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Long-time Series in Icelandic Waters in Relation to Physical Variability in the Northern North Atlantic

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Abstract

This review is mainly based on two papers the author has published in the ICES Journal of Marine Science Symposia. One dealing with the hydro-biological variability in the ICES Area (Malmberg and Kristmannsson, 1992) and the other on capelin and cod, and climatic change (Malmberg and Blindheim, 1994). These papers deal with hydrographic conditions in Icelandic waters and adjacent seas in relation to large scale pan Atlantic conditions.

Additional updated information from Icelandic waters are included in this review and compared with hydrographic variations elsewhere along the Subpolar Gyre in the North Atlantic. Some ecological impacts of the observed hydrographic conditions in the northern North Atlantic are also discussed.

Key words: Hydrography, Iceland, salinity

Introduction

This review is partly based on two papers, with some additional remarks, in the ICES journal of Marine Science Symposia. The first dealing with hydro-biological variability in the ICES Area (Malmberg and Kristmannsson, 1992) and the other on capelin and cod, and climatic change (Malmberg and Blindheim, 1994). These papers deal with hydro-biological conditions in Icelandic waters and adjacent seas in relation to large scale pan Atlantic conditions. Additional information was available to update the above studies, and it was found useful to review these and compare them with variations elsewhere, along the Subpolar Gyre in the North Atlantic. Some ecological impacts of the observed hydrographic conditions in the northern North Atlantic are discussed.

Data

The hydrographic data used in this paper are partly from joint multidisciplinary Danish – Icelandic research cruises into the western part of the Iceland Sea in September during 1987–91 (Anon., MS 1991; Fig. 1). The investigations were undertaken as a part of the international Greenland Sea Project (Meincke *et al.*, 1990). Also routine long-time investigations in Icelandic waters are included (Fig. 2), as well as some more remote information from adjacent ocean regions. Some emphasis is laid on the hydrographic conditions in time and space in relation to ecological conditions.

Results

The joint Danish – Icelandic hydrographic program in the western Iceland Sea in September during 1987–91 (Fig. 1) and long-time investigations in Icelandic waters (Fig. 2) revealed the following:

a) The bottom water from the north at 1 000–1 500 m depth flowing southwards into the Denmark Strait area was of Arctic origin (Fig. 3; t = -0,8 , S>34.92; Swift and Koltermann, 1988; Malmberg *et al.*, MS 1990; Rudels and Quadfasel, MS 1991; Buch *et al.*, MS 1992).

b) The intermediate water also from the north (West Spitzbergen Current origin) at 200–600 m showed some interannual variability as regards the strength of its salinity maximum (Malmberg *et al.*, MS 1990). Thus, in 1987, 1988 and 1991 salinity in the intermediate layer was above 34.92 ppt in a wider extend, and in general with higher core values, than in 1989 and 1990 (Fig. 1; Malmberg and Blindheim, 1994).

c) The polar water component in 1988 (t<0 , S<34.7) showed by far the strongest input into the Iceland Sea during the period 1987–92 (Fig. 4; Malmberg and Blindheim, 1994). The conditions found in the Iceland Sea in 1988 are in agreement with the hydrographic conditions found in the East-Icelandic Current, where temperature and salinity were extremely low in 1988 together with severe ice conditions in North Icelandic waters (Fig. 5; Malmberg and Kristmannsson, 1992).

d) In North Icelandic waters, three different hydrographic regimes have been identified in the water column structure (Malmberg and Kristmannsson, 1992; Malmberg and Blindheim, 1994):

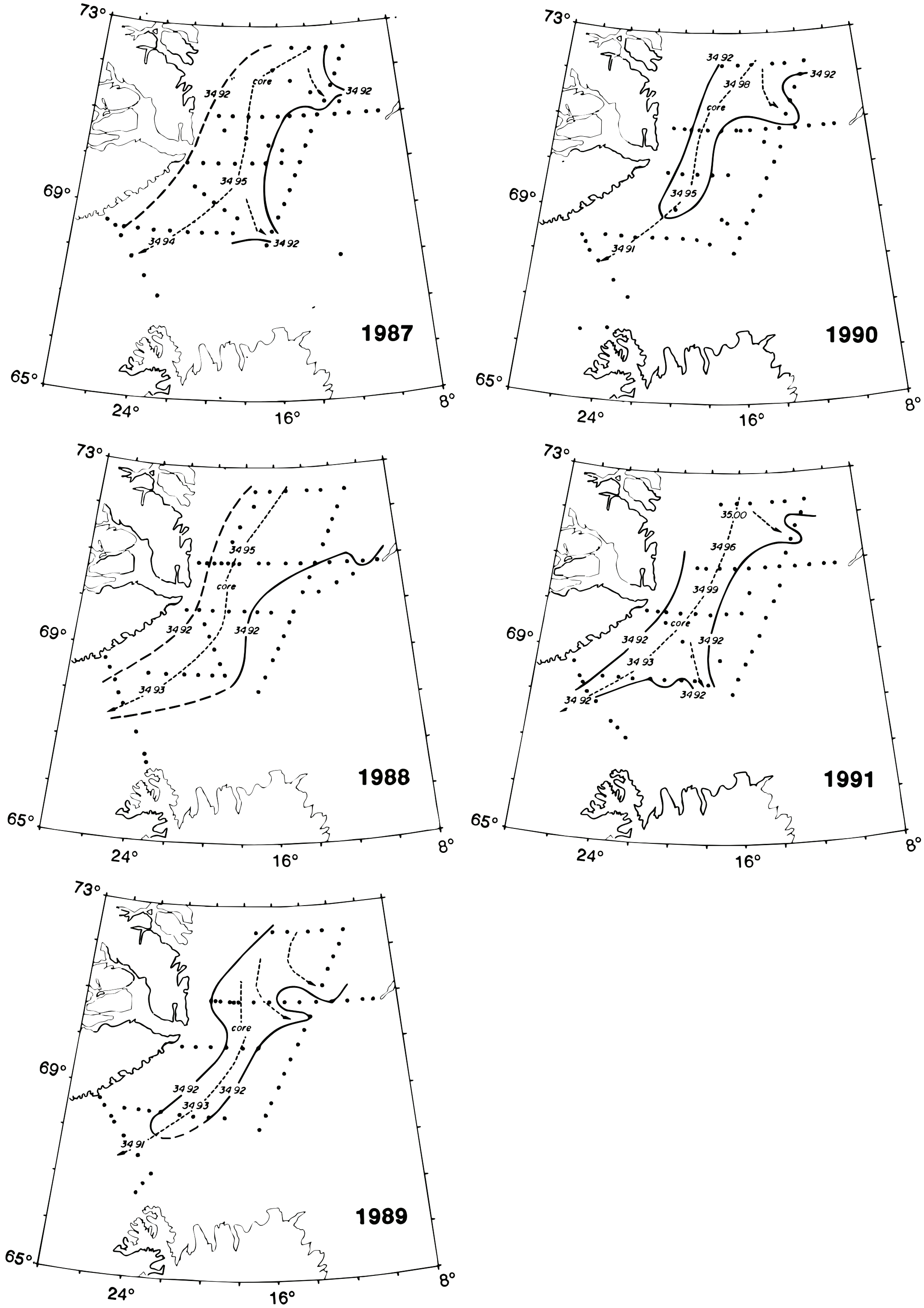

Fig. 1. Location of stations in the joint Danish-Icelandic GSP Project 1987–91 in the western Iceland Sea and horizontal distribution of salinity maximum in the 0–500 m layer expressed by the 34.92 ppt isohaline and the core values.

