Ödemål, Kville sn, Bohuslän

Hällristning
Fiskare från
bronsåldern

Rock carving
Bronze age
fishermen

MEDDELANDE från HAVSFISKELABORATORIET · LYSEKIL

nr 55

1) Further Investigations of the Diurnal Changes in the Vertical Distribution of Herring-Fry in the Kattegat
by HANS HÖGLUND, 1938

2) On the Feeding Habits of Herring Larvae and Post-Larvae
by HANS HÖGLUND, 1948

October, 1968

The following investigations have been presented by Dr. HANS HÖGLUND before the Plankton Committee of the International Council for the Exploration of the Sea on 27 May, 1938 and on 7 October, 1948, respectively.

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October 1968

FURTHER INVESTIGATIONS OF THE DIURNAL CHANGES IN THE VERTICAL DISTRIBUTION OF HERRING-FRY IN THE KATTEGAT

BY

HANS HÖGLUND

(27 May 1938)

At the last meeting of the Plankton Committee I spoke about an investigation of the diurnal changes in the vertical distribution of herring-fry in the Kattegat, made in the autumn of 1936. The results of the investigation were noteworthy, for they were quite opposed to those obtained by previous investigators working in spring and early summer. The vertical distribution in the autumn of 1936 indicated that herring fry occur in the surface layers during the daytime and that, during the night, they chiefly frequent the deeper layers. It seems to be an upward migration during the day and a downward migration during the night.

Dr JOHANSEN, who made similar investigations in the Kattegat in 1925, found that in spring there was an upward migration at night and a downward migration in the day.

Thus, it seemed as if conditions in autumn differ from those in spring, and I tried to explain this on the basis of differences between the light intensities prevailing in the two seasons of the year.

However, I emphasized that, owing to the varying currents and hydrographic conditions in the Kattegat, one must be cautious in drawing inferences and so I decided to repeat the investigation. This was done last autumn and I will now give a brief account of the new results.

Tobegin with I must describe in a few words the method of investigation. Every fourth hour, starting at 15 o'clock on the 29th of October and ending at 15 on the 31st of October, a series of four horizontal hauls with a 1 m Ringtrawl was made at the surface, and at the depths of 10, 25 and 40 metres. A bottom haul was also made with a sledge-net. (The depth of the station was 56 m.) Further, regular hydrographic observations were made of salinity, temperature, the direction and velocity of the current, and the variation in light intensity both above and below the surface at different depths.

Each figure in the diagram (Fig. 1) represents a series of horizontal hauls at 0, 10, 25 and 40 metres. The catch at each level is expressed as a percentage of the total number caught in the four hauls of the series to which it belongs.

The investigation lasted for 48 hours, and you will see from the distribution figures that there is fairly good agreement between the two days. In the daytime the frequency maximum occurred at a depth of 25 metres but at night it had moved down to the 40 metre level or deeper. The amplitude of the vertical movement of the larvae is not very large and you will see that they never appear in great numbers in the surface layer or even at 10 metres' depth.

The bottom catches cannot be compared with the plankton catches with the ring-trawl. Firstly, the opening of the sledge-net is much smaller than that of the ring-trawl, and, secondly, the ring-trawl was used as a closing-net, and this was not possible with the sledge-net.

You will see that there is a marked maximum the first night and a smaller one the second. Although it is not advisable to draw any farreaching conclusions from the bottom catches, they do seem, at least, to form an argument against the hypothesis, that herring fry migrate from the bottom at night.

On the whole, the last observations in the autumn of 1937 confirmed the results from 1936 (Fig. 2), viz. that the larvae migrate upwards in the daytime and downwards at night. However, there is a remarkable difference in the behaviour of the fry on the two occasions of observation. In 1936 the larvae occurredin great numbers at the surface in the daytime, but in 1937 they did not even reach the 10 metre level.

This is, indeed, a very great disagreement. But I think it may possibly be explained by the different hydrographic conditions prevailing during the investigations.

In the autumn of 1936, as will be seen from Fig. 3, the water column was comparatively unstratified. The intervals between the isohalines (and also the isoterms) were very large and even, and there was no boundary layer. The 29 ‰ water reaches the surface.

In 1937, on the other hand, there was a very marked boundary layer at 15 to 20 metres,(Fig. 4). The isohalines here run very close and there is an increase in the salinity from 23 ‰ at 15 metres to 31 ‰ at 20 metres depth.

Now, I imagine the conditions to be the following. During autumn the herring fry tend to congregate in the surface layer in the daytime, where the optimum light intensity is assumed to be. On the occasion of the investigation in the year 1936 there was nothing to prevent the larvae from reaching the surface. But in the autumn of 1937, on the other hand, there was a strongly marked boundary layer, which divided the water column into two parts of different hydrographic character and formed an obstacle which brought the herring fry to a standstill in their migration upwards.

ON THE FEEDING HABITS OF HERRING LARVAE AND POST-LARVAE

BY

HANS HÖGLUND

(7 October 1948)

METHODS AND MATERIAL

During four different autumns (1936, 1937, 1938, and 1947) researches were carried out at a fixed station in the Kattegat in order to study the vertical distribution and the supposed diurnal vertical migration of the larval and post-larval stages of the herring. I have no intention now to enter upon the results concerning the main object of the investigation which, by the way, do not indicate any great regularity in the vertical distribution of the herring larvae. In this preliminary paper my intention is only to elucidate some aspects of the feeding habits of herring fry, for the material collected seems exceedingly suitable for this purpose.

