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ON THE HERRING LARVAE OF NORWEGIAN SPRING SPAWNERS EFFECT OF TIME AND LOCATION OF SPAWNING ON YEAR-CLASS STRENGTH IN THE PERIOD 1959-1965

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INTRODUCTION

Short term as well as long term variations in abundance of recruits in the Norwegian spring spawning stock have been described by several authors, e.g. Hjort (1914), Lea (1930), Devold (1963), Marty and Fedorov (1963). Marty (1959) has compared the relative strengths of poor and rich year-classes in different tribes of herring. In Baltic herring he found a ratio of 1:2-3, in North Sea herring 1:8-10 and in the Norwegian spring spawning stock 1:25-30. Lea (1930) estimated the ratio of the 1903:1904 year-classes in the latter stock to about 1:90, whereas Østvedt (1963) for the 1949:1950 year-classes found a ratio of 1:15. Thus year-class fluctuations are more pronounced in the Norwegian spring spawning stock than in the majority of other stocks and the time interval between the appearence of abundant year-classes can be relatively long, in some periods even more than 10 years (Marty and Fedorov 1963).

The causes of these fluctuations are not yet understood. Possible explanations might be found along the following lines: The changes in abundance of recruits could be explained if the spawning potential of the parent stock determines the number of recruits produced. Such relationship is known for some species of fish with low fecundity and for some relatively small stocks of Clupea pallasii (Taylor 1963) and Clupea harengus in Baltic (Lishev 1966). No such relationship has yet been established for the main stocks of Clupea harengus in the North Sea and the Norwegian Sea. However, a correlation between spawning potential of the parent stock and year-class strength is difficult to trace due to changes in natural mortality of the very young stages from one year to another probably caused by environmental factors. Most of the fertilized eggs deposited and the newly hatched larvae die before recruitment and slight changes in mortality rate of the young stages should therefore result in strong variations in year-class strength.

Little is known about the causes and magnitude of natural mortality of young herring, and whether or not there exist periods in the life history when catastrophic mortalities take place. There are many hints that year-class strength in most marine fishes is determined during the early stages of life, and Hjort (1914,1926) expounded the concept of the critical period in marine fishes at the end of the yolk sac stage when larvae have to change over to external feeding. Thus natural conditions during the early stages in life history might determine the abundance of recruits to the fishery in later years.

In view of the recent serious decline in the fisheries based on the Norwegian spring spawning stock, special attention has been given on recruitment problem in this stock. At the Institute of Marine Research special emphasis has been put on investigations on location of spawning centres, the larval population, identification of possible critical stages of development and larval drift. Also studies on O-group herring with regard to the determination of the principle pre-recruit centres have been carried out. Recently more comprehensive investigations have started on environmental factors governing the larval survival rate (Anon. 1967). The results of the investigations on adolescent herring will be presented in a separate paper, and the present account will be confined to: (1) allocation of spawning grounds along the Norwegian coast during the period 1959-1965 and discussion on the effect of time and location of spawning on subsequent year-class strength, (2) larval studies during the first month after hatching and discussion of Hjort's hypothesis of a critical period caused by lack of suitable food immidiately after the time of yolk absorption and (3) larval transport in Norwegian coastal waters indicated by drift bottle experiments, wind observations and current cross experiments.

MATERIAL AND METHODS

The material included in the present work was derived from:

(1) herring samples collected during the Norwegian winter herring fishery,
(2) information from catch statistics of herring,
(3) wind observations at permanent meteorological stations along the Norwegian coast,
(4) observations from cruises.

The general sampling procedure of the material and other information on the methods applied is presented below, whereas further treatment of the data is partly dealt with in connection with the different subject items. The statistical methods applied are described in most elementary books on statistical analysis and the reference books used in this investigation were Godske (1966) and Bonnier and Tedin (1940).

Herring samples

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, Bergen. The age was determined from scale analysis, and 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). This scale comprises eight stages and the maturation cycle of adult fish passes through six stages, stages III-VIII, the latter passing into stage III again. Stages V-VII represent respectively last prespawning, spawning and first spent phases. The gonads of these three stages are characterized as follows:

Stage V Gonads fill body cavity. Eggs large, round, some are transparent. Overies yellowish, testes milk white. Eggs and sperm do not flow, but sperm can be extruded by pressure.

Stage VI Ripe gonads. Eggs transparent. Testes white. Eggs and sperm flow freely.

Stage VII Spent herring. Gonads baggy, bloodshot. The ovaries empty or containing only a few residual eggs. Testes may contain remains of sperm.

The age and maturity data dealt with in the present paper are either rearranged from reports published by Østvedt (1961,1962,1965,1966), Devold and Østvedt (1963,1964) and Dragesund (1967,1968) or obtained from the files at the Institute of Marine Research.

Catch statistics

Statistical information on the Norwegian landings was obtainable from Norway's official statistics 1959-1966 (1961-1968). Those of the landings of foreign vessels were available from the reports of the Atlanto-Scandian Herring Working Group (Anon. 1963,1964,1965) and for the period 1959-1966 more detailed catch data were obtained from Knipovich Polar Research Institute of Marine Fisheries and Oceanography (PINRO), Murmansk.

Meteorological data

The wind data used were collected at the meteorological stations at Ona (62°54' N, 06°30.5' E), Nordøyane (64°48' N, 10°33' E), Skomvær (67°25' N, 11°53' E) and, reported in Norsk Meteorologisk Årbok 1959-1965 (1960-1966). The wind observations were transformed into wind vectors, i.e. the products of monthly mean wind forces and the number of cases with wind in the different directions.

Larval cruises

Herring larvae were caught on regular surveys in Norwegian coastal waters by Wiborg (1960,1961,1962[a] and 1962[b]) and by Dragesund and Wiborg (1963), by Dragesund (1965) and by Dragesund and Hognestad (1966). The grid of stations and the survey routes are found in these reports. The surveys were usually performed from south to north and south again, covering the coastal banks from Stad to Lofoten.

Oblique hauls were taken with Clarke-Bumpus plankton samplers (Clarke and Bumpus 1950). Two samplers, equipped with nets of silk (mesh size 0.50 mm) were towed simultaneaously at different depths and raised in 5 m steps. The sampling depths were 25-5 m and 50-30 m and the total towing time was 20 minutes. At the end of the (3 mm) wire was attached a weight of 28 kg, and the wire was kept at a 40° angle to the vertical. The towing speed was 1½-2 knots. During the surveys in 1959 and 1960 sampling with this gear was mainly carried out in the second part of the cruises (20-28 April in 1959 and 25 March-9 April in 1960) and hauls were only taken from 25-5 m. The diameter of the aperture of the brass tube was 13 cm and the length of the net 60 cm. The samplers were equipped with flowmeters and hence the volume of filtored water could be estimated. Larvae were also collected in vertical hauls mainly from bottom to surface with Nansen net (Sverdrup et al. 1946) or Juday net (Bogorov 1959) with mesh size 0.50 mm, except in 1961 and 1962 when the mesh size was 0.33 mm. In 1959 and 1960 the samples were taken with Nansen net (aperture diameter of 1.0 m and 0.7 m respectively) and in 1961, 1962 and 1964 with Juday net (aperture diameter of 0.4 m). In 1963 and 1965 Juday net was also used the aperture diameter being 0.8 m, except in 1965 when also some samples were collected with net of aperture diameter 0.4 m.

All samples were preserved in 5-10 % formaldehyde. The larvae were counted and measured to the nearest millimeter below and sorted into larvae with and without yolk sac. To make the data compar able the number of larvae caught at each station were multiplied by the sampling depth and thereafter devided by the water volume filtered:

$$\frac{\text{Number of larvae x sampling depth in m}}{\text{Water volume filtered in m}^3}$$

Thus the figures were converted to larvae per m^2 surface, and when describing the distribution of larvae per m^2 surface average number for stations located inside rectangle (Fig.1), covering about (30x30) square nautical miles, were estimated. Analysing the vertical distribution of larvae in 10 m layers number of larvae per m^3 water was used. During the larval cruises drift bottles were released in 1961, 1963, 1964 and 1965. The bottles had an inner volume of 348 ml, weighing 529.4 g. A letter was put inside requesting the finder to give information of the date and place of recapture.

To study the drift pattern of larvae in more detail current crosses were used at different localities in 1963, 1964 and 1965. These were made of two thin iron sheets $(1 \times 1)m^2$ at right angles to each other. The cross was suspended by thin nylon gut from a plastic float to which a pole was fastened, equipped with a light on the top, about 2 m from the surface (Fig.31). The position of the current crosses was determined at intervals by Loran and Radar.

Terminological and technical remarks

In the present paper either geographical names or codes for area breakdown are used (Fig.1). The key to the code is illustrated by the following example: $\left(\frac{07}{02,05,06}\right)$ i.e. localities 02,05 and 06 in area 07. Dates listed in the tables and on some of the figures are written in the following way: e.g. 26.2 reads 26 February.

TIME AND LOCATION OF SPAWNING

The spawning time was estimated by studying the composition of the maturity stages of winter herring just prior to and during the spawning season. For allocation of the spawning localities catch distributions of spawning and spent herring and newly-hatched larvae were analysed. Since the composition and abundance of spawners might have influence on time and location of spawning as well as on larval distribution and abundance, a short description of the spawning stock will be given. Moreover the survival rate of larvae might depend on age and size of the parents.

Spawning stock

Herring approaching the Norwegian coast for spawning are, according to the Norwegian terminology, called winter herring. During the period 1959-1965 the herring arrived at the Møre coast about the end of January or during February (Devold 1959,1960,1961,1962,1963[b], 1964,1965) and the fishery started immediately afterwards (Table 3), though in one year (1964) also just before the arrival. In 1963,1964 and 1965 adult herring also appeared in the Lofoten region, migrating from a wintering area off the coast of Troms and Vest-Finnmark, midway between Norway and Bear Island (Devold 1964,1965 and 1966). The herring approaching the Møre coast migrated from the usual wintering area east of Iceland. To illustrate the more long term variations in the yield of adult herring in the Norwegian spring spawning stock the total annual catches of winter herring by Norway and U.S.S.R. in the period 1931-1966 are shown (Fig.2). The Soviet catches refer to the first three months of the year, except for the period 1964-1966, when April is also included. The Norwegian catches refer to the winter herring season lasting to the end of March/ beginning of April. Østvedt (1963) has described the change in catch of the Norwegian winter herring fishery during the post-war period up to 1960. Evidence was found that increasing catches per unit effort usually coincided with the recruitment of rich year-classes to the spawning stock. He also concluded that the declining catches of winter herring from 1957 onwards mainly resulted from depletion of the spawning stock, due to low recruitment and not because of higher mortality rates due to increased effort. The stock was on a low level during the seasons

1959-1963 compared with the previous period 1952-1958 (Fig.2). It decreased from an estimated size of 5.0 million tons at the beginning of 1959 to 2.5 million tons at the end of 1961, whereas an increase again took place from 2.8 million tons at the end of 1962 to 6.8 million tons at the end of 1964 (Dragesund and Jakobsson 1963, Fedorov, Truskanov and Yudanov 1963, Anon.1965). The stock size estimates for 1963 and 1964 did not include the component spawning off Lofoten.

The distribution of the Norwegian winter herring catches according to area in the seasons 1959-1966 are shown in Table 1. The most important fishing localities were off Møre$\left(\frac{07}{05,06,07,19}\right)$, except in 1964, when about half of the total catch was caught in the Lofoten region$\left(\frac{05}{03,04,09,10,15}\right)$. In 1963 and 1965 the catches in this region were considerably lower than off the Møre-Trøndelag coast. The 1959 season was the only one when fishing took place in area 08 and the figures clearly demonstrated a northward trend of the catch distribution in the period 1959-1966.

During the seasons 1959-1963 the rich 1950 year-class strongly predominated in the adult stock. Table 2 shows that this year-class made up between 54.1-64.4 % of all the herring in samples collected from the purse-seine catches in the main fishing district, area 07. During this period very few recruits were found in the catches and the serious decrease in the yield, starting already in 1957, continued until 1963. In this year a change took place in the age composition of the stock, as first time spawners of the 1959 year-class appeared in the catches, and this year-class showed up with 4.0 % off Møre, 13.1 % off Sklinna and 89.8 % in Lofoten. In 1964 and 1965 the figures for this year-class were 51.5 % and 62.7 % off Møre and 88.4 and 74.1 % in Lofoten. In the two latter years herring of the 1960- and the 1961 year-classes were also present in the catches. In 1965 and 1966 these three year-classes made up between 80.0-85.0 % of the total catches, whereas the 1950 year-class yielded only 10.0-15.0 %. This increase in number of recruits was followed by an increase in the Norwegian catches from 61.438 tons in 1963 to 281.724 tons and 206.291 tons in 1964 and 1965 and to 460.857 tons in 1966 (Table 1). These two characteristic features concerning the size and composition of the spawning stock were noticed during the period 1959-1965: (1) The stock was on a low level, especially in 1961-1963. (2) The mean age of the stock increased during the period 1959-1963, whereas in 1964 the mean age decreased considerably, the stock comprising two dominating age groups young and old fish. In 1965 young herring predominated.

Spawning time

Exact data for the duration of the spawning stage (stage VI) of the individual fish are not available for Norwegian spring spawners. According to Blaxter and Holliday (1963) herring can remain for a variable length of time in a maturity stage depending on the suitability of the environment for further maturation. The maturity stage VI is passed through more quickly than the other stages. Holliday (1958) has described the spawning behaviour of herring in tanks and he concluded that there was no pairing or courtship behaviour. It was an indiscriminate mass spawning. This behaviour has also been seen by the author when observing the spawning behaviour of spring herring in a small purse seine. It is likely, therefore, that when the release of eggs and sperm starts, the duration of the individual spawning is short, probably a few hours. Not all the herring change from maturity stage VI to VII simultaneously and consequently they do not spawn at the same time even in the same locality. It is reasonable that groups of herring keep together and become gradually ready for spawning, while other groups release their eggs and sperms at a slightly different time.

Thus in the present work the duration of the spawning season is defined to be the time interval between the onset of spawning for the first and last group of herring. The time is estimate by considering the percentage maturity composition of winter herring grouped in five days periods over the spawning season (Figs.3 and 4). The duration of the maturity stage V is, somewhat longer for males than females Østvedt (1962), whereas stages VI and VII will coincide. Since the duration of the two latter stages represents spawning and newly spent herring and are considered to cover the actual spawning period the sexes are pooled. The time corresponding to the five days period when the first fish were found in maturity stage VII is taken as the commencement (T_1) of spawning . The end time (T_2) for the spawning season is more difficult to determine from the present material, since herring in stage V occurred in samples collected at the end of the sampling period. These herring have to pass through stage VI before the season can be considered as ended. To get approximate figures for the duration of stage VI the time interval (T_d) between the first occurrence of stages VII and VI is estimated. By adding T_d to the last period when herring in maturity stage V occurred, the end time (T_2) for the spawning season is found. The distribution of the maturity stages V-VII and the durations of the spawning seasons in the different areas are illustrated in Figs 3 and 4 and the time intervals for the seasons are listed in Table 3. The spawning in area 07 (off Møre) started earliest in 1959, 1960 and 1965, i.e. 18-22 February. Especially in 1962 and 1963 the spawning started late (5-9 March and 28 February-4 March). The duration of the spawning season was especially long in 1959,1960 and 1961, lasting for about 30 days. In the other years the season lasted only for about 20 days. The duration of the spawning in 1959 in area 08 (between Bokn and Stolmen) was similar to that in area 07. The time of spawning and duration of the season in area 06 can not be dealt with in the same way due to the scarcity of samples.

However, it seems likely that the spawning took place almost at the same time as in area 07, although the samples collected on Halten Bank $\left(\frac{06}{10,11}\right)$ indicated that the spawning here started somewhat later than elsewhere in area 06. In area 05 (the Lofoten region) the spawning started late both in 1963 and 1964 and lasted for only about 10 days. In 1965 the starting time and duration of spawning were the same as in area 07. Because spent herring (fish in stage VII) gradually leave the fishing grounds after spawning, the modes of the distribution curves for stage VI are somewhat delayed. Therefore the peak of spawning was considered to be the median period between onset and end of spawning (Table 3).

In 1959 first time spawners made up 11.8 % of the herring caught off Møre (area 07) and 22.3 % between Bokn and Stolmen (area 08). During the seasons 1960-1963 relatively few first time spawners appeared on the spawning grounds, except in 1963 in the Lofoten region (area 05), when the herring entirely consisted of this spawning group (Table 4). However, in 1964 and 1965 first time spawners made up 34.4 % and 35.9 % of the herring off Møre (area 07) and 93.7 % and 76.4 % in area 05. No significant difference in spawning time between first time and repeat spawners in the same region could be traced from the present material, although the latter group seemed to reach maturity stage VI slightly earlier than first time spawners, especially in the years 1964 and 1965 (Table 6), when relatively young recruit spawners appeared (Table 2).

Spawning location

The herring probably remain on the same grounds just before and throughout the spawning process before they gradually migrate from the coastal waters. By studying the distribution of the herring catches during the spawning season, localities where spawning has taken place can be allocated (Table 6.). Only catches after the estimated onset of spawning (Table 3.) were considered. In Figs. 5 and 6 the relative yield distribution according to area and locality is illustrated.

In 1959 the biggest catches were taken between Bokn and Stolmen $\left(\frac{08}{03,04}\right)$ and between Stad and Ona $\left(\frac{07}{05,06}\right)$, but herring in spawning and spent condition were also caught further north in the Halten and Sklinna regions $\left(\frac{06}{10,11,12}\right)$ and $\left(\frac{06}{17,18,23}\right)$. In 1960 no herring were caught in area 08, whereas the catch distribution in area 07 was almost the same as in 1959. From 1961 onwards a slight northward movement of the fishery was noted in area 07, the localities between Ona and Grip $\left(\frac{07}{06,07}\right)$ being the most important. No herring were caught in area 06 in 1960 and 1961. During the period 1962-1965 spawning and spent herring were fished both off Møre and in the Halten and Sklinna regions, the former region giving the highest catches. In 1963, 1964 and 1965 spawning and spent herring were also caught in the Lofoten region, mainly in $\left(\frac{05}{03,04,09,10}\right)$.

Another way of allocating the spawning grounds is to survey the coastal banks for newly-hatched larvae. The occurrence of lavae with yolk indicates that spawning must have taken place not too far from the locality of catch. Since both the time of spawning and sampling of larvae varied from one year to another a comparison between the period of survey with the approximate time of hatching would make the material easier to analyse.

The approximate period for peak of hatching can be found by adding the incubation time to the peak period of spawning. Knowing the temperatures on the spawning grounds approximate figures for the incubation time can be estimated from Blaxter and Hempel's paper (1963). Unfortunately temperature observations during the actual spawning seasons are only available from e few stations on some of the spawning grounds (Fig.7).

According to Runnstrøm (1941) the spawning is not evenly distributed in the different spawning regions, but restricted to special spawning grounds with sandy or rocky bottom separated by fjords or deeper ridges with a soft bottom. Such bottom structure is mainly found above 250 m off Møre. Thus the main spawning probably takes place above 250 m, the most frequent depths ranging from 50-to 200 m as the depths on the shelf from Stad to Grip and on the Frøya Bank and Halten Bank are less than 200 m (Fig.8). Therefore, figures for the maximum tempereture range between 50 and 200 m/or bottom in the different localities are listed in Table 7. The temperature range was highest in area 07 resulting in a corresponding varying incubation time (Table 7). This was especially pronounced in 1959 and 1963 when the temperature varied between 4.8° and 7.6°C and 3.7° and 8.1°C respectively. The range was more narrow in 1962 (6.5°-8.0°C) and in 1964 (6.8°-7.5°C). In area 06 the vertical temperature distribution did not show the same variability as in area 07. A relatively high temperature range was observed on the spawning grounds in the Lofoten region$\left(\frac{05}{04,05,09}\right)$ in 1963, varying between 3.9° and 6.7°C (Table 7). According to Runnstrøm (1941) the herring tended to spawn most intensively in water of 5° and 6°C indicating that spawning in Lofoten took place below the thermocline, whereas off Møre and Trøndelag (areas 07 and 06) herring spawned also above the thermocline except in 1963 (Fig.7).

Comparisons of the periods for peak of spawning, peak of hatching and the first and second part of the larval cruises are given in Table 8. In area 07 the first part of the surveys was carried out almost at the same time in relation to peak of hatching except in 1960 and 1964. The former survey took place at the beginning of the main hatching, whereas the latter covered a relatively late period. However, the second part of the 1960 survey could be compared with the other years.

The first part of the sampling in area 06 was made at about the same time in relations to peak of hatching except in 1959, 1961 and 1964, when the sampling was carried out at a later period (Table 8). In 1964 and 1965 the sampling in area 05 was undertaken just after hatching, whereas in 1963 the survey was carried out prior to it. Thus the period considered concerning the distribution of yolk sac larvae coincided mainly with the first part of the larval surveys (Figs. 5 and 6). In accordance with the late survey period in 1964 few larvae with yolk were found in areas 07 and 06. Similarly larvae were scarce in area 06 in 1959, whereas in 1961 larvae with yolk were numerous in this area (Fig. 5). In 1959 larvae with yolk sac were most abundant in the Stad-Ona region $\left(\frac{07}{05}\right)$. The larvae found further south, in $\left(\frac{07}{02}\right)$ were most likely derived from the Bokn-Stolmen region $\left(\frac{08}{03,04}\right)$. In area 06 the larvae were mainly concentrated off Sklinna $\left(\frac{06}{18,23}\right)$. In 1960 larvae with yolk sac were relatively numerous between Stad and Grip $\left(\frac{07}{05,06,08}\right)$ and in the Halten and Sklinna regions $\left(\frac{06}{11}\right)$ and $\left(\frac{06}{17,22}\right)$. In 1961 almost the same distribution pattern as in 1960 was found, although the most dense concentration was observed south of Stad $\left(\frac{07}{07,04}\right)$. The larvae collected in the Halten region might either derive from a relatively late spawning in this region or have been transported from southern spawning grounds. In 1962, 1963 and 1965 the larvae in area 07 were distributed somewhat further north than in 1960 and 1961, whereas the larvae in area 06 were found mainly in the same localities as in 1960 and 1961. In 1965 only few larvae were observed in this region. In 1964 and 1965 larvae with yolk sac were also observed in area 05, on the shelf off Lofoten, the distribution being slightly more westerly and northerly in 1965 than in 1964. The lack of larvae in this region in 1963 was expected due to the fact that the area was surveyed before hatching started. The localities where spawning and spent herring were caught coincided fairly well with the distribution of larvae with yolk sac (Figs. 5 and 6). However, in some years the larvae seemed to be sligthly more westerly and northerly distributed than the herring catches, especially in area 07. This is reasonable since the yolk sac stage for Atlanto-Scandian herring lasts for about 10 days at 8°C (Blaxter and Hempel 1963). A dispersion from the actual spawning grounds, therefore, may have taken place for some of the larvae before they were caught.

Discussion

Long term changes in time and location of spawning of Norwegian spring spawners have been discussed by Devold (1963[a]). During the eighteen nineties the winter herring arrived off Møre in September/October, and the spawning probably took place somewhat earlier than in the present. For the period 1927-1960, Aasen (1962) found that the average time between the arrival of the winter herring and the spawning was 38 days with a standard deviation of one week. The onset of spawning was defined to be the time when 50 % of the herring in the continuous series of samples during the same season reached stage VI.

By this definition commencement of spawning co[illegible]
time somewhat before peak of spawning in the p[illegible]; [illegible] time interval between arrival and spawning was considerably lower in most of the years 1959-1965 (Table 3.). It is reasonable to conclude therefore that the time interval between arrival and spawning necessarily does not need to be constant, but varies from one period to another. According to Devold (1963[a]) and Aasen (1962) however, the spawning time changed during the period 1927-1960 as the commencement of spawning started in end of January/beginning of February during the first part of the period (1929-1941), whereas in the latter part the spawning started in the second half of February.

More detailed knowledge of the location of spawning of Norwegian spring spawners during the nineteen thirties is based largely on work by Runnstrøm (1941). He found spawning along the Norwegian coast from Lindesnes to Vesterålen, but certain regions seemed to constitute localities of more intense spawning. Such spawning centres were found off the south-west coast between Lindesnes and Bergen, off the Møre coast and on the banks off Lofoten and Vesterålen. In the years 1948-1959 there has been a striking change in the location of spawning. The arrival of the winter herring occurred about three weeks later than in the nineteen thirties and the spawning took place gradually further to the north (Devold 1963).

During the present period a further northward displacement was traced. Although the material does not allow to allocate the spawning places quite precisely, it is reasonable to conclude that the main spawning was concentrated in the following regions:

(1) Between Bokn and Stolmen $\left(\frac{08}{03,04}\right)$ in 1959

(2) Between Kinn and Ona $\left(\frac{07}{04,05,06}\right)$ in 1959 and 1960
Between Stad and Frøya $\left(\frac{07}{05,06,07,08}\right)$ in 1961,1962 and 1963
Between Ona and Frøya $\left(\frac{07}{06,07,08}\right)$ in 1964 and 1965

(3) Between Halten and Sklinna $\left(\frac{06}{10,11,12,13}\right)$ and $\left(\frac{06}{17,18,23}\right)$ in all the years during the period 1959-1965.

(4) Off Lofoten $\left(\frac{05}{02,03,04,08,09,10}\right)$ in 1963,1964 and 1965

Except in 1959 spawning was insignificant on the traditional spawning grounds south of Bergen (area 08). The most important spawning centre was in area 07 extending from Kinn to Ona in 1959 and 1960 and from Stad to Frøya in 1961,1962 and 1963, with a further restriction in the southern part of the region in 1964 and 1965, covering mainly the district between Ona and Frøya. Spawning in area 06 certainly took place in 1960 and probably also in 1961, even if no spawning and spent herring were caught in these two seasons. According to the present investigation spawning in the northernmost area 05 mainly took place during the last three years. Spawning in this region has definitely taken place also in previous years as pointed out by Runnstrøm (1934) and Marty (1956).

Allocation of spawning grounds based on larval surveys has also been made by Yudanov (1962,1963,1964,1966). He found insignificant spawning in the Lofoten region in 1959,1961 and 1962, whereas in 1960 spawning was observed on the banks between Lofoten and Vesterålen. Yudanov carried out his surveys in 1960 in this region from 9 April onwards, this being about two weeks later than the period covered by Wiborg (1960). Yudanov found newly -spawned fertilized eggs in the stomachs of haddock between 13-26 March on the banks west and south-west of the Lofoten Islands, indicating that mass spawning took place during March in this region. The location of spawning further south given by Yudanov during the period 1959-1965 coincided fairly well with the present investigation.

The trends described for the period 1959-1965 can be summarized by: (1) delay in spawning compared with earlier periods in this century e.g. 1929-1941 (2) varying time intervals for the spawning season and (3) progressively northward displacement in location of spawning. This features might affect the survival rates of larvae and their drift pattern. The timing between hatching and the need of suitable food for the larvae when they change over to external feeding is, in accordance with Hjort's hypothesis, considered to be of great importance for subsequent year-class strength. It is likely that the period for this timing will change with location of spawning, being somewhat delayed on the northernmost spawning grounds compared with those further south. From earlier works, e.g. Lea (1929), Marty (1956), Wiborg (1960a), Dragesund and Olsen (1965), it is evident that the distribution pattern of larvae throughout the period from hatching to the end of the first year of life is closely connected to the geographical distribution of the spawning grounds and the water transport from these grounds. Thus larvae drifting in the water masses moving northward along the Norwegian coast will have different environmental conditions depending on which spawning grounds they were hatched..

THE LARVAE AND THEIR DISTRIBUTION

The herring larvae and their distribution off western and northern Norway have so far mainly been investigated by Soviet and Norwegian workers e.g. Runnstrøm (1934), Ryzhenko (1938,1939), Wiborg (1950, 1954,1956) and Yudanov (1962,1963,1964,1966). According to these authors the larvae are mainly found on the Norwegian coastal banks during the first month after hatching. In the post-war period interest has increased in quantitative investigation on herring larvae.

Although considerable effort has been devoted to sampling of larvae, reliable data on the abundance distribution are still lacking. In the present chapter variations in distribution abundance and length composition of larvae for the period 1959-1965 are dealt with.

Errors associated with the sampling technique

The major sources of variability in the assessment of annual abundance of planktonic fish eggs and larvae have been pointed out by several authors, e.g. English (1963) and Saville (1963) These are according to the latter author:

(1) errors associated with actually taking the sample,
(2) errors involved in integrating samples representing points in space over space, to give estimates of abundance over the total area of distribution.
(3) errors introduced by similarly integrating cruise totals over time to give estimates of the total production over a certain period (spawning period) and
(4) errors due to mortality up to the end of the sampling stage.

In the present investigation the closing mechanism of the Clarke-Bumpus plankton samplers were not in operation when taking the hauls, due to difficulties of keeping the shutter open in rough weather. The shutter, therefore, was kept in open position during the whole sampling procedure by locking it with thin nylon gut. When the towing was over, the ship was stopped and the samplers hauled in vertically. Theoretically, therefore, larvae caught during the vertical hauling represent a bias in the number of larvae when dealing with the vertical distribution in different depth strata. This error, however, is relatively small, as the sampling volume by hauling the net vertically from 30 m to the surface usually amounts to about 5 % of the total sampling volume during the oblique towing procedure when this is lasting for 20 minutes. The bias may be somewhat larger in cases when the density of larvae is significantly higher in 25-5 m than in the depth strata below. Clogging of the nets reduces the sampling volume and apparently the number of larvae should decrease in the same ratio. However, clogging may increase the net avoidance and carefully cleaning of the nets therefore, was undertaken when clogging arised.

A good deal of work has been done on the variability of repeated hauls in the same body of water with various types of plankton gear, e.g. Windsor and Clarke (1940) and Silliman (1946). Even if the variations in catch will depend on the kind of organism and its patchiness, this error in majority of cases must be relatively small in comparison with that introduced by taking a sample over a small area as being representative of a much larger area. In the present work no attampt has been made to integrate over area and the data presented represent single observations or mean values of a few stations in certain localities.

Three sampling procedures were used to investigate the variability in number of larvae caught in oblique hauls with Clarke-Bumpus plankton samplers:

(1) Comparison of number of larvae caught at the same station in two subsequent hauls (Table 9.).

(2) Comparison of number of larvae caught in two samplers attached just above each other (1 m apart), (Table 11).

(3) Samples collected around current crosses (Table 13).

