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# Return of Norwegian Spring Spawning Herring (Clupea harengus L.) to historical spawning grounds off southwestern Norway.

by

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ABSTRACT

From the mid-1940s to mid-1960s a northward displacement of the spawning areas of the Norwegian Spring Spawning Herring was observed. Further retraction of the population from traditional feeding and spawning grounds occurred as the stock collapsed in the late 1960s. The spawning grounds off southwestern Norway were abandoned after 1959. Ever since, spawning appears to have been restricted to a few coastal grounds and offshore banks off mid-Norway, primarily off the Møre district.

At present, the abundance of the spawning stock remains comparatively low; 1.5-2 mill. tonnes as compared with 7-10 mill. tonnes in the 1950s. However, in the spawning seasons from 1989 onwards, spring spawners have again been observed at the southwestern grounds. The herring at these southern grounds in 1990 and 1991 were Norwegian Spring Spawners and utilized traditional spawning sites. The spawning time was about a month later than in the 1930s but similar to that in the 1950s. Results of acoustic surveys showed that of the total spawning stock, 1.5 - 2 % used the southwestern grounds i 1990 and 1991.

## INTRODUCTION

Prior to the severe decline in abundance in the mid-1960s (Dragesund et al. 1980), the Norwegian Spring Spawning Herring stock utilized numerous coastal banks and nearshore areas along the coast of Norway from Lindesnes to Lofoten as spawning grounds (Figure 1, Runnstøm 1941a,b, Devold 1963). Based on the landings data and distributions of eggs and yolk sac larvae, Runnstrøm (1941a) regarded the southwestern grounds, i.e. those south of Bergen, as the most significant in the 1930s and also in earlier times of rich herring catches. Between 70 and 80 % of the landings during the first three decades of this century came from the southern grounds (e.g. Runnstrøm 1941a, Røttingen 1990). Among the southern grounds, sites off the Rogaland district were the more important, particularly the ones to the west and south of the island of Karmøy. Spawning grounds off the Møre district were used regularly. Grounds north of Møre seemed however to have been used for few seasons only and were considered insignificant.

Devold (1963) showed the importance of the southwestern grounds in the late 1940s and onwards (Figure 2a). However, a trend towards a more northerly spawning in the last years of the period 1946 - 1958 was observed. Dragesund (1970) further

described the distribution patterns in the 1950s and 1960s (Figure 2b). The grounds south of Bergen were not utilized after 1959. Ever since, spawning appears to have been restricted to a few northern sites, primarily the Møre grounds (Figure 2b, Dragesund et al. 1980, Røttingen 1990b). Dragesund found significant numbers of yolksac larvae north of the main fishing areas at Møre. That indicated that banks north of Møre and even the Lofoten islands were important in the early 1960s.

This northward movement of the spawning activity began prior to the decline in the abundance of the stock (Figure 3). A similar northward displacement of the spawning areas was noted towards the end of a 19th century "herring period". Runnstrøm (1941a) and Devold (1963) described how the herring disappeared from the southern grounds from 1870 onwards, in advance of the subsequent period of low catches.

In the late 1960s when the severe depletion occurred, the stock furthermore drastically changed its feeding and overwintering areas and hence migrations. Oceanic nursery, feeding and wintering areas were abandoned to the extent that the entire life cycle was spent in coastal waters and the fjords (Figure 4, Dragesund et al. 1980, Hamre 1990, Røttingen 1990b).

With the exception of the 1983 year class which was comparatively abundant, the recruitment to the stock has been poor throughout the 1970s and 1980s (Anon. 1991). The recent growth of the spawning stock can be almost entirely attributed to the 1983 year class. In 1991, this year class contributed 80-90 % to the spawning stock in terms of numbers. The 1983 year class was observed in the traditional Barents Sea nursery areas and to some extent in feeding areas off the coast in the eastern Norwegian Sea. However, the migration pattern of this year class as adults has differed from that of the abundant year classes of the 1950s and early 1960s (Figure 4, Røttingen 1989). The wintering areas have changed. Prior to the collapse, wintering areas were found in the Norwegian Sea east of Iceland. At present the adult stock have wintering areas in fjords of northern Norway (Røttingen 1990a).

When spawning for the first times in 1987 and 1988, the 1983 year class utilized grounds off Møre and Helgeland. Not until 1989 did a small fraction of the spawning stock appear at the spawning grounds south of the Møre district (Røttingen 1989). Spawning herring were primarily found at the grounds off Karmøy but also to a lesser extent off southern Rogaland (Jæren). This was herring that had most probably spawned once or twice at the northern grounds in the previous years. Thus 30 years after the herring abandoned the area,

fish which had never been there before located the very same sites which were so important in times of higher abundance (Røttingen 1989).

This paper describes results of studies of the still minor southern spawning group in the years 1989 - 1991 aimed at estimating the abundance of spawners and mapping the distribution of spawners and eggs in space and time. The work formed part of a comprehensive study of herring as well as the resident fish community at a herring spawning ground.

## MATERIALS AND METHODS

In the winter of 1989 the spawning grounds south of Bergen were not surveyed systematically by research vessels. However, echo recordings of herring schools were made, and samples from commercial catches showed that some spring spawners did occur that year (Røttingen 1989). In 1990, survey effort was directed towards the southern grounds. The results from 1989 and 1990 stimulated the initiation of the more comprehensive studies in 1991.

### 1990

The surveys were severely hampered by bad weather throughout February and March. RV Eldjarn surveyed the grounds to the west and south of Karmøy 13 - 15 February (Figure 6) before continuing northwards towards the Møre grounds. In late February-early March, RV Håkon Mosby worked the Karmøy grounds and also the Boknafjord (Figure 7). The same vessel also briefly visited the Karmøy grounds on 28 and 29 March (Figure 8).

Hydroacoustic equipment and settings used by the to vessels are given in Table 1. All the hydroacoustic observations were made at night.

The herring concentrations were sampled by bottom trawl (Campelen 1800 fitted with "rockhopper" ground gear, Engås and Godø 1989) and midwater trawl (the "Harstad trawl", see e.g. Bergstad 1990).

Temperature and salinity measurements were made by CTD profiler at scattered stations at and around the spawning areas (Figure 7 & 8).

### 1991

Starting in the south on 13 March, RV Michael Sars carried out

a major acoustic survey of all the herring spawning areas (Figure 11). From early February onwards, the fisheries were monitored closely and reports and samples were obtained from local fishermen and fishing authorities.

In the period 4 - 11 March, RV Håkon Mosby surveyed all the southern grounds (Figure 12). Later in the month the same vessel made two additional surveys; one of the Karmøy and Boknafjord areas, and one of the main herring concentration to the west of Karmøy (Figure 13 & 14). Finally, on 24 and 25 March, the coast from Karmøy northwards to Korsfjorden was surveyed (Figure 15). The weather was near optimal for acoustic recording throughout these surveys.

Both vessels used the SIMRAD EK 500 sounder and echointegrator and only nighttime recordings were used for estimating numerical abundance. Settings used are given in Table 2. Samples of herring and other fishes were collected by the same trawls as in 1990.

Conversion of integrator readings ($S_a$) to number of herring was achieved by the relation between target strength (TS) and total fish length (L) recommended by the ICES' working group on Atlanto-Scandian herring (Foote 1987, Anon. 1988):

$$TS\ (dB) = 20.0 \log L - 71.9$$

The number of individuals (N) within a certain area (A) was given by:

$$N = ((\bar{S}_a/4\ )\ 10^{-0.10\ TS})\ A$$

The area A with positive integrator values was delimited after plotting the one-mile integrator values attributed to herring along the survey lines. The mean integrator value ($\bar{S}_a$) was the arithmetic mean of all positive one-mile values within the area A.

A problem throughout the spawning area and at all times of the day was that the herring schools were distributed very close to the bottom. Integrator values for many schools became unreliable because of poor discrimination between bottom and fish signals. In a number of cases the only option was to compare poorly recorded schools with seemingly correctly integrated ones of similar size and character and thereby obtain a more reasonable value. An alternative procedure used during the repeated sampling to the west of Karmøy towards the end of the 4-11 March survey (Figure 13), was to manipulate continuously the limits of two pelagic channels of the integrator. One channel integrated the bottom signal only, while the other integrated both bottom signal and other near-

bottom signals. In this way, reasonable values for near-bottom fish recordings were obtained by subtracting the integrator values of the bottom signal from the value for the sum of bottom signal and near-bottom fish. One tenth of a nautical mile recording intervals were used.

Attempts were made to locate and delimit the spawning grounds on the basis of egg samples by van Veen and Petersen grabs, triangular dredges and a drague spatangue (Jaquotte 1962). Concentrating the sampling at the historically important grounds to the west and south of Karmøy (Runnstrøm 1941b) and in areas of dense concentrations of herring, 215 grabs, 6 dredge hauls and 3 hauls with the drague spatangue were made. This exercise provided information on bottom substrates but only very few egg samples were obtained. Some information on egg distributions was gained by examination of stomach contents of demersal fish. In the period 11-24 March, incidence of herring eggs in the stomachs of cod (Gadus morhua), haddock (Melanogrammus aeglefinus), pollack (Pollachius pollachius) and saithe (Pollachius virens) caught by bottom trawl was recorded.

In addition to those collected by the research vessels, a few samples of herring were obtained from commercial catches. On 22-25 April demersal fishes were sampled from commercial Danish seine catches at the Karmøy spawning ground. From these, the incidence of stomachs containing herring eggs was recorded.

## RESULTS

### 1989

The samples of ripening and ripe herring collected at the Karmøy grounds in March 1989 had length and age frequency distributions which were very similar to those of Norwegian Spring Spawners in the wintering areas and at the Møre spawning grounds (Figure 5). Approximately 90 % of the herring in the samples belonged to the 1983 year class. Thus it seemed very likely that the Karmøy spawners were Norwegian Spring Spawners (Røttingen 1989).

### 1990

No spring spawning herring was observed during the mid-February survey, neither at the Karmøy grounds (Figure 6), nor further north towards Møre along the likely migration routes from the northern wintering areas. On 14 February, a sample of mostly maturing fish (stage 4), was obtained from a commercial gillnet catch close to the southern tip of Karmøy. The mean

number of vertebrae of this sample was 57.13 and the larger fish belonged to the 1983 year class. This indicated that the herring were Norwegian Spring Spawners. Some early arrivals were reported elsewhere, yet neither survey data nor information from local fishermen suggested substantial concentrations of herring at the southern grounds in mid-February.

During the late February-early March survey (Figure 7), however, scattered herring schools were found in northern parts of Boknafjord and to the west of Karmøy. The densest concentrations were observed at the historically significant spawning grounds off Ferkingstad and Åkrehamn southwards to Sandve. Characteristically, the herring occurred as near-bottom concentrations (Figure 9). At that time, about 15 % of the herring from trawl catches had running gonads (Stage 6). The rest was in rather advanced stages of maturation (Stage 4 and 5).

Length and age frequency distributions of the samples from southern grounds are shown in Figure 10. Also included is a sample from the same period at the main spawning area at Møre (Figure 1). Seven year old fish, i.e. of the 1983 year class, dominated all the samples. Only the early gillnet sample from mid-February contained significant proportions of younger fish. The close similarity between the age and length distributions of samples from Møre and the southern grounds suggested they were drawn from the same population, i.e. the Norwegian Spring Spawning Herring.

Spawning herring were still present at the Karmøy grounds towards the end of March, again primarily at the grounds off Ferkingstad (Figure 8, stn. 1). At that time only spent and running herring were caught. The length frequency distribution was very similar to those from samples collected at the beginning of the month (Figure 10). The stomachs of haddock, cod and pollack contained herring eggs.