The following account is based mainly on the material from 1947 and partly on that from 1937. A few words are necessary to explain how the collections were made. The station chosen was situated WNW of Klåback in the Kattegat at 57°10'N Lat. and 12°00'E Long. over a depth of 52 m. During three consecutive 24-hour periods between 15.00 hours on October 28th and 15.00 hours on October 31st, nineteen series of collections were obtained at an interval of four hours. In each series horizontal 10-minute hauls were made with the 1- metre closing net at five (in 1937 four) different depths and one bottom haul with the sledge net.

The catches were preserved in formalin, and after having been picked out at the laboratory the herring larvae and post-larvae, which measured between 7 and 14 mm were examined by dissecting their alimentary canals with fine needles under the microscope and the food content when present was identified. As several thousands of specimens had to be dissected the identification could not go into closer details as to the specific position of the food organisms. In addition notes were made of the condition of the gut.

RESULTS

Number of food-containing specimens

Out of 4627 specimens examined of the material from 1947, 1039 were found to have food in their guts. Let us, to begin with, only consider whether the larvae contained food or not. Then, putting all six catches in each series together and plotting the percentages of food-containing specimens in a diagram, Fig. 5, we got a curve of unusual regularity, showing strongly pronounced minima at 3 hours on all of the three consecutive nights and decided maxima at 15 hours in the daytime. So far the results indicate that the ingestion of food is greatest in the daytime.

Position of food content in the gut

A closer examination of the material, however, will give us more complete information about the feeding habits of young herrings. Let us now consider the position of the food in the alimentary canal. Then it will be found that by far the largets number (about 86 %) of the specimens had the food in the last quarter of the gut, which suggests that the passage of the food through the intestine is very rapid. In those cases where the food was situated in the middle part of the gut, indicating that the food was quite recently taken, the specimens in question were all captured in the daytime; not a single specimen of this kind being caught by dark, as will be seen from the table at the end of this paper.

This points to the conclusion that herring larvae feed in the daytime only, and that feeding is totally suspended in the dark.

The composition of the food content

Let us now turn to the food content itself and pay special attention to its composition. In the table at the end of this paper the young herrings are divided into seven different groups with regard to their food content:

1. Containing copepod nauplii only;
2. " copepodites and/or adult copepods;
3. " both nauplii and later stages of copepods;
4. " larval bivalves only;
5. " both copepod nauplii and larval bivalves;
6. " both nauplii, copepodites (or adult copepods) + larval bivalves;
7. " other food organisms.

By far the greatest part of the copepod nauplii consisted of *Pseudocalanus* and *Microcalanus*; nauplii of larger copepods, such as *Calanus finmarchius*, being very scarce and only present in the largest of the post-larval herrings. (Let it be remembered that the post-larvae in the 1947 material did not exceed 14 mm.)

Item 7 comprises all food organisms which did not fit into the other six headings. Among these were small eggs, about 0.1 mm in diameter, possibly of *Calanus*; very small numbers of larval gastropods, and also some unidentifiable matter similar perhaps to what Dr. LEBOUR has called "green food remains".

We shall now compare groups 1-3 with groups 4-6, i.e. those herring specimens containing copepodal food only, with those with bivalves in their guts. If all daytime catches put together are compared with all night catches the food-containing specimens will be found to group in the following way:

	With copepodal food only	With bivalves	With other food organisms
In the daylight collections	85,5 %	11,3 %	3,2 %
In the night collections	49,4 %	49,0 %	1,6 %

This is to say that in those specimens which were caught by dark the bivalves play a considerably greater part in the food content than in those specimens which were caught by daylight From the table at the end of this paper will be seen immedately that there is a definite change in the constituents of the food content as we turn from the daylight collections to those obtained in the dark.

This fact must not by any means be interpreted to mean that young herrings change their taste as the sun sets and the daylight wanes. It may more easily, and probably more correctly, be explained as a consequence of differences in the digestibility of the different food organisms; bivalves being much more difficult to digest than crustaceans. And the conclusion would be that the contents found in specimens captured at night are to be looked upon as remnants of food taken before sunset.

The condition of the intestine

Finally, there is one more feature well worth mentioning, namely concerning the condition of the intestine. When examining the young herrings it soon proved possible to distinguish between empty specimens that apparently had not contained any food for a rather long time, and those that had emptied their guts shortly before capture. In the first case the whole alimentary canal was transversely contracted with no hollowness visible. In the latter case the hindmost part of the gut immediately before the anus was distended and the anus was more or less wide open.

Thus it appeared convenient to divide the young herrings into three categories with regard to the condition of the intestine: (1) Empty specimens with contracted gut; (2) food-containing specimens; and (3) empty specimens with distended gut. Since I did not become aware of this feature until very much of the 1947 material had been processed I have here to reply on the collections of 1937, which did not cover more than two 24-hour periods. In these collections the specimens in the catches at 25 metres were distributed with regard to the gut conditions as follows:

Time	Empty specimens with contracted gut %	Food-containing specimens x) %	Empty specimens with distended gut %
29.X			
1557-1607	20	64	16
1955-2005	22	56	22
0005-0015	40	4	56
30.X			
0400-0410	66	0	34
0755-0805	64	36	0
1229-1239	12	66	22
1602-1612	32	34	34
2004-2014	40	30	30
0008-0018	62	4	34
31.X			
0350-0400	94	0	6
0802-0812	64	36	0
1146-1156	20	64	16
1555-1605	12	74	14

X x) This column has been put into a diagram in Fig. 6

If, for the sake of clarity, the catches from the same time of the day are put together and the mean percentages computed we get the following table representing one 24 hour period:

Approximate time	Empty specimens with contracted gut %	Food-containing specimens %	Empty specimens with distended gut %
08	64	36	0
12	16	65	19
16	21	58	21
20	31	43	26
24	51	4	45
04	80	0	20

To this table may be added that sunrise occurred at about 0720 and sunset at about 1630.

