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Theme Session P



POTENTIAL BIAS IN GROWTH RATE MEASUREMENTS ASSOCIATED WITH
DIFFERENTIAL MORTALITY OF COD IN POOR CONDITION: THE CASE OF COD IN
THE NORTHERN GULF OF ST. LAWRENCE

by

Jean-Denis Dutil and Yvan Lambert

Ministère des Pêches et des Océans
Institut Maurice-Lamontagne
C.P. 1000, Mont-Joli
Québec, Canada
G5H 3Z4

(*Gadus morhua*)

ABSTRACT

Growth rate of cod in the northern Gulf of St. Lawrence has likely been overestimated in recent years due to an increased rate of natural mortality among adult individuals in poor condition. The growth rate of cod in the northern Gulf of St. Lawrence is one of the lowest observed in the North Atlantic with those of cod in the southern Gulf of St. Lawrence, Labrador and the northern Grand Bank. The growth rate of cod in St. Lawrence has also declined over the last 10 years. This decline has been followed more recently by a decline in fish condition. In 1993 and 1994, some of the cod in that stock reached in spring levels of condition similar to those of cod dying from exhaustion (food privation) in laboratory experiments. The highest level of condition reached in fall was also much lower than that of cod fed capelin 3 times weekly in controlled experiments. These results suggest that growth rate of cod in the northern Gulf of St. Lawrence is limited by either low temperature or low food availability not only in winter when negative growth takes place, but also in summer when cod have to recover from poor condition. They also suggest that natural mortality has increased in recent years. Because fish in poor condition have lower growth rates and have lower chances of survival, growth rates have probably been lower than estimated based on survivors in recent years. Field studies on the relation between growth and biotic and abiotic factors should examine changes in growth rate over shorter time periods (weeks for instance). Indicators of growth rate such as enzyme activity in muscle could be used for such purposes.

Xiphophorus villosus

Cod fishing was closed in many areas in 1993 in the Northwest Atlantic. Many stocks had been declining steadily for a few years, but management decisions were not introduced early enough or were not strong enough to prevent a moratorium in 1993. This situation has raised many questions concerning potential causes. The fishery itself likely was a major cause. Cod stocks in the Gulf of St. Lawrence and the Grand Banks were heavily exploited. Fishing mortality was very high and fishing pressure remained high as the stocks started to decline. Recent evidence however suggests that 2 factors may have interacted to precipitate the outcome, namely high fishing pressure and lower stock productivity. There is a large body of information concerning fishing pressure as a potential cause for the decline. Stock productivity on the other hand has not been given the consideration that it deserves. This paper briefly examines the available information for the cod stock in the northern Gulf of St. Lawrence. In line with the theme of this session, we examine in particular whether our estimates of size at age may have been biased in recent years by an increased rate of natural mortality among adult individuals in poor condition.

Growth rate of cod in the northern Gulf of St. Lawrence is slow (Figure 1) and has been declining over the years (Figure 2). Brander (1995) presented data on mean size at age for 17 cod stocks. His data show that the mean weight of 6 year old fish for instance varies considerably between stocks. Values range from less than 1 kg to more than 11 kg. The stocks with the lowest mean weight at age 6 are those located in the Gulf of St. Lawrence. Stocks in Labrador and northern Grand Bank also have a slow growth. These stocks do not only grow more slowly, but their rate of growth has also been declining since the early 80's. This decline in growth rate is demonstrated by the decrease in the mean weight at age 6 (Figure 2) of cod in the northern Gulf of St. Lawrence (data from Fréchet et al. 1994). Six year old cod used to average 1.5 kg in the 70's. Mean weight dropped in 1984 as a result of slower growth in the early '80s. From 1984, mean weight at age 6 was close to 1.1 kg, with lower values being observed in the 90's.