Based on the acoustic observations at the beginning of March, a very rough estimation of abundance was made. This could only be achieved by comparing schools from Karmøy and Møre showing similar density and size composition. Schools at Møre make diurnal vertical migrations and reliable integrator values can normally be obtained at night when most fish are found pelagically. At Møre, concentrations the size of the one off Ferkingstad yielded an integrator value of about 50.000 $m^2/n.m.^2$. The Ferkingstad school was distributed over an area of about 1 $n.m.^2$. Assuming that this school alone accounted for about half the total number of herring present at the southern grounds at that time, estimates of abundance and biomass of southern spawners became 113 million individuals and 32.000

tonnes (Table 3).

Further support for the assumed identity of the spring spawners at Karmøy came from recoveries of herring tagged in northern waters. During experimental fishing off Karmøy, 4 recoveries were made from a 350 tonnes catch. The four specimens had been released in the years 1984 - 1988 at Møre or further north (65° - 67° N).

1991

Distribution and abundance

During the mid-February survey (Figure 11), only small quantities of herring were observed south of the Møre spawning grounds. In the period 8 - 23 February, scattered gillnet catches of spring spawners were reported from the island of Bømlo well to the north of Karmøy and also off northwestern Karmøy. Length and age frequency distributions of two early samples are shown in Figure 16 a,b. These samples contained herring with gonads in pre-spawning condition. Vertebral counts indicated that these were Norwegian Spring Spawners (Sample 1: mean number of vertebrae = 57.36, SD = 0.65, n = 42; sample 2: mean number of vertebrae = 57.42, SD = 0.57, n = 97). The Bømlo sample was dominated by 4 yr olds. Also the Åkrehamn sample, although dominated by 8 yr olds of the 1983 year class, contained a significant number of 4 yr olds.

The main immigration to the southern area seemed to happen in late February. An extensive gillnet fishery developed from about 23 - 25 February onwards, primarily off Karmøy but also south of this island and in nearshore waters of the northern Boknafjord (Figure 1). At the same time, scattered gillnet catches were reported from grounds further south along Jæren and at the bank called Siragrunnen further east.

The results of the second and most extensive research vessel survey of the southern grounds conducted in the period 4 - 11 March are shown in Figure 12. Three main areas of concentration were found: one major area off Ferkingstad at Karmøy, and two smaller ones immediately to the south of Karmøy and south of Bokn. The concentrations at other grounds were insignificant compared with the ones seen near Karmøy. Only small schools were recorded to the south of Boknafjorden and north of Karmøy. At Siragrunnen, a few schools believed to be herring were observed. Trawling is difficult at this shallow rocky ground and very little commercial fishing was going on at the time, hence no samples were obtained for identification.

Later on in March, there were no indications of significant

concentrations of herring at other grounds than those near Karmøy. Hence, further surveys were restricted to the latter (Figure 13 & 14). Also in mid-March and around 24 March, a major concentration was found off Ferkingstad at 55 - 80 m depth. In mid-March, the density at this western ground had decreased significantly, whereas an increased density was found south of Bokn. Unfortunately, due to lack of ship-time, the last survey did not cover the eastern grounds.

Abundance estimates of the different concentrations at different times are given in Table 4. The mean length and weight used in the calculations were obtained from a bottom trawl sample from off Karmøy of 7 March. The variation throughout the period was so small that the same values were used for all surveys. In early March, an estimated 12.000 tonnes of herring occurred in the three main areas of concentration.

In the middle of March (14 - 18 March), the total abundance at these same three grounds had been reduced to about 3000 tonnes. This may be somewhat too low since the eastern extent of the easternmost concentration was undefined. Compared with the early March survey, the drop in abundance was most pronounced off Karmøy and the increase substantial south of Bokn. This corresponded with changes in the gillnet fishery which around 15 March almost came to an end off Karmøy, while near Bokn fishing continued into April.

The results of the short 24 March survey showed that some herring remained at the grounds off western Karmøy until late March. The concentrations were found in the same area as earlier but somewhat shallower at 30 - 55 m.

The coastal area northwards from Karmøy to Korsfjorden was surveyed on 24 - 25 March (Figure 15). However, no herring was observed in that area.

Length and age frequency distributions from the March surveys are shown in Figure 16. All the samples except that from stn. 58 were dominated by the 1983 year class, now 8 yrs old. As in 1989 and 1990, this suggested that the herring at the southern grounds in 1991 were Norwegian Spring Spawners. The proportion of 3 and 4 yr olds was relatively high in some samples.

Spawning area

Attempts were made to map the main spawning area in greater detail by sampling eggs by grabs and bottom dredges. This proved largely unsuccessful, probably because egg densities were low and because the preferred spawning substrate was coarse gravel and rock. Based on the grab and dredge samples,

a map showing the distribution of bottom substrates was drawn (Figure 17). The few egg samples were collected at stations within the rectangular subarea in Figure 17.

The frequency of occurrence of herring eggs in fish stomachs (i.e. percentage of the stomachs examined which contained herring eggs) was recorded at individual bottom trawl stations to the west of Karmøy. Pooled data for haddock, cod, saithe and pollack are shown in Figure 18. The highest values were observed in the area where most adult herring was observed, i.e. off Ferkingstad at Karmøy.

Spawning period

The percentage of spent (i.e. Stage 7) herring caught by bottom trawl at different dates are given in Table 5. These are all data from the west of Karmøy grounds. On 7 March, only ripe and running fish were caught, none were spent. Samples with a high proportion of spent fish occurred from 12 March onwards. However, later on (until 22 March), samples with less than 10 % spent fish occurred as well. This variation probably reflected immigration and emigration of mature and spent fish respectively, as the spawning progressed.

On 22-23 April, examination of stomachs of haddock, cod and saithe from Danish seine catches at the spawning grounds confirmed the presence of herring eggs. These eggs were aged according to Klinkhardt and Biester (1984) and appeared to have been deposited around 10 April.

Based on the above, the 1991 spawning season appeared to last for 5-6 weeks, starting in early March.

DISCUSSION

The conclusion that Norwegian Spring Spawners were absent from the traditional sothwestern grounds from 1960 until 1988 is mainly based on fishermen's reports. The survey effort in the area has been limited over the past decades. The old herring grounds are, however, important Danish seine and gill-net grounds for groundfish year round. Numerous vessels, including a number of North Sea trawlers, make regular observations in the area. It seems thus unlikely that herring concentrations should have been left undetected and unreported. In March 1989, 1990 and 1991, however, maturing, running and spent herring was observed at the traditional spawning grounds off Karmøy and further south.

In all three seasons, there was a striking similarity between the age distributions of samples from the main spawning

grounds of the Norwegian Spring Spawners at Møre and those from the southern spring spawners. This, together with recaptures of tags and vertebral counts, strongly suggested that the latter were indeed also Norwegian Spring Spawning Herring. The strong dominance of the 1983 year class is a characteristic of this stock not observed in minor local stocks or the North Sea Herring.

The occurrence of 4 yr olds, i.e. recruit spawners, in 1991 was particularly interesting. As 0-group and immatures the 1987 year class was almost entirely confined to the Møre area (Anon. 1991). The nursery area was thus different from that of the 1983 year class which grew up in the Barents Sea. The estimated abundance of the 1987 year class as 0-group was only 2 % of that of the 1983 year class. At Møre in 1991, only few specimens of the 1987 year class was found. These young fish may have taken part in an early migration wave to the southern spawning area.

Reports from local observers indicated that this southern component of the stock utilized the very same grounds that were regarded as the more important in earlier times. The survey data from 1990 and 1991 confirmed this. The main concentrations were found off Karmøy at the local grounds considered by Runnstrøm (1941b) to be the most significant among the numerous southern grounds mapped in the 1930s. These grounds were abandonded in 1959 and not utilized for 30 years (Devold 1963, Dragesund et al. 1980, Røttingen 1990b). More scattered observations were also made at other historically significant spawning grounds, e.g. off Jæren and at Siragrunnen.

The spawning period at the southern grounds have changed over time (Dragesund 1970). The spawning period in 1991 was about one month later than in the 1930s, but not very different from that in the 1950s. In the 1950s the spawning peaked in the first half of March as was probably the case in 1991.

In 1989, at least, the migration to traditional southern grounds was not a case of homing. The herring appearing at the southern grounds were too young to have been born there, and they had not spawned there previously. Not all the southern spawners in 1989 were first-time spawners, hence some must have spawned once or twice at the Møre grounds the previous years.

The mechanisms underlying this change of migration pattern are unclear, as are the factors involved in the selection of spawning grounds and the apparent development of preference for certain local grounds. The Karmøy ground can be characterised as a rather wide coastal bank, well flushed by a

modified coastal watermass of temperature 4.0 - 6.5°C and salinity 33.0 - 34.0 ‰ (own unpubl. data). Coming south from the Møre plateau, the Karmøy and Utsira shallows may appear as the first wide coastal bank encountered. The immigration route to the area is however not known. At this bank, the border area between rocky substrates and coarse gravel at between 40 and 70 m depth appeared to be selected as spawning site.

The abundance estimates from the acoustic surveys in 1990 and 1991, albeit uncertain due to normal measurement errors and the near-bottom distribution of the schools, indicated that some 20 - 30,000 tonnes of herring occurred at the southern grounds. Even if this is an underestimate, it shows that the southern component is still a small fraction, probably no more than 1.5-2 % of the total spawning stock now considered to measure 1.6 million tonnes (Anon. 1991).

Yet occurrence of Norwegian Spring Spawners at the southern grounds may be considered a positive sign of change. Recolonisation of traditional grounds can indeed happen, and might eventually lead to further rejuvenation of the stock. Dragesund (1970) hypothesised that the more important factors determining recruitment to the stock were 1) the extent of the spawning area, 2) the duration of the spawning period, 3) the rate of dispersion of larvae from the spawning ground; and 4) the coincidence in time between the availability of suitable food and hatching of the herring larvae. Lambert (1987, 1990) reanalysed historical data and found support for the hypothesis that the age structure of the spawning population influenced the amplitude and number of spawning events and then also the duration of the spawning period. Medium-sized or strong year classes were produced when the age distributions were polymodal because this resulted in several spawning events and extended spawning periods.

In the light of these hypotheses, any spreading of the still rather small spawning stock onto unused spawning grounds may seem promising. In addition to spreading eggs- and larvae over larger areas, this may lead to a longer spawning period, both factors which seem favourable for the survival of larvae and juveniles. The southern spawning, albeit limited, has lead to an expansion of the spawning area. It has also prolonged the spawning season from February well into March and probably early April. Increased spatial and temporal distribution of the spawning products may increase the chances that larval cohorts encounter favourable abiotic and biotic environmental conditions which may result in improved survival.

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Table 1. Instruments and settings used by the research vessels in 1990 during the surveys at the herring spawning grounds.

| Vessel | RV Eldjarn | RV Håkon Mosby |
|---|---|---|
| Sounder | SIMRAD EK 400 | SIMRAD EK 400 |
| Transm. frequency | 38 KHz | 38 KHz |
| Equivalent beam angle | -19.6 dB | -19.6 dB |
| Transducer | Ceramic, 8°x8° | Ceramic, 8°x8° |
| Bandwidth | 3.3 KHz | 3.3 KHz |
| Pulse duration | 1 ms | 1 ms |
| TVF/attenuator | 20 log R/-10 dB | 20 log R/-10 dB |
| Echo integrator | Nord-10 | SIMRAD QD |
| Source level + receiver sensitivity | 139.5 dB | 138.4 dB |
| Integrator constant | 0.155 | 1.670 |
| Date of last calibration | 6 January 1990 | 6 February 1990 |

Table 2. Instruments and settings used by the research vessels in 1991 during the surveys at the herring spawning grounds.

| | |
|---|---|
| Sounder and integrator | SIMRAD EK 500 |
| Transm. frequency | 38 KHz |
| Equivalent beam angle | -21.0 dB |
| Transducer | ES 38 B (Splitbeam) |
| Bandwidth | 3.8 KHz |
| Pulse duration | 1 ms |
| TVG | 20 log R |

Table 3. Estimates of abundance and biomass of herring at the Karmøy spawning ground in early March 1990.

| | |
|---|---|
| Integrator value* | 50,000 $m^2$/nautical $mile^2$ |
| Area, A | 2.0 nautical $mile^2$ |
| Mean total length (cm) | 33.0 |
| Mean body weight (g) | 285 |
| | |
| Abundance | $113 \cdot 10^6$ individuals |
| Biomass | 32,255 tonnes |

* value for a single major school, estimated by comparison of schools from different areas.

