Part IV. The Relation between Catches of Herring and Phytoplankton Collected by the Plankton Indicator.

By

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With 4 Figures in the Text.

CONTENTS.

INTRODUCTION.

THE object of these investigations, discussed in full in Part I, is an attempt to correlate the catches of the drift-net herring fishery with the conditions in the plankton at the time of fishing, and if possible to establish useful indications as to suitable and unsuitable waters for fishing. In Parts II and III the zooplankton-herring correlations in the English and Scottish fisheries have been dealt with separately. The phytoplankton material with which this section deals is not so extensive, so that the data from both fisheries will be dealt with together. The pioneer observations of Pearcey (1885) in regard to the herring, of Bullen (1908) in regard to the mackerel, and the fact that fishermen have for long regarded what they call " weedy " or " stinking " water as a bad sign for fishing, have been referred to in Part I, page 148.

In 1922–23 Hardy (1926), making the first experiments with the Plankton Indicator in the Southern Bight, found that the catches associated with Indicator discs coloured green by phytoplankton were much lower than those with discs not so coloured. The number of records obtained was small, but the results, in support of those of Pearcey, appeared to be of considerable significance. In the autumn fishery of 1922 twelve discs were obtained with associated catches of herring. The average catch was 14·1 crans. Six of the discs were coloured green by

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Phæocystis and had associated catches varying from 0·5 to 6·0 crans (av. 2·9 crans), and six discs were free of phytoplankton and had catches ranging from 15 to 45 crans (av. 25·3 crans). In March, 1923, only two records were obtained, one was green with diatoms and was associated with a catch of 1·5 crans and the other (not coloured green) was taken with a catch of 24 crans.

During the investigations carried out from Hull in 1930–33 further information has been obtained on this relationship. We have only considered those discs which were definitely green or greeny brown with phytoplankton, i.e. those which could be easily recognised as green or brown by the fishermen if using the indications as a guide to fishing. Out of 1,256 samples with the standard Indicator only 55 were definitely coloured. This was after the discs had been stored for a considerable period in formalin; it is likely that a larger number would have been included in the category of green or brown discs if they had been examined whilst fresh, i.e. as the fishermen could have used them for indications. The small proportion of green discs may perhaps be due to several causes, (1) that the bulk of the material was collected in the summer when dense phytoplankton concentrations are rare, (2) that a very small number of samples was obtained in the autumn East Anglian fishery (see p. 282) and (3) that the fishermen, who believe that "stinking" or "weedy" water is a bad sign for fishing, will have avoided such dense phytoplankton when once aware of its presence.* In the autumn fishery of 1934 a special experiment was designed with a miniature Plankton Indicator for phytoplankton only and 150 discs were obtained of which 42 were green in colour. The results with the standard Indicator will be dealt with first.

Results with the Standard Indicator, 1930–33.

A list of the green or brown discs with their associated catches is shown in Table I, together with the associated numbers of *Calanus finmarchicus* (Gūnn) and *Limacina retroversa* (Flemming).† The names of the principal forms of phytoplankton are given in brackets. Table II gives a comparison between the average catches of herring associated with the green or brown discs and those with discs not so coloured, separated into half-monthly periods for the different fishing areas. Similar averages for Calanus and Limacina are also given. The 1922 and 1923 results are added. There are twenty-two periods when comparison can be made, in only four of these are the catches associated with the green discs higher than the remainder, and in three instances these are only based upon one green

* Although occasionally dense phytoplankton concentrations may be detected at the surface, as a rule they are only evident after the nets have been shot and hauled in such conditions.

† See notes concerning these two forms on page 179 of Part II of this series.

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disc.* There appears to be no significant difference between the catches associated with Phæocystis and those associated with diatoms. The average catch of those recorded as definitely Phæocystis only, is 1·6 crans (for 13 samples), and for diatoms only, it is 2·1 crans (for 29 samples). The average catch for all the 62 green or brown discs is 1·9 crans.

There can be no doubt that such an indication must be reliable and valuable to the industry when it is used to save both time and money by avoiding waters in which it is highly probable that the catches will be poor.

