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Size-at-age of Cod (*Gadus morhua*) off West Greenland, 1952–92

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Abstract

Size-at-age of Atlantic cod (*Gadus morhua*) in West Greenland waters is known to have changed substantially over time. Analysis of sample data from the offshore (NAFO Div. 1D) commercial catches of trawlers in the second quarters of the years 1952–92, showed maximum mean size-at-age of age groups 5, 6 and 7 in the early-1960s and in the late-1970s, while the minimum occurred in the early-1970s and in the mid-1980s. No evidence was found of a relationship between cod stock biomass and fishing mortality derived from Virtual Population Analysis and the size-at-age of the cod stock. It was found that the well documented emigration pattern of large mature cod from the West Greenland area may affect size-at-age of cod in the Greenlandic catches, especially in the most recent large year-classes of 1984 and 1985, although the observed pattern of changes in size-at-age at West Greenland was not likely to be explained by emigration alone. Size-at-age was well correlated with a mid-June Fylla Bank water temperature index, indicating a link between size of cod and climate.

Key words: biomass, cod, migration, mortality, size-at-age, temperature, West Greenland

Introduction

Both long-term and short-term changes in size-at-age of Atlantic cod (*Gadus morhua*) have been studied for many stocks, and several attempts to identify factors affecting growth have been made. Field studies on growth have generally focused on the effects of cod stock abundance, prey abundance and temperature.

Abundance is commonly assumed to affect the competition for food in cod stocks and thereby their growth rate. An inverse relation between growth and stock abundance may therefore be indicative of density-dependent growth. Indications of density-dependent growth have been suggested for the Northeast Arctic cod by Rollefsen (1953) and Ponomarenko (MS 1967), while Jørgensen (1992) found no such indications for immature cod during a 40 year period of study. Also for cod in the North Sea (Houghton and Flatman, 1981) and in the Northwest Atlantic (Millar *et al.*, MS 1990) indications of density-dependent growth have been reported.

Brander (1995) showed that most of the variability in growth between cod stocks throughout the North Atlantic was due to temperature. Temperature changes in the environment may therefore be considered as a possible cause for changes in cod growth, both directly affecting the growth rate and as an indirect effect of food availability. In general changes in water temperature have been related to changes of cod growth for the North-east Arctic cod (Nakken and Raknes, 1987; Jørgensen, 1992), Labrador/Newfoundland stock (Millar *et al.*, MS 1990; Cárdenas, 1994) and Iceland (Jonsson, 1965).

The literature leaves, therefore, uncertainties as to which factors are the most important in affecting the growth rate of cod stocks. At West Greenland substantial changes in size-at-age of cod have been known for a long time (Hansen, 1949; Hermann and Hansen, 1965; Hansen, 1987). Furthermore, both cod stock abundance and sea water temperature at West Greenland have fluctuated substantially since World War II (Hovgård and Buch, 1990). The West Greenland cod stock may therefore be suitable to study the influence of cod abundance and climate on changes in size-at-age. Size-at-age data of the West Greenland cod has previously been analysed in relation to cod abundance and climate. Hermann and Hansen (1965) studied the period 1924–62, however, in that study no estimates were made of stock biomass and fishing mortality and also the temperature index of the water temperature has been improved since. Hansen (1987) studied the period 1979–84, which covered only a period of five years with decreasing size-at-age of the cod stock but also decreasing cod abundance and water temperature, making separation between possible causes difficult.

The purpose of this paper is to document changes in size-at-age over a long period (1952–92) and discuss the changes in relation to cod stock biomass, fishing mortality, migration pattern and water temperature.

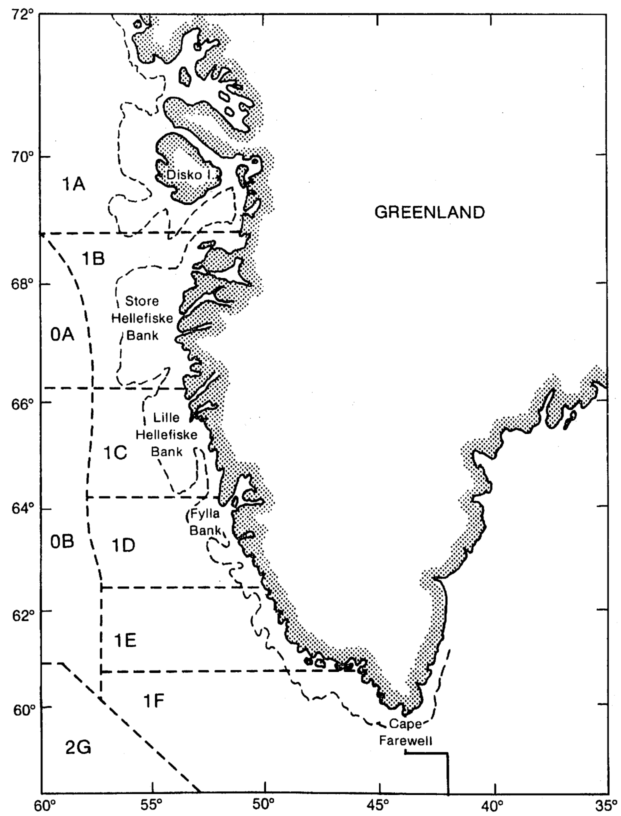

Fig. 1. Map showing NAFO Divisions.

