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Frequency and distribution of post-larval stages of herring (Clupea harengus L.) in Icelandic waters.

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I. INTRODUCTION

Investigations on the frequency and distribution of herring fry in Icelandic waters were initiated by JOHANNES SCHMIDT during the period 1903—1908, when the work was carried out from the research vessel „Thor". These investigations were resumed in 1924, and collections are available from many years during the period 1924—1939, when the research vessel "Dana" and H. M. S. "Fylla" were engaged in this work.

The material collected during the period 1903—1908 was treated by JESPERSEN (1920), while TÅNING (1936a) described the results of investigations during the years 1924—1934 and summarized all available data up to that time. Since then TÅNING (1943, 1948) has published cruise reports from 1938, 1939 and 1946 with data on the frequency and distribution of herring fry in Icelandic waters.

The results of previous investigations are summarized by TÅNING (1936a, p. 18) in the following way:

"1. The aim of the work was first and foremost to determine, how far our present knowledge extends with regard to spawning times and spawning places of the herring communities spawning in spring and summer at Iceland; shortcomings in our knowledge have been emphasized.

2. Both communities spawn apparently within the 75 m line approximately, perhaps chiefly about the 50 m line; in any case there is no evidence of any extensive spawning out in greater depths. How near the spawning places are of the coast, on the other hand, is not yet known, detailed investigations being lacking.

3. The tiny fry of the *spring herring* have so far only been found on the south coast and only in the month of April; but we still lack detailed investigations for March. The spawning is probably mainly over in April; when it begins is uncertain. Possibly the warmer part of the south coast is normally the only important spawning place for the spring herring at Iceland.

4. The tiny fry of the *summer herring* are found from the Horns along the whole south coast and on the west coast at least as far as Snaefellsnes (whether any important spawning occurs in Brede Bay, is yet not known); the spawning period lies between the last part of June and probably mid-August, but its termination is still uncertain as we have no suitable material from September.

5. In certain years at any rate there is a very important spawning ground for the summer herring at south-east Iceland near V. Horn, which has not been known hitherto. In this area and in the area round Faxe Bay we apparently have spawning maxima.

6. Though of quite subordinate importance, sporadic spawning, presumably due to exceptional conditions, may occur outside the normally frequented areas and normal periods.

7. As SAEMUNDSSON has already indicated, the spring herring apparently spawn at a temperature of about 5—7° C; the summer herring spawn however at about 7—9°C.

8. It is possible, that the present warmer period in the waters of Iceland has produced a certain amount of change in respect to the spawning times, spawning places and relative amounts of the two communities of the herring; but a more detailed consideration of this interesting problem is not possible owing to the lack of adequate and continuous investigations."

The present investigation is a direct continuation and amplification of the Danish research work, the results of which have been summarized above. During this work the same sampling technics were used as during the period 1924—1934, except that oblique hauls were taken instead of horizontal hauls, as this technic was used in the Danish work during 1938, 1939 and 1946.

As the location of the spawning grounds in the southern and south-western coastal waters was but imperfectly known, a general survey was repeated several times during 1948, while two surveys were carried out in the following years, one in spring (April—May), and the other in summer (July—August). However, the laboratory failed to get support for cruises during the spring of 1949 and summer of 1952, and this was the more infortunate as later events have shown, that a rich year-class originated in the spring spawning stock during 1949. These gaps in the series of observations were very discouraging as the study was intended to serve as a basis for conclusions regarding fluctuations in the number of post-larval stages of herring from one year to another. The great work involved in sorting this large material makes it imperative that uninterrupted series of observations are procured.

The material from the years 1948—1951 comprises about 76000 larval specimens (against 16000 taken during the period 1924—1934). The largest samples were divided into aliquot parts, but usually all the post-larval stages were sorted out and 50 or 100 of each sample were measured. When the numbers were less than 50, all undamaged specimens were measured. A copy of all the measurments in mm is kept at the Institute in Reykjavík.

The Icelandic waters are divided into areas as shown in fig. 1. The hauls were all of 30 minutes duration, but for comparison with earlier records the numbers per 1 hour haul have been calculated and the material generally arranged in much the same way as previously done by TÅNING (1936a, 1936b) and the present author (EINARSSON 1951b).

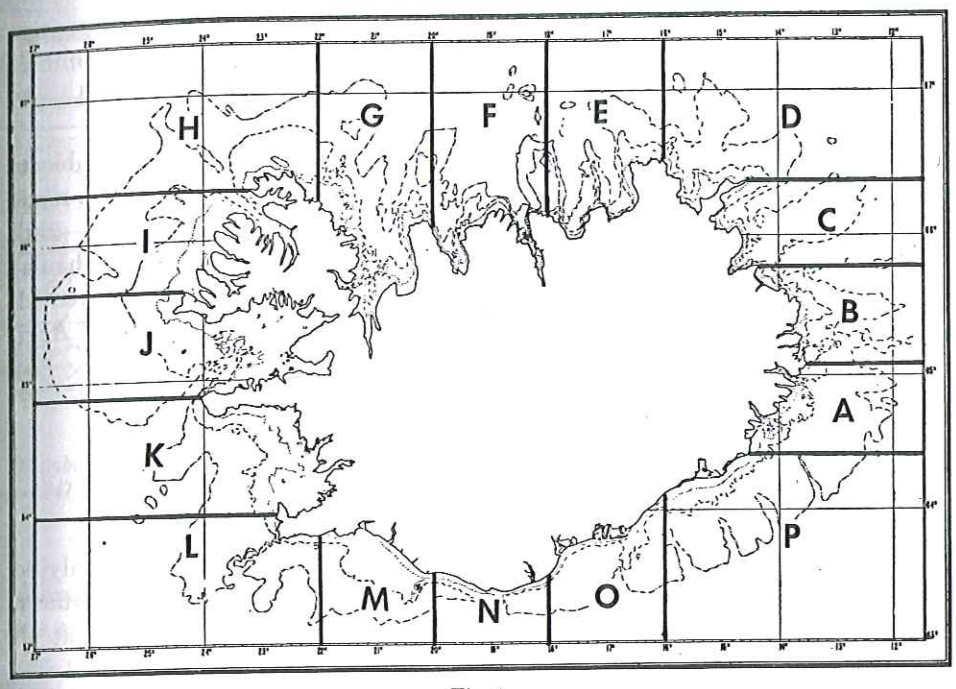


Fig. 1.
Division of the Icelandic coastal waters into areas (A—P).

II. INVESTIGATIONS DURING 1935—1947.

As previously mentioned, the collections obtained up to and including 1934, were discussed by JESPERSEN (1920) and TÅNING (1936a).

1935—1937. No collections of fish fry were made.

1938. Hauls were made by "Dana" off the NW and N coasts in late July and the beginning of August, but only two post-larval spring spawners were found, one off Látrabjarg (16 mm) and one off Horn (29 mm), both on 17. July (TÅNING, 1943).

1939. Hauls were made off all the coasts of Iceland in July—August and post-larval summer fry was found in areas *J* (one positive station, 7 specimens) *K* (two positive stations, 322 and 1595 specimens) and *P* (two positive stations, 27 and 12 specimens), (TÅNING, 1943).

1940—1945. No hauls were made.

1946. Collections were made from 10th to 16th September off the west and western part of the south coast. Post-larval summer spawners were found in areas *I* (three positives stations, 1498, 24 and 1221 specimens), *J* (two positive stations, 224 and 203 specimens), *K* (three positive stations 138, 2 and

44 specimens), *L* (one positive station, 4 specimens) and *M* (three positive stations, 2, 16 and 11 specimens). During this period the largest numbers were thus found off the north-west coast, the average size there being 17—18 mm (TÅNING, 1948).

1947. The present investigations started that year. It was not possible to use the S. 200 net, but a large number of Hensen net vertical hauls were made instead; 13th—16th March in area K (Faxaflói, no positive hauls), 20th—26th March in areas K. L, M, N, O (Faxaflói and south coast, no positive hauls) and 1st—12th April in areas K, L, M, N, O and P (positive hauls in area M, N and O). These show that hatching did not begin until the beginning of April (EINARSSON, 1949).

III. INVESTIGATIONS DURING 1948

A. Summer fry from 1947.

Records of the occurrence of post-larval summer fry from 1947 are analysed in table 1. In January they were found in considerable quantities in the southern part of Faxaflói, expecially in the night hauls. They were also found at all

TABLE 1.

Survey of O-group summer spawners in Jan., Apr. and May 1948 according to areas.

Area	Date	Size groups (mm) 25–29	30–34	35–39	40–44	45–49	No. m.	?	Total no.	Av. size	No. of stat.	No. pos. stat.	No. per 1h. pos. st.
K	6–9/1	9	164	342	175	9	699	16	715	36.99	11	9	159
L	9–10/1		2	8	2		12	1	13	37.33	3	3	9
K	8–24/4		15	55	52	2	124	4	128	38.63	30	10	26
I	29–30/4	4	4	7	1		16	1	17	37.19	17	4	9
B	21/5			1			1		1	(35.00)	4	1	2
Total:		13	185	413	230	11	852	22	874		65	27	

three stations investigated outside Faxaflói, off Reykjanes, but they were not encountered at two stations in the northern part of Faxaflói (see fig. 2).

This yearclass was again found to be of common occurrence in Faxaflói in the beginning of April, both in the southern and eastern part of the bay, (see fig. 3). At the end of April it was found at one station in Faxaflói and three stations in Ísafjarðardjúp.

This was the only sampling done in January and there are only a few collections from April, and therefore it is not possible to make a valid comparison. However, other April collections do not show such an abundance of the O-group summer spawners and it seems probable that this yearclass was much above the average in costal waters.

These collections show clearly the size to which the summer spawners attain during the autumn and first winter of their life. The range of the O-group

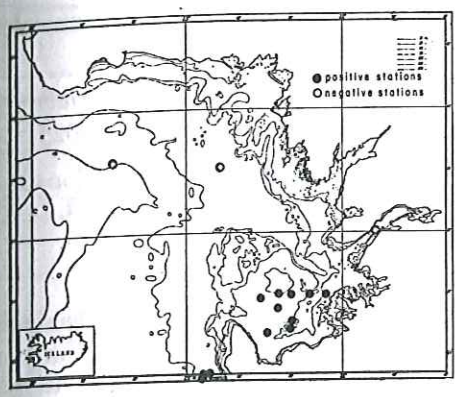


Fig. 2.
Distribution of post-larval summer fry from 1947 in January 1948 in Faxa Bay and Miðnessjór.

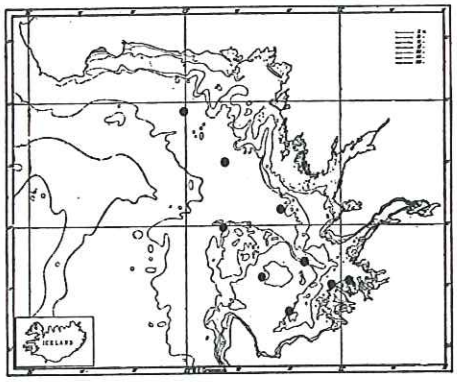


Fig. 3.
Distribution of post-larval summer fry from 1947 in the beginning of April 1948 in Faxa Bay.

summer spawners in April is from 27 to 47 mm. In the beginning of January the average size in Faxaflói is 37.0 mm (n=699), but in April it is 38.6 mm (n=124). In Ísafjarðardjúp it is less, i. e. 33.9 mm (n=16). Here two size-groups seem discernible (27—30 mm and 33—40 mm). Two size-groups are also indicated in Faxaflói (27—37 mm and 38—47 mm). The post-larvae had not begun to form scales.

TABLE 2.

Survey of post-larval spring spawners, April—July 1948.

Area	Date	Size groups (mm) 6–9	10–14	15–19	20–24	25–29	30–34	35–39	No. m.	?	Total no.	Av. size	<10mm %	No. of stat.	No. pos. stat.	No. per 1h. pos. st.
K	8–24/4	2	11						13		13	11.15	15.4	30	3	9
L	12–20/4	52	131						114	5	188	10.54	27.7	13	8	47
M	12–20/4	486	1126	18					507	25	1655	10.54	29.4	25	23	144
N	16–18/4	57	102						159	5	164	9.82	34.8	9	8	41
O	16–18/4		7						7	1	8	11.33	0.0	8	3	5
P	17/4		18						18		18	12.17	0.0	6	3	12
K	3–7/5	1	144	164					175	19	328	14.45	0.3	22	13	51
L	8–9/5		500	398	36				248	10	944	14.40	0.0	10	9	210
M	11–12/5	5	1117	1122	73				351	12	2329	14.32	0.2	13	11	424
N	18/5		1		1				2	1	3	16.00	0.0	8	1	6
O	18/5		1	1	1				3		3	16.33	0.0	8	2	3
P	19/5			1					1		1	17.00	0.0	11	1	2
K	3–10/6		4	65	80	13			162	1	163	19.76	0.0	15	13	25
K	30/6					1	2		3		3	31.00	0.0	12	2	3
I	6/7						1		1		1	30.00	0.0	11	1	2
I	19/7							1	1		1	37.00	0.0	5	1	2
Total no.		603	3162	1769	191	14	3	1	1765	79	5822			206	102	114

Number of vertebrae were counted from 667 specimens taken in January, with tho following results:

No. of vertebrae	*55*	*56*	*57*	*58*	*59*	*Total:*	*Av. no. of vertebrae*
Number:	4	124	442	92	5	667	56.955 ± 0.024

This vertebral number is in accordance with the value usually found for the summer spawners (EINARSSON, 1951a).

