

ON THE ABUNDANCE OF MACKEREL (*SCOMBER SCOMBRUS* L.) IN THE NORTHERN AND NORTH-EASTERN NORTH SEA IN THE PERIOD 1959-1969

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Although fishing intensity on North Sea mackerel during the years 1959-1966 was estimated to be very low as indicated by a low total mortality-rate ($Z = 0.28$), the abundance of the mackerel as measured by the catch-per-unit-effort in the Dutch trawl-fisheries declined due to a failing recruitment. Recruitment to the North Sea population was poor after the strong year-class 1958 appeared in the trawl-fisheries in 1962. The combined effect of a very moderate fishing intensity and poor recruitment, gave the mackerel population the appearance of an old accumulated stock by the middle sixties.

Since the introduction of the purse-seine fishery in 1964 the total international catch of North Sea mackerel started to rise, reaching an unprecedented level of about 900000 tons in 1967.

As a result of these substantial catches mortalities rose to an average of $Z = 0.80$ in the late sixties. In 1968 and 1969 mackerel abundance in the North Sea dropped to a very low level as a consequence of the high fishing intensity and the persisting failure of recruitment to the now decimated stock.

Although the yield curve in mackerel does not suggest large gains from protection-measures such as minimum size or effort restriction, the danger of an unlimited fishery on a stock of small sized mackerel are discussed.

INTRODUCTION

The total landings of mackerel from the North Sea, the Skagerak and the Kattegat increased from 20000 tons to 100000 tons in the period 1945 to 1965. After the introduction of the Norwegian purse-seine fishery in the northern and north-eastern North Sea in 1964 the landings increased rapidly to 930000 tons in 1967 (REVHEIM and HAMRE, 1968).

The Dutch landings of mackerel from the North Sea are in sharp contrast with those of the total international landings (Table 1); after 1961 the Dutch landings decreased continuously. The decrease of the Dutch landings was accompanied by a decline of the Dutch catch-per-unit-effort in the most profitable mackerel fishing areas in the North Sea (Table 2). A study was made of the mackerel fishery and stock in the northern and north-eastern North Sea to analyse the causes of the decline in the Dutch mackerel landings.

TABLE 1. Total international and Dutch mackerel landings (in metric tons) from the North Sea, the Skagerak and the Kattegat. Data from *Bulletin statistique des pêches maritimes*, Volumes 31 to 54.

Year	Total landings metric tons	Dutch landings metric tons	Year	Total landings metric tons	Dutch landings metric tons
1945.....	19 659	571	1958.....	87 900	17 971
1946.....	25 452	533	1959.....	93 751	18 866
1947.....	36 161	1 795	1960.....	91 550	26 425
1948.....	53 693	5 614	1961.....	101 365	24 855
1949.....	62 963	7 142	1962.....	79 655	19 651
1950.....	57 255	6 605	1963.....	73 419	11 846
1951.....	73 004	10 732	1964.....	115 329	17 084
1952.....	66 862	11 688	1965.....	208 786	16 997
1953.....	65 187	11 231	1966.....	529 971	12 213
1954.....	68 009	11 832	1967.....	939 194	9 945
1955.....	80 110	16 333	1968.....	821 445	5 322
1956.....	65 663	11 230	1969.....	738 783	4 526
1957.....	97 520	15 483			

MATERIAL AND METHODS

The mackerel population in the North Sea was analysed from catch-effort data and biological information collected from a trawl fishery on mackerel in the northern and north-eastern North Sea along the slopes of the Norwegian Deep in April and May (see Figs. 2 and 3). Only this trawl fishery can be used for mackerel stock analysis as in all the other fisheries in the North Sea by Dutch vessels the mackerel has to be considered as a by-catch (POSTUMA and ZIJLSTRA, 1963). Catch-effort data and biological information of the Dutch mackerel catch have been published each year in the *Annales Biologiques*, from 1959 onwards.