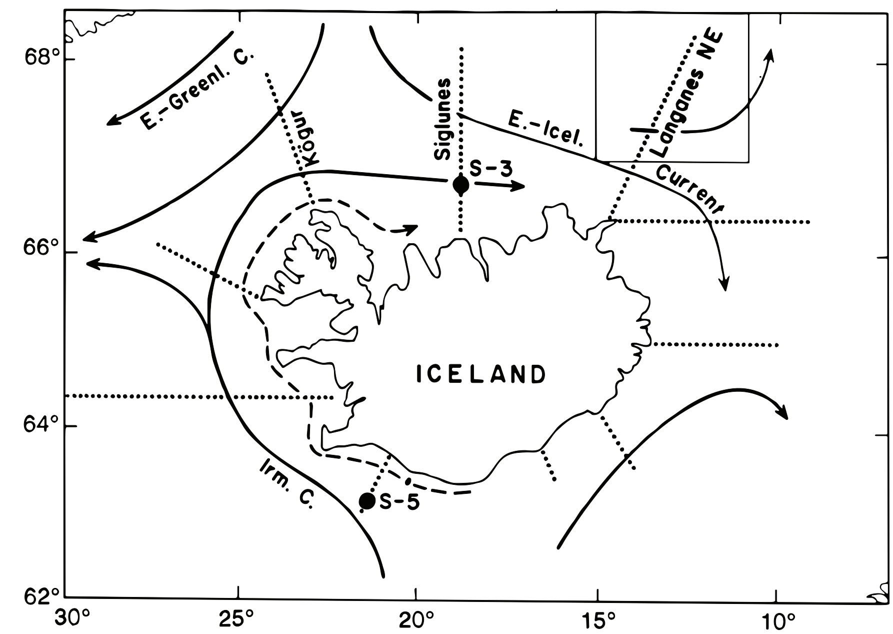

Fig. 2. Main ocean currents and location of standard hydro-biological sections in Icelandic waters. Selected areas and stations dealt with in the paper are indicated. (Malmberg and Kristmannsson, 1992).

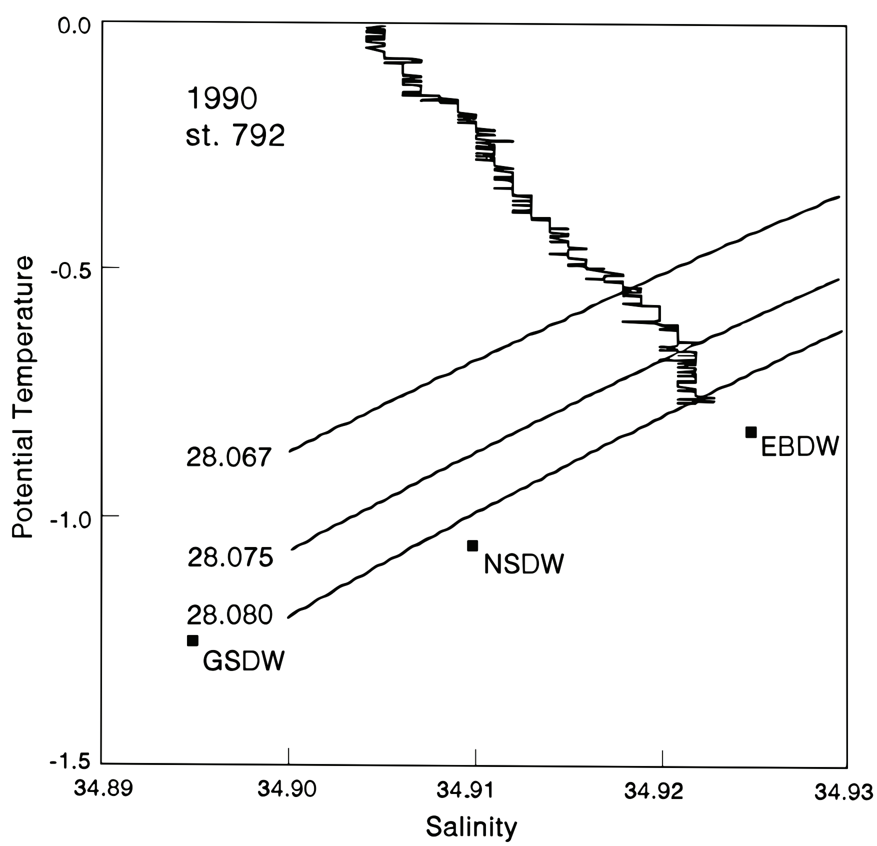

Fig. 3. Potential temperature – salinity diagram from a station of the southernmost section shown in Fig. 1. GSDW: Greenland Sea Deep Water NSDW: Norwegian Sea Deep Water ESDW: Arctic Ocean Deep Water (Buch *et al.*, 1992).

