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MORTALITY OF HERRING DURING THE LARVAL STAGE

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INTRODUCTION

Proves of the existence of critical periods for herring larvae in the sea are still lacking. It is generally accepted that the 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, e.g. Dragesund and Hognestad (1960), Dragesund and Olsen (1965) and Dragesund (1968), gave evidence of a proportional relationship between the abundance of O-group herring 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 O-group stage, whereas the 1962 year-class was scarce. These same year-classes showed up as relatively strong and poor broods in the adult stock.

The O-group surveys carried out in autumn of 1967 (Anon. 1967) suggested that the 1967 year-class was exceptionally poor. Tentatively, therefore, it was assumed that the mortality of this year-class was especially high prior to the O-group stage. In the present paper a quantitative analysis of 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: (a) 29 March - 3 April
(b) 4 - 6 April
(c) 9 - 11 April
(d) 18 - 20 April
(e) 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. 1963). The method applied for estimating the duration of the spawning season was the same as described by Dragesund (1968).

-29 April
Several larval surveys were carried out during the period 29 March 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, a resampling was carried out between Halten and Lofoten. Also the area from Grip to Halten was surveyed twice, 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.1. 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.1, framed). The number of stations surveyed during the different periods are listed in Table 2.

Oblique hauls were taken with Clarke-Bumpus plankton samplers equipped with nets of silk, 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 briefly the same as described by Dragesund (1968). All samples were preserved in 5-10 % formaldehyde. The larvae were counted and measured to nearest mm below, and sorted into larvae with and without yolk sac. The catch of larvae was converted to number of larvae per m^2 surface (Dragesund 1968).

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 was made of two iron sheets at right angles to each other with an area of 1 m^2 each. 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 in 25 m depth, which approximately corresponded to the average depth of the main larval concentration.

Results

In contrast to the four previous seasons (1963 - 1966) no herring penetrated the Lofoten region in winter of 1967 for spawning (Devold 1967). The spawning took place off Møre and Trøndelag, but due to extremely bad weather it was difficult to allocate 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 1 and 2).

The onset of spawning could not be estimated accurately because of the scarcety of samples during the spawning season. The first sample with herring in stage VII (spent) appeared in the five days period 18-22 February, whereas no spent herring was observed during the next five days

period, 23-27 February (Fig.2). However, the distribution of stages V and VI indicated that the spawning started during the period 20-25 February (T_1, Fig.2), and lasted until 22-27 March (T_2, Fig.2). The peak of spawning was estimated to fall in the median period between T_1 and T_2, i.e. 7-12 March. The temperature on the spawning grounds between 50-200 m depth 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 2 shows the number of larvae according to length and time. These figures were converted to average number per m^2 surface (Table 2, in brackets) and the quantitative length distributions obtained are illustrated in Fig.3. A slight decrease in mean length was observed between the first and second period of survey, 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 yolk in the period 8-20 April must derive from a relatively late hatching, the spawning region probably being located close to the area of sampling (Fig.1, framed).

In Fig.4 the number of larvae per m^2 surface in each mm group is shown as a function of time. The number of newly hatched larvae ranging in length from 7 to 9 mm (Fig.4, upper part) indicated that the main hatching took place during the first 10 days of April. The hatching started at the end of March and was almost finished about 20 April. It should be noted that a decrease in total abundance (Fig.4, lower part) commenced before the hatching was over. Judging from the number in the 10-12 mm groups, larvae were considerably more numerous in the 10 mm than in the two subsequent mm groups.

Larvae observed north of - Grip were scarce. Thus no larvae were found in the northernmost area from Halten to Andenes, and the larvae caught in the district just north of Stad - Grip (i.e. Frøya - Halten) were too few for any quantitative treatment. The results of the current cross measurements are shown in Fig.5. The dates of release and duration of the experiments are listed in Table 3. During the period in question almost no drift took place along the coast in northward direction.

DISCUSSION

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

(1) Emigration of newly hatched larvae from the area of sampling.
(2) Higher net avoidence of the bigger larvae.
(3) Mortality of larvae.

