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STOCK SIZE FLUCTUATIONS AND RATE OF EXPLOITATION OF THE NORWEGIAN SPRING-SPAWNING HERRING, 1950-1974.

by

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INTRODUCTION

Traditionally the main fishery on the adult stock of Norwegian spring spawning herring has taken place along the Norwegian west coast prior to and during the spawning season. The landings of the so-called winter herring fishery, i.e. herring in pre-spawning and spawning condition, indicate two periods of high stock level: 1830-1870 and 1945-1957. Extremely low catches were obtained during the period 1875-1890 suggesting a minimum stock size (Bakken and Dragesund 1971). Another important fishery (the summer and autumn herring fishery) has taken place on the feeding grounds along the Polar Front in the Norwegian Sea. This fishery was for a long period located off North and Northeast Iceland and is also mainly exploiting the adult stock. During the last two decades there has been a drastic change in the migration pattern of the adult stock, and this has strongly influenced the location of the summer and autumn as well as the winter herring fishery (Devold and Jakobsson 1968).

Although the total catch of adult herring (including the summer and autumn fishery) to a large extent has fluctuated in relation to the entrance of strong year-classes throughout the history of the fisheries this phenomenon has been especially pronounced during the period 1950-1970. Thus, the very rich 1950 year-class caused high catches in the adult herring fisheries in the mid 1950s and the strong year-classes of 1959 and 1960 gave a high level in the years 1964-1967 (Table 1). Both periods of high catches were followed by a decline, which was most striking in the latter period when the decrease in the adult stock was accelerated by an increase in exploitation rate compared to earlier periods. However, primarily the decline was caused by practically no recruitment to the adult stock after the 1959 and 1960 year-classes were fully recruited to the stock in 1966.

From 1965 onwards a rapid decrease in the stock size took place, and in 1969-1971 the catches both in the adult summer and winter herring fisheries were negligible compared with earlier years. During the spawning season of 1972 almost no herring were recorded on the traditional spawning grounds and the spawning stock was reduced to an extraordinary low level. In 1973-1975 a slight increase in the spawning stock took place due to recruitment from the 1969 year-class However, there is no evidence of any significant improvement in the state of the Norwegian spring spawning stock.

In addition to the fishery on adults there has been a fishery on young and adolescent herring in the Norwegian fjords, mainly in North Norway. This fishery is based on the small-herring (småsild) i.e. mainly 0- and I-group fish,and on the fat herring (feitsild) i.e. I- to IV-group herring (Dragesund 1970). The catches of small-herring have declined since the mid 1960s (Table 2). This decline was largely determined by the low abundance of small-herring, due to a series of weak to moderate year-classes since 1965. Catches of the fat-herring increased considerably in the years 1966-1968, having fluctuated with no definite trend in the years 1950-1965 (Table 2).

The lack of recruitment to the adult stock during the last decade was due both to a series of weak year-classes and a high rate of exploitation of young and adolescent herring. During a period of low production the fishery on young herring most likely has had a serious influence on the population dynamics of the stock. The description of the collapse of the stock of Norwegian spring spawning herring is well known from several reports (ANON. 1970, 1972, 1975). As regards the causes of the collapse the views differ ranging from a puristic environment conditional natural-based cause to a full fishery-induced effect. In two previous reports Dragesund and Ulltang (1972, 1973) raised the question whether low recruitment and high exploitation rate were the only causes of the collapse of the stock.

MATERIAL AND METHODS

Stock size and fishing mortality were calculated from cohort analysis, the main input data being the total cath in number by age in the different years. Catches in tons were converted to catch in number by age separately for the adult fisheries and the young and adolescent herring (small- and fat-herring)fisheries.

The catch in number by year-class in the adult fisheries 1962-1970 given in the Working Group on Atlanto-Scandian Herring (ANON. 1970, 1972) was extended to cover the period 1950-1971 and all age-groups in the adult fisheries (Table 3) by utilazing:

(i) Data on age-composition in the winter fishery 1950-1970 and the summer and autumn fishery 1962-1970 given in ANON. (1970, 1972).

(ii) Data on mean weight in catch in the winter fishery 1950-1961 available from the records of Institute of Marine Research, Bergen.

(iii) Icelandic data on age-composition in the summer and autumn fishery 1950-1961 published in Anal.Biol.

(iv) Icelandic tata on mean weights by age during the summer and autumn fishery (Jakobsson personal communication).

(v) Data on age-composition and mean weight in catch in the Norwegian winter fishery 1971.

The catch in number by year-class in the young and adolescent herring fishery in 1950-1974 (Table 4) were obtained by utilizing:

(i) Data on catch by year-class in the small-herring fishery given in Dragesund (1970) and data from the records of the Institute of Marine Research, Bergen.

(ii) Data on age-composition in the fat-herring fishery given in Dragesund (1970) and data from the records of the Institute of Marine Research, Bergen.

(iii) Data on mean weight by month and district for year-classes going through the small- and fat-herring fishery from the O-group to the adolescent stage given in Dragesund (1970).

A constant natural mortality M=0.16 was assumed for the whole period 1950-1974 for all age-groups. The validity of this assumption will be discussed in later sections of the paper.

RESULTS

Adult stock

In Table 6 are shown the spawning stock size in number and weight and the fishing mortality on 4 years old, 5 years old, 6 years old, 7 years old and older herring for the years 1950-1971, assuming a fishing mortality on the fully recruited year-classes in 1971 of 0.3. A fishing mortality of 0.3 gives a spawning stock size of about 30 000 tons in 1971. The results of the calculations given in Table 6 are also plotted in Fig. 2 (stock size in number), Fig. 3 (stock size in weight) and Fig. 4 (fishing mortality on 7 years old and older herring).

The fishing mortalities are those generated by the total catch of an age group, and not only the catch in the adult fisheries. It appears from Table 4 that some 4, 5 and 6 years old herring are also taken in the fat-herring fishery. The fishing mortalities on 4-6 years old herring have generally been lower than on 7 years old and older herring. The main reason for this is probably that these age groups showed a more oceanic distribution throughout the year than the older age groups. Thus, they have not been heavely exploited in the fat-herring fishery and on the other hand they have not been fully recruited in the adult stock. The extremely high fishing mortalities on 4 and 5 years old herring in 1968 (Table 6) were generated by the fat-herring fishery.

The spawning stock size was calculated by assuming full recruitment to the adult stock at an age of 7 years.
To the stock size of 7 years old and older herring given by the cohort analysis was added portions of the younger year-classes. The quantity to be added for a year-class of age t ($t < 7$) was calculated by

$$N_t, \text{adult} \quad = \frac{p_t}{p_{7+}} \cdot N_{7+}$$

where N_{7+} = total number of 7 years old and older herring

p_t = percentage t years old herring in the winter fishery (Table 5)

p_{7+} = percentage 7 years old and older herring in the winter fishery.

