

Interannual variations in the liver condition index of cod as an indicator of temperature and feeding conditions in the Barents Sea

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Background

Northeast Arctic cod, inhabiting the edge of the species area, experience variable environmental conditions and feeding resources, one of the main of them is capelin.

Lipids are an important biochemical link between capelin and cod. Lipids constitute approximately 10-15% of the total wet weight of capelin at the peak of their seasonal cycle in lipid accumulation (Jangaard 1974). In contrast, approximately 1% of the wet weight of the muscle tissue of cod is composed of lipids (Lie et al. 1988). The liver is the primary site of stored lipid reserves in cod. These reserves are utilized during periods of food limitation and the annual cycle of gonad maturation. Starved cod can replenish liver reserves rapidly in response to increased food (Karlsen et al. 1995). Liver weight is likely to be a dynamic index of the physiological condition of cod.

Data

Large period of liver condition index (LCI) recordings were examined (1927-2000), including published historical data and the monthly mean values of LCI for 10-cm cod length groups for 1967-2000. Age-based data of LCI were also used for 1984-2000.

LCI variations

The full LCI time series (1927-2000) shows rapid fluctuations which are relatively synchronous across size classes (Fig.1). Values of LCI varied between approximately 3 and 9% through time and across all five of the

length classes. Decreases in LCI_y occurred during 1977-1979 and 1984-1987. The strongest variation in LCI_y was observed in the most recent years (1987-2000) when minima in 1987 and 1995 coincided with or followed minima in capelin stock biomass. In 1986-1988 values of LCI_y for the two largest length classes were equal to or lower than those of the smallest length classes suggesting that the decline in LCI_y was disproportionately great for large cod. Values of LCI increased again by 2000 in coincidence with capelin stock biomass.

Trophic influences on interannual variation in LCI

LCI is appeared to be positively correlated with indices of feeding, including the frequency of capelin occurrence in cod stomach, the percent of capelin in cod stomachs, the capelin stock biomass and the cod/capelin biomass ratio.

Significant ($p^* < 0.01$), positive relationships were observed between LCI_y and ln-transformed values of capelin stock biomass. Below a capelin stock biomass of one million t values of LCI_y decreased rapidly, whereas, only slight increases in LCI_y occurred above a capelin stock biomass of two million t. High capelin stock biomass results in higher values of LCI_y in large cod compared to small cod. There were significant ($p^* < 0.01$), positive relationships between LCI_y and the ratio of capelin stock biomass to cod stock biomass. Values of LCI_y decreased rapidly below a capelin:cod biomass ratio of approximately one.

The relationship between LCI_y and F_{cap} was positive for all five length classes (Fig.2). The pattern of variation in the smallest length classes was distinctive: both low and high values of LCI_y were observed at low values of F_{cap} but only high values of LCI_y were observed when the F_{cap} was high. These length classes had an upper boundary of LCI_y between 6 and 7%. The relationships between LCI_y and F_{cap} for the two largest length classes were comparatively linear and there was less evidence of an upper boundary in LCI_y .

Temperature effects on interannual variation in LCI

Temperature seems to have less effect on LCI variations.

The single model included annual mean temperature at the Kola section shown that temperature had a significant effect ($p=0.02-0.03$) only for the smallest size group (41-50 and 51-60 cm) (Fig.3). In the multivariate model which included ln-transformed capelin biomass and annual mean temperature as independent variables, the capelin biomass term was

consistently significant. Annual mean temperature had a significant ($p = 0.02$) effect on LCI_y for only one of the length classes and a marginally significant effect ($p = 0.05$) for two others .

Seasonal variation in LCI and in capelin consumption

Significant differences between high and low capelin biomass years in LCI_m were observed for the months of February through July in all five length classes. From September through January, LCI values for the high and low capelin biomass years were not significantly different from each other.

