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Climate Change and the Migratory Pattern for Norwegian Spring–Spawning Herring - Implications for Management

by

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Abstract

Norwegian spring-spawning herring (C*lupea harengus)* has been an important source of food for centuries, mainly for Norway, Iceland and Russia, but also for other European countries. Herring is a migratory fish stock, and during the last 50 years the migratory pattern has changed several times. There seems to be a connection between altering climatic conditions and the size of fish, yearclass strength and the migratory pattern. The distribution and the changing migratory pattern takes on significance for the international management of the stock. The changing judicial status of the herring has caused problems and conflicts between the parties involved in the fishery. Investigating whether the change is due to over fishing or to environmental causes, or a combination of both, was one of the objectives of the analysis. Furthermore, we have looked at the processes involved in finding solutions to the problem of managing straddling stocks.

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1. Introduction

Norwegian spring-spawning herring[1] (C*lupea harengus)* is, historically, the largest fish stock in the North Atlantic. The stock has been an important source of food for centuries, mainly for Norway, Iceland and Russia, but also for other European countries.

Since the 1950s, the global pressure on the fish stocks has increased dramatically, and we may expect a further increase due to improved technology and continued population growth. Fish stocks migrating between different areas of jurisdiction or in international waters need special attention as the management of these stocks demand inter state cooperation. Without such collaboration, the stocks are in danger of being over exploited, as individual actors will try to maximise the benefit by exploiting the resource as much as possible. Norwegian spring-spawning herring is a prime example of this. Due to the development of new technologies, harvest levels increased tremendously in the early 1960s, causing the stock to collapse. The recovery period lasted more than two decades.

In addition to the human pressure on the fish stocks, the climate can influence size, yearclass strength and the migratory pattern of the fish. Norwegian spring spawning herring have altered the migratory pattern several times since the 1950s. From being a straddling stock in the 1950s, the herring became an exclusive Norwegian stock in the 1970s. From the mid 1980s, the stock was shared between Norway and Russia, while in the 1990s the stock again migrated through different countries' jurisdiction and in international waters. The distribution and the altering migratory pattern takes on significance for the international management of the stock, as the changing judicial status of the herring has caused problems and conflicts between the parties involved in the fishery. Investigating whether the change is due to over fishing or to environmental causes, or a combination of both, is one of the objectives in the following discussion. Furthermore, we will look at the processes involved in finding solutions to the problem of managing straddling stocks.

This paper is organised as follows: we will look at the migratory pattern of the stock from the 1950s until today (section 2), then we will discuss some of the climatic changes in the same period (section 3), and finally we will examine the international management of the stock and

[1] Norwegian spring spawning herring will also be referred to as herring.

the possibility of predicting future migratory pattern, stock size, ecological changes and international cooperation (section 4).

2. Migratory pattern for Norwegian Spring - Spawning Herring

The fishery for Norwegian spring-spawning herring has a thousand year long tradition, with the main fishery of adult herring conducted during winter along the Norwegian west coast, prior to and during the spawning season. Data show sharp fluctuations in the catches during the 19th century, with an increase from a few hundred tonnes in 1810 to 70.000 tonnes in 1830. The catches reached a peak of 100,000 tonnes in 1860, followed by a sharp decline, ending at 13.000 tonnes in the 1890s. At the beginning of the 20th century, the catches increased, reaching one million tonnes in the early 1950s. In 1957, the Norwegian spring-spawning herring stock reached a peak of 10 million tonnes, followed by a sharp decrease to about three million tonnes in 1963 (Kronvin and Rodionov, 1992). In the same period the spawning stock biomass altered from less than two million tonnes in 1907 to a peak of 14 million tonnes in 1950 and down to near extinction in the 1970s.

In the early 1960s, there was a tremendous expansion in the fishery due to the introduction of new technology in the form of the power block and sonar (Bjørndal, 1988). Rapidly increasing catches led to a collapse of the stock in the second half of the 1960s. After the collapse, restrictions were set in force in the 1970s and 1980s, leading to a slow recovery of the stock. In the 1990s the stock increased dramatically due to good recruitment, and reached a peak of 12 million tonnes in 1997. In 2001, the Spawning Stock Biomass (SSB) was estimated at 5,1 million tonnes (Marine Institute, 2003). Spawning stock biomass and catches in the twentieth century are illustrated in figure 1.

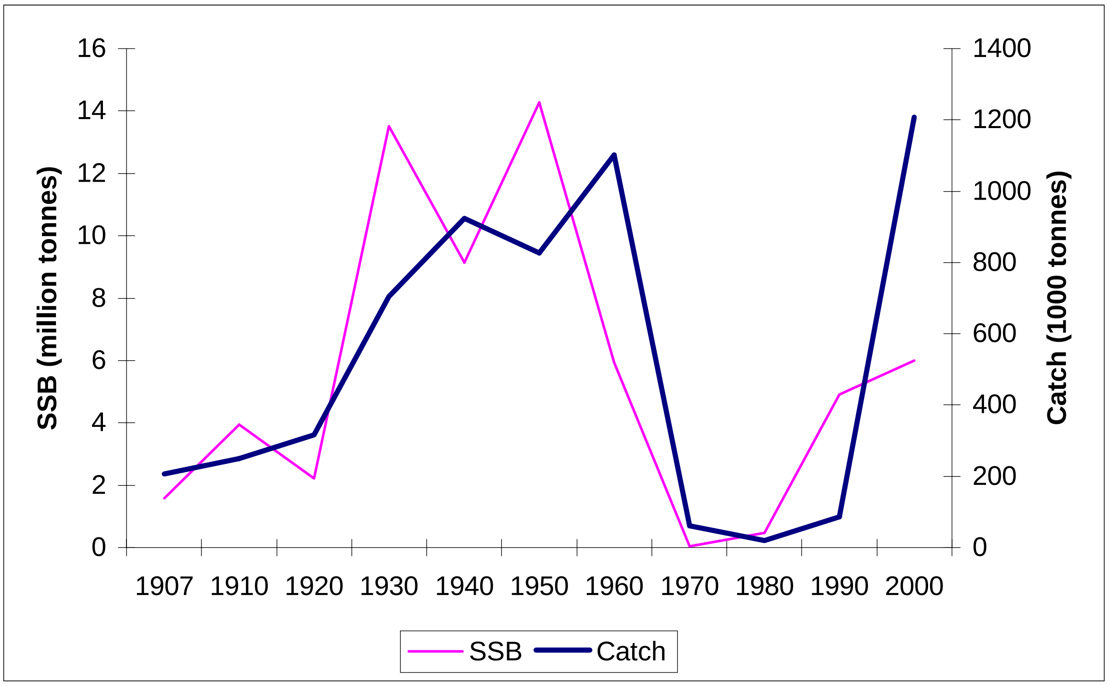

Figure 1. Spawning Stock Biomass and Catch of Norwegian spring-spawning herring.
Source: Toresen and Østvedt (2000) and Marine Institute (2003)

The migratory pattern of the Norwegian spring-spawning herring consists in general of four phases, spawning, nursery, feeding and wintering. In January, the adult herring start the migration to the spawning area, and the spawning takes place from February to April. After spawning, the adult herring migrate to the feeding area, while the currents carry the larvae to the nursery areas. The feeding period is over by medio September, and the adult stock migrates to the wintering areas. The phases are usually stable, but the geographic locations have shifted over time, see figure 2.