Age determination was done by reading otoliths which were mounted in autoplax. Counts were made of the alternate opaque and hyaline zones as described by AKER (1961) and 1. January was taken as the official birthday of the mackerel. Up to an age of five years the method is reliable, but with older fish there are difficulties. In simultaneous age-reading experiments it became apparent that after the age of five years the percentage of agreement in the age determination was decreasing significantly.

TABLE 2. Catch-per-effort expressed in metric tons per 100 hours fishing of a 500 b.h.p. Dutch trawler in two areas of the North Sea. Data from POSTUMA (1968); PEERAER, POSTUMA, and ZIJLSTRA (1964); ZIJLSTRA and POSTUMA (1961-63; 1965-68).

Year	North-eastern North Sea	Northern North Sea	Northern and North-eastern North Sea
1959....	26.6	12.8	19.3
1960....	22.3	16.0	18.7
1961....	23.4	11.2	16.2
1962....	23.0	7.4	19.2
1963....	9.0	3.2	6.9
1964....	13.5	8.3	11.9
1965....	11.8	2.0	10.5
1966....	14.3	6.5	14.8
1967....	12.8	13.5	13.3
1968....	4.5	6.4	6.0
1969....	5.1	5.3	5.2

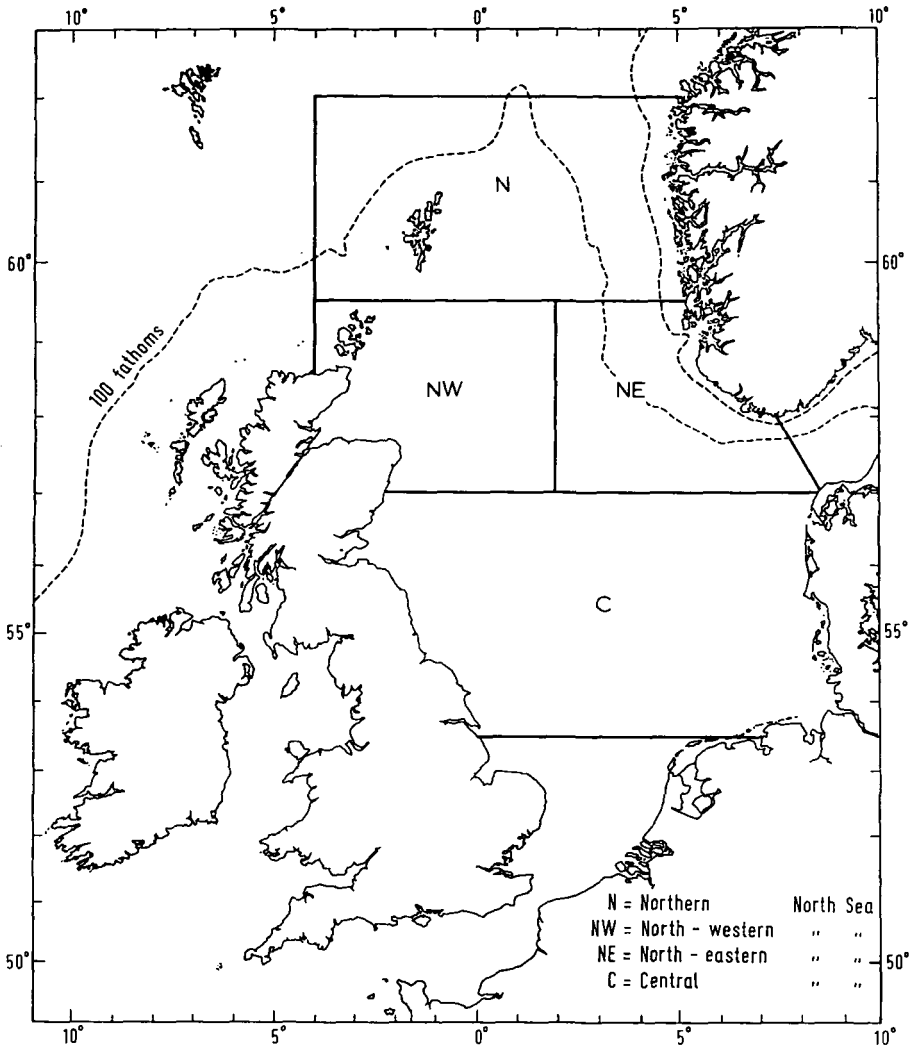


Figure 1. The fishing areas as used in the Dutch statistics for the mackerel fishery