Declining growth rates in the 80's were followed by a decline in the general condition of cod in the 90's (Figure 2). Lambert and Dutil (1995) have shown that the condition factor in cod is a good indicator of their energy reserves. Dutil et al. (1995) made recommendations for an adequate monitoring program of condition as part of the annual stock assessment. Recommended measures included condition factor (based on somatic weight), liver index (based on somatic weight) and water content of muscle and liver tissue. The trend in condition factor along with growth rate for 6 year old cod in the northern Gulf of St. Lawrence (data from Fréchet et al. 1994) is shown in Figure 2. Decreasing growth rates in the 80's were followed by a decline in condition in the 90's. This situation may have resulted from a progressive deterioration of environmental conditions from the early 80's through the 90's. Depressed growth rate could be argued to be an immediate response to a deterioration of environmental conditions followed by a decline in condition as an ultimate response to further deteriorations in environmental conditions.

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Slower growth and poor condition have many consequences on the productivity and resilience of the stocks, particularly as concerns their . Not all potential consequences have been explored, however, as concerns poor condition. Fish in poor condition may have a lesser swimming capacity and hence may be more vulnerable to predators or less able to catch their preys. They may also contribute less to recruitment through lesser gamete production or lessened viability of gametes. Their resistance to diseases and stress may also be reduced. Finally, they may actually die from exhaustion of their energy reserves. This latter possibility has been examined for adult cod in the northern Gulf of St. Lawrence.

The condition of cod in the Gulf of St. Lawrence followed a clear seasonal pattern with maximum condition being reached in early fall and minimum condition being reached in spring during spawning period (Figure 3). Samples of cod collected monthly over 2 years in the northern Gulf of St. Lawrence (Lambert and Dutil 1995) and over 3 years in the southern Gulf of St. Lawrence (Sinclair et al. 1994) showed similar patterns of variation for the 2 regions. Lower energy reserves were characteristic of mature fish in spring. Post-spawners recovered gradually in summer and maximum energy reserves were observed in late summer. Interestingly, condition started to decline early suggesting that environmental conditions in fall had started to deteriorate. Cod in the northern Gulf of St. Lawrence were in poorer condition than cod in the southern Gulf of St. Lawrence (Dutil et al. 1995).

Laboratory experiments suggest that condition levels reached in spring are close to those of cod exposed to prolonged periods of fasting and overlap those of cod actually dying from exhaustion. The condition of cod in the northern Gulf of St. Lawrence was compared to that of cod maintained under controlled conditions of food availability (Figures 4 and 5). Laboratory results are shown as bar histograms. The histogram on the left shows the distribution of condition values for cod dying from exhaustion of energy reserves. The histogram on the right shows the distribution for cod fed capelin 3 times weekly for 3 months (10°C). The line plots refer to wild cod. Wild cod in spring (Figure 4) were characterized by poor condition with some degree of overlap with the distribution for cod dying from exhaustion, particularly in 1994. The mean condition of wild cod in fall (Figure 5) was far below the mean value for fed cod in the laboratory. Some of the cod in fall actually had condition levels similar to those of fish dying from exhaustion.

Growth rate estimates based on size at age may overestimate actual growth rates. This may have occurred in recent years for cod in the northern Gulf of St. Lawrence. This stock and other cod stocks in the Northwest Atlantic have experienced poor environmental conditions as the comparison of size at age for various stocks suggests. This situation has resulted in poor growth and low levels of energy reserves. Natural mortality likely increased as a result of exhaustion so that cod with a smaller size at age were undetected and size at age may have been overestimated. Thus, correlations between changes in environmental conditions and changes in size at age should be examined with caution. This extreme situation is limited to a few stocks however. Nevertheless, new methods are required to

precisely monitor changes in growth rate, particularly over short periods. Such methods, including enzyme assays, are being examined in several laboratories.

