THE 1983 YEAR CLASS OF NORWEGIAN SPRING SPAWNING HERRING AS JUVENILES AND RECRUIT SPAWNERS

by

Ingolf Røttingen

Institute of Marine Research
P.O. Box 1870 Nordnes
N-5024 Bergen, Norway

ABSTRACT

This paper gives the geographical distribution and the migrations of the 1983 year class of Norwegian spring spawning herring in the period 1983-1989. These migrations are compared with herring migrations of earlier periods. Further, the acoustic abundance estimates of this year class is reviewed.

INTRODUCTION

The stock of Norwegian spring spawning herring collapsed in the late 1960's (Dragesund et al. 1980). From a level of approximately zero in 1972 the spawning stock recovered in a slow but steady manner to a level of about 0.5 million tonnes in 1983 (Hamre 1989). This was, however, far below the average stock size in the period prior to the stock collapse. The strength of the year classes in the period 1970-1982 was also below the average year class strength of earlier periods.

In 1983 large amounts of 0-group herring were recorded in the Barents Sea, indicating favourable conditions for survival and growth of the herring larvae and 0-group. Since then, information on this year class has been obtained by:

1) Acoustic surveys
2) Sampling commercial catches
3) Tagging

Results from these surveys and investigations are given in papers presented to the ICES Statutory Meetings by the present author (Røttingen 1984,1985,1986,1987 and 1988), in ICES Working Group reports (Anon. 1984,1985,1986,1987,1988 and 1989) and in unpublished cruise reports to the Institute of Marine Research.

The aim of this paper will be the following:

1) To make a chronological review of the seasonal geographical distribution and various aspects of the behaviour and biology of the 1983 year class from its birth in spring of 1983 to 1988/89 when the bulk of this year class recruited to the spawning stock.

2) Discuss the abundance estimates obtained for the 1983 year class.

3) Outline the migration patterns which the 1983 year class has undertaken, and compare these with migration patters from previous time periods.

RESULTS

Geographical distribution

YEAR 1983

The spawning in 1983

At the end of the 1970's and beginning of the 1980's release and recapture data showed that tagged herring did not mix randomly within spawning stock of Norwegian spring spawning herring, but that the spawning stock consisted of at least two units or "components" (Hamre 1989). In 1983, these units (one southern and one northern), were estimated to be of approximately the same size. The southern unit spawned mainly on the traditional spawning grounds on the coastal banks south of 63°N, the northern unit spawned north of 63°N. The Working group on Atlanto-Scandian herring has estimated the total spawning stock to 615 thousand tonnes in 1983. This estimate was derived from a VPA run which was tuned to the 1984 spawning stock estimate obtained by tagging (Anon. 1988).

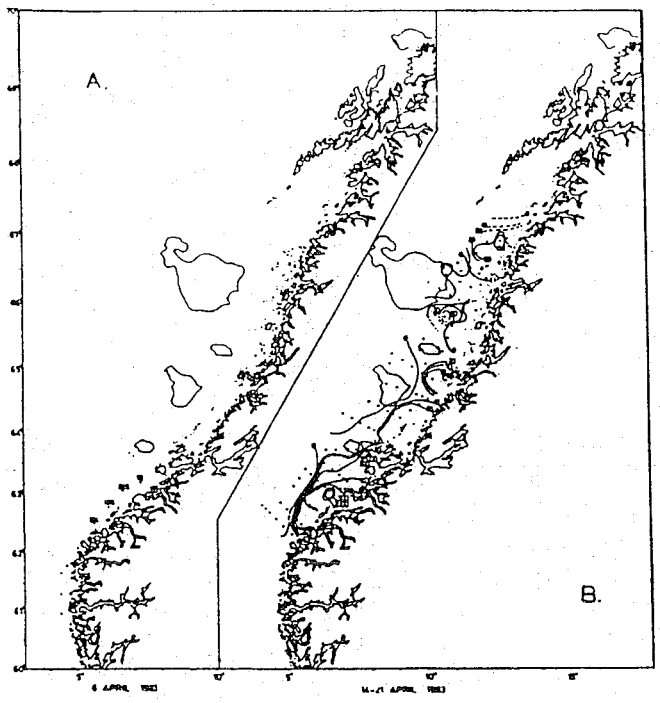

Fig. 1. Norwegian spring spawning herring.
A. Number of larvae on Gulf III stations, April 6th 1983.
B. Number of larvae per m^2 surface 14-21 April 1983.
(Bjørke, unpublished data).

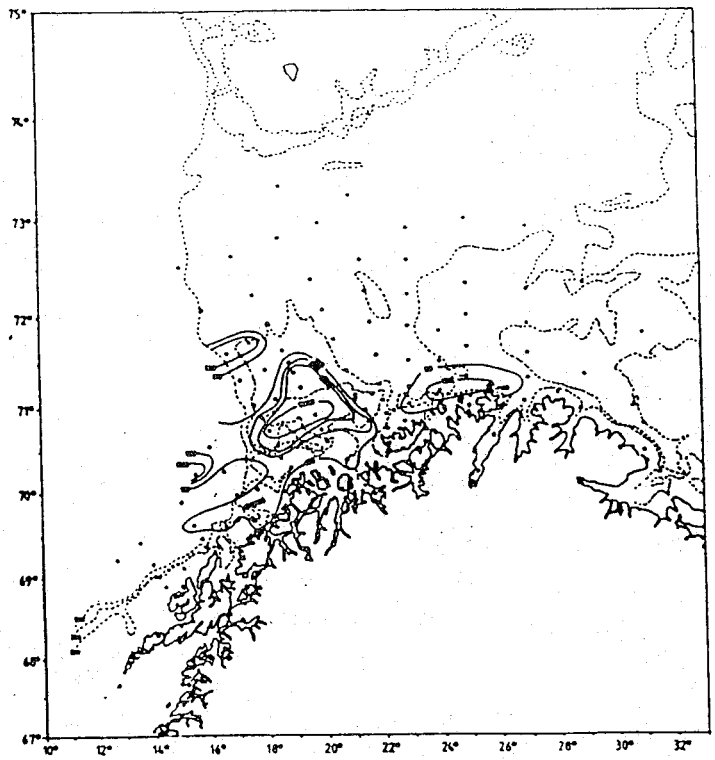

Fig. 2. Norwegian spring spawning herring
Distribution of postlarvae 20 June-16 July 1983.
(Bjørke, unpublished data).

April 1983 - herring larvae

The following paragraph on herring larvae in 1983 is a summary from Bjørke (pers.com). On April 5 four stations using a Gulf III plankton recorder were taken in the area from Statt to Smøla. The number of larvae is shown in Fig 1a. Most of the larvae were newly hatched, but there were observations of larvae up toward 14 mm. This indicates that hatching took place on the spawning fields on Møre in last week of March 1983. In the period 14-21 April herring larvae were recorded from Statt to Bodø (Fig 1b). 5200 larvae, of which 390 were larger than 12 mm, were taken in 1983. This was until then the largest number of larvae observed since the stock collapse in the late 1960's.

The distribution of the herring larvae (Fig 1) may be taken as an indication of the extent of the spawning in 1983. The general conclusion is that there seems to have occured a widespread spawning in 1983 from Statt and northwards to Bodø, but the main spawning seems to have occured in the traditional spawning sites off Møre.

June-July 1983

Postlarvae off northern Norway were recorded on a survey in the period 20 June-16 July 1983. The sampling was done by pelagic trawl. Fig 2 shows the distribution of the herring postlarvae. (H. Bjørke, unpublished data). The main concentrations were found off Tromsøflaket (Approximately 71°N, 19°E). The western limit of the distribution is not recorded. The main part of the postlarvae is found relatively close to the shore.

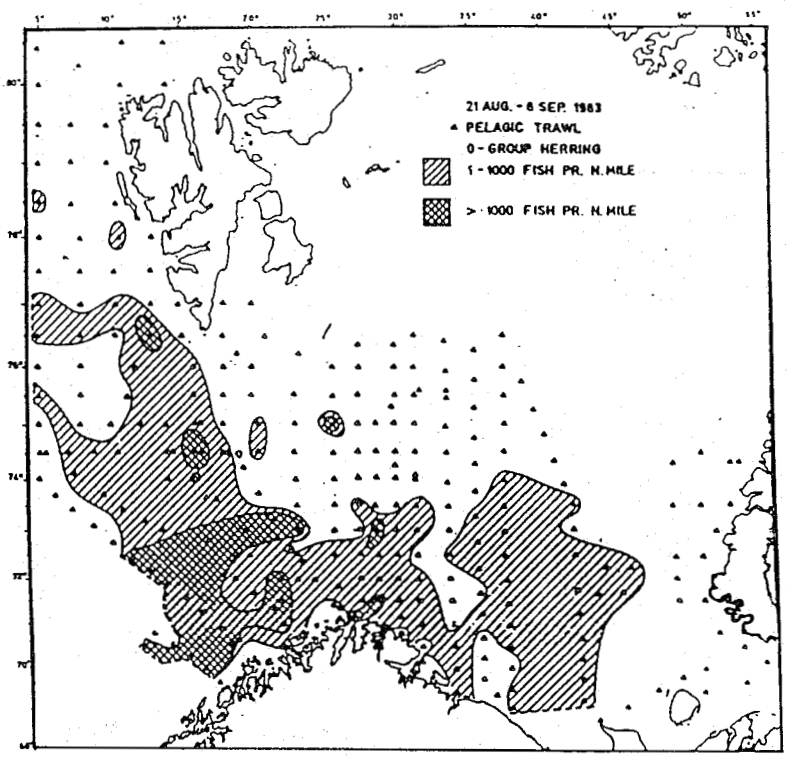

Fig. 3. Norwegian spring spawning herring.
Distribution of 0-group, International 0-group survey August-September 1983 (Anon 1983).

August-September 1983

The distribution of the 0-group recorded during the international 0-group cruise in the Barents Sea in the period 21 August-8 September 1983 is given in Fig 3 (Anon 1983).This is a trawl survey, the dense and very dense areas shown in Fig 3 are defined according to the catch of 0-group herring in the trawl stations. The 0-group herring have now, compared with the postlarvae situation in June-July, a far more offshore and eastern distribution. In 1983, 0-group herring were found on a larger number of stations and the number of specimens at each station was higher than previously observed on the international 0-group surveys. These surveys started in 1965.

November 1983

Fig 4 shows the area where 0-group herring was recorded in November 1983. Bad weather and some technical difficulties limited the investigation area during this survey. There is therefore a possibility that 0-group herring were located in other areas of the Barents Sea than shown in Fig 4. However, if the figure shows the main distribution area, then a considerable east to southeast migration of the 0-group herring took place in the late autumn months of 1983.

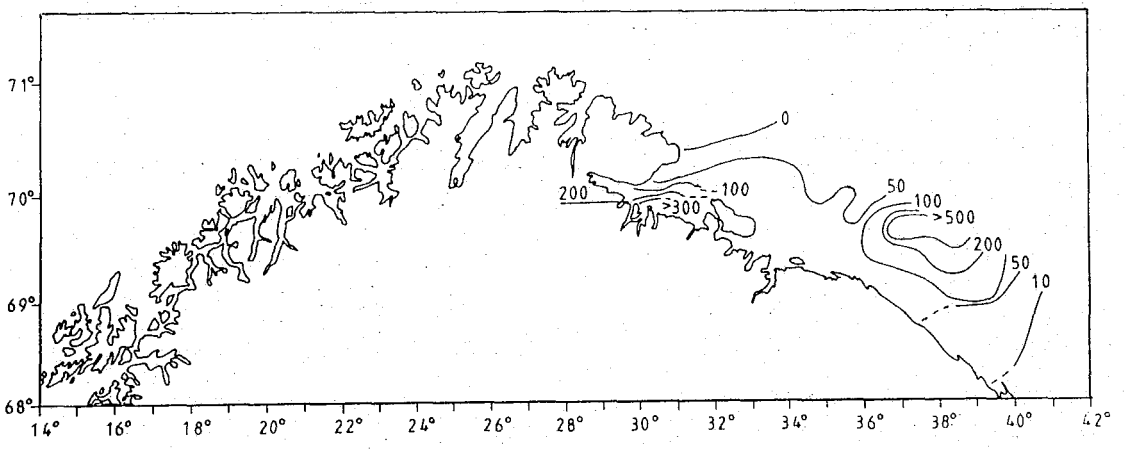

Fig. 4. Norwegian spring spawning herring.
Distribution of 0-group November 1983. Integrator output presented as total integrated scattering cross section per nautical mile multilplied by 10.

A 0-group herring survey was carried out in the fjord and coastal areas of northwest and north Norway in November 1983. This was part of a yearly investigation series that started in 1975 (Røttingen 1987a). The abundance of 0-group herring recorded in the fjord areas in 1983 was considerably higher than in the period 1975-1982.

Scenario at the end of 1983

By the end of 1983 it was clear that the 1983 year class of Norwegian spring spawning herring was abundant and distributed over wide areas in the Barents Sea and in the fjord and coastal areas of Norway. But how strong was this year class? Was it comparable to the large year classes of the 1950's and 1960's? Was it by the end of 1983 possible to make any quantitative comparisons with other year classes?

Dragesund (1970) made investigations of the strength of the year classes 1959-1965 as 0-group, and he also measured the subsequent year class strength at recruitment to the spawning stock. However, the

methodology, equipment and calibration methods used during these investigations were different from those applied in 1983. This makes a direct comparison between acoustic abundance estimates from the 1960's and 1980's impossible.

Based on the results from the international 0-group surveys in the Barents Sea the Working group on Atlanto-Scandian herring in October 1983 calculated an abundance index for the 0-group herring in 1979 and 1983. The result is given in the text table below:

	Year	
	1979	1983
Abundance index	8	431

The number of the 1979 year class as 4 year old fish was estimated by tagging to 1350 x 10^6 individuals (Anon. 1984). Assuming at least an equal abundance of 0-group herring in the coastal areas in 1983 as in 1979 the Working group stated:"The Working group concluded that the 1983 year class was very strong as 0-group compared to any year class since the collapse of the stock in the late 1960s, and that it could well turn out to be of the same order of magnitude as the year classes produced in the period 1961-66. These year classes had an avcerage strength of 17 x 10^9 individuals in terms of VPA estimates of 0-group fish (Dragesund and Ulltang, 1978). The corresponding average of 4 year old fish for the year classes 1961-1966 was 1507 x 10^6 individuals." (Anon 1984).

YEAR 1984

January 1984

Herring of the 1983 year class (now I-group) were recorded during the investigations of spawning capelin. Fig 5 gives the trawl stations taken during these investigations. The trawl stations with catches of I-group of herring are marked with filled symbols. If Fig. 4 is representative of the distribution in November 1983, the catches in January 1984 indicate that the herring had migrated northwards.

May-June 1984

Fig 6 gives the geographical distribution of the I-group herring in the Barents Sea in May-June 1984 (Toresen 1984). There were two main distribution areas. In the eastern part of the Barents Sea the I-group herring were distributed from north of the Rybachi peninsula (approx. 70°30'N, 32°,00'E) to the Goose Bank area (approximately 73°00'N, 48°00'E). There were more or less continuous recordings of I-group herring as a scattering layer in 100-150m depth (Fig 7) over a distance of approximately 250 nautical miles. The other distribution area off the Finnmark coast to about 50 nautical miles offshore. In this area some of the I-group herring formed schools near the surface, and there were some mixing with adult capelin.

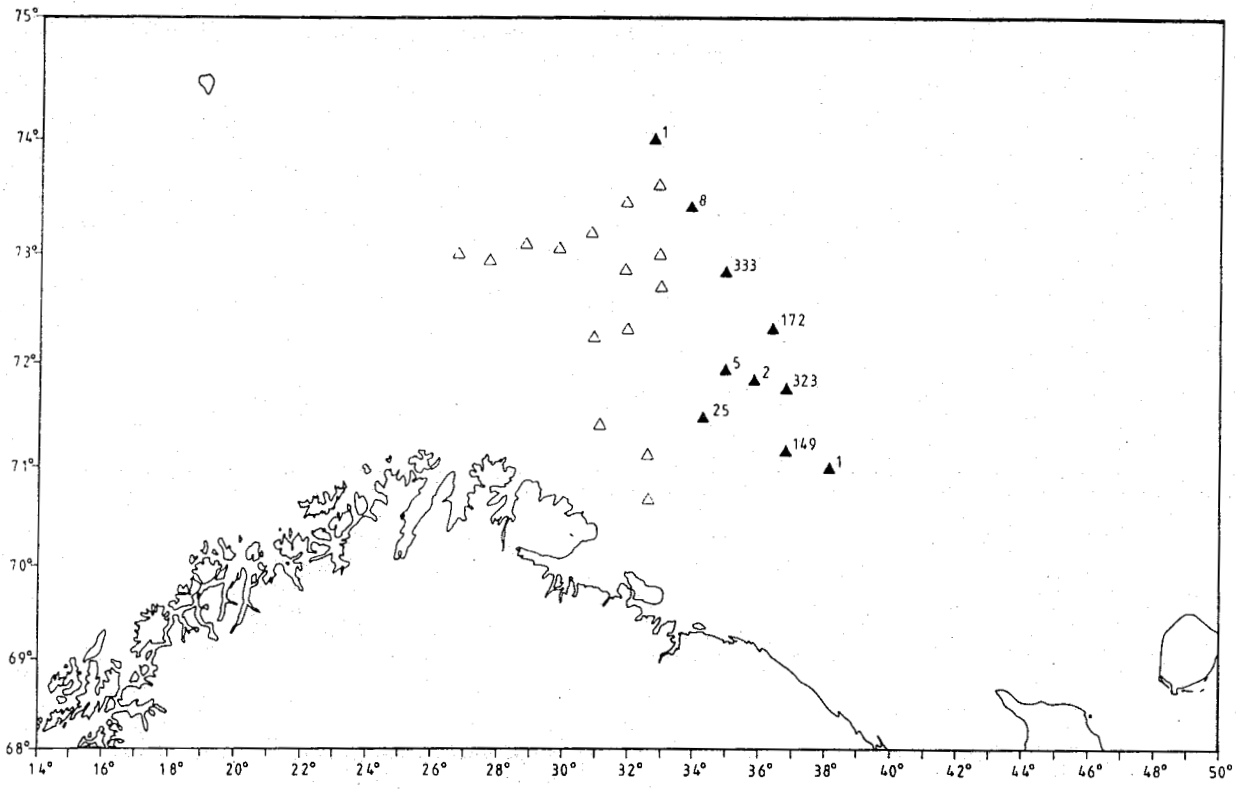

Fig. 5. Norwegian spring spawning herring.
Number of I-group per trawled nautical mile, January 1984.