RESULTS

ABUNDANCE

For this analysis the mackerel stock in the northern and north-eastern North Sea (see Figure 1) has been considered as a unit stock, characterised by the fish caught in the spring fishery in the north-eastern North Sea.

Several tagging experiments have shown that mackerel tagged during spring in the north-eastern North Sea migrate over the whole North Sea, Skagerak and the Kattegat in summer (REVHEIM, 1951, 1954). The tagged mackerel

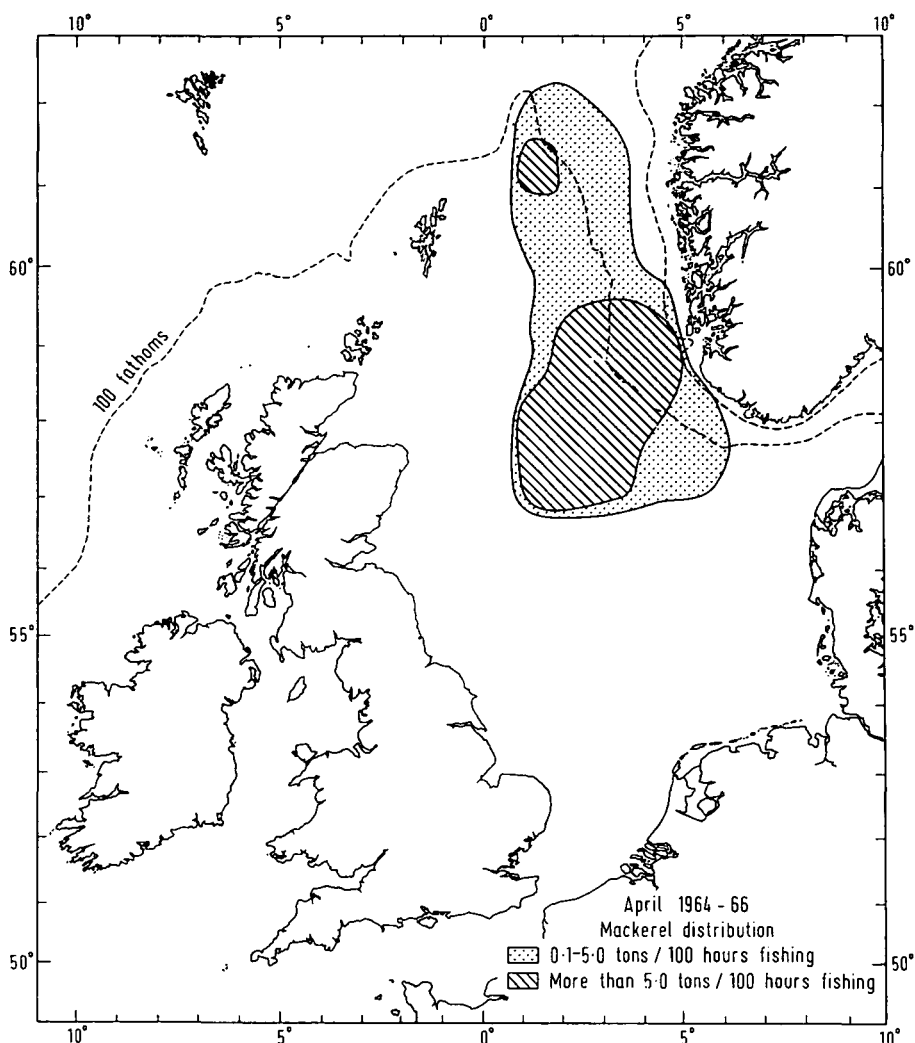


Figure 2. The mackerel distribution according to the catch per 100 hours fishing of a Dutch standard trawler of 500 b.h.p. in April in the period 1964-1966. The dotted area represents the area with a catch-per-effort of 0.1-5.0 tons, the striped area a catch-per-effort of over 5.0 tons.