The conclusions drawn from the maturity distribution presented in Fig.2 concerning time and duration of hatching are in full accordance with the

results obtained from the larval observations (Fig.4, upper part). It is therefore assumed that the larval surveys covered the whole period of hatching.

The major part of emigration of larvae from an area must be caused by water-transport. It is evident from the drift experiments that the current component along the coast was almost negligible during the period of investigation (fig.5). This feature was in accordance 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, where as closer to the 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 (1968) no significant differences were found in mean lengths of larvae below 15 mm caught by Clarke-Bumpus plankton samplers and 3 feet Isaacs-Kidd midwater trawl. Nor could any clear differences be recorded between lengths of larvae caught at night and during daytime. It is, therefore, reasonable to assume that the net avoidance was relatively small below 15 mm, and it is concluded that the decrease in number of larvae observed was neither due to emigration of larvae from the area covered, nor to higher net avoidance of the bigger larvae.

The first larvae reaching 12 mm seemed to appear 7-8 April (Fig.4). Provided that the hatching started 29-30 March and that the mean length at hatching was 9 mm, the growth rate per day during this first period was estimated to 0.33 mm. This growth rate was in agreement with that found by Blaxter and Hempel of yolk sac larvae hatched in tanks (1963).
Larvae measuring 12 mm showed an average number per m^2 surface of respectively 8, 6 and 15 in the periods 9-11, 18-20 and 23-26 April, the mean value within the period 10-24 April being 7 per m^2 surface (Fig.4). The corresponding figures of the 11 mm and 10 mm groups applying a growth rate of 0.3 mm per day were respectively 41 and 120 (Fig.4 and Table 4). Similarly the number at 11 and 10 mm were estimated by using growth rates of 0.2 mm and 0.4 mm per day (Table 4).

The survey carried out during the fourth period (18-20 April) obviously did not cover the Stad-Grip region satisfactorly, and the results obtained during this survey might give a bias in number and length of larvae in the mentioned 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 figures found during the fourth period were resonable and could be used in the series of observations for estimating the larval mortality. Thus evidence was found for an extremely high mortality rate of larvae passing from 10 to 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 yolk absorption found by Blaxter and Hempel (1963).

SUMMARY

1 A quantitative analysis of number of larvae according to length and time was carried out for larvae collected in an area off Møre in April of 1967.

2 A marked decrease in number was found when the larvae passed from 10-12 mm.

3 It was concluded that a mortality in the order of 94 % took place at this stage, which corresponded to the period when the yolk was absorbed.

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Table 1. Catches of spawning and spent herring according to region in 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
Total	31.756	100.0

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

Period of survey	No. of stations	7	8	9	10	11	12	13	14	15	16	Total	$\bar{l}$	s	With yolk %
29.3-3.4	38	1 (0.1)	13 (0.6)	416 (17.5)	1034 (41.2)	79 (3.2)						1543 (62.6)	9.8	0.58	91.5
4.4-6.4	20		81 (8.4)	676 (69.8)	926 (97.0)	91 (9.6)						1774 (184.8)	9.6	0.65	82.5
9.4-11.4	19		46 (4.6)	485 (49.2)	1561 (163.5)	608 (61.9)	88 (8.8)	2 (0.2)				2790 (288.2)	10.1	0.81	76.6
18.4-20.4	14	1 (0.1)	1 (0.1)	53 (5.9)	524 (56.3)	255 (26.2)	18 (2.3)	8 (0.9)				860 (91.8)	10.3	0.66	92.4
23.4-26.4	28			8 (0.4)	85 (4.9)	272 (15.9)	264 (15.6)	140 (8.3)	74 (4.5)	20 (1.3)	2 (0.1)	865 (51.0)	11.9	1.25	16.2
Total	119	2 (0.0)	141 (2.4)	1638 (26.0)	4130 (63.3)	1305 (19.4)	370 (5.3)	150 (2.1)	74 (1.1)	20 (0.3)	2 (0.0)	7832 (119.9)	10.1	0.98	76.0

Table 3. 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 "

Table 4. Average number of larvae per m^2 surface in the mm groups 10 to 12 mm applying different growth rates.

