ABUNDANCE ESTIMATES OF BARENTS SEA CAPELIN

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INTRODUCTION

The Barents Sea capelin is fished commercially during winter and spring when the mature stock enters coastal waters to spawn, and it is apparent from the history of the fisheries that great variations in spawning time and area have occurred and that the total abundance or stock strength has fluctuated widely. The impact of these fluctuations is strongly felt, not only in the fisheries for capelin itself, but since this little fish is a very important food organism for other fishes, changes in total abundance and distribution will have a marked effect on the fisheries for other species as well, notably on the fisheries for Arctic cod.

The Norwegian fisheries statistics contain data on capelin catch, number of vessels and duration of season, but it seems that the effects of changes in availability, weather conditions, market demands etc. are so great that catch per unit effort estimates are of rather doubtful value as realistic indices of stock abundance. Nevertheless, it is obvious from the output of the fisheries in recent years, and from research vessel observations, that the stock of capelin, which around 1960 seemed to be quite numerous, has since the season of 1961 declined greatly. The present paper describes an attempt to estimate the magnitude of this decline on the basis of the available data of age distribution on the mature stock.

Table 1. Percentage age distribution in the spawning stock of Barents sea capelin, 1959 to 1964.

Year	1959*		1960*		1961		1962		1963		1964	
Age \ Sex	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
2	1.8	2.6							0.2	0.1		0.3
3	67.0	70.4	33.1	49.5	1.2	4.7	2.0	8.4	2.3	7.7	1.9	6.5
4	31.2	27.0	66.1	50.0	94.2	94.5	63.9	66.9	93.5	91.1	47.2	58.0
5			0.8	0.5	4.6	0.8	33.9	24.4	4.0	1.1	50.9	35.2
6							0.2	0.2				

* Data from PROKHOROV (1960)

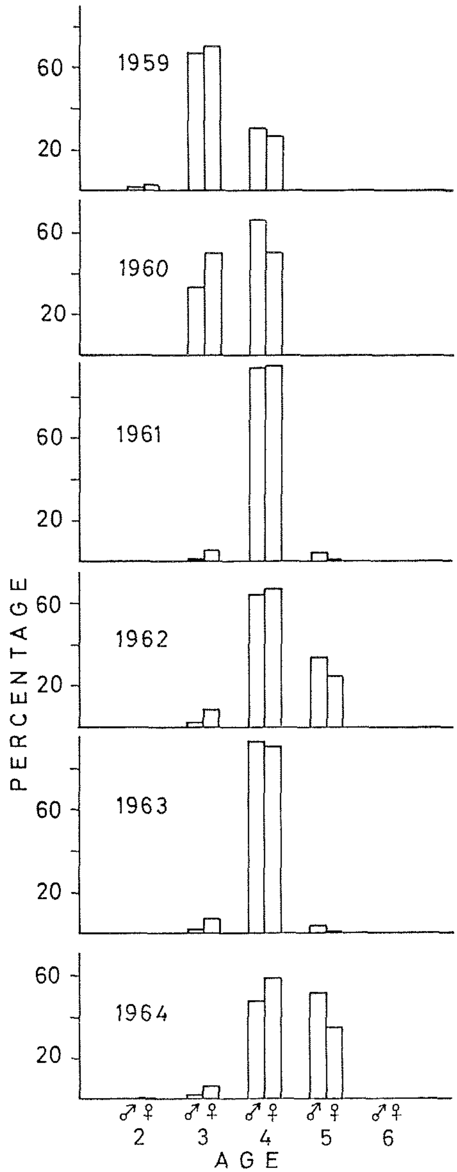

Fig. 1. Age distribution of the spawning stock of capelin, 1959 to 1964.

MATERIAL AND METHODS

Routine market and research vessel sampling of mature capelin has been carried out by the Institute of Marine Research each year since 1961, and combined with the data collected in 1959 and 1960 by the Polar Institute in Murmansk (PROKHOROV 1960) they provide estimates of the age distribution of the spawning stock in six consecutive years, i. e. 1959 to 1964. (Table 1 and Fig. 1).

It is clear that the Barents Sea capelin spawn mainly when 3, 4 and 5 years old and the lack of older fish strongly supports the theory of a very heavy post-spawning mortality. TEMPLEMAN (1948) and PROKHOROV (1969) have reported observations suggesting that at least some capelin do survive to spavn for a second time, and similar observations of spent females maturing again, were made in August 1961 during a cruise with the R/V "G. O. Sars" to the Hopen Island banks. However, for the present purpose the small proportions of second time spawners may be disregarded, as well as the few 2 and 6 year-olds, which in so me years occur in the spawning stock. Accordingly:

$$p_3 + p_4 + p_5 = 1 \qquad (1)$$

when p_3, p_4 and p_5 denote the proportions spawning at age 3, 4, and 5 respectively, of the total number of a year-class (N) which survive until the age of maturity. These proportions may be different for the two sexes, and they may also vary from year-class to year-class.