The fact that both Calanus and Limacina also more frequently show smaller numbers in the phytoplankton regions is of considerable interest. The problem of the inter-relations between the zooplankton and the phytoplankton has been discussed at length in a recent publication by Hardy (1935). He believes that, in addition to the grazing effect of the zooplankton on the phytoplankton (cf. Harvey, 1934, and Harvey, Cooper, Lebour and Russell, 1935), there is a tendency for the smaller numbers of plankton animals to occur in regions of denser phytoplankton due to some direct or indirect excluding influence of the latter. The fact that here Limacina as well as Calanus bears a general inverse relationship to the phytoplankton would suggest support for the exclusion hypothesis, for here Limacina occurs in comparatively small numbers and so it can scarcely be regarded as controlling the phytoplankton, if indeed it is feeding on it. The question as to whether the herring avoids the phytoplankton because its food is distributed in inverse relation to it is also discussed by Hardy (loc. cit.). He believes it unlikely that such a habit, even if formed in the feeding season, would be retained in the autumn spawning season when the herring are not feeding and when the evidence shows (Savage and Hardy, 1935) that they may be deflected from, or delayed in arriving at, their collecting grounds by the phytoplankton patches. The factors underlying the relationship between the phytoplankton and marine animals are by no means fully understood as yet and a complex of different factors may contribute to the observed effects.

Results with the Miniature Indicator, Autumn, 1934.

It was considered that, while there was little doubt as to the basic fact of avoidance by herring shoals of areas of dense phytoplankton, further information should be obtained on the actual relation between catches of

* The catches obtained during these 22 periods may be examined statistically. For each period, column 3 of Table II shows the average catch associated with the green discs whilst column 4 shows that with the non-green discs. We find that the mean catch of column 3 is only 31·6% of the sum of the means of columns 3 and 4 whilst that of column 4 is 68·4%. Thus the difference of the means is 36·8% of their sum. The Standard Error of this difference is found to be $\pm 10{\cdot}8\%$ with a corresponding value for "t" of 3·42. There is thus a high degree of probability of the significance of this difference.

TABLE I.

List of Discs, in Areas and with Dates, Coloured Green, Pale Green, Greenish or Brownish.

		Calanus.	Limacina.	Catch (crans).
1931. Scotland West Coast.				
1st July	Diatoms (N. Ch. Th.)*	36	770	0·0
,,	,, (N. Ch. Th.)	36	2522	0·25
,,	,, (N. Ch. Th.)	36	2522	1·25
,,	,, (Sk. M.)	24	572	0·0
21st July	Phæocystis	17	1620	2·25
,,	Diatoms (Rh. spp.)	35	400	3·25
26th August	?	456	600	0·0
,,	?	456	600	1·75
1931. Scotland East Coast.				
26th June	Phæocystis	15	14	0·5
30th ,,	,, and Diatoms (Rh. spp. N.)	8	8	3·25
2nd July	,, ,, (Rh. spp.)	40	0	1·5
3rd ,,	,, and some Diatoms (Rh. spp.)	10	0	0·0
7th ,,	,,	12	0	4·0
9th ,,	? (Diatoms and possibly Phæocystis)	3	30	3·0
11th ,,	Diatoms (Th. N.)	0	8	4·0
14th ,,	Phæocystis	0	0	1·0
15th ,,	,,	0	20	1·25
16th ,,	?	0	20	1·0
17th ,,	Phæocystis	0	4	1·0
20th ,,	,,	18	10	0·5
30th ,,	,,	86	8	0·5
6th August	,,	240	48	0·0
10th ,,	?	656	72	1·0
1931. Southern Bight.				
6th October	Phæocystis	10	72	1·0
13th ,,	,,	0	0	1·0
1932. Scotland East Coast.				
27th May	Diatoms (Th.)	184	0	7·0
11th July	Phæocystis	195	125	8·0
1932. Shields.				
2nd May	Diatoms (Ch. Th. Rh. N.)	10	0	1·75
3rd ,,	Phæocystis and Diatoms (Th.)	0	0	0·25
4th ,,	Diatoms (Ch. Th. Rh. N.)	10	0	0·0
7th ,,	,, (Rh. Ch.)	108	16	3·0
8th ,,	,, (Ch. N.)	58	0	2·25
10th ,,	,, (Ch. Th.)	4	0	0·125
12th ,,	,, (Ch.)	192	8	2·5
12th ,,	Phæocystis and Diatoms (Ch.)	10	0	0·0
15th ,,	Diatoms (Th.)	80	0	10·25
15th ,,	,, (Th.)	120	0	0·0
15th ,,	,, (Th.)	24	0	0·0
16th ,,	,, and possibly Phæocystis	840	0	2·5
18th ,,	,, ,, ,,	280	0	2·5

* The letters in brackets are symbols for diatom genera, as follows: N.= *Nitzschia closterium*; Ch.= *Chætoceros* spp.; Th.= *Thallassiosira* spp.; Rh.= *Rhizosolenia* spp.; Sk.= *Skeletonema costatum* and M.= *Melosira* spp. Where the identification was doubtful due to the presence of scum and long periods of storage the sign ? is used.

