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## RECENT MIGRATION ROUTES OF NORWEGIAN SPRING SPAWNING HERRING

by

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### ABSTRACT

The migration routes of Norwegian spring spawning herring have changed considerably during the last decades. In the 1950s and beginning of the 1960s the stock spawned off the west coast of Norway in late winter, were distributed in the feeding season in the Iceland-Jan Mayen area, and wintered east of Iceland. In the mid 1960s a large part of the stock wintered and spawned of northern Norway and were distributed in the northern part of the Norwegian sea during the feeding season. The stock collapsed in the late 1960s, and during the rebuilding period the stock wintered in different fjords on the Norwegian coast, spawned at Møre and were located in near coastal waters of Norway in the feeding season. However, from 1988 when the strong 1983 year class recruited to the spawning stock a new change in the migration pattern was observed. At present the stock spawns at several locations along the Norwegian coast, including the traditional spawning grounds at Karmøy in south-western Norway where spawning was resumed in 1989. In the feeding season the herring is distributed over large areas in the Norwegian Sea. In late July and August the herring migrates eastwards, and in September enters the wintering areas in northern Norway.

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## BACKGROUND

Biological studies conducted since the latter part of last century gradually led to the understanding of a migration pattern of the Norwegian spring spawning herring. Fridriksson (1944) suggested a relation between the herring caught in summer and autumn off northern Iceland and the herring which was caught on the spawning grounds off western Norway in winter. This was later confirmed by tagging (Fridriksson and Aasen 1950). In order to obtain more systematic information on these migrations, many investigations were coordinated by the International Council for the Exploration of the Sea (ICES) in the following years. Sonar-surveying was an important tool in this work, and by the end of the the 1950s various details of the migration routes which the herring followed had been mapped (Devold 1963). These routes are shown in Fig 1A, and this migration pattern has been often been referred to as the "normal", "traditional" or "classical" migration pattern of the Norwegian spring spawning herring.

However, variations in this "normal" migration pattern were observed in the 1960s. Although some herring of the strong 1959 migrated westward to the "traditional" feeding areas as adolescent herring in summer/autumn 1962, the major part of this year class spent the summer and autumn season off northern Norway where they also wintered. They spawned as recruit spawners off Lofoten in 1963, and returned to the feeding areas in the northeastern part of the Norwegian Sea. This part of the stock, augmented by the 1960 year class, continued these migrations until 1967, when the herring (then strongly reduced in abundance by fishing) took up the "traditional" migration pattern (Devold 1968, Jakobsson 1968, Dragesund 1970). This is illustrated in Fig 1B and 1C.

## THE PRESENT SITUATION

With the collapse of this stock in the early 1970s, the migration to the Norwegian Sea in summer was interrupted, the herring stayed the whole year in Norwegian coastal waters. However, the Norwegian Sea was again established as a feeding area by the strong 1983 year class. This year class migrated from the nursery areas in the Barents Sea in spring/summer of 1986 to the eastern part of the Norwegian Sea (Røttingen 1990). The herring of 1983 year class were recruit spawners in spring 1988. At present the herring stock feeds in summer in scattered concentrations over wide areas in the Norwegian Sea. In August the herring concentrates in an area west of the Lofoten Island, and in September the herring begin a migration to the wintering areas in the tributary fjords of Vestfjord. Here they winter in dense schools. They begin the spawning migration in the beginning of January. The main spawning fields are of Møre, but since 1989 a minor part of the stock has resumed spawning at Karmøy (Røttingen 1989), which was the main spawning area in the first half of this century. The present distribution areas and migration routes of the herring are shown in Fig 1D.

## DISCUSSION

*Wintering areas.*

The present wintering areas are completely different compared to the situation in the 1950s. Then the herring wintered in open sea in arctic waters of the East Island Current (Fig 1A), at present the herring winters in fjord areas in northern Norway. Fig 2 shows the wintering area in winter 1987/88, by winter 1991/92 the wintering areas were restricted to only Ofotfjord and Tysfjord. At present, the herring winters in considerably warmer water masses ( $6^{\circ} - 8^{\circ}\text{C}$ ) than in the period prior to the stock collapse ( $2^{\circ} - 4^{\circ}\text{C}$ ).

