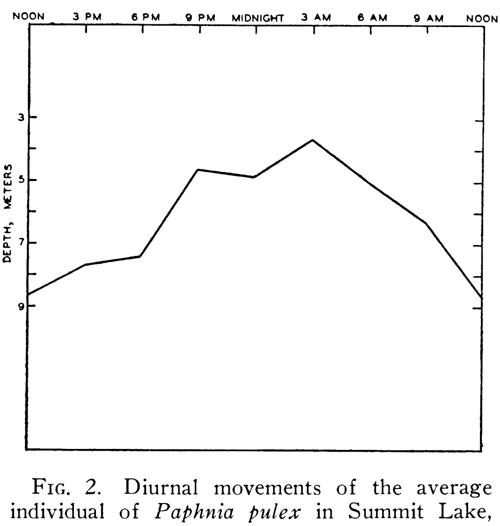

FIG. 2. Diurnal movements of the average individual of *Paphnia pulex* in Summit Lake, Colorado, August 3 and 4, 1940.

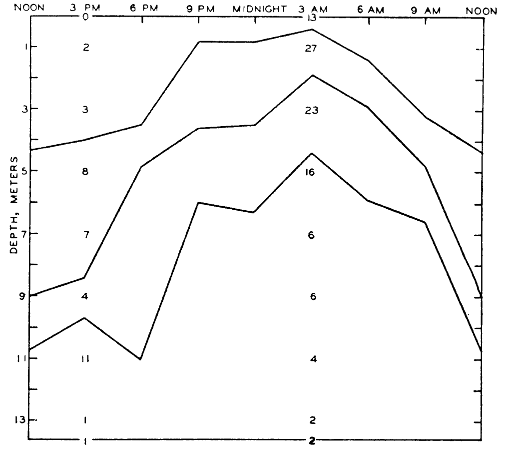

FIG. 3. Quartile curves showing the diurnal movements of *Daphnia pulex* in Summit Lake, Colorado, August 3 and 4, 1940. Actual numbers of organisms per ten-liter plankton trap sample have been inserted for 3 P.M. and 3 A.M.

the field, however, and cannot be satisfactorily overcome regardless of the manner in which the data are treated. The only obvious remedy is to make sure that the plankton samples are taken at frequent depth and time intervals so that the results will more closely approach true significance.

The advantages of using such a system for demonstrating diurnal migration are obvious from a comparison of table I and figures 1, 2, and 3, all of which were constructed from the same raw data. Whereas the other methods require a certain amount of study, figure 3 can be quickly understood and interpreted. It shows much more plainly and compactly than the other devices the general vertical distribution of the entire population, as well as the speed of vertical migration as indicated by the slope of the individual curves. Furthermore, it shows, without disproportionate exaggeration, relatively slight movements and tendencies of the population as a whole. These can be seen in table I and figure 1 only after a more careful examination. Lastly, in conjunction with the curves, the picture is made more apparent by the use of specific collection data for representative vertical series of samples.

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NOTES ON THE BASILISK AT BARRO COLORADO ISLAND, CANAL ZONE

The most conspicuous lizard on Barro Colorado is *Basiliscus basiliscus*. It is abundant along the shore and to a lesser degree in the ravines along the numerous small streams flowing into Gatum Lake. The island is densely wooded except for a few small clearings. The shoreline is very irregular, resulting in a large number of coves where beaches are practically nonexistent and the forest extends to the water's edge. The writer spent a few weeks during July and August of 1938 observing the Basilisks in a cove just to the north of the laboratory inlet and clearing. Previous observations (Park, '38; Park, Barden and Williams, '40) have reported the general activity of animals on this island and the cove was chosen for its accessibility rather than for an unusual concentration of Basilisks. It was forested to the water's edge except for about 50 feet at one end. At the head of the cove two small streams flowed in, as well as a number of lesser streams along the sides. It was hoped that the number of Basilisks might be determined and the extent of their movements and possibly some evidences of territoriality found.

As a first step the shoreline was divided into 50-foot strips and a numbered marker placed at each 50-foot interval. As thus measured the cove shoreline was 2100 feet long and roughly V-shaped in outline, the distance across the opening of the V being about 500 feet. It was essential to mark the lizards so that they could be identified when seen again. A considerable amount of time was spent at first in trying to noose the lizards. With the aid of another person to handle the noose while the writer paddled, two lizards were finally captured. Another Basilisk was taken by hand at night as it slept in the hollow top of a stub located in the water. Alone, the writer was not able to control the cayuco and at the same time successfully manipulate a long pole with a noose at the end, so noosing was abandoned in favor of marking the animals with white paint. At first a rather primitive method was employed, consisting of dipping a wad of cotton in the paint and shooting it at the lizards with a slingshot. An improvement over this was the use of a rubber bulb to squirt paint at the lizards. This allowed more accurate shots at a distance of 20 feet. If a lizard was missed, it would frequently remain undisturbed for a second shot. If a hit was made, the markings were quickly noted with the aid of binoculars and recorded along with the position as determined by means of the numbered markers.

By these various methods 23 lizards were marked distinctively. Of this number four were