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Relationship of Fluctuations in Cod Recruitments off West Greenland to Long-term Variations of the Physical Environment

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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 was observed that warm/saline and cold/diluted periods in the oceanic climate lasted for about 3 to 5 years. A similar 3–5 years periodicity was observed for strong cod year-classes through 45 years up to 1973.

Introduction

There have been many published discussions on climatic changes in West Greenland waters (Stein and Buch, 1985a; Stein, MS 1986, MS 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 has varied considerably. 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 off-shore Irminger Current component, which is a branch of the subtropical Gulf Stream 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 Greenland's fishery banks, sometimes after years. This is called the advective part of climatic changes. This, however, is 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, MS 1985b, c), as well as global teleconnections (Stein, 1986) can add to the climatic situation off West Greenland. In this study, the question whether the occurrence of strong cod year-classes off West Greenland can be related to changes in ocean climate is examined. Observation of these variations, which is only possible on data collected on continuous long-term investigations, was carried out on data from any sources.

Data and Methods

Since 1963 the Institut für Seefischerei, Hamburg, has performed oceanographic and biological observations on the West Greenland shelf and on the continental shelf break. The observations were mostly during November, along the Fylla Bank Section (Fig. 1). The years in which data were missing in the oceanographic time-series were completed using data from the Greenland Fisheries Research Institute, Copenhagen. Standard station oceanographic measurements were performed in each year according to ICNAF Standard Oceanographic Sections and Stations list (*ICNAF Selected Papers*, No. 3, 1978). From the available station data, 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 (Fig. 3 and 4) covered the period of the recent 25 years, from 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 Green-

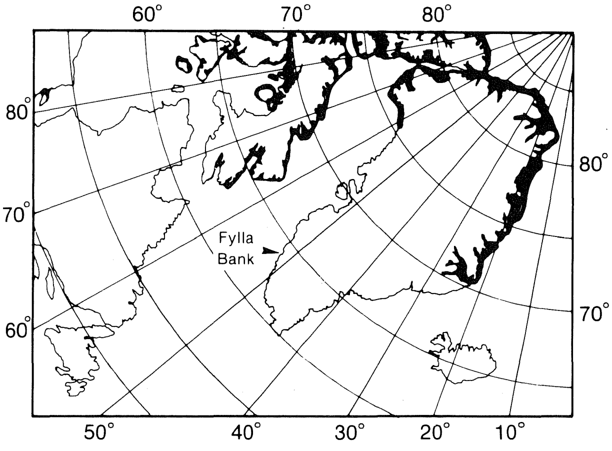

Fig. 1. Location of Fylla Bank Section.