Table 4. Estimates of abundance and biomass of southern spawners of herring in March 1991 from surveys by RV Håkon Mosby. See Figs 11, 12 and 13 for survey tracks and distributions of sub-concentrations in different subareas. During all surveys, mean total length was 34.5 cm and mean body weight 313.7 g.

| Survey | Date | Subarea site | Subarea area ($n.m.^2$) | Average integrator value ($m^2/n.m.^2$) | Abundance (millions) | Biomass (tonnes) |
|---|---|---|---|---|---|---|
| 1 | 5 - 8 March | | | | | |
| | | Karmøy,W. | 15 | 2125 | 33.0 | 10,366 |
| | | Karmøy,S. | 3 | 957 | 3.0 | 941 |
| | | Bokn | 2.3 | 1208 | 2.8 | 878 |
| 2 | 14 - 18 March | | | | | |
| | | Karmøy,W. | 3 | 615 | 1.9 | 600 |
| | | Karmøy,S. | 3.5 | 441 | 1.6 | 500 |
| | | Bokn | 3 | 2014 | 6.3 | 2,000 |
| 3 | 24 March | | | | | |
| | | Karmøy,W. | 3 | 944 | 2.9 | 920 |

Table 5. Incidence of spent herring from samples collected at different dates in 1991. All samples from the Karmøy spawning ground. n - number of individuals staged.

| Date | Percentage spent | n |
|---|---|---|
| 26 February | 0 | 97 |
| 7 March | 0 | 100 |
| 12 " | 65 | 43 |
| 13 " | 8 | 115 |
| 17 " | 73 | 33 |
| 20 " | 7 | 44 |
| 20 " | 21 | 67 |
| 22 " | 16 | 77 |
| 22 " | 41 | 116 |

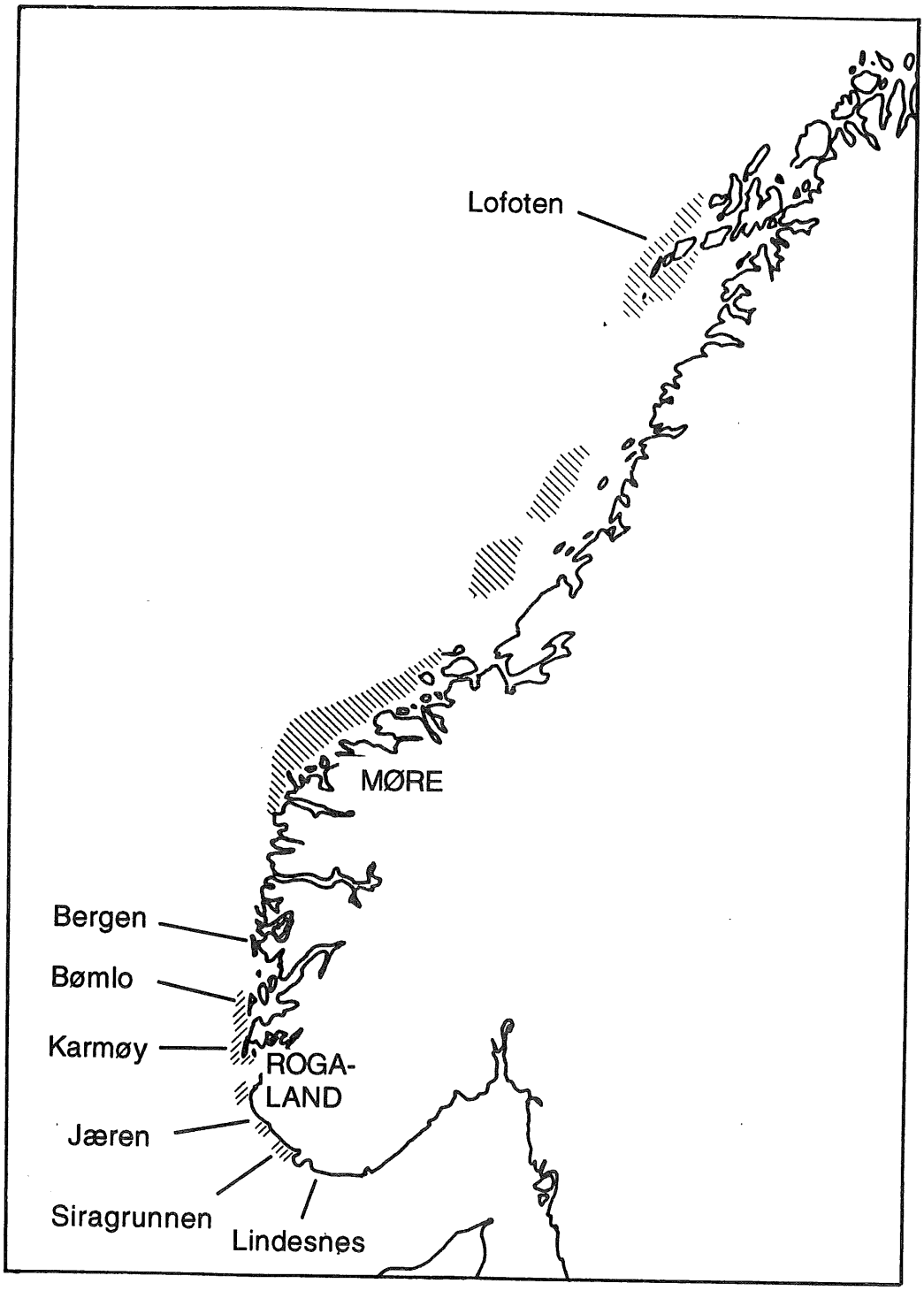



Figure 1. Spawning areas of Norwegian Spring Spawning Herring. Composite based on various sources (Runnstrøm 1941a,b, Dragesund 1970 and others).

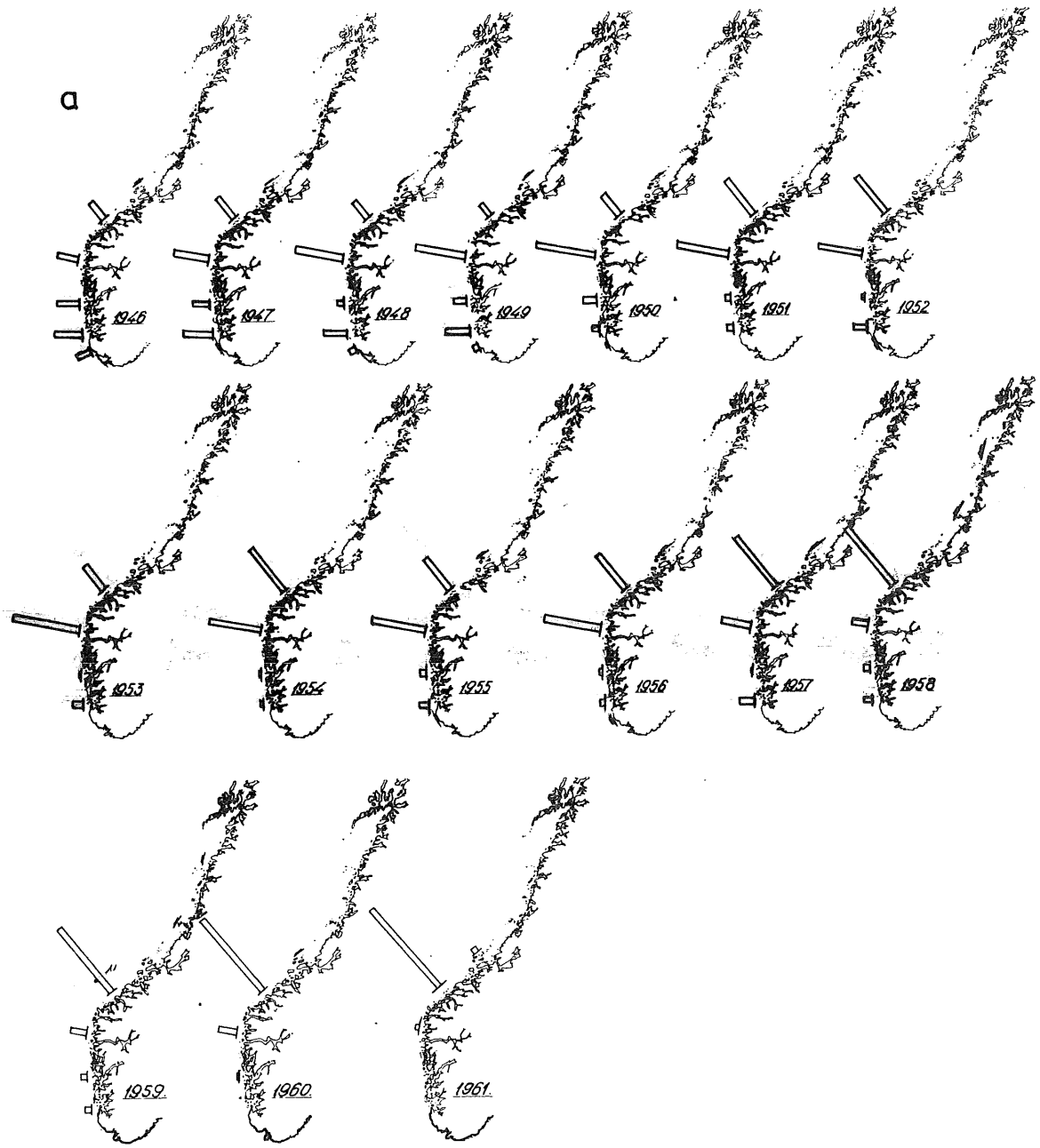



Figure 2: Relative significance of different spawning grounds of the Norwegian Spring Spawning Herring in the period 1946 - 1965 as indicated by landings statistics and density of yolksac larvae: a) Distribution of the total landings during the spawning period by districts (modified from Devold 1963), b) Proportions of the total catch (hatched areas) and numbers of yolksac larvae pr. $m^2$.

