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Some Considerations About Annual Growth Rate Variations in Cod Stocks¹

by

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Abstract

In the present paper the annual evolution in the mean weight at age in the stock is studied for 3 populations of cod (Northeast Arctic cod stock, Icelandic cod stock, and 2J3KL NAFO Divisions cod stock).

In the three populations analysed, a strong annual effect is appreciated since all ages of the same stock seem to have the same trends each year.

The behaviour of ages 3-7 is very similar, though older ages differ somewhat more.

The annual increases seem to have little relationship with the stock biomass. Nevertheless, the maximums of biomass usually bring about falls in growth rates.

Growth rate appears to be related to both temperature and availability of capelin (capelin biomass/cod biomass ratio).

Introduction

Growth rates suffer great variations according to the environment. Some of the most important factors affecting growth are availability of food (which provides energy) and temperature (which accelerates the metabolism).

Wootton (1990) carried out a revision 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 could have two effects on fish growth, one direct, as it regulates the rate of fish metabolism, and another indirect acting on the growth of prey, and that of the prey of prey, affecting the biomass of prey available to the predator.

A possible relationship between cod growth and density has been suggested, for example, Lett and Doubleday (1976) suggest that this relationship would constitute a mechanism which regulates the population of Gulf of Saint Lawrence cod. Where an increase in density of cod will bring about a fall in the quantity of food per predator, consequently increasing the time spent in the search for food and the period of time between

¹ This is a share of a contribution presented by the author in the Workshop of Fish Stock Enhancement (Copenhagen May 1994)/

feeding, which will affect the quantity of energy brought, and, as we have seen (Wooton, 1990), the growth and fecundity of cod will decrease. Pérez-Gándaras and Zamarro (1990) also suggested that growth was density dependent at the time of Flemish Cap cod recruitment. A good relationship between the density and the fall in the quantity of food can be only expect when the quantity of food available at the beginning of the year is constant. Nevertheless, the quantity of food available (prey biomass), does not only fail to remain constant, but tends to vary even more than predator biomass, given that, as these organisms come earlier in the food chain, they are usually more opportunist than their predators and will consequently fluctuate more according to fluctuations in the environment.

For this reason, authors like Joergensen (1992), search for a more accurately index of food availability, and successfully test the relationship between growth and the capelin biomass fraction (the main prey of cod in that area) divided by total cod biomass.

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 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.

Material and Methods

For the present study, data of average weight by age in the stocks corresponding to three cod populations (Northeast Arctic cod, Icelandic cod and NAFO Divisions 2J3KL cod) has been used.

The data comes from ICES Working Group reports (Anon. 1993; 1994;) and Bishop et al. (1993).

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

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

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:

$$\Delta \bar{W}_y = \Sigma \Delta W_y / N$$

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

$$\text{dif } W_y = \Delta W_y - \Delta \bar{W}_y$$

The standard deviation of these was extracted and used to normalise each of the series, dividing them by their standard deviation.

This permits the representation of the behaviour of each age in the same units.

The normalised 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 normalised to be analogous to the series of growth rate by age.

As the expected relationship between growth and density is negative, the series of normalised 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 to 7.

Icelandic cod growth rates were compared with the series of normalised capelin biomass/cod biomass, which is a index of availability of the main prey of cod.

Finally, the growth rates of cod from NAFO Divisions 2J3KL were compared with the normalised series of the CIL area (Cold Intermediate Layer) of Bonavista (Sinclair, 1992), with the sign changed, which can be considered as an index of winter coldness.

Results

In each of the 3 populations studied, similar trends are detected in the behaviour of all ages (Figs. 1-3).

In each of the stocks studied, a great similarity exists in growth behaviour of the series of age groups less than 7 years (Figs. 1, 2, 3; below).

Comparing the annual growth with biomass with the sign changed it can be seen that in the case of Arctic cod there is a one year delay in the growth response to changes in biomass, although this relationship disappears in the last two years (Fig. 4). Nevertheless, in the case of Icelandic cod the response seems to come in the same year. Nor does there seem to be a great relationship if the period 1980-88 is excluded (Fig. 5 above). Lastly, in cod from NAFO Divisions 2J3KL, the growth rate change even seems to come forward a year, with which the relationship between these two parameters is not clear either (Fig. 6 above).

When growth rates are analysed as a function of the index of available prey in the case of Icelandic cod, a much better fit is obtained than when the stock biomass is used, although age 3 tends to deviate from the general tendency with respect to the biomass with the sign changed (Fig. 5 above and below).