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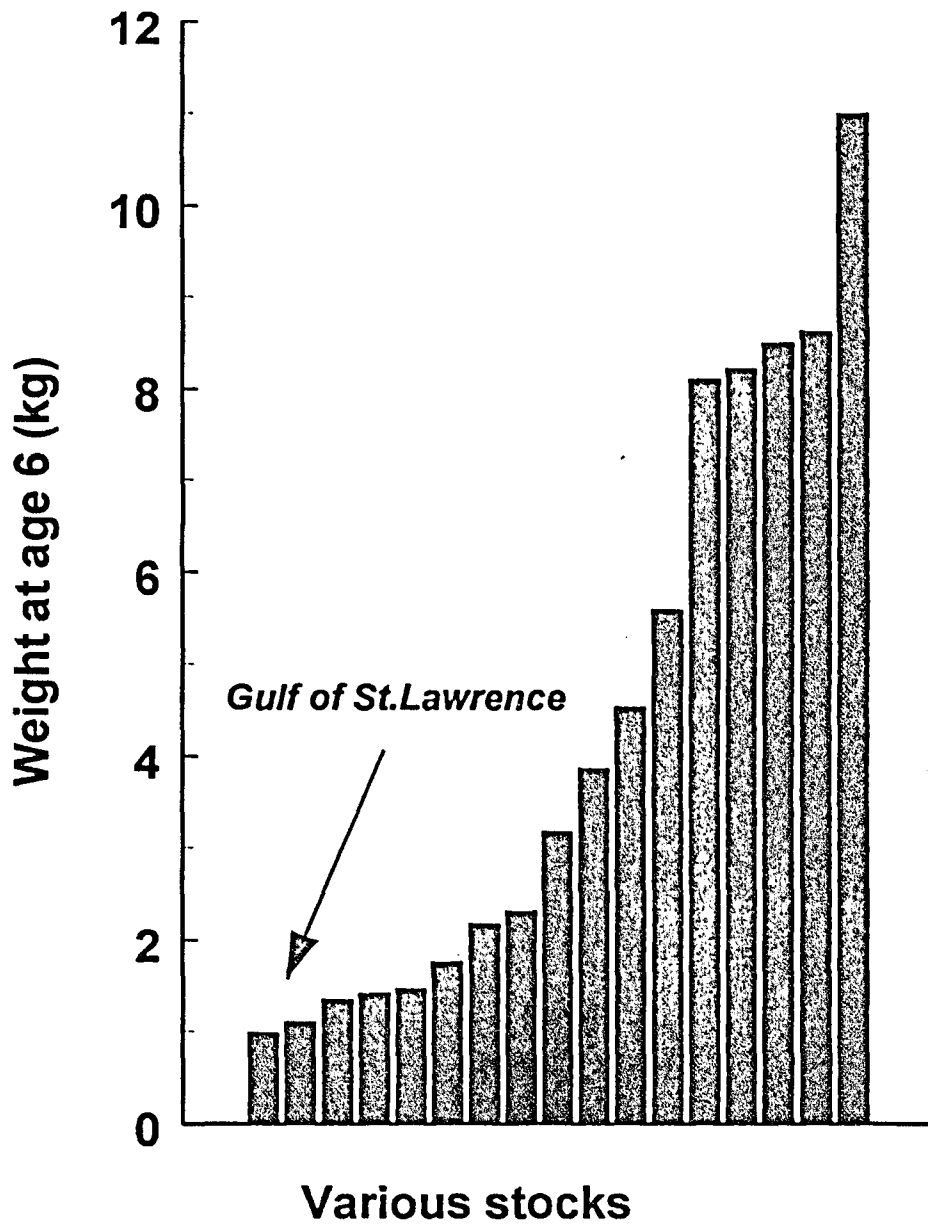


Figure 1. Weight at age 6 for 17 cod stocks (data from Brander 1995).