The geographical distance between the former and present wintering areas is more than 1000 km. Why has the change in the wintering areas occurred?

When the herring of the 1983 year class migrated out of the Barents Sea in spring 1986, it began feeding in an area west of northern Norway where there were no older herring present. This in contrast to earlier periods where the adolescent herring, when migrating out into the Norwegian Sea came into contact with concentrations of older herring in the area.

The mean length of the herring of the 1983 year class increased from 20 cm in May 1986 to 24 cm in August (Røttingen 1990). This indicates that the food supply for the herring was abundant, and the 1983 year class stayed in the same area throughout summer 1986 (Fig 3).

A combination enough food in the eastern areas of the Norwegian Sea and the fact that there were no older herring present carrying out the traditional feeding migration may be reasons why the 1983 year class did not migrate further westward in 1986. As a consequence of the summer distribution in the eastern Norwegian Sea (Fig 3), the 1983 year class did not migrate to the "traditional" wintering areas of East Iceland at the end of the 1986 feeding season.

Devold (1963) linked a shift in wintering areas from the East Icelandic current to Norwegian coastal waters with late spawning. This because the herring, when leaving the spawning grounds late, had to pass the Norwegian continental shelf after the copepods had entered the surface layers. The herring would therefore start feeding there and then move northwards off the Norwegian coast following the zooplankton bloom. In autumn, the herring used to migrate to the cold arctic water in the East Icelandic Current for wintering. Being off northern Norway they will be far from the arctic water of the East Icelandic Current. Cold water would, however, be available near the Norwegian coast, were the winter cooling of the coastal waters will have started. Thus the herring would "choose" to migrate east to these waters instead of migrating westwards to the waters of the East Icelandic Current.

However, there is no evidence of later spawning in 1988-1992 than in the period 1950-1965. In the latter period average main spawning took place in the first week of March (Dragesund 1970). Fig 4 gives the percentage of spawning and spent herring in samples from the Møre region in 1991, indicating a main spawning in the beginning of March.

There are historical records of what may be a similar autumn/winter situation as we observe at present. In autumn 1861 schools of herring

with large gonads, however not ready to spawn, were observed near shore west of the Lofoten Island (Fig 2 for geographical names). These observations were repeated the following years, and in 1863 the same type of herring were also caught around islands situated south of the Vestfjord. The sightings of the herring started in October, usually first in the northern part of the distribution area. No spawning were observed off northern Norway, and the herring disappeared "out to sea" by the end of December, in all likelihood commencing on a spawning migration. Gradually a fishery developed in the fjord and coastal areas between Andøy and Rana each autumn on this type of herring (called "storsild"="large herring"), the catches increased to approximately 100 thousand tonnes by 1871. The yearly appearance of the herring continued until 1874. The records tell that the herring came earlier and earlier to the coast, in 1874 the herring appeared on the coast at the end of August (Solhaug 1976). In the last years of appearance it seems that the herring had a more northerly distribution, with large concentrations around Andøy. The appearance of the herring off northern Norway in autumn coincided with a decline in the herring fisheries on the spawning grounds in southern Norway. From 1868 the fishery on the spawning grounds began to decline drastically, and by 1872 practically no herring appeared on the spawning grounds at Karmøy. This was the end of a "herring period" in southern Norway, but it is not certain if this was due to a large decrease in stock abundance or if the occurrence of the new wintering areas of northern Norway was linked to a change of spawning grounds to areas where the herring could not be observed or fished with the technology of the 1870s.

#### *Spawning areas.*

The present spawning areas are comparable to the spawning areas in the 1950s. However, in the period from the beginning of the present century up to the stock collapse in the late 1960s a northward shift in of spawning grounds together with a progressive later spawning was observed (Devold 1963).