The catch figures (Tables 9 and 11) apparently showed some variability both when repeating the hauls in the same body of water and when sampling simultaneously with two gears in approximately the same depths. Grouping the data in Table 9 in two series and applying an analysis of variance (Table 10), no significant difference between series of haul was found. ($F= 0.583$, $P > 0.01$). Nor was the difference in number significant (Table 12.) when sampling simultaneously with two gears attached 1 m apart ($F= 0.412$, $P > 0.01$).

The distribution pattern during day and night was studied by sampling around current crosses at different localities on the 1964 and 1965 cruises (Table 13.). In 1964 two current crosses were released in 10 and 20 m every second hour during 24 hours, hauls were made in 25-5 m and 50-30 m. To study the vertical distribution in more detail samples in 10 m stratas from 50 m to the surface at station 1 and from 70 m to the surface station 2 were taken in between (Figs. 9 and 10). The results obtained at drift station 1 (off Sklinna, $\frac{06}{23}$) clearly demonstrated that number of larvae caught between sunset and sunrise was significantly higher ($F= 40.18$, $P < 0.01$) than in the light period (Table 14). The increase in number of larvae caught at night was due to higher catches in the upper 25 m, the larvae being especially numerous above 20 m (Fig. 9, middle part). At station 2 (off Eggum, $\frac{05}{14}$) no significant diurnal difference in number of larvae was found (Table 14, $F= 1.029$ $P > 0.01$). This station was situated far north and the sampling was carried out at the end of April. At this time of the year the dark period is relatively short and even if the larvae showed a vertical migration towards the surface at night, this pattern was not as pronounced as at station 1 (Fig.9, middle part). No larvae were caught below 60 m. In 1965 the drift buoys were connected to current crosses in 10 and 40 m (station 3, off Halten, $\frac{07}{06}$). The sampling procedure was the same as in 1964, the sampling depth being extended to 75 m (Table 13, Fig.11). The number of larvae caught at night was not significantly higher than during daytime (Table 14, $F= 4.476$, $P > 0.01$).

the number of larvae caught in the depth range 70-55 m was scarce during the second half of the sampling period, whereas larvae were more numerous during the first four samples. Larvae were not found below 70 m. Also at this station the highest concentration was found in the upper 30 m during the night. Considering the three stations simultaneously and excluding the sampling in 70-55 m at drift station 3, significant difference between day and night catches was found on the 5 %, but not on the 1 % level (Table 15).

The effect of net avoidance on the variability of the catches is difficult to judge from the present material. Apparently larger larvae were not caught more frequently at night than during the day (Fig.9,10,and 11, lower part). Comparing the mean lengths of larvae caught at night with the means obtained during daytime significant differences were found at drift station 3 applying a t-test (Table 16), whereas at stations 2 and 3 the significance was not clear. The mean lengths of larvae caught by Clarke-Bumpus samplers and 3 feet Isaacs-Kidd midwater trawl (Table 17) did not usually show differences for larvae below 15 mm, whereas a significant difference was observed above this length. It is concluded, therefore, that the larvae caught by Clarke-Bumpus apparatus gave true length distributions of larvae below 15 mm, and it is reasonable to assume that the net-avoidance was relatively small below this length.
The variability in catches was more likely due to patchiness, the larvae being more evenly distributed during the night.

Errors introduced by integrating cruise totals over time to give estimates of the total production over a certain period is a serious problem met with in abundance estimates of eggs and larvae. According to English (1963) the major source of variability is the time effect,with number of stations being less important and duplication (paired hauls) least important. To make adjustments for the variability in time, it is necessary, among other factors, to know the shape of the curve of egg abundance with time and, the hatching rate of the larvae. In the present material the duration of the spawning season fluctuated between 20-30 days in area 07 and 10-20 days in area 05. This variation will definitely complicate the estimation of larvae abundance and, make the comparison from year to year difficult. Other important time effect factors are the dispersion and mortality of larvae. Thus the present material does not allow for any exact adjustments of the estimates of larval abundance.

Distribution

In Figs. 12 and 13 are shown the average number of larvae per m^2 in the different localities along the coast. One to eight stations, mainly two to four, were located in each rectangle. Where more than half of the hauls fell in the dark period, figures are set in brackets.

To compare the distributions in the different years with each other, the sampling period in relation to hatching and the procedure of sampling should be the same. These requirements were only partly fulfilled. In 1959 the survey was carried out from 2-28 April, covering the periods first week and fourth week after peak of hatching in area 07, and the second and fourth week in area in area 06 (Table 8). Larvae were distributed all along the coast from Bergen to Andenes, the main concentrations, however, being found near the coast from central part of area 07 to the northern part of area 06 (Fig.12). In area 05 insignificant number of larvae was found. A few larvae were caught in three localities off the continental shelf west of Stad. Comparing the distribution during the first period (2-21 April) with the second one (20-28 April) the same general pattern was found, although the most dense concentrations were observed somewhat further north than during the first part of the cruise, indicating a general drift of the larvae in a northward direction.

The 1960 survey covered the period 21 March - 9 April, the first part falling within the main hatching period both in areas 07 and 06, whereas in the second period of the cruise the peak of hatching had just passed when these areas were surveyed (Table 8). The number of larvae caught was extremely high compared with the previous year, especially in the northern part of area 07 and the central part of 06 (Fig. 12). Larvae were only traced in one locality in the Lofoten region which was covered during the period 28 March - 2 April. In 1961 the cruise lasted from 6-29 April, and sampling in areas 07 and 06 was undertaken during first and second week after peak of hatching (Table 8). In the period 6-19 April, the main concentrations were found in the central part of area 07, between Kinn and Grip and in the Halten region (Fig.12). The larvae were significantly more northerly distributed during the second part of the survey (20-29 April), especially in area 07, but as late as 24 April no larvae were found in area 05. Also this year larvae were scarce in the localities south of Kinn $\left(\frac{07}{01,02,03}\right)$, whereas they were numerous between Kinn and Stad $\left(\frac{07}{04,05}\right)$ during the first part of the cruise.

The first cruise in 1962 commenced 2 April and continued to 13 April. A second survey was carried out 24-28 April. Both cruises covered a smaller area than the previous years (Fig.13). The main hatching in areas 07 and 06 took place during the first week of April, the first survey falling within and just after this period (Table 8). The highest concentrations were observed between Grip and Frøya and in the Halten-Sklinna regions. The number of larvae found south of Stad was negligible. The second survey covered only area 07 and larvae were still numerous between Grip and Frøya. The larvae surveys in 1963 started 2 April and lasted until 23 April. As in 1960 and 1962 sampling in areas 07 and 06 was carried out in the main hatching period during the first part of the

cruise (Table 8). The second part covered a period about two weeks after peak of hatching. During the first period, 2-10 April, the main concentrations were observed between Ona and Frøya, and between Halten and Sklinna. No larvae were found in area 05 (Fig.13).
In the second period larvae were found in almost the same regions, but were somewhat more widely distributed and appeared as far north as Vesterålen. The herring migrating to the shelf off Lofoten consisted almost entirely of recruit spawners and spawning took place mainly from 25-29 March. Thus the larvae were not hatched at the time when the surveys were undertaken in this region (Table 8). In 1964 the survey started relatively late compared with the previous years, the first part covering the period 14-24 April and the second 26 April - 5 May. Prior to this survey a cruise was undertaken during the period 2 - 10 April. However, since this survey covered only a small part of the actual area, the results are not presented in Fig. 13. The peak of hatching in areas 07 and 06 was in the last week of March. In the Lofoten region the hatching took place during the second half of April. Consequently larvae, also with yolk, were numerous in this region. During the 1964 survey larvae were found over a wide area, distributed from Stad to Andenes with the highest concentrations in the Lofoten region (Fig. 13). The 1965 survey commenced 29 March, about one week after the peak of hatching in areas 07,06 and 05, and continued until 12 April (Fig. 13). Larvae were especially numerous during the first part of the survey in a limited region between Grip and Halten. In contrast to the previous year, the concentrations in area 05 were highest off the western side of the Lofoten Islands. Between Halten and Lofoten very few larvae were caught. The number of larvae caught during the second part of the cruise was considerably lower in most of the localities covered, although dense concentrations were still found in the Grip-Frøya region.

The main larvae concentrations from spawning grounds in areas 07 and 06 were found between Stad and Sklinna, extending to the southernmost part of area 07 in 1959-1961. The distribution indicated a somewhat more dispersed pattern in 1959 than the other years. During the period 1962-1965 larvae were scarce south of Ona, being in accordance with a restriction of spawning on the southern grounds. In 1964 and 1965 the distribution was characterized by two main centres, one off the Møre-Trøndelag coast and another one off the coast between Lofoten and Andenes. Most of the larvae in the latter region were derived from the spawning on the shelf off Lofoten. Thus especially in 1964 and 1965 the major part of the larvae population was located further to the north than those hatched at the beginning of the period considered (1959-1961).

Abundance

To indicate the abundance in the different years the number of larvae per m^2 surface caught in six sections between Stad and Træna were analysed, the sections, running from the coast towards north-west. The stations in each section were numered seaward, 1-6 off Stad, 1-5 off Ona and Frøya, 1-8 off Halten, 1-4 off Sklinna and 1-9 off Træna..(Fig.8). The positions of the stations in the different sections were nearly the same each year. The number of larvae caught per m^2 surface are shown in Table 18-23. At stations where no haul was taken, the place has been left open in the tables.

The 1959 samples are difficult to judge since no Clarke-Mumpus hauls were taken before the last week of April. The catches obtained in the Stad section (Table 18) by Nansen net indicated that larvae were relative abundant throughout April. It is clearly demonstrated that the larvae were most numerous at the innermost stations in the section. The number of larvae caught in 1960 (7 April) and 1961 (7-10 April) was relatively high. In 1962, 1963 and 1964 no larvae were caught during the first part of the surveys, whereas a few larvae were caught during the second part at station 1. In 1965 no larvae were found in the Stad section. Adding up the number of larvae per m^2 surface at this section, the abundance was highest during the first half of April in 1960, followed by 1961 and 1959. However, during the latter half of April the figures were highest in 1959. No hauls were taken during this period in 1960 nor in 1965. In the Ona section (Table 19) the abundance of larvae was especially high in 1960 being somewhat less in 1961 and 1962. In the latter year the larvae were concentrated at the innermost station. In 1963 and 1965 the number of larvae was still lower in this section, and in 1964 the abundance was insignificant. In 1959 larvae were relatively scarce throughout April. During the first half of the month i.e. one to two week after peak of hatching larvae were most numerous in 1960, followed by 1961, whereas in the second half when the yolk was absorbed the abundance was highest in 1963 (in 1960 no samples were taken). In 1962 and 1965 (12 April) no larvae were found, and in 1961 the number of larvae was considerably lower than during the first half of April. Few larvae were found in 1964. Also at this section the number decreased seawards. In Frøya section the abundance was high both in 1960, 1961, 1962 and 1965 (Table 20). In 1961 the number of larvae was highest during the second half of April indicating a northward drift in the time interval between first and second part of the survey. During the 1962 surveys larvae were numerous throughout April at the two innermost stations. The abundance in 1963 and 1964 were of the same order of magnitude during the first week of April. In 1959 the number of larvae per m^2 surface caught by Nansen net were relatively high in the first half of April, whereas in the second half of the month the larvae were rather scarce and could be compared with the figures for 1963 and 1964.

Further north in the Halten section (Table 21) the abundance was high during the first half of April in 1960, 1961 and at a few stations in 1962. Again the figures were high during the second part of the survey in 1961. The figures for 1959 indicated relatively high concentrations throughout April. The abundance was almost the same during the first and second survey in 1963 and 1964, the figures, however, being considerably lower than in 1961. In 1965 the number of larvae caught at this section was of little significance. In the Sklinna section (Table 22) larvae were also most numerous in 1960 and 1962. The other years in question are difficult to rank with regard to number of larvae, except in 1965 when the figures indicated relatively low abundance. The larvae caught in the Træna section (Table 23) were again almost negligible, except in 1964 and 1965. The abundance seemed to be especially high in years when sampling fell in the main hatching period or just after it,e.g. in 1960,1961,1962 and 1965. In the two latter years the high figures were restricted to relatively few stations. A decrease in abundance during the time interval between the yolk sac stage and just after the absorption of yolk was indicated in 1965. Thus to compare the variations in abundance between years, the sampling period after the yolk sac stage should be chosen, i.e. two-three weeks after peak of hatching. In 1959, 1960,1961 and 1964 this stage was passed 15-20 April (for areas 07 and 06), 10-15 April in 1965 and 20-25 April in 1962 and 1963 (Table 8). In 1960 sampling was not carried out after 9 April and the figures can not be compared with other years. Judging from Tables 18 -23 the concentrations of larvae were especially high in 1961 in the Frøya and Halten sections, being considerable less abundant south and north of this regions. However, in 1959 larvae were widely distributed showing relatively high figures at all sections. In 1962, 1964 and 1965 larvae were either lacking or scarce south of Ona, whereas in the Frøya sections larvae were numerous these years, being less abundant again in the Halten and Frøya sections. Further north off Træna larvae from the spawning in areas 07 and 06 were mixed with those hatched in the Lofoten region. This was especially pronounced in 1964. Excluding larvae spawned in this northernmost region it seems reasonable to conclude that larvae having passed the yolk sac stage were numerous in 1959 taking into account their wide area of distribution and bearing in mind that the oblique sampling was carried out only from 25-5 m. Similarly the abundance was high in 1961, although it should be stressed that larvae were especially abundant in limited regions. A such cincentrate distribution pattern was even more characteristic for the 1962 and partly also for the 1965 larvae, whereas in 1963 and 1964 larvae showed a somewhat more dispersed pattern.

Length

To study the length distribution of larvae, the catches in the different years were grouped according to region (Figs. 14-20) and the statistics,mean length , standard deviation and variation coefficient were estimated (Tables 24-25). In 1959,1960 and 1961 evidence was found of somewhat larger mode lengths in the Stad-Ona and Grip-Frøya regions than further south and north of these regions Figs. 14-16). A similar trend was found in the mean lengths (Table 24). It is reasonable, therefore, that spawning started in the central part of the main spawning area i.e. between Stad and Grip. The onset of spawning was slightly later in the regions south and north of this centre. In 1962 only small differences in the mean lengths (Fig. 17 and Table 24) were found according to region and time. The spawning centre this year was located somewhat further north and the highest mean length was found in the Grip-Frøya region indicating that spawning started first here. From 4-12 April only a small increase in length was noticed between Stad and Halten (Table 24). The very small differences in mean lengths of larvae caught 11-12 April and 26-27 April might give limits of a high mortality rate in this time interval.

Also in 1963 the mean length was highest in the Grip-Frøya region during the first part of the survey (3-8 April). The mean length became slightly lower off Halten and Sklinna (Table 25). The low average length found on 3 April between Stad and Ona, indicated late spawning in this region, again being in accordance with the assumption of slightly earlier onset of spawning in the main spawning centre (Grip-Frøya). During the period 1959-1963 the length distribution showed highest variation coefficients in 1959. This was clearly demonstrated in the Halten, Sklinna and Træna regions (Fig. 14, Table 24). The variation coefficients were especially high (11 and 13-14 April) off Halten and Sklinna where the larvae consisted of a mixture of small and large larvae. This feature confirmed that hatching took place over a relatively long period in 1959.

The length compositions in 1964 were characterized by curves showing a bimodal distribution and by high variation coefficients.The lengths of the larvae caught during the period 15-17 April between Grip and Frøya and off Halten showed almost the same picture. Off Sklinna and Træna the distributions were clearly bimodal with modes of respectively 10 mm and 16 mm. In the Lofoten region the biggest mode was less pronounced, although an admixture of bigger larvae was noticed. The influx of smaller larvae predominated in this region. The wide range in length can be explained by the fact that first time spawners made up 34.4 % of the mature stock in area 07. According to Blaxter and Hempel (1963) and Hempel and Blaxter (1967) recruit spawners produce slightly smaller eggs and hence smaller larvae. Also a somewhat later spawning by recruit than repeat spawners may result in a bimodal distribution. The largest larvae found in areas 07 and 06 were probably derived from old fish which were spawning relatively early in the season, whereas the smaller larvae probably had their origin from recruits spawning slightly later. In the Lofoten region the herring consisted almost entirely of recruit spawners and the larger larvae caught between Lofoten and Andenes were most likely transported from spawning grounds south of this region. During the first part of the 1965 cruise no significant differences were found in mean lengths between Stad and Halten, indicating spawning almost at the same time in these regions (Table 25, Fig.20). The larvae caught between Lofoten and Andenes were almost certainly derived from the spawning grounds off Lofoten. Although the spawning took place at the same time in this region and further south 70-75 % of the larvae caught between Lofoten and Andenes still had yolk 4-6 April, whereas only 17-18 % had yolk in the regions between Ona and Halten 30 March-1 April. Significantly lower temperatures in the surface layer off Lofoten might explain somewhat longer duration of the yolk sac stage in this area.

Discussion

Distribution of larvae in relation to their spawning location have been discussed by Runnstrøm (1934), Wiborg (1956), Marty(1956) and Yudanov (1962). During the period 1900-1910 and 1922-1932 Runnstrøm found larvae ranging in length from 10-15 mm in different regions along the coast from the southernmost part of Norway to Andenes. It is evident from his investigations that larvae caught off Lofoten in February-April were spawned in this region. Elsewhere along the coast larvae were concentrated off Møre and Bokn-Stolmen, indicating that these districts were important spawning centres.Larvae were also traced off Halten. During the postwar period,e.g. Wiborg (1956,1960) and Yudanov (1962) larvae observed were almost in the same regions The importance of spawning on the coastal banks between Grip and Frøya was stressed by these investigations. During the period 1959-1963 larvae were mainly found between Stad and Sklinna and in 1964 and 1965 also off the Lofoten Islands. In this latter region the concentrations were unimportant during the other years in question, although spawning took place in the Lofoten region also in 1960 (Yudanov 1962) and in 1963. The reason why no larvae were caught during the 1960 and 1963 surveys was due to the fact that area 05 was surveyed too early in relation to hatching. In 1959 and 1961 (in 1962 area 05 was not covered) the larvae found off Lofoten were negligible, being in conformity with Yudanov's findings (1962). No mass spawning, therefore, did take place there these years. Thus the spawning off Lofoten seemed to be variable both in scope and time. Further south, between Sklinna and Bokn a significant change compared with prewar periods had taken place. A restriction in area of distribution, mainly south of Ona,was found from 1962 onwards.

During the years 1962-1965, the mass spawning was most likely concentrated between Ona and Sklinna, whereas in the previous period (1959-1961) important spawning took place as far south as Stad, the main centre being between Stad and Grip. The distribution pattern during the first months after hatching was characterized by high concentration near the coast, decreasing rapidly seaward, and outside the shelf almost no larvae were found south of Lofoten. Also off Lofoten the larvae were mainly observed near the shore, although a somewhat more dispersed distribution was found in this region than further south. It is reasonable to conclude, therefore, that no admixture of larvae from spawning grounds located outside the Norwegian shelf, e.g. from the Shetland and Faroe plateaues, had taken place.

Due to changes in spawning location, hatching time and dispersion of larvae, it is difficult to compare the variations in total abundance between the different years. An eventual mass mortality at certain periods in the early larval stage will also complicate a comparison between years. The present investigations indicated a significant decrease in abundance during the time interval two to four weeks after hatching, e.g. in 1962 and 1965. Further indication of a critical stage during this period might be seen from the length distributions. In case the time for peak of hatching was the same each year in all localities and the larvae were randomly distributed, the following general trend should be found: At the time when all the larvae were hatched, and provided that no drift and mortality existed, the lengths should have a normal distribution. If the growth conditions for larvae were good the increase in length with time should show high. If larvae go through a critical stage with high mortality during the period when they change from their yolk to external food sources, i.e. at about 11 mm the curve for the length frequency distribution should change its shape when the larvae pass this critical length. Instead of showing a normal distribution, a positive skewness of the curve should be found being accompanied for a period by a somewhat smaller increase in the mean length. A schematical illustration of an example of this kind is given in Fig.21. A situation like this might be completely masked since length distribution and mean length is not only influenced by differential mortalities at certain lengths, but also on: (1) length at hatching, (2) growth rate, (3) selection in mortality of slow and fast growing larvae and (4) emigration and immigation (drift and dispersion). The relative importance of these factors is difficult to adjust for. However, during the period 1959-1963 the spawning stock comprised fish of mainly one year-class (the 1950) and loratively few young recruits appeared in the stock. This feature should account for a relatively uniform length at hatching.

Figs. 12 and 13 show that during this period almost all the larvae were found in area 07 and in the southern and central part of 06. The range and time of spawning within area 07 was considered to be almost the same, although the spawning in the central region Ona-Grip started slightly earlier than further south and north. In area 06 the spawning might especially on the Halten Bank, be somewhat delayed in relation to the spawning in area 07. However, the larvae found between Stad and Sklinna is considered to consist of one population hatched almost at the same time. Thus plotting the mean lengths according to time, with reference to peak of spawning (Fig. 22), the growth pattern can be studied. Also data from Yudanov's surveys in the same areas were plotted.

Indication of a relatively slow increase in mean length during the period 25-45 days after peak of spawning, i.e. about a mean length between 10 and 14 mm was found. In 1960 and 1962 the average growth per day was about 0.10-0.12 mm and 0.14-0.16 mm in 1963 and 1965. A significant layer increase (0,18-0,20 mm) was noticed in 1959 and 1961, the latter year being somewhat less pronounced. The figures for 1964 is difficult to judge due to the great variations in mean lengths. A relatively low growth rate during this period might support the theory of a critical period just after the end of the yolk sac stage. According to Blaxter and Hempel (1963) the lengths of larvae of Norwegian spring spawners at the end of their yolk sac stage were ranging from 10.5-11.5 mm showing a growth rate of 0.3 mm per day during the yolk sac stage. Their results were based on experiments carried out during the Norwegian winter-herring season in 1961 and 1962.

Tentatively therefore, it is concluded that the survival of the larvae was highest in 1959 followed by 1961. A ranking of the other years can not be undertaken, but it is likely that the mortality was high in 1962. This might also be seen from the length distributions in Fig.17. The low growth rates in 1960 and 1965 (area 05 omitted) indicated high mortalities. It should be noted, however, that the sampling in 1960 was mainly carried out during and just after the main hatching period.

The long spawning period in 1959-1961 should account for a subsequent dispersed length distribution of larvae. The dispersion is excepted to be greatest in 1959, since the percentage fall off of the maturity stage V was relatively slow (Fig.3), resulting in a corresponding slow increase of the percentage turning over to maturity stage VI, again resulting in spawning at a more constant rate. The variation coefficients according to time, with reference to peak of spawning are plotted in Fig. 24. Relatively high values were found in 1959. The coefficients for 1960 and 1961 did not show such high figures indicating that although the spawning season was long spawning and subsequent hatching might be more concentrated in these years. Also the high abundances of larvae at certain stations these years support this assumption.

In 1964 varying and high variation coefficients were found. The reason for this might be quite another than that the 1959. According to Hempel and Blaxter (1967) the variation in egg weight within a spawning group was dependent only to a slight extent on the differences of length and age of mother. In very young recruits the eggs were significantly lighter than in fish recruiting at an older age and in repeat spawners. The difference in egg weight between the youngest recruit spawners and the next age group was about 10-14 % in Norwegian spring spawners. It is likely therefore, that the egg size did not affect the variability of the length distribution to any great extent during the season 1959-1963. In 1964 however, a mixture of young recruit spawners and old repeat spawners (off Møre and Trøndelag) should give rise to a high dispersion in the length distribution, even if the period of spawning inside each area was relatively short. This was clearly demonstrated in the variability of the variation coefficients. Also spawning at different time of recruit and repeat spawners might have contribute to the high dispersion. In 1965 the figures did not show the same variation as the previous year presumeably because the relative importance of old repeat spawners was less this year than in 1964 and also due to more concentrate spawning. Thus the high abundance found in certain localities both in 1961, 1962 and 1965 after the yolk sac stage compared with 1959, might be explained by a more concentrate spawning and subsequent hatching in the former years, the larvae being transported northward in dense patches. It is likely that the mortality during this transport was particular high in 1962 and probably also in 1965, whereas in 1961 the survival rate was higher. In 1960 the spawning was also concentrated in time, even if the spawning period was long. However, spawning took place over wide areas and even if indications of a low growthrate was found during the period of yolk resorption the larvae were widely distributed. The abundance distribution in 1963 was also less concentrated than in 1961, 1962 and 1965 indicating a dispersed pattern. Further consideration on the transport of larvae will be given in the following chapter.

DISTRIBUTION OF LARVAE IN RELATION TO THE WATER TRANSPORT IN COASTAL WATERS OF WESTERN AND NORTHERN NORWAY

According to Helland-Hansen and Nansen (1909) water with salinity less than 35.0 ‰ is defined as coastal water and water with salinity higher than 35.0 ‰ as Atlantic water. The former is moving as a coastal current from the Skagerak to the Barents Sea, whereas the Atlantic water moves northward somewhat more offshore, mainly outside the edge of the continental shelf. Where the shelf is lying deeper than 150-200 m it is usually covered with Atlantic water. A lateral movement of the coastal water takes place during the year, the extension seaward being greatest in summer. During this part of the year, however, the depth of the coastal water is rather shallow, whereas in winter it is narrow, but deeper.

In February 1906 the 35.0 ‰ isohaline in 50 m was found to be about 50 nautical miles offshore in the Sognefjord section, in May 56 nautical miles (Helland-Hansen and Nansen 1909).The salinity distribution in 30 m between Stad and Træna during the period 18-24 February 1956 is showed in Fig.24 (Ljøen personel communication). The distance from the coast varied from 30 to 60 nautical miles.The salinity in the coastal water is increasing northwards, while in the Atlantic water it is decreasing, indicating that some intermixing takes place in the boundary layers between the two water masses. Helland-Hansen and Nansen (1909) stated that the velocity of the coastal current varies greatly. Off Breisund they found currents, which in the upper 20 m run seawards, but below 20 m towards the coast. Near the edge of the continental shelf the currents at all depths were moving north-eastwards along the continental slope. On some occasions the current was found to be moving very slowly(northwards) and vortex movements were supposed to occur. Martens(1929) measured the current at Storegga, the bank outside Ona, and calculated the water transport as 5 nautical miles per 24 hours. In February/March 1937 Eggvin(1940) found current velocity in the upper water layers between Sognesjøen and Ona of 15.1 cm per sec., or approximately 7 nautical miles per 24 hours.Off the coast between Lofoten and Andenes Ljøen (1962) found the maximum current velocity in July 1957 immidiately off the edge of the shelf, directed north-eastwards. In this region the water was characterized by salinity less than 35 ‰ in the uppermost 50 m, whereas below this depth the water was of Atlantic origion. In the shallow part on the shelf at this section the current also flowed to the north-east, the velocity, however, being considerably lower. As the spawning of herring takes place on the coastal banks relatively close to the shore, the larvae are presumably transported northwards in coastal water during the first few weeks after hatching. In the present chapter the distribution pattern of the herring larvae will be compared with the distribution of recoveries of drift bottles launched on the spawning grounds. The wind during the drift period and its influence on the distribution will also be considered as well as the drift experiments with current crosses in larval patches.

Drift bottles

Drift bottles were released in winter and spring 1961,1963,1964 and 1965 on different localities off the coast (Figs.25 and 26). Mainly five bottles in each station were launched (Table 26). The bottles were most frequently recovered near the coast, just outside or inside the skerries, or ashore. Of a total of 10 bottles released in 1961 off Møre (area07), 5 were recovered further north in this area and 3 in the southern and middle part of area 06 (Fig.25). All the bottles were recovered within 30 days after release and the distribution indicated that the bottles were transported northwards close to the shore. The 1963 recoveries showed quite another distribution. None of the bottles launched in areas 07 and 06 were recaptured within 30 days.

All the returns were found further north in areas 05,04 and 03 (Figs. 25 and 26). This distribution demonstrated that the bottles drifted northwards some distance offshore during the first period after release, being transported closer to the shore further north. Bottles from the 1964 and 1965 experiments launched in areas 07 and 06 were frequently recovered in these same areas (Figs. 24 and 25) No special trend in distribution pattern of bottles liberated in area 05 was noticed, although the 1963 as well as the 1964 experiments were recovered somewhat further north than the 1965 experiment. The frequency of return was highest for bottles launched in area 07, decreasing northwards with area of liberation (Table 26). The high percentage of return indicated that the dispersion of bottles into the open sea was insignificant, especially for those released in area 07. Bottles launched further north might be distributed more offshore since intermixing of Atlantic and coastal water takes place during the transport northward. Off Torsvåg, where a great shelf is located, the drift is probably more influenced by Atlantic water, which in this area is intensively mixed with coastal waters (Ljøen 1962). However, in 1963 the frequency of returns was almost the same for bottles released in areas 07,06 and 05. In this year the bottles were transported somewhat off the coast also in areas 07 and 06.

An indication of the drifting speed northward might be found by estimating the average distance drifted per bottle, recovered within certain periods (Table 27). In February and March 1961 the velocity seemed to be especially high in areas 07 and 06, the average drifting distance per day being estimated to 8.7 nautical miles. None of the bottles launched in 1963 in area 07 was recovered within the first 45 days, whereas 3 were returned between 46 and 90 days after release, giving an average distance drifted per bottle per day of 4.2 nautical miles. The distance drifted for bottles recovered between 91 and 180 and 181 and 360 days were 3.0 and 3.2 nautical miles respectively. The corresponding values for the bottles launched in areas 06 and 05 are given in Table 27, where also the results of the 1964 and 1965 experiments are listed. The average distance drifted per day was highest for bottles returned during the first 45 days after launching, decreasing with increasing time at liberty. The reason for this might be due to the fact that these bottles have generally drifted a longer distance than those recovered within the first month after release and thus have been influenced by varying current conditions during their drift. Also an eventual delay in returning bottles already recovered might give rise to lower average drifting distances The drifting distance per day was frequently lowest for bottles in the 1965 experiment indicating that the surface current northward this year was weaker than the two previous years (Table 27). In 1961 the drifting speed was high during the first month after release. It should be born in mind that the current velocities indicated by the drift bottles represent minimum figures.

The experiments were also divided into offshore and nearshore liberations to see whether the drift pattern might be different for these two categories of liberations(Table 28). The frequency of return was slightly higher for some of the nearshore libarations, but the over all picture indicated no different trend in distribution of returns.

Although the total number of bottles released in the different years were rather few and thus also the estimates subject to great variations, evidence of a variable strength of the surface current was found. The main drift took place near the coast, but in 1963 also with a pronounced drift northward further offshore. The flow of bottles along the coast from Møre to Finnmark was clearly demonstrated and it is likely that larvae hatched off Møre might be transported far into the Barents Sea.

