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Changes in growth of Northeast Arctic cod in relation to food consumption in 1984–1988

Sigbjørn Mehl and Knut Sunnanå

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From 1984 to 1988 the average weight of cod (*Gadus morhua*) by age group in the Northeast Arctic stock was reduced by about 60% in most age groups. During the same period, the estimated individual food consumption by age group has decreased by 40–70%. It is concluded that these two features are closely correlated and that the decimation of the stock of one of the major prey species, the capelin (*Mallotus villosus*), is ultimately largely responsible.

S. Mehl and K. Sunnanå: Institute of Marine Research, P.O. Box 1870, Nordnes, N–5024 Bergen, Norway.

Introduction

During the first half of the 1980s average weight-at-age in the Northeast Arctic cod (*Gadus morhua*) stock increased to peak values in 1984–1985 (Anon., 1989), then rapidly declined. During the period 1984–1986 the cod stock increased from about 1 million tonnes to 1.5 million tonnes, mainly due to improved recruitment from the 1982 and particularly the 1983 year classes.

The two main prey species during this period (Mehl, 1989) were capelin (*Mallotus villosus*) and deep-sea shrimp (*Pandalus borealis*). However, at the end of 1986 the capelin stock became seriously depleted (Anon., 1987) and Hylen and Øynes (1986) showed that from 1984 to 1986 the shrimp stock was reduced by more than half (Fig. 1). The increased consumption by the cod stock was probably one of the reasons for the decline in the prey stocks (Mehl, 1989).

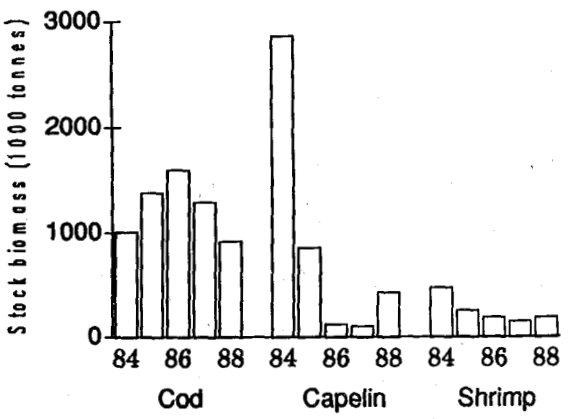

Figure 1. Stock biomass in 1000 t of cod, capelin, and shrimp in the Barents Sea and Svalbard area in 1984–1988.

Lilly (1987, 1991) has shown that cod in eastern Canadian waters did not prey more intensively on other prey at times of low capelin abundance. And Magnusson and Palsson (1989) observed that cod in Icelandic waters had lower stomach contents, a reduced feeding level, and a smaller growth rate when the capelin stock declined to low levels. In this paper we estimate the total annual consumption of individual cod by age group during the period 1984–1988 and compare the results with changes in average weight over the same period.

Materials and methods

The primary data used in the calculations are annually collected stomach content data for cod by age group, area, and season from the Barents Sea (Mehl, 1989). Distribution of the trawl stations where stomachs have been collected is shown in Figure 2. In addition, acoustic survey data for determining the geographical distribution of the different cod age groups (Hylen *et al.*, 1989; Jakobsen *et al.*, 1989; and unpubl. data) have been used. The temperature-corrected evacuation rates from the North Sea, which had been applied earlier, were substituted by new gastric evacuation rates from Northern Norway (J. Santos, pers. comm.; Mehl, 1989), because the latter are based on prey species and temperatures which are typical for the Barents Sea. The annual consumption of individual cod was estimated using essentially the same approach as Mehl (1989), where total consumption by the cod stock has been estimated by multiplying the mean stomach weight by