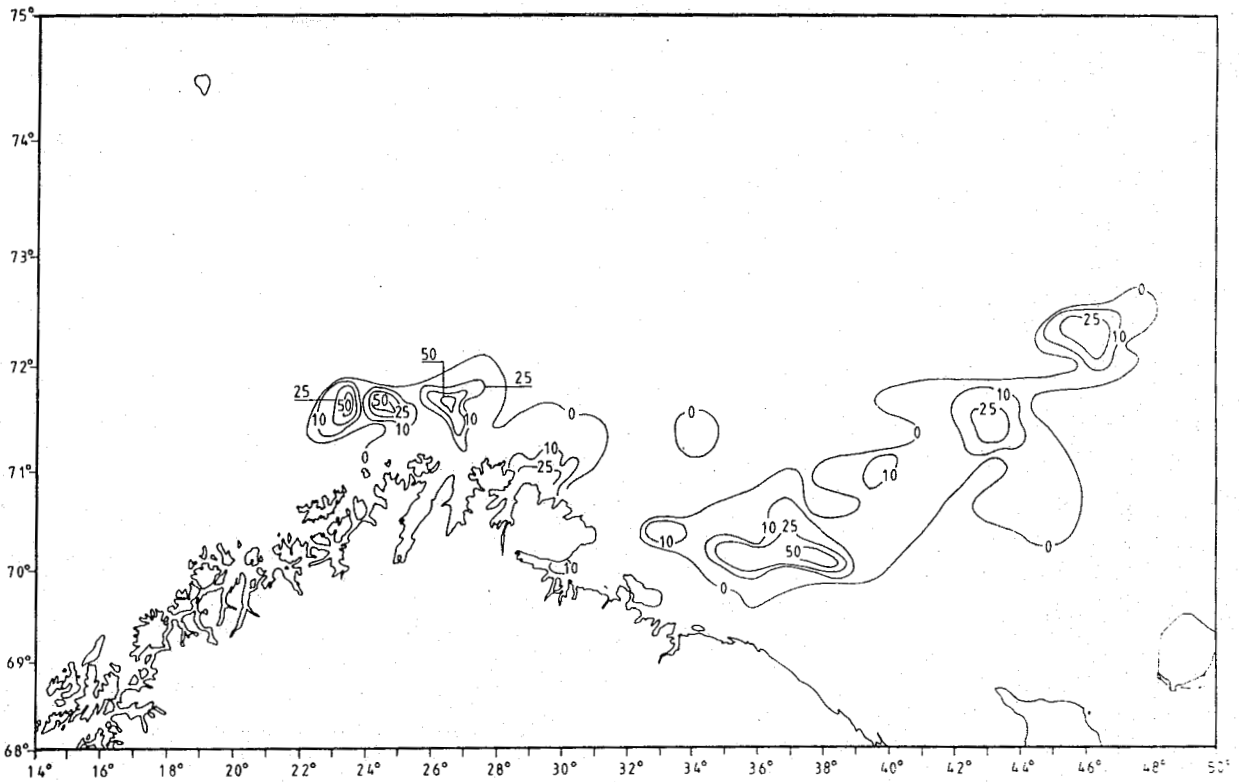

Fig. 6. Norwegian spring spawning herring.
Distribution of I-group in May-June 1984. Integrator output as in Fig. 4. Modified from Toresen 1984.

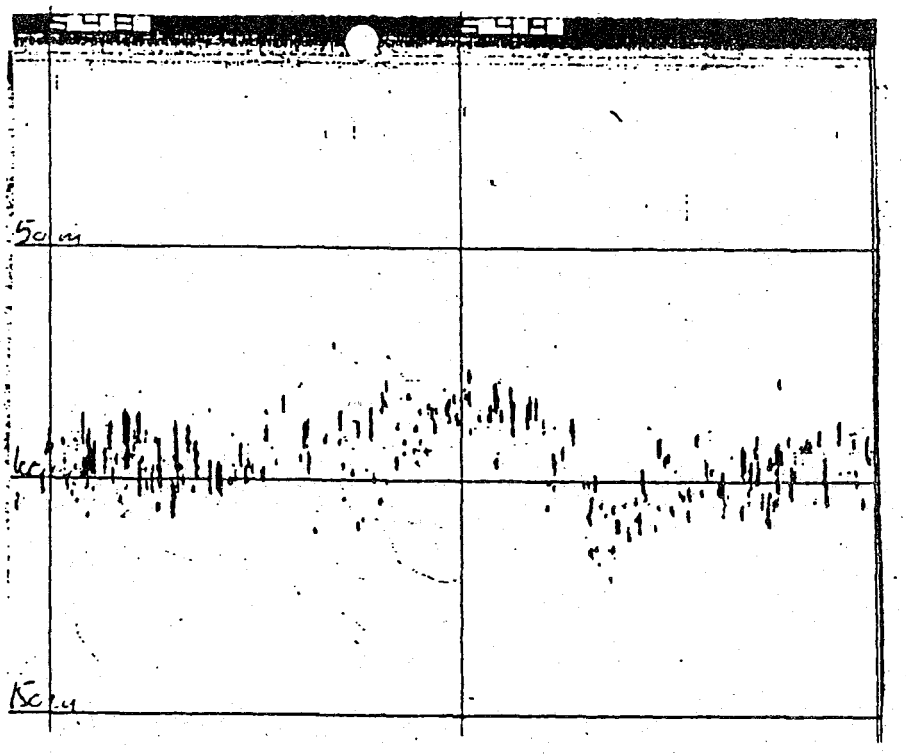

Fig. 7. Norwegian spring spawning herring.
Echogram showing scattering layer of I-group at 100 m depth.
Goose Bank. (Approx. 72°N, 47°E), May 1984 (Toresen 1984).

November-December 1984

A survey of the fjord and coastal areas of Norway, utilizing the same course lines as the corresponding survey in November-December 1983, showed that the 1983 year class was distributed over much smaller areas than the year before. However,there still remained considerable consentrations of this year class in some fjord areas, especially in northern Norway. Fig 8 shows a typical recording of the I-group herring from a fjord in northern Norway.

Scenario at the end of 1984

The corresponding surveys on the coast and fjord areas in November 1983 and November 1984 showed that the abundance (in numbers) and geographical distribution area of the 1983 year class had decreased considerably in these areas in this period. This was due to emigration and/or mortality.

Unfortunately, it cannot be stated with absolute certainty if any of the 0-group of the 1983 year class in the fjords of northern Norway emigrated from the fjords and joined the offshore population in the Barents Sea. Due to the possible underestimate of the 1983 year class during the acoustic survey in November 1983, the abundance estimates from the surveys in 1984 in the Barents Sea could not give any clear answer to the question if the offshore part of the 1983 year class had increased in 1984 due to emigration from the fjords. However, Fig 6 shows that I-group herring were distributed close to the entrance of the fjords east of Sørøya (approximately 23°E) in June 1984. This may be herring which has emigrated from the fjords. Although a major part of the 0-group herring in 1983 were distributed in the fjords from

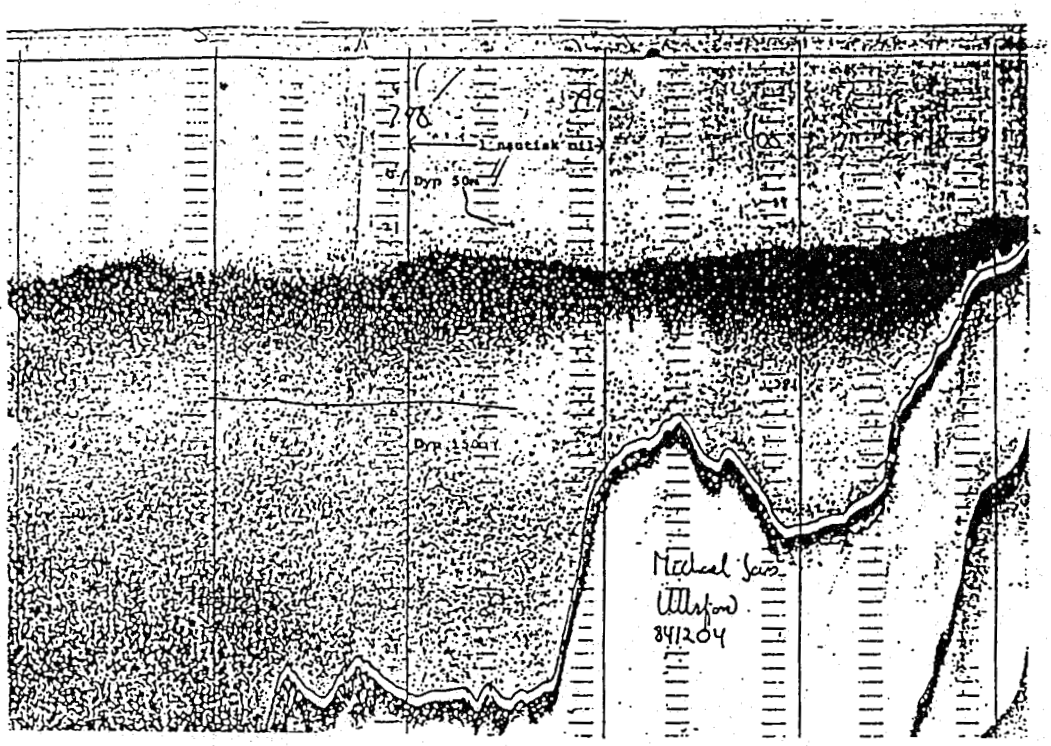

Fig. 8. Norwegian spring spawning herring.
Echogram of I-group in Ullsfjord, northern Norway, December 1984.

Sørøya to Lofoten, there were no records of I-group herring in the open sea outside this coastal area.

Based on the information available by October 1984, the Working Group restated their opinion,in a more confident way, about the 1983 year class in the following manner: "As observed last year, and confirmed in this year's report, the 1983 year class is strong and in view of the greatly improved prospects for recruitment to the spawning stock, a fishing mortality on the adult component of the stock in the order of F = 0.05 will have very little effect on the long-term development of the stock." (Anon. 1985).

YEAR 1985

January 1985

Fig 9 gives an indication of the distribution of the 1983 year class in the eastern part of the Barents Sea in January 1985. The acoustic survey in January 1985 was designed to cover the distribution area for cod, some areas where II-group herring may have been distributed may not have been surveyed. This may particulary be the case for the northern borders of the herring distribution.

However, taking the results from the January survey as an indication of the general distribution, it can be seen that the distribution of the herring is, in general, a little more to the east than the distribution in June 1984 (Fig 6). The behaviour had changed, in January the herring mostly occured in schools in contrast to the scattering layers in June 1984. There were also concentrations of capelin in the same area as the herring. The sonar and echo recordings

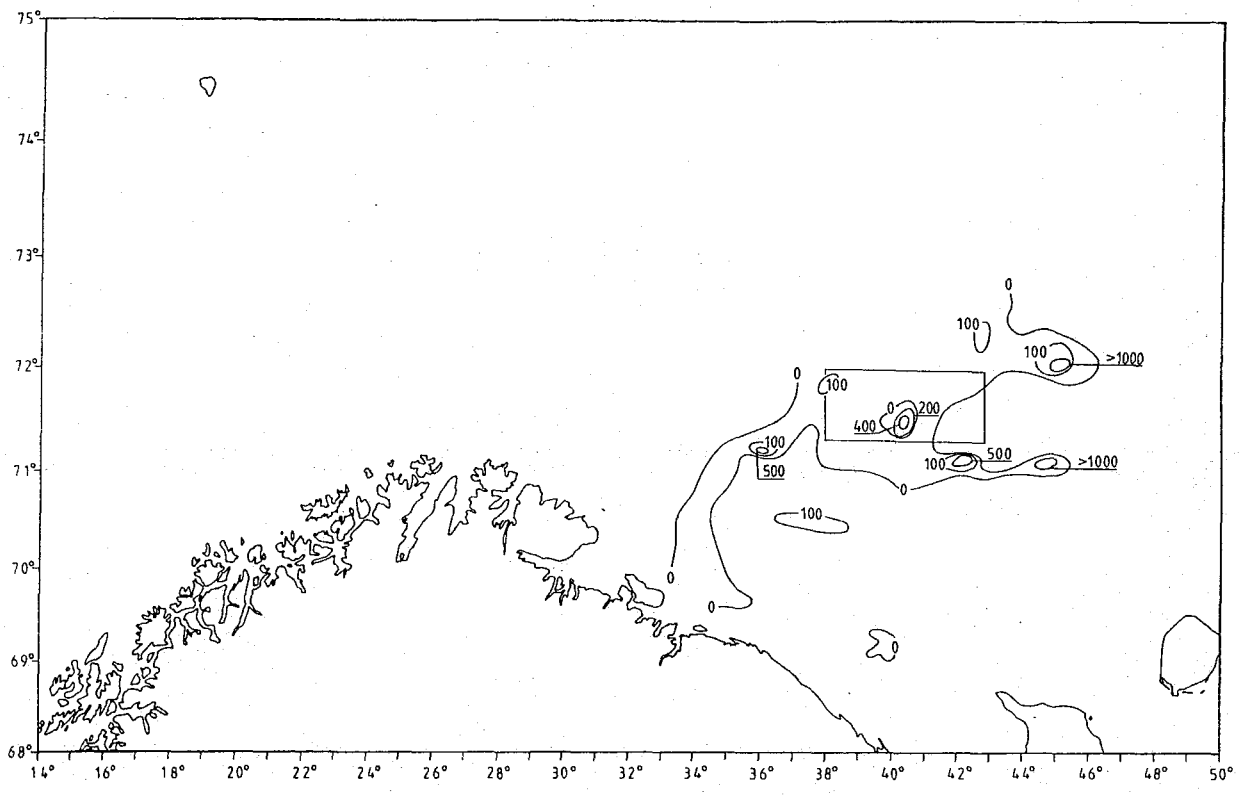

Fig. 9. Norwegian spring spawning herring.
Distribution of 1983 year class in January 1985. Integrator output as in Fig. 4. The Norwegian capelin winter fishery took mainly place within the small frame shown in the figure.

of capelin and herring were difficult to discriminate and this caused considerable difficulties in carrying out the Norwegian capelin winter fishery in January 1985. The area where the capelin fishery took place is within the frame included in Fig 9. A maximum by-catch of 10% herring was enforced in the Norwegian capelin winter fishery in 1985. The by-catch statistics show that approximately 2500 tonnes of II-group herring were caught in the Norwegian and 1800 tonnes in the USSR winter capelin fishery in 1985 (Anon 1986).

May 1985

Fig 10 gives the distribution of the 1983 year class in May 1985 (Hamre and Dommasnes 1985). Compared with January a westerly migration has taken place, and the eastern border is now approximately at 40°E. The herring was recorded both as small schools and as scattering layers form 50 m to 100 m depth. In some parts of the distribution area the herring was mixed with capelin, the capelin layer was usually deeper than the herring recordings.

Returning to the coastal areas, a tagging survey was conducted on the Norwegian coast south of 68°N in April-May. Small schools of herring of the 1983 year class were recorded off Møre and Helgeland. This herring had a far greater growth rate than the herring recorded in the Barents Sea. (Fig 11).

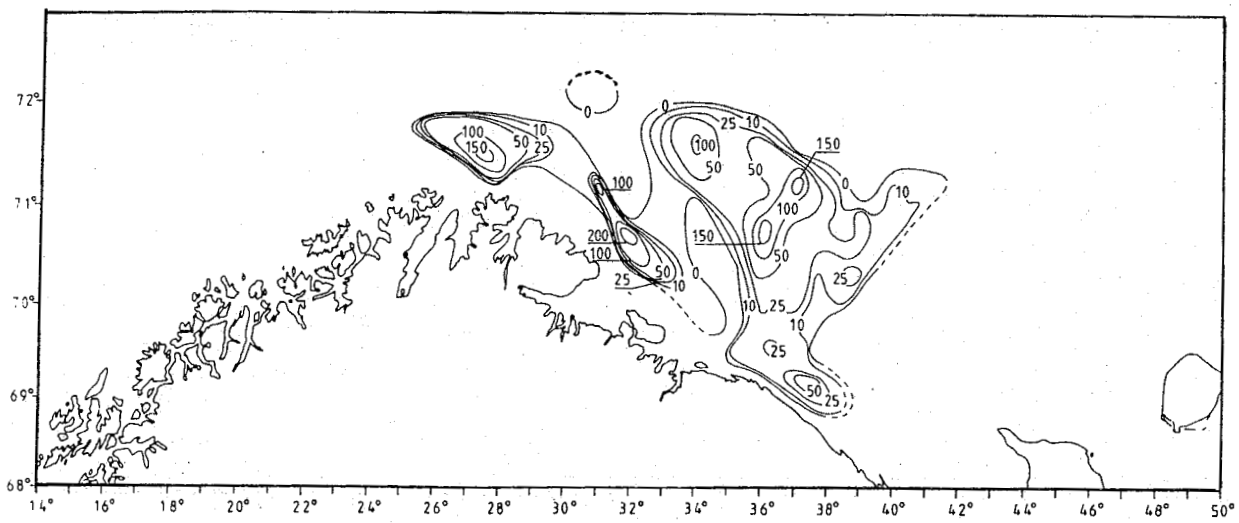

Fig. 10. Norwegian spring spawning herring.
Distribution of the 1983 year class in May 1985. Numbers denote tonnes per naut. mile^2. (Hamre and Dommasnes 1985).