returned again in autumn to the north-eastern North Sea and the results therefore suggest that the north-eastern part of the North Sea is the over-wintering area of the North Sea mackerel (REVHEIM, 1955; POSTUMA, 1965). This conclusion is supported by the pattern of the Dutch mackerel fishery (POSTUMA, 1965).

The Dutch fishing season in April and May coincides with the start of the spawning season of the mackerel and with the onset of the spring migration

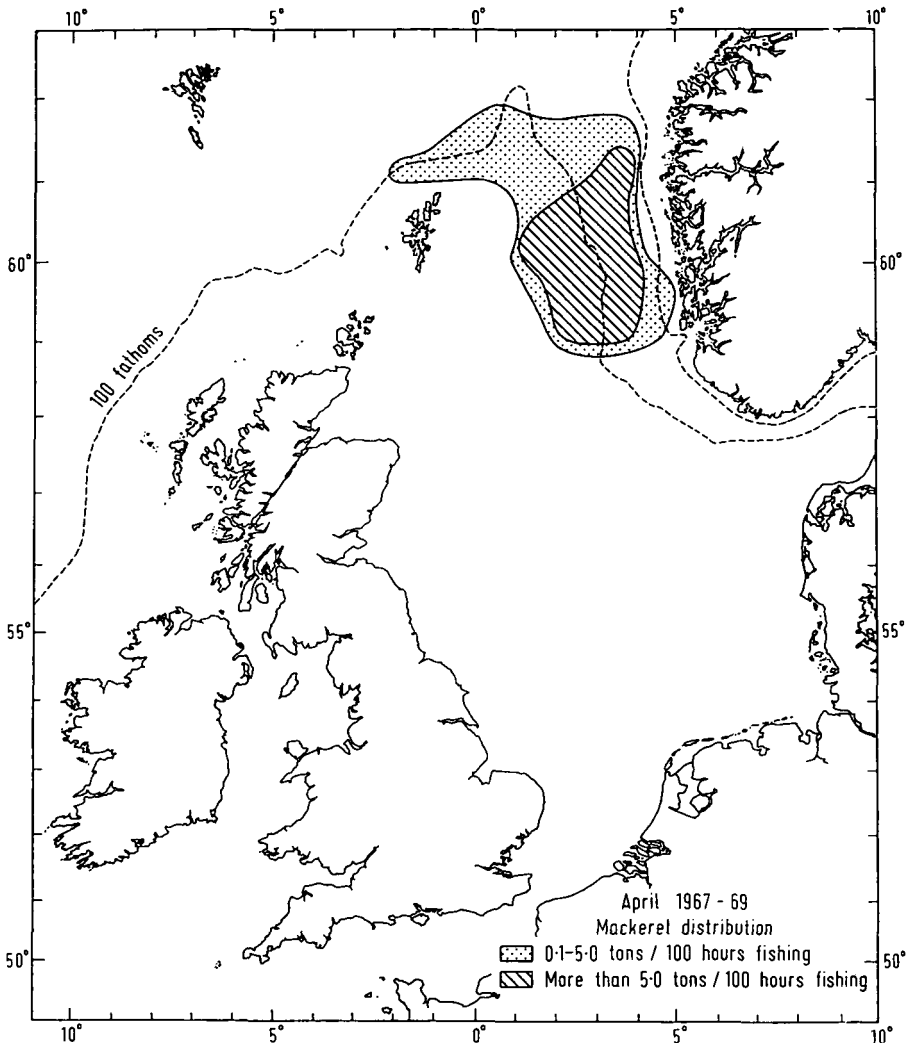


Figure 3. The mackerel distribution according to the catch per 100 hours fishing of a Dutch standard trawler of 500 b.h.p. in April in the period 1967-1969. The dotted area represents the area with a catch-per-effort of 0.1-5.0 tons, the striped area a catch-per-effort of over 5.0 tons.

