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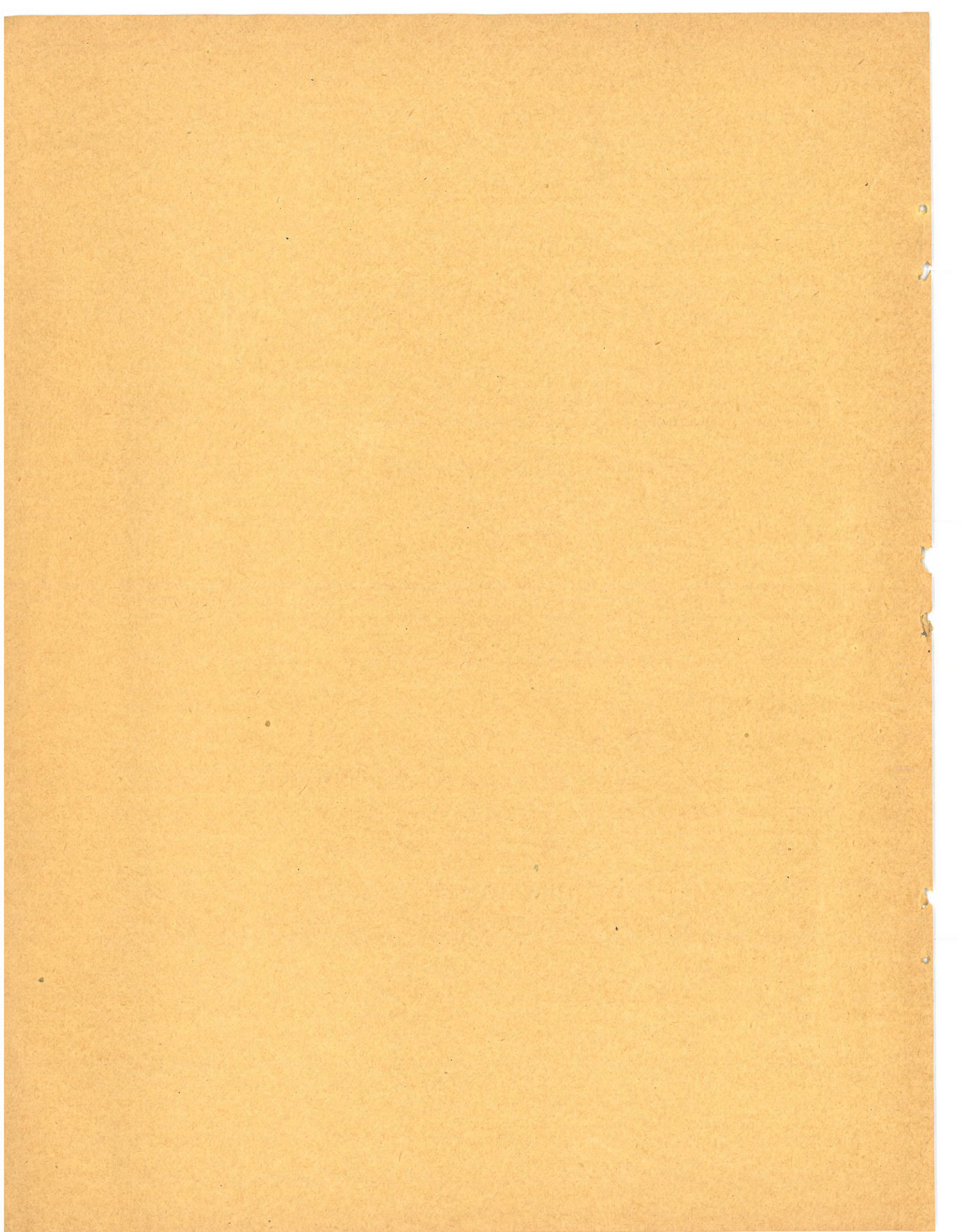
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RAPPORTS ET PROCÈS-VERBAUX DES RÉUNIONS DU CONSEIL  
PERMANENT INTERNATIONAL POUR L'EXPLORATION DE LA MER  
VOL. XCV, 1935

*Hardy*



Vlaams Instituut voor de Zee  
Flanders Marine Institute



Eigendom van het  
Westvlaams Economisch Studiebureau  
Brugge Reeks / Boek

# THE CONTINUOUS PLANKTON RECORDER: A NEW METHOD OF SURVEY

BY

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A brief account of the method together with examples  
of some of the results obtained in collaboration with

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C. E. LUCAS, B. Sc. and  
J. H. FRASER, M. Sc.,

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University College, Hull.

ON being invited to give a preliminary account of the experiments we are making from Hull in the charting of the North Sea plankton, I accepted with some diffidence, because we are only just reaching a stage in our survey when it is possible to consider correlations and make comparisons between *one year and another*. I did so because I felt that if the methods and a few examples of the results were discussed at the present stage, the work would benefit most by my inviting the criticism of members of the International Council.

Whilst the present survey has been in progress for just three years, experiments in the method began in 1925 on the first of the present series of expeditions to the Antarctic under the Discovery Investigations. I had been impressed by the sometimes remarkable patchiness of the plankton distribution in the North Sea. By using tow-nets at stations not very close together one must at times obtain a very inadequate impression of the true plankton distribution. It seemed desirable to construct a machine, which could be towed at any required depth below the surface, and, by continually sampling the plankton mile by mile as the ship proceeded on her course, would enable one to measure the size, density and frequency of patches, and compare the irregularity of distribution in different areas. Further, by correlating the varying populations of different species one could make an uninterrupted line of ecological observation across the sea.

The first machine (Hardy 1926), whilst presenting many difficulties and undergoing considerable changes, successfully recorded the variations in the plankton for over 4,000 miles of sea, and showed that the method was practicable.

It now seemed possible to apply the method to a wide and repeated survey of the sea using commercial ships, and to this end a new machine was designed embodying the improvements gained from former failures and reduced to the smallest size consistent with efficiency (Fig. 1). A full description of this machine will be published shortly. It is torpedo-shaped and provided with a system of planes which make it dive and swim horizontally at

a constant depth for a given length of towing rope (for speeds of 6 to 13 knots). A shock absorber placed at the towing head eliminates vibration. The water to be sampled enters by a small unobstructed opening at the front, passes down a tunnel, the cross-section of which increases greatly in area, until it reaches the filtering gauze and then out at the back. The filtering gauze, silk bolting cloth of 60 meshes to the inch, is a long banding arranged to wind off one roller and pass across the water tunnel, immediately after which it is met by another gauze banding winding off a second roller and together they pass between two driving rollers and on into a tank of formalin. In passing across the water tunnel the gauze is supported behind by a grid work of fine metal rollers. The filtering gauze banding is ruled with transverse numbered lines, two inches apart. The bandings are wound on by the action of a propeller in the passing water outside, so that for every mile of sea through which the instrument is towed a fresh section of gauze samples the plankton, which

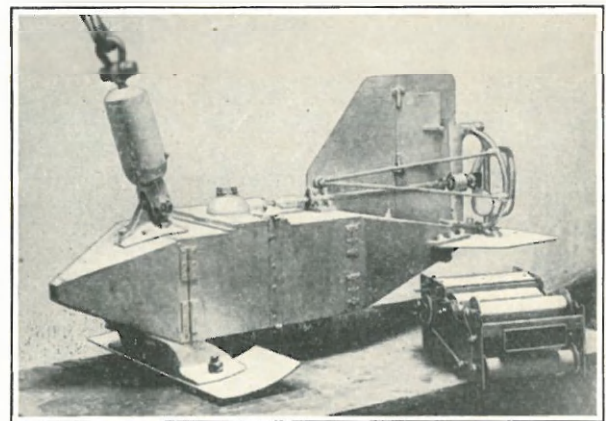


Fig. 1. The Continuous Recorder

Note the diving planes, the entrance to water-tunnel in front, and the propeller behind for driving the internal mechanism, which, for the purpose of the photograph, has been taken out and placed alongside to show the system of rollers.

remains pressed against it till it meets the second fabric and is imprisoned between the two. The driving rollers grip the banding only at their edges, which are free from plankton. In the formalin preservative chamber the fabrics are wound on a storage roller operated by a friction drive, so that there is no acceleration in winding speed due to increasing diameter. At the end of a run the roll is taken out, placed in a special examination stage, which separates the two fabrics and allows the plankton to be examined *in situ* under a travelling microscope. The number of organisms per division of silk can thus be estimated, and since the actual number of miles travelled is known from the ship's log the distance of sea represented by each division of silk is known. The pitch of the propeller blades may be adjusted, so that the speed of winding and thus the scale of working may be varied from one to more miles per division as desired.

