Northwest Atlantic Fisheries Organization

Serial No. N1475

NAFO SCR Doc. 88/36

SCIENTIFIC COUNCIL MEETING - JUNE 1988

Are Fluctuations in Cod Recruitment off West Greenland Related to Long-term Variations of the Physical Environment

by

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ABSTRACT

Based on 25 years of oceanographic measurements off West Greenland, on air temperature observations at Godthaab/West Greenland over the last 112 years, and on biological data over the last 45 years, the possible influence of the physical environment on the development of West Greenland cod year- classes is discussed. It is shown that warm/saline and cold/diluted periods in the oceanic climate lasted for about 3 to 5 years. A similar periodicity is observed for strong cod year-classes up to 1973.

INTRODUCTION

During previous years there was much discussion about climatic changes in West Greenland waters (STEIN and BUCH, 1985; STEIN, 1986 ; STEIN, 1987). Due to variations of the main current components of the West Greenland Current system the oceanic climate on the fishery banks off West Greenland is considerably variable. The cold near-shore component derived from the East Greenland Current which is the main southward outflow from the North Polar Basin, and the warm offshore component the Irminger Current which is a branch of the subtropical Gulfstream system, import variability from their originating regions to the waters off West Greenland. Thus changes in tropical and polar regions affect the ocean climate on West Greenlands fishery banks sometimes after years. This so-called advective part of climatic changes is, however, not the only source of cold or warm periods in this area of the North Atlantic. Local events, like stationary cold air masses (STEIN and BUCH, 1985 a,b), as well as global tele-connections (STEIN, 1986) can add to the climatic situation off West Greenland. The question wether the occurrence of strong cod year-classes off West Greenland can be related to changes in ocean climate is examined.

DATA AND METHODS

Observation of the afore-mentioned variations is only possible on the basis of continous long-term investigations. Since 1963 the Institut für Seefischerei, Hamburg performs oceanographic and biological observations on the West Greenland shelf and above the continental shelf break. The observations are performed mostly during November along the Fylla Bank Section (Fig.1). Those years missing in our oceanogrphic time-series were completed mutually from the Greenland Fisheries Research Institute, Copenhagen. From the available station data - standard stations were performed in each year according to ICNAF Standard Oceanographic Sections and Stations list (ICNAF Selected Papers No. 3, 1978) - mean profiles of temperature, salinity and density were calculated (Fig. 2). Monthly means of air temperature observations at Godthaab/Greenland (1876-1987) were made available by the Greenland Fisheries Research Institute. The time-series of anomaly computations (Figs.3 to 6), cover the period of the recent 25 years, 1963 to 1987. The occurrence of strong cod year-classes during the past 45 years were taken from literature. Regular stratified-random bottom trawl surveys off West Greenland were introduced by the Federal Republic of Germany in 1982 and conducted yearly in late autumn and cod recruitment as well as biomass and abundance estimates were derived from survey results since.

RESULTS AND DISCUSSION

The mean vertical temperature field above the Fylla Bank and off the West Greenland shelf break is given in Fig. 2a. On the bank (0 - 200m) the values range from 1°C to 4.5°C with pronounced thermal gradients in the upper 50m. Standard deviation in the upper 100m amounts to about 1°C indicating largest variability on short-time scale (STEIN and BUCH, 1985) and on the annual scale. At depth the influence of the warm Irminger component on the thermal regime of the West Greenland Current system clearly emerges from the isotherms. Centered around 500m the core layer of this component is warmer than 5°C. The bottom layer of this section is governed by water masses which derive their properties by mixing with the upper Labrador Sea Water (LAZIER, 1973). From the vertical distribution of salinity the saline core of the Irminger component clearly emerges around 500m depth (Fig. 2b) with salinities above 34.94 PSU. Within the top level of the water column the cold diluted waters indicate the influence of the East Greenland component on the West Greenland Current system. The density field (Fig. 2c) reveals steady stratification with tilted isopycnals in the upper 500m indicating geostrophically balanced flow to the north.

ANOMALIES

To analyse variations within the oceanic upper layer (0-200m) temperature and salinity anomalies were computed from the annual standard depth data at station 4 of the section. The actual mean temperature/salinity value of this layer amounts to 2.67°C/33.50 PSU. This value corresponds to the "0" line in figs. 3, 4. In a smoothed presentation these figures indicate variations which amount to a maximum of about 4°C/1.3 PSU. These values partly represent single events which do not follow the general trend of the time series, e.g. 1964 (T), 1965 (S). To elaborate the basic trend of both time series a specific trend analysis was performed for both anomaly data vectors. The results as displayed in figs. 5 and 6 show similar, as well as diverging trends within the previous 25 years. From the thermal trend analysis (Fig. 5) the early eighties are the salient feature, whereas for the salinity trend (Fig. 6) the early seventies are the prominent event of the time series. Both time series reveal negative anomalies in both periods. As mentioned by BUCH and STEIN (1988) the reason of the early seventies anomaly is probably part of the "Mid-seventies anomaly" which was advected through the North Atlantic Current system, whereas the early eighties anomaly is explained by the same authors by changed regional conditions in the Davis Strait preventing a normal inflow of Irminger Water to the site of the Fylla Bank during winter 1983/84.

As can be traced from figs. 5, 6 the time range of warm/saline and cold/diluted periods lasted for about 3 to 5 years within the last 25 years. It seems probable that after the warming period which we experience now, a cooling period will follow. Based on the "periodicity" of 3 to 5 years the cooling should be likely to start around 1990. Whether this forecast will, however, be true depends to a large extent on the climatic steering mechanisms mentioned above.
Indication for cooling of the core layer of the Irminger component is evident already from the 1986 and 1987 data. This decreasing temperature within the depth range of 400-600m amounts to 0.3°C below the 25 years mean.