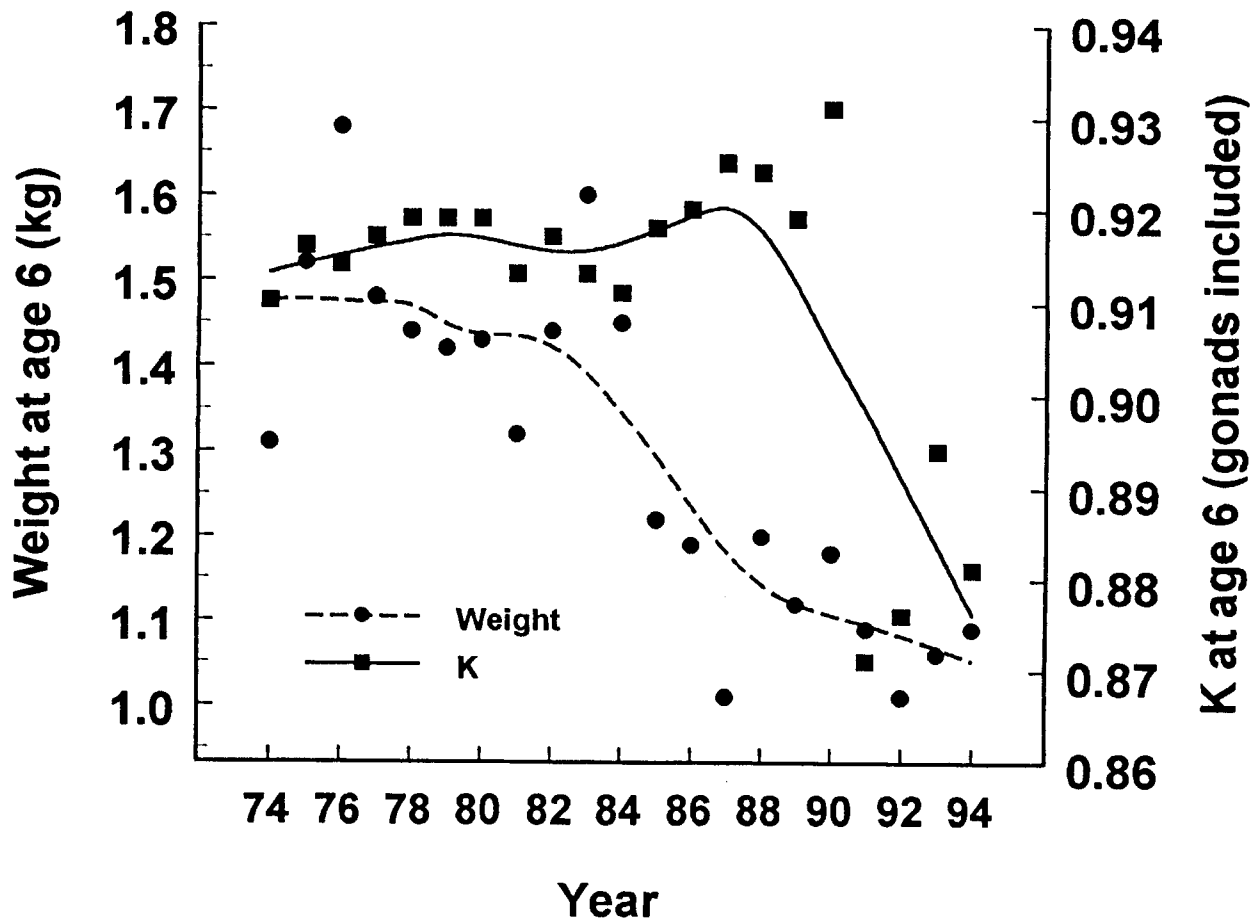


Figure 2. Weight at age 6 and condition factor at age 6 for cod in the northern Gulf of St. Lawrence (data from Fréchet et al. 1994).

