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Environmental Continuity in Fluctuation of Fish Stocks in the North Atlantic Ocean; With reference to Atlantic salmon stocks.

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Abstract

Large masses of cold, low salinity, or warm, high salinity water move with ocean currents in the North Atlantic Ocean, drasticly changing the condition for the biota. Fish stocks are also affected. Oceanic condition in the Barents Sea seem to occur in the Iceland Sea 2 to 3 years later. Sea temperature in these areas show similar fluctuations with 2 and 3 year time lag. Correlation coefficients being 0.63 and 0.62 for 2 and 3 year difference, respectively ($p<0.05$). Atlantic salmon (*Salmo salar* L.) stocks in rivers in North Iceland show similar fluctuation in abundance as salmon stocks in rivers in the Kola Peninsula 2 to 3 years earlier. Correlation coefficients of salmon stock size in 3 rivers of Kola Peninsula and salmon catch in 3 rivers in North Iceland were 0.62 to 0.90 ($p<0.01$). Similar trends can be observed in the recruitment of cod (*Gadus morhua* L.) and the catch of capelin (*Mallotus villosus* L.) and the catch of cod in these distant areas. It is prospected that fish stocks in other areas in the North Atlantic Ocean show similar fluctuations in abundance with time difference based on the rate of movement of the ocean currents.

Introduction

In 1909 Helland-Hansen and Nansen brought forward a hypothesis of movement of oceanic condition north along the coast of Norway. Since then knowledge about the oceanography of the North Atlantic Ocean has been growing. In 1988, Dickson, Meincke, Malmberg and Lee, described the movement of the low saline anomaly, where large mass of cold, low salinity sea moved around the Atlantic ocean. Wherever this mass of water came, it profoundly affected the biota and the fish stocks. Based on the information on the rate of movement of the water masses from Dickson *et al.* (1988) between distant ocean areas, it takes between 2 and 3 years for the water masses to move from the Barents Sea to Iceland (Figure 1). Using this time lag, sea temperatures in the Barents Sea and in the sea north of Iceland, the Iceland Sea, were compared. Sea temperature and salinity are indicators of the conditions in these areas describing the presence or absence of warm Atlantic water. The flow of warm Atlantic water to these ocean areas depends on the strength and the specific gravity of the waters of the ocean currents from the South and the North. The stock size of some populations of Atlantic salmon were compared in rivers in the Kola Peninsula and in rivers in North Iceland. Other fish stocks in these areas both capelin and cod were also examined.

Materials and methods

For comparison three year running annual mean temperatures in the Barents Sea on a section from the Kola Peninsula, at 0-200 m depth, were used (Loeng, Blindheim, Adlandsvik and Ottersen 1992) for the years 1960 to 1989. Similarly three year running mean spring temperatures in the sea north of Iceland on a transect from Siglunes, at 0-200 m depth, were used (Marine Research Institute 1993) for the years 1962 to 1992.

Counting of adult salmon migrating into the rivers have been conducted in river Kola, river Tuloma and river Ponoy (Anon 1993). The numbers for the years 1973 to 1989 were used for the former two and for the years 1974 to 1990 for river Ponoy. Number of salmon caught in 3 rivers in NE-Iceland in the years 1976 to 1992 were used. These were river Hofsa, river Sela and river Laxa i Adaldal. The fishing effort in these rivers is constant and the catch reflects the stock size (Gudbergsson and Arnason 1993, Gudjonsson, Einarsson, Antonsson and Gudbergsson 1993).

The salmon run in a given year in the 3 Kola Peninsula rivers were compared to 3 years average temperature (in the that year, the year before and 2 years before) at the Kola transect in the Barents Sea. In the same way the salmon catch in a given year in the 3 rivers in North Iceland were compared to 3 years average temperature (in that year, the year before and 2 years before) at the Siglunes transect in the Iceland Sea. The salmon catch in the 3 rivers in Iceland were also compared to the 3 years average temperature 3 years earlier in the Barents Sea.

Correlation coefficients were calculated when temperatures and salmon stocks were compared. Level of significance was determined as $p<0.05=*$, $p<0.01=**$ and $p<0.001=***$. Degrees of freedom were calculated as n-1 were n are number of independent measurements.

