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FURTHER STUDIES ON STOCK SIZE FLUCTUATIONS AND RATE OF EXPLOITATION OF THE NORWEGIAN SPRING SPAWNING HERRING, 1950-1971

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INTRODUCTION

The marked decline in the adult stock of Norwegian spring spawning herring during the late 1960s and early 1970s is well known from several reports (ANON. (1970, 1972). In order to investigate if high exploitation rate and low recruitment were the only causes for the collapse of the stock, a cohort analysis was carried out on three selected year classes, those of 1959, 1960 and 1961 (DRAGESUND and ULLTANG 1972).
Indication was found that the drastic decline in the adult stock could not be explained by the fishery alone, provided that stock size figures given in the report of the Working Group on Atlanto-Scandian Herring (ANON. 1970) and the catch figures for the recent years were not completely wrong.
It was suggested that other factors also could have accelerated the decline, e. g:

(1) a marked increase in natural mortality from 1968 onwards
(2) the herring might have dispersed to other areas.

In the present paper further studies have been carried out on all the available year-classes forming the adult stock during the period 1950-1971 using a cohort analysis (POPE 1971).

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in this investigation are from the report of the Working Group on Atlanto-Scandian Herring (ANON. 1970, 1972) and from unpublished data available at the Institute of Marine Research, Bergen.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 $\underline{i}$ and N_i is the number of fish in the year-class at the beginning of year $\underline{i}$.

Z_i is calculated from the expression

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

and F_i from

$$F_i = Z_i - M$$

RESULTS

Year class strength and stock size estimates

The cohort analysis was carried out for two alternatives of natural mortality:

(1) a constant natural mortality of $M = 0.16$

(2) a higher natural mortality of $M_2 = 1.2$ in 1968 and later years, and $M = 0.16$ in the earlier years.

The value of $M_2 = 1.2$ was chosen because it gives estimates of the 1959-61 year-classes corresponding well with those obtained by the Working Group on Atlanto-Scandian Herring (ANON. 1970, DRAGESUND and ULLTANG 1972).

The calculated size of the 1946-1966 year-classes as four years old for the two alternatives is given in Table 1 and Fig. 1. Alternative (2) results in an increase in the estimated size of the later year classes. For the earlier year classes (1946-1958) the two alternatives give almost identical values. There are very strong variations in year class strength. The 1950- and 1959-year classes were far above the average strength, while the 1954-58 and 1962-66 year classes were very weak. The last year class which gave catches of any considerable amount in the adult fisheries was that of 1961.

The estimated total stock size in number and weight of four year old and older herring in the period 1950-71 is given in Figs. 2 and 3. As for the estimates of year class strength, the effect of using a higher M in the later years is a rise in the estimates. For the earlier years in the period (1950-62), the difference between the two alternatives is almost negligible.

The stock size was at a maximum of about 18.4 million tons in 1954, when the 1950- year class entered the adult stock. From 1954 onwards the stock declined until 1963, when the 1959- year class was recruited. From 1964 onwards there has been a steady decline and the stock size is now at a very low level.

The estimated stock size of four year old and older herring is an over-estimate of the spawning stock since the herring are not fully recruited at an age of four years. Taking this into account the correspondance between the calculated stock size from the cohort analysis and the estimates from tagging data and echo surveys given by the Working Group (ANON. 1972) is indeed very good (Fig. 3). A high value of natural mortality in 1968 and later corresponds better with the Working Group estimates.

Fishing mortality and effort

Using a constant natural mortality of M = 0. 16, alternative (1) in the cohort analysis, F - values for the period 1950-1968 were estimated assuming full recruitment at six years of age (Fig. 4). The fishing mortality was fairly constant throughout the 1950s, showing a slight increase in the early 1960s. During 1963-1965 the fishing mortality was significantly higher than in the previous years and from 1965 to 1967 a further and more marked rise was noticed from a value of F = 0. 38 in 1965 to 1. 45 in 1967 (Fig. 4).

The average values of F in the three year periods 1960-1962, 1963-1965 and 1966-1968 were respectively: 0. 14, 0. 34 and 1. 10. Comparing the periods 1960-1962 and 1963-1965 there was an increase in F of about 143 %. From 1963-1965 to 1966-1968 F increased with about 223 %.

