

# MORTALITY OF HERRING DURING THE EARLY LARVAL STAGE IN 1967

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## INTRODUCTION

The existence of critical periods for herring larvae in the sea has still to be proved. However, it is generally accepted that natural mortality must be high in the very early stages of life, but little is known about its magnitude and variability. Investigations carried out by the Institute of Marine Research during the period 1959–1967 (DRAGESUND and HOGNESTAD, 1960; DRAGESUND and OLSEN, 1965; DRAGESUND, 1970 a), provided evidence of a proportional relationship between the abundance of 0-group herring at six months of age of a particular year-class and the subsequent abundance of the same year-class at later stages. Thus the 1959 year-class was numerous at the 0-group stage, whereas that of 1962 was scarce. These same year-classes showed up as relatively strong and poor ones in the adult stock.

The 0-group surveys carried out in autumn of 1967 (ANON., 1967) suggested that the 1967 year-class was exceptionally poor. Accordingly the mortality of this year-class must have been very high prior to the 0-group stage. In the present paper a quantitative analysis of the number of larvae according to length and time is given for larvae collected in spring of 1967.

## MATERIAL AND METHODS

The material included in the present work was derived from: (1) herring samples collected during the winter herring fishery in 1967; (2) larval surveys carried out in spring of 1967 between Stad and Grip during the periods 29 March – 3 April, 4–6 April, 9–11 April, 18–20 April, 23–26 April. The winter herring samples were collected from commercial catches several times a week and the fish were analysed fresh or iced at the Institute of Marine Research. The maturity stages were classified according to the maturity scale recommended by the International Council for the Exploration of the Sea in 1962 (ANON., 1962). The method applied for estimating the duration of the spawning season was the same as described by DRAGESUND (1970 b).

Several larval surveys were carried out during the period 29 March–29 April 1967. A survey from 29 March to 14 April covered the coastal banks from

Stad to Andenes (northern Norway), and during a later period, 24–29 April, resampling was carried out between Halten and Lofoten. Also the area from Grip to Halten was surveyed twice, during 1–2 April and 6–8 April. However, the sampling was concentrated further south between Stad and Grip, and this area was surveyed five times. The grid of stations during the first period, 29 March–3 April, is shown in Fig. 76. During the subsequent periods the stations were located almost at the same positions, except 18–20 April, when only the central part of the area was covered (Fig. 76, framed). The number of stations surveyed during the different periods are listed in Table 56.

Oblique hauls were taken with Clarke-Bumpus plankton samplers equipped with silk nets of mesh size 0.50 mm. The sampling depths were 25–5 m, 50–30 m and 75–55 m and the procedure of sampling was the same as described by Dragesund (1970 b). All samples were preserved in 5–10 % formaldehyde. The larvae were counted and measured to the nearest mm below, and sorted into larvae with and without yolk sac, the results being expressed as the number of larvae per m<sup>2</sup> surface.

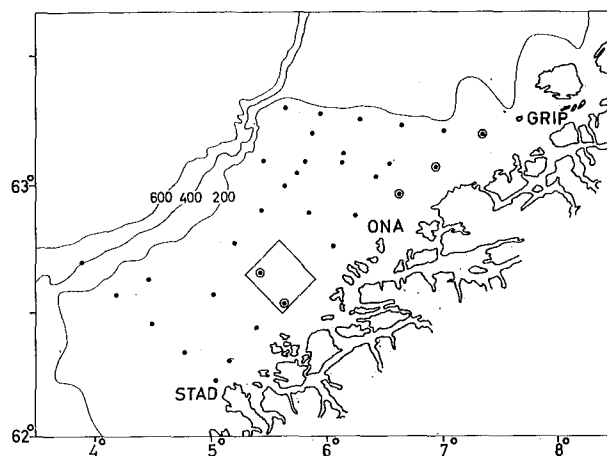


Figure 76. Grid of stations during the first survey period, 29 March–3 April 1967. Repeated stations are encircled. The stations during the fourth period (18–20 April) were located inside the area framed.

In order to study the drift of larvae, four experiments with free floating drogues (current crosses) were carried out at different places during the surveys. The current cross consisted of two iron sheets, each with area of 1 m<sup>2</sup>, set at right angles to each other. The cross was suspended by a thin wire from a surface plastic float to which a pole was fastened, equipped with a light on the top. During all the measurements the cross was floating at 25 m depth, which approximately corresponded to the average depth of the main larval concentration.