The spawning stock size was at a level of about 9 million tons in 1950 (Table 6, Fig. 3) and decreased to about 7 million tons in 1953. From 1954 to 1957 the strong 1950 year-class gradually recruited the spawning stock (Table 5) resulting in an increase in stock size which reached a peak of about 10 million tons in 1957 when the year-class was fully recruited. The stock then decreased again as a result of poor recruitment, reaching a minimum level of about 1.6 million tons in 1963. The fishing mortalities were in the whole period 1950-1963 on a low or moderate level (Table 6, Fig. 4).

The strong 1959 year-class started to recruit the spawning stock only to a small extent in 1963, but in 1964 it contributed by about 60% to the spawning stock in number (Table 5). The stock increased to about 3.7 million tons in 1964 and 4.5 million tons in 1965 (Fig. 3) when also the relatively strong 1960 year-class recruited the stock.
From 1965 onwards there was a rapid decrease in spawning stock size due to an almost complete stop in recruitment to the adult stock and strongly increasing fishing mortalities.
The last year-class which recruited the stock to any extent

was that of 1961. The increase in fishing mortalities on the adult stock from 1964 onwards was primarily a result of the escalation in the summer and autumn fisheries off Iceland, where the catch reached a peak of 1069 thousands tons in 1966 (ANON. 1972).

A drawback by the method used to calculate the spawning stock size is that the information available from the cohort analysis about the strength of year-classes younger than 7 years is not utilized in the calculations. Errors in the age composition in the winter fishery one year may have great influence on the calculation of the spawning stock that year, especially when strong year-classes younger than 7 years are in the spawning stock. This will be the case in the years 1954-1956 and 1963-1965.

By comparing the age composition in the winter herring fishery with the age composition in the total stock calculated by cohort analysis, the estimates show that for the 1950 year-class 16% of the 4 years old, 47% of the 5 years old, and 60% of the 6 years old had spawned. For the 1959 year-class the figures are 3%, 63% and 100% respectively.

The fishing mortalities in the adult stock show an increasing trend with age. This is illustrated in Fig. 5 where mean fishing mortalities on the age groups 7-9, 10-12 and 13-15 are plotted for the period 1950-1965. From 1965 onwards the estimates of the fishing mortalities for year-classes older than the 1959 year-class are very uncertain. In the period 1950-1955 there is no clear trend. In the period 1956-1965 however, the fishing mortality is consistently lowest for the age groups 7-9 and highest for those of 13-15. The oldest age group used in the cohort analysis is the 20 years old herring, and the difference illustrated in Fig. 5 therefore can hardly be explained by the fishing mortalities assumed for the oldest age group used in the cohort analysis.

There may be several explanations for the observed increase with age in the fishing mortalities. Limitation in time did not allow to investigate this topic thoroughly in the present paper, but two possible explanations will be indicated: The exploitation rate on old herring may have been higher than on younger herring in the summer and autumn fisheries, as indicated by an observed difference in age composition between the winter fishery and the summer and autumn fishery, especially in the 1950s. It is interesting to note that the catches in the summer and autumn fishery show a significant increase around 1955, i.e. at the same time as the observed increase in fishing mortalities with age starts.

Another possibility is that natural mortality increases with age. In the cohort analysis the natural mortality is assumed constant and an increasing natural mortality with age will therefore in the calculations show up as increasing fishing mortalities.

Dragesund and Ulltang (1973) presented the estimates of stock size from cohort analysis as the total stock of 4 years old and older herring and found a remarkable good correspondence between their estimates of stock size and the estimates of adult stock size given in the Working Group on Atlanto-Scandian Herring (ANON. 1970, 1972) except for the latest years (1965-1967). When the stock size estimates from the cohort analysis are presented as the size of the spawning stock, calculated as in the present investigation, there is greater discrepancies between the two sets of estimates, especially in the years when the 1950 and 1959 year-classes are recruiting the spawning stock. This is illustrated in Fig. 3. It should be noted, however, that the Working Group estimates are mainly based on tagging experiments.

Young herring

In Table 7 is shown the fishing mortality on the age groups 0-3 for the year-classes 1950-1969, and in Table 8 is shown the year-class size in number at different ages. In Fig. 1 are plotted year-class size as 0-group and 4 years old herring.

During the whole period of 1950-1969 the exploitation rate on young herring has been high. From Fig. 1 and Table 8 it is seen that there is a clear correlation between year-class size and the survival during the young herring stages. The survival rate decreases with decreasing year-class strength. This is illustrated in Fig. 6 where the logarithm of the number (ln N) is plotted against age for two weak year-classes (1955 and 1962) and two strong year-classes (1950 and 1959). Year-classes recorded in the 1950s which traditionally have been called weak were all, compared to the results presented in Fig. 1, of what could be called an ordinary strength of 10×10^9 - 30×10^9 in number at the 0-group stage. However, of year-classes of strength less than 20×10^9 as 0-group, very small quantities survived the fishery to an age of 4 years old. In addition to the year-classes of ordinary strength there were three extraordinary strong year-classes (those of 1950, 1959 and 1960). The 1965 year-class (or possibly that of 1962) is in light of Fig. 1 and Table 8 the first one in the period studied which really should be characterized as weak.

The decreasing survival rate with year-class strength indicates that the same fishing effort in a purse seine fishery like that for young herring going on in coastal waters may generate a much higher fishing mortality when stock abundance is low than when the abundant is higher, but it also reflects that strong year-classes had a more off-shore distribution and that part of those year-classes therefore were outside the traditional fishing areas (Dragesund and Nakken 1973).

The 1961 year-class were the last one which recruited the spawning stock in any quantities (Table 5). From Fig. 1 and Table 8 it is seen that some quantities of the relatively strong 1963 and 1964 year-classes survived to an age of 4 years. The portions of these two year-classes which survived the fishery during the first years of life where however practically fished out in the fat-herring fishery in 1968 going on off the coast of Finnmark. Cohort analysis gives for that year fishing mortality estimates as high as 4.5 (Table 6). The mortality on these two year-classes at different ages is also illustrated in Fig. 6 where ln N is plotted against age.

At the O-group stage the year-classes of 1964 and 1966 were approximately of the same strength (Table 8, Fig. 1). However, the 1966 year-class was practically fished out in the small-herring fishery in 1967 which generated a fishing mortality of 2.6 (Table 7). The 1967-1969 year-classes were as O-group of the order of only 10% of the 1963, 1964 and 1966 year-classes (Table 8), and the 1969 year-class is the only one which have been observed in the spawning stock in any quantities the last years.

The cohort analysis gives no reliable estimates of strength of the year-classes after 1969, but they are all very weak, tentatively of the order of 10% of the 1967-1969 year-classes i.e. of the order of only 1% of the 1963, 1964 and 1966 year-classes.