Length group (mm)	Growth rate (mm) per day		
	0.2	0.3	0.4
10	110	120	115
11	38	41	40
12	7	7	7

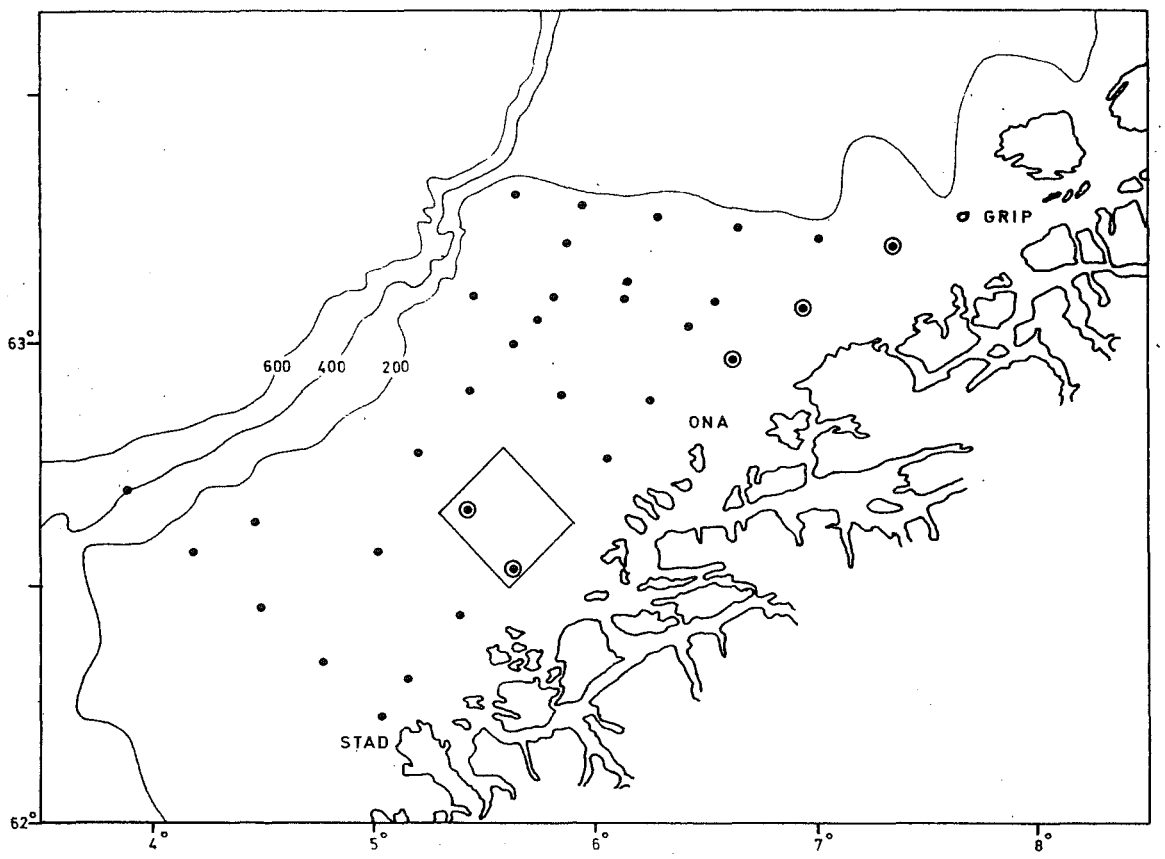

Fig. 1 Grid of stations during the first survey period, 29 March-3 April 1967. Repeated stations are encircled. The stations during the fourth period (18-20 April) were located inside the area framed.