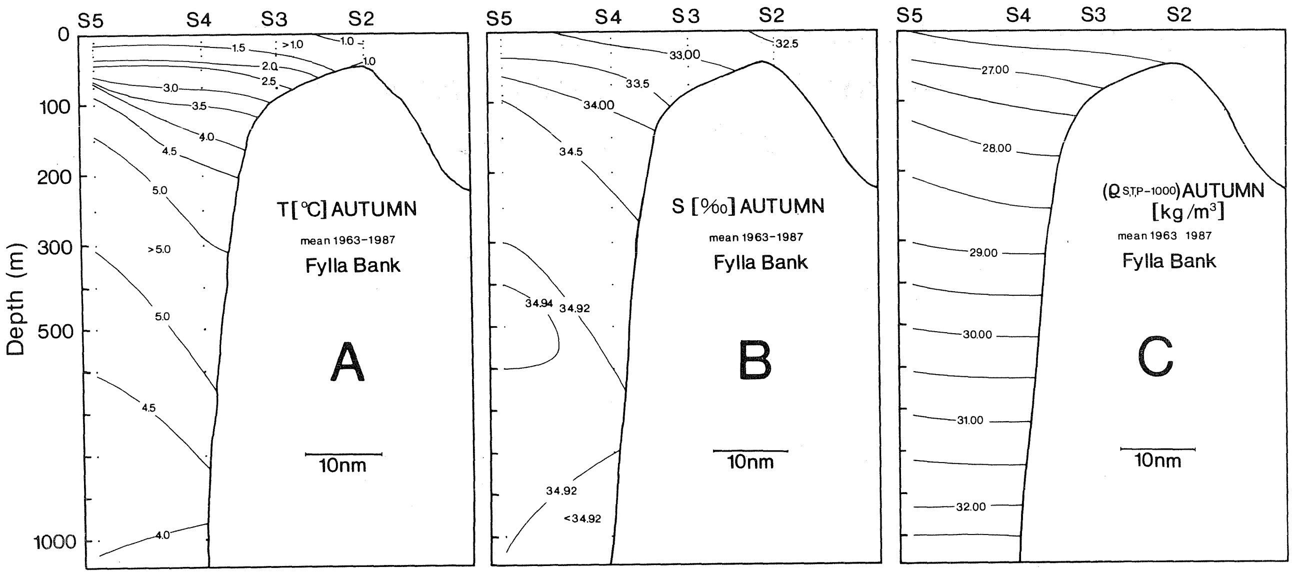

Fig. 2. Mean vertical fields of (**A**) temperature, (**B**) salinity and (**C**) density.

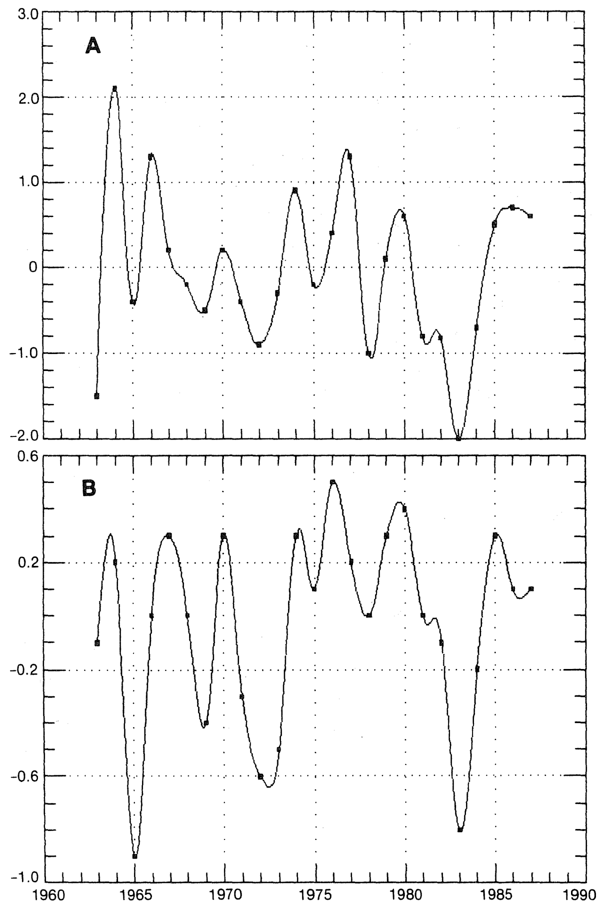

Fig. 3. (**A**) Mean temperature anomaly and (**B**) mean salinity anomaly (0-200 m) from 1963 to 1987, Fylla Bank.