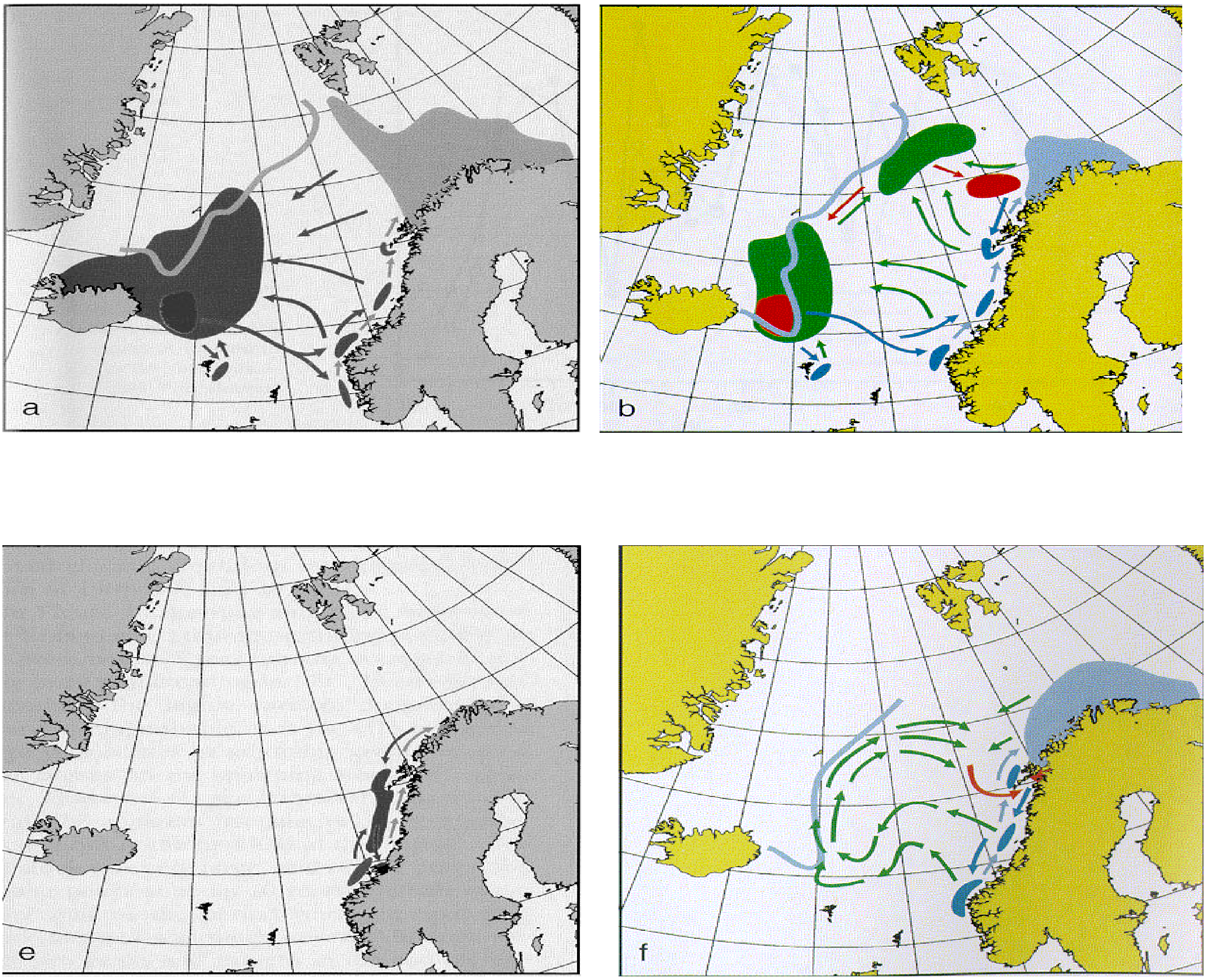

Figure 2. The migration pattern for Norwegian Spring-Spawning Herring, 1950 (a), 1965-66 (b), 1972-86 (e), 1995-99 (f). Source: Vilhjalmsson (1997)

During the last 50 years, we can find four migration routes for the Norwegian spring-spawning herring. In the 1950s, when the stock was large, the most important spawning area was along the western coast of Norway, and the juvenile herring stayed in the maturing area along the Norwegian coast and the Barents Sea. The feeding area for the adult herring was located in the Norwegian Sea, north of Iceland, while the wintering area was east of Iceland. During the 1950s, fishing mortality was low, allowing a high spawning stock biomass due to good recruitment. In this period the catches were high, and in the early 1960s catches increased even if the stock was declining. Despite strong year-classes in 1959, 1960, 1963, 1964 and 1966, the stock continued to decline, as the fish was caught before it reached maturity.

With a new stock component, consisting of the 1959 and 1960 year-classes, a new migration pattern emerged from 1963 to 1966. Instead of spending the winter east of Iceland, a part of the strong 1959 year-class wintered near Lofoten and then migrated north. The feeding area was located further north than earlier, in the north eastern part of the Norwegian Sea. The 1960 year-class joined this migration pattern, and these two components represented the largest part of the herring stock. The stock continued the more northern migration pattern for four years, before resuming its initial migration pattern.

After years of over exploitation, the stock collapsed at the end of the 1960s, and a new migration route emerged. Now, both the juvenile and the adult herring stayed in Norwegian coastal waters all year. The stock consisted of two components, one southern, spawning at Sunnmøre, feeding from Møre to Nordland and wintering in the fjords of Nordmøre, and one northern component, spawning and feeding in the area from Nordmøre to Troms and wintering in Lofoten. In addition, the juvenile herring stayed in Norwegian coastal fjord areas, and no herring were found in the previous maturing areas in the Barents Sea.