Catch of capelin in the winter fishing seasons in the years 1964+5 to 1985+6 in the Barents Sea (Hamre 1986, Vilhjalmsson *pers. comm.*) and in the winter fishing seasons in the years 1966+7 to 1986+7 in Icelandic waters (Institute of Marine Research, Iceland 1993 and Vilhjalmsson 1991) were compared. In 1986 drastic measures were taken to limit catch of capelin in the Barents Sea so comparison is not relevant thereafter. Such measures were also taken in Iceland, the fishing season in the years 1982+3.

Recruitment numbers of cod (3-year-old cod in millions of individuals) in the years 1961 to 1988 and catch of cod (tons) in the years 1960 to 1987 in the Barents Sea (Tore Jakobsen *pers. comm.*, Institute of Marine Research, Norway 1992) and the cod recruitment (3-year-old cod in millions of individuals) in the years 1963 to 1990 and cod catch (tons) in the years 1962 to 1989 in Icelandic waters (Institute of Marine Research, Iceland 1993) were compared using 3 year running means.

Results

Temperatures in the Barents Sea and in the Iceland Sea 2 and 3 years later (Figures 2 and 3) showed significant correlation; $r=0.63*$ and $r=0.62*$, respectively.

The size of salmon stocks in the Kola Peninsula showed significant correlation to each other (Table 1) (Figure 4) and to salmon catch in rivers in Iceland 2 years (in the case of Ponoy) and 3 years later (Tuloma and Kola). The salmon catch in the Icelandic rivers also showed significant correlation to each other (Table 1) (Figure 5).

The catch of capelin in Icelandic waters and the catch in the Barents Sea 2 years earlier showed the same tendency in fluctuation (Figure 6) as did cod recruitment (Figure 7) and the catches of cod (Figure 8).

Discussion

It has been shown that environmental changes occur in the oceans and affect fish stocks. Dickson *et al.* (1988) described the movement of the low salinity anomaly in the North Atlantic Ocean. Jakobsson (1992) showed that various fish stocks in the North Atlantic Ocean changed in stock size due to environmental changes and because of fisheries. Loeng *et al.* (1992) showed connection between changes in oceanic condition and fish stocks in the Barents Sea. Malmberg and Blindheim (1993) showed strong environmental affects on capelin and cod stocks in Northern waters. Environmental changes can explain large part of the variation in the size of year-classes of young cod (Hansen and Buch 1986, Mayers 1992).

Climatic condition are strongly affected by the oceanic condition expressed in sea temperature and there are connection between the air temperature in Jan Mayen and in Iceland 6 month later (Bergthorsson 1972). Similarly there are connection between the air temperature in Spitsbergen and in Iceland 2 to 3 years later (Bergthorsson 1972 and *pers. comm.*). That time lag coincides with the rate of movement of the ocean currents from the north to Iceland (Dickson *et al.* 1988). Furthermore, Loeng *et al.* (1992) found connection between oceanic and climatic condition in the Norwegian and the Barents Seas and explained the changes in oceanic condition by meterological events. The mechanism of the movement of oceanic currents by climatic mechanism with the Icelandic Low playing the major role is explained by S. Jonsson (1993).