Materials and Methods

A long time series (1952 to 1992) of length and age data were only available from the sampling of commercial catches. In choosing data to study changes in size-at-age it is desirable to minimise sampling biases derived from different sampling gear, sampling area or sampling time. Based on these considerations data time series of age-length keys and length composition of commercial catches were chosen from the second quarter (April–July) of the year taken in the offshore area of NAFO Div. 1D (Fig. 1). However, in some years it was necessary to include samples from just outside this region and season. The data being from such a long period, could not be limited to a single sampling gear. Before 1969, all samples were from long-line or handline catches, whereas samples from 1969 to 1992 were from trawl catches.

At West Greenland three different cod stock-components are involved: local stocks in fjords, offshore stock with spawning grounds at the south West Greenland banks, and cod of Icelandic origin (Buch *et. al.*, 1993). The selected stocks for sampling commercial catches was believed to be composed mainly of the two offshore stock components between which a distinction has not been possible.

Total length measurements of the cod were recorded to the cm below. Mean length-at-age was calculated by combining age-length keys and length distributions pertinent to that fishery. Only mean length-at-age based on at least 5 age determinations have been included in the data base.

Mean length-at-age data for the period 1952–92 used in this study are given in Table 1. Several age groups were not sufficiently abundant in the samples to calculate mean length, simply because some year-classes were very scarce. In the 1950s and 1960s, the catch was generally composed of many year-classes, and older cod constituted a significant part of the catch. In the 1970s the catch dropped dramatically, and the fishery was based on few year-classes. From 1989 and until 1992, only two year-classes (1984 and 1985) constituted nearly 100% of the total catch, and since 1992 no offshore cod fishery has taken place due to a complete recruitment failure on the West Greenland fishing grounds.

TABLE 1. Mean length-at-age of cod from the second quarter of each year of commercial catches at West Greenland in NAFO Div. 1D.

Age	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
4	–	–	–	–	54.2	45.9	–	–	50.0	50.8	54.5	52.8	49.1	49.4
5	55.1	52.8	–	56.2	51.1	54.1	57.8	–	57.5	61.2	63.4	61.7	58.2	60.3
6	59.1	61.6	59.9	60.2	61.1	61.3	63.3	65.4	63.0	70.9	70.5	69.7	67.3	68.6
7	69.8	66.6	63.6	64.4	72.8	67.5	70.3	–	69.5	73.8	75.3	78.4	73.2	74.2
8	74.7	72.6	70.4	69.1	67.5	71.9	72.2	73.0	75.0	78.1	83.5	80.9	79.6	79.7
9	73.8	77.5	71.9	74.3	71.9	74.5	–	77.5	75.9	81.9	83.6	–	84.2	85.5
10	77.5	74.9	76.1	76.5	–	76.1	–	–	80.9	82.9	–	89.4	–	85.4
11	79.8	77.2	–	–	78.3	–	78.5	–	–	85.8	–	91.3	87.4	–
12	–	–	83.6	79.5	80.2	83.4	–	80.2	–	85.2	85.8	–	–	91.4
13	–	80.8	92.4	–	76.3	84.9	–	–	82.0	88.7	–	–	–	–
14	–	–	89.7	–	84.1	–	–	–	–	88.3	–	–	–	–
15	–	–	85.2	–	81.5	86.9	–	–	–	–	–	–	–	–

Age	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
4	47.1	52.8	44.8	43.9	42.9	41.4	47.5	51.1	–	50.3	48.3	48.7	51.1	48.0
5	57.2	56.0	54.7	53.5	58.5	54.4	55.7	53.7	–	57.9	59.8	54.3	60.4	60.4
6	65.0	66.0	61.2	64.2	56.5	66.5	64.7	60.4	66.1	65.8	67.0	62.3	67.5	69.2
7	72.6	73.8	69.7	72.7	63.4	67.0	73.1	67.7	71.6	75.1	74.1	–	76.9	77.2
8	77.0	79.7	73.6	77.2	70.0	72.6	71.2	80.5	82.0	80.5	75.4	–	–	86.6
9	83.7	82.5	76.8	80.6	80.8	78.6	76.6	–	–	86.5	77.4	–	–	89.0
10	86.7	88.0	–	–	87.4	83.2	80.5	–	–	–	89.5	–	80.4	95.0
11	86.4	96.7	87.5	–	89.3	88.8	84.4	–	–	–	89.7	–	87.4	96.6
12	85.0	95.7	–	–	88.3	–	89.1	–	–	–	100.0	–	91.4	–
13	89.6	94.4	–	–	94.9	–	–	–	–	–	–	–	–	–
14	–	96.6	–	–	–	93.3	–	–	–	–	–	–	–	–
15	–	106.8	–	–	–	–	96.6	–	–	–	–	–	–	–

Age	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
4	48.7	50.2	46.0	46.0	43.6	47.7	47.9	–	48.7	48.4	–	47.1	–
5	57.5	58.0	55.2	49.4	51.3	49.9	54.8	56.5	51.4	53.2	48.9	49.1	47.7
6	67.0	67.2	63.0	57.0	60.8	56.2	58.8	61.3	58.9	–	53.4	–	–
7	73.3	74.6	71.6	66.5	64.1	64.3	63.3	65.6	69.6	–	58.9	–	–
8	80.2	79.4	76.2	70.5	71.4	67.0	67.9	69.0	65.0	–	–	–	–
9	88.5	78.1	73.6	74.8	76.1	–	71.4	–	68.4	–	–	–	–
10	–	85.7	–	–	81.1	68.8	–	72.4	–	–	–	–	–
11	–	–	–	–	–	–	–	–	–	–	–	–	–
12	–	–	–	–	–	79.0	–	–	–	–	–	–	–
13	–	–	–	–	–	–	–	–	–	–	–	–	–
14	–	–	–	–	–	–	–	–	–	–	–	–	–
15	–	–	–	–	–	–	–	–	–	–	–	–	–

Cod stock biomass and fishing mortality were estimated by Virtual Population Analysis (VPA) (Anon., MS 1996). These data are given in Table 2.