Having obtained the kind co-operation of different steamship lines and their officers, and equipped the ships with special winches, davits, etc. for handling the machines, we began, after a



Fig. 2.

The continuous plankton recorder (ringed with white) as fitted on the s.s. *Albatross* between Hull and Bremerhaven, ready for lowering away.

series of preliminary trials, a programme of surveying the southern North Sea, in June, 1932. Fig. 2 shows the recorder on the S.S. "Albatross" plying between Hull and Bremerhaven. The main objects of the survey are to chart the broad monthly changes in the density of the plankton along a series of lines across the North Sea run as nearly as practicable at the same time, to correlate as far as possible the seasonal and yearly variations observed with changing hydrological and meteorological conditions on the one hand, and with fluctuations in the fisheries on the other, and in addition to provide extensive material for the study of ecological relationships between different

members of the phyto- and zooplankton. As far as possible lines have been run every month between Hull and the Skagerak, Hull and Bremerhaven, and Hull and Rotterdam, and more recently a fourth quarterly line between Hull and the Pentland Firth has been added. The instruments are set ready for action in the laboratory before being sent to the ship, put overboard on leaving the coast and taken in on the other side by the officer in charge, definite points, usually lightships, being chosen to mark the beginning and end of a run. When a mark on the wire towing-rope is veered to the water-line the instrument swims at a constant depth of 10 metres.

Space will only permit of a few examples of results being given; later, when four or five years' work has been completed, a full report will be published jointly with my colleagues Dr. G. T. D. Henderson, Mr. C. E. Lucas and Mr. J. H. Fraser, who have carried out the analyses. The correlations with hydrology, meteorology and fisheries will then be dealt with. The present examples are only intended to illustrate the types of changes in distribution we are finding.

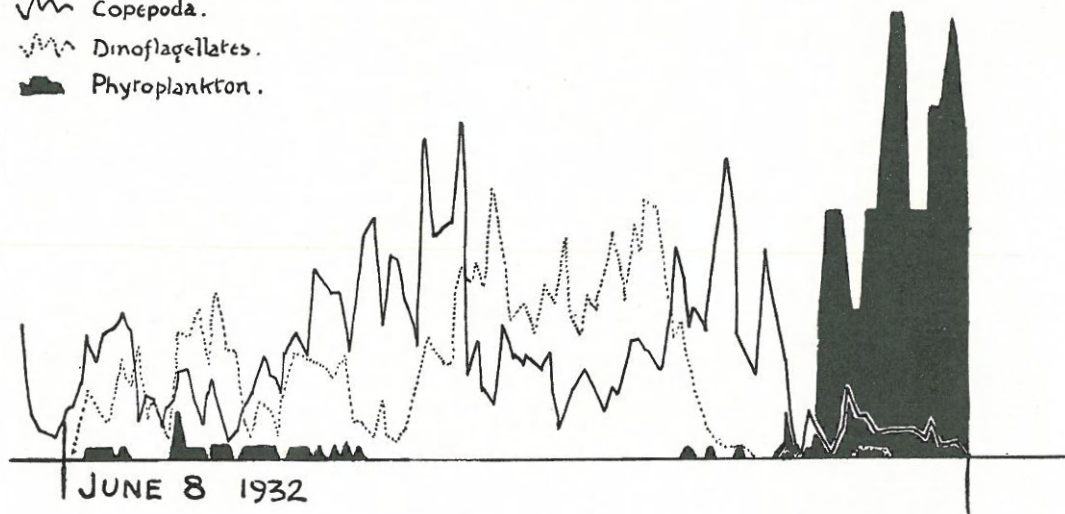
With our limited staff it is impossible at present to analyse the plankton in complete detail. Already records of some 20,000 miles of plankton have been made. Whilst we are paying particular attention to the different species of the larger phytoplankton (the smaller forms not being adequately sampled by the mesh we are at present using), we are only attempting to record the changes in density of the main groups of zooplankton: total Copepoda, *Sagitta*, *Limacina*, *Evadne*, *Podon*, etc. The plankton for each section of the rolls is however removed and stored separately, so that any line may be worked up in fuller detail if later it is required and time is available. A rough estimate of the proportions of the common species of Copepoda is however recorded for each section. Such limitations in analysis are to be regretted, but we hope that information regularly obtained regarding the variations in the production of the main groups of plankton organisms in different seasons and in different years will throw new light on the fundamental changes taking place in the area investigated.

Fig. 3 shows examples of the changes in production of Phytoplankton, Dinoflagellates (largely *Ceratium*), and Copepoda during four months on 182 miles of the Hull—Bremerhaven line, between the Outer Dowsing and Borkum Lightships (vertical lines left and right respectively).

Fig. 4 shows the changes in Copepoda and phytoplankton patches in the autumn of 1933.

Fig. 5 shows the varying density of *Phaeocystis*, *Rhizosolenia styliiformis* Brightw., and *Biddulphia sinensis* Grev. on the Hull—Bremerhaven line during 1932, 1933 and 1934, the vertical lines left