B. The Year-classes from 1948.

During 1948 efforts were made to delimit the spawning areas of the herring and locate the main spawning centres, as this was a prerequisite for planning the annual surveys. To this end the whole spawning area or parts of it were surveyed six times during the period April—September.

The records can be divided into two parts, April—May and July—September, with only a slight overlapping in June. In the former period the post-larval spring spawners are encountered whilst in the second were found the post-larval summer spawners. In June were found the last traces of spring spawners, when the hatching of summer spawners was just beginning. The two seasonal races will now be considered separately.

1. Spring fry from 1948.

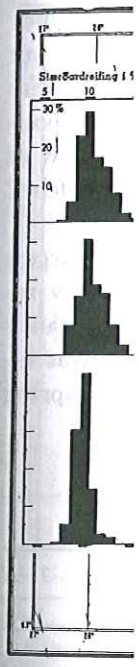
In table 2 a survey of the whole material of this year-class is given, divided into periods and areas.

The April observations (8.—20. April, fig. 4) show that hatching of herring fry occurred in areas K, L, M, N, O and P, the main spawning centre lying in the waters west of Vestmannaeyjar, i. e. in area M. In this area 144 specimens were taken per positive haul, while the number decreased both westwards and eastwards.

The size distribution was very similar in all areas and a considerable proportion of the larvae were recently hatched. In areas O and P the hatching seems to have been of very short duration as no larvae < 10 mm in length were found after about the middle of April. The hatching area seems to have been divided into two parts, one to the west and one to the east. The western part around and west of Vestmannaeyjar was of very great importance, but in area N and especially in area O several negative stations were found, while numbers again showed a slight rise in area P.

The May observations (21. April — 29. May, fig. 5) show that the herring fry had drifted westwards, the largest numbers were still found in area M, but great numbers were then also encountered in area L and even K.

The size distribution indicates that hatching had practically finished by the first half of May. The average size was then 14—15 mm. The size distribution was very similar in all three areas where the fry occurred, indicating only one spawning and hatching maximum.



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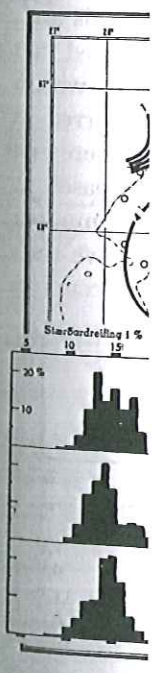

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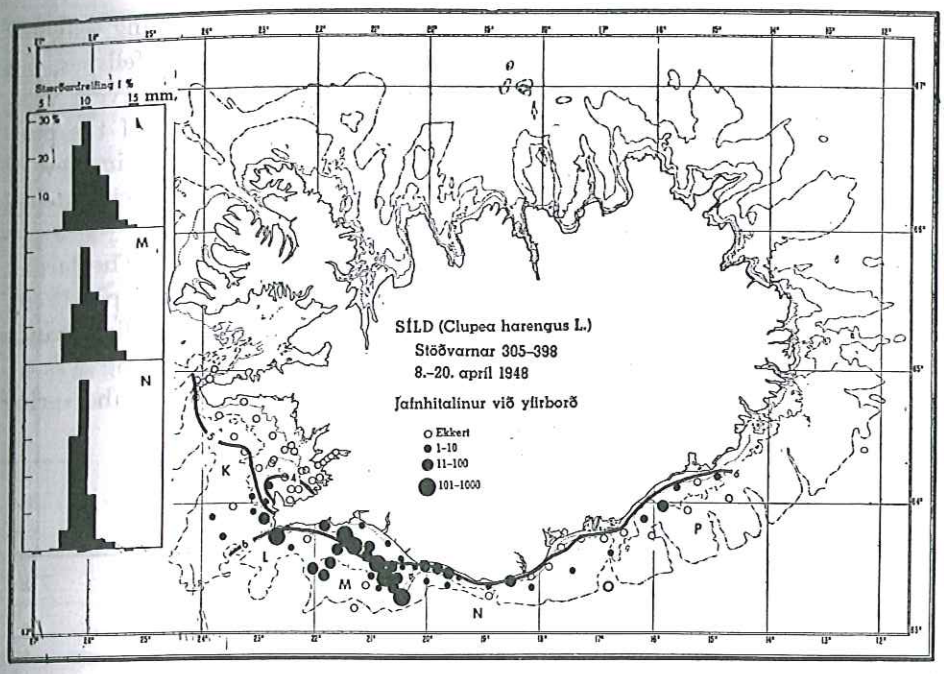

Fig. 4.
Distribution of spring fry 8.—20. April 1948. Surface isotherms. Size distribution in areas L, M and N.

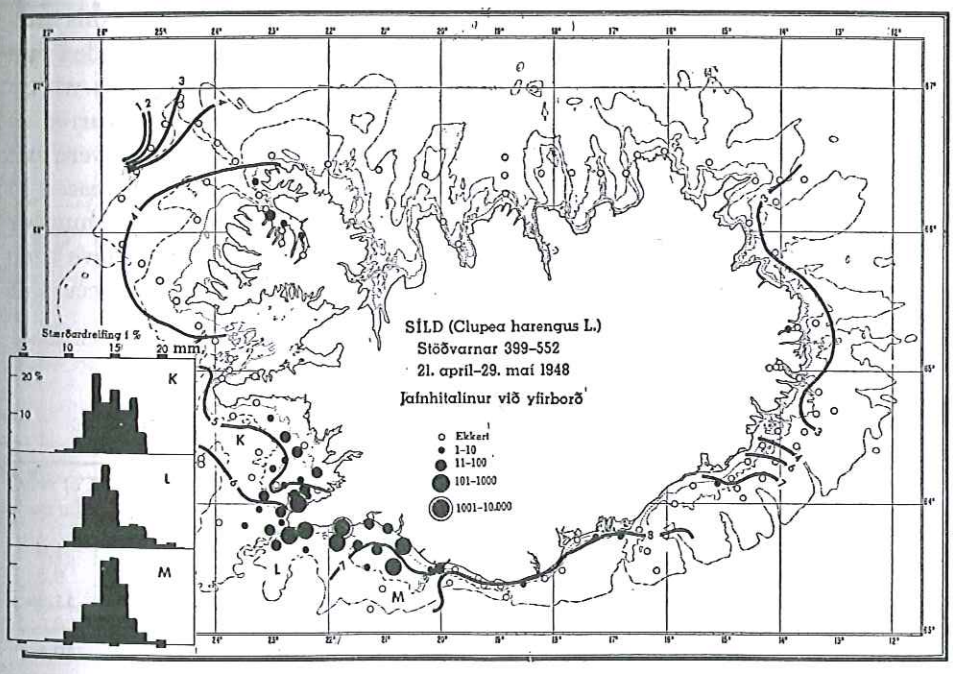

Fig. 5.
Distribution of spring fry 21. April — 29. May 1948. Surface isotherms. Size distribution in areas K, L and M.

During June and July (31. May — 18. July, figs. 6 and 7) spring spawned fry were found in the beginning of June in Faxaflói and off Snæfellsnes, but nowhere else in any quantities. During June and July extensive surveys were made off the west and north coasts in order to follow the drift of the post-larvae, but without success. This negative result is very interesting in view of the success in following the drift of the *Mallotus* fry which had been hatched in the same areas as the herring.

Numbers found in the differnt months are shown in table 3. The largest numbers occurred in May, and the small post-larvae were rather poorly represented, which conforms to earlier findings. The reasons for this discrepancy will be discussed in a later chapter. The table shows that hatching was almost entirely confined to the month of April, and that after June the spring spawned fry were very rarely caught, as previously mentioned.

TABLE 3.

Number of post-larval spring spawners during April—July 1948.

	April	*May*	*June*	*July*	*Total*
Total no. of larvae	2046	3608	166	2	5822
No. of positive hauls	48	37	15	2	102
Av. no. per 1^h positive haul	85	195	22	2	114
Larvae <10 mm	597	6	0	0	603
Small larvae %	29,2	0,2	0,0	0,0	10,4

Numbers according to depth are shown in table 4. The results of this analysis differ greatly from those described by TÅNING (1936a). He concluded that spawning occurred chiefly within the 75 m depth contour or perhaps within the 50 m line, whereas our results show that the main hatching occurred in depths between 75 and 150 m. Fry of less than 10 mm in length were not found deeper than 150 m, and the percentages of small larvae decreased in shallower water. However, it must be pointed out that the greatest number of hauls were made between 75 and 150 m depth, but as the results have been confirmed by later observations, it seems certain that the spawning occurs in deeper water than previously assumed.

TABLE 4.

Number of post-larval spring spawners during April—July 1948 according to depth of locality.

Depth in m	*No. of pos. hauls*	*Total no. of larvae*	*No. per 1^h pos. haul.*	*Larvae <10mm*	*% of small larvae*
< 50 m	16	449	56	7	1,6
50—75 m	19	296	31	29	9,8
75–150 m	59	4786	162	567	11,8
150–250 m	8	291	73	0	0,0
Total:	102	5822	114	603	10,4

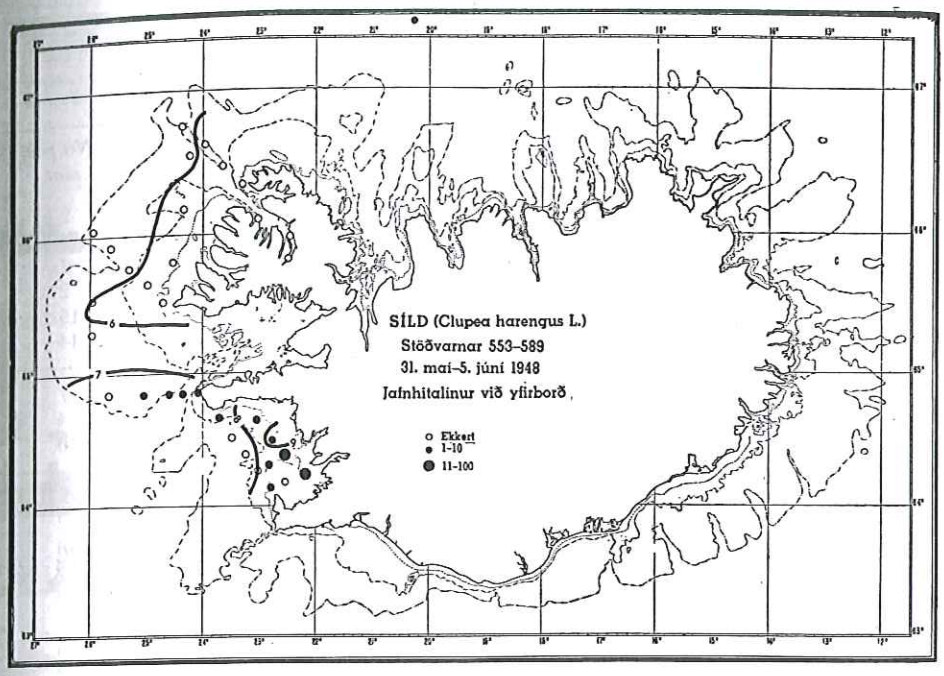

Fig. 6.
Distribution of spring fry 31. May — 5. June 1948. Surface isotherms.

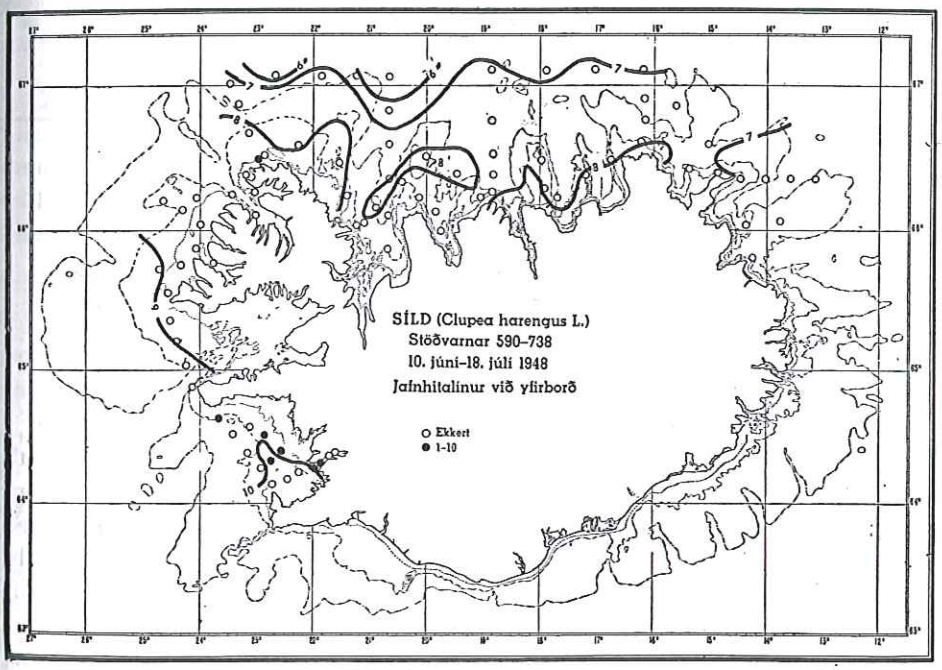

Fig. 7.
Distribution of spring fry 10. June — 18. July 1948. Surface isotherms.