## RESULTS

Larvae observed north of Grip were few in number, no larvae being found in the northernmost area from Halten to Andenes. The number caught in the district just north of Stad-Grip (i.e. between Frøya and Hal-

Table 55. Catches of spawning and spent herring according to region during the Norwegian winter herring fishery 1967

Region	Catch	
	Thousands of metric tons	%
Stad-Ona .....	21-866	68.8
Ona-Grip .....	9-683	30.5
Grip-Halten .....	0-207	0.7

ten) amounted to about 4% and 2% of the total larval population in the first and second period, respectively. This feature was in contrast to the four previous seasons (1963-1966) when herring larvae were observed as far north as the Lofoten region (DRAGESUND, 1970 b). Spawning in 1967 took place off Møre and Trøndelag (DEVOLD, 1967), but due to

extremely bad weather it was difficult to locate the spawning grounds precisely (BJØRKE, DRAGESUND and NAKKEN, 1967). According to the catch distribution of spawning and spent herring and the distribution of yolk sac larvae, it is likely that the spawning was concentrated on the coastal banks between Stad and Grip (Tables 55 and 56).

The onset of spawning could not be estimated accurately because of the scarcity of samples during the spawning period. The first sample with herring in stage VII (spent) appeared in the five day period 18-22 February, whereas no spent herring was observed during the next five day period, 23-27 February (Fig. 77). However, the distribution of stages V and VI indicated that the spawning started during the period 20-25 February ( $T_1$ , Fig. 77), and lasted until 22-27 March ( $T_2$ , Fig. 77). The peak of spawning was estimated to fall in the medial period between  $T_1$  and  $T_2$ , i.e. 7-12 March. The temperature on the spawning grounds between depths of 50-200 m varied from 5.5° C to 6.5° C (BJØRKE, DRAGESUND and NAKKEN, 1967). According to BLAXTER and HEMPEL (1963) this should correspond to an incubation time of 20-25 days, resulting in a peak of hatching during the period 27 March-6 April.

Table 56 shows the number of larvae according to length and time. These figures were converted to the average number per m<sup>2</sup> surface (Table 56 in brackets) and the quantitative length distributions obtained are illustrated in Figure 78. A slight decrease in mean length was observed between the first and second period of sampling, indicating that the latter survey fell in the main period of hatching. Although an increase in mean length was observed both during the third and fourth period of sampling (9-11 April and 18-20 April), the increments were small. The relatively high percentage of larvae with

Table 56. Number of larvae according to length (mm) and time during the larval survey 1967. In brackets average number of larvae per m<sup>2</sup> surface

Period of survey	No. of stations											Total	$\bar{l}$	s	With yolk %
		7	8	9	10	11	12	13	14	15	16				
29/3- 3/4 .....	38	1	13	416	1034	79	-	-	-	-	-	1543	9.8	0.58	91.5
		(0.1)	(0.6)	(17.5)	(41.2)	(3.2)	-	-	-	-	-	(62.6)			
4/4- 6/4 .....	20		81	676	926	91	-	-	-	-	-	1774	9.6	0.65	82.5
			(8.4)	(69.8)	(97.0)	(9.6)	-	-	-	-	-	(184.8)			
9/4-11/4 .....	19		46	485	1561	608	88	2	-	-	-	2790	10.1	0.81	76.6
			(4.6)	(49.2)	(163.5)	(61.9)	(8.8)	(0.2)	-	-	-	(288.2)			
18/4-20/4 .....	14	1	1	53	524	255	18	8	-	-	-	860	10.3	0.66	92.4
		(0.1)	(0.1)	(5.9)	(56.3)	(26.2)	(2.3)	(0.9)	-	-	-	(91.8)			
23/4-26/4 .....	28			8	85	272	264	140	74	20	2	865	11.9	1.25	16.2
				(0.4)	(4.9)	(15.9)	(15.6)	(8.3)	(4.5)	(1.3)	(0.1)	(51.0)			
Total .....	119	2	141	1638	4130	1305	370	150	74	20	2	7832	10.1	0.98	76.0
		(0.0)	(2.4)	(26.0)	(63.3)	(19.4)	(5.3)	(2.1)	(1.1)	(0.3)	(0.0)	(119.9)			

