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Some Considerations About Annual Growth Rate Variations In Cod Stocks*

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Abstract

In this paper the annual evolution in the mean weight-at-age in the stock is studied for 3 populations of cod in the North Atlantic area: viz Northeast Arctic cod stock, Icelandic cod stock, and NAFO Div. 2J+3KL cod stock. A strong annual effect was observed in the three populations analyzed, since all ages of each stock seemed to have the same trends each year. The behaviour of ages 3–7 were very similar, but older ages differed somewhat. The annual increases seemed to have little relationship with the stock biomass. Nevertheless, the maximums of biomass usually brought about declines in growth rates. Growth rate appears to be related to both temperature and availability of the prey species, when capelin (prey species) biomass/cod biomass ratio was used as an index of abundance.

Key words: Cod, environment, growth

Introduction

The mean weight-at-age of cod stocks show great annual variations according to the environment. This is particularly apparent in the younger ages of less than 7 years, where the maximum of the series could double the minimum value (Anon., MS 1994). It is well known that some of the most important factors affecting growth are availability of food, which provides energy, and temperature, which relates directly to the rate of metabolic activity. Wooton (1990) carried out a review of factors affecting teleost fish growth from studies done in both natural environments and laboratory. He summarises, among others, the following conclusions: "Growth depends on energy and nutrients provided in food, the relationship between growth rate and ration size at the same temperature is usually curvilinear approaching an asymptote at high rations", and "At maximum rations growth rate increases with increase in temperature up to a peak but then decreases with further increase in temperature. At low rations growth rate declines with increasing temperature." Temperature in fact could have two levels of effect on fish growth. The first as noted above is a direct effect as it regulates the rate of fish metabolism. There is another indirect effect. This is the effect it has on the growth of prey, and that of the prey of prey, and this in turn affects the biomass of prey available to the predator.

Among others, some studies have highlighted a possible relationship between cod growth and density. Lett and Doubleday (1976) for example suggested that this relationship would constitute a mechanism which regulates the population of Gulf of Saint Lawrence cod. It was suggested that an increase in density of cod will bring about a decrease in the quantity of food per predator, consequently there would be an increase in the time spent in the search for food and the period of time between feeding. This general effect is, it will decease the quantity of energy flow and, has been seen by Wooton (1990), the growth and fecundity of cod will decrease. Pérez-Gándaras and Zamarro (MS 1990) also suggested that growth was density dependent at the time of cod recruitment on the Flemish Cap. However, a good relationship between the density of cod and the decrease in the quantity of food can only be expected to be observable is if the quantity of food available at the beginning of the year is constant. The quantity of food available (prey biomass) unfortunately does not only fail to remain constant, but tends to vary even more than predator biomass. This is particulary so, as these organisms are in the lower levels of the food chain and they are usually more opportunistic feeders than their predators. Consequently their biomass fluctuate more according to fluctuations in the environment than the cod as a predator.

For this reason, authors like Joergensen (1992), searched for a more accurately definable index of food availability, in relation to growth. The study particulary addressed the long-term changes in growth of immature Arctic cod and related these to variations in the ratio of capelin to cod stock abundance (an index of food availability) and temperature fluctuations.

* This is a share of a contribution presented by the author in the Workshop of Fish Stock Enhancement (Copenhagen May 1994).

Growth of cod was found to be positively related to the index of food availability and to increasing water temperature.

The aim of the present study is to analyse the behaviour of the increases in the average weight-by-age for the different age groups of cod to see whether they follow similar trends, and to try to relate these trends to the stock biomass, to an index of availability of prey and to an index of temperature.

Materials and Methods

For this study, data of average weight-by-age in the stocks corresponding to three northern cod populations, viz Northeast Arctic cod, Icelandic cod and cod in Div. 2J+3KL obtained from published sources were used. The data for Northeast Arctic cod and Icelandic cod were from ICES Working Group reports (Anon., MS 1993; MS 1994;) and data for cod in Div. 2J3KL were from Bishop *et al*. (MS 1993).

For each of the stocks studied, weight increases were calculated for each year and age using the formula:

$$\Delta W_{ya} = W_{y+1\,a+1} - W_{ya}$$

where ΔW_{ya} = Weight increase undergone by the age group a throughout, the year y.

$W_{y+1\,a+1}$ = Average weight of the age a+1 in the year y+1.

W_{ya} = Average weight of the age a in the year y.

