RELATIONSHIP OF PARENT STOCK SIZE AND YEAR CLASS STRENGTH IN NORWEGIAN SPRING SPAWNING HERRING

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INTRODUCTION

Attempts to gain a better understanding of the recruitment of marine fishes have been approached in several ways. Contributions to the study of the interrelationship between the size of the parent stock and recruitment have already been given by Ricker (1954), Beverton and Holt (1957) and Cushing (1968). Extensive larval studies have been carried out at several laboratories in order to elucidate the fluctuations in year class strength (Blaxter 1965, Hempel and Blaxter 1963, Ahlstrom 1954, 1965). Factors controlling the recruitment mechanism in the adult stocks and the effect of fisheries on immature fish are problems frequently being investigated (Cushing 1962, Zijlstra 1963, Anon. 1965).

The annual number of fertilized eggs and the subsequent number of young fish (the recruits) are related in some way to the abundance of the spawning stock. The nature of this relation is not known. A marked relationship between the annual number of eggs produced (the spawning potential of the parent stock) and the number of subsequent recruits is demonstrated in spurdog, which has a low fecundity (Holden 1968). Similarly, an indication of such a relationship is found in some relatively small stocks of Pacific herring (*Clupea pallasii* Valenciennes) in British Columbia (Taylor 1963) and in the Downs stock of herring in the North Sea (Burd and Holford 1968), but no trend of decreasing recruitment with decreasing spawning stock has as yet been demonstrated for the major stocks of herring in the North Sea (the Buchan and Bank stocks) and in the Norwegian Sea (the Norwegian spring spawning herring). However, to establish a relationship between the spawning potential of the parent stock and subsequent year class strength is difficult due to the variation in the normally high natural mortality during the very young stages.

In this paper, the parent stock size is compared with subsequent abundance of the resulting year class as adults and before the herring are fished (at about six months of age). The spawning potential of the parent stock is compared with subsequent larval abundance, and estimates of larval mortality during the spring of 1968 and 1969 are presented. The predator effect during the egg stage and early larval development is discussed, and some concluding remarks are given on the probability of the spawning stock to produce abundant year classes when the stock size fluctuates at the present low level.

MATERIAL AND METHODS

The main sources of data used in this investigation were as follows:

1) tagging experiments conducted during 1952—1965;
2) regular sampling programmes during the Norwegian winter herring and young and adolescent herring fisheries during 1947—1970;
3) 0-group fish surveys conducted during 1959—1969;
4) surveys conducted during and subsequent to spawning and hatching in 1968—1970;
5) official fishery statistics.

ADULT HERRING

Results of the tagging experiments conducted by the Fisheries Research Institute, Reykjavik and the Institute of Marine Research, Bergen, have been published by Fridriksson and Aasen (1950, 1952), Dragesund and Jakobsson (1963) and Dragesund (1970 a). The method used to estimate the adult stock size from tag returns has been described by Dragesund and Jakobsson (1963). Estimates available for the period 1953—1968 are given by Dragesund (1970 a, 1970 b).

The sampling procedure for age, length and weight determination of adult herring during the Norwegian winter herring fishery (the spawning season) has been described by Østvedt (1962) and Dragesund (1970 a). In order to analyse the year by year variation of the spawning potential, the stock size in different years was converted to numbers at length (Dragesund 1970 a). With data on fecundity by length (Baxter 1959, Parrish and Saville 1965) the egg production potential each year could be estimated.

YOUNG AND ADOLESCENT HERRING

The material on young and adolescent herring includes data from acoustic surveys and herring samples. The method used for estimating 0-group abundance at about six months of age is described by Dragesund (1970 b), where estimates of the year classes 1959–1965 are also given, while data for 1966–1969 are available from the international 0-group fish surveys (Anon. 1969, Benko *et al.* 1970).

Data on the age compositions of young and adolescent herring were taken from reports published by Dragesund (1963, 1970 b) and from unpublished records available at the Institute of Marine Research, Bergen.

HERRING EGGS AND LARVAL HERRING

Herring eggs and larvae were collected on regular surveys, shown in Figures 4 and 5, covering the coastal banks off the Norwegian west coast, from Stad to Sklinna. Eggs were collected with dredge or obtained from stomach content of haddock and saithe, fished with bottom trawl. In 1968 four, and in 1969, five successsive larval surveys were conducted during the five to six weeks following hatching. In these surveys, 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. The total towing time was 20 minutes, and the towing speed was between 1·5 and 2·0 knots. All samples were preserved in diluted formalin containing 4 ‰ 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 below 1 m^2 of surface (e. g. Wiborg 1961, Dragesund 1970 a).

ECHO COUNTING

Counting of fish (mainly for haddock and saithe) with the help of a Simrad echo integrator (QM) in conjunction with a 38 kHz Simrad scientific sounder was carried out in 1970 within a limited area off Møre. When possible the integrator was calibrated by paper counts. The integrator readings were converted to fish densities and the number of fish was found by area integration of the densities. The method used is described by Midttun and Nakken (1968).

RESULTS OF ANALYSES

STOCK SIZE

Estimates of spawning stock size for 1953–1968 were based on tagging experiments (Dragesund and Jakobsson 1963, Dragesund 1970 a, 1970 b) and acoustic surveys combined with underwater photography experiments (Fedorov, Truskanov and Yudanov 1963, Anon. 1970), while those for the period 1947–52 were obtained from catch-per-unit-effort data for the Norwegian drift net fishery, given by Østvedt (1963). Estimates for 1969 and 1970 were derived from the data given in the report of the Atlanto-Scandian Herring Working Group (Anon. 1970), applying a total annual instantaneous mortality coefficient of $Z = 0{\cdot}44$. The etimates for the whole period 1947–1970 are given in Table 1.

Table 1. Spawning stock size in millions of metric tons during the period 1947–1970

Year	Tagging experi-ments	Acoustic surveys, underwater photography	Deduced figures	Mean
1947....	–	–	10·7	10·7
1948....	–	–	10·7	10·7
1949....	–	–	10·7	10·7
1950....	–	–	10·7	10·7
1951....	–	–	10·7	10·7
1952....	–	–	10·7	10·7
1953....	12·5	–	–	12·5
1954....	12·2	–	–	12·2
1955....	13·9	–	–	13·9
1956....	12·0	–	–	12·0
1957....	9·4	–	–	9·4
1958....	6·6	–	–	6·6
1959....	5·0	6·0	–	5·5
1960....	–	–	4·5	4·5
1961....	–	–	3·5	3·5
1962....	–	2·5	–	2·5
1963....	–	2·9	–	2·9
1964....	5·0	3·3	–	4·3
1965....	7·7	6·8	–	7·3
1966....	–	6·5	–	6·5
1967....	–	4·0	–	4·0
1968....	–	2·0	–	2·0
1969....	–	–	1·3	1·3
1970....	–	–	0·9	0·9

These data show that the stock size was on a relatively high level during 1947–1956. From 1957 onwards a decrease in the stock took place and this continued until 1962, when it was about 2·5 million tons; it then increased in the following three years to reach 7·3 million tons in 1965 (the estimates given for 1963–1965 exclude the component spawning at Lofoten, and hence the spawning stock during these years is an underestimate). From 1966 to 1970 a rapid decrease in stock size took place.