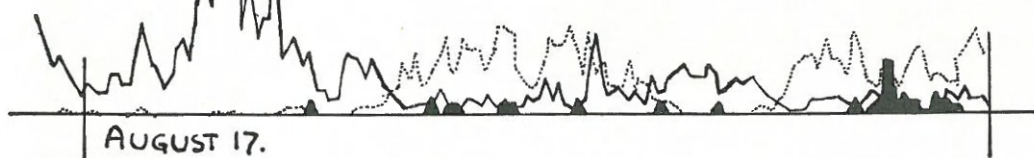
~~~~~ Copepoda.  
..... Dinoflagellates.  
■ Phytoplankton.



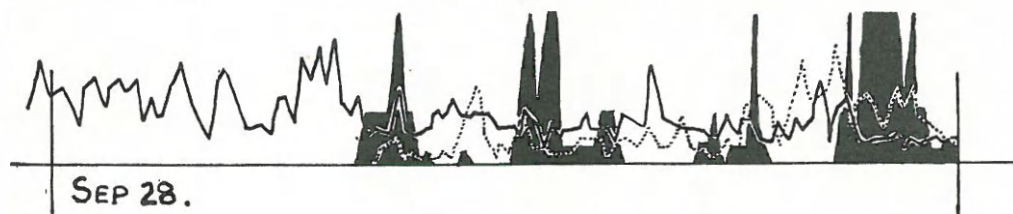
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Fig. 3.

Comparative graphs showing variations in the plankton during four months on 182 miles of the Hull—Bremerhaven line between the Outer Dowsing and Borkum Lightships (shown as vertical lines left and right respectively): Copepoda, Dinoflagellates (largely *Ceratium*) and other Phytoplankton (Diatoms, except for *Phaeocystis* at eastern end of June line).

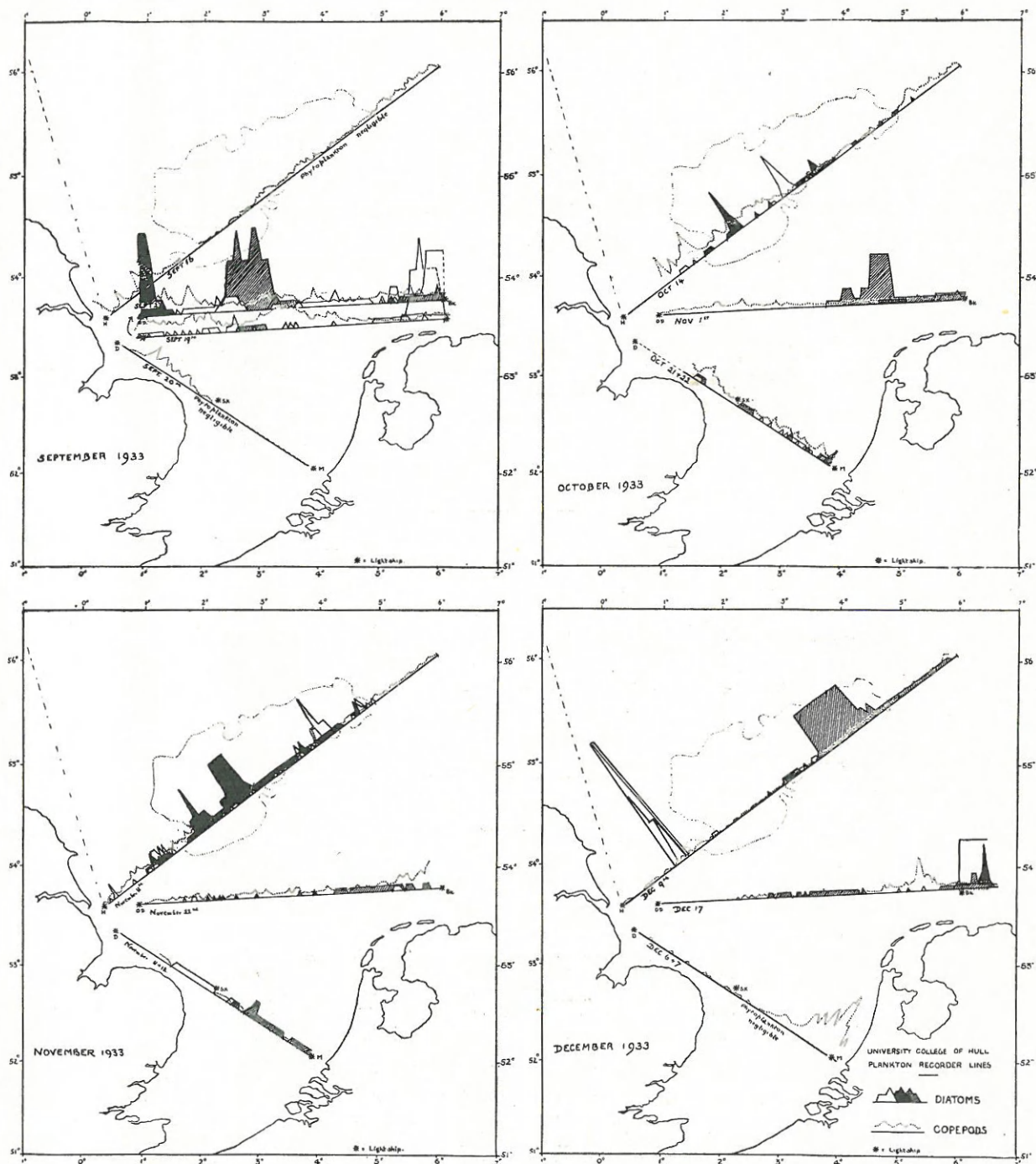


Fig. 4.

Charts showing diatom patches on the Hull—Skagerak, Hull—Bremerhaven and Hull—Rotterdam lines during the autumn of 1933. *Rhizosolenia styliformis* shown black, *Biddulphia sinensis* shaded, other species in line. In addition the total Copepoda are shown by dotted line.

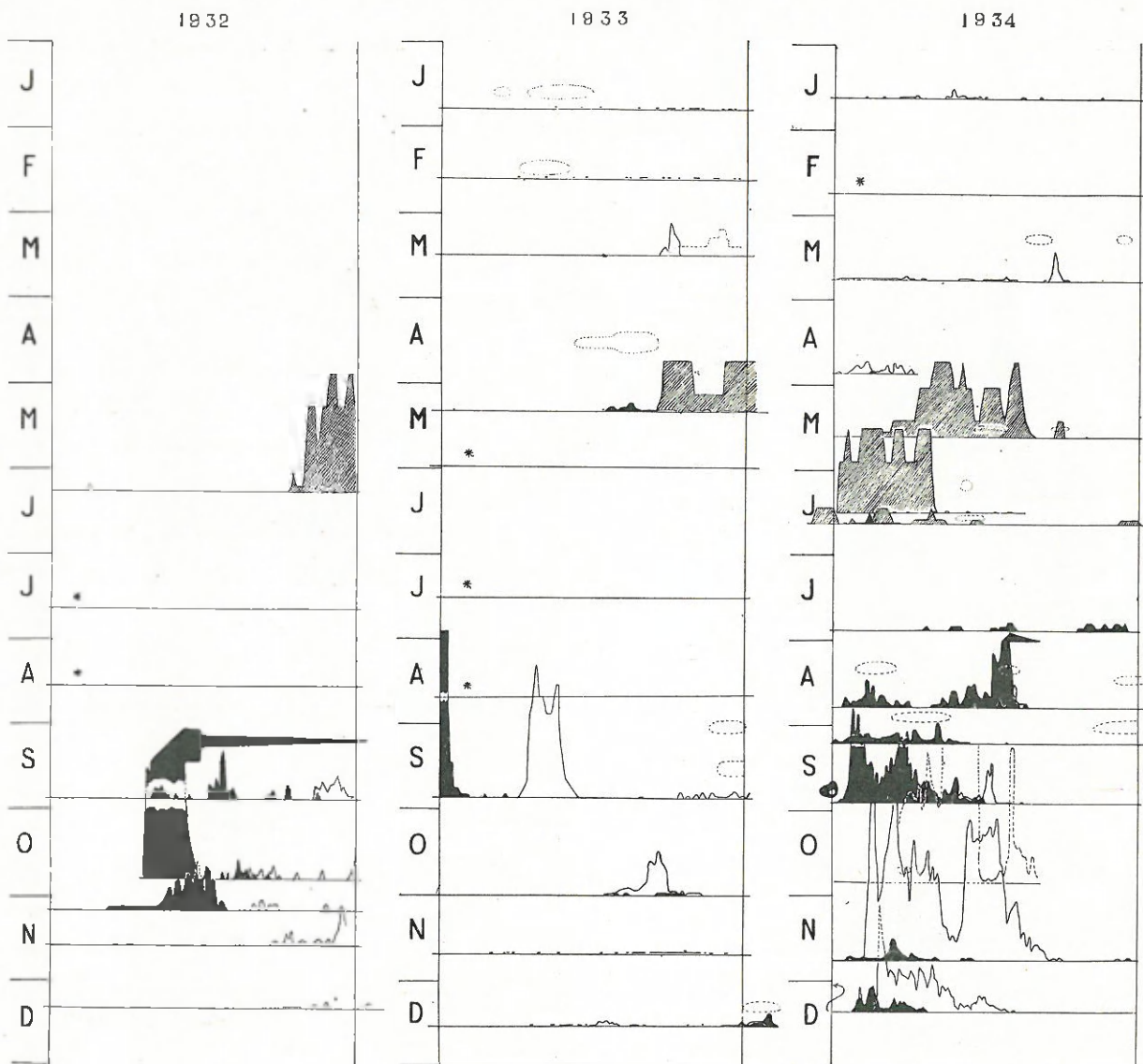


Fig. 5.

Graphs showing the varying density of *Phaeocystis* (shaded), *Rhizosolenia styliiformis* (black) and *Biddulphia sinensis* (line) on the Hull—Bremerhaven line during the years 1932, 1933 and 1934. Concentrations of smaller species shown enclosed by broken lines. An asterisk indicates phytoplankton is negligible. The records are arranged in their correct time positions in relation to the scale of months at the side, shown as J, F, M etc. The positions of the Outer Dowsing and Borkum Lightships are shown by the vertical lines left and right respectively.

and right again marking the position of the Outer Dowsing and Borkum Lightships respectively. A time scale in months marked J, F, M etc. is given at the side and the records drawn in opposite their appropriate dates. Figs. 6, 7 and 8 in a similar manner show the varying densities of Dinoflagellates (largely *Ceratium*), Copepoda and *Sagitta*. Similar charts, not shown, have been prepared for other lines. They illustrate clearly the broad changes in plankton production, which it is the