when the mackerel moves out to the summer-grounds. During this phase in the yearly life cycle the North Sea mackerel population seems to be well concentrated in the northern and north-eastern North Sea and to be available for bottom trawling.

For the period 1959-1968 the mean catch in tons per 100 hours trawling in April and May (Table 2) is given as an index of abundance of the mackerel population. It appears that the catch-per-unit-effort in the late fifties and the

TABLE 3. Numbers of statistical rectangles fished by Dutch trawlers and effort expressed as hours fished by a Dutch standard trawler of 500 b.h.p. in the north-eastern North Sea in April and May, during the period 1958–1969.

Year	Number of statistical rectangles fished	Fishing hours
1958.....	16	13 789
1959.....	26	15 701
1960.....	25	14 968
1961.....	25	28 604
1962.....	28	21 595
1963.....	20	26 947
1964.....	27	32 329
1965.....	25	47 794
1966.....	24	36 584
1967.....	18	19 421
1968.....	9	7 826
1969.....	5	1 631

beginning of the sixties was higher than during the late sixties and does show a steady decrease over the whole period. The very low catch-per-unit-effort in 1963 is not in accordance with the general trend. It seems possible that this low catch-per-unit-effort was caused by a low availability in 1963, related in some way with the abnormal environmental conditions (temperature?) during the severe winter 1962/63.

With the increase of the total international catch from 115000 tons in 1964 to 900000 tons in 1967 a major change in position as well as in extension of the fishing area of the Dutch trawlers from the northern and north-eastern North Sea can be observed. This is shown clearly in Figure 2 and 3, which show the distribution of the Dutch fishery in April 1964–1966, before the major increase of the total international catch, and in April 1967–1969, when the Norwegian purse-seine fishery yielded large catches.

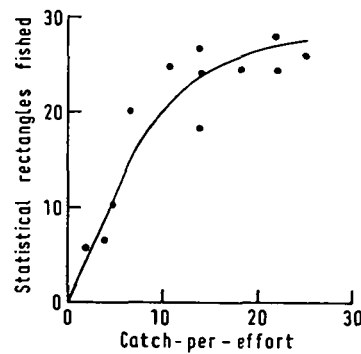


Figure 4. The relation between mackerel abundance, expressed as the catch per 100 hours fishing in metric tons of a Dutch standard trawler of 500 b.h.p., and the area fished, expressed in the number of statistical rectangles fished in the north-eastern North Sea by Dutch trawlers in April and May.

The Dutch April and May fisheries in the north-eastern North Sea virtually disappeared in 1968 and shifted completely to the northern North Sea, concentrating on other species, mainly coalfish (*Pollachius virens* L.) and taking mackerel as by-catch only. The shift of the Dutch trawl fishery occurred gradually, as is shown in Table 3 by the fishing hours and the statistical rectangles fished in the area north-east in the years 1958–1968. The movement started in the year after the introduction of the Norwegian purse-seine fishery on mackerel in 1965.

In a number of fisheries a relation between the size of the area fished (numbers of statistical squares) and the abundance as measured by the catch-per-unit-effort has been found *e. g.* the young herring in the southern North Sea (ANON, 1969). For mackerel this relation in the area north-east in the years 1958–1968 is shown in Figure 4. The gradual shift and the disappearance of the mackerel fishery from the north-eastern North Sea to the northern Sea has therefore been interpreted as the consequence of a decreasing abundance of the mackerel stock.