As an index of the temperature conditions, observations taken at Fylla Bank off West Greenland (approximately 64°N) were used. These observations had been made in mid-June each year since 1950. The temperature of the near-surface layer was calculated by averaging the observations at 0, 10, 20, 30 and 40 m. This Fylla Bank mid-June time series has been presented as Fig. 2 in Buch (MS 1993), and is given here in Table 2.

The relationships between variables were investigated by means of two-variable correlation coef-

TABLE 2. Cod stock biomass ('000 tons) and fishing mortality (F) estimated by Virtual Population Analyses, and Mid-June Fylla Bank temperature (°C) (from Buch, 1993).

Year	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966
Biomass	3 286	2 855	2 848	2 882	2 771	2 144	2 222	2 157	2 649	2 653	2 433	2 414	2 428	2 247	2 311
F	0.14	0.11	0.14	0.11	0.15	0.21	0.20	0.19	0.19	0.26	0.40	0.37	0.39	0.41	0.40
°C	1.6	2.1	2.3	1.2	0.9	2.3	2.2	1.6	2.7	3.2	2.2	1.6	2.3	2.1	1.6
Year	**1967**	**1968**	**1969**	**1970**	**1971**	**1972**	**1973**	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**
Biomass	2 070	1 463	893	654	558	379	228	143	105	222	204	200	225	178	173
F	0.41	0.44	0.38	0.22	0.40	0.47	0.43	0.67	0.91	0.82	0.76	0.27	0.29	0.50	0.41
°C	1.5	2.1	0.3	0.3	0.8	0.7	1.7	1.0	1.9	1.4	2.1	0.9	2.2	1.9	1.6
Year	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**				
Biomass	160	124	93	59	61	250	334	329	168	54	25				
F	0.75	0.91	0.67	0.24	0.16	0.10	0.79	0.83	1.33	0.70	0.81				
°C	0.8	0.5	1.0	2.1	2.2	2.1	2.0	0.9	0.8	–	1.1				

ficients (Pearson's correlation coefficient), and by means of partial correlation coefficients, which express the degree of association between two variables after the effect of an additional variable has been removed (Johnson and Wichern, 1988). A significance level of 5% has been used.

Results and Discussion

Size-at-age

The general growth pattern calculated as the average length-at-age for the whole period is shown in Fig. 2, together with a fitted von Bertalanffy growth curve. The relatively flat growth curve with a low K-value of the von Bertalanffy growth equation seems typical for Atlantic cod stocks (see Taylor, 1958). If a narrower age range is considered, say 4 to 9 years old, the growth curve becomes nearly linear, as found for the Northeast Arctic cod (Jørgensen, 1992) and cod on the Scotian Shelf and Georges Bank in the Northwest Atlantic (Beacham, 1982).

Growth of cod differs between year-classes as shown in Fig. 3, where mean length-at-age for each year-class (year-class 1945 to 1984) is depicted together with the overall mean. It may be interpreted from Fig. 3 that year-classes with mean length-at-age above average and year-class with mean length-at-age below average are found in certain periods, rather than shifting from one year-class to the next and perhaps back again. This is apparent from the year-classes 1945 to 1950 which have mean length-at-age below average and are followed by the year-classes 1952 to 1960 with mean length-at-age above average. The year-classes 1961 to 1968 have length-at-age close to the average or a little higher than average and are followed by year-classes 1969 to 1974 with length-at-age above average. The remaining year-classes mostly have mean length-at-age be-

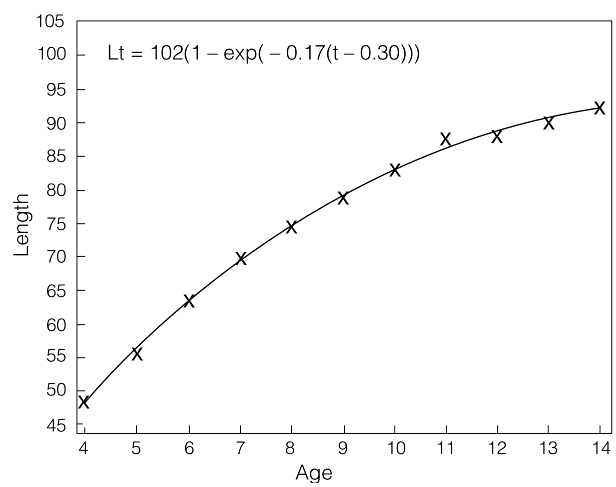

Fig 2. Average length-at-age of cod for the period 1952–90 together with a fitted von Bertalanffy growth curve.

low average. Such differences in growth between year-classes at West Greenland have been know for a long time. For a period ealier than the present study, Hansen (1949) identified fast and slow growing year-classes. He found that some of the year-classes in 1920s (1922, 1924 and 1926) had more growth than some of the year-classes in the 1930s (1931, 1932, 1934 and 1936).