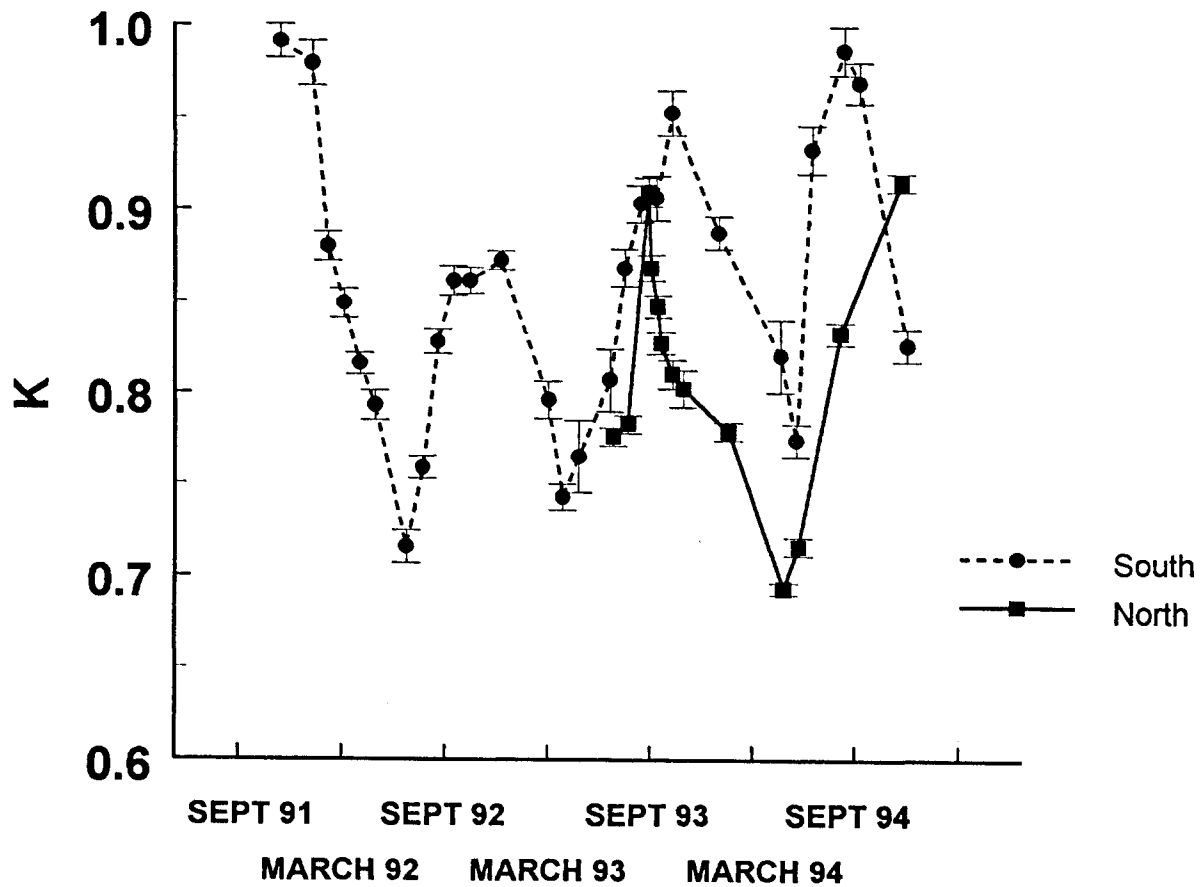


Figure 3. Seasonal changes in condition factor for 30 - 55 cm cod in the northern Gulf of St. Lawrence and for 40 - 50 cm cod in the southern Gulf of St. Lawrence from 1991 to 1995. The error bar indicates ± 1 s. e..