This marked rise in F during the 1960s was obviously due to the impact of the technical innovations in the purse seine fishery. Because of the changes in the composition of the fleet and in the fishing efficiency of the vessels, the number of boats can not be used as an index of the effort exerted. The Working Group on Atlanto Scandian Herring used the USSR catch per drift-net to calculate the total effort exerted on the Norwegian spring spawning herring (ANON. 1970, 1972). The estimates for the period 1958-1968 (in drift-net units) showed a clear increase, but not by far as large as indicated by the F-values obtained from the cohort analysis using a constant M = 0. 16. Comparing the periods 1960-1962 and 1963-1965 the increase in effort was about 25 % and comparing 1963-1965 with 1966-1968 the increase was about 53 %. It should also be noted that the fishing mortality obtained from the cohort analysis increased by about 100 % from 1966 to 1967 (Table 2), whereas the fishing effort did not show any increase at all (ANON. 1972).

By using alternative (2) of the natural mortality in the cohort analysis (M_2 = 1. 2 and M = 0. 16) the estimated F-values in 1966-1968 were considerably reduced being comparable with those in the previous three year period (Fig. 4). This alternative gave about the same F-values for the years 1966 and 1967.

The impact of the small and fat herring fishery on subsequent year class strength

Much attention has been drawn to the probable serious effect of the exploitation of immature herring on the recruitment to the adult stock. DRAGESUND (1970) showed that abundant year classes have a proportionally greater

offshore occurrence than less abundant. Hence the fishery in the fjords of Norway will have a comparatively greater effect on a weak year class. 0-group abundance indices given by DRAGESUND and NAKKEN (1970) show that the year classes produced in 1962-1969 were all weak compared with the rich 1959 and 1960 year classes. Consequently the number of recruits of the 1962-1969 year classes entering the adult stock was expected to be low. However, with the relative high exploitation rate during the juvenile stages of these year classes it is evident that the young herring fishery had a serious effect on the recruitment to the adult stock (Fig. 5).

CONCLUDING REMARKS

Obviously the recruitment to the adult stock has completely failed during the recent years. The exploitation of immature herring in Norwegian fjords and coastal waters during the late 1960s has had a significant effect on subsequent year class strength. In contrast to previous periods a long series of poor year classes have been produced during the 1960s. With the high fishing effort in the juvenile fishery a marked increase in the exploitation rate of both small and fat herring took place (DRAGESUND 1970, ANON. 1970, 1972). This again resulted in an extraordinary low recruitment to the adult stock.

On the other hand the results obtained in the present investigation, suggest that something else, other than low recruitment to the adult stock and high exploitation rates during the mid 1960s, have contributed to the complete collapse of the adult stock. The drastic decline in number of herring already recruited in the adult stock cannot be explained by the fishery alone, and other factors might have accelerated the decline. The most reasonable explaination is that an increase in the natural mortality had taken place sometime after 1968

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Table 1. Year-class size in number (10^6) as 4 years old

Year-class	M = 0.16	M_2 = 1.2, M = 0.16
1946	3718	3812
1947	8526	8766
1948	4584	4694
1949	3182	3219
1950	39755	39971
1951	5877	6017
1952	2767	2831
1953	2424	2467
1954	473	509
1955	391	476
1956	115	143
1957	97	121
1958	167	188
1959	15819	20717
1960	5492	9925
1961	1748	3977
1962	91	249
1963	66	472
1964	7	246
1965	3	28
1966	6	23

Table 2. Stock size (4 years old and older) in number (10^9) and weight (million tons) and fishing mortality (on 6 years old and older herring) for the period 1950-1971.