Wind

Although the motion of the coastal water is directed northward the surface water may be turned in various directions by the wind force. According to Ekman's theory (1923) the angle between the direction of the wind and current is 45° at the surface, increasing with the depth, so that the agregated water transport is at a right angle to the wind direction, provided the transport is not influenced by land, and that the sea is sufficiently deep. At smaller depths the angle will be less. The wind current is strongest at the surface, decreasing rapidly with the depth. During the summer the wind current along the Norwegian coast will probably not reach deeper than to the thermocline. In winter, however, the wind current reaches deeper, depending on the wind force and duration of the wind. Along a coast line in south-north direction as along the Norwegian coast between Stad and Andenes the wind produces not only a pure wind current to the right of the wind direction (in the northern hemisphere), but also a relative current that runs parallel to the coast (Sverdrup et al. 1946), northwards when the wind blows from southerly direction to the south when the prevailing winds come from north. Winds from S 30° W to W should be the most important directions for transporting surface water towards the coast of western and northern Norway, whereas winds from N 30°E to E move the water away from land. When surface water is accumulated along the coast the effect of the relative current will increase the transport northwards, whereas in the opposite case (periods with prevailing winds from N 30°E to E) water is transported away from the coast, giving rise to a diminishing effect on the strength of the coastal current. In the former case larvae will be transported relatively fast and nearshore northwards, whereas offshore winds should result in a more dispersed drift pattern. In view of this consideration wind data from the meteorological stations, Ona, Nordøyane and Skomvær were dealt with. The resultant of the wind vectors within each month from March to May (inclusive) were estimated for the years 1959-1965 and are illustrated on Figs.28-30.

The directions of the wind vectors in 1959 were rather similar at all stations. In March wind mainly from south existed at Ona and Nordøyane, whereas further north the directions changed somewhat more towards south-west to west, the wind vectors being relatively large at all stations. In April the prevailing winds came from south to south-easterly directions at all stations, the wind vectors being relatively small at Ona. In May the direction of the wind vectors varied between west and south-west except at Ona where the direction was north-westerly. Thus the wind in spring 1959 most likely moved the coastal water towards land in March resulting in a rather strong transport northward, whereas in April a somewhat more offshore transport existed. The latter situation might result in a more dispersed distribution pattern of larvae. In May the wind vectors again was directed towards land. In 1960 south to south-easterly winds were dominating in March and April, except at Ona in April. In May mainly north-easterly winds were blowing. The wind distribution in March and April was almost similar to that in 1959. However, the trend of the transport established in 1960 might be somewhat more in offshore direction. In March 1961 large wind vectors from south-west to west were observed at all stations and surface water was transported towards the coast. The recoveries of drift bottles this month clearly demonstrated a strong drifting speed northwards of bottles released off Ona in February 1961. In April small offshore wind vectors were found off Ona and Nordøyane. The prevailing winds in May came from north at all stations. Thus the wind vectors in April and May indicated a hampered transport northward during these months.

The situation in 1962 was characterized by prevailing wind vectors from north varying from north-west to north-east. This wind distribution should mainly diminish the strength of the coastal current and result in a moderate transport of coastal water northwards. The wind distribution in 1963 resembled that found in 1960, with prevailing offshore winds at all stations. As in 1960 the wind should transport surface water seawards and it is reasonable, therefore, that drift bottles launched in 1963 were transported somewhat offshore northwards. The wind vectors in 1964 were mainly from south-east to south-west at all stations except at Skomvær in April, when wind from north-east was prevailing. The wind distribution had a similar trend as that in 1959, although the wind vectors were significantly smaller and consequently did not affect the water transport to the same extent. The transport of surface water should partly be directed towards the coast and partly offshore. The situation in 1965 was characterized by varying wind directions. At Ona and Nordøyane relatively strong south-westerly winds were blowing in March, whereas winds from south-est were prevailing in April. In May north to north-easterly winds predominated. At Skomvær north-westerly winds were predominating in March, south-easterly in April and north-easterly winds in May. This wind distribution should have varying effect on the water transport, mainly diminishing the strength of the coastal current at the northernmost station. The average drift per bottle per 24 hours was also relatively low indicating that the drifting speed northwards was weak in 1965. Thus evidence of a relationship between distribution of drift bottle returns and the movement of water caused by the wind was found. Since the larvae are distributed in the uppermost surface layer it is reasonable to concluds that the wind strength and direction play an important role for the distribution pattern of the larvae.

Current crosses

To follow the drift of a herring larval patch Wiborg (Dragesund and Wiborg 1963) made use of current cross. During the 1963 survey a current cross was released off Frøya($\frac{07}{23}$) and kept in 15 m for 24 hours. Practically no wind was blowing when the experiment was undertaken except a light breeze for about two hours. The total drift was 18 nautical miles in north-easterly direction from the position of release. Similar experiments were carried out by the author at several places along the coast in 1964. Two current crosses were released 18 April off Sklinna($\frac{06}{17}$) one at 10 m and one at 20 m (Fig.30), and followed for 24 hours. At the beginning the current cross in 10 m drifted slightly faster than that in 20 m. However, at the end of the experiment the 20 m current cross had reached the 10 m cross and even passed it. The length of the drift path was 26 nautical miles, the direction changing from north-east to north-west during the drift. The direct total distance drifted from the position at release to the end position was 24 nautical miles in 24 hours. There was practically no wind during the experiment. From 28 to 29 April current crosses were also followed for 24 hours off Eggum ($\frac{05}{14}$ Fig. 32). The direct total distance drifted was only 7 nautical miles. Also during this experiment the current crosses in 10 and 20 m followed each other. A third drift experiment was carried out in the Lofoten region 22-23 April($\frac{05}{10}$). In this locality extensive herring spawning took place in 1964, and at the time when the experiment was undertaken dense patches of larvae were observed. However, the crosses were followed only for 8 hours and during this time only a slight drift in south-westerly direction was noticed. As the drifting time was too short this experiment will not give the true picture of the current strength in this locality. Off Træna($\frac{06}{31}$)current crosses in 10 and 20 m were released 30 April and followed for 12 hours. The total drift this period was 4.3 nautical miles, indicating that the drift was considerably weaker than further south off Sklinna 12 days earlier.

In 1965 two current crosses were released 9 April($\frac{06}{06}$)off Halten, one cross in 10 m and the other one in 40 m. The drift was followed during 24 hours and no wind was blowing. The cross in 10 m drifted slightly faster than the 40 m cross during the first few hours, whereas at the end of the experiment the two crosses were almost at the same position, the total direct distance drifted being 24 nautical miles in north-easterly direction. Thus no significant differences with regard to direction and velocity of the current in 10 m, 20 m and 40 m was found. These observations support the assumption that the drift bottle experiments gave good indications of the drift pattern of larvae in the upper 50 m.

Discussion

Since larvae were found mainly in the upper 50 m on the coastal banks off western and northern Norway during the first month after hatching, they should be transported in coastal water northward. This feature can be demonstrated by plotting the extent of the larval distribution in seaward direction together with the salinity distribution corresponding sections. Fig.33 illustrated the distribution in 1959 off Stad, Ona and Træna. All the larvae in the two southernmost sections were distributed in coastal water, whereas further north off Træna, the larvae were more dispersed, being found also in Atlantic water. However, the most dense concentrations were observed near the coast in typical coastal water where the main transport of larvae took place. Also the drift bottle experiments indicated a northward transport near the coast. Larvae hatched south of Stad will presumably have a similar drift pattern as those hatched off Møre and Trøndelag, but the possibility of a more offshore distribution exists during their drift, especially for those from the southernmost spawning grounds. Indication of a such offshore drift of larvae hatched south of Stad was found in 1959 (Fig.12). A westward drift from the Møre plateau was observed for one of the drift bottles released in this region (Fig.25). The drift of larvae hatched between Stad and Ona might be somewhat delayed compared with those hatched north of this region. Current crosses released in 1967 off Ona $(\frac{07}{06})$ drifted clock wise and the resultant in northeastward direction during 168 hours was insignificant (Dragesund and Nakken 1968). According to Helland-Hansen and Nansen (1909) the surface water near the coast north off Stad seems to move away from land until it is deflected towards the north and north-east near the edge of the continental shelf, where it joins the coastal current coming from south. Thus the larvae may be transported north-westward when passing the coast off Stad and Ona or they may follow a more vortex movement during their drift over the southern part of the Møre plateau. The length distributions of larvae caught off Sklinna especially in 1959 and 1964 showed a bimodal distribution with high variation coefficients, indicating that the drift northward had taken place through this region, relatively near the coast. Also the distribution off Lofoten support the assumption that the main larval transport takes place in coastal water when passing this region.

Reliable data on the speed of Larval drift is still lacking. Although the drift is strongly dominated by the water transport from the spawning grounds, the drift is not excusively passive.

If the larvae drifted with the same speed as the current crosses indicated the drifting speed should be relatively high in the region between Frøya and Sklinna and somewhat weaker further north off Træna and near the coast off Eggum. Applying the figures obtained from the current crosses experiments using a drifting speed of 1 knot between Frøya and Sklinna and 0.4 knot between Sklinna and Træna the transport of larvae from the Grip-Frøya to the Træna region should take about 16 days measuring the distance parallel to the coast. Some of the larvae observed 19-20 April 1964 off Træna$\left(\frac{06}{06,07}\right)$had reached lengths of 17-19 mm (Fig.19). If these were hatched off Grip-Frøya during the peak period of hatching in this region (24-26 March), the drifting time should be about 26 days. Picking out five of the most fast drifting bottles released in 1964 in area 07 and recovered within 50 days after release (Fig.25) the average drifting distance per day was estimated to 6.7 nautical miles giving a drifting time of about 35 days. The larval drift were presumably somewhat slower than indicated by the current crosses, which also showed that the drift varied both in speed and direction. It might be reasonable to assume that the larvae not only made vertical, but also horizontal migrations within the patch, so that the larvae tended to orientate against the current. Blaxter and Dickson(1959) found that herring larvae about 8 mm long would orientate against a current passing through a tube. Such behaviour will hamper the drift of a larval patch. Comparing the distributions of larvae during the first and second part of the larval surveys, the situation in 1961 was the most striking one (Fig.12). A considerable northward displacement of the larvae in the region between Frøya and Halten was found between the periods 11-13 and 25-27 April. In March prevailing and strong south-westerly wind existed at Ona and Nordøyane. Thus surface water accumulated near the coast, where a strong northward drift took place. Northward displacements of larval concentrations could be noticed in most of the years (Figs. 12 and 13). However, the time interval between the first and second part of the surveys were too small to allow any estimate of the drifting speed.

Concerning the drift pattern of larvae in the different years, it is tentatively conducded that larvae hatched in 1963 off Møre and Trøndelag had a somewhat more offshore drift northward during the first two-three months after hatching than the 1964 larvae hatched in the same region. However, the average distance drifted for bottles released in area 07 in 1963 was almost the same as those launched in 1964, indicating that the drifting speed was of the same order these years. The drift of larvae hatched in the Lofoten region should have similar pattern in 1963 and 1964. During a cruise carried out in May to June 1963 (Fig.14 no larvae were found along the coast of Finnmark, whereas larvae were frequent on the coastal banks between Torsvåg and Træna. The reason why no larvae were caught along the Finnmark coast (in areas 04 and 03) was due to the fact that the transport took place somewhat more offshore.

This feature could be stated on a cruise carried out later in the year in August-Deptember 1963 (Dragesund and Olsen 1965), showing that the main transport of larvae into the Barents Sea took place between latitudes N 72° and N 73°. The wind distribution in 1960, especially in March resembled that of 1963 and the distribution in 1959 that of 1964 the latter being characterized by prevailing south-easterly to south-westerly winds in March and April. In May the wind vectors varied somewhat more at the various stations. As a whole the wind was slightly more offshore in 1960 and 1963 than in 1959 and 1964. Tentatively, therefore, it is assumed that the drift pattern of larvae in 1960 was similar to that in 1963 and the 1959 pattern to that of 1964, the transport northward being strongest in 1959 and 1960. In 1961 the prevailing winds came from southwest in March, giving rise to a strong nearshore transport northward this month, whereas the wind vectors in April and May probably hampered the drift northward. A similar changeable trend was found in 1962 and 1965 resulting in a rather weak northward transport. Although the transport conditions might change from one year to another, it is likely that an extensive northward drift of larvae takes place from all spawning grounds along the coast. Thus larvae spawned off Møre and Trøndelag might pentrate the areas off Finnmark as well as the eastern and northern part of the Barents Sea. This tentatively conclusion seems to be in some disagreement with Runnstrøm (1934) and Marty (1954), the former believing that the major part of the larvae drifted into the fjords bordering the spawning areas. Marty stated that the bulk of the larvae from the southern spawning grounds settled down south of the Lofoten Islands, while the larvae spawned around Lofoten penetrate the eastern part of the Barents Sea.

CONCLUDING REMARKS

Of the year-classes hatched during the period 1959-1962 the 1959 year-class has been the most numerous one in the adult stock, followed by the 1960,1961 and 1962 year-classes. This is clearly demonstrated from the age composition of the winter-herring (Table 2). The other year-classes in question (1963-1965) have not yet reached the adult stage and can not be compared with the previous year-classes in the winter herring catches.

It is generally accepted that the natural mortality may be extremely high in the very early stages of life, but little is known about the magnitude of the early mortality rate, its variability, and the exact time of leveling off. Various authors have suggested that critical periods exist during early life when mass mortality may occur e.g. Hjort (1914,1926). The hypothesis of critical periods has been discussed by Marr (1956), who concluded that although catastrophic mortalities, restricted in time, will always remain as a possibility, evidence points towards survival at a constant rate or at a constantly increasing rate, rather than towards the existence of critical periods. Wiborg(1957) did not find any correlation between the abundance of eggs and larvae and the relative strength of the subsequent year-class of cod in the commercial catches. Nor did he trace any increased mortality at any stage in the early life history of the cod. He concluded that following conditions should exist for establishing a rich year-class: (1) a long spawning period, (2) a prolonged hatching or spawning late in season, (3) an extension or northward displacement of the spawning centre and (4) a successful transport of the eggs and larvae from the spawning region to the nursery grounds by currents.

In the present investigations it seems reasonable to conclude that the duration of the spawning season was relatively long in 1959, 1960 and 1961 (about one month), whereas in 1962 the season lasted only for about three weeks. Thus the relatively long spawning seasons in 1959, 1960 and 1961 should lead to subsequent long hatching periods. However, the shape of the spawning curves were somewhat more steep in 1960 and 1961 than in 1959. Adjusting for the effect of temperature on the incubation time, this might give rise to a slightly more narrow range for peak of hatching in 1961 than in 1959 and 1960. In 1962 the peak period of hatching was especially short lasting only for about five days (Table 8).

Lea (1930) concluded that the number of larvae hatched must be relatively independent of the number of eggs deposited and more dependent on the area covered by eggs. He considered it more favourable for the hatching when small quantities of roe were distributed over a great area than the contrary. A restriction in spawning location might result in a higher egg density in case the size of spawning stock remained on the same level. During the period from 1959-1962 both a restriction in spawning location and decrease in stock size took place. Lea (1930) showed that thick egg layers on the spawning grounds resulted in a high mortality, since eggs in the deepest layers were found in a state of putrefaction. Runnstrøm did not found any clear increase of mortality with increasing density of the egg layer except when extremely large quantities of eggs were deposited (10 000 to 12 500 cm^3 per m^2). The average mortality of the whole egg material collected by Runnstrøm was 12.1 %. Hart and Tests (1934) who carried out investigations in British Columbia found that the dead eggs on the spawning beds constituted from 1.4-10.5 %. Investigations made by Parrish et al. (1959) in the firth of Clyde showed that only very few dead or unfertilized eggs occurred in the samples, but the stage of development varied through the egg layer. Dragesund and Nakken (unpublished) also observed few dead and unfertilized eggs in a locality near Grip during the spawning season in 1968. Saithe (<u>Gadus virens</u>)fished in the same region feeded on herring roe and the predator effect was apparently of some importance at this locality. Runnstrøm (1941) concluded that a egg-mortality of 12 % was of minor importance for the numerical strength of year-class and that the mortality must be much greater at a later stage.

When the larvae have resorbed their yolk suitable food must be available or a mass mortality will start. In case lack of suitable food is a limiting factor which again might be a question of timing, a long hatching period accordingly would buffer the increasing mortality. According to Bjørke (1968) more than 80 % of the stomach content of larvae investigated during the period from hatching and the following three weeks in 1967 off Møre consisted of eggs of Calanus finmarchicus. Thus the timing between the Calanus spawning and hatching of herring larvae might be an important factor. Lie (1965) found that the spawning of Calanus finmarchicus at Sognesjøen$\left(\frac{07}{04}\right)$started usually in the first half of March in 1959, 1960 and 1961, slightly later in the latter year, whereas the spawning in 1962 started probably at the beginning of April. The mean total volume of zooplankton in April and May was considerly lower in 1962 than in 1960 and 1959, indicating less available food in 1962 than in the two former years. It should be noted that at the Skrova and Eggum stations in the Lofoten region no such differences neither in time of spawning nor in total plankton were found (Lie 1965). However, these stations were located north of the areas where larvae were observed at the time when the resorption of yolks took place. It is also important to note that in 1959, and to some extent also in 1960 and 1961, spawning took place south of Stad, and with a relatively extensive spawning in time and scope, the probability for a subsequent numerous year-class is better than in seasons when spawning takes place in more limited localities over a short period.

Considering the two most extreme year-classes concerning the numerical strength 1959 and 1962, the present investigations gave hints of a greater mortality of larvae of the latter year-class. This mortality was probably especially high during and just after the yolk period of absorption. A similar condition as in 1962 was found in 1967 (Dragesund and Nakken) when a significant decrease in number of larvae was found during this stage. Also earlier investigations by Soleim (1942) supported this assumption. The conditions for a successful timing with a subsequent numerous year-class should exist in 1959, as spawning took place over relatively wide regions, the duration of the spawning/hatching period was long and the possibility for a dispersed distribution was good. The 1962 season was the most striking one when the opposite conditions existed.

Bridger (1960,1961) and Cushing and Bridger (1964) obtained evidence which suggested that recruit herring in the southern North Sea were producing less viable larvae than older herring. According to Blaxter and Hempel (1963) and Hempel and Blaxter (1967) the volume and weight of the yolk sac increased with egg size and consequently the survival time of the larvae from hatching to starvation increased significantly with egg size. They also found that very young recruits produced significantly lighter eggs than fish recruiting at an older age and in repeat spawners. The analysis of the 1964 larvae showed great variations in lengths and it is suggested that the smallest larvae were derived from young recruit spawners. Thus the parental effect may play some part, especially in years when the age of the spawning stock changes from relatively old to very young parents.

In Table 29 the information deduced from the preceding chapters has been compiled concerning conditions assumed to be advantageous for the development of numerous year-classes of herring during the period 1959-1965. The most reasonable causes to be focused at should be:

(1) the time and range of hatching in relation to suitable food for the larvae at the end of the yolk sac stage,

(2) the dispersal of the larvae just after hatching and

(3) parental factors.

SUMMARY

1. Variations in time and location of spawning of Norwegian spring spawning herring during the period 1959-1965 have been analysed.

2. Spawning took place from the second half of February throughout March on the central spawning grounds off Møre and Trøndelag, the peak of spawning being latest in 1962 and 1961. The spawning in the Lofoten region was significantly later in 1963 and 1964 than off Møre and Trøndelag, whereas in 1965 spawning took place almost at the same time in these two regions.

3 The spawning period in 1959, 1960 and 1961 was relatively long and lasted for about one month, whereas in 1962 spawning lasted only for about three weeks. In Lofoten the spawning season was narrow both in 1963, 1964 and 1965.

4. Spawning took place mainly at certain localities between Stad and Sklinna, with a significant restriction in spawning on the southern part of the Møre plateau during the period 1959-1965. The spawning centre in 1962-1965 was located in the Grip-Frøya region. Spawning on the traditional grounds off the southwestern part of the Norwegian coast was insignificant except in 1959. Spawning around Lofoten was observed in 1963-1965, the location of spawning being concentrated more on the western side of the Lofoten Islands in 1965 than in the two forenr years. Spawning probably took place also in 1960, whereas in 1959, 1961 and 1962 spawning was negligible.

5. Larvae collected during the period 1959-1965 were analysed with regard to variations in distribution, abundance and length.

6. Some evidence of a drop in abundance during the time interval from hatching to three to four weeks after was found.

7. Indication of a slower growth rate for the 1962 than the 1959 larvae was found, giving hints of a higher mortality rate of the former larvae. Tentatively it is concluded that the mortality of larvae might be especially high during and just after the period of yolk absorption
8. The drift pattern and speed of larvae were discussed. It was suggested that the larval drift in 1964 from the spawning centre off Grip-Frøya to the region off Træna amounted to almost four weeks.
9. Larvae hatched off Møre might pentrate the areas off Finnmark and further into the eastern and northern part of the Barents Sea.
10. Information deduced from the present and other investigations concerning the conditions assumed to be advantageous for the development of numerous year-classes were analysed.

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Table 1. Catches (in thousands of metric tons) according to area and locality in the Norwegian winter herring fishery, 1959-1966.

Area / Locality	1959	1960	1961	1962	1963	1964	1965	1966
08 / 03	19.918	-	-	-	-	-	-	-
08 / 04	24.864	.005	.004	-	.001	-	-	-
07 / 01	.269	.200	-	-	.002	-	-	-
07 / 02	.326	.698	.018	-	.007	-	-	-
07 / 03	.005	.549	-	-	.024	-	-	-
07 / 04	32.452	33.629	1.957	-	.059	-	-	-
07 / 05	135.580	127.576	11.620	3.776	2.803	3.641	-	2.594
07 / 13,14	-	-	-	-	-	15.504	-	2.636
07 / 06	154.738	111.326	19.897	59.897	37.692	32.291	55.024	53.815
07 / 07,19	37.739	26.100	30.416	5.740	7.031	48.861	86.227	242.868
07 / 08	2.957	.009	5.129	.042	.021	21.475	2.508	73.738
07 / 23,24	-	-	-	-	-	5.427	.579	40.568
06 / 06	-	-	-	1.984	-	9.847	-	.205
06 / 10,11,12,17,18,23	5.785	-	-	12.629	6.531	7.282	19.247	11.366
06 / 27,30,31	1.279	-	-	-	-	-	10.705	10.200
05 / 03,04,09,10,15	-	-	-	-	7.267	137.396	31.464	14.393
05 / 13,14,20,24	.009	.051	-	-	-	-	.537	8.474
Total	415.921	300.143	69.041	84.068	61.438	281.724	206.291	460.857

Table 2. Age composition (%) of herring caught by purse-seine during the Norwegian winter herring fishery 1959-1966 according to area.

Year-class	1959			1960	1961	1962		1963			1964		1965			1966		
	08	07	06	07	07	07	06	07	06	05	07	05	07	06	05	07	06	05
1962	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1	-	0.3
1961	-	-	-	-	-	-	-	-	-	-	-	0.6	3.2	18.8	5.8	10.3	3.6	8.0
1960	-	-	-	-	-	-	-	-	-	9.5	4.0	10.1	10.7	26.0	19.6	27.7	25.1	39.1
1959	-	-	-	-	-	0.1	-	4.0	13.1	89.8	51.5	88.4	62.7	55.2	74.1	53.4	60.8	51.6
1958	-	-	-	-	-	-	-	0.3	0.3	0.7	0.4	0.3	0.1	-	0.1	0.2	-	0.3
1957	-	-	-	-	0.4	0.5	-	0.4	-	-	0.2	-	0.2	-	-	0.2	-	-
1956	0.4	-	-	0.2	0.9	1.0	-	0.7	-	-	0.7	-	-	-	-	0.1	0.2	-
1955	1.3	0.7	-	1.4	3.3	2.7	-	1.8	-	-	1.3	-	0.4	-	-	0.2	-	-
1954	4.0	1.1	-	1.2	2.9	1.5	1.3	1.7	0.3	-	0.5	-	0.9	-	-	0.3	-	-
1953	17.4	7.1	2.1	6.1	7.7	7.8	11.2	8.7	7.3	-	4.2	0.1	2.0	-	0.3	0.7	0.6	-
1952	6.0	5.7	3.2	3.6	4.8	4.2	2.5	3.6	3.2	-	2.2	-	1.4	-	-	0.7	0.6	0.1
1951	8.0	8.4	4.2	5.3	6.5	6.6	7.5	8.3	7.3	-	3.2	-	2.2	-	-	0.4	0.2	0.3
1950	51.8	54.1	73.4	64.4	59.0	62.7	73.7	61.1	62.5	-	28.0	0.5	14.4	-	-	5.2	8.5	0.3
1949	2.0	2.4	1.1	2.0	4.4	2.3	-	2.3	1.3	-	0.7	-	0.6	-	-	0.1	-	-
1948	2.0	3.8	5.3	4.0	3.0	3.8	1.3	3.4	2.5	-	1.2	-	0.6	-	-	0.1	0.2	-
1947	2.7	5.4	6.3	4.8	2.3	3.6	-	1.8	1.6	-	1.6	-	0.4	-	0.1	0.3	0.2	-
1946	0.7	2.6	1.1	1.5	1.5	0.7	-	0.5	-	-	0.1	-	-	-	-	-	-	-
1945	1.3	3.0	-	1.3	1.4	1.1	-	0.7	0.3	-	0.1	-	0.1	-	-	-	-	-
1944	1.1	2.2	1.1	1.4	0.9	0.9	2.5	0.5	0.3	-	0.1	-	0.1	-	-	-	-	-
1943	0.5	1.1	1.1	1.0	0.3	0.3	-	0.1	-	-	-	-	-	-	-	-	-	-
1942	0.2	0.6	-	0.4	0.4	-	-	0.1	-	-	-	-	-	-	-	-	-	-
1941	-	0.6	-	0.4	0.1	0.2	-	-	-	-	-	-	-	-	-	-	-	-
1940	0.4	0.4	-	0.5	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-
1939	-	0.3	1.1	0.3	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-
1938	0.2	0.2	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1937	-	0.2	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1936	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total number	553	2106	94	3038	666	992	80	923	314	433	1198	1089	1141	96	719	2963	471	749
Mean age	8.4	9.5	9.5	10.3	10.7	11.7	11.7	12.2	11.6	3.9	8.7	4.9	7.8	5.4	5.7	7.2	7.6	6.5

Table 3. Commencement of the Norwegian winter herring fishery and duration of spawning according to area in the seasons 1959-1965. The start peak and end periods of spawning are estimated from the curves of the maturity distribution in Figs. 3 and 4.

Year	Area	Commencement of fishery	Period for start of spawning	peak of spawning	end of spawning	Approximate duration of spawning in days
1959	08	-	18-22.2	5-9.3	20-24.3	30
1959	07	26.1	18-22.2	5-9.3	20-24.3	30
1959	08+07	-	18-22.2	5-9.3	20-24.3	30
1960	07	2.2	18-22.2	4-8.3	19-23.3	30
1961	07	15.2	23-27.2	10-14.3	25-29.3	30
1962	07	27.2	5-9.3	15-19.3	25-29.3	20
1963	07	23.2	28.2-4.3	10-14.3	20-24.3	20
1963	05	23.3	20-24.3	25-29.3	30.3-3.4	10
64	07	12.2	23-27.3	4-8.3	14-18.3	20
1964	05	2.3	19-23.3	24-28.3	29.3-2.4	10
1965	07	13.2	18-22.2	28.2-4.3	10-14.3	20
1965	05	6.2	18-22.2	28.2-4.3	10-14.3	20

Table 4. Summary showing the number (in brackets percentage) of first time and repeat spawners in the material examined during the seasons 1959-1965.

Year	Area / Locality	First time spawners No.	First time spawners %	Repeat spawners No.	Repeat spawners %	Total number
1959	08 / 03,04 , 07 / 02	174	21.3	642	78.7	816
1959	07 / 04,05,06,07	207	11.7	1554	88.3	1761
1960	07 / 01,05,06,07	155	3.9	3836	96.1	3991
1961	07 / 05,06,07	27	1.0	2583	99.0	2610
1962	07 / 05,06,07	13	0.5	2829	99.5	2842
1963	07 / 05,06,07,08	100	5.2	1838	94.8	1938
1963	05 / 03,04,09	434	100.0	0	0.0	434
1964	07 / 06,07,08	722	34.4	1375	65.6	2097
1964	05 / 03,04,09,10,14	1102	93.7	74	6.3	1176
1965	07 / 06,07	456	35.9	814	64.1	1270
1965	06 / 12	84	87.5	12	12.5	96
1965	05 / 03,05,09	491	76.4	152	23.6	643

Table 5. Maturity composition (%) of winter herring grouped according to region and date (five days period) over the spawning seasons 1964 and 1965.

Area / Locality	Year	Date	First time spawners: Maturity stage IV	V	VI	VII	No.	Repeat spawners: Maturity stage IV	V	VI	VII	No.
07 / 06,07,08	1964	13-17.2	20.4	78.8	0.8	-	137	17.1	82.9	-	-	228
		18-22.2	9.0	87.0	4.0	-	223	0.8	95.4	3.8	-	238
		23-27.2	1.4	57.7	39.4	1.5	208	0.2	59.6	39.7	0.5	428
		28.2-3.3	1.2	26.5	54.2	18.1	83	0.4	21.2	52.7	25.7	237
		4-8.3	-	14.1	71.8	14.1	71	-	7.4	65.6	27.0	244
05 / 03,04,09,10	1964	28.2-3.3	2.5	97.5	-	-	79	-	100.0	-	-	3
		4-8.3	-	-	100.0	-	80	-	-	100.0	-	14
		9-13.3	-	2.2	97.8	-	92	-	-	100.0	-	3
		14-18.3	-	0.2	99.8	-	513	-	-	100.0	-	27
		19-23.3	-	-	99.1	0.9	338	-	-	100.0	-	27
07 / 06,07	1965	13-17.2	26.1	73.9	-	-	115	3.0	97.0	-	-	202
		18-22.2	9.6	72.6	17.8	-	146	-	79.8	19.8	0.4	258
		23-27.2	2.2	33.3	57.8	6.7	45	-	29.0	68.0	3.0	203
		28.2-4.3	1.8	1.8	63.6	32.8	110	-	5.3	88.4	6.3	95
		5-9.3	-	2.5	95.0	2.5	40	-	-	92.9	7.1	56
06 / 12	1965	15-19.3	-	-	92.9	7.1	84	-	-	100.0	-	12
05 / 03,05,09	1965	13-17.2	2.9	91.4	5.7	-	70	-	96.0	4.0	-	25
		18-22.2	5.4	86.0	7.8	0.8	129	2.2	76.1	21.7	-	46
		23-27.2	-	2.8	94.4	2.8	71	-	-	100.0	-	23
		28.2-4.3	-	2.2	57.0	40.8	142	-	-	60.0	40.0	45
		5-9.3	1.3	12.7	49.6	36.4	79	-	-	30.8	69.2	13

Table 6. Catches (in thousands of metric tons) of spawning and spent herring according to area and locality in the Norwegian winter herring fishery 1959-1965.