For three consecutive year-classes there are the following relationships:

$$\frac{N_i \cdot {}_ip_4}{N_j \cdot {}_jp_3} = a \tag{2}$$

$$\frac{N_i \cdot {}_ip_5}{N_j \cdot {}_ip_4} = b \tag{3}$$

$$\frac{N_j \cdot {}_jp_4}{N_k \cdot {}_kp_3} = c \tag{4}$$

and

$$\frac{N_i \cdot {}_ip_5}{N_k \cdot {}_kp_4} = d \tag{5}$$

where the ratios a, b, c, and d are estimated from the percentage age distributions.

From these equations a formulae for N_j is established:

$$N_j = N_i\left(\frac{{}_ip_4}{a} + \frac{{}_ip_5}{b} + \frac{{}_ip_5 \cdot d}{bc} \cdot \frac{{}_kp_4}{{}_kp_3}\right) \tag{6}$$

Thus, if the parameters for the i-th year-class are known, N_j may be estimated, provided some measure of the ratio ${}_kp_4/{}_kp_3$ can be established. As a first approximation it is assumed that this does not differ much from that of the j-th year-class and hence:

$$\begin{aligned} N_j &\approx N_i\left(\frac{{}_ip_4}{a} + \frac{{}_ip_5}{b} + \frac{{}_ip_5 \cdot d}{bc} \cdot \frac{{}_jp_4}{{}_jp_3}\right) \\ &= N_i\left(\frac{{}_ip_4}{a} + \frac{{}_ip_5}{b} + \frac{ad\,({}_ip_5)^2}{b^2c \cdot {}_ip_4}\right) \end{aligned} \tag{7}$$

Dividing (3) with (2) gives:

$$\frac{{}_jp_3 \cdot {}_ip_5}{{}_jp_4 \cdot {}_ip_4} = \frac{b}{a} \tag{8}$$

and, similarly, from (4) and (5):

$$\frac{{}_kp_3 \cdot {}_jp_5}{{}_kp_4 \cdot {}_ip_4} = \frac{d}{c} \tag{9}$$

It is noticed that if there were no difference from year-class to year-class in the p-values these ratios would be identical. In this case the year-indices may be deleted and only one additional information is required to calculate p_3, p_4 and p_5.

If no additional information is available, alternative estimates may still be possible if the average age distribution can be assumed to indicate the right order of magnitude of the p-values.

In this case, by applying different values of, for example the ratio p_3/p_5, around that derived from the average age distribution, several series of estimates may be made.

In the present material of males ${}_{56}p_3 \cdot {}_{55}p_5/{}_{56}p_4 \cdot {}_{55}p_4 = 0.0257$ and ${}_{57}p_3 \cdot {}_{56}p_5/{}_{57}p_4 \cdot {}_{56}p_4 = 0.0244$. Such a close agreement would be expected if the p-values of these year-classes were nearly identical and it is reasonable to assume that this is in fact the case.

The average age distribution for the years during which these year-classes participated in the spawning, gives a value for the ratio p_3/p_5 of about 4, and hence, three series of estimates have been made applying values 3, 4 and 5 for the ratio p_3/p_5 of these year-classes. These have been used to estimate N_{55} and N_{57} relative to N_{56}, and to find the parameters for the subsequent year-classes by means of equation (7).

Contrary to that found for the males, in the material of females the ratio $p_3.p_5/p_4.p_4$ is not nearly constant for the first years of sampling. To follow the same procedure in the calculations as for the males one further assumption had therefore to be made, namely that the ratio p_3/p_4 is nearly the same for both the 1955 and the 1956 year-classes. Tables 2a and 2b give a record of the three series of parameters estimated for males and females separately, and in Table 3 are given the corresponding figures for the estimated relative abundance of the spawning stock.

DISCUSSION

The material on which these estimates are based are drawn from various sources and collected in different localities and at different periods of the spawning seasons. This might significantly bias the age distribution in the samples, particularly in the case of the females, since the younger females seem to be more abundant on the spawning grounds at the end of the season than the older ones. For the males, however, no change in age distribution during the season has been apparent, and the present data of the age distributions from 1959 to 1964 is probably more reliable for males than for females.

Nevertheless, it is noticed that the results obtained from both sets of data fluctuate in the same manner from year to year. In view of the fact that this good agreement is obtained from two quite independent sets of data, it would seem reasonable to conclude that the various assumptions

Table 2a. Males. Estimates of the parameters p_3, p_4, p_5 and N. applying different values for the ratio ${}_{55}p_3/{}_{55}p_5$ and taking N_{56} as unity.