Murawski (1993) found that the distribution and abundance of many fish stocks in the North-West Atlantic Ocean were affected by ocean temperatures. In warmer periods the distribution areas were larger for many stocks as were the stocks more abundant. In the Pacific Ocean the fisheries of salmon were variable and could be explained by changes in ocean condition which are controlled by the Aleutian low pressure system (Beamish and Bouillon 1993). The available winter habitat for salmon at sea has been variable in the Labrador Sea as later seen in variable salmon catches in several countries (Friedland, Reddin and Koccik 1993). J. Jonsson (1993) showed connection between air temperatures and cod fisheries in Iceland in the years 1600 to 1900. Oceanic condition strongly affect the abundance of salmon, capelin and cod in the Iceland sea (Antonsson, Gudbergsson and Gudjonsson 1993). Scarnecchia (1984) and Scarnecchia, Isaksson and White (1989) found relation of sea surface temperature and salmon abundance in Icelandic rivers. Similarly there are relationship between the sea temperatures in the Barents sea and the spawning run in the rivers in the Kola Peninsula (Zubchenko and Kuzmin 1989). Fluctuations in fish stocks due to environmental changes are therefore well known. Relation of fluctuation in fish stock in distant areas in the oceans are on the other hand not well documented. It seems that pulses of favourable and unfavourable condition travel around the oceans affecting different oceanic areas at different time. The rate of movement of the ocean currents are well documented and since climatic condition depend on ocean condition the rate has been used to forecast drift ice both in Iceland (Bergthorsson 1972) and in Norway (Loeng *et al.* 1992). Due to these changes in environmental condition the biota in the sea and on land is affected (Antonsson *et al.* 1993). In favourable periods biotic production seems to increase both in unit per area and the production area increases in size. This is seen in more abundant zooplankton (Astthorsson, Hallgrimsson and Jonsson 1983), and later at higher trophic levels, as in various fish stocks. It is likely that natural mortality decreases and growth rate increases. In unfavourable periods the production area is reduced and the production per unit area is reduced and fish stocks decrease in size. Natural mortality increases and growth rate is reduced. This is for example seen in different mortality rate of salmon at their first year at sea (Scarnecchia 1984, Antonsson *et al.* 1993) and at their second year at sea (Gudjonsson *et al.* 1993).

Changes in oceanic conditions can affect different species at different life stages. There are also variation in smolt production in the rivers. These factors and many more would tend to decrease the correlation between the salmon stocks in these two distant areas. However, increase in salmon abundance in the Kola Peninsula rivers are clearly seen some years later in North Iceland. Similar trends are seen in other fish stocks such as capelin and cod even though many local factors would influence these stocks. The environmental factors have, therefore, very strong influence on these fish stocks. Fish stocks in other distant areas, could be examined using the knowledge of the rate of movement of the ocean currents in the North Atlantic (Figure 1). Furthermore, it is possible to use physical parameter such as temperature and salinity and the status of fish stocks in distant area to forecast the status of fish stocks in another area several years later.

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Gudbergsson, G. and Arnason, F. 1993. Laxveidin 1992. Institute of Freshwater Fisheries VMSTR/93016. 18p. (In Icelandic).

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Table 1. Correlation coefficients of salmon counts in 3 rivers of the Kola Peninsula, salmon catch in 3 rivers in North Iceland and 3 years mean temperature at the Kola transect in the Barents Sea. Also correlation coefficients of salmon catch in the 3 Icelandic river and 3 years mean temperature at Siglunes transect in the Iceland Sea. p<0.01=**, p<0.001=***.

	Tuloma	Kola	Ponoy	Hofsa	Sela	Laxa i Adaldal
Tuloma	1					
Kola	0,79***	1				
Ponoy	0,83***	0,79***	1			
Hofsa	0,71**	0,62**	0,70**	1		
Sela	0,90***	0,74***	0,88***	0,88***	1	
Laxa i Adaldal	0,70**	0,76***	0,88***	0,72**	0,85***	1
Temp. Kola sect.	0,77***	0,62**	0,79***	0,79***	0,89***	0,79***
Temp. Siglunes sect.				0,78***	0,76***	0,71**