aim of the method to reveal: for example, the greater production of Copepoda and *Sagitta* in the late autumn of 1932 as compared with the two subsequent years, the repeated increase in Copepoda towards the east in the early months of 1933 and 1934, which is confirmed again in the present year, the dying down and reappearance of a second crop of Dinoflagellates in 1934, and the marked differences in phytoplankton production in the three years. The probable importance of these

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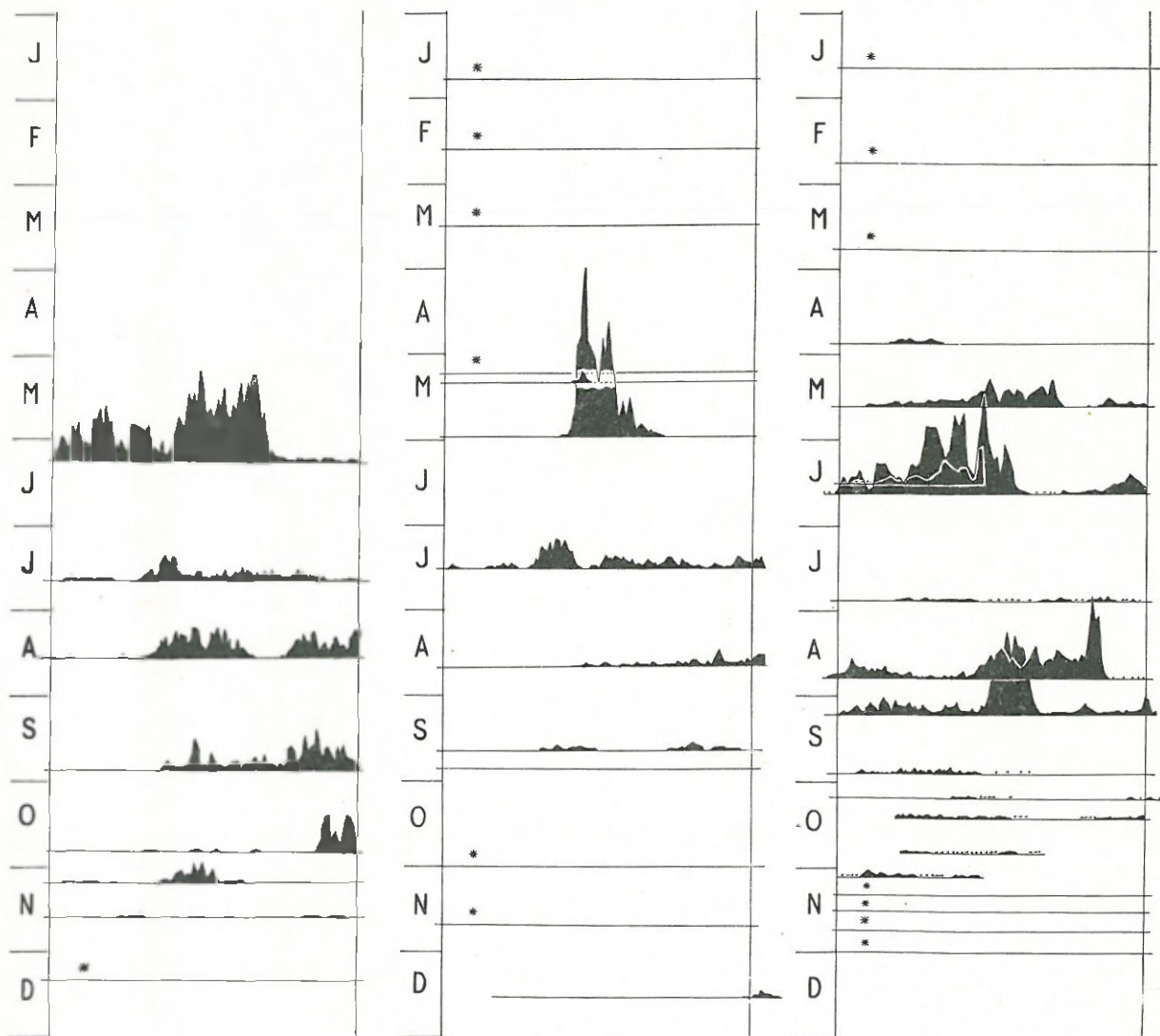


Fig. 6.

Graphs showing the varying density of Dinoflagellates (mainly *Ceratium*) on the Hull—Bremerhaven line during the years 1932, 1933 and 1934. An asterisk indicates Dinoflagellates are negligible. The records are arranged in their correct time positions in relation to the scale of months at the side, shown as J, F, M etc. The positions of the Outer Dowsing and Borkum Lightships are shown by the vertical lines left and right respectively.

phytoplankton patches to the East Anglian herring fisheries has recently been demonstrated (Savage and Hardy 1935). We are working in close co-operation with the Ministry of Agriculture and Fisheries, who are carrying out more detailed surveys of these patches from research ships. Fig. 9 shows a more intensive study of these patches carried out on weekly lines in the autumn of 1934.

The continuous recorder is in no sense intended as a rival to the older methods of research, but we

hope it may be regarded as a supplementary method indicating in outline the larger changes characterising the different seasons and different years. We hope it may be the means of establishing a service of *marine phenology*, in that from year to year standard records will be available from different parts of the North Sea of the dates when this or that organism reaches a certain degree of density or when a decline sets in. We hope too that the knowledge of the meteorological, hydrological and