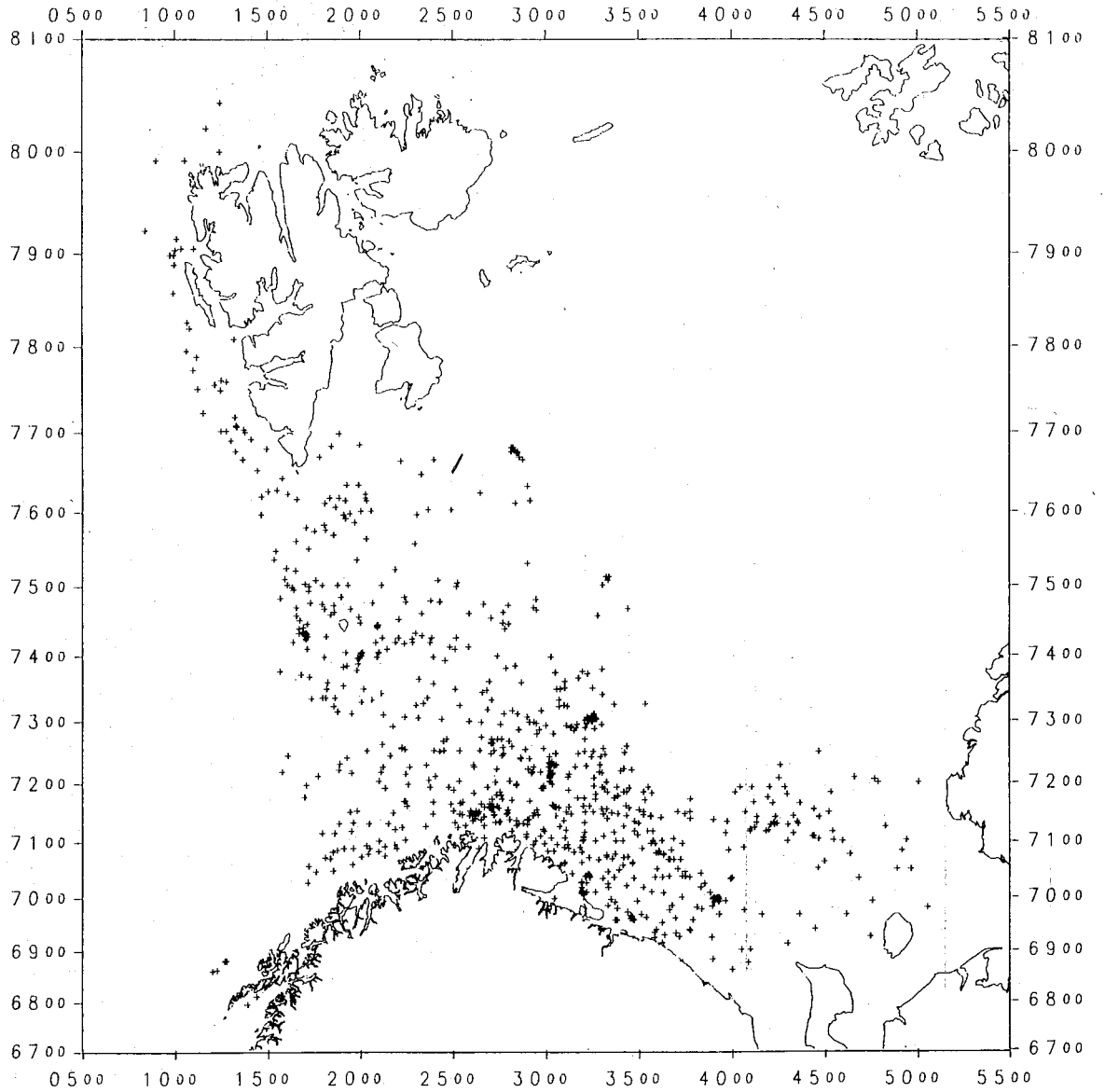

Figure 2. Geographical distribution of trawl stations in the Barents Sea and Svalbard area with sampling of cod stomachs in 1984–1988.

the rate of gastric evacuation and the number of cod in each age group, area, and season. Here, the number of cod were excluded from the calculations.

Weights-at-age in the cod stock are averages of values derived from Norwegian surveys in January–February and USSR surveys in November–December. They are assumed to be representative of the weights in the stock at 1 January (Anon., 1990).

Results and discussion

Figure 3 presents the estimated annual consumption of capelin and other prey by age group of individual cod in 1984–1988. Because of the way consumption is calculated, the figures are directly proportional to the weight of the stomach content. Although J. Santos (pers. comm.) observed slower evacuation rates at large meal sizes, meal size effects have not been taken into account so far. The stomach content weights are generally highest during the winter season, when cod feed intensively on capelin during the spawning migration of the latter (Mehl, 1986, 1989). A very high content of capelin was observed in most age groups particularly during the winter survey in 1985. This may reflect a larger degree of overlap between cod and capelin during the survey in 1985 compared to the survey in 1984. Since unpublished

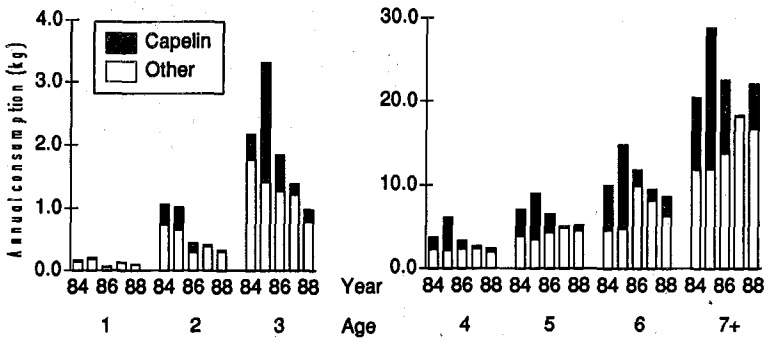

Figure 3. Annual consumption of capelin and other prey per cod by age group in 1984–1988.

data indicate that the overlap during the 1985 survey was higher than during other parts of the season when cod prey upon capelin, the consumption in 1985 is probably overestimated.

