# A review of variability in the distribution and abundance of Norwegian spring spawning herring and Barents Sea capelin

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The historic data on the fisheries on Norwegian spring spawning herring and Barents Sea capelin show that the migration pattern and time of spawning have changed for these species. Furthermore, modern techniques like tagging, hydroacoustic abundance estimation and virtual population analysis have shown that the abundance, both of the adult and the immature parts of the population, fluctuates widely. Predators (other fish, seabirds, sea mammals) of pelagic fish must have experienced corresponding fluctuations in food availability.

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There have been great changes in the abundance and stock structure of the pelagic fish species in northern waters. We have seen the collapse of the Norwegian spring spawning and North Sea herring stocks in the 1960s (Dragesund et al. 1980; Jakobsson 1985), and the Icelandic and Barents Sea capelin stocks in the 1980s (Vilhjalmsson 1983; Tjelmeland 1989). The North Sea herring stock and the Icelandic capelin stock have recovered. The Norwegian spring spawning herring is slowly recovering, but the Barents Sea capelin is still at a low level. These fluctuations in the pelagic fish stocks will certainly have large consequences not only for the fisheries which are dependent on them, but also for the whole ecosystem, including the organisms (other fish, marine mammals and seabirds) which are trophically linked to these pelagic species.

The collapse of fish stocks is often regarded as a phenomenon linked to overfishing caused by the modern, highly efficient fishing fleets. Overfishing has in several cases undoubtedly led to a decrease in the stock size of some pelagic species, e.g. the Norwegian spring spawning herring in the late 1960s (Dragesund et al. 1980). It has consequently been argued that overfishing is the main cause when seabird species fail to find sufficient food, and death due to starvation occurs (Lid 1981).

However, the historical record of the fisheries indicates that there have occurred changes in abundance, migration and distribution of important pelagic fish species many times in the past. The aim of the present paper is to examine the variations that have taken place during the last two centuries with regard to the Norwegian spring spawning herring and the Barents Sea capelin.

## Fish migration

It is well known that fish stocks, in particular the large pelagic ones, migrate from place to place. The migration will be a key factor determining the availability to predators and for the fisheries on the species in question.

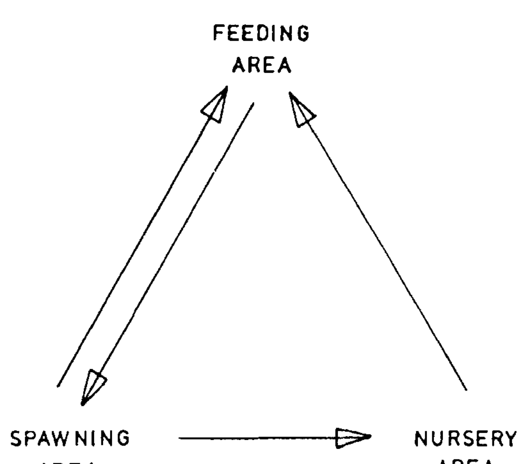


*Fig. 1.* General pattern of fish migrations. (Modified from Harden Jones 1968.)

The concept of fish migration can be simply visualized, as being triangular in pattern, with the spawning area, nursery area and adult stock at the three corners (Harden Jones 1968). This is shown in Fig. 1.

The currents are of major importance for the determination of the migration pattern. The young stages drift with the current to the nursery ground. The spawning migration is often against the current, and spent fish return to the feeding grounds with the current. If the currents change their intensity or direction, this will obviously have a great impact on the system by the carrying of larvae further away from their spawning fields. This can also have an influence on such factors as growth rate and mortality.