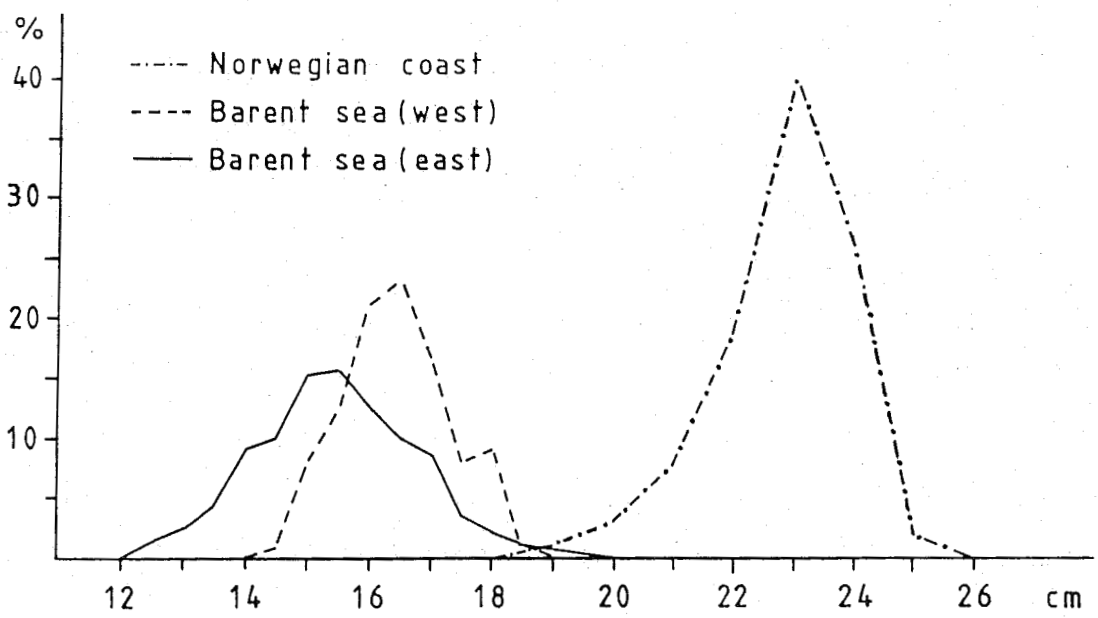

Fig. 11. Norwegian spring spawning herring.
Length distribution of the 1983 year class in May 1985).

September 1985

Fig 12 shows the distribution of the 1983 year class in September 1985 A comparison with Fig 10 (May 1985) shows that there was no major change in geographical distribution of the 1983 year class in the Barents Sea during the summer season of 1985. In September the herring were mostly distributed in dense schools near the surface during daytime, but there were also recorded schools of herring down to 100-150 m depth. During night time the schools were dissolved and the

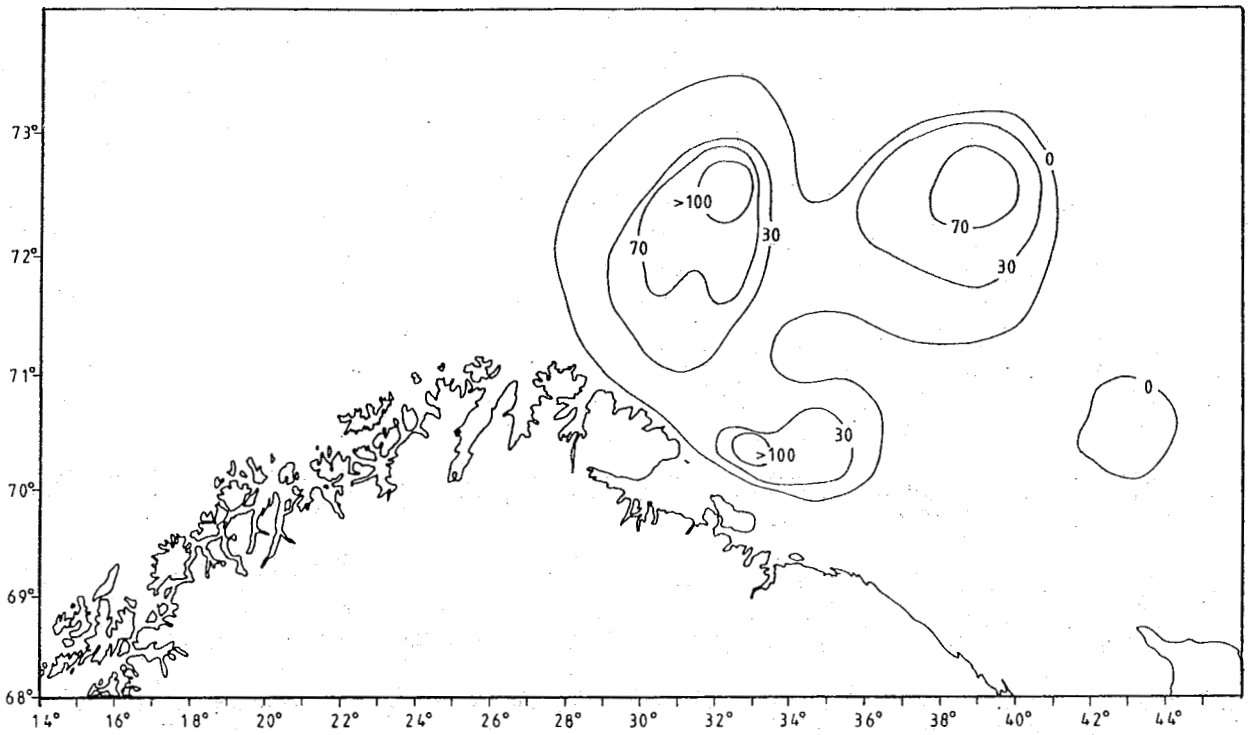

Fig. 12. Norwegian spring spawning herring.
Distribution of the 1983 year class in September 1985.
Numbers denote tonnes per naut. mile^2.

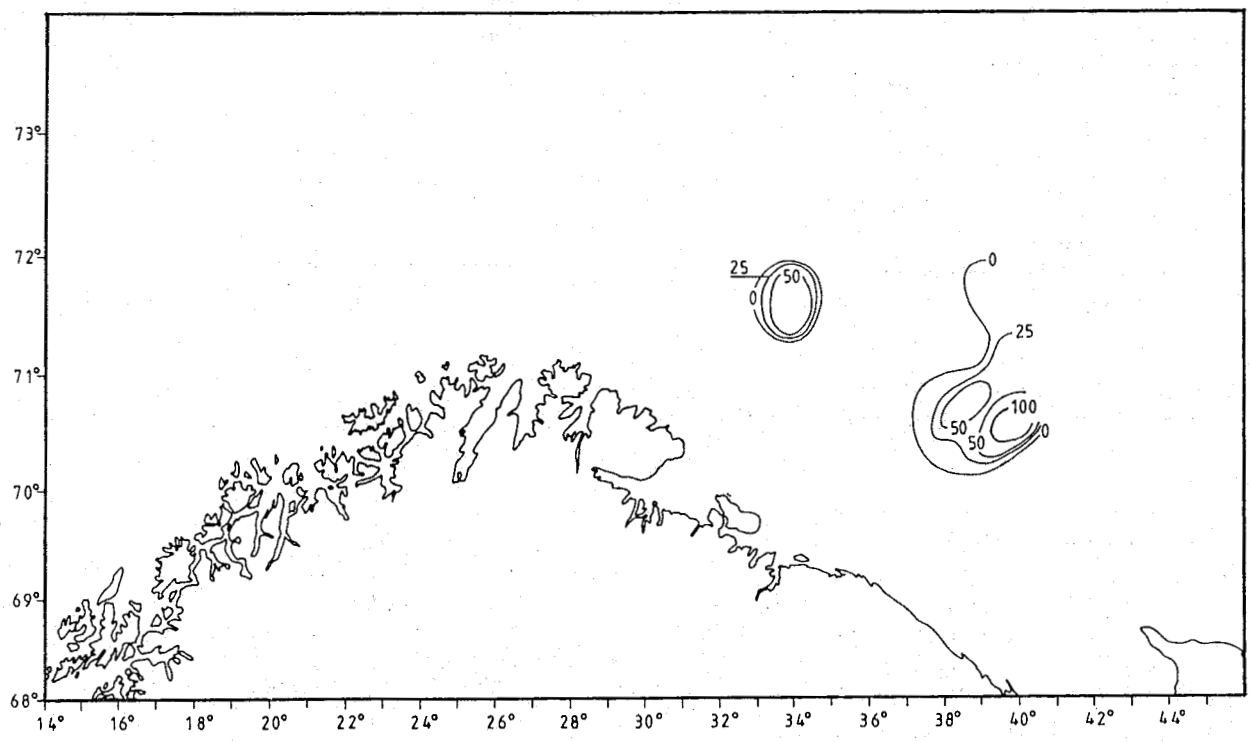

Fig. 13. Norwegian spring spawning herring.
Distribution of the 1983 year class in November 1985.
Numbers denote tonnes per naut. mile^2.

herring was recorded in scattering layers. Some 0-group herring and juvenile cod and haddock were recorded together with the II-group herring.

November 1985

Fig 13 shows the distribution of the 1983 year class in November 1985. The herring of the 1983 year class occurred together with 0-group herring. Only the area west of 41°E was surveyed. Fig 11 and 13 show that a comprehensive migration had taken place eastwards during a time interval of 2 months.The herring in the eastern part of the distribution area were mostly recorded as a scattering layer in the upper 50m of the water masses.

In November 1984 considerable amounts of I-group herring were recorded in the fjords of Northern Norway, especially north of 69°N. Very little II-group herring were recorded in these areas in November 1985, by this time the far greater part of the herring of the 1983 year class had migrated from this area. South of Lofoten (68°N) no herring of the 1983 year class were found in the fjord areas in November 1985.

Scenario at the end of 1985

Two different "populations" of the 1983 year class could still be recognized:

A) In the Barents Sea, the main concentrations of the 1983 year class undertook a western migration in the winter months, from an area around 40°E to an area off eastern Finnmark and Kola. In the summer season the geographical distribution remained relatively constant, but in October a migration to the eastern part of the Barents Sea took place. In winter the herring in the Barents Sea occurred together with capelin,in autumn the concentrations of the 1983 year class were mixed with 0-group herring (1985 year class).

B) On the coast, herring of the 1983 year class migrated from the inner part of the fjords where they were distributed as 0-group. Minor parts of the herring were found in the outer coast areas south of 68°N in spring. Further,the 1983 year class began to appear in the coastal herring fishery in autumn of 1985. This herring had a larger growth rate than the herring distributed in the Barents Sea.

YEAR 1986

January 1986

Fig 14 shows the distribution of III-group herring in January 1986. This was the most eastern distribution of the 1983 year class that had been observed since June 1984. From about 38°E and eastwards, the herring was recorded as a "carpet"near the bottom. At some locations, (approximately 72°N, 46°E), denser concentrations appeared as "columns" rising up to 50m from the sea bed. West of 38°E, some large schools of herring were detected, particulary in the area north and east of the Skolpen Bank. In the period January-April 1986 a fishery on the 1983 year class of herring was carried out by USSR in ICES area I (eastern part of the Barents Sea). The total catch in this fishery was approximately 25 thousand tonnes.

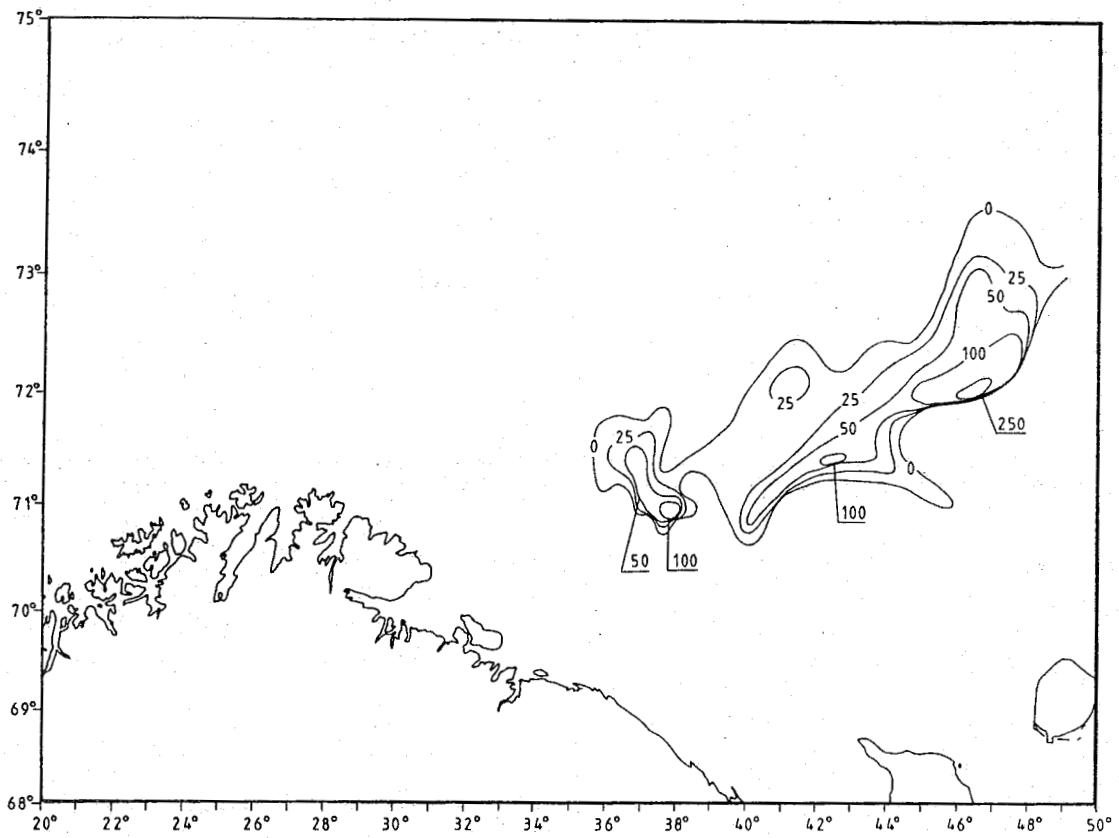

Fig. 14. Norwegian spring spawning herring.
Distribution of the 1983 year class in January 1986.
Numbers denote tonnes per naut. mile^2.

Spawning season, February-March 1986

In 1986 herring of the 1983 year class appeared for the first time on the spawning grounds off Møre. About 7% of the herring in the spawning areas (large variations from area to area) belonged to this year class. This was herring with a larger growth rate than that of the herring of the same year class in the Barents Sea. However, less than 10% of the 1983 year class which appeared on the spawning grounds had maturing gonads and may therefore have been recruit spawners, the rest were immature fish.

May 1986

Fig 15 gives the distribution in May 1986. There was now an extended east-west distribution in a "belt" of approximately 40-50 nautical miles width. The herring was mostly recorded as a scattering layer in 150-200 m depth. The density of the herring was much lower than recorded during previous surveys.

Herring were also recorded in the coastal areas. During a tagging survey in April 1986 schools consisting of 1983 year class herring only were recorded in the outer coastal areas between 66°N and 67°N. This herring had a larger growth rate than the herring in the Barents sea (Fig 16).

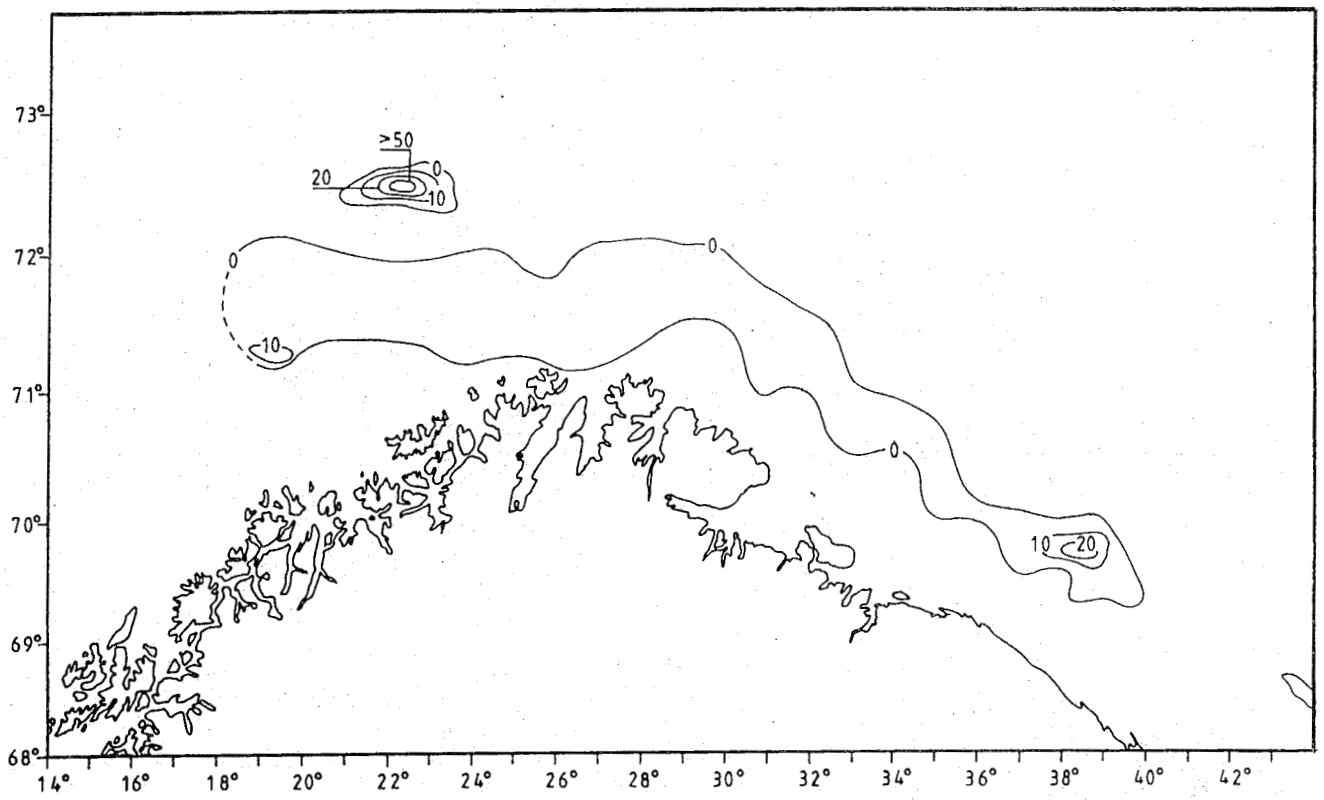

Fig. 15. Norwegian spring spawning herring.
Distribution of the 1983 year class in May 1986.
Numbers denote tonnes per naut. mile^2.