TABLE 5.

Survey of post-larval summer spawners June—September 1948.

Area	Date	Size groups (mm) 6–9	10–14	15–19	20–24	25–29	30–34	No. m.	?	Total no.	Av. size	<10mm %	No. of stat.	No. pos. stat.	No. per 1h. pos. st.
K	30/6	5						5		5	7.40	100.0	12	2	5
J	20–28/7		11	7				18		18	14.42	0.0	5	4	9
K	24/7–1/8	86	53	13	1			153	9	162	10.19	53.1	19	7	46
L	1/8	82	5	1				88	14	102	8.08	80.4	8	2	102
M	1–3/8	19548	2207	731	23	1		920	31	22541	11.50	86.7	16	15	3005
M*	1–3/8	1692	620	334	23	1		820	31	2701		62.6	15	14	386
N	3–4/8	42	72	239	45			398	1	399	15.36	10.5	7	7	115
O	4/8	40	226					266	3	269	10.49	14.9	7	4	134
P	4–5/8	66	266	27	5			300	7	371	11.21	17.8	10	10	74
J	19–20/8		117	279	156	16		301	35	603	18.10	0.0	12	4	301
K	20–27/8	69	951	388	173	17	2	315	2	1602	15.67	4.3	17	12	267
L	27–30/8		91	203	49	7		228	26	376	17.18	0.0	8	8	94
M	30–31/8	1	8	52	74	43	4	122	3	185	20.86	0.5	10	7	53
N	31/8–1/9		1	9	11	5	1	27	2	29	21.00	0.0	4	2	29
O	1/9		4	30	13			47	6	53	18.02	0.0	4	4	26
P	1–2/9		27	218	144	39		175		428	19.20	0.0	7	5	171
A	3–5/9			3				3		3	18.33	0.0	7	2	3
J	12–13/9		116	571	682	300	51	150		1720	20.96	0.0	2	2	1720
K	13/9		1	26	140	17	2	91	4	190	21.73	0.0	3	3	127
Total no.		19939	4156	2797	1516	445	60	3607	143	29056			158	100	581
Total no*		2083	2569	2400	1516	445	60	3507	143	9216			157	99	186

*excluding station 783 (19840).

2. Summer fry from 1948.

A survey of all post-larval summer spawners found during our investigation in the summer of 1948 is given in table 5, the material being divided into areas and dates of capture.

Recently hatched fry were first encountered in Faxaflói on June 30th, but only from a single station. Probably slight spawning occurs outside the spawning period proper, as TÅNING has previously pointed out, and this is supported by the fact that we may occasionally find adult individuals that differ greatly from the rest of the stock in the degree of maturity. The present observations indicate that this pre-spawning or post-spawning was insignificant but this question deserves a closer study. Presumably the main hatching does not start until about the middle of July, but these observations do not cover that period.

f	No. pos. stat.	No. per pos. st.
	2	5
	4	9
	7	46
	2	102
	15	3005
	14	386
	7	115
	4	134
	10	74
	4	301
	12	267
	8	94
	7	53
	2	29
	4	26
	5	171
	2	3
	2	1720
	3	127
	100	581
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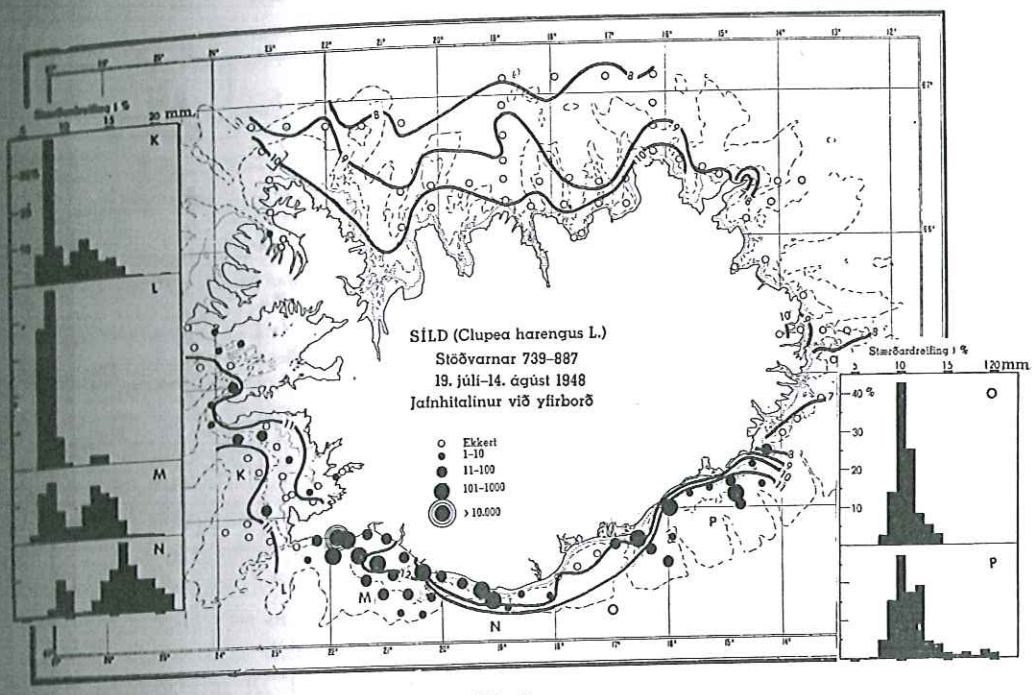

Fig. 8.
Distribution of summer fry 19. July — 14. August 1948. Surface ishotherms. Size distribution in areas K, L, M, N, O and P.

The July—August observations (19. July — 14. August, fig. 8) show that this time hatching is going on in all areas from K eastwards to C. Probably some hatching occurs also in area J (Breiðafjörður), but small post-larvae (<10 mm) were not found in that area during this survey. Our records show three main hatching centres, viz.:

1. The Faxaflói area (area K),
2. The Selvogsgrunn area (area M) and
3. The Meðallandsbugur area (areas O and P).

Of these areas M is of the greatest importance during this season, but earlier and later observations show that P may be of equal or even greater importance in certain years. During this survey an exceptionally rich haul was made off Grindavík, which contained about 20000 specimens in a 30 min. haul.

However, it must be taken into consideration that this survey shows only one phase in the hatching activity. This is clearly shown by the bimodal form of the size distribution graphs from areas K, L, M and N. The lower model langth is about 7—8 mm, while the higher is about 12—15 mm. The higher modal form indicates an earlier hatching maximum in areas K, M and especially

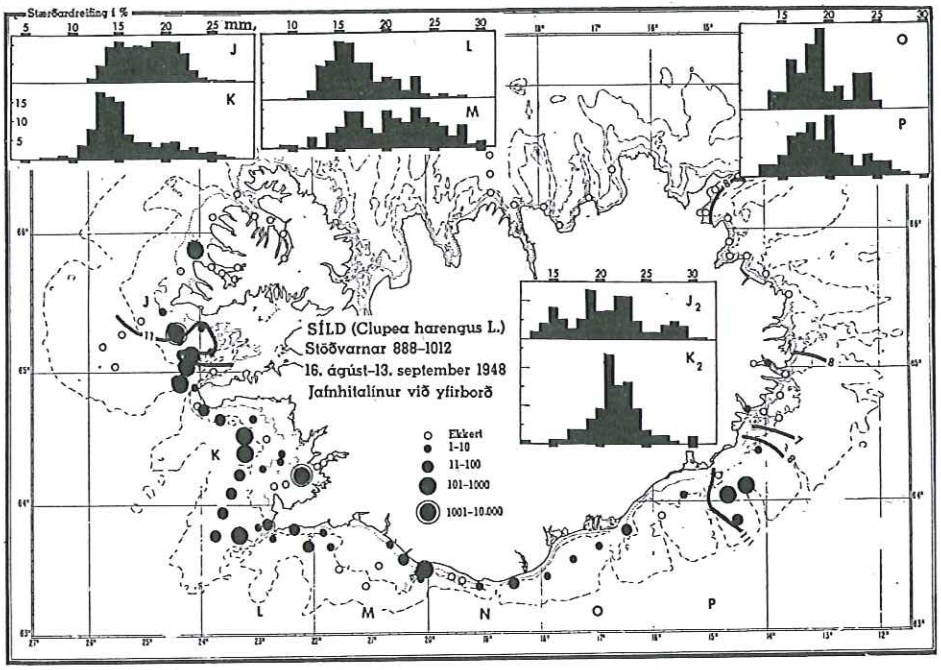

Fig. 9.
Distribution of summer fry 16. August — 13. September 1948. Surface isotherms. Size distribution in areas F, K, L, M, O and P.

N, where the later maximum seems of less importance. Areas O and P differ in this respect and only one hatching maximum is found as shown by the size distribution. During this survey the average size of the post-larvae was between 8 and 15 mm.

The August—September observations (16. August — 13. September, fig. 9) can be divided into two series (see table 5). The first covered the period 19. August — 5. September, and it is seen that the larval stock, hatched in the main spawning areas, had drifted westwards and northwards with the coastal current, the largest numbers then being found in areas J and K. On the other hand, the post-larvae hatched in area P drifted away from the coast, but the observations do not show how far.

The average size was lowest in area K, but hatching seemed practically finished in all areas by that time. Thus the hatching seems of longest duration in Faxaflói, as the first traces of hatching were found there in the last days of June. During this survey the average size varied between 15 and 21 mm.

The second series covered the period 12.—13. September and showed a further increase in the numbers encountered in area J (see table 5). In area

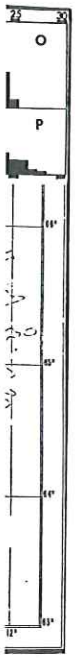

TABLE 6.

Number of post-larval summer spawners during June—September 1948. (Station 783 excluded).

	June	*July*	*August*	*September*	*Total*
Total no. of larvae	5	86	6707	2418	9216
No. of positive hauls	2	10	70	17	99
Av. no. per 1h positive haul	5	17	192	284	186
Larvae <10 mm	5	6	2072	0	2083
Small larvae %	100	7,0	30,9	0	22,6

J (J_2 in fig. 9) a great range of size was found, with an indication of three modal lengths which were not very clearly defined, but they seemed to be about 15 mm, 21 mm and 28 mm. In Faxaflói only the middle modal length of about 21 mm was found.

In the first series a great size range was also found, but the modal lengths were not as well defined as during July—August. To some extent this may be due to post-larvae of about 20 mm evading the net, but below that size the graphs show clear differences between areas, as seen for instance by comparing areas J and K. The disappearance of the modal lengths may indicate a thorough mixture of post-larvae from various areas, which is reflected in the great range of size.

Numbers found in the different months are shown in table 6. Ever increasing numbers per positive haul were taken from June to September, probably because the catching power of the net increases with decreasing light. The small larvae are rather poorly represented in this as in other collections from Icelandic waters.

Numbers according to depth are shown in table 7. Two noticeable features are evident. Firstly, the number per positive haul was largest inside the 50 m line and decreased with increasing depth. Secondly, the small post-larvae were

TABLE 7.

Number of post-larval summer spawners during June—September 1948. according to depth of locality. (Station 783 excluded).

Depth in m.	*No. of pos. hauls*	*Total no. of larvae*	*No. per 1h pos. haul*	*Larvae <10mm*	*% of small larvae*
< 50 m	7	852	243	564	66,2
50—75 m	19	2010	212	162	8,1
75–150 m	65	5896	181	1349	22,9
150–250 m	8	458	115	8	1,7
Total:	99	9216	186	2083	22,6

most abundant in 75—150 m depth, as also were the spring spawners. On the other hand, a second maximum in numbers per positive station was found inside the 50 m line, but this secondary maximum may not be real.

It seems reasonable to assume that hatching starts earlier in shallow water and then spreads to deeper water. This survey seems to cover the second phase in the hatching, but the bimodal forms of the size distribution graphs indicate an earlier sequence of events. This will be more clearly understood, if we consider the frequency of small post-larvae from area M, which is shown in fig. 10. A definite trend in these figures can be seen. In the western part of the Selvogsgrunn were high percentages of small post-larvae, on the bank proper there were low percentages, while south of the bank high percentages were again found.

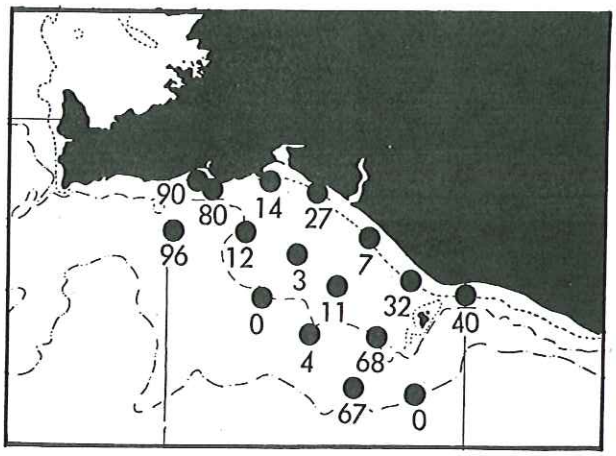

Fig. 10.
Percentages of small fry (<10 mm) on Selvogsgrunn and adjacent waters, 1.—3. August 1948 (see fig. 8).