The spawning potential of the stock is a function of the size of spawning stock. However, fecundity increases with length and weight of the fish (Parrish and Saville 1965, Jakobsson *et al.* 1969) and thus the spawning potential of the stock is a function both of the number and the length of fish. Preliminary figures of the spawning potential for the spawning seasons 1947—1969 are given in Figures 2 and 3.

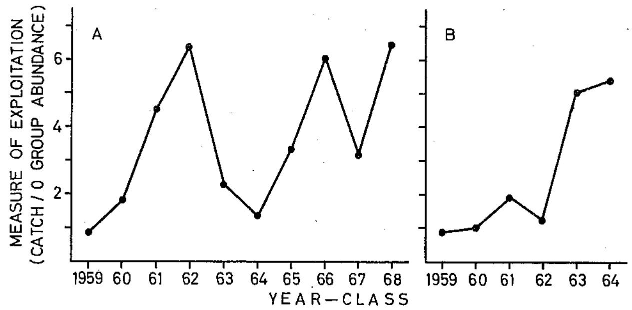


Figure 1. Measure of exploitation indicated by the ratio of catch in tons/0-group echo abundance (A) during the small-herring stage for the year classes 1959–1968 and (B) during the fat-herring stage for the 1959–1964 year classes.

YEAR CLASS STRENGTH

The estimation of year class strength for adults is complicated by the wide range of ages over which individuals of a given year class attain sexual maturity. However, knowing the size and age composition of the spawning stock, an estimate of year class strength can be obtained by calculating the abundance of the year class at six years of age when most of the year class has entered the adult stock (Østvedt 1958, 1963, Dragesund 1970 a) (the 1965—1969 year classes had not reached the adult stage (six years of age) in 1970 and cannot be compared with the previous year classes in the adult stock).

By calculating year class strength at an age of six years, the effect of fishing on the immature herring is not taken into consideration. However, the results of recent investigations (e. g. Devold 1950, Devold 1958, Dragesund and Hognestad 1960, Dragesund and Olsen 1965, Dagesund 1970 b), show that a correlation exists between the abundance of 0-group herring (at about six months of age) and the abundance at later ages. Nevertheless a fishery which is of considerable importance to the population dynamics of the Norwegian spring spawning herring is carried out on young and adolescent herring in Norwegian coastal waters. This fishery is divided into the following two components: (1) that based on the "small-herring", i. e. mainly 0- and I-group herring with the former predominating and (2) that based on the "fat-herring", i. e. I to IV group herring with the II and III groups predominating.

The effect of these fisheries on the recruitment to the adult stock has been discussed by several authors (e. g. Lea 1924, Devold 1953, 1958, 1963, Dragesund 1970 b). Both Devold and Dragesund concluded that the fishery for 0-and I-group herring (the small-herring fishery) carried out in the Norwegian fjords during the 1950s and early 1960s did not have a primary effect on the recruitment of year classes to the adult stocks. This conclusion was based mainly on the fact that the fjord population is only a part of the total 0- and I-group population. Marti and Fedorov (1963) on the other hand attribute recent low recruitment to the adult stock to the effects of small-herring fishery.

During the period 1965—1968 a considerable increase in the exploitation of both "small-herring" and "fat-herring" took place as the fishery was extended into the open sea (Dragesund 1970 b). This resulted in a marked reduction of the 1963 and 1964 year classes before they entered the adult stock. The effect is also expected to be significant for the 1965—1968 year classes, though it should be stressed that the strength of these year classes were extremely low at the 0-group stage.

Estimates of 0-group abundance are available for the 1959—1969 year classes, whereas direct estimates of year classes prior to these are lacking. Assuming that a relationship exists between the abundance of 0-group herring and the subsequent catch of "small-herring", tentative estimates of the 0-group abundance have been made for the 1950—1958 year classes. The variation in exploitation of both "small-herring" and "fat-herring" can be measured by taking the ratio between catch at different stages during the young and adolescent phases and the total echo abundance of 0-group herring (Dragesund 1970 b). In Figure 1 is shown the variation in the exploitation of "small-herring", for the 1959—1968 year classes, and of "fat-herring" for the 1959—1964 year classes. It is clearly demonstrated that poor year classes were more heavily exploited as "small-herring" than the rich ones. The major reason for the higher exploitation of poor year classes (e. g. those of 1961 and 1962 compared with those of 1959 and 1960) is ascribed to their different distribution pattern. In 1959 and 1960, 0-group herring had an oceanic distribution and only a minor part of the 0-group population entered the fjords of northern Norway; in 1961 and 1962 their distribution was more restricted to the coastal areas, and a greater portion of the population was available in the fjords. It was assumed, therefore, that in most of the years during the 1950s, when poor year classes occurred, they had a coastal distribution comparable with those of 1961 and 1962, whereas that of 1950 had a similar distribution to the year class of 1959. The average ratio of small-herring catch to 0-group abundance for the 1961 and 1962 year classes, of 5·43, was therefore applied to the 1951—1958 year classes, while the value of 0·85 for the 1959 year class was applied to the 1950 year class. The estimates of 0-group abundance obtained using these ratios are given for the 1950—1958 year classes with those for 1959—1969 in Table 2.

Table 2. Catch of small herring for the 1950–1968 year classes and estimated abundance of 0-group herring (for explanation see text)

Year class	Catch in thousands of tons	0-group abundance
1950	270	318
1951	175	32
1952	215	40
1953	180	33
1954	135	25
1955	90	17
1956	127	23
1957	115	21
1958	117	22
1959	277	326
1960	267	147
1961	169	38
1962	94	15
1963	121	54
1964	102	75
1965	30	9
1966	136	23
1967	12	4
1968	9	2
1969	–	5

Although the abundance estimates for the 1951—1958 year classes are tentative and should be used with caution, primarily because the distribution patterns of the respective year classes are unknown, the results in Table 2 suggest that they were all very weak. It is likely that the abundance of the 1950 year class is underestimated, compared with that of 1959, due to its higher abundance at six years of age and that the yield subsequent to the small-herring stage was considerable greater for the 1950 year class.

STOCK AND RECRUITMENT

Figure 2 a shows the spawning potential of the parent stock for the period 1947—1964 against the resulting year class strength at six years of age, and in Figure 2 b the spawning potential for the period 1950—1969 is plotted against year class strength at the 0-group stage.

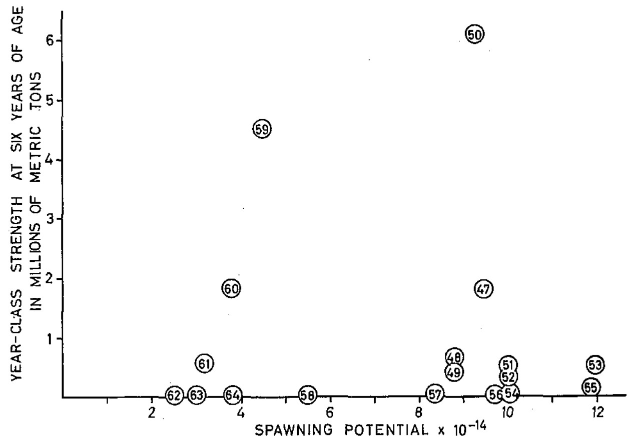


Figure 2a. Relationship between the spawning potential of the parent stock and the subsequent year class strength at six years of age for the 1947–1964 year classes. The respective year classes are indicated inside each circle.