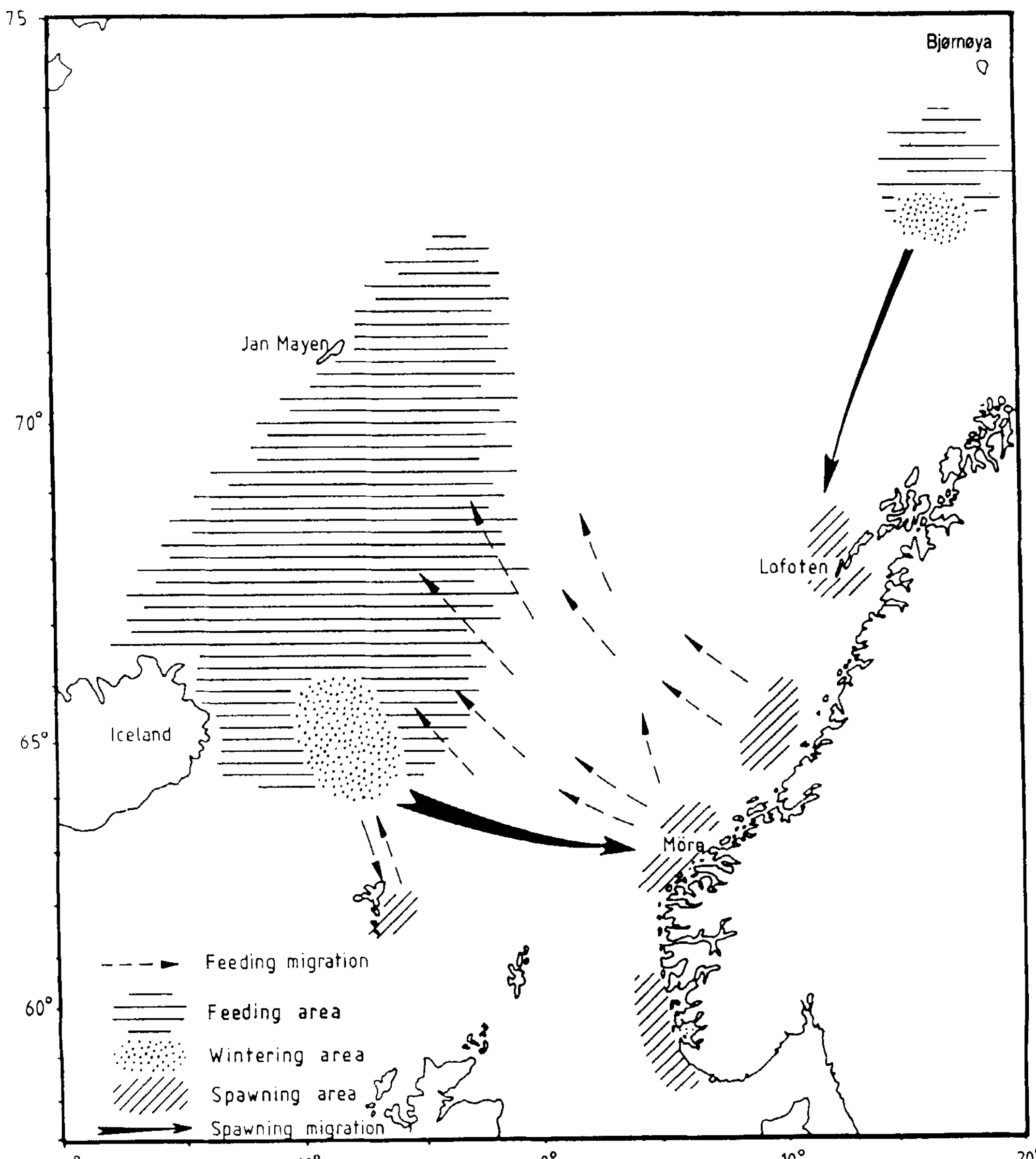


*Fig. 2.* Norwegian spring spawning herring. Distribution areas and migration routes prior to 1970. (From Dragesund et al. 1980.)

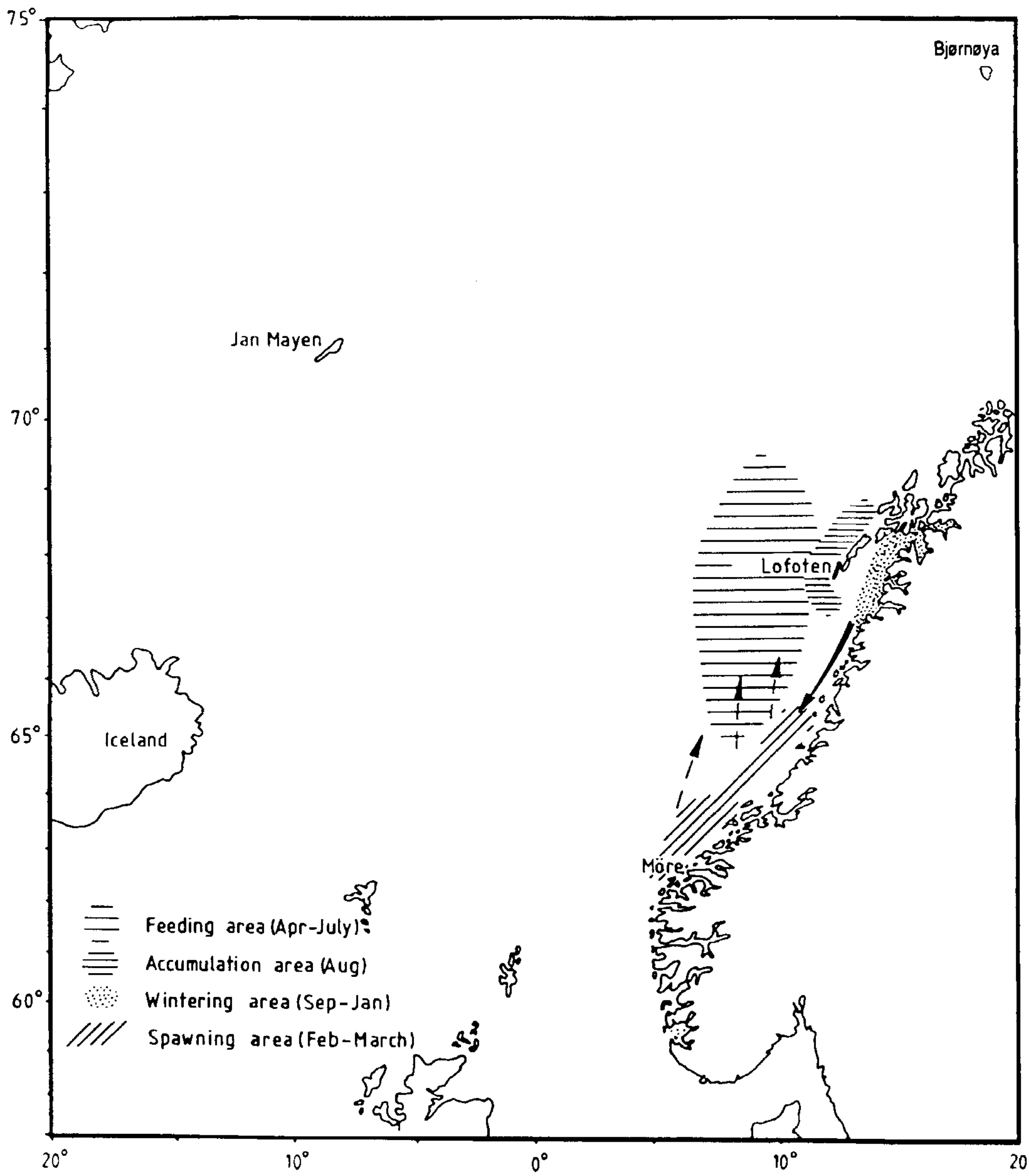


*Fig. 3.* Norwegian spring spawning herring. Distribution areas and migration routes 1986–1988. Legend as Fig. 2.