During the 1970s and the 1980s, fishing was restricted, and the spawning stock slowly increased. With the strong year-class of 1983, the Barents Sea was re-established as a nursery area. In 1986, the herring left the Barents Sea and migrated to the eastern part of the Norwegian Sea, re-utilising the previous feeding area. Since 1987, most of the herring spawn at the coastal banks off Møre, but there have also been reported spawning herring south of Stad[2]. The main part of the juvenile herring feed in the Barents Sea, while a minor part feed in the Norwegian coastal areas from Trøndelag and northwards to Finnmark. The adult stock migrates westward to feed, and is thus available for fisheries in international waters. At the end of May, the adult herring migrate north and northeast, while it turns eastward in July, ending up in the wintering area in the fjords of Northern Norway in September. Except for the wintering area, the herring have resumed the same geographic migration route as in the 1950s. At the time, the herring wintered east of Iceland before migrating eastward to spawn along the

[2] Spawning herring have been reported near Karmøy since 1989, but according to the Institute of Marine Research (1993), less than 5% of the herring spawn in areas south of Stad.

west coast of Norway. However, the herring have wintered in the fjords of Norway earlier as well, last reported in the 1970s, but also between 1850 and 1875 (Bjørndal *et al.* 1998).

3. Climatic Changes

There seems to be a correlation between stock size and migratory pattern for the herring. Strong year-classes and large stocks seem to migrate over a greater area than weak year-classes and small stocks. In the following we will look at the factors determining the strength and the size of the stocks.

The management of fisheries is multifaceted, especially with regard to transboundary stocks (Bjorndal and Munro, 2003). Fisheries in international waters are managed by international agreements, but so far these agreements have come short in including the question of climatic regime shifts. These shifts may influence the migration pattern of the fish stocks and thereby undermine the international cooperation. At present, uncertainty around how the physical changes in the ocean environment affect biological processes, that again influence the recruitment of harvested fish, makes the management issues even more complex (Miller and Munro 2003).

Stenseth *et al.* (2002) claim that ecological processes are influenced by climatic conditions, such as temperature, wind, rain, snow, and ocean currents, and interactions among these. The North Atlantic Oscillation (NAO) and the El Niño Southern Oscillation (ENSO) affect major variations in weather and climate around the world. Research show that the synchrony between predator and prey may be affected by phenomena such as the NAO and the ENSO, and in our case, higher temperatures give faster growth of both herring and its main predator, cod. This may cause a high predation pressure on the herring.

The NAO has two phases, one positive and one negative. The positive phase gives strong, westerly winds over northern Europe, bringing warm and stormy winter weather, while the same phenomenon causes dry conditions in southern Europe, the Mediterranean and Western Asia and cold winters in Canada and Greenland. During a period of positive NAO, the transport of warm Atlantic water into the Barents and the Arctic Seas increases. The negative phase gives cold winters in northern Europe and milder conditions than normal over Greenland, northeastern Canada and the Northwest Atlantic. This results in colder water in the Barents and the Arctic Seas. Research show that the NAO can affect the recruitment of

Norwegian Artic cod. Since the Norwegian spring-spawning herring has its spawning area off the Møre coast and northwards, we can expect the NAO to affect this stock as well.

The NAO was mostly positive during the first half of the 20th century, followed by a decrease and a negative index after 1952. During the same periods, the herring stock was increasing with positive NAO (1900-20, 1930, 1950, 1980-00) and decreasing with negative NAO (1920, 1940, 1960-70), see figure 1 and 3.

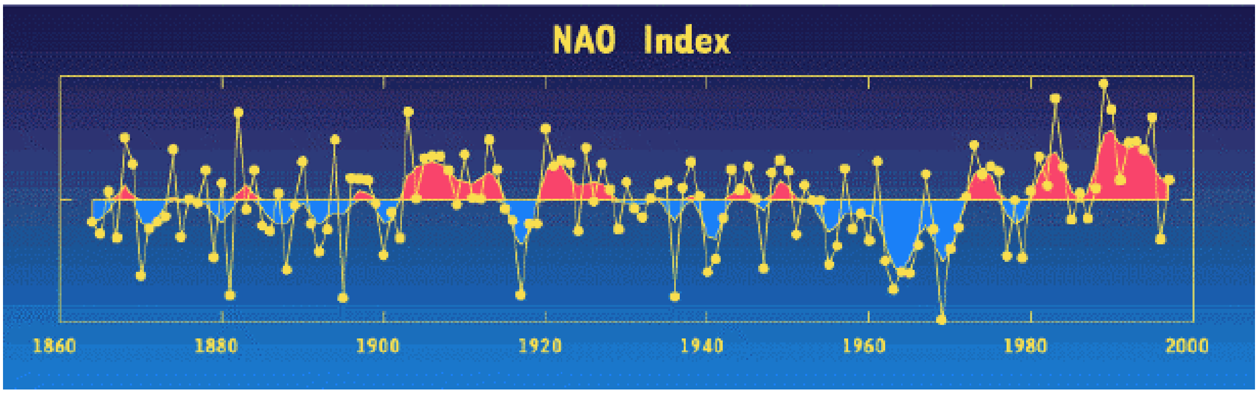

Figure 3. NAO Index, 1860-2000. Source: North Atlantic Oscillation web site.

Analysts have noted that warm conditions in the Norwegian Sea (associated with positive NAO) increase the likelihood of good recruitment years for the Norwegian spring-spawning herring. Recruitment and the spawning stock size seem to be positively correlated with the average temperatures in the Kola section in the Barents Sea during the winter months (Toresen and Østvedt, 2000), see figure 4. Observations show that good year-classes occur simultaneously for herring, cod and haddock in the Norwegian and Barents Seas, occurrences that coincide with years of high Atlantic inflow and thus warm water (positive NAO). In warm years the recruitment rises, the size of the fish increases and the year-classes are stronger (Sætre *et al*, 2002). Ottersen and Loeng (2000) further suggest that high temperatures give better growth rates, better survival rates and lower mortality in the vulnerable larval and juvenile stages. Survival is thus directly related to growth rates during the pre-recruit period. In warm years, the spawning season begins earlier than in cold years, and the development of phytoplankton and zooplankton starts earlier, the process is more intensive and the duration shorter. This means that the herring start feeding in spring and attain maximum fattiness in June-July, as opposed to in August-September when the water is colder and the plankton grow at a slower pace. Hence, temperature influences the development of the fish larvae directly by giving better and faster growth in warmer years. Finally, research show that warm waters lead to a distribution of herring larvae to the northern and north eastern parts of the Norwegian and the Barents Seas, whereas cooler years leave the larvae in coastal waters along southern and central Norway (Krovnin and Rodionov, 1992).