Year	M = 0.16			M_2 = 1.2 M = 0.16		
	Stock size		Fishing mortality	Stock size		Fishing mortality
	N	W		N	W	
1950	41.55	10.54	0.08	41.64	10.56	0.08
1951	41.45	12.50	0.09	41.77	12.59	0.09
1952	37.27	11.33	0.09	37.66	11.44	0.09
1953	32.45	9.81	0.10	32.81	9.92	0.10
1954	65.10	18.40	0.15	65.63	18.55	0.15
1955	57.32	14.70	0.12	57.90	14.85	0.12
1956	47.55	13.10	0.12	48.12	13.26	0.12
1957	38.40	10.77	0.11	38.93	10.92	0.11
1958	29.68	8.80	0.08	30.16	8.95	0.08
1959	23.39	7.53	0.11	23.88	7.69	0.11
1960	17.73	5.75	0.14	18.18	5.89	0.14
1961	13.15	4.25	0.11	13.56	4.38	0.11
1962	10.24	3.44	0.18	10.61	3.56	0.18
1963	23.07	4.85	0.28	28.29	5.95	0.27
1964	23.30	6.28	0.37	32.17	8.67	0.35
1965	18.31	4.68	0.38	28.10	7.18	0.28
1966	11.66	2.77	0.74	20.16	4.78	0.39
1967	4.97	1.35	1.45	12.58	3.43	0.37
1968	1.03	0.26	1.10	7.76	1.91	0.17
1969	0.30	0.08	0.39	2.02	0.56	0.09
1970	0.18	0.06	0.61	0.58	0.19	0.28
1971	(0.09)	(0.03)	(0.30)	(0.14)	(0.04)	(0.30)