CONCLUDING REMARKS

The serious effect of the young herring fishery on the recruitment to the adult stock is clearly illustrated in Fig. 1. A year-class even in the 1950s had apparently to be of a size of about 20 x 10^9 in number as 0-group if a significant quantity should get a chance to escape the small- and fat-herring fishery. This means a year-class strength of 2-3 times the average strength for the North Sea Herring stock which have been estimated to be able to sustain an annual yield of about 800 thousands tons if properly managed (ANON. 1973). All year-classes in the period 1950-1966 except those of 1962 and 1965 would have recruited the adult stock in at least the same quantity as the very strong 1960 year-class did if they had not been fished as juveniles.

The 1963 and 1964 year-classes were the last ones which survived to four years old in any quantity, but these to year-classes were practically fished out in the fat-herring fishery in 1968 (Table 6, Fig. 6). Dragesund and Ulltang (1972, 1973) discussed the possibility that increased natural mortality from 1968 onwards increased the rate of decline in the adult stock. The authors still regard this as a possibility, and it is also possible that some more fish were left of the 1963 and 1964 year-classes after 1968 which never showed up in the spawning stock because of increased natural mortality. Fishing mortalities of about 4.5 as estimated for these two year-classes in 1968 mean that only 1% of the fish present at the beginning of the year survived the fishery, and this seems unlikely as the year-classes in question had an off-shore distribution in 1968.

The results of the present investigation leave, however, no doubt that the fishing pressure, especially on young and adolescent herring but also on adult herring in the years 1965-1968, was the primary factor for the collapse of this herring stock. A possible increased natural mortality in later years may have been a result of the already extremely low stock size. In the same way as the fishing fleet was able to generate a much higher fishing mortality on weak than on strong year-classes as demonstrated in Fig. 6 and Tables 7 and 8, the stocks of predators may have been able to generate a much higher natural mortality when the stock was so strongly depleted by the fishery.

Instead of looking for natural (environmental) causes for the collapse one should perhaps better look for the natural (environmental) factors which delaied the collapse. It seems evident from Fig. 1 and Fig. 4 that the collapse could have been a reality at a much earlier stage if it had not been for the extraordinary strong year-classes of 1950, 1959 and 1960.

The weak year-classes from 1967 onwards were probably a result of the low spawning stock size. If the decline in spawning stock size in 1967 reached the critical level where there is a clear relationship between spawning stock biomass and subsequent recruitment it means that this critical level for the Norwegian spring spawning herring may be of the order of 1-2 million tons. The spawning stock size is estimated to be 1.3 million tons (0.8 if catch in the winter fishery is subtracted) in 1967. The lowest level ever recorded earlier in the period studied was 1.6 million tons (1.5 if catch in the winter fishery is subtracted) in 1963, and the 1963 year-class was relatively strong.

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Table 1. Total catch (in thousands tons) of adult Norwegian spring spawning herring 1950 - 1971.

Year	Iceland	Norway	USSR	Faroes	Germany	Total
1950	30.7	781.4	14.0	-	-	826.1
1951	48.9	902.3	43.0	-	-	994.2
1952	9.2	840.1	69.9	-	-	919.2
1953	31.5	692.2	110.0	16.2	-	849.9
1954	15.2	1103.6	160.0	27.6	-	1306.4
1955	18.1	979.3	207.0	13.1	-	1217.5
1956	41.2	1160.7	235.0	23.7	-	1460.6
1957	18.2	813.1	300.0	17.0	-	1148.3
1958	22.6	356.7	388.0	17.7	-	785.0
1959	34.5	426.9	408.0	13.7	-	883.1
1960	26.7	318.4	465.0	11.0	-	821.1
1961	85.0	111.0	285.0	16.9	-	497.9
1962	176.2	156.2	209.0	9.8	-	551.2
1963	177.5	130.4	350.0	12.9	-	670.8
1964	367.4	366.4	365.8	18.3	-	1117.9
1965	540.0	259.5	489.2	31.5	5.6	1325.8
1966	691.4	497.9	447.4	60.7	26.1	1723.5
1967	359.3	423.7	303.9	34.9	9.7	1131.5
1968	75.2	55.7	124.3	16.1	1.8	273.1
1969	0.6	15.6	3.2	4.4	0.3	24.1
1970	-	20.3	-	0.6	-	20.9
1971	-	6.9	-	-	-	6.9

Table 2. Catches (in thousand tons) of small and fat herring taken by Norway and USSR 1950-1974. Herring caught south of Stad is excluded except for Norwegian small herring catches in 1950-1959.

	Small herring			Fat herring			Grand
Year	Norway	USSR	Total	Norway	USSR	Total	total
1950	72.9	-	72.9	29.7	4.3+	34.0	106.9
1951	190.1	10.5	200.6	80.5	2.5	83.0	284.2
1952	276.4	2.1	278.5	55.2	1.9	57.1	335.6
1953	147.0	3.8	150.8	84.7	5.2	89.9	240.7
1954	190.1	8.8	198.9	138.0	1.2	139.2	338.1
1955	94.3	3.0	97.3	36.0	9.0	45.0	142.3
1956	86.8	-	86.8	102.0	10.0	112.0	198.8
1957	118.5	3.8	123.3	46.4	1.5	47.9	171.2
1958	133.5	8.1	141.6	55.1	4.6	60.0	201.6
1959	164.5	7.2	171.7	46.8	9.5	56.3	228.0
1960	212.0	5.7	217.7	62.2	0.8	63.0	280.7
1961	222.7	0.9	223.6	108.5	0.1	108.6	332.2
1962	124.5	0.7	125.2	171.3	0.9	172.2	297.4
1963	157.9	-	157.9	143.8	12.0	155.8	313.7
1964	106.8	-	106.8	56.9	0.2	57.1	163.9
1965	116.9	-	116.9	94.3	10.7	105.0	221.9
1966	61.7	-	61.7	147.9	21.9	169.8	231.5
1967	107.1	-	107.1	346.0	92.6	438.6	545.7
1968	26.3	-	26.3	341.1	71.7	412.8	439.1
1969	14.4	-	14.4	21.2	8.1	29.3	43.7
1970	5.2	-	5.2	36.2	-	36.2	41.4
1971	1.1	-	1.1	13.1	-	13.1	14.2
1972	3.3	-	3.3	9.9	-	9.9	13.2
1973	0.3	-	0.3	6.5	-	6.5	6.8
1974	0.6	-	0.6	5.7	-	5.7	6.3

+ Average catch for the period 1941-1950

Table 3. Catch in numbers of Norwegian spring spawning herring in the adult fisheries (millions) 1950-1971