For each of the ages, the average for the period studied was obtained using the formula:

$$\Delta \overline{W}_a = \Sigma \ \Delta W_{ay}/N$$

where $\Delta \overline{W}_a$ Mean weight increase of the age a during the period.

The differences of each year with respect to the average were obtained as follows:

$$\text{dif}\ \overline{W}_{ay} = \Delta W_{ay} - \Delta \overline{W}_a$$

The standard deviation of these was extracted and used to normalize each of the series, dividing them by their standard deviation. This permits the representation of the patterns of each age in the same units. The normalized series are represented together, to observe whether similar trends exist in the growth evolution of different ages, and separated to check that ages behave in similar ways.

To analyse whether a relationship exists between annual increases and population density, the total stock biomass was used as an index of its density. The series of total stock biomass was normalized to be analogous to the series of growth rate-by-age. As the expected relationship between growth and density is negative, the series of normalized total biomass was multiplied by -1 to represent this factor more clearly, and is shown together with the series of growth rates of ages 3–7. Icelandic cod growth rates were compared with the series of normalized capelin biomass/cod biomass, which is an index of availability of the main prey of cod.

Finally, the growth rates of cod from Div. 2J+3KL were compared with the normalised series of the Cold Intermediate Layer (CIL) in the area of Bonavista, Newfoundland (Sinclair, Department of Fisheries and Oceans, Moncton, Canada, pers. comm.), with the sign changed, which can be considered as an index of winter coldness.

Results

In each of the 3 populations studied, similar trends were detected in the growth patterns of all ages (Fig. 1–3). In each of the stocks studied, a great similarity existed in growth patterns of the series of age groups less than 7 years (Fig. 1–3).

Comparing the annual growth with biomass with the sign changed, it can be seen that in the case of Arctic cod there was a one year delay in the growth response to changes in biomass, although this relationship disappeared in the last two years (Fig. 4). Nevertheless, in the case of Icelandic cod, the response seemed to come in the same year, and there seemed to be no great relationship if the period 1980–88 was excluded (Fig. 5). In the case of cod in Div. 2J+3KL, the growth rate change even seemed to come forward a year, with which the relationship between these two parameters was not clear (Fig. 6).

When growth rates were analyzed as a function of the index of available prey, in the case of Icelandic cod a much better fit was obtained than when the stock biomass was used, although age 3 tended to deviate from the general tendency with respect to the biomass with the sign changed (Fig. 5).

Examining cod growth rates in NAFO Div. 2J+3KL with respect to the coldness index in the area (area of the CIL multiplied by -1), a much better fit was observed in the evolution of this variable with respect to the growth rates than those seen considering the stock biomass with the sign changed (Fig. 6).

Discussion

The trends in weight growth of different ages were similar for the 3 cod stocks studied. This is

