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THE COLLAPSE OF THE NORWEGIAN SPRING SPAWNING HERRING STOCK

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INTRODUCTION

Since mid-1960 a strongly marked decline in the adult stock of Norwegian spring spawning herring has been recorded (ANON. 1970a, 1972). The stock size decreased due to lack of recruits, but the decline was accelerated by the higher exploitation rate in 1965-1967 compared with earlier periods.

There has been practically no recruitment to the adult stock since the 1959-1961 year-classes were fully recruited in 1966 and the stock size decreased from 7.3 mill. tons in 1965 to 2.0 mill. tons in 1968. The stock continued to decline from 1969 to 1971, and the catches both in the summer and winter herring fisheries were almost negligible compared with earlier years (Fig. 1).

During the winter season of 1972 no herring were recorded on the traditional spawning grounds, and the spawning stock was probably reduced to an extra-ordinary low level. Accordingly, only one herring larvae was caught during a larval survey carried out during the first half of April 1972 (DRAGESUND in preparation).

As regards recruitment to the adult stock in the coming years, information from the international 0-group fish survey (BENKO et al, 1970, ANON. 1069, 1970b, 1971) indicates that the 1968-1971 year-classes are all very poor except for the 1969 year-class, which is slightly more abundant, and probably will show up in the adult stock in 1973.

In order to investigate if low recruitment and high exploitation rate were the only causes for the collapse of the stock, a cohort analysis (POPE 1971) was carried out on three selected year-classes, namely those of 1959, 1960 and 1961.

MATERIAL AND METHODS

The main sources of data used in this investigation are from the Report of the Working Group on Atlanto-Scandian Herring (ANON. 1970a, 1972) and from unpublished data available at the Institute of Marine Research, Bergen.

The total number of each year-class at the beginning of 1971, the last year used in the cohort analysis, was calculated from the equation

$$N = C \cdot Z/F \ (1-e^{-Z}) \qquad (1)$$

where C is the catch in numbers, F the instantaneous fishing mortality coefficient and Z the total instantaneous mortality coefficient.

The number of fish divided on year-classes at the beginning of the other years was calculated from the recurrence relation

$$N_i = C_i e^{M/2} + N_{i+1} e^{M} \qquad (2)$$

where C_i is the catch in numbers in year <u>i</u> and N_i is the number of fish in the year-class at the beginning of year <u>i</u>.

Z_i is calculated from the expression

$$Z_i = \ln \frac{N_i}{N_i + 1}$$

and F_i from

$$F_i = Z_i - M$$

The total catch in the adult herring fisheries (all year-classes included) and the catch separated on the three selected year-classes for the period 1965-1971 are given in Table 1.

RESULTS

Stock size

The calculated numbers of each of the 1959-1961 year-classes for the period 1965-1968 were compared with the estimates obtained from tagging experiments and from combined acoustic surveys and underwater photography experiments (ANON. 1970a). The value for F in 1971 was tentatively set to 0.3, corresponding to a spawning stock size of about 28 thousand tons. In 1971 the total catch of adult herring was 6 789 tons. Cohort analysis was then carried out on the selected year-classes for three alternative values of M (0.16, 0.20 and 0.24). The result for the 1959 year-class is shown in Fig. 2, where the calculated size of the year-class in numbers at different age can be compared with the numbers given by the Working Group. The year-class strength as estimated by the Working Group was in 1968 about ten times greater than the figures obtained from the cohort analysis for all three alternative values of M. The relative difference between the two estimates decreases with decreasing age. The values given by the Working Group for the years 1967 and 1966 are two to three times higher than those obtained from the cohort analysis. The relative difference between the two estimates was almost the same for the 1960 and 1961 year-classes.