b

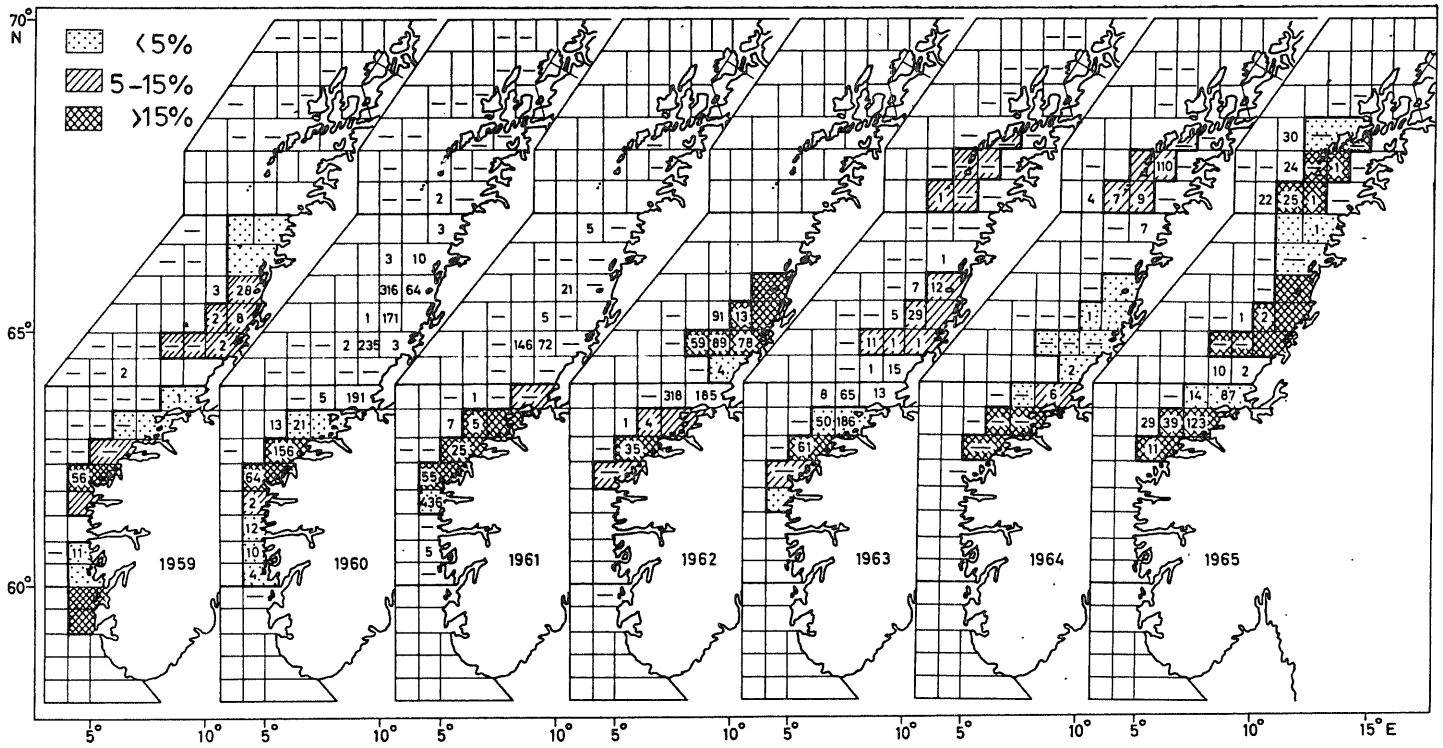



Figure 2. Continued

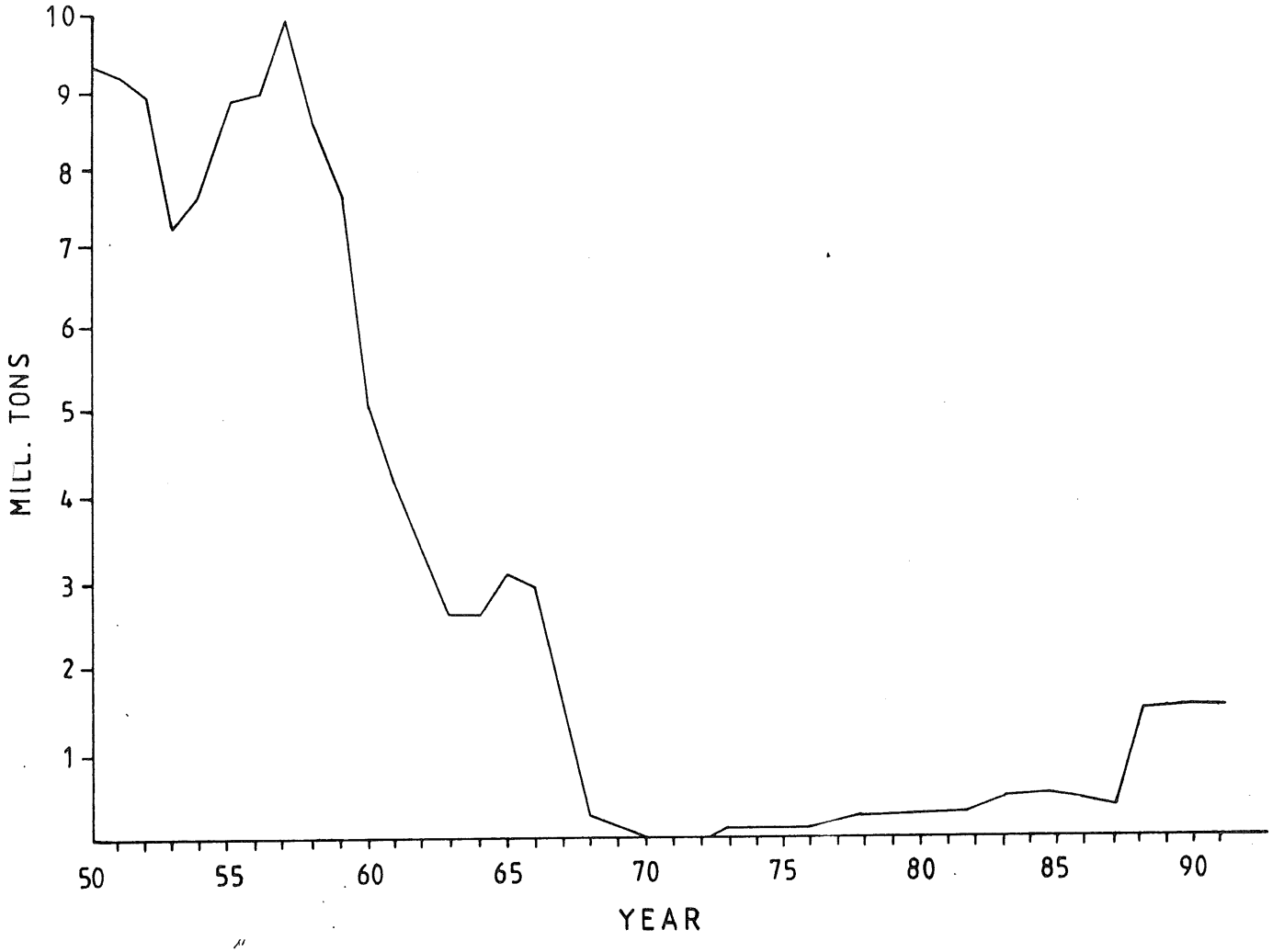



Figure 3. Biomass of the spawning stock of Norwegian Spring Spawning Herring (From Røttingen 1990).

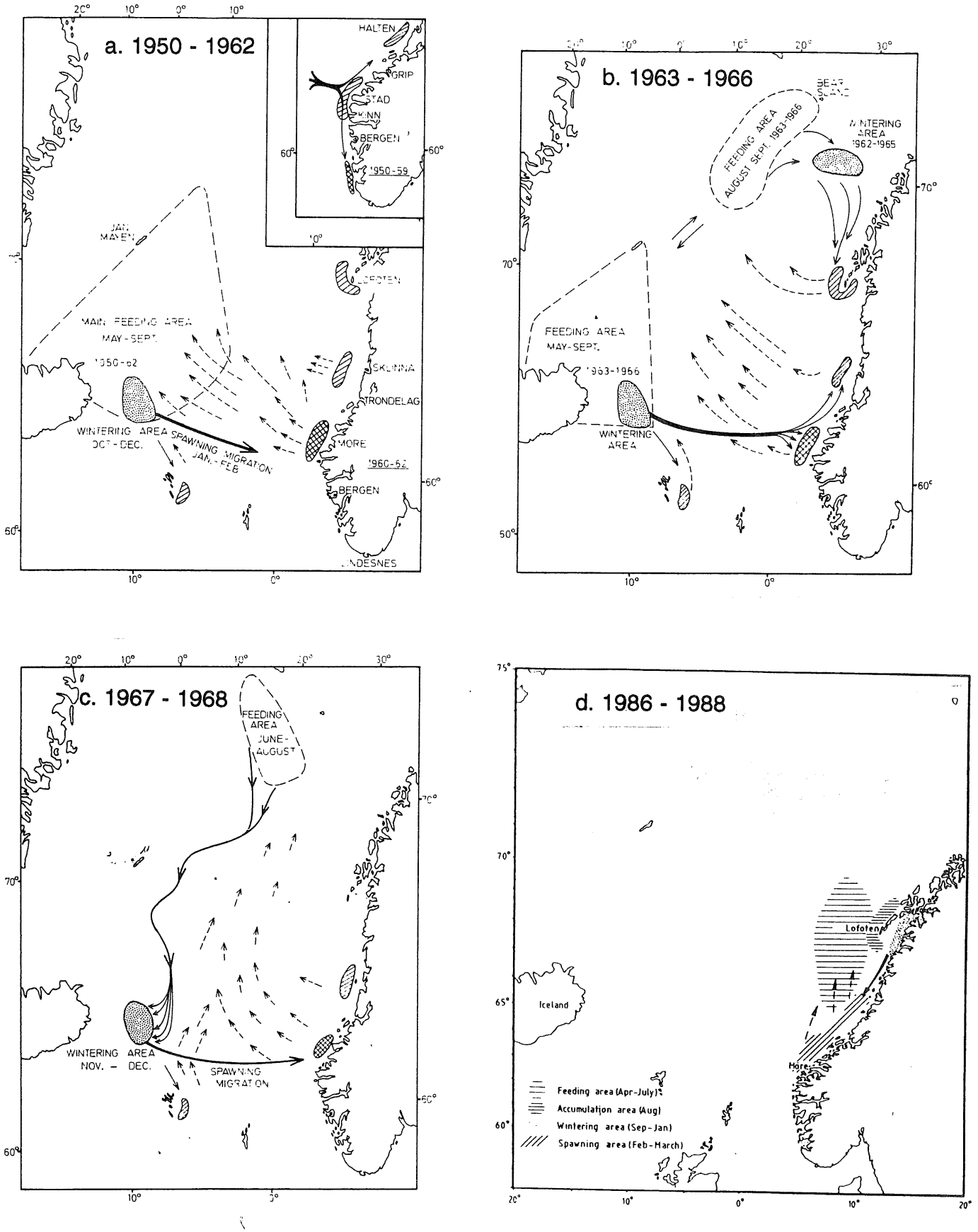



Figure 4. Distribution and migrations of the Norwegian Spring Spawning Herring in different time periods (from Dragesund et al. 1980, Røttingen 1990).

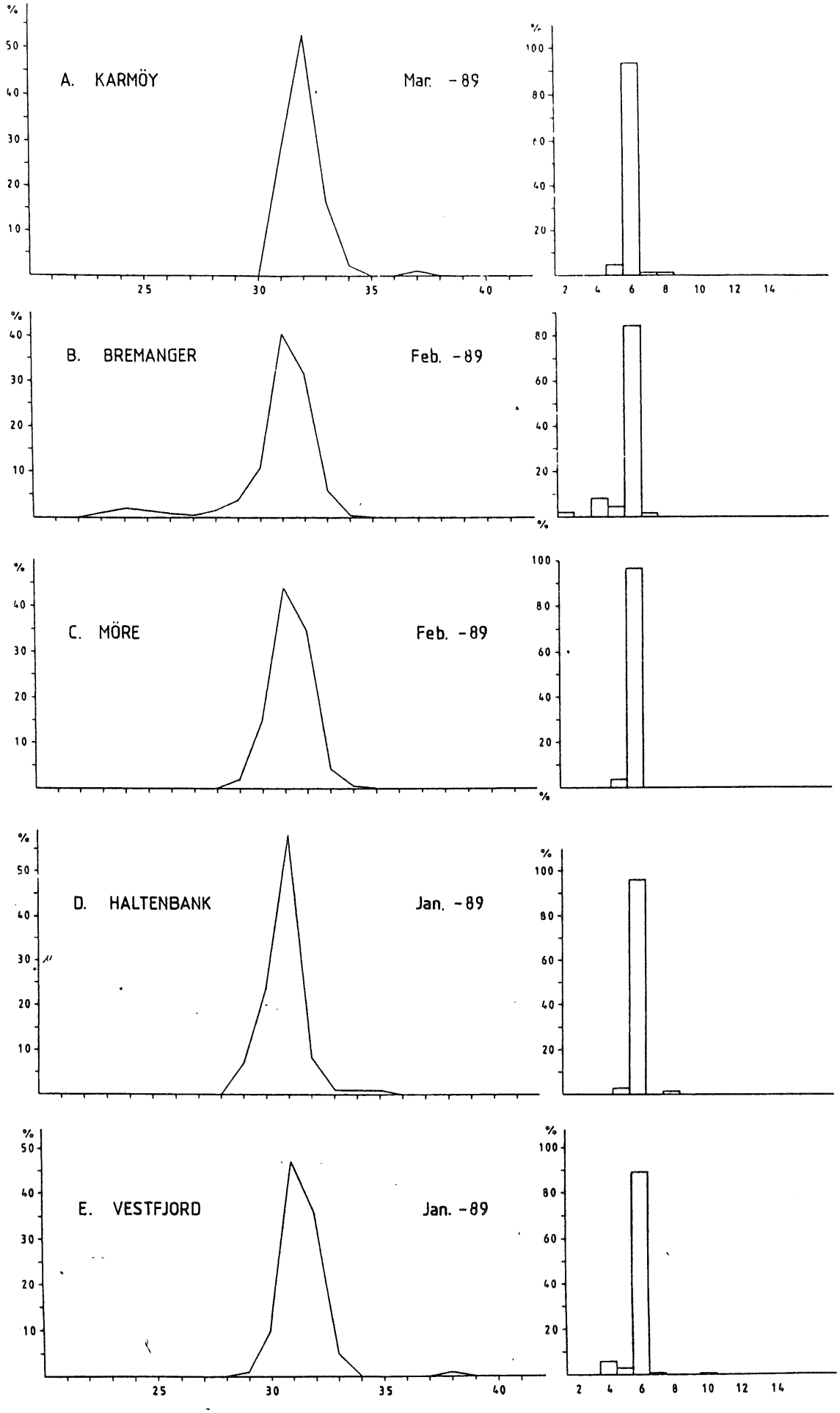



Figure 5. Length and age frequency distributions from different spawning areas of the Norwegian Spring Spawning Herring in 1989.

