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HERRING LARVAE (*Clupea harengus*) INVESTIGATIONS IN THE SKAGERRAK AREA, DECEMBER 1987 TO MARCH 1988. A PRELIMINARY REPORT.

By

Erlend Moksness and Tore Johannessen
Flødevigen Biological Station
N-4800 Arendal, Norway

ABSTRACT

From December 1987 to March 1988 two transects, Torungen - Hirtshals and Oksøy - Hanstholm, were performed once a month for sampling of herring larvae. The gear used was a 9 feet Isaac-Kid Midwater trawl sampling in the upper 60 m of the water column. High numbers of herring larvae were caught in the inflowing waters to the Skagerrak area from January to March 1988 and in the Norwegian Coastal Current moving out of the Skagerrak area, specially in January and February 1988. All the sampled herring larvae were stored in 80 % buffered alcohol, and were examined within 7 days for total and standard length. Later between 38 and 70 larvae from each cruise were examined for daily increments in their otoliths. In addition the wet and dry weights of the same larvae were decided. Estimated hatching date of the examined larvae ranged from 18 August 1987 to 28 November 1987 with a main hatching period in the middle of September, except for the larvae sampled during the March survey. These larvae had an average hatching date in the first part of October. The estimated hatching periods indicate that the larvae entering the Skagerrak area mainly came from the spawning area of the Northern and Central North Sea in December 1987 to February 1988, while the larvae collected in March have their origin in the Central North Sea.

INTRODUCTION

The Skagerrak and Kattegat areas are important nursery grounds for herring larvae and juveniles hatched in the western North Sea (Anon 1987). The herring are transported as larvae by eastern moving currents and this transportation is important for the recruitment in North Sea herring (Corten 1986). Still there are questions to be answered, such as; when do the herring larvae arrive the Skagerrak and Kattegat area and are any of the main spawning grounds of more importance to the recruitment than others. Possible answers to these questions are control of the areas of arrival to estimate the inflow of larvae and by reading the age in days of the inflowing herring larvae and thereby estimate the hatching time of the larvae and consequently the spawning areas. This report gives preliminary results from monthly cruises from December 1987 to March 1988, sampling along two transects between Norway and Denmark, a gateway the herring larvae have to pass whether they enter or leave the Skagerrak/Kattegat region. The two transects cover most of the inflowing and outflowing currents to and from the area. Further, the report gives the results of daily increment estimates from reading the otoliths of the sampled herring larvae. To use otolith analyses in such a study, the increments have to be regular with one increment each day independently of the growth rate. Such a regularity and independence has not been observed in laboratory experiments, but on the other hand reports from mesocosm studies show that the increments are daily, the regularity is independent of the growth rate and the zone widths reflects the larval growth rate as in Norwegian spring spawning herring (Gjøsæter and Øiestad 1981) and Pacific herring larvae (Moksness and Wespestad 1988). An initial growth rate above 0.10 mm/day has been suggested necessary for having daily increments deposited from the end of the yolk sac stage and onwards in Norwegian spring spawning herring (Moksness et al. 1987). However Nichols et al. (1986) calculated initial growth rate to be around 0.30 mm/day in field caught herring larvae hatching west of the central North Sea. In this paper daily increments in the otoliths of North Sea herring are expected to be present, which is in accordance with studies of autumn spawned herring larvae in the Gulf of St. Laurence, Canada (Messieh et al. 1987).

MATERIALS AND METHODS

The Norwegian research vessel "G.M.Dannevig" was used in four cruises:

19-23 December 1987 - (12-87)
20-24 January 1988 - (1-88)
19-24 February 1988 - (2-88)
20-24 March 1988 - (3-88)

sampling herring larvae along two transect between Norway and Denmark (Fig. 1).

The gear used was a 9-feet Isaac-Kid Midwater Trawl (IKMT) (Anon 1986), sampling down to 60 m depth of the water column. On echo-depths greater than 60 m, sampling started at 60 m and continued in steps of 10 m up to a depth of 10 m below the surface. The IKMT was dragged for 5 min at each depth, which gave at total sampling time of 30 min. When the echo depth was less than 60 m a corresponding shorter total sampling time was used. On sampling in single depths the IKMT was dragged for a total of 12 min. A Scanmar depth sensor was attached to the gear giving the sampling depth at all times. Table 1 gives the echo depths along the two transects.

All the sampled herring larvae were preserved in 80% buffered alcohol, and were measured for total and standard length within 7 days. Otoliths from about 30 to 50 larvae from each cruise were dissected out and mounted on glass slides according to Andersen and Moksness (1988). Dry weight was measured on the same larvae. The reading of daily increment and backcalculation of age in days and increment widths were performed according to Andersen and Moksness (1988). To the estimated age in days, 10 days was added to compensate for the yolk sac period. However, there are big differences reported (Blaxter and Hempel 1963) on the duration of the yolk sac stage from 5.5 days in Buchan and Dogger to 14 days in Downs at 8°C.

The shrinkage in length of the sampled herring larvae was examined by measuring the larvae fresh and after 5 days in 80% alcohol. A 2.5% shrinkage was observed, as indicated in Fig. 2. In addition a shrinkage due to net handling has to be accounted for to compute a live length of the larvae. The shrinkage will vary with fish size and duration of time the larvae remain within the net, as reported for anchovy larvae, *Engraulis mordax*, by Theilacker (1980). No correction has been made for shrinkage in the present material.