The discrepancy between the estimates will not be appreciably reduced by a decrease in F from 0.3 to 0.03 for 1971 (Fig. 3). An F-value of 0.03 gives a spawning stock size of about 245 000 tons, and a still smaller value of F would, of course, give better correspondance between the two estimates. However, a spawning stock significantly above this size in 1971 seems unlikely. Fig. 3 shows that it will make practically no difference whether the value of 0.03 or 0.3 for F is used, and in the further analysis the value 0.3 is used.

The serious decline in catch occurred in 1968. If other factors than fishing and lack of recruits contributed to the decline, these could be taken account of in the value of M. The cohort analysis was, therefore, carried out with higher values of $M = M_2$ for 1968 and later years. For 1967 and earlier years a value of $M = 0.16$ was used, as estimated by the Working Group. The results are shown in Figs. 4-6. In order to achieve better correspondance between the two sets of estimates, M_2 had to be adjusted to values above 1.0.

In order to check the stock size estimates made by the Working Group based on tagging data, a tagging experiment carried out in summer of 1966 was selected. The herring caught for tagging consisted entirely of Norwegian spring spawners. A total of 1 500 herring were tagged with internal steel tags at the Bear Island feeding grounds (DEVOLD 1968). During the subsequent winter herring fishery, 49 tags were recaptured in a total catch of 174.8 thousand tons, the effective quantity of herring processed at reduction plants equipped with magnets. By converting the catch to numbers (C), the stock size in numbers (S) in the summer of 1966 (by 1 July) was calculated. Assuming no recruitment to the stock between the time of tagging and the following winter season

$$S = \frac{N \cdot C \cdot s}{R} \qquad (3)$$

where N is the total number of tagged fish, R the number of recaptures and s the tagging survival rate, taking into account both tagging mortality and shedding of tags.

Assuming $s = 0.85$, equation (3) gives

$$S = 15.898 \cdot 10^9$$

Applying the Icelandic age and weight data (ANON. 1970a, JAKOBSSON 1968) the number caught in the summer and autumn fishery of 1966 was estimated. Assuming a value of $M = 0.16$, the stock size in number at the beginning of 1967 was then calculated. This number was divided on the 1959-1961 year-classes according to the age composition of the Norwegian winter fishery in 1967. Table 2 shows that the estimates in the present investigation is somewhat lower than those given by the Working Group. However, the difference between the two estimates is by far large enough to explain the discrepancy in later years. With the recalculated stock size it is still necessary to use $M_2 > 1.0$ to get correspondance with the estimates obtained from the cohort analysis.

Fishing mortality

By using two alternatives of natural mortality, (a) $M = 0.16$ and (b) $M_2 = 1.0$ and $M = 0.16$ in the cohort analysis, two sets of F-values for the 1959 year-class were estimated (Table 3). In the Working Group report F-values, assuming full recruitment at seven years, were calculated based on, (a) total catch per effort data and (b) winter catch per effort data (Table 4). Comparing the F-values in Table 4 with the F-values in the first column of Table 3, it will be seen that an $M = 0.16$ for the whole period in the cohort analysis, results in higher values of F than those obtained from catch per effort data. Applying a value of $M_2 = 1.0$ gives lower values for F than the catch per effort data. By decreasing M_2 a better correspondance could be obtained. However, the estimates based on catch per effort data should not be given too much confidence. It seems that a natural mortality coefficient of $M = 0.16$ for the whole period overestimates F, but no firm conclusion can be drawn.

DISCUSSION

The equation (2) used to estimate the number of fish of a year-class at the beginning of each year, should only be applied when the fishing is approximately evenly distributed over the year. In 1969 and 1970, nearly all the herring were caught in the winter fishery. This could have been corrected for in equation (2) by replacing $C_i e^{M/2}$ with $C_i e^{M/n}$ where $n > 2$. But for the purpose of this paper, corrections are not necessary. If a correction was made, slightly higher values of M_2 had to be used in order to reduce the difference between the two sets of estimates. However, the aim of this paper is not to estimate M_2, which is here used only as a tool in the mathematical analysis. The biological meaning of this parameter, which might include also other factors than natural mortality, is not known.