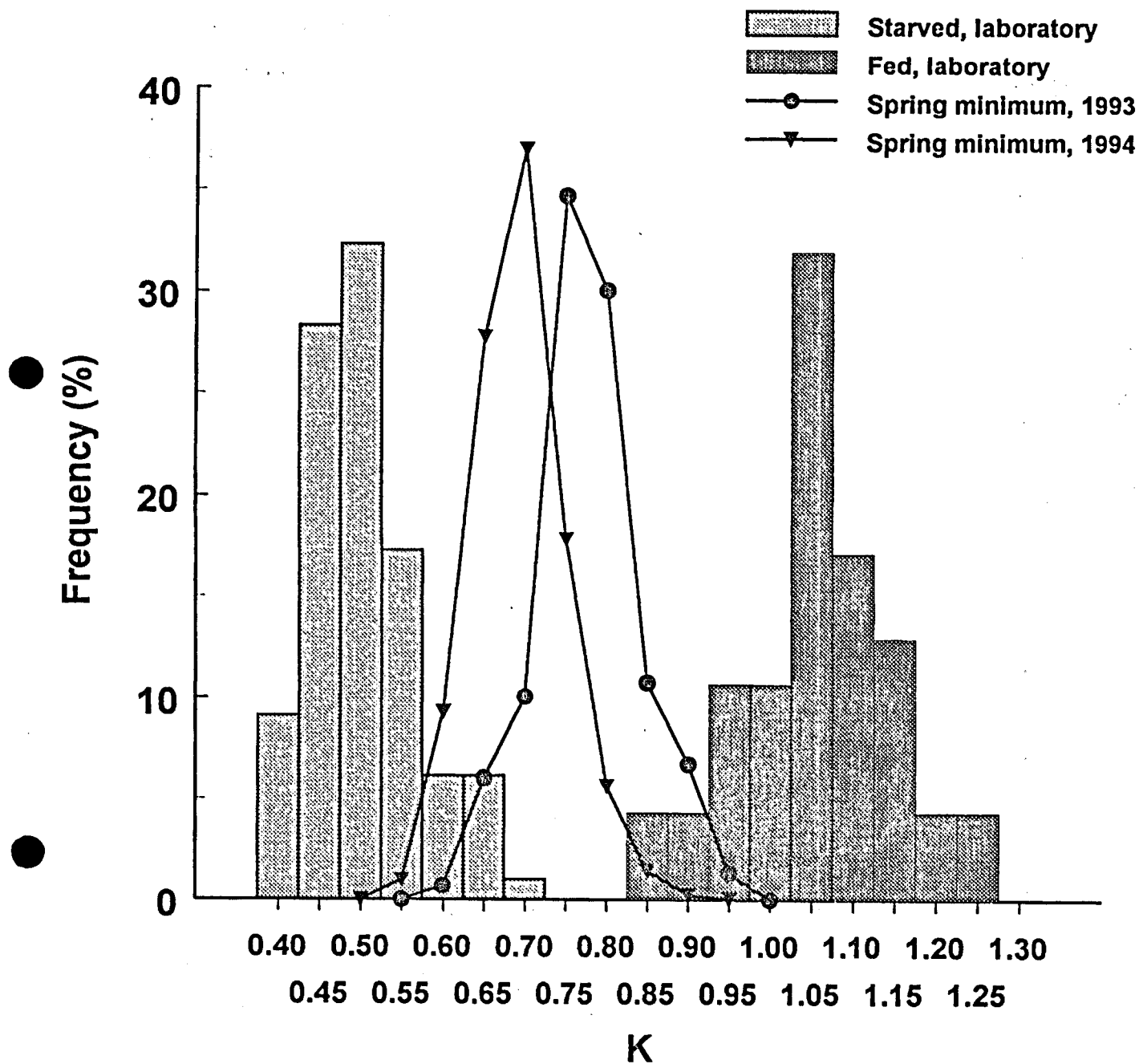


Figure 4. Distribution of condition factor for wild cod in spring compared to the distribution for cod under controlled feeding conditions. Laboratory cod were either starved to death (left hand side histogram) or fed capelin 3 times weekly for 3 months (10 °C)(right hand side histogram).