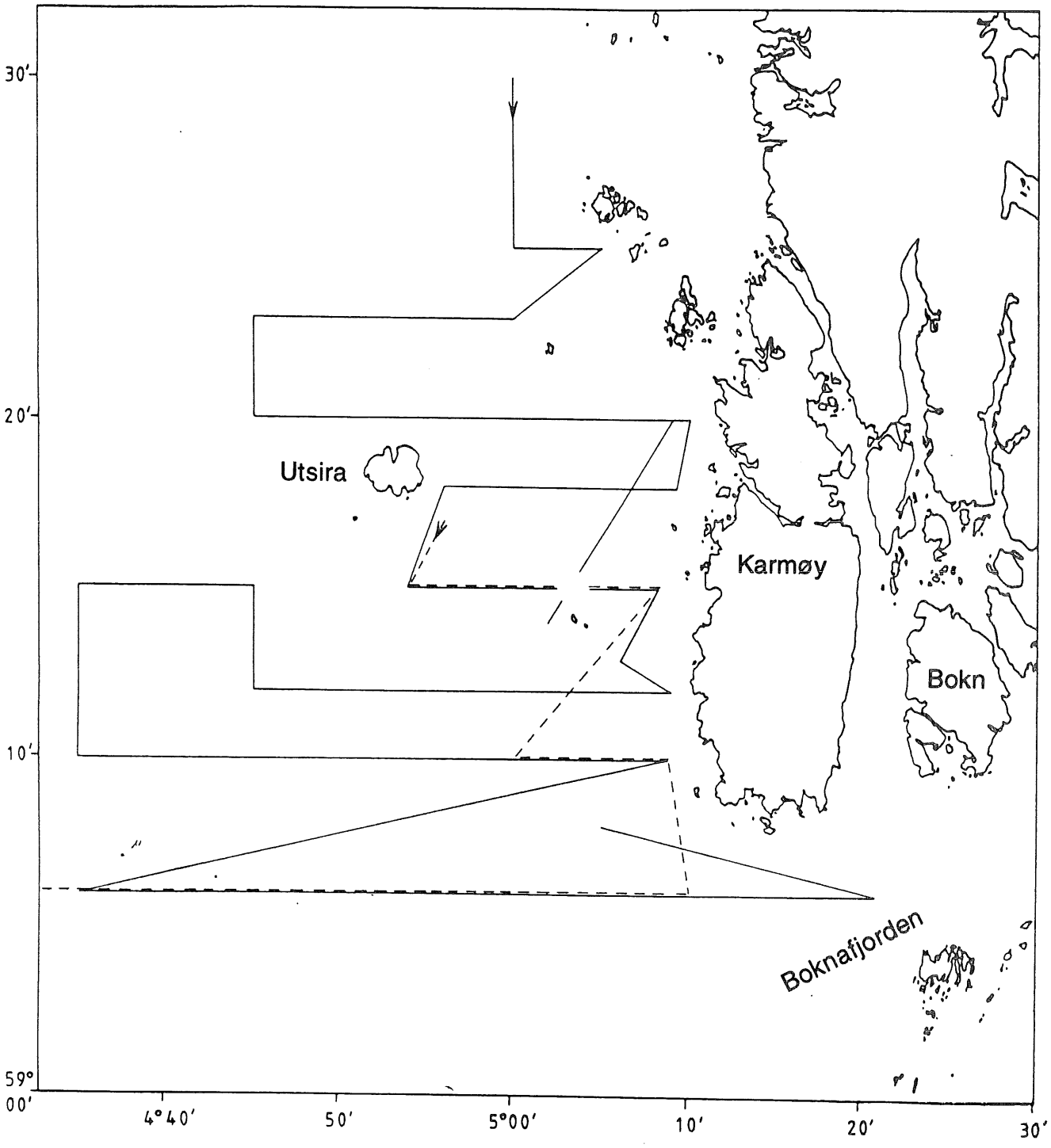



Figure 6. Survey track of the RV Eldjarn in mid-February 1990. Unbroken lines: 13 - 14 February, broken lines: 14 - 15 February.

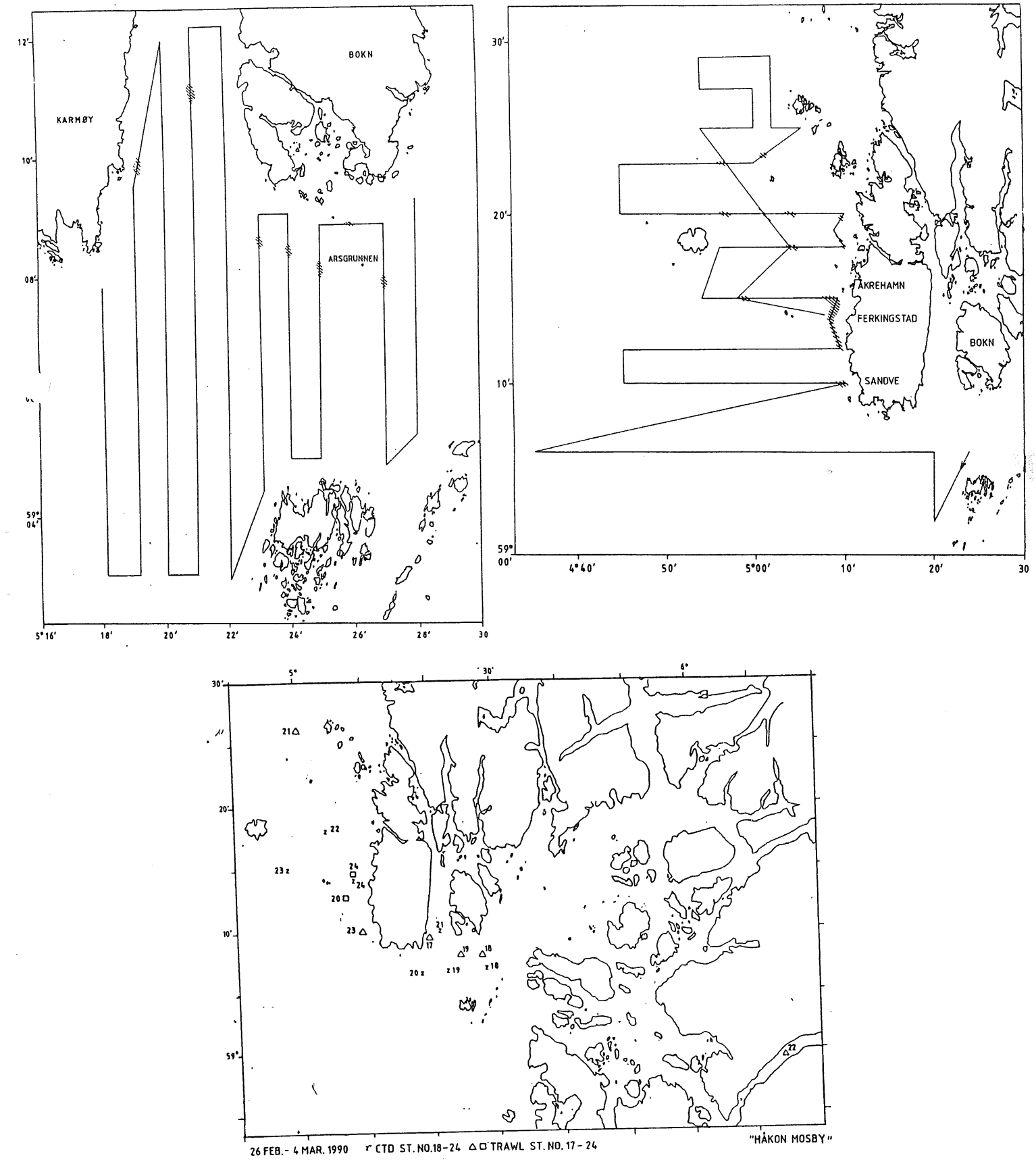



Figure 7. Observations of herring concentrations (cross-hatched areas) and survey track, trawl stations and CTD casts of the RV Håkon Mosby in late February - early March 1990.

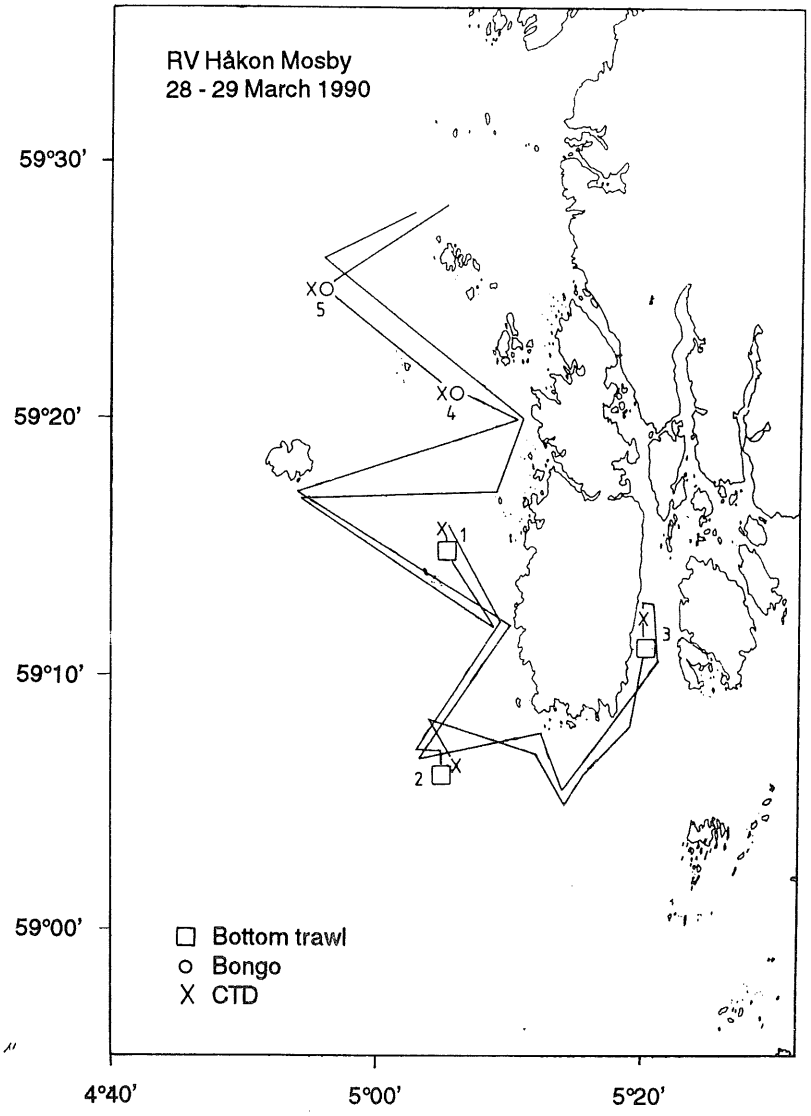



Figure 8. Survey track and trawl stations of the RV Håkon Mosby on 28 - 29 March 1990.