Year-class	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
1930	3.6																					
1931	0.9	0.5																				
1932	18.5	8.7	3.8																			
1933	42.4	18.4	28.1	22.2																		
1934	171.9	158.0	127.7	95.4	63.2																	
1935	107.0	119.5	83.2	89.6	80.0	43.0																
1936	66.4	47.4	65.3	73.8	89.2	72.6	45.0															
1937	368.3	348.0	256.3	233.9	247.4	104.6	75.7	31.3														
1938	194.5	253.5	186.5	215.5	196.6	141.6	137.5	52.0	32.7													
1939	86.9	107.6	106.8	98.8	126.8	115.2	122.8	61.8	27.7	27.6												
1940	109.5	103.1	107.7	94.1	133.0	103.6	95.2	60.1	46.6	27.7	15.1											
1941	88.6	82.7	85.7	91.2	100.6	84.6	88.9	42.5	44.9	31.2	19.9	2.1										
1942	79.5	77.1	79.2	61.7	88.4	58.7	63.0	33.7	34.3	22.6	19.8	3.4	5.1									
1943	628.6	602.0	377.9	394.9	460.7	203.2	163.3	131.6	69.4	41.6	27.9	4.5	13.5	1.9								
1944	547.0	515.6	380.2	314.1	440.4	295.6	272.8	149.3	70.9	85.2	39.0	12.7	16.8	7.7	10.8							
1945	185.5	164.4	204.5	110.9	199.8	193.4	198.3	121.2	77.4	77.4	47.2	15.7	30.3	19.3	14.3	4.3						
1946	184.8	172.4	136.3	81.9	128.1	85.5	130.7	88.4	98.7	88.5	56.7	21.7	30.3	25.1	7.2	8.7	5.5					
1947	276.2	383.8	602.3	355.6	490.3	274.7	264.2	182.5	200.9	198.0	153.5	63.0	79.2	61.8	46.6	21.7	16.5					
1948		6.6	60.5	100.9	236.0	189.6	203.9	127.3	123.0	124.3	129.7	45.0	64.1	60.6	43.2	52.1	8.8					
1949			39.3	46.6	142.9	114.3	110.0	72.0	70.7	88.6	85.2	49.7	49.3	79.8	46.1	70.2	14.9	1.9				
1950				98.2	1083.9	1954.3	2375.4	1946.4	959.1	1084.8	1163.0	727.6	959.3	932.7	771.6	703.0	392.7	64.3	5.4	1.1	0.2	
1951					55.8	262.2	275.8	220.5	192.9	239.7	203.9	136.1	138.9	174.1	151.9	137.7	96.9	14.3	4.1	0.2	-	
1952						62.4	232.7	144.0	87.5	113.8	73.2	49.2	59.8	92.5	83.2	106.9	72.1	14.3	3.6	0.3	0.1	0.02
1953							27.9	246.1	100.3	138.0	93.8	61.5	64.1	107.7	96.3	100.5	69.1	17.5	1.8	0.2	0.1	0.02
1954								13.0	16.1	24.6	21.6	19.4	13.3	9.3	29.3	40.0	11.0	8.9	2.6	-	0.1	0.02
1955									8.0	22.8	23.3	14.9	20.2	18.3	24.9	19.1	26.1	8.5	2.5	0.3	0.1	0.06
1956										7.0	4.0	4.1	6.5	3.5	3.0	7.4	17.4	3.5	0.8	0.2	0.1	-
1957												1.8	2.0	1.7	1.5	14.9	14.4	5.7	1.1	0.3	0.1	0.02
1958													1.4	4.9	13.1	19.5	38.0	8.9	2.0	-	0.1	-
1959													255.7	408.9	1917.7	2195.8	2868.3	1718.2	345.9	36.3	28.2	5.45
1960													49.8	38.2	307.6	570.4	1290.6	1135.0	134.8	33.5	26.7	6.91
1961															90.2	245.9	459.1	422.2	93.9	11.6	13.2	4.41
1962															2.2	12.1	26.1	27.0	14.3	0.7	1.0	0.36
1963																45.1	80.6	25.7	15.2	2.9	3.3	1.13
1964																				-	0.4	1.01
1965																				0.2	0.3	0.36
1966																					1.3	0.94
1967																					0.2	0.62
1968																						0.32
Total	3160.1	3169.3	2931.1	2579.3	4363.1	4358.8	4883.1	3723.7	2261.1	2443.4	2176.8	1232.4	1859.6	2048.0	3660.7	4375.3	5508.1	3475.9	628.0	87.8	75.5	21.65

Table 4. Catch in numbers of Norwegian spring spawning herring in the young herring fisheries (small and fat herring) 1950 - 1974 (millions)

Year-class	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962
1950	5112.6	7607.7	1232.9	641.9	351.6	90.8	179.7	38.9	14.4	19.0	-	0.5	
1951		1635.5	9149.7	581.3	210.5	14.2	38.4	8.0	1.5	1.0	-	-	
1952			13721.6	5055.0	855.4	30.6	18.9	9.8	1.8	1.0	0.1	-	
1953				5697.2	7071.1	510.1	88.6	127.2	10.6	8.6	2.4	0.1	
1954					10676.0	2871.1	627.1	10.3	1.8	1.3	2.8	-	
1955						5175.6	2023.7	219.5	9.5	4.0	4.8	0.1	
1956							5363.9	3290.8	666.4	8.1	14.2	-	
1957								5001.9	2798.1	325.5	121.7	6.3	0.7
1958									9667.0	1985.3	392.5	31.2	6.6
1959										17896.3	13530.3	2884.8	1641.1
1960											12884.3	16075.6	1006.5
1961												6207.5	4049.2
1962													3687.5
Total	5112.6	9243.2	24104.1	11975.5	19164.6	8692.5	8340.2	8706.4	13171.1	20250.1	27003.5	25206.1	10391.6

Year-class	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
1956	0.1											
1957	0.1											
1958	0.4	0.6										
1959	422.8	128.1	4.1	9.6								
1960	722.2	91.4	0.7	17.2								
1961	2051.7	24.4	10.3	5.9								
1962	2122.3	218.1	78.0	1.1								
1963	4811.0	2728.3	2806.5	1957.8	3241.4	1367.2	1.8					
1964		3613.0	3752.0	1671.0	1395.5	1900.6	8.9	2.9	0.1	0.5		
1965			2303.0	664.0	70.3	98.8	0.6	0.3	-	0.2		
1966				3893.0	9911.1	385.4	188.1	17.3	0.3	1.0		
1967					428.0	435.3	142.2	6.4	0.4	2.2		
1968						1782.0	507.9	33.5	1.5	1.6		
1969							555.9	530.1	85.1	33.6	0.1	8.4
1970								118.9	42.9	8.5	0.9	0.1
1971									30.5	52.3	0.4	0.4
1972										178.5	70.1	9.1
1973											18.2	8.2
1974												35.6
Total	10130.5	6803.9	8954.5	8219.0	15046.3	5969.2	1405.3	709.4	160.8	278.4	89.7	61.8

Table 5. Percentage age composition of Norwegian spring spawning herring during the Norwegian winter fishery 1950 - 1970.