The preliminary results obtained in the present investigation, suggest that something else, other than low recruitment to the adult stock and high exploitation rates during the years 1965-1967, might have contributed to the collapse of the Norwegian spring spawning herring stock. It should be emphasized, however, that the data used in this investigation are almost the same as those given in the report of the Working Group on Atlanto Scandian herring (ANON. 1970a, 1972) and no attempt has been made to reconsider the analysis presented in the Working Group report.

The stock size estimates based on tagging experiments and acoustic surveys are certainly subject to errors and the confidence intervals for the estimated stock sizes must be considerable. In order to get approximately the same results as in the present investigation, assuming an M in the order of 0.2 for the whole period, the stock size figures given by the Working Group have to be reduced by one-half to one-third. So far no further comments can be given concerning the confidence intervals of the estimates in the Working Group report. Provided that the stock size figures given in the report are approximately correct and the catch figures for the recent years are not completely wrong, the recent drastic decline in the stock cannot be explained by the fishery alone, and other factors must have accelerated the decline. Two of the causes might be:

(1) a marked increase in natural mortality from 1968 onwards,

(2) the herring might have dispersed to other areas.

Which one of the explanations suggested is the most likely, is difficult to judge, and before any firm conclusion can be given all the available data on Norwegian spring spawning herring should be reconsidered in light of more recent investigations.

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Table 1. Catch in numbers (10^6) of Norwegian spring spawning herring in the adult fisheries, 1965-1971.

	Year						
Year-class	1965	1966	1967	1968	1969	1970	1971
1959	2195.8	2868.3	1718.2	345.9	36.3	28.2	5.45
1960	570.4	1290.6	1135.0	134.8	33.5	26.7	6.91
1961	245.9	459.1	422.2	93.9	11.6	11.6	4.41
1948-1967	4340.6	5486.5	3475.9	628.0	87.7	75.5	21.33

Table 2. Year-class size in number (10^9) at the beginning of 1967

Year-class	Estimates obtained from the Bear Island tagging experiment	Estimates given by the Working Group (Anon. 1970a)
1959	5.95	6.81
1960	4.14	4.48
1961	1.57	1.87

Table 3. Estimates of F for the 1959 year-class obtained from cohort analysis for different values of M.

Year	M = 0.16	M_2 = 1.0, M = 0.16
1966	0.73	0.52
1967	1.43	0.65
1968	1.39	0.40
Mean	1.18	0.52

Table 4. Estimates of F derived from, (a) total catch per effort and (b) winter catch per effort (Anon. 1970a).