The Torungen - Hirtshals transect was divided into three main parts: Part 1 from 0-15 N mile (Station 1 to 3), Part 2 from 15-30 N mile (Station 4 to 7) and Part 3 more than 30 N mile (Station 8 to 11) off the Norwegian coast. Part 3 covered most of the inflowing currents in the upper 60 m to the Skagerrak area, Part 1 the Norwegian Coastal Current moving out of the Skagerrak area and Part 2 water masses in between the two main current systems.

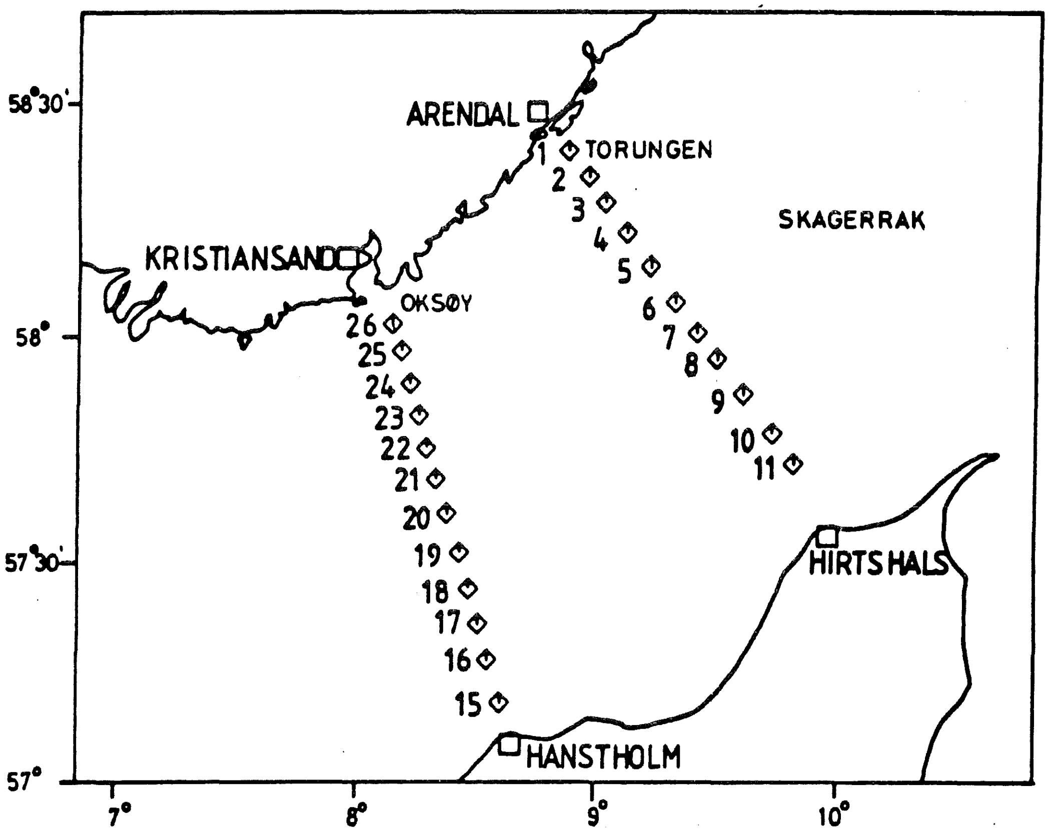

Fig. 1. The transects Torungen - Hirtshals and Hanstholm - Oksøy with station numbers.

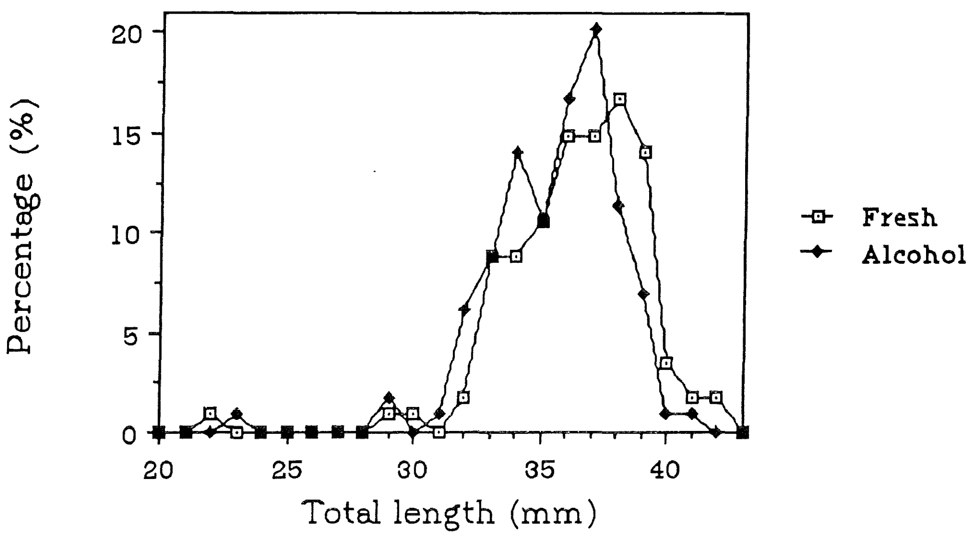

Fig. 2. The length frequency distribution of herring larvae measured fresh and after 5 days in 80 % alcohol. Average total length were 36.3 ± 2.8 mm and 35.4 ± 2.5 mm respectively.

Table 1. Echo depth at the different IKMT-stations (St.no.) along the two transects. N. mile = Nautical miles from the Norwegian coast line. * = not sampled.