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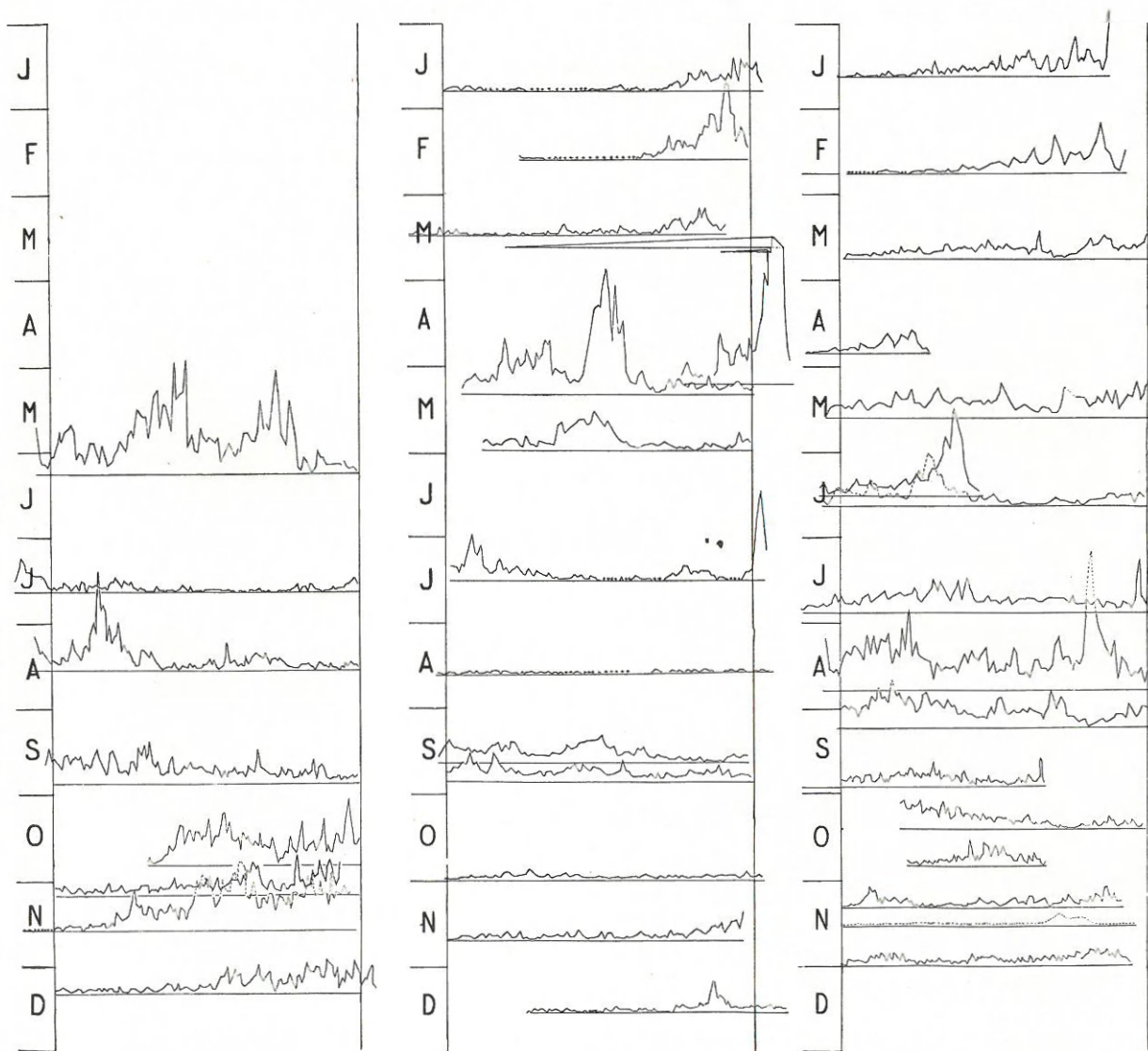


Fig. 7.

Graphs showing the varying density of total Copepoda on the Hull—Bremerhaven line during the years 1932, 1933 and 1934. The records are arranged in their correct time positions in relation to the scale of months at the side, shown as J, F, M etc. The positions of the Outer Dowsing and Borkum Lightships are shown by the vertical lines left and right respectively.

biological correlations, built up over a number of years, will reveal some of the causes governing the major fluctuations.

As in all methods, there are disadvantages. There are, we believe, two major ones. Firstly, in regions of rich plankton the small filtration area of the silk is apt to become somewhat clogged, so that filtration and catching power are reduced. This difficulty applies, although to a lesser extent,

in ordinary tow-nets. We believe, however, that it is not a serious one. It means that whenever organisms are taken in very large numbers one must realise that the actual numbers present in the sea are very much larger.

The second and more serious difficulty is that due to the use of only one instrument making a record at a uniform depth when some of the organisms are carrying out diurnal vertical migrations. Our

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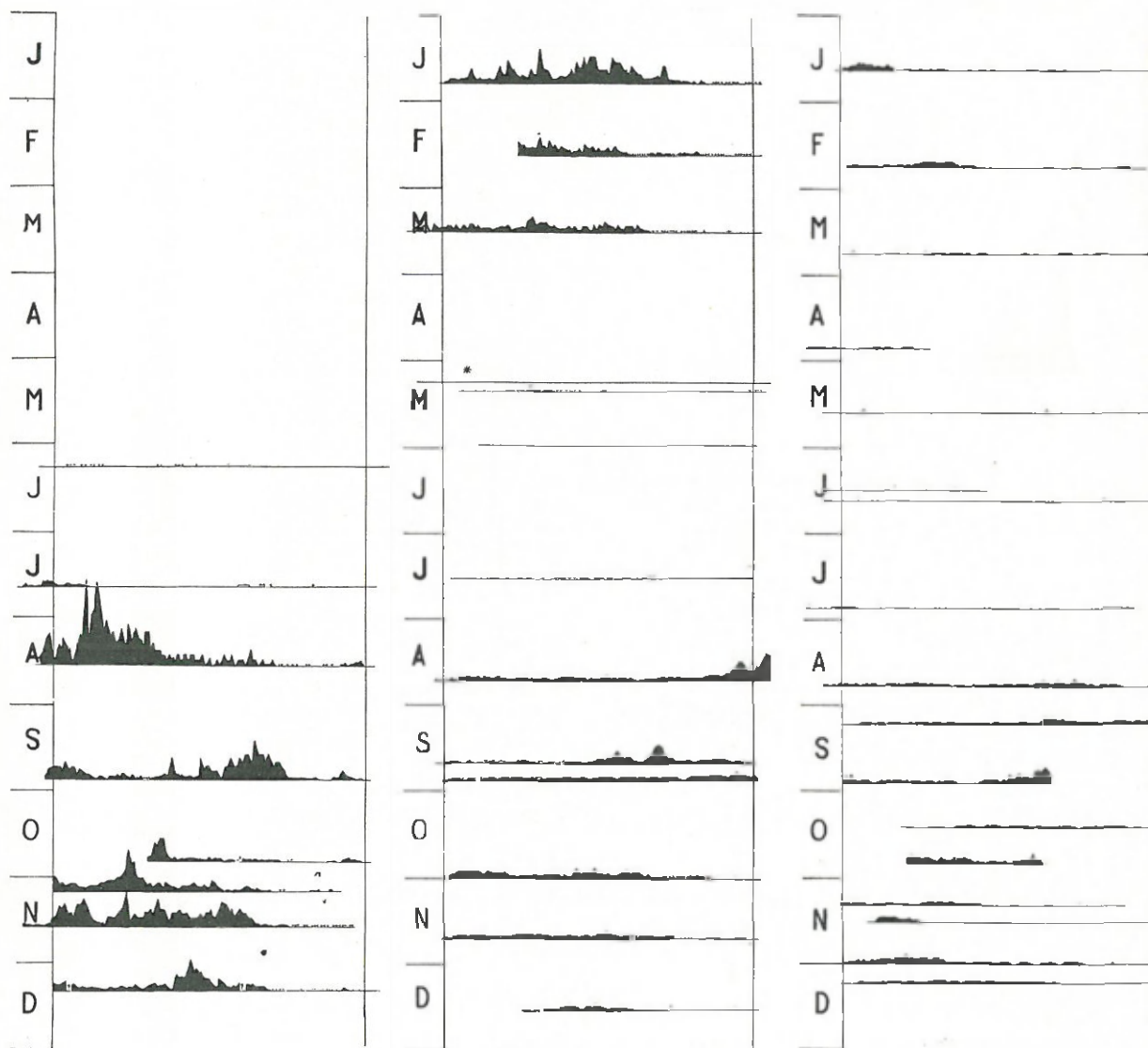
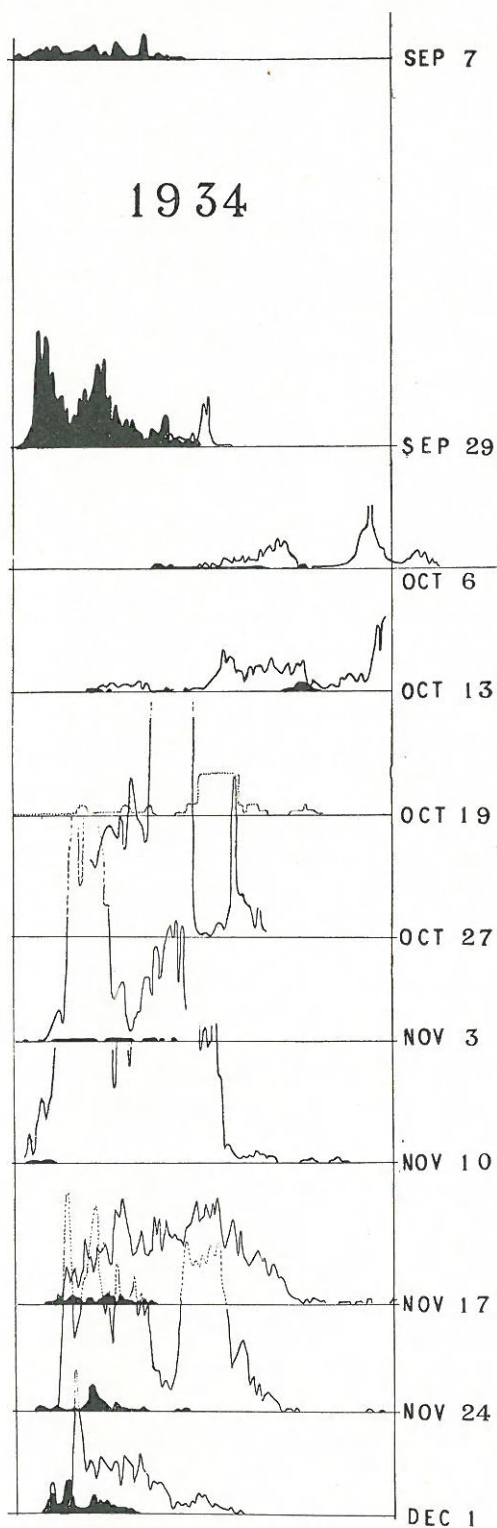


Fig. 8.

Graphs showing the varying density of *Sagitta* on the Hull—Bremerhaven line during the years 1932, 1933 and 1934. An asterisk indicates that *Sagitta* is negligible. The records are arranged in their correct time positions in relation to the scale of months at the side, shown as J, F, M etc. The positions of the Outer Dowsing and Borkum Lightships are shown by the vertical lines left and right respectively.