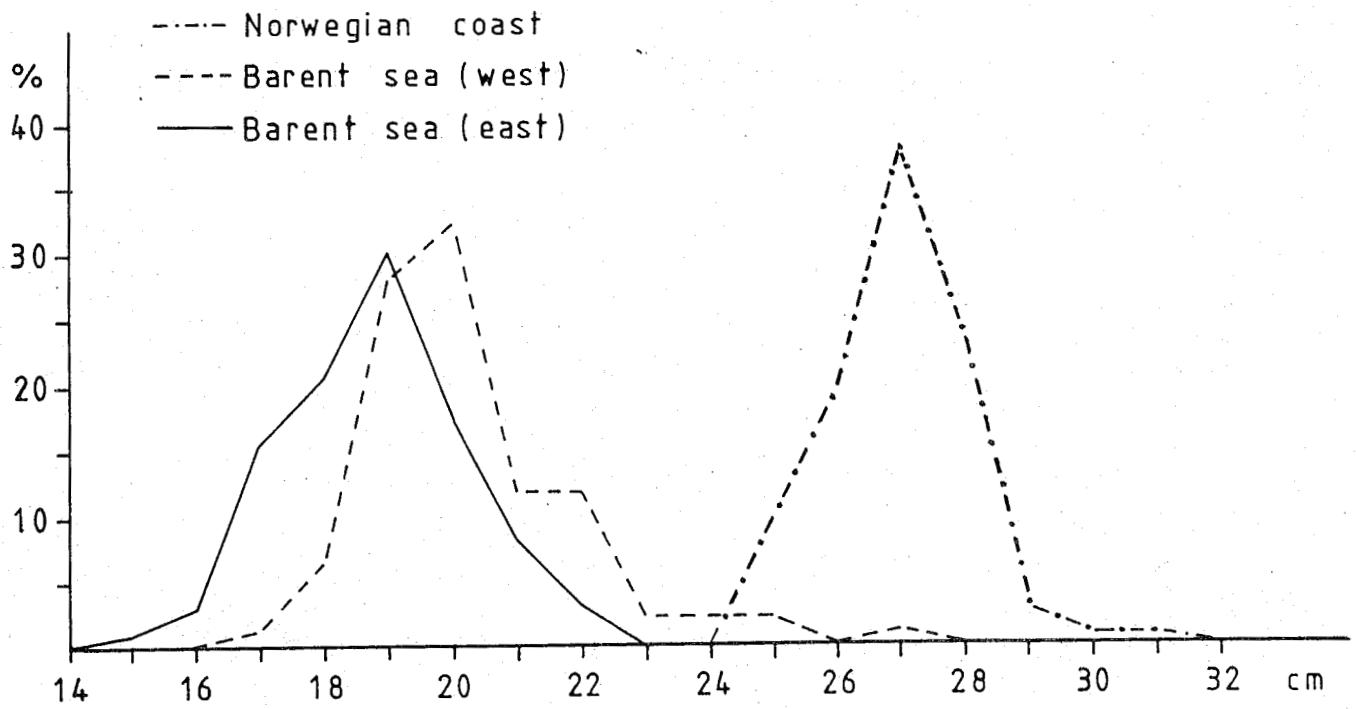

Fig.16. Norwegian spring spawning herring.
Length distribution of the 1983 year class in May 1986.

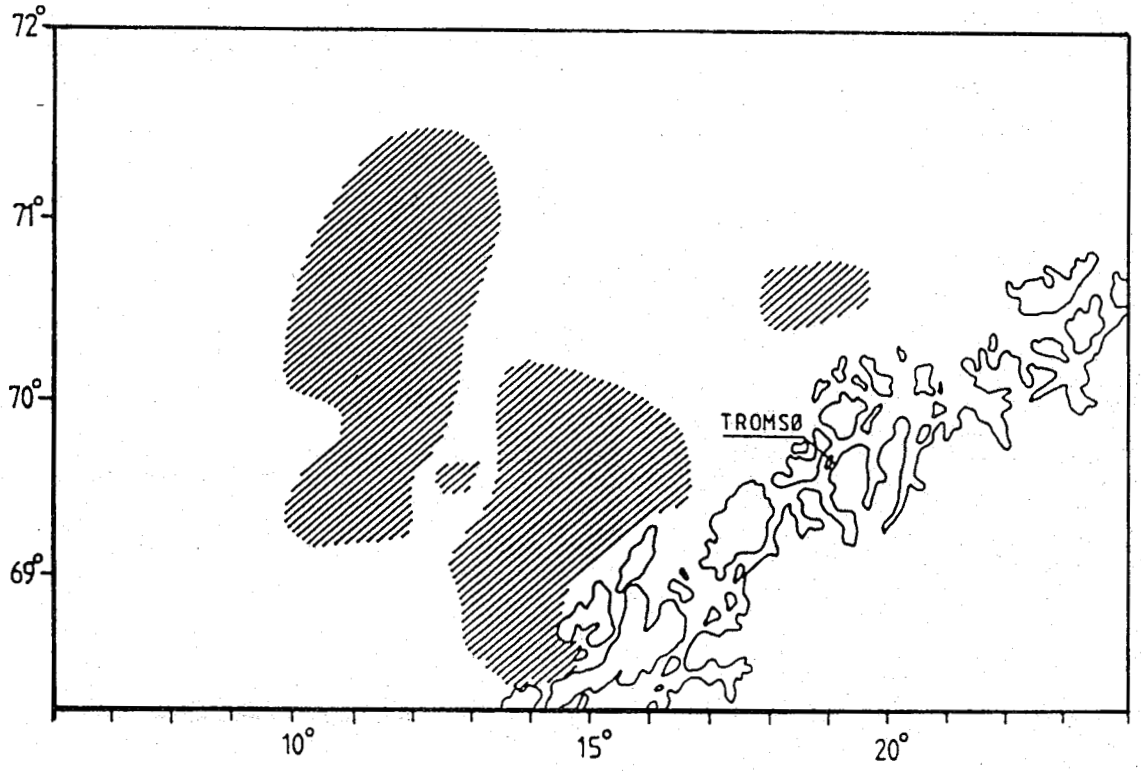

Fig. 17. Norwegian spring spawning herring.
Distribution of the 1983 year class in August 1986.

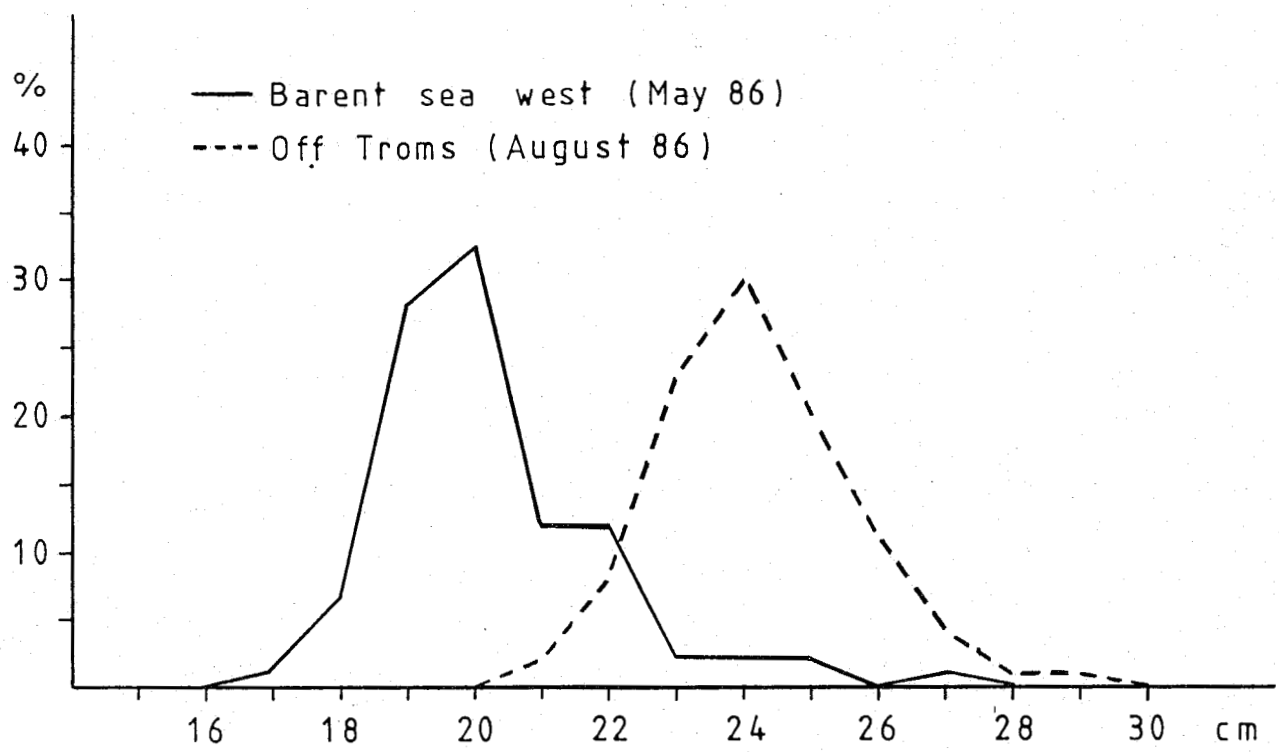

Fig. 18. Norwegian spring spawning herring.
Length distribution of the offshore distributed herring
in May 1986 (Barents Sea) and August 1986 (Norwegian Sea).

August 1986

By this time the 1983 year class had emigrated from the Barents Sea and there were observations of scattered concentrations up to 150 nautical miles of the coast of Norway from 64°N to 70°N (Fig 17).The main concentrations were found north of 68°N. In this period the herring were located in various depths from near the surface to depths of 200-300m. The sonar recordings near the surface consisted of small schools, the larger schools were located in depths of 50m and deeper. The mean length of the 1983 year class had increased considerably since the herring left the Barents Sea (Fig 18).

November 1986

The herring in the offshore areas had concentrated nearer the coast, between 66°N and 67°N. (Fig 19). The herring were now located in schools near the surface during night time (0-50m) and near bottom or down to 250-300m depth during daytime. The size of the schools showed large variations, during night the herring often split into small loose schools.

In autumn 1986 the 1983 year class became abundant in the catches in Norwegian herring fishery. The fishery took place in the fjord areas were the herring had wintered since the stock collapse and the migration to the feeding and wintering grounds in the Norwegian Sea terminated. The 1983 year class occurred together with older herring on the wintering grounds.

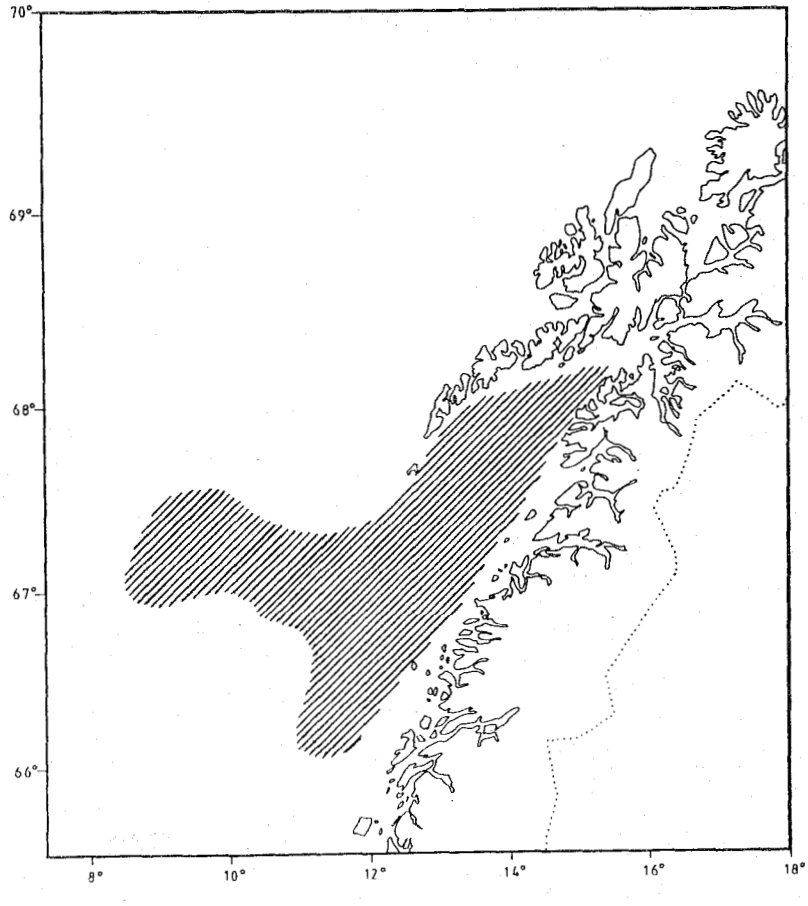

Fig. 19. Norwegian spring spawning herring.
Distribution of the 1983 year class in November 1986.

Scenario at the end of 1986

A very small fraction of the 1983 year class (less than 1%) seemed to be recruit spawners in winter 1986. These herring spawned on the traditional spawning grounds off Møre. They were not herring originating from the Barents Sea nursery area.

In 1986 the two types of herring of the 1983 year class could still be recognized. Some herring were recorded on the traditional spawning sites off Møre in February-March,in the outer costal areas in spring and in wintering areas in some fjords from October/Nowember. These herring had a large growth rate.

But by far the larger part of the 1983 year class was in winter/early spring of 1986 located in the eastern part of the Barents sea. In spring of 1986 a fundamental change in the distribution of the 1983 year class took place. In May-June the whole offshore population of the 1983 year class migrated westwards out of the Barents Sea and into the Norwegian Sea off the Norwegian coast. The "stay" in the Barents Sea nursery area had thus terminated.

YEAR 1987

January 1987

Fig 20 shows the wintering distribution area of the herring (January 1987). During day time the herring occurred in schools in 100-200m depth, during night time the herring ascended to the upper 50m and often occurred in large dense schools.

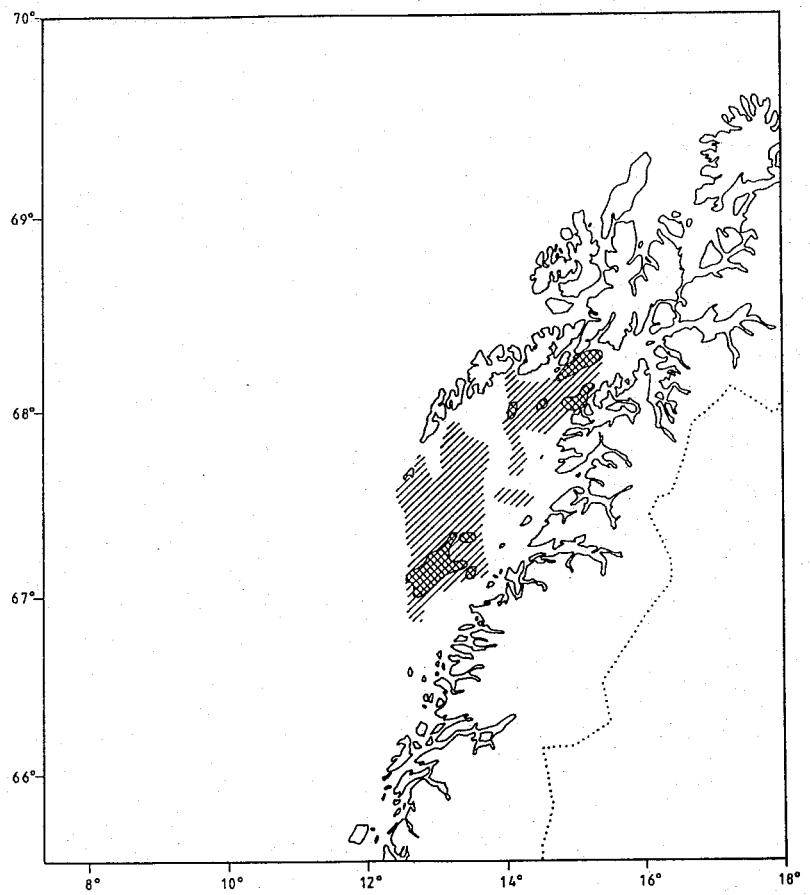

Fig. 20. Norwegian spring spawning herring.
Distribution of the 1983 year class in January 1987.