The following changes within the general framework have been observed:

1. Geographical changes in migration.
2. Changes in the timing of the migrations, resulting in changes in spawning time and feeding seasons.

## Fish abundance

From early times, the catch data for the fisheries are the only source for analysing changes in relative population abundance. From the middle of the last century, 'modern' communication

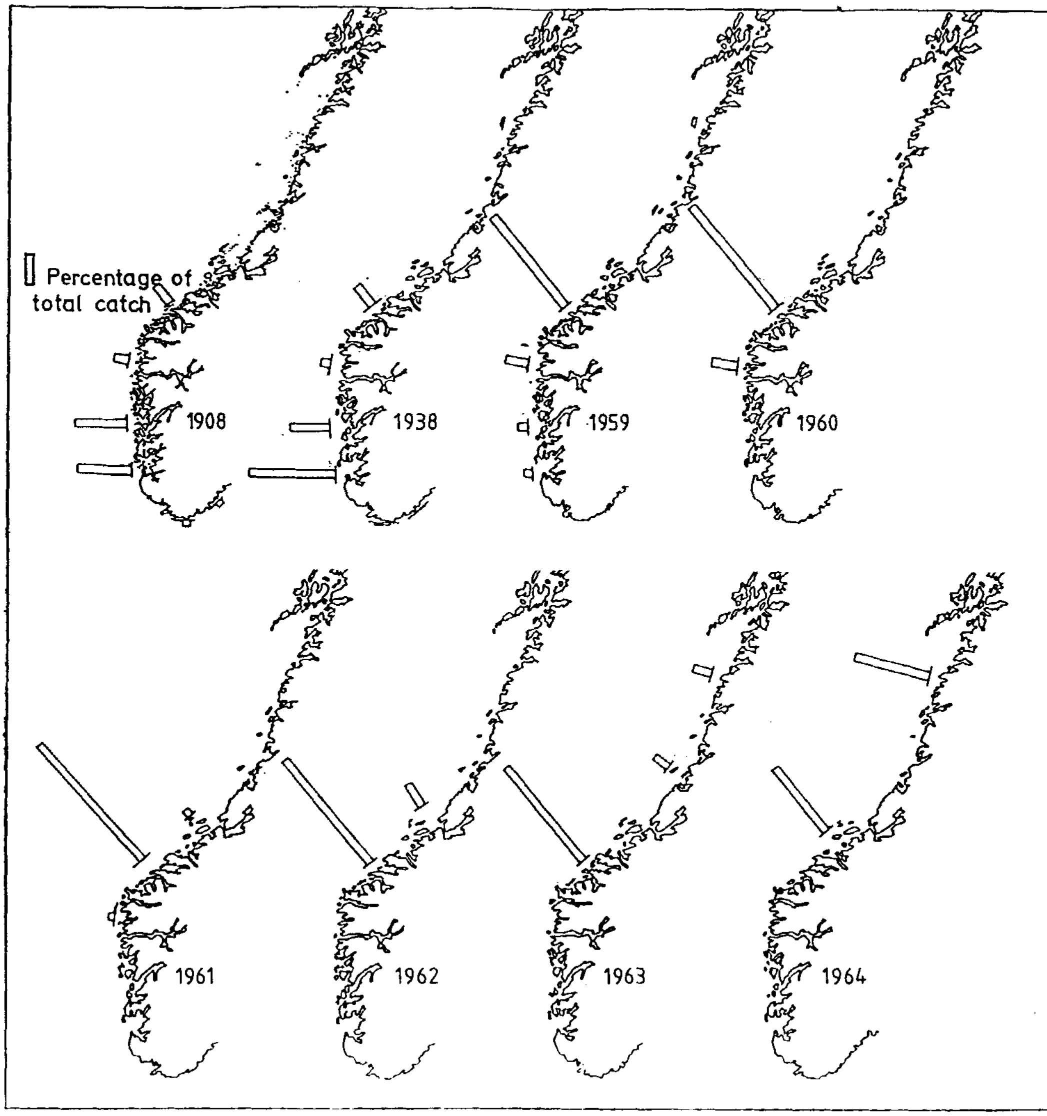


*Fig. 4.* Norwegian spring spawning herring. Percentage distribution of winter herring catches in different areas in 1908, 1938 and 1959–1964.

(steamships, telegraph) could spread information on to the fishing fleet about any new developments in the distribution of fish. The fishing fleet had by then become relatively mobile, and could to a certain degree respond to such changes. Therefore, a decreasing trend in the catch will probably reflect a decrease in abundance or a drastic change in the migration pattern (or both) of the species in question.

In later years, one has been able to obtain estimates of the size of the Norwegian spring spawning herring stock by the use of tagging (Aasen 1958; Dragesund & Jacobsson 1963; Anon. 1989) and VPA-techniques (Virtual Population Analysis) (Dragesund & Ulltang 1978; Anon. 1987). The abundance of the Barents Sea capelin has been assessed by acoustic methods (Dommasnes & Røttingen 1985) since 1972.

## Norwegian spring spawning herring

Biological studies conducted over many years gradually led to the understanding of the migration routes 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 fields off western Norway in winter. This was later confirmed by tagging (Fridriksson & 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 1950s the various details of the migration routes which the herring followed had been mapped (Devold 1963). The migration routes which were prevalent in the 1950s are shown in Fig. 2.

The locations of the main spawning sites have shifted. This can be deduced from the shifting locations of the winter herring fishery (a fishery on herring in the spawning season). Fig. 4 shows that there is a northward shifting trend in the location of the main spawning fields from the beginning of this century up to the 1960s.