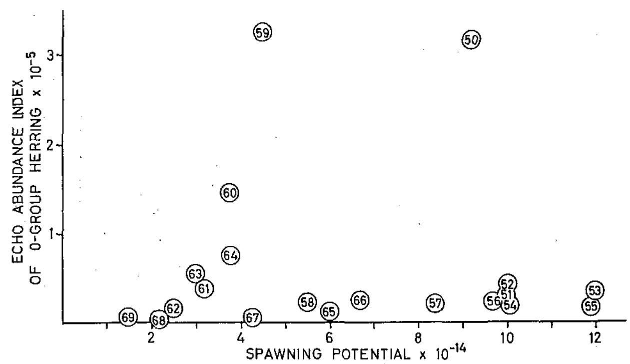


Figure 2b. Relationship between the spawning potential of the parent stock and the subsequent year class strength at about six months of age for the 1950–1969 year classes. The respective year classes are indicated inside each circle.

No firm conclusions can be drawn from these data about the relationship between parent stock size and the abundance of the resulting year class. They may indicate that in some years within the period considered, year class strength was affected by the size of the parent stock, even though in most of the years it was determined by other factors. Thus, in at least twelve out of twenty-three years during the period 1947—1969, the size of the parent stock has apparently not been the primary factor controlling subsequent year class strength. In years when abundant year classes were produced as in 1950 and 1959 other factors may have given rise to favourable conditions for the survival of the progeny.

Factors considered to be of importance in determining year class strength of Norwegian spring spawning herring have been discussed by Dragesund (1970 a). Strong year classes seemed to occur when a combination of the following conditions existed:

1) widespread distribution of spawning;
2) long duration of the spawning period;
3) a rapid dispersion of larvae from the spawning grounds.

The coincidence in time between the occurrence of suitable food and hatching of herring larvae is assumed to be the most important environmental factor controlling year class strength during the early larval development. The gradual northward displacement of the main spawning centre during the last decades has probably increased the importance of the timing factor, since only two definitely rich year classes, those of 1950 and 1959, occurred during the period 1947—1965.

STOCK SIZE AND LARVAL ABUNDANCE

Although no reliable estimates are available for the spawning stock sizes in 1969 and 1970, it is obvious that the stock has continued to decrease from 1968 onwards, due to lack of recruits, to the order of 1·3 and 0·9 million tons, in 1969 and 1970 respectively (see Table 1).

Larval abundance estimates of the 1959—1965 year classes just after hatching, suggest that the variation in the size of the spawning stock was reflected in the larval abundance figures (Dragesund 1970 a). However, the sampling procedure was not satisfactory to give reliable abundance estimates during that period. During the years 1967—1970 greater effort was devoted to sampling of herring larvae and the quantitative distributions were studied during successive sampling periods. The results of the surveys conducted in 1967 have already been published by Dragesund and Nakken (1970) but those for the 1968 and 1969 surveys are given in Figures 3 and 4. The data show that in contrast to 1963—1966 no major spawning was observed in the Lofoten region during 1967—1969. The spawning took place off Møre—Trøndelag with the centres off Ona—Grip and Halten. The main spawning occurred from 10 to 15 March, with a subsequent peak of hatching in the first week of April.

The abundance of larvae in the different periods of sampling in 1968 and 1969, obtained by integrating the density of larvae within the isolines of larval abundance drawn in Figures 3 and 4 is shown in Figure 5, Two striking features of the 1969 data, compared with 1968, are evident; viz. an unexpected low adundance of hatched larvae and a significantly lower larval mortality. The reduction in spawning potential from 1968 to 1969 was in the order of 30 per cent, whereas the reduction in number of newly hatched larvae was about 85—90 per cent. This might be explained by a markedly higher mortality during the incubation period in 1969 than in 1968, or parts of the stock might have spawned in other areas. The former explanation appears to be more likely.

Lea (1930) showed that thick egg layers on the Norwegian spawning grounds resulted in high mortality. According to Dragesund and Nakken (unpublished) no such thick layering of eggs could be found in 1967—1970 and the layering was probably of insignificant importance to the mortality. Also few unfertilised eggs were found during the same period.

During the spawning seasons in 1967—1970 the relative importance of the predator effect seemed to have increased as it was noticed that gadoïd fishes (haddock and saithe) had been feeding heavily on herring eggs. Some preliminary figures indicating the number of eggs observed in the stomachs of samples of haddock and saithe are shown in Table 3. During the winter of 1970 an attempt was made to count, by echo-counting techniques, the number of fish predators (mainly haddock and saithe) present within a part (about one-third) of the main herring spawning area off Ona—Grip, shown in Figure 6. If it is taken that a similar or somewhat smaller spawning area was located off Halten (say two-thirds of that off Ona—Grip) and that the density of fish there was the same, it was estimated that a total number of $2 \cdot 10^7 \times 5$ predators were present on the spawning grounds in 1970. Trawl samples taken in the echo-counting area gave estimates of the proportion of haddock and saithe in the counted population of 83 and 17 per cent respectively. About 80 per cent of the haddock and 15 per cent of the saithe in the trawl catches had herring eggs in their stomachs. Assuming that each fish filled its stomach once in each 24 hour period and that the incubation period lasted 20 days, it was estimated that a total of 3×10^{13} herring eggs were consumed by the haddock and saithe in 1970, which is equivalent to about 40 per cent of the estimated egg production potential.

Investigations carried out in 1968—1970 showed that spawning took place almost on the same grounds every year. Thus, provided that a similar quantity of eggs was consumed by haddock and saithe in 1968 and 1969 this corresponded to about 15 and 20 per cent of the spawning potential respectively. It was reasonable to assume that the reduction in number of eggs spawned in 1969 was even greater than indicated in the present estimates. In addition to the larger fishes a significant number of I- and II-group haddock and saithe was feeding on herring roe both in 1969 and 1970. These are not included in the counted number of fishes as referred to above.