Torungen - Hirtshals			Oksøy - Hanstholm		
St.no.	N.mile	Depth	St.no.	N.mile	Depth
1	1	90	26	1	*
2	5	250	25	5	300
3	10	390	24	10	500
4	15	410	23	15	520
5	20	700	22	20	435
6	25	600	21	25	310
7	30	400	20	30	170
8	35	175	19	35	100
9	40	85	18	40	55
10	47	30	17	45	35
11	52	60	16	50	25
			15	54.5	20

RESULTS AND DISCUSSION

Occurrence of herring larvae in the transects

The herring larvae were caught in high numbers on the January (1-88) and February (2-88) cruises, as shown in Fig. 3. This indicates that the main portion of the North Sea herring larvae arrived the Skagerrak area during January and February 1988. In addition, as also shown in Fig. 3, high numbers of herring larvae were caught in the Norwegian Coastal Current moving out of the Skagerrak area. The actual numbers of herring larvae caught along the two transect are shown in Fig. 4 and 5. Only in the most eastern transect (Torungen - Hirtshals, Fig. 4) high numbers of herring larvae were caught in the Norwegian Coastal Current. Due to bad weather conditions the February survey could not be carried out along the Oksøy - Hanstholm transect (Fig. 5), but the January cruise indicates only half the number of herring larvae in the Norwegian Coastal Current in this transect compared to the more eastern Torungen - Hirtshals transect. There is no obvious explanation for this discrepancy between the two transects. The herring larvae observed in the Norwegian Coastal Current probably recruit to the coastal areas along southern and western Norway. In Fig. 6 the average number of herring larvae in the three sections (Part 1, Part 2 and Part 3) along the Torungen - Hirtshals transect is shown. Fig. 6 indicates, in addition to Fig. 3, that herring larvae also enter the Skagerrak area in March, with the highest number of herring larvae in March observed closer to the Danish coast. Unfortunately, the sampling close to the Danish coast could not be performed in March along the Oksøy - Hanstholm transect due to bad weather condition. However, a high number of herring larvae was observed on a station 22 N.miles off the Danish coast, indicating a high number of herring larvae entering the Skagerrak area. This indicates that the herring larvae in March mainly enter the Skagerrak area by the Jutland current. In addition, very few herring larvae seem to be leaving the Skagerrak area by the Norwegian Coastal Current during March. What mechanisms that make the larvae leave the Skagerrak area by the Norwegian Coastal Current or remain in the area are not known. Table 2 shows the average total length of the herring larvae sampled in the section along Torungen - Hirtshals. There is no systematic difference in the average total length in the three sections during the four cruises. These larvae might cross the area in both directions or remain in the area. There was no indication of starvation of these larvae.

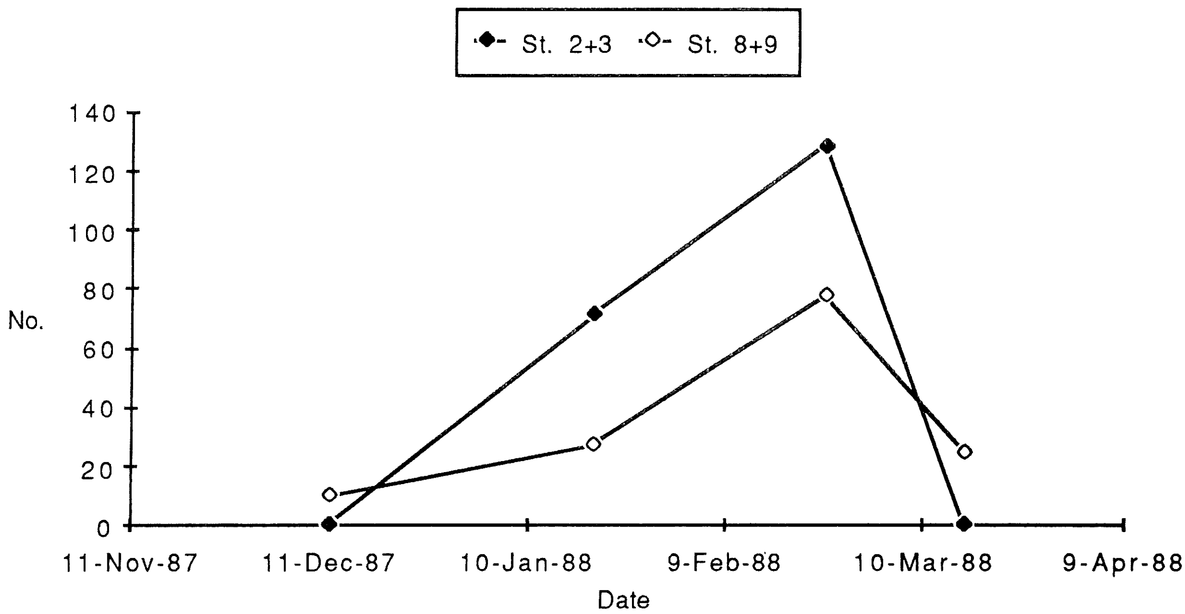

Fig. 3. The number of herring larvae caught at Station 2+3 (Norwegian Coastal Current) and Station 8+9 (Danish side).