The arrival of the herring in Norwegian coastal waters as well as the actual spawning in the same period have been delayed year by year (Fig. 5), as seen from the date when the mature herring appears on or near the spawning grounds (first day of the winter herring catch). The actual first day of spawning will be a week or two later. Such displacements in time and space have been described earlier (Boeck 1871).

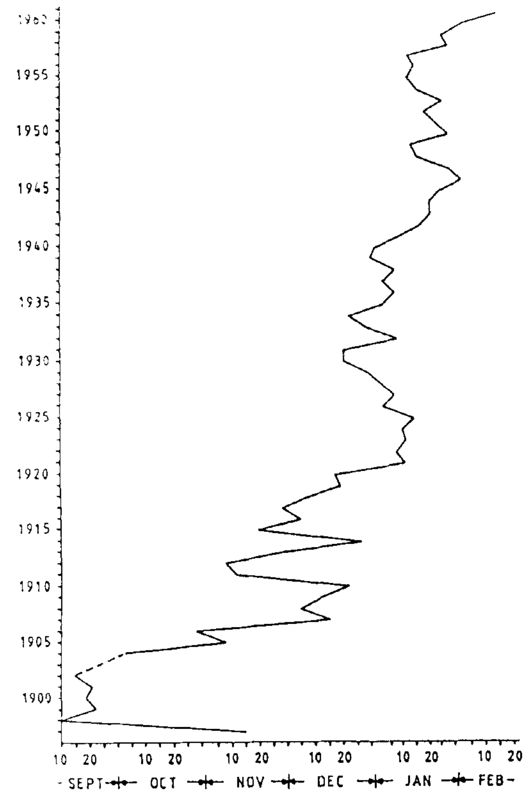


*Fig. 5.* Norwegian spring spawning herring. Data of first catch of winter herring on or near the spawning fields. (Modified from Devold 1963.)

Fig. 6 shows the total catch of the fishery on spawning herring off the west coast of Norway in the period 1755–1988. An absence of the fishery at the end of the eighteenth century and around 1880 indicates that the herring was absent from the traditional spawning grounds during these periods. The reason for the absence was obviously not due to overfishing, but it cannot be stated with certainty whether there was a change in the migration routes or a 'natural' change in abundance. However, the decline in the fishery in the 1960s was almost certainly due to overfishing (Dragesund et al. 1980). The disappearance of the herring from the spawning fields of western and northern Norway would of course have had great effects on the whole ecosystem, including the organisms dependent upon the herring, irrespective of it being due to overfishing or natural causes.

The size of the spawning stock back to 1950 (Fig. 7) has been calculated by using virtual population analysis (Dragesund & Ulltang 1978; Anon. 1989). Fig. 7 shows that there has been an increase in the stock since 1970. At present, the spawning stock size is estimated to be in excess of 1 million tons. This is mainly due to the recruitment of the strong 1983 year class to the spawning stock in 1987–1988. During this rebuilding phase, some biological features, such as the migration pattern, have changed compared to the time prior to the stock collapse (Fig. 3).

Changes in the adult population will also be reflected in the immature part of the herring stock. After hatching, the larvae are transported northward with the currents system, and in the autumn the herring fry are distributed in the fjord

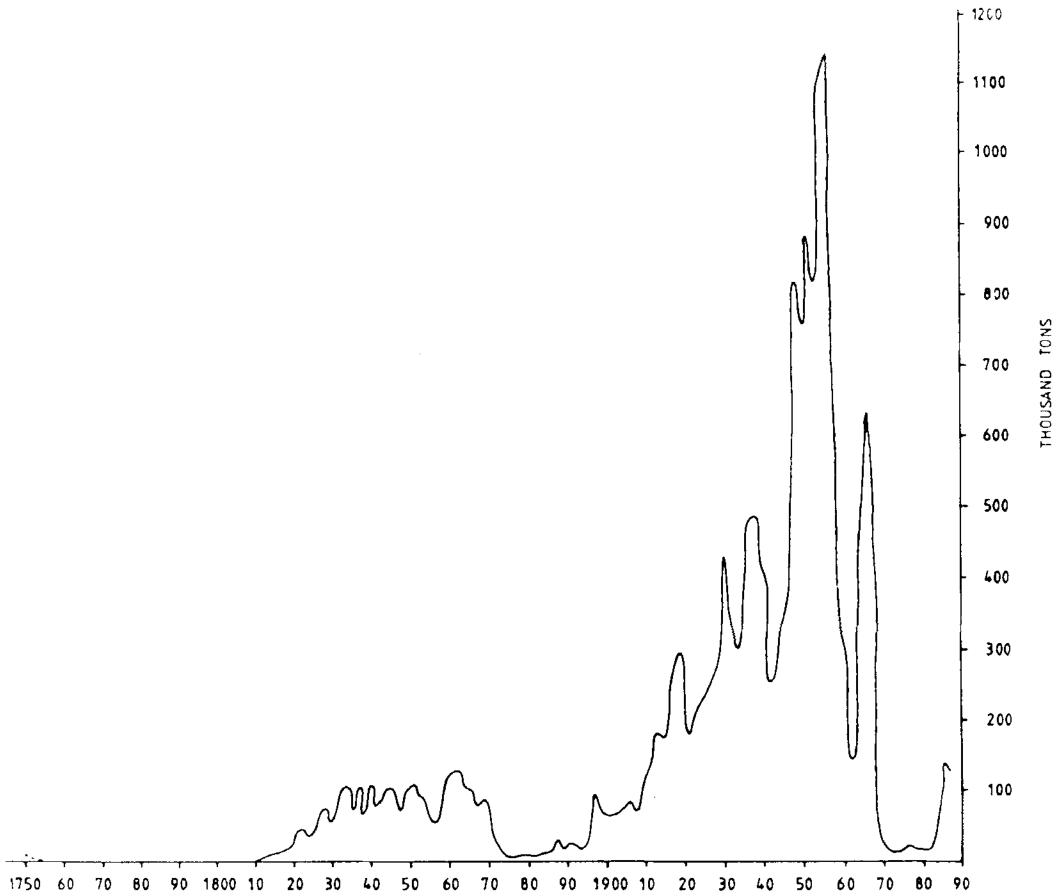


*Fig. 6.* Norwegian spring spawning herring. Catch of winter herring since 1755.