TABLE I—*contd.*

		Calanus.	Limacina.	Catch (crans).
1932. Shields.				
18th May	Diatoms (N. Ch. ?)	220	0	6·0
19th ,,	,, and possibly Phæocystis	0	0	0·0
23rd ,,	,, (Ch.)	270	0	1·0
24th ,,	Phæocystis	160	0	0·0
29th ,,	Diatoms (Th.)	240	24	1·0
5th June	,, (Th.)	345	0	7·0
1932. Southern Bight.				
3rd July	Diatoms (Ch. N.)	0	0	0·2
,,	,, (Ch. N.)	0	0	0·0
1933. Scotland East Coast.				
16th April	Diatoms (Th. N.)	10	0	5·0
22nd June	,, (Th. N.)	145	65	1·0
1933. Shields.				
13th April	Diatoms (Th.) and possibly Phæocystis	1115	65	0·0
2nd June	,, (Th. Ch. Sk.)	9	0	1·0
1933. Southern Bight.				
8th June	Diatoms (N.) and Phæocystis	0	0	0·25
9th ,,	,, (Th.) ,,	0	0	0·25
15th October	,, (Rh.)	0	0	4·0

Average for all Green discs 1930, 1931, 1932, 1933 $= \frac{99·075}{55} = 1·80^{55}$ crans.

herring and the phytoplankton. This applied particularly to the area covered by the autumn East Anglian Fishery, where phytoplankton is encountered, to a greater or lesser extent, in most years (Hardy, 1923, 1926, Savage, 1930, Savage and Hardy, 1935); and where in 1933 the influence of dense phytoplankton patches on the movements of the shoals was most marked.

Difficulty has been experienced in persuading the drifter skippers to use the standard Indicator during the autumn fishery on account of the concentration of so large a fleet of vessels and the race to secure the most suitable " berths." In addition to the time taken in towing the Indicator there is the danger of fouling the nets of other drifters. Since the sampling of the zooplankton is not of primary importance in this fishery, as the herring are not feeding at the time, Professor Hardy planned a modification of the experiment using a miniature Indicator suitable for phytoplankton indications, which could be towed by the drifter whilst the nets were being shot. A line of water could be sampled along the whole length of the fleet of nets* at a speed (although only two knots approx.) sufficient

* The number of nets in a fleet, and therefore the length of tow, was, with a few occasional exceptions, practically constant at 91–97 in this fishery in 1934. In any case, *it is considered that, even if the fleet was only of 60 nets, in concentrations of* phytoplankton dense enough to affect the catches quite adequate indication would be given on this length of tow.

TABLE II.

COMPARISON OF THE AVERAGE CATCHES OF HERRING (IN CRANS) AND THE AVERAGE NUMBERS OF CALANUS AND LIMACINA CORRESPONDING TO GREEN (PHYTOPLANKTON) DISCS WITH THOSE CORRESPONDING TO OTHER DISCS. THE HIGHER OF EACH PAIR OF AVERAGES IS SHOWN IN HEAVY TYPE.

Fishery and Area.	Date.	Average herring in crans. Green discs	Average herring in crans. Other discs.	Average Calanus.* Green discs	Average Calanus.* Other discs.	Average Limacina.* Green discs	Average Limacina.* Other discs.
	1931						
Western Scottish	July	1·14^{6}	**2·02^{3}**	31	**149**	1,401	**1,793**
,, ,,	August	0·88^{2}	**2·62^{29}**	456	**969**	**600**	230
Eastern Scottish 56°–58° N.	1–15 August	0·50^{2}	**1·64^{7}**	**448**	267	**60**	58
,, ,, 58°–59° N.	16–30 June	**1·88^{2}**	0·82^{11}	12^{2}	**42^{8}**	**11^{2}**	4^{8}
,, ,, ,,	1–15 July	1·55^{5}	**12·88^{6}**	**10**	1	6	**17**
,, ,, ,,	16–31 July	0·83^{3}	**1·32^{12}**	29	**73**	11	**178**
,, ,, 59°–60° N.	1–15 July	**3·00^{1}**	1·83^{9}	3	**91**	30	**40**
,, ,, N. of 60°	1–15 July	4·00^{1}	**16·96^{7}**	12	**54**	0	**2**
,, ,, ,,	15–31 July	0·50^{1}	**0·81^{4}**	18	**112**	**10**	4
Humber	October	1·00^{2}	**39·2^{5}**	5	**49**	36	**625**
	1932						
Eastern Scottish 56°–58° N.	16–31 May	7·0^{1}	**25·75^{2}**	184	**676**	0	**8**
,, ,, ,,	1–15 July	8·0^{1}	**8·36^{11}**	195	**224**	125	**128**
Shields	1–15 May	1·83^{11}	**3·0^{5}**	56	**506**	2	**3**
,,	16–31 May	1·86^{7}	**3·8^{36}**	287	**501**	3	3
,,	1–15 June	**7·0^{1}**	4·07^{49}	345	**875**	0	**16**
East Anglian	3 July	0·1^{2}	†	0	†	0	†
	1933						
Eastern Scottish 56°–58° N.	16–30 June	1·0^{1}	**13·4^{9}**	145	**421**	65	**663**
,, ,, 58°–59° N.	16–30 April	5·0^{1}	†	10	†	0	†
Shields	13–30 April	0·0^{1}	**3·0^{2}**	**1,115**	1,080	**65**	20
,,	1–15 June	1·0^{1}	**2·09^{39}**	9	**205**	0	**20**
East Anglian	1–15 June	0·25^{2}	**2·0^{1}**	0	**1**	0	0
,, ,,	1–17 October	**4·0^{1}**	0·0^{2}	0	**20**	0	**30**
	1922–23						
East Anglian	Oct.–Nov. (1922)	2·92^{6}	**25·33^{6}**	—	—	—	—
,, ,,	March (1923)	1·5^{1}	**24·0^{1}**	—	—	—	—
Frequency of higher averages		4	18	3	17	5	13