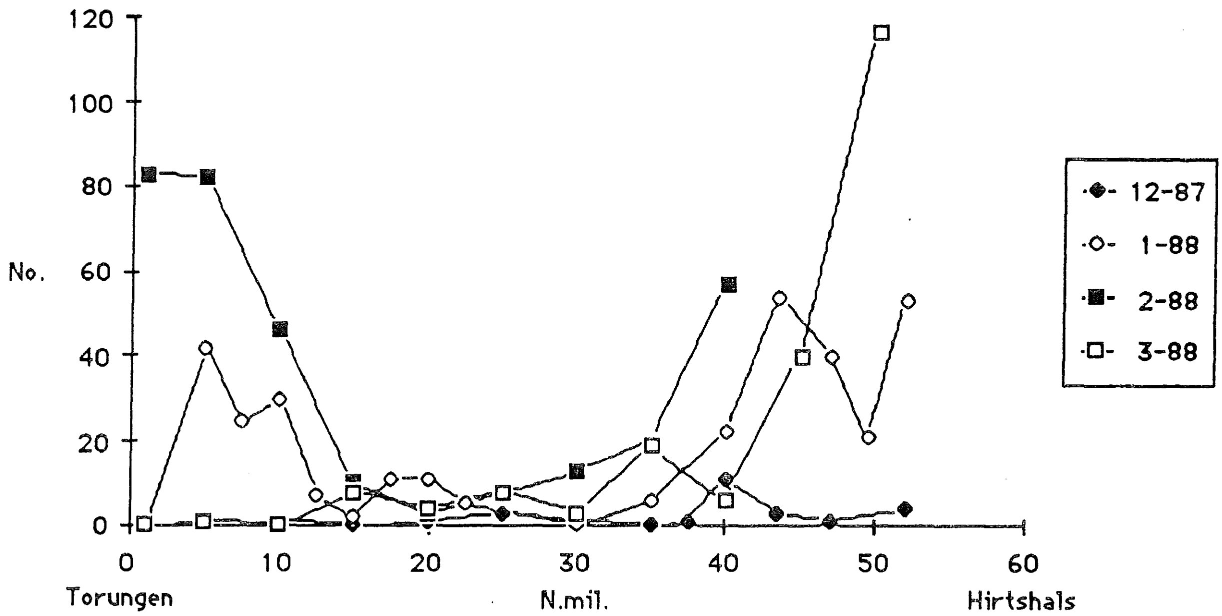

Fig. 4. Number of herring larvae caught at each station along the Torungen - Hirtshals transect. 12-87 = 19 - 23 December 1987; 1-88 = 18 - 22 January 1988; 2-88 = 23 - 26 February 1988; 3-88 = 15 - 18 March 1988.

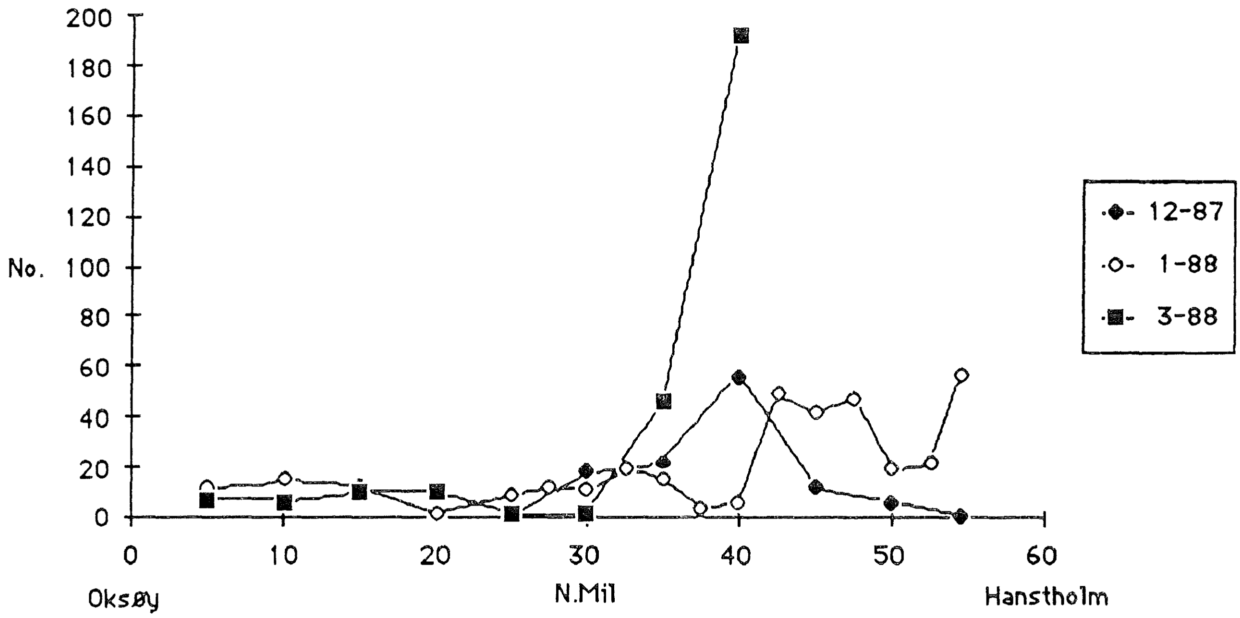

Fig. 5. The number of herring larvae caught at each station along the Oksøy - Hanstholm transect. 12-87 = 19 - 23 December 1987; 1-88 = 18 - 22 January 1988; 3-88 = 15 - 18 March 1988.