The mean size-at-age shows substantial annual variations (Table 1). As an example, mean length of 5 year and 7 year old cod recorded in the mid-1980s were about 50 cm and 64 cm, respectively, and in the beginning of the 1960s they were about 60 cm and 75 cm. This corresponds to a difference in weight of about 1 kg for the 5 year old and 1.6 kg for the 7 year old. Similar differences in size-at-age of this magnitude in the West Greenland cod stock have been reported earlier by Hermann and Hansen (1965), who studied the period 1924 to 1962. Such variations in growth has of course great influence on the management of the cod stock, especially because of the prognoses they create in the scientific assessment of stocks.

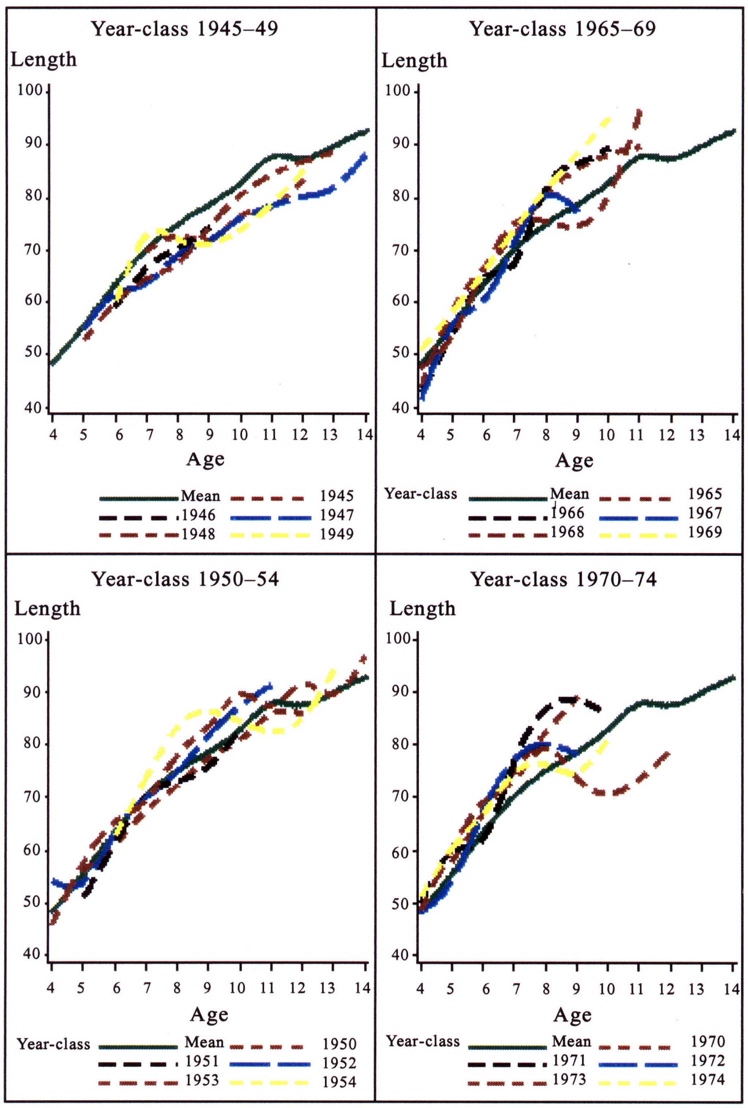

Fig. 3. Size-at-age cod year-classes 1945–84. The solid line show the mean size-at-age for the period 1952–90.