Finally, examining cod growth rates in NAFO Divisions 2J3KL with respect to the coldness index in the area (area of the Cold Intermediate Layer multiplied by -1) a much better fit is 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 above and below).

Discussion

It is not surprising that the trends in weight growth of different ages are similar, since the determining factors of growth each year, which, as we have seen in the introduction are mainly availability of food and temperature, tend to affect the whole population. However, their different relative importance in some age groups than in others may bring about greater similarity in ages below 7 years in cod, particularly when we take into account that cod reach maturity at around 6-7 years, with the physiological and behavioural changes that come with it (remember migrations).

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 falls 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 fall in weight growth. 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 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 increments. Magnusson and Palsson (1991) explain this relationship "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 Garasimova et al. (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 "The results indicate that cod growth, biomass and yields, are not greatly affected as long as capelin biomass is above approximately 2 million tonnes. 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 (Joergensen, 1992).

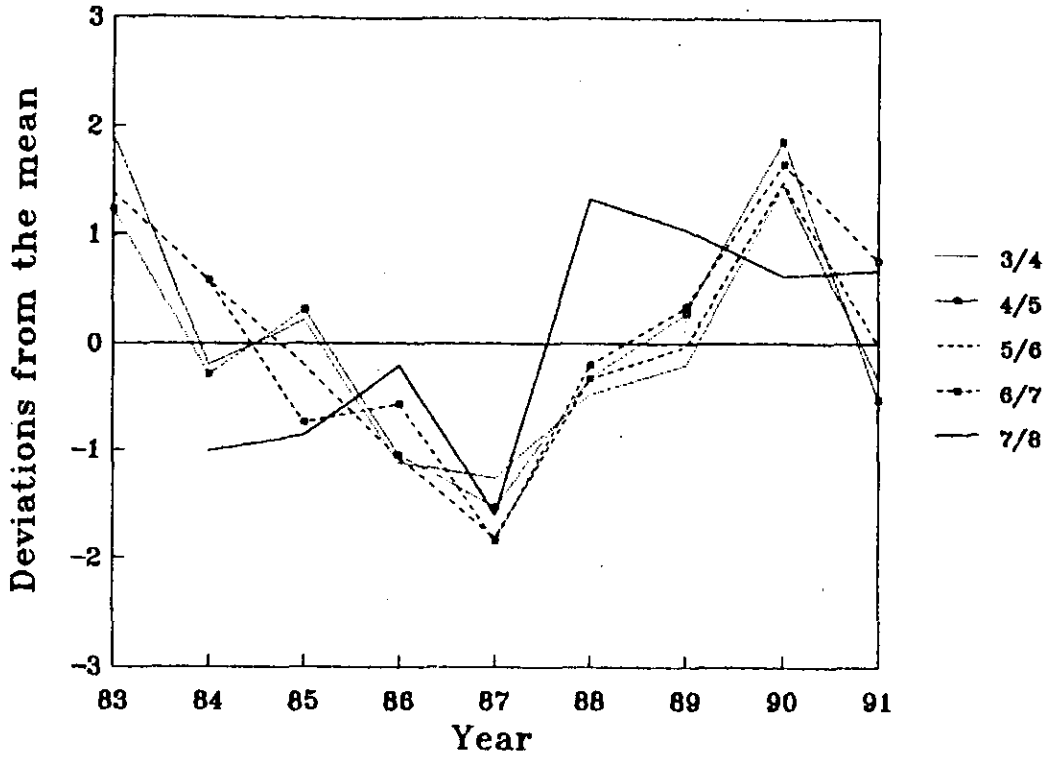
With respect to increases in growth rates due to physical factors, we also find a relationship between growth increases and the area of the CIL at Bonavista, for Divisions 2J3KL cod. CIL area can be used to estimate the variability in the oceanographic conditions on the continental shelf off Newfoundland and southern Labrador (Narayanan et al., 1992). So a greater area of the CIL, could indicate that the year is colder, with the double effect mentioned in the introduction that this may have on fish growth, but it could also be acting on its concentration, since cod does not penetrate the area of the CIL (Hardy, 1978) and so as the area of the CIL increases the area available to cod is consequently reduced, and it is obliged to concentrate at the bottom or over the slope.