RECRUITMENT

The age composition of the mackerel caught in the north-eastern North Sea in April and May during the period 1959–1969 is given in Table 4. Two strong year-classes can be followed in the different years. The mackerel is

TABLE 4. Percentage age-composition of Dutch trawl-caught mackerel in the north-eastern North Sea in the period 1959–1969 in April and May.

Year	Age in years							
	2	3	4	5	6	7	8	> 8
1959.....	0	0	37	22	17	7	5	11
1960.....	0	3	4	56	13	14	4	6
1961.....	9	25	14	27	16	5	3	3
1962.....	1	3	20	1	0	40	1	25
1963.....	2	7	11	23	2	1	32	22
1964.....	15	9	13	10	14	8	9	21
1965.....	2	12	6	11	7	20	6	39
1966.....	0	7	5	7	8	13	14	46
1967.....	32	7	3	9	5	5	9	31
1968.....	20	12	5	5	14	7	7	31
1969.....	16	55	10	2	3	4	2	9

TABLE 5. Catch in metric tons and thousands of fish per 100 h trawling of a Dutch standard-trawler of 500 b.h.p. in the north-eastern North Sea in April and May during the period 1959–1969.

Year	Catch in metric tons	Numbers of mackerel caught in thousands		
		All ages	4 years of age	Over 4 years of age
1959.....	26.6	98.9	36.6	61.4
1960.....	22.3	84.3	3.4	78.4
1961.....	23.4	91.6	12.8	49.5
1962.....	23.0	74.8	14.9	50.1
1963.....	9.0	28.5	3.1	22.8
1964.....	13.5	42.3	5.5	26.2
1965.....	11.8	32.0	1.9	26.6
1966.....	14.3	38.9	1.9	34.2
1967.....	12.8	46.4	1.4	28.7
1968.....	4.5	12.6	0.6	8.1
1969.....	5.1	18.9	1.9	3.8

caught from its second year of life onwards, when one year old, and recruitment to the trawl fishery seems to be completed in the fourth year of life, at the age of three years (see Table 4). The decline of the catch-per-unit-effort in weight is certainly partly caused by a failure of recruitment. This follows from the poor recruitment to the mackerel stock measured by the number of four year old mackerel since 1963 (Table 5). The 1955 and 1958 year-classes recruiting in 1959 and 1962 respectively are the only good year-classes coming to the fishery in the period 1959–1969 (Table 5). No other strong year-classes followed to reinforce the stock, except the year-class of 1965 which appeared in 1967 as two year olds. This year-class, however, did not reappear in quantity in 1968 and 1969.

MORTALITY

Instantaneous mortality rates were estimated by the number of mackerel older than three years of age in the year *a* and the number of mackerel older than four years of age in the year *a* + 1, caught per 100 h fishing by a Dutch standard trawler of 500 b.h.p. The data are summarized in Table 5. Difficulties in the age determination of mackerel of over five years old compelled us to follow this method.

For the period 1959–1969 in the area north-east and the areas north-east and north combined unsmoothed and smoothed mortality estimates are given in Table 6. The mortality rates in the two sets show large fluctuations between –0.31 and 1.32, which are presumably connected with variations in the availability of mackerel. This difficulty can be overcome by taking averages over longer periods. Average instantaneous mortality estimates have been computed for the whole period studied (1959–1969) and for periods before and after the impact of the purse-seine fishery, that is for 1959–1969 and for 1967–1969. The results are summarised in Table 7.

Mortality rates in the mackerel stock prior to 1966 seem to have been very low ($Z = 0.28$) and the mackerel population had the appearance of an old accumulated stock as shown by the age compositions in Table 4. The sudden increase of the total catch in the years 1965–1969 from a level of 100000 tons to 900000 tons had a marked effect on the abundance and the mortality rates. In the last two seasons 1968 and 1969 very low abundances and high mortality rates were recorded. The age compositions have become markedly different from those in the years before 1966.

