HULL BULLETINS
OF
MARINE ECOLOGY

VOLUME II

EDITED BY

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CONTENTS

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(In 1948 Dr. Lucas was appointed Director of Fisheries Research, Scottish Home Department, and Mr. K. M. Rae became the acting Head of the Department.)

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G. A. COOPER, 1947–
Miss M. F. JOBSON, B.Sc.(St. Andrews), 1947–
Miss D. E. JOHN, 1947–
Miss D. E. Williams (Mrs. A. Saville), B.Sc.(Wales), 1947–1948.

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F. H. Dewing, 1937–1949.

Names in italics indicate those members who have left the Department.

EXPLANATION

A non-technical account of the contents of Volume II by the Editors

THE inclusion of this brief introduction to the volume may itself require some explanation and this can most readily be given by quoting from the preface to Volume I :

" Oceanographic researches must often appear to members of the (fishing) industry to be remotely removed from their immediate interests. Since reports such as the present ' Bulletins,' which are intended primarily as contributions to the scientific literature of the subject, will necessarily be too detailed and technical to be read by the layman, each volume will be accompanied by an explanation of its contents : a non-technical account pointing out its bearing on the future welfare of the industry."

This preface was followed by an explanation which, since it dealt with the very beginnings of the work, was also largely a discussion of the scope and nature of marine ecology in general. It dealt particularly with the importance of the plankton in the understanding of the natural economy of the sea before passing to a description of the methods for its survey which have been developed as a special feature of the present research. This second volume is concerned with a continuation of the work described in the first so that the former explanation will largely serve also for this and need not be repeated ; the general reader who has not yet read that first explanation should refer back to it before going further with the present volume. Since in quoting from the original preface we have referred to the relation of the work to the fishing industry it may be well to repeat also a word or two of caution from the first explanation :

" We are just at the beginning ; we have a very long way to go before the goals we are working towards can be realized. They must be approached slowly, making sure of the ground step by step ; there will be many temptations to jump to conclusions on too slender evidence. The limitations of the methods we are employing must be carefully weighed and a good deal of space in the coming ' Bulletins ' will be concerned with these. Direct economic results must not be expected quickly. The more immediate outcome will be a better understanding of the nature of the changes taking place in the North Sea plankton community as a whole ; any steps, however, towards a better knowledge of the biology of the North Sea is a step towards ultimate economic advantage."

The first volume described the results of the plankton recorder survey of the North Sea in its early experimental stages from 1932 to 1937 when it was confined to the southern North Sea. The essential feature of the method is the use of a number of machines, the continuous plankton recorders, which, when towed by steamships across the sea, automatically and continuously sample the plankton at a standard depth of 10 metres so that subsequently estimates of the varying quantity of different organisms may be made for the different parts of the sea. By using such instruments at monthly intervals on a number of different lines across the sea knowledge may be gained of the main changes in the distribution and abundance of the principal constituents of the plankton with the passage of time. We want to know how far, in this or that month, conditions in this or that part of the sea are exceptional or not; only by knowing this can we begin to correlate such deviations from the normal with variations in the fisheries on the one hand and with changing hydrological or weather conditions on the other. Before this can be done, however, many years of observations must be taken and compared in order to establish what may be regarded as the normal state of affairs, or at least, a " standard " from which the deviation can be measured. We are still in this pioneer stage.

The results of the first five years' trial in the restricted region of the southern North Sea were so promising that in 1938 a new laboratory was opened in Leith and the recorder survey was extended by the addition of new lines to cover the greater part of the North Sea; a year later, in 1939, the first line into the North Atlantic towards Iceland was begun. Then the outbreak of the second world war for the time being brought the whole programme to a stop. The ' Bulletins ' in the present volume, except the last, deal entirely with the results of this expanded survey of 1938 and 1939.; they show us for the first time, month by month, the main changes in the plankton over practically the whole of the North Sea for a year and eight months. They form an important basis for comparison with the results of the post-war survey, happily revived on an even more extensive scale and to be described in later volumes.

We will now deal briefly with each ' Bulletin ' in turn.

' Bulletin ' No. 7.