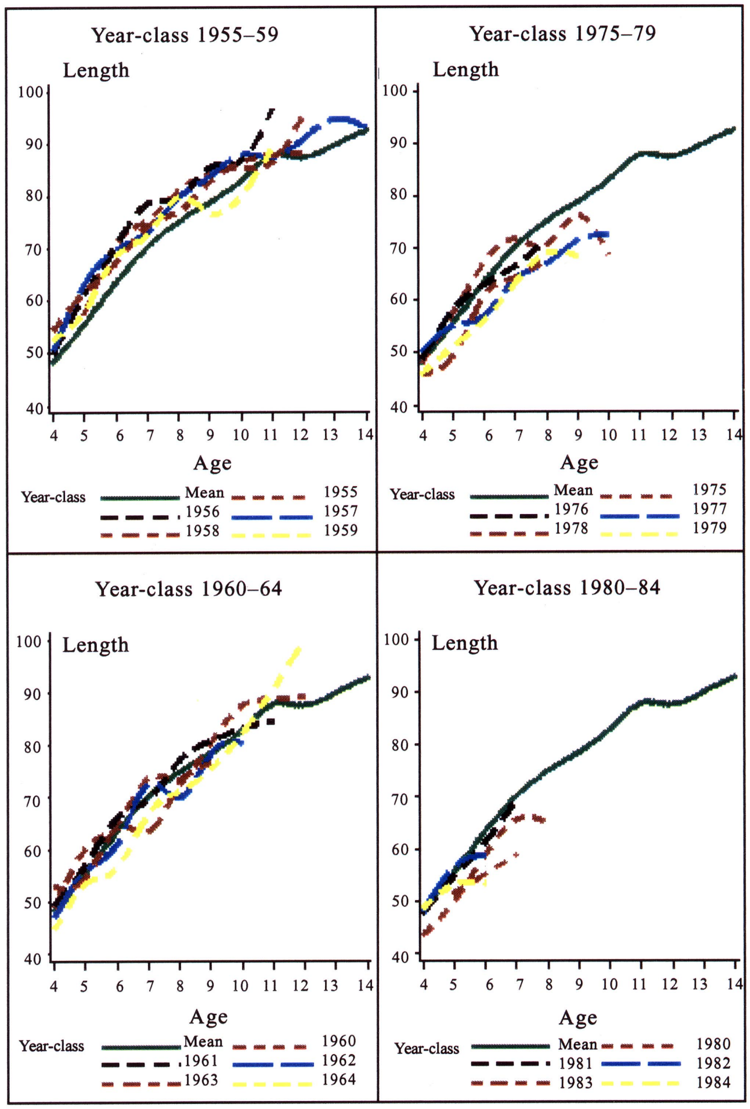

Fig. 3. (Continued). Size-at-age of cod year-classes 1945–84. The solid line show the mean size-at-age for the period 1952–90.

The mean size-at-age of 5 year old cod and older are believed to be less affected by size selectivity of the gear in the capture process than younger cod. Among these age-groups, the 5, 6 and 7 year old cod were the best sampled. Therefore they were chosen to show trends in mean length of cod. Mean length-at-age for age groups 5,6 and 7 year olds shows that they were at a maximum in the early-1960s and in the late-1970s, while they were at a minimum in the early-1970s and in the mid-1980s (Fig. 4). This interpretation was reinforced by the fact that the three selected age groups were highly correlated (Table 3).

Fishing pattern and fishing mortality

Fishing practices have changed during the period (almost 40 years) of this study. Before 1969 mean size-at-age data were based on samples from longline and handline catches, while after 1969 the samples were from trawl catches. Minimum mesh size regulation for trawls was introduced in 1966 (130 mm), and a minimum landing size of 42 cm was introduced in 1969. The minimum landing size was changed to 40 cm in 1973. Interestingly, however, around 1969, after the introduction of the minimum landing size and the beginning of the

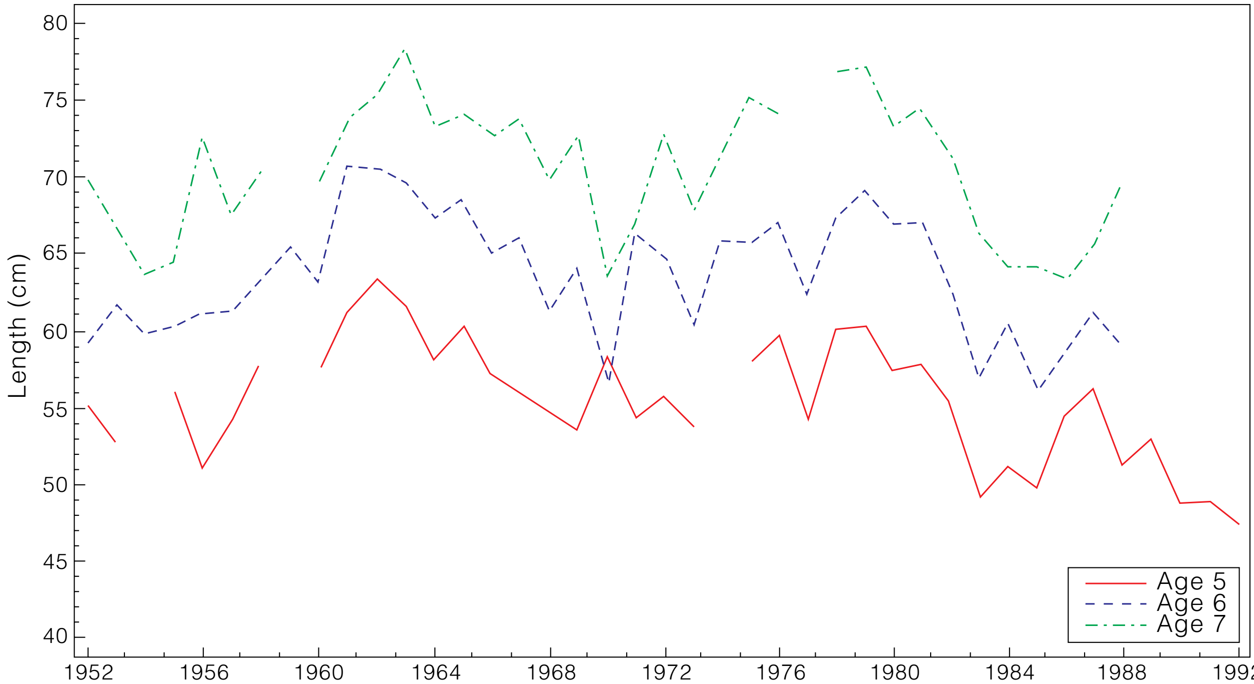

Fig. 4. Size-at-age of cod age groups 5, 6 and 7 years in the period 1952–90.

TABLE 3. Correlation coefficients between age-groups 5 and 6, 6 and 7, and 5 and 7, giving the probability of the correlation under the null hypothesis that the statistic is zero.