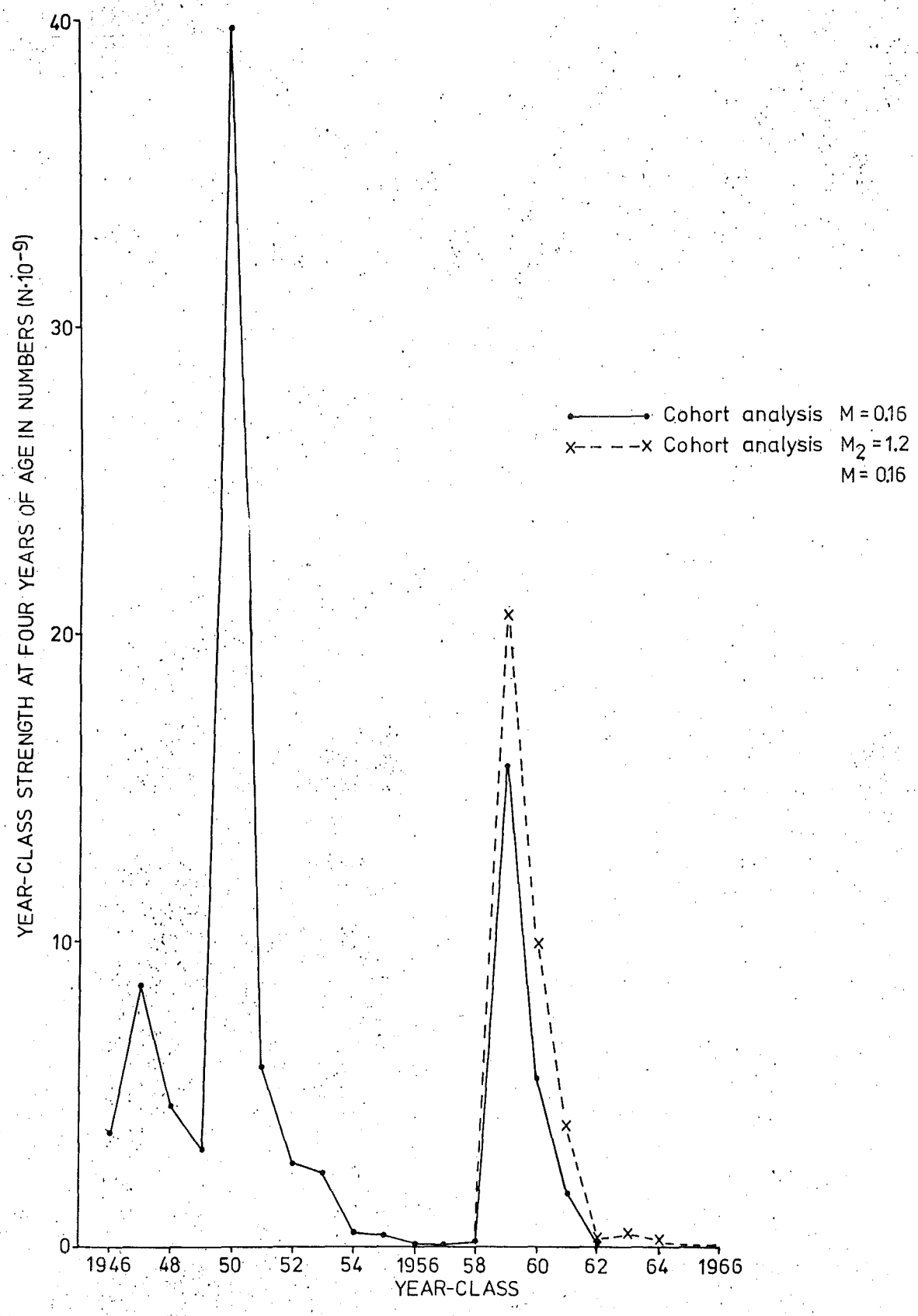

Fig. 1. The calculated size of the 1946-1966 year-classes at four years of age for two alternatives of natural mortality, (1) M= 0.16 and (2) M_2= 1.2, M= 0.16.

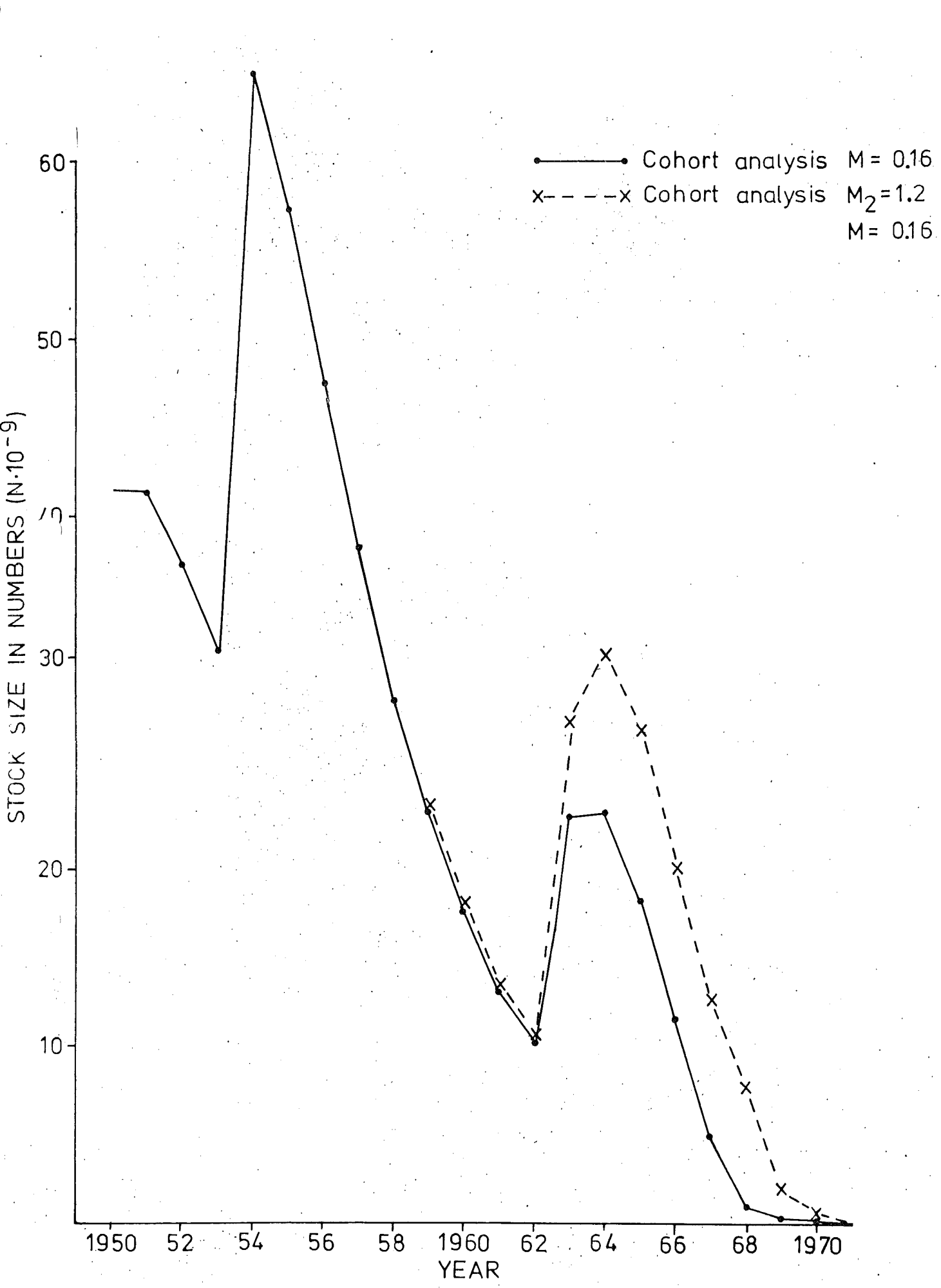

Fig. 2. The calculated total stock size in number of four year old and older herring for two alternatives of natural mortality, (1) M= 0.16 and M_2= 1.2, M= 0.16.