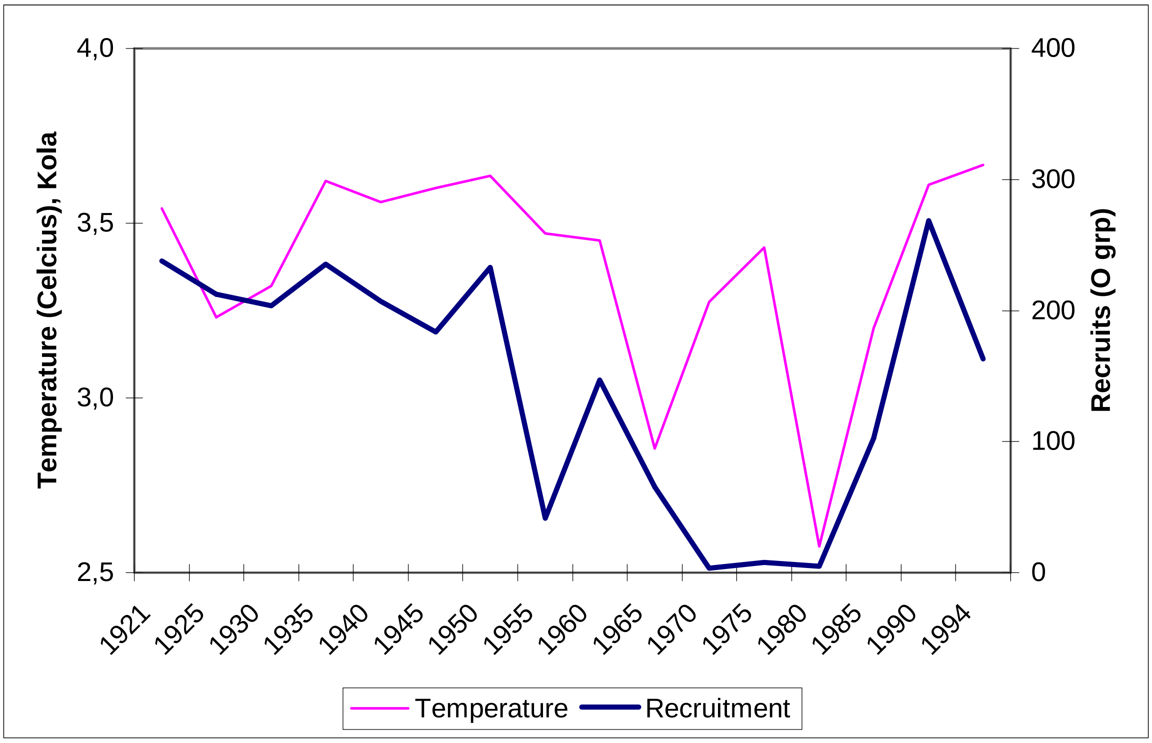

Figure 4. Time series of number of recruits and winter temperature at the Kola Section. Source: Toresen and Østvedt (2000).

Temperatures and climatic changes may thus influence the herring stock directly by providing warm or cold conditions, giving respectively good or bad growing conditions. But the climatic regime can also play a more indirect role in the determination of the herring stock by its influence on cod and capelin. Herring play an important role as transformer of plankton production to higher trophic levels, among them cod. As we have seen, the success of both cod and herring recruitment is dependent on common environmental factors, where the inflow of warm Atlantic waters gives strong year-classes. Small cod are however not able to feed on small herring of the same year-class, but they are efficient predators on the following herring year-classes. In 1984 and 1985, average year-classes of herring were reported, but a high predation pressure from the strong 1983 year-class of cod reduced these year-classes from average to poor. The reproduction capacity of herring is lower than that of cod, and at low levels of abundance, the herring are even more vulnerable to a stock of predators, resulting in a higher level of natural mortality. If the capelin is available, however, the pressure on the herring decreases, as the cod seem to prefer capelin to herring (Sætre *et al.* 2002, Barros *et al.*, 1998).

Between 1983 and 1986, the rapidly growing stock of cod and other predators ate the plankton feeders, herring included, and when these resources were exhausted, the cod stock in the Barents Sea decreased. In a situation of imbalance in the relationship between predator and prey, climatic changes from cold to warm may thus be detrimental for some fish stocks, as the conditions for the main species are improved. The depletion of herring may have changed the balance in the ecosystem, leading to more crises in the Barents Sea in the following years (Krovnin and Rodionov, 1992).

A third factor influencing the year-classes of herring is the high wind speeds in April. The more wind, the better the feeding conditions for the herring larvae and the better the conditions for strong year-classes. The wind also affects the transportation of the larvae. Persistent northerly winds during spring and early summer lead the larvae about 100 km out to the continental shelf break off Røst and thus too far away from the fourth regulating factor, the young puffins. The puffins feed on the herring when the stock is near the shore, but when they are driven far ashore, they are out of reach of the puffin and therefore more capable of surviving (Sætre *et al*, 2002).

Fluctuations in the Norwegian Current also have an impact on the growth rate, maturation age and variations in recruitment to the spawning stock. Normal and rich year-classes, emerging in warm years, recruit to the spawning stock at the age of three to four years, while weak year-classes normally enter the spawning stock at the age of four to five years. The age structure and the size of the stock are important factors for the migratory pattern and for the zonal attachment. According to a scientific working group on zonal attachment of Norwegian spring-spawning herring (1995), it was possible to point out some prominent features for the migration pattern during the mid 1990s. The young herring, up to about three years, stayed in the Barents Sea and along the Norwegian coast, migrating eastwards into the Norwegian Sea and staying there for a couple of years. The oldest and largest herring, from six years and older, held a more westerly pattern, migrating into the Icelandic, Jan Mayen and Faeroese zones, and partly also into international waters.