From this table, too, it can be inferred that no feeding occurs in the dark.

From the fact that there were no empty specimens with distended gut early in the morning whereas at noon this category was represented by 19 % it might be concluded that a lapse of about four hours would suffice for the digestion to be completed. And, furthermore, that probably more than one "meal" is taken on the same day by each individual.

DISCUSSION

All these indications are evidence that feeding occurs in the daylight only and is suspended in the dark. This holds true at least in late autumn and as far as the smaller herring larvae and post-larvae are concerned. Since the 1947 collections were taken at a period of full moon, the moonlight does not appear to be sufficient to stimulate the feeding activity of these young herring larvae and post-larvae. According to BATTLE's,HUNTSMAN's and collaborator's investigations in the Passamaquoddy region, however, young (adult) herring do feed in moonlight, but not in total darkness.

It would certainly be highly interesting and of great importance to be able to fix the light intensity threshold below which no feeding occurs. My researches, however, give no points for the settlement of this problem, although light-measurements were carried out in connection with the serial hauls. But, as will be seen from the table, no regular differences in the feeding habits could be traced in the specimens from the different depths between the surface and the bottom. This much may be said, however, that the threshold intensity seems to be very low, for, judging from the series No. 1 and No. 13 in the table, feeding did occur at the bottom even half an hour before sunset.

It has already been established by several workers, for instance Mr. SOLEIM in Norway and the Canadian workers mentioned above, that the feeding of the herring, the post-larval stages as well as the adult, is performed by an act of capture. From this and from the indications put forward in this paper it might be gathered that the sense of sight is highly developed in all stages of the herring. This dependence and reliance upon its sense of sight in the herring larvae and post-larvae give us cause to take up again the old question about the ability of these tiny fry to escape a towing net. I am fully aware that many experienced investigators do not think such an ability to be possible. But since all attempts to explain why the night catches of herring larvae and post-larvae are as a rule many times larger than the daylight catches have failed, I think it wise not to reject definitively the possibility of an escaping ability.

TABLE showing the numbers and percentages of food-containing Herring larvae and post-larvae every four hours during three consecutive 24-hour periods from Oct. 28th to Oct. 31st 1947 at station "WNW of Klåback" in the Kattegat over a depth of 52 m. The table also shows the types of food taken, and the position of the food in the alimentary canal. The material has been obtained by making 10-minute hauls with a 1-metre net at 6 different levels.

					No. of specimens containing the following types of food							No. of specimens with the food situated		
No. of series & Time	Depth m	No. examined	No. food-containing specimens	%-age food-containing specimens	Only copep. naupl.	Only copepodites or adult copepods	Both naupl. & later stages of copepods	Only bivalves	Naupl. & bivalves	Both naupl. copepodites & bivalves	Other food organisms	in the middle part of the gut	in the middle & hindmost parts of the gut	in the hindmost part of the gut
1.	0	8	2	25.0	1		1						1	1
	10	23	10	43.5	7		2				1	1	1	8
15	25	16	10	62.5	8	1	1					2		8
Day-	40	21	10	47.6	8			1	1				2	8
light	49	4	1	25.0	1									1
	Bott.	14	8	57.1	5		2	1				2	2	4
	Total	86	41	47.7	30	1	6	2	1		1	5	6	30
2.	0	18	3	16.7				2			1			3
	10	26	7	26.9				5	2					7
19	25	55	15	27.3	5	1	2	7						15
	40	51	23	45.1	9		2	8	3		1			23
Dark	49	15	12	80.0	5			5	2					12
	Bott.	8	2	25.0	2									2
	Total	173	62	35.8	21	1	4	27	7		2			62
3.	0	9	1	11.1				1						1
	10	83	9	10.8				7	2					9
23	25	63	5	7.9				5						5
	40	68	11	16.2	1			10						11
Dark	49	64	7	10.9	1			6						7
	Bott.	43	4	9.3	1			3						4
	Total	330	37	11.2	3			32	2					37
4.	0	158	0	0										
	10	192	2	1.0				2						2
03	25	235	1	0.4				1						1
	40	80	0	0										
Dark	49	49	2	4.1				2						2
	Bott.	79	5	6.3				4			1			5
	Total	793	10	1.3				9			1			10
5.	0	30	14	46.7	13	1						1	3	10
	10	9	8	88.9	8								1	7
07	25	5	4	80.0	4									4
Day-	40	25	4	16.0	3			1				1		3
light	49	12	6	50.0	3	1		1			1	1	1	4
	Bott.	13	1	7.7	1								1	
	Total	94	37	39.4	32	2		2			1	3	6	28