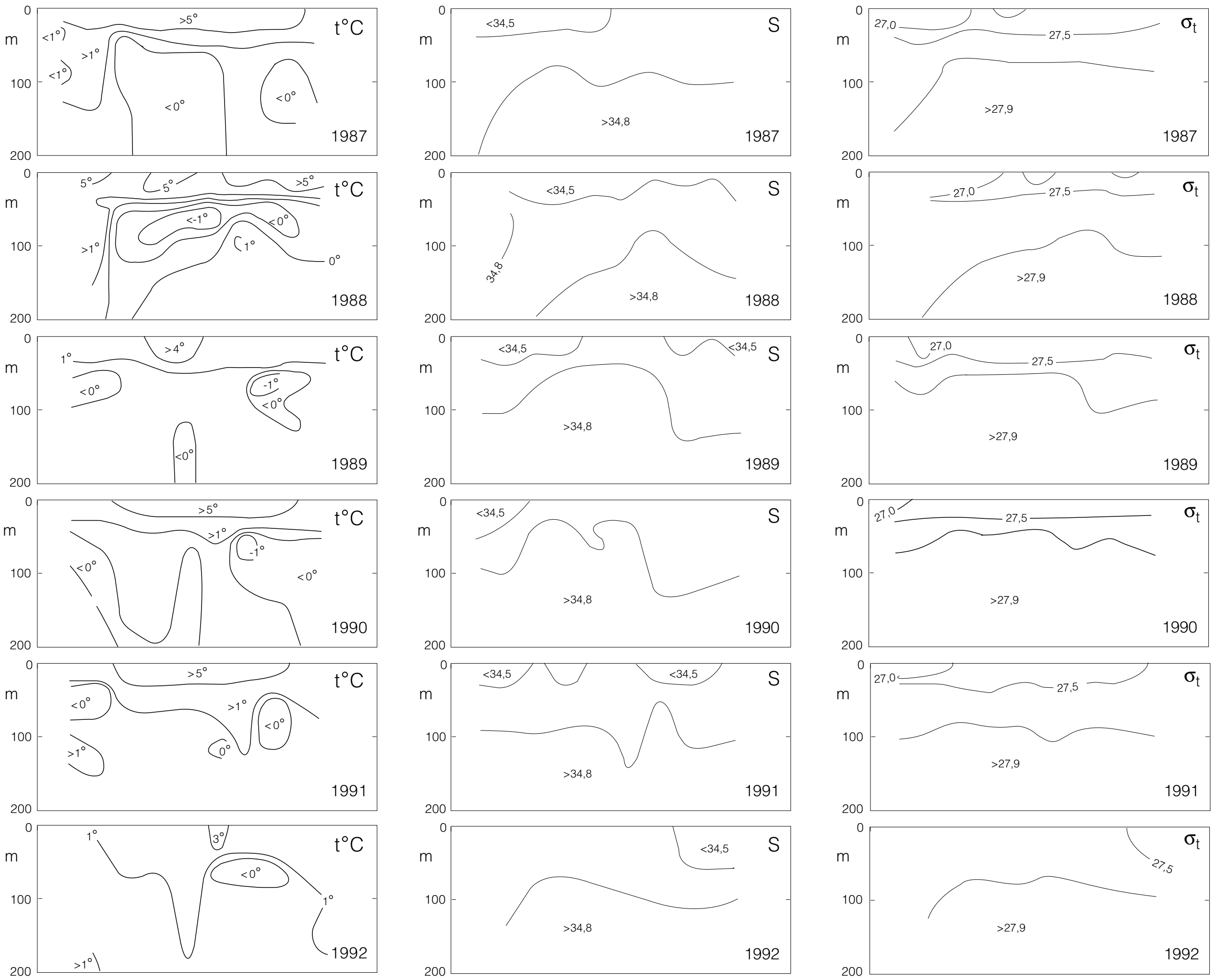

Fig. 4. Vertical distribution of temperature, salinity and density of a section across the Iceland Sea proper from 68°N to 71°N – the easternmost section in Fig. 1 – in September 1987–91 and October 1992.

Polar conditions (see 1979 in Fig. 6) are characterized by cold and fresh surface water – the low salinity strengthening the stratification. High maxima in temperature and salinity in intermediate and near-surface depths characterize Atlantic conditions (see 1980 in Fig. 6), with the high temperatures strengthening the stratification. The Atlantic conditions may even occur below the Polar conditions. During Arctic conditions (see 1981 in Fig. 6), the intermediate salinity maxima are less pronounced.

These above-mentioned different hydrographic conditions in North Icelandic waters are reflected in time series of the maximum salinity observed in spring in the upper 300 m layers in North Icelandic waters (S-3 in Fig. 2) during the period 1978–94 (Fig. 7; Malmberg and Blindheim, 1994). The results show periods of relatively low but moderate salinities or Arctic conditions around 1981–83 and 1989–90, which lead to relatively weak vertical stratification in the upper layers below the seasonal thermocline in North Icelandic waters. These hydrographic conditions may again be reflected in the conditions of the Icelandic capelin stock (Fig. 7), which feeds in the Iceland Sea (Vilhjálmsson, 1994), as well as weight of cod in Icelandic waters (Fig. 7), which feeds to a high degree on capelin (Pálsson, 1983).

Discussion

The Arctic conditions observed in North Icelandic waters during 1981–83 have been related to the so-called "Great Salinity Anomaly" (Dooley *et al.*, 1984; Dickson *et al.*, 1988). It was initiated during the period of Polar conditions in North Icelandic waters during 1965–71 (Fig. 5, 8, 9), and was traced around the Subpolar Gyre in the northern North