standard depth of towing is 10 metres, chosen for the southern North Sea as the most suitable depth to give most consistent results. An ideal arrangement would be the towing of two instruments, one below the other, at a convenient depth apart. Their cost at the moment precludes this. Mr. J. O. Borley has recently made the very interesting suggestion that it might be possible to alter con-

tinually the tilt of the diving plane by a cam action from the driving mechanism, so that the instrument oscillates regularly in depth once or twice for each mile covered, thus giving a similar effect to an oblique tow-net haul. Whilst maintenance of stability may be difficult to achieve under such conditions, it should not be impossible, and experiments will shortly be made in this



direction. Actually, on the results (from 10 metres depth) we are obtaining from the shallow regions of the southern North Sea, differences in the quantity of zooplankton at different times along the lines of observation do not suggest a marked influence through vertical migration. Fig. 10 shows the Hull—Bremerhaven Copepod records arranged with the mid-day points directly below each other; the positions of sunrise and sunset are shown by dotted lines. If vertical migration were pronounced, then there should be a general tendency for larger and smaller quantities to be taken in relation to times of day. Considerations of vertical migration cannot be held to explain the major differences in plankton production illustrated in the sample figures 5 to 8. More serious are the variations in the general depth distribution of the plankton at different seasons and in different years, giving false impressions of relative density of populations. This factor emphasises the importance of putting Mr. Borley's valuable suggestion into practice.