No. of series & Time	Depth m	No. examined	No. food-containing specimens	%-age food-containing specimens	No. of specimens containing the following types of food: Only copep naupl	Only copepodites or adult copepods	Both naupl. & later stages of copepods	Only bivalves	Naupl. & bivalves	Both naupl. copepodites & bivalves	Other food organisms	No. of specimens with the food situated: in the middle part of the gut	in the middle & hindmost parts of the gut	in the hindmost part of the gut
6.	0	14	13	92.8	13							2	4	7
	10	25	22	88.0	22							2	9	11
11	25	13	2	15.4	2									2
Day-	40	33	6	18.2	3						3			6
light	49	24	7	29.2	5			2					2	5
	Bott.	27	9	33.3	5			3	1			3	3	3
	Total	136	59	43.4	50			5	1		3	7	18	34
7.	0	9	9	100	8		1						3	6
	10	65	55	84.6	44	4	5		1		1	2	15	38
15	25	37	14	37.8	7			5			2	4	1	9
Day-	40	18	10	55.6	7	1	1	1				1	3	6
light	49	10	2	20.0		1			1					2
	Bott.	8	5	62.5	2	1					2			5
	Total	147	95	64.6	68	7	7	6	2		5	7	22	66
8.	0	11	1	9.1	1									1
	10	31	11	35.5	9			2						11
19	25	202	57	28.2	31	1	2	19	2	1	1			57
	40	66	30	45.4	18		2	4	5		1			30
Dark	49	35	14	40.0	5	1	1	3	2	1	1			14
	Bott.	19	12	63.2	4			5	3					12
	Total	364	125	34.3	68	2	5	33	12	2	3			125
9.	0	6	0	0										
	10	75	3	4.0				3						3
23	25	111	4	3.6	1			3						4
	40	183	4	2.2				4						4
Dark	49	20	4	20.0	2			2						4
	Bott.	55	11	20.0	2			9						11
	Total	450	26	5.8	5			21						26
10.	0	24	0	0										
	10	32	0	0										
03	25	121	0	0										
	40	96	0	0										
Dark	49	57	3	5.3				3						3
	Bott.	6	0	0										
	Total	336	3	0.9				3						3
11.	0	92	22	23.9	15	3	1	2			1	3		19
	10	16	9	56.2	8			1				1		8
07	25	51	36	70.6	35		1					3	5	28
Day-	40	12	9	75.0	9							2		7
light	49	13	4	30.8	4								1	3
	Bott.	16	10	62.5	10							2	3	5
	Total	200	90	45.0	81	3	2	3			1	11	9	70

No. of series & Time	Depth m	No. examined	No. food-containing specimens	%-age food-containing specimens	No. of specimens containing the following types of food: Only copep. naupl.	Only copepodites or adult copepods	Both naupl. & later stages of copepods	Only bivalves	Naupl. & bivalves	Both naupl. copepodites & bivalves	Other food organisms	No. of specimens with the food situated: in the middle part of the gut	in the middle & hindmost parts of the gut	in the hindmost part of the gut
12.	0	7	4	57.1	4									4
	10	19	13	68.4	13								1	12
11	25	27	17	63.0	17							3	1	13
Day-	40	32	12	37.5	12							1	2	9
light	49	8	3	37.5	2			1				1		2
	Bott.	2	1	50.0	1									1
	Total	95	50	52.6	49			1				5	4	41
13.	0	6	5	83.3	5								1	4
	10	33	28	84.8	21	1			5		1	1	4	23
15	25	30	26	86.7	23		1	1	1			2	8	16
Day-	40	19	15	78.9	8		1	2	4			2	3	10
light	49	9	5	55.6	3			2					1	4
	Bott.	9	8	88.9	7			1				1	3	4
	Total	106	87	82.3	67	1	2	6	10		1	6	20	61
14.	0	26	11	42.3	9			2						11
	10	48	28	58.3	23			3	1		1			28
19	25	77	33	42.8	12	1	4	9	6		1			33
	40	47	26	55.3	20	1	2	2	1					26
Dark	49	57	40	70.2	16	2	4	10	7	1				40
	Bott.	16	12	75.0	9		1	1	1					12
	Total	271	150	55.4	89	4	11	27	16	1	2			150
15.	0	14	3	21.4	3									3
	10	90	18	20.0	10			8						18
23	25	75	6	8.0	2			4						6
	40	118	32	27.1	8			24						32
Dark	49	68	24	35.3	8	2		14						24
	Bott.	16	5	31.2	2			3						5
	Total	381	88	23.1	33	2		53						88
16.	0	18	0	0										
	10	124	0	0										
03	25	126	1	0.8				1						1
	40	54	0	0										
Dark	49	35	0	0										
	Bott.	10	0	0										
	Total	367	1	0.3				1						1

No. of series & Time	Depth m	No. examined	No. food-containing specimens	%-age food-containing specimens	No. of specimens containing the following types of food: Only copep. naupl.	Only copepodites or adult copepods	Both naupl. & later stages of copepods	Only bivalves	Naupl. & bivalves	Both naupl. copepodites & bivalves	Other food organisms	No. of specimens with the food situated: in the middle part of the gut	in the middle & hindmost parts of the gut	in the hindmost part of the gut
17.	0	55	5	9.1	3						2	1		4
	10	30	8	26.7	8								1	7
07	25	24	3	12.5	2						1			3
Day-	40	5	1	20.0				1						1
light	49	13	1	7.7				1						1
	Bott.	9	4	44.4	2			1			1			4
	Total	136	22	16.2	15			3			4	1	1	20
18.	0	11	5	45.4	2	2				1			2	3
	10	32	24	75.0	17	4	3					2	2	20
11	25	14	4	28.6	2	2								4
Day-	40	35	14	40.0		1		12		1		1	2	11
light	49	60	7	11.7		1		5			1	2		5
	Bott.	10	2	20.0	2								1	1
	Total	162	56	34.6	23	10	3	17		2	1	5	7	44
19.	0													
	10	59	38	64.4	32	2			4			2	4	32
15	25	-	-											
Day-	40	-	-											
light	49	-	-											
	Bott.	8	4	50.0	3	1								4
	Total	67	42	62.7	35	3			4			2	4	36

Fig. 1.