Ages	Correlation coefficients	Probability
5–6	0.85	0.0001
6–7	0.88	0.0001
5–7	0.72	0.0001

trawl fishery, the mean size-at-age showed increases (Fig. 4) which were opposite to what was expected from the longline selecting bigger cod than the trawl (Hovgård and Riget, 1992). Furthermore, the mean length of the 7 year old age group, which was believed to be little affected by size selectivity of either gears, showed substantial changes around 1969. Therefore, it seems unlikely that the observed trend in size-at-age over the time period was caused by either size selectivity of the gear or the mesh size regulations.

Nevertheless, if the cod fishery in some complicated way was related to the size selectivity of the gear in the range of the lengths of the 5 to 7 year old fish, then changes of fishing mortality may influence the size-at-age. It is noted that fishing mortality had indeed changed substaintially during the period of investigation (Table 2). During the 1960s fishing mortality increased from about 0.2 in 1960 to about 0.9 in 1975 and from the late-1970s onward the fishing mortality fluctuated substantially. Through the entire period a significant negative correlation was observed between the fishing mortality and size-at-age of the 5 year old cod, but not with the 6 and 7 year old cod (Table 4).

However, the size of cod in a particular year may not be influenced by the fishing mortality of that year alone, but also by the fishing mortality of the preceeding years. Figure 5 shows a plot of a fishing mortality index *versus* time, where the index is calculated as the three year running mean of the fishing mortality, i.e. the particular year and the two years ahead. Two years ahead was choosen because it is approximately the time period in which they may have been affected by the fishery. The general trend of the index shows similarity to the observed trends of fishing mortality although the fluctuations were not as pronounced, especially during the 1970s and 1980s. Also this fishing mortality index was observed to be significantly negatively correlated with the size-at-age of the 5 year old cod and not correlated with the 6 and 7 year old cod (Table 4). However, Table 4 also shows that

TABLE 4. Correlation coefficients and partial correlation coefficients between size-at-age and fishing mortality (F), three year running average of fishing mortality (F_i), cod stock biomass (B), temperature (T) and five years running average of temperature (T_i). p = is the significance probability of the correlation under the null hypothesis that the statistic is zero.

	Correlation coefficients					Partial correlation coefficients		
	F	F_i	B	T	T_i	$F_i \mid BT_i$	$B \mid F_iT_i$	$T_i \mid F_iB$
Age group 5	-0.39	-0.48	-0.20	0.35	-0.04	0.38	0.45	0.33
p	0.02	<0.01	0.26	0.03	0.84	0.03	0.02	0.07
Age group 6	-0.13	-0.20	-0.11	0.17	-0.06	0.26	0.38	0.30
p	0.43	0.24	0.55	0.30	0.54	0.11	0.02	0.09
Age group 7	-0.03	-0.09	-0.03	0.11	-0.09	0.13	0.32	0.29
p	0.86	0.62	0.87	0.51	0.63	0.44	0.07	0.11

there was no correlation between the fishing mortality index and size-at-age, when the effects of cod stock biomass and a temperature index were removed.

Cod stock biomass

It is commonly inferred that there is a density dependent growth if there is an observed correlation between size-at-age and stock abundance (Lett and Doubleday, 1976; Pérés-Gándaras and Zammaro, 1990). Estimates of cod stock abundance derived from a VPA are shown in Table 2 and Fig. 5. The patterns observed shows that stock biomass decreased dramatically from about 3 million tons in the early-1950s to about 200 000 tons in the early-1970s, and remained at this historical low level there after. A positive correlation between size-at-age of the 5 year old cod and the stock biomass was seen, but this was not found for the 6 and 7 year old cod (Table 4). When accounting for the effects of fishing mortality and temperature, no correlation was found (Table 4).

Some effects of density dependence may especially be seen when big year-classes occur. If a big year-class is arbitarily defined as a year-class with a VPA estimated size of more than 100 million 3 year old cod, the following year-classes are regarded as big year-classes: 1945, 1947, 1948, 1950, 1951, 1952, 1953, 1956, 1957, 1958, 1960, 1961, 1962, 1963, 1973, 1977 and 1984. Among these year-classes, some were observed to have above average size-at-age (e.g. 1953, 1956, 1957 and 1958), some had below average size-at-age (e.g. 1945, 1947, 1948 and 1977) and some around average (e.g. 1950, 1951 and 1960) as judged from Fig. 3. Therefore, this study gave no evidence of a relationship between cod stock biomass and mean size-at-age. This is in accordance to the conclusions made by Hermann and Hansen (1965) from the period 1924 to 1962.

Prey abundance

Beside changes in cod abundance, there may also be changes in the abundance of important prey species which also may influence the cod growth. Capelin is known to be an important prey species for cod where the two species distribution areas overlap (Barents Sea: Ponomarenko and Ponomarenko, MS 1975; Iceland: Palsson, 1983; Newfoundland/Labrador: Lilly, 1987). Capelin abundance may therefore be a good indicator for food availability for cod. Indications of capelin biomass to affect cod growth is suggested by Steinarsson and Stefánsson (MS 1991) for the Icelandic cod stock while this seemed not to be the case for the Labrador/Newfoundland cod stock (Millar *et al.*, MS 1990). For the Northeast Arctic cod growth in length of cod was found to be related to the ratio of capelin to cod stock abundance (Jørgensen, 1992). The information of food availability for cod off West Greenland is scarce, and there are no stock assessments carried out for any of the important prey stocks such as capelin and sand eel. Except for some incidental studies on cod stomach contents during the period (Köster, Danish Institute of Fisheries and Marine Research, pers. comm.), no information is available.