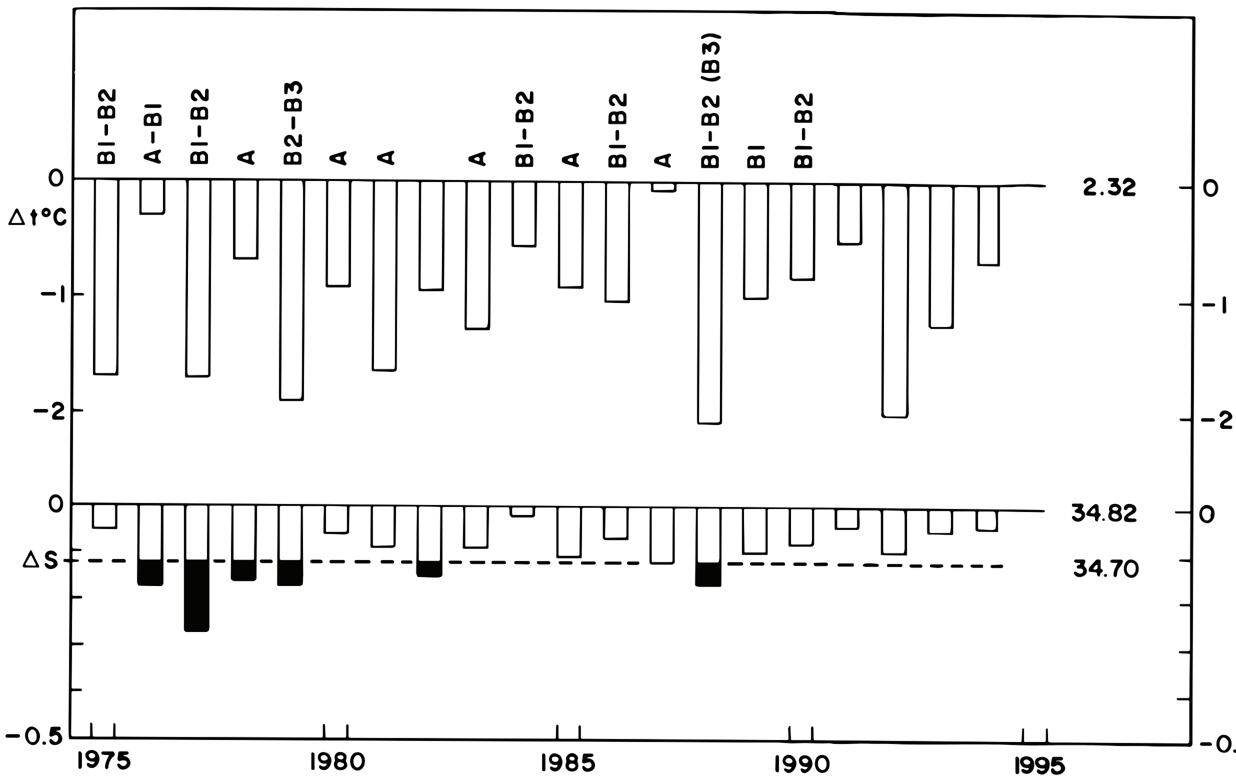

Fig. 5. Anomaly of temperature and salinity in spring 1975–94 at a depth of 25 m in the East Icelandic Current study area shown in Fig. 2. The average for the period 1950–58 is shown as well as a brief classification of ice years in Icelandic waters. Key: A – ice free; B1 – insignificant ice (NW ice); B2 – moderate ice (N and NW ice); B3 – heavy ice (NW, N, E ice) (from Sigurdsson and Jakobsson, 1991, and pers. comm.).

Atlantic – reaching the West Greenland and Newfoundland waters during 1969–72 (Fig. 12, 13), the waters off Scotland and South Iceland around 1976 (Fig. 10, 9), the waters off northern Norway around 1979 (Fig. 11), and at last North Icelandic waters again during 1981–83 (Arctic conditions). Its possible pan-Atlantic impact on living marine resources has been outlined by Jakobsson (1992).

Since the period 1965–70, Atlantic, Polar and Arctic conditions have occurred in North Icelandic waters (Fig. 8, 9). The question arises if the Polar conditions in North Icelandic waters observed during 1975–79 may be reflected in low salinities in South Icelandic waters during 1985–88 (Fig. 9) and again in the Arctic conditions found in North Icelandic waters in 1989 and 1990. Corresponding hydrographic data from the Rockall Trough (Fig. 10; Ellett and Blindheim, 1992) in the waters off northern Norway (Fig. 11; Loeng *et al.*, 1992) may or may not go along with this hypothesis, but these data indeed show minima in salinity during the same periods in 1985–88, and during 1988–90. It should also be noted that during 1981–83, cold periods were observed in the waters off West-Greenland and Newfoundland (Fig. 12, 13; Hovgaard and Buch, 1990; Borovkov and Tevs, MS 1991). These conditions in the western regions of the northern North Atlantic were suggested to be of regional origin (Buch, 1985), but they might also possibly be connected with conditions north of Iceland during 1975–79, and even during 1981–83 (Fig. 9). Furthermore, it will be interesting to follow the fate of the 1988 Polar conditions in North Icelandic waters, which again may possibly be reflected in the cold years in the West Greenland and Labrador area during 1992–94. Also, it would be interesting to observe if its response will be found in low salinity in South Icelandic waters around year 1996, and then once more with its impact on the Icelandic capelin stock in North Icelandic waters around year 2000.

Whether it is the large scale anomalies or just local variations, the conditions observed here may in general be considered valuable for further studies with regard to large scale circulation and variability in the North Atlantic Subpolar Gyre. On the one hand these speculations certainly include large-scale ocean-atmospheric interactions, as well as regional conditions which may strengthen or weaken the processes in the long run across the northern North Atlantic. On the other hand it is also exciting

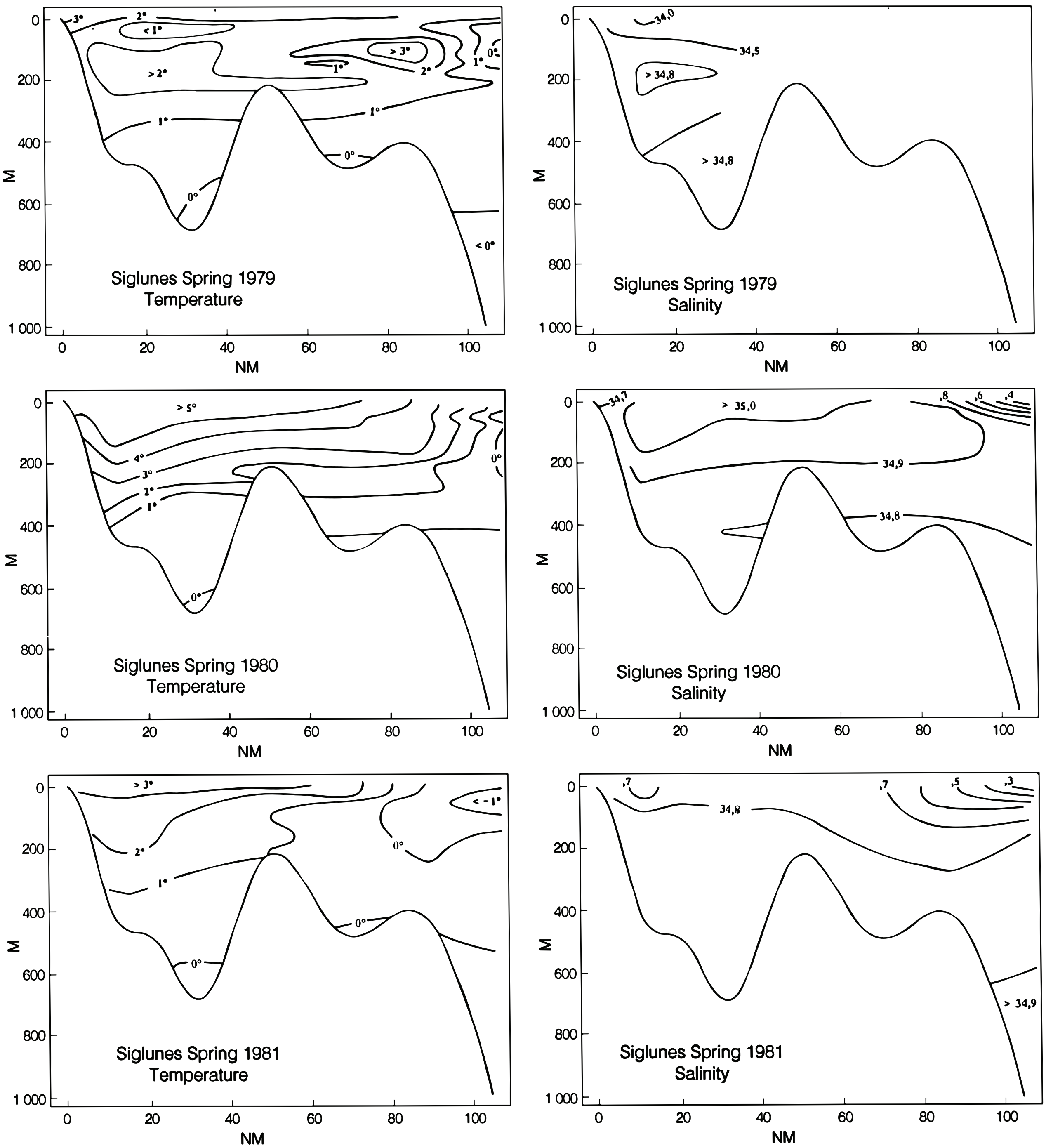

Fig. 6. Vertical distribution of temperature and salinity on a section in North Icelandic waters (Siglunes, for location see Fig. 2) in May/June 1979, 1980 and 1981. (Malmberg and Blindheim, 1994).