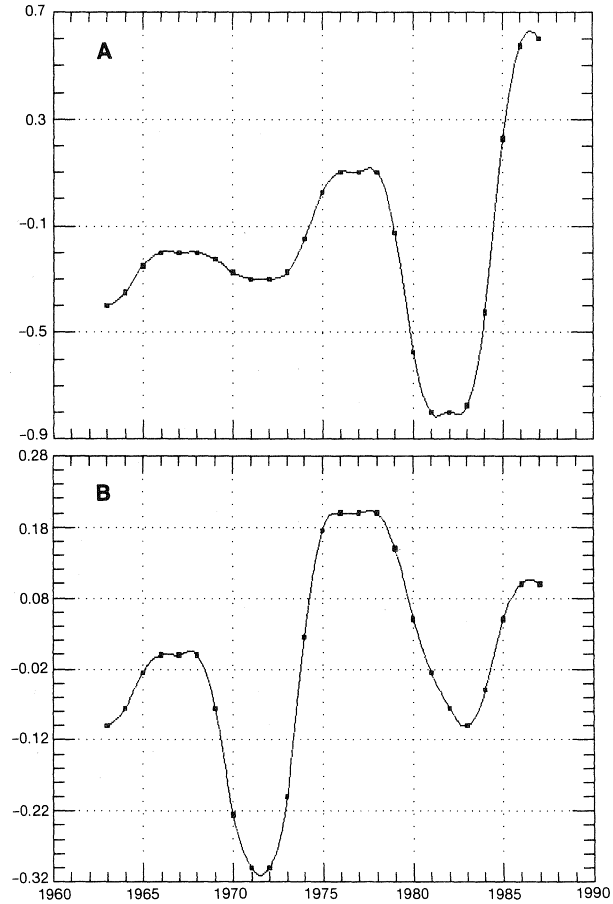

Fig. 4. Trend analysis of (**A**) temperature anomaly data and (**B**) salinity anomaly data from 1967 to 1987, Fylla Bank.

land were introduced by the Federal Republic of Germany in 1982 and conducted yearly in last autumn. Cod recruitment as well as biomass and abundance estimates were derived from those survey results.

Results and Discussion

The mean vertical temperature field on Fylla Bank and off the West Greenland shelf break is given in Fig. 2A. The values ranged from 1° to 4.5° C at the 0–200 m stratum on the Bank with pronounced thermal gradients in the upper 50 m. Standard deviation in the upper 100 m amounted to about 1° C, and this indicated the largest variability on a short-time scale (Stein and Buch, 1985a) and on an annual scale. At deeper depths, the influence of the warm Irminger component on the thermal regime of the West Greenland Current system clearly emerged from the isotherms. Centered around 500 m, the core layer of this component was warmer than 5° C. The bottom layer of this section was governed by water masses which derived 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 emerged around the 500 m 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 500 m indicating geostrophically balanced flow to the north.

Anomalies

To analyze variations within the oceanic upper layer (0–200 m) 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 amounted to 2.67° C/33.50 PSU and this value corresponded to the "0" line in Fig. 3. In smoothed presentations, these figures indicated variations which amounted to a maximum of about 4° C/1.3 PSU. The values partly represented single events which do not follow the general trend of the time series, for example temperature in 1964 and salinity in 1965. 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 Fig. 4 show similar, as well as diverging, trends within the last 25 years. From the thermal trend analysis (Fig. 4A) the early-1980s show the salient feature, whereas for the salinity trend (Fig. 4B) the early-1970s show the prominent event of the time-series. Both time-series reveal negative anomalies in both periods. As discussed by Buch and Stein (MS 1988) the reason of the early-1970s anomaly was probably part of the "Mid-seventies anomaly" which was advected through the North Atlantic Current system, whereas the early-1980s anomaly was explained 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.

The time range of warm/saline and cold/diluted periods can be traced in Fig. 4 to have lasted for about 3 to 5 years within the last 25 years. It seems probable that after the warming period which is currently being experienced, a cooling period will follow. Based on the "periodicity" of 3 to 5 years, the cooling would be likely to start around 1990. Whether this forecast will be true depends to a large extent on the other climatic steering mechanisms mentioned above. However, indications of cooling of the core layer of the Irmingr component is evident already from the 1986 and 1987 data. This decreasing temperature within the depth range of 400–600 m 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 during the period 1963–87 the trend was analyzed in the same manner as the temperature/salinity anomalies. The analysis revealed quite diverging features for individual months. The year means clearly demonstrated the early-1980s being anomalously cold (Fig. 5), whereas the monthly trend analysis data indicated February, May, June and especially November, December (Fig. 6) to be cold in the early-1970s and the early-1980s (Fig. 6). Regarding the annotated temperature scales, it must be pointed out that the trend analyzed time-series are adjusted to means and the anomalous low temperatures of January/February 1984 (−19.1°/−19.8° C) thus do not in fact occur. Cross-correlations for the oceanic time-series (Fig. 4A) and the individual trend analyzed monthly air