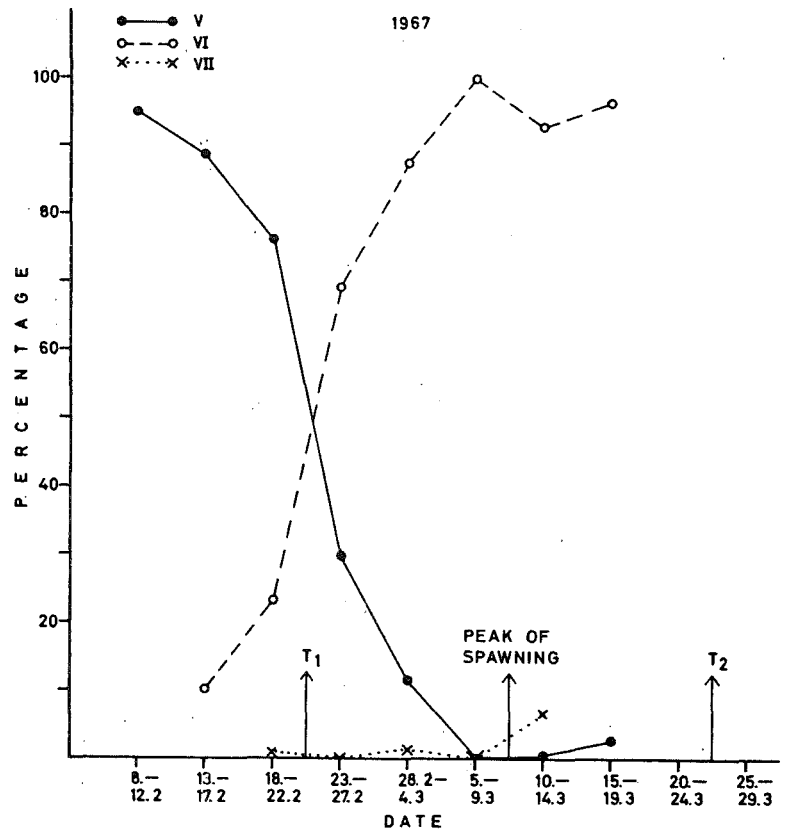

Fig. 2 Percentage maturity composition (stages V-VII) of winter herring during the season of 1967 (males and females pooled). T_1 and T_2 are the estimated dates of respectively onset and end of spawning.