AIR TEMPERATURE AND OCEANIC CLIMATE

Based on monthly means of air temperature at Godthaab/West Greenland the period 1963 to 1987 was trend analysed in the same manner as the temperature/salinity anomalies. This analysis reveals for the individual months quite diverging features. The year mean clearly demonstrates the early eighties being anomalous cold (Fig. 7), whereas the months of February, May, June and especially November, December (Figs. 9, 12, 13, 18, 19) indicate both the cold early seventies and the cold early eighties. Regarding the annotated temperature scales one has to bear in mind that the trend analysed time-series are adjusted to means and the anomalous low temperatures of January/February 1984 (-19.1°C/-19.8°C) thus do not occur. Cross-correlations for the oceanic time-series (Fig. 5) and the individual trend analysed monthly air temperature series yield highest correlation coefficients for the months of June (lag 0: 0.76), and November (lag 0: 0.77). Similar to the ocean climatic series the air temperature trend series for November indicates the large anomaly during the early eighties which exceeds the early seventies anomaly by far. This again stresses the regional character of the recent cold period. The correlation data would suggest that intensive interaction between ocean and atmosphere off West Greenland plays an important role in the formation of climate. Since the changes as discovered in the ocean climate are due to regional and far distant variations in the North Atlantic Current system, the climate at Godthaab is very likely to be influenced by the same variations.
Indication for cooling can be depicted from several monthly series. Especially the winter and post-winter months reveal this trend. The year mean, as well as the November series point at a temperature maximum which has been passed between 1986 and 1987 and a new cooling period is likely to come as mentioned above.

FLUCTUATIONS IN COD RECRUITMENT

Fisherybiological investigations of the West Greenland cod stock over the last 45 years (SCHMIDT, 1970) have shown a similar periodicity of 3 to 5 years in the occurrence of strong year-classes up to 1973 (1942,45,47,50,53,57,61,65,68 and 1973). Compared to the long-term oceanographic observations over the last 25 years (1963-87) discussed above, the strong year-classes of 1965, 68 and 73 appeared during warming periods when water temperatures were close to the long-term average. Extremely high fishing pressure during the sixties and recruitment failure during the cooling period in the early seventies resulted in a considerable reduction in stock size. The next strong year-class appeared at the beginning of the following warming period. For the next ten years (1974-83) there was a complete lack of good year-classes resulting in a further severe decline in stock size. During this time span the dominating although below average year-classes of 1975, 77, 79 and 81 appeared every second year when water temperatures were close to the long-term average (Fig. 3). During the extreme cooling period of the early eighties regular stratified-random bottom trawl surveys off West Greenland were introduced by the Federal Republic of Germany in 1982. The continued decline in stock size of cod to its lowest level in 1984 and a complete failure of recruitment is well documented. However, at the beginning of a new warming period the unexpected strong 1984 year-class appeared and produced up to the present a considerable increase in cod abundance and biomass off West Greenland (Figs. 20,21).

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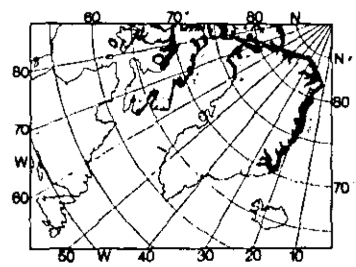

Fig. 1 Location of Fylla Bank Section

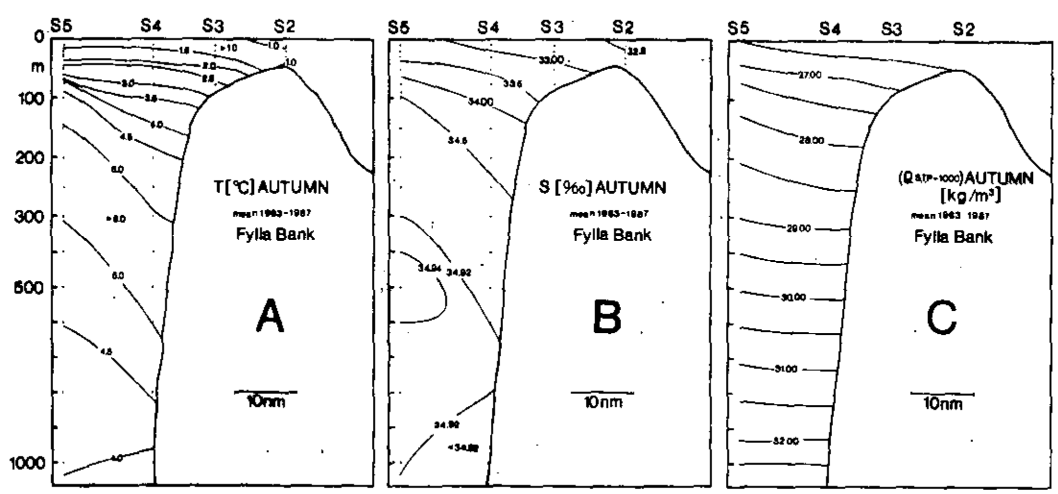

Fig. 2 Mean Vertical Fields of Temperature (A), Salinity (B) and Density (C)