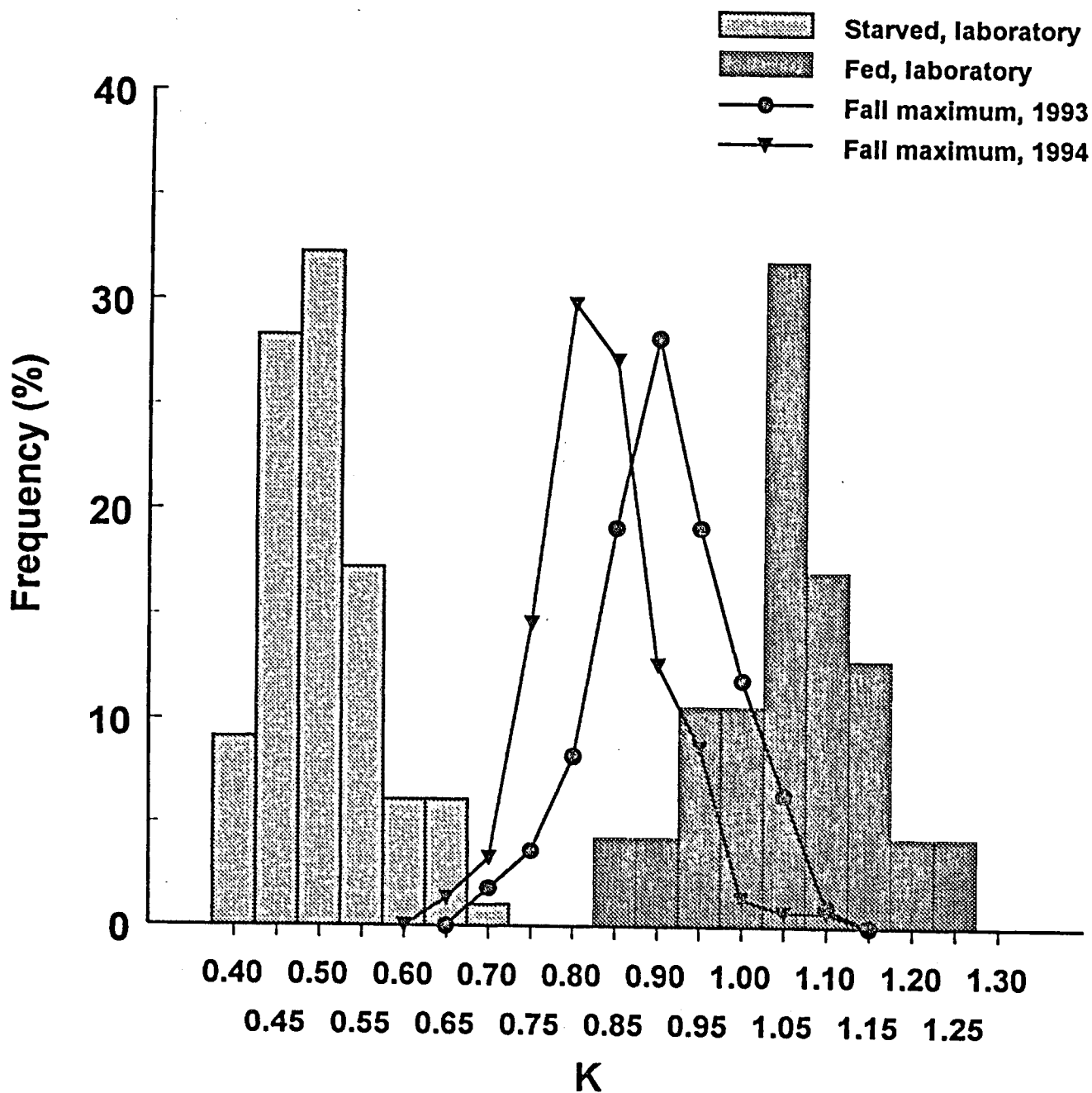


Figure 5. Distribution of condition factor for wild cod in fall compared to the distribution for cod under controlled feeding conditions. Laboratory cod were either starved to death (left hand side histogram) or fed capelin 3 times weekly for 3 months (10 °C)(right hand side histogram).