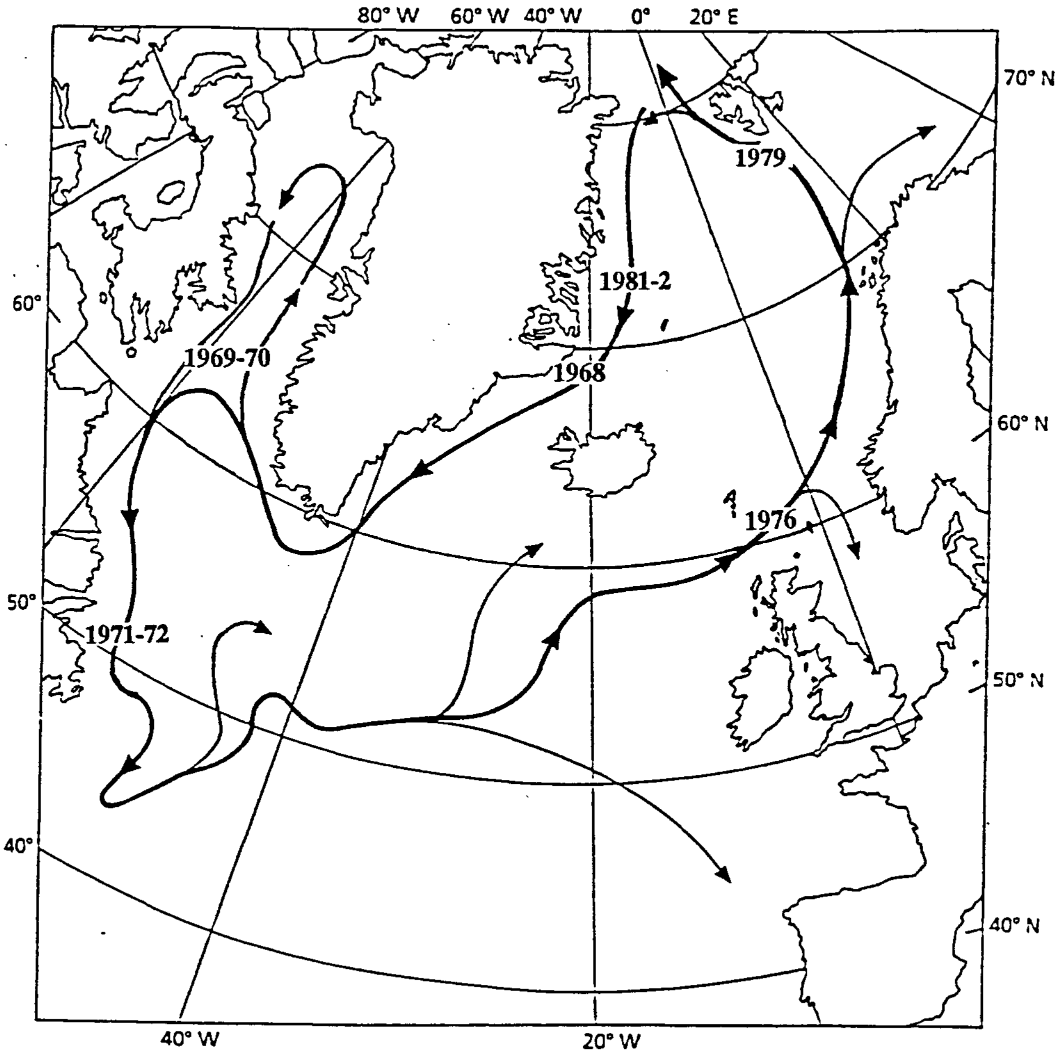

Figure 1. The movement of ocean currents in the North Atlantic and years when the great salinity anomaly occurred in selected sites according to Dickson *et al.* (1988). (redrawn from S. Jonsson 1993).