The Indices denote the number of samples on which the average is based.

* In these columns the averages are based on the same number of samples as in columns 1 and 2 excepting the period 16–30 June, 1931 (Area 58°–59° N.), when 13 catches were associated with only 10 samples of plankton.

† During these periods there were no other samples to compare with the green discs.

to sample the phytoplankton. The Indicator was similar in design to the standard instrument described in Part I, but only 13 inches in length and

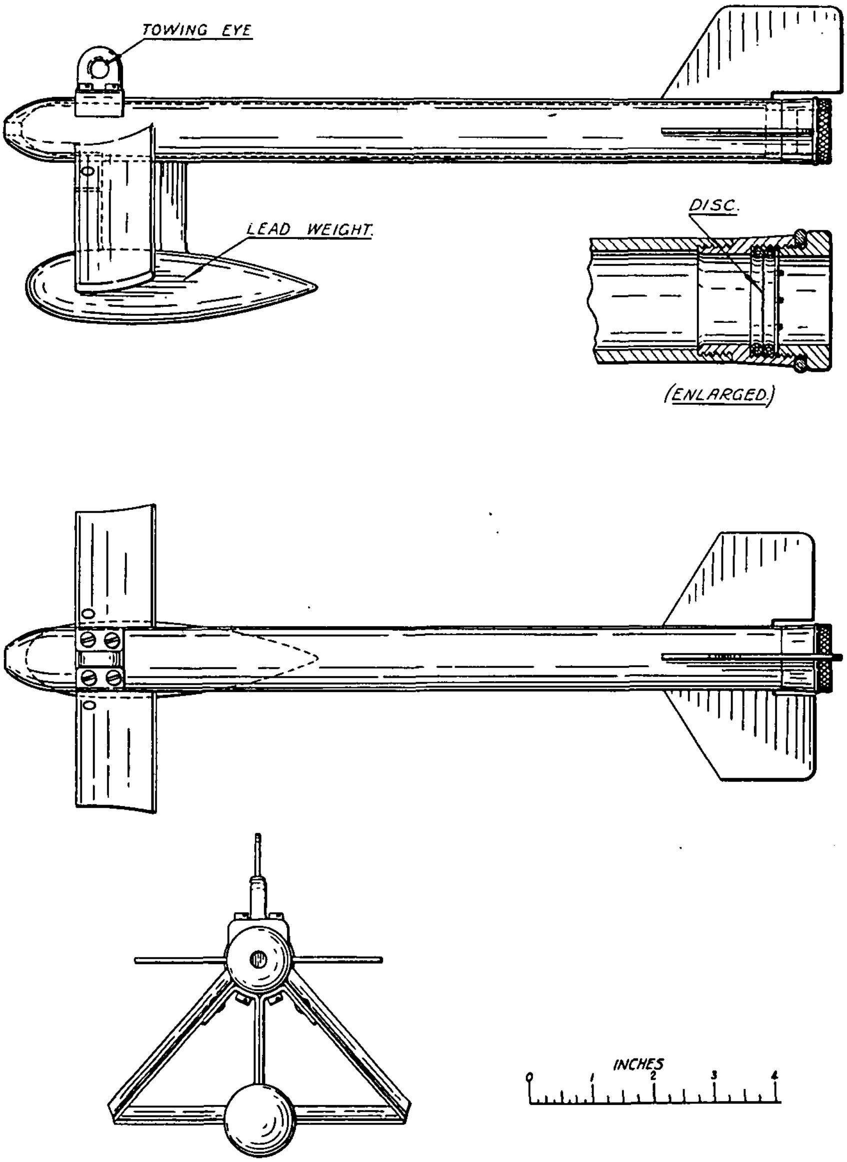

Fig. 1.—The miniature Plankton Indicator designed for sampling phytoplankton.