These observations indicate two centres of hatching at this time, one southwest of Vestmannaeyjar, and the other south of Grindavík. Both of these centres lie either beyond the 100 m line or in close proximity to it (e. g. Stations 783 and 784). A little drifting could thus have brought the small post-larvae inside the 50 m line.

Thus the most probable explanation of the bimodality and the frequency distribution of small post-larvae seems to be that hatching started earlier on the bank proper, reflected in the higher modal length, but then spread to deeper water, as indicated by the distribution of small post-larvae during the July—August survey.

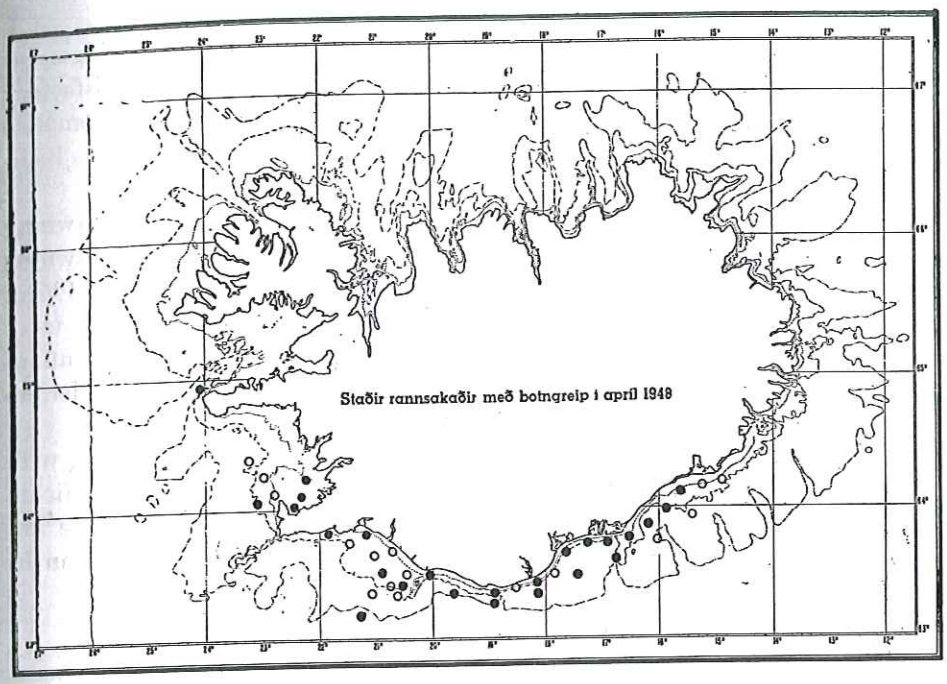

Fig. 11.
Localities investigated with a bottom grab in April 1948. Filled circles: Bottom samples obtained. Open circles: No sample obtained.

C. Bottom investigations during April 1948.

Bottom investigations made by FRIÐRIKSSON in 1935 and 1936 did not yield any evidence concerning the occurence of herring spawn (FRIÐRIKSSON, 1944), and a fairly thorough bottom grab survey made by present author in late July 1939 in Faxaflói, did not show any evidence of herring eggs in that region (EINARSSON, 1941).

In spite of these negative results it was again decided to try to find the eggs by means of a bottom grab. It was not known at that time, where the main egg deposits would be located, and bottom samples were therefore taken at 41 stations scattered over Faxaflói and the southern coastal waters. This experiment could at the same time say if this kind of work gave comparable results with the net hauls, the results of which have been described above. Fig. 11 shows the localities investigated during this survey, filled circles showing where bottom deposits were obtained and open circles where there were no samples obtained.

The resault was entirely negative. From previous experience the author is of the opinion that the bottom grab is very unsatisfactory for this kind of work; firstly, because herring eggs are deposited on a rather hard bottom, where

it is difficult to get adequate samples and secondly, because the spawning areas may be very spasmodic. In fact it proved very difficult to get satisfactory samples even from a gravelly bottom, as small pebbles prevented the complete closing of the grab, thus allowing the finer material to silt out during the hauling process.

Although this method seems very inadequate for surveying the spawning grounds, it might be of value for the closer investigation of known spawning areas, as already done by FRIÐRIKSSON and TIMMERMANN (1950, 1951), especially if a more efficient apparatus than the Petersen grab was used. FRIÐRIKSSON and TIMMERMANN succeeded in getting 8 bottom samples containing herring spawn, in the main spawning area west of Vestmannaeyjar, so clearly indicated by the results of the net hauls during April 1948.

However, the present investigations with the bottom grab, together with the results of the net hauls, show that previous statements on insignificant spring spawning based on negative results of bottom grab surveys were unwarranted, as the method does not yield results on which conclusions can be based.

IV. INVESTIGATIONS DURING 1949

Summer fry from 1949.

As previously mentioned, no sampling was done in the spring of 1949 and the summer sampling during August was rather incomplete. A survey of the material is given in table 8 and fig. 12 and 13.

Curiously enough no post-larvae were encountered in the two main spawning areas delimited during 1948, viz. areas M and P; the stations lay farther off-shore than in the 1948 survey, but nevertheless this seems a noticeable feature. This spawning season in general yielded the lowest mean per positive haul of any of the summer spawnings investigated.

TABLE 8.

Survey of post-larval summer spawners, August 1949.

Area	Date	Size groups (mm) 6–9	10–14	15–19	20–24	25–29	30–34	No. m.	?	Total no.	Av. size	<10mm %	No. of stat.	No. pos. stat.	No. per 1h. pos. st.
O	10/8	1	2					3		3	10.66	33.3	4	1	6
N	11/8		30	3	1			34	6	40	13.12	0.0	4	1	80
L	14/8		112	257	13			150		382	15.60	0.0	3	2	382
K	14–15/8	12	146	164	14	6	3	118		345	14.82	3.5	9	5	138
I	15–18/8		11	28	1		2	42		42	14.59	0.0	6	3	28
Total:		13	301	452	29	6	5	347	6	812			26	12	135

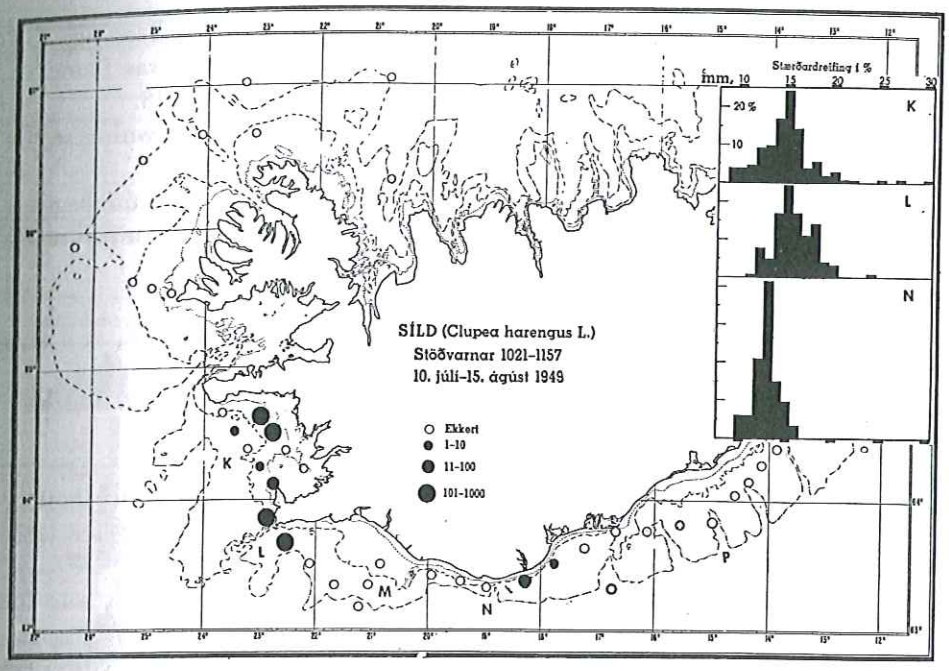

Fig. 12.
Distribution of summer fry 10. July — 15. August 1949. Size distribution in areas K, L and N.

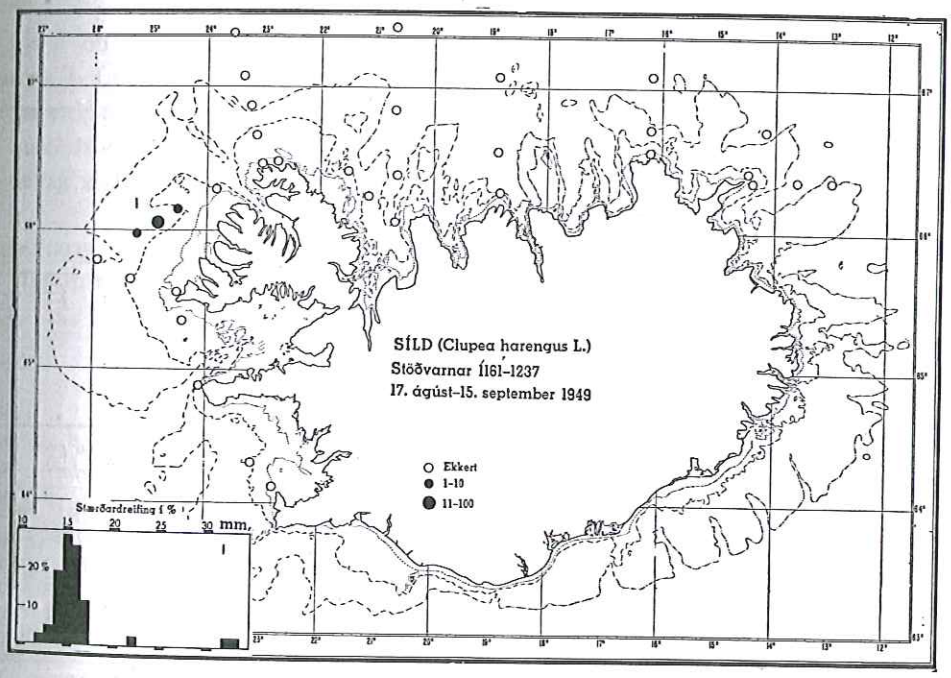

Fig. 13.
Distribution of summer fry 17. August — 15. September 1959. Size distribution in area I.

No. pos. stat.	*No. per 1h pos. st.*
1	6
1	80
2	382
5	138
3	28
12	135

The highest average numbers were found in areas K and L, the average size at this time being about 13—16 mm. The lowest average size was found in area N which is in contrast with the results of the summer of 1948.

Judging from this rather incomplete material, the summer spawning seems to have failed in the usual main spawning areas.

A survey off the west and north coasts during late August and the beginning of September, yielded only a few post-larvae off the northwestern peninsula (area I), while the north coast stations were all negative.

V. INVESTIGATIONS DURING 1950

A. Spring fry from 1950.

The survey was made rather late in the spring, viz. in the latter half of May, but this can be compared with the second survey during 1948 (see table 2). An analysis of the material is shown in table 9 and fig. 14.

The hatching had practically finished at that time, as was also true for 1948. The average number per one hour positive haul was 139 specimens. The largest numbers were found in area K, and compared with 1948 low numbers were found in areas L and M which then yielded the greatest numbers. The main hatching area during this spring seems to be area K, as seen for the summer of 1949.

B. Summer fry from 1950.

Fairly extensive collections were made during late July and the beginning of August 1950 all around the country. The stations off the south coast were worked by the Danish research vessel. An analysis of the material is given in table 10 and on figs. 15 and 16.

No post-larvae were encountered off the north and east coasts. The greatest numbers were found in areas M and P, but the averages are unfortunately

TABLE 9.

Survey of post-larval spring spawners, May—July 1950.