Due to the higher water temperature of the present wintering areas it would be reasonable to expect a shorter time span for the maturation cycle and consequently an early spawning. Keeping in mind that spawning occurs over a long time period (from the middle of February to end of March) and that the present migration pattern was not established before 1987/88, there is not a long enough time series to detect systematic changes in mean spawning time for the 1983 year class.

However, the Norwegian spring spawning herring seems to be gradually recolonizing spawning grounds further and further south. By 1989 the herring reappeared on the traditional spawning grounds of Karmøy. In 1992 spent herring of the 1983 year class were observed at Siragrunnen ( $58^{\circ} 15'N$ ,  $06^{\circ} 15'E$ ), less than 30 nautical miles from Lindesnes, the southernmost tip of Norway.

A consequence of such a development is that the herring will have to swim longer distances during the spawning migration. A factor governing this development may be the potential of increasing swimming speed ability of the spawning stock. Since 1988 there has been a very limited recruitment to the spawning stock, in 1992 the 1983 year class still made up about 80% of the spawning stock. There has thus been a gradual increase in mean length of the spawning stock since 1988 (Fig 5). The swimming speed of the herring is believed to be a function of body length (Blaxter and Hunter 1982, Røttingen and Røttingen 1991).

The migrating schools would thus have a potential to cover greater distances within the same time interval in 1992 compared with 1988.

#### *Feeding areas.*

At present the Norwegian spring spawning herring feed in the Norwegian sea, mostly east of approximately 5°W (Fig 1D). In the 1950s a larger part of the stock fed at the polar front area (Fig 1A), ie in an area west of 5°W.

It is not known in detail if there has been any significant change in the timing of the spring bloom of zooplankton or of the ocean climate as a whole which could be related to the difference in summer and autumn distributions between the periods 1950-1965 and present.

Spawning stock size may influence the summer distribution. A large herring stock may need a larger feeding area. In the period 1950-1965 the spawning stock varied from 10 million tonnes in the mid 1950s to about 3 million tonnes in the beginning of the 1960s. At present the spawning stock is estimated to be in the order of 2 million tonnes, an eventual increase in stock size may result in the occupation of new feeding areas.

#### *General migration pattern.*

Harden Jones (1981) gives the following description of the migration pattern of the Norwegian spring spawning herring: "The herring move anticlockwise round the circuit and while there is no detailed evidence to show how the direction of swimming compares with that of the water, the overall migration is more consistent with a movement downstream, and so with the current, rather than against it."

At present this has changed, the overall migration of the Norwegian spring spawning herring is now carried out in a clockwise direction (Fig 6), and especially during the spawning migration the herring swim against the currents.