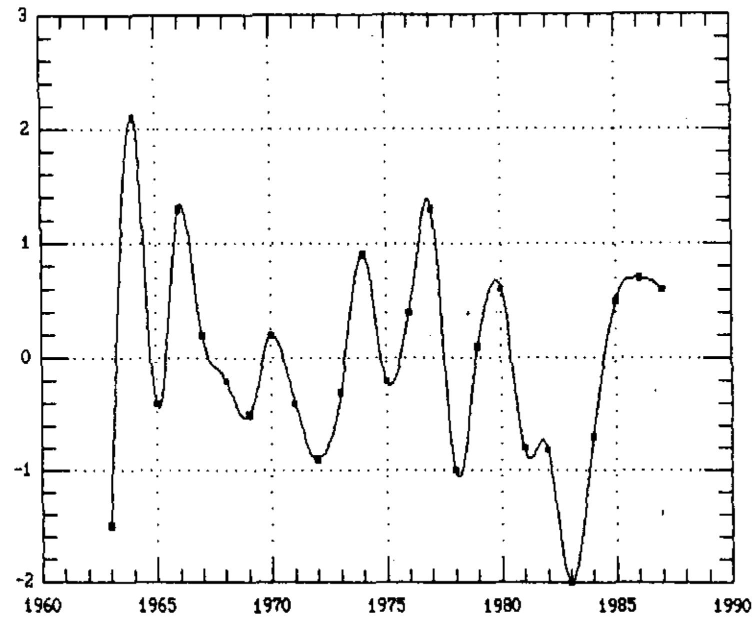

Fig. 3 Mean Temperature Anomaly (0-200m) 1963-1987 Fylla Bank

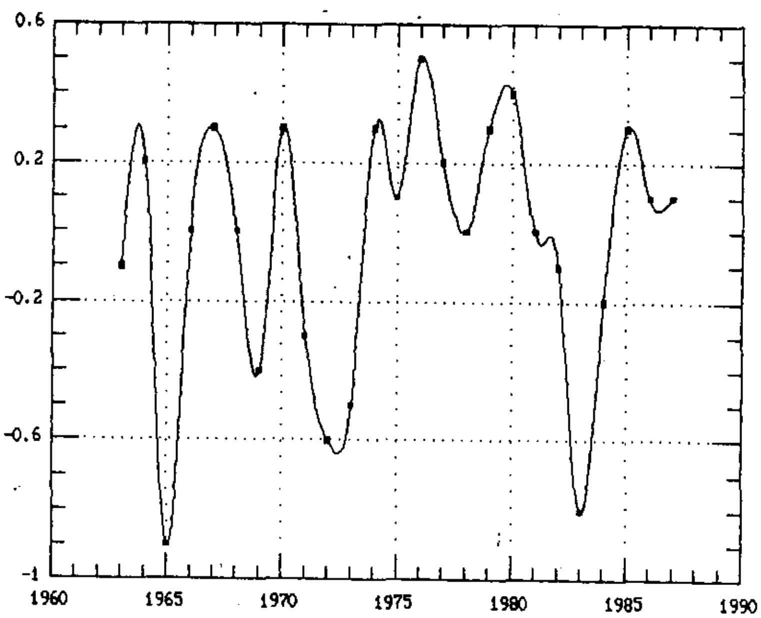

Fig. 4 Mean Salinity Anomaly (0-200m) 1963-1987 Fylla Bank

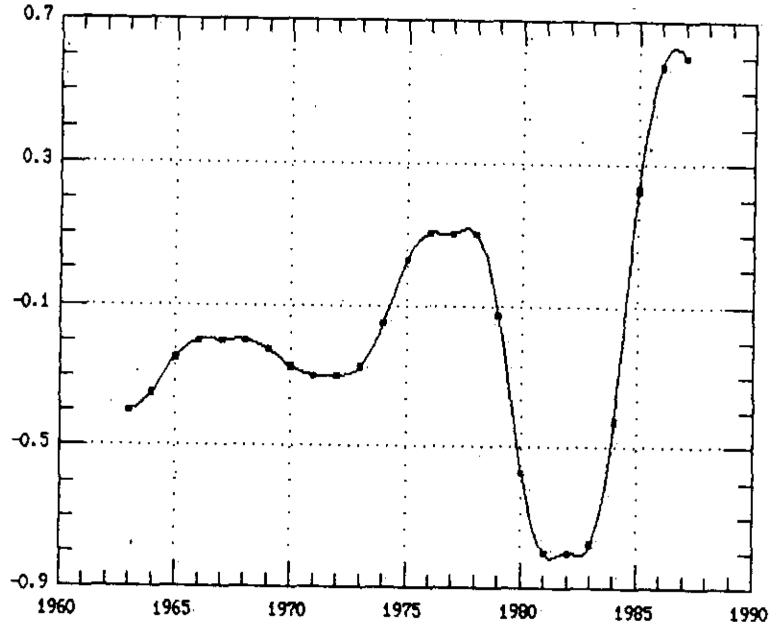

Fig. 5 Trendanalysis of Temperature Anomaly Data 1967-1987
Fylla Bank

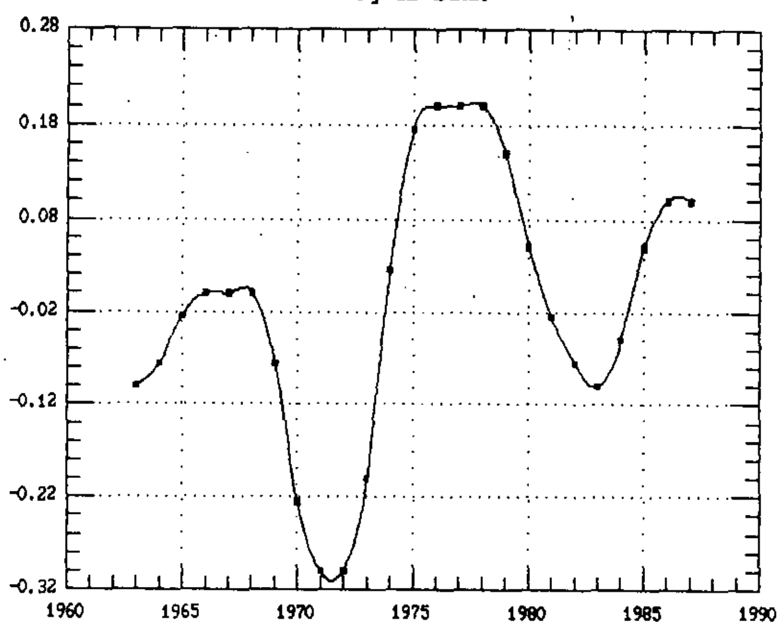