Differences in the magnitude of P_{cap} among months and years are striking. Poor capelin feeding years, defined as years having values of P_{cap} consistently less than 50%, include 1987, 1988, 1995, and 1996, 1997, 1998. Good capelin feeding years include 1990, 1991, 1993, 1994, 1999 and 2000. Within given years, maximum values of P_{cap} occurred most often in March and April. In several years (1989, 1991-1994, 1999, 2000) a secondary peak was observed in the second half of the year. Thus, fall peaks as well as spring peaks in P_{cap} appear to characterize good capelin feeding years.

Size-dependent differences in LCI

There are likely size-dependent differences in energy allocation. Relationship between annual mean LCI and mean total length was positive for the youngest cod group (age 3 and length 31-40 cm) for the period 1967-2000 ($p=0.02$). There was no relationship between LCI and total length for larger cod (age 4, 5, 6 and at length 41-50, 51-60 , 61-70 cm). Negative relationship ($p<0.001$) between these indexes was observed for the oldest age groups (age 7-9 and length 71-80, 81-90 and 91-100 cm) (Fig. 4). The same types of correlations were observed for LCI and total weight. Thus, the fast growing young cod have usually more lipid reserves than slow growing. For the middle-aged cod these variables fluctuate independently. The oldest cod have the lower LCI at the larger length.

Energy allocation strategies of different age/size groups of fish changes during their life span. It reflects specific environment in an area (food availability of proper sizes for a predator as well as correspondence between energy/food demands and real/actual rations) and shifting priorities of growing fish to higher reproduction and metabolism demands.

References

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Karlsen Ø., Holm J.C., and Kjesbu O.S., 1995. Effects of periodic starvation on reproductive investment in first-time spawning Atlantic cod (*Gadus morhua* L.) Aquaculture, 133: 159-170.

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Figure 1: Annual mean LCI (%) of different length groups of Northeast Arctic cod.