1 inch in diameter, with additional planes placed at a marked inverted dihedral angle to give the necessary stability and sinking effect to so small an instrument. This miniature Indicator is illustrated in Fig. 1.

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It was necessary that the discs should be worked up immediately in the fresh condition, so that their colour would not be changed by long immersion in preservative, as almost certainly occurred with some of the earlier material; and also it was most important that the amount of work required from the fishermen using the instrument should be reduced to the absolute minimum. Each of the writers at different times took part in the work of collecting and examining the discs.

The method adopted was as follows :—A number of the small Plankton Indicators ready loaded with discs were issued to skippers of drifters working from Yarmouth, who were requested to shoot the instrument from the port quarter* when commencing to shoot their nets, allow it to tow at the full length of line supplied (6 fathoms) till they had finished shooting their gear, then haul it in and put it safely aside till they returned to port next morning. Details of catch, position, time, etc., were obtained and noted by the worker, who reloaded the instrument ready for the next haul. The used disc was wrapped up temporarily in a piece of damp calico, and examined later in the day when all the drifters had been visited.

Twenty-five of these small Indicators were in use, and a total of 150 samples was obtained between 7th October and 20th November, the period of maximum productivity in the fishery. The distribution of these samples is shown in Fig. 2. The total would have been greater had the market conditions not been in such a chaotic state, for there were times when less than a third of the fleet working from Yarmouth was at sea (and therefore probably only six or eight indicators), and on two occasions fishing operations were entirely suspended for several days owing to glutting of the market. This was unfortunate, as it reduced considerably the number of samples which could be obtained on any one day.

In view of these interruptions in fishing, and since the distribution of the samples is irregular in space, we decided to arrange the samples into groups of not less than six and extending over 1, 2, 3 or 4 days, so reducing gaps in the time sequence when samples were not available. There are 15 such groups varying from six to seventeen samples.

It seems very probable that the phytoplankton was not so abundant in this area in 1934 as it was in 1933, and less than one-third of the discs obtained were visibly coloured by diatoms or flagellates. In all 42 discs were obtained which could be described as visibly green or greeny brown in colour. The average catches associated with such discs have been compared with the catches of those not so coloured, but a further correlation has been made, based on the actual numbers of phytoplankton cells

* The vertical rudder on the indicator was bent a little to make the instrument sheer out a bit on the port quarter and so tow well clear of the nets, which are shot over the starboard side. In only three hauls out of 150 was any damage to nets experienced, and in two of these cases the damage was slight.