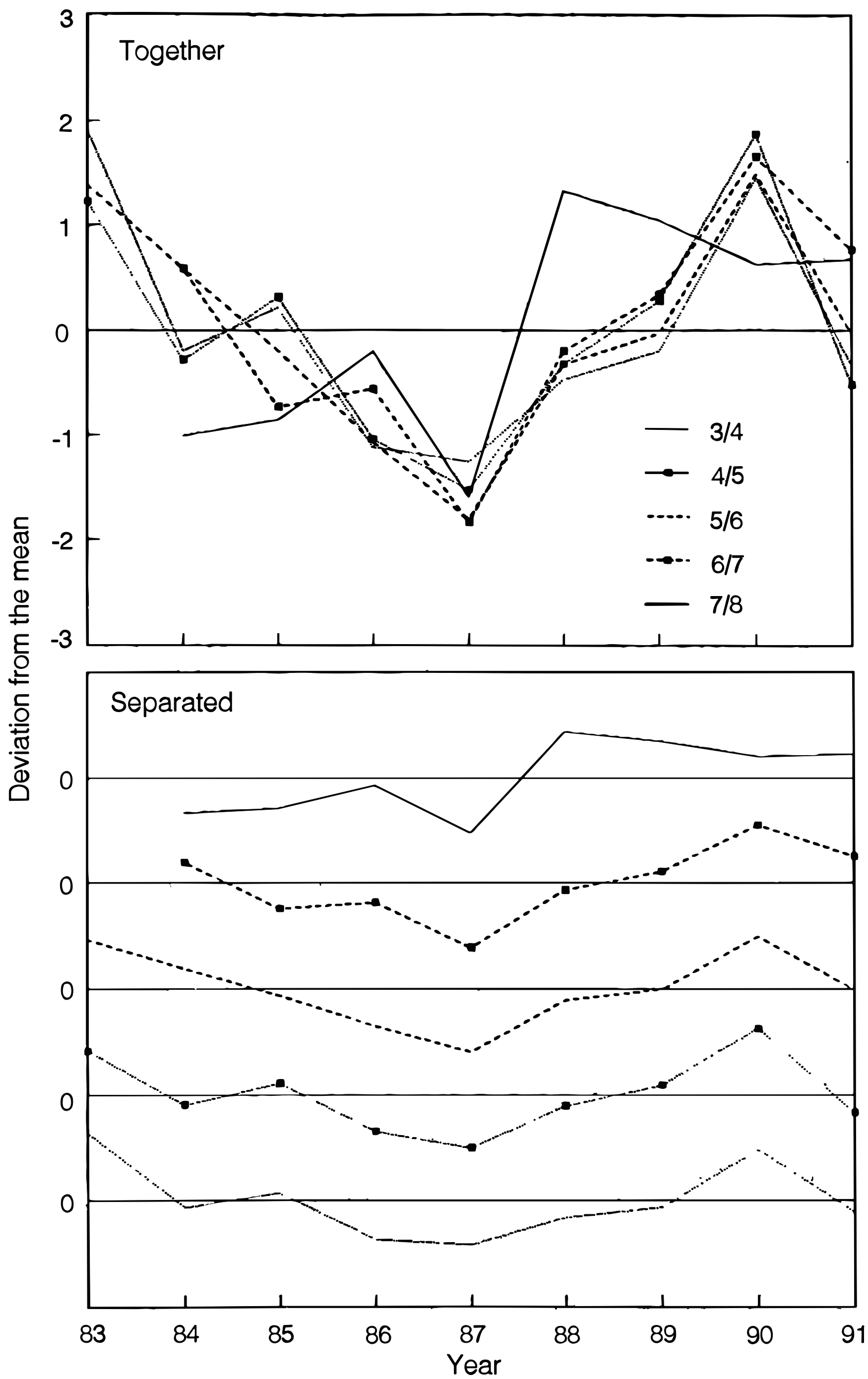

Fig. 1. Annual deviations in the mean weight increments for ages 3–7 in North-East Arctic cod stock, together (**A**) and separated (**B**).

not surprising since the determining factors of growth each year, which, as we have seen in previous studies (Joergensen, 1992; Wooton, 1990) are mainly availability of food and temperature, tend to affect the whole population. However, the differences in relative importance were observed in some age groups more so than in others, particularly in the older age groups. The greater similarity in ages below 7 years in cod, can be explained when we take into account that cod reach maturity at around the ages 6–7 years, with the physiological and behaviourial changes that come with it (especially migrations).