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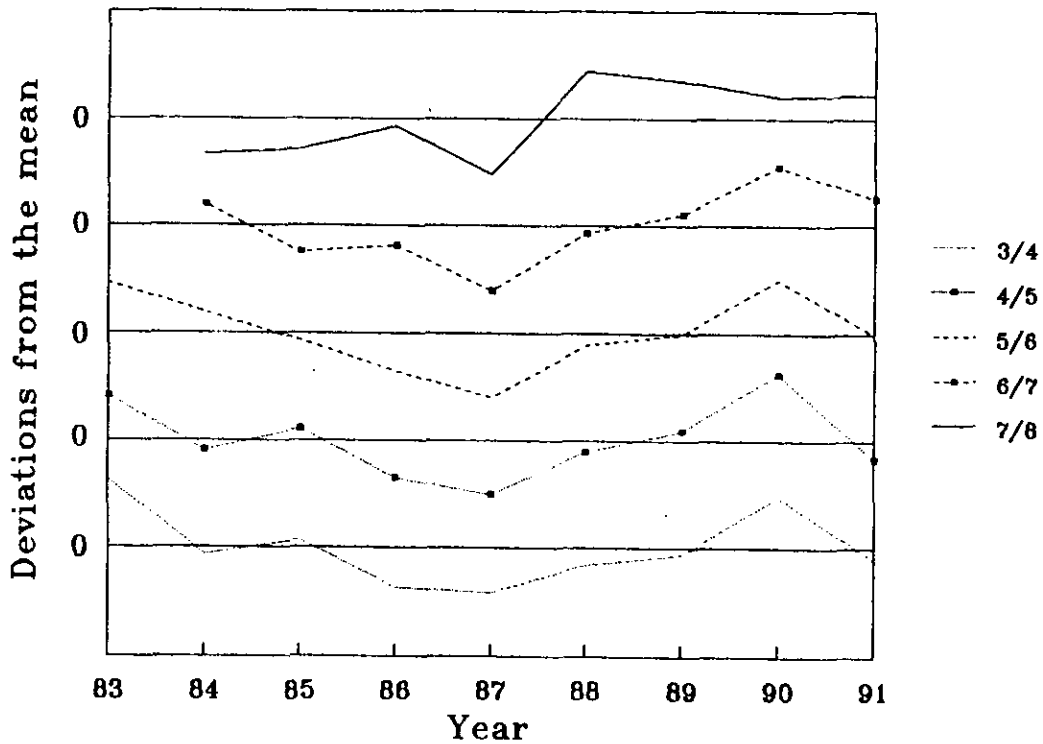
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North-East Arctic cod



Above.- Together.