to look forward with some expectance to what will be found in future oceanographic expeditions. These aspects also stress the importance of international oceanographic research for understanding the impacts of the marine environment on climate and biological conditions.

Finally, since the 'Great Salinity Anomaly' could be traced as it advected around the Subpolar Gyre in the northern North Atlantic, the ecological impact of the event on several cod stocks can be compared, i.e. the stocks of Iceland, West Greenland, Newfoundland and Norway (Jakobsson, 1992). On

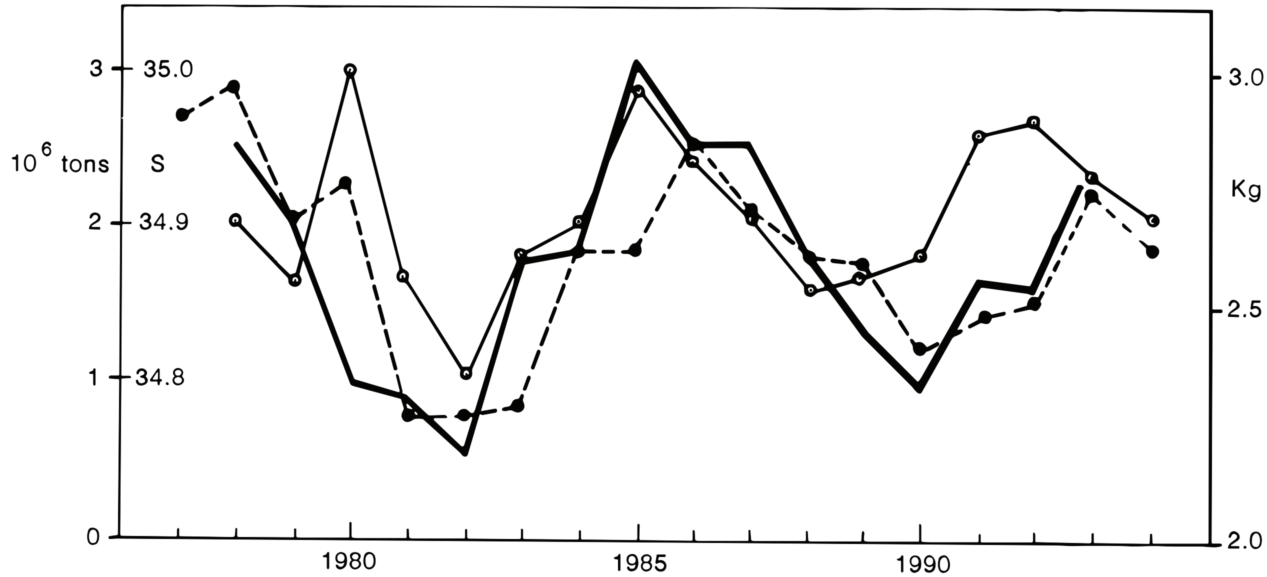

Fig. 7. Maximum salinity in the upper 300 m observed at a hydrographic station in North Icelandic waters (S-3, for location see Fig. 2) in May/June 1978–94 (solid thin line). The abundance of the Icelandic capelin stock in 1978–93 (Hjalmar Vilhjálmsson, pers. comm.) (Solid thick line). Weight of five year-old cod in Icelandic waters in 1978–94 (Anon., 1994, broken line).

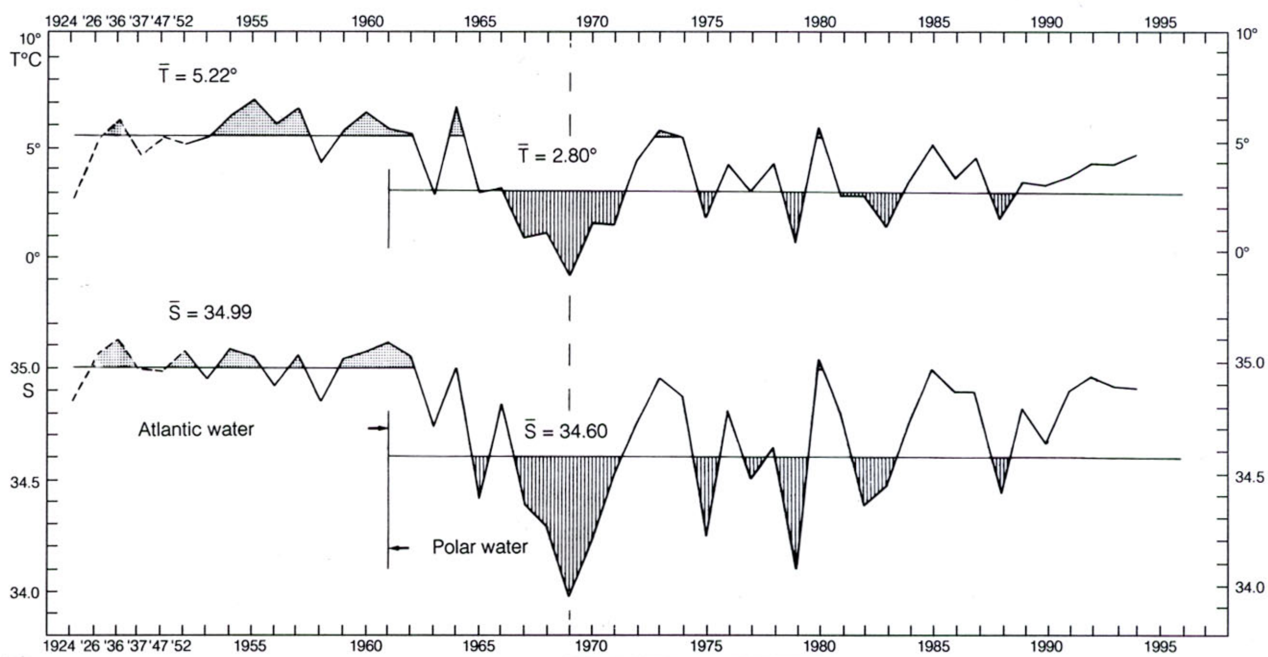

Fig. 8. Temperature and salinity at 50 m depth at a hydrographic station in North Icelandic waters (S-3, for location see Fig. 2) in May/June 1924, 1926, 1936, 1937, 1941 and 1952–94.

these fishing grounds the catches of cod (Table 1) declined from 1960 to 1990 by about 50%, recruitment by about 67% and spawning stock by about 75%. This indicated an increasing fishing pressure from 1960 to 1990 (Malmberg and Blindheim, 1994). Furthermore, in Icelandic waters, improvement of hydrographic conditions after 1990 (Fig. 8, 9) did not result in new strong year-classes of cod. It is questioned whether this failure in recruitment was due to a critically small spawning stock (Fig. 14).