Fig. 6 Trendanalysis of Salinity Anomaly Data 1967-1987
Fylla Bank

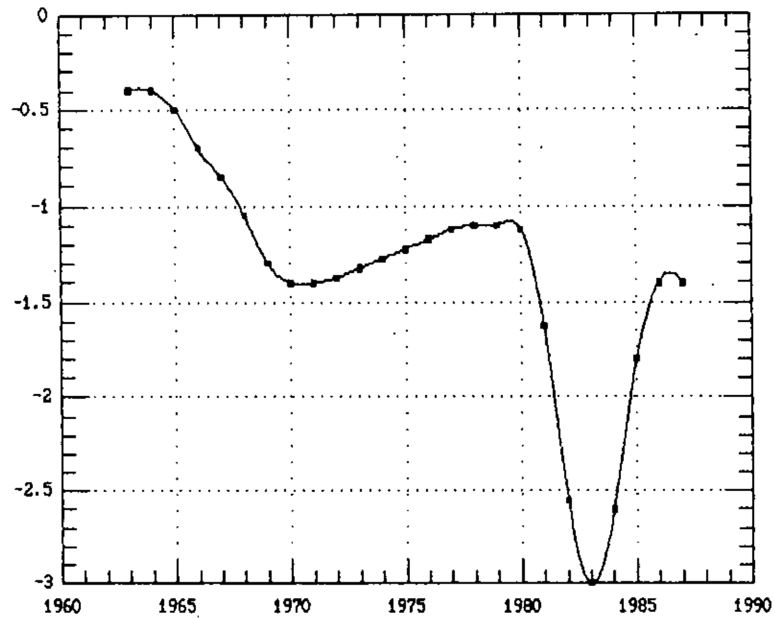

Fig. 7 Trendanalysis of Godthaab Air Temperature Data 1967-1987 Year Mean

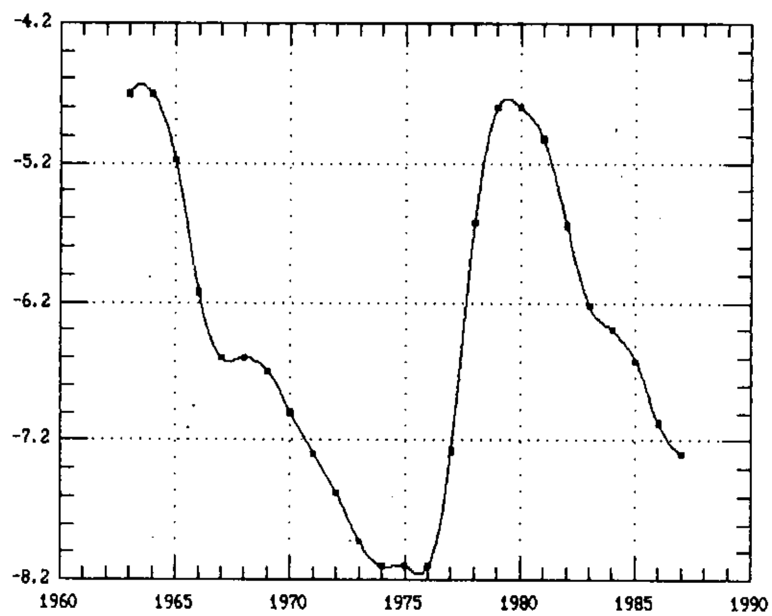

Fig. 8 Trendanalysis of Godthaab Air Temperature Data 1967-1987 January

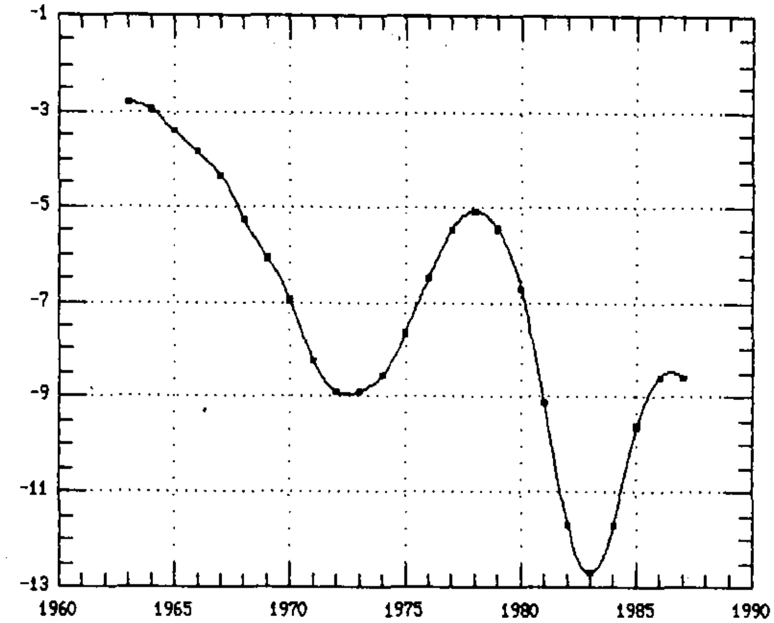