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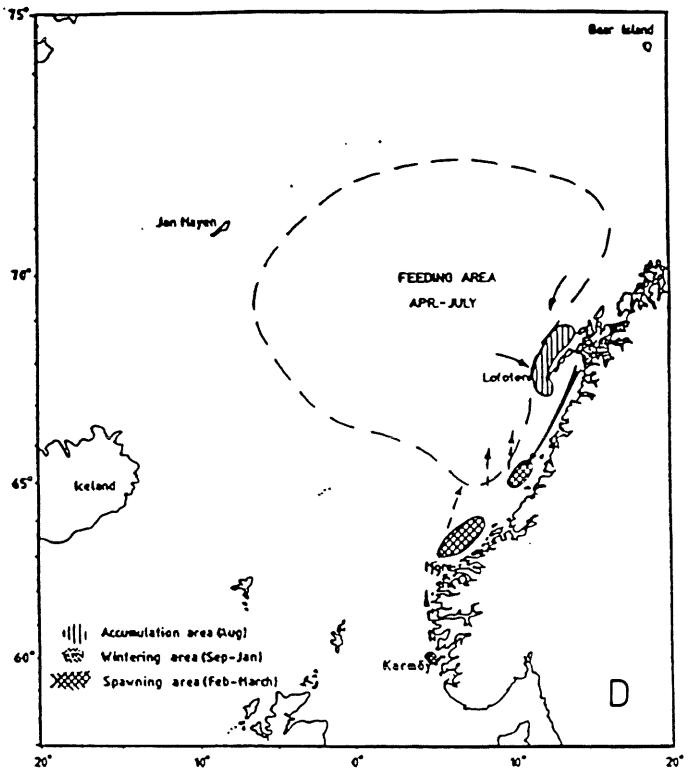
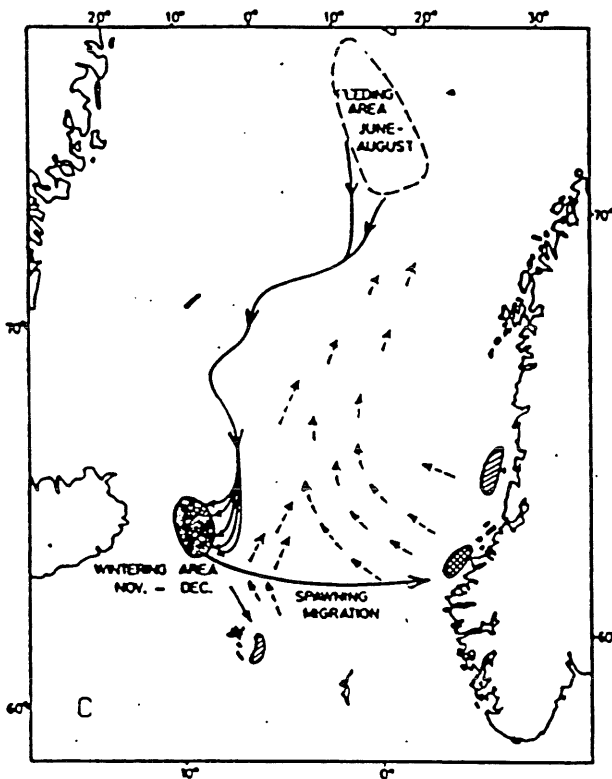
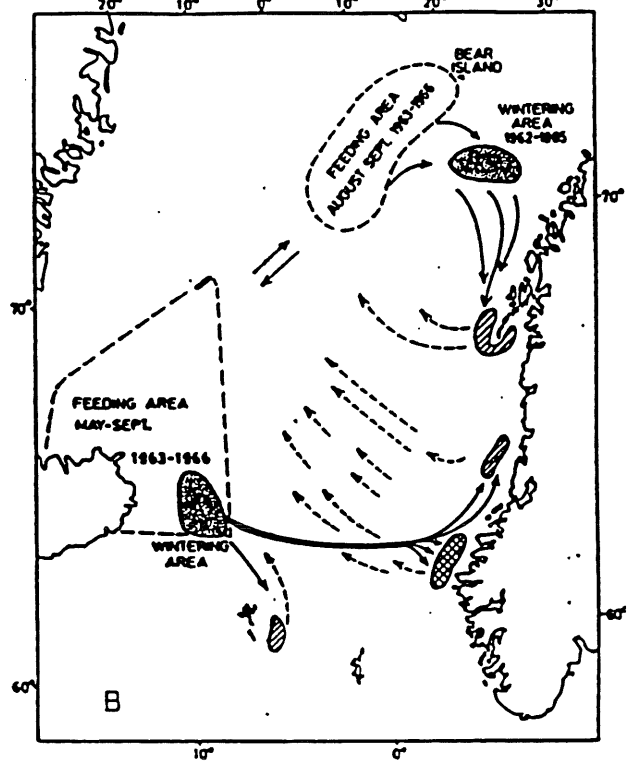
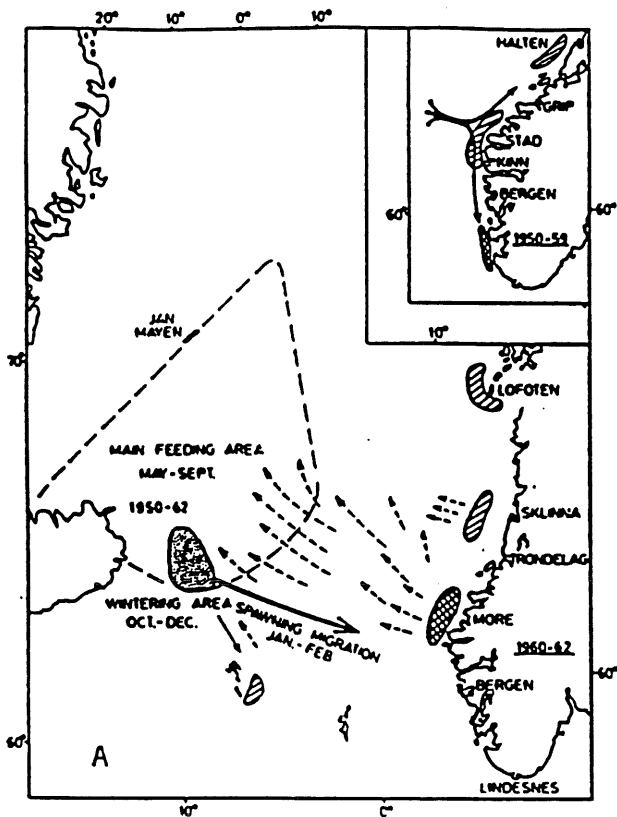