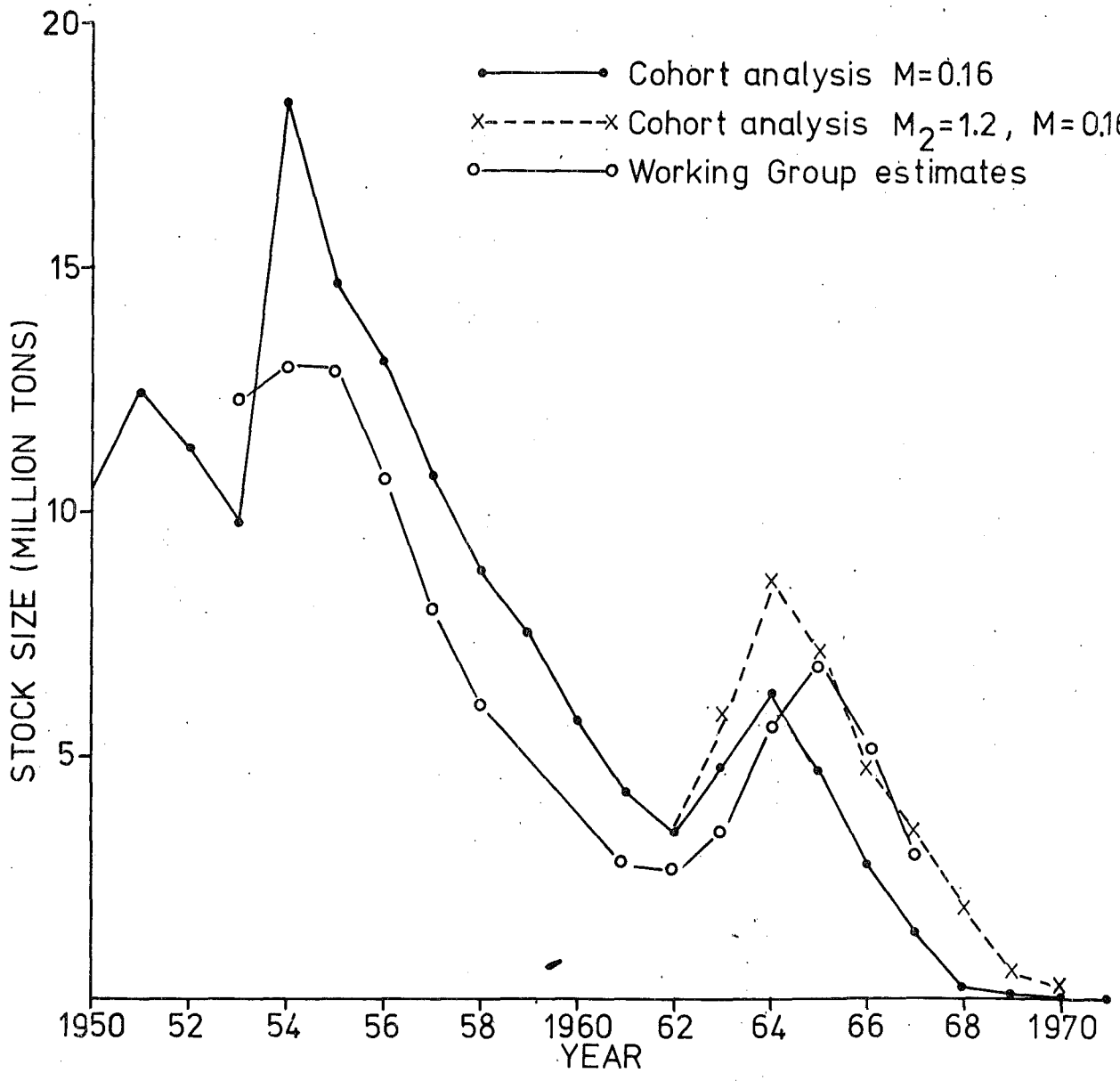

Fig. 3. The calculated total stock size in weight of four year old and older herring for two alternatives of natural mortality, (1) M= 0.16 and M_2 = 1.2, M= 0.16. Stock size estimates from the report of the Working Group on Atlanto-Scandian Herring are also indicated in the figure.