Spawning season, February-March 1987

This year the 4 year old herring dominated the biological samples from the traditional spawning sites off Møre. The geographical distribution of the 1983 year class is given in Fig 21. On the spawning grounds the herring mostly occurred in loose schools or in scattering layers. There were observed only a few dense schools in February-March 1987. The herring of the 1983 year class were mixed with older herring on the spawning fields. About 40-60% of the 1983 year class which was

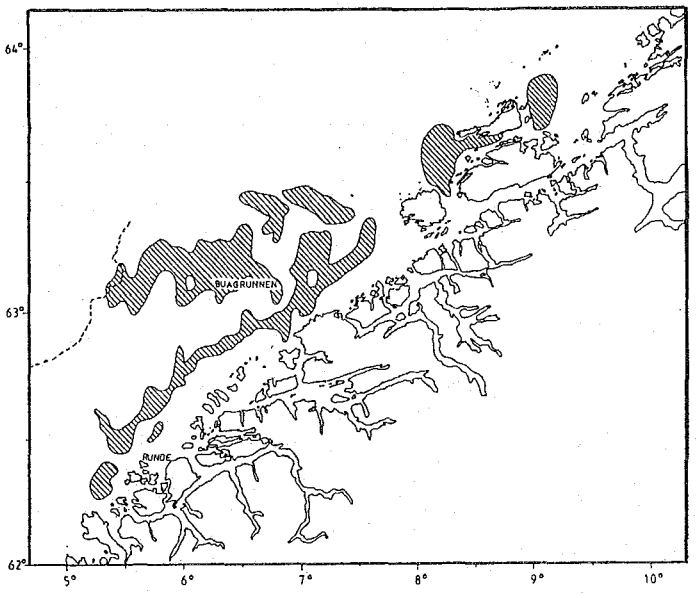

Fig. 21. Norwegian spring spawning herring.
Distribution of the 1983 year class on the spawning sites off Møre in February/March 1987.

recorded on the spawning grounds were recruit spawners. But the greater part of the 1983 year class were still immature and therefore did not appear on the spawning grounds. The average length of the herring of the 1983 year class in the spawning areas was approximately 28 cm. However, one sample from the southern part of the distribution area had a mean length of 31 cm. This may have been herring of coastal origin.

April-May 1987

The main offshore concentrations were now located to the north of the spawning sites (Fig 22), and the extension of the distribution area had increased.

In April-May 1987 schools consisting of 1983 year class of herring were recorded in the outer coastal area between 66°N and 67°N. However, according to the length distributions, this was obviously not the same type of herring as was recorded in the same area in April-May in 1985 and 1986. The mean length of the herring was actually greater in 1986 than in 1987 (Fig 23), indicating that the fast growing herring in this area in 1985 and 1986 had been replaced by a herring with a slower growth rate in 1987. The "new" herring in this area probably originated from the nursery areas in the Barents Sea.

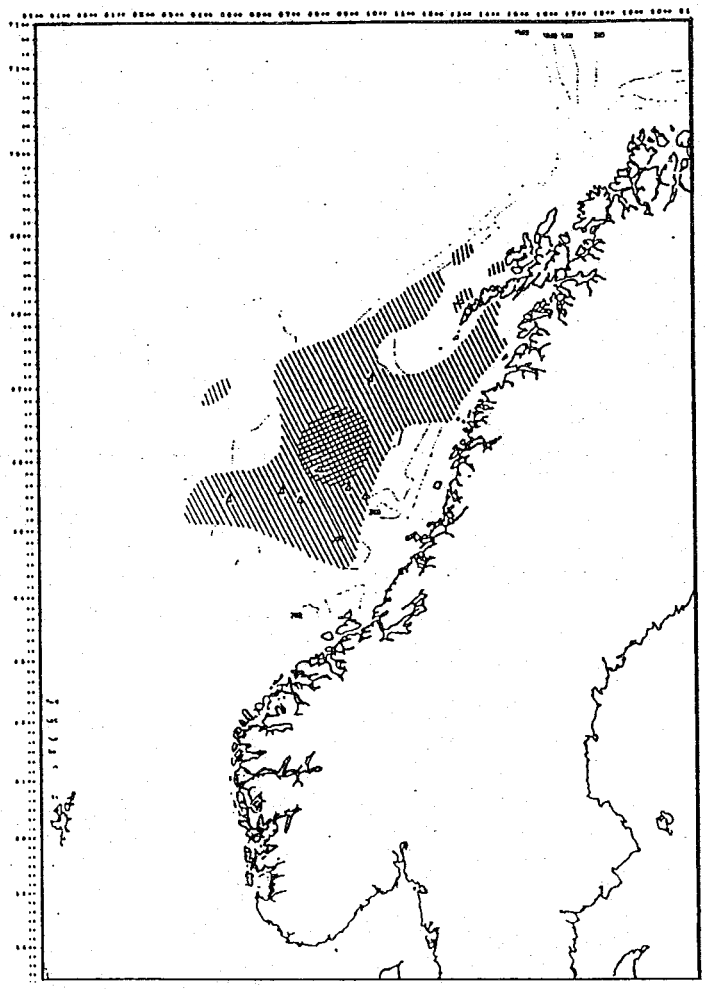

Fig. 22. Norwegian spring spawning herring.
Distribution of the 1983 year class in May 1987.

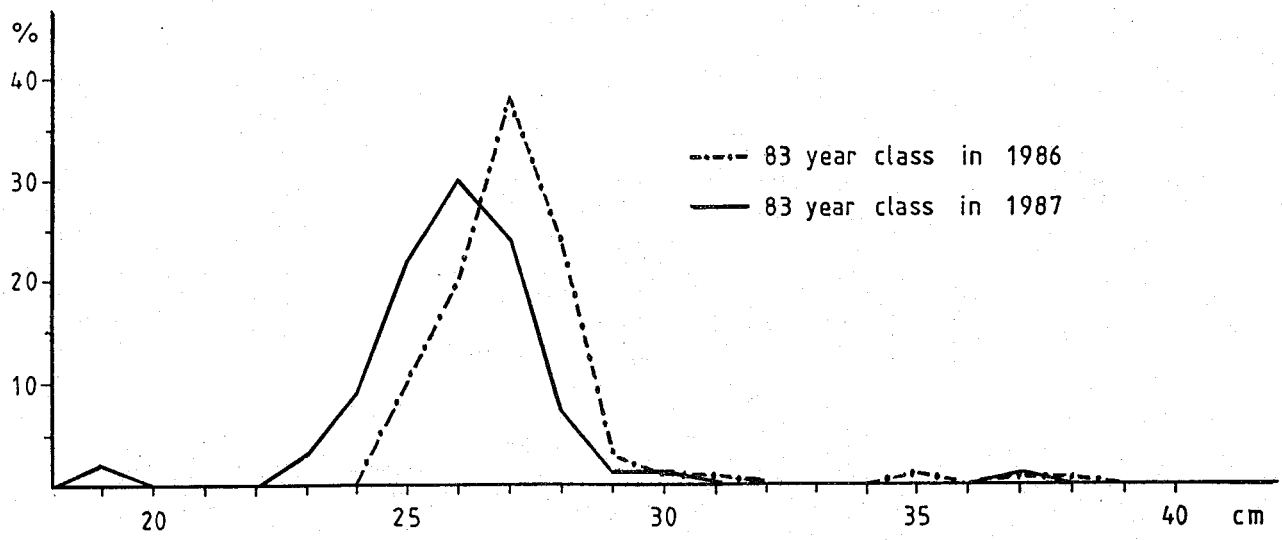

Fig. 23. Norwegian spring spawning herring.
Length distribution of the 1983 year class in Norwegian coastal waters off Helgeland (between 65°N and 68°N) in April 1986 and April 1987).

June-July 1987

The migration of the offshore distributed herring continued northwards; the distribution area for July 1987 is given in Fig 24. In the period April-July 1987 the herring mostly occurred in small schools near the surface. The herring recordings were mixed with plankton recordings.

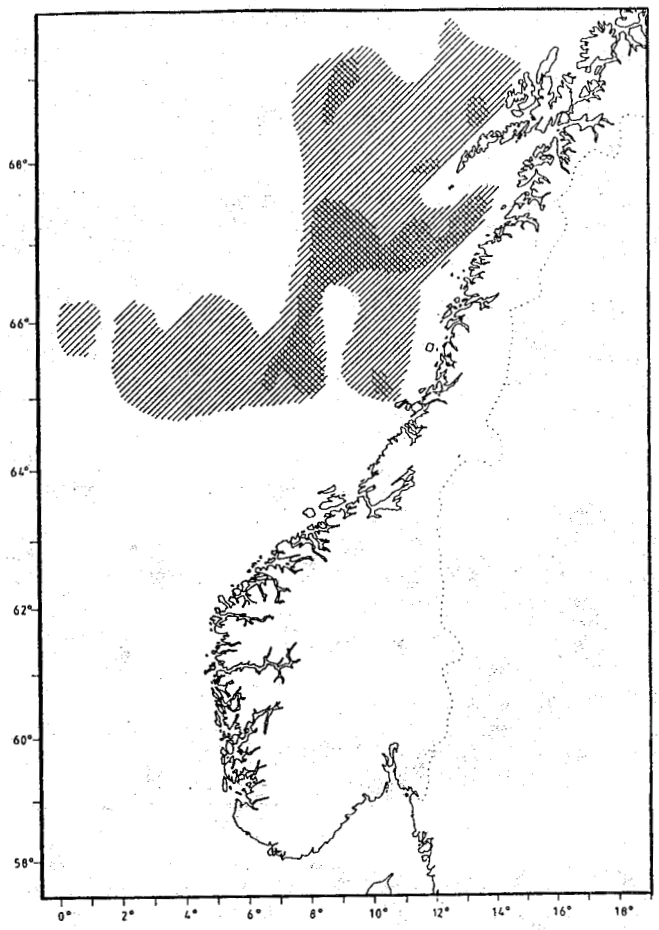

Fig. 24. Norwegian spring spawning herring.
Distribution of the 1983 year class in July 1987.

August 1987

Medio August 1987 the 1983 year class concentrated in the area west of Lofoten (Fig 25). Compared with the period April-July, the behaviour of the herring had changed. The herring concentrated in a rather dense scattering layer in about 10-20m depth during most of the day. This was typical "fat herring", with a lot of fat in the intestine area. The gonads were poorly developed.

September 1987

In September the main concentrations of herring had migrated into the Vestfjord area (Fig 26). By this time the herring began to make extensive vertical migrations. During day time the herring were recorded in schools at 250 m to 300 m depth, rising towards the surface and dispersing during night. The gonads were considerably more developed than in August.

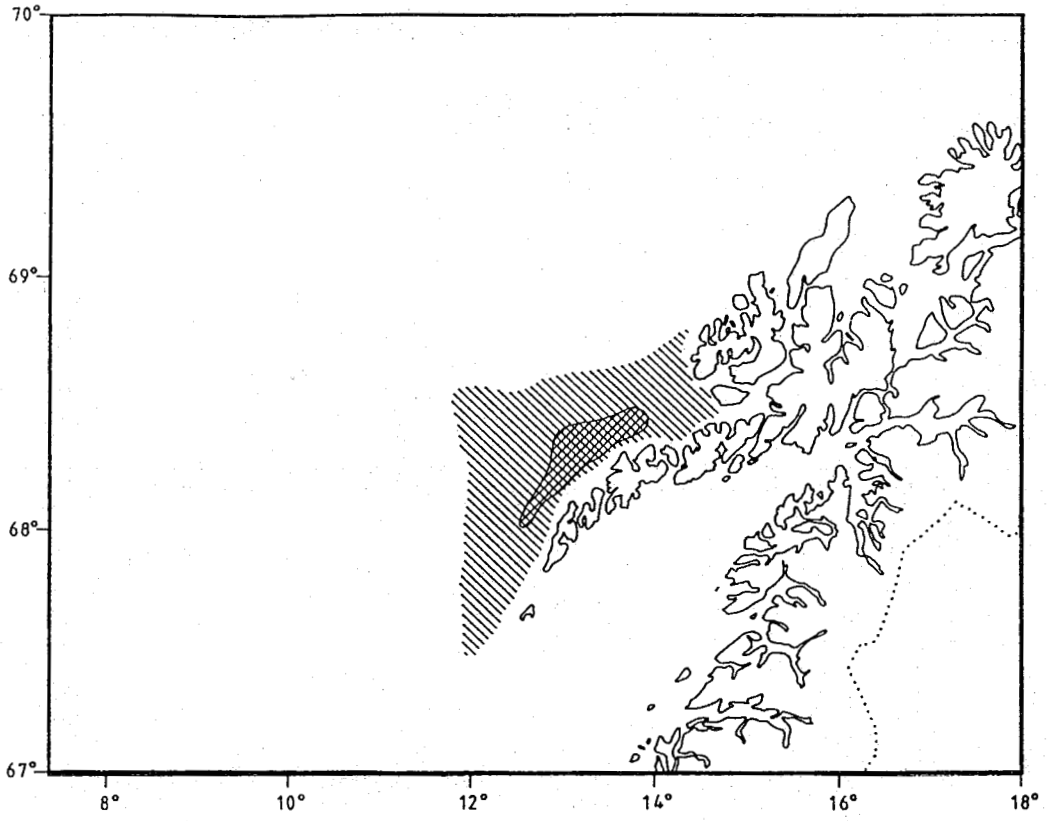

Fig. 25. Norwegian spring spawning herring.
Distribution of the 1983 year class in August 1987.

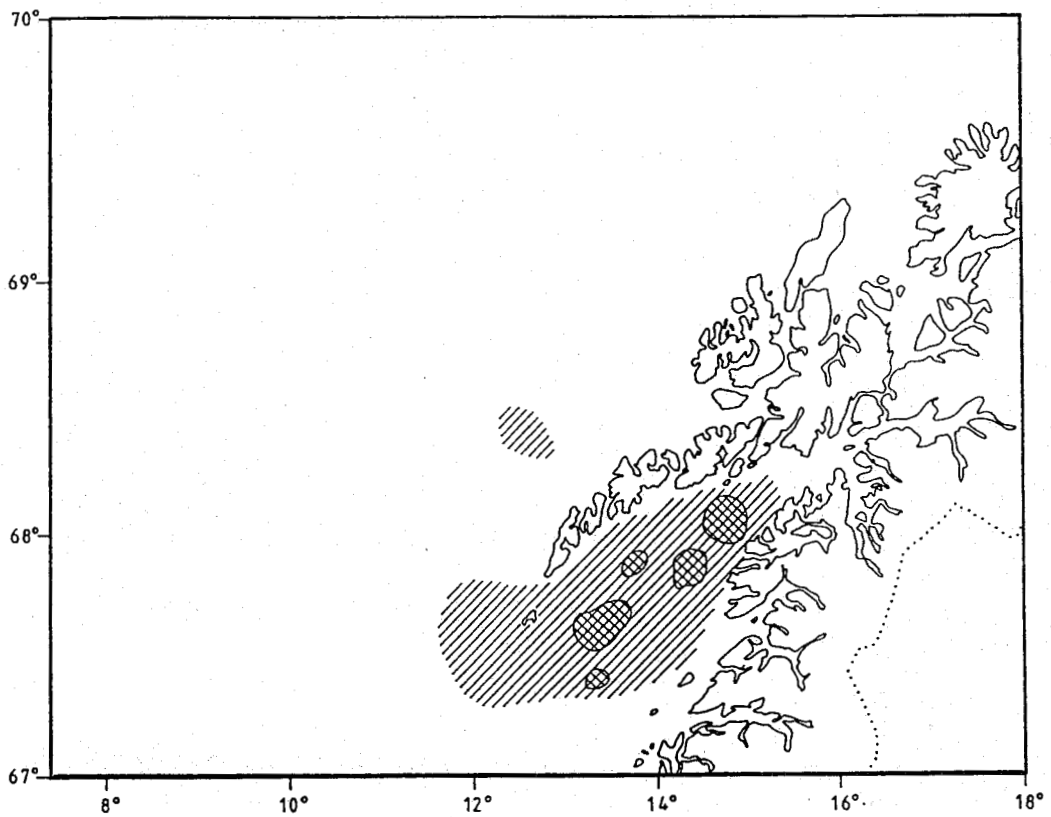

Fig. 26. Norwegian spring spawning herring.
Distribution of the 1983 year class in September 1987.

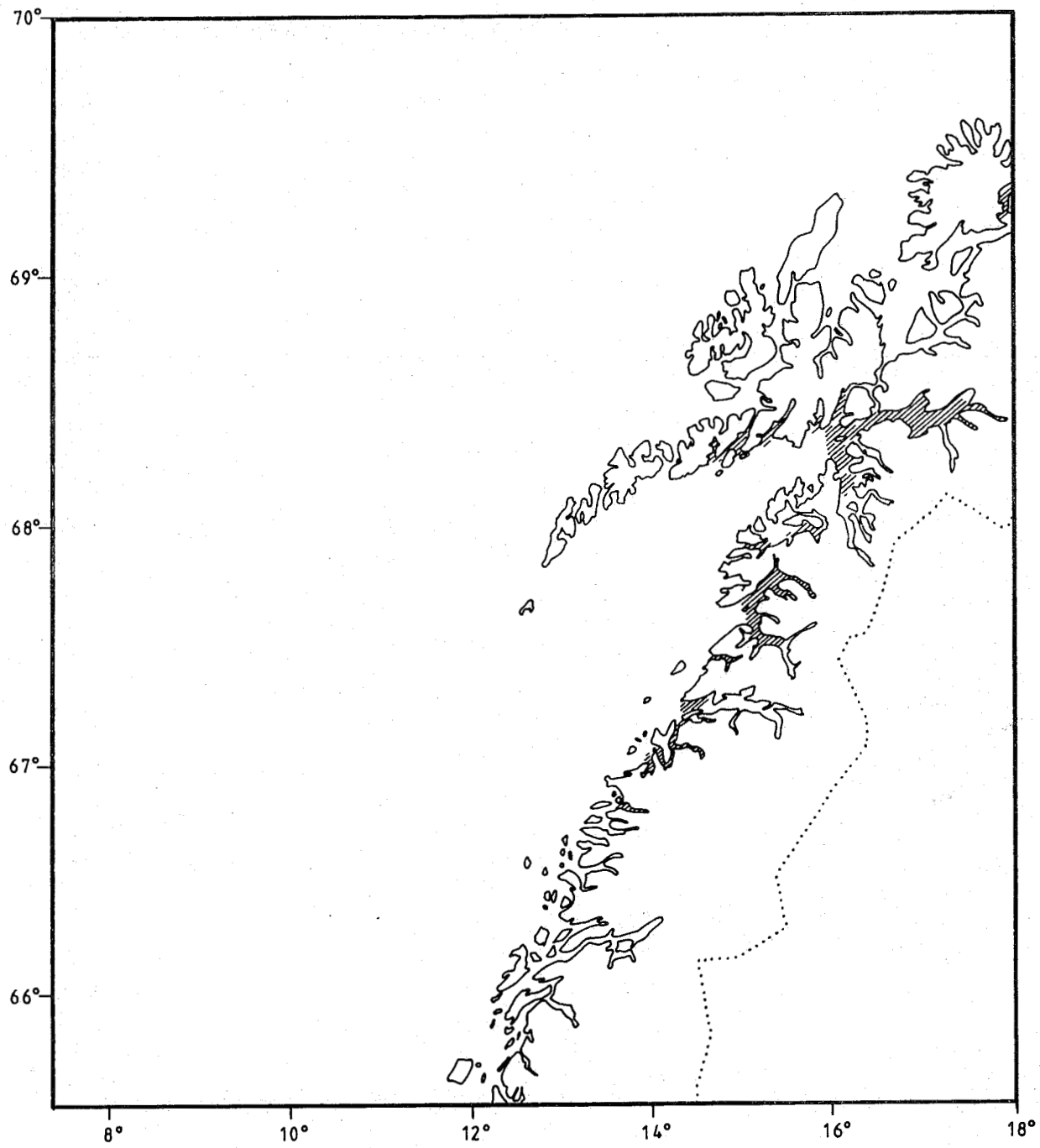

Fig. 27. Norwegian spring spawning herring.
Distribution of the 1983 year class in November 1987.