Area	Date	Size groups (mm) 6-9	10-14	15-19	20-24	40-44	No. m.	?	Total no.	Av. size	<10mm %	No. of stat.	No. pos. stat.	No. per 1h. pos. st.
L	16/5			19	3		22		22	17.95	0.0	4	2	22
M	17–18/5	2	77	244	103		243	14	440	15.95	0.5	10	8	110
K	18–19/5	10	399	705	78		367	6	1198	16.44	0.8	10	10	240
J	21/5		2	3			5		5	13.60	0.0	4	2	5
O	6/6				1		1		1	(23.00)	0.0	4	1	2
K	28/7					1	1		1	(44.00)	0.0	6	1	2
Total:		12	478	971	185	1	639	20	1667			38	24	139

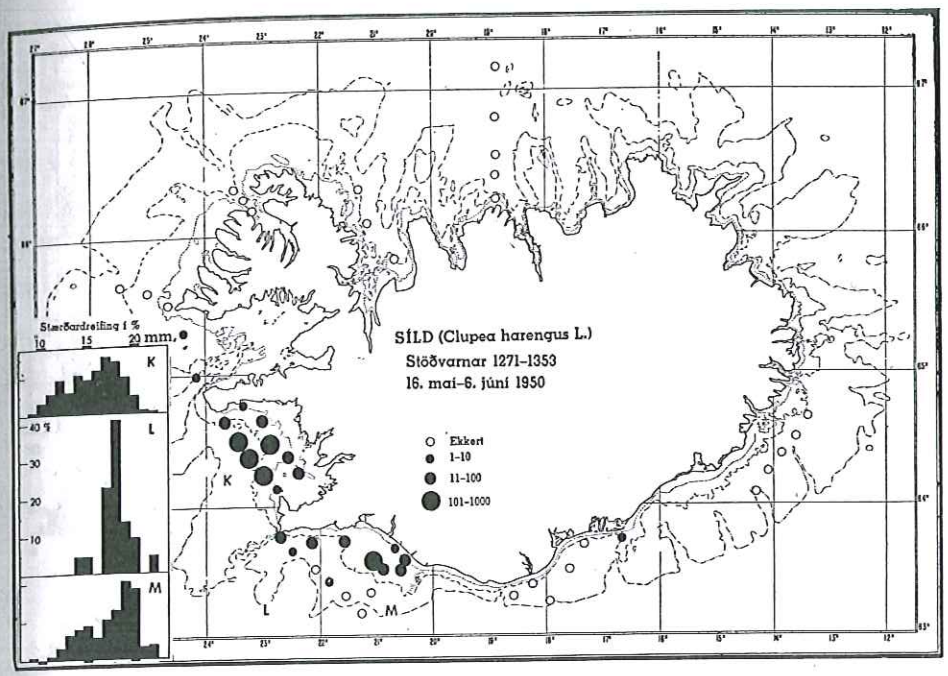

Fig. 14.
Distribution of spring fry 16. May — 6. June 1950. Size distribution in area K, L and M.

based on few observations. Unmistakeable evidence is seen of hatching in area J. In fact, hatching was going on in all areas from J to P. The average number per positive station was high, viz. 671 specimens.

TABLE 10.

Survey of post-larval summer spawners, June—August 1950.

Area	Date	Size groups (mm) 6–9	10–14	15–19	20–24	25–29	30–34	No. m.	?	Total no.	Av. size	<10mm %	No. of stat.	No. pos. stat.	No. per 1h. pos. st.
O	6/6		2					2		2	(11.00)	0.0	4	1	4
K	28/7	53	97	216				144	2	368	13.70	14.4	6	5	147
J	28–29/7	2	14	12				28		28	13.75	7.1	5	3	19
L	1/8	8						8		8	8.94	100.0	1	1	16
M	1/8	623	729	7				400		1359	10.13	45.8	2	2	1359
N	2/8			3				3		3	(16.00)	0.0	1	1	6
O	2/8	19	84	24				127		127	11.61	15.0	1	1	254
P	2–3/8	43	1929	348				400		2320	11.90	1.9	2	2	2320
A	15–16/8		2	3	1			6	1	7	(16.00)	0.0	2	2	7
P	15–16/8	678	2086	2392	500			413	14	5670	14.39	12.0	8	8	1417
J	29/8	186	209	286	268	67	31	195		1047	17.67	17.8	3	3	698
K	30/8	12	24	69	16	1		122	8	130	15.63	9.2	4	4	65
Total		1624	5176	3360	785	68	31	1856	25	11069			39	33	671

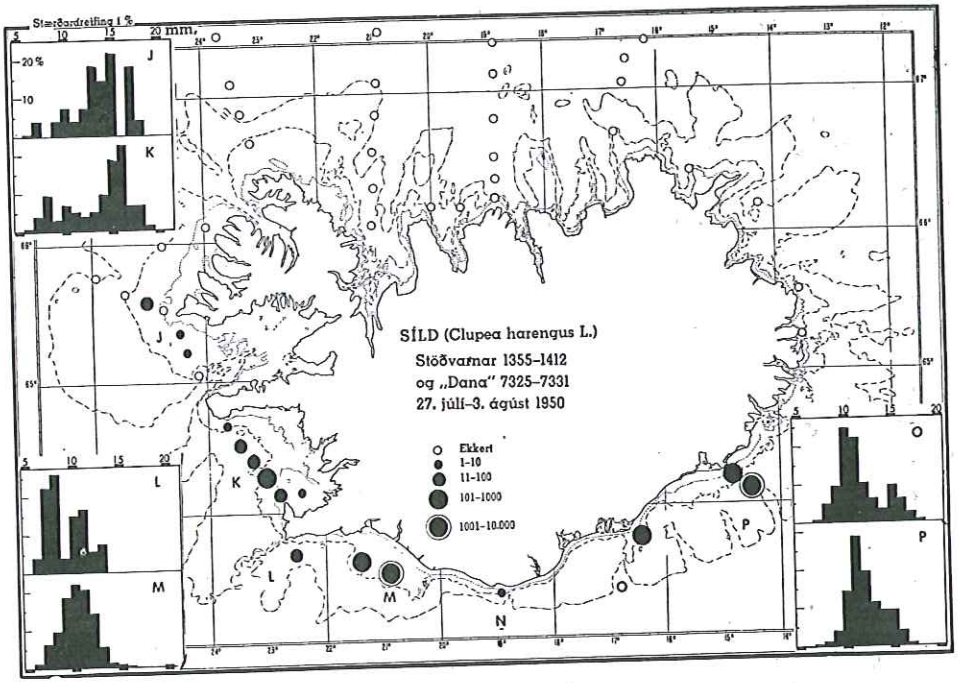

Fig. 15.
Distribution of summer fry 27. July — 3. August 1950. Size distribution in areas J, K, L, M, O and P.

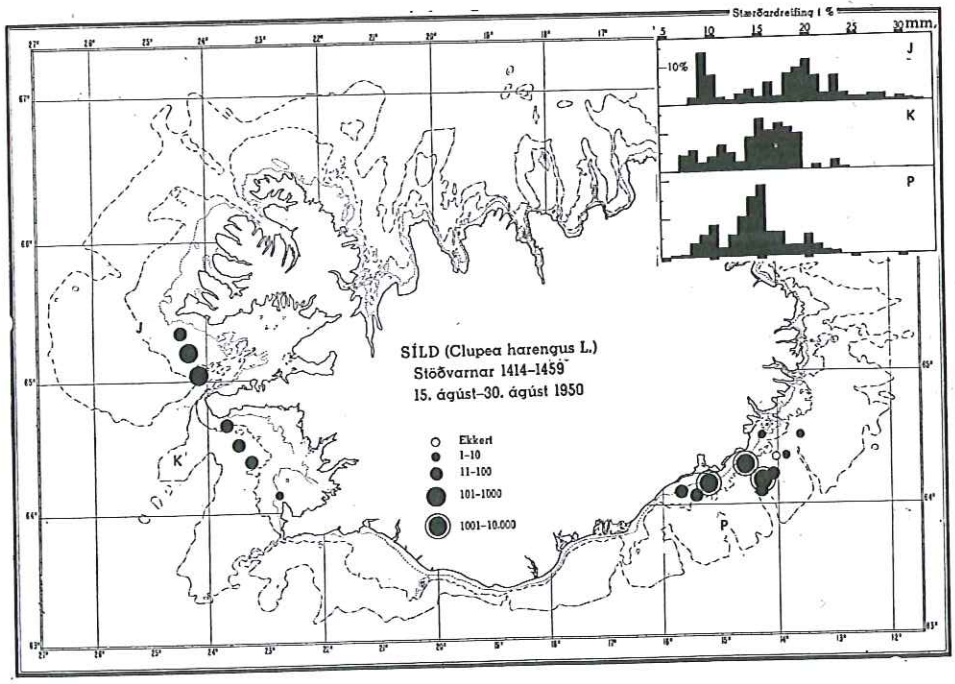

Fig. 16.
Distribution of summer fry 15. — 30. August 1950. Size distribution in areas J, K and P.

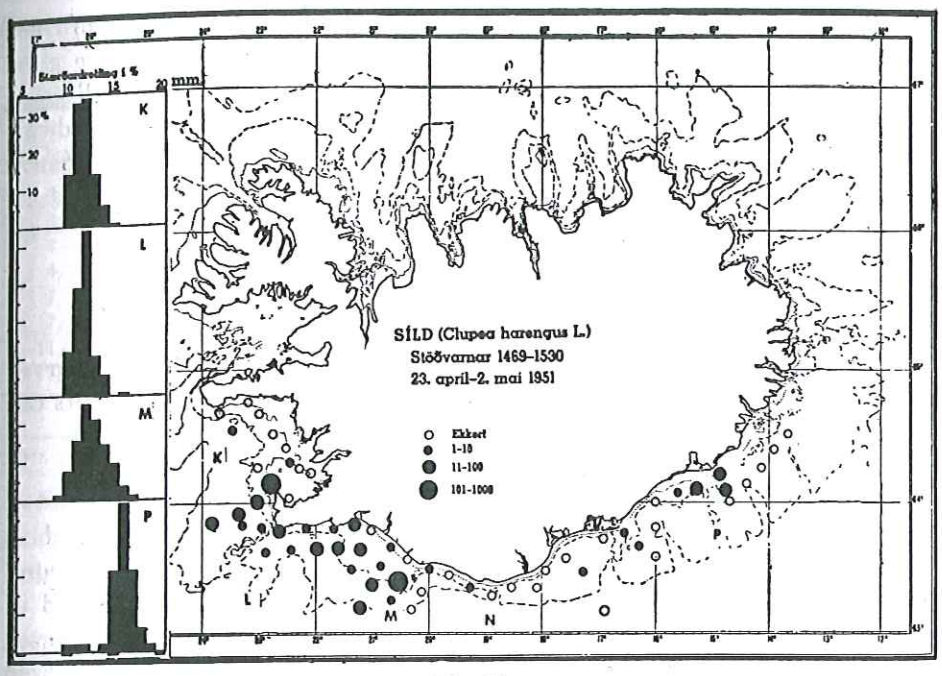

Fig. 17.
Distribution of spring fry 23. April — 2. May 1951. Size distribution in areas K, L, M and P.

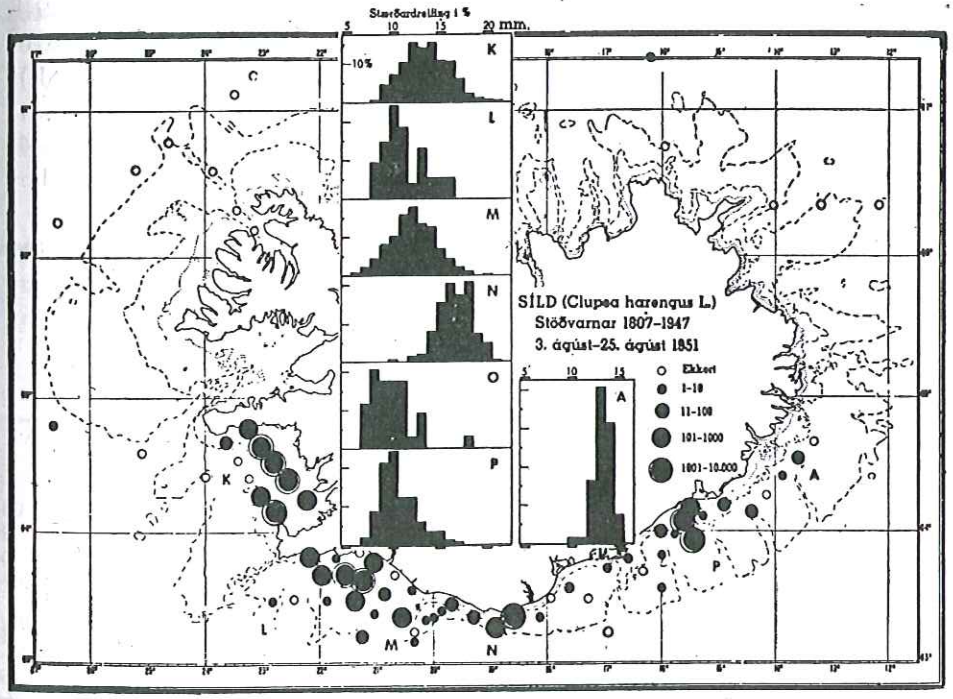

Fig. 18.
Distribution of summer fry 3.— 25. August 1951. Size distribution in areas K, L, M, N, O, P and A.

Icelandic investigations in the latter half of August (see fig. 16) confirmed that considerable spawning had occurred in area P, where there were great numbers of post-larvae at three stations. Hatching was at this time still going on in the areas considered, J, K and P. The size distribution seems to indicate two or even three spawning phases. The observations tend to show that hatching seems to have been successful this summer.

VI. INVESTIGATIONS DURING 1951

During 1951 we again got an opportunity of making a thorough survey according to the plans made and carried out during 1948. These two years can therefore be more closely compared.

A. Spring fry from 1951.

An analysis of the material is given table 11 and fig. 17. The numbers found during this survey were rather low and very similar to those found during the April survey in 1948. The highest numbers were encountered in areas K and M, and it will be noted that in comparison to 1948 the post-larvae were more numerous in area K. However, it will be seen that the post-larvae were mostly found in the southernmost part of area K and this larval stock was thus probably partly derived from hatching in area L.

There seems to be a recurrence of the phenomenon observed during 1948 that the hatching of spring spawners had two centres; a major one west of Vestmannaeyjar (areas L and M) and a minor one off Hornafjörður (area P), while very insignificant hatching occurred in areas N and O.