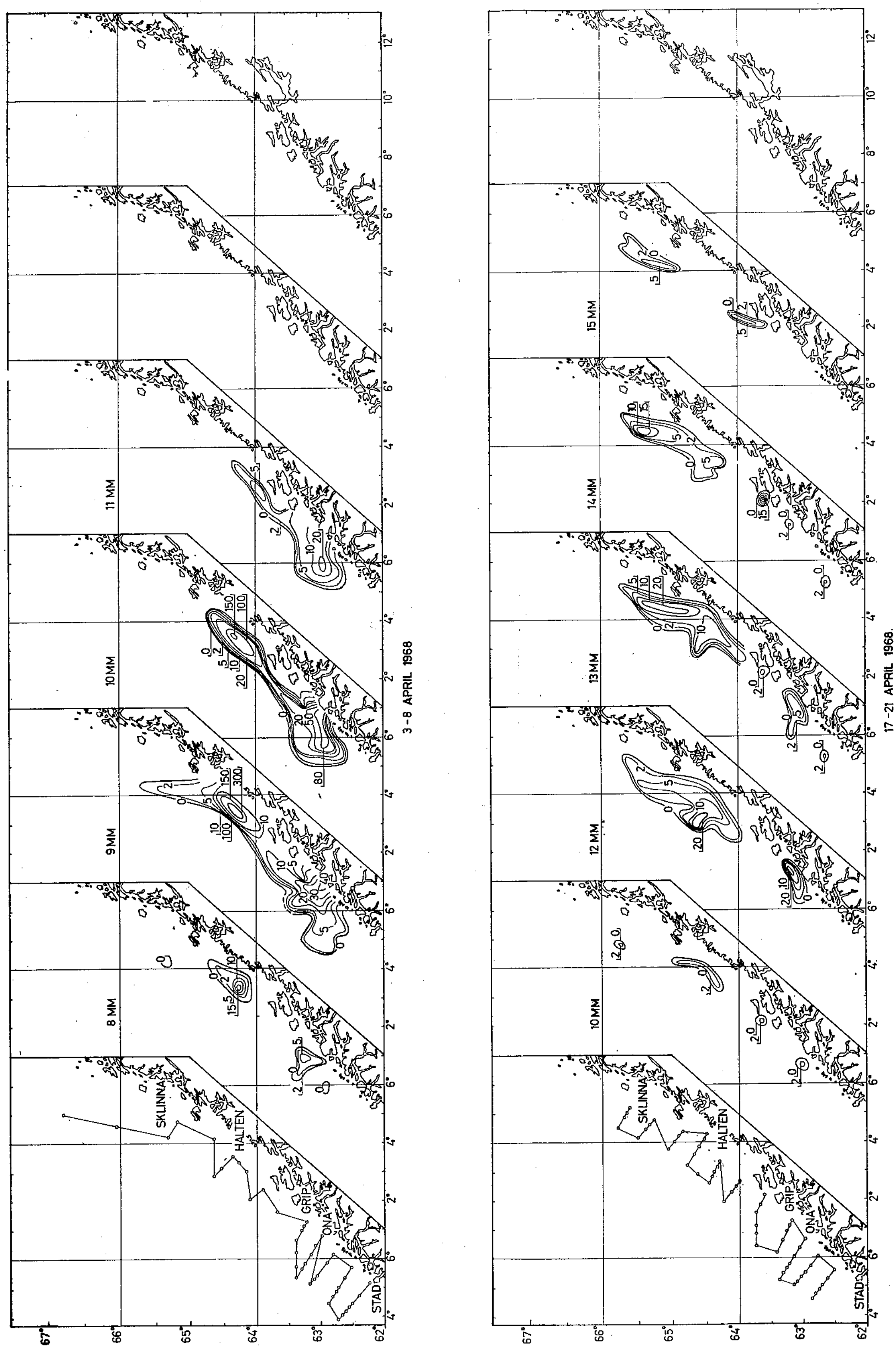

3 - 8 APRIL 1968
17 - 21 APRIL 1968
8 MM
9 MM
10 MM
11 MM
10 MM
12 MM
13 MM
14 MM
15 MM
SKLINNA
HALTEN
GRIP
ONA
STAD
67°
66°
65°
64°
63°
62°
2°
4°
6°
8°
10°
12°

Figure 3.

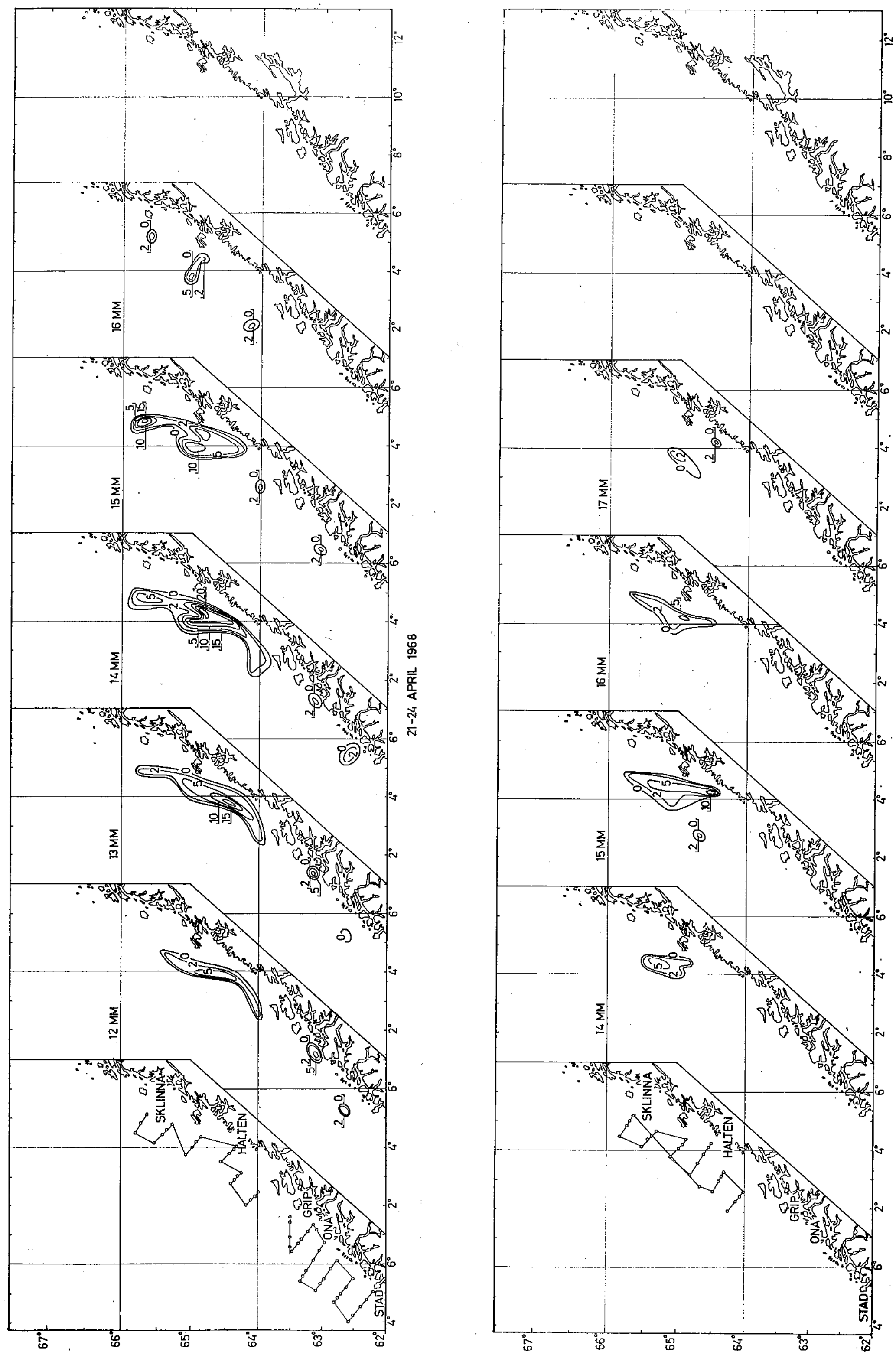
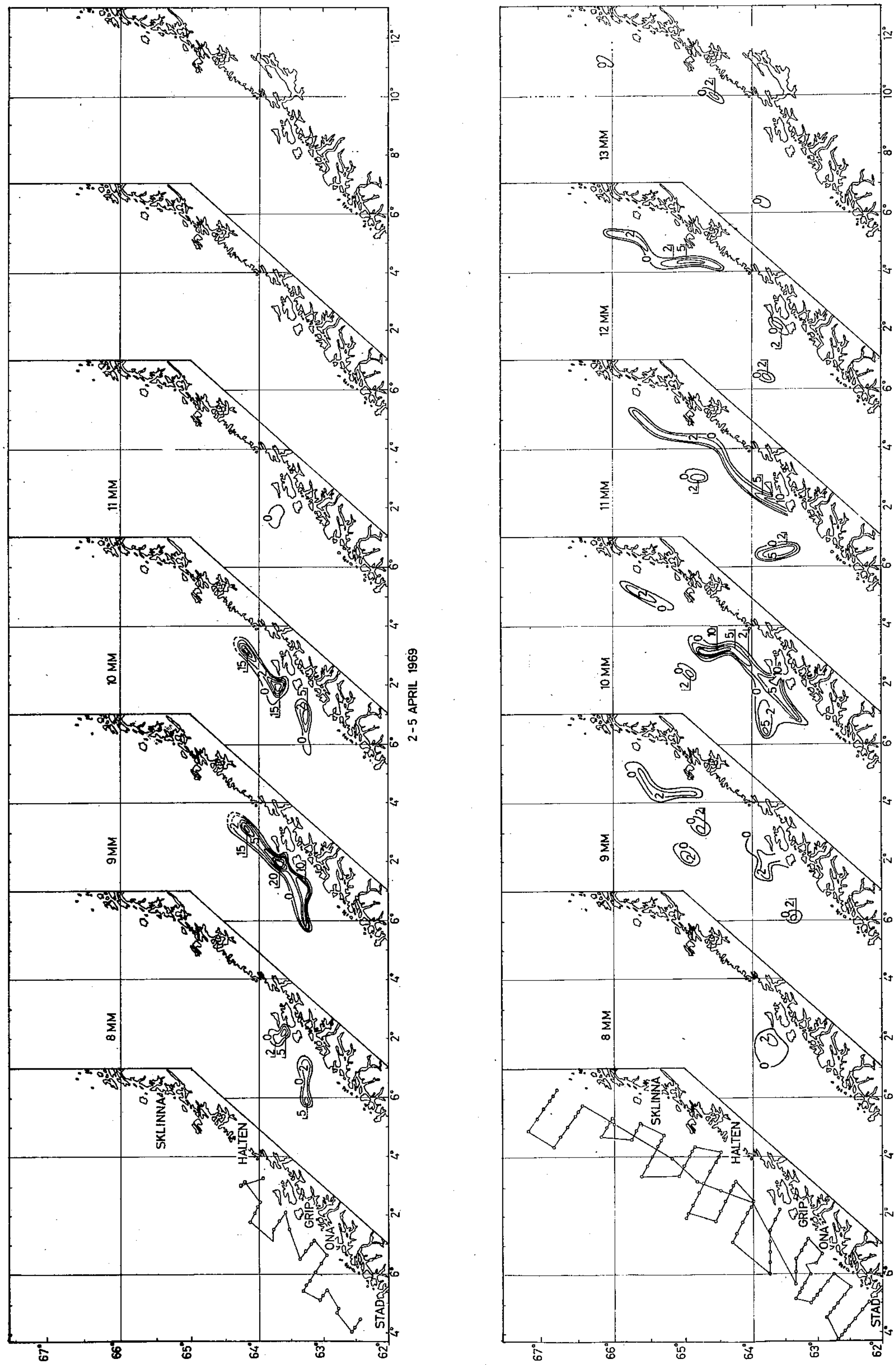