Fig. 9 Trendanalysis of Godthaab Air Temperature Data 1967-1987 February

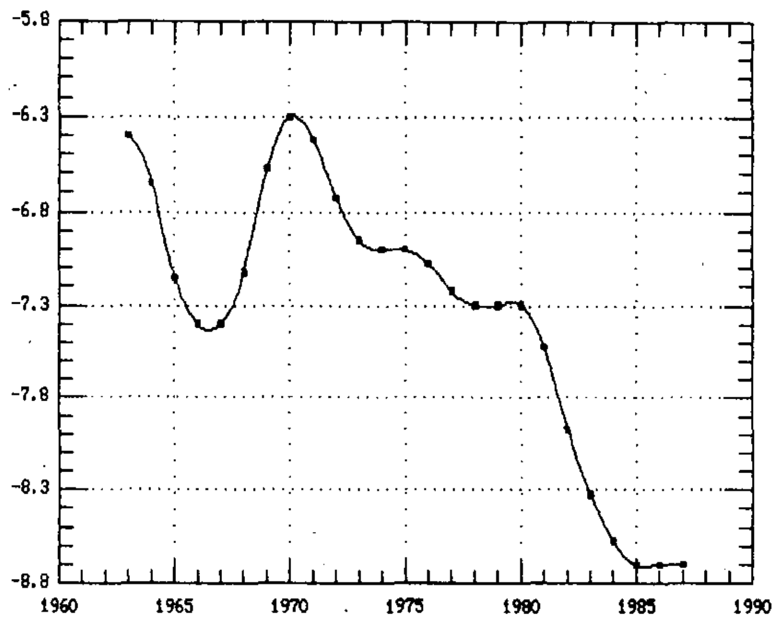

Fig. 10 Trendanalysis of Godthaab Air Temperature Data 1967-1987 March

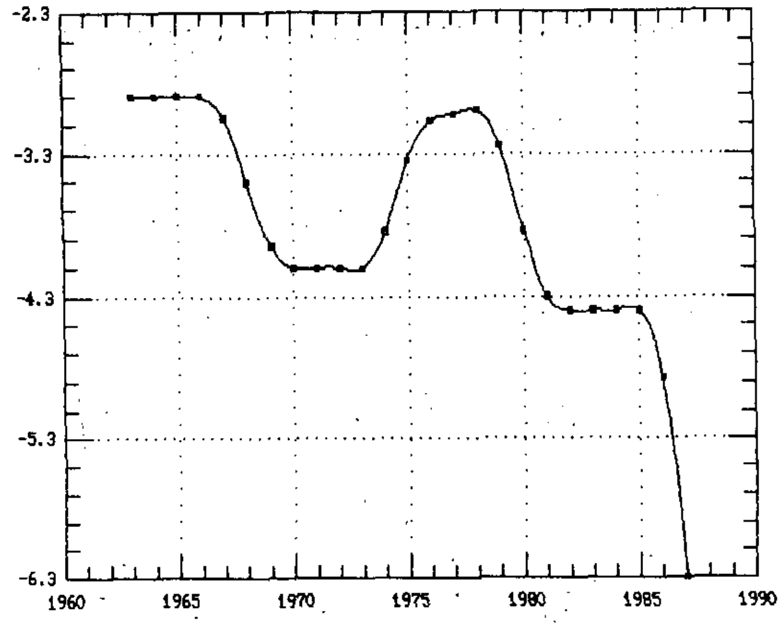

Fig. 11 Trendanalysis of Godthaab Air Temperature Data 1967-1987 April

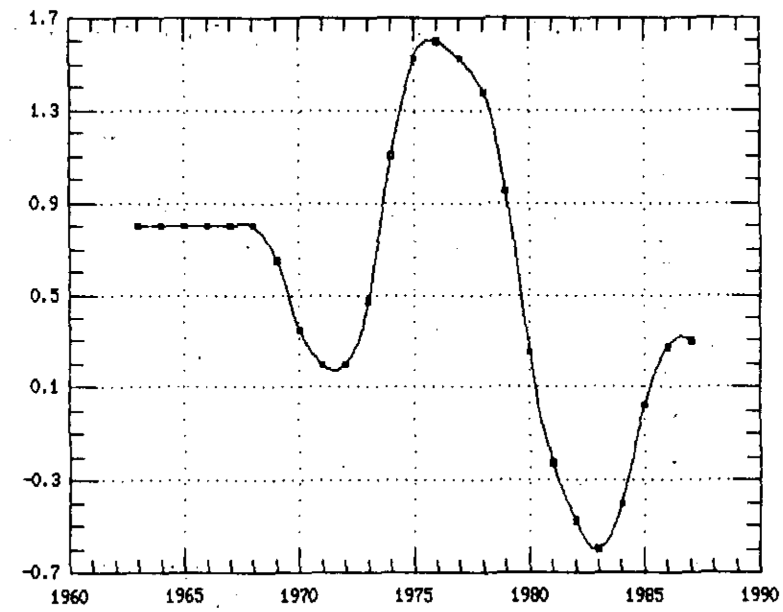

Fig. 12 Trendanalysis of Godthaab Air Temperature Data 1967-1987 May