The size distribution shows very similar features in areas K, L and M, while the average was considerably higher in area P, indicating an earlier spawning there.

It will be seen that the general picture of the extent and magnitude of the hatching was similar in 1951 and 1948.

TABLE 11.

Survey of post-larval spring spawners, April—May 1951.

Area	Date	Size groups (mm) 6–9	10–14	15–19	20–24	25–29	No. m.	?	Total no.	Av. size	<10mm %	No. of stat.	No. of pos. stat.	No. per 1^h. pos. st.
K	24–26/4		375	1			110		376	11.69	0.0	11	4	188
L	26–27/4		112	1			113	5	118	11.73	0.0	8	8	29
M	27–28/4	7	454	84			280	22	567	12.65	1.2	16	12	94
N	29/4		6	3			9	3	12	13.89	0.0	6	2	12
O	1/5	2	10				12		12	10.33	16.7	9	3	8
P	1–2/5		3	42	1	1	47	1	48	17.10	0.0	8	4	24
Total		9	960	131	1	1	571	31	1133			58	33	69

TABLE 12.

Survey of post-larval summer spawners, August 1951.

Area	Date	Size groups (mm) 6–9	10–14	15–19	20–24	No. m.	♀	Total no.	Av. size	<10mm %	No. of stat.	No. of stat.	No. per 1h. pos. st.
A	3/8		70	6		54		76	13.20	0.0	4	2	76
P	3/8	1927	2942	182		186	1	5052	10.39	38.1	7	7	1443
O	4/8	17	16	1		34	8	42	9.79	40.5	9	6	14
N	4/8		194	1394	113	178	27	1728	16.59	0.0	7	7	494
M	5–7/8	703	3043	1018	45	386	12	4821	12.03	14.6	17	14	689
L	7/8	39	99	16		54	2	156	11.15	25.0	3	2	156
K	10–11/8	266	7519	3035	112	419	4	10936	13.38	2.4	13	9	2430
G	17/8		1	1		2		2	14.50	0.0	2	1	4
Total		2952	13884	5653	270	1313	54	22813			62	48	950

B. Summer fry from 1951.

The summer survey was made during the first half of August, and an analysis of the material is given in table 12 and fig. 18.

Very rich hauls were obtained in areas K, M, N and P, with the highest average number in areas K and P. The general picture was very similar to that found during 1948, with the exception that post-larvae were much more numerous in area K during 1951. However, the same three main spawning centres, off Hornafjörður, on Selvogsgrunn and in Faxaflói are clearly distinguishable.

The size distribution shows also similar trends, but is unimodal throughout. As hatching was still going on a second maximum might have appeared later, but it seems more probable that only one maximum developed during this year.

If the size distribution inside each area during 1948 and 1951 is compared a surprisingly good conformity is seen. In both years the size distribution in areas K and M was very similar, while in L a greater number of small post-larvae were found. The average in N was higher, and in both O and P a great percentage of small post-larvae was found in both years.

VII. GENERAL DISCUSSION

A. Some methodological remarks.

The deficiency of the sampling gears used was felt greatly during the present investigation. Hauls were made with 2 m stramin net, this gear having been used in the Danish investigations from 1924—1946. During the period 1924—1934 horizontal hauls were made, with 15 m and 65 m wire respectively, but in 1938, 1939 and 1946 oblique hauls of 30 minutes duration were made. The

wirelengths were 300—200—100, 200—150—50 or 150—100—50, each step being of 10 minutes duration, the upwards hauls included. When starting the present work with this gear in 1948, this method of sampling was adopted.

Investigations on the distribution of post-larval stages of herring seem to indicate that the numbers found must be evaluated with great care, as the gear does not seem to sample them effectively enough. Thus RUSSELL (1930) had to exclude the Clupeoids from his quantitive treatment of the post-larval stages of fishes in Plymouth waters, and TÅNING (1936a, 1936b) found the tiny fry of the herring poorly represented, both in Faroese and Icelandic waters.

Our survey seems to indicate that both the lower (<10 mm) and higher (>20 mm) size categories are very ineffectively sampled, but the causes of this are probably quite different. With regard to the lower size categories there are probably two main reasons for the deficiency. Firstly, the net is undoubtedly too coarsely meshed for the small post-larvae. But this can hardly be the main reason, as we have occasionally got very great numbers of tiny specimens in our nets. On the other hand, the present author is of the opinion that the main reason for the feeble representation of small larvae must be ascribed to the circumstance that the yolk sac stage lingers over the bottom, while later stages are more active and seek towards the surface layers. But towings near the bottom are difficult and therefore seldom carried out. It is desirable that vertical hauls be tried in order to test if this explanation holds true. However, it must also be pointed out, how spasmodic the occurrence of the fry seems to be. This might indicate that the spawning occurs on selected patches of ground from where swarms of newly hatched fry emerge. We seem to have run into such swarms occasionally, when the net actually gets clogged by the fry (e. g. the haul off Grindavík on station 783). In these cases we have the greatest difficulties in cleaning the net properly, and there are probably thousands of larvae left when we have done our best. Fry swarms of other species, especially *Mallotus villosus*, are also frequent in the same areas.

Our statement that the small post-larval stages of the herring do not frequent the upper layers of the sea, can be supported by recent observation on the size frequencies of herring and sandeel fry during the main hatching season in Faroese waters (TÅNING 1936b, EINARSSON 1951b). The newly hatched *Ammodytes* fry are in fact a little smaller than the herring fry, and we might therefore assume that similar size frequencies would be found. But this did not happen, as shown by table 13.

TABLE 13.

Percentage frequencies of size groups of post-larvel stages of herring and sandeels in Faroese waters.

Size-groups (mm)	*<10*	*10–14*	*15–19*	*20–24*	*>25*	*Total no.*
Herring	8.4	69.2	18.7	2.9	0.9	698
Ammodytes	59.0	29.6	7.7	2.9	0.8	6970

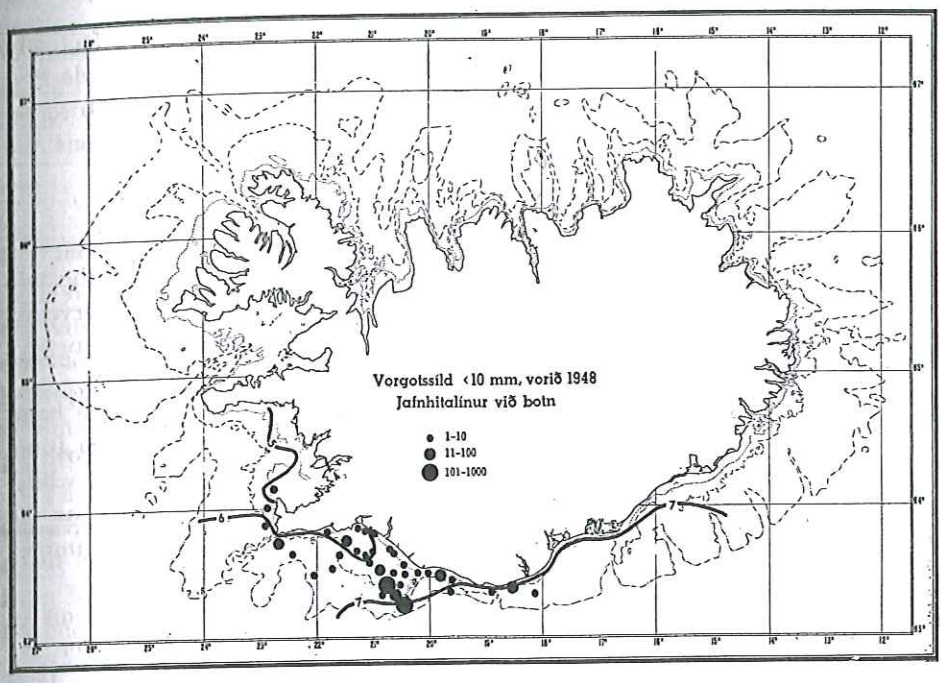

Fig. 19.
Distribution of small spring fry (< 10 mm) in the spring of 1948. Bottom isotherms.

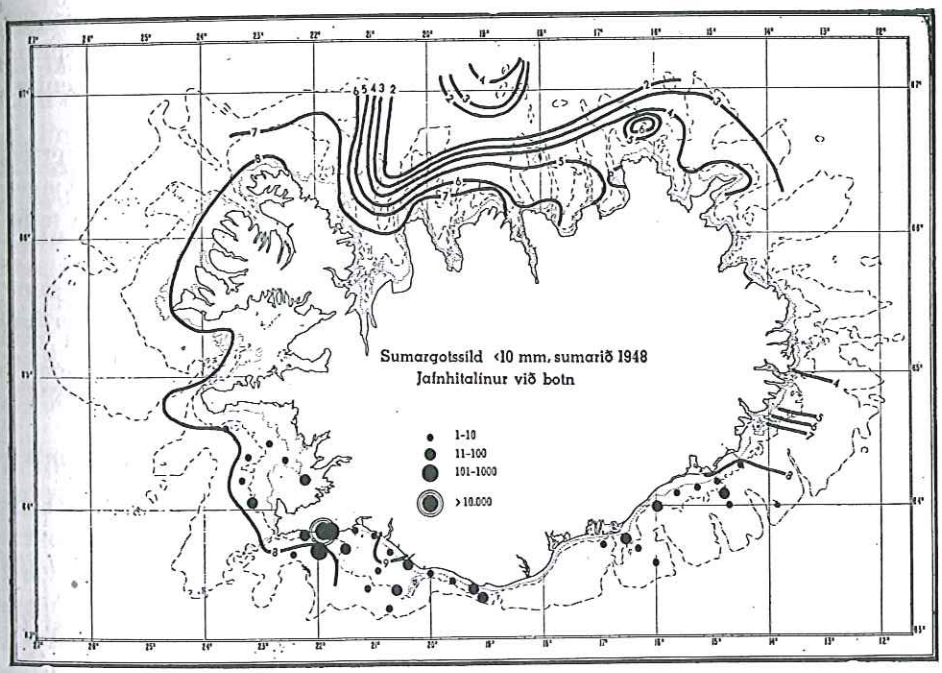

Fig. 20.
Distribution of small summer fry (< 10 mm) in the summer of 1948. Bottom isotherms.

The table shows that while the yolk sac stages of *Ammodytes* are effectively sampled, the same does not apply to the herring, and we must conclude that this is due to their absence from the surface layers of the sea. Although somewhat deeper layers have been fished during the present investigations the shortcomings have not been overcome.

B. On the limits of the spawning area.

During 1948 efforts were made to delimit the hatching areas of the two races and to this end the whole spawning area or parts of it were surveyed six times during the period April—September. The results of these surveys have been discussed above.

The records can be divided into two parts, April—May on the one hand and July—September on the other. There is only a slight overlapping in June. In the former period the post-larval spring spawners are encountered, whilst in the later period the post-larval summer spawners are found. In June we found the last traces of spring hatched fry, when the hatching of summer spawners was just beginning.

The extension of the spawning area of the two respective races seems to be similar during the years of investigations. However, it is clearly borne out that the summer spawners use a wider area than the spring spawners. It is thought that almost identical pictures derived from investigations in different years (especially in 1948 and 1951 when observations were most complete) confirm the main trends in the general distribution of the fry. Besides this, the eggs of spring spawning herring have actually been found during the spring of 1950 by Friðriksson and Timmermann in one of the main hatching centres west of Vestmannaeyjar.

According to these surveys the spawning area inhabited by the spring spawners extends from off Hornafjörður on the south-east coast to Reykjanes on the south-west coast. The lower temperature limits for hatching seems to be about 5°C, and the main hatching occurs from this limit to about 7°C.

The spawning activity of the summer spawners is carried out in the same areas, but in addition Faxaflói is a hatching ground of importance in certain years and spawning may occur off Breiðafjörður occasionally. The temperature limits are about 7°C and 9°C, the main hatching going on between 8° and 9°C.

These main features are clearly shown in figs. 19 and 20 where the number of small fry (<10 mm) during the surveys of 1948, is given. Bottom temperatures at the time of investigation are also shown.

C. Temperature variations on the spawning grounds.

In connection with oecophenotypical characters, it is of great interest to compare temperature in various years at different seasons. For this purpose the temperature conditions at three stations in the Selvogsgrunnsection, west of

Vestmannaeyjar, are graphically described in figs. 21—26. The positions of the stations are the following:

Selvogsgrunn I: 63° 41′ N — 20° 40′ V
— II: 63° 31′ N — 20° 52′ V
— III: 63° 21′ N — 20° 04′ V

D. Time and duration of spawning and hatching.

Hatching experiments on Norwegian herring (Soleim, 1942) indicate that the hatching process requires about 128 day-degrees. From this figure we can conclude that the hatching of Icelandic spring spawners, at temperatures between 5° and 7°C, should last from about 19—24 days. The hatching time of summer spawners, at temperatures between 7° and 9°C should last about 15—19 days.

The earliest record of newly hatched spring fry dates from April 1st (1947). Consequently, the first spawning seems to occur in the beginning of March, i. e. about March 10th. The latest record of newly hatched spring spawners dates from May 12th (1948). Thus the spring spawning seems to last until about the end of April.