We have discussed the factors affecting the size and the strength of the herring stock and how these two elements can be linked to the long-term shifts in migratory pattern. In general, rich year-classes seem to coincide with climatic warming, and the migratory pattern is more widespread than the one of the poorer year-classes. The air temperature in the Northeast Atlantic and over the Northern Hemisphere was at its highest in the late 1930s, followed by a cold period eventually leading to a cooling of the ocean temperatures by the 1960s. A cold climatic regime shift was started, and frequent outbreaks of cold air east of Greenland gave an increase in ice cover in the region. By 1968, the expansion of the ice cover along the eastern coast of Iceland had reached its southernmost limit of the century. In the same period, the Norwegian spring-spawning herring stock was reduced substantially, from a large stock in the 1950s and 1960s to almost extinction in the 1970s.

The East Icelandic Current changed from an ice-free Arctic current in 1948 to a polar current in 1963, transporting drift ice between 1964 and 1971, and Krovnin and Rodionov (1992) claim that the environmental conditions prevailing north and east of Iceland played a key role in changing the migratory pattern of the herring. As the stock was decreasing, the herring tended to stay closer to the Norwegian coast and not migrate west and north. Further research has showed that the cold water did damage the important feeding areas on the coastal banks outside Northern Iceland, leading to a relocation of the feeding areas further north in the Norwegian Sea.

When the stock is small, it remains close to the spawning grounds along the Norwegian coast, and when abundant, the herring migrate more broadly through international waters and through the Exclusive Economic Zones (EEZs) of Iceland, Faeroe Islands and European Union (Alheit and Hagen 1997; Arnason *et al*. 2001). At the end of the 1960s, though, some exceptions were observed when small stocks made long oceanic migrations.

According to these theories, we would have expected the warm climatic regime from 1971-75 to be favourable for the Norwegian spring-spawning herring, but because of the depletion of the stock, no signs of strong year-classes were observed. By the end of the 1970s however, the regional climate conditions changed, and a cold regime was reintroduced. Due to the weakened stock, the strengths of the year-classes were hard to estimate. In the 1980s, a new warming appeared, possibly contributing to the strong year-class of 1983. In 1989, favourable thermal conditions prevailed in the region, but as far as we know, this year's year-class was not particularly strong. In the beginning of the 1990s, however, rich year-classes were again observed, and the pattern of high temperatures and rich year-classes was repeated at the end of the decade. With the growth of the stock, the migration pattern changed, resuming some of the pattern of the 1950s, except for the feeding- and wintering areas (see figure 2).

Comparing the pattern we saw in the 1950s, when the stock was large, and the one of the 1970s, when it was small, we might conclude that the migratory pattern of the Norwegian spring-spawning herring is affected by the size of the stock, which again is dependent on the number of predators, harvest effort and environmental factors. When the stock is large we expect it to migrate westwards in search of food as it did in the 1950s. Today, however, the Norwegian spring-spawning herring remain in Norwegian waters, despite being a large stock. One explanation is the cold waters around Iceland that stop the herring from migrating to this area.

Causal relationships are noted between fish stock recruitment and water circulation patterns and through changes in wind-driven currents. A link is thus made between regional pelagic fish fluctuations and global climatic variations. The questions are how the climate will be in the future and if the migratory pattern of the Norwegian spring-spawning herring will continue to change with the climate. As the effects of the global climate changes are not clear, predictions are difficult to make, but there seems to be a connection between migratory pattern and climate regime.

4. International management of Norwegian Spring Spawning Herring

Norway, Russia, Iceland, Faeroe Islands and EU are the main actors in the fishery for Norwegian spring-spawning herring. The Norwegian fishery exploits the stock as it migrates to and remains in the wintering areas and during the spawning period, while the Icelandic fishery takes place around the Jan Mayen Exclusive Economic Zone (EEZ) and in international waters during May and June. The Russian fishery is located along the shelf region of the Norwegian EEZ when the stock moves from the spawning areas in spring and in the eastern part of the international area and in the Norwegian zone during early autumn. The Faeroe Islands utilise the area in the Norwegian zone and around Jan Mayen for their catches in spring and early summer, while most of the EU catches come from the international area and from the Norwegian zone (Marine Institute, 2003). See portrayal of the economic zones in figure 5.

