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A Note on Natural Mortality in Labrador Cod

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Introduction

Scarcity of data on cod mortality in Subarea 2, in particular the lack of any estimates of natural mortality, has hindered attempts at fishery assessments (Beverton and Hodder, editors, 1962). Age distributions are now available from research vessel surveys in Division 2J in 1963 and 1964. These are for the Spring period when the population is highly concentrated in the spawning area on the southeastern edge of Hamilton Inlet Bank (Templeman and May, 1965), and when the heaviest seasonal fishing occurs (May, MS, 1966). The age distribution data, combined with the great increase in offshore fishing since the early 1950's, allow preliminary estimates of natural mortality in the area.

Material and Method

Collections for length and age distributions were made from a total of five cruises of the C.G.S. A.T. Cameron; three during the April-May period of 1963 and two during the same period in 1964. Random samples were chosen for length measurements and these were adjusted to catch for each fishing set. Random subsamples of the measured fish were collected for age determination. These were supplemented by additional samples of the smallest and largest sizes. Age distributions of the total catch in each year were constructed using age-length keys based on otolith ages. The combined age and length distributions for each year are shown in Fig. 1A. Fishing was carried out in a series of depths using an otter trawl having the codend lined with small-meshed netting. Most of the positions fished in 1963 are shown by Templeman and May (1965). Further details are summarized below.

Year	Dates	Depths fished (m)	No. in catch	No. otoliths
1963	Apr. 9-16	183-549	9,452	1,328
	May 2-4	198-329	15,446	727
	May 27	223-318	3,282	232
			28,180	2,287
1964	Mar. 31-Apr. 2	238-459	2,291	471
	May 10-16	183-241	12,751	413
			15,042	884

The resultant percentage age distributions (Fig. 1A) were averaged for the two years to smooth variations in recruitment. Estimates of total

mortality (Z) were made from the catch curve formed by plotting natural logarithms of the average percentage values against age (Fig. 1B).

Mortality Estimates

It would appear from the catch curve that age at full recruitment to the research vessel gear is at least 6. In fact it is probably several years less than this, but the true age at recruitment is masked by the variable year-class survival evident from the age distributions (Fig. 1A). Another possibility is that the younger (immature) fish were more heavily concentrated in areas other than those surveyed.

The descending limb of the catch curve is markedly concave, though the area from ages 12 to 19 may be described by a straight line (Fig. 1B). Total mortality estimates for the portion between ages 7 and 11 range between 1.34 (ages 7 to 8) and 0.36 (ages 10-11). A least squares straight line fitted to the portion between ages 12 and 19 gives a negative slope (i.e. Z) of 0.30.

Catch curves of this type are typical following an increase in fishing (Ricker, 1958). The newly recruited age-groups are subjected to the full force of the higher fishing intensity from their entry to the fishery. The oldest age groups reflect the effects of fishing at the earlier, lower levels. Thus the areas of greatest and least slope on the catch curve give measures of present and previous total mortality. In such a situation, if the fishing effort is known to have increased from a former stable level to a new stable level, and if a measure of this increase is available, it is possible to separate the components of mortality into that due to fishing and that due to natural causes. The procedure is ascribed to Silliman (1943) and is reviewed by Ricker (1958).

The recent increase in offshore fishing in Labrador appears to meet the conditions outlined. Hodder (1965) gives offshore effort in standard trawler hours for Subarea 2 (almost entirely Division 2J) from 1954-62. Trawl effort for 1963 was calculated by the same procedure. Total effort in each year was estimated by dividing the residual landings (inshore) by the annual standard trawler catch per unit effort, and adding the result to

offshore effort. Effort data for 1964 were not available at the time of writing, but effort was assumed similar to 1963 (total landings decreased in 1964 by only 0.6%). Trawl effort increased from about 4,600 hours in 1954 to a peak of 112,000 hours in 1961. Total effort in the same years increased from 12,000 to 121,000 hours. Most of this increase occurred from 1958 to 1961. Average values for the early and recent levels are as follows:

Trawl effort	1955-57	13.3 thousand hours
	1961-64	93.6 thousand hours
Total effort	1955-57	20.2 thousand hours
	1961-64	103.6 thousand hours

Thus trawl effort has increased about 7 times between the two periods; total effort about 5 times.