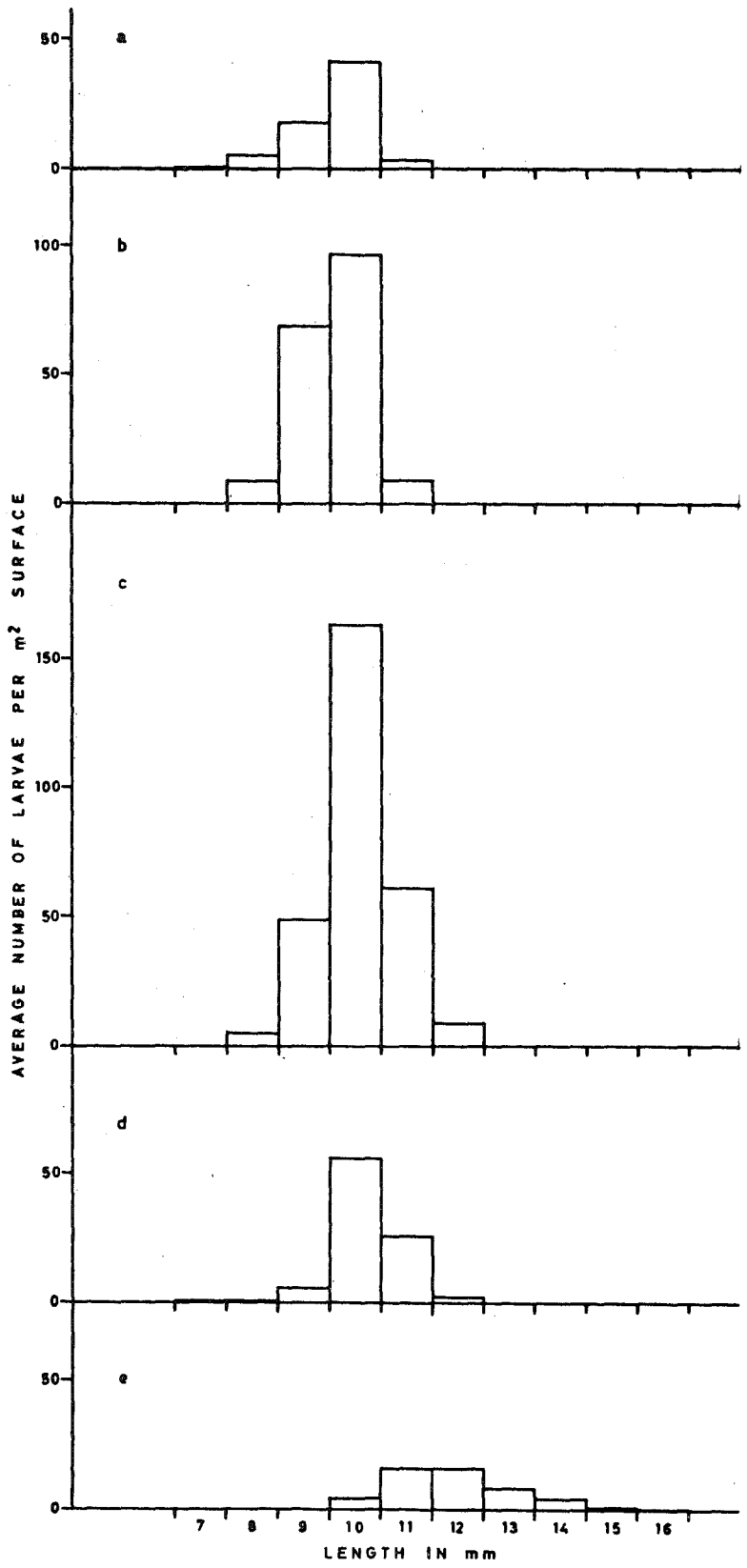

Fig. 3 Quantitative length distribution in the different periods of sampling. (a) 29 March - 3 April, (b) 4-6 April, (c) 9-11 April, (d) 18-20 April and (e) 23-26 April, 1967