Another disadvantage of the method is the condition of the specimens; they are often crushed and broken in the process of winding, rendering identification a longer and more tiring process than the examination of ordinary tow-net samples. This too is a difficulty which we hope will in future be largely overcome by improved mechanism. It should be noted that the plankton is not mangled between the driving rollers, which do not press together, except at their ends where they grip tightly the edges of the silk.

Important points for discussion by planktologists are those concerned with size of mesh, detail of analysis and scale of working to be adopted. Given a limited number of workers and time available, one may choose between a more detailed analysis and larger scale of working (i. e. more miles per division of silk), and a less detailed analysis but smaller scale of working (fewer miles per section). At present we are working on a scale of 1.5 to 2 miles per section. It will be realised that if one section of silk is wound on for each mile of sea passing the machine, then that section will collect plankton not only from one mile of water, but it will also sample a fraction of the preceding and succeeding miles as well. Thus when the plotted curve of results shows marked irregularities, it is in reality a smoothed effect, and the irregularities in the sea are even more pronounced. A closer approximation to the true irregularities can be obtained by calculation. Whilst the mileage per section varies slightly on different runs, the graphs of results are made

Fig. 9. Graphs showing a more intensive study of the varying density of *Rhizosolenia styliiformis* (black) and *Biddulphia sinensis* (in line) on the Hull—Bremerhaven line during the autumn of 1934. The positions of the Outer Dowsing and Borkum Lightships are shown by the vertical lines left and right respectively.