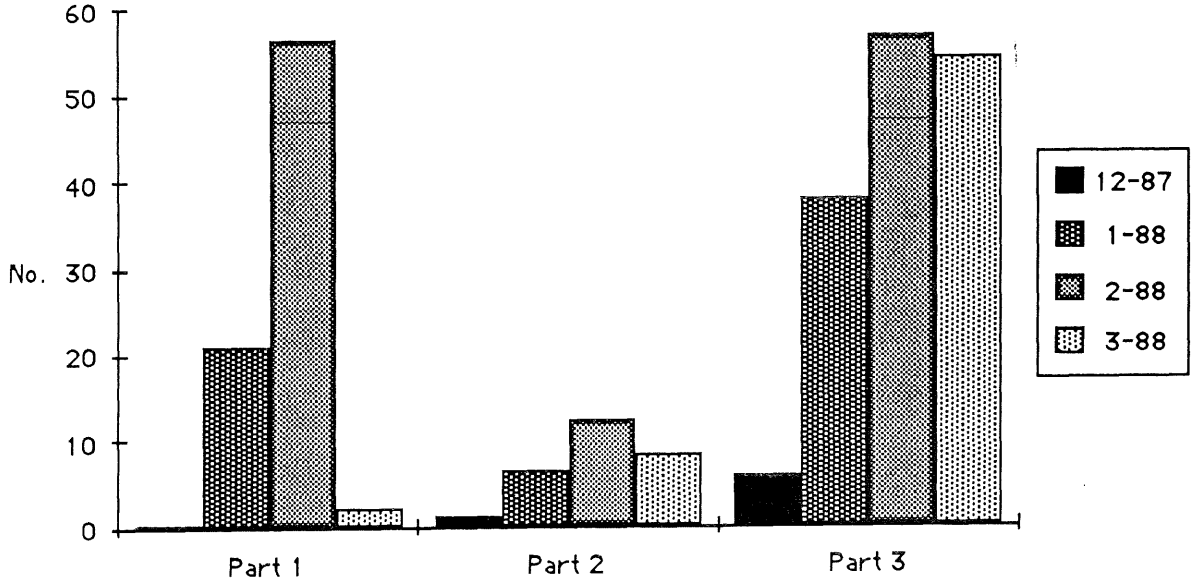

Fig. 6. The average number of larvae caught in the three parts of the Torungen - Hirtshals transect. 12-87 = 19 - 23 December 1987; 1-88 = 18 - 22 January 1988; 2-88 = 23 - 26 February 1988; 3-88 = 15 - 18 March 1988.

Table 2. Average total length with standard deviation (mm) of the herring larvae caught in the three parts of the Torungen - Hirtshals transect.

	Part 1		Part 2		Part 3	
Cruise	Average	SD	Average	SD	Average	SD
12-87	30.2		24.2	5.4	24.8	2.5
1-88	30.1	4.3	28.9	3.3	32.7	5.3
2-88	33.8	3.2	34.2	4.5	34.5	3.2
3-88	26.0		36.3	2.2	34.8	2.7

Size distribution of the herring larvae

The length distribution of the caught herring larvae is shown in Fig. 7 and average total length with standard deviation is given in Table 3. The smallest larvae (average total length = 23.8 mm) were caught in December 1987, while the highest average total length (36.5 mm) was observed in January 1988. According to Munk (1987) the smallest larvae present during the December survey might have been underestimated due to the sampling gear. No correction has been made for this. On the January cruise (1-88) a bimodal distribution is indicated in Fig. 7, and such a distribution was confirmed using a separation test (MacDonald and Pitcher 1979). The results from this test are shown in Table 4. These results indicate that two cohorts arrive the Skagerrak area, but the origin of these cohorts can not yet be explained from their length frequency distribution. The average total length of the herring larvae caught during the February and March cruises were 34.0 and 35.1 mm respectively. The differences in average length between the different cruises might indicate that the larvae hatched at different times at the same spawning areas or that the larvae origin from different spawning areas. The average length in February (2-88) and March (3-88) is below the calculated average length of the largest cohort in January, indicating that these larvae either did not hatch at the same spawning area, or if they did, have had two distinct feeding areas. Swedish data from the young fish survey in February in the Kattegat area (Hägstrøm, Lysekil Institute, Pers. comm.) indicate that the larvae entering in January had ended up in this area.