Year	(a)	(b)
1966/67	0.43	0.82
1967/68	0.83	1.10
Mean	0.63	0.96

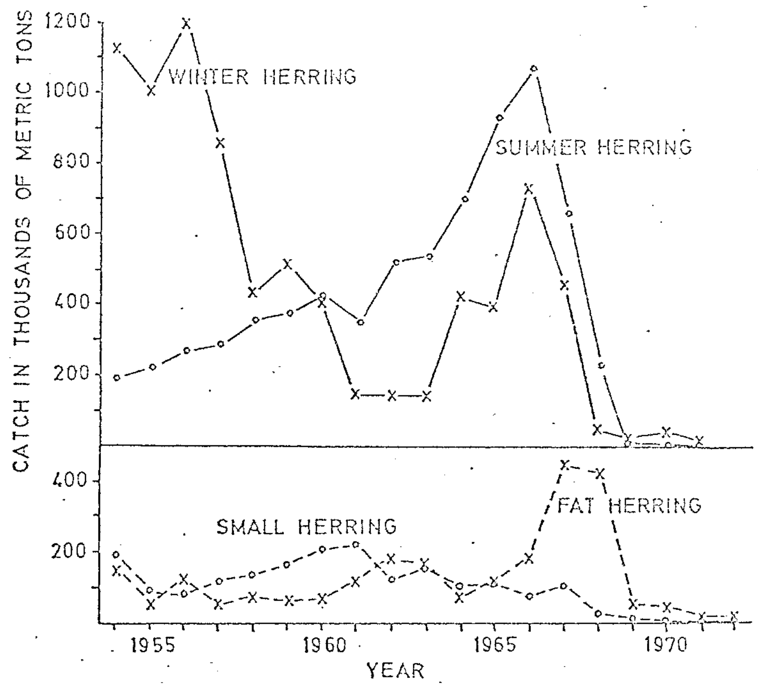

Fig. 1 Adult herring catches (winter and summer herring) and young herring catches (small and fat herring) 1954-1972.

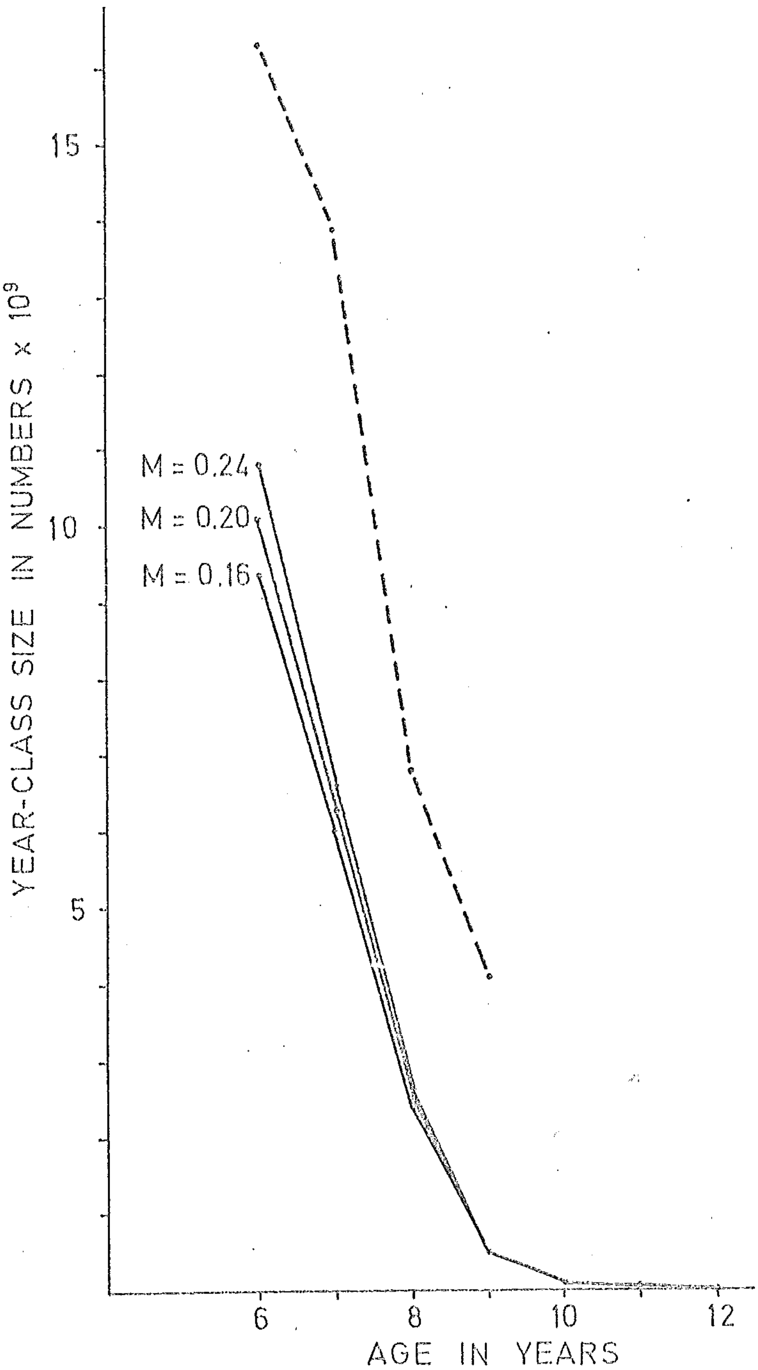

Fig. 2. Calculated stock size for the 1959 year-class at different age based on cohort analysis for three values of M, compared with the numbers given by the Working Group (1970a), broken line.