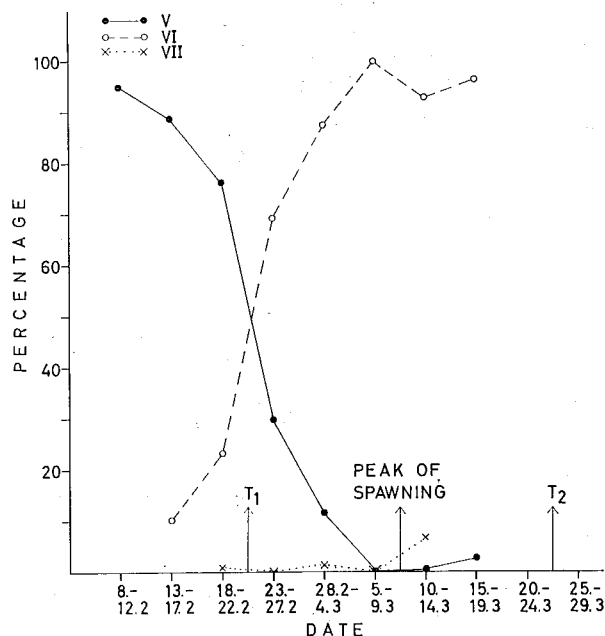


Figure 77. Percentage maturity composition (stages V-VII) of winter herring during the 1967 season (males and females pooled).  $T_1$  and  $T_2$  are the estimated dates of the beginning and end of spawning, respectively.

yolk in the period 18-20 April must be derived from a relatively late hatching, the spawning region probably being located close to the area of sampling (Fig. 76, framed).

The number of newly hatched larvae ranging in length from 7 to 9 mm (Fig. 79) indicated that the main hatching took place during the first ten days of April. The hatching started at the end of March and was almost finished by the 20 April. A decrease in total abundance (Fig. 79) commenced before hatching was over, the reduction in numbers obviously being due to lack of larvae subsequent to those in the 10 mm group (Fig. 80). However, in comparing the number of larvae in the different mm groups during a limited sampling period, the growth rate has to be taken into account. Assuming a constant growth rate ( $k$ ) during the time interval  $t_2-t_1$  the following equation can be derived

$$l_2 - l_1 = k(t_2 - t_1) \quad (1)$$

where  $l$  is the length in mm and  $t$  the time in days.

The time interval between two successive mm groups is therefore

$$t_2 - t_1 = \frac{1}{k} \quad (2)$$

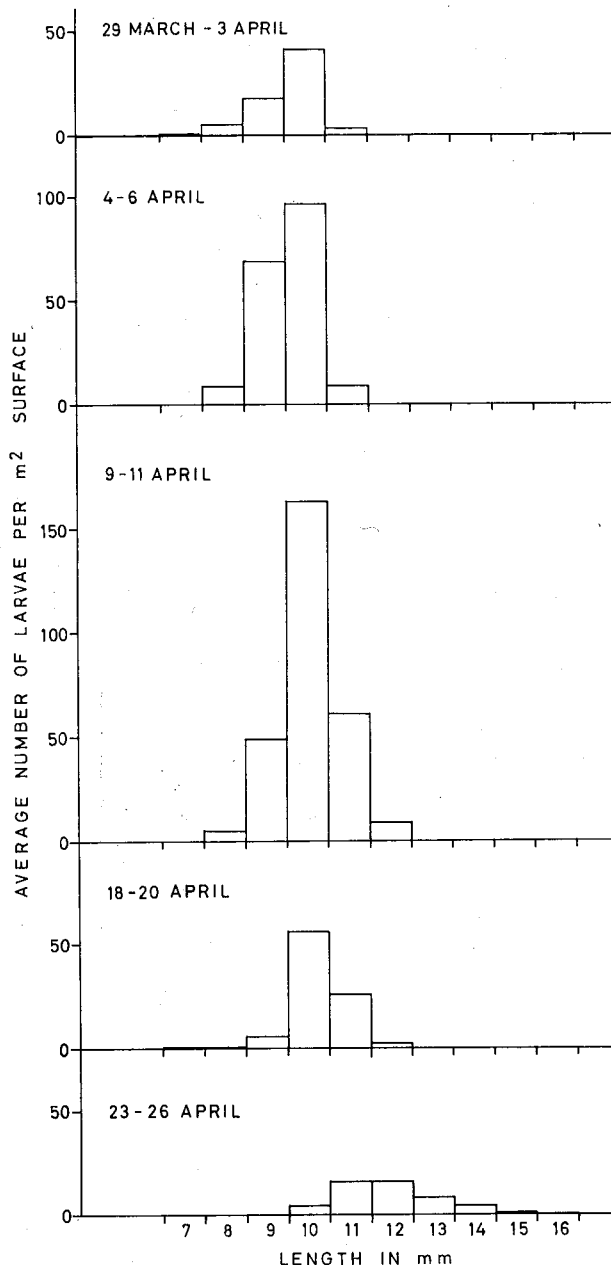


Figure 78. Quantitative length distribution in the different periods of sampling during the 1967 surveys.