Fig 1 Migration routes of Norwegian spring spawning herring.

A. 1950-1962

B. 1963-1966

C. 1967-1968

D. Present

(A, B and C from Dragesund *et al.* 1980).

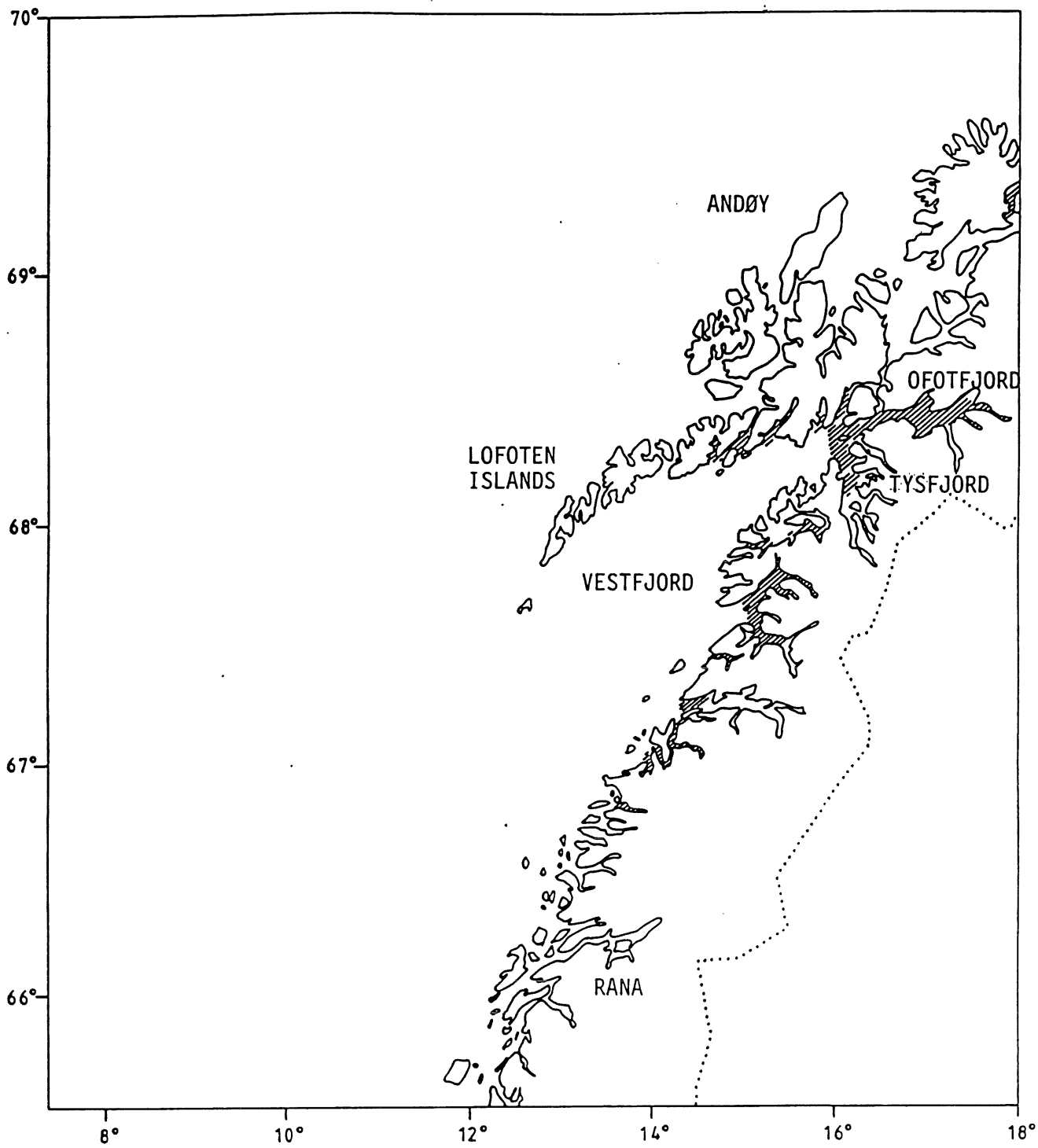