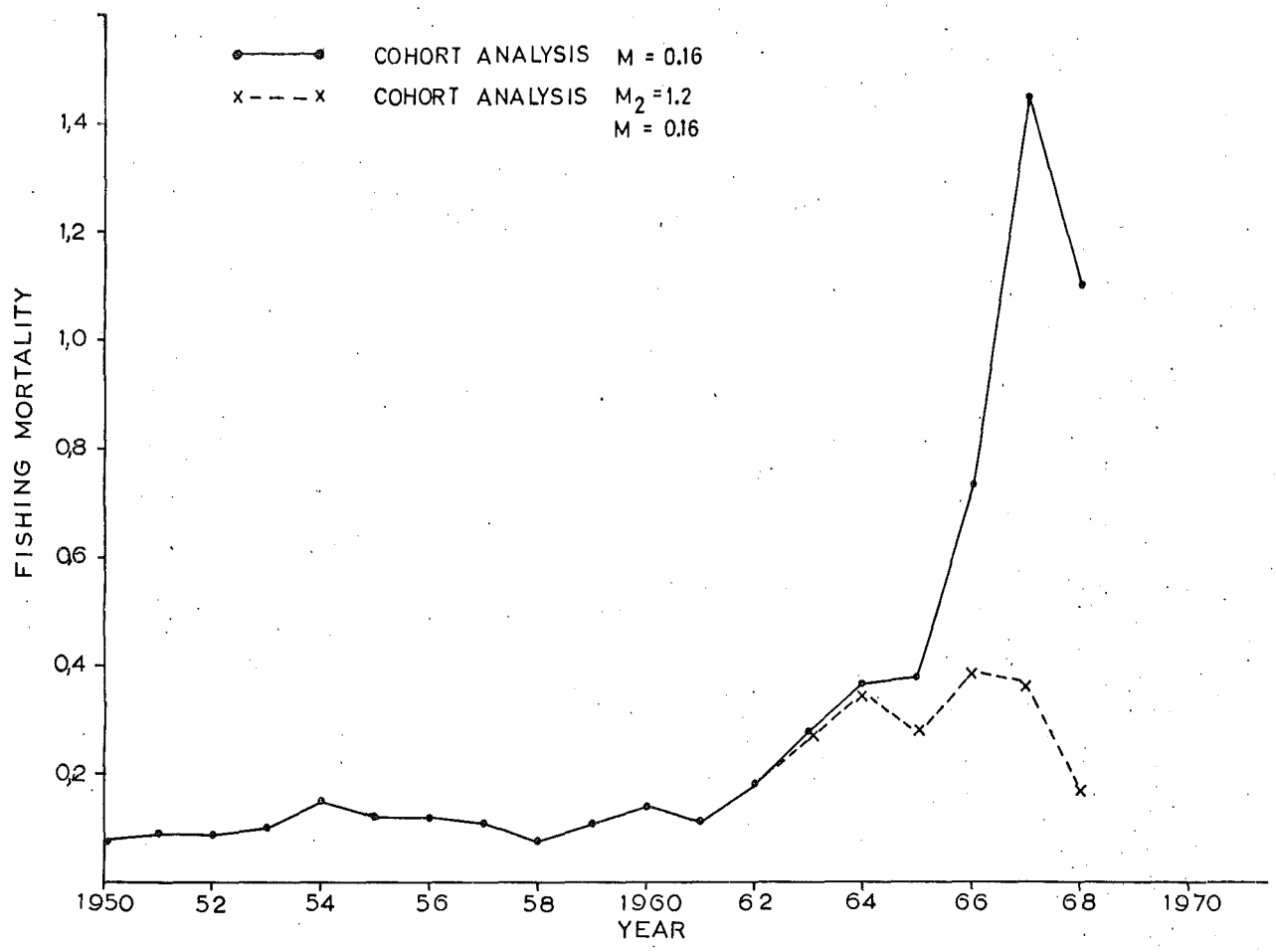

Fig. 4. Estimates of fishing mortality assuming full recruitment at six years of age for the period 1950-1968 using two alternatives of natural mortality, (1) M= 0.16 and (2) M_2= 1.2, M= 0.16.