TABLE 6. Total instantaneous mortality in the north-eastern North Sea and northern and north-eastern North Sea in the period 1959–1969.

Season	North-eastern North Sea	Smoothed data	North-eastern and northern North Sea	Smoothed data
59/60.....	0.22	—	0.01	—
60/61.....	0.50	0.36	0.79	0.46
61/62.....	0.22	0.36	–0.06	0.36
62/63.....	1.05	0.64	1.16	0.55
63/64.....	–0.01	0.53	–0.12	0.52
64/65.....	0.17	0.08	0.14	0.01
65/66.....	–0.18	0.00	–0.31	–0.08
66/67.....	0.23	0.02	0.25	–0.03
67/68.....	1.32	0.78	0.99	0.62
68/69.....	0.83	1.07	1.16	1.07

TABLE 7. Mean instantaneous mortalities of mackerel in the period 1959–1969.

Period	North-eastern North Sea	North-eastern and northern North Sea
1959–1969.....	0.44	0.41
1959–1966.....	0.28	0.28
1967–1969.....	0.79	0.80

DISCUSSION AND CONCLUSIONS

The abundance of the mackerel stock has declined significantly in the period 1959–1969. This is shown by the decreasing catches-per-unit-effort in the areas north and north-east, and also by the shift and contraction of the area fished by the Dutch trawlers in the North Sea.

Although differences in availability may have influenced the abundance estimates, the decline has been rather steady and this is particularly clear when the data from the north-eastern North Sea are considered (Table 2). The age analysis in the period 1959–1969 showed a failure of recruitment after 1962, the only strong year-classes entering the fishery at four years of age in the period 1959–1969 being the 1955 and 1958 year-classes, in 1959 and 1962 respectively.

The mortality estimates (Table 6) showed great fluctuations presumably caused by variation in availability to the gear. Average mortalities were low ($Z = 0.28$) in the period 1959–1966 before the substantial increase of the total international catch.

During the period of high catches (1967–1969) the average mortalities increased to $Z = 0.80$. The combination of a low total mortality rate ($Z = 0.28$) and a failure of recruitment led to a stock of rather old fish and the decrease in abundance in the period 1959–1966 can be explained in terms of a failing recruitment. With the development of the purse-seine fishery and the increase of the total mortality in the period 1966–1969 this old stock was fished down drastically and abundance dropped steeply as recruitment did not improve. The severe drop in abundance in the period 1966–1969 was presumably caused by failing recruitment as well as by a very intensive fishery.

A rather serious aspect of the intensive purse-seine fishery was the fishery on small sized mackerel in the year 1967. In this year the year-class 1965 was caught in quantity for reduction purposes as reported by REVHEIM and HAMRE (1968). This year-class 1965 was well represented in the age composition of the Dutch trawler landings in 1967. This led to the expectations that year-class 1965 would reappear in force as three year-olds in 1968 (POSTUMA and

TABLE 8. Mean length and weight of Dutch trawl-caught mackerel from the north-eastern North Sea in April and May in the period 1959–1969. The mean length and weight are calculated as the straight mean of the mean lengths and weights of the mackerel at the different ages in the age distributions in the years 1959–1968. The age distributions of every year are based on 16 samples of 50 individuals from Dutch trawl-caught mackerel landed from the north-eastern North Sea in April and May.