Figure 3 (continued). Grid of stations (left) and quantitative distribution of larvae according to length during the different survey periods in 1968. Equal levels of larval abundance are indicated by isolines. The figures represent number of larvae below 1 m^2 surface.



8 MM
9 MM
10 MM
11 MM
2-5 APRIL 1969
8 MM
9 MM
10 MM
11 MM
12 MM
13 MM
7-15 APRIL 1969
SKLINNA
HALTEN
GRIP
ONA
STAD
67°
66°
65°
64°
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4°
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6°
8°
10°
12°

Figure 4.

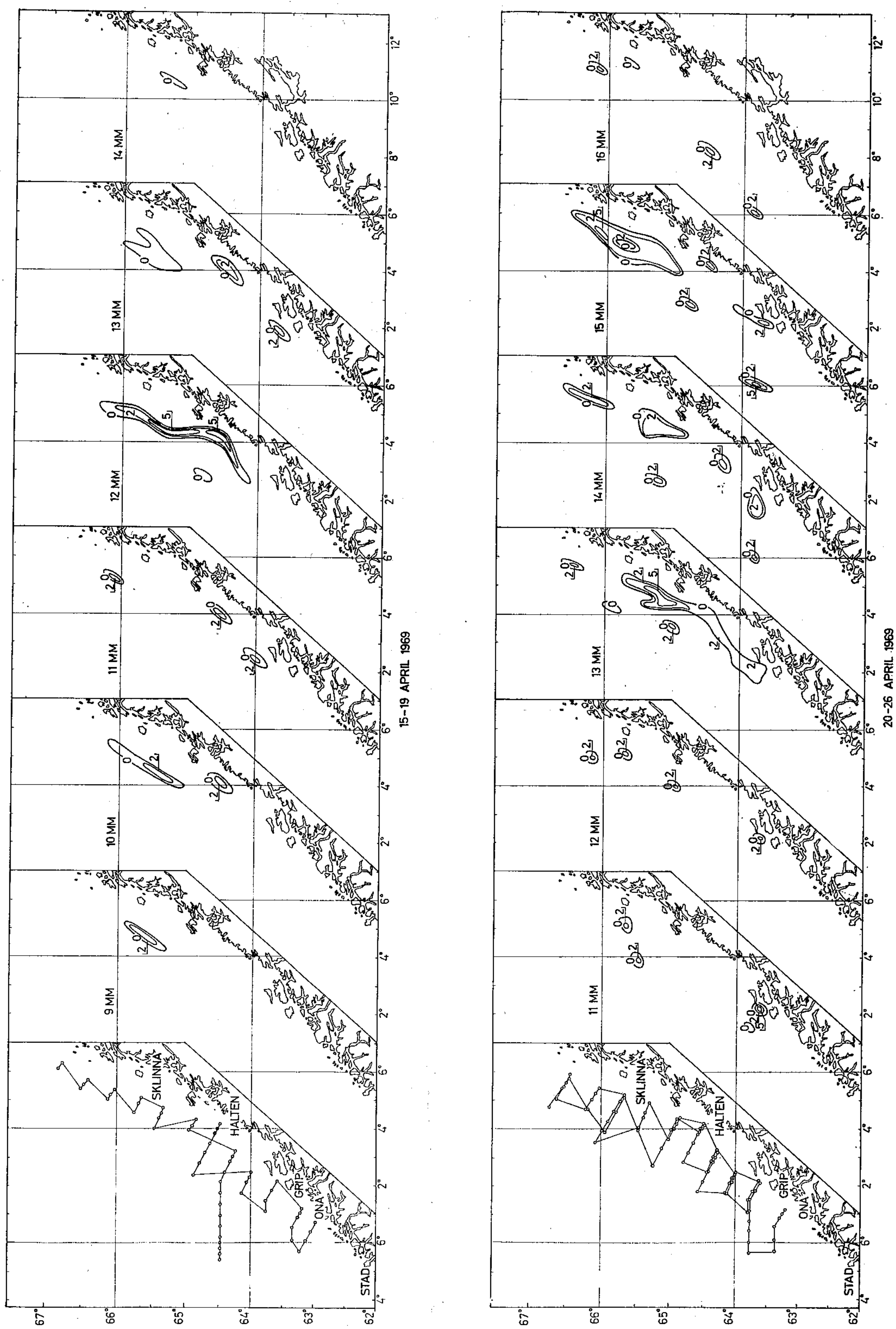

Figure 4 (continued).