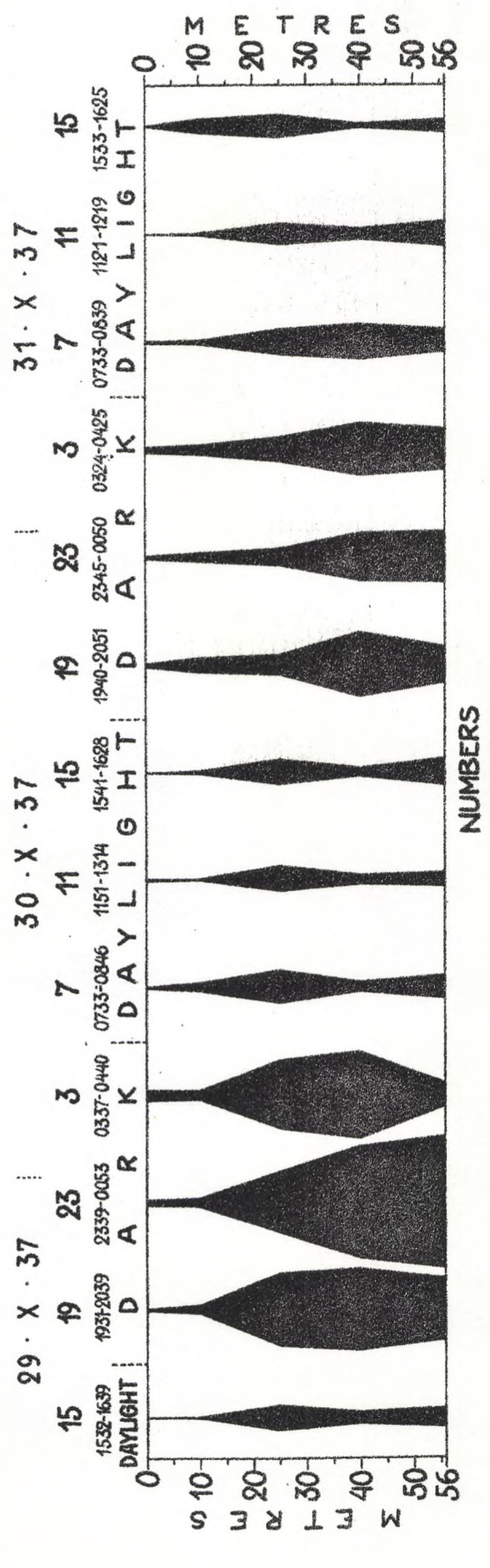
29 · X · 37
30 · X · 37
31 · X · 37
DAYLIGHT
DARK
15 19 23 3 7 11 15 19 23 3 7 11 15
1532-1639
1931-2039
2339-0053
0337-0440
0733-0846
1151-1314
1541-1628
1940-2051
2345-0050
0324-0425
0733-0839
1121-1219
1533-1625
METRES
NUMBERS
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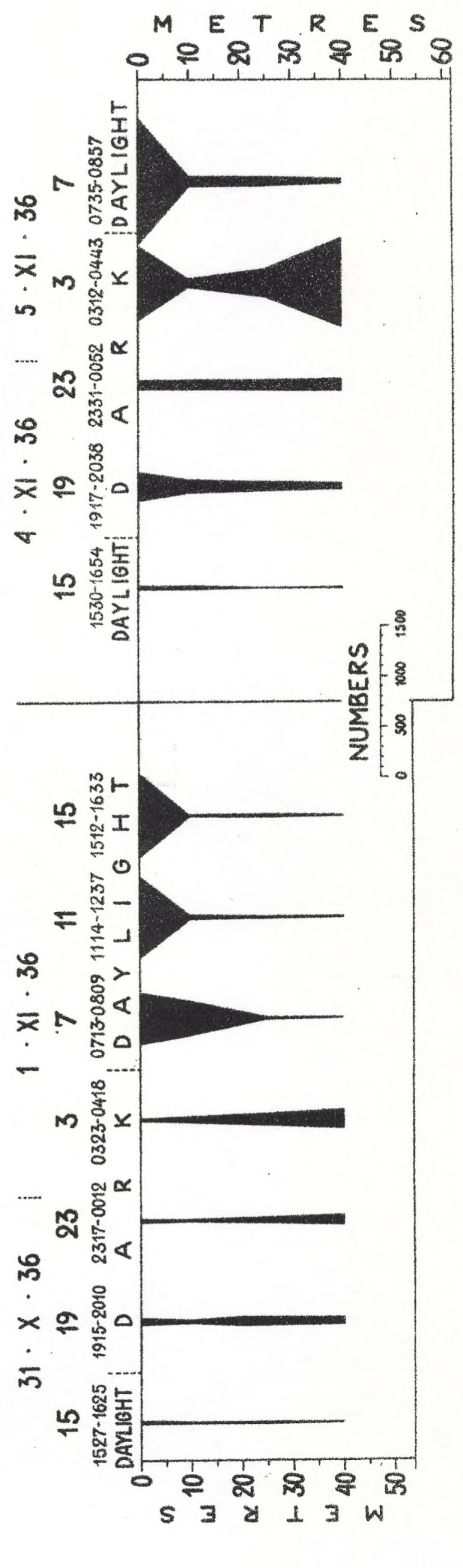