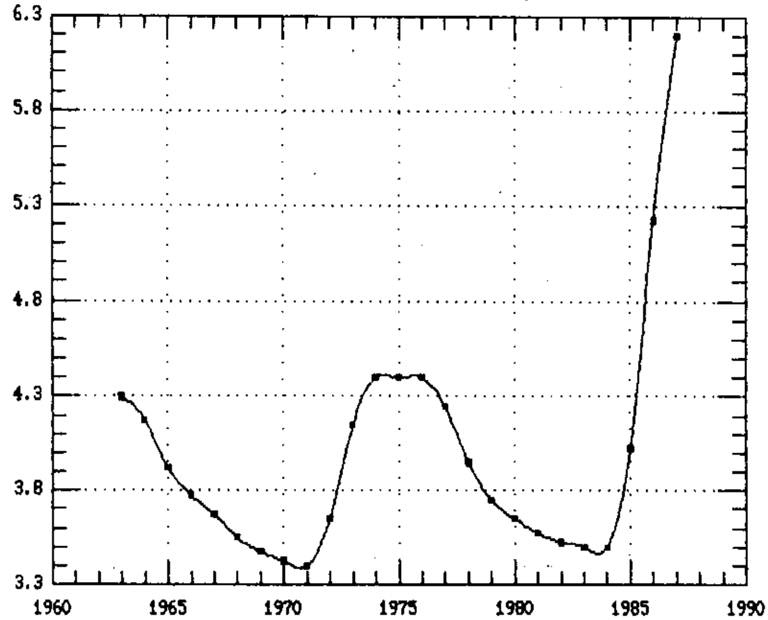

Fig. 13 Trendanalysis of Godthaab Air Temperature Data 1967-1987 June

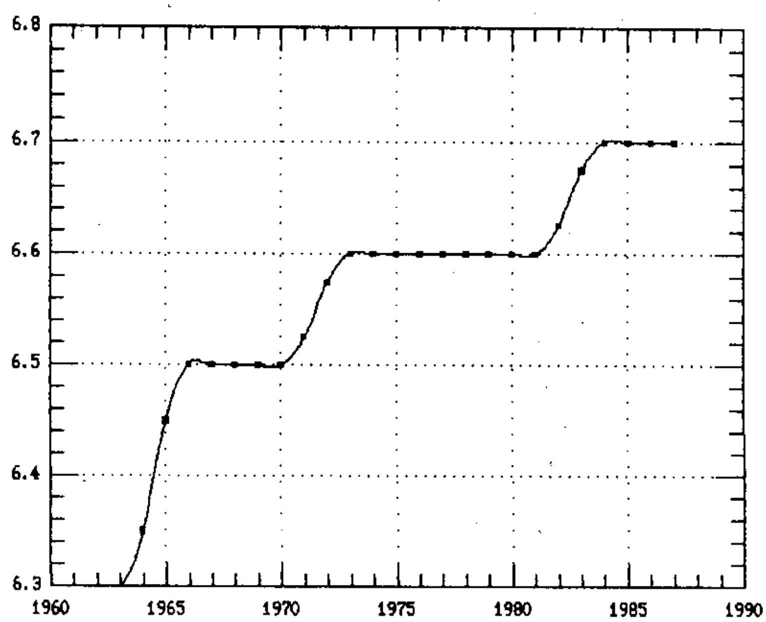

Fig. 14 Trendanalysis of Godthaab Air Temperature Data 1967-1987 July

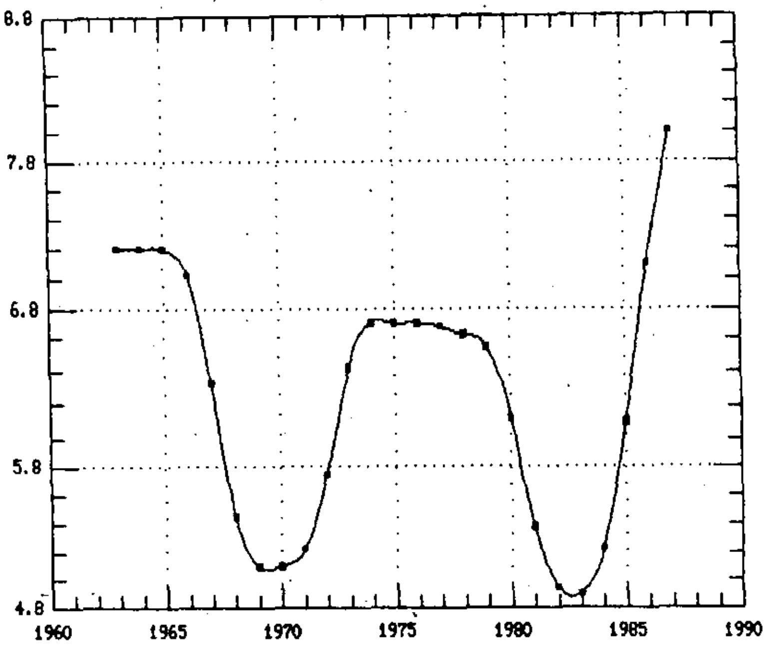

Fig. 15 Trendanalysis of Godthaab Air Temperature Data 1967-1987 August