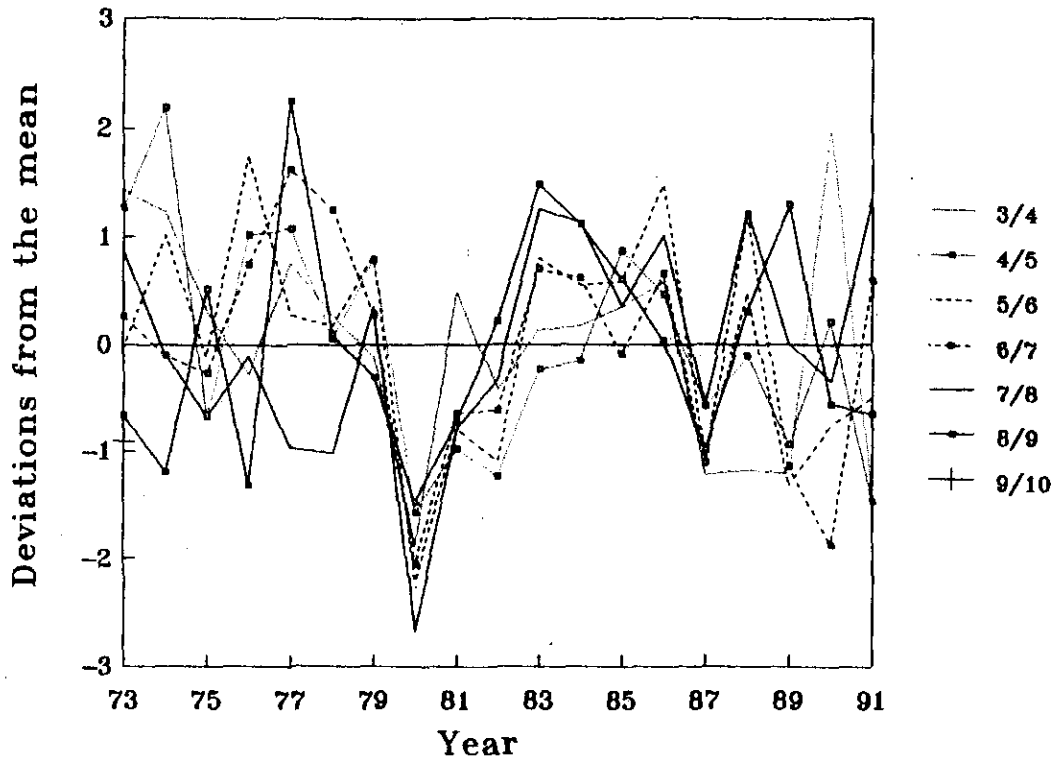
North-East Arctic cod



Below.- Separated

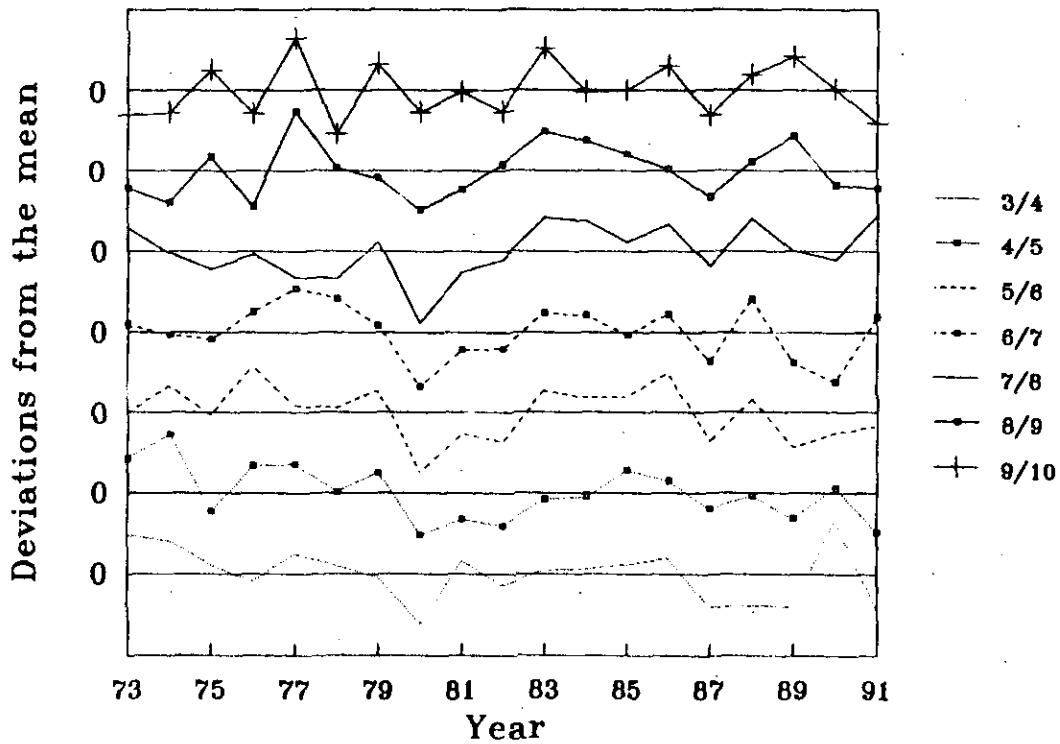
Fig. 1.- Annual deviations in the mean weight increments for ages 3-7 in North-East Arctic cod stock.

Icelandic cod



Above.- Together.