Another estimate of total mortality in the period of low fishing may be obtained from age composition data prior to 1959 (May, 1959). These were small research vessel collections, representing a total of 888 fish from random samples taken in the June-September period in Division 2J in 1950, 1951, 1953, 1954 and 1958. Averaging the percentage age distributions for each year as before, and plotting natural logarithms of these values, resulted in the catch curve of Fig. 2. The estimate of Z from a straight line fitted between ages 8-18 was 0.50. This is exactly the estimate of Z given by Beverton and Hodder (editors, 1962) for Subarea 2 for ages above 13, and based on 1956-58 commercial trawler samples.

Since F and M are additive, and assuming that M has remained the same while F is proportional to the fishing effort, values of Z may be substituted in the relation $Z = F + M$ for the previous and recent periods as follows:

for the previous period	$Z_1 = F_1 + M$
for the recent period	$Z_2 = CF_2 + M$

where C is the ratio of recent to previous effort levels. The simultaneous equations may then be solved for M. Subtraction of this value from Z_1 and Z_2 gives estimates of F_1 and F_2.

Taking Z_1 as 0.30, Z_2 as 1.34 (Fig. 1B, ages 7 to 8) and C as 5, a low extreme estimate of 0.04 is obtained for M. If Z_1 is taken as 0.50, Z_2 as 0.91 (Fig. 1B, ages 8 to 9) and C as 7, M reaches an upper extreme of 0.43. The true value hopefully lies somewhere between these.

Discussion and Conclusions

The estimate of Z for the early years of the offshore fishery (0.50) seems too high, considering the lower estimate (0.30) for age groups 12-19 from the more abundant 1963-64 material. On the other hand the 1963-64 estimate of 1.34 for ages 7 to 8 is also probably too high due to the great relative abundance of the 1957 year-class in each of these years (Fig. 1A), and its inclusion in the catch curve (Fig. 1B) at age 7 but not at age 8. If the Z-value for ages 8-9 in 1963-64 is taken instead (0.91), and assuming Z of 0.30 for the earlier period and C = 5, the estimated M becomes 0.15.

Ricker (1958), discussing Silliman's method, observes that if the unit of gear becomes more efficient over the period considered (i.e. F is not actually proportional to fishing effort as the method assumes), the estimated values of M will be too low. The effect is to increase C, with the result that the calculated M would be higher. Annual catch per unit effort in the offshore fishery has increased from an average of 1.52 tons/hour in 1955-57 (Hodder, 1965) to 2.28 tons/hour in 1961-63; the increase due entirely to the large catches in the Spring fishery in the latter period. Thus gear efficiency has increased. However, taking Z_1 as 0.30 and Z_2 as 0.91, the calculated M changes relatively little for large changes in C. Taking C for trawl effort (7) rather than total effort (5), M increases to 0.20 from 0.15. If C were as high as 10, M would become 0.23.

No previous estimates of M for Subarea 2 have been made but Beverton and Hodder (editors, 1962) consider M for cod in Divisions 3K and 3L, which are included in the range of the Labrador-Newfoundland stock complex (Templeman, 1962), to lie between 0.15 and 0.35. The average M in Subarea 2 is probably within the lower half of this range. In the lightly fished areas to the north (Divisions 2G and 2H) age distributions from inshore collections during 1959-63 indicate Z of 0.22 for ages 9-15 (unpublished data, St. John's Biological Station).