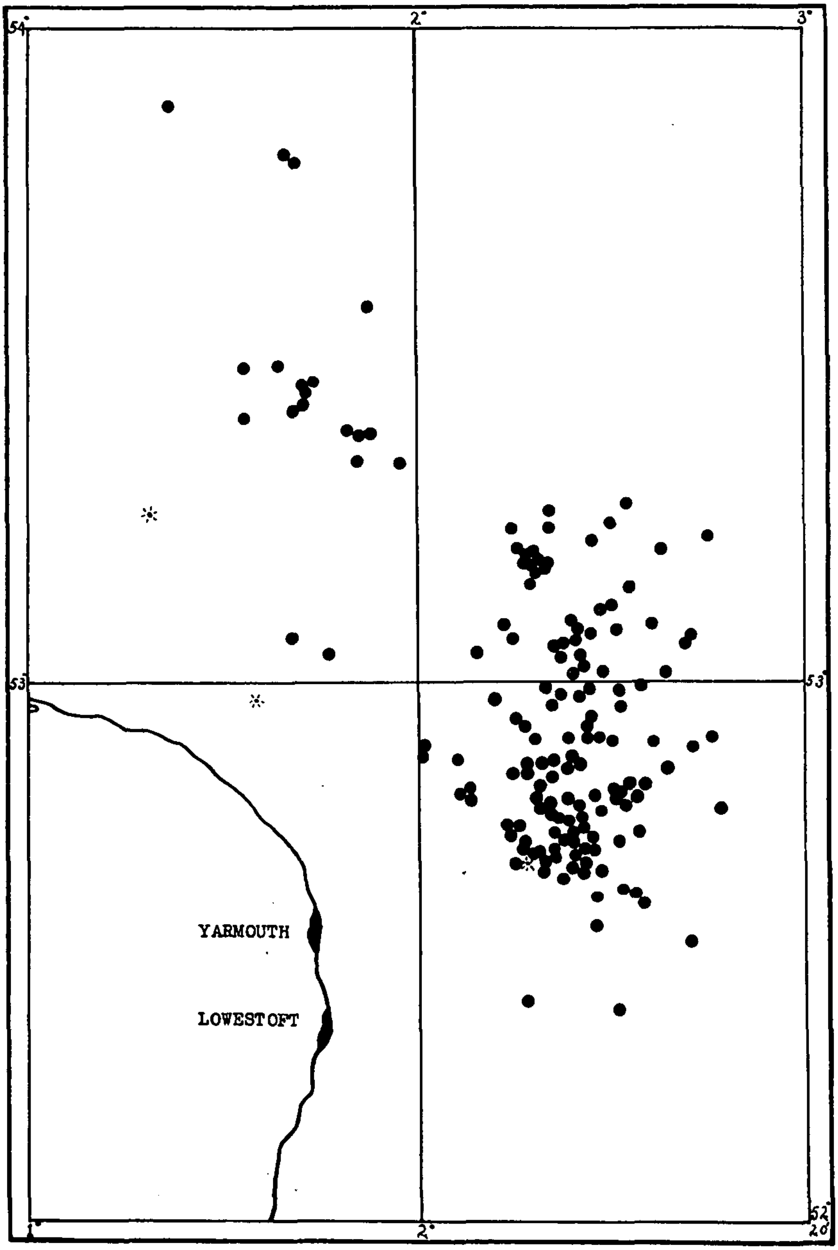

FIG. 2.—Chart showing the distribution of phytoplankton samples obtained with the miniature Plankton Indicator in the autumn East Anglian fishery, 1934. Light vessels are indicated thus *.

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present. The principal forms found were *Rhizosolenia styliformis*, ranging from 0–2280 cells, and *Biddulphia sinensis* and *mobiliensis*, ranging from 0–2314 cells and composed almost entirely of *B. sinensis*.

Other diatoms were present on occasion, but seldom in appreciable numbers. *Chætoceros* spp. and *Bellarochia malleus* were the commonest of these, but as their cells are so much smaller than those of Rhizosolenia and Biddulphia they can safely be omitted from the correlations. Phæo-

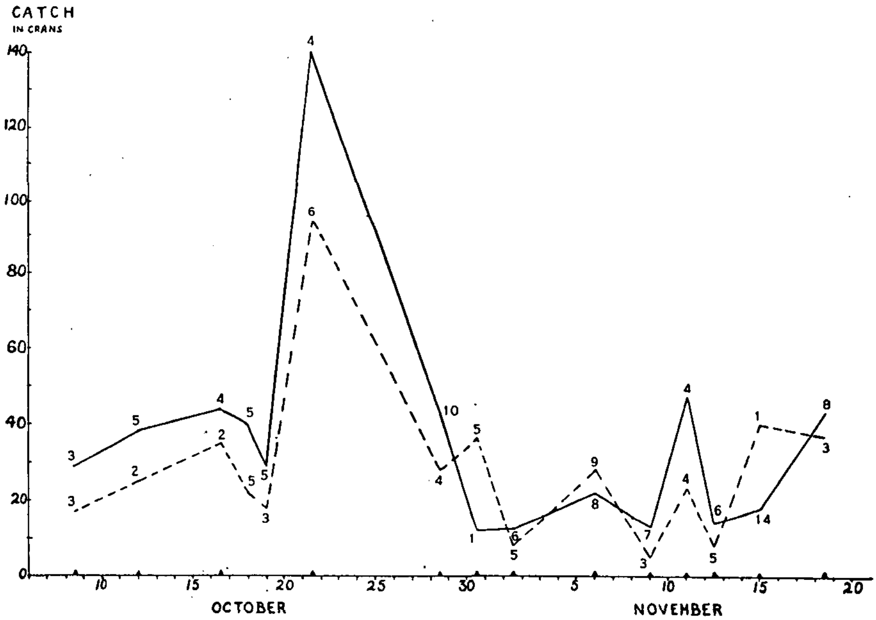

FIG. 3.—The average catch of herring associated with miniature Indicator discs having little phytoplankton (points connected by continuous line) compared with the average catch associated with discs having abundant phytoplankton (points connected by broken line) for thirteen short periods during the autumn East Anglian fishery of 1934. The figures against the graphs indicate the number of catches averaged. For details of phytoplankton measurement and length of periods chosen see text.

cystis and Halosphæra were found on a few discs, sometimes abundant enough to colour the disc.