These two equations will be used in the next chapter when discussing the larval mortality.

The results of the current cross measurements are shown in Figure 81. The dates of release and the duration of the experiments are listed in Table 57. During the period in question almost no drift took place along the coast in a northward direction.

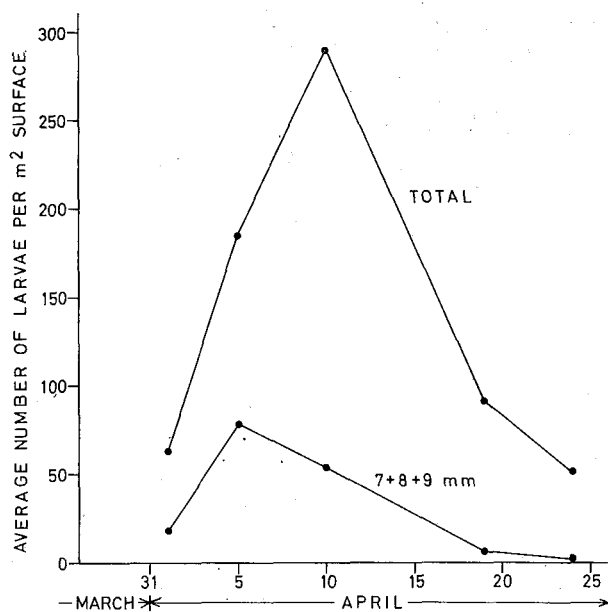


Figure 79. Average number of larvae as a function of time for the area surveyed, total and newly hatched (7+8+9 mm).

Table 57. Summary showing the number of current cross stations, date of release and duration of experiment

Station No.	Date of release	Duration of experiment
1	3 April, 1967	138 hours
2	12 - -	13 -
3	18 - -	13 -
4	22 - -	25 -

#### DISCUSSION

The decrease in abundance of larvae according to length and time in the area covered might have resulted from the following causes:

- (1) Emigration of newly hatched larvae from the area of sampling.
- (2) Increased net avoidance by the larger larvae.
- (3) Mortality of larvae.

The conclusions drawn from the maturity distribution presented in Fig. 77 concerning the onset and duration of hatching are in full accord with the results obtained from the larval observations (Fig. 79). It is therefore assumed that the larval surveys covered the whole period of hatching.

The main cause of larval emigration from an area must be due to drift migration. It is evident from the drift experiments that the current component along

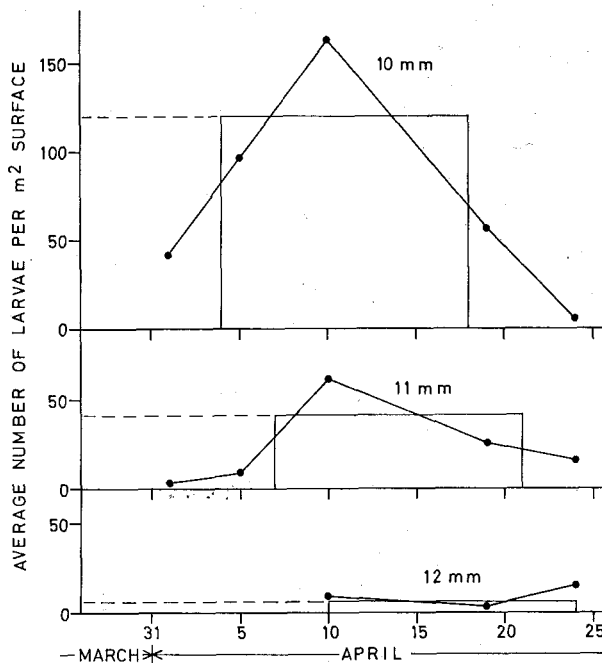


Figure 80. Average number of larvae as a function of time in the 10, 11 and 12 mm groups. The mean values of the three different mm groups within a 14 day period applying a growth rate of 0.33 mm per day are indicated.