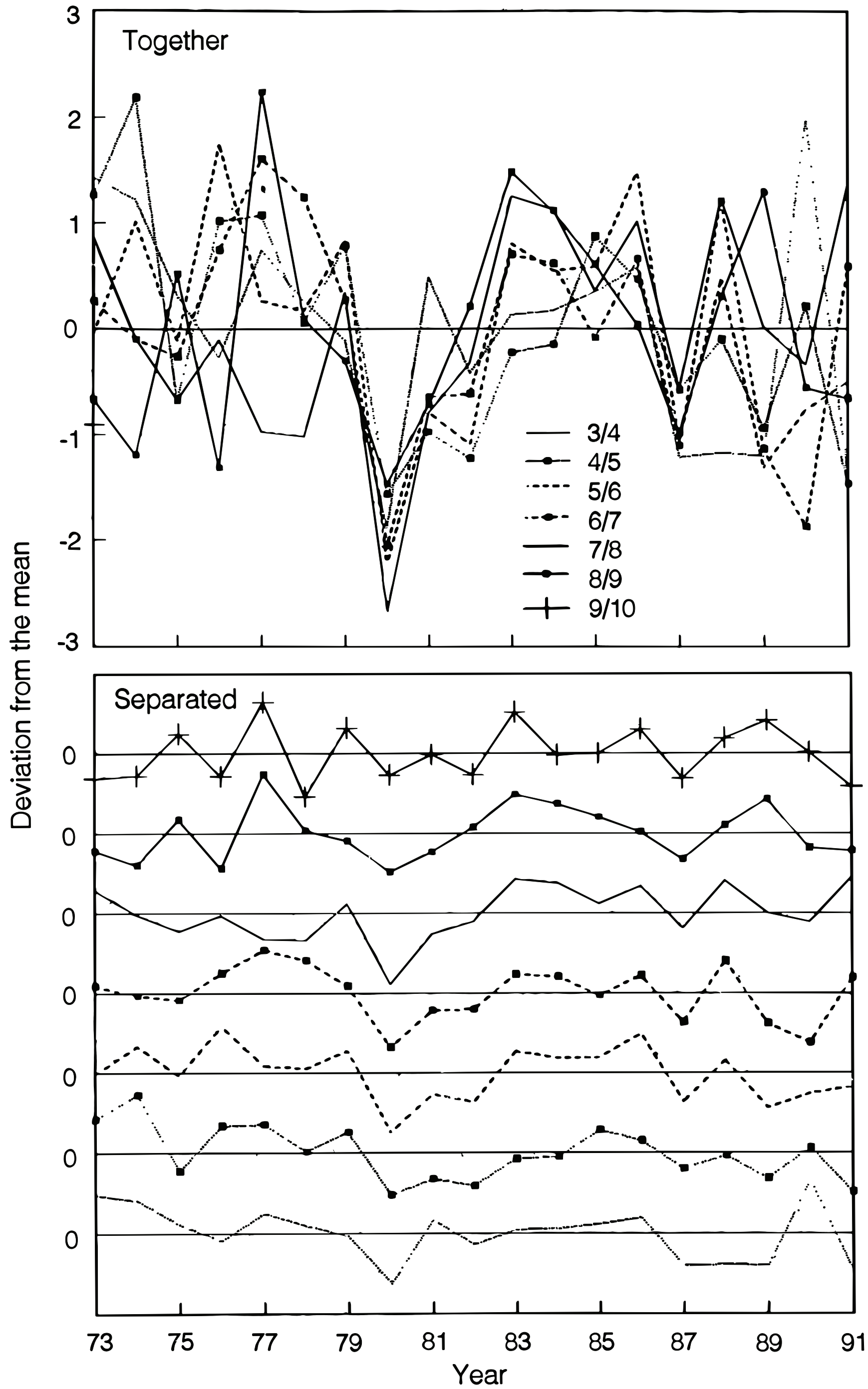

Fig. 2. Annual deviations in the mean weight increments for ages 3–9 in the Icelandic cod, together (**A**) and separated (**B**).

None of the stocks observed seem to present a good correlation between growth rates and total stock biomass. Nevertheless, the maximums of biomass usually bring about decreases in growth rates.

This would seem surprising at first, since a relationship between predator density and diminishing availability of food was expected, and this lesser availability of food would bring with it a decrease in growth in weight. The lack of a clear relationship between stock biomass and growth rates is due, among other reasons, to two factors: 1) An increase in the biomass of the population is not always strictly manifested as an increase in density, since it can