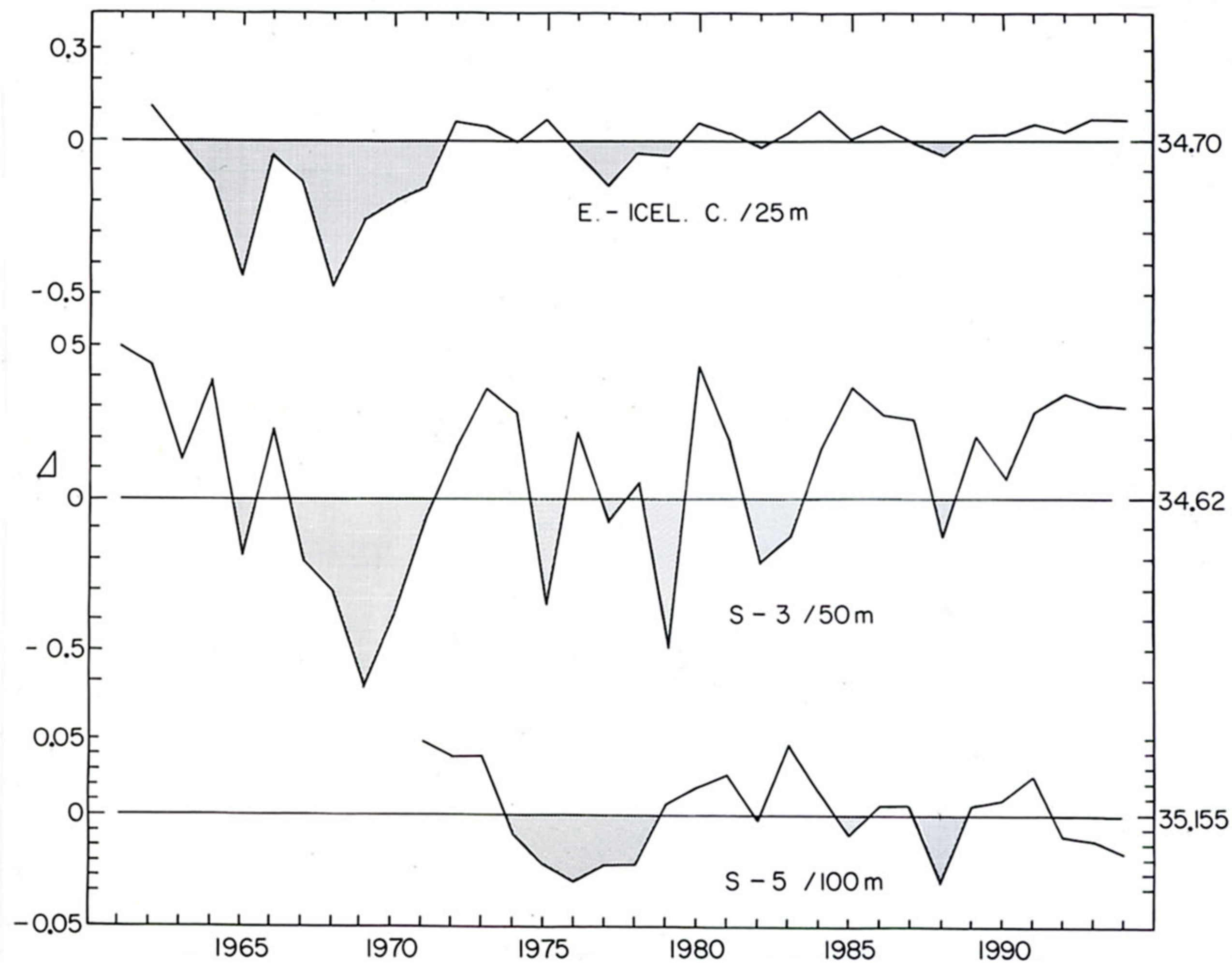

Fig. 9. Salinity deviation in spring at 25 m in the East Icelandic Current 1962–94; at 50 m in North Icelandic waters (S-3) 1961–94; and at 100 m in the Irminger Current south of Iceland (S-5),1971–94. (For location see Fig. 2).

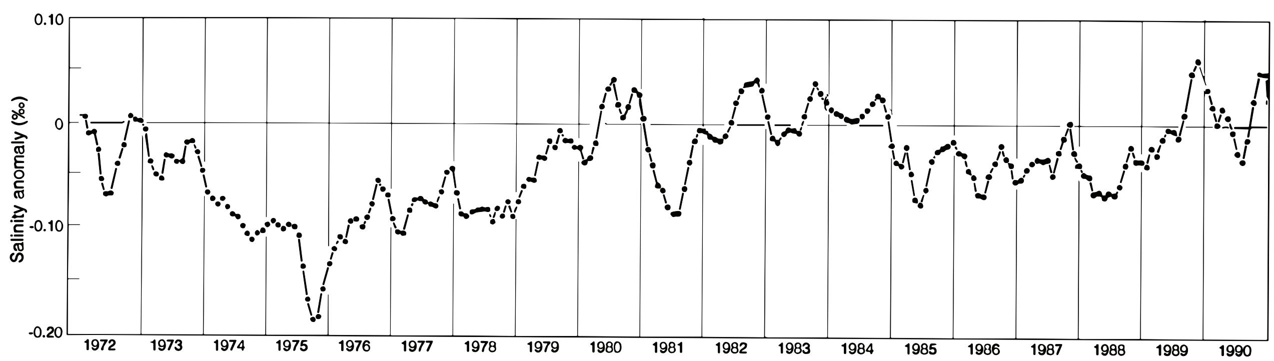

Fig. 10. Running three-monthly means of monthly salinity anomalies from 1961–70 means for the Rockall Trough 1972–90 (Ellett and Blindheim 1992).