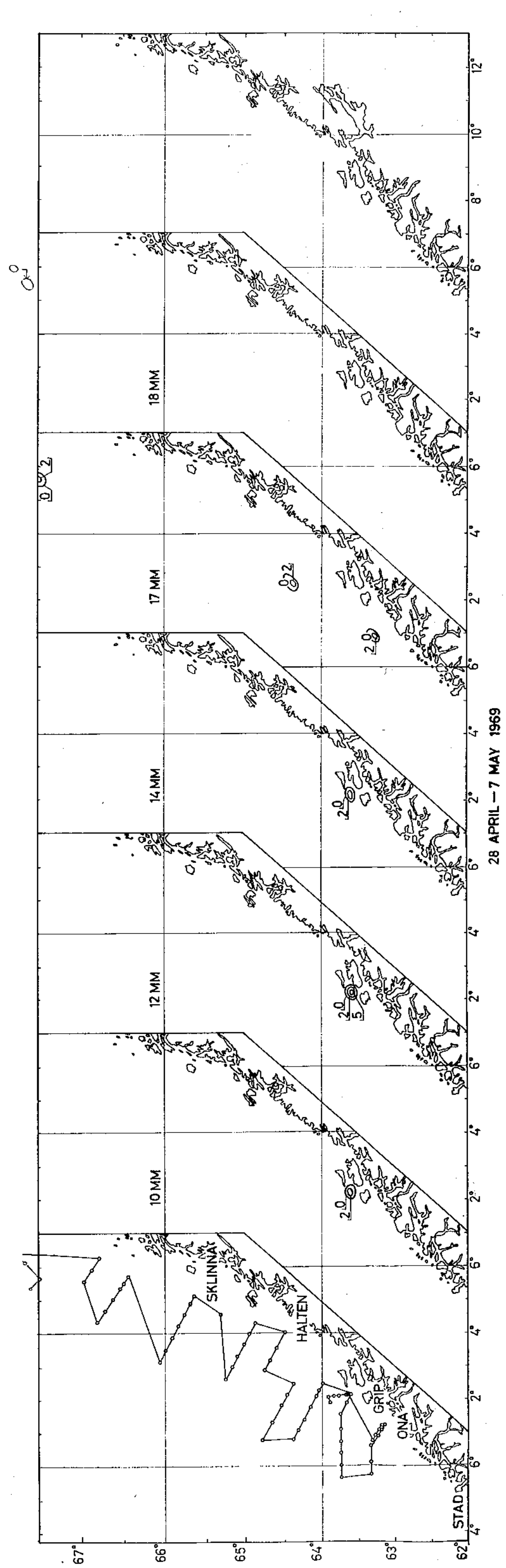

Figure 4 (continued). Grid of stations (left) and quantitative distribution of larvae according to length during the different survey periods in 1969. Equal levels of larval abundance are indicated by isolines. The figures represent number of larvae below 1 m² surface.

LARVAL MORTALITY

The size of a larval stock at a given time can be expressed as

$$N(t) = N_{l_0}(t) + N_{l_1}(t) + N_{l_2}(t) + \ldots\ldots. \quad (1)$$

where l_0 is the length at hatching and l_1, l_2 . . . etc. are the subsequent length groups in millimetre.

When sampling is carried out at different time intervals t_1, t_2, t_3 . . . . . . etc., the following expressions according to length are established

$$\left.\begin{aligned} N(t_1) &= N_{l_0}(t_1) + N_{l_1}(t_1) + N_{l_2}(t_1) + \ldots. \\ N(t_2) &= N_{l_0}(t_2) + N_{l_1}(t_2) + N_{l_2}(t_2) + \ldots. \\ N(t_3) &= N_{l_0}(t_3) + N_{l_1}(t_3) + N_{l_2}(t_3) + \ldots. \\ &\vdots \end{aligned}\right\} \quad (2)$$

The time variation of the number of larvae within one length group is determined by the rate of hatching, the growth rate (k) and the mortality (m). It is assumed that spawning takes place in a limited area within a certain time interval. After an incubation time of, say, three weeks the larvae start to hatch. The duration of hatching and the growth rate will deter-

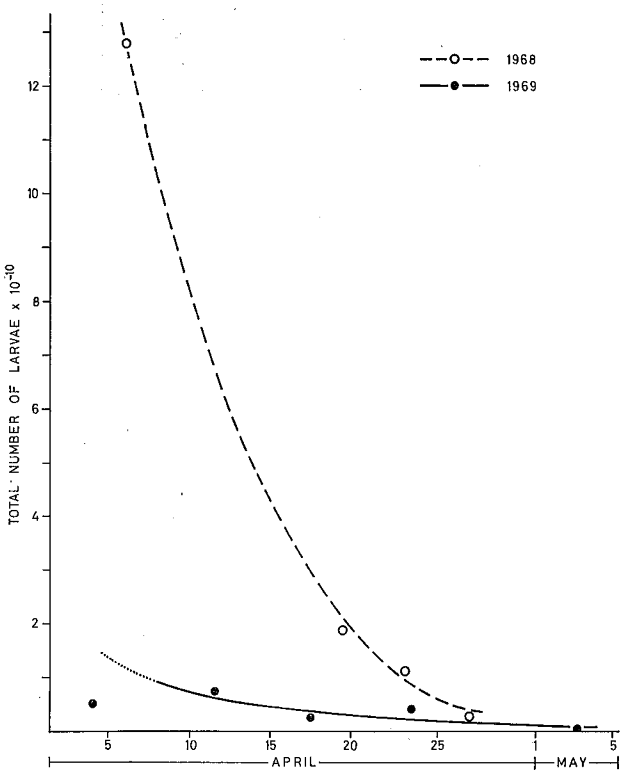

Figure 5. Estimated total number of larvae during different periods of sampling in 1968 and 1969.

Table 3. Number of herring eggs in stomachs of haddock and saithe in 1969 and 1970[1]

Year	Haddock			Saithe		
	No. of fish investigated	Length range (cm)	Average no. of eggs	No. of fish investigated	Length range (cm)	Average no. of eggs
1969	20	46–60	34 200	2	50–80	49 000
1970	13	40–70	24 200	7	49–86	21 100

[1] The figures are preliminary.

mine the time interval in which larvae of lengths l_0, l_1, l_2, etc. occur.

When larval sampling starts at the time when the first larvae are hatched and continues until hatching is finished, expressions (2) will have the following form

$$\left.\begin{array}{lll} \mathcal{N}(t_1) & = \mathcal{N}_{l_0}(t_1) + 0 + 0 & + \dots \\ \mathcal{N}(t_2) & = \mathcal{N}_{l_0}(t_2) + \mathcal{N}_{l_1}(t_2) + 0 & + \dots \\ \mathcal{N}(t_3) & = \mathcal{N}_{l_0}(t_3) + \mathcal{N}_{l_1}(t_3) + \mathcal{N}_{l_2}(t_3) & + \dots \\ \mathcal{N}(t_4) & = 0 \quad + \mathcal{N}_{l_1}(t_4) + \mathcal{N}_{l_2}(t_4) & + \dots \\ \vdots & \vdots \quad \vdots \quad \vdots & \end{array}\right\} \quad (3)$$

At the time t_4 all the larvae are hatched.

From expressions (3) it is possible to obtain estimates of both growth rate and mortality. The growth rate can be estimated from the distance between the peaks of the length distributions, according to time.