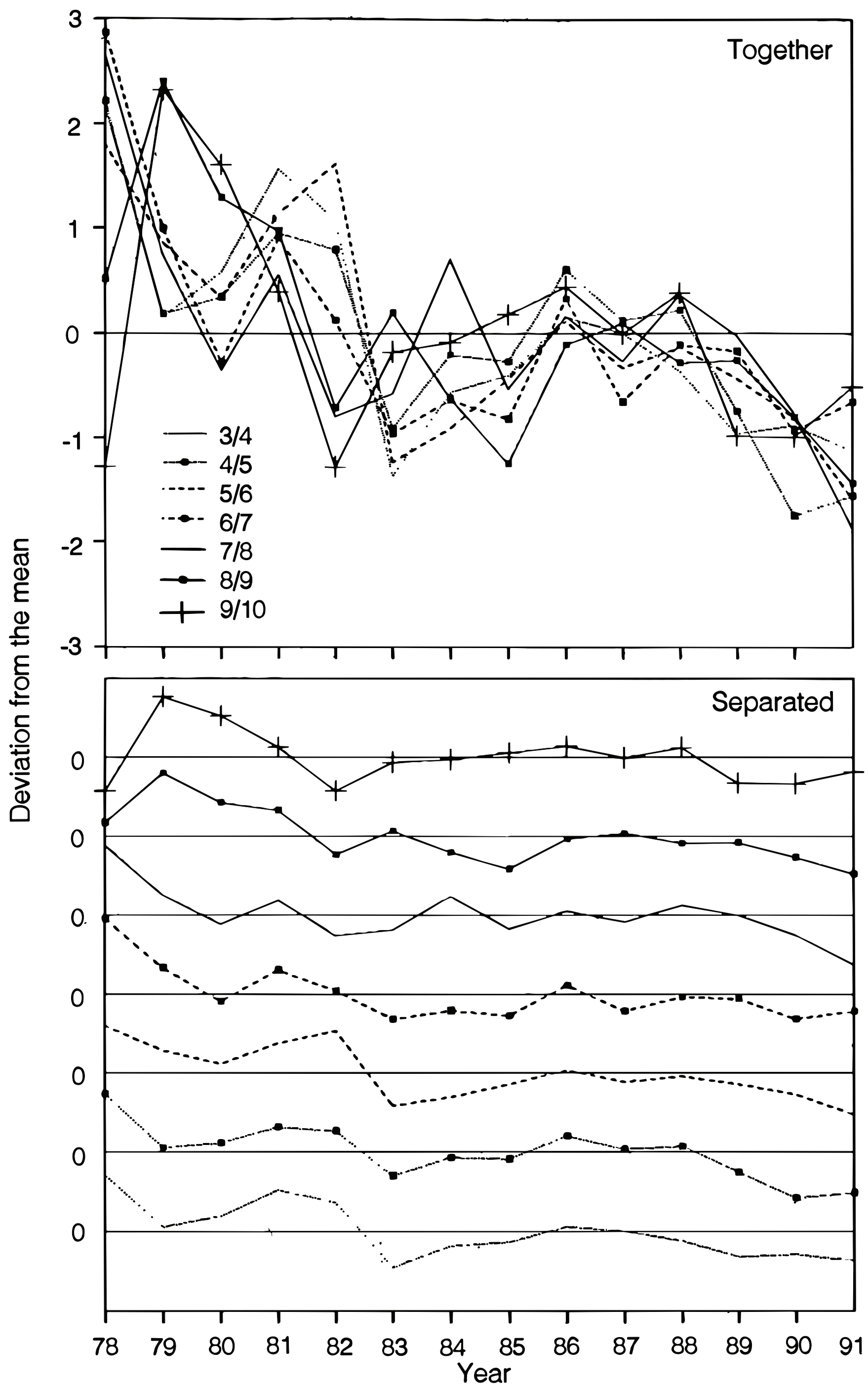

Fig. 3. Annual deviations in the mean weight increments for ages 3–9 in NAFO Div. 2J+3KL cod stock, together (**A**) and separated (**B**).

bring about an increase in the area of distribution. This phenomenon is well known in pelagic fish of short lifespan such as the anchovy or sardine (Mac Call, 1990), but also appears in demersal species like cod (Swain and Wade, 1993). 2) Prey density will also constitute a regulating factor of the availability of food and while the prey/predator ratio remains constant, growth should not be affected by the availability of food as long as the overlapping of the distribution of predator and prey remains constant. In fact, when we analyse the evolution of an index of food availability, such as the capelin stock biomass/cod stock biomass ratio in the case of Icelandic cod, we find a better fit with the weight