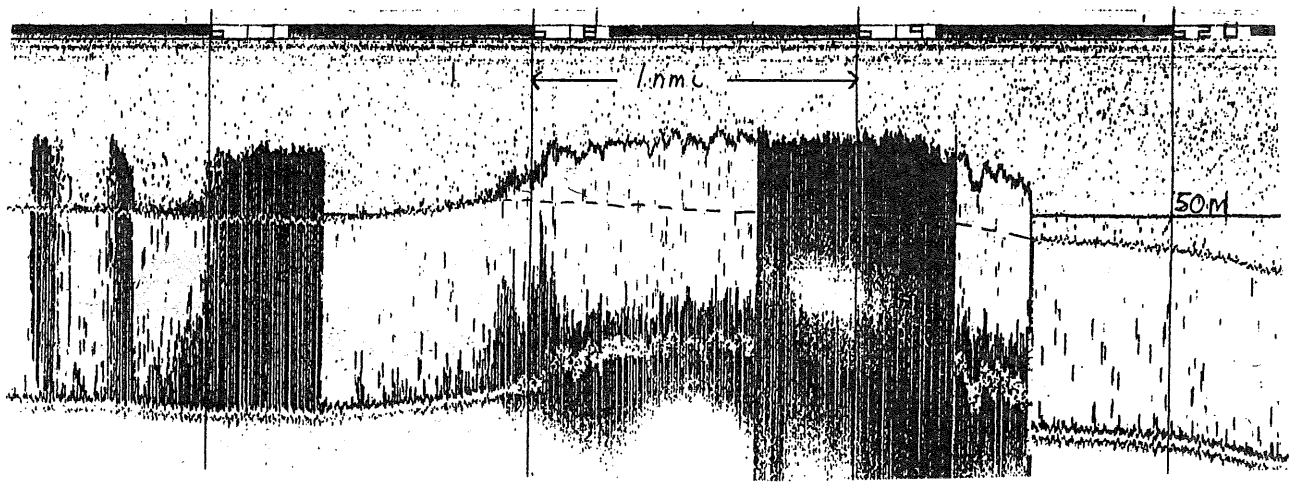



Figure 9. Echogram showing near-bottom concentration of herring at the Karmøy spawning ground in March 1990.

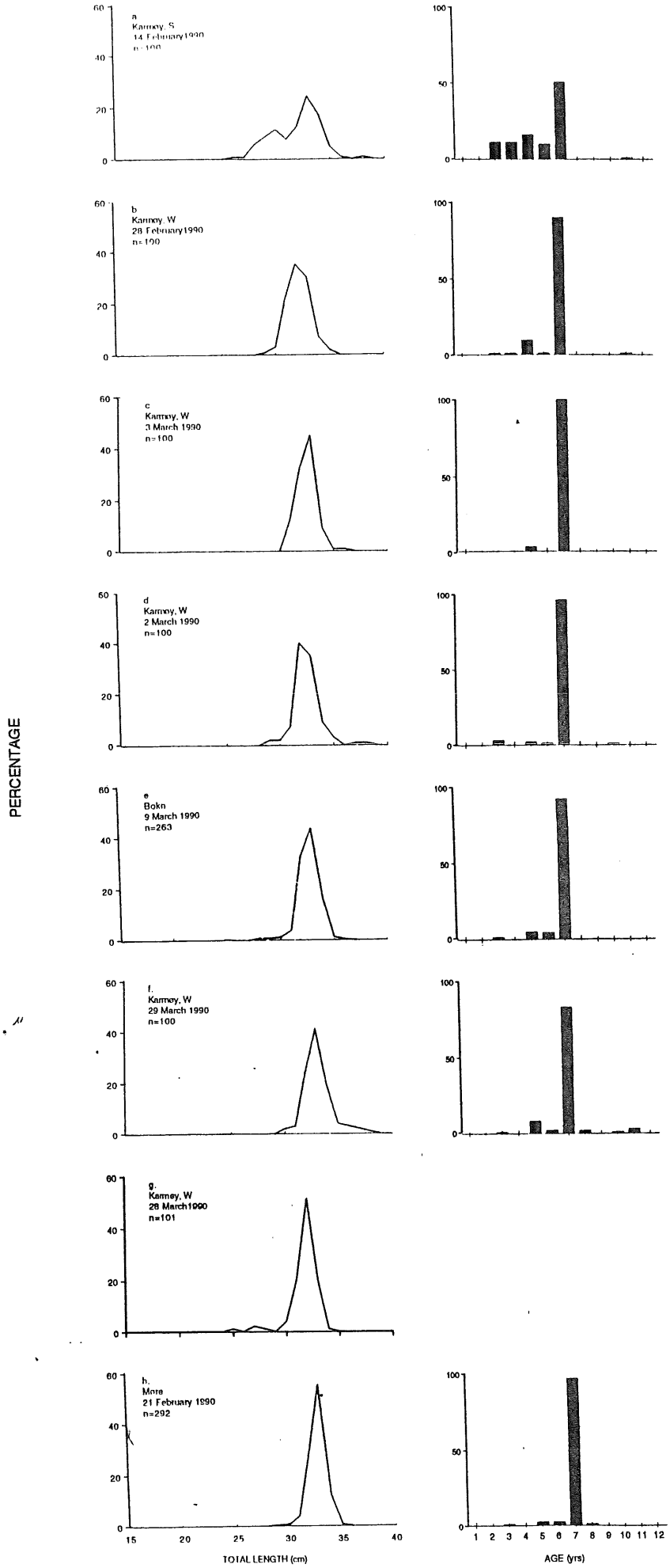



Figure 10. Length and age frequency distributions of spring spawning herring in 1990 from different spawning areas and time periods.

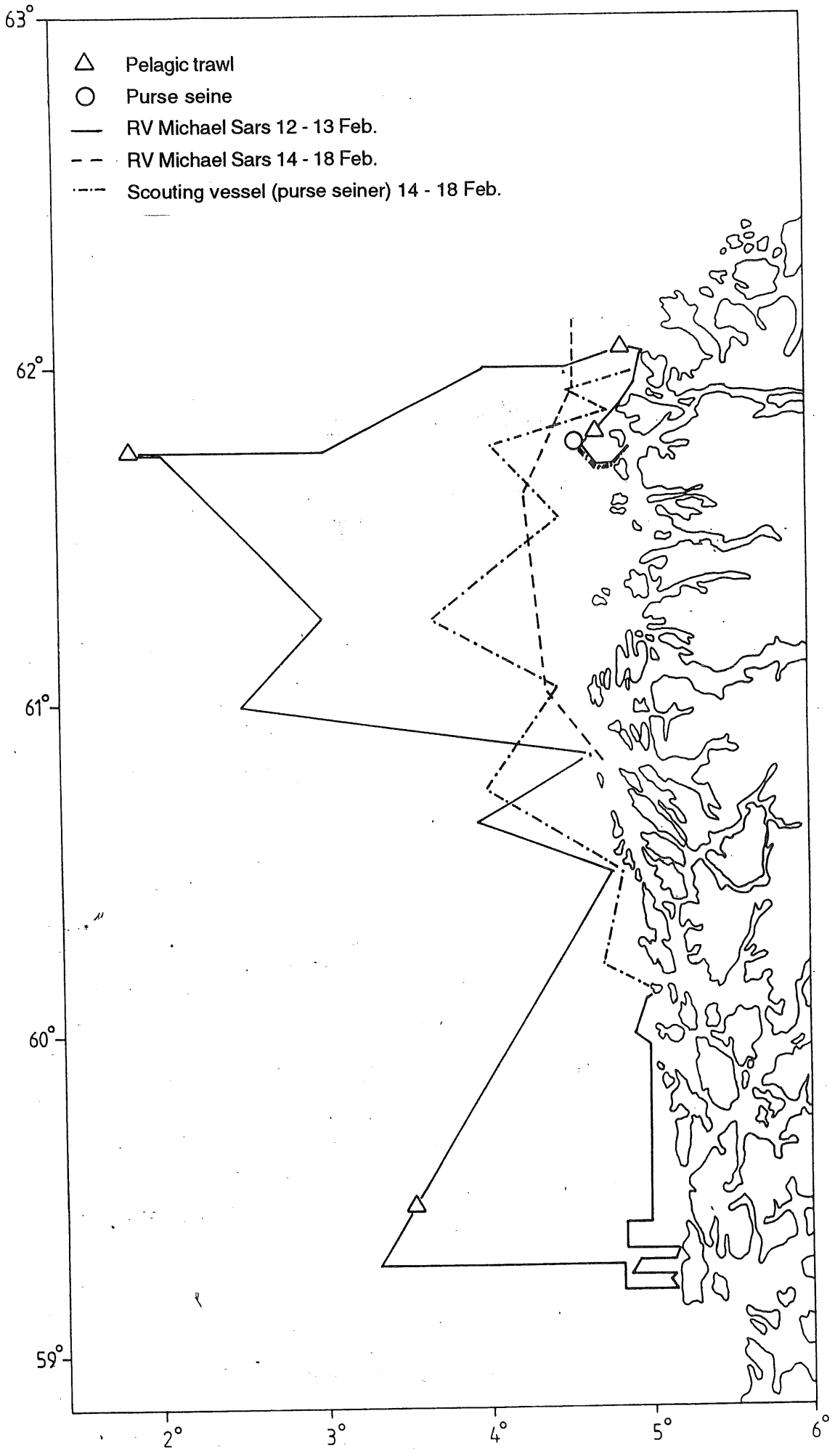



Figure 11. Investigations in mid-February 1991.