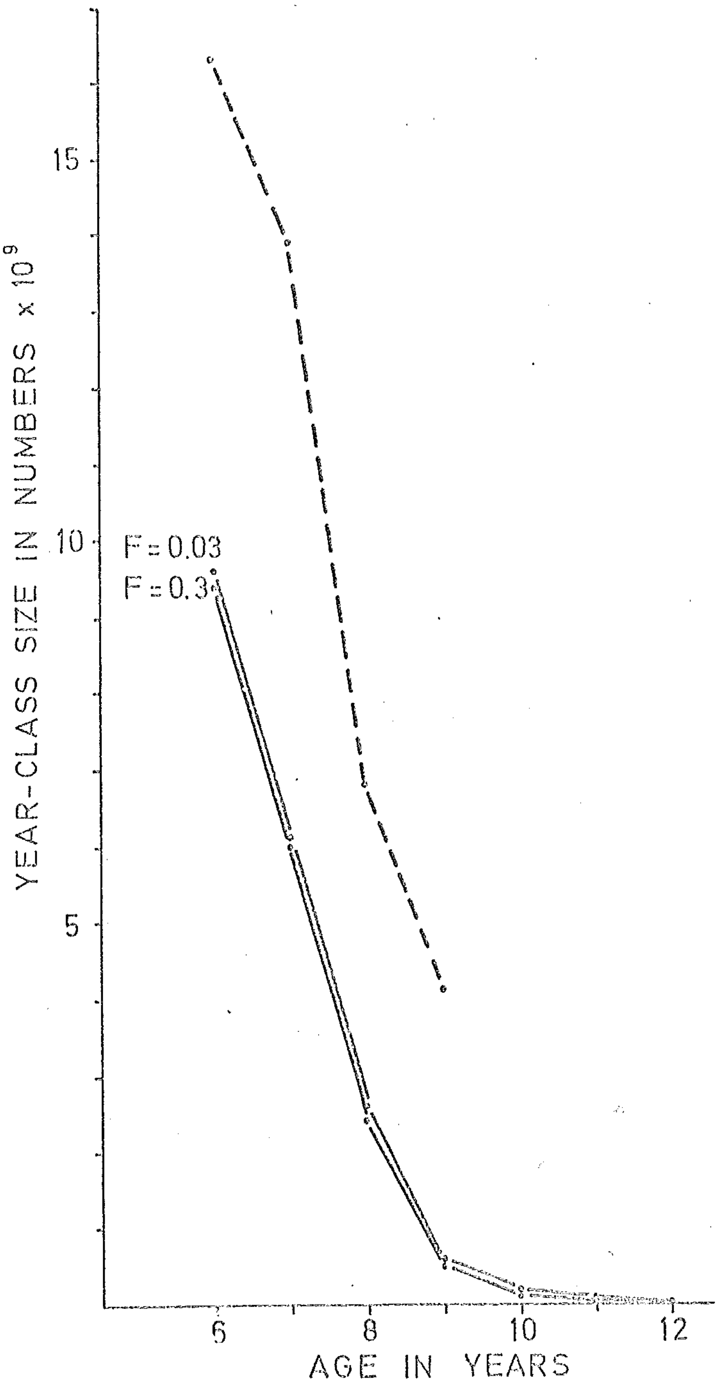

Fig. 3. Calculated stock size for the 1959 year-class at different age based on cohort analysis using M = 0.16 over the whole period and F = 0.3 and 0.03 for 1971, compared with the numbers given by Working Group (1970a), broken line.