Recently hatched summer fry were first recorded in Faxaflói on June 30th, but from only a single station. Probably slight spawning occurs outside the spawning period proper, as Täning has previously pointed out. This is supported by the fact that herring eggs have actually been found in haddock stomachs during May (Friðriksson and Timmermann, 1950), and also by the fact that we may occasionally find adult individuals that differ greatly from the rest of the stock in the degree of maturity.

Presumably the main hatching does not start until about the middle of July. Jespersen (1920) records small larvae from July 15th and Täning (1936a) from July 17th.

In my material the latest catch record of small larvae dates from August 31st, and they may presumably by found in the beginning of September.

From this we can conclude that the summer spawning goes on from about July 1st to the middle of August. Some years at least the spawning may be of longer duration as we have found recently spent individuals in the beginning of October.

E. Relation to depth of locality.

Täning concluded that the main spawning occurred inside the 75 m depth contour or perhaps even inside 50 m depth. During our 1948 surveys the main hatching at the time of investigations was between 75 and 150 m of depth as regards the spring spawners. The summer spawners had two centres, one inside 50 m depth, the other between 75 and 150 m depth. However, we must bear in mind that our surveys constitute static pictures subjected to continuous changes. There is certain evidence pointing to the fact that hatching

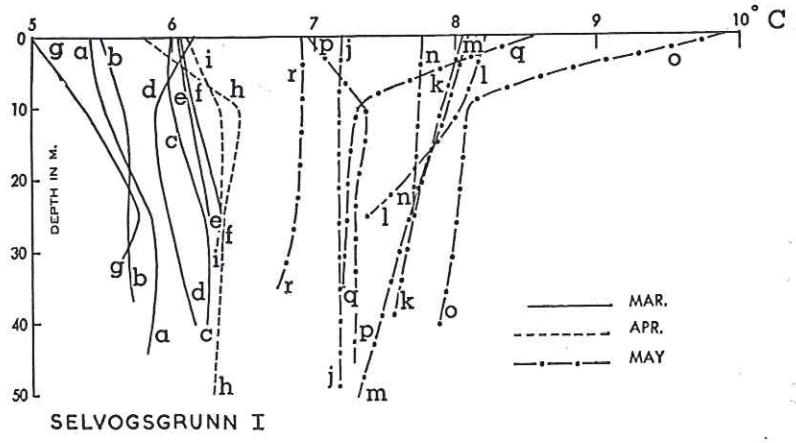

Fig. 21.
Temperature conditions at different depths at station Selvogsgrunn I in various years during March, April and May: a) 31/3 1934, b) 25/3 1935, c) 5/3 1936, d) 25/3 1947, e) 6/3 1948, f) 26/3 1950, g) 1/3 1953, h) 13/4 1948, i) 28/4 1951, j) 9/5 1934, k) 16/5 1935, l) 14/5 1936, m) 29/5 1936, n) 19/5 1937, o) 17/5 1939, p) 12/5 1948, q) 17/5 1950, r) 5/5 1953.

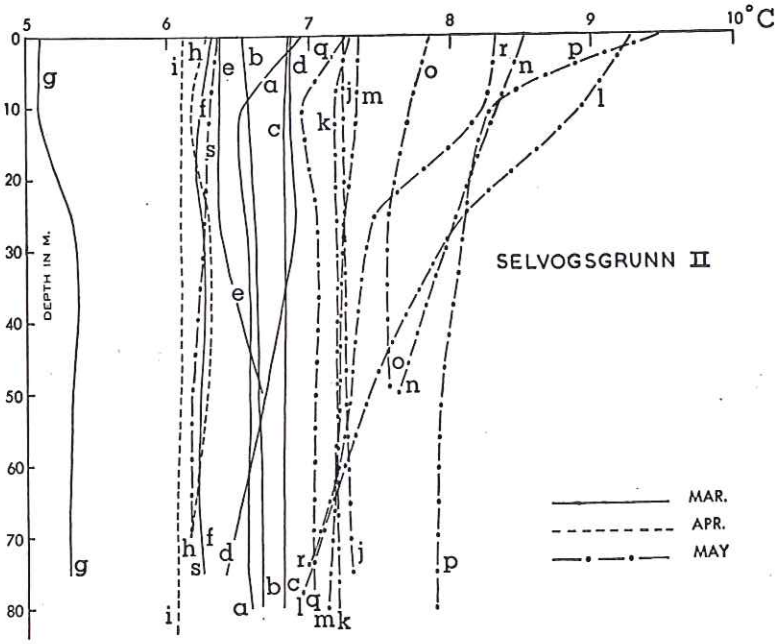

Fig. 22.
Temperature conditions at different depths at station Selvogsgrunn II in various years during March, April and May: a) 31/3 1934, b) 25/3 1935, c) 5/3 1936, d) 25/3 1947, e) 3/3 1948, f) 26/3 1950, g) 1/3 1953, h) 19/4 1948, i) 28/4 1951, j) 9/5 1934, k) 16/5 1934, l) 16/5 1935, m) 14/5 1936, n) 29/5 1936, o) 19/5 1937, p) 17/5 1939, q) 11/5 1948, r) 17/5 1950, s) 5/5 1953.

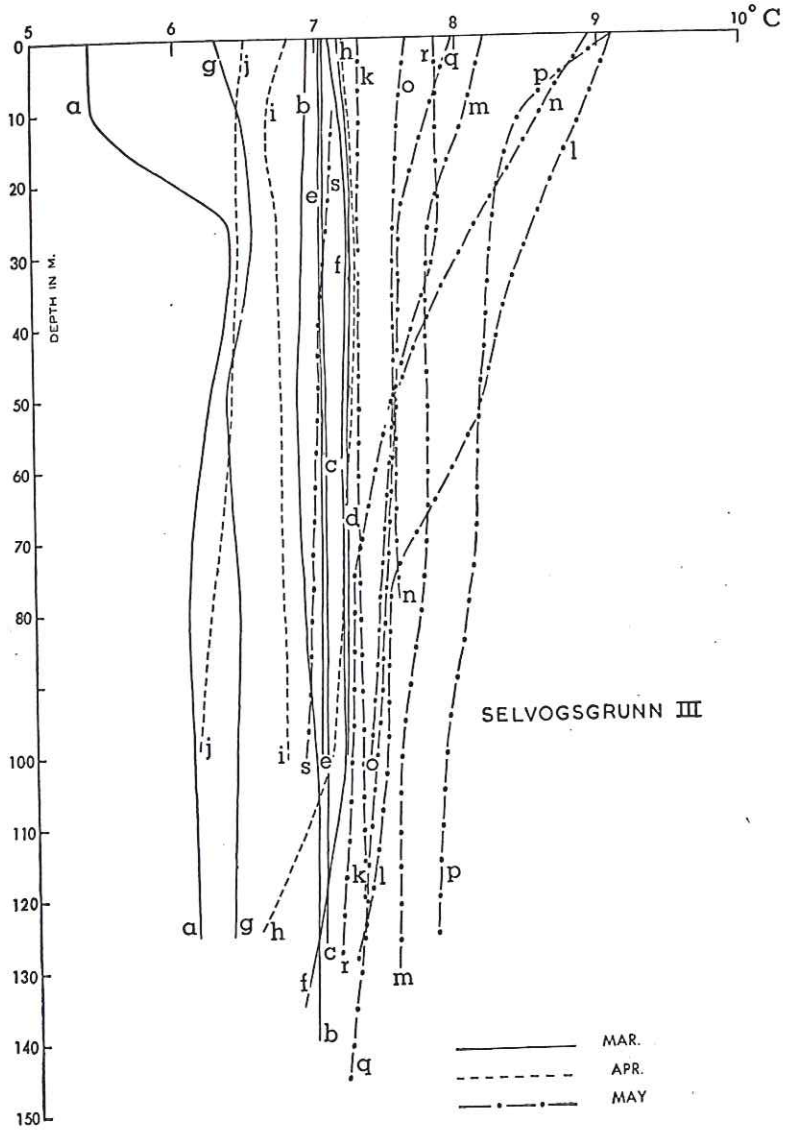

Fig. 23.
Temperature conditions at different depths at station Selvogsgrunn III in various years during March, April and May: a) 31/3 1934, b) 25/3 1935, c) 5/3 1936, d) 25/3 1947, e) 6/3 1948, f) 26/3 1950, g) 1/3 1953, h) 3/4 1947, i) 19/4 1948, j) 28/4 1951, k) 9/5 1934, l) 16/5 1935, m) 14/5 1936, n) 29/5 1936, o) 19/5 1937, p) 17/5 1939, q) 11/5 1948, r) 17/5 1950, s) 4/5 1953.

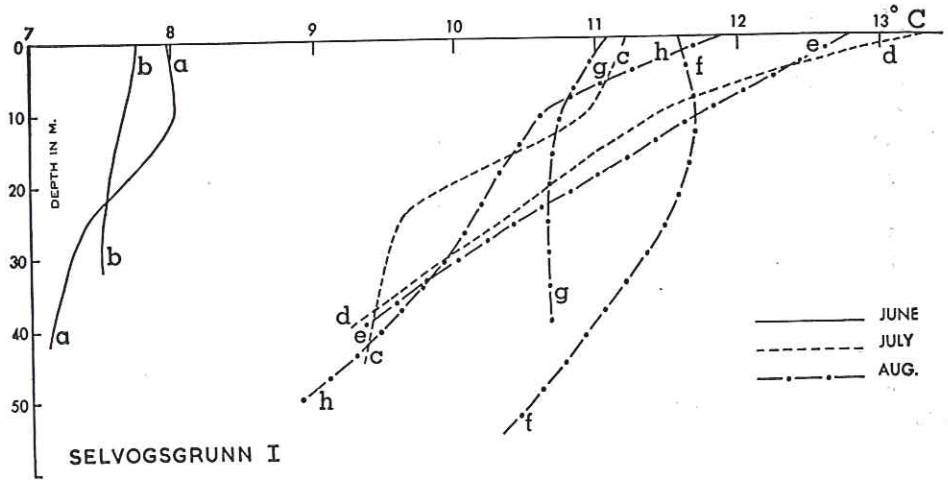

Fig. 24.
Temperature conditions at different depths at station Selvogsgrunn I in various years during June, July and August: a) 1/6 1934, b) 2/6 1938, c) 11/7 1936, d) 21/7 1939, e) 2/8 1948, f) 30/8 1948, g) 13/8 1949, h) 6/8 1951.

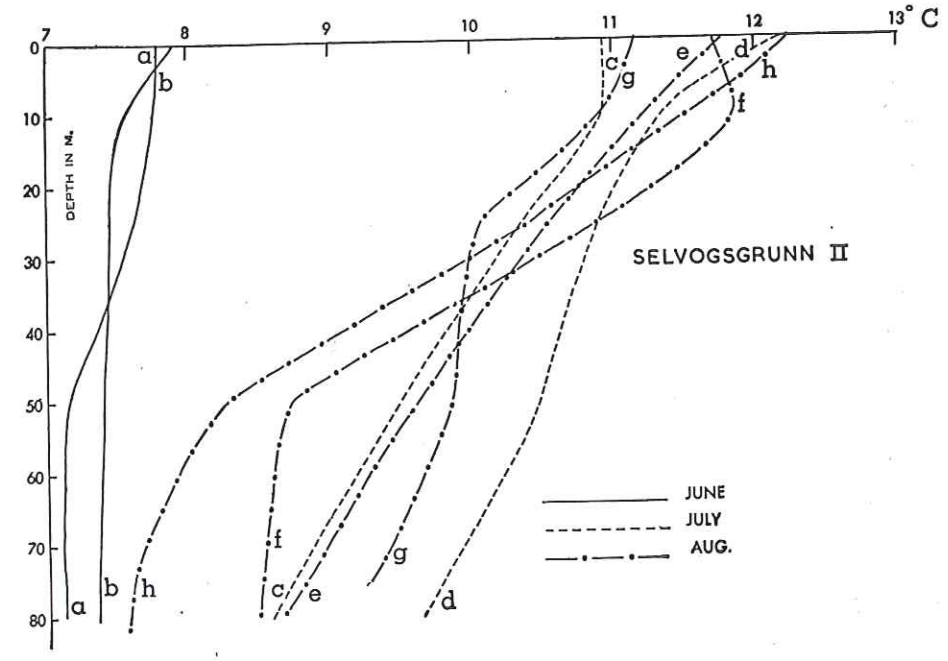

Fig. 25.
Temperature conditions at different depths at station Selvogsgrunn II in various years during June, July and August: a) 1/6 1934, b) 2/6 1938, c) 11/7 1936, d) 21/7 1939, e) 2/8 1948, f) 30/8 1948, g) 13/8 1949, h) 6/8 1951.