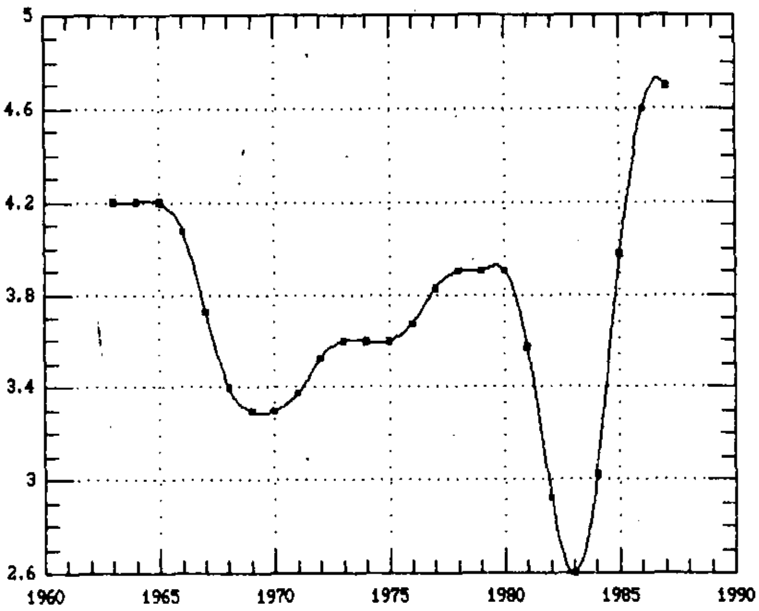

Fig. 16 Trendanalysis of Godthaab Air Temperature Data 1967-1987 September

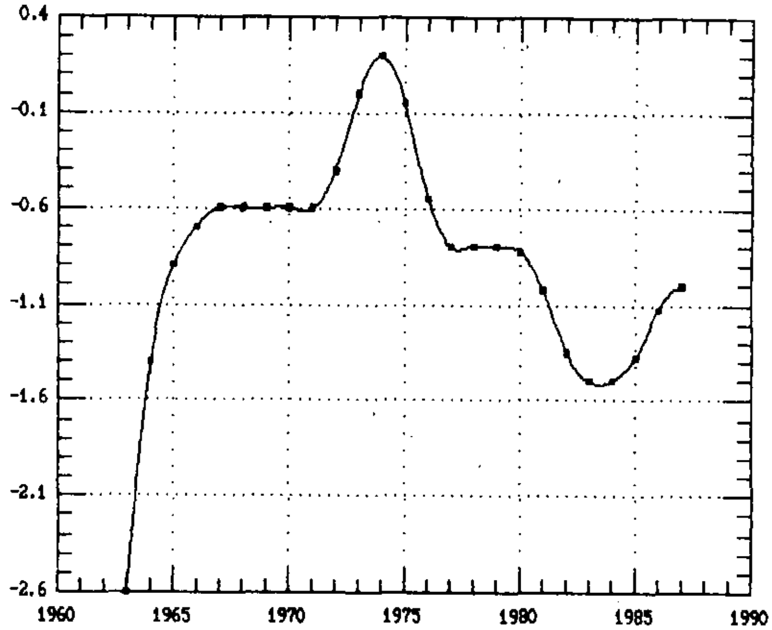

Fig. 17 Trendanalysis of Godthaab Air Temperature Data 1967-1987 October

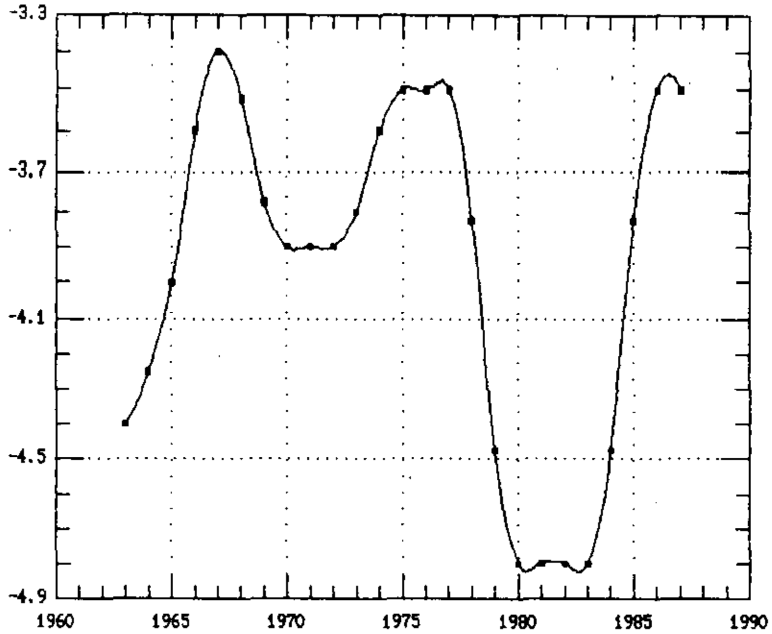

Fig. 18 Trendanalysis of Godthaab Air Temperature Data 1967-1987 November

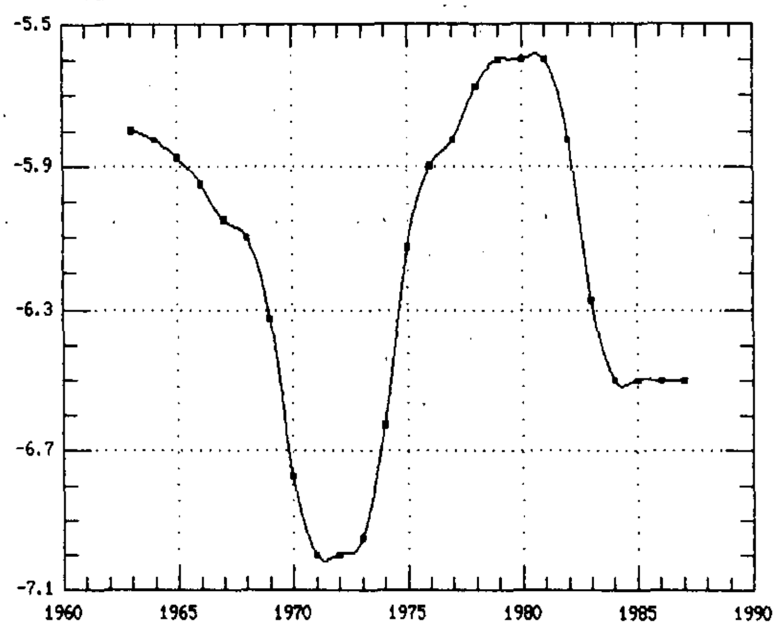