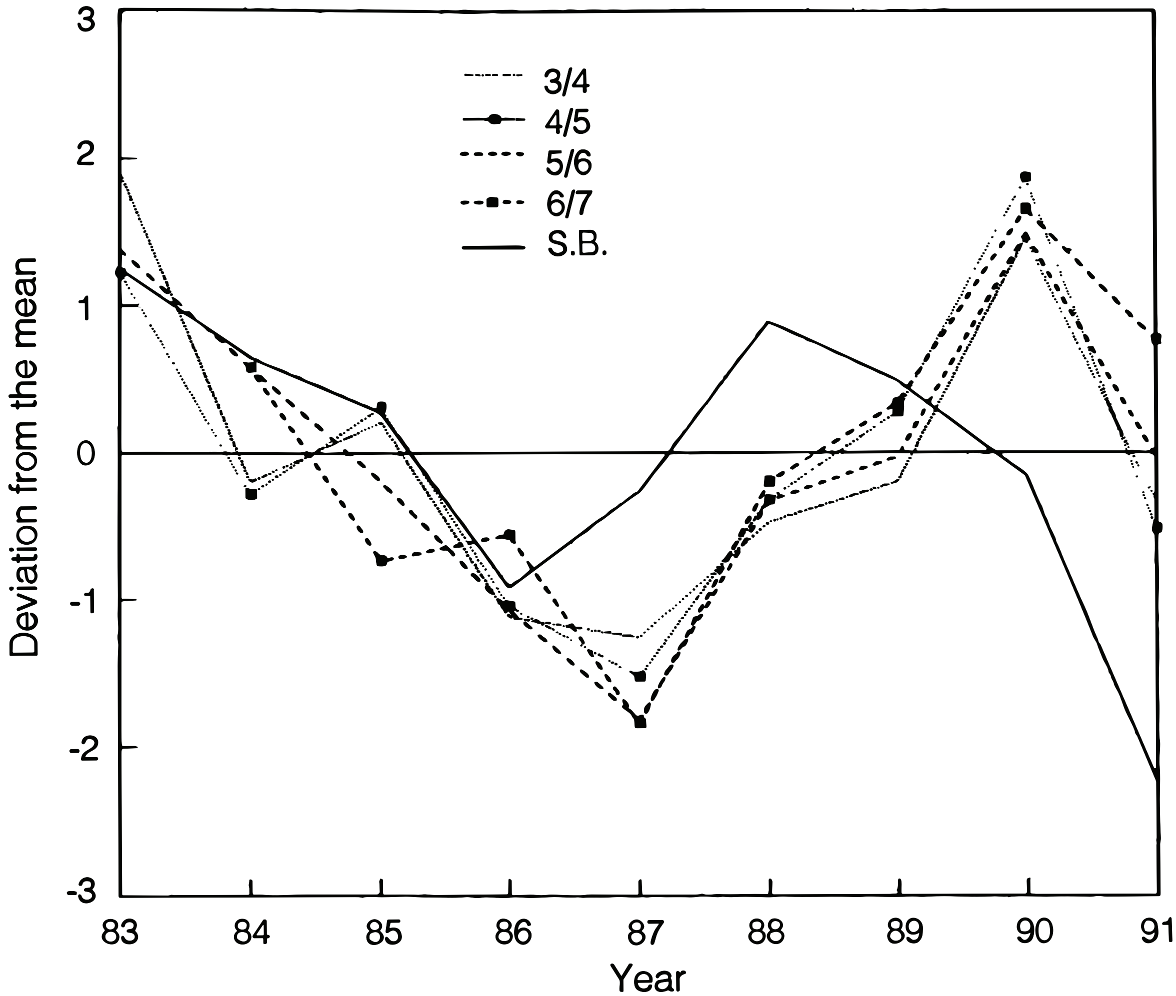

Fig. 4. Annual deviations in the mean weight increments for ages 3–6 in North-East Arctic cod stock, represented with the trend in stock biomass (sign changed).

increments. Magnusson and Palsson (1991) explain this relationship as "cod can only partially compensate for the loss of capelin by switching to other food. This holds true for all age groups of cod between 3 and 8 years old". The greater difference found at age 3 could be due to the fact that at this age capelin still makes up a small percentage of diet as can be seen, for example, in Gerasimova *et al.* (MS 1992). Magnusson and Palsson (1991) also suggest that capelin have greater importance in cod diet at age 5–7 years than at 3 years. The same authors provide another interesting piece of information in that their results "indicate that cod growth, biomass and yields, are not greatly affected as long as capelin biomass is above approximately 2 million tons. When capelin biomass is further reduced a more rapid decline in growth, biomass and yield is observed". This capelin/cod index was also used successfully in Norwegian Arctic cod (Jørgensen, 1992).