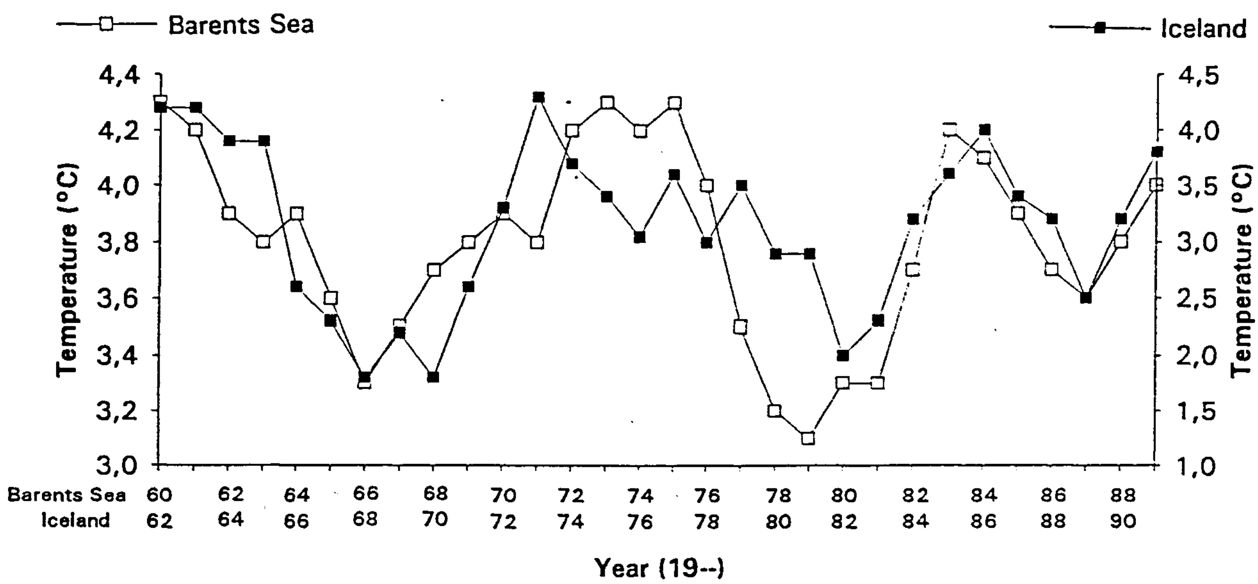

Figure 2. Annual mean temperature in the Barents Sea in the years 1960 to 1989 and spring mean temperature in Iceland Sea 2 years later. (Three years running means).

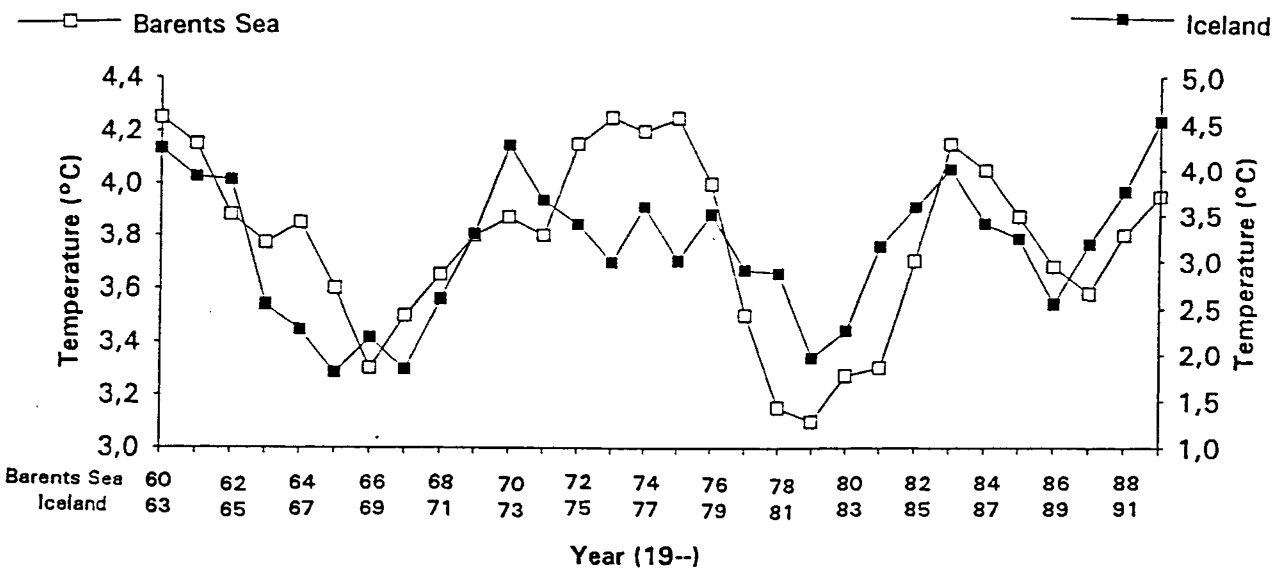

Figure 3. Annual mean temperature in the Barents Sea in the years 1960 to 1989 and spring mean temperature in Iceland Sea 3 years later. (Three years running means).