Fig. 19 Trendanalysis of Godthaab Air Temperature Data 1967-1987 December

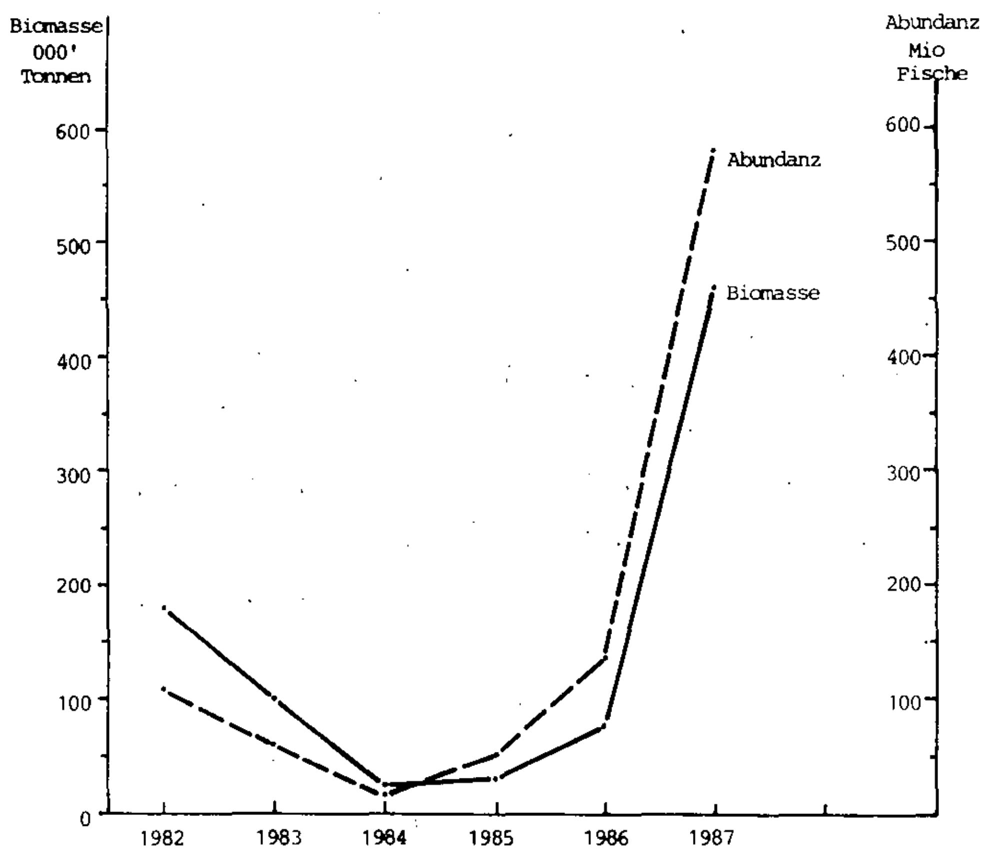

Fig. 20 West Greenland Cod. Trends in Survey Biomass and Abundance, 1982 - 1987

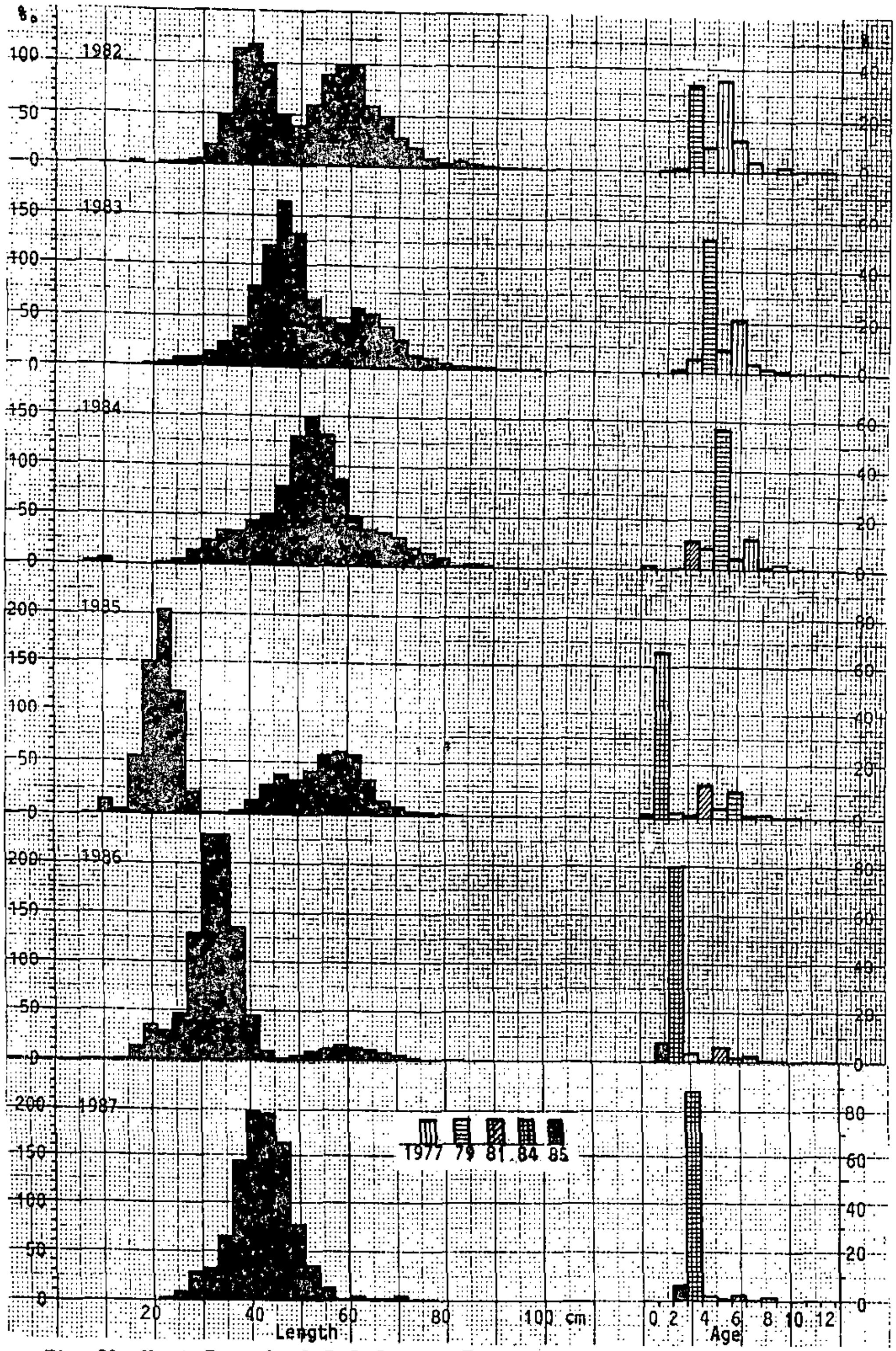

Fig. 21 West Greenland Cod. Length Frequencies (per mille) and Age Composition (per cent) from Autumn Survey Results, 1982-1987