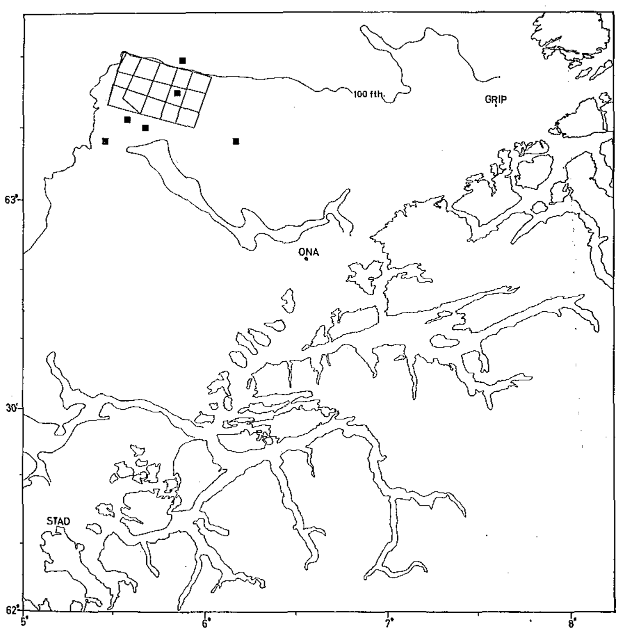

Figure 6. Echo survey grid where counting of fish was carried out in 1970. Bottom trawl stations are indicated by filled squares.

The mortality can be found from the reduction in number from one length group to another

$$m_{i-n} = \frac{\int_0^T \mathcal{N}_{l_i}(t)\,dt - \int_0^T \mathcal{N}_{l_n}(t)\,dt}{\int_0^T \mathcal{N}_{l_i}(t)\,dt} \quad (4)$$

where the time interval T is large enough to ensure that $\mathcal{N}_{l_i}(0) = 0$ and $\mathcal{N}_{l_n} \cdot (T) = 0$. Then expression (4) gives an average mortality rate between length groups. Usually the survey time is limited and the observation series too short to get $\mathcal{N}_{l_n} \cdot (T) = 0$, at least for the larger length groups. However, when the growth rate is known the mortality can be estimated by using the growth rate to determine the integration limits.

$$m_{i-n} = \frac{\int_{t_1}^{t_3} \mathcal{N}_{l_i}(t)\,dt - \int_{t_2}^{t_4} \mathcal{N}_{l_n}(t)\,dt}{\int_{t_1}^{t_3} \mathcal{N}_{l_i}(t)\,dt} \quad (5)$$

where t_2 and t_4 are determined from

$$(t_4 - t_3) = (t_2 - t_1) = 1/k(l_n - l_i) \quad (6)$$

A similar method was used by Dragesund and Nakken (1970) for estimating larval mortality in 1967. It should be noted that a series of mortality estimates is obtainable by this method when successive and frequent synoptic larval abundance figures are available.

The numbers of larvae according to length and time during 1968 and 1969, estimated from the density charts presented in Figures 3 and 4, are given in Table 4. Due to the gap in the observations from 5 to 19 April 1968, mortality rates between length groups cannot be estimated. An average growth rate (k) of 0·29 mm per day between 9 and 13 mm is found for this year applying expression (6), where l_i and l_n refer to 9 and 13 mm respectively and t_1 and t_2 to 5 and 19 April. The reduction in total number of larvae

Table 4. Number of larvae × 10^{-8} according to length and time

Year	Period	8	9	10	11	12	13	14	15	16	17	Total
1968	3– 8 Apr.	11	711	475	82	–	–	–	–	–	–	1 279
	17–21 –	–	–	1	2	61	85	31	8	–	–	188
	21–24 –	–	–	–	–	10	28	38	33	2	–	111
	24–29 –	–	–	–	–	–	–	6	14	7	1	28
1969	2– 5 Apr.	4	32	15	1	–	–	–	–	–	–	52
	7–15 –	3	7	31	18	9	1	1	–	–	–	70
	15–19 –	–	2	4	1	13	5	1	–	–	–	26
	20–26 –	–	1	0	3	1	12	6	16	1	1	41
	28 Apr–7 May	–	–	–	0·29	0·42	–	0·29	–	–	0·32	2

from 5 to 19 April, estimated from Figure 6 amounted to 86 per cent. This figure can reasonably be taken as a minimum estimate of larval mortality (m) between 9 and 13 mm, as hatching obviously would have occurred later than 5 April.

Figure 7 shows the number of larvae according to length and time in 1969. An average growth rate of 0·29 mm is found between 9 and 14 mm. Mortality estimates were obtained from equation (5) by area calculation from the data in Figure 7, and are given in Table 5.

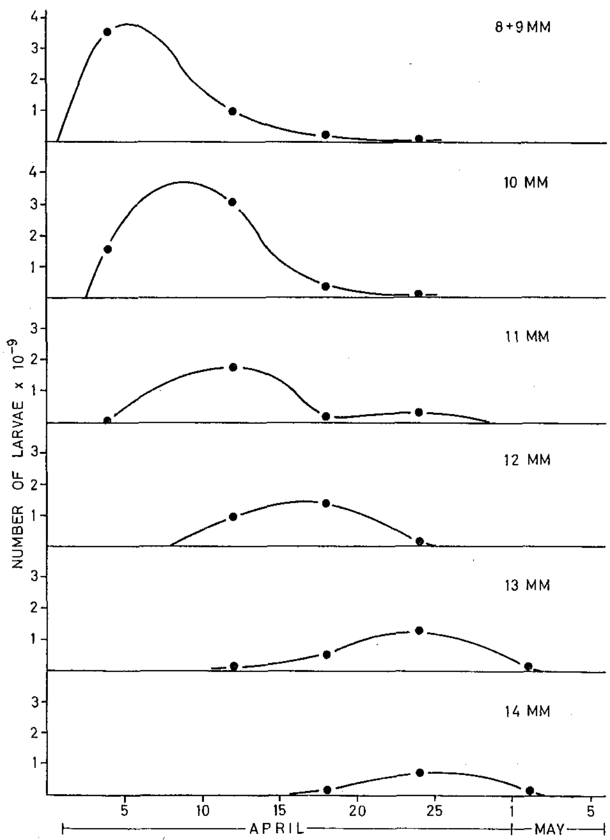

Figure 7. Number of larvae in each mm groups as a function of time in the area surveyed in 1969. The 8 and 9 mm group are pooled.