Fig 2 Norwegian spring spawning herring. Wintering areas (shaded) in 1987/88.



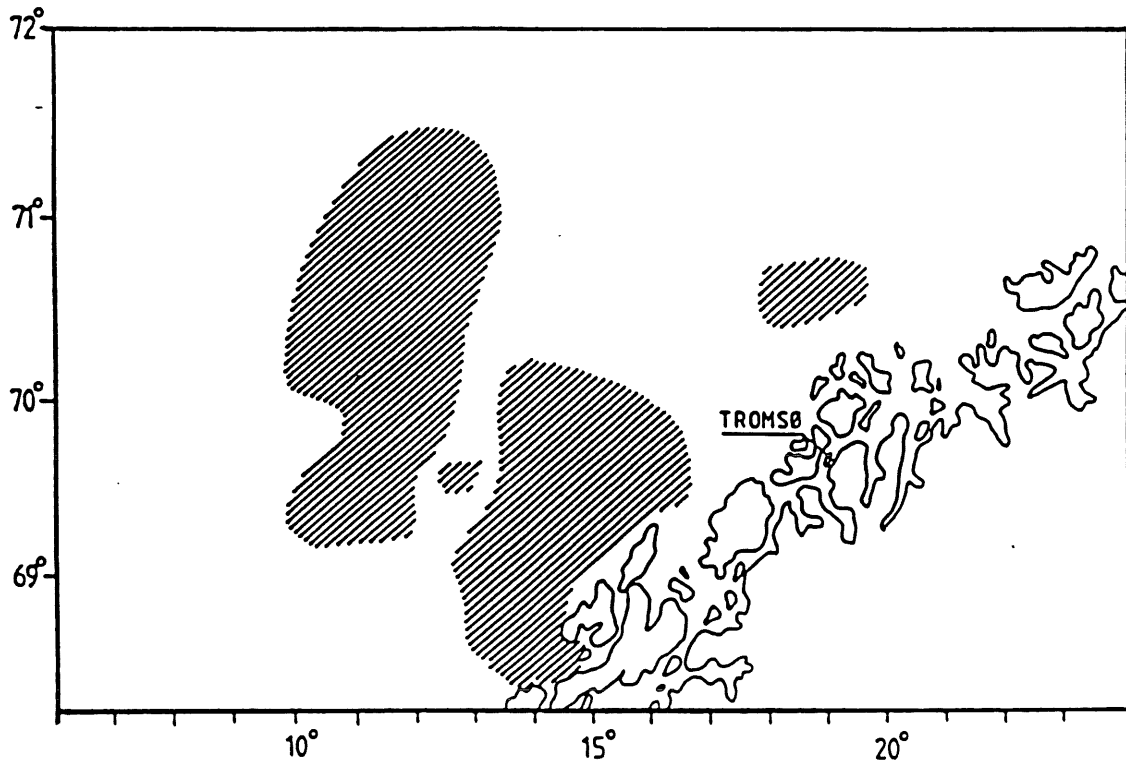


Fig 3 Norwegian spring spawning herring. Distribution of the 1983 year class in August 1986.