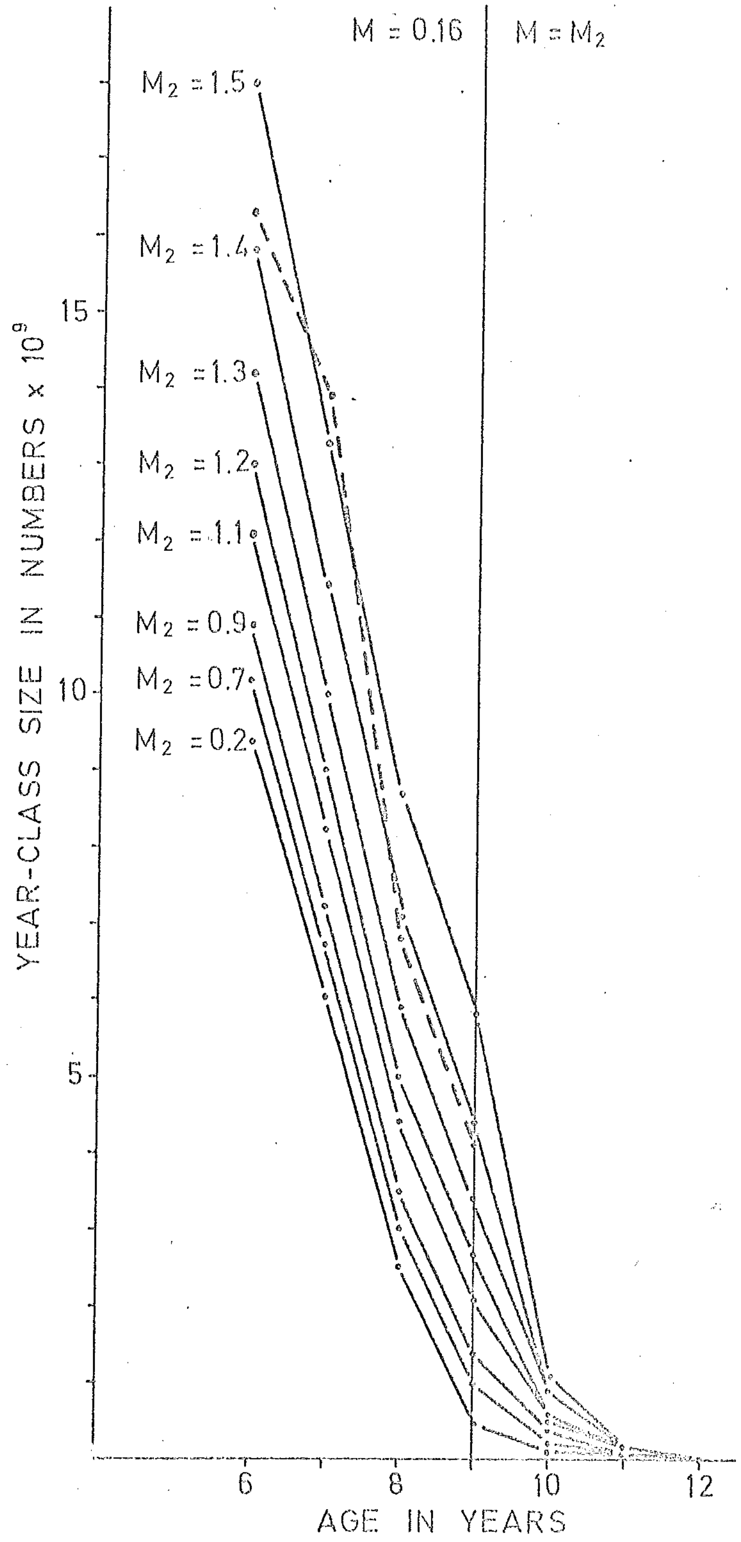

Fig. 4. Calculated stock size for the 1959 year-class at different age based on cohort analysis for eight values of $M = M_2$, compared with the numbers given by the Working Group (1970a), broken line. Prior to 1968 M was set to 0.16.