November 1987

In October the herring migrated further into the Vestfjord, and by November the herring which since 1983 had been distributed offshore, were now located in the tributary fjords of the Vestfjord (Fig 27). Here the herring occurred in enormous schools, often extending over several nautical miles. The herring undertook vertical migrations (Fig 28). The gonads were further developed, and the amount of fat in the intestine had clearly decreased compared with August/ September. The herring wintered in the Vestfjord until the end of January 1988.

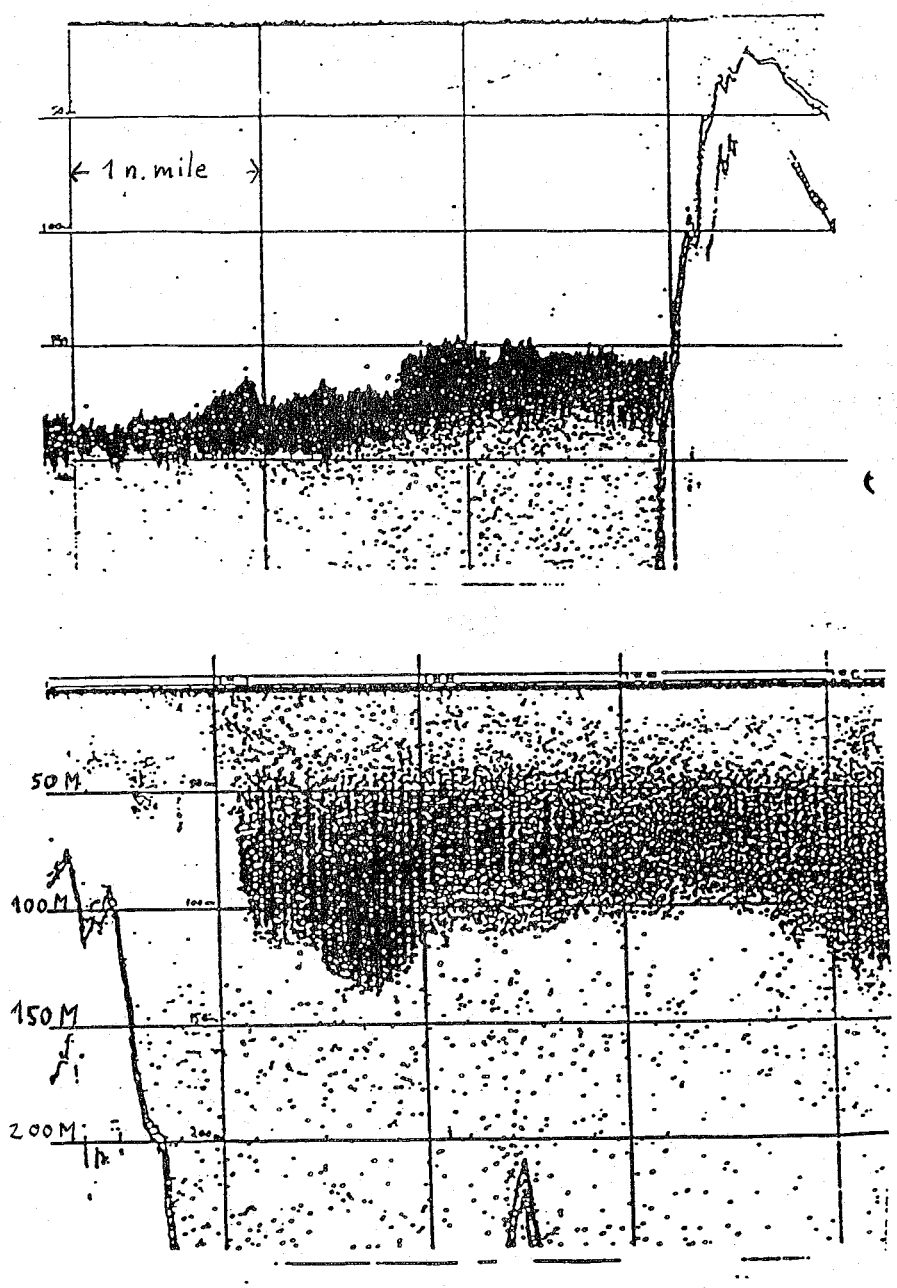

Fig. 28. Norwegian spring spawning herring
Echo recordings during daytime (upper) and nighttime (lower) of the 1983 year class from approximately the same location in the Ofotfjord in November 1987.

Scenario at the end of 1987

A minor part of the 1983 year class matured and spawned on the traditional spawning sites in 1987. After spawning the herring did not resume the feeding migration routes from the time prior to the stock collapse, i.e. to the Jan Mayen- North Iceland area. The feeding areas in 1987 were from the coastal areas of northern Norway between 64°N and 70°N and extending approximately 200 nautical miles in the Norwegian Sea. In August the herring concentrated west of the Lofoten Islands, and in September they migrated into the Vestfjord, and in October further east into the tributary fjords of the Vestfjord. The wintering areas in 1987/88 (Fig 17) were thus slightly different from 1986/87, the latter wintering area was in the outer part of the Vestfjord (Fig 20).

YEAR 1988

February 1988

According to data from the fisheries, the main part of the 1983 year class appeared on the spawning sites off Møre in mid-February. Fig 29 gives the area where spawning herring were recorded in the period 22.2-19.3 1988. The main spawning grounds were from Statt (62°N) to Kristiansund, and some spawning was also recorded north to Vikna.

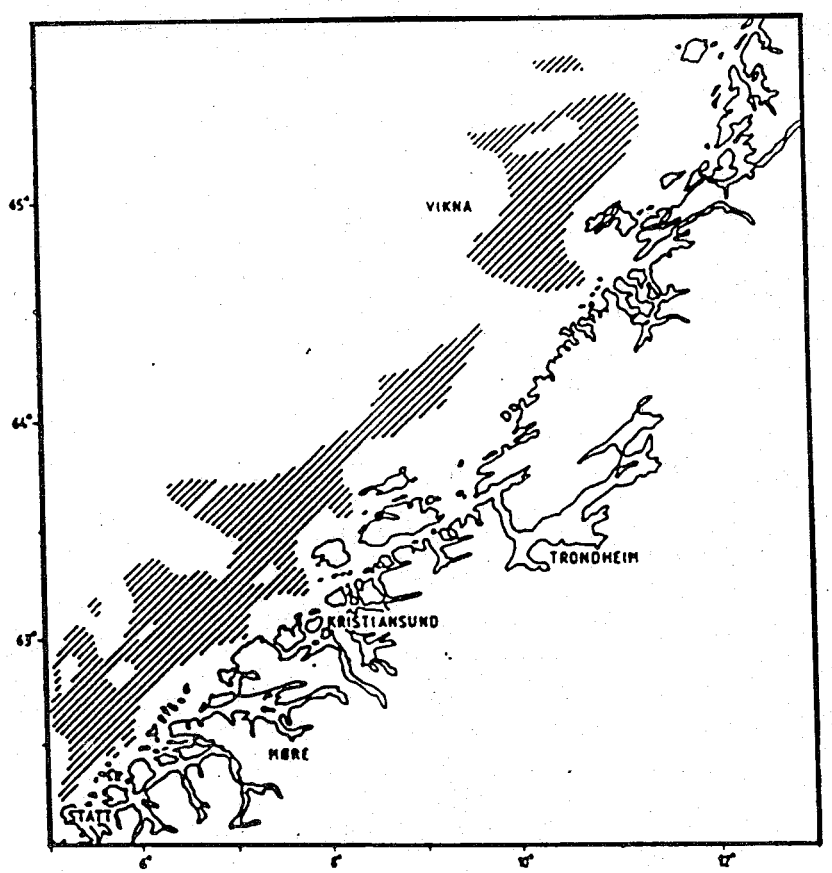

Fig. 29. Norwegian spring spawning herring.
Distribution of the 1983 year class on the spawning sites off Møre in February/March 1988.

There were very few records of spawning herring in the Lofoten-Vesterålen area. The spawning grounds were essentially the same as in the period 1974-1987. In 1988, approximately 95% of the spawning stock consisted of 1983 year class herring. During day time the herring on the spawning grounds were distributed "hard" down to the bottom and were very difficult to observe on the echo recorder. Only in a few restricted areas could schools be seen near the bottom. However, during night time the herring rose and dispersed in the upper 100 meters of the water masses. Fig 30 shows a typical night recording on the spawning fields in February 1988. The main spawning commenced by the end of February in the southernmost part of the distribution area. Spawning on spawning grounds south of Statt was not resumed to any extent in 1988.

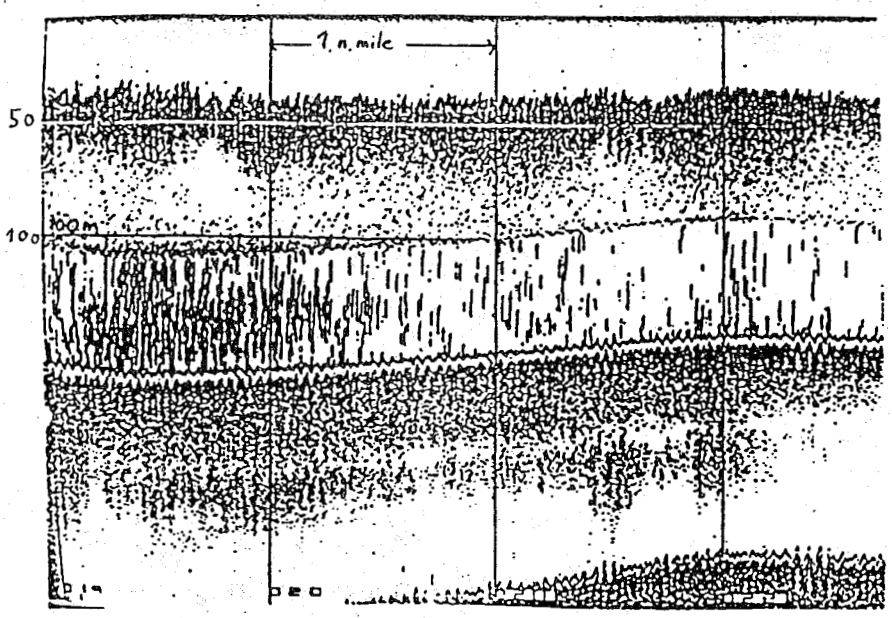

Fig. 30. Norwegian spring spawning herring.
Nighttime echo recording of spawning herring.
Møre, February 1988.

April 1988

The feeding migration in 1988 seems to have followed the same pattern as in 1987. The spent herring have moved in a northern direction from the spawning grounds and the geographical distribution at the end of April 1988 is outlined in Fig 31. The distribution area is located off the Norwegian coast mainly between 64°N and 68°N and extending approximately 150 nautical miles westwards.

May 1988

The geographical distribution in May 1988 is shown in Fig 32. Compared to the end of April 1988 the herring have migrated further north and are dispersed over a wider area.

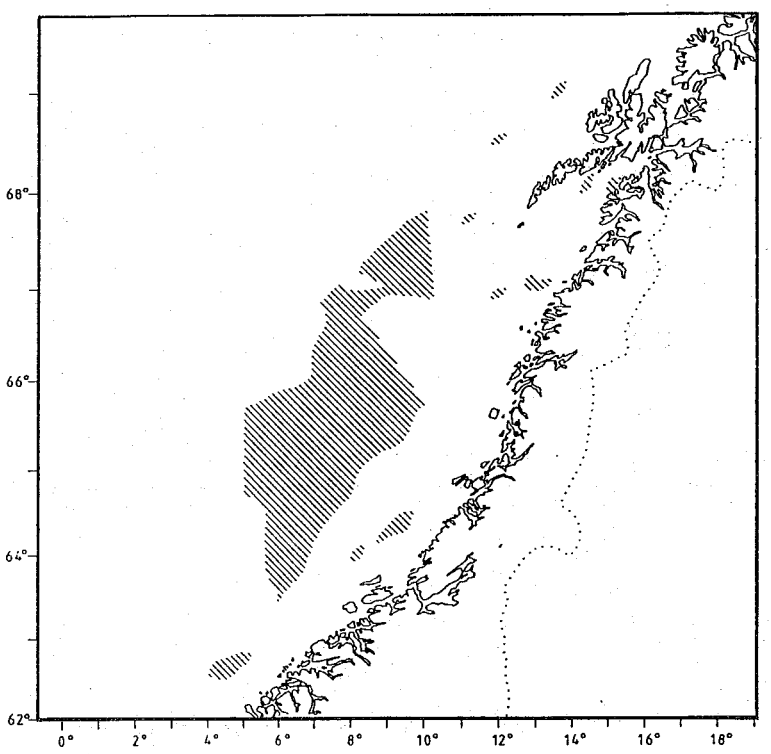

Fig. 31. Norwegian spring spawning herring.
Distribution of the 1983 year class in April 1988.

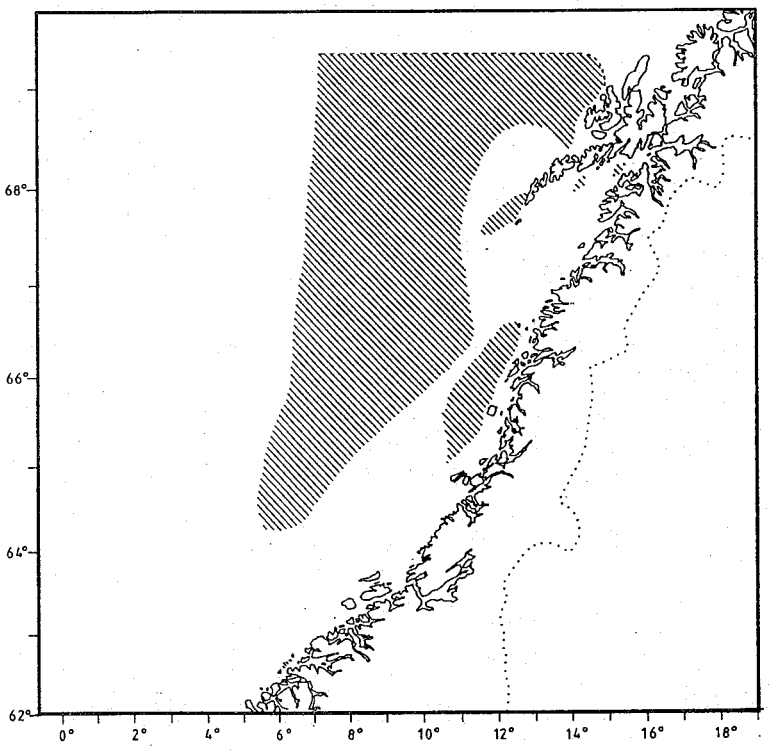

Fig. 32. Norwegian spring spawning herring.
Distribution of the 1983 year class in May 1988.

August 1988

The herring migrated eastwards during summer, and were located in the outer part of the Vestfjord in August(Fig 33). However, some herring were distributed west of the Lofoten Islands were the main concentrations were located in August 1987 (Fig 25). The herring were recorded as a more or less continuous layer at the bottom (approximately depth 200-250 m) and to about 30-40m above bottom. But from midnight to approximately 4 a.m., the herring rose and formed a scattering layer in the upper 50 meters of the water masses.