Fig. 2.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1 · XI · 36
4 · XI · 36
5 · XI · 36
DAYLIGHT
DARK
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2317-0012
0323-0418
0713-0809
1114-1237
1512-1633
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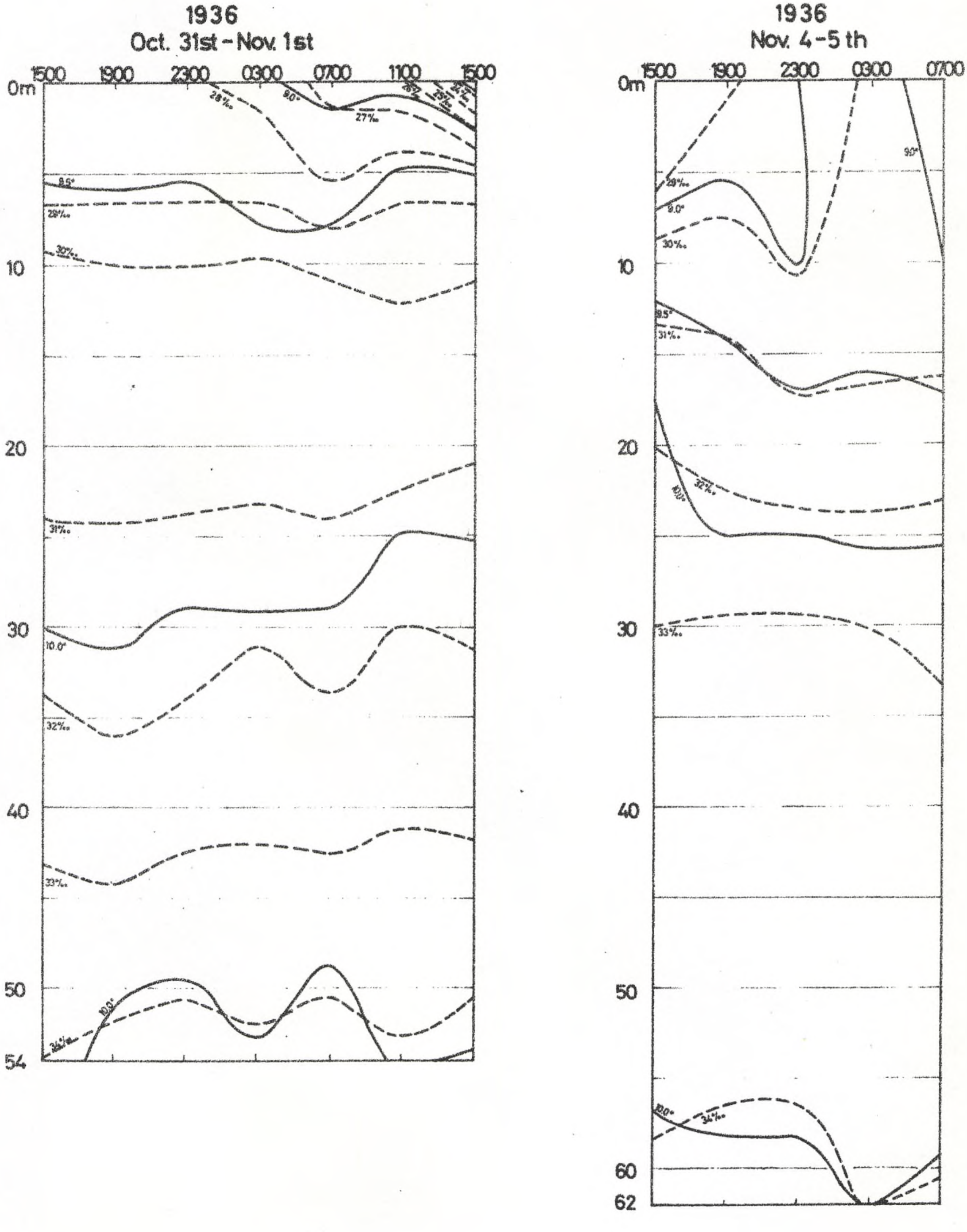
Fig. 3.