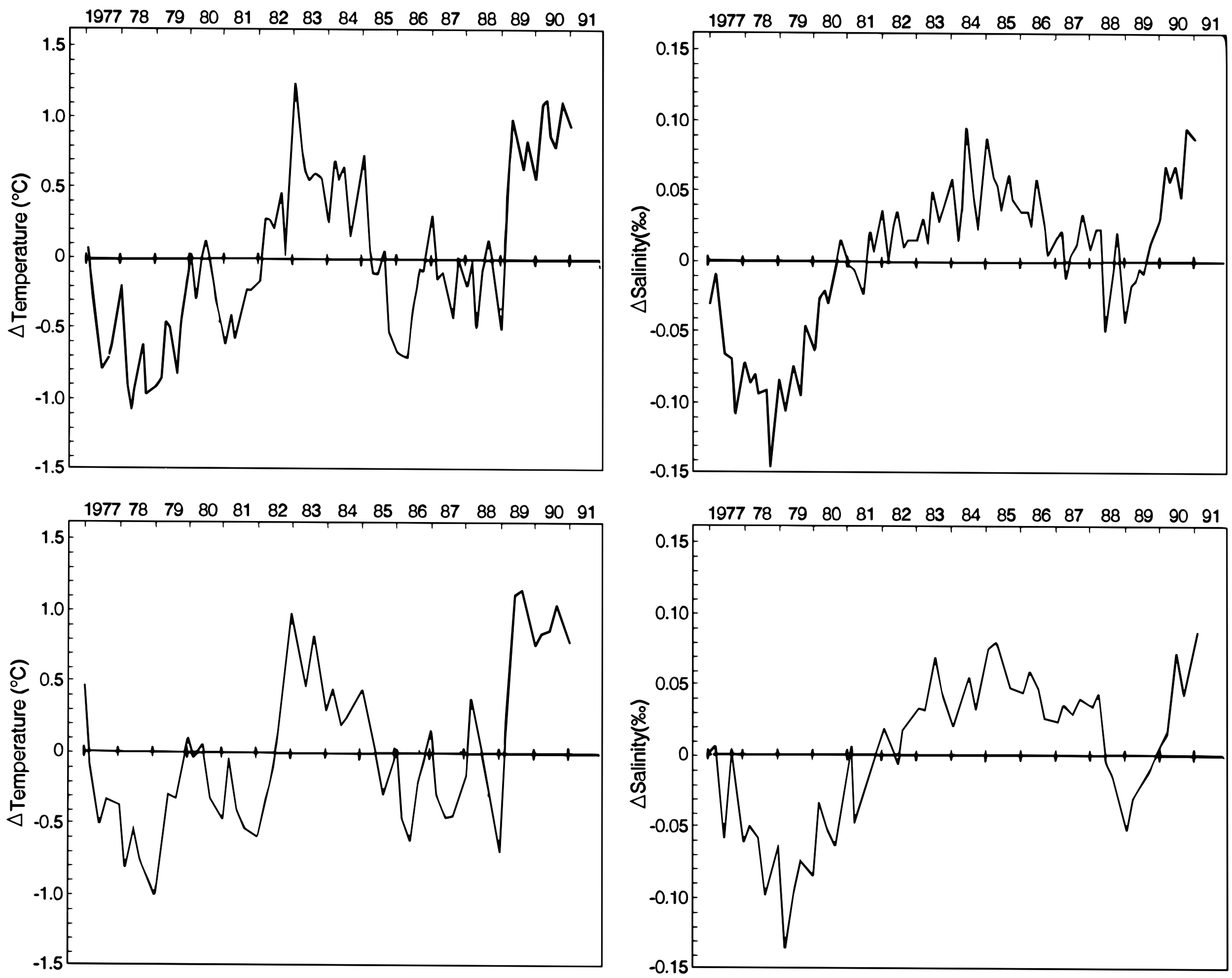

Fig. 11. Observed temperature and salinity anomalies in sections off northern Norway for the period 1977–90 (Loeng *et al.*, 1992).

TABLE 1. Catches, recruitment and spawning stock biomass of cod in northern waters around 1960 and 1990 (Iceland, West Greenland, Newfoundland and NE Arctic; From Jakobsson, 1992).

	Catch 10^3 (tons)		Recruitment 10^6 (numbers)		Spawning stock 10^3 (tons)	
Country	1960	1990	1960	1990	1960	1990
Iceland	450	300	300	100	700	200
West Greenland	400	100	400	100	1 000	100
Newfoundland	600	300	1 000	150/500	1 000	300
NE Arctic	1 000	200/500	1 500	300	600	250
Total	2 450	1 200	3 200	1 000	3 300	850

It is hard to say which of the factors, fishery or environment, is most influential of the decline in the cod stocks. The crucial difference between these two factors is, however, that while we are unable to do anything with environmental fluctuations, we should be able to manage the fishery. Careful regulations are particularly important when a fish stock is weak due to unfavourable environmental conditions. Pushed to extremes, it may not be impossible for an efficient trawling fishery to exploit a

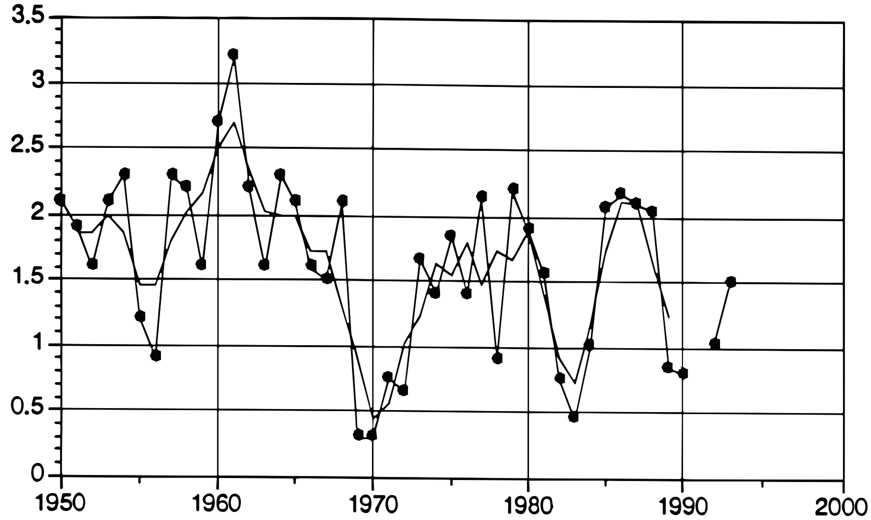

Fig. 12. Near surface sea temperature in June off West Greenland 1950–93 (Hovgaard and Buch, 1990).