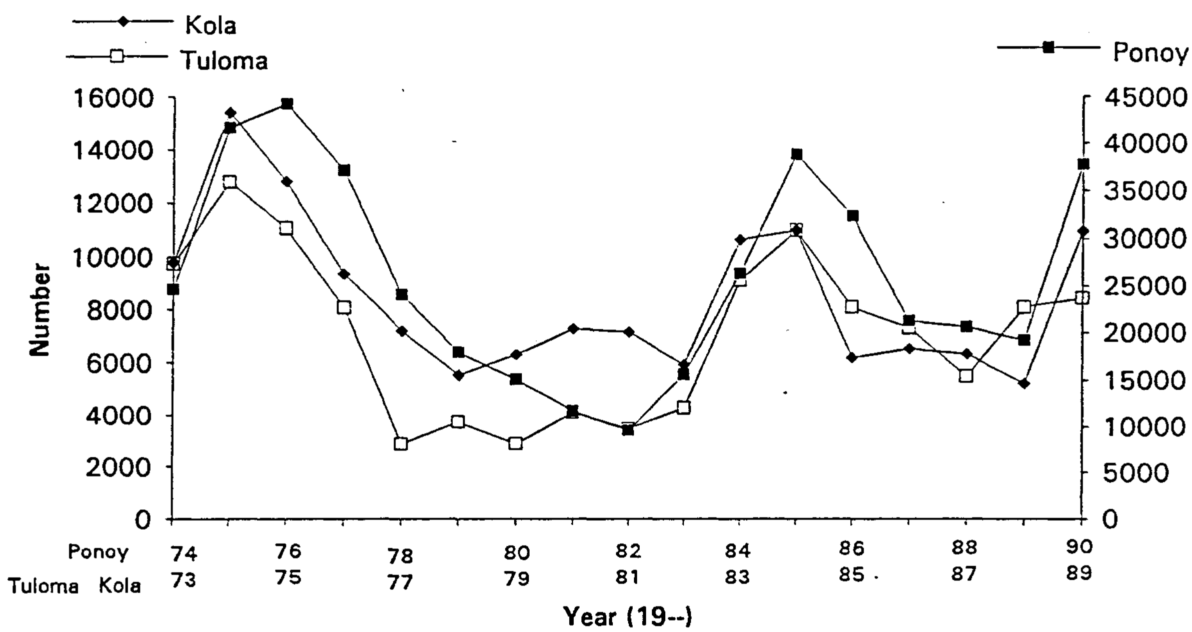

Figure 4. Number of salmon entering 3 rivers in the Kola Peninsula, in the years 1973 to 1989 for rivers Kola and Tuloma, and in the years 1974 to 1990 for river Ponoy.

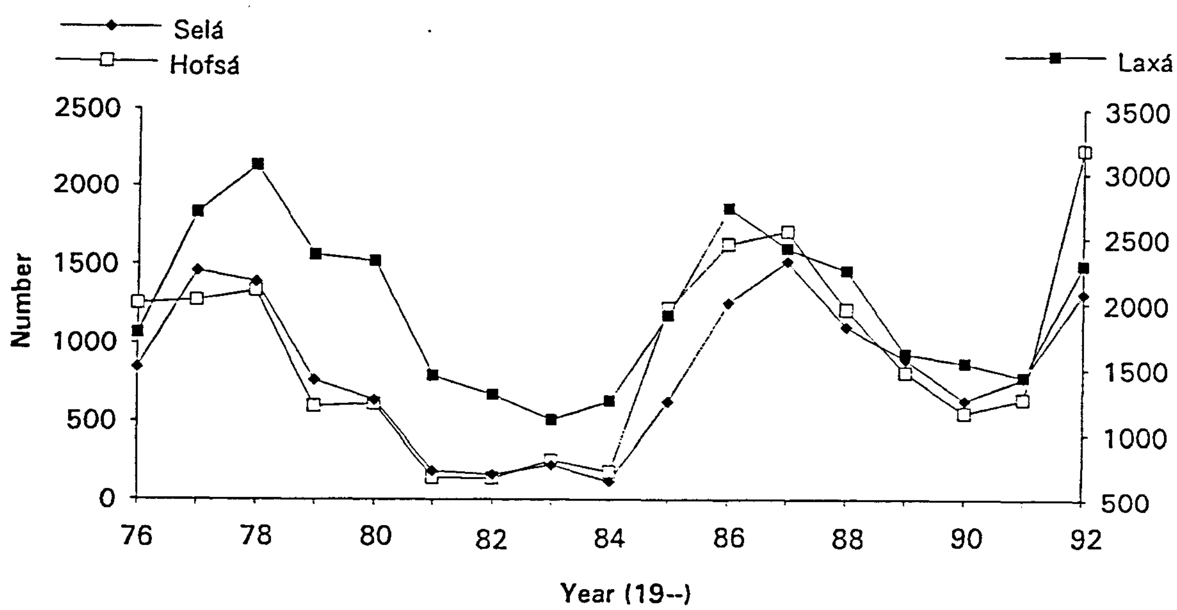

Figure 5. Salmon catch in three rivers in North Iceland, rivers Hofsa, Sela and Laxa i Adaldal in the years 1976 to 1992.