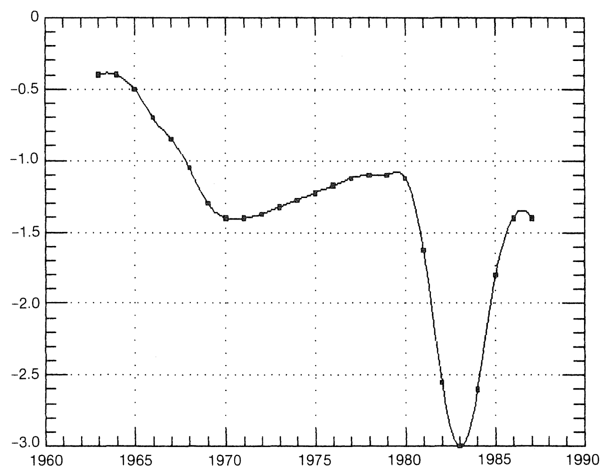

Fig. 5. Trend analysis of Godthaab air temperature year mean data for 1963–87.

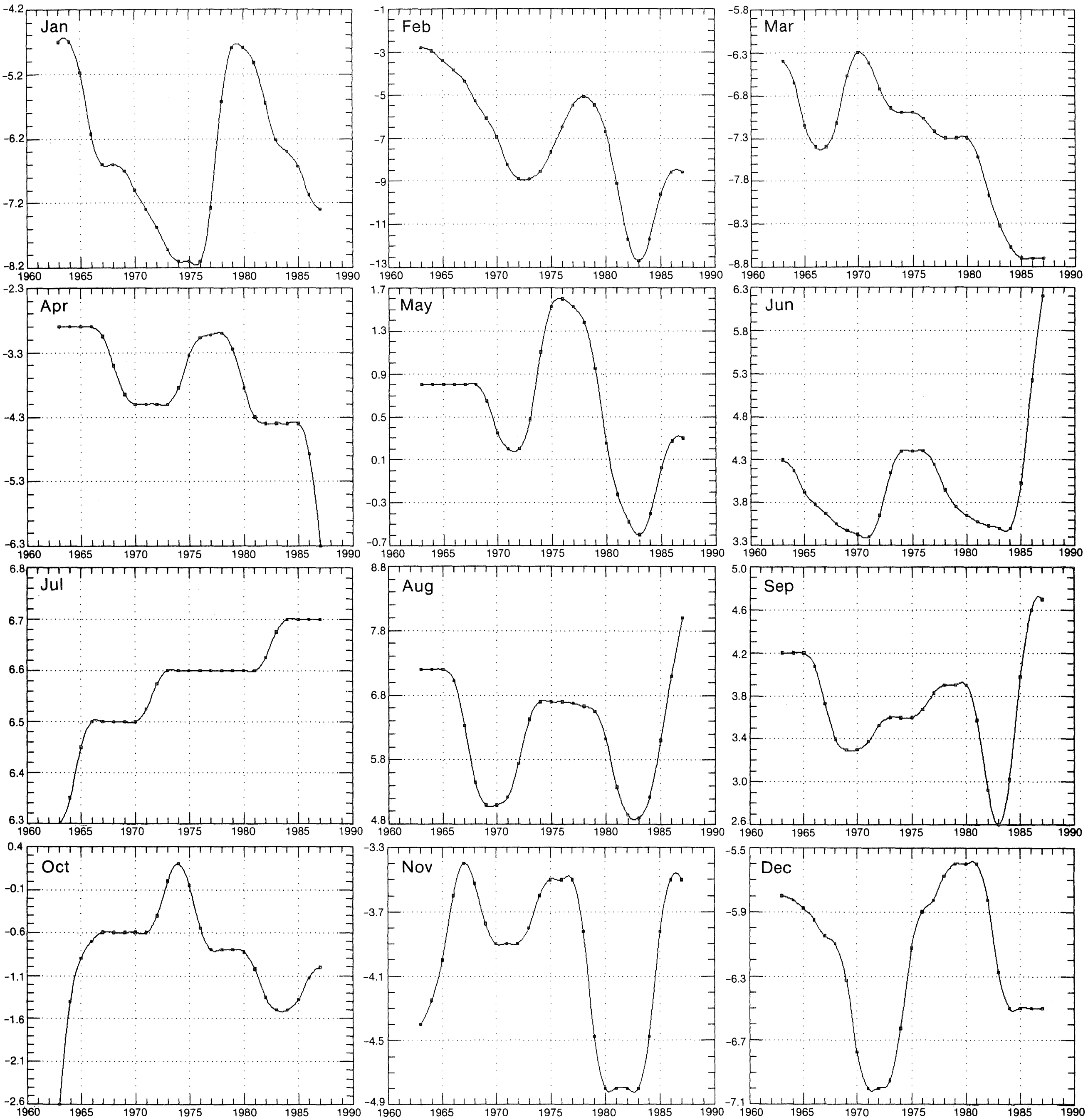

Fig. 6. Monthly trend analysis of Godthaab air temperature data during 1963-87.

temperature series, yielded 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 indicated a large anomaly during the early-1980s which exceeded the early-1970s anomaly by far. This again stressed 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 ocean climate. Since the changes as discovered in the ocean climate are due to regional and distant variations in the North Atlantic Current system, the climate at Godthaab is very likely to be influenced by the same variations.

Indication of cooling can be depicted from several monthly series. The winter and post-winter months especially reveal this trend. The year mean, as well as the November series, point at a temperature maximum which has passed between 1986 and 1987 and a new cooling period is likely to come.