DISCUSSION

The mortality of eggs spawned and of larvae hatched in 1967–1969 is illustrated in Figure 8. A reduction of 95 and 99 per cent respectively took place in 1967 and 1969 from spawning to hatching. Mortality estimates of herring eggs during the incubation period given by Runnstrøm (1941), Baxter (1968), Hempel and Hempel (1968) varied mainly between 4

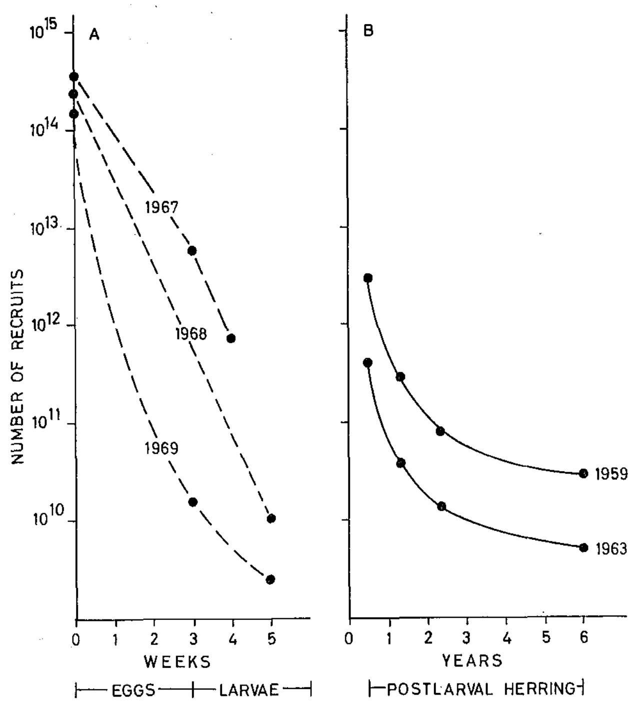

Figure 8. Survival of recruits (A) during the incubation period and early larval development in 1967–1969 and (B) of the 1959 and 1963 year classes from six months to six year of age.

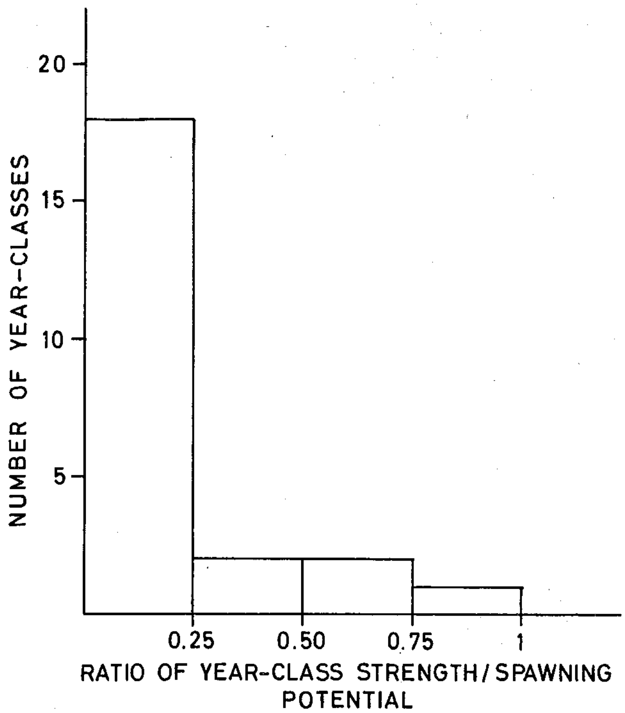

Figure 9. Histogram showing the frequency of the ratio between year class strength (measured at six years of age for the 1947–1950 year classes and at six months of age for the 1951–1969 year classes) and spawning potential.

and 12 per cent. Dragesund and Nakken (unpublished) have observed earlier, few dead and unfertilised eggs at spawning localities near Grip in 1968. None of these findings include mortality at hatching or by predation.

During the spawning seasons in 1967—1970 the predator effect was probably by far the most important mortality factor and the relative importance of this effect has increased during this period (Fig. 9 A). The echo counting survey carried out in 1970 was restricted to a very limited area and the results may not be fully accurate. The results of the echo counting are most likely to be an underestimate since a significant number of smaller haddock and saithe not included in the number of fish counted was feeding on herring eggs, both in 1969 and 1970. The counting, therefore, suggests that a large mortality during the incubation period was to be expected. A further reduction of the larval population of the order of 70—95 per cent during the early larval development (9—13 mm) will add to this effect.

Table 5. Mortality estimates of herring larvae between different length groups in 1969

Length in mm	Relative figures of larval abundance	Mortality between 10 mm and successive groups in per cent
10..........	100	–
11..........	49	51
12..........	38	62
13..........	32	68
14..........	16	84

In order to discuss the possible obtainable magnitude of year class strength from the larval populations in 1967, 1968 and 1969 the number of larvae four to five weeks after hatching was compared with the number of herring at different stages from six months onwards for the 1959 and 1963 year classes. Tentative estimates of the abundance (converted to number of herring) at different ages for the 1959 and 1963 year classes are obtained from data given by Dragesund (1970 b). In the estimates, the loss due to fishing during the young and adolescent phases is taken into account (Fig. 9 B). The following annual instantaneous natural mortality coefficients have been used: $M_1 = 2{\cdot}76$ from October (during 0-group stage) to April (during the I-group stage); $M_2 = 0{\cdot}69$ from May (in the I-group) to April (in the II-group stage) and $M_3 \ldots . M_6 = 0{\cdot}24$ from May (in the II-group) to January (in VI-group stage).

It is suggested that the abundance of the larval populations present in the sea four to five weeks after hatching in 1967—1969 was too low to produce a year class of the magnitude of that spawned in 1959. Even a year class like that of 1963, which was in the order of one tenth of that in 1959 (Table 2), is unlikely to occur.

The number of larvae hatched in 1970 was negligible and the predator effect in 1970 was probably even greater than in 1969 (Dragesund and Nakken unpublished). It is therefore possible that with the present high predator effect and the low spawning stock size the larval population may be too low to produce strong year classes.

The diagrams of Figures 2 a and 2 b may be used to discuss the probability of obtaining strong year classes with the present parent stock size. During the period 1947—1969 it is likely that the best survival conditions for herring eggs, larval and postlarval herring existed in 1959. This can be seen by taking the ratio between year class strength and spawning potential. By grouping these ratios in four categories, taking that for the 1959 year class as equal to one, the distribution of the survival ratios during the period 1947—1969, shown in Figure 9, is obtained. This shows that on eighteen out of twenty-three occasions the ratios between year class strength and spawning potential fell in the group 0—0·25, and only one out of twenty-three in the group 0·75—1·0. This indicates that in the immediate future the probability of survival conditions being as favourable as those of 1959 is low. Assuming that survival conditions like those of 1959 do occur during 1971—1973, this would result in a spawning stock size (excluding fishing during the young and adolescent phases) of the magnitude of about 2—3 million tons in the late 1970s. With the present low spawning potential and the high predator effect the probability of rebuilding the spawning stock in the near future, appears to be rather low. However, better survival conditions than those experienced during the period under consideration may, of course, occur.

SUMMARY

Estimates of the size of the spawning stock of Norwegian spring spawning herring for the period 1947—1969 are presented. The spawning stock size varied between 2·0 and 13·9 million tons during the period 1947—1968, but it decreased rapidly after 1966 to about 0·9 million tons in 1970.

The parent stock size is compared with subsequent abundance of the resulting year class at six years of age for the 1947—1969 year classes, and at six months of age for the 1950—1969 year classes. Although no firm conclusions can be drawn, the results may indicate a relationship between the parent stock size and subsequent abundance of the resulting year class when favourable conditions for spawning and hatching exist. However, in most of the years, year class strength was determined by factors other than the size of spawning stock.

The spawning potential of the parent stock for the years 1967—1969 is compared with subsequent larval ≥ 99 per cent respectively took place in 1967 and 1969 abundance at hatching. A reduction of ≥ 95 and of from spawning to hatching. Most of this reduction is ascribed to predation by haddock and saithe.

Estimates of larval mortality during the early larval development (9—13 mm) are given. These varied between 70 and 95 per cent.

With the present low spawning potential and the high predator effect the probability of rebuilding the spawning stock in the near future appears to be low.

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