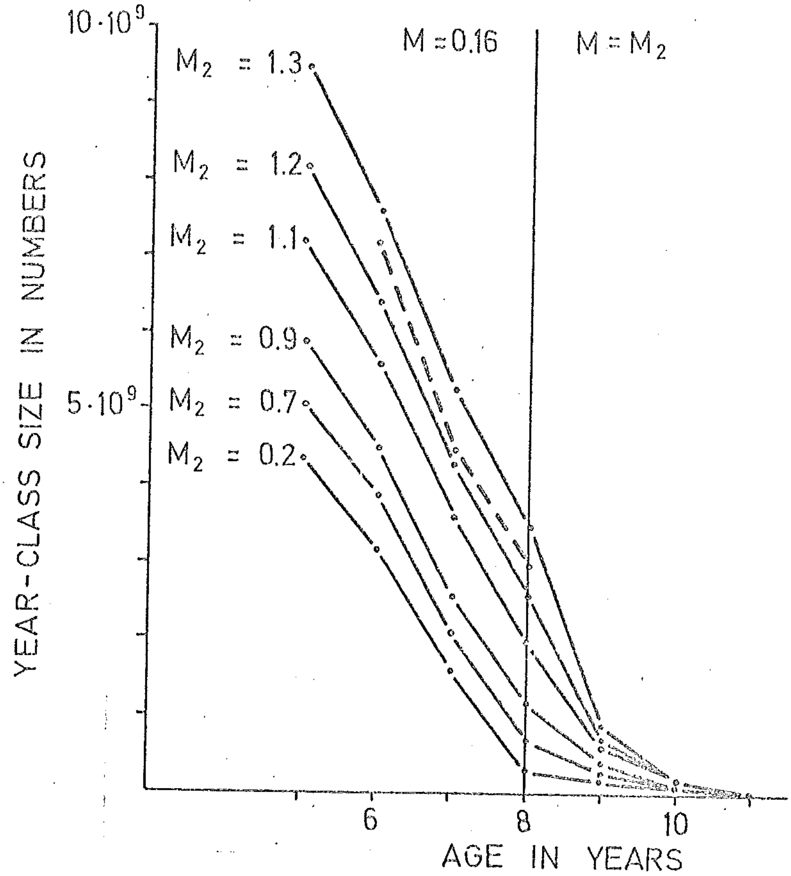

Fig. 5. Calculated stock size for the 1960 year-class at different age based on cohort analysis for six values of $M = M_2$, compared with the number given by the Working Group (dotted line). Prior to 1968 M was set to 0.16.

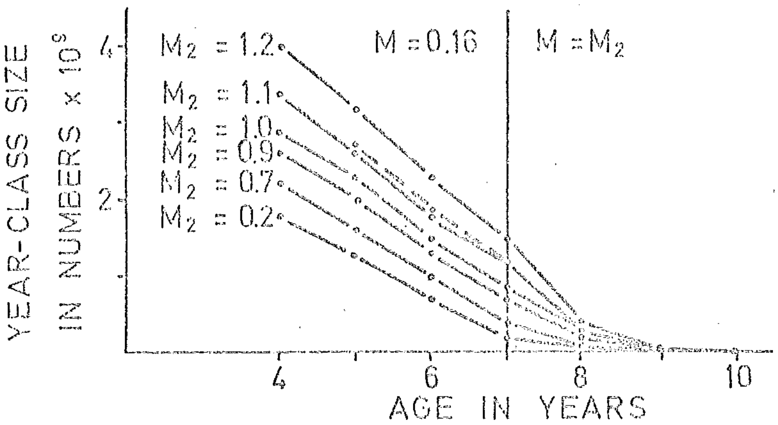

Fig. 6. Calculated stock size for the 1961 year-class at different age based on cohort analysis for six values of $M = M_2$, compared with the numbers given by the Working Group (1970a), broken line. Prior to 1968 M was set to 0.16.