This requires little explanation, for it is itself a general introduction to this 1938–39 survey. It describes the expansion of the area covered, charts the position of the new lines together with the old, and shows their relation to the varying depth of the sea bed. There is a complete summary list of records as well as a series of charts showing the lines along which successful recording was achieved in each of the twenty months of the survey. In these charts the parts of each record taken between sunset and sunrise are shown by a much thicker line than those parts taken in the day-time; this enables one to compare them with the plankton distribution charts which follow in later ' Bulletins ' to see whether some of the results may be

effected by the diurnal changes in the vertical distribution of some of the animals. This is one of the possible limitations to the method to which a good deal of attention has been given in these ' Bulletins '; actually it is found that this effect is of significance in only a comparatively small number of species and its importance is discussed in the subsequent ' Bulletins ' concerned. During this twenty-month period 188 records were made covering a total distance of 47,806 miles; this compares with 44,246 miles recorded in the previous six years.

' Bulletin ' No. 8.

Here Dr. Lucas, assisted by Mr. MacNae, describes the distribution of the diatoms, those single-celled plants of many species which occur in enormous numbers, and make up a large proportion of the phytoplankton, the floating, microscopic vegetation, which forms the marine pastures upon which almost all the animal life of the sea ultimately depends for food. In the plates of Volume I, illustrating the distribution of the different organisms in the preliminary survey, the varying quantities found along the recorder lines were shown as graphs; in the present work, where there are so many intersecting lines across the area, such a method becomes impossible, and the relative values are shown as a series of numbers and other symbols representing the average quantities per mile for each consecutive ten-mile section of a record. In Text-fig. 1 a comparison is made between the old and new methods which will enable the results of this 1938–39 survey, as shown in the plates, to be more readily considered in relation to those obtained in 1932–37. As in the former survey, special attention has been given to the distribution of the diatoms *Rhizosolenia styliformis* and *Biddulphia sinensis*, which both may form dense concentrations in the southern North Sea in the autumn and are thought to be of particular importance in relation to the herring fisheries. Many more species have been dealt with in this survey than in the previous one, and Plates VIII to XXXVIII show the changing monthly patterns of distribution of some twenty different forms. This survey gives new evidence on the patchy nature of the diatom distribution and of possible water movements in the area. The principle contribution which this ' Bulletin ' makes to our knowledge of the North Sea plankton is the presentation for the first time of many of the changes in diatom distribution month by month over the whole area for a twenty-month period; compared with an occasional survey of the area it has something of the quality of a moving or cinematograph picture compared with that of a still photograph. This and the other similar ' Bulletins ' in this volume dealing with different groups of organisms are essentially studies of the ways in which the plankton distribution *changes;* they are specially designed to show movements with the passage of time. Each chart by itself is of little value compared with the consideration of a number of such charts in sequence. It is with the continued study of these changes, together with the changes recorded in meteorology, hydrology and in the fisheries, that we hope eventually to make a contribution towards a better understanding of cause and effect in the sea.

'Bulletin' No. 9.

In this 'Bulletin' Dr. Lucas describes the distribution of those other important elements of the phytoplankton, the dinoflagellates and Phaeocystis; examples of these forms, together with the principal diatom species, are described and illustrated in the first explanation (see Text-fig. 12 on page xxv of Volume I). In the 1932–37 survey of the southern North Sea it was only possible to describe the detailed distribution of two different species of dinoflagellates—*Ceratium furca* and *C. fusus;* in the present 'Bulletin' for 1938–39 the monthly distribution of five other species in addition to these two is given for the whole North Sea area—*Ceratium lineatum, C. tripos, C. macroceros, C. horridum,* and *C. longipes.* As in the former 'Bulletin' for the diatoms these give us new knowledge of the actual *changing* distribution of plankton with the passage of time over a period of twenty months and over a wide area. Here too there is much interesting evidence on patchiness and of possible water movements. A striking feature of the distribution of the dinoflagellates as a whole, which is brought out in this survey, is the relative abundance found in the north-west and south-east corners of the area, and the comparative scarcity in the central region; this is well shown in Text-fig. 1 on p. 50.