Yearclass	A				B				C			
	${}_{55}p_3/{}_{55}p_5=3$				${}_{55}p_3/{}_{55}p_5=4$				${}_{55}p_3/{}_{55}p_5=5$			
	p_3	p_4	p_5	N	p_3	p_4	p_5	N	p_3	p_4	p_5	N
1955	0.203	0.730	0.068	0.131	0.226	0.717	0.057	0.151	0.248	0.702	0.050	0.168
1956	0.203	0.730	0.068	1.000	0.226	0.717	0.057	1.000	0.248	0.702	0.050	1.000
1957	0.203	0.730	0.068	1.821	0.226	0.717	0.057	1.601	0.248	0.702	0.050	1.436
1958	0.066	0.917	0.017	0.255	0.078	0.908	0.014	0.188	0.085	0.902	0.013	0.150
1959	0.050	0.694	0.255	0.145	0.061	0.716	0.223	0.088	0.069	0.727	0.203	0.061
1960	(0.050)	(0.694)	(0.255)	(0.050)	(0.061)	(0.716)	(0.223)	(0.020)	(0.069)	(0.727)	(0.203)	0.016

Table 2b. Females.

Yearclass	A				B				C			
	${}_{55}p_3/{}_{55}p_5=3$				${}_{55}p_3/{}_{55}p_5=4$				${}_{55}p_3/{}_{55}p_5=5$			
	p_3	p_4	p_5	N	p_3	p_4	p_5	N	p_3	p_4	p_5	N
1955	0.189	0.736	0.076	0.098	0.253	0.697	0.051	0.137	0.295	0.665	0.093	0.170
1956	0.198	0.777	0.026	1.000	0.260	0.732	0.107	0.100	0.306	0.681	0.031	1.000
1957	0.189	0.757	0.054	4.060	0.253	0.711	0.036	2.925	0.297	0.676	0.028	2.273
1958	0.200	0.796	0.005	0.765	0.260	0.736	0.003	0.384	0.301	0.697	0.002	0.254
1959	0.176	0.687	0.137	0.434	0.247	0.063	0.091	0.144	0.325	0.615	0.060	0.068
1960	(0.176)	(0.687)	(0.137)	(0.143)	0.247	(0.663)	(0.091)	0.033))	(0.325)	(0.615)	(0.060)	0.011

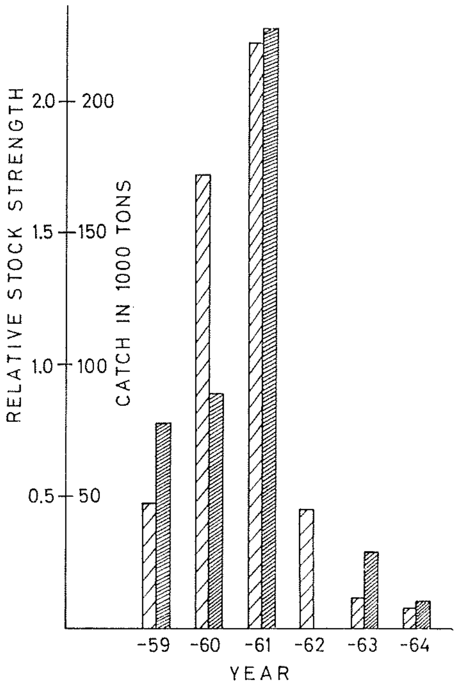

Fig. 2. Norwegian catch of capelin (right hand columns) in the years 1959 to 1964, and corresponding estimates of stock strength.

made in establishing the population model applied and in estimating the parameters are not quite unreasonable.

In Fig. 2 is shown the estimated relative strength of the mature stock of capelin in the years 1959 to 1964. These are the means of the estimates for males and females from series B in Table 3, added with provisional estimate of 1964. For comparison the Norwegian catch of capelin in the corresponding years is illustrated on the same figure. Except for the year 1962, when the capelin did not appear at the Norwegian coast at all, the trend in stock strength estimates is very similar to that of the yield of the fishery. This tend to indicate that in those years when the capelin are available to the Norwegian fishermen, the magnitude of the catch is largely governed by the size of the stock.

Table 3. Estimates of relative abundance of the spawning stock of Barents Sea Capelin 1959 to 1963.

Year	Males			Females		
	A	B	C	A	B	C
1959	.454	.560	.664	.218	.400	.564
1960	1.658	1.826	1.930	1.257	1.624	1.833
1961	2.144	2.046	1.937	2.631	2.387	2.187
1962	.551	.448	.384	.630	.472	.353
1963	.163	.112	.085	.285	.117	.063

NOTE ADDED IN PROOF

Since the manuscript was prepared a more recent work by PROKHOROV (1965) has been published, in which the yearly age distribution since 1954 is given for the spawning stock of capelin. For a period of several years in the 1950-ies the mean age of spawning was much lower than in recent years, i.e. the variation in the p-values is in fact much greater than what is apparent from the material presented in this paper. However, the method described would still be applicable for the period dealt with during which the age of maturity seems to have varied but little.

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