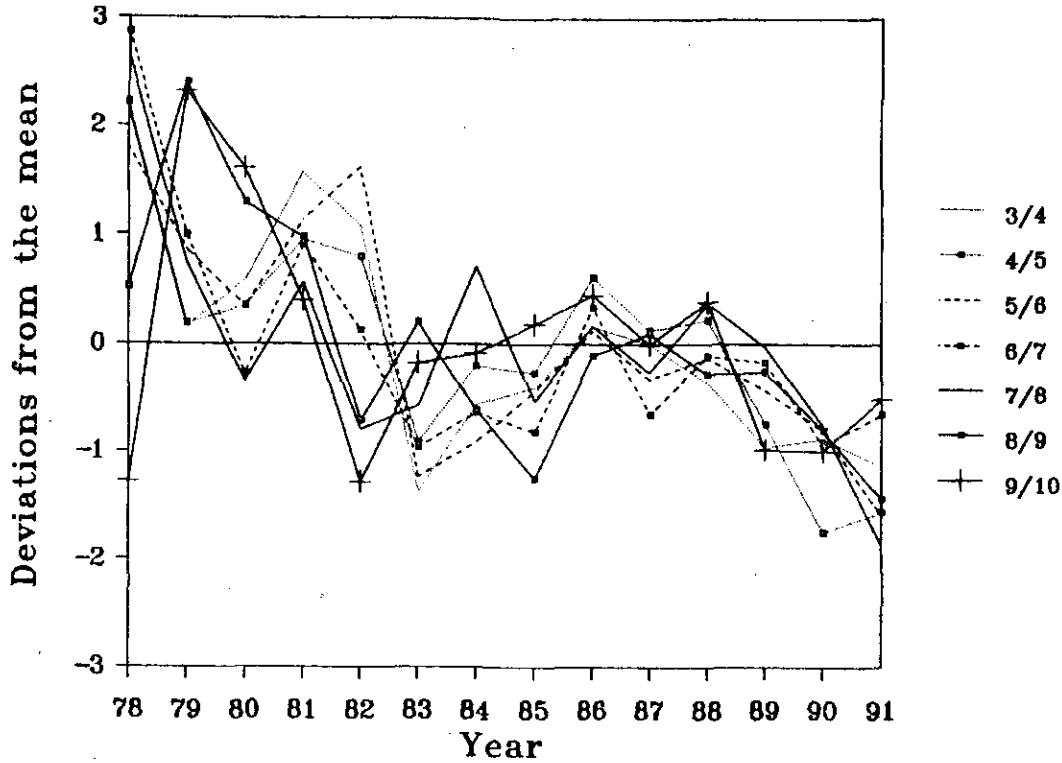
Icelandic cod



Below.- Separated

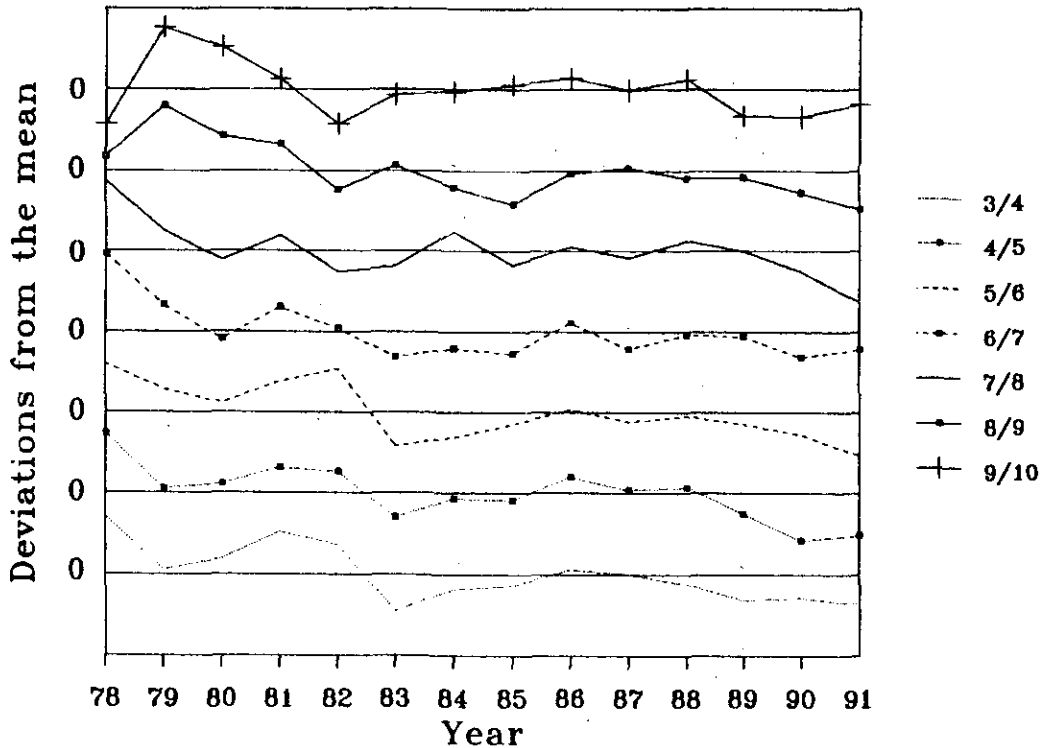
Fig. 2.- Annual deviations in the mean weight increments for ages 3-9 in the Icelandic cod.

2J+3KL NAFO Divisions cod stock



Above.- Together.

2J+3KL NAFO Divisions cod



Below.- Separated

Fig. 3.- Annual deviations in the mean weight increments for ages 3-9 in 2J + 3KL NAFO Divisions cod stock.