'Bulletin' No. 10.

Here are described the results of the first six recorder runs taken in the Atlantic on a line from the North of Scotland across the southern entrance to the Faeroe-Shetland Channel and out beyond the edge of the Faeroe Bank towards Iceland. This was a new venture begun in April, 1939, just before the outbreak of war. Phyto- and zooplankton are dealt with together. It represents a pioneer attempt to provide information to enable one to compare planktonic conditions in the North Sea with those further back in the Atlantic stream to the westward; this series of records, cut short by the war, is of course too small to form the basis for any definite conclusions. The interest of these data, however, will be increased when they can be compared with similar Atlantic records which have been taken since the war and will be described in subsequent 'Bulletins'; they are published here as records of more value for the future than the present.

'Bulletin' No. 11.

Here Mr. Rae and Mr. (now Dr.) Rees deal with the copepods, those small crustacea which as a group are consistently the commonest forms in the zooplankton. Illustrations of a number of different species will be found in Text-fig. 13 on page xxxvii of the Explanation to Volume I. At certain times, in restricted localities, the larvae of some other animal may outnumber them in the plankton for a period, but throughout the year they are the most abundant single type, and because of

their numbers alone they play a vital part in converting the plants to animal protein. Relatively speaking, the copepod community is at low ebb during the winter in the North Sea, but in the spring, some time in April or May, they begin to multiply enormously. The authors show that there are several centres from which this rapid increase in the population starts and that one or two commoner species are responsible for their rapid build-up. Indeed, some of the less common species may be most numerous in the autumn or even during the winter months. The less common or less abundant species are not without interest, however, because they show well-defined limits of distribution and so may have value as *indicators* of water or, more important, of the movement of unusual environmental conditions. Four types of distribution are described in this 'Bulletin.' First, *Corycaeus* is restricted to an inshore band along the continental coast, rarely stretching far into the North Sea. Secondly, two species, *Labidocera* and *Isias*, are found only in the centre of the area concentrated over the Dogger Bank. Thirdly, *Euchaeta norvegica* and *Calanus hyperboreus* only appear over the Norwegian Deep. Fourthly, two species, about which we shall hear more, are found in the north-western part of the area where one might expect Atlantic conditions to impinge on those of the North Sea; they are *Metridia lucens* and *Candacia armata*. Particularly interesting is the fact that the south-eastern boundary of the distribution of these two forms appears to move progressively into the North Sea month by month from July or August until the end of the year. Between 1932 and 1937, when our most northerly route was that running between Hull and Copenhagen, odd specimens of both *Metridia* and *Candacia* were taken each year off the Humber or over the Dogger Bank during the winter months, and they now appear to have been those which have gone furthest in their annual north to south progression, or of their penetration into the North Sea.

'Bulletin' No. 12.

As we said above (for 'Bulletin' No. 8), two species of diatoms hold particular interest, *Rhizosolenia styliformis* and *Biddulphia sinensis*, and warrant special attention. Dr. Lucas and Dr. Stubbings measured large numbers of individual cells to see what type of variation in size might be expected, and whether it was possible to detect different strains by this method. They found that in the 20 months for which they had samples of *Rhizosolenia* from the North Sea, those found off the Scottish coast in the influence of the Atlantic water were only about half the diameter of those in the southern part of the area, and on their size alone could be recognized as having a northern origin. In the case of *Biddulphia* the larger cells were to be found close to the shore in the Heligoland Bight and the size range decreased as one sampled further towards the centre of the North Sea, i.e., the Dogger Bank region.

Possibly we should explain here something about why the size, the diameter in particular, of a diatom may be of considerable significance. Each diatom is a single vegetable cell contained in a rigid shell made largely of silica. In principle,

this shell comprises two halves, the one slipped inside the other like the two halves of a pill-box. When a cell divides, the two halves separate and each grows a new half pill-box inside itself; the outcome of this division is two daughter-cells, one identical in size to the former one, and the other fractionally smaller because it has grown a new half shell *inside* the smaller half of the old one.