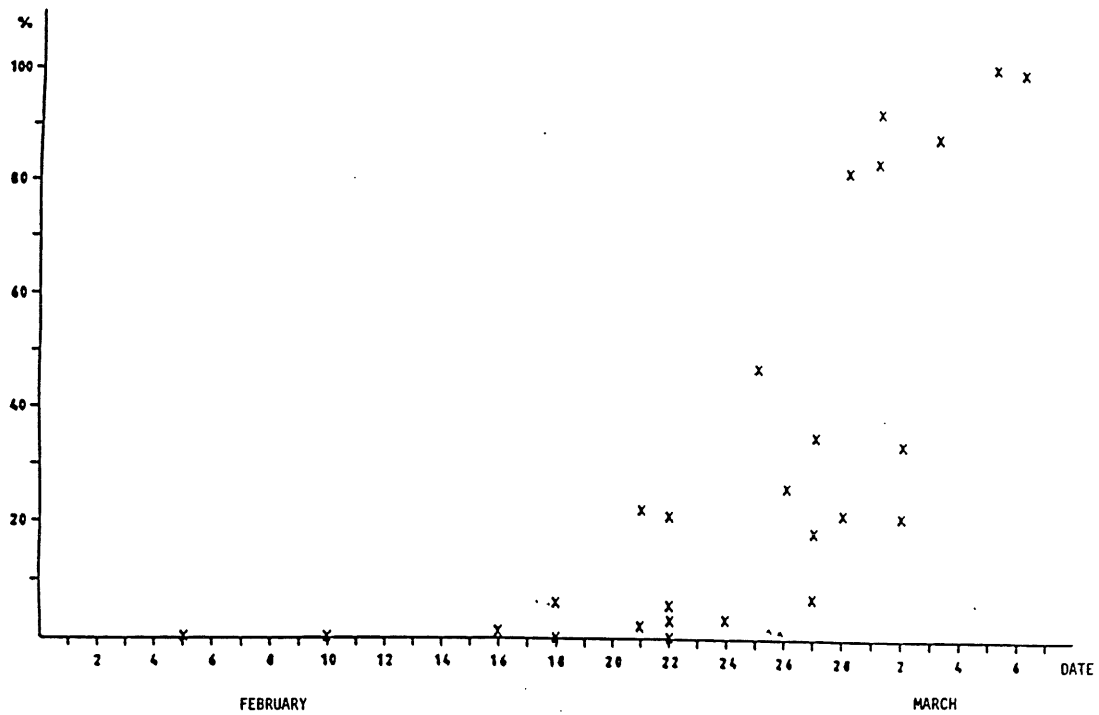


Fig 4 Percentage spawning and spent herring in February-March 1991.