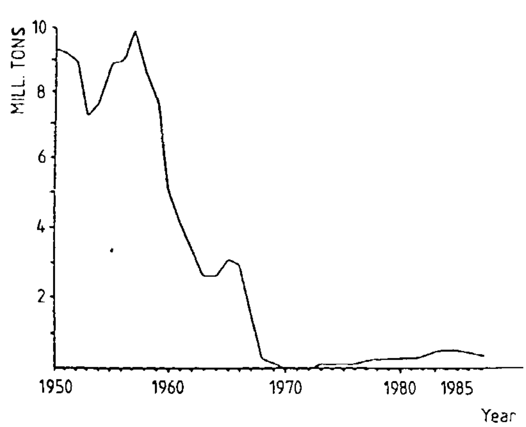


*Fig. 7.* Norwegian spring spawning herring. Size of spawning stock 1950–1987.

and coastal areas of western and northern Norway and in the Barents Sea. There are of course no data on distribution and drift of larvae and fry from earlier times, but an example of changing larval abundance with changing spawning stock size can be illustrated by the recorded larval abundance at the time of the stock collapse. When the spawning stock was at a minimum in 1970–1972 (and thus almost absent from the traditional spawning sites of western Norway) it can be seen from Fig. 8 that the larvae practically disappeared from the northern transportation system. The abundance of herring fry in the autumn will also vary considerably from year to year, and Fig. 9 illustrates the scale of this variability in the Barents Sea nursery area in recent years.

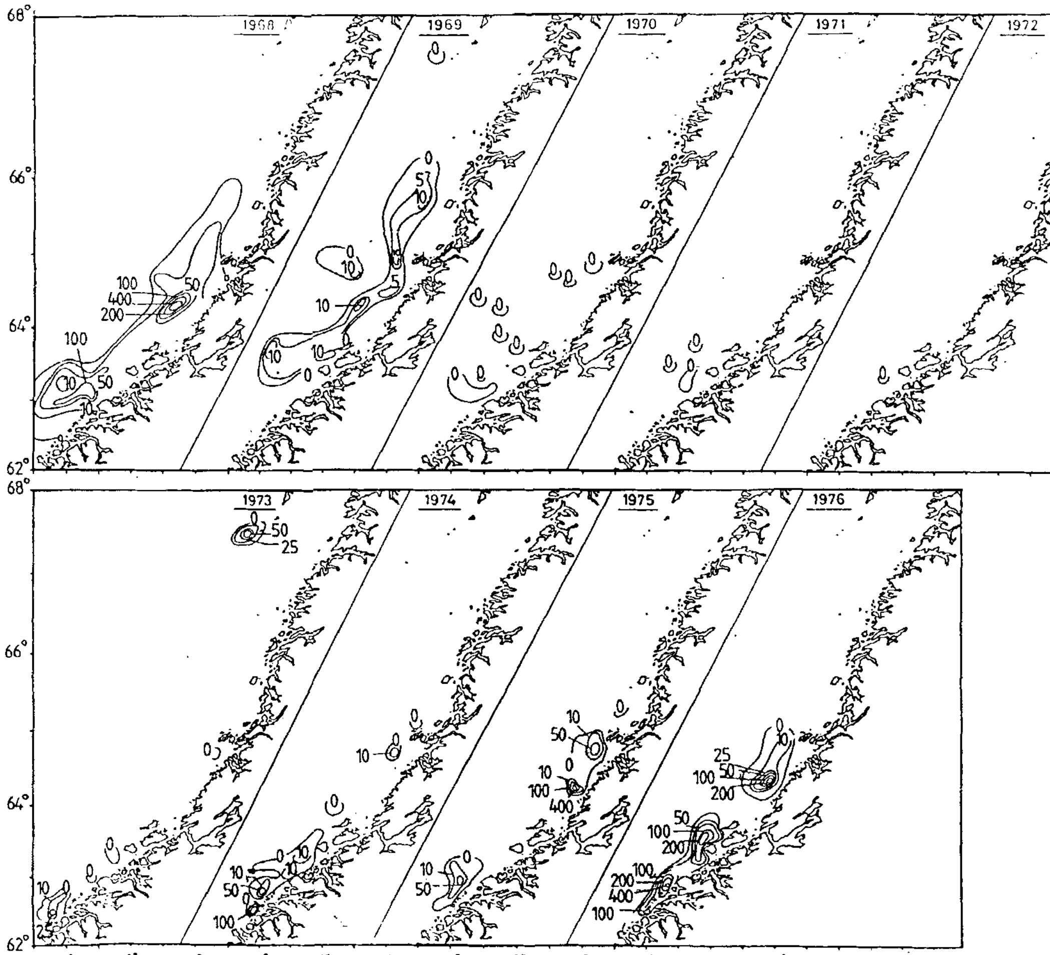


*Fig. 8.* Norwegian spring spawning herring. Larval distribution (numbers indicate number of larvae per metre of surface) in April 1968–1977 (H. Bjørke unpublished).