Age (Years)	1	2	3	4	5	6	7	8
\bar{L} (cm)	20.1	28.1	32.2	34.5	34.9	35.6	37.8	37.8
\bar{W} (g)	90	134	264	358	389	394	458	478

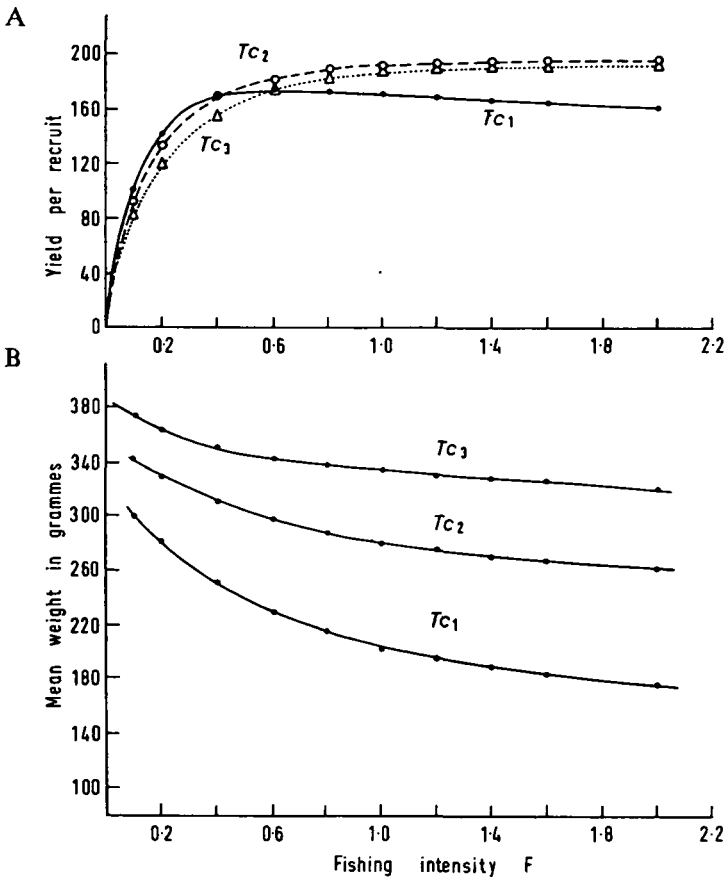


Figure 5. The yield-per-recruit curves (A) of mackerel when recruitment to the fishery takes place at one (Tc_1), two (Tc_2) and three (Tc_3) years of age with the corresponding mean weights (B) of the fish at different fishing intensities

ZIJLSTRA, 1967). The 1965 year-class, however, failed to turn up in good numbers in 1968 as three year-olds and did not appear as four year-olds in 1969; it seems likely that the 1965 year-class was already decimated by the fishery in 1967.

In order to investigate if the introduction of minimum sizes in the mackerel fisheries would be profitable in terms of an increased yield per recruit, yield curves at different ages of recruitment of mackerel to the fishery were computed.

The mackerel grows fast in both weight and length during the first three years of life, after which growth declines considerably, as shown in Table 8. The following stock parameters were used for computing yield curves; $L_\infty = 37.5$; $k = 0.57$; $t_0 = -0.05$; $W_\infty = 411$ g and $M = 0.20$. Recruitment to the fisheries was varied in the calculations between ages of one to three years (curves Tc_1 , Tc_2 and Tc_3 in Figure 5).

Figure 5A shows that, with the stock parameters used, the yield curves for

recruitment to the fishery at the ages one to three years are not very different. A low fishing mortality gives somewhat better yields with a low age of recruitment, whereas with a high fishing mortality the yields tend to be higher at higher age of recruitment, but the differences are only small. Differences, however, in the mean weight, length and age of the fish caught related to the different age of recruitment are much more pronounced (Figure 5B).

An introduction of a minimum size in the mackerel fishery seems therefore hardly justified in terms of yield-per-recruit. On the other hand a very intensive fishery on small sized mackerel endangers recruitment to the spawning-stock. The spawning-stock will consequently become very small, which will effect egg-production and might endanger the future production of young fish. Moreover, from the point of view of the fish trade, the landings of good-sized mackerel for human consumption will be low only when there is a much reduced stock of older and larger mackerel. This could also be a good reason to either reduce the fishing effort on mackerel from the high level experienced in the last years or introduce a minimum size.

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