From 1985 onwards, the estimated total consumption declines rapidly in most age groups mainly due to the large reduction in consumption of capelin (Fig. 3). Apparently, the reduced contribution of capelin was only partly compensated by a higher consumption of other prey species. The reduction in annual consumption from 1985 to 1988 is largest in age groups 2–4 (60–70%), while in the older age groups the reduction is about 40–50%.

Figure 4 presents the mean weights by age group in the cod stock during the same years. The general trend is very similar to the one in total annual consumption: a large reduction from 1984–1985 to 1988. For age groups 2, 3, 4, and 5 the reduction in mean weight starts as early as 1985, while the older age groups show the first signs of a reduction in average weight in 1986. One explanation might be that at first the older age groups managed to compensate for a reduced intake of capelin by preying more intensively on larger fish prey, e.g. herring (*Clupea harengus*), haddock (*Melanogrammus aeglefinus*), and young cod. Overall, the reduction in weight-at-age from 1984 to 1988 varied between 20 and 70%.

The reduction in both consumption and mean weight is largest for medium-sized fish (age groups 2–5). The stomach content data show (Fig. 3) that the food of these age groups contains the highest percentages of capelin, and obviously they have been least successful in replacing this main prey item. Age group 1 is less dependent on capelin and continued to feed more upon smaller crustaceans. Older cod have managed to find other suitable prey species to a larger extent.

It seems questionable whether the weight reduction is caused entirely by a reduction in total food intake. The quality of the food may have changed when the cod had to replace capelin by food containing less energy. This is indicated by the fact that fishes of different ages but of the same weight do not show weight increments proportional to the annual consumption (Figs. 3 and 4).

Other factors may be related to fishing or to the hydrographic conditions. Since the decline in mean weight in age groups not yet or only partly recruited to the fishery is similar to the one in fully recruited age groups, fishing can hardly be considered an important factor.

The temperatures during the winter surveys in 1984–1985 were close to the 30-year mean. However, they were about 0.5°C lower in 1986 (Hylen *et al.*, 1986) and also in 1987 (Godø *et al.*, 1987). In 1988, they had increased slightly again but were still below the long-term mean (Hylen *et al.*, 1988). It seems doubtful whether a decrease by half a degree could have any significant effect on growth. The rate of gastric evacu-

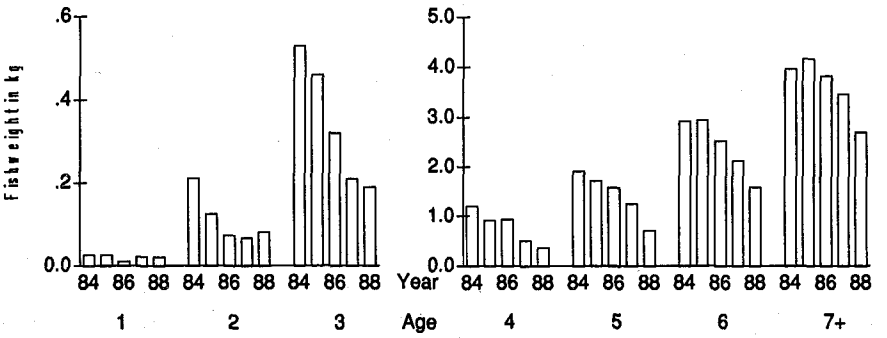

Figure 4. Mean weight of cod by age group in 1984–1988.

ation will obviously decline slightly, but so will the maintenance ration. At the beginning of the 1980s, the winter temperatures in the Barents Sea were more than 2°C lower (Dalen *et al.*, 1983), but, even though, the annual length increments were higher than in 1985–1988 (Anon., 1985). Daan (1974) observed a higher growth rate in cod during winter than during summer in the southern North Sea, indicating that lower temperatures can be more than compensated for by better feeding conditions. Also cod in the Barents Sea usually have the highest stomach content during the first part of the year when temperatures are relatively low (Mehl, 1986).

We therefore conclude that the reduced total annual consumption following the depletion of the capelin stock is closely correlated with the large reduction in mean weight-at-age in the cod stock. The latter has caused severe management problems. Because of lower individual weights, more fish than expected have been caught for the TAC set and, in addition, discards have increased. Also, natural mortality has probably increased during the period because cannibalism was raised by a factor of 3 (Mehl, 1989). These factors have caused several downward amendments in the prognosis on stock biomass and catch. In order to overcome the associated management problems of revisions in stock assessment, it is extremely important that multispecies considerations are included in the assessment and management of the main predator and prey stocks in the Barents Sea.

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