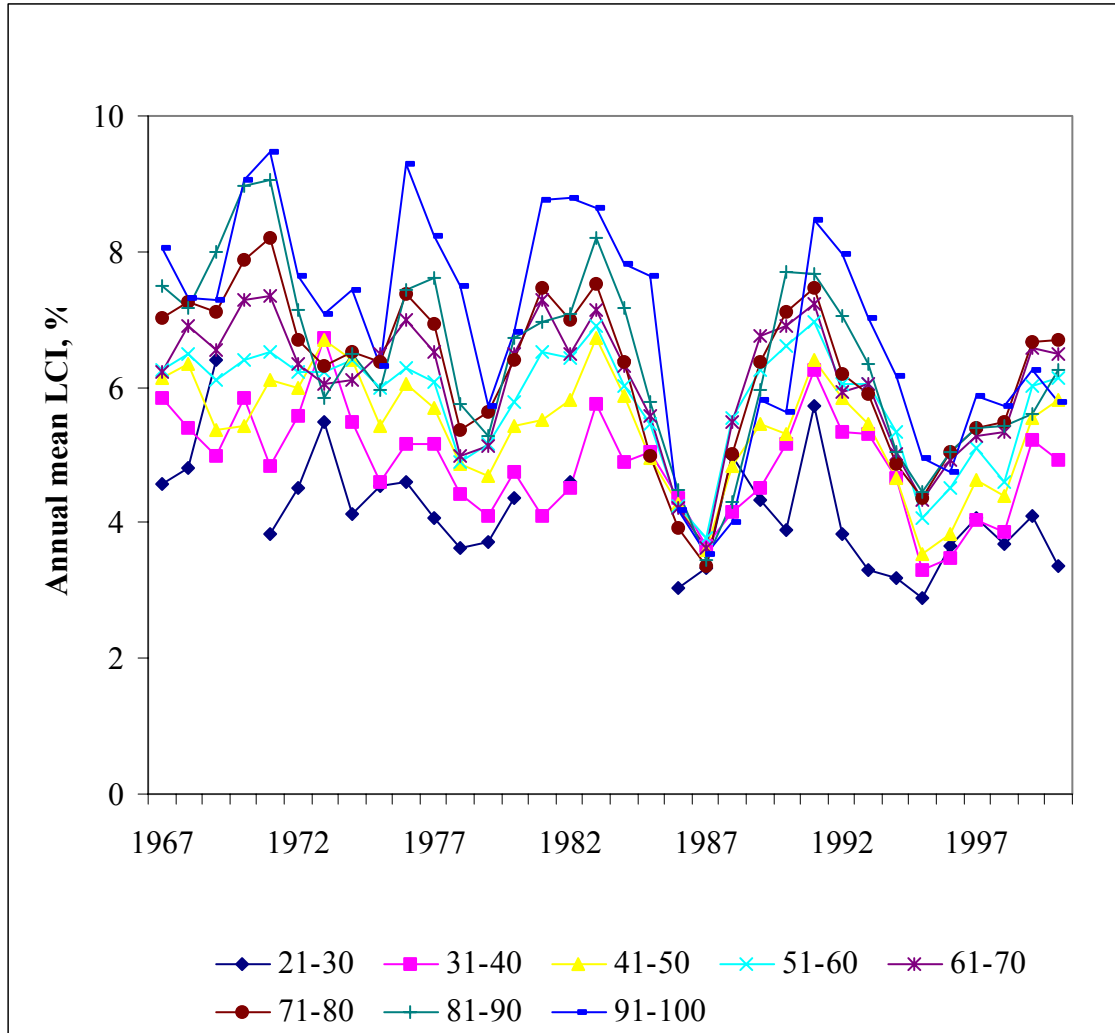


Figure 2: Relationship between annual mean LCI (%) (y-axis) and frequency of occurrence of capelin in cod stomachs (x-axis) for five length groups (1967-2000). Lines indicate the regression relationships between annual mean LCI and \ln -transformed F_{cap}