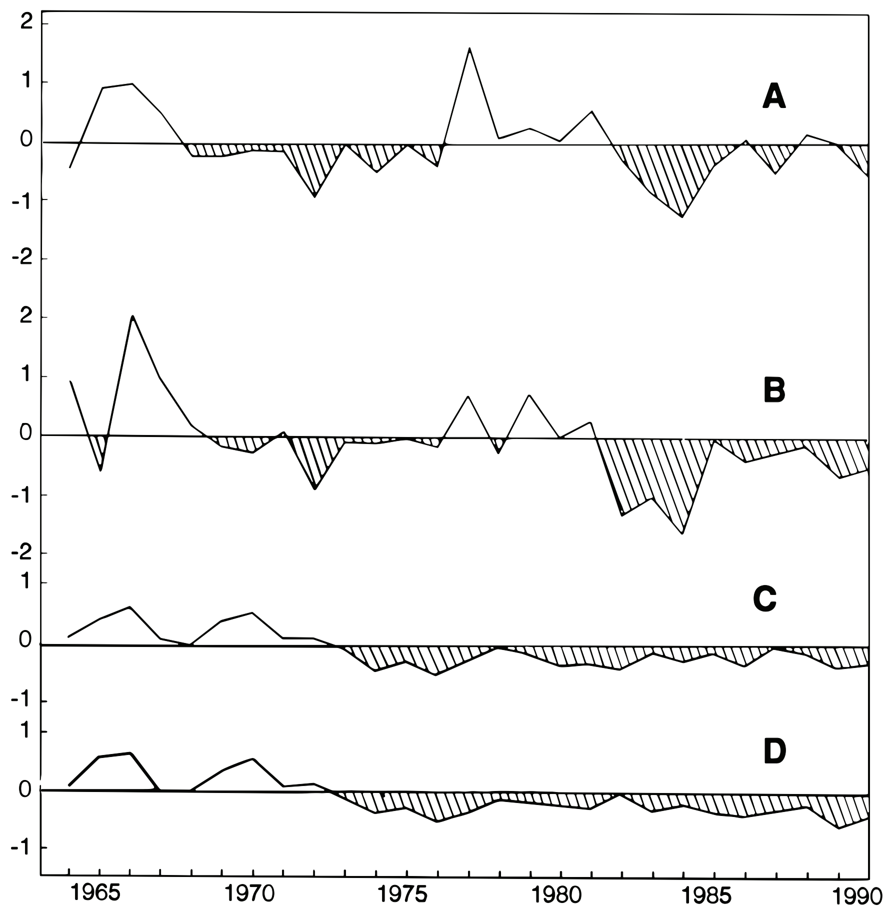

Fig. 13. Sea temperature off Newfoundland from 1964–90 in (**A**) Polar water 0–200 m; (**B**) Irminger water 0–200 m; (**C**) Irminger water 200–500 m; and (**D**) Irminger water 500–1 000 m. (Borovkov and Tevs, MS 1991).

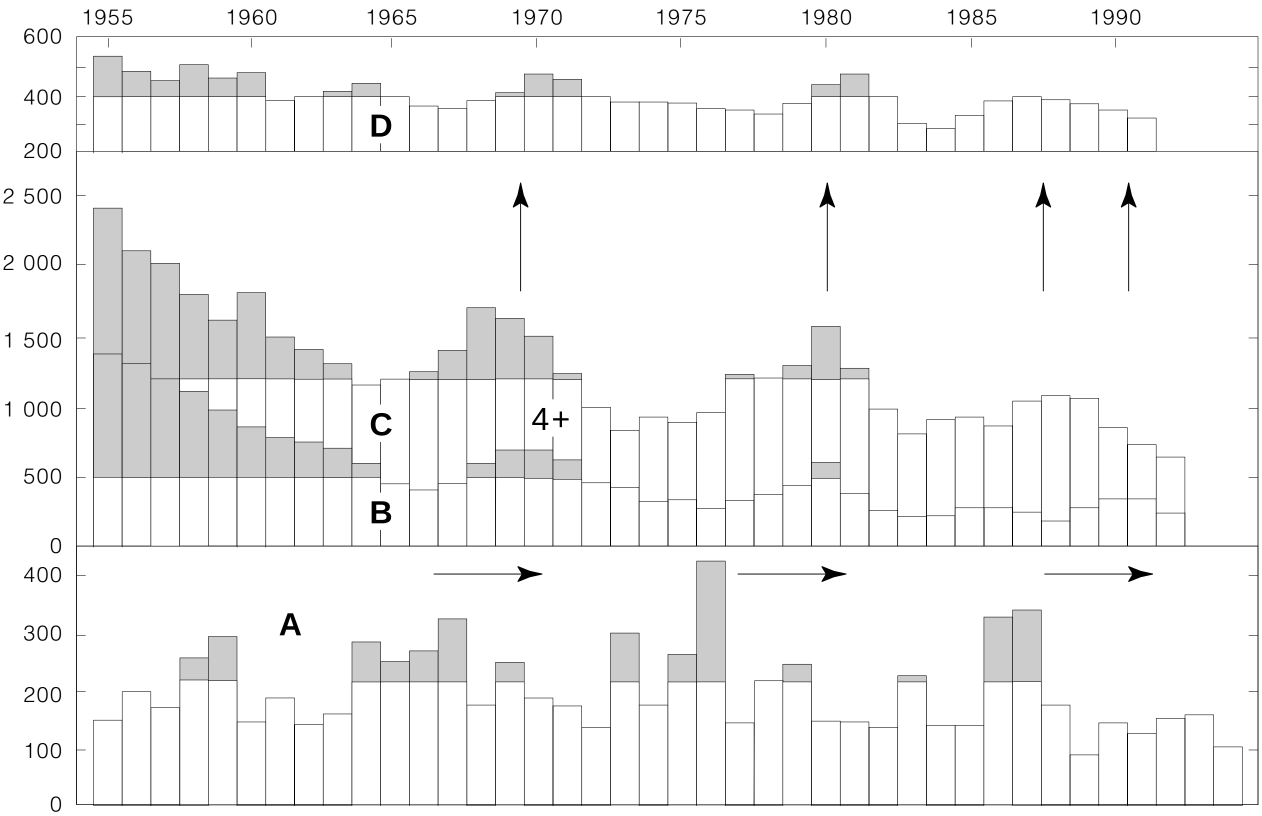

Fig. 14. Conditions of the Icelandic cod stock 1955–91/92 in (**A**) 3-year recruits in millions by number; (**B**) spawning stock biomass in thousand tons; (**C**) fishing stock biomass (4-years-old and older fish) in thousand tons; (**D**) catches in thousand tons (Anon., 1994). Shaded columns indicate periodic maxima observed and the arrows the time lack from 3–4 years-old recruits up to the year of maximum in fishing and spawning stocks as well as catches a few years later. (Malmberg and Blindheim, 1994).

spawning stock below a critical level of abundance, from which it may take many years for the stock to be restored (Malmberg and Blindheim, 1994).

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