Migration

It is well documented from tagging experiments that some of the adult cod, mainly mature cod, migrate from West Greenland to East Greenland and

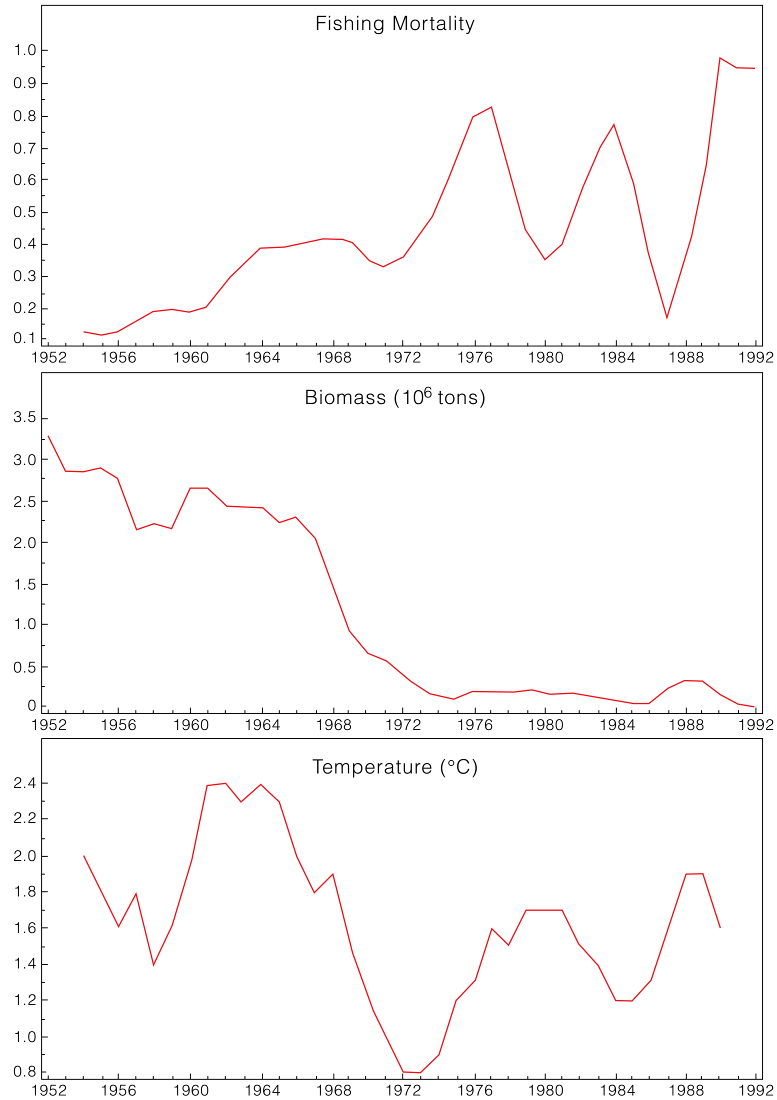

Fig. 5. Three-year running average of fishing mortality, cod stock biomass and five-year running average of Mid-June Fylla Bank temperature during the period 1952–90.

Iceland (Hovgård *et al*., MS 1989; Harden-Jones, 1968; Hansen, 1949). Schopka (1993) has identified a number of year-classes as having a high number of immigrants to Icelandic waters from Greenland. Among these year-classes, the following were included in this study: 1945, 1950, 1953, 1956, 1961, 1962, 1963, 1973 and 1984. These year-classes were all regarded as big year-classes at Greenland.

The proportion of the stock at West Greenland which migrate out of the area is uncertain, but it seems to increase in a southern direction along the West Greenland coast line (Hovgård, 1991; Hansen, 1949). The migration of large mature component of the cod stock from West Greenland would be observed as a decrease in the size-at-age in the catches at West Greenland. Looking at Fig. 3, such a decrease in size-at-age seems to occur from about 7 years and older for year-classes of 1945, 1953, 1956, 1973 and 1984. However, it is difficult to judge whether these observed decreases are more pronounced for these year-classes than for other year-classes not identified as immigrating to Iceland.

The 1984 and 1985 year-classes have shown a very slow growth rate, judging from the West

Greenlandic catches (Table 1). This may in fact be in part an artifact due to migration of larger cod away from West Greenland. At West Greenland three different stock-component are involved: local cod stocks in fiords, offshore cod spawning at Greenland, and cod of Icelandic origin (Buch *et. al.*, 1993). The 1984 and 1985 year-classes are believed mainly to have drifted as larvae from spawnings in Iceland and East Greenland waters, and after having sustained a fishery during 1988–90 they left West Greenland waters (Buch *et. al.*, 1993). It is believed that this stock component which originated from spawning areas in the east, totally dominated the West Greenlandic stocks in the late-1980s, while the local West Greenland stock component was at the same time at a very low level. Therefore, when spawning migration of these year-classes started at age 5, the effects on the size-at-age in the catches at West Greenland became very clear in contrast to the situation ealier when all three stock components were abundant.

Changes in size-at-age in the catches over a period of time can occur if the maturity ogive of a population changes as a result of different proportions of the age groups migrating out. Unfortunately only few intermittant studies of maturity ogives exist for the time period of this study, and no relationships or trends in size-at-age could be made from these reports. The trends of size-at-age for the 5 to 7 year old age groups were very similar, irrespective of the different proportion of mature fish in these age groups. Therefore, although migrations out of West Greenland may have affected the size-at-age observed in the Greenlandic catches, they were not adequately represented to explain the observed trends in size-at-age.