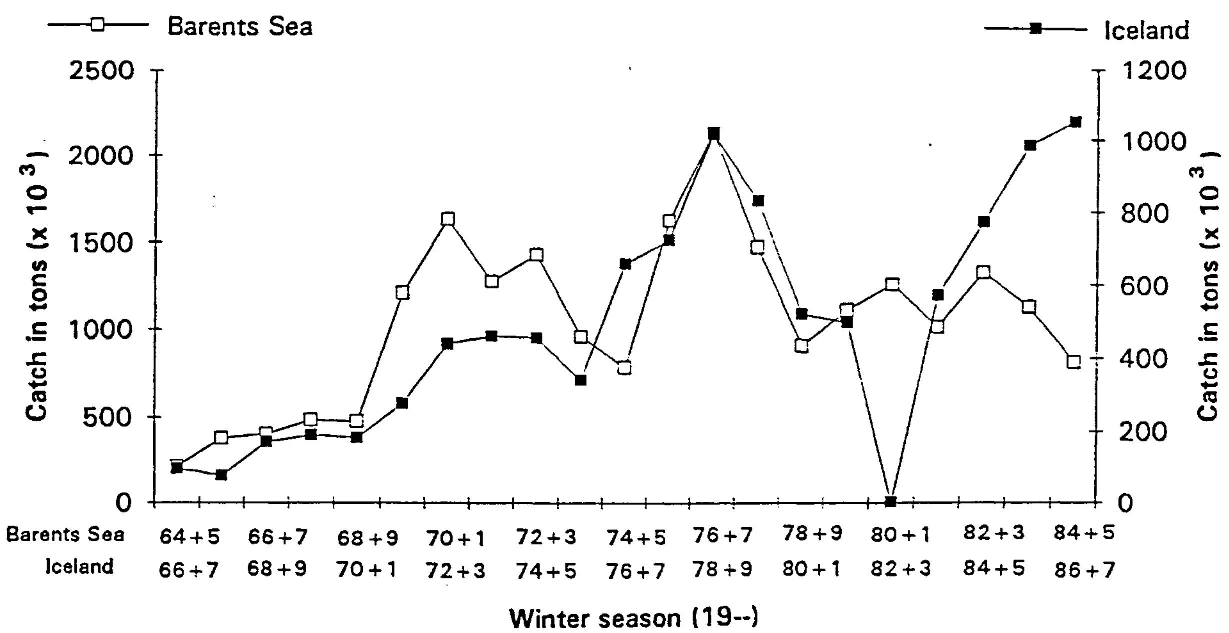

Figure 6. Catch of capelin during the winter fishing seasons 1964+5 to 1984+5 in the Barents sea and during the winter fishing seasons in the years 1966+7 to 1986+7 in Iceland.