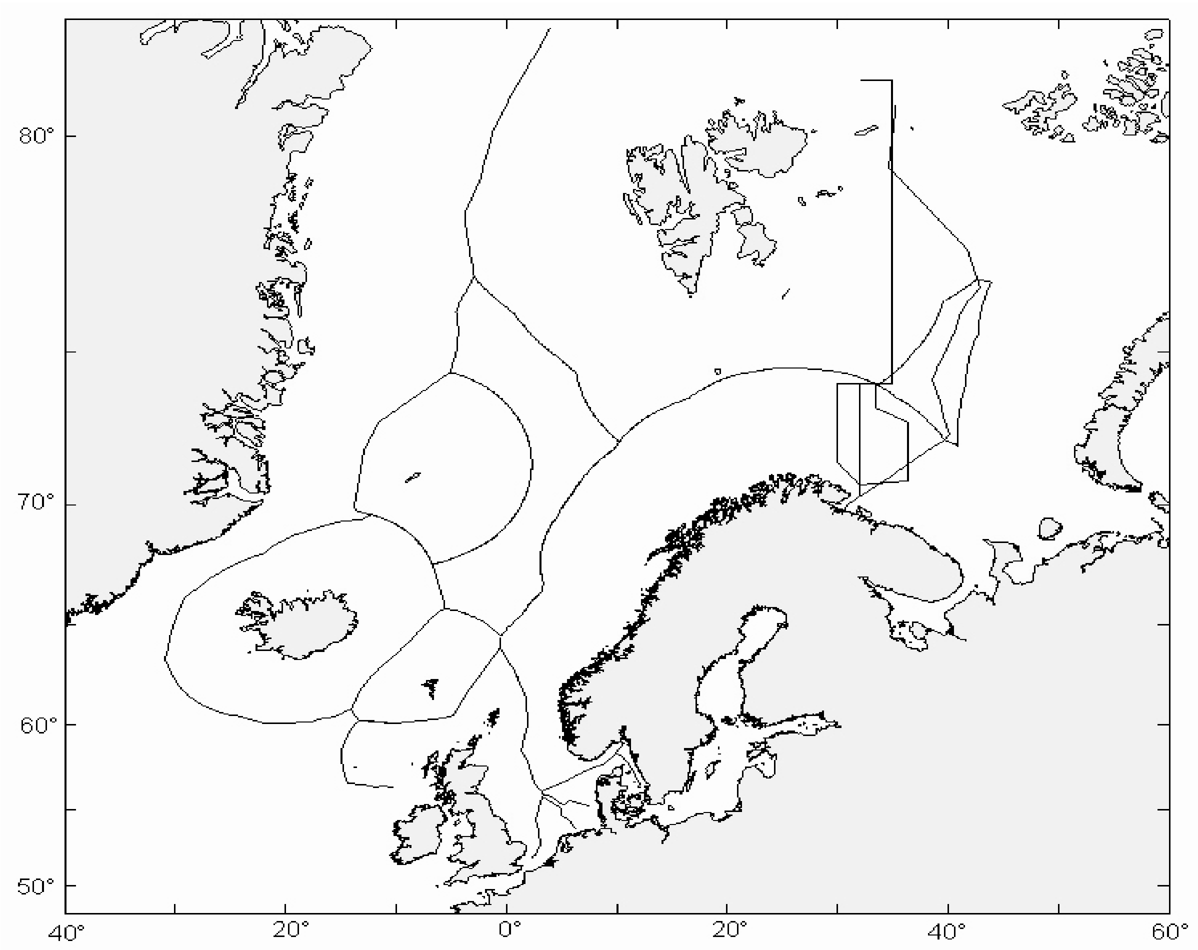

Figure 5. The economic zones of Norway, United Kingdom, Faeroe Islands, Iceland, Jan Mayen, the Svalbard zone and international waters. Source: Institute of Marine Research.

The migration pattern of the Norwegian spring-spawning herring takes on importance since, as a straddling stock, the herring are exposed to territorial and possibly distant water fleets with strong incentives to harvest the population before it moves elsewhere (Bjørndal *et al.*, 1998). If a co-operative management policy, with an equitable distribution of harvest, cannot be agreed upon, Norway, Iceland, Faeroe Islands, countries of the EU, Russia and possibly distant water vessels fishing in the Ocean Loop, may resort to 'strategic over fishing' that could jeopardise continued recovery of the stock.

The question of fishery regulations was raised already in the early 1950s, when the size of the stock still was abundant and the catches were rising. A Soviet delegation visited Norway in 1956 to discuss fishing in Northern European waters. The Norwegians and the Russians noted that despite the high abundance of the Norwegian herring, the stock would not be able to withstand the increased fishing pressure. The issue was raised again at the 45th International

Council for the Exploration of the Sea (ICES) session in 1957, but the Norwegian scientists claimed that there was no reason to worry as the stock biomass was assessed at 40 million tonnes with fishing mortality of two to three percent. This was renounced later, as errors were discovered in the Norwegian stock assessment method, and one discovered that the stock biomass had been over estimated by at least a factor of three or four (Kronvin and Rodionov, 1992).

The drastic declines in catches in the 1960s led to the conclusion that the exploitation of the adult and juvenile herring had to stop, and a minimum landing size of 25 cm was introduced. From 1971, the use of herring for reduction into fish meal and fish oil was prohibited, preventing the complete extinction of the 1969 year-class. Soviet fishing of young herring ceased already in 1963, the fishery for adult and fat herring was stopped by the Soviet Union and Iceland in 1969, while the Norwegian ban on winter fishery for adults was introduced in 1972. Norway, Iceland and the USSR agreed on a limited fishery between 1972 and 1975. The regime continued in 1975, despite an advise of complete end to commercial fishing from ICES the same year. The fishery was closed from 1976 to 1978, reopened for a Norwegian quota in 1978, followed by a closure in 1979. Between 1980 and 1983, small quotas limited the Norwegian fishery. The restrictions gave results, and the fishery on the Norwegian stock was reopened in 1984. In 1987, the Norwegian government set the Total Allowable Catch (TAC) for Norwegian spring-spawning herring, giving Russia a share of the TAC after the yearly fishery negotiations between the two countries. Figure 6 illustrates the TACs and the landings from 1987 to 2002.

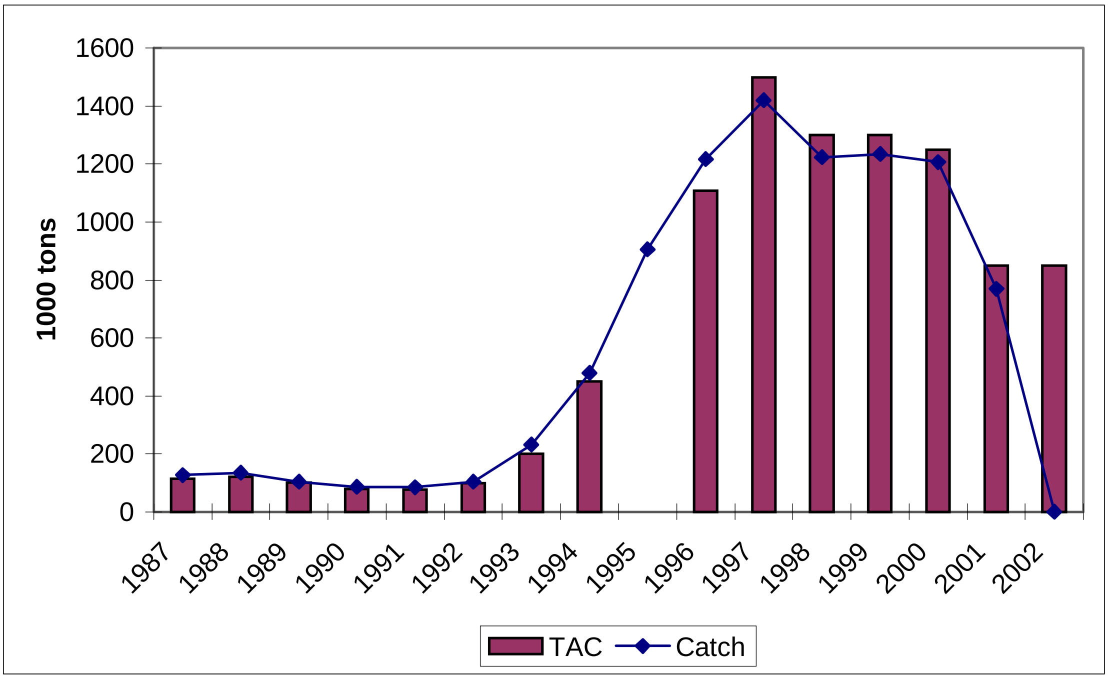

Figure 6. TACs and catch of Norwegian spring-spawning herring, 1987-2002. Source: Marine Institute.