North-East Arctic cod

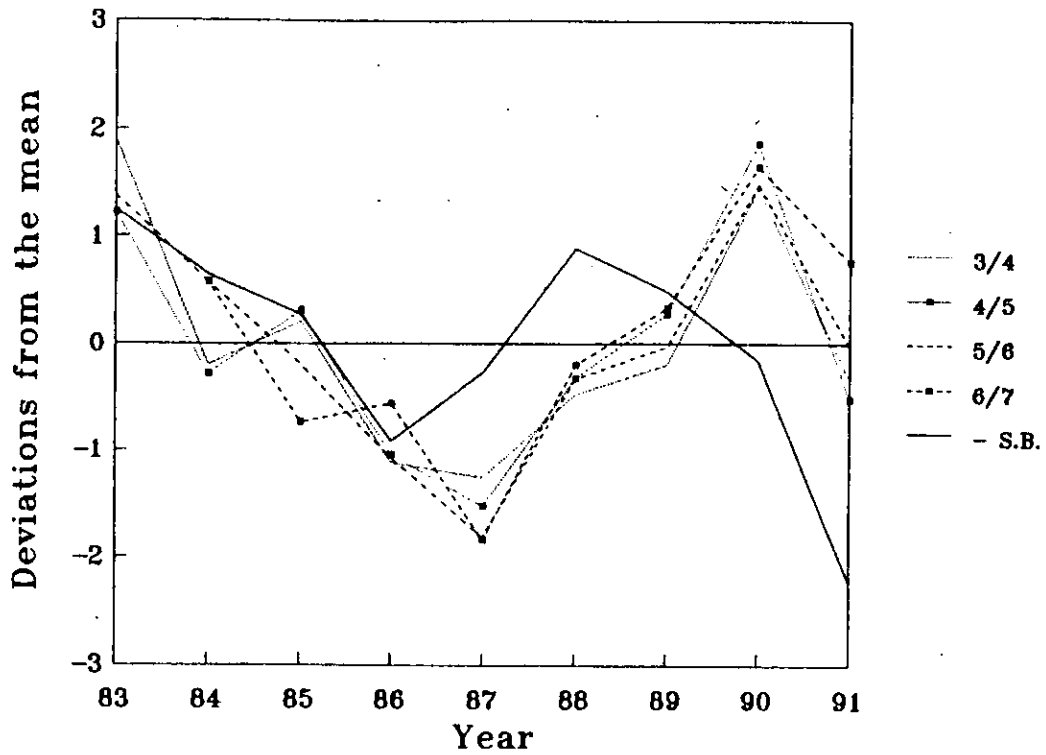
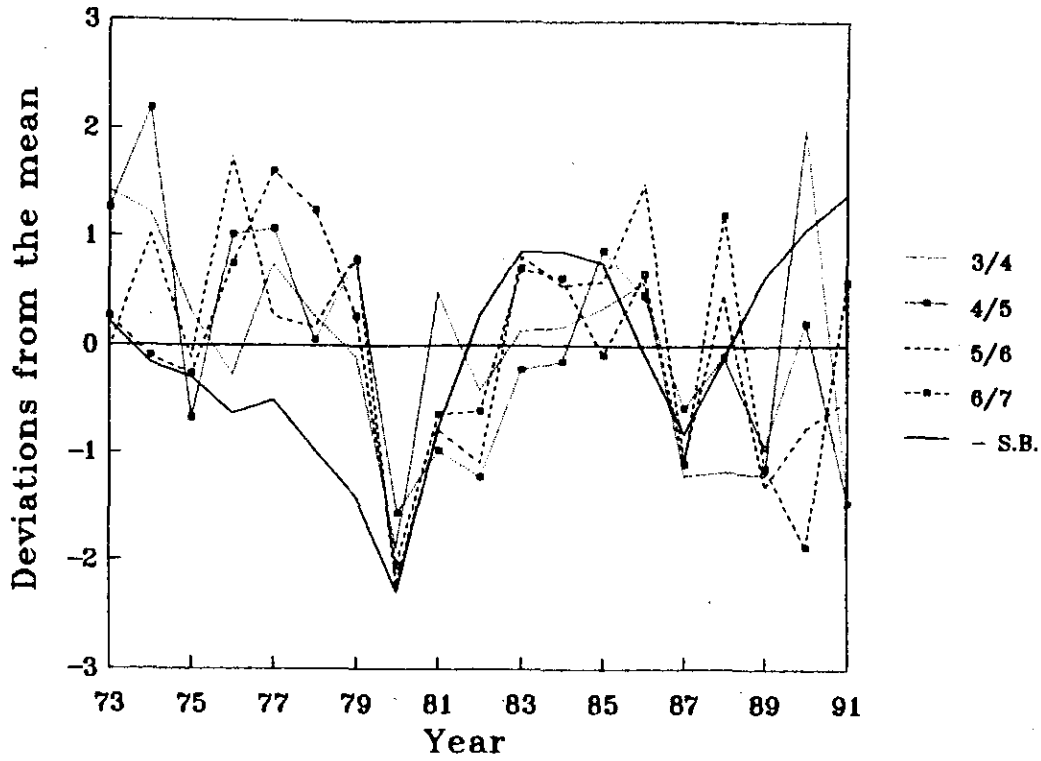