Area / Locality	1959	1960	1961	1962	1963	1964	1965
08 / 03	19.918	-	-	-	-	-	-
08 / 04	24.864	.005	.004	-	.001	-	-
07 / 01	.269	.200	-	-	.002	-	-
07 / 02	.326	.698	.018	-	.007	-	-
07 / 03	.005	.508	-	-	.024	-	-
07 / 04	7.524	16.284	1.957	-	.059	-	-
07 / 05	18.479	78.230	11.620	3.776	2.803	-	-
07 / 06	12.369	39.134	19.897	49.908	36.045	31.973	19.801
07 / 07,19	1.939	2.292	29.300	4.684	2.519	42.669	39.162
07 / 08	1.716	.009	4.929	.042	.002	14.761	2.508
07 / 23	-	-	-	-	-	1.507	.579
06 / 06	-	-	-	1.984	-	9.847	-
06 / 10,11,12,17,18,23	5.785	-	-	12.629	6.531	6.685	19.247
06 / 27,30,31	1.279	-	-	-	-	-	2.117
05 / 03,04,09,10,15	-	-	-	-	7.267	13.011	17.861
05 / 13,14,20,24	.009	.051	-	-	-	-	.093
Total	94.482	137.411	67.725	73.023	55.260	120.453	101.368

Table 7. Relationship between temperature and incubation time. The maximum temperature range on the spawning grounds within the depth interval 50-200 m/or bottom are listed (confr. Fig.7) and the corresponding incubation time estimated (Blaxter and Hempel 1963).

Area / Loc.	Year	Date	Max. temp. range in C° from 50-200 m/ or bottom	Depth to bottom in m	Corresp range of incubation time in days
08/03	1959	5.3	5.7-7.6	128	23-17
"	"	6.3	5.3-7.6	182	25-17
07/04	"	19.2	4.8-7.8	250	28-16
07/05	"	17.2	4.8-8.4	250	28-15
06/2	"	13.4	6.8-7.3	330	18-17
[illegible]/23	"	"	6.1-6.3	150	21-20
07/05	1960	16.2	5.0-8.7	292	28-14
07/06	"	9.3	5.2-8.2	180	26-16
07/08	"	"	5.8-8.3	294	22-15
06/11	"	10.3	7.8-7.2	208	16-18
06/17	"	"	5.9-7.7	215	22-16
07/04	1961	4.3	5.4-8.1	310	24-16
07/05	"	7.3	5.6-7.8	340	23-16
07/0[illegible]	"	"	5.6-8.3	400	23-15
0[illegible]/0[illegible]	"	8.3	6.0-6.1	240	21
"	"	"	7.2-7.6	200	18-17
06/10	"	9.3	7.5-7.4	150	17
06/27	"	12.3	6.5-7.0	230	19-18
07/05	1962	7.3	7.5-8.0	275	17-16
"	"	1.3	6.5-7.7	250	19-16
07/06	"	6.3	6.2-6.5	80	20-19
07/19	"	3.3	6.4-7.3	140	20-17
06/05	"	30.3	6.9-6.7	120	18-19
06/16	"	"	7.3-7.7	210	17-16
07/05	1963	1.3	3.4-7.9	165	28-16

Area / Loc.	Year	Date	Max. temp. range in C° from 50-200 m/ or bottom	Depth to bottom in m	Range of incubation time in days
07/05	1963	2.3	3.5-8.1	250	28-16
07/06	"	4.3	4.6-6.9	155	28-18
07/19	"	5.3	4.1-7.1	225	28-18
06/10	"	7.4	6.3-6.1	208	20-21
06/12	"	6.4	4.5-[illegible]	260	28-18
06/16	"	6.4	6.4-6.4	210	20
06/23	"	"	4.4-5.9	160	28-22
05/04	"	4.4	4.5-6.7	200	28-18
05/05	"	5.4	3.5-6.6	260	28-19
05/09	"	4.4	3.4-4.6	190	28
07/19	1964	24.3	6.3	55	20
"	"	"	6.5-7.5	100	19-17
06/10	"	23.3	7.0-7.0	180	18
06/17	"	"	6.3-7.2	160	20-18
05/04	"	22.3	5.1-6.6	150	28-19
05/05	"	22.3	5.9-7.2	200	22-18
05/09	"	23.3	5.3-6.9	198	25-18
07/05	1965	4.3	5.6-7.4	110	23-17
07/06	"	5.3	5.5-7.7	160	24-16
07/19	"	6.3	5.2-7.4	210	26-17
06/06	"	1.4	5.7-6.6	270	23-19
06/11	"	"	6.5-6.8	220	19-18
06/17	"	2.4	6.2-6.9	170	20-18
05/04	"	1.3	5.6-7.1	148	23-18
05/05	"	"	6.1-7.7	200	21-16

Table 8. Comparison between the periods for peak of spawning, peak of hatching and the first part of the larval surveys.

Year	Area	Period for peak of spawning	peak of hatching	the larval surveys first part	second part
1959	07	5 - 9.3	20-24.3 - 2-6.4	2 - 9.4	25-28.4
"	06	"	22-26.3 - 26-30.3	9 - 14.4	23-25.4
"	05	-	-	14 - 21.4	21-23.4
1960	07	4 - 8.3	18-22.3 - 1-5.4	21 - 24.3	4-9.4
"	06	"	20-24.3 - 26-30.3	24 - 28.3	2-4.4
"	05	-	-	28 - 30.3	30.3-2.4
1961	07	10-14.3	25-29.3 - 3-7.4	6 - 12.4	27-29.4
"	06	"	27-31.3 - 29.3-2.4	12 - 14.4	21-26.4
"	05	-	-	18 - 19.4	20-21.4
1962	07	15-19.3	31.3-4.4- 4-8.4	2-5.4 and 24-28.4	11-13.4
"	06	-	31.3-4.4- 3-7.4	5-9.4	10-11.4
1963	07	10-14.3	26-30.3 - 7-11.4	2-4.4	20-23.4
"	06	"	28.3-1.4 -7-11.4	4-9.4	16-20.4
"	05	25-29.3	12-16.4 -22-26.4	9-10.4	13-16.4
1964	07	4-8.3	21-25.3 -24-28.3	14-17.4	2-5.5
"	06	"	22-26.3 -24-28.3	17-20.4	30.4-2.5
"	05	24-28.3	11-15.4 -18-22.4	20-24.4	26-30.4
1965	07	28.2-4.3	16-20.3 -26-30.3	29-31.3	10-12.4
"	06	"	18-22.3 -23-27.3	31.3-3.4	7-10.4
"	05	"	16-20.3 -23-27.3	3-5.4	5-7.4

Table 9. Number of larvae per m^2 surface caught with Clarke-Bumpus plankton samplers in two subsequent pair of oblique hauls in the same locality during the larval cruise in 1964.

Area Locality	Date	Series 1				Series 2			
		Hour	Depth in m 25-5	Depth in m 50-30	Total	Hour	Depth in m 25-5	Depth in m 50-30	Total
06/10	17.4	0840	3	2	5	0910	3	2	5
"	"	1503	0	4	4	1530	2	2	4
06/11	"	0152	18	11	29	0225	27	7	34
"	"	0400	9	4	13	0428	2	2	4
"	"	0605	4	0	4	0730	10	0	10
06/12	16-17.4	2350	37	16	53	0020	45	30	75
06/14	"	1937	2	0	2	2005	0	0	0
06/15	"	1730	5	0	5	1800	0	0	0

Table 10. Summary showing the results of analysis of variance from data in Table 9.

Source of variation	Sums of squares	Degrees of freedom	Variance of estimate	Level of significance
Between series of haul	9.03	1	9.03	
Between hauls	3924.97	15	261.66	
"Residual"	232.47	15	15.50	F = 0.583
Total	4166.47	31		Not significant

Table 11. Number of larvae per m^2 caught in oblique hauls with Clarke-Bumpus plankton samplers attached 1 m apart during the larval cruise in 1964.

Area / Locality	Date	Series 1 Hour	Series 1 Depth in m 24-4	Series 1 Depth in m 25-5	Series 2 Hour	Series 2 Depth in m 49-29	Series 2 Depth in m 50-30
05/10	23.4	0115	162	290	0320	338	280
"	"	-	-	-	0505	348	263
05/14	28.4	1105	27	50	1315	135	161
"	"	1455	43	47	1715	67	42
"	"	1900	69	70	2110	43	23
"	28-29.4	2310	69	120	0110	106	49
"	29.4	0310	76	64	0508	132	58
"	"	0705	87	85	0910	134	82
C/31	30.4-1.5	2345	31	29	0105	12	11
"	1.5	0300	2	10	0524	0	0
"	"	0741	10	23	0940	2	0

Table 12. Summary showing the results of analysis of variance from data in Table 11.

Source of variation	Sums of squares	Degrees of freedom	Variance of estimate	Level of significance
Between series of haul	440.38	1	440.38	
Between hauls	329699.62	20	16484.98	
"Residual"	21379.62	20	1068.98	F = 0.412
Total	351519.62	41		Not significant

Table 13. Number of larvae per m^2 surface caught in oblique hauls with Clarke-Bumpus plankton samplers around current crosses.

Station	Area / Locality	Date	Year	Hour	Depth in m 25-5	50-30	75-55	Total
1	06/23	18.4	1964	1340	5	5		10
"	"	"	"	1600	0	0		0
"	"	"	"	1820	9	13		22
"	"	"	"	2005	6	12		18
"	"	"	"	2205	64	7		71
"	"	19.4	"	0015	39	2		41
"	"	"	"	0213	49	16		65
"	"	"	"	0420	29	9		38
"	"	"	"	0605	6	12		18
"	"	"	"	0805	13	6		19
"	"	"	"	1000	2	2		4
"	"	"	"	1205	9	4		13
"	"	"	"	1400	2	4		6
2	05/14	28.4	1964	0920	74	91		165
"	"	"	"	1105	50	117		167
"	"	"	"	1315	66	161		227
"	"	"	"	1455	47	58		105
"	"	"	"	1715	52	42		94
"	"	"	"	1920	70	45		115
"	"	"	"	2110	94	23		117
"	"	"	"	2310	120	60		180
"	"	29.4	"	0110	199	49		248
"	"	"	"	0310	64	53		117
"	"	"	"	0508	120	58		178
"	"	"	"	0705	85	108		193
"	"	"	"	0910	53	82		135
3	07/06	9.4	1965	1415	18	34	21	73
"	"	"	"	1617	21	71	24	116
"	"	"	"	1829	9	94	42	145
"	"	"	"	2020	115	43	16	174
"	"	"	"	2220	53	77	7	137
"	"	10.4	"	0035	18	18	0	36
"	"	"	"	0210	121	29	2	152
"	"	"	"	0414	60	18	3	81
"	"	"	"	0624	15	69	0	84
"	"	"	"	0820	0	23	2	25
"	"	"	"	1015	0	17	4	21
"	"	"	"	1120	0	30	7	37

Table 14. Summary showing the results of analysis of variance from data in Table 13.

Station	Source of variation	Sums of squares	Degrees of freedom	Variance of estimate	Level of significance
1	Between day and night	4775.69	1	4775.69	
	Within day and night	1304.31	11	118.57	$F = 40.180$
	Total	6080.00	12		$P < 0.01$
2	Between day and night	2372.93	1	2372.93	
	Within day and night	25359.07	11	2305.37	$F = 1.029$
	Total	27732.00	12		Not significant
3	Between day and night	8228.29	1	8228.29	
	Within day and night	18382.63	10	1838.26	$F = 4.476$
	Total	26610.92	11		Not significant

Table 15. Summary showing the results of analysis of variance from data in Table 13 when considering stations 1,2 and 3 simultaneously. The larvae caught between 55-75 m at st. 3 are excluded in this analysis.

Source of variation	Sums of squares	Degrees of freedom	Variance of estimate	Level of significance
Between stations	114357.7	2	57178.85(s^2_B)	
Within stations	60422.9	35	1726.37(s^2_W)	
Between day and night	15373.9	3	5124.63(s^2_b)	
Within day and night	45049.0	32	1407.78(s^2_w)	$0.01 < P < 0.05$ (s^2_b/s^2_w)
Total	174780.6	37		$0.01 < P < 0.05$ (s^2_B/s^2_b)

Table 16. Comparison between mean lengths ($\bar{l}$) in mm of larvae caught at night and during day-time with Clarke-Bumpus plankton samplers at three drift stations.

Station	Area/Locality	Date	Period	Depth in m	$\bar{l}$	s^2	No.	Level of significance
1	06/23	18-19.4	Dark	50-5	16.10	3.81	244	t = 1.988
"	"	"	Light	"	15.60	5.63	94	0.05 < P < 0.01
2	05/14	28-29.4	Dark	"	12.01	2.25	505	t = 2.390
"	"	"	Light	"	12.20	2.31	1276	0.02 < P < 0.01
3	07/06	9-10.4	Dark	"	12.23	1.85	157	t = 5.726
"	"	"	Light	"	11.48	1.62	271	P < 0.01

Table 17. Comparison between mean lengths ($\bar{l}$) in mm of larvae caught with Isaacs-Kidd 5 feet midwater trawl (IKMT) and Clarke-Bumpus plankton samplers (CBPS) during the larvae survey in 1964.

Area/Locality	Date	Hour	Gear	Depth in m	$\bar{l}$	s^2	No.	Level of significance
06/05	16.4	1724-1910	IKMT	25-5	12.7	1.20	7	t = 0.362
"	"	"	CBPS	"	12.4	1.84	7	Not significant
06/17	18-19.4	1920-1540	IKMT	50-30	14.9	1.97	113	t = 0.746
"	"	"	CBPS	"	15.3	2.26	16	Not significant
05/14	28-29.4	1455-0910	IKMT	"	12.2	2.26	84	t = 0.152
"	"	"	CBPS	"	12.1	1.53	334	Not significant
06/31	1.5	0145	IKMT	"	18.2	1.95	159	t = 8.257
"	"	0105	CBPS	"	14.7	3.74	27	P < 0.01
"	"	0558-0820	IKMT	"	17.2	2.43	90	t = 4.380
"	"	0524-0741	CBPS	"	14.2	3.03	16	P < 0.01
06/23	2.5	0227	IKMT	"	18.7	2.18	42	t = 4.632
"	"	0150	CBPS	"	14.9	4.66	30	P < 0.01
06/10	3.5	0228	IKMT	"	21.1	1.65	63	t = 3.717
"	"	0150	CBPS	"	18.0	3.32	5	P < 0.01
06/06	"	1047	IKMT	"	16.3	2.21	23	t = 0.455
"	"	1055	CBPS	"	15.7	1.25	3	Not significant
07/07	4.5	0543	IKMT	"	19.0	0.00	1	–
"	"	0343	CBPS	"	14.3	2.94	4	

Table 18. Number of larvae per m^2 surface according to station in the Stad section. The figures in brackets represent night hauls. NN = Nansen net, JN = Juday net, CBPS = Clarke-Bumpus plankton sampler.

Year	Date	Gear	Depth in m	Station 1	2	3	4	5	6	Total
1959	5.4	NN	Bottom-0		(41)	(1)	(-)	-	-	42
"	26-27.4	NN	- " -	(4)	(87)	(3)	(-)	-	-	94
"	"	CBPS	25-5	(1)	(4)	(-)	(-)	-	-	5
1960	22.3	NN	Bottom-0	10	3	-	-	-	-	13
"	7.4	NN	- " -		125					125
"	"	CBPS	25-5	145	862	45	6	7		1065
1961	7-10.4	JN	Bottom-0	80	-	16	-	-	-	96
"	"	CBPS	25-5	274	48	487	-	3	-	812
"	"	"	50-30	75	2	66	-	-	-	143
"	28.4	JN	Bottom-0	(-)	-	-	-	-	-	-
"	"	CBPS	25-5	(-)	-	-	-	-	-	-
"	"	"	50-30	(-)	-	-	-	-	-	-
1962	12.4	JN	Bottom-0	(-)	(-)	(-)	-	-	-	-
"	"	CBPS	25-5	(-)	(-)	(-)	-	-	-	-
"	"	"	50-30	(-)	(-)	(-)	-	-	-	-
"	25.4	CBPS	25-5	2	-	-	-	(-)	(-)	2
"	"	"	50-30	-	-	-	-	(-)	(-)	-
1963	2-3.4	JN	Bottom-0	(-)	(-)	(-)				-
"	"	CBPS	25-5	(-)	(-)	(-)				-
"	"	"	50-30	(-)	(-)	(-)				-
"	22.4	JN	Bottom-0	-	-	-	(-)			-
"	"	CBPS	25-5	11	-	-	(-)			11
"	"	"	50-30	-	-	-	(-)			-
1964	14.4	CBPS	25-5	(-)	-	-				-
"	"	"	50-30	(-)	-	-				-
"	5.5	"	25-5	(2)						2
"	"	"	50-30	(2)						2
1965	30.3	JN	Bottom-0	-	-					
"	"	CBPS	25-5	(-)	-					
"	"	"	50-30	(-)	-					

Table 19. Number of larvae per m^2 surface according to station in the Ona section. The figures in brackets represent night hauls. Legend Table 18.

Year	Date	Gear	Depth in m	Station 1	2	3	4	5	Total
1959	7.4	NN	Bottom-0	6	8	-	-	-	14
"	26.4	NN	-"-		17	-	(-)		17
"	"	CBPS	25-5		12	-	2		14
1960	23.3	NN	Bottom-0	(120)	(33)	(-)	5	3	161
"	5.4	NN	-"-	(4900)	(1125)	80	23	-	6128
"	"	CBPS	25-5	(2390)	(2236)	230	189	3	5048
1961	11.4	JN	Bottom-0	(128)	(24)	24	-	-	176
"	"	CBPS	25-5	(362)	(44)	482	59	-	947
"	"	"	50-30	(14)	(11)	4	2	-	31
"	28.4	JN	Bottom-0	(48)	-	-	-	-	48
"	"	CBPS	25-5	(27)	2	-	-	-	29
"	"	"	50-30	(-)	3	-	-	-	3
1962	4.4	JN	Bottom-0	16	-	-	-	-	16
"	"	CBPS	25-5	26	9	3	2	-	40
"	"	"	50-30	164	20	-	9	3	196
"	11-12.4	JN	Bottom-0	(1032)	(16)	(-)	(-)	(-)	1048
"	"	CBPS	25-5	(312)	(-)	(-)	(-)	(-)	312
"	"	"	50-30	(292)	(-)	(-)	(-)	(-)	292
"	26.4	CBPS	25-5	-	-	-	-	-	-
"	"	"	50-30	-	-	-	-	-	-
1963	3.4	JN	Bottom-0	52	-	-			52
"	"	CBPS	25-5	93	-	-			93
"	"	"	50-30	153	-	-			153
"	22.4	JN		-	-	(-)	(-)		-
"	"	CBPS	25-5	84	19	(23)	(-)		126
"	"	"	50-30	23	2	(2)	(-)		27
1964	2.4	JN							
"	"	CBPS	25-5	4	-	-			4
"	"	"	50-30	-	-	-			-
"	15.4	CBPS	25-5	(9)	(-)	-	-		9
"	"	"	50-30	(2)	(-)	-	-		2
1965	30.3	CBPS	25-5	3	4	10	4		21
"	"	"	50-30	23	28	54	4		109
"	12.4	CBPS	25-5	(-)			(-)		-
"	"	"	50-30	(-)			(-)		-

Table 20. Number of larvae per m^2 surface according to station in the Frøya section. The figures in brackets represent night hauls. Legend Table 18.

Year	Date	Gear	Depth in m	Station 1	2	3	4	5	Total
1959	8-9.4	NN	Bottom-0	69	123	16	6	1	215
"	25.4	NN	– " –	(5)		–	–	–	5
"	"	CBPS	25-5	34		1	4	3	42
1960	23-24.3	NN	Bottom-0	143	625	155	18	–	941
"	4.4	NN	– " –		5	5		8	18
"	"	CBPS	25-5		292	297	250		839
1961	11-12.4	JN	Bottom-0	–	(–)	(–)	(24)	(48)	72
"	"	CBPS	25-5	1	(–)	(9)	(13)	(48)	71
"	"	"	50-30	–	(–)	(6)	(4)	(11)	21
"	27.4	JN	Bottom-0	96	(72)	(48)	(16)		232
"	"	CBPS	25-5	528	(650)	(115)	(27)		1320
"	"	"	50-30	570	(50)	(5)	(–)		625
1962	5.4	JN	Bottom-0	216	128	8	–	–	352
"	"	CBPS	25-5	276	870	5	–	–	1151
"	"	"	50-30	482	532	5	2	–	1021
"	12.4	JN		16	16	–	8		40
"	"	CBPS	25-5	132	720	11	50		913
"	"	"	50-30	405	284	24	26		739
"	27.4	CBPS	25-5	(851)	(85)	(2)	(2)	–	940
"	"	"	50-30	(76)	(24)	(–)	(–)	–	100
1963	4.4	JN		(5)	(10)	–	–	–	15
"	"	CBPS	25-5	(7)	(83)	9	–	–	99
"	"	"	50-30	(–)	(19)	–	–	–	19
"	20-21.4	JN			–	–	–		–
"	"	CBPS	25-5		113	12	2		127
"	"	"	50-30		28	5	–		33
1964	2.4	CBPS	25-5	(11)	(49)	(7)	–		67
"	"	"	50-30	(3)	(9)	(1)	–		13
"	16.4	CBPS	25-5	(39)	(33)	(4)	2	–	78
"	"	"	50-30	(67)	(12)	(7)	–	–	86
"	3-4.5	CBPS	25-5	(2)		(–)			2
"	"	"	50-30	(2)		(–)			2
1965	31.3	CBPS	25-5	141	304	4	–	–	449
"	"	"	50-30	1164		–	11	–	1175
"	10-11.4	CBPS	25-5	(627)	(–)	(–)	(4)		631
"	"	"	50-30	(144)	(–)	(–)	(4)		148

Table 21. Number of larvae per m^2 surface according to station in the Halten section. The figures in brackets represent night hauls. Legend Table 18.

Year	Date	Gear	Depth in m	Station 1	2	3	4	5	6	7	8	9	Total
1959	10.4	NH	Bottom-0	6	3	5	(164)	(12)	(1)	(-)	(-)		191
"	24-25.4	JN	- " -	3		3	13	(14)	(6)				39
"	"	CBPS	25-5	3		3	(127)	(11)	(3)				147
1960	24-25.3	JN	Bottom-0	(-)	(-)	(-)	(95)	(-)	(-)	-	-		95
"	3-4.4	NH	- " -	60	(88)	(1)	(315)	(50)					514
"	"	CBPS	25-5	91	(86)	(4)	(1024)	(13)					1218
1961	12-13.4	JN	Bottom-0	(-)	(16)	(136)	(224)	-	112	-	-		488
"	"	CBPS	25-5	(2)	(4)	(12)	(178)	37	151	-	-		384
"	"	"	50-30	(-)	(2)	(9)	(223)	100	850	116	-		1300
	26.4	JN	Bottom-0	(24)	232	24	-	16					296
"	"	CBPS	25-5	(173)	13	32	55	231					504
"	"	"	50-30	(221)	69	328	232	314					1164
1962	6.4	JN	Bottom-0	-	-	-	400	(-)	(8)	(-)	(-)		408
"	"	CBPS	25-5	-	-	-	51	(-)	(-)	(2)	(-)		53
"	"	"	50-30	-	-	1	361	(-)	(-)	(-)	(-)		362
"	10.4	JN	Bottom-0	16	-	-	16	120	72				224
"	"	CBPS	25-5	69	21	2	264	17	201				574
"	"	"	50-30	-	5	-	12	-	254				271
1963	5.4	JN	Bottom-0	(5)	(3)	-	-	-	3	384	63	-	458
"	"	CBPS	25-5	(25)	(4)	-	-	-	2	14	-	-	45
"	"	"	50-30	(10)	(-)	-	-	2	-	76	-	-	88
	21.4	JN	Bottom-0	(50)	(5)	-	-	-	-	-	-		55
"	"	CBPS	25-5	(44)	(5)	-	-	-	-	-	-		49
"	"	"	50-30	(2)	(7)	-	2	-	-	-	-		11
1964	6.4	CBPS	25-5	6	-	-	2	5	14	16	(41)	(-)	84
"	"	"	50-30	3	-	-	-	2	5	2	(2)	(-)	14
"	16-17.4	CBPS	25-5	(37)	(18)	(9)	4	2	-	5	2	(-)	77
"	"	"	50-30	(16)	(10)	(4)	-	2	4	-	-	(-)	36
"	1-2.5	CBPS	25-5	5	2	-	-	(2)	(9)	(3)	(-)	-	21
"	"	"	50-30	2	-	-	-	(-)	(2)	(-)	(-)	-	4
1965	1.4	CBPS	25-5	(-)	(-)	(-)	-	-	-	-	-	-	-
"	"	"	50-30	(10)	(-)	(-)	-	-	-	-	-	-	10
"	8-9.4	CBPS	25-5	(2)	(-)	(2)	(-)	(-)	(-)	-			4
"	"	"	50-30	(5)	(-)	(-)	(4)	(-)	(-)	2			11

Table 22. Number of larvae per m^2 surface according to station in the Sklinna section. The figures in brackets represent night hauls. Legend Table 18.

Year	Date	Gear	Depth in m	Station 1	Station 2	Station 3	Station 4	Total
1959	13.4	NN	Bottom-0		8	-	-	8
"	24.4	NN	- " -	(53)		(62)		115
"	"	CBPS	25-5	(59)		(99)		158
1960	25.3	NN	Bottom-0	-	5	5	63	73
"	"	CBPS	25-5	3	42	-	155	200
"	3.4	NN	Bottom-0	(25)	93	38	(95)	251
"	"	CBPS	25-5	(327)	946	53	(265)	1591
1961	13.4	JN	Bottom-0	16	96	48	-	160
"	"	CBPS	25-5	-	-	2	-	2
"	"	"	50-30	-	2	74	-	76
"	25.4	JN	Bottom-0	-	8	-		8
"	"	CBPS	25-5	28	65	18		111
"	"	"	50-30	52	56	3		111
1962	6-7.4	JN	Bottom-0	(376)	(1480)	(424)		2280
"	"	CBPS	25-5			(27)		27
"	"	"	50-30			(3)		3
1963	6-7.4	JN	Bottom-0	(38)	(8)	(190)	-	236
"	"	CBPS	25-5	(31)	(-)	(12)	11	54
"	"	"	50-30	(1)	(2)	(7)	30	39
"	17-18.4	JN	Bottom-0	3	-	3	-	6
"	"	CBPS	25-5	125	10	6	26	167
"	"	"	50-30	13	5	-	2	20
1964	18.4	CBPS	25-5	5	2	211	5	223
"	"	"	50-30	2	4	67	5	78
"	2.5	CBPS	25-5	-	4	-	(-)	4
"	"	"	50-30	-	2	-	(-)	2
1965	2.4	CBPS	25-5	(-)	(-)	(-)		-
"	"	"	50-30	(-)	(-)	(19)		19
"	8.4	CBPS	25-5	4	-	-		4
"	"	"	50-30	57	6	-		63

Table 23. Number of larvae per m^2 surface according to station in the Træna section. The figures in brackets represent night hauls. Legend Table 18.

Year	Date	Gear	Depth in m	Station 1	2	3	4	5	6	7	8	9	Total
1959	23.4	NN	Bottom-0	3	1	3	-	-		(6)		(1)	14
"	"	CBPS	25-5	-	5	21	1	7		(4)		(-)	38
1960	28.3	NN	Bottom-0	-	-	-	-	-	-	-			-
"	"	CBPS	25-5	5	-	-	-	-	-	-			5
"	2.4	NN	Bottom-0	3									3
"	"	CBPS	25-5	1									1
1963	16.4	CBPS	25-5	(-)	(-)	-	-	4					4
"	"	"	50-30	(2)	(-)	-	-	2					4
1964	10.4	CBPS	25-5	18	6	10	2	5	10	-	-	-	51
"	"	"	50-30	25	9	24	2	12	9	-	-	-	81
"	20.4	CBPS	25-5	44	50	27	44	76	19				260
"	"	"	50-30	17	73	24	51	131	23				319
"	30.4	CBPS	25-5	15	8	7	19	11	8	18	(7)	(2)	95
"	"	"	50-30	-	-	-	-	-	-	3	(4)	(-)	7
1965	2-3.4	CBPS	25-5	(-)	(-)	(-)	(-)	13	4				17
"	"	"	50-30	(4)	(2)	(-)	(68)	58	-				132
"	6-7.4	CBPS	25-5	-	-	-	-		(-)	(-)	(-)	(-)	-
"	"	"	50-30	4	-	-	2		(-)	(-)	(-)	(-)	6

Table 24. Mean lengths ($\overline{l}$) in mm, standard deviations (s) in mm and variation cofficients (v.c.) in % of larvae caught in different regions, 1959-1962. The grouping according region, year and date is similar to that of the length distributions presented in Figs. 14-17.