The Norwegian spring spawning herring is only one of several stocks causing conflict in the international arena. The United Nations Convention on the Law of the Sea (1982) gave sovereign rights to the coastal states to exploit and explore, conserve and manage the natural resources in their respective EEZs. Still, conflicts arose between coastal states and distant fishery nations on the management of straddling and highly migratory stocks, as fishery in international waters easily could undermine management regimes in the different EEZs. Years of conflict lead to the United Nations Fish Stocks Agreement[3] in 1995. This agreement applies to the management of staddling stocks, such as Norwegian spring-spawning herring, as well as highly migratory stocks. According to the Agreement, these stocks are to be managed by Regional Fisheries Management Organisations (RFMOs), consisting of coastal states and distant water fishing nations with a ”real” interest in the fishery[4].

In 1994, the herring migrated outside the Norwegian EEZ for the first time in 26 years, leading to a call for international cooperation on the management of the stock. In December 1994, the Norwegian government set a TAC of 650.000 tonnes, giving 100.000 tonnes to Russia on the basis of the established practice of yearly negotiations. The Icelandic fishing

[3] The Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks

industry reacted negatively on this decision, claiming their right to a part of the TAC due to the new status of the herring as an international stock. The Norwegian side argued that the quotas had to be set as early as possible to regulate the fishery starting in the beginning of 1995.

EU, Russia and the Faeroe Islands expressed a wish for consultations with Norway on the management of the herring during 1995, as the new migratory pattern created new conditions for the fishery and for the management of the stock. The question took importance, both because of the changing biological conditions for the stock and because of the great political and economic aspects for the countries involved. The access to the herring would ease the pressure with regard to over capacity and lack of resources both on Iceland and on the Faeroe Islands, while the Norwegian government spoke up for their role as a "re-builder" of the herring stock. The Norwegians feared that their strict regime during the last decade would be wasted and that the involvement of more nations in the fishery would cause another collapse of the stock.

Due to the international pressure, the Norwegian government initiated negotiations in April 1995 on the issue of the management of the herring. The first agreement was signed in May 1996 by Norway, Russia, Iceland and the Faeroe Islands (the Four-Party Agreement). The parties agreed to cooperate on the preservation, the exploitation and the management of the herring to keep the stock above safe biological limits. The next step, the Five-Party-Agreement including the EU in the cooperation on the management of the herring, was signed in December 1996. This agreement also included the stipulation and the distribution of TAC between the parties. In 1997, the final step came with the signing of the agreement on the management of the herring in international waters. Now, both the size and the distribution of quotas and geographical areas were covered by regulations, and the countries had agreed on following the recommendations by ICES (Ramstad, 2001).

In 1995, the Advisory Committee on Fishery Management (ACFM) of ICES recommended a total allowable catch for the Norwegian spring spawning herring of 513.000 tonnes. However, Norway announced an individual TAC of 650.000 tonnes of which 100.000 tonnes would be allocated to Russian vessels. Iceland and Faeroe Islands followed suit and announced their

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[4] See Bjorndal and Munro (2003) for a discussion of RFMOs the concept "real" interest.

own combined TAC of 250.000 tonnes. In total, the collective harvest of Norway, Russia, Iceland, Faeroe Island and EU was approximately 902.000 tonnes of herring, almost twice the quantity recommended by ACFM (Bjørndal *et al.*, 1998). Nevertheless, in spite of these high catch levels, the herring spawning stock continued to increase due to good growth and recruitment.

In 1996, with the Four-Party-Agreement in force, Norway, Russia, Iceland and the Faeroe Islands shared a quota of 1.107.000 tonnes, giving the countries a share of 63 percent, 15 percent and 22 percent[5] respectively. The EU was not yet part of the agreement and fished at full capacity in international waters. From 1997, Norway, Russia, Iceland, Faeroe Islands and EU have jointly set a yearly quota, negotiating on the shares to the respective countries. The TAC is fixed on the basis of the recommendations of ICES (North-East Atlantic Fishes Commission, NEAFC), and the parties negotiate bilaterally on the rights to fish within the different countries' EEZs. According to the UN Fish Stocks Agreement, NEAFC maintains the formal responsibility for the distribution and the fixation of the TAC in international waters (Ramstad, 2001).

The yearly negotiations on the TAC always cause conflict. Both in 1997, 1998 and 1999 disagreements came up between Norway and Iceland on the one hand and Russia, the Faeroe Islands and the EU on the other, on the fixation of the TAC. Norway and Iceland wanted to go along with the advice from ICES, whereas the other countries wanted higher quotas. In 1997 the countries agreed on making a long-term management strategy by October 1998 to ensure stable and lasting catches. In 1998, the strategy was put forward, suggesting smaller quotas than previous years. The same conflict arose, with Norway and Iceland on one side arguing for smaller quotas and the rest, wanting to pursue the regime from the year before. Another repetition came in 1999, but in 2000 the EU changed position and agreed with Norway and Iceland on setting smaller quotas. Russia and the Faeroe Islands did not agree, and again compromises had to be reached, but with a larger cut in the quotas than in previous years. The disagreements continue on the size of the quota, but the countries seem to be able to reach compromises every year (Ramstad, 2001).

[5] The 22% share was split between Iceland and the Faeroe Islands.

When in comes to the distribution of the shares of the TAC, agreement has been reached more easily than with the size of the TAC, but also in this field, discontent has been expressed. From 1997 to 2001 Norway received 57 percent of the quota, Russia 14 percent, Faeroe Islands five percent, Iceland 16 percent and the EU eight percent. In 2002, however, the Norwegian share increased to 61 percent at the expense of Iceland and the EU (Ministry of Fisheries, 2003). This was a result of years of frustration among Norwegian fishermen who consider themselves entitled to at least 70 percent of the quota, according to the migration pattern of the herring. The distribution for 2003 was similar to that of 2002, under the conditions of allowing foreign fishermen to catch their quota in Norwegian waters. The first meetings between the parties concerning the quotas for 2004 have so far been fruitless, as the Norwegians are still pushing for a 70 percent share of the quota. The Norwegian fishermen are disappointed with the results of the negotiations of previous years, as they have calculated a yearly loss of 65 million dollars in export. According to the migratory pattern, Norway can claim up to 80 percent of the resources of Norwegian spring-spawning herring, but to keep in line with the Five-Party agreement from 1996, the country can only get 57 percent of the share. The increase in share during the two past years has come as a result of the discrepancy between the two figures, but Norwegian fishermen are still not satisfied and will continue the battle for higher shares (Norsk Skipsfart og Fiskeriaktuelt, 2003).