With respect to increases in growth rates due to physical factors, we also found a relationship between growth increases and the area of the CIL at Bonavista, for Div. 2J+3KL cod. The CIL area can be used to estimate the variability in the oceanographic conditions on the continental shelf off Newfoundland and southern Labrador (Narayanan *et al.*, MS 1992). So a greater area of the CIL, could indi-

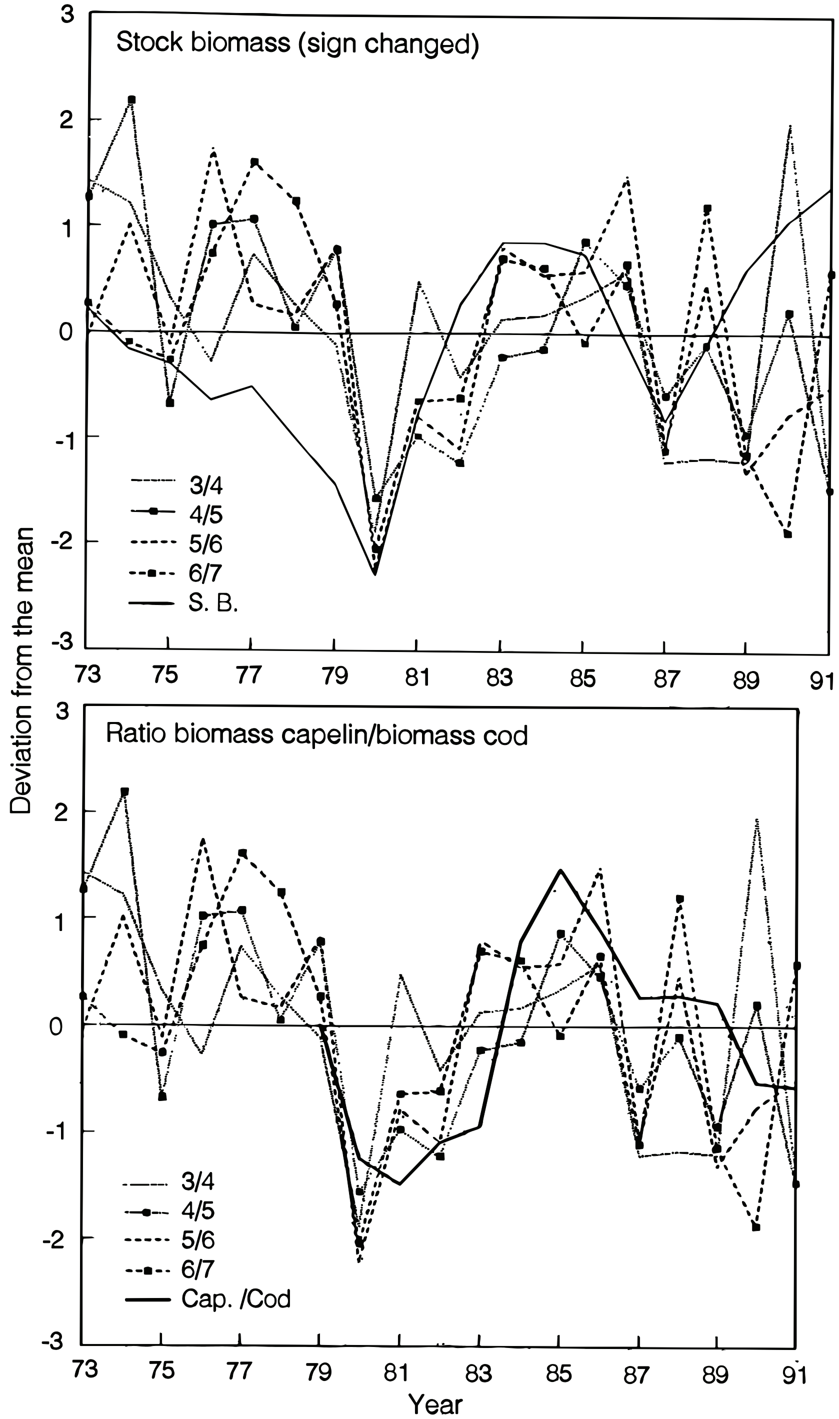

Fig. 5. Annual deviations in the mean weight increments for ages 3–6 in the Icelandic cod, represented with the trend in: **A**) stock biomass (sign changed) and **B**) ratio (capelin biomass)/(cod biomass).

cate that the year is colder, with the double effect mentioned above that this may have on fish growth. But the greater area of the CIL could also be acting on the concentration of cod. Since cod does not penetrate the area of the CIL (Hardy, 1978), as the area of the CIL increases and the area available to cod is consequently reduced, and it is obliged to concentrate at the bottom or over the slope.

