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BEHAVIOUR OF PLANKTON IN RELATION TO HYDROGRAPHIC FACTORS

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by

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BEHAVIOUR OF PLANKTON IN RELATION TO HYDROGRAPHIC FACTORS

The majority of the animals in the upper levels of the sea carry out a marked diurnal migration. Such vertical movement is significant from various aspects. It exposes the animals during a 24-hour period to widely ranging environmental conditions. It enables them to make use of differential current systems and perform limited horizontal navigation. It is mechanism for vertical transport of dissolved and particulate substances. In addition, the propagation of sound in the sea is significantly affected by planktonic and nectonic organisms; this is particularly marked in the case of the deep scattering layer. This layer may in some cases consist of planktonic crustacea (Hersey and Moore, 1948), or, as later work of Hersey and others has indicated, may yield echoes from the swim bladders of fishes whose movements closely follow those of the smaller plankton on which they prey. In addition, it is believed that the distribution of certain noise-producing marine animals is affected by the distribution of smaller planktonic animals. In either case it is important to understand the behaviour of the plankton.

Preliminary studies (Moore, 1955) of the vertical distribution of plankton showed that there was a common pattern of behaviour running through the different groups; they all adjusted in a comparable way to the complex stimuli of external temperature, light, and other factors. Thus, study of a single selected group would yield results which would be of general application. For later studies, we decided to concentrate on copepods. They are not so active that they escape the nets. They offer a larger number of common species for comparison than any other group. Finally, they seem to exhibit certain characteristics such as brood differences more clearly than any of the other groups tried.

Since copepods are unlikely to behave normally when brought into the laboratory, it seemed preferable to obtain a wide range of observations of vertical distribution of the copepods under natural conditions in the sea, and of the environmental conditions, and to analyze these by statistical methods. The Florida current is unusual in the strong slope of the isotherms across it, which results in the subjection of plankton of a common origin to a wide range of conditions at a given depth. Such range is essential to correlation and regression analysis.

Plankton collections made at different times were available from the National Geographic Society, the National Science Foundation, and the Office of Naval Research. These provided full 24-hour net sampling on about twelve occasions at a number of stations between Miami and Bimini. Not all species were present in sufficient numbers on all occasions to allow the full series of stations to be employed in the statistical analysis.

Taking into account the stimuli of temperature, illumination, and pressure, a mathematical model has been developed in the form: T. Factor $(T - T_n)$ + 1. Factor $(I - I_n)$ + P. Factor $(P - P_n)$ + Date Factor (Date) = 0 in which T, I, and P are the ambient temperature, illumination and pressure, and T_n , I_n, and P_n the corresponding values at which the animals would not be stimulated to move vertically. The date enters the equation to allow for a seasonal rhythm, probably resulting from successive broods. The four factors equate responses to unit stimuli to the! several stimuli. It is assumed that the plankton are found at a level where their several responses are balanced. A population of a species is composed of individuals with widely differing responses, this being one of the significant facts which has emerged from the study. Separate analyses are therefore made at 10 percent intervals through the population. There are also marked diurnal rhythms in both the factors, so it is necessary to make separate analyses at 4-hour intervals.

Initially, eighteen species of copepods were counted, but only twelve proved to be present in adequate numbers throughout the year. Determination of the factors was made by partial regression analysis. Because the form of the mathematical model was being modified as the study progressed, the work was carried out on a Frieden calculator and was very time consuming. Now that the form of the equation has been standardized, any further work undertaken can be simplified by the use of an electronic computer. Solving for the nulls called for a special analogue computer which we built for the purpose.

Analysis of the factors is completed, and that of the nulls will be complete in a few weeks. Although the ONR contract has expired, the study is continuing, since, as expected, it is opening up a number of very interesting lines. We have shown that zooplankton behaviour is much more complicated than had previously been supposed and cannot be simply accounted for in terms of either a single factor or a simple response to that factor. At least three environmental factors are important: individual animals vary in their response to stimuli from these factors and there are both diurnal and seasonal variations in these responses. In addition, of course, there are differences between species. By inserting the values of factors and nulls which we have determined into the equation, we have compared the predicted with observed plankton distributions under a range of hydrographic conditions, and we have obtained a reasonable agreement. We have also made predictions using typical values, and, by varying one factor or null at a time, shown the relative sensitivity of the copepods to temperature, illumination, and pressure. A point which emerges from this phase is the importance of pressure as a controlling environmental factor. Until now, this has received very little consideration.

There appears to be a general trend in behaviour pattern from deep- to shallow-living animals; and as soon as the last analyses are complete, we should be in a better position to understand what underlies the different levels at which different species characteristically live.

In earlier work on the relation between the deep scattering layer and euphausids, it was shown that the geographical range of a species, and its relative abundance within this range, could best be explained in terms of the conditions at their deep day levels combined with those at their shallower night levels. Both must be satisfactory for the survival of the animals. The constants we have determined for the twelve copepods should afford a more refined method of testing this. In anticipation of such a test, we have been accumulating information on the distribution of the various species. Surprisingly little is known about this, and there are no quantitative charts of their North Atlantic distribution. Gaps in the charts which we are compiling have been considerably reduced by the results available from Russian collections made during the IGY. We hope to be able to follow up the comparison in the future.

Several papers have been published on the work (Moore, 1953, 1955, Moore *et al.*, 1953, Moore and Corwin, 1957, Moore and O'Berry, 1957) and others are in preparation.

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