1936
Oct. 31st - Nov. 1st
1500
1900
2300
0300
0700
1100
1500
0m
10
20
30
40
50
54
28‰
9.0°
27‰
8.5°
29‰
30‰
31‰
10.0°
32‰
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1936
Nov. 4-5 th
1500
1900
2300
0300
0700
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10
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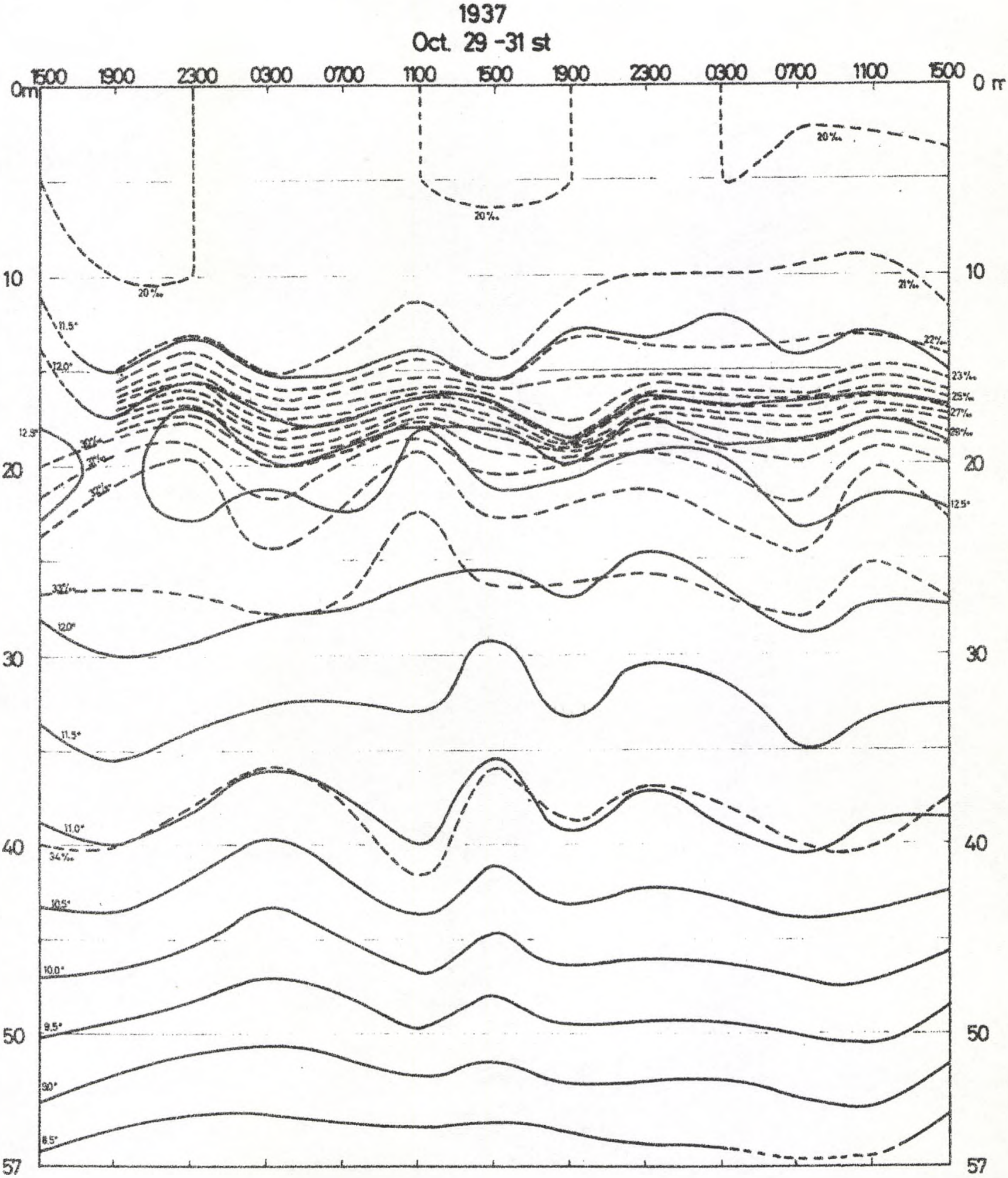
30
40
50
60
62
29‰
9.0°
30‰
9.0°
8.5°
31‰
10.0°
32‰
33‰
10.0°
34‰