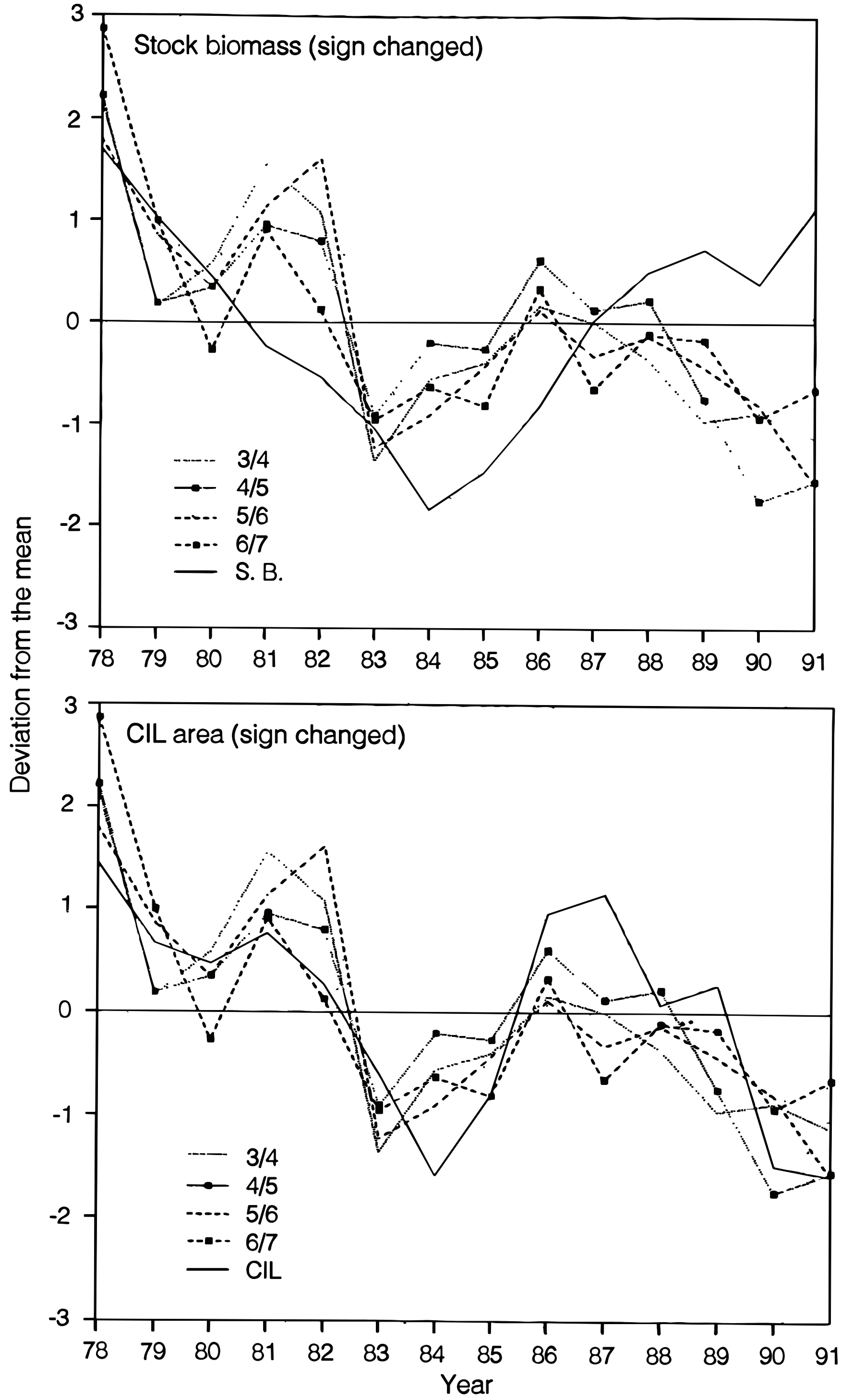

Fig. 6. Annual deviations in the mean weight increments for ages 3–6 in NAFO Div. 2J+3KL cod stock, represented with the trend in: **A**) stock biomass (sign changed) and **B**) Bonavista CIL area ratio (sign changed).

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Discussions

Comment: 1. There is good agreement between trends of growth of different ages.

Comment: 2. This is not surprising since climate changes must have an effect on all age groups. Also from the point of view of food availability this agreement makes sense.

Comment: 3. It would appear that the cold events as seen in the Icelandic paper (SCR Doc. 94/69) coincide with the minimum events in growth of Icelandic cod.

Comment: 4. Similar trends may be observed when comparing north-east Arctic cod and the increase of salinity at the end of the 1980s.