Year / Age	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972 1)	1973 1)	1974 1)
2	0.1	-	0.1	0.1	0.1	-	-	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	8.3	0.2	1.3	4.0	1.3	1.5	0.6	0.4	0.5	0.4	-	-	0.1	-	0.2	-	-	-	-	-	0.3	-	-	0.2	6.7
4	5.5	11.6	2.0	1.9	25.2	6.3	5.0	7.4	1.0	1.3	0.3	0.4	-	6.9	5.9	5.2	0.1	0.2	-	0.1	1.8	0.6	44.1	5.1	2.0
5	5.5	5.2	19.9	4.1	3.3	46.9	5.9	4.3	6.1	1.4	1.6	0.9	0.5	0.4	60.6	13.6	8.8	0.4	0.7	-	0.4	3.3	19.5	83.7	7.3
6	16.3	4.8	4.5	14.4	5.4	2.7	50.6	5.6	4.7	7.5	1.2	3.3	0.9	0.4	0.3	66.3	28.9	12.8	1.3	3.3	0.6	4.4	13.1	2.8	82.0
7	18.7	15.2	6.7	3.2	11.0	4.3	2.3	56.5	6.6	5.1	6.5	2.9	2.5	0.5	0.1	0.1	54.5	33.7	12.1	0.8	4.4	1.8	9.1	4.1	0.9
8	2.3	17.7	12.4	4.2	2.8	5.8	3.9	1.8	50.5	7.8	3.5	7.7	1.5	1.7	0.2	0.2	0.2	48.5	35.0	13.2	1.3	4.9	2.2	1.7	0.8
9	2.5	2.0	12.2	12.0	4.2	1.7	4.6	2.6	2.6	47.3	5.0	4.8	8.0	1.0	0.8	0.1	0.1	0.2	47.7	38.2	17.0	5.1	4.2	0.8	0.2
10	3.1	2.2	2.4	14.4	9.2	4.0	2.2	2.4	3.5	2.2	58.1	6.5	4.0	8.6	0.5	0.3	0.1	-	0.1	41.6	35.2	1.7	0.9	0.6	-
11	2.4	2.6	2.5	2.0	9.5	5.5	3.5	1.6	3.4	3.3	1.6	59.0	6.6	3.6	3.4	0.5	0.2	0.1	-	-	37.9	20.9	0.1	0.9	0.1
12	5.4	2.7	3.1	2.8	1.7	3.3	4.1	2.2	2.3	4.5	3.8	4.4	63.5	8.2	1.8	1.4	0.2	0.3	0.2	0.3	0.1	32.1	2.3	+	-
13	10.4	6.7	3.0	2.9	1.9	1.0	1.9	2.7	2.2	1.9	4.1	3.0	2.1	60.0	2.6	0.8	0.6	0.2	0.2	0.1	0.1	25.0	2.3	+	-
14	1.6	9.1	5.0	3.0	2.5	1.4	0.9	1.5	1.8	2.3	1.5	2.3	3.6	2.0	20.9	1.3	0.6	0.5	0.3	0.3	0.1	-	2.2	+	-
15	2.7	1.5	7.0	6.6	2.2	1.8	1.2	0.5	1.1	2.2	1.0	1.5	3.4	2.7	0.6	9.2	0.4	0.3	0.5	-	0.1	+	-	+	-
16	4.8	3.0	1.6	7.0	3.4	1.9	1.4	0.6	0.6	0.9	1.3	1.4	0.7	2.0	0.7	0.3	5.0	0.3	0.4	0.2	0.1	-	-	+	-
17	1.1	4.0	2.2	2.2	4.3	2.2	1.7	0.8	0.7	0.5	0.9	0.9	1.0	0.8	1.1	0.3	-	2.5	-	0.3	0.2	+	-	+	-
18	0.5	0.4	3.4	2.9	1.7	1.3	1.6	1.0	0.7	0.7	0.5	0.3	1.0	0.5	0.1	0.3	-	-	1.4	0.1	0.2	+	-	-	-
19	-	0.2	0.8	2.9	1.4	1.5	0.6	0.7	0.5	0.4	0.3	0.4	0.3	0.4	0.1	-	0.3	-	-	1.3	-	+	-	-	-
20	0.1	-	0.1	0.7	1.0	0.7	0.6	0.3	0.3	0.3	0.5	0.1	-	0.2	0.1	-	-	-	-	-	0.3	+	-	-	-
21	-	0.1	-	0.1	0.1	0.2	0.3	0.2	0.2	0.2	0.3	0.1	0.2	-	-	0.2	-	-	-	-	-	-	-	-	-
22	-	-	-	-	0.1	0.1	0.1	-	-	0.1	0.1	0.1	-	-	-	-	-	-	-	-	-	+	-	-	-
22	-	-	-	-	-	-	-	-	-	0.1	0.1	-	0.1	0.1	-	-	-	-	-	-	-	-	-	-	-
?	8.6	10.8	9.8	8.6	7.8	5.9	7.0	6.6	10.6	10.0	7.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
n	3973	3841	3336	2796	4839	4174	4998	2779	972	1116	1155	452	398	399	1481	1402	2531	1599	2255	2207	3511	2516	856	1994	2178

1) Age data from samples taken during experimental fishing

Table 6. Spawning stock size in number ($N \times 10^{-9}$) and weight (million tons) and fishing mortalities 1950 - 1971. The figures in brackets are very uncertain because of too few years catch for the cohort analysis.

	Spawning stock size		Fishing mortalities			
Year	Number	Weight	4 years old	5 years old	6 years old	7 years old and older
1950	36.9	9.4	0.054	0.047	0.091	0.095
1951	30.3	9.1	0.050	0.062	0.051	0.12
1952	28.8	8.8	0.014	0.098	0.061	0.12
1953	23.5	7.1	0.016	0.028	0.074	0.14
1954	27.0	7.6	0.038	0.059	0.082	0.22
1955	34.1	8.8	0.051	0.067	0.058	0.17
1956	32.3	8.9	0.10	0.072	0.11	0.21
1957	35.8	10.0	0.17	0.079	0.066	0.13
1958	28.7	8.5	0.040	0.065	0.057	0.097
1959	23.3	7.5	0.074	0.072	0.110	0.13
1960	17.3	5.6	0.16	0.10	0.087	0.15
1961	13.1	4.2	0.089	0.048	0.068	0.11
1962	9.9	3.3	0.050	0.037	0.096	0.19
1963	7.5	1.6	0.057	0.041	0.030	0.29
1964	13.6	3.7	0.081	0.18	0.14	0.40
1965	17.8	4.5	0.17	0.15	0.29	0.75
1966	11.2	2.7	0.39	0.51	0.58	0.83
1967	4.8	1.3	1.1	0.80	1.2	1.5
1968	1.0	0.24	4.5	4.4	1.4	1.1
1969	(0.29)	(0.08	(0.28)	(0.71)	(0.39)	(0.42)
1970	(0.17)	(0.06)	(1.31)	(0.34)	(0.60)	(0.63)
1971	(0.09)	(0.03)	(0.10)	(0.24)	(0.33)	0.3+

+ Assumed value

Table 7. Fishing mortality by year-class and age of young herring. The figures in brackets are very uncertain because of too few years catch for the cohort analysis.