	1959					1960					1961					1962				
Region	Date	$\overline{l}$	s	v.c.	No.	Date	$\overline{l}$	s	v.c.	No.	Date	$\overline{l}$	s	v.c.	No.	Date	$\overline{l}$	s	v.c.	No.
Bergen-Kinn	2.4	10.6	0.75	7.1	39	8.4	10.0	0.98	9.8	122	6-7.4	9.3	1.08	11.6	129					
"	28.4	14.8	2.12	14.3	8	-	-	-	-	-	-	-	-	-	-					
Stad-Ona	5-7.4	11.8	1.66	14.1	443	23.3	9.5	1.24	13.1	114	10-11.4	11.0	0.95	8.6	245	4.4	9.6	0.84	8.8	53
"	26-27.4	16.3	1.74	10.7	101	7.4	10.9	0.85	7.8	499	28.4	14.9	0.91	6.1	22	12.4	10.8	0.89	8.2	378
Grip-Frøya	8-9.4	11.3	0.97	8.6	141	23.3	10.1	0.89	8.8	294	11-12.4	11.3	0.85	7.5	383	4-5.4	10.1	0.66	6.5	1339
																11-12.4	10.9	1.21	11.1	1129
"	25-26.4	15.7	1.70	10.8	139	4-5.4	11.4	0.86	7.5	400	27.4	13.5	1.35	10.0	630	26-27.4	11.2	1.50	13.4	674
Halten	11.4	10.5	1.02	9.7	120	24.3	7.6	-	-	38	12.4	9.6	0.77	8.0	254	5-6.4	9.7	0.88	9.1	509
"	24-25.4	14.2	2.05	14.4	133	3.4	10.4	0.73	7.0	148	25-26.4	12.3	1.47	12.0	1074	10.4	9.9	1.08	10.9	480
Sklinna	13-14.4	10.8	2.42	22.4	65	25.3	9.8	0.75	7.7	123	13.4	9.2	0.62	6.7	142	6.4	9.5	0.92	9.7	277
"	23-24.4	14.6	2.04	14.0	450	2-3.4	10.6	0.73	6.9	400	25.4	12.7	1.07	8.4	344					
Træna	20-23.4	14.6	2.16	14.8	65	28.3	9.9	0.90	9.1	55	-	-	-	-	-	-	-	-	-	-

Table 25. Mean lengths ($\bar{l}$) in mm, standard deviations (s) in mm and variation cofficients (v.c.) in % of larvae caught in different regions, 1963-1965. The grouping according region, year and date is similar to that of the length distributions presented in Figs. 18-20.

Region	1963					1964					1965				
	Date	$\bar{l}$	s	v.c.	No.	Date	$\bar{l}$	s	v.c.	No.	Date	$\bar{l}$	s	v.c.	No.
Stad-Ona	3.4	8.8	1.01	11.5	175	-	-	-	-	-	30.3	10.1	0.88	8.7	38
	8.4	10.5	0.77	7.3	29										
"	22.4	11.7	1.20	10.3	161										
Grip-Frøya	3-4.4	10.1	0.62	6.1	271	2.4	10.9	1.10	10.1	46	30-31.3	10.2	0.79	7.7	1419
	7-8.4	10.4	0.79	7.6	266										
"	20-22.4	12.3	1.45	11.8	341	15-16.4	13.3	1.94	14.6	110	10-11.4	11.9	1.44	12.1	756
Halten	5-7.4	9.5	0.73	7.7	50	6.4	10.7	1.32	12.3	42	31.3-1.4	10.6	0.81	7.6	835
"	18-19.4	12.4	1.21	9.8	190	16-17.4	14.5	1.70	6.3	107	9-10.4	12.5	1.12	9.0	56
Sklinna	6-7.4	9.8	1.11	11.3	139	17-19.4	11.4	2.57	22.5	144	2.4	10.1	0.30	3.0	14
"	18-19.4	11.9	0.97	8.2	139	2.5	16.1	4.42	27.5	45	7-8.4	11.9	1.47	12.4	38
Træna	16-17.4	11.7	0.77	6.6	56	10.4	13.2	1.31	9.9	29					
						19-20.4	12.6	2.67	21.2	185					
Lofoten						10.4	12.9	1.96	15.2	37	3-4.4	9.5	0.97	10.2	132
						20-22.4	11.0	2.32	21.1	503	6-7.4	10.5	1.01	9.6	103
						29-30.4	13.4	3.08	23.0	104					
Eggum-Andenes						20.4	11.5	2.07	18.0	84	5-6.4	10.9	1.11	10.2	110
						26-27.4	13.5	2.22	16.4	78					
						27-29.4	12.5	1.65	13.2	290					

Table 26. Summary showing the number of drift bottles released during the experiments in 1961-1963 and 1965 and distribution of returns according to area.

Release				Return										Total	
Area	Year	Date	No.	07		06		05		04		03			
				No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
07	1961	22-24.2	10	5	50.0	3	30.0	-	-	-	-	-	-	8	80.0
"	1963	7-8.4	23	-	-	-	-	8	34.8	3	13.0	1	4.4	12	52.2
"	1964	14-16.4	25	5	20.0	8	32.0	4	16.0	4	16.0	-	-	21	84.0
"	1965	30-31.3 11.4	20	4	20.0	9	45.0	2	10.0	3	15.0	-	-	18	90.0
06	1963	5-7.4	20			-	-	4	20.0	3	15.0	3	15.0	10	50.0
"	1964	17-19.4	20			3	15.0	3	15.0	7	35.0	-	-	13	65.0
"	1965	2-9.4	16			5	31.3	1	6.2	1	6.2	-	-	7	43.8
05	1963	3-4.4	10					4	40.0	-	-	1	10.0	5	50.0
"	1964	20-27.4	15					1	6.7	4	26.6	-	-	5	33.3
"	1965	3.4	10					4	40.0	-	-	-	-	4	40.0

Table 27. Average drifting distance (in nautical miles) for bottles recovered in different periods after release. Bottles recovered more than one year after release are omitted.

Release		Average drifting distance per bottle recovered											
Year	Area	Between 1 and 45 days			Between 46 and 90 days			Between 91 and 180 days			Between 181 and 360 days		
		Total	Per day	No. of returns	Total	Per day	No. of returns	Total	Per day	No. of returns	Total	Per day	No. of returns
1961	07	86	8.7	8	-	-	-	-	-	-	-	-	-
1963	07	-	-	-	307	4.2	3	404	3.0	4	653	3.2	3
"	06	-	-	-	315	5.1	1	323	3.1	4	508	2.0	2
"	05	34	1.9	4	375	5.2	1	-	-	-	-	-	-
1964	07	146	4.9	7	180	3.1	4	337	2.3	5	198	0.9	2
"	06	113	5.2	2	405	7.8	4	356	3.1	5	90	0.3	2
"	05	-	-	-	240	3.5	3	150	1.5	1	-	-	-
1965	07	72	7.8	5	68	1.0	3	274	2.5	4	75	0.4	2
"	06	20	1.8	2	220	3.3	2	-	-	-	213	1.1	2
"	05	80	2.8	3	-	-	-	-	-	-	220	1.2	1

Table 28. Returns of bottles according to near-shore and off-shore releases.

Year of release	Near-shore release		Return	Off-shore release		Return	Near-shore release		Return	Off-shore release		Return	Near-shore release		Return	Off-shore release		Return
	Area/Locality	No.	No. %	Area/Locality	No.	No. %	Area/Locality	No.	No. %	Area/Locality	No.	No. %	Area/Locality	No.	No. %	Area/Locality	No.	No. %
1961	07/06.07	10	8 80.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1963	07/19,24	14	8 57.1	07/15,23	9	4 44.4	06/10,16	10	5 50.0	06/14,29	10	5 50.0	05/29	5	3 60.0	05/12	5	2 40.0
1964	07/05,19,24	15	12 80.0	07/18,23	10	9 90.0	06/10,16	10	8 80.0	06/14,26	10	5 50.0	05/04,19	10	3 30.0	05/08	5	2 40.0
1965	07/07,24	10	9 90.0	07/18	10	9 90.0	06/06,27	10	7 70.0	06/14	5	-	05/03	10	4 40.0	-	-	-

Table 29. Parameters of suspected importance for the development of numerous year-classes in the Norwegian spring spawning stock during the period 1959-1965.

Parameters	Area	1959	1960	1961	1962	1963	1964	1965
Spawning period	07	Long	Long	Long	Moderate	Moderate	Moderate	Moderate
	05	-	-	-	-	Short	Short	Moderate
Shape of spawning curve	07	Broad	Narrow/ Moderate	Narrow/ Moderate	Narrow	?	Moderate	Moderate
	05	-	-	-	-	Narrow	Narrow	Narrow
Median of hatching period, reference 1959	07	Normal	Normal/ Late	Normal/ Late	Late	Late	Early	Early
	05	-	-	-	-	Late	Late	Early
Extension of spawning area	08	Moderate	-	-	-	-	-	-
	07	Large	Large	Large	Moderate	Moderate	Moderate	Moderate
	06	Large	Large	Large	Large	Large	Moderate	Large
	05	?	?	?	?	Small	Moderate	Large
Displacement northward of spawning centre, reference 1959	07	None	Little	Little	Little	Significant	Significant	Significant
	06	None	None	None	None	None	None	None
	05	-	-	-	-	None	None	Little
Drifting speed north-ward March May	07 06	Strong (offshore)	Strong	Strong Weak (near-shore March)	Weak (change-able)	Moderate (offshore)	Moderate	Weak (change-able)
Average age of recruits	07	High	High	High	High	Moderate	Low	Low
	05	-	-	-	-	Low	Low	Low

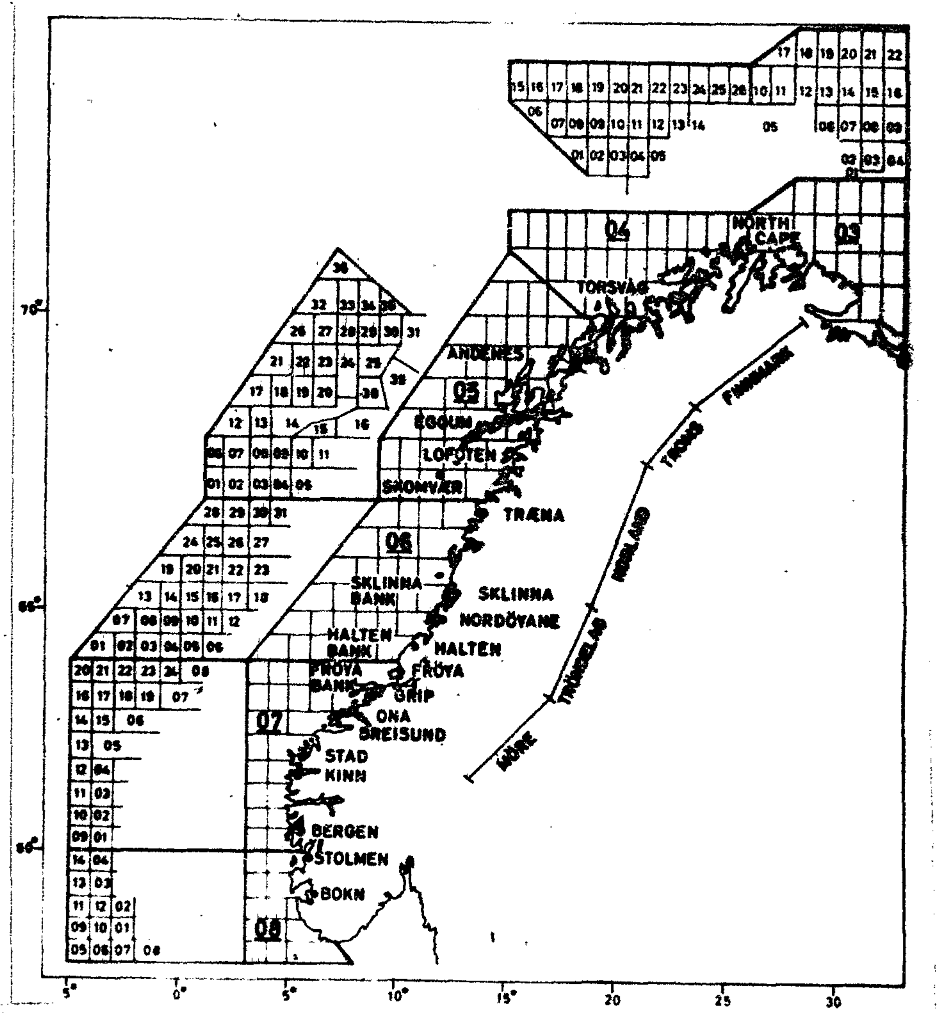

Fig. 1 Approximate positions of geographical names mentioned in the text and the code for area breakdown (left).

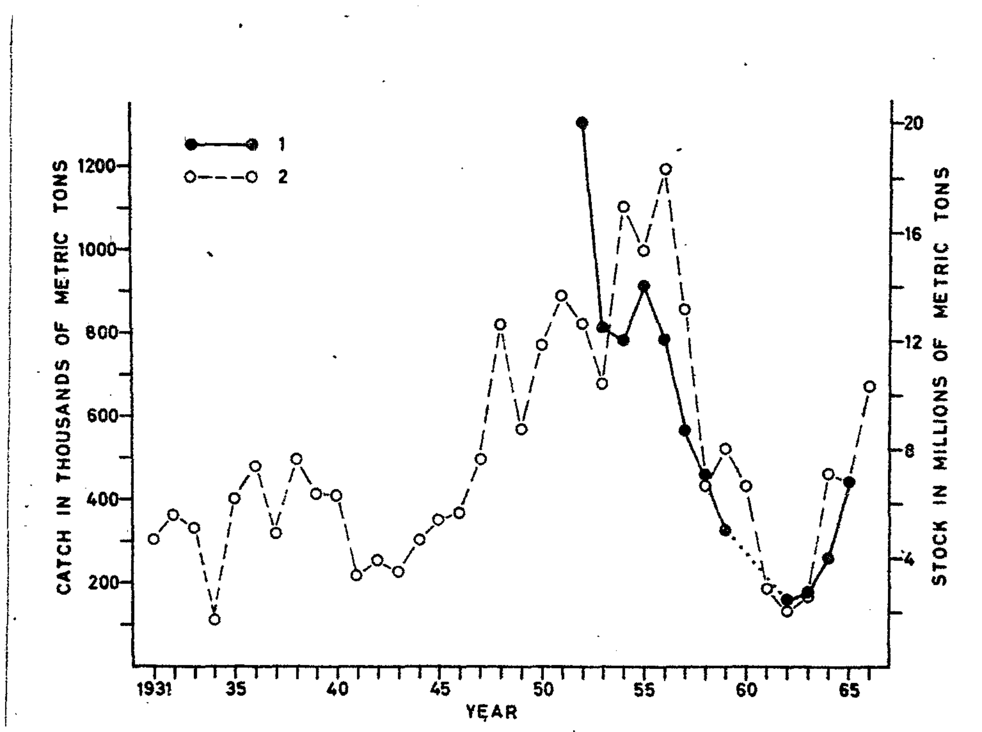

Fig. 2 (1) estimated stock size of Norwegian spring spawners during the period 1952-1965 and (2) annual catches taken by Norway and U.S.S.R during the winter herring fishery 1931-1966.

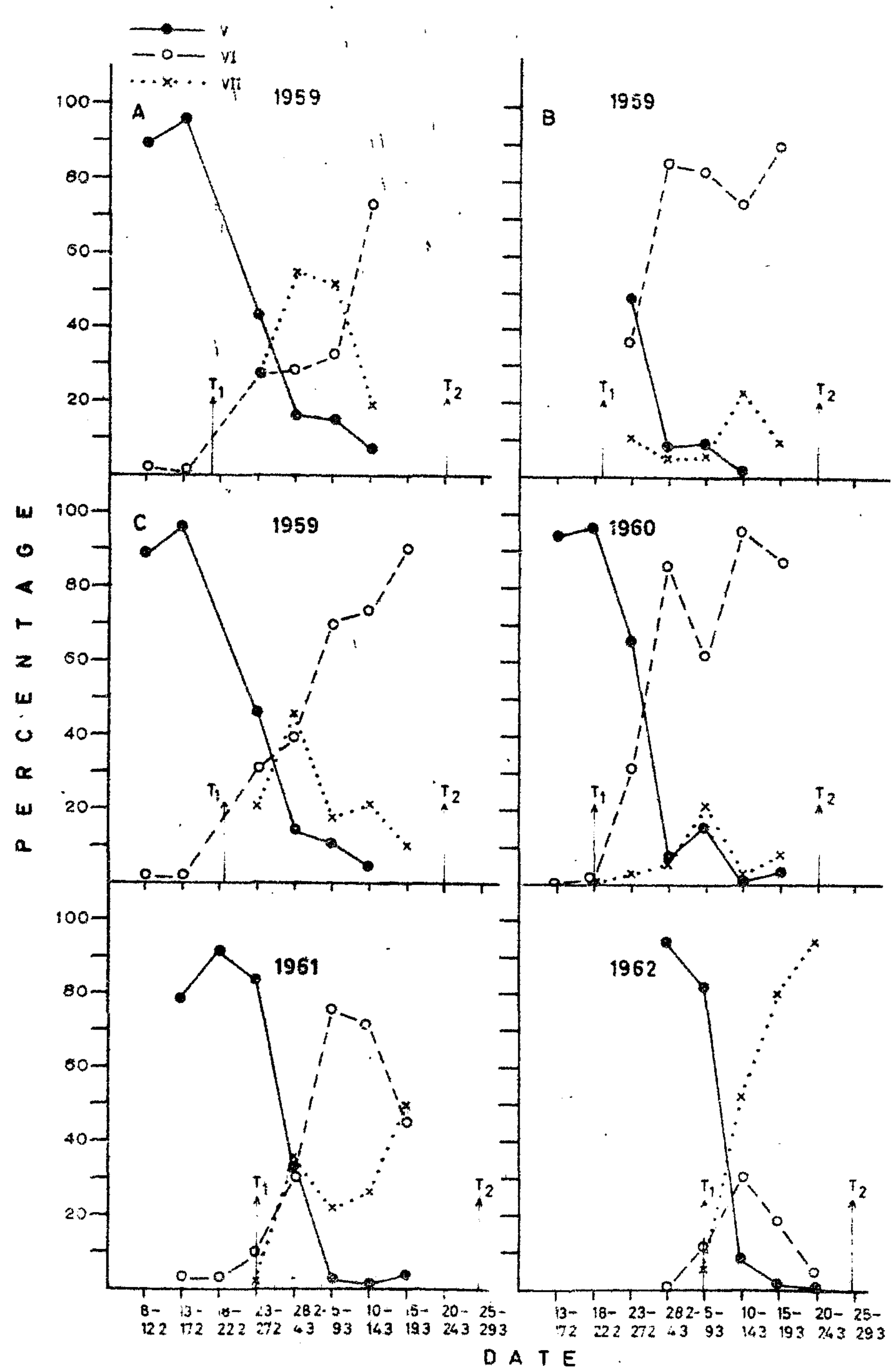

Fig.3 Percentage maturity composition (stages V-VII) of winter-herring in different districts (males and females pooled) according to 5 days period during the seasons 1959-1962. 1959 A: $\frac{07}{04,06,07,}$ B: $\frac{08}{03,04,}$ C: A and B pooled, 1960: $\frac{07}{01,05,06,07}$ 1961: $\frac{07}{05,06,07,}$ 1962: $\frac{07}{05,06,07.}$ T_1 and T_2 are time of commencement and end of spawning.

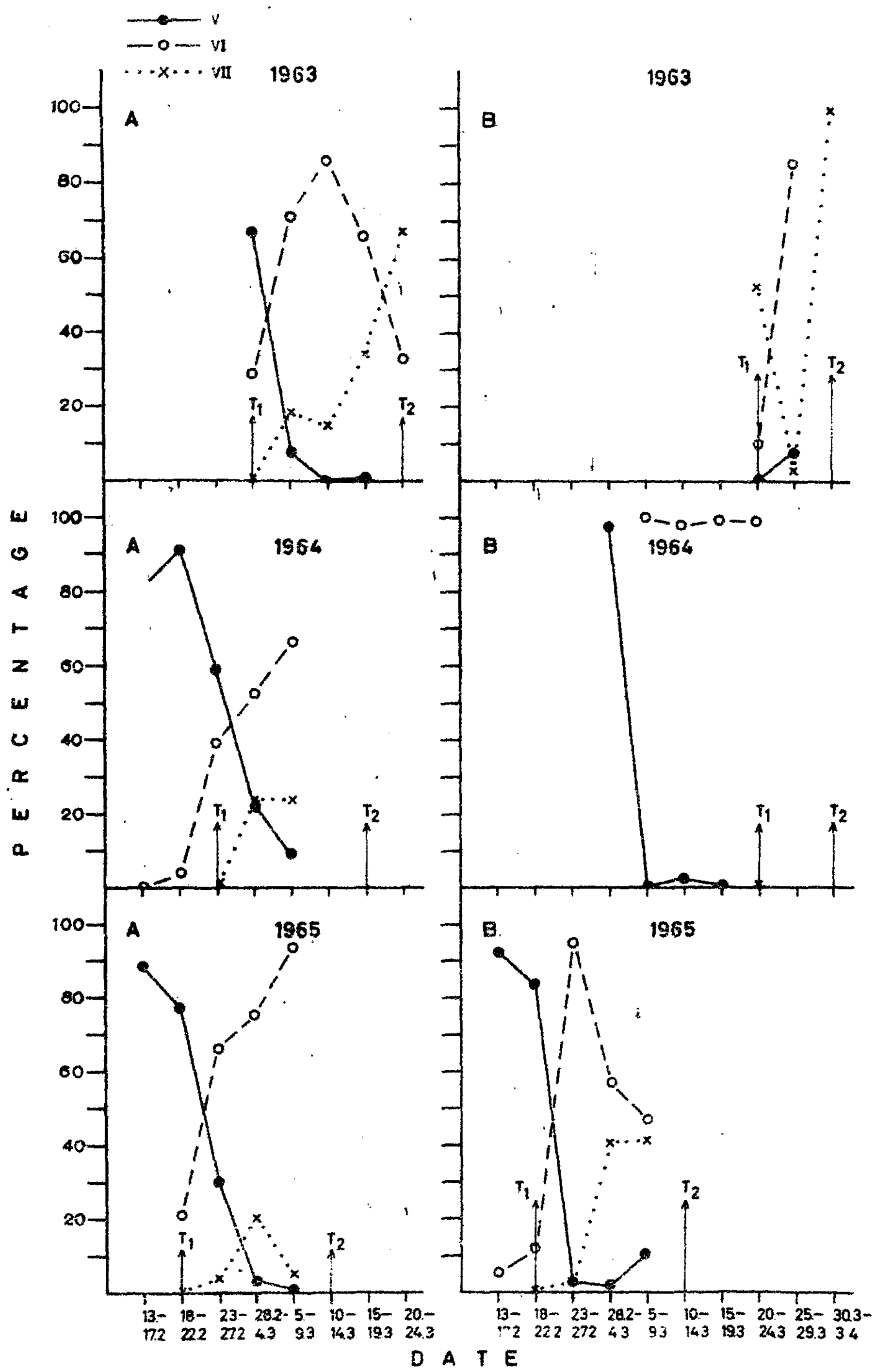

Fig. 4 Percentage maturity composition (stages V-VII) of winter-herring in different districts (males and females pooled) according to 5 days period during the seasons 1963-1965.

1963 A: $\frac{07}{05,06,07,08,}$ B: $\frac{05}{03,04,09,}$ 1964 A: $\frac{07}{06,07,08,}$ B: $\frac{05}{03,04,09,10,14,}$ 1965 A: $\frac{07}{06,07\ ,}$ B: $\frac{05}{03,05,09,}$

Legend Fig. 3.

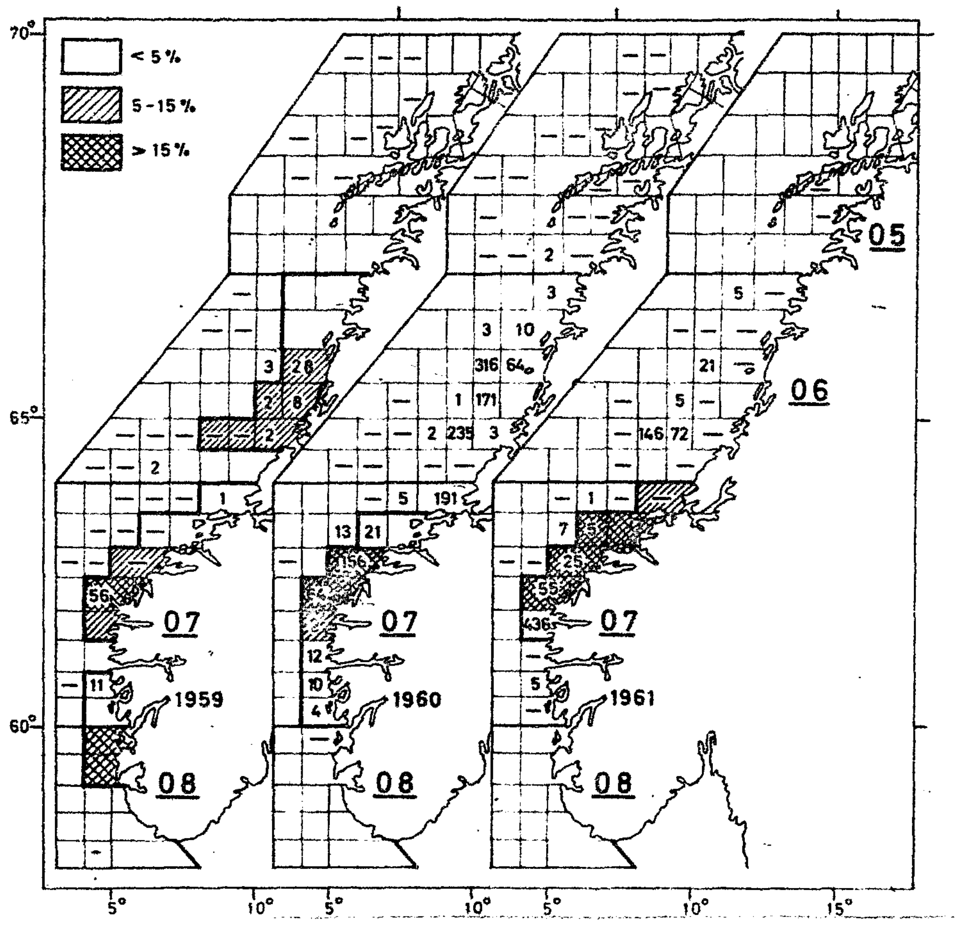

Fig. 5 Relative distribution of herring catches (spawning and spent fish) during the period 1959-1961 and distribution of larvae with yolk sac. The figures in rectangles are number of larvae per m^2 surface. Negative hauls are marked with a stroke and in rectangles where no hauls were taken are left blank. The 1959 survey represent the period 2-21 April, 1960,25 March-9 April and 1961, 6-19 April. The code for the area breakdown is shown in Fig. 1.

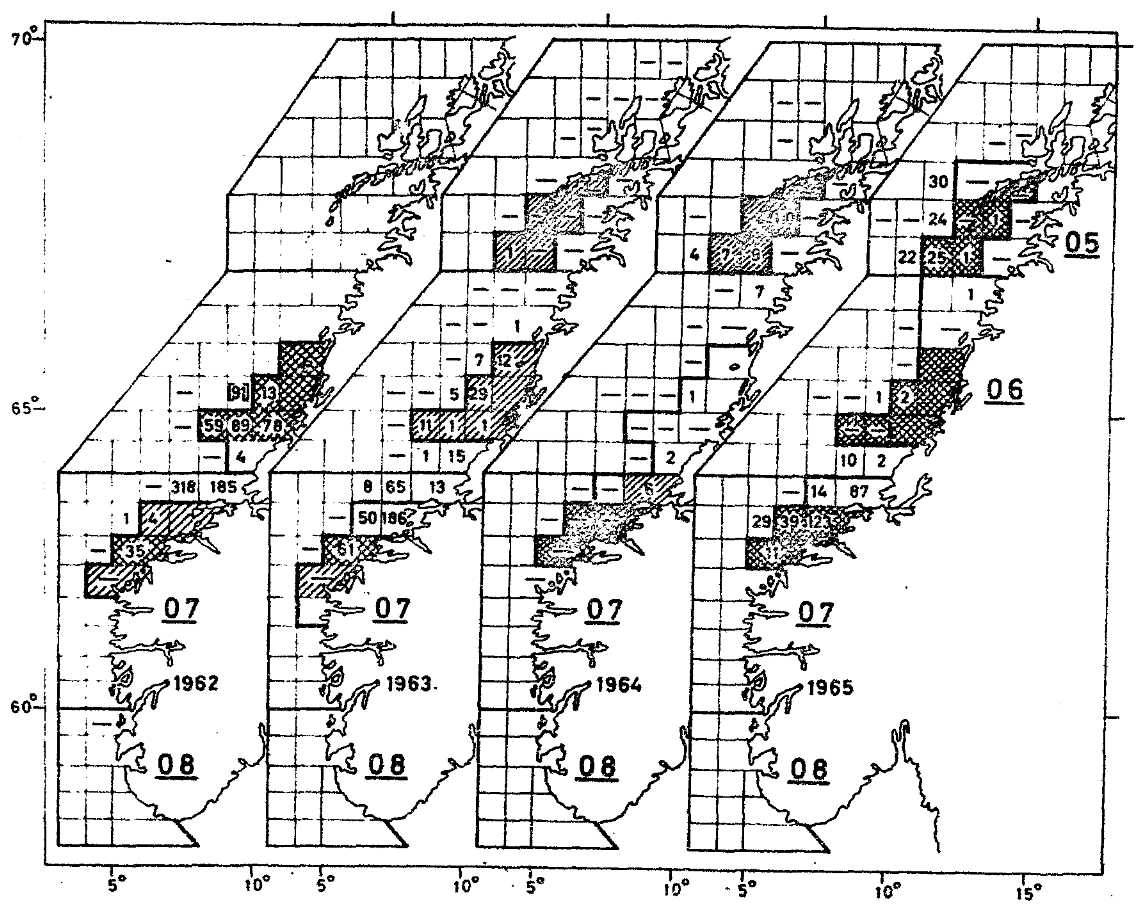

Fig. 6 Relative distribution of herring catches (spawning and spent fish) during the period 1962-1965 and distribution of larvae with yolk sac. The 1962 survey represent the period 2-13 April, 1963, 2-10 April, 1964,14-24 April and 1965, 29 March-5 April. Legend Fig. 5.