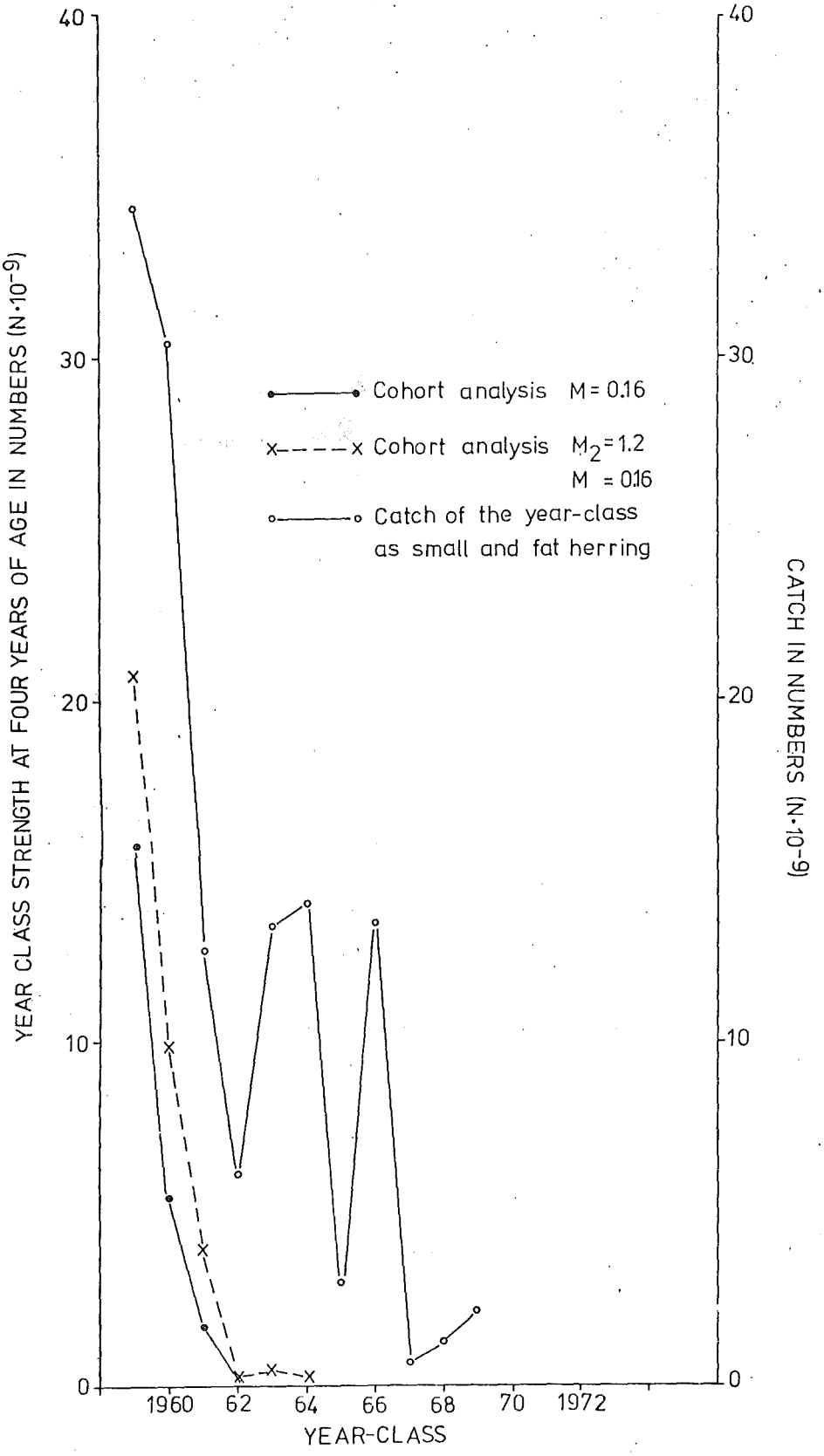

Fig. 5. Year-class strength at four years of age for two alternatives of the natural mortality, (1) M= 0.16 and (2) M_2= 1.2, M= 0.16. The catch in number of small and fat herring for the 1959-1969 year-classes are also given in the figure.