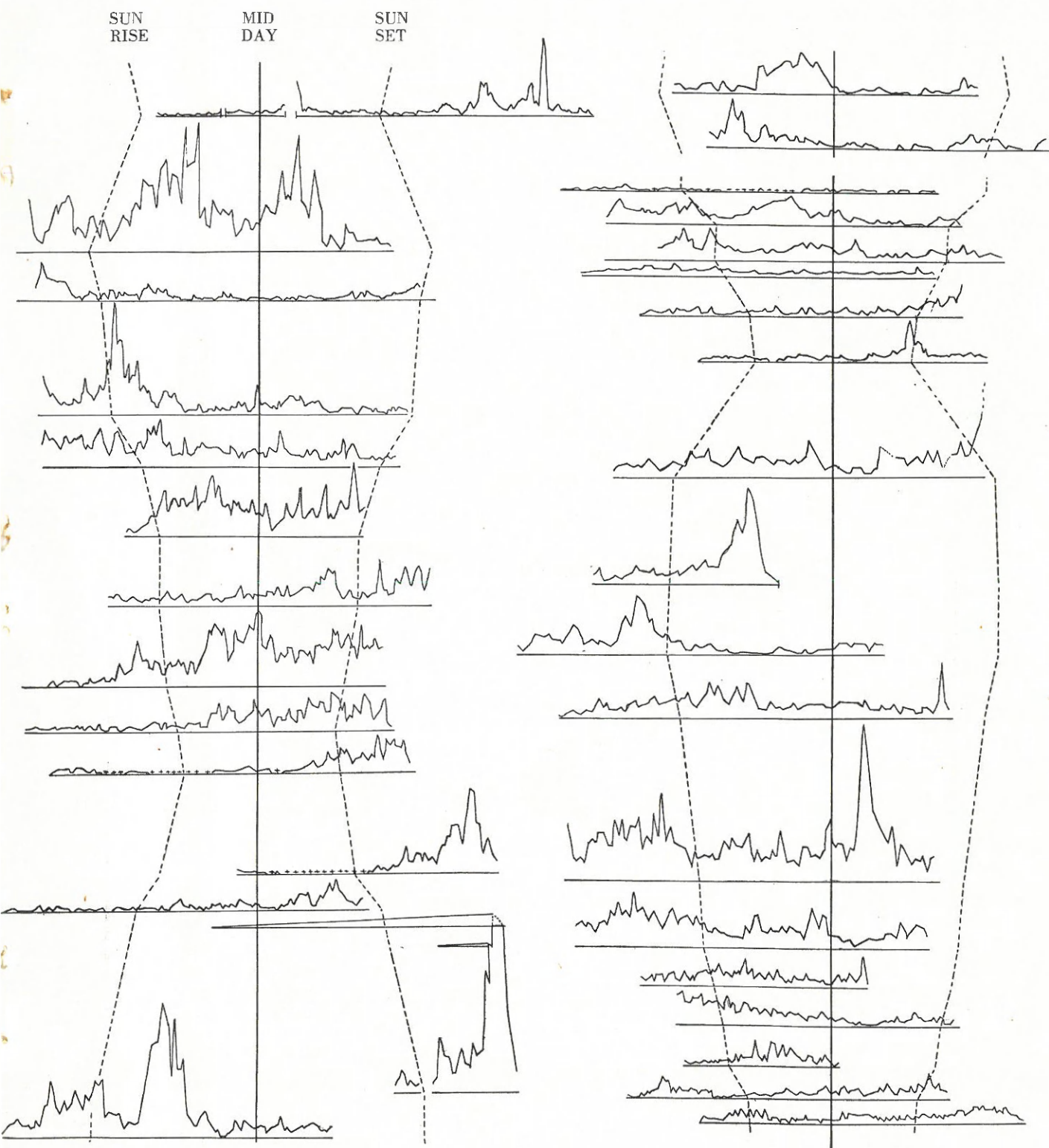
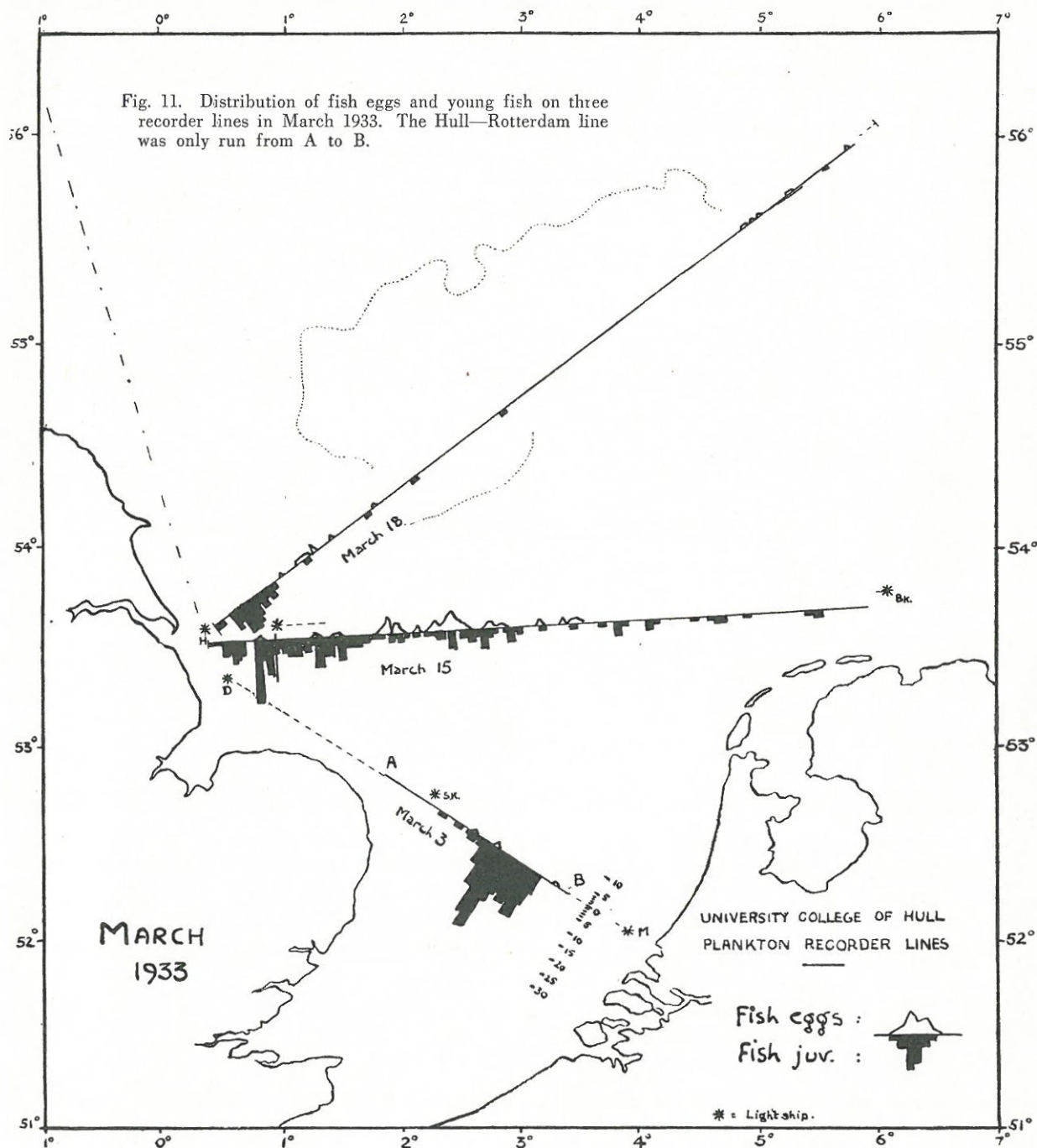


Fig. 10.  
Copepod graphs from the Hull—Bremerhaven line arranged so that their mid-day points are directly below one another (vertical line). The dotted lines show the positions of sunrise and sunset. For further explanation see text p. 44.



comparable by plotting the values as numbers per mile for each division.

The mesh of 60 threads to the inch was chosen as one which would effectively sample the Copepoda and at the same time record the denser patches of the larger phytoplankton organisms,

which are probably of such importance to the herring fisheries. It is hoped in later models to combine with the present system a narrower banding of very much finer gauze for the smaller phytoplankton. Rolls of much wider mesh could be used with a larger opening to the water tunnel for

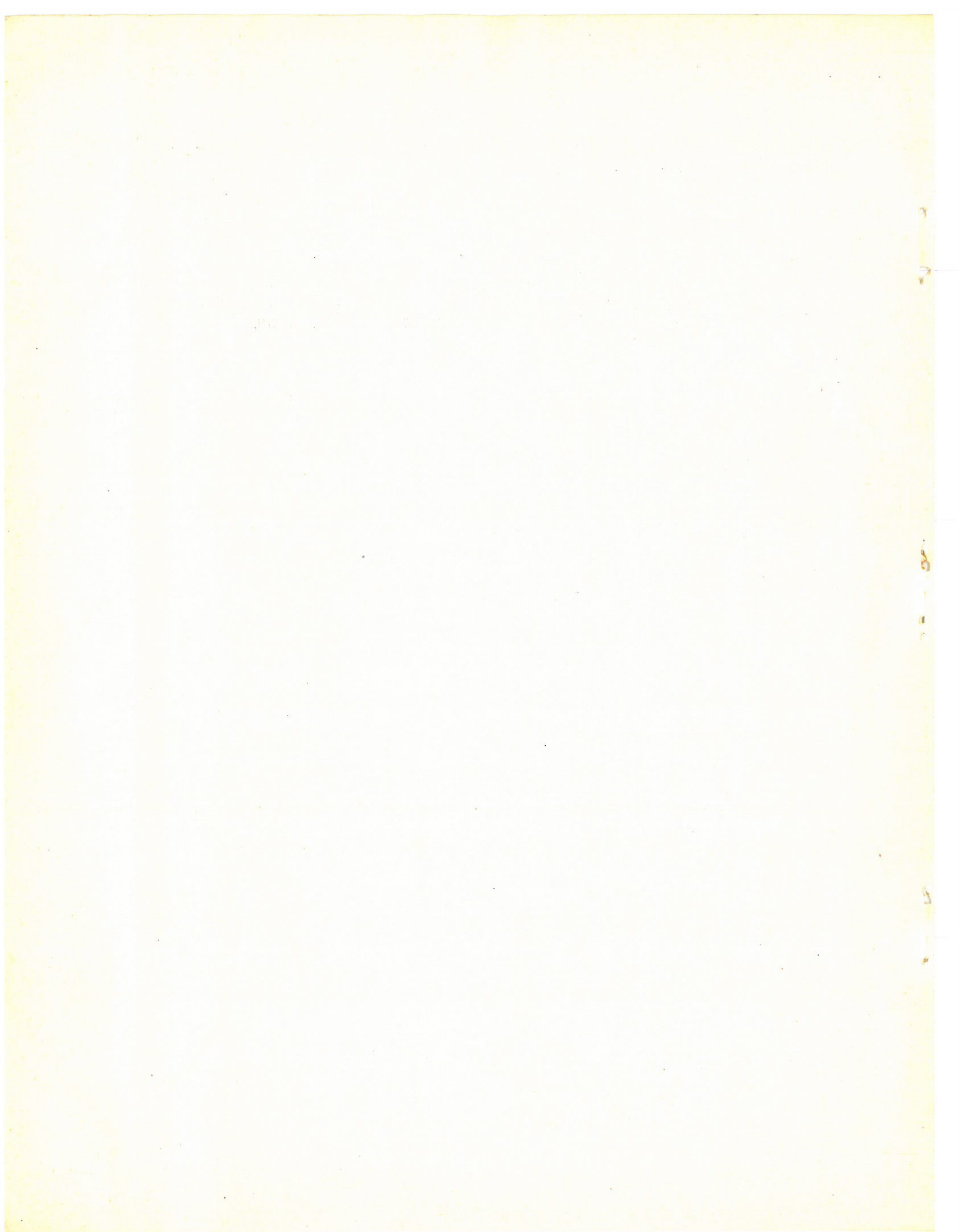
the capture of larval and post-larval fish in larger quantities. Fig. 11 shows an example of young fish and fish egg distribution as obtained with the present aperture ( $\frac{3}{4}$ " square) and mesh. It is hoped as the survey work advances to be able to make extra runs with larger aperture and wider mesh, so that perhaps three times the quantity of water would be sampled for the better estimation of young fish and fish egg production.

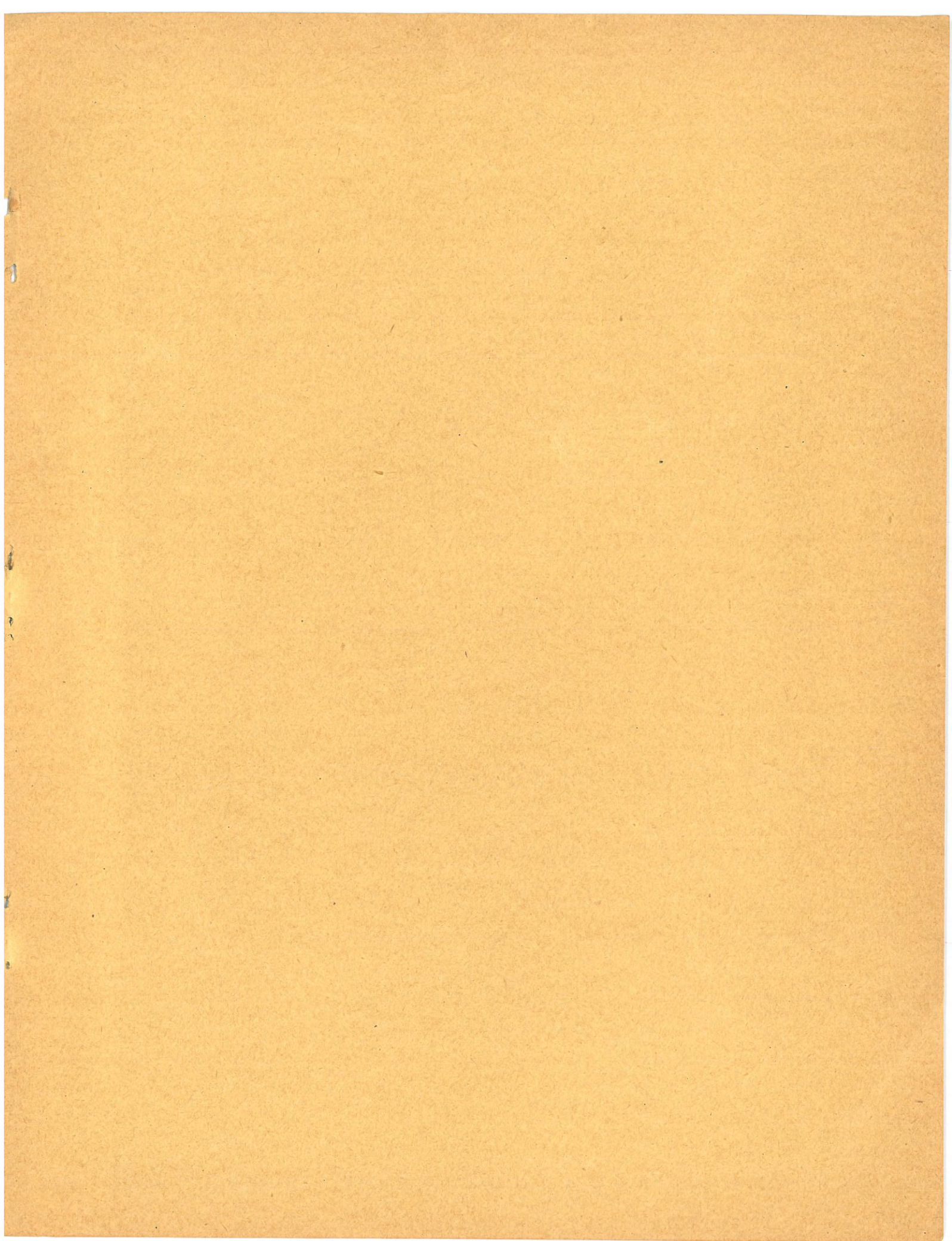
We hope that the lessons we are learning from these experiments and from the criticisms of those interested will enable us to provide an improved

service of value to the International Investigations, and that in time the means may be found for extending the lines of observation, particularly to include more of the lines upon which monthly thermograph records are now being taken.

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