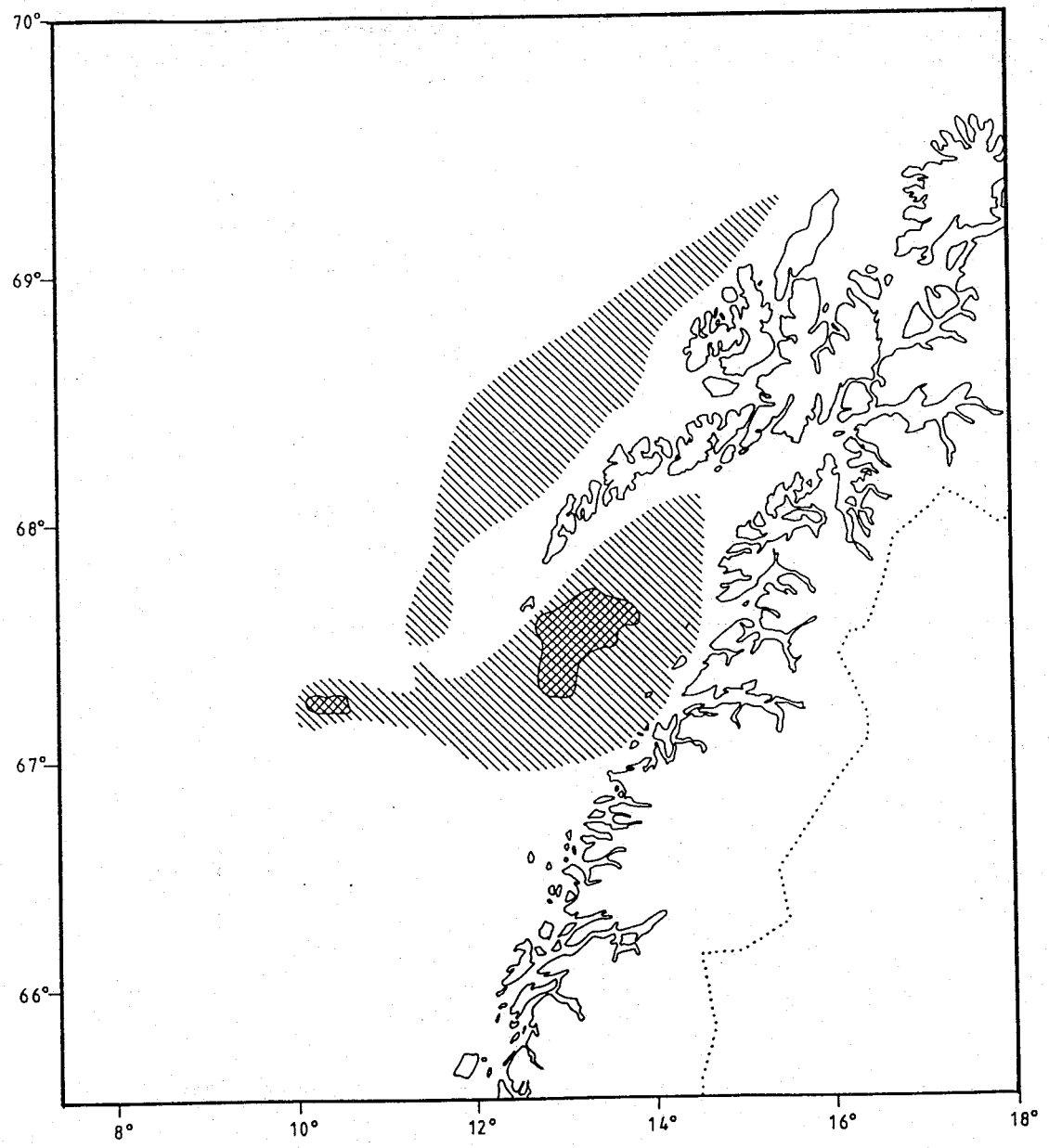

Fig. 33. Norwegian spring spawning herring.
Distribution of the 1983 year class in August 1988.

November 1988

By November 1988, as was the case in November 1987, the herring had migrated further into the Vestfjord and were now located in the tributary fjords. In 1988 the main concentrations were found in Ofotfjord, Tysfjord and Lavangen. The behaviour was similar to that of November 1987.

Scenario at the end of 1988

In 1988 the major part of the 1988 year class matured and spawned. The spawning and feeding migrations in 1988 were similar to 1987, thus the 1983 year class seemed to have established the spawning and wintering areas and the migration cyclus. This cyclus was different from that of the time prior to the stock collapse, as the 1983 year class did not resume the feeding migration to the Jan Mayen/North Iceland area.

YEAR 1989

February-March 1989

Fig 34 gives the distribution of herring on the spawning fields in February-March 1989. The main spawning fields are similar to 1988.

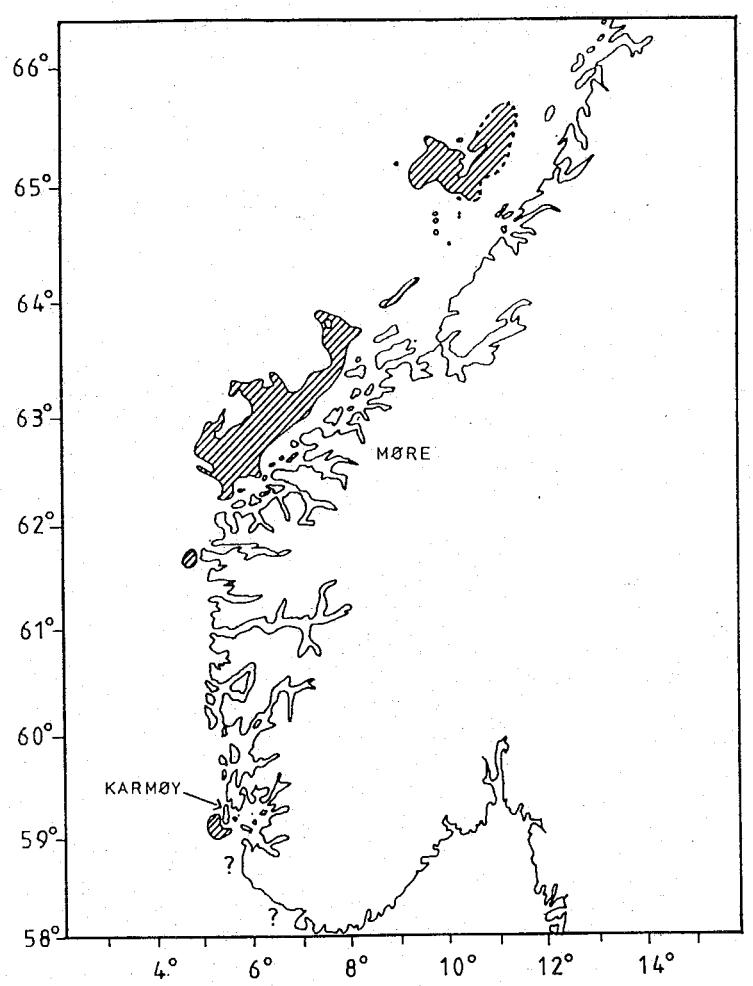

Fig. 34. Norwegian spring spawning herring.
Distribution of the 1983 year class on the spawning sites in February/March 1989.

However, spawning herring were recorded off Karmøy (approximately 59°N) and there were also reports of spawning herring from areas further south, perhaps to Siragrunnen (approximately 58°N) Prior to 1955, these were important spawning grounds for the Norwegian spring spawning herring. Fig 35 gives the length and age distribution of the herring from the spawning area at Karmøy. This was practically the same length and age distribution as the herring on the spawning sites off Møre. At present it is not known if this herring had their nursery area in the Barents Sea, or if they are of coastal origin.

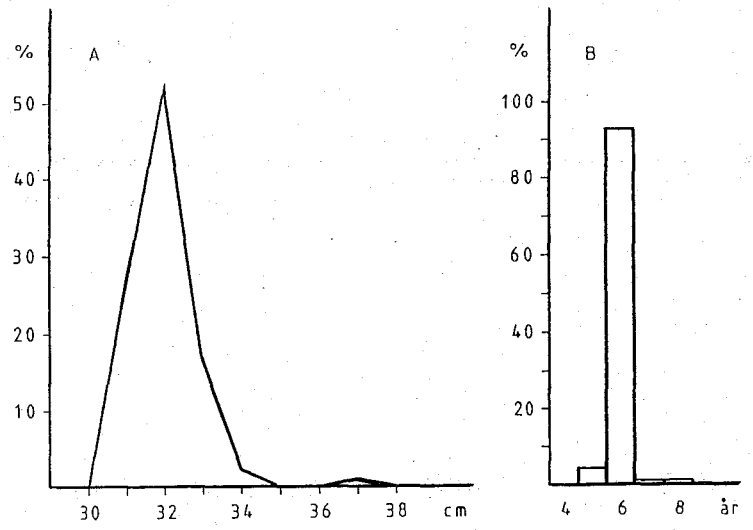

Fig. 35. Norwegian spring spawning herring.
Length and age distribution of spawning herring at Karmøy, March 1989.

Acoustic abundance estimates

Absolute abundance estimates of the 1983 year class have been made by the use of acoustic techniques. The procedures, development history, theoretical basis and the application of this technique to pelagic fish in northern waters are described in a paper to the Soviet-Norwegian symposium on Barents Sea capelin in August 1984 (Dommasnes and Røttingen 1985).

A central key in the acoustic abundance estimation is the target strength - fish length relation which is used to convert the acoustic data to number of fish. The 0-group herring in Norwegian waters have been measured acoustically since 1975 (Røttingen 1987a). The following target strength - length relation has been utilized to convert the acoustic data to number of fish during these surveys:

$$TS = 19.1 \log L - 74.0$$

This is the same target strength - length relation as is utilized for absolute abundance estimates of Barents Sea capelin, and its origin is a combination of:

1) Counting capelin traces on the echogram paper and relating this to the actual integrator value obtained from the recording.

2) The length dependant dimension (19.1 logL where L is the length of the fish) originates from experimental measurements of several clupeoid fish (Dalen et al. 1976).

The target strength - length relation is not based on 0-group herring data exclusively, and abundance estimates of 0-group and young herring based on this conversion factor should be used with care when applied in an absolute sense. However, this was the only target strength - length relation "available" when the systematic 0-group herring investigations started in 1975.

The Working group on Atlanto-Scandian herring has thus not applied these estimates as absolute, they have applied the estimates as abundance "indices", and a non-biological "conversion factor" has been used to convert the 0-group number for a certain year class to number of recruit spawners 4 years later. Other difficulties have been encountered during the acoustic survey work on the 1983 year class in the Barents Sea. The survey in November 1983 was severely hampered by bad weather and the total distribution area was therefore probably not covered. In 1984 and especially in 1985 the herring recordings were mixed with capelin, making an exact estimation of the herring abundance difficult. In January 1986 the herring were recorded close to the bottom. Table 1 gives the abundance estimates of the 1983 year class using the target strength - length relation described above.

Table 1. Acoustic abundance estimates of immature 1983 year class (TS = 19.1 logL - 74.0)

YEAR	PERIOD	ABUNDANCE ($N \times 10^{-6}$)	COMMENTS	
1983	Nov	13730	Coastal areas	
	Nov	35700	Barents Sea	(Fig 4)
1984	June	42700	Barents Sea	(Fig 6)
	Nov	3600	Coastal areas	
1985	May	39800	Barents Sea	(Fig 10)
	Sep	23300	Barents Sea	(Fig 12)
1986	Jan	16100	Barents Sea	(Fig 14)
	May	5900	Barents Sea	(Fig 15)
	Nov	7353	Outer Vestfjord	(Fig 19)

There has been considerable discussion of the "real" target strength value for herring (Anon. 1987b). There has now been presented strong evidence for accepting a general "20 logL" dependance in the target strength - length regression equation for herring. However, the target strength is not a fixed value. It is strongly related to the swimbladder area and volume and will change due to physiological changes of the swimbladder with depth and fish condition. Thus the intercept value in the target strength -length regression equation wil vary according to season, depth etc.

From the chronological review given in the present paper, it can be seen that herring have been recorded with varying behaviour according to season, geographical distribution etc., some examples are given below:

1) recordings of I-group in small schools in deeper water, summer season (Fig 7).

2) Vertical migration, adult herring in wintering areas. The "correct" target strength value will probably change dramatically from night to day situation (Fig 28).

3) Night scattering layer, spawning areas (Fig 30).

By using only one TS - value one should of course be careful to compare estimates made during different times of year and/or day. The most reliable results will be obtained by comparing estimates made under the same conditions, i.e. the same time of the year.

From 1987 the abundance estimates of the 1983 year class of herring have been used as absolute estimates in the assessment work of the Working Group. Taken into account the information available in October 1987, the Working Group on Atlanto-Scandian herring recommended the following target strength - length equation for use in acoustic abundance estimations of adult Norwegian spring spawning herring:

$$TS = 20.0 \log L - 71.9 \quad \text{(Foote 1987, Anon. 1988)}$$

This value is based on "in-situ" target strength measurements of adult herring and may not be the correct target strength - length relation for 0-group and young herring.

Table 2 gives the acoustic absolute estimates of the 1983 year class obtained since August 1987 by the use of the recommended target strength-length equation. The estimates of the adult herring obtained in 1987 are lower than the estimates in 1988 and 1989. Reasons for this may be dense schooling in Vestfjord/Ofotfjord (Fig 28) with a possible acoustic shadowing. Further, the herring of coastal origin may not have recruited to the main stock in 1987.

Table 2. Acoustic abundance estimates of adult 1983 year class (TS = 20.0 logL - 71.9)

YEAR	PERIOD	ABUNDANCE ($N \times 10^{-6}$)	COMMENTS	
1987	Aug	4100	Off Lofoten	(Fig 25)
	Sept	2000	Vestfjord	(Fig 26)
	Nov	2800	Vestfj/Ofotfjord	(Fig 27)
1988	Feb	6805	Spawning area	(Fig 29)
1989	Feb	5118	Spawning area	(Fig 34)

Migration

In autumn 1983 the 0-group herring were distributed in two geographically different nursery grounds:

1) The main part of the 0-group population was distributed in the offshore regions of the Barents Sea

2) A minor part of the population was distributed in the fjord areas of northwestern and northern Norway

It has been possible to map the general migration routes of the part of the population distributed in the Barents Sea. This population has probably been augmented by herring which spent their first (or first and second) winter in the fjords of northern Troms and Finnmark and then emigrated to the offshore areas of the Barents Sea. (The term "component" should therefore be used with care to discriminate the herring in the fjords and offshore areas respectively, as "component" indicates a static situation with minimum interchange). The migrations of the herring distributed in the fjord areas have been more difficult to follow.

1) This herring stayed in the Barents Sea until May-June 1986, i.e. a time period of 3 years. Fig 36 gives a schematic presentation of the migrations which the herring in the offshore regions of the Barents Sea carried out in the period it stayed in the Barents Sea. The wintering areas were in general located further to the east than the feeding areas.

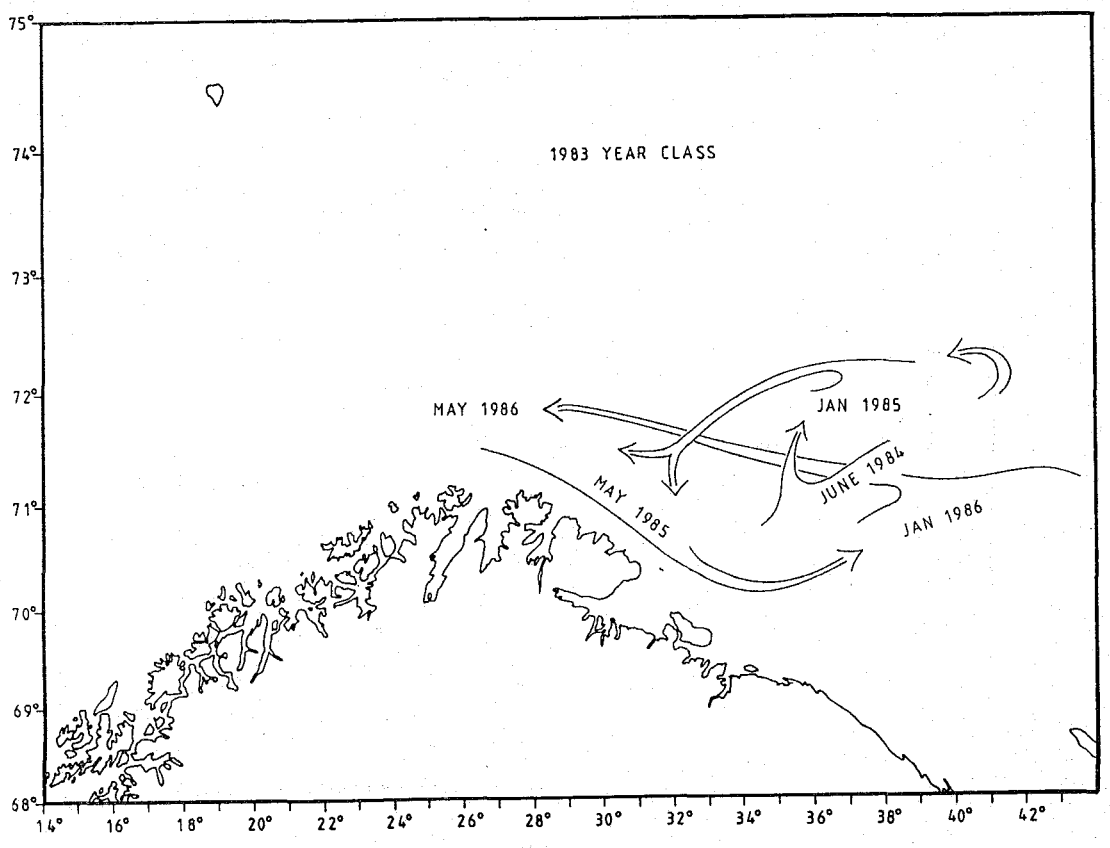

Fig. 36. Norwegian spring spawning herring.
Migration routes (schematic) for the 1983 year class in the Barents Sea.

2) Fig 37 gives a schematic presentation of possible migrations which the fjord distributed 0-group herring later undertook. In spring and summer 1984 it is possible that I-group herring emigrated from the fjords of northern Troms and from Finnmark and joined the herring in the offshore regions of the Barents Sea. If this was not the case, the disappearance of herring from the fjord areas must be due to natural mortality. Dragesund (1970) states that the herring of the rich 1959 year class which wintered in 1959/1960 in the fjords of Northern Norway migrated from the fjords to offshore areas in the Barents Sea in spring 1960 and thus increasing the offshore population of young herring in the Barents Sea. Contrary to 1960, when schools of I-group herring originating from the fjords of Troms (Dragesund 1970) were observed in the area between Lofoten and Sørøya, no I-group herring were observed in this area in 1984. Samples of young and adolescent herring with faster growth rates than the herring in the Barents Sea were observed off Helgeland in spring 1985 and 1986, in the wintering grounds at Møre in 1985-1987, and on the spawning sites off Møre in 1986 and 1987. It is thought that this herring had a coastal origin. From the spawning seasons 1987/1988 this herring has probably followed the migrations of the main population, i.e. the herring from the Barents Sea. However, the nature of this mixing is not known. There may still be groups of herring of coastal origin within the main population, a total mixing needs not to have taken place.