the coast was almost negligible during the period of investigation (Fig. 81). This feature was in agreement with the findings of HELLAND-HANSEN and NANSEN (1909), who suggested that the coastal current off Møre showed maximum northwards speed at the edge of the continental shelf, whereas closer to the

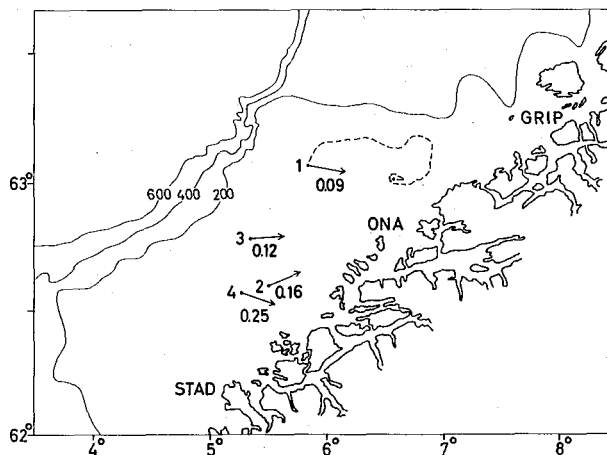


Figure 81. Current cross measurements in April of 1967 (stations 1-4). The mean velocities of current crosses are given, the arrows show the direction and the figures the speed in knots. The dotted line indicates the drift path.

coast the velocity was weaker and had various directions. Thus the drift experiments indicated that the transport of larvae out of the area covered was small. This was also in agreement with the observation that larvae were scarce north of Grip.

According to investigations carried out by DRAGESUND (1970 b) no significant differences were found in mean lengths of larvae below 15 mm caught by Clarke-Bumpus plankton samplers and a 3 foot Isaacs-Kidd midwater trawl, nor could any clear differences be observed between lengths of larvae caught at night and during the day. It is, therefore, reasonable to assume that net avoidance was relatively small below 15 mm. Thus it is concluded that the decrease in number of larvae observed was neither due to emigration of larvae from the area covered, nor to increased net avoidance by the larger larvae.

The first larvae reaching 12 mm appeared on 7-8 April (Fig. 80). Provided the hatching started 29-30 March and the mean length at hatching was 9 mm, the growth rate per day during this first period was estimated to be 0.33 mm, applying equation (1). This growth rate is in agreement with that found by BLAXTER and HEMPEL (1963) of yolk sac larvae hatched in tanks. Larvae 12 mm long showed an average number per m<sup>2</sup> surface of 8, 6 and 15 in the periods 9-11, 18-20 and 23-26 April respectively, the mean value within the 14 day period 10-24 April being 7 per m<sup>2</sup> surface using graphical calculation (Fig. 80). The corresponding figures of the 11 mm and 10 mm groups can be found first by estimating the time interval between two successive mm groups applying equation (2), and thereafter estimating the average number within the 14 day period graphically from Figure 80. Similarly the numbers at 11 and 10 mm were calculated by using other growth rates, e.g. 0.2 and 0.4 mm per day (Table 58). These estimates did not show significantly different figures from those obtained by applying the 0.33 mm growth rate per day.

The survey carried out during the fourth period (18-20 April) obviously did not cover the Stad-Grip region sa-

Table 58. Average number of larvae per m<sup>2</sup> surface in the mm groups 10 to 12 mm estimated graphically from Figure 80 applying three different growth rates

Length group (mm)	Growth rate (mm per day)		
	0.20	0.33	0.40
10	110	120	115
11	38	41	40
12	7	7	7

tisfactorily, and the results obtained during this survey might give a bias in the number and length of larvae in this region. However, during the last period (23-26 April) the grid of stations again was comparable with the previous periods and the results obtained indicated that the numbers found during the fourth period were reasonable and could be used in the series of observations for estimating the larval mortality. Thus evidence was found for a very high mortality rate of larvae between 10 and 12 mm. A reduction of the larval population of about 94 % took place at this stage, and it is assumed that 11 mm might be a critical length. This length corresponded to the period of completion of yolk absorption found by BLAXTER and HEMPEL (1963).

#### SUMMARY

- (1) A quantitative analysis of the number of larvae according to length and time was carried out for larvae collected in an area off Møre in April 1967.
- (2) A marked decrease in number was found between larvae of 10 and 12 mm length.
- (3) It was concluded that a mortality of the order of 94 % took place at this stage, which corresponded to the period when the yolk was absorbed.

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