Age	Year-class																			
	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
0	0.058	0.07	0.75	0.35	1.12	0.92	0.73	0.80	1.38	0.30	0.35	0.45	0.79	0.22	0.26	1.17	0.28	0.46	1.32	0.50
1	0.11	0.64	0.66	0.91	1.06	1.18	1.45	1.59	1.27	0.37	0.92	0.58	1.62	0.18	0.44	1.38	2.63	1.18	2.36	(1.26)
2	0.023	0.07	0.21	0.14	0.67	0.34	1.52	0.78	0.91	0.12	0.12	0.62	0.69	0.28	0.34	0.47	0.93	1.96	(1.41)	(0.65)
3	0.016	0.04	0.03	0.04	0.043	0.04	0.10	0.73	0.15	0.10	0.12	0.06	0.65	0.31	0.50	3.26	1.98	(0.41)	(0.22)	(0.56)
Total	0.21	0.82	1.65	1.43	2.89	2.48	3.80	3.90	3.71	0.89	1.51	1.71	3.75	0.98	1.53	6.28	5.82	(4.01)	(5.31)	(2.97)

Table 8. Stock size in numbers (N x 10^{-6}) of young herring by year-class and age and survival (S) from 0-group to 4 years old. The figures in brackets are very uncertain because of too few years catch for the cohort analysis.

Age	Year-class 1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
0	97375	26081	27910	20973	16878	9188	11098	9725	13723	74965	47478	18327	7242	26264	17305	3560	17334	1245	2587	1522
1	78267	20718	11254	12642	4680	3114	4558	3723	2937	47442	28631	9927	2807	17957	11426	942	11194	669	589	(788
2	59690	9289	4969	4330	1377	816	906	644	702	27965	9751	4754	475	12792	6297	201	682	175	(47)	(190
3	49721	7380	3448	3220	600	494	169	252	241	21175	7337	2175	203	8281	3832	107	230	(21)	(10)	(84
4	41687	6043	2852	2637	490	405	130	103	176	16297	5552	1747	91	5185	1987	4	(27)	(12)	(7)	(41
S	0.428	0.232	0.102	0.126	0.029	0.044	0.012	0.011	0.013	0.217	0.117	0.095	0.013	0.197	0.115	0.001	(0.002)	(0.010)	(0.003)	(0.0[illegible]

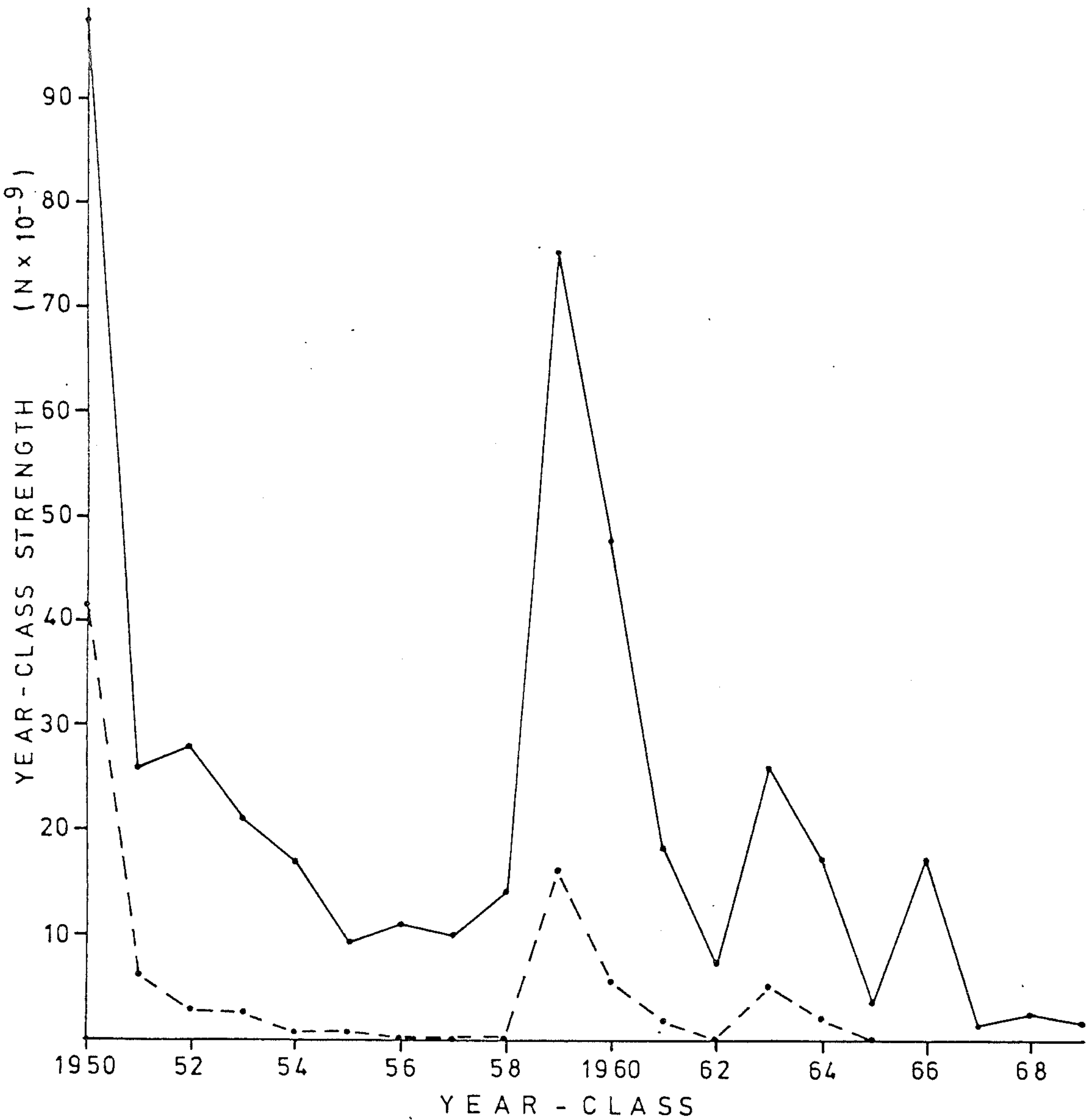

Figure 1. Year-class strength in number as 0-group and four years old (broken line).

Figure 2. Spawning stock size in number and total number of four years old and older herring (broken line).