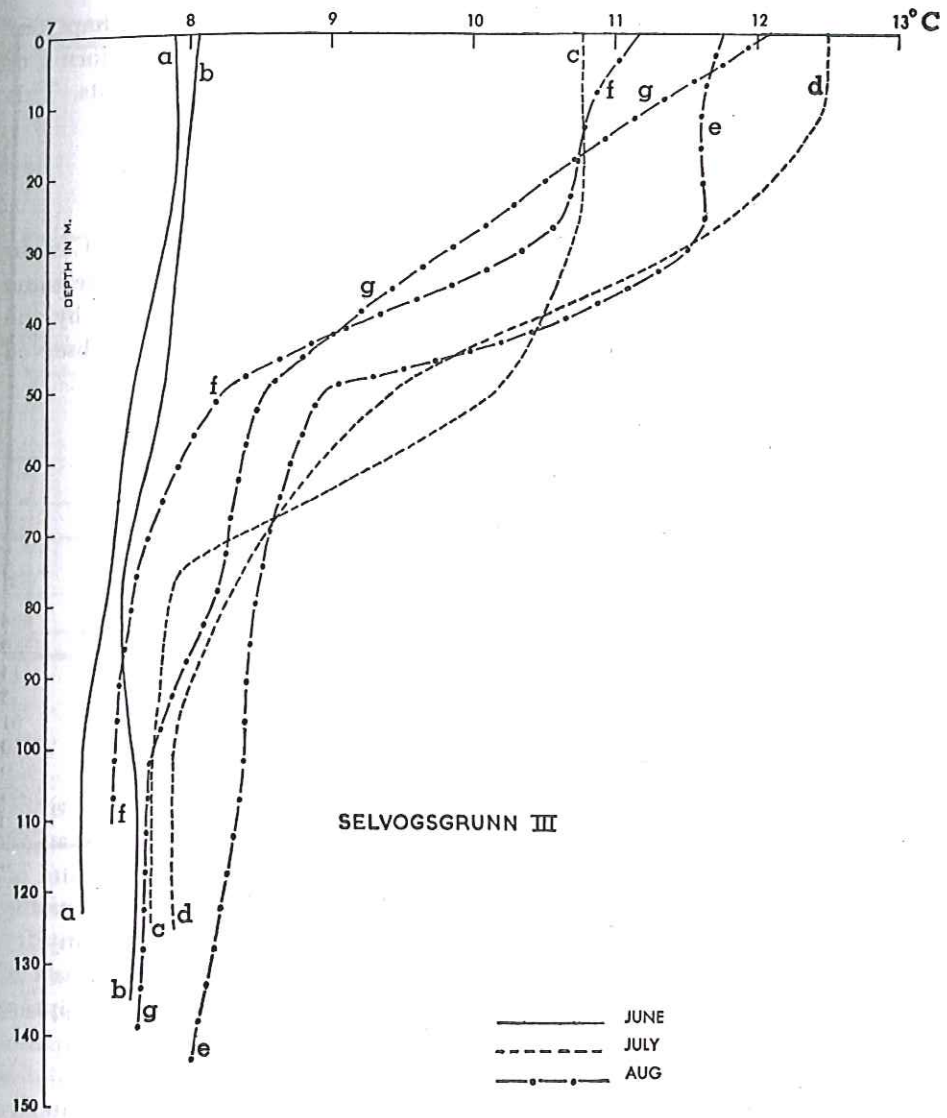

Fig. 26.
Temperature conditions at different depths at station Selvogsgrunn III in various years during June, July and August: a) 1/6 1934, b) 2/6 1938, c) 11/7 1936, d) 21/7 1939, e) 30/8 1948, f) 13/8 1949, g) 6/8 1951.

starts earlier in shallow water and then spreads to deeper water. Perhaps our surveys cover the second phase in the hatching, and the bimodal forms of the size frequency curves do indeed indicate such a course of events. This problem deserves closer attention.

F. On spawning centres.

The fry are not evenly distributed throughout the spawning region. Certain areas are more prolific than others, and our observations show that the same areas tend to dominate in successive years. This is clearly borne out by the following table showing number of all fry less than 10 mm in length observed during the years in question, arranged according to area and month.

TABLE 14.

Number of post-larval herring <10 mm, arranged according to area and month.

Month	*Area J*	*K*	*L*	*M*	*N*	*O*	*P*	*Total*
April		2	52	493	57			604
%		0.3	8.6	81.6	9.4			99.9
May		6		6		2		14
June		5						5
July	2	59						61
August	186	444	129	2918	143	77	2713	6610
%	2.8	6.7	1.9	44.1	2.2	1.2	41.0	99.9
Total	188	516	181	3417	200	79	2713	7294
%	2.6	7.1	2.5	46.8	2.7	1.1	37.2	100.0

According to our surveys the spawning of the spring spawners is mainly confined to one area, Selvogsbanki (area U), where about 81% of the tiny fry were found in April. The easternmost part of the neighbouring area east of Vestmannaeyjar may contribute to this maximum. A smaller maximum appears off Hornafjörður on the south-east coast, but the hatching starts here a little earlier and is of shorter duration.

The spawning centres of the summer spawners are mainly located in the same two areas, the Selvogsbanki and the Hornafjörður areas, where respectively 44% and 41% of the small fry were caught in August. In a single year, 1950, Faxaflói constituted a spawning centre of equal importance to the other two.

Observations do not provide definite answers to questions regarding the cause of the patchiness in the distribution of herring fry. However, I may be allowed to make a few suggestions about external factors which may be relevant.

Firstly, the spawning centers seem to be related to the width of the shallow part of the continental terrace, especially depths between 50 and 100 m. These

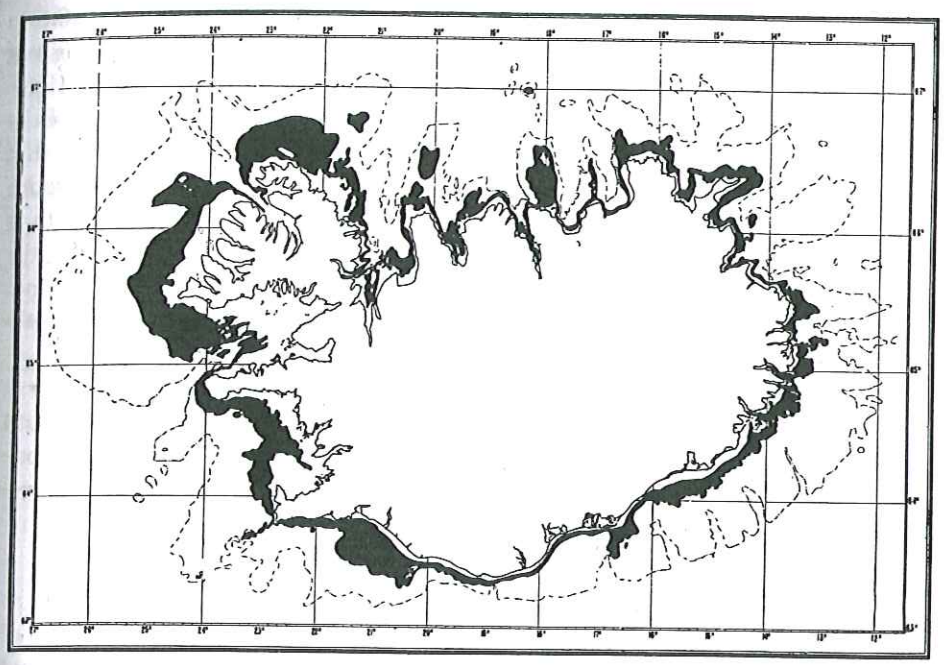

Fig. 27.
Black areas denote depths between 50 and 100 m around Iceland.

depths have the maximal extension in southern waters off Hornafjörður on the one hand and from Vestmannaeyjar to Faxaflói on the other (see fig. 27). In the intervening area which is an area of paucity as regards herring fry, they constitute only a narrow strip of bottom.

Secondly, the type of bottom deposits is of a paramount importance. In Faxaflói the most suitable bottom material for deposition of the spawn appears to be rock or shell gravel, which cover the bottom in the southern middle part of the bay. West of Vestmannaeyjar hard bottom is frequently found, as bottom grab investigations have shown. Basaltic gravel or coarse sand is also of common occurrence in this area, and herring spawn found in haddock stomachs is frequently mixed up with bottom material of this kind. On this type of bottom Friðriksson and Timmermann actually found herring spawn. Off Hornafjörður bottom conditions are rather imperfectly known, but rock, gravel or sand is frequently noted on the charts of navigation for this area.

Thirdly, it is possible that especially unfavourable conditions exist for the development of fish fry off a great part of the south coast of Iceland. In the area between Ingólfshöfði and Hornafjörður some of the largest glacier rivers of Iceland enter the ocean. Enormous quantities of silt material are carried into the ocean in this area, and it may be presumed that the silt has adverse effects on many marine organisms, especially those provided with filter mechanisms.

Whether post-larval herring is susceptible to damage because of contamination with silt must be studied experimentally, but to my knowledge, this has not been studied so far.

Fourthly, it is possible that in the spawning centres mentioned there exist especially favourable nourishing conditions. There are a number of deeps that cut into the continental terrace surrounding Iceland. Off the west and south coast these are on the one hand located off the south-western coast with a submarine trough or gorge east of Vestmannaeyjar (Háfadeep), and on the other hand off the south-east coast with a submarine trough that cuts into the ridge between Iceland and the Faroes and terminates in the area south-east of Hornafjörður.

It seems to me possible, or even probable, that some of Dr. L. H. N. Coopers conclusions can with advantage be applied to conditions existing off the south coast of Iceland (Cooper, 1952a-b). But unless we get continous observations in one or more of these areas, this possibility remains a working hypothesis only.

G. Relative abundance of spring spawners and summer spawners.

Previous investigations indicated that a change in the relative abundance of spring fry and summer fry had occurred between the period 1903—1908 and 1924—1934, the spring and summer fry being of similar importance during the former period, while the summer spawners had increased and the spring spawners decreased in abundance during the latter period (Tåning, 1936a).

As regards the occurence of post-larval stages less than 10 mm in length all available data during three periods are summarized in the following table:

Period	*March*	*April*	*May*	*June*	*July*	*August*	*Sept.*	*Total*
1903—08	—	219	0	0	90	194	—	503
1924—34	—	125	0	0	5061	752	(0)	5938
1947—51	(0)	604	14	5	61	6610	(0)	7294

These figures seem to confirm Tånings conclusions about possible changes in the relative abundance between the first period and the two later periods. However, if we examine the position of localities and time of investigation during 1903—1908, it is obvious that we must abstain from making this conclusion. Firstly, because during July 1904 most of the localities were investigated during the first half of the month and our recent studies indicate that hatching has not generally started at that time. Secondly, during August only a few localities situated in the spawning centers or in their neighbourhood were investigated (vide Jespersen, 1920, figs. 5 and 6, pp. 8—9). Because of the indadequate sampling during the first period we will not be able to ascertain from the available data whether such changes in abundance have occurred.

On the other hand, it seems safe to conclude from TÅNING's and our own data that during the periods 1924—1934 and 1948—1951 the summer spawning has generally been of far greater magnitude than the spring spawning. It is thought that this difference can be stated as a fact.

H. Annual variations in the abundance of fry.

One of the main objectives of this survey was to ascertain whether there is any correspondence between the abundance of fry and the resulting yearclasses of mature herring. Unfortunately we have no data from the spring of 1949, when a strong yearclass was hatched. At present I think we must answer the question with great reservation.

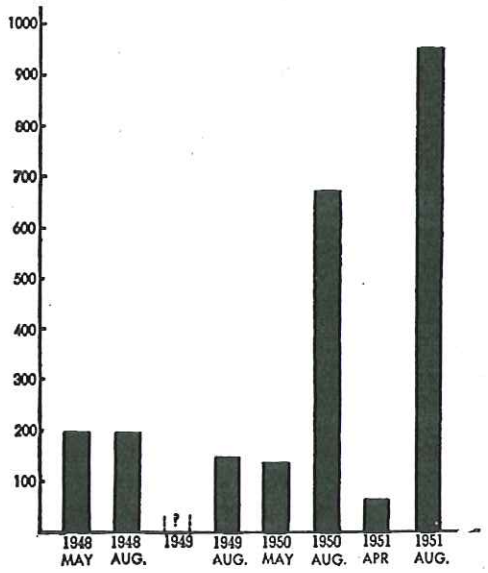

Fig. 28.
Average number of herring fry per positive station and one hour's haul during the years 1948—1951.

For two main reasons we cannot expect clear correlations between abundance of fry and the resulting yearclasses of mature herring. Firstly, because of deficient gears employed, which do not give adequate quantitative material of all sizes of post-larval stages, as previously mentioned. Secondly, because the surveys could not be properly timed, as our institute had no research vessel of its own. With the elimination of these shortcomings there seems to be a fair chance that regular surveys would give valuable quantitative results.

The graph fig. 28 shows average numbers of herring fry per one hour's haul, per positive station in different years.

In the summer spawners we have already encountered strong yearclasses from 1948 and 1950 and a weak one from 1949 which corresponds roughly with the graph. An evaluation of the 1951 yearclass cannot yet be made.

In the spring spawners we have strong yearclasses from 1949 and 1950, but our larval material does not include any collections from the spring of 1949 and is rather inadequate from the spring of 1950. On the other hand, a low number of fry during spring 1951 corresponds to a weak yearclass in the mature spring herring (EINARSSON, 1956).

I. Concluding remarks.

It is hoped that this survey may give an impetus to a further study of these problems. It is obvious that new methods of collecting data are urgently needed and this matter is now being given serious consideration.

Before we embark on an extensive programme of research in this field, it would be of great advantage to try out new nets. We still lack information about the whereabouts of yolk sac larvae, and neither has the problem of catching late post-larval stages been solved. Then the problem of day and night hauls must be tackled and we are giving a serious consideration to the question whether plankton recorder material would fulfill our needs.

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