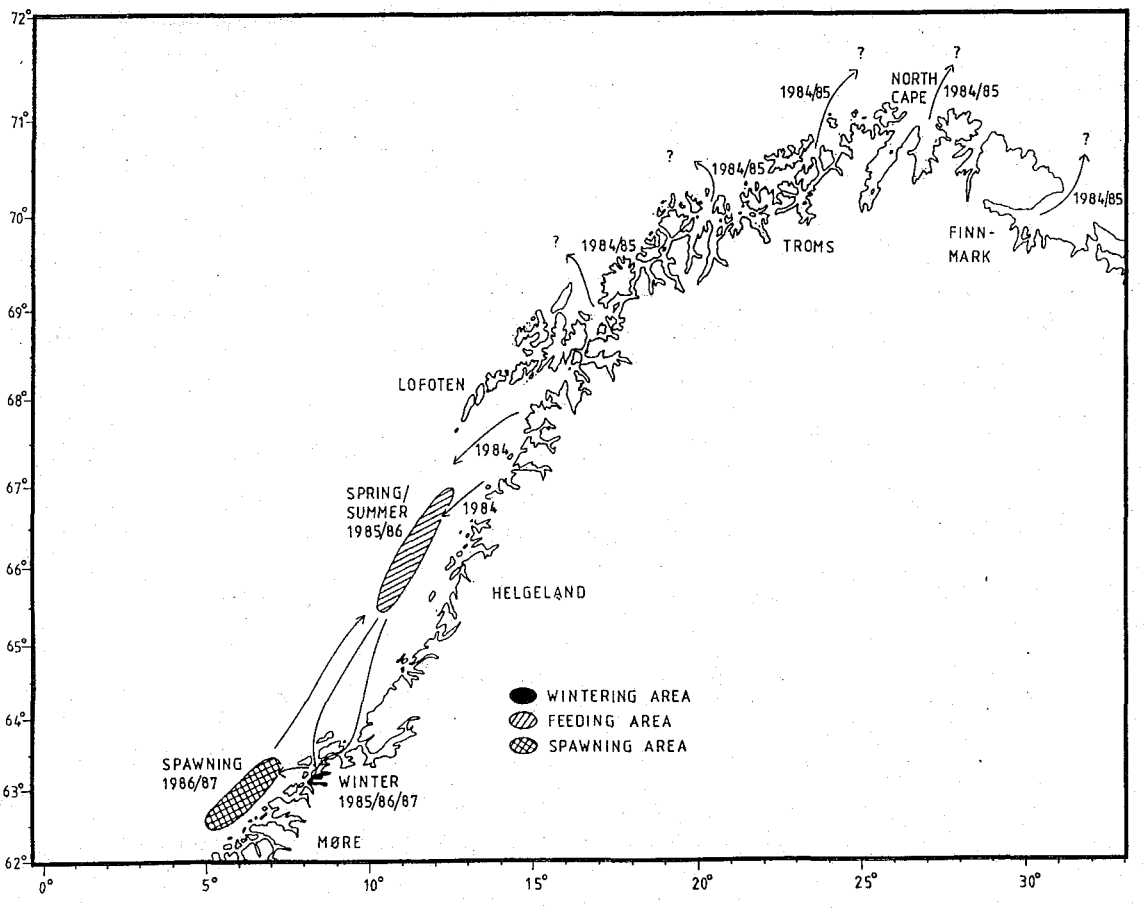

Fig. 37. Norwegian spring spawning herring.
Possible migration routes for the 1983 year class of coastal origin.

The 1983 year class migrated from the Barents Sea and into the eastern part of the Norwegian Sea as 3 year old immature herring in May-June 1986. The following movements of that component for the period August 1986 to February/March 1989 can be outlined as follows. In the beginning of August the herring accumulates in an area west of the Lofoten Islands and in the outer part of the Vestfjord. Medio August to primo September the migration into the Vestfjord starts. The wintering areas were however somewhat different in 1986/87 compared to 1987/88 and 1988/89. In 1986/87 the herring wintered in the middle and outer part of Vestfjord, but in the latter winter the herring wintered closer to the shore and in tributary fjords of the Vestfjord. The spawning migration started at the end of January. The 1983 year class spawned on the traditional spawning grounds off Møre. After spawning the herring undertakes a northward feeding migration. During summer the herring are dispersed in small scattered schools, and feed in an area from approximately 64°N to 69°N and extending to 200 miles from the Norwegian coast, an area of approximately 40 thousand square nautical miles. These seasonal changes and migrations are summarized in Fig 38D.

DISCUSSION

The biology and migrations of the early stages of Norwegian spring spawning herring have been a topic of discussion for many years. Lea (1929) was of the opinion that most of the 0-group herring entered the fjords of western and northern Norway and were distributed in coastal waters, but at that time no attempt had been made to search for 0-group herring in the open sea. Devold (1950) showed that herring of the rich 1950 year class were distributed far offshore in the northeastern part of the Norwegian Sea, and he suggested that only a small part of the total 0-group population entered the Norwegian fjords. Others (Marty and Fedorov 1963) argued that most of them were distributed in the Norwegian coastal waters. Dragesund (1970) studied the year classes 1959-1965 and his conclusion was that strong year classes (e.g. 1959,1960) had an oceanic distribution, and only a minor part of the 0-group population entered the fjords of northern Norway. For weak year classes (e.g. 1961,1962) the distribution was more restricted to the coastal areas, and a greater proportion of the total 0-group population was present in the coastal areas.

In the 1950's and 1960's the distribution of the young herring and the recruitment to the spawning stock was a central point in the discussion of the population dynamics and assessment of the Norwegian spring spawning herring. If most of the young herring were distributed in the coastal waters, then the industrial fishery on the 0- and I-group herring, which up to the mid 1960's only took place in the inshore waters, would have great effect on the recruitment to the spawning stock. Contrary, if most of the 0-group herring had an offshore distribution then the coastal industrial fishery would be of less importance to the population dynamics of the stock.

The situation after the stock collapse supports the theory that young herring of weak year classes have a mainly coastal distribution, and the young herring of strong year classes have an offshore distribution. The year classes which have occurred since the stock collapse up until 1982 were all weak, and were as young herring mainly distributed in coastal waters. The strong 1983 year class had a typically oceanic distribution as 0-group, only a minor part of the year class had their nursery area in the coastal waters. The general

distribution picture for young herring is thus in principle the same for the 1983 year class as for other strong year classes in the time prior to the stock collapse. But are the migrations similar?

According to Dragesund (1970) herring of the strong 1959 year class were observed in the regions of Bear Island and Hope Island as I-group. Later the herring migrated south to the central and southern parts of the Barents Sea. The seasonal migrations of the 1983 year class in the Barents Sea are shown schematically in Fig 36. The 1983 year class had a more eastern distribution than the 1959 yearclass in the Barents Sea. For the 1983 year class the wintering areas are generally distributed further to the east than the feeding areas in summer, the migrations have therefore, in some contrast to the 1959 year class, taken place in an east-west direction

In May-June 1986 the offshore distributed herring of the 1983 year class emigrated from the Barents Sea and into the eastern part of the Norwegian Sea. Have the later migrations been comparable to the migration routes of the adult herring before the stock collapse?

Figs 13A-C (Dragesund et al. 1980) show the migration routes for adult Norwegian spring spawning herring from 1950 to the stock collapse at the end of the 1960's. From the begining of the 1970's to 1986 the adult herring stock was distributed in the Norwegian coastal areas. The situation for the period August 1986 to August 1988 is shown in Fig 13D.

Some herring of the 1959 year class migrated westwards to the feeding areas in the Jan Mayen-North Iceland area in summer/autumn of 1962, but the main part of this year class spent the summer and autumn seasons off Troms, where they also wintered.They appeared as recruit spawners and spawned off Lofoten in winter 1963 (Devold 1968, Dragesund 1970).

After the emigration from the Barents Sea in May-June 1986, the 1983 year class was distributed off Lofoten (Figs 17 and 38D), that is further south than the 1959 year class was distributed as 3 years old. The 1983 year class wintered in 1986/87 in outer Vestfjord (Fig 20). Contrary to the herring of the 1959 year class, the 1983 year class did not spawn in the Lofoten area, but migrated south to the traditional spawning areas off Møre (Fig 38D). The main part of the northern population of the 1959 year class became recruit spawners in 1963, i.e. 4 year old fish (Devold 1968). The majority of the 1983 year class, however, were recruit spawners in 1988, one year older than the 1959 year class.

Fig 38 shows that the 1983 year class, until now, has not migrated out to the "old" feeding grounds in the North Iceland-Jan Mayen area. The feeding areas of the 1983 year class has been from the coastal areas and extending approx. 200 nautical miles out in the Norwegian Sea.

At present it cannot, of course, be said with any certainty if the 1983 year class in the future will keep to the same migration routes as it has done since summer 1986. It should be kept in mind that the northern "component" of the 1959 year class made an abrupt change in the migration pattern in autumn 1966 as 7 year old fish. (Devold 1968). Is the fact that the herring in spring 1989 appeared on the spawning grounds off Karmøy (Fig 34) for the first time in 30 years an indication that the migration pattern of the 1983 year class is changing?

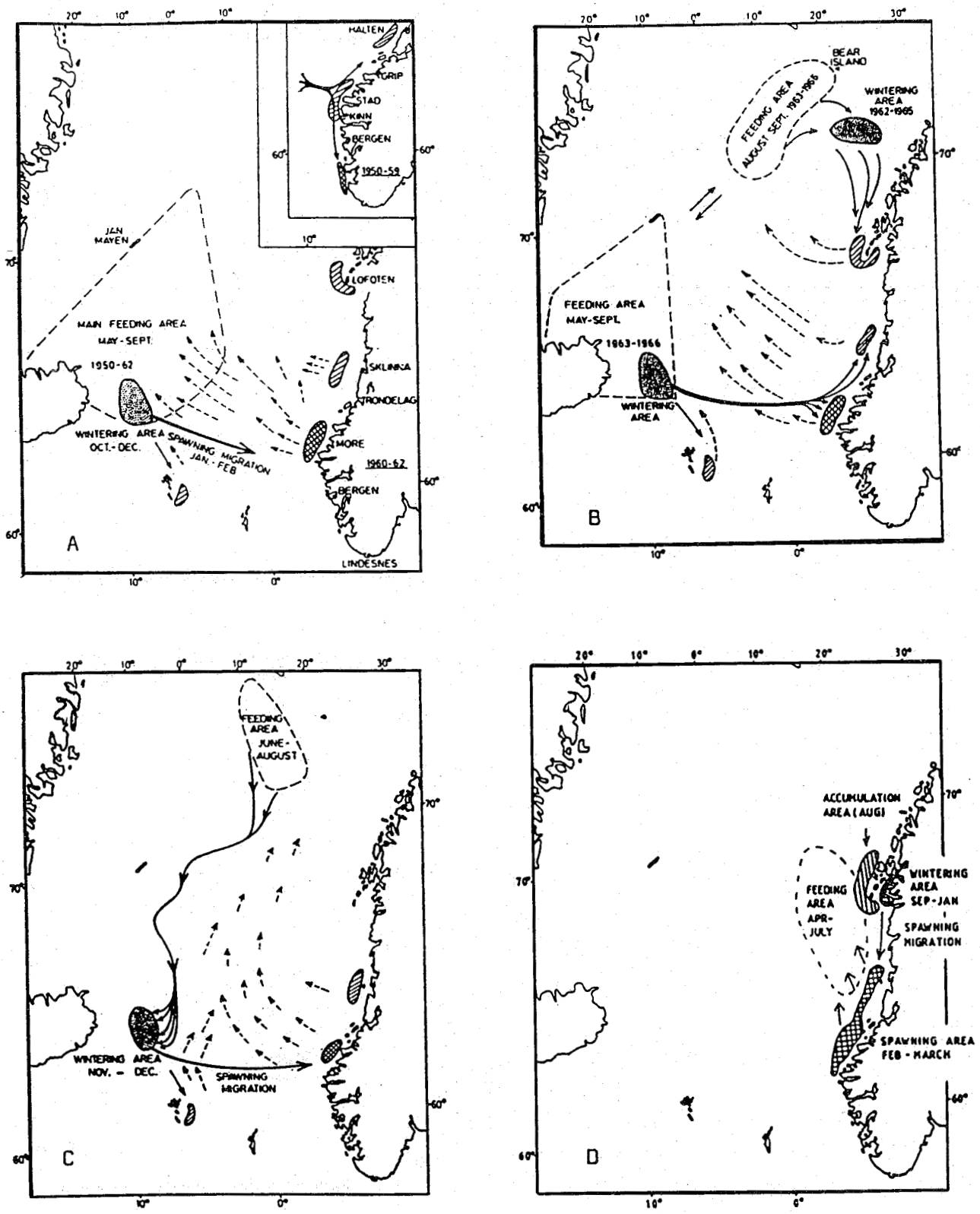

Fig. 38. Migration routes of Norwegian spring spawning herring.
A. 1950-1962
B. 1963-1966
C. 1967-1968
D. August 1986 to present.
(A,B and C from Dragesund et al. 1980).

REFERENCES

Anon. 1983. Preliminary report of the international 0-group fish survey in the Barents Sea and adjacent waters in August September 1983. ICES C.M. 1983/G.35: 1-28 (Mimeo).

Anon. 1984. Atlanto-Scandian Herring and Capelin Working Group Report. ICES C.M. 1984:Assess:4: 1-31 (Mimeo).

Anon. 1985. Report of the Atlanto-Scandian Herring and Capelin Working Group. ICES C.M. 1985/Assess:4: 1-25 (Mimeo).

Anon. 1986. Report of the Atlanto-Scandian Herring and Capelin Working Group. ICES C.M. 1986/Assess:7: 1-47 (Mimeo).

Anon. 1987. Report of the Working Group on Atlanto-Scandian Herring and Capelin. ICES C.M. 1987/Assess:8: 1-57 (Mimeo).

Anon. 1987a. Report of the Working Group on Fisheries Acoustic Science and Technology (FAST). Seattle, USA, 26-28 June 1987. ICES C.M. 1987/B:34: 1-19 (Mimeo).

Anon. 1988. Report of the Atlanto-Scandian Herring and Capelin Working Group. ICES C.M. 1988/Assess:10: 1-49 (Mimeo).

Anon. 1989. Report of the Atlanto-Scandian Herring and Capelin Working Group. ICES C.M. 1989/Assess:7: 1-48 (Mimeo).

Dalen, J., Raknes, A. and Røttingen, I. 1976. Target strength measurements and acoustic biomass estimation of capelin and 0-group fish. ICES C.M. 1976/B:37: 1-9 (Mimeo).

Devold, F. 1950. Sildetoktet med "G O Sars" 5 juli-24 august 1950. Fiskets Gang, 36: 464-466. (In Norwegian).

Devold, F. 1968. The formation and disappearance of a stock unit of Norwegian herring. FiskDir.Skr.Ser.Havinders.,15: 3-15.

Dommasnes, A. and Røttingen, I. 1985. Acoustic stock measurements of the Barents Sea capelin 1971-1984: A review. In H. Gjøsæter (ed): The proceeding of the Soviet - Norwegian symposium on the Barents Sea capelin, Bergen, 14-19 August 1984: 45-108.

Dragesund, O. 1970. Distribution, abundance and mortality of young and adolecent Norwegian spring spawning herring (Clupea harengus L.) in relation to subsequent year class strength FiskDir.Skr.Ser.HavUnders.,15:451-556.

Dragesund, O. and Ulltang, Ø. 1978. Stock size fluctuation and rate of exploitation of the Norwegian spring spawning herring. FiskDir.Skr.Ser.HavUnders.,16:315-337.

Dragesund, O., Hamre, J. and Ulltang, Ø. 1980. Biology and population dynamics of the Norwegian spring spawning herring. Rapp. P.-v.Reun.Cons.int.Explor.Mer,177:43-71.

Foote, K. 1987. Fish target strengths for use in echo intergrator surveys. J. Acoust. Sos. Am. 82(3): 981-987.

Hamre, J. 1989. Life history and exploitation of the Norwegian spring spawning herring. Contribution to the USSR-Norwegain symposium on "Biology of Fisheries of the Norwegian spring spawning herring and blue whiting in the Northeast Atlantic, Bergen, June 1989.

Hamre, J. og Dommasnes, A. 1985. God vekst i sildebestanden i Barentshavet. Fiskets Gang, 11: 383-385. (In Norwegian).

Marty, Y. and Fedorov, S. 1963. Features of the population dynamics of marine herring as seen from the Atlanto-Scandian stock. Rapp.P.v.Reun.Cons.perm int.Explor.Mer,154: 91-97.

Røttingen, I. 1984. Investigations on the 1983 year class of Norwegian spring spawing herring. ICES C.M. 1984/H:39: 1-14 (Mimeo).

Røttingen, I. 1985. Norwegian investigations in 1984-1985 on juvenile herring. ICES C.M. 1985/H.53: 1-9 (Mimeo).

Røttingen, I. 1986. Data on the 1983 year class of Norwegian spring spawning herring from the period June 1985-August 1986. ICES C. M. 1986/H:19: 1-13 (Mimeo).

Røttingen, I. 1987. Data on the 1983 year class of Norwegian spring spawning herring from the period August 1986-August 1987. ICES C.M. 1987/H:36: 1-14 (Mimeo).

Røttingen, I. 1987a. Acoustic abundance estimates of 0-group Norwegian spring spawning herring, and their role in the management advice for rebuilding of this stock. Int.symp. Fisheries Acoustics, Seattle, June 22-26 1987 (Contribution no 108):1-12.

Røttingen, I. 1988. Distribution and migration of the 1983 year class of Norwegian spring spawning herring in the period July 1987-August 1988. ICES C.M. 1988/H:41: 1-15 (Mimeo).

Toresen, R. 1984. Mye mussa i Barentshavet. Fiskets Gang, 12: 323-324. (In Norwegian).