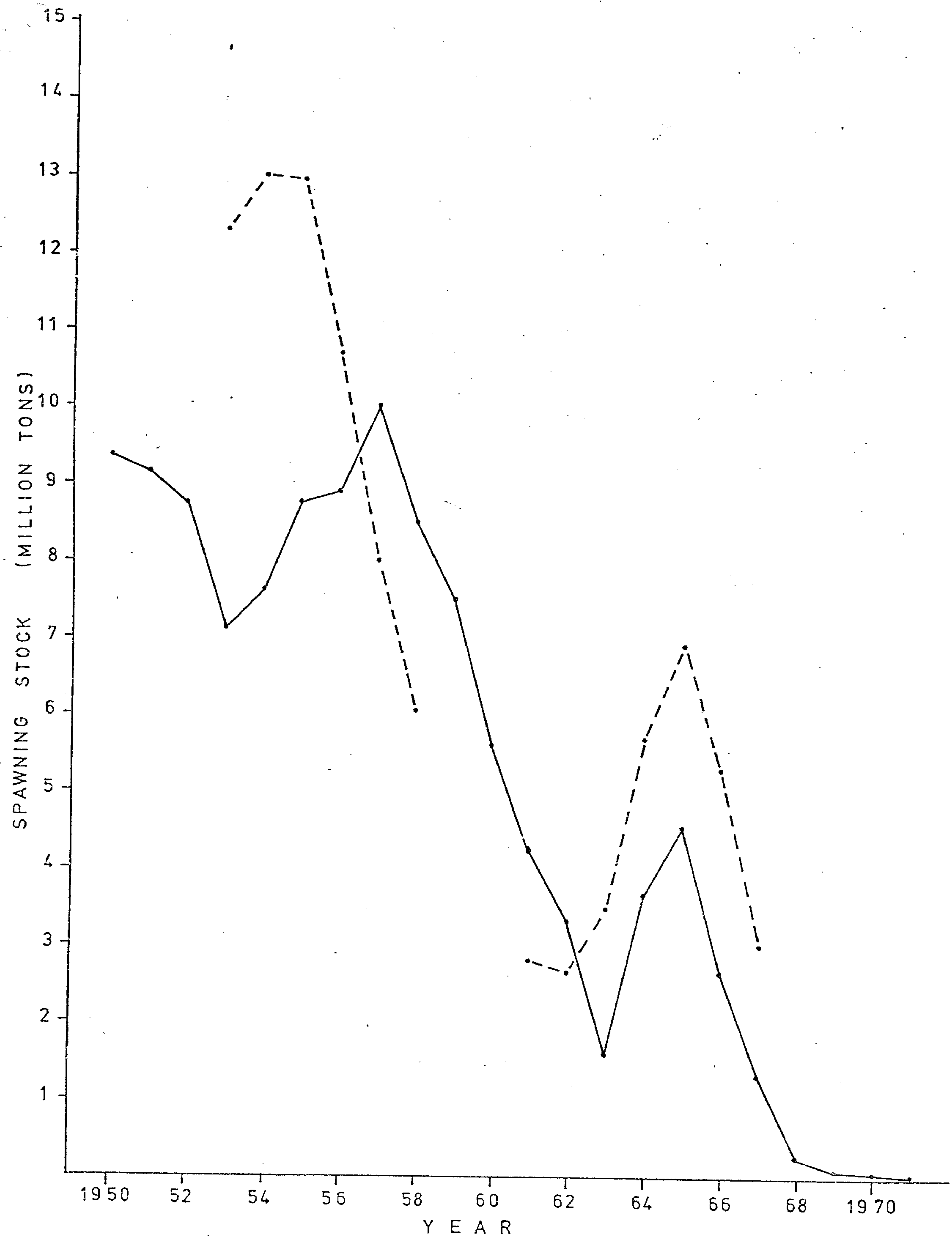

Figure 3. Spawning stock size in weight. Broken line: Stock size estimates given by the Working Group on Atlanto-Scandian Herring (ANON. 1970, 1972).

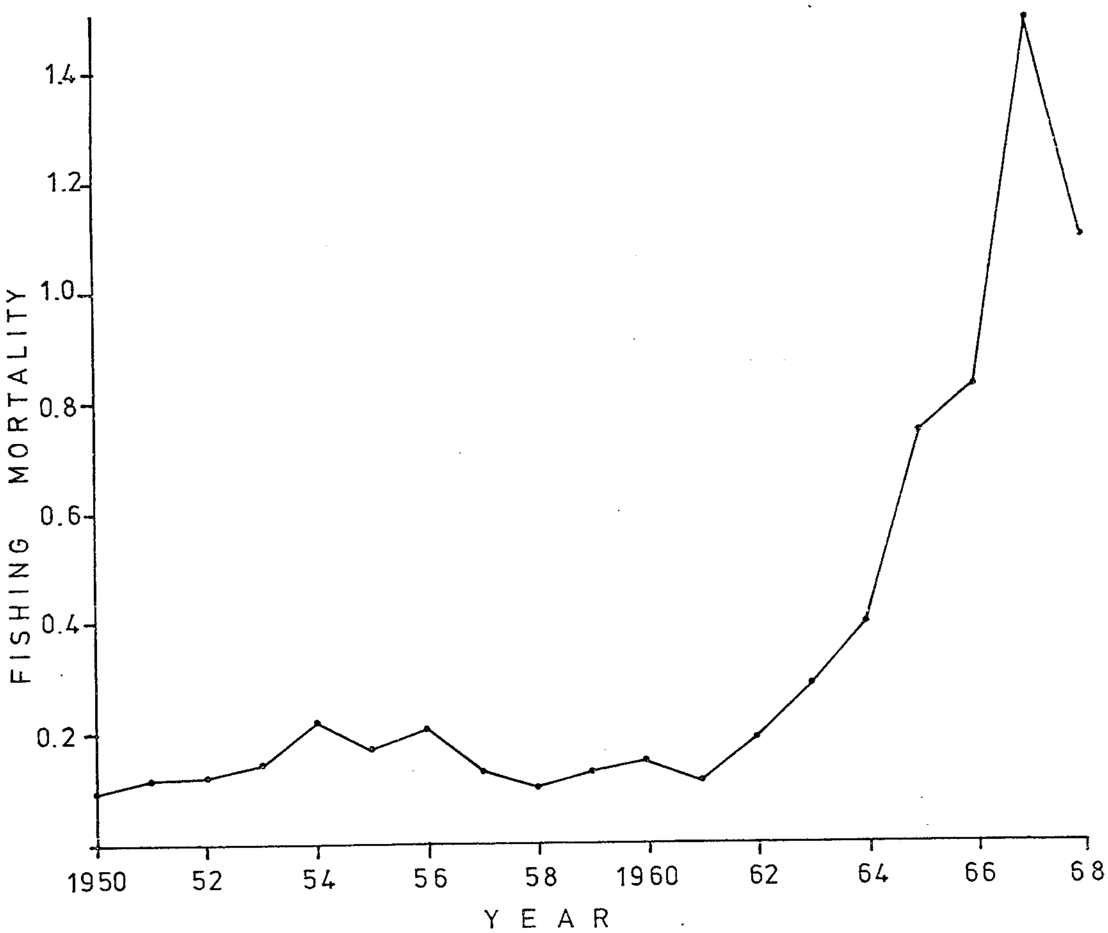

Figure 4. Fishing mortality on 7 years old and older herring.