## Barents Sea capelin

Compared with the herring, the historical data on long-term fluctuations of capelin are few. This is due to the fact that there was no large scale fishery on capelin until the end of the 1950s. However, when the capelin migrated towards the coast to spawn, they were followed and preyed on by young cod. These immature cod were the basis for a winter cod fishery off Finnmark and northern Troms. There is a historical record of this fishery starting at the beginning of the last century. This record shows that there was no cod fishery in the period 1828–1840 (Solhaug 1976) or in 1938–1942 (Møller & Olsen 1962). The absence of spawning capelin on the coast, due to changes in abundance or spawning areas, has been given as the reason for the cessation of the winter cod fishery in these periods. Furthermore, there was no spawning capelin off the coast in 1962 and very little in 1963 (Olsen 1968). Following the stock collapse in 1985–1986, the amount of spawning capelin in 1987 and 1988 was negligible compared to earlier years.

Hamre (1988) argues that the periods 1938–1942 and 1962–1963 were characterized by the occurrence of strong herring year classes in the preceding years. Competition and probable predation of herring on capelin larvae and fry

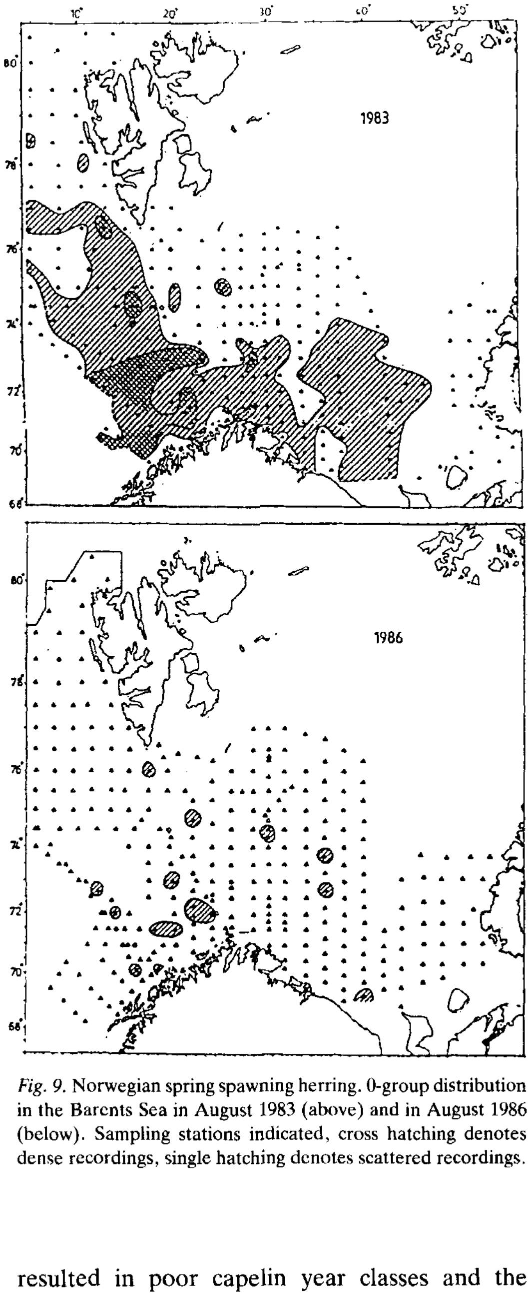


*Fig. 9.* Norwegian spring spawning herring. 0-group distribution in the Barents Sea in August 1983 (above) and in August 1986 (below). Sampling stations indicated, cross hatching denotes dense recordings, single hatching denotes scattered recordings.

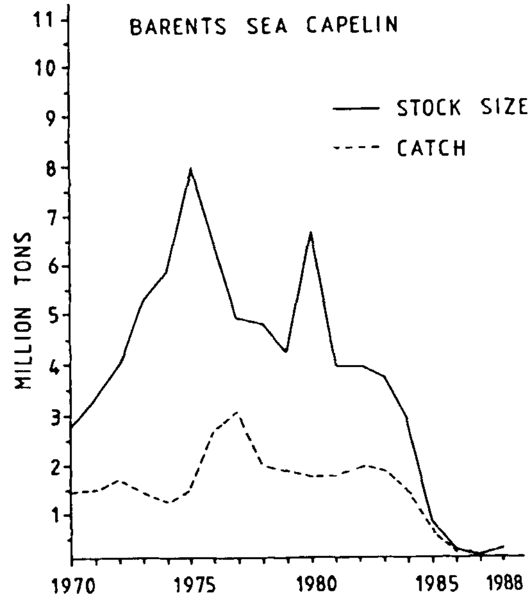


*Fig. 10.* Acoustic stock estimates and catch of Barents Sea capelin 1970–1988.

resulted in poor capelin year classes and the absence of spawning capelin was thus due to decreased capelin abundance in these periods. In contrast to what happened to the Norwegian spring spawning herring stock, the fishery is not believed to be the single, major factor of the capelin stock collapse in 1985–1986. The capelin fishery had in the late 1970s and the beginning of the 1980s been regulated on the assumption that the predation on capelin was constant from year to year. However, in the middle of the 1980s this predation increased dramatically due to a large stock of young cod. Tjelmeland (1989) argues that this increased predation was the decisive element of the capelin stock collapse.

There are very few quantitative data about stock abundance prior to 1970. After 1970, a large effort has been put into investigations of this stock. Acoustic abundance estimates of the capelin have been made each year since 1972 (Dommasnes & Røttingen 1985). The estimates of the capelin stock are shown in Fig. 10, and it is apparent that the stock has fluctuated appreciably.