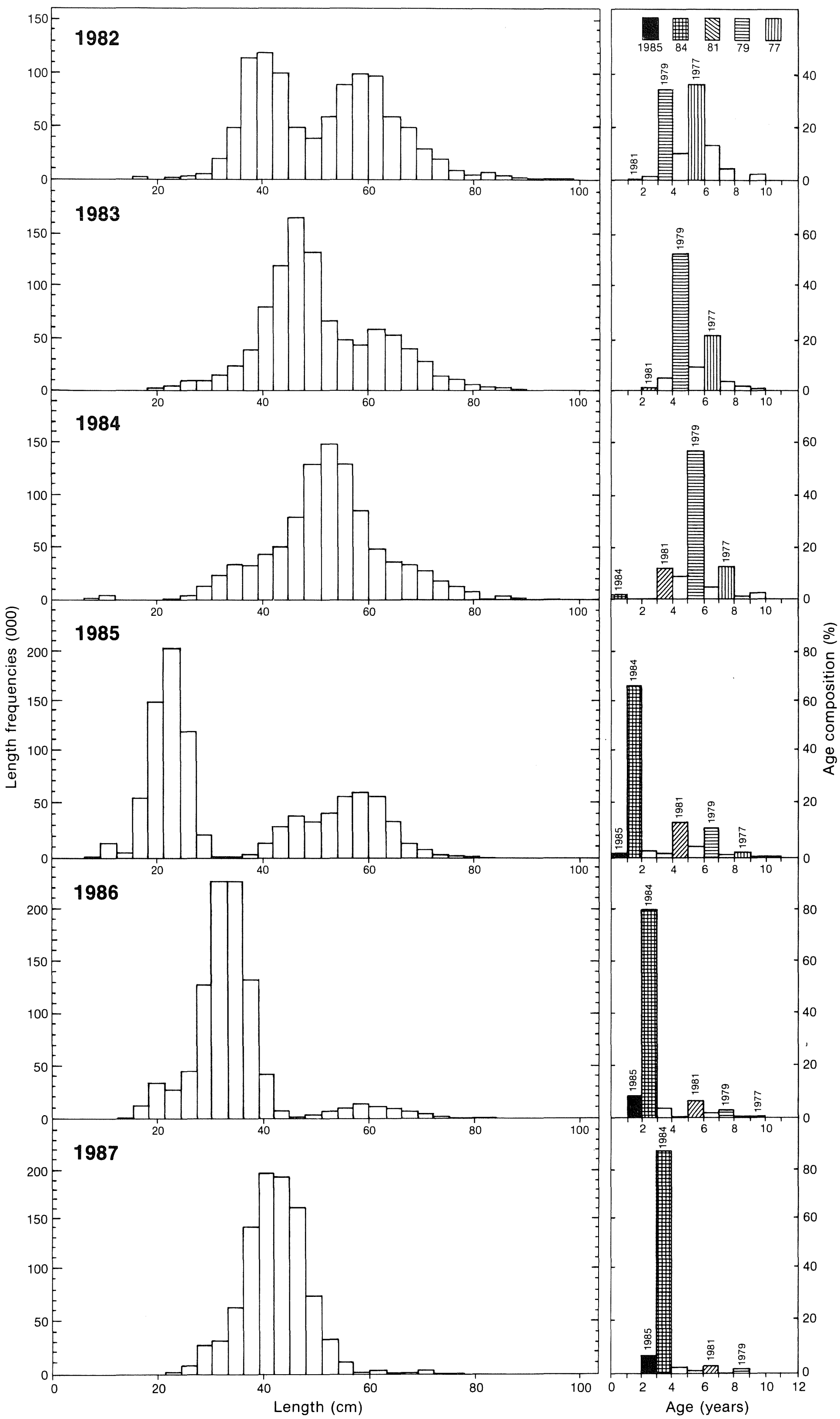

Fig. 7. West Greenland cod. Length frequencies and age composition from autumn survey results, 1982–87.

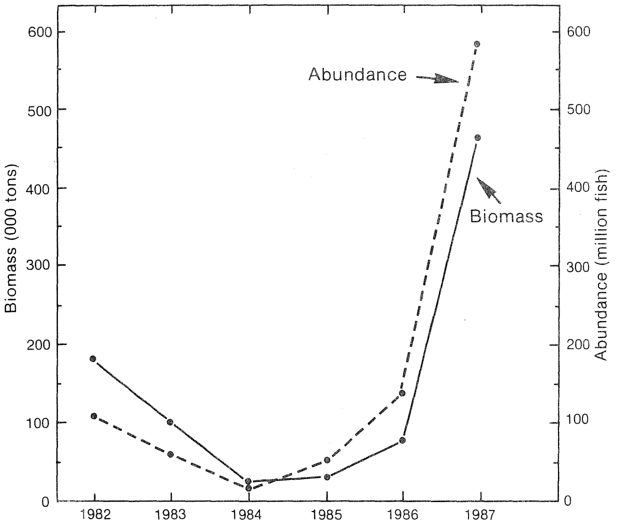

Fig. 8. West Greenland cod. Trends in survey biomass and abundance, 1982-87.

Fluctuations in cod recruitment

Fishery biological investigations of the West Greenland cod stock over a period of 45 years up to 1973 (Schmidt, 1970), have shown a similar periodicity of 3 to 5 years in the occurrence of strong year-classes. Specifically they were 1942, 1945, 1947, 1950, 1953, 1957, 1961, 1965, 1968 and 1973. Compared with the long-term oceanographic observations over the last 25 years (1963-87), the strong year-classes of 1965, 1968 and 1973 appeared during warming periods when water temperatures were close to the long-term average. Extremely high fishing pressure during the 1960s and recruitment failure during the cooling period in the early-1970s 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 10 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 year-classes of 1975, 1977, 1979 and 1981, although below average, appeared every second year when water temperatures were close to the long-term average (Fig. 3). During the extreme cooling period of the early-1980s (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 period an unexpected strong 1984 year-class appeared and produced, up to the present, a considerable increase in cod abundance and biomass off West Greenland (Fig. 7 and 8).

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