The frustration we see from the industry today originates in the 1996 Agreement. At the time, the industry was willing to continue without any international agreements, as they assumed the herring would stay in the area under Norwegian jurisdiction. When the politicians introduced the Agreement, one argument was that the herring would resume its traditional migratory pattern. In such a scenario, an international agreement would guarantee the rights of all the countries involved without risking over fishing. In addition, Norway was interested in letting the Russians fish in the Norwegian EEZ, as they otherwise would exploit the young herring residing in the Russian EEZ. In 2003 we know that the herring remain in Norwegian waters, resulting in the 1996 Agreement being problematic for Norwegian authorities, as it does not reflect the migratory pattern of the herring.

According to the UN Fish Stocks Agreement, however, zonal attachment is not the only criterion for the distribution of the TAC. The parties are also obliged to consider the degree of dependency on the fishery for the countries involved, the situation of the stock, interests of new and old members and the historical practice of the fishery. Here, both Iceland and the

Faeroe Islands have strong arguments concerning the dependency of the fishery, as their economies are mainly based on fishing (St.prp.nr. 43, 1995-96).

As we have seen in the discussion, the states involved in the fishery for Norwegian spring-spawning herring have managed to agree on a common regime, but the yearly negotiations on the quotas still prove difficult because of dissatisfaction with the agreement. Hence, we will look at the possibilities of achieving better international agreements.

Five entities are involved in the management of the herring, Norway, Iceland, Russia, Faeroe Islands and EU. The problem in the management of Norwegian spring-spawning herring is the division of the shares of the TACs among the different parties involved. The economic theory necessary in the analysis of the management of the stock will thus include bioeconomic analysis and the theory of strategic behaviour, or game theory.

If the entities sharing a transboundary resource do not have a binding agreement, we would expect a non-cooperative game and overexploitation as result. In the 1960s, the herring stock collapsed as a result of over exploitation, not just due to the technical progress, but also because of the non-existing cooperation between the states involved and lack of regulations. As a schooling species, herring is particularly vulnerable to over-exploitation under an open access regime, and the strict regulations of the 1970s and 1980s did result in a recovery of the stock (Bjørndal, 1988).

There is also another matter in question at this stage, the issue of environmental influence on the stock and its migratory pattern. If a climate change disrupts a functioning management regime between the states, the result might be the same as with no cooperation, namely overexploitation.

Unpredictable climate regime shifts are usually not included in game models, something that limit their relevance, as we cannot fully understand the implications of the long-term climate regime shifts for international fisheries management. To achieve better agreements between the states involved in the management of the resources, greater attention should be given to how onr can maintain incentives to cooperate in the presence of environmental changes taking place at unpredictable intervals (Miller and Munro, 2003).

Information about trends in the plankton populations and in the fish stocks is available, but to obtain ecological forecasts, we need details of behaviour of plankton and fish larvae. According to Bailey and Steele (1992), natural environmental factors seemed to have played some role in the collapse of the herring in the 1960s, but the role of management – or lack thereof – was crucial.

The lack of causal explanations of the recruitment-stock relationship limits the predictions of recruitment to one or two years and thus also the future influence of ecological factors on the stocks. Insecurity about environmental influence on the fish stocks makes international agreements on future management even more difficult. The parties involved can, however make some directives on how to protect the stock and on how to react to declining stocks, as is done today by both international and bilateral agreements. Such agreements must take into account the characteristics of the past:

- The historic stability of Norwegian spring-spawning herring as a resource
- Over fishing and the collapse of the stock in the 1960s
- The reversibility of the collapse and the recovery of the stock due to international agreements, including strict regulations, and possibly a change in the climatic regime.

As the Norwegian spring-spawning herring appear to respond to hydrographic variability, a continuous but flexible[6] regime seems to be the right answer for future management. If the events of the 1960s should be repeated in the future, catches should be restrained in order to keep the stock from collapse and to protect the fisheries from closure.

In 1948, ICES started surveys on the possibility to assess abundance and describe the distribution of the pelagic fish, and their general biology and behaviour in relation to the physical and biological environment. The surveys were conducted until the late 1970s, and then continued by national surveys. Since 1995, the Faeroe Islands, Norway, Iceland and Russia, and since 1997 also the EU, have coordinated their examinations on the pelagic fish stocks in the Norwegian Sea. In 2002, ICES reintroduced its surveys on herring and the environment in the Norwegian Sea, with the objective of mapping the distributions and the migrations of the pelagic fish and assessing their biomass. Further, ICES wanted to monitor environmental conditions of the Norwegian Sea and adjacent waters and to estimate the

[6] Flexible in the sense that one has to be aware of the climatic changes that may influence the stock.

quantity of available food in the sea (ICES, 2002). The combination of knowledge of the climatic influence on the fish stocks, surveys and international agreements might prevent another collapse of the Norwegian spring-spawning herring stock.

5. Conclusion

Norwegian spring-spawning herring has been an important resource for fishermen for more than a thousand years. In the 1960s, intensified fishing effort coincided with regional climatic changes and led to a collapse of the stock. It is difficult to estimate the role of the two factors in the collapse, but analysis show that dramatic declines in the herring stock have concurred with climatic changes also in the past.

There are still open questions concerning the climatic changes and their influence on the fish stocks, but we know that during warm periods, the appearance of strong year-classes is more frequent than during the cold ones. Observations show that when the stock is large, the Norwegian spring-spawning herring tend to migrate over longer distances than in poorer years. In these periods, we have also seen that some of the year-classes move further north than usual. This may be explained by the early feeding that takes place in the warm periods and by the currents that drive the larvae northwards. In colder years, however, the feeding starts later, the currents are different, and the stock remains closer to the Norwegian coast. Nonetheless, the opposite may also occur, as there is no simple, strong relationship between recruitment and environmental factors.

Due to the uncertainty of the climatic influence on the fish stocks, efficient and timely fishery regulatory measures must be part of the management of the Norwegian spring-spawning herring. In the 1960s, despite the existence of symptoms of changes in the stock, the importance of regulatory measures was underestimated, and regulations were set too late to be successful. With the collapse of the stock, strict regulatory measures were introduced, leading to a slow recovery. In the 1990s, international agreements were signed on the management of the herring as a result of the new migratory pattern. The yearly conflicts on the setting of the TAC show the difficulties in maintaining such a contract, but the history of the herring fishery demonstrates its necessity. To be able to manage the herring stock properly in the future, we need further studies on the influence of the climate to estimate both strength and size of the stocks and the migratory pattern.

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