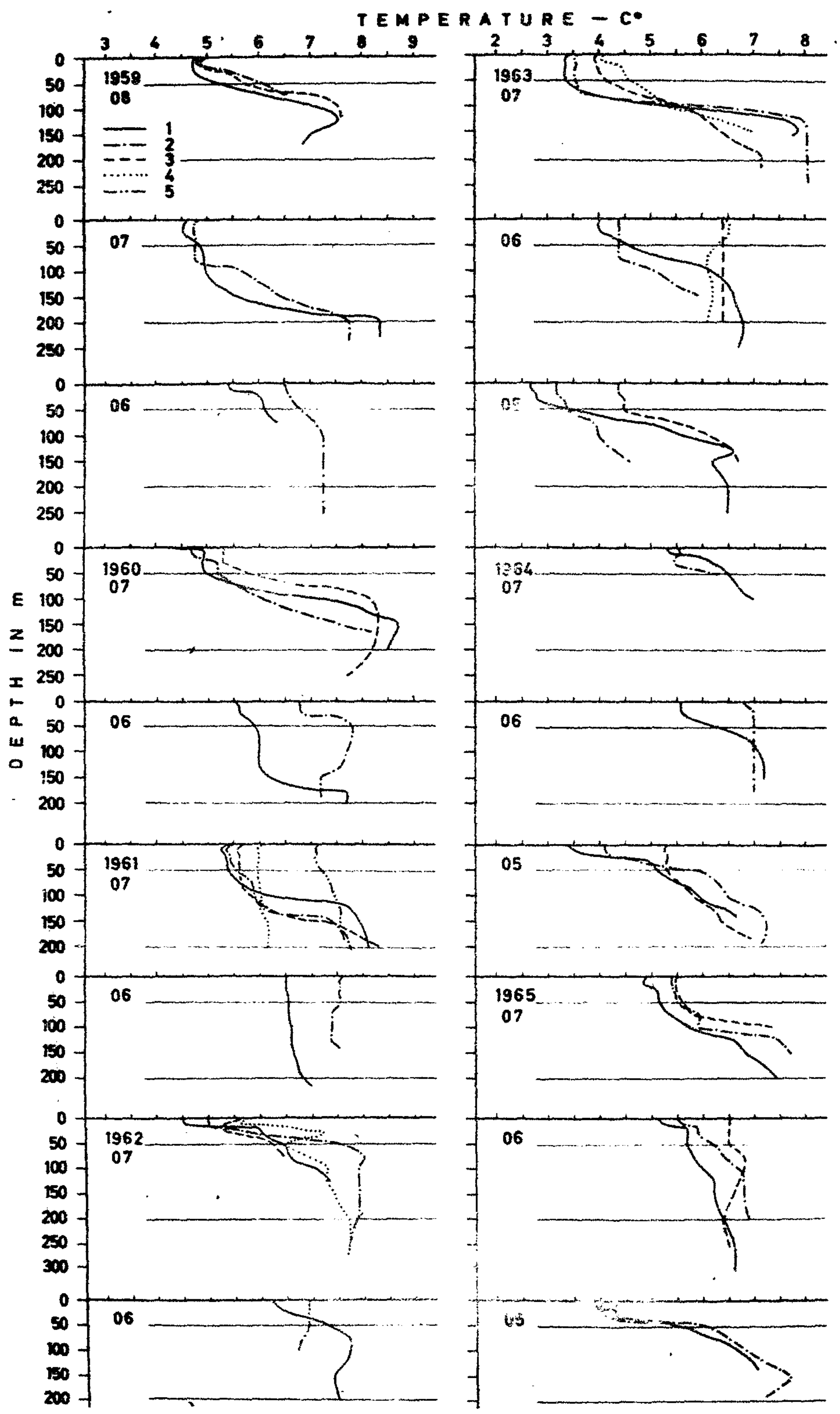

Fig. 7 Vertical distribution of temperature in different localities.
Legends: 1959 area 08 Bokn-Stalmen 1) 6 March 2) 5 March 3) 6 March, 1959 area 07 Kinn-Stad 1) 17 February 2) 19 February, 1959 area 06 off Sklinna 1) 13 April 2) 13 April, 1960 area 07 Stad-Frøya 1) 16 February 2) 9 March, 1960 area 06 Halten-Sklinna 1) 10 March 2) 10 March, 1961 area 07 Kinn-Ona 1) 4 March 2) 7 March 3) 7 March 4) 8 March 5) 8 March, 1961 area 06 Halten-Sklinna 1) 12 March 2) 9 March, 1962 area 07 Stad-Ona 1) 3 March 2) [illegible] March 3) 6 March 4) 1 March, 1962 area 06 Halten-Sklinna 1) 5 March 2) 30 March, 1963 area 07 Stad-Grip 1) 1 March 2) 2 March 3) 5 March 4) 4 March, 1963 area Halten-Sklinna 1) 6 April 2) 6 April 3) 6 April 4) 7 April, 1963 area 05 off Lofoten 1) 5 April 2) 4 April 3) 4 April, 1964 area 07 off Frøya 1) 24 March 2) 24 March, 1964 area 06 Halten-Sklinna 1) 23 March 2) 23 March, 1964 area 05 off Lofoten 1) 23 March 2) 22 March 3) 22 March, 1965 area 07 Stad-Frøya 1) 6 March 2) 5 March 3) 4 March, 1965 area 06 Halten-Sklinna 1) 1 April 2) 2 April 3) 1 April and 1965 area 05 off Lofoten 1) 1 March 2) 1 March.

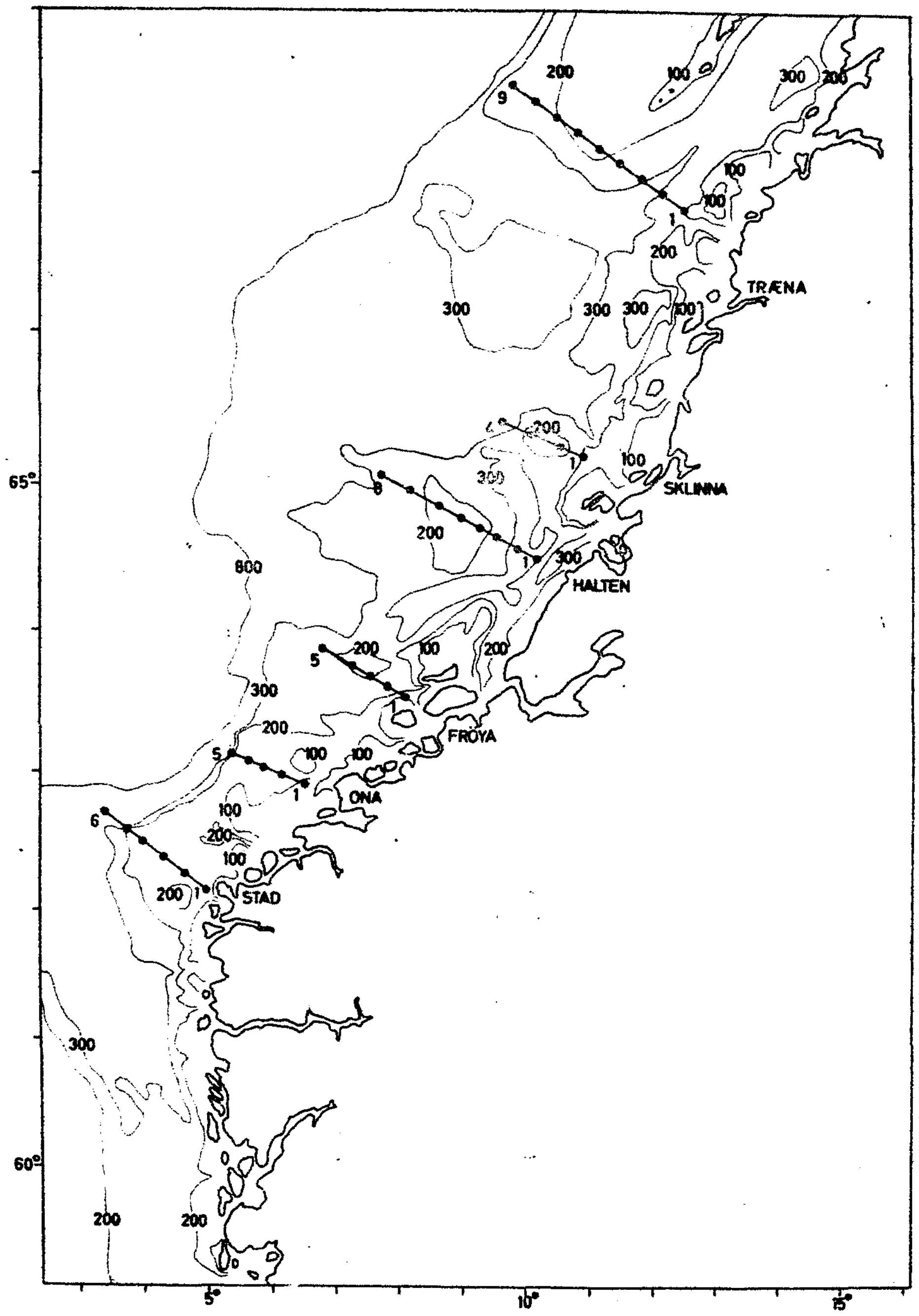

Fig. 8 Bathy-metrical features of the coastal banks between Bokn and Lofoten (depths in m). The location of six of the standard sections where larvae sampling were carried out are also illustrated. The stations in each section are numbered seaward.

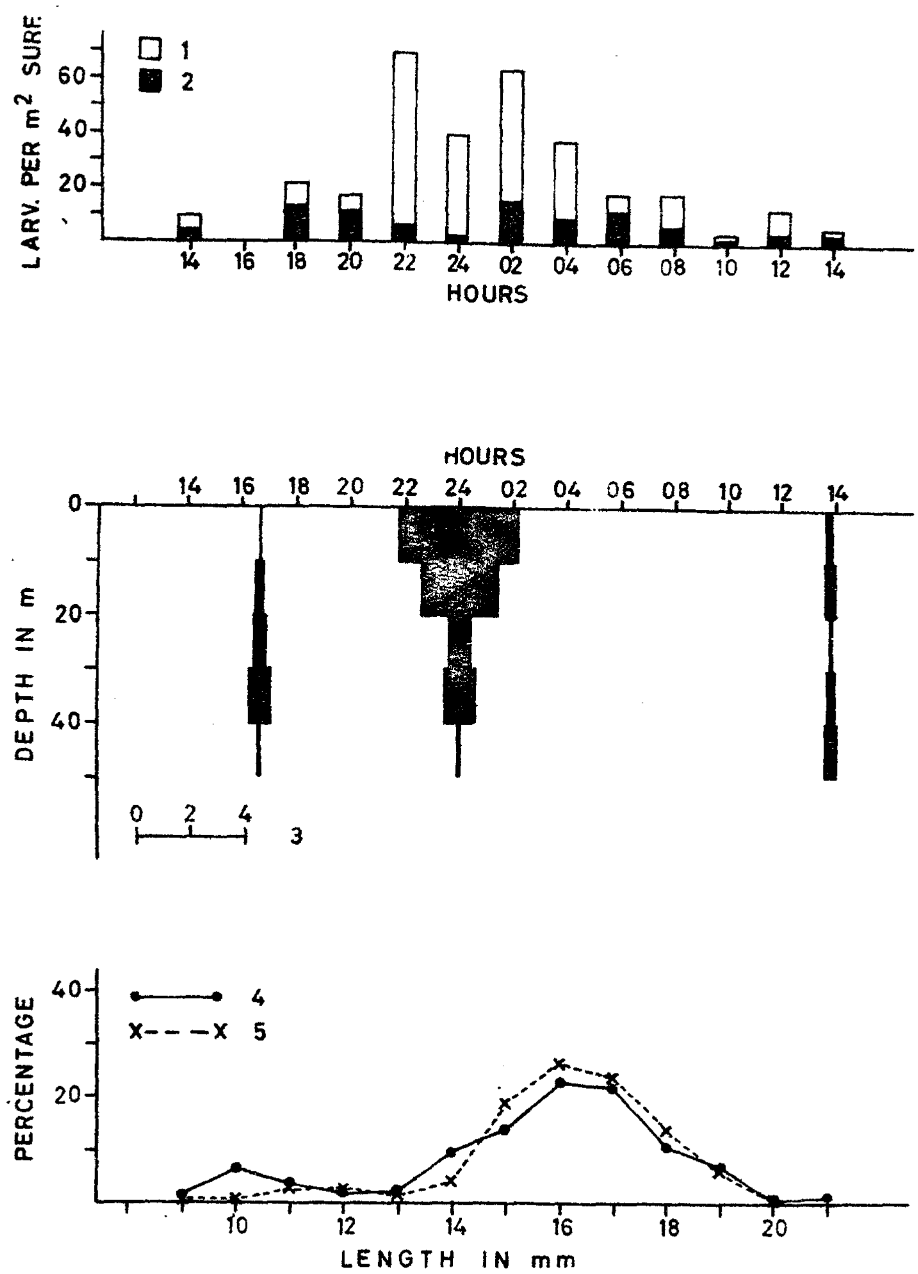

Fig. 9 Number of Larvae per m^2 surface caught in oblique hauls with Clarke-Bumpus plankton samplers at drift station 1, off Sklinna $\frac{06}{26}$ (above), vertical distribution of larvae per m^3 in 10 m layers at the same station (in the middle) and (below) the length distributions of larvae caught with Clarke-Bumpus plankton samplers during day and night (hours 2108-0517). Legends: (1) 25-5 m, (2) 50-30 m, (3) scale for larvae per m^3, (4) day and (5) night.

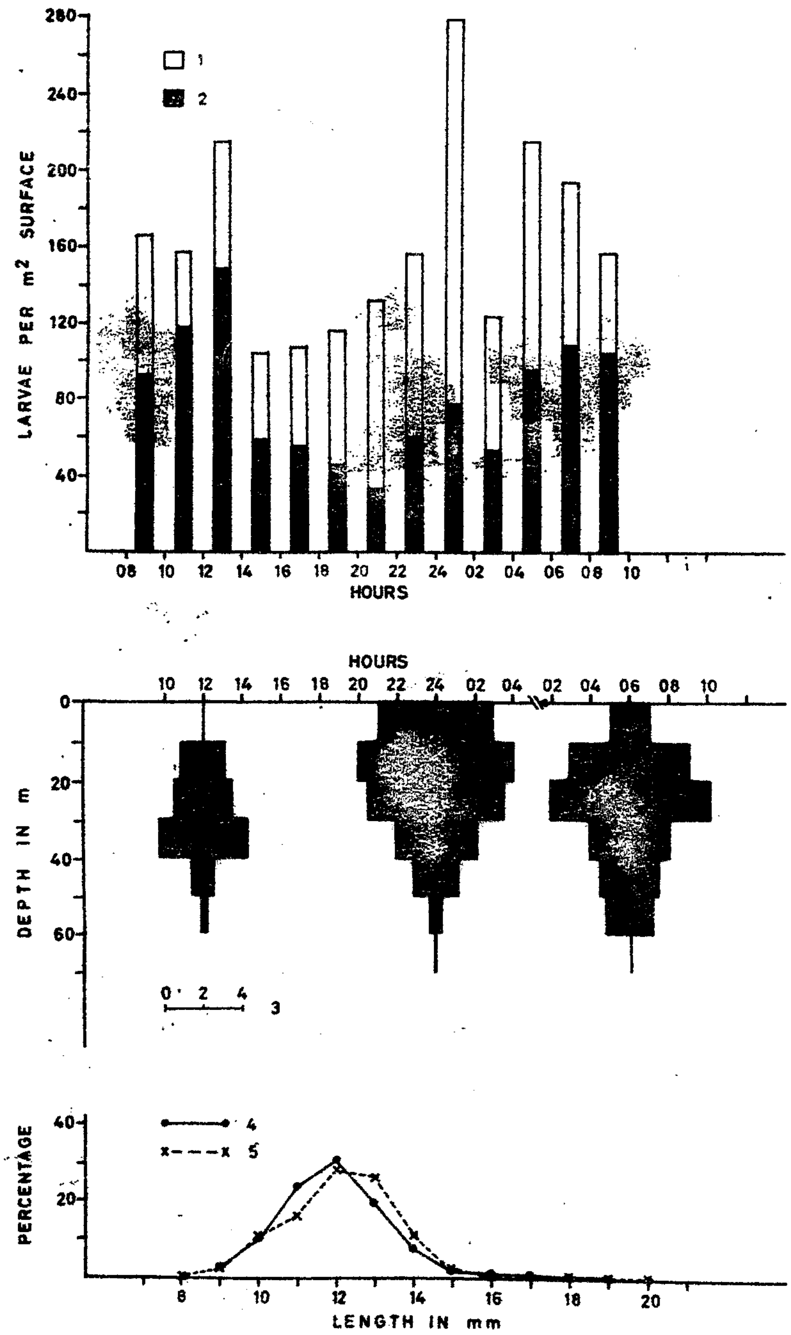

Fig. 10 Number of larvae per m^2 surface caught in oblique hauls with Clarke-Bumpus palnkton samplers at drift station 2, off Eggum, $\frac{05}{14}$ (above), vertical distribution of larvae per m^3 in 10 m layers at the same station (in the middle) and (below) the length distributions of larvae caught with Clarke-Bumpus plankton samplers during day and night (hours 2155-0446). Legend Fig. 9.

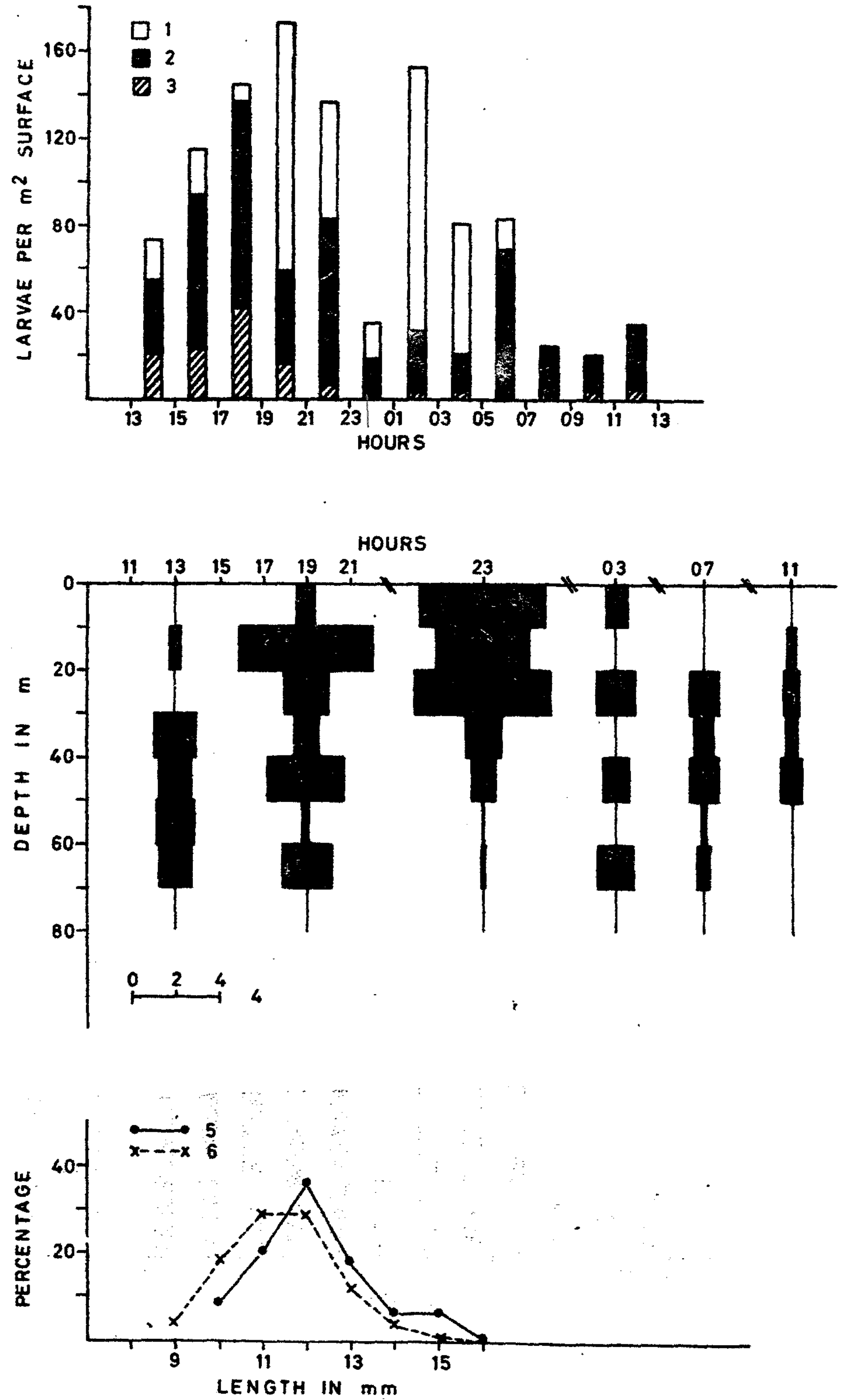

Fig. 11 Number of larvae per m^2 surface caught in oblique hauls with Clarke-Bumpus plankton samplers at drift station 3, off Frøya $\frac{07}{06}$ (above), vertical distribution of larvae per m^3 in 10 m layers at the same station (in the middle) and (below) the length distributions of larvae caught with Clarke-Bumpus plankton samplers during day and night (hours 2031-0615). Legend Fig. 9.

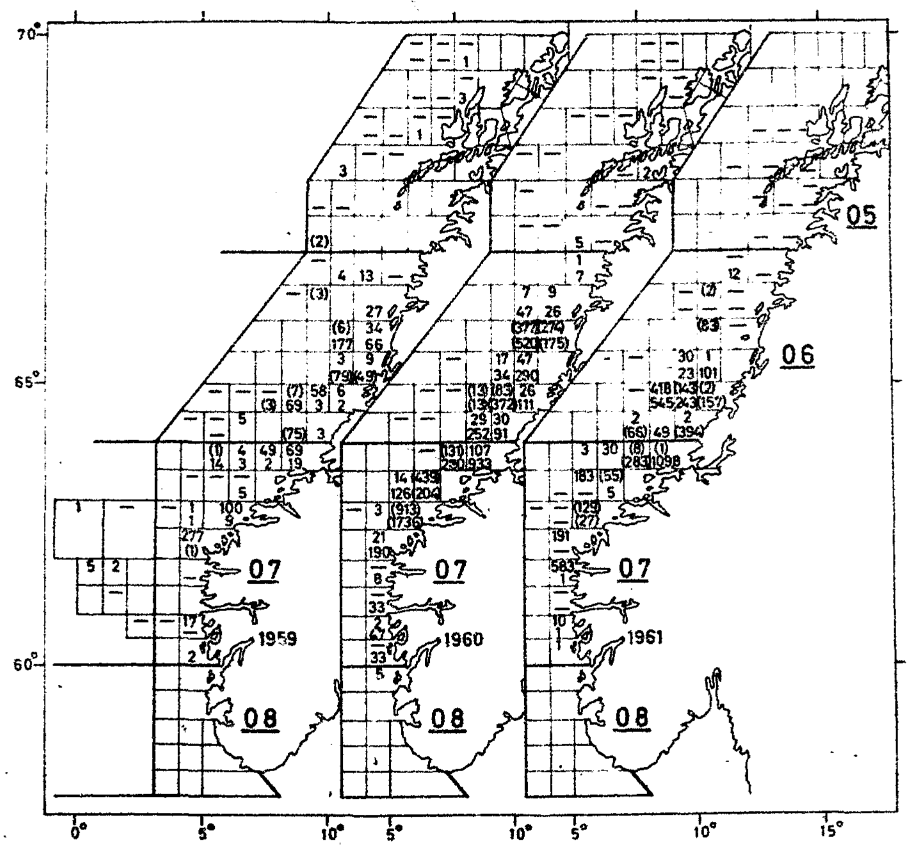

Fig. 12 Distribution of larvae per m^2 surface in the different localities, 1959-1961. Where more than half of the stations fell in the dark period figures are put in brackets. The 1959 survey represents larvae caught in vertical hauls with Nansen net 2-21 April (above) and with Clarke-Bumpus plankton samplers 20-28 April (below). In 1960 the figures represent larvae caught in vertical hauls with Nansen net 21 March- 7 April (above) and with Clarke-Bumpus plankton samplers 25 March- 9 April (below) and in 1961 with Clarke-Bumpus plankton samplers 6-19 April (above) and 20-29 April (below). The code for area breakdown is shown in Fig. 1.

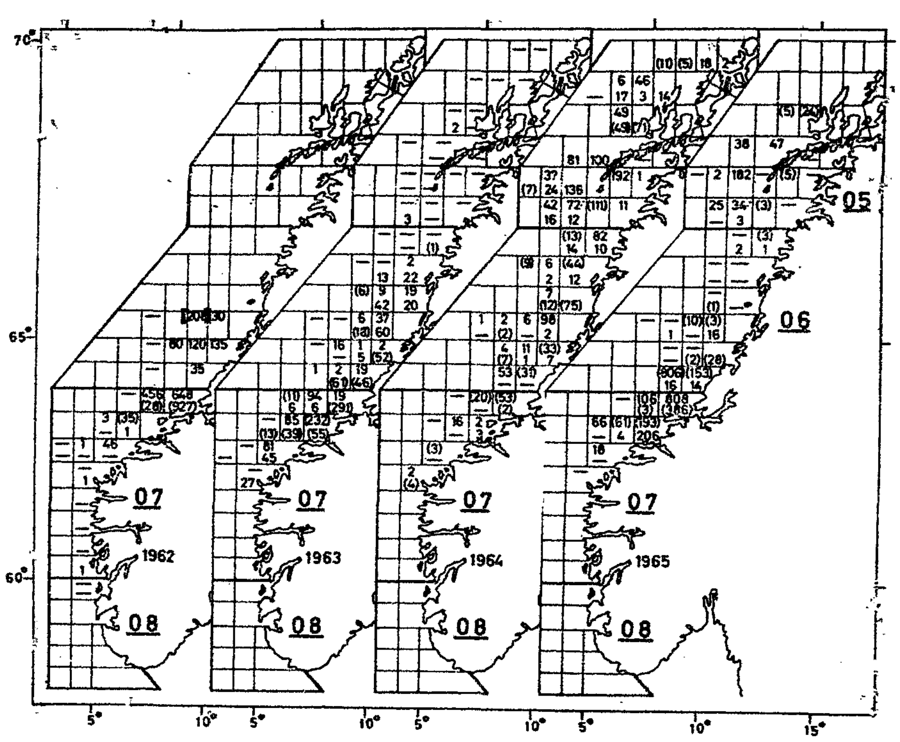

Fig. 13 Distribution of larvae per m^2 surface caught with Clarke-Bumpus plankton samplers in the different localities, 1962-1965. The 1962 surveys covered the period 2-13 April (above) and 24-28 April (below), the 1963 surveys 2-10 April (above) and 13-23 April (below), the 1964 surveys 14-24 April (above) and 26 April-5 May (below) and the 1965 surveys 29 March-5 April (below) and 5-12 April (above). Legend Fig. 12. The larvae in 06 in 1962 were caught with Juday net.

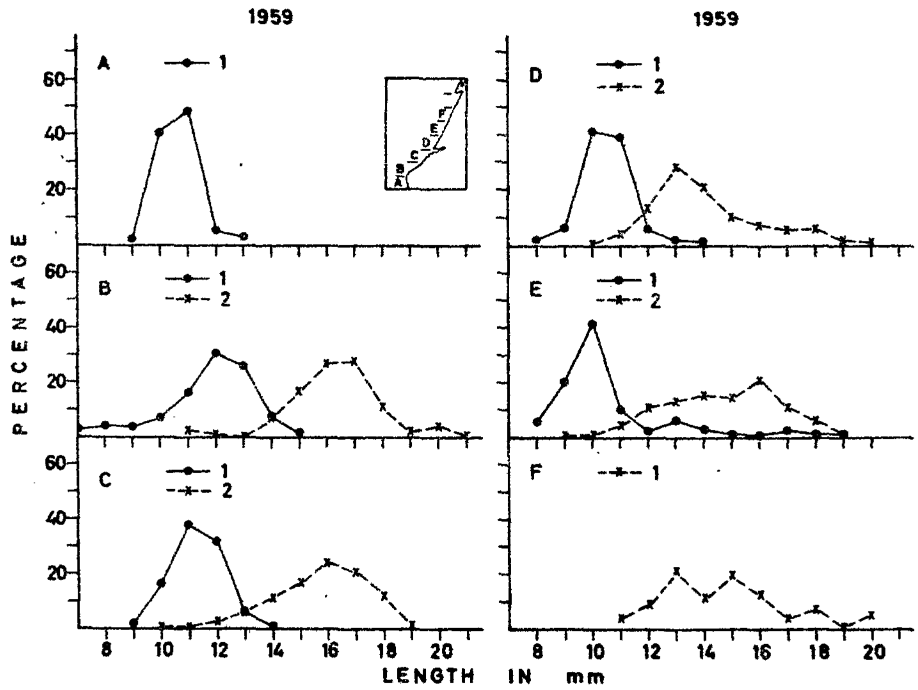

Fig. 14 Length distribution of larvae in different regions during the 1959 survey; .Larvae caught with Clarke-Bumpus plankton samplers and Nansen net are pooled during the second part of the cruise (20-28 April). Prior to this period the larvae were caught with Nansen net. A: Bergen-Kinn (1) 2 April. B: Stad-Ona (1) 5-7 April (2) 25- 26 April. C: Grip-Frøya (1) 8-9 April (2) 25-26 April. D: Halten (1) 11 April (2) 24-25 April. E: Sklinna (1) 13-14 April (2) 23-24 April. F: Træna (1) 20-23 April.