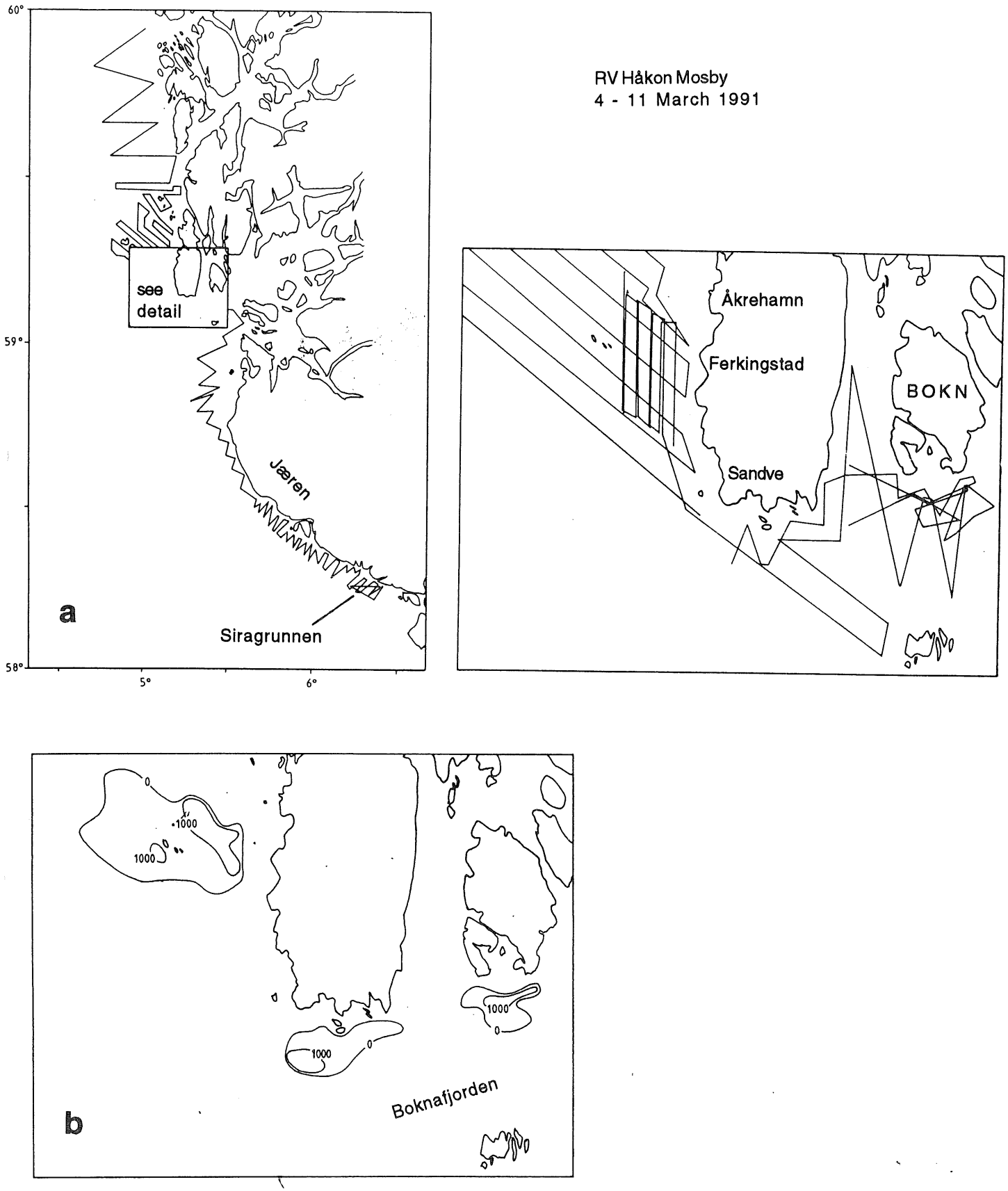
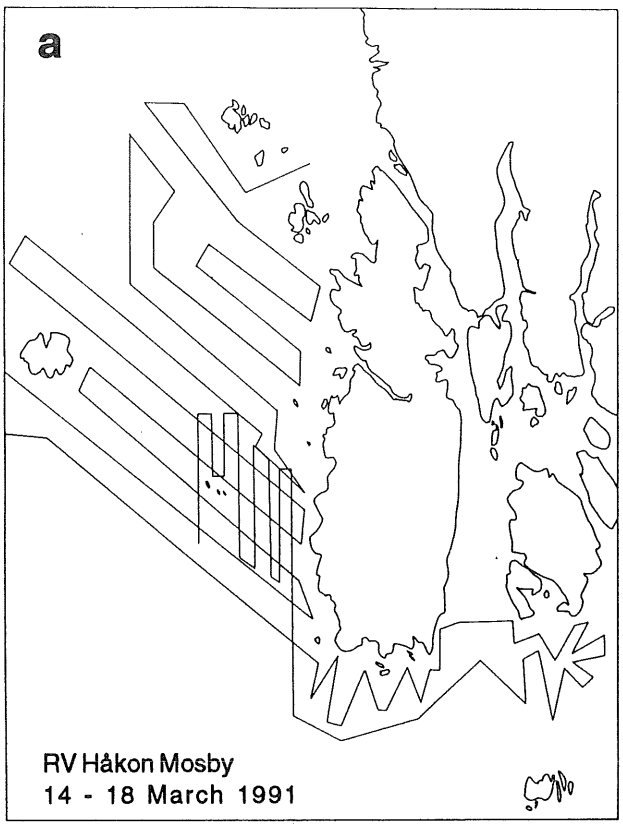



Figure 12. Hydroacoustic survey of the southern grounds in early March 1991. a) Survey track of the RV Håkon Mosby, b) distribution of herring based on echo-integration (values are integrator readings as $m^2/n.m.^2$).



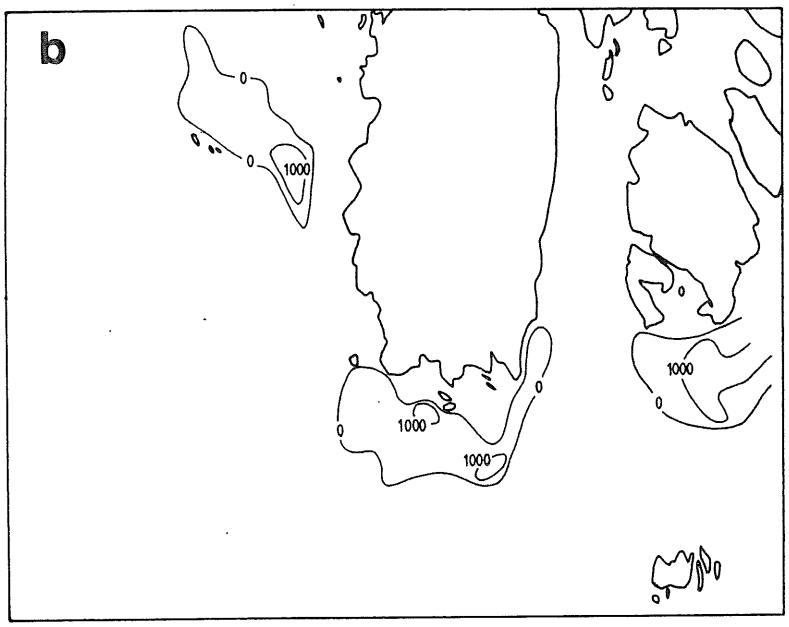
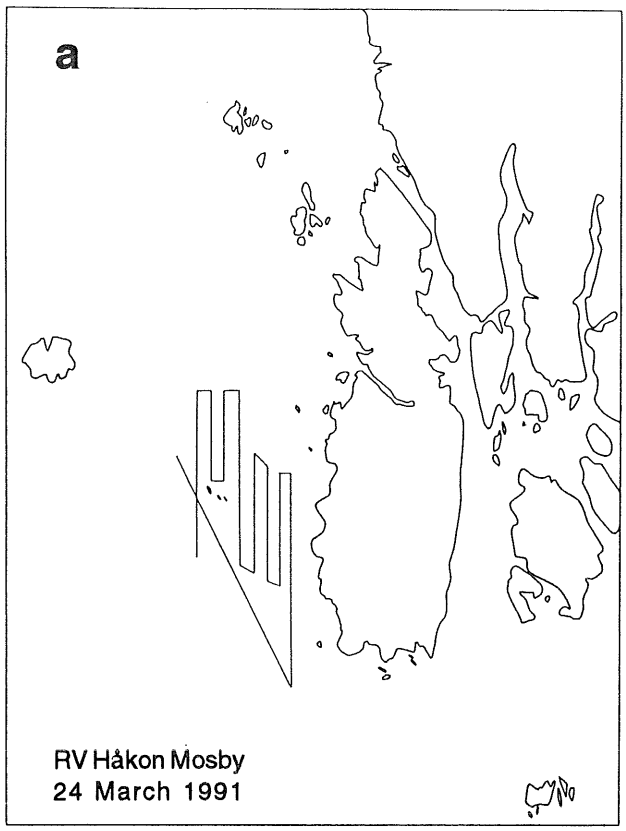




Figure 13. Hydroacoustic survey of the spawning grounds near Karmøy 14 - 18 March 1991. a) survey track, b) distribution of herring (as in Fig. 10)



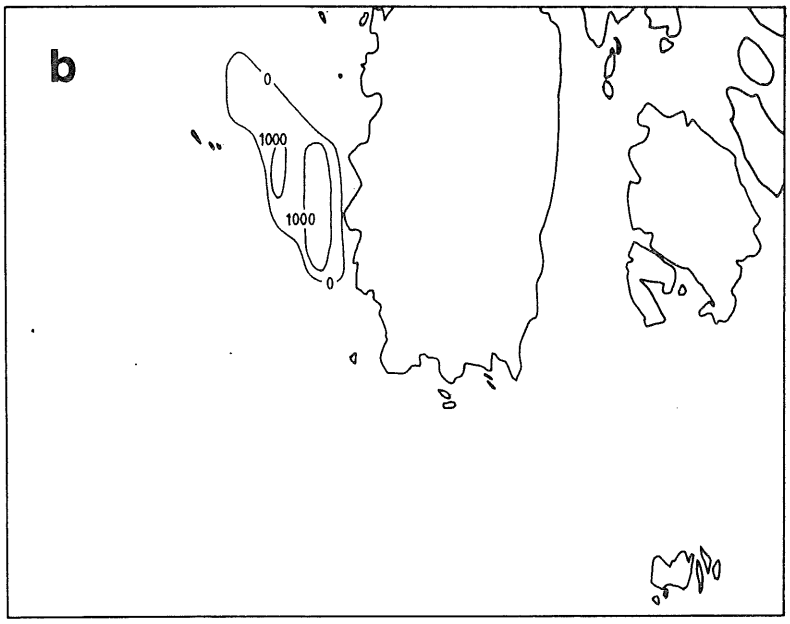




Figure 14. Hydroacoustic survey of the spawning ground west of Karmøy on 24 March 1991. a) survey track, b) distribution of herring (as in Fig. 10).

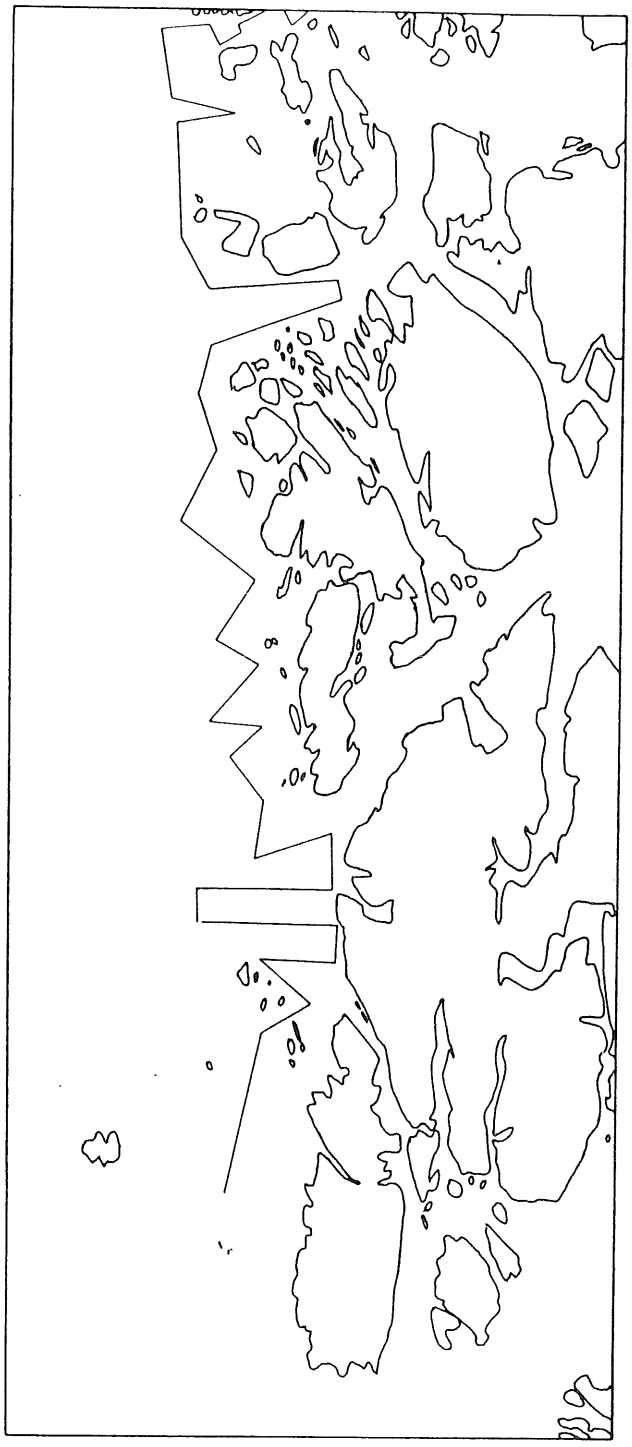


Figure 15. Survey track of the survey by RV Håkon Mosby on 24 and 25 March 1991 from Karmøy to Korsfjorden.