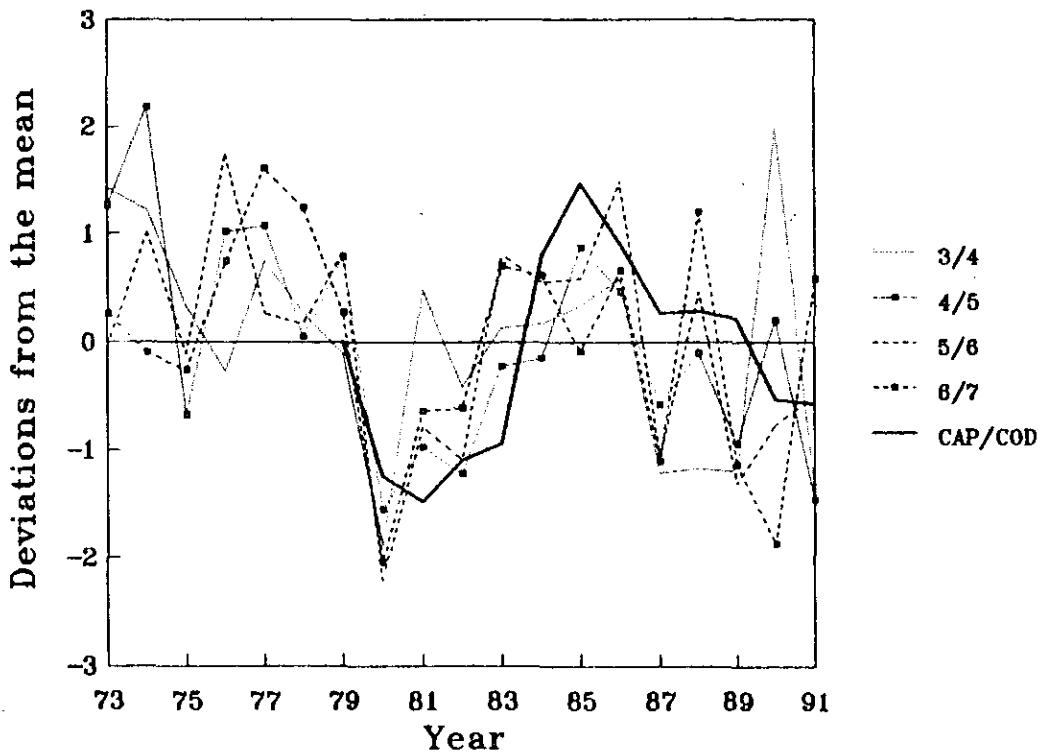
Fig. 4.- Annual deviations in the mean weight increments for ages 3-6 represented with the trend in stock biomass (sign changed).

Icelandic cod



Above. S.B. (Sign changed)