Fig. 4.


1937
Oct. 29 -31 st
1500
1900
2300
0300
0700
1100
1500
1900
2300
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10
20
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57
20‰
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27‰
28‰
12.5°
11.5°
12.0°
12.5°
30‰
31‰
32‰
33‰
12.0°
11.5°
11.0°
34‰
10.5°
10.0°
9.5°
9.0°
8.5°

Fig. 5.

Diagram showing the percentages of food-containing herring larvae and post-larvae every four hours during three consecutive 24-hour periods from Oct. 28th to Oct. 31st, 1947, based on the combined material from six different depths.

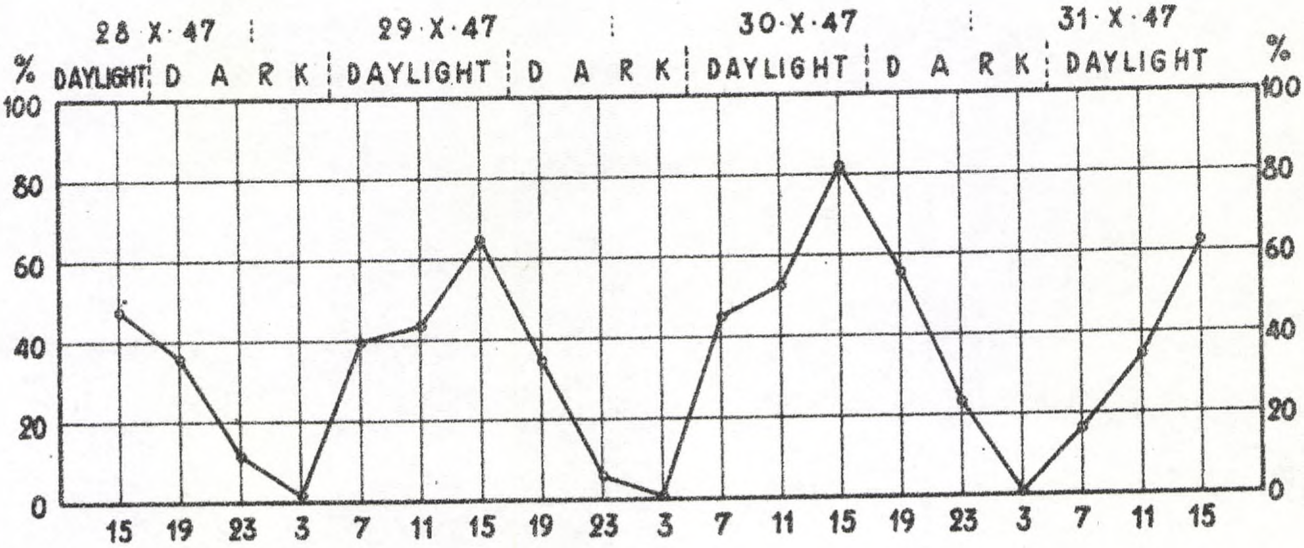


Fig 6.

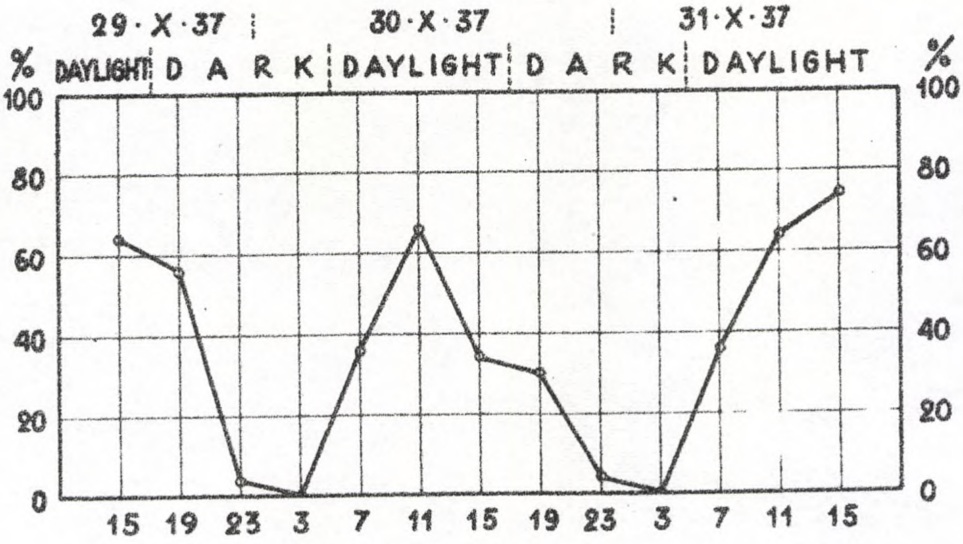
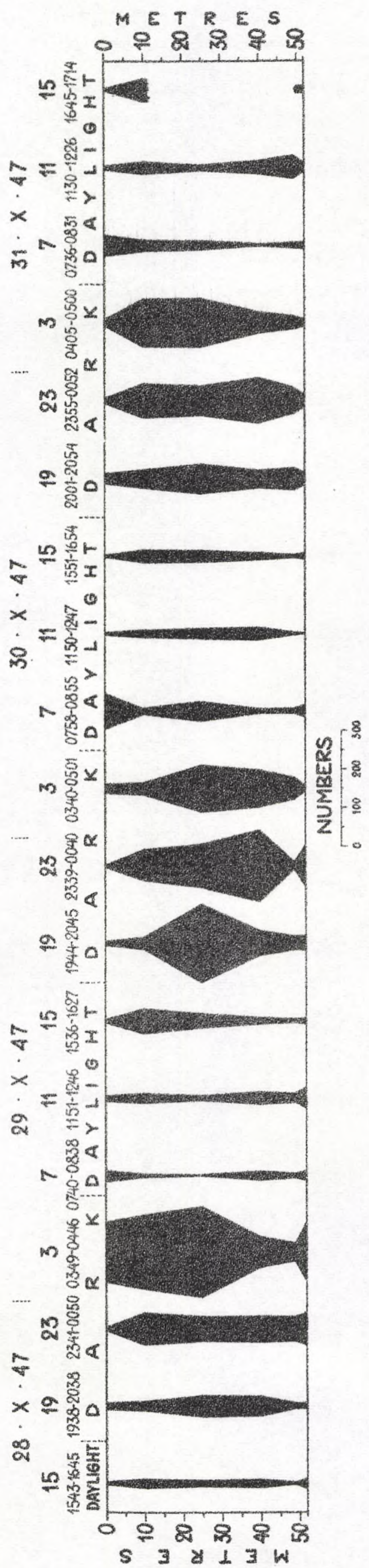


Diagram showing the percentages of food-containing herring larvae and post-larvae every four hours during two consecutive 24-hour periods from Oct. 29th to Oct. 31st, 1937, based on material taken with the 1-metre net at 25 m depth.

Fig. 7.


28 · X · 47
29 · X · 47
30 · X · 47
31 · X · 47
15 19 23 3 7 11 15 19 23 3 7 11 15 19 23 3 7 11 15
1543-1645 1938-2038 2341-0050 0349-0446 0740-0838 1151-1246 1536-1627 1944-2045 2339-0040 0340-0501 0758-0855 1150-1247 1551-1654 2001-2054 2355-0052 0405-0500 0736-0831 1130-1226 1645-1714
DAYLIGHT
DARK
DAYLIGHT
DARK
DAYLIGHT
DARK
DAYLIGHT
METRES
0 10 20 30 40 50
NUMBERS
0 100 200 300