Temperature

The major influencing factor of the sea water temperature at West Greenland is the West Greenland Current. The West Greenland Current is derived from two current components: the cold East Greenland Current of polar origin and the warm, more saline Irminger Current, which is a branch of the North Atlantic Current (Buch, 1984). The two components meet in an area southeast of Greenland and flow side by side and undergo some mixing around Cape Farewell before turning northward along the west coast of Greenland. It is then known as the West Greenland Current. The intensity of the two current components shows distinct seasonal variations as well as great interannual variations (Buch, 1984).

The water temperature may be considered as a possible cause for changes in size-at-age, both directly affecting the growth rate and indirectly with an effect on prey abundance. Temperature may also change the distribution pattern of the cod population in a way that affect size-at-age. In the early-1980s a southern movement of the cod stock took place observed by the annual bottom-trawl surveys conducted by research vessels of Germany (Messtorff and Cornus, MS 1984). These surveys also found a gradual increase in size of cod from north to south during these years, and an identified decrease of size-at-age in one particular area.

In general, there are considerable problems in choosing appropiate temperature data that might indicate effects on growth. Millar *et al.* (MS 1990) used bottom temperature in their analysis, while Steinarsson and Stefánsson (MS 1991) used mean temperature at 50 m depth and Jørgensen (1992) used average temperature for the 0-200 m depth interval. In the present study, a temperature index for the surface layer on a standard hydrographic station was used. Although this is not the depth stratum where the cod is found, it was assumed that this index may be more representative of conditions of the ecosystem, such as conditions for primary and secondary production, than the bottom temperature would be.

During the study period, the temperature of the surface layer showed great interannual variations ranging from 0.3°C in 1969 and 1970 to 3.2°C in 1961 (Table 2). Size-at-age of age group 5 was found to be correlated with the temperature at the 5%-level, while this was not the case for age group 6 and 7 (Table 4). Figure 5 shows the trends of a 5-year running average of the surface temperature calculated as the mean of the temperature of that particular year and the 4 years ahead. The plot shows relatively high running average temperatures in the 1960s followed by a period in the early-1970s with low average temperatures and then again increasing in the late-1970s. In Fig. 6 is shown plots of the temperature index *versus* size-at-age of age groups 5, 6 and 7. For age group 5 and 6 significant correlations were found, and for age group 7 the significance probability was just above the 5%-level (Table 4). However, these correlations were found to be just above the 5% level for all age

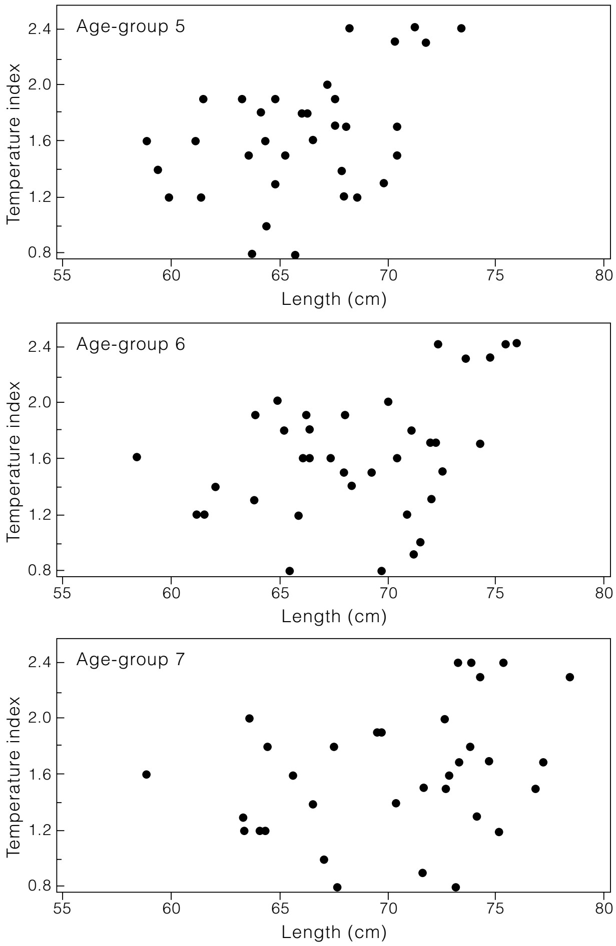

Fig. 6. Plots of five-year running average of mid-June Fylla Bank temperature (°C) *versus* size-of-age of cod age groups 5, 6 and 7 years.

groups, if the influence of fishing mortality and cod stock biomass are removed from the size-at-age.

In previous studies changes of size-at-age have been observed with climatic change Hansen (1949). The study showed that there are great fluctuations in size-at-age, especially in the northern areas of West Greenland for the year-classes in the 1920s and the 1930s, and these fluctuations were partly explained by changes in climate. From the 1920s to the beginnings of the 1950s the size-at-age decreased steadily and from about 1955 to the beginnings of 1960s the size-at-age increased (Hermann and Hansen, 1965). They believed that variations in size-at-age were mainly due to an effect of temperature variations. Hansen (1987) documented the dramatical decrease of size-at-age that occurred in the late-1970s, and discussed the possible influences the climate may have had.

In conclusion the results presented here together with previous studies indicate a link between temperature and size-at-age of the West Greenland cod stocks.

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