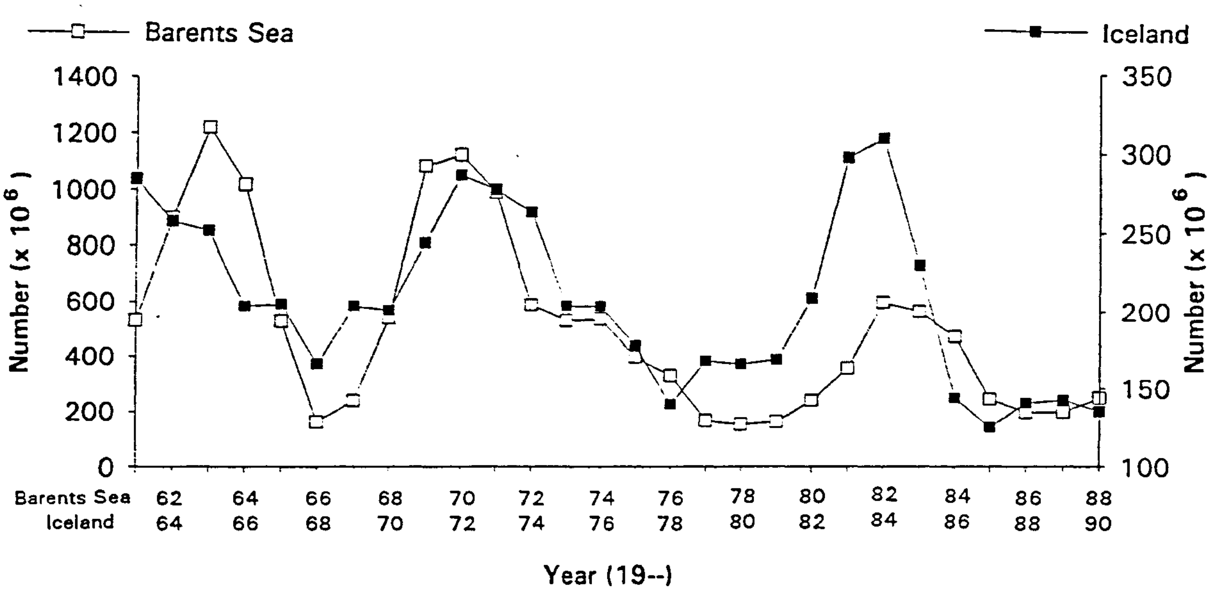

Figure 7. Three years running mean of cod recruitment (numbers of individuals) in the Barents Sea in the years 1961 to 1988 and cod recruitment two years later in Iceland.

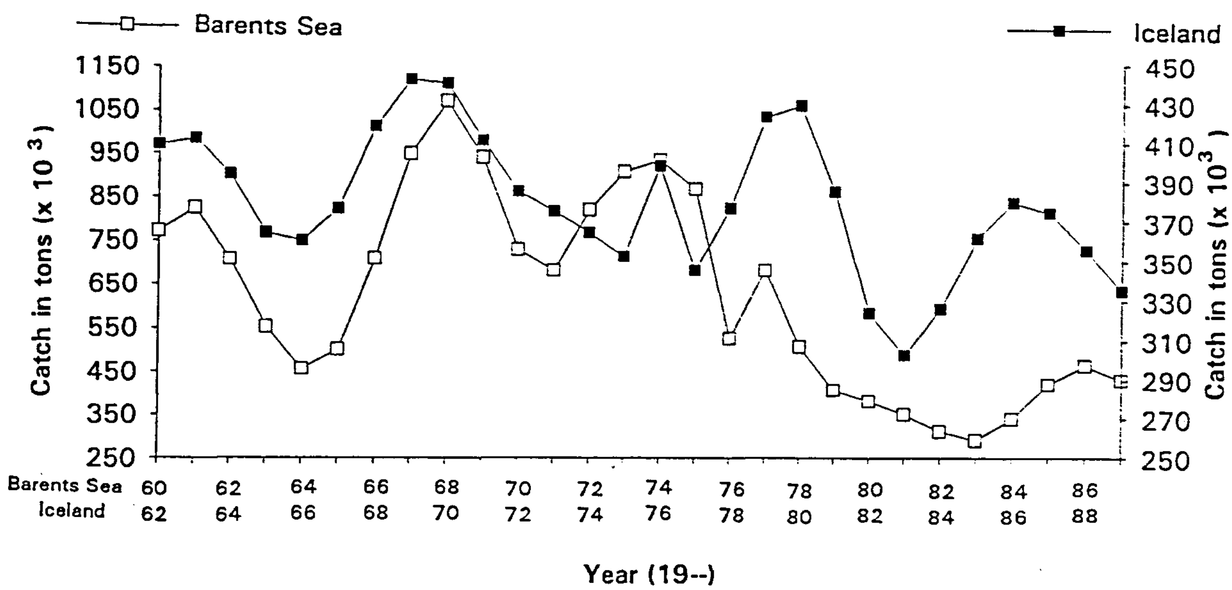

Figure 8. Three years running mean of cod catch in the Barents Sea in the years 1960 to 1987 and cod catch two years later in Iceland.