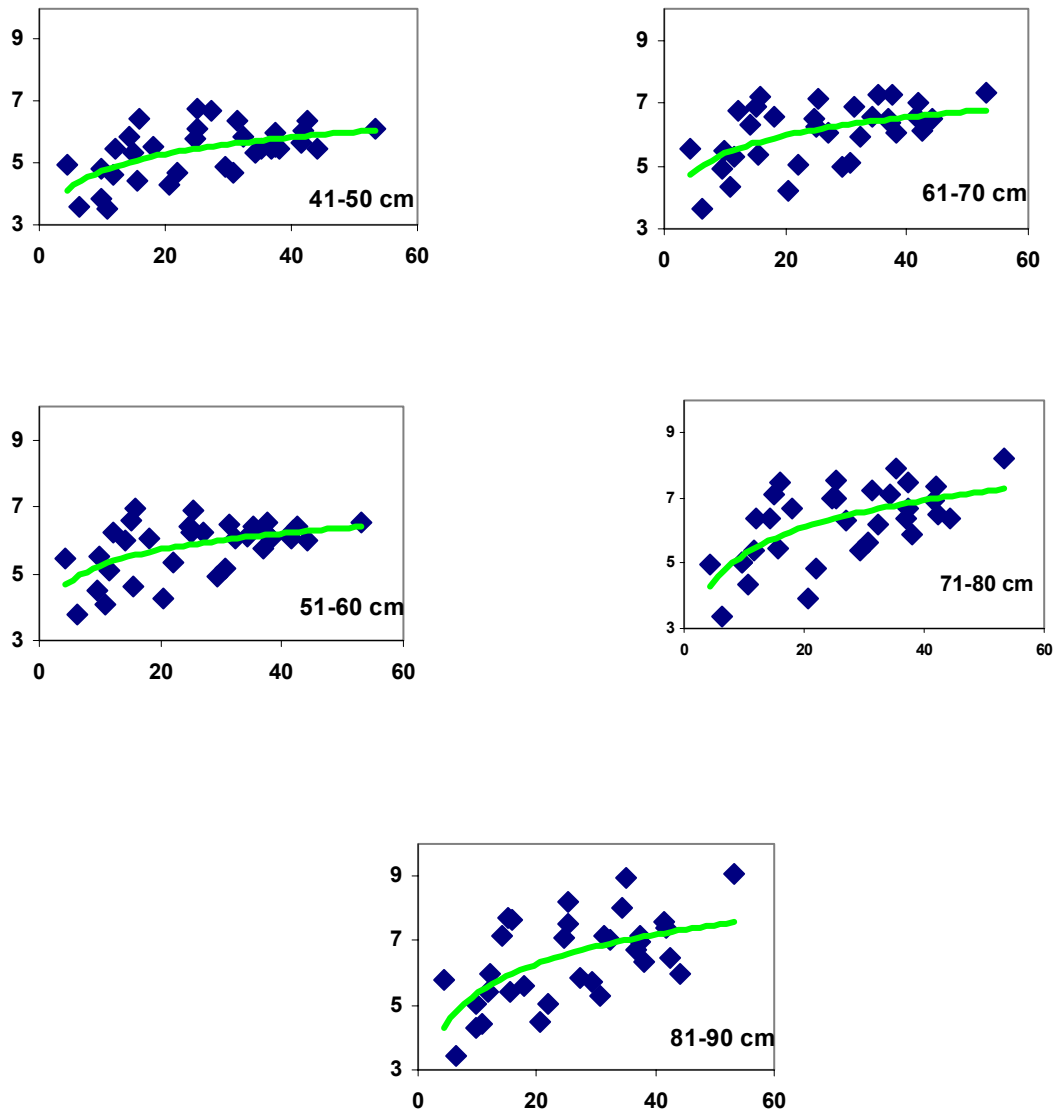
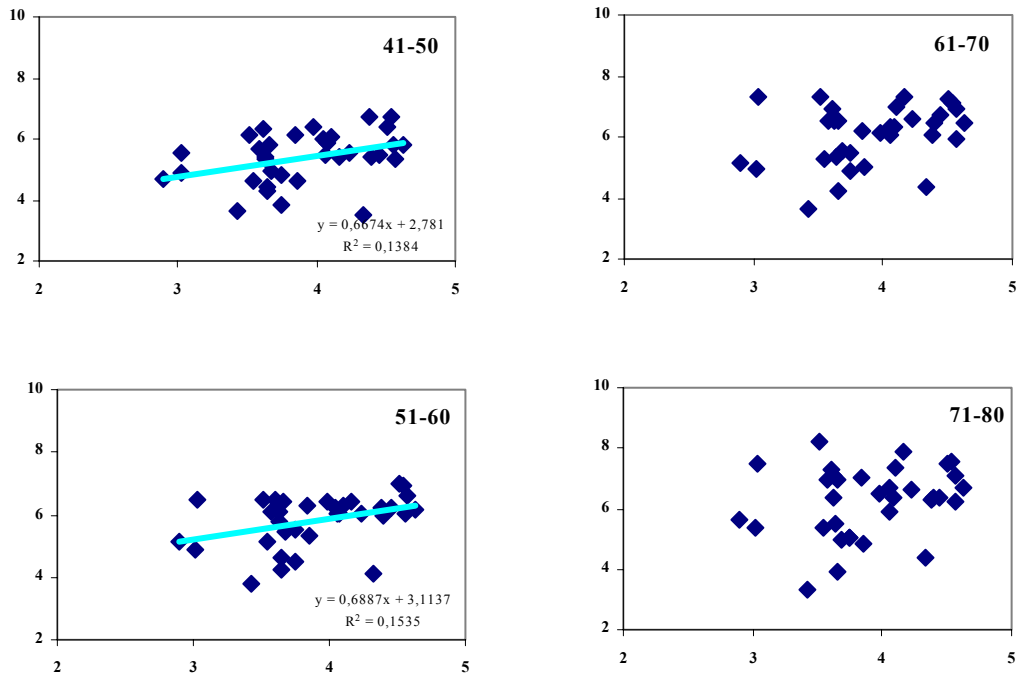


Figure 3. Relationship between annual mean LCI (%) (y-axis) of four cod length group and annual mean temperature (x-axis) (1967-2000).



Temperature, C

Figure 4: Relationship between annual mean LCI (%) of three cod length group and mean length at age 3, 5 and 8 years (1967-2000).