It was decided to divide the samples into lower and higher phytoplankton values: the lower values having less than 50 cells of Rhizosolenia plus Biddulphia, no Phæocystis, and Halosphæra not causing visible green coloration when present, and the higher values having more than 50 cells of Rhizosolenia plus Biddulphia and (or) Phæocystis present and (or) Halosphæra present and causing visible green coloration. There were 90 samples in the lower phytoplankton category and 60 in the higher. The average catches for each of these categories corresponding to each short period, are shown in Table III, columns 1 and 2 ; columns 3 and 4

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show the average catches of uncoloured and coloured discs for the same periods. Column 5 shows the average landings at the port for the same periods. The results are also shown graphically in Figs. 3 and 4. The table shows that 12 out of 15 periods suggest that lower catches of herring are to be associated with higher phytoplankton values. Only one of the three positive correlations is seriously opposed to this general tendency (i.e. on 5–7 November), the others having only one catch on the lower or the higher side of the correlation. Such a result is interesting in itself as giving a very clear demonstration of the avoidance of phytoplankton by

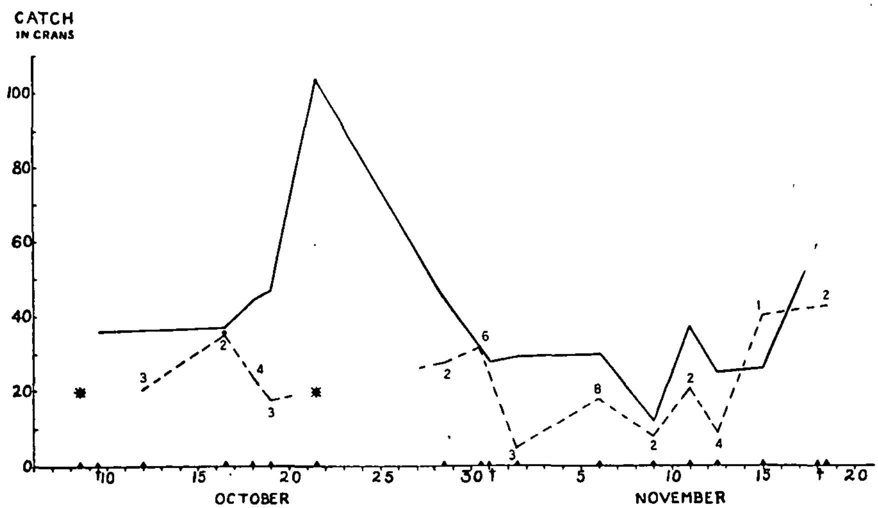

FIG. 4.—The average catch of herring associated with miniature Indicator discs which are coloured green (points connected by broken line) compared with the average landings at Yarmouth (points connected by continuous line) for the periods used in Fig. 3. In the two periods marked by an asterisk no green discs were taken. For the three periods marked by a dagger the dates for the port averages differ slightly from those used for the disc groups (see Table III, col. 6).

the herring, even though the patches are not very dense. Of the 60 samples having the denser phytoplankton, 42 were visibly coloured green or greeny brown, i.e. distinguishable from the other discs by the naked eye : columns 3 and 4 show how the associated herring catches are definitely lower when the sample is coloured than when it is not. Only two of these correlations are positive, and to some extent this arrangement explains the positive results in the previous correlations : that on the 30–31 October is explained by the fact that all the discs were green and on the 5–7 November the positive correlation based on numbers becomes negative on a colour basis. The results on the 14–16 November are similar in both sets, only one green disc being obtained ; the last result having only two green discs is slightly positive, whereas it was negative in the previous correlations. Thus in only two of the periods do the greenish discs show a positive tendency. As a whole the coloured discs are associated with lower catches than those having merely the higher numbers of phytoplankton ; the results from coloured discs are also on the whole more consistently negative.*

It will be seen in column 4 of Table III that even where the discs were coloured the associated catches were sometimes quite appreciable (the

TABLE III.

For explanation, see text.