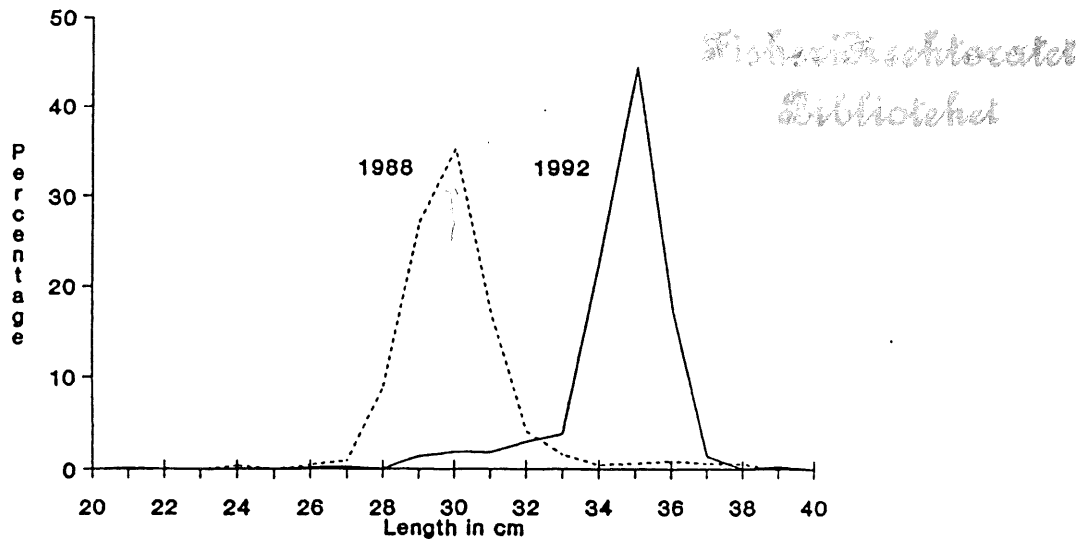


Fig 5 Norwegian spring spawning herring. Length distribution of spawning stock in 1988 and 1992.

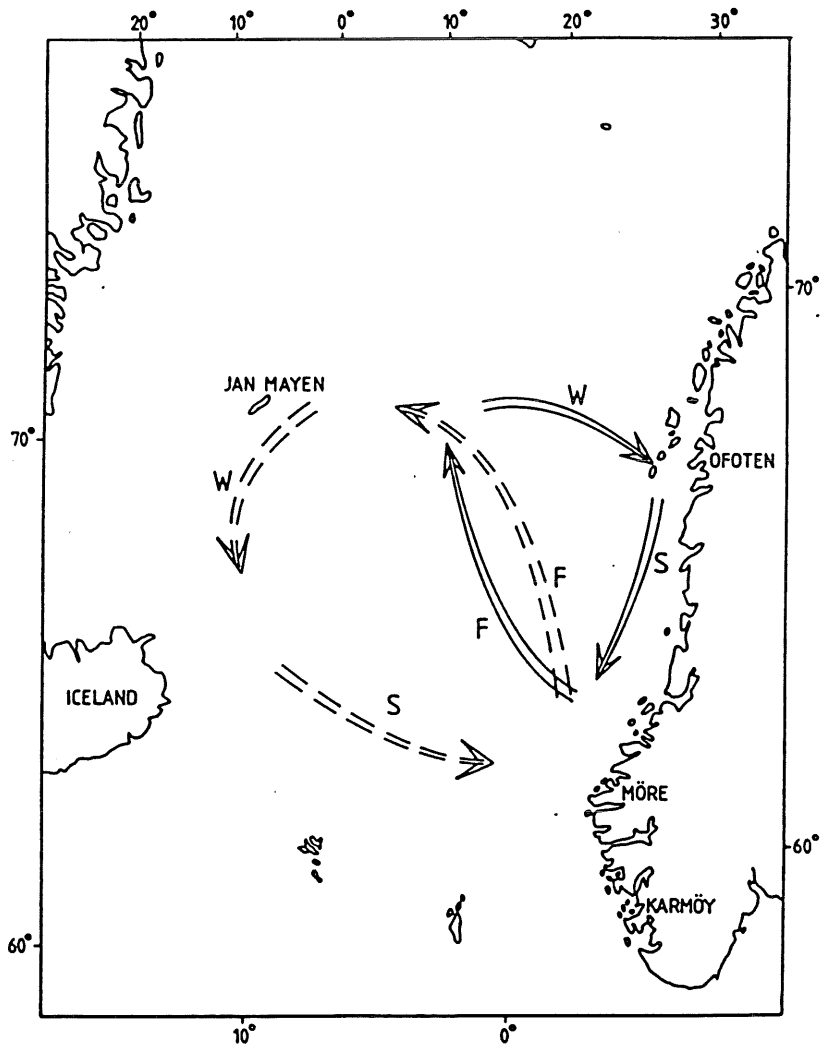


Fig 6 Norwegian spring spawning herring. Comparison of the overall migration pattern in the 1950s (dotted line) and present (solid line). F=feeding migration, W=migration to wintering areas, S=spawning migration.