The multiplication of the diatom crop at the time of the spring and autumn outburst is caused almost entirely by a rapid series of such cell divisions, some cells dividing into two as frequently as every few hours, but at each division half the daughter-cells are a little smaller than their parent so that gradually the average diameter of the population is reduced. Clearly such a procedure cannot go on indefinitely, and every so often, by a different mechanism of reproduction, a new population of large cells is formed. By measuring cells from samples taken each year from 1932 to 1939 and by combining these measurements with results of other workers, the authors are able to show in a most convincing manner the steady reduction in the average size of the cells and the sudden recovery at the time of spore formation. It appears that it takes something like three years for the cell diameter to drop from about 1/300 of an inch to 1/600th. This may at first seem to be a point of very little importance, but it may not prove to be so in the long run. If we could next determine accurately enough just how much a cell dropped in size at each division, we would have a type of estimate of how many cell divisions there had been in a given time or, indeed, how much plant life had been made available for the animal community. This might possibly, with much further work, be one of the ways of estimating productivity in the sea.

'Bulletin' No. 13.

In this Mr. Marshall deals with the distribution of the forms of zooplankton other than the copepods and the young fish. His results confirm and amplify the ideas of geographic communities and boundaries of distribution outlined for the phytoplankton ('Bulletins' 8 and 9) and the copepods ('Bulletin' 11); the weight of this confirmation is considerable, particularly for the north western community (see page 191). Not only does he find five or six animals of very different types behaving almost exactly in the same way as the two species of copepods, but amongst these is a species of arrow-worm, *Sagitta elegans*, which previous workers have demonstrated to be a typical inhabitant of the mixed Atlantic and North Sea water usually found at the north-western entrance to the North Sea and also of similar conditions in the English Channel. Another species of arrow-worm, *Sagitta setosa*, he found over the central North Sea, together with other characteristic forms, and the boundary between the two species of Sagitta moves south-east and north-west as the Atlantic flow into the North Sea waxes and wanes.

In another part of his 'Bulletin' Marshall compares the occurrence of the larvae of certain bottom-living forms, which are important in the diet of demersal fish in the plankton, with the previous surveys of the distribution of the adults

on the North Sea bed. This work has been continued in greater detail and will be reported in future ' Bulletins.'

'Bulletin' No. 14.

Here we consider in greater detail a single species of copepod during the 1938–39 period of the survey. Dr. Rees selected *Calanus* for his studies for a number of reasons ; it had already been studied more than most species ; it was sufficiently abundant to be of undoubted importance in the plankton complex, and it had a direct significance in being the staple diet of the herring. He shows that there are differences in the abundance and behaviour of *Calanus* in various parts of the North Sea and that, by and large, we may expect everywhere four periods of breeding or four generations in each year. Of these, the second, which takes place in April or May, is far and away the most successful.

For many years there has been discussion and argument between those concerned as to whether there were two recognizably *different* types of *Calanus finmarchicus* in the North Sea. On the one hand it was argued that there was another species called *Calanus helgolandicus*, and on the other that this form was indistinguishable from *Calanus finmarchicus*. That there is a recognizable difference between the two Rees has put beyond doubt by pointing out a consistent variation in the shape of one of the pairs of legs. Using this difference he is also able to show that one form is centred in the north and the other towards the south of the area.

'Bulletin' No. 15.

A series of charts show the distribution of young fish and fish eggs during the 1938 and 1939 survey and also for the earlier years, 1932 to 1937. Unfortunately Dr. Stubbings left the staff before his account of this interesting side of the work was completed, so the consideration of these results must await a subsequent ' Bulletin ' (No. 24 in Vol. III).

'Bulletin' No. 16.

The small plankton-collecting device known as the Plankton Indicator and its use in herring research have been described in the Explanation to Volume I. The comparison between herring catches and the plankton found in the immediate vicinity has been continued but some modifications of the Indicator have been introduced. In this last ' Bulletin ' of the volume, Dr. Barnes (of the Scottish Marine Biological Association) makes an experimental and statistical study of the reliability of the results obtained with the two models and compares their catching power and filtering efficiency. This highly technical paper is an important contribution to the herring-plankton work to be described later in that it establishes the validity of the method of sampling upon which so much of this work is based.