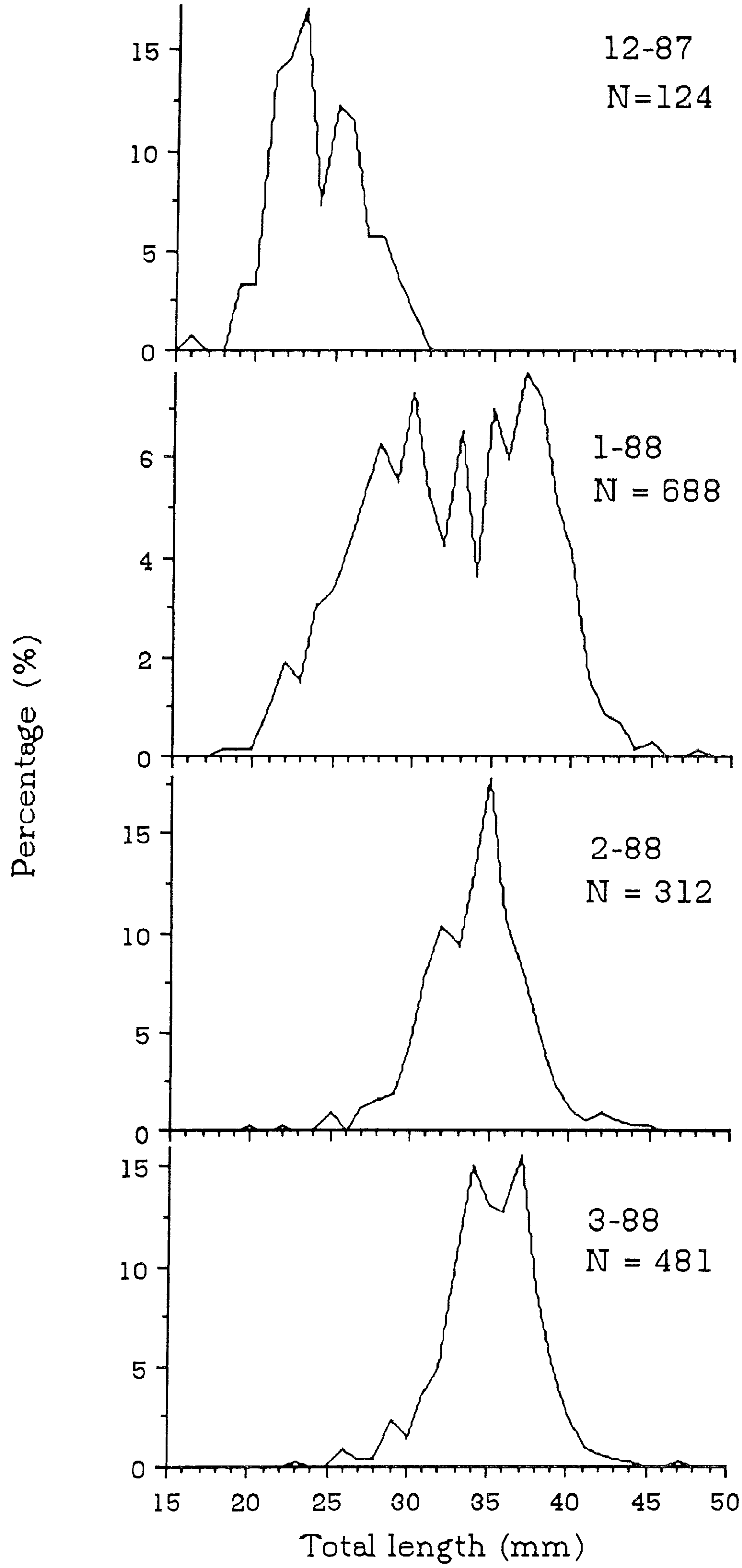

Fig. 7. Length frequency distribution of the herring larvae caught on the 19 - 23 December 1987 cruise (12-87), 18 - 22 January 1988 cruise (1-88), 23 - 26 February 1988 cruise (2-88) and the 15 - 18 March 1988 cruise (3-88).

Table 3. The average total length with standard deviation, minimum and maximum lengths on the four cruises. The estimated average lengths of the two components caught in the January cruises are also shown.

Cruise	Average total length (mm)	SD	Min (mm)	Max(mm)
12-87	23.8	2.7	16.1	29.6
1-88 (Total)	32.8	5.4	17.9	47.5
Component 1:	28.1	3.6		
Component 2:	36.5	2.7		
2-88	34.0	3.3	19.5	44.5
3-88	35.1	2.9	22.5	47.0

Table 4. The numbers from a separation test using the total length of the larvae caught during the January 1988 cruise (1-88). SE = Standard error. The test gave a Degree of freedom = 25 and Chi-Squared = 41.8910.

	Component 1	SE	Component 2	SE
Proportions	0.55	0.04	0.45	0.04
Means	28.1	0.4	36.5	0.4
Standard deviation	3.6	0.2	2.7	0.2

Otolith analyses

Results from the studies of mean increment size and standard deviation of the otoliths are shown in Fig. 8 and 9. The figures indicate similar growth pattern during the first 100 days after hatching for herring larvae on all the cruises, except for the larvae caught during the February cruise (2-88). Beyond the 100 days the herring larvae caught during the January cruise (1-88) show the best growth rate. There was no big discrepancy in standard deviation between the different cruises, except for the period 75 to 125 after hatching of the larvae caught during the January cruise (1-88) being 50 % higher then the other. This indicates a big variation in these data, probably due to the fast growing larvae in the largest cohort (Table 3). This has to be analyzed closer in the future.

The relation and correlation of the number of increments and the radius of the otoliths to the standard length of the herring larvae are given in Fig. 10 and 11. Both figures indicate relationships, but still important data are missing in the length range from 8 to 20 mm. When these data are available daily increments in length and weight can be computed as done by Moksness and Wespestad (1988). In Table 5 the estimated number of increments is given. The table indicates a wide range in hatching time (SD = 20 days) for the larvae caught during the January cruise.

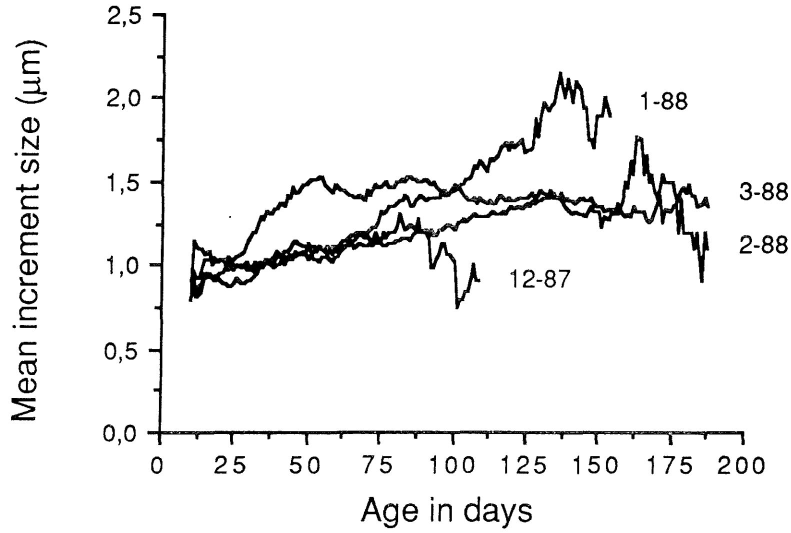

Fig. 8. The average increment size (µm) of all the examined otoliths from each cruise. 12-87 = 19 - 23 December 1987; 1-88 = 18 - 22 January 1988; 2-88 = 23 - 26 February 1988; 3-88 = 15 - 18 March 1988.