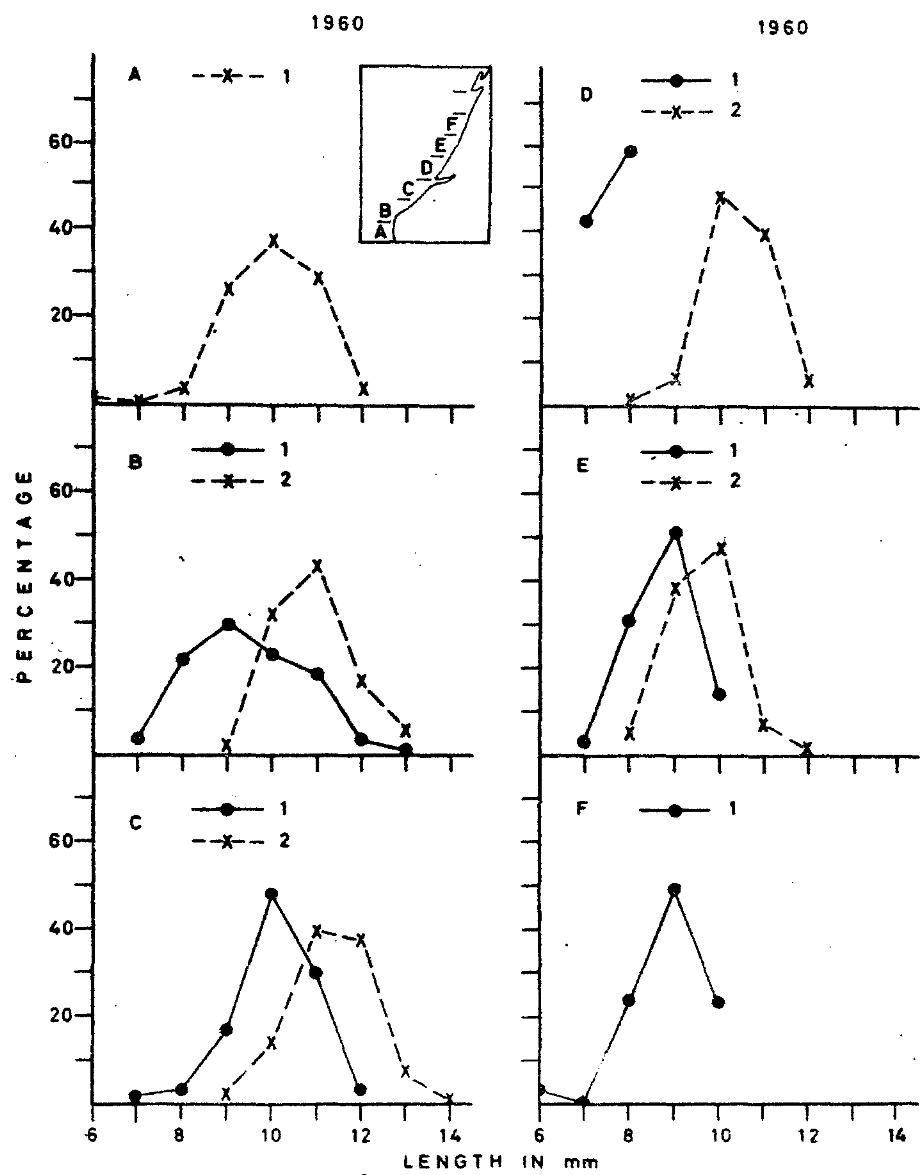

Fig. 15 Length distribution of larvae in different regions during the 1960 survey. The distributions after 26 March represent larvae caught with Clarke-Bumpus plankton samplers, prior to that date, Nansen net. A: Bergen-Kinn (1) 8 April. B: Stad-Ona (1) 23 March (2) 7 April. C: Grip-Frøya (1) 23 March (2) 4-5 April. D: Halten (1) 24 March (2) 3 April. E: Sklinna (1) 25 March (2) 2-3 April. F: Træna(1)28 March.

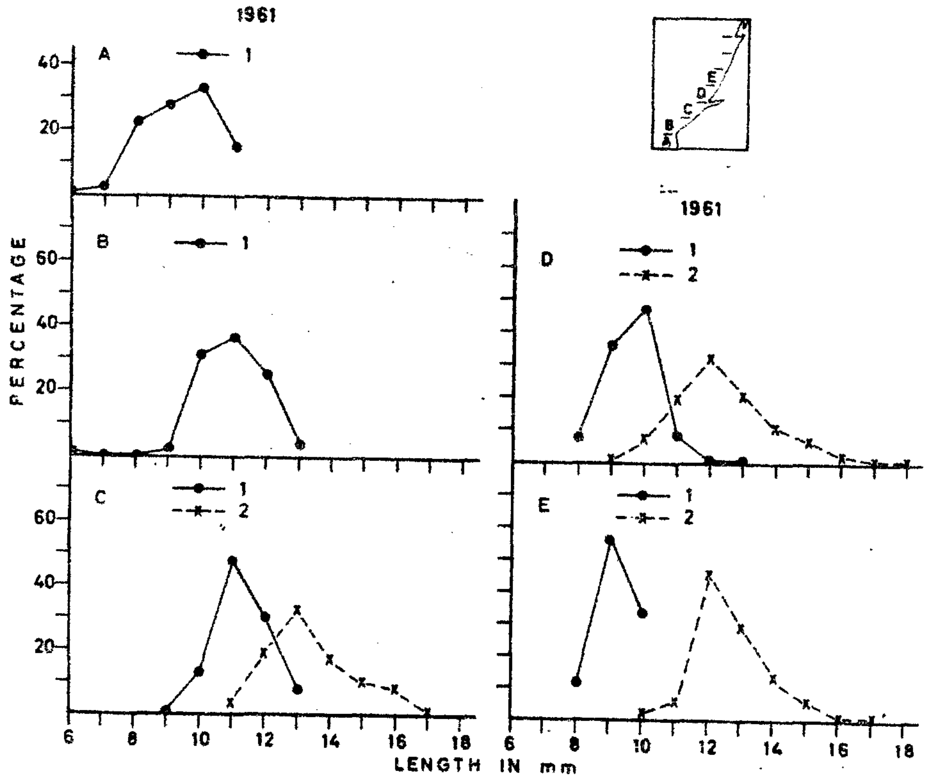

Fig. 16 Length distribution of larvae in different regions caught with Clarke-Bumpus plankton samplers during the 1961 survey. A: Bergen-Kinn (1) 6-7 April. B: Stad-Ona (1) 10-11 April. C: Grip-Frøya (1) 11-12 April (2) 27 April. D: Halten (1) 12 April (2) 25-26 April and E: Sklinna (1) 13 April (2) 25 April.

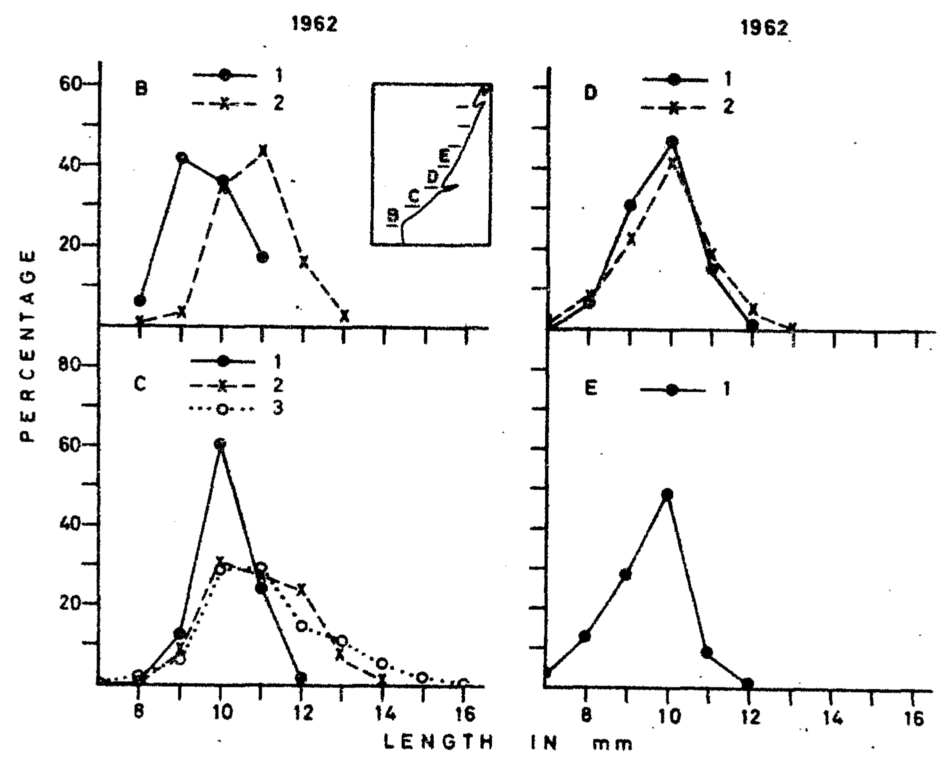

Fig. 17 Length distribution of larvae in different regions caught with Clarke-Bumpus plankton samplers during the 1962 surveys. A: Stad-Ona (1) 4 April (2) 12 April. B: Grip-Frøya (1) 4-5 April (2) 11-12 April (3) 26-27 April. C: Halten (1) 5-6 April (2) 10 April and D: Sklinna (1) 6 April. The larvae caught with the Juday net in the latter region are included.

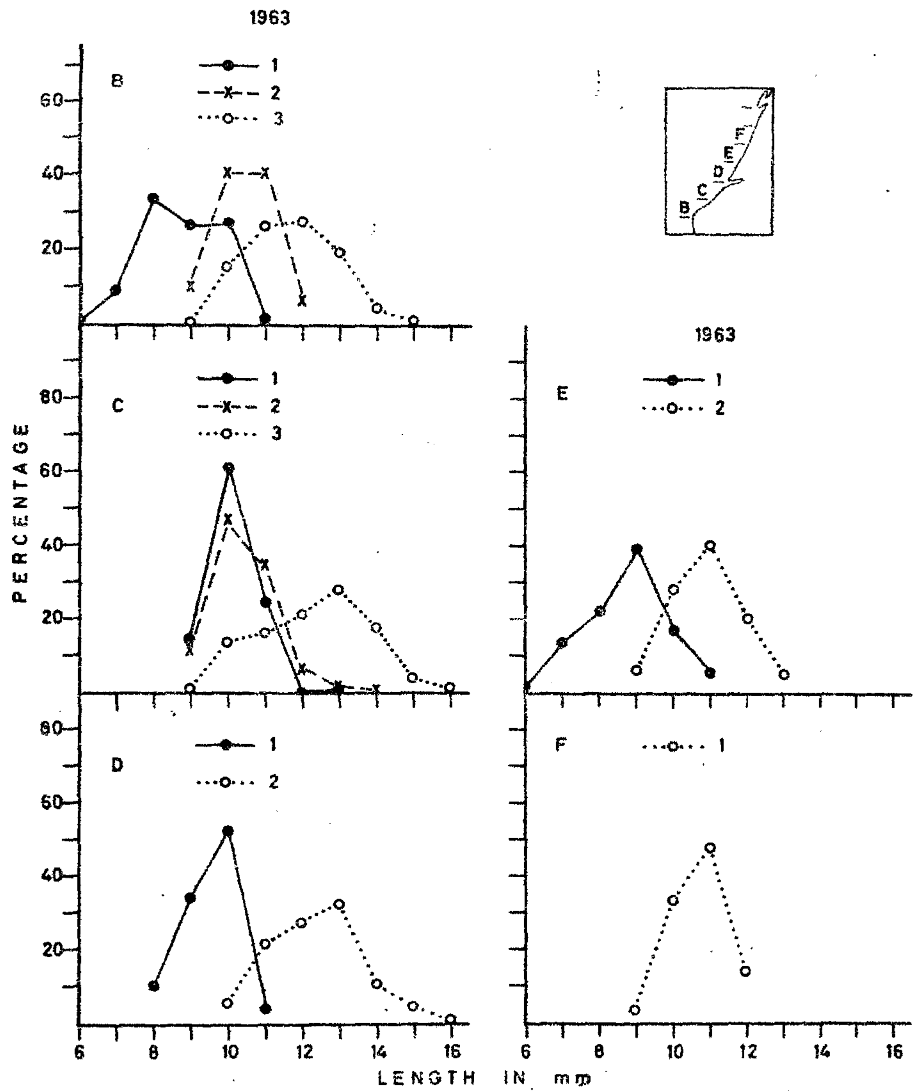

Fig. 18 Length distribution of larvae in different regions caught with Clarke-Bumpus plankton samplers during the 1963 survey. A: Stad-Ona (1) 3 April (2) 8 April (3) 22 April. B: Grip-Frøya (1) 3-4 April (2) 7-8 April (3) 20-22 April. C: Halten (1) 5-7 April (2) 18-19 April D: Sklinna (1) 6-7 April (2) 18-19 April E: Træna (1) 16-17 April.

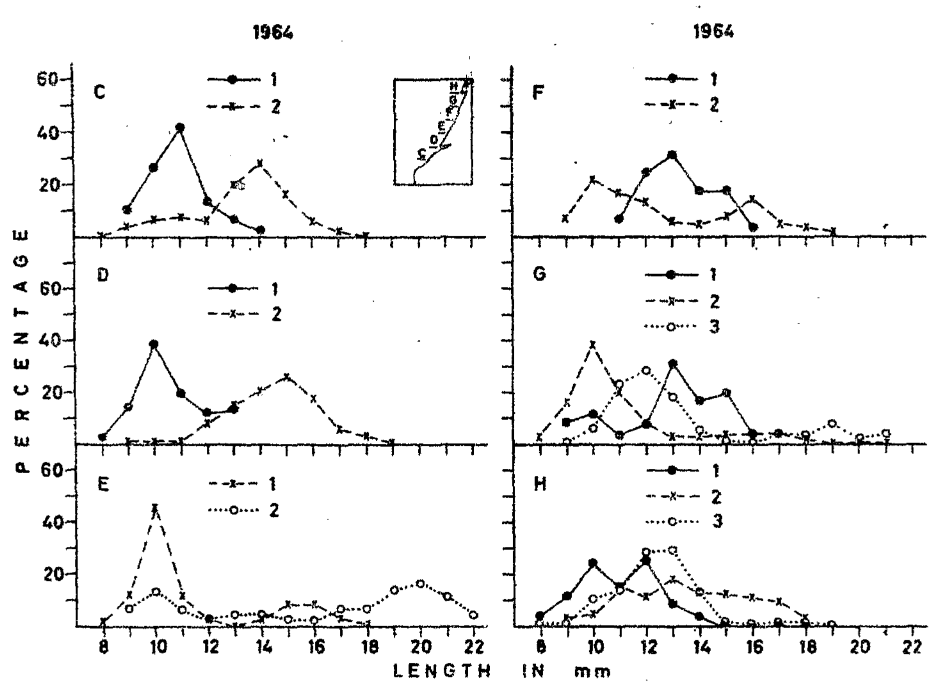

Fig. 19 Length distribution of larvae in different regions caught with Clarke-Bumpus plankton samplers during the 1964 survey. A: Grip-Frøya (1) 2 April (2) 15-16 April. B: Halten (1) 6 April (2) 16-17 April C: Sklinna (1) 17-19 April (2) 2 May. D: Træna (1) 10 April (2) 19-20 April. E: Lofoten (1) 10 April (2) 20-22 April (3) 29-30 April. F: Eggum-Hekkingen (1) 20 April (2) 26-27 April (3) 27-29 April.

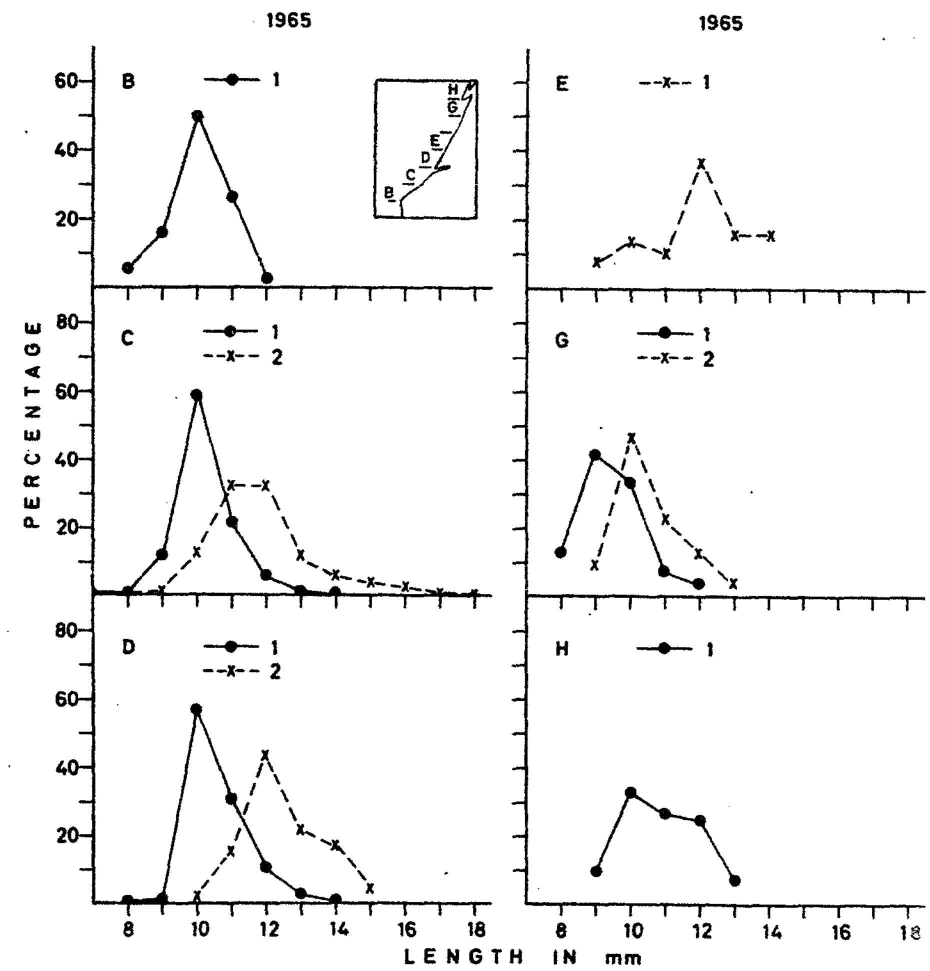

Fig. 20 Length distribution of larvae in different regions caught with Clarke-Bumpus plankton samplers during the 1965 survey. A: Stad-Ona (1) 30 March. B: Grip-Frøya (1) 30-31 March. C: Halten (1) 31 March-1 April (2) 9-10 April. D: Sklinna (1) 7-8 April. E: Lofoten (1) 3-4 April (2) 6-7 April and F: Eggum-Hekkingen (1) 5-6 April.

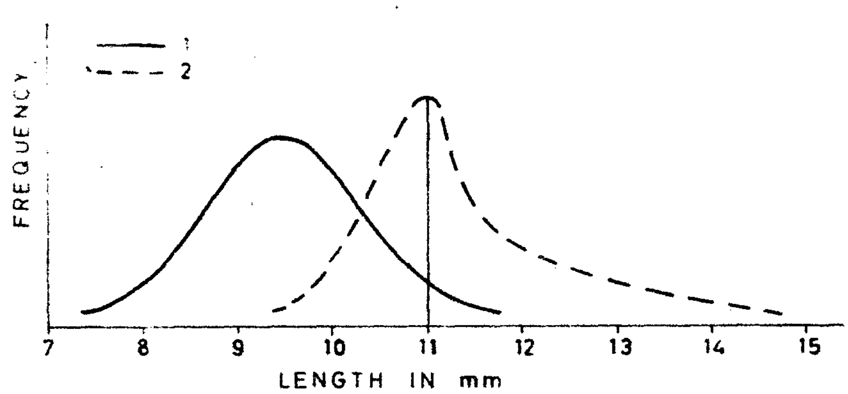

Fig. 21 (1) Schematical illustration of a length distribution where no mortality existed and all larvae were hatched (before the critical stage, i.e. a length of about 11 mm). (2) expected length distribution two-three weeks later when part of the larvae have passed the critical stage.

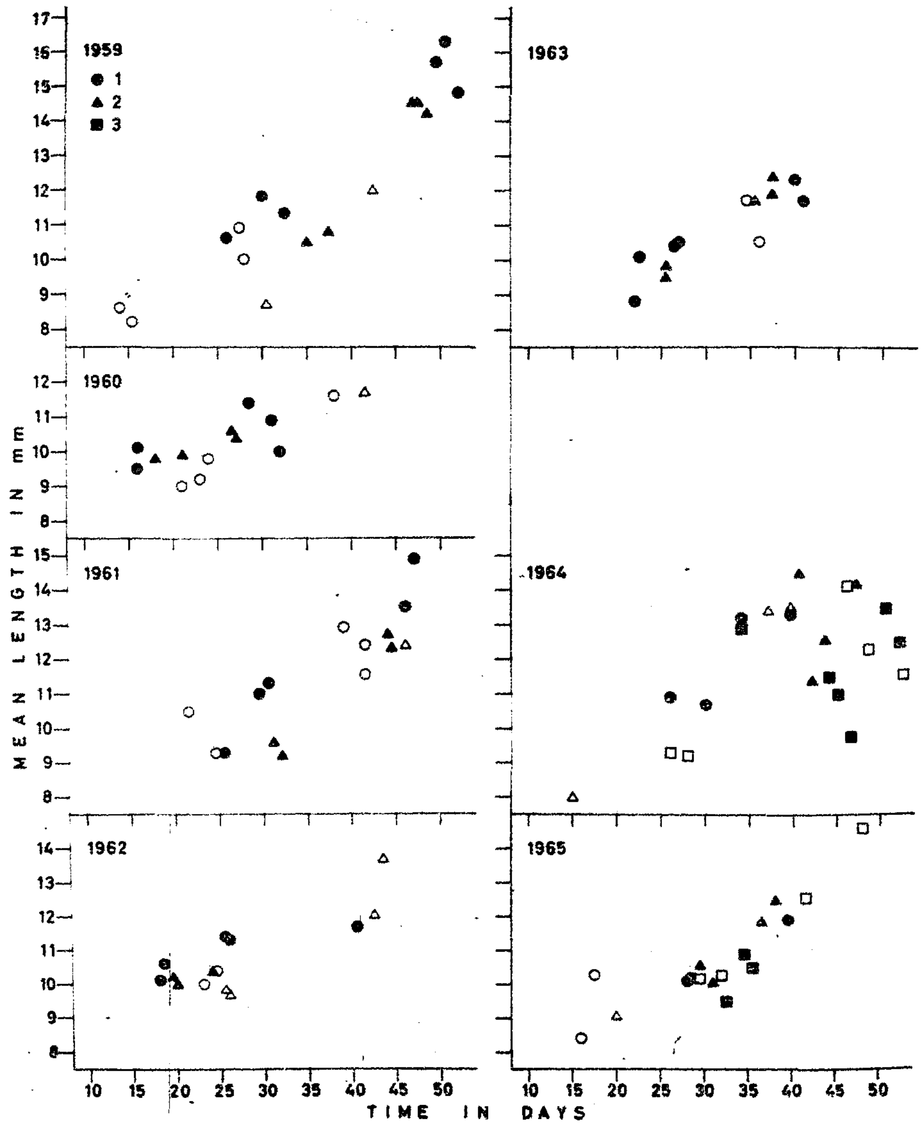

Fig. 22 Mean lengths of larvae plotted against time (reference peak of spawning) during the seasons 1959-1965, (1) area 07, (2) area 06, (3) area 05. Filled symbols refer to Norwegian observations, blank to Soviet.

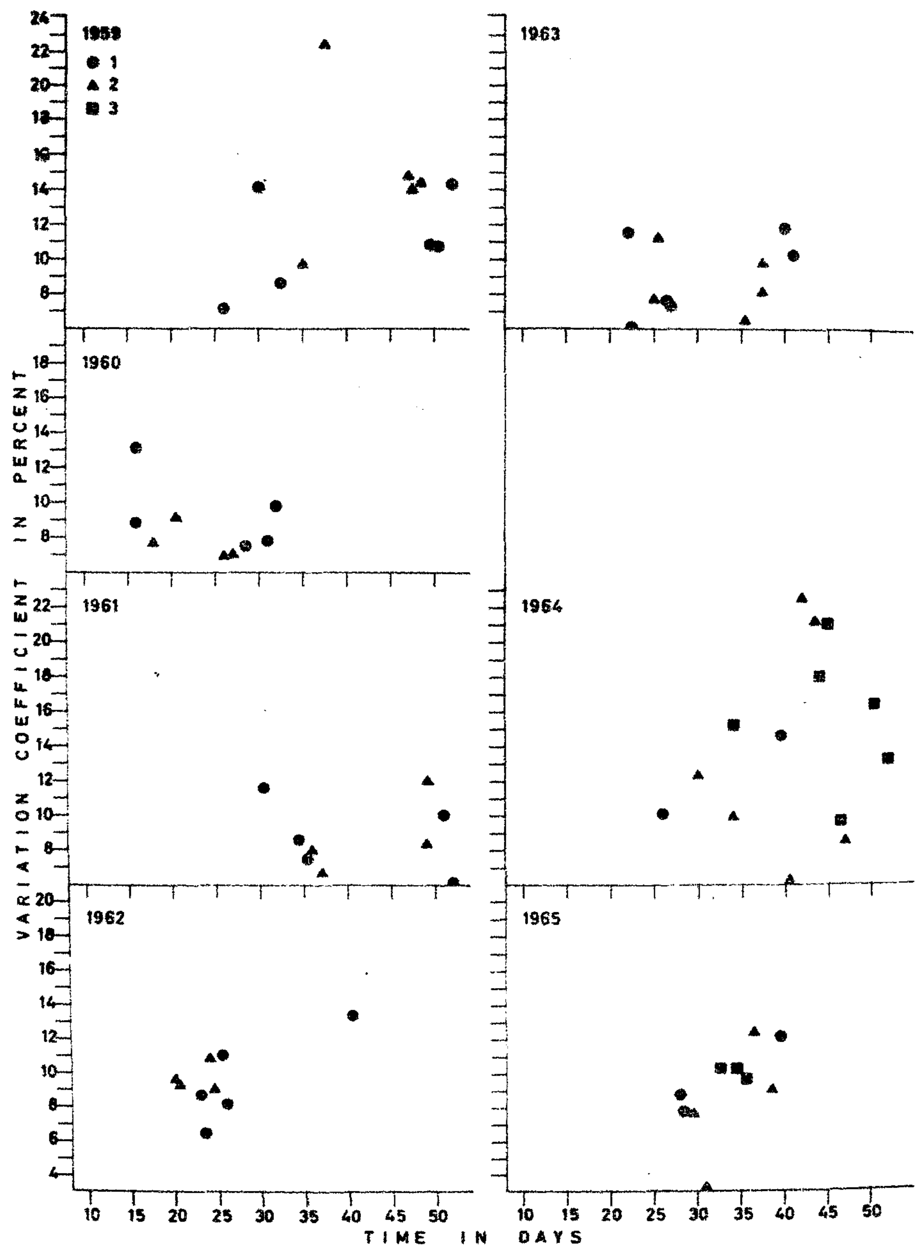

Fig. 23 Variation coefficients plotted against time (reference peak of spawning) during the seasons 1959-1965, (1) area 07, (2) area 06, (3) area 05.

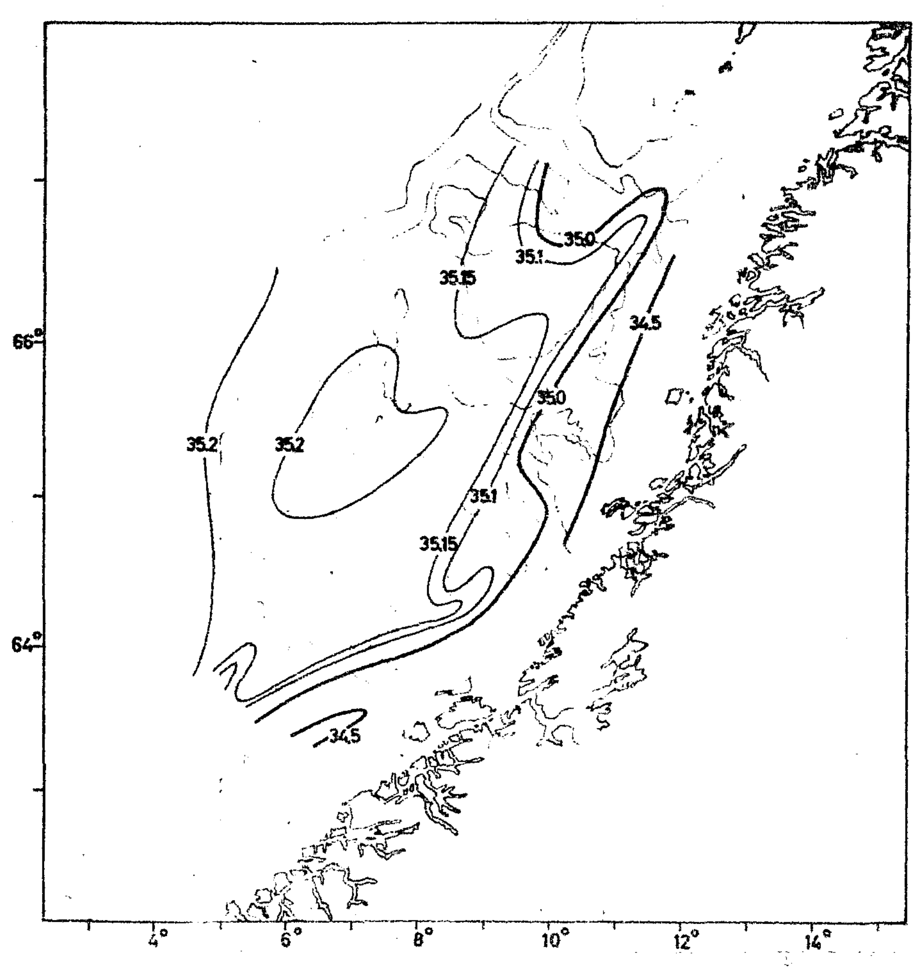

Fig. 24 Salinity at 30 m 18-24 February 1956.

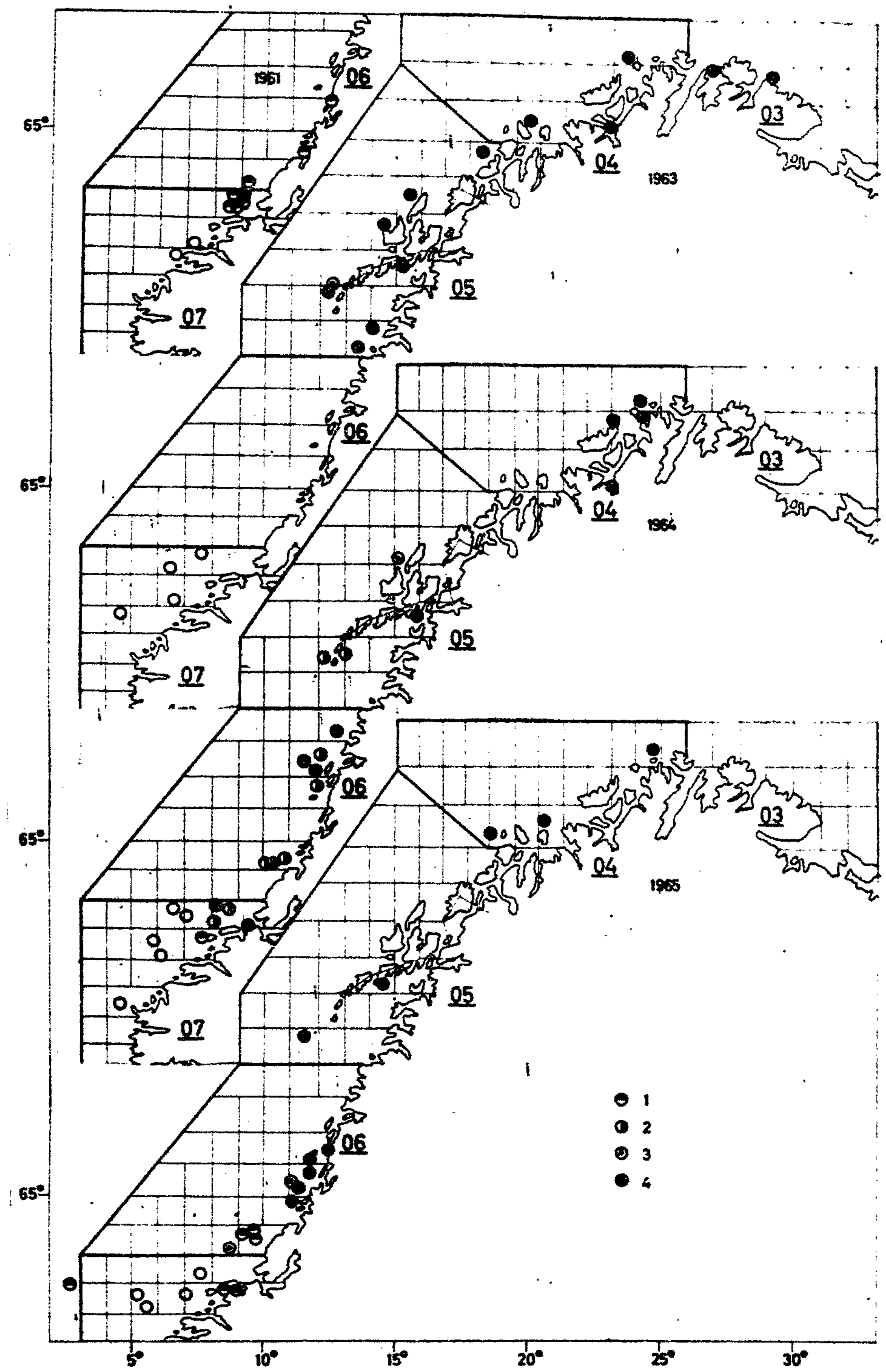

Fig. 25 Drift bottle releases (open) in 1961, 1963, 1964 and 1965 in area 07 and distributions of returns, (1) within 30 days, (2) between 31-60 days, (3) between 61-90 days and (4) more than 90 days after release.