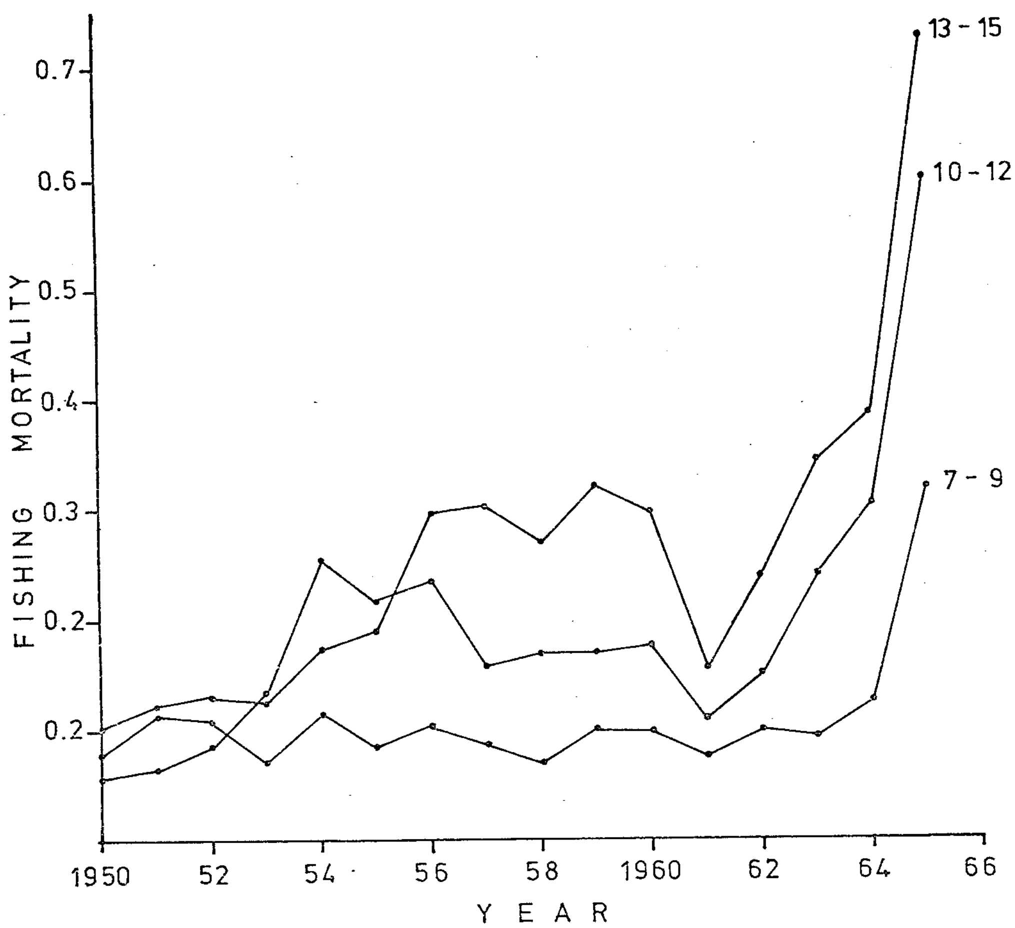

Figure 5. Mean fishing mortality on 7-9, 10-12 and 13-15 years old herring.

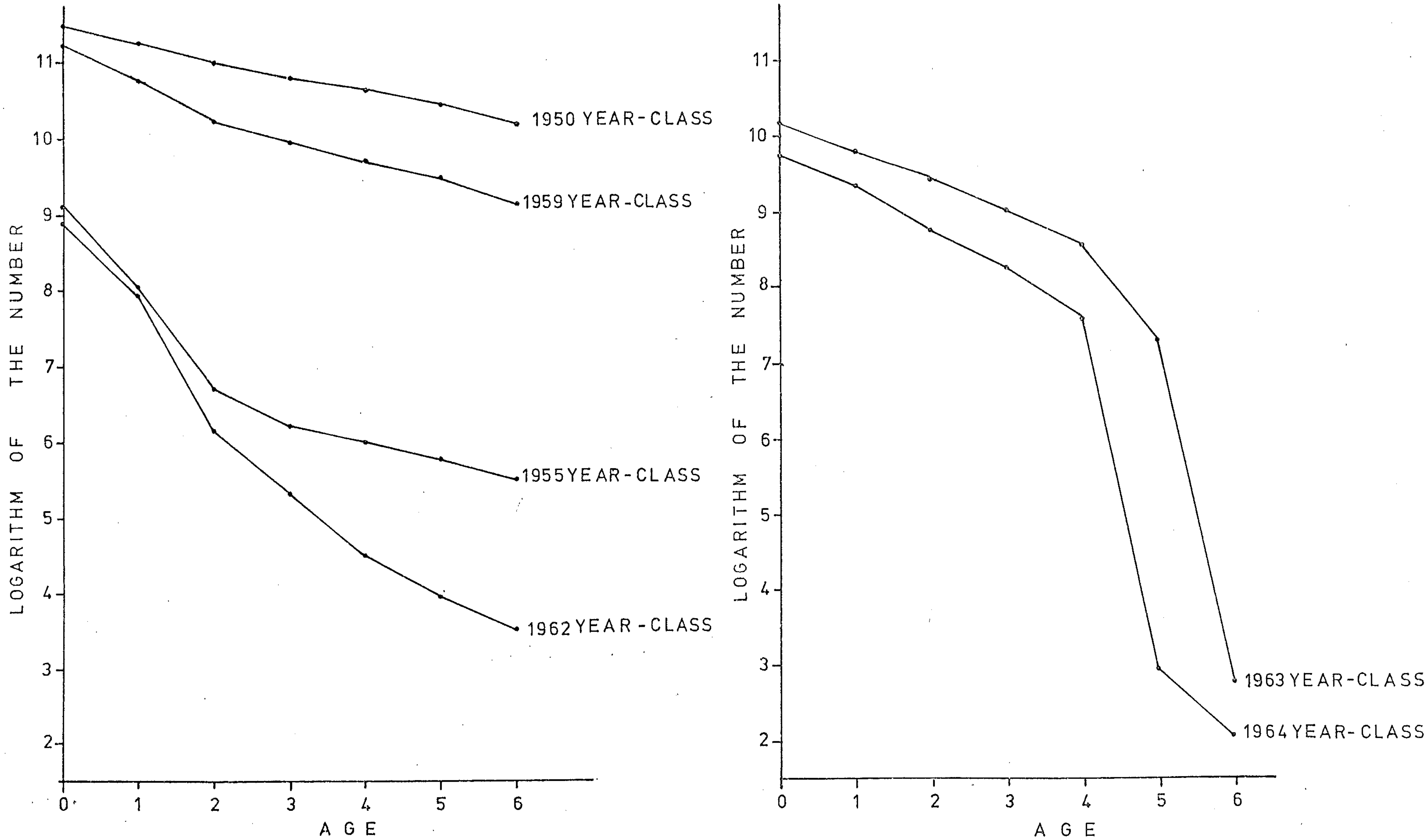

Figure 6. Logarithm of the number against age for selected year-classes.