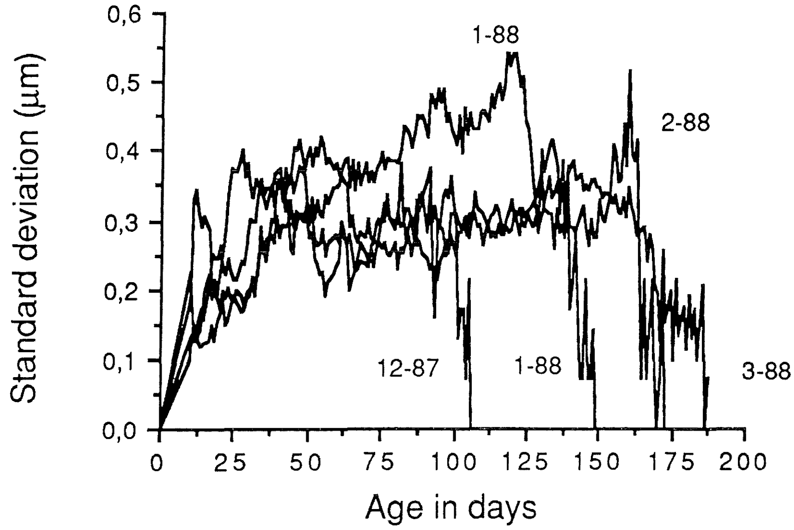

Fig. 9. The standard deviation of the average increment size of all the examined otoliths from each cruise. 12-87 = 19 - 23 December 1987; 1-88 = 18 - 22 January 1988; 2-88 = 23 - 26 February 1988; 3-88 = 15 - 18 March 1988. The low values in the last part of the curves indicates low number of larvae examined.

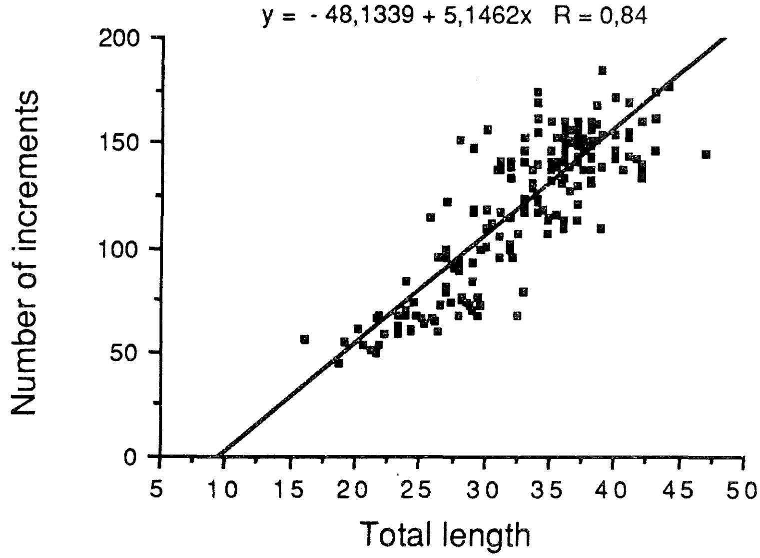

Fig. 10. The relationship between the number of increments and the total length (mm) of the herring larvae.

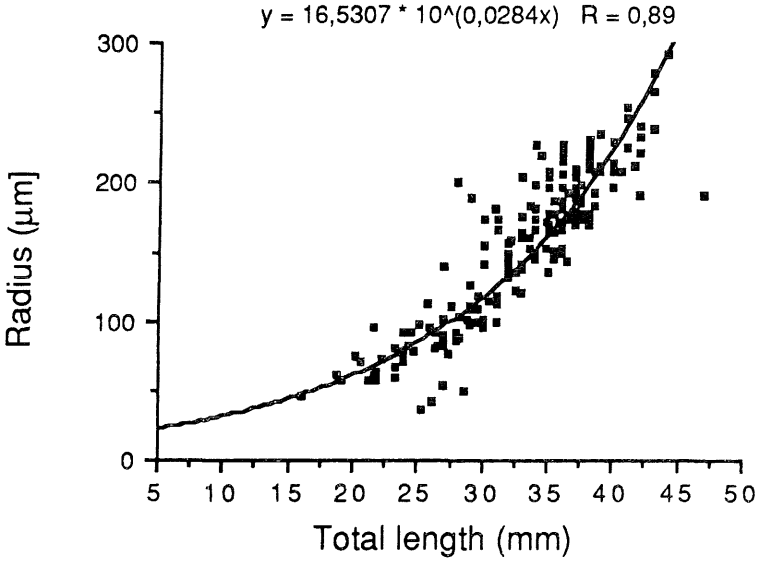

Fig. 11. The relationship between the otolith radius (μm) and the total length (mm) of the herring larvae.

Table 5. Average numbers of increments with standard deviation (SD) and minimum and maximum number of increments in the otoliths of the examined specimens. Diff 1 = Number of days between the cruises and Diff 2 = number of days in differences between average number of days in the otoliths.