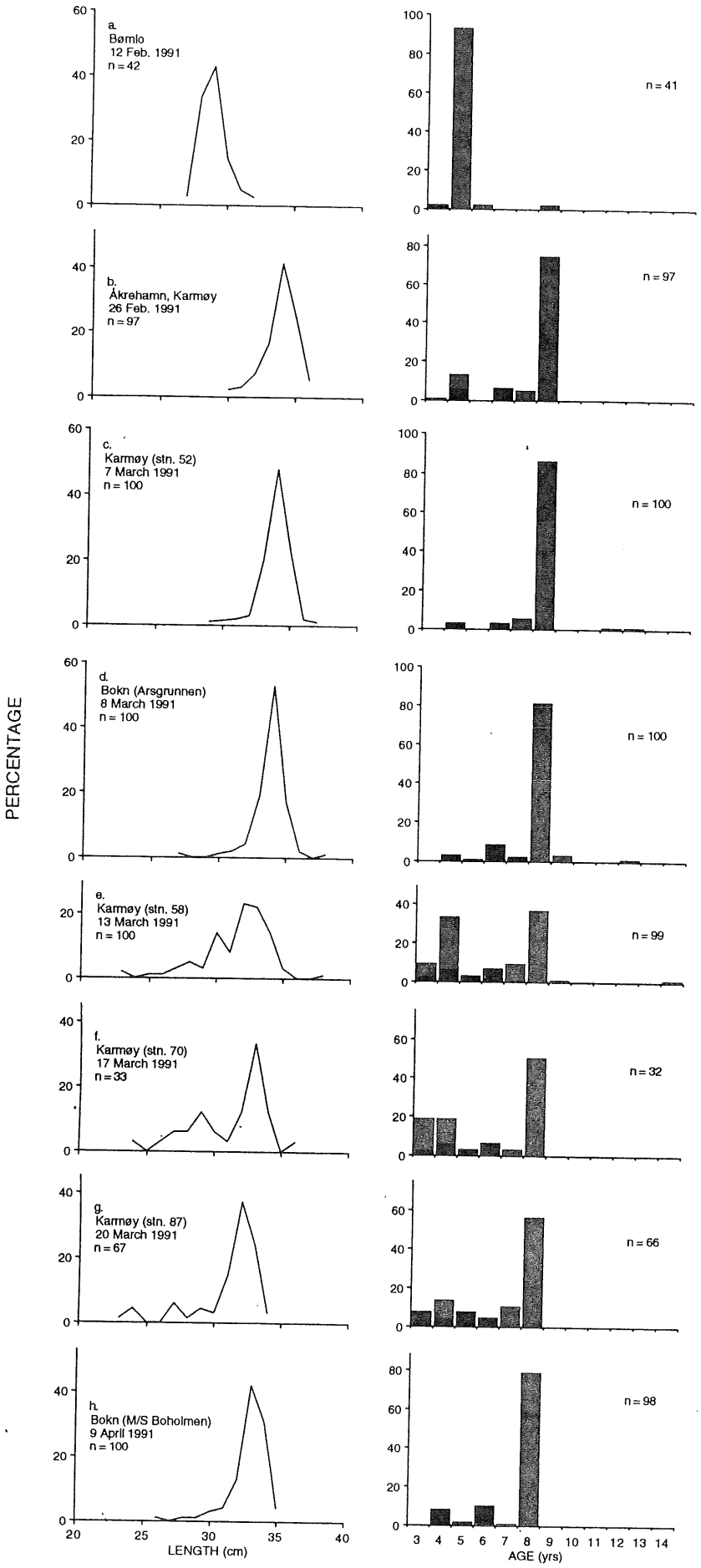



Figure 16. Length and age frequency distributions of herring from the 1991 spawning season.

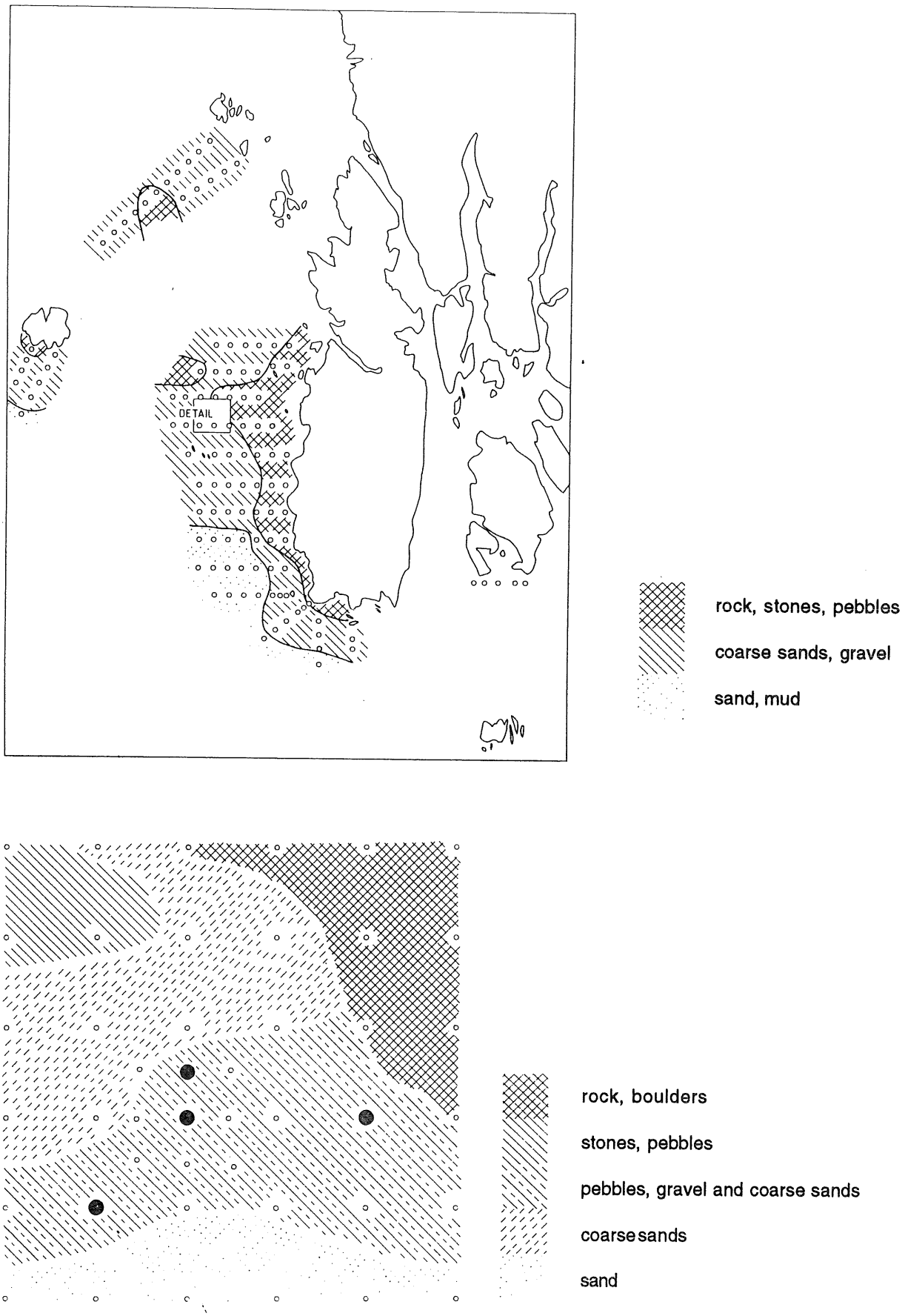



Figure 17. Bottom substrates at the spawning grounds of the Norwegian spring spawning herring. Circles represent grab stations. Stations with catches of herring eggs are represented by dots (all within the expanded subarea).

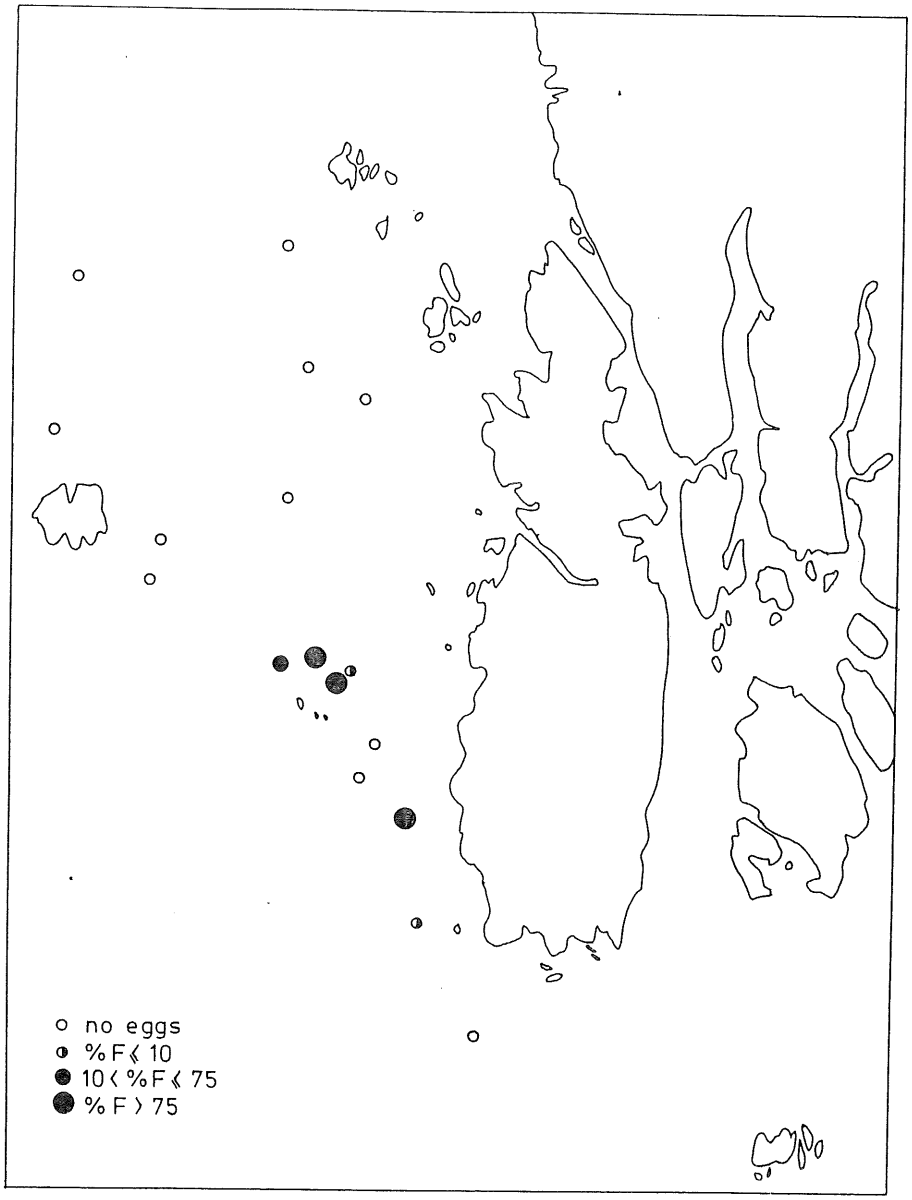



Figure 18. Percentage frequency of occurrence (% F) of herring eggs in stomachs of haddock, cod, pollack and saithe at individual bottom trawl stations. RV Håkon Mosby, latter half of March 1991.