Date.	Average catch of Herrings in Crans. Lower phyto-plankton.	Higher phyto-plankton.	Plain discs.	Green or brown discs.	Av. catch at Port.
October					
7–10	**29**^{3}	17^{3}	No coloured discs		36 (Av. for week ending 13th)
11–13	**38**^{5}	25^{2}	**45**^{4}	20^{3}	
16–17	**44**^{4}	35^{2}	**44**^{4}	35^{2}	37
18	**40**^{5}	22^{5}	**36**^{6}	24^{4}	44
19	**29**^{5}	18^{3}	**29**^{5}	18^{3}	47
21–22	**140**^{4}	94^{6}	No coloured discs		104
28–29	**43**^{10}	28^{4}	**41**^{12}	27½^{2}	45
30–31	12^{1}	**36**^{5}	—	31½^{6}	28 (31st)
November					
1–2	**12½**^{6}	8^{5}	**12½**^{8}	5^{3}	29
5–7	22^{8}	**28**^{9}	**31**^{9}	18^{8}	30
8–10	**13**^{7}	5^{3}	**11**^{8}	8^{2}	12
11	**47**^{4}	23^{4}	**39½**^{6}	20½^{2}	37
12–13	**14**^{6}	8^{5}	**13**^{7}	9^{4}	25
14–16	18^{14}	**40**^{1}	18^{14}	**40**^{1}	26
17–20	**43**^{8}	37^{3}	41^{9}	**42½**^{2}	59 (17th, 18th, 19th)

Index figures indicate the number of samples on which the figure is based.

average of all coloured discs being 21^{42} crans). Comparison with page 281 shows that this average is very much higher than the average (1·80 crans) of the green discs collected by the larger Indicator over the whole of the area under investigation. The following factors may help to account for this : (1) Phytoplankton was relatively sparse over the fishing area in 1934. (2) The average catch in the East Anglian fishery is in a general way very much higher than the average in the other fisheries ; thus the average of the catches associated with the samples obtained in 1934 was

* We can examine these data statistically as in the previous example quoted on page 279. Comparing the mean catches associated with the lower and higher phytoplankton numbers (see above) we find a difference of 12·6% of the sum of the mean catches obtained under both conditions (Standard Error of $\pm$6·79%). For the mean catches of the green and non-green discs there is a difference of 17·4$\pm$6·06%, and the catches associated with the green discs compared with the average catches landed at the port show a difference of 23·6$\pm$6·57%. In each example the catches associated with the denser phytoplankton were the lower. The corresponding values for "t" are 1·86, 2·86 and 3·63.

32 crans (for 150 samples) whereas the average catch associated with all the samples taken in 1930–33 was 10 crans (1,256 samples). (3) The discs labelled green in the 1930–33 tests, after some period of immersion in formalin, would undoubtedly be the densest of a larger number which may have appeared green whilst fresh ; we feel that these would tend to be associated with a rather lower average catch than that of the fresh green discs.

These results as a whole suggest that the discs obtained with the small Indicator could be used with advantage by fishermen in avoiding the less profitable waters ; any green coloration could be observed easily by fishermen using the instrument. The 1934 material offers substantial support to the more scattered information obtained in 1930–33 in various fisheries round the British coast, and points to the value of the Indicator as a commercial instrument. There is no doubt that the miniature Indicator, so readily hauled inboard, could, in the autumn fishery, be easily used without risk of damaging the nets of other vessels and such an instrument might usefully be issued as an auxilliary to the standard Indicator.

Dinoflagellates.

The correlations which have been dealt with above have all been concerned with diatoms or green flagellates. A large amount of dinoflagellate material has been collected in the course of the five years, and we tried to find whether the abundance of dinoflagellates (mainly Ceratium spp.) could be correlated with the catches of herring. In 1931, off the Shields coast, there seemed to be a definite negative association between dinoflagellates and herring catches, but in Scottish waters this appeared to be reversed in 1932. These were the dominant years for these areas ; in the other years the dinoflagellates were relatively scarce, though in 1933 they were much more abundant in Scottish than in the English waters and on the whole the higher numbers in the Scottish areas indicated lower catches. We have not found any definite and continuous correlation as with the other phytoplankton, but perhaps this is not remarkable, considering the differences in metabolism between these forms.

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SUMMARY.

1. An analysis is made of the catches of drift-net herring and associated samples of phytoplankton collected with the standard Hardy Plankton Indicator and also with a miniature form of this instrument.

2. Fifty-five green discs and their associated catches obtained off the east and west coasts of Scotland, off Shields and the East Anglian coast during the years 1930–33 are compared with the other catches in these waters period by period. The results strongly suggest a negative correlation between the herring and dense patches of phytoplankton.

3. A more detailed investigation of the autumn East Anglian herring fishery in 1934 with the miniature Indicator produced similar results and shows how such a miniature instrument should be of use in these waters, enabling fishermen to avoid unsuitable waters for fishing.

4. The correlation between the phytoplankton and the associated numbers of Calanus and Limacina is shown to be negative for each of these animals. The significance of this is discussed.

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