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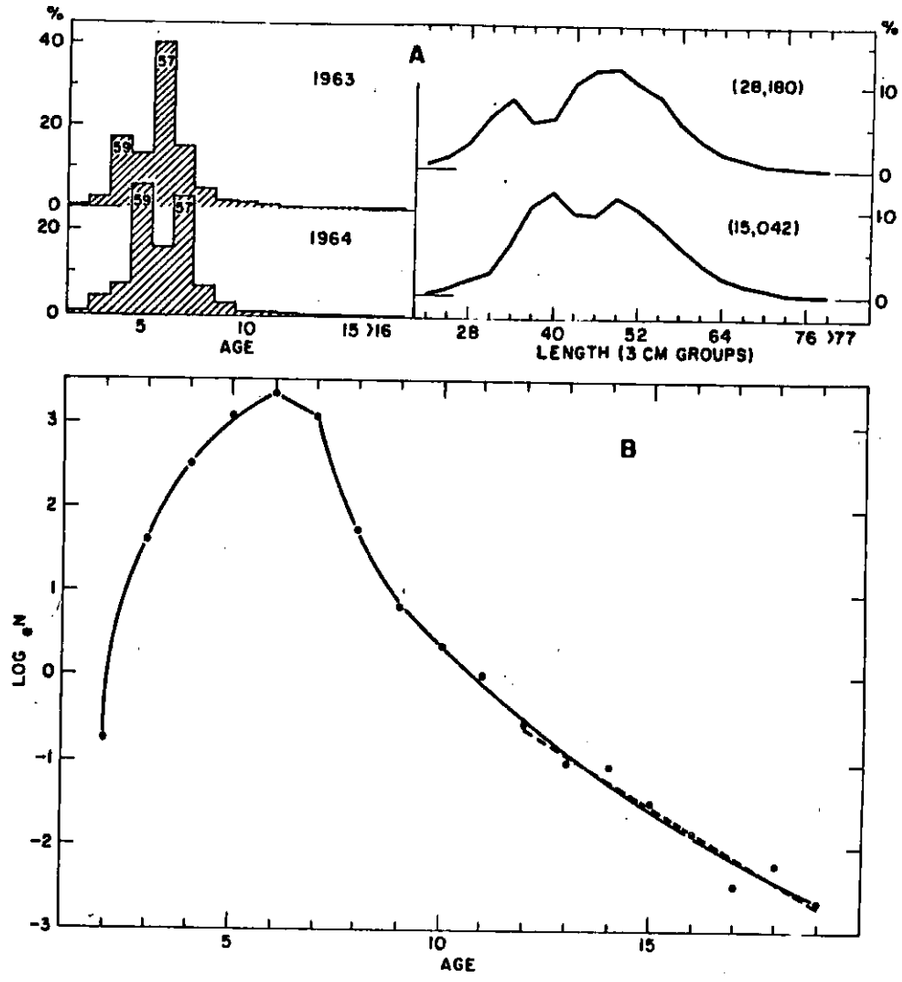

Fig. 1. A. Age and length distributions from research vessel surveys in Spring, Division 2J, 1963 and 1964. Numbers of fish are in brackets. B. Catch curve from combined age distributions.

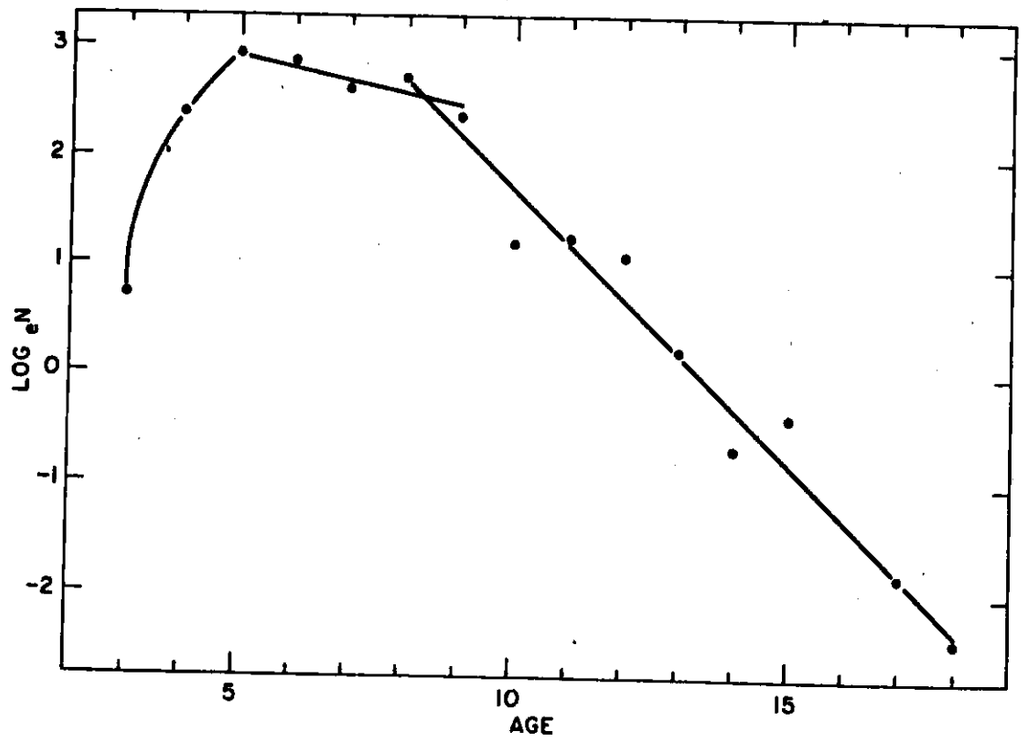

Fig. 2. Catch curve from combined 1950-58 research vessel age distributions.