There has also been a corresponding shift in eastern and western location of spawning grounds. So-called western, i.e. areas west of the North Cape, or eastern (east of the North Cape) spawning has been observed recently. In earlier periods the catch statistics for the winter cod fishery show that the main part of the winter cod fishery, and thereby probably the largest capelin concentrations, in some years took place west of the North Cape, and in some years east of the North Cape.

There are also recorded changes in time of spawning (Møller & Olsen 1962). These data do

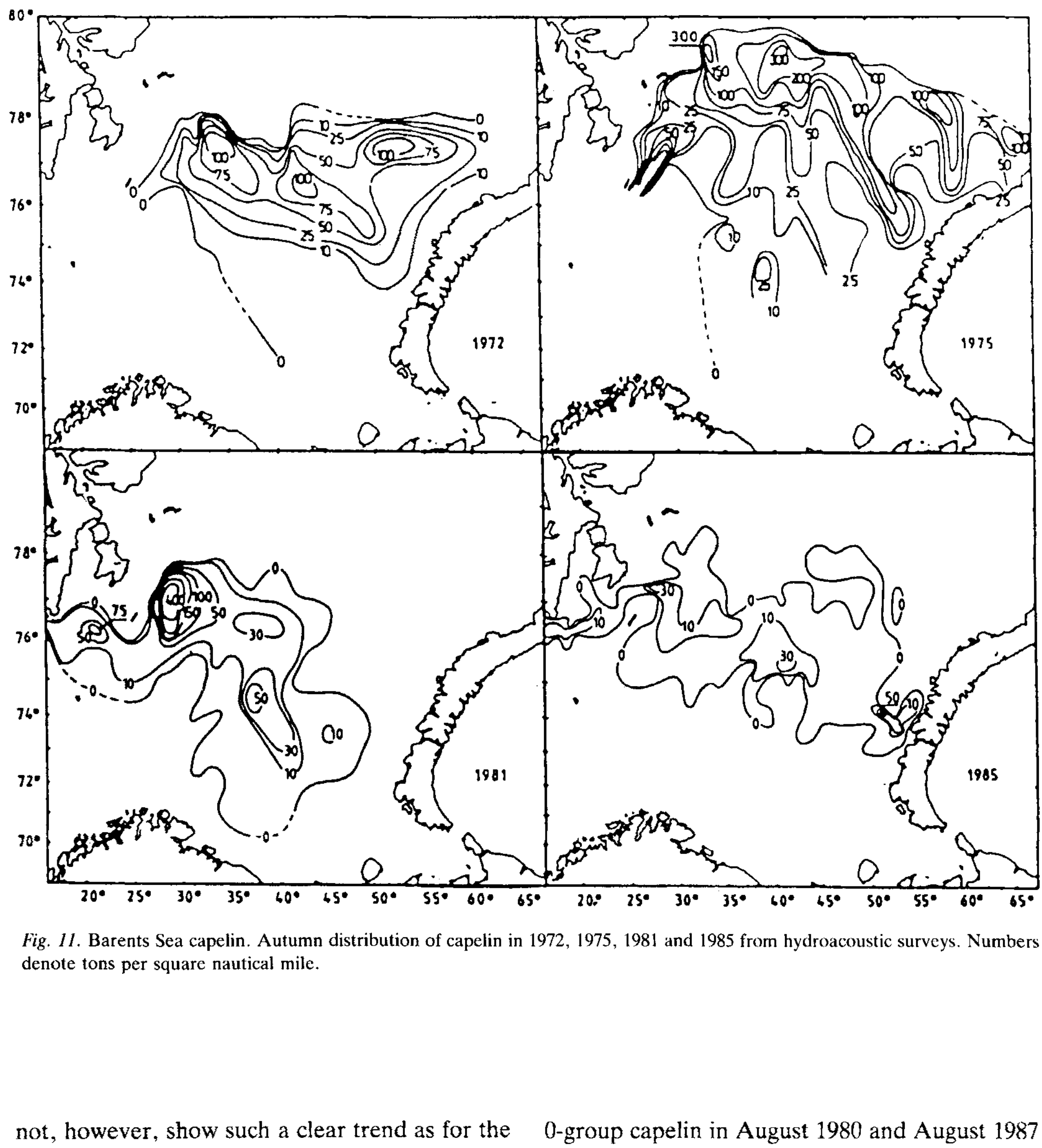


*Fig. 11.* Barents Sea capelin. Autumn distribution of capelin in 1972, 1975, 1981 and 1985 from hydroacoustic surveys. Numbers denote tons per square nautical mile.

not, however, show such a clear trend as for the Norwegian spring spawning herring.

There have been detailed systematic investigations on the summer feeding grounds of this stock since the beginning of the 1970s. These investigations show that in some years the summer feeding grounds are located in the eastern part of the Barents Sea, in other years there is a more western distribution (Fig. 11).

These fluctuations in the adult stock will, as was the case for Norwegian spring spawning herring, be reflected in the amount and distribution of the spawning products, larvae and fry. This variation is illustrated in the distribution of 0-group capelin in August 1980 and August 1987 (Fig. 12).