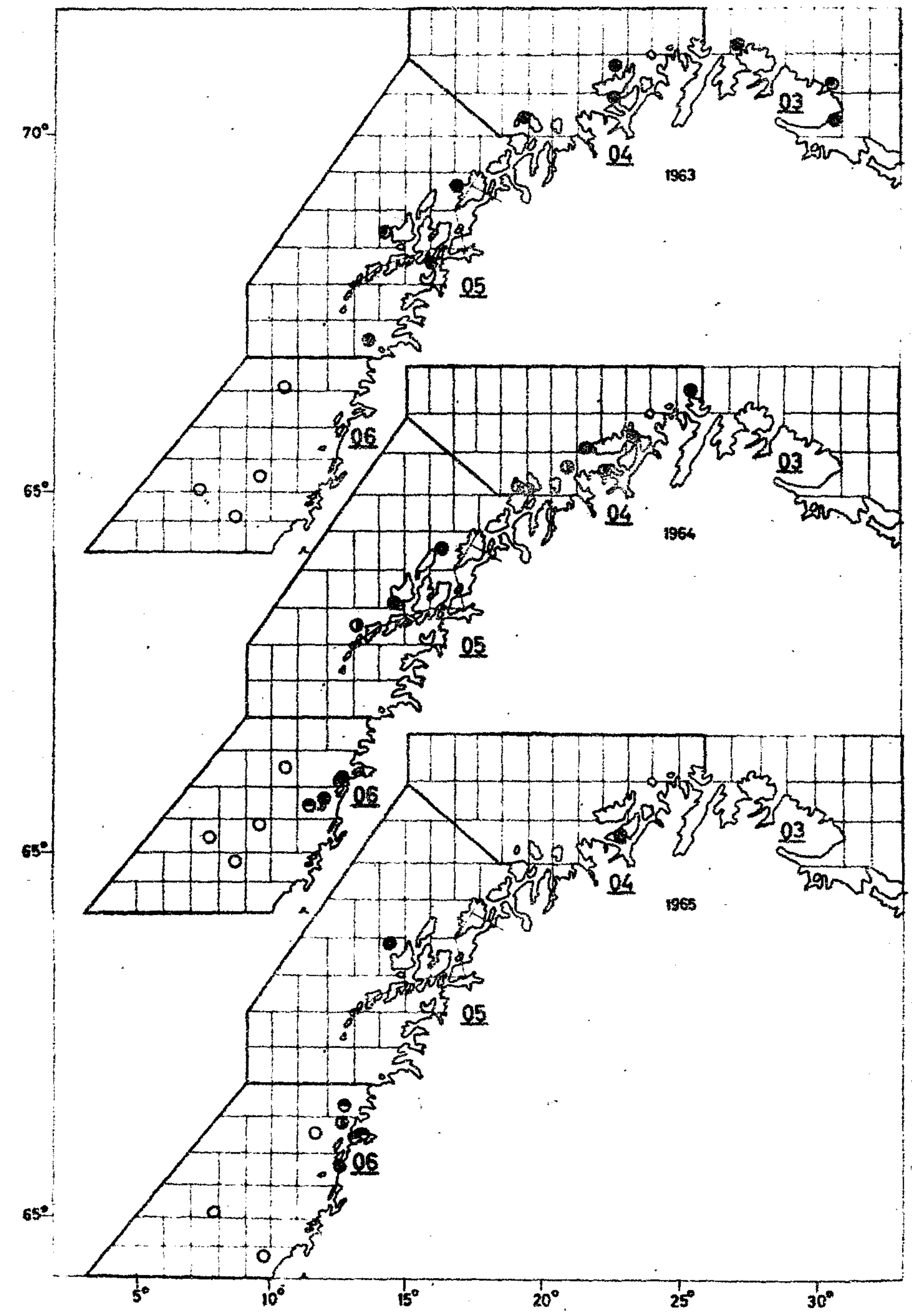

Fig. 26 Drift bottle releases in 1963, 1964 and 1965 in area 06 and distribution of returns. Legend Fig. 25.

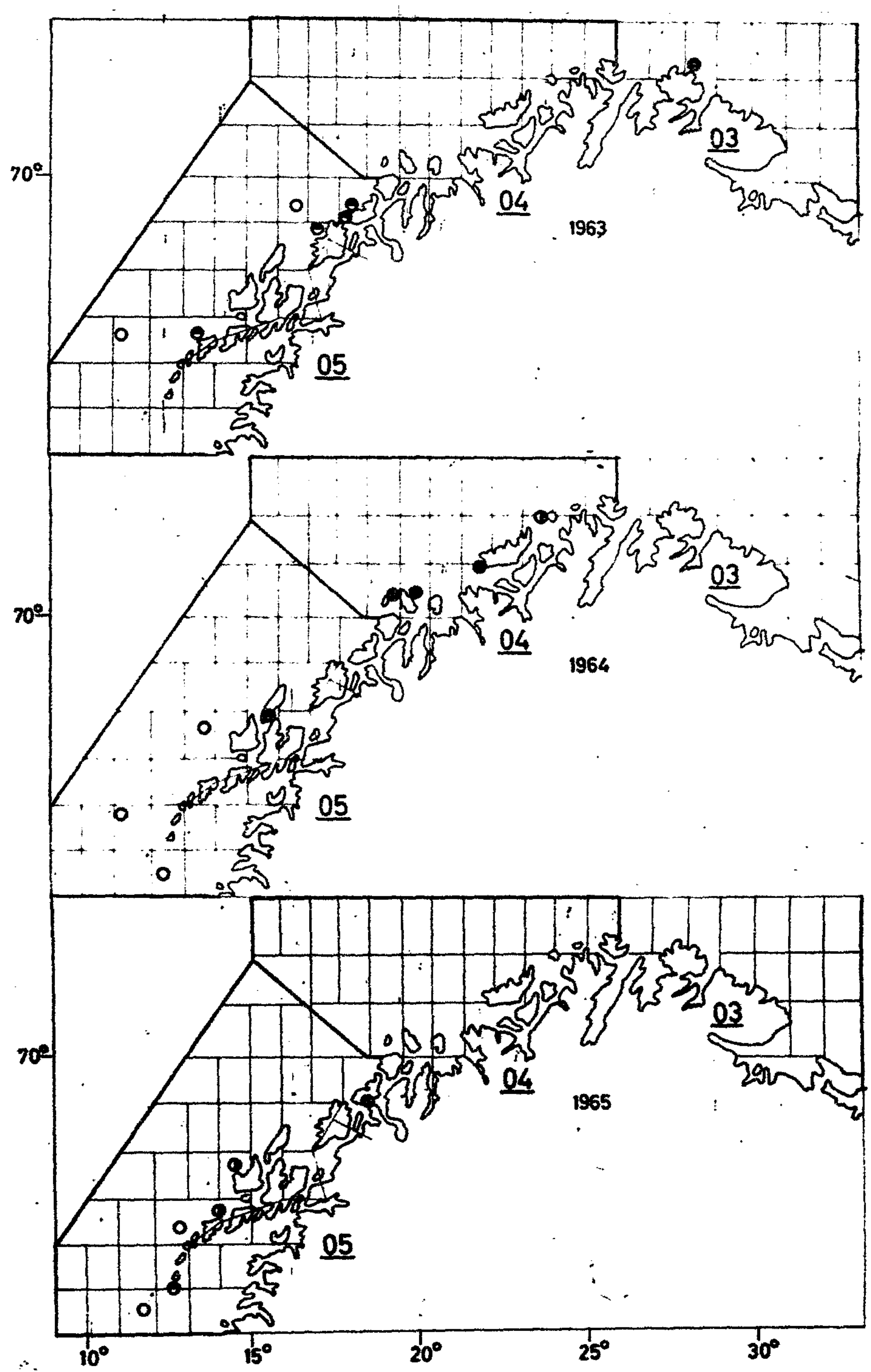

Fig. 27 Drift bottle releases in 1963, 1964 and 1965 in area 05 and distribution of returns. Legend Fig. 25.

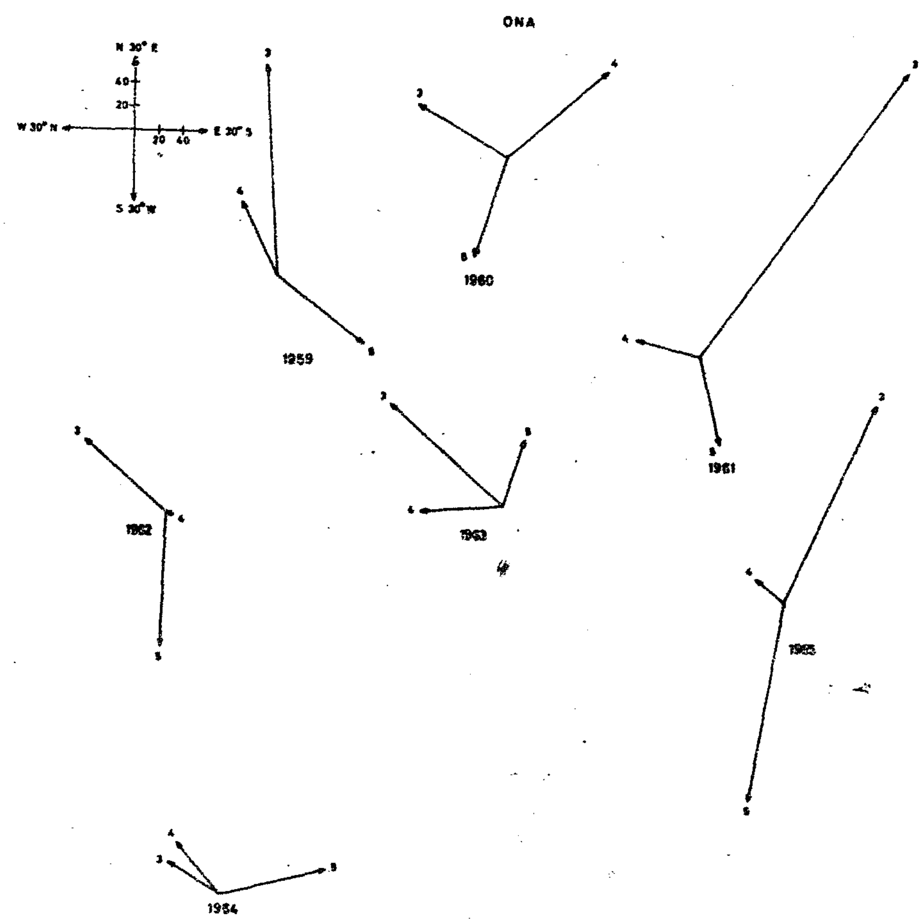

Fig. 28 Average wind vectors in different months at Ona during the period 1959-1965, 3:March, 4: April, 5: May. Reference to direction and relative strength of the wind vectors are given to the left (top of the figure).

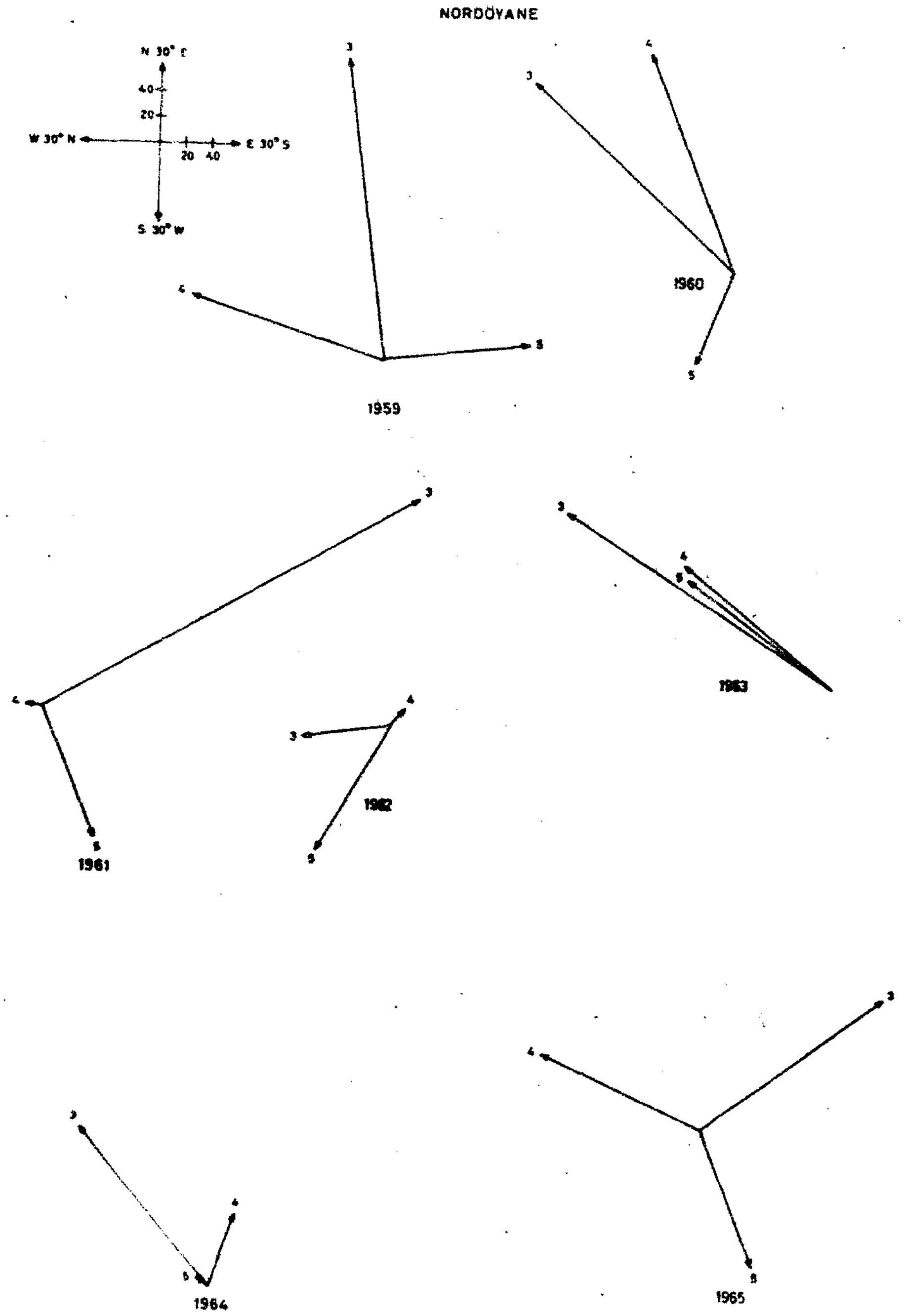

Fig. 29 Average wind vectors in different months at Nordøyane during the period 1959-1966. Legend Fig. 28.

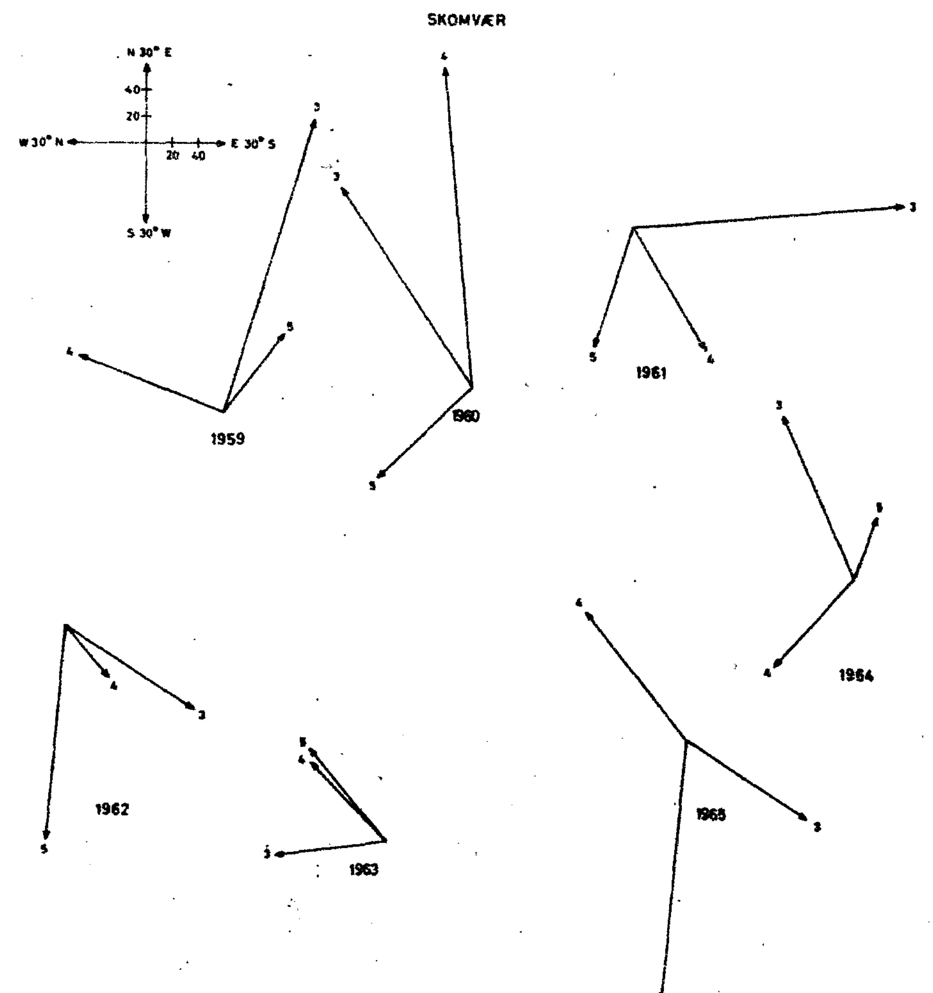

Fig. 30 Average wind vectors in different months at Skomvær during the period 1959-1966. Legend Fig. 28.

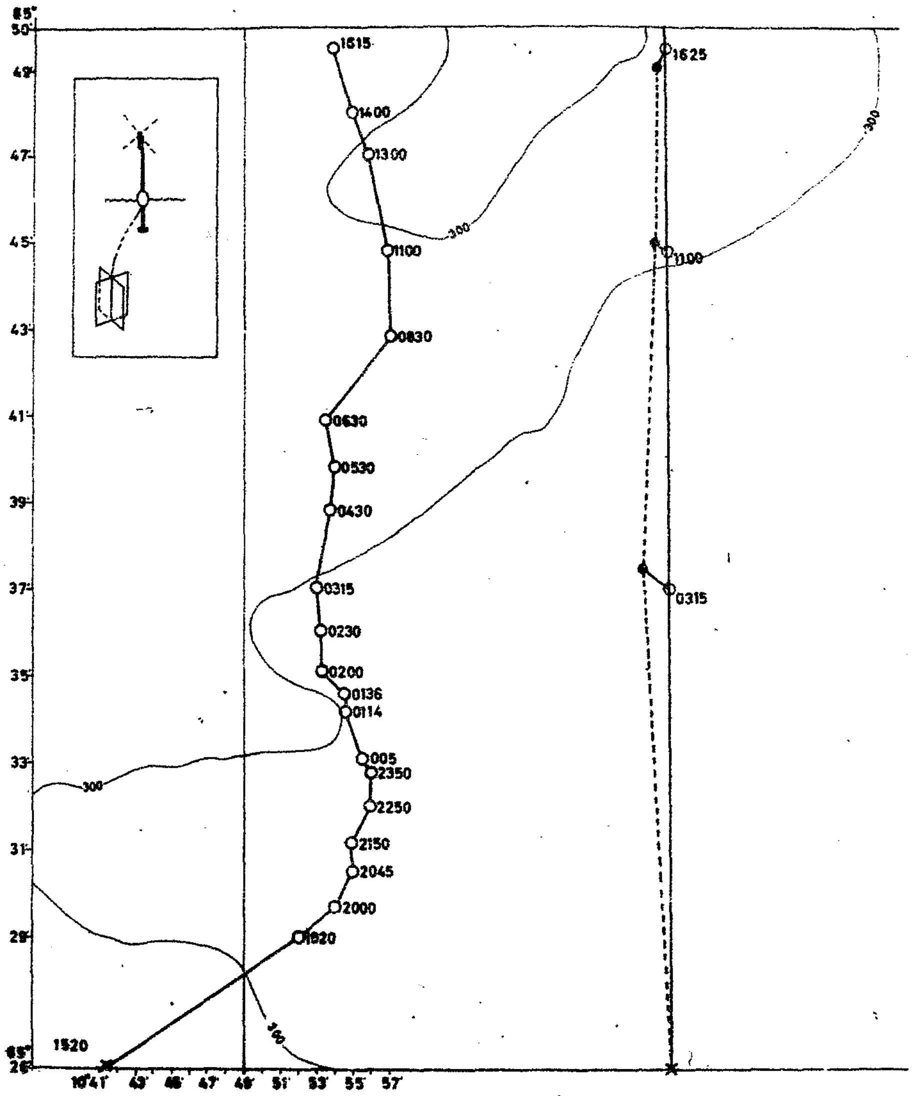

Fig. 31 Path of current cross(left) during 24 hours at 20 m off Sklinna, released at 1520 hrs. 18 April 1964. The time is listed along the path. To the right on the figure the position of the current cross at 20 m is compared with that at 10 m. To the left(top) schematical illustration of the current cross used (not drawn to scale).

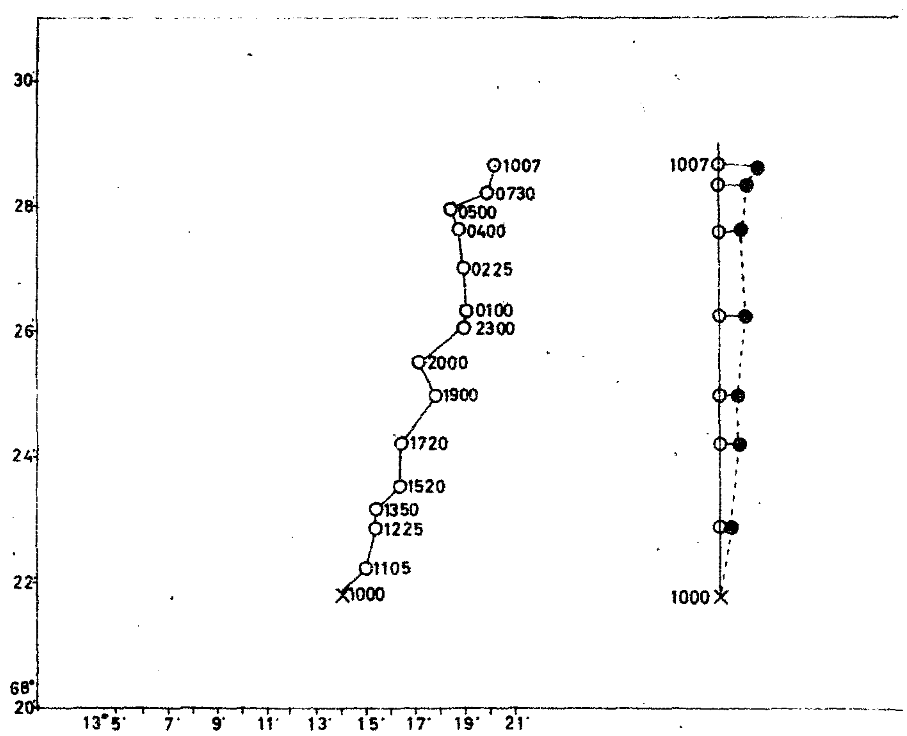

Fig.32 Path of current cross (left) during 24 hours at 20 m off Eggum (Lofoten). To the right on the figure the position of the current cross at 20 m is compared with that at 10 m.

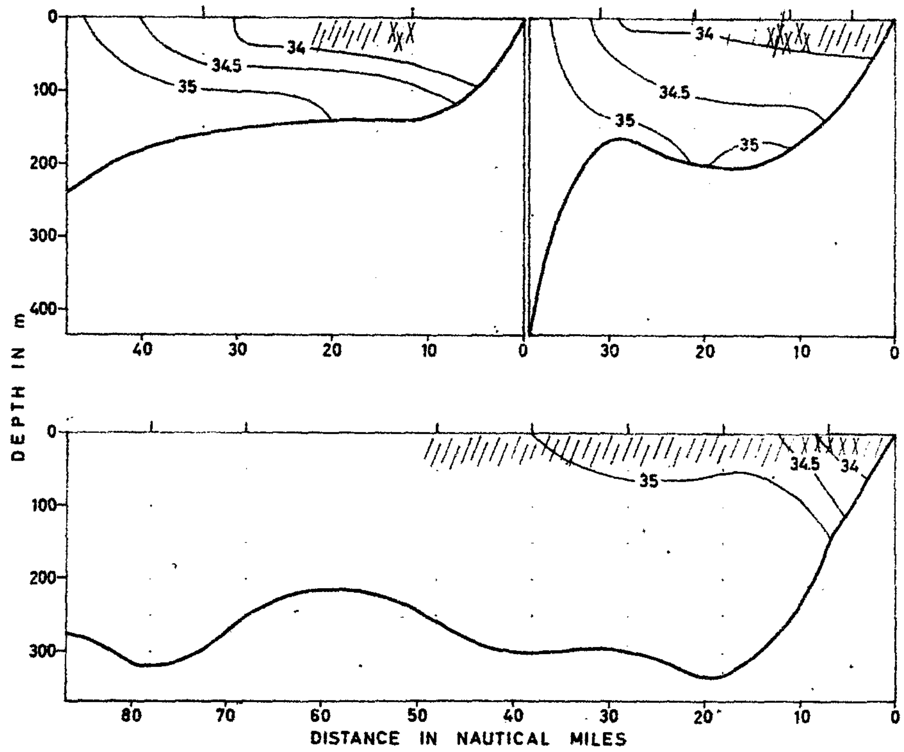

Fig. 33 Vertical salinity sections Stad-NW (above,left)-Ona-NW (above, right) and Træna-NW (below) and schematical illustration of distribution of larvae (hatched).

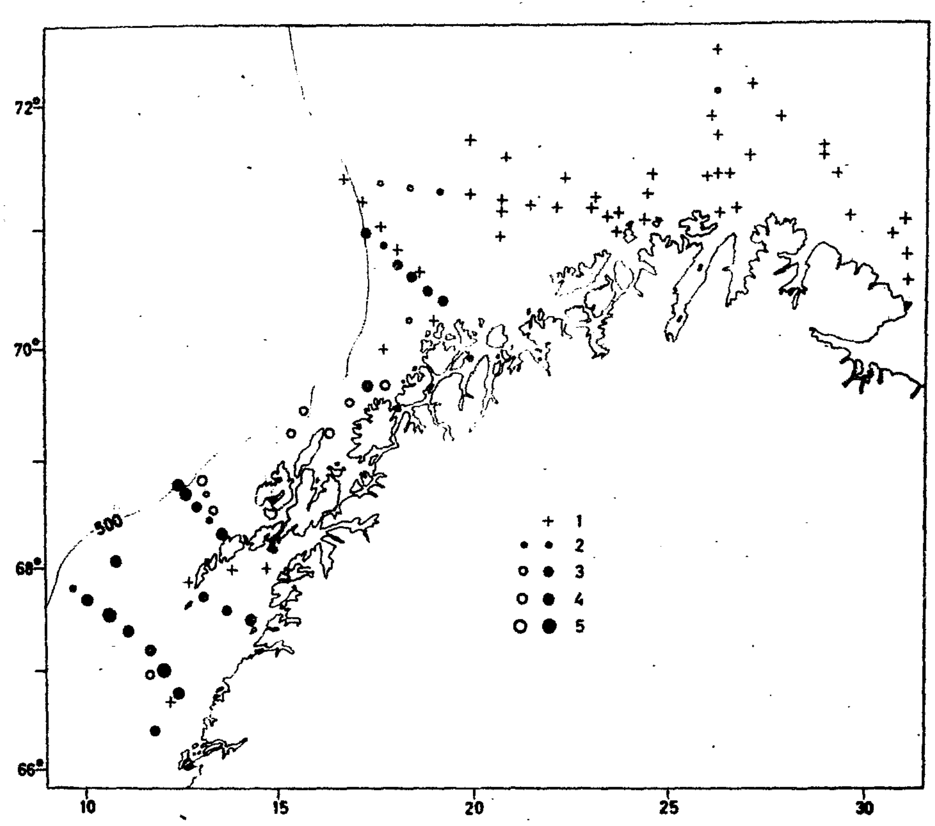

Fig. 34 Distribution of larvae caught with Isaacs-Kidd 3 ft. midwater trawl according to station during a survey in 1963, filled symbols refer to the period 27 May-21 June, blank 21-26 June. (1) no larvae per haul,(2) 1-10,(3) 11-50, (4) 51-200 and (5) more than 200 per haul.