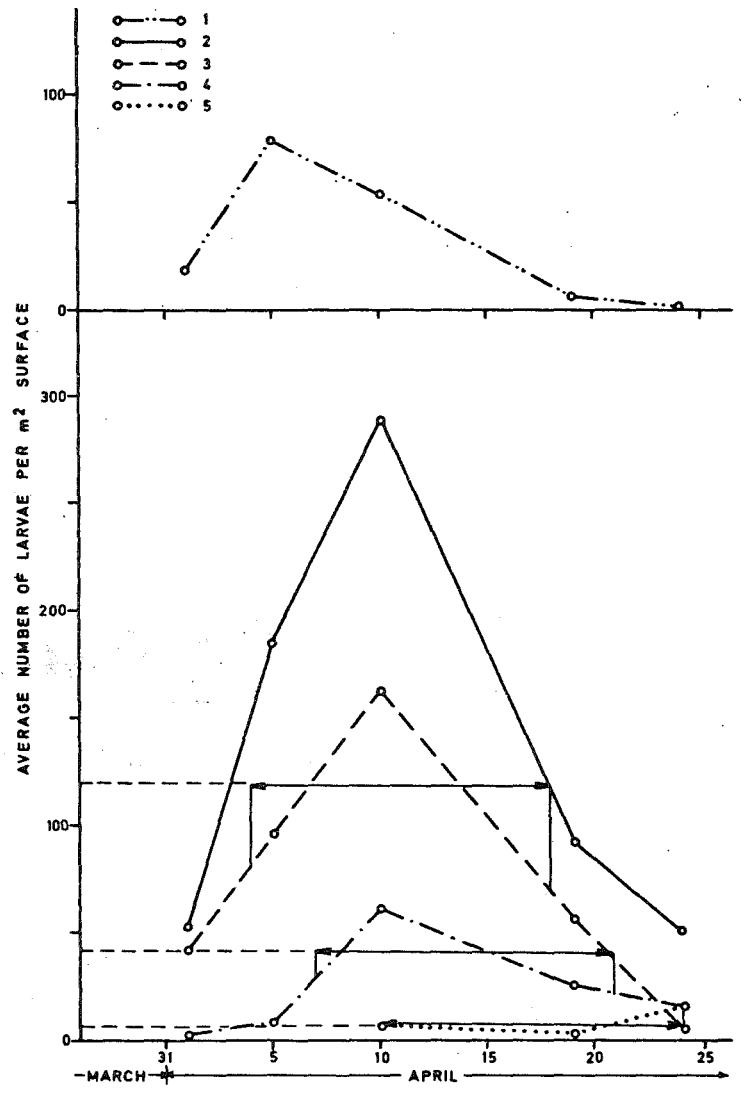

Fig. 4. Average number of larvae according mm group for the area surveyed as a function of time, upper part (1) 7+8+9 mm, lower part, (2) total, (3) 10 mm, (4) 11 mm and (5) 12 mm. The mean values of the 10-12 mm groups, applying a growth rate of 0.3 mm per day are indicated.

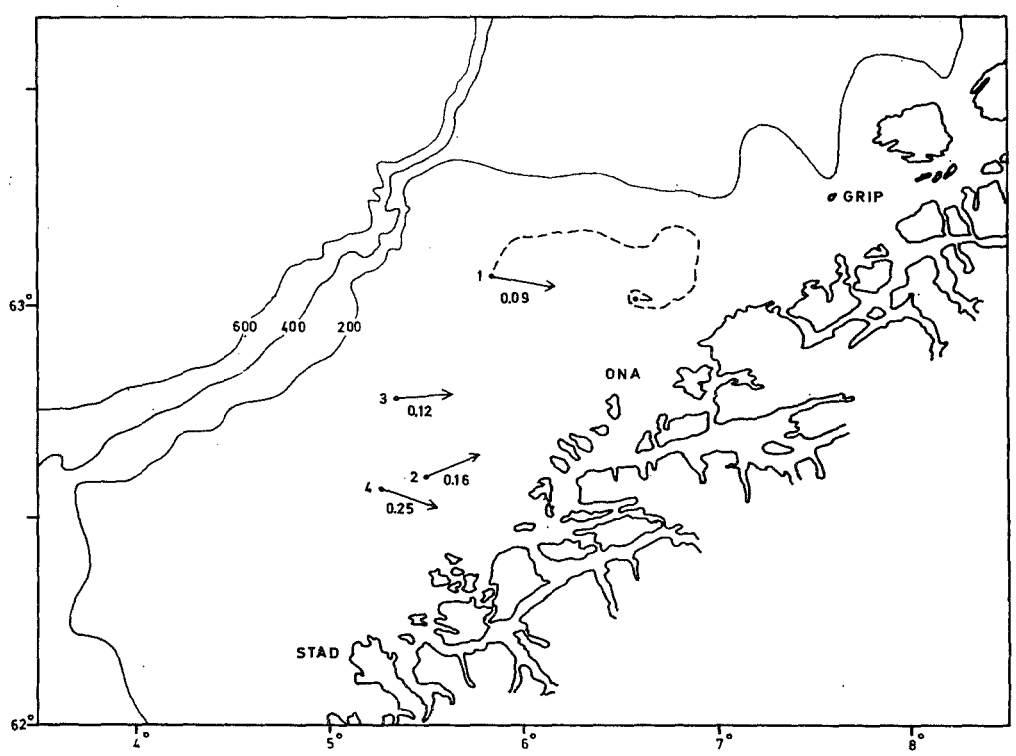

Fig. 5 Current cross measurements in April of 1967. The mean velocities of current crosses are illustrated. The arrows indicate the direction and the figures the speed in knot.