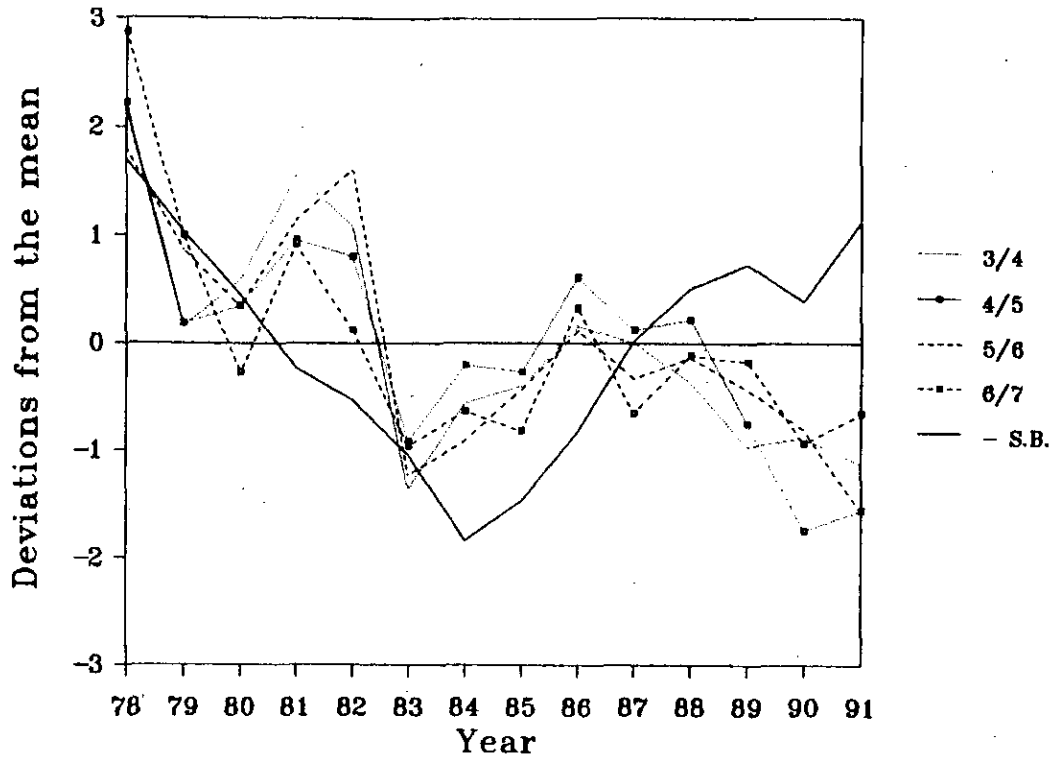
Icelandic cod



Below. Ratio biomass Capelin/biomass cod.

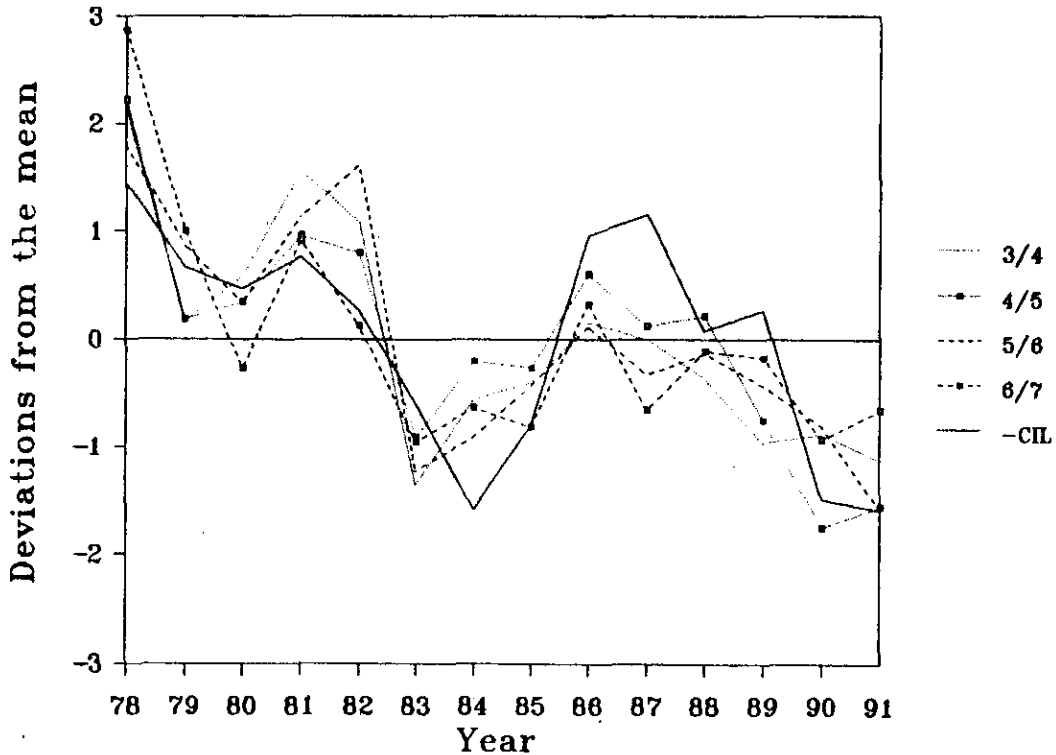
Fig. 5.- Annual deviations in the mean weight increments for ages 3-6 represented with the trend in stock biomass (above) and with the trend in the ratio cap/cod (below).

2J+3KL NAFO Divisions cod stock



Above. S.B. (Sign changed)

2J+3KL NAFO Divisions cod stock



Below. CIL area (Sign changed).

Fig. 6.- Annual deviations in the mean weight increments for ages 3-6 represented with the trend in stock biomass (above) and with the trend in the CIL area (below).