## Concluding remarks

The present paper has shown that the adult and immature stocks of two very important pelagic stocks in northern waters, Norwegian spring spawning herring and Barents Sea capelin, have fluctuated considerably in distribution and abundance over the last two centuries. These large variations must repeatedly have had profound consequences for the ecosystems both in the

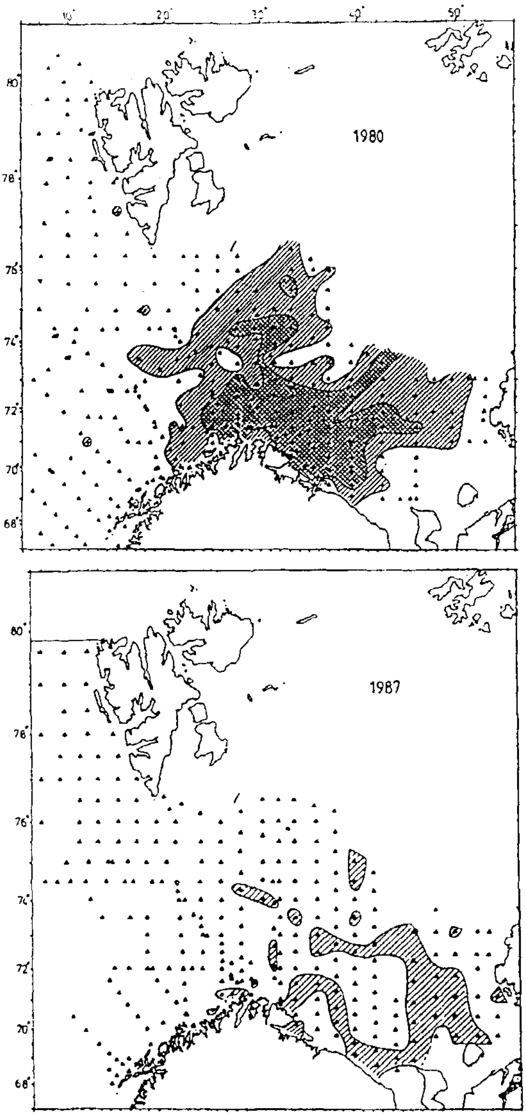


*Fig. 12.* Barents Sea capelin. 0-group distribution in the Barents Sea in August 1980 and in August 1987. Legend as in Fig. 9.

Norwegian and Barents Seas. The author has not speculated to any extent about the underlying reasons for these changes. These reasons are complex, and one has to take into account factors from both the biological and physical regimes, and sometimes, but not necessarily always, human activity.

# References


Aasen, O. 1958: Estimation of the stock strength of Norwegian winter herring. *J. Coun. int. Explor. Mer 24*, 95–110.

Anon. 1987: Report of the working group on Atlanto-Scandian herring and capelin. *Coun. Meet. int. Coun. Explor. Sea 1987 (Assess. 8)*, 1–57 (mimeo.).

Anon. 1989: Report of the Atlanto-Scandian herring and capelin working group. *Coun. Meet. int. Coun. Explor. Sea 1989 (Assess. 7)*, 1–48 (mimeo.).

Boeck, A. 1871: Om Silden og Sildefisket, navnlig om det norske Vaarsildfiske. Pp. 1–131 in *Indberetning til Departementet for det Indre.* Christiania (in Norwegian).

Devold, F. 1963: Life history of the Atlanto-Scandian herring. *Rapp. P.-v. Reun. Cons. int. Explor. Mer 154*, 98–108.

Dommasnes, A. & Røttingen, I. 1985: Acoustic stock measurements of the Barents Sea capelin 1972–1984. A review. Pp. 45–108 in Gjøsæter, H. (ed.): *Proc. Soviet-Norwegian Symp. Barents Sea capelin, Bergen-Norway, 14–17 August 1984.* Institute of Marine Research, Bergen.

Dragesund, O. & Jacobsson, J. 1963: Stock strengths and rates of mortality of the Norwegian spring spawnings as indicated by tagging experiments in Icelandic waters. *Rapp. P.-v. Reun. Cons. int. Explor. Mer 154*, 83–90.

Dragesund, O. & Ulltang, Ø. 1978: Stock size fluctuation and rate of exploitation of the Norwegian spring spawning herring. 1950–1974. *FiskDir. Skr. Ser. HavUnders. 16*, 315–337.

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

Fridriksson, A. 1944: Nordurlandssildin (The herring of the North coast of Iceland). *Rit Fiskideild. 1.* 338 pp.

Fridriksson, A. & Aasen, O. 1950: The Norwegian-Icelandic herring tagging experiments. Rep. 1. *FiskDir. Skr. Ser. HavUnders. 9*, 1–43.

Hamre, J. 1988: Some aspects of the interrelation between the herring in the Norwegian Sea and the stocks of capelin and cod in the Barents Seas. *Coun. Meet. int. Coun. Explor. Sea 1988 (H.42)*, 1–15 (mimeo.).

Harden Jones, F. R. 1968: *Fish Migration.* Edward Arnold, London. 325 pp.

Jakobsson, J. 1985: Monitoring and management of the Northeast Atlantic herring stocks. *Can. J. Fish. Aquat. Sci. 42 (Supp. 1)*, 207–221.

Lid, G. 1981: Reproduction of the Puffin on Røst in the Lofoten Islands in 1964–1980. *Fauna norv. Ser. C, Cinclus 4*, 30–39.

Møller, D. & Olsen, S. 1962: Lodda og loddefisket. *Fiskets Gang 3*, 27–35 (summary in English).

Olsen, S. 1968: Some results of the Norwegian capelin investigations 1960–1965. Pp. 18–23 in Blacker, R.V. (ed.): *Symposium on the ecology of pelagic fish species in Arctic waters and adjacent seas. Rapp. P.-v. Reun. Cons. int. Explor. Mer 158.*

Solhaug, T. 1976: *De norske fiskeriers historie 1815–1880.* Universitetsforlaget, Oslo. 770 pp. (in Norwegian).

Tjelmeland, S. 1989: Cod-capelin interactions in the Barents Sea: A new light on past management of capelin. Contributions to ICES. *Symposium on multispecies models relevant to the management of living resources, The Hague, 1989* (in press).

Vilhjalmsson, H. 1983: Biology, abundance estimates and managements of the Icelandic stock of capelin. *Rit. Fiskideild. 3*, 153–181.