Cruise	Average	Min	Max	SD	Diff 1	Diff 2
12-87	68	44	99	12		
1-88	104	67	143	20	31	36
2-88	140	102	177	12	31	36
3-88	151	101	185	14	30	11

Estimated hatching periods

The estimated hatching periods based upon otolith analyzes are given in Fig. 12 and Table 6. For the larvae caught during the first three cruises a similar hatching period has been estimated with a peak around 25 September 1987, while the larvae from the March cruise had a peak two weeks later (6 October). As indicated in the length distribution and in the increment pattern of the otolith, the larvae might origin from different spawning areas. The larvae caught during the first three cruises probably mainly come from the Shetland, Buchan and Central North Sea spawning areas. The estimated hatching periods fall well together with estimated hatching periods from larval surveys, as given in Table 7. The larvae arriving in the Skagerrak area in March have a later hatching estimated from the otolith analyses and these larvae probably mainly come from the Central North Sea area. It has to be taken into consideration that the end of the yolk sac stage in the present work has been set to 10 days for all the larvae analyzed. In the paper by Blaxter and Hempel (1963) it is clearly shown that there is a great variation in the duration of the yolk sac stage (5 to 14 days) of the herring larvae from the different spawning areas in the North Sea. This variation in yolk sac stage will influence the estimated hatching periods and peaks and make them less accurate.

To get a better understanding of the present material it will be necessary to consider it closely together with the results from the ACE (Autumn circulation experiment) programme winter 1987/88.

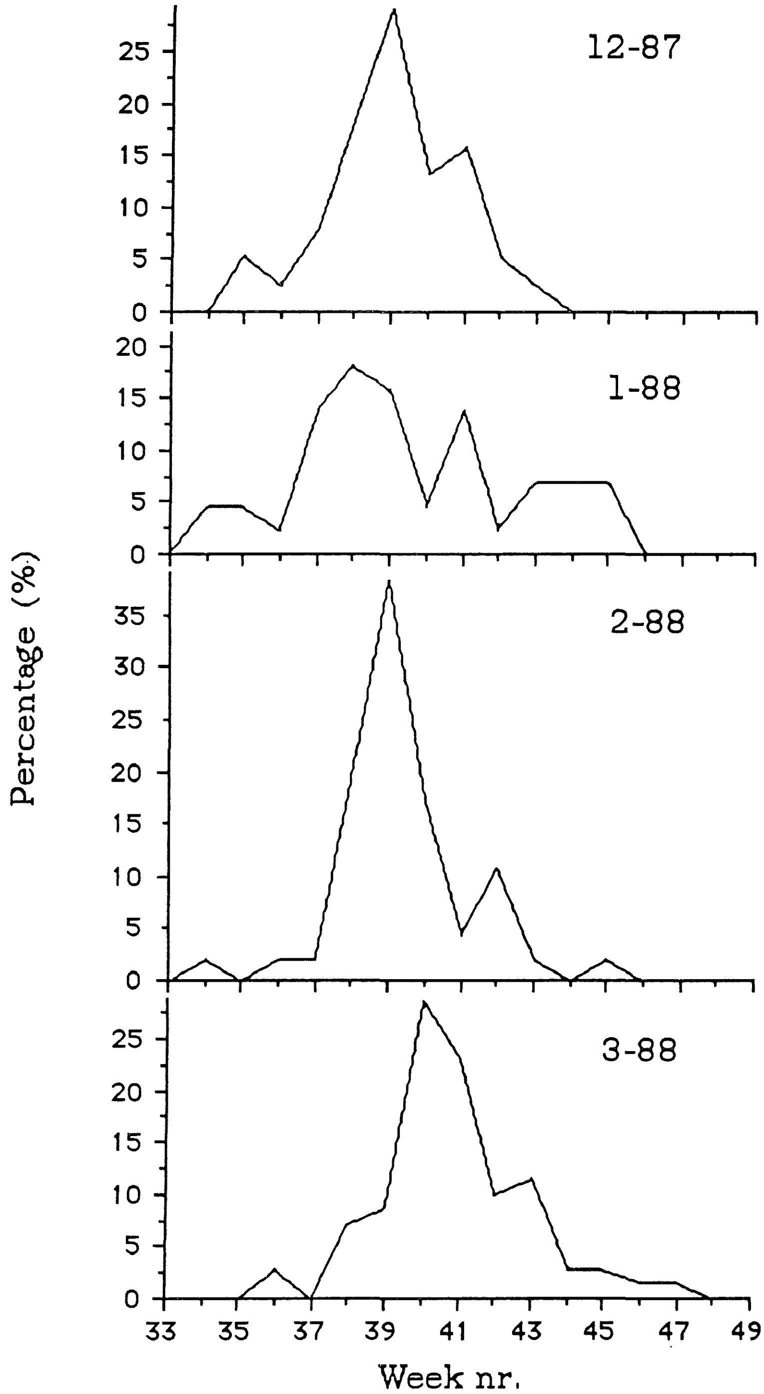

Fig. 12. Frequency distribution of the estimated hatching periods of the herring larvae from the four cruises. 12-87 = 19 - 23 December 1987; 1-88 = 18 - 22 January 1988; 2-88 = 23 - 26 February 1988; 3-88 = 15 - 18 March 1988.

Table 6. Average hatching date with standard deviation (in days) and minimum and maximum hatching dates estimated from daily increments in the otoliths. No. = Number of specimens examined.

Cruise	Average	SD (Days)	Min	Max	No.
12-87	24. Sept	12	25. Aug	19. Oct	38
1-88	27. Sept	20	18. Aug	5. Nov	44
2-88	26. Sept	12	21. Aug	3. Nov	47
3-88	6. Oct	14	4. Sept	25. Nov	70

Table 7. Estimated hatching periods from field studies (Paul Rankine, DAFS, Aberdeen, Scotland; Pers. comm.).

Area	Period of hatching	Estimated peak
Shetland area	20. Aug. - 1. Oct.	5. - 10. Sept.
Buchan	1. Sept. - 1. Oct.	1. - 10. Sept.
Central North Sea	1. Sept. - 20. Oct.	15. - 30. Sept.
Southern Bight		5. - 10. Dec.

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