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Assessment of the Mackerel Stock in ICNAF SA 3-6

by

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Abstract

Numbers at age for the SA 3-6 mackerel catch in 1968-1975 were recalculated, and comparison with numbers used previously indicated substantial differences primarily at younger ages. Numbers at age were also calculated for the SA 3-6 catch in 1962-1967 using unreported Canadian sampling data. USA spring (1968-1976) and autumn (1963-1976) bottom trawl survey abundance indices were presented. Fishing mortality in 1975 was estimated to be 1.00 using two separate methods. Cohort analysis using the 1962-1975 numbers at age was performed assuming F = 1.00 at ages 2 and older in 1975. Fishing mortality increased continuously from 1962 to 1975; stock biomass (age 1+) increased from about 480,000 tons in 1962-1965 to 2.1 million tons in 1969 and then decreased to 625,000 tons in 1975. Spawning stock biomass (50% age 2 and 100% age 3+) was estimated to be only 247,000 tons at the beginning of 1976. Recruitment was very poor in the early 1960s, with the 1962-1963 year-classes being the smallest observed. The 1967 year-class was 2.5 times larger than the next largest year-class (1969). The 1974 year-class was estimated to be above average and appears to be the strongest since 1969. Based on the relationships of autumn and spring survey catches at ages 0 and 1 with calculated year-class sizes at age 1, the 1975 and 1976 year-classes were estimated to contain about 500 million and 1.2 billion fish, respectively, at age 1. Catches in 1976 of between 220,000 and 260,000 tons would generate an F of 1.20-1.67 and result in a continued decrease in spawning stock biomass. Fishing mortality at $F_{0.1}$ = 0.35 in 1977 would result in a catch of 46,000-35,000 tons and would achieve an increase in spawning stock biomass in 1978.

Introduction

This paper presents an assessment of the SA 3-6 mackerel stock based on (1) cohort analysis using recalculated numbers at age for the 1962-1975 international catch and (2) USA research vessel bottom trawl survey catch data for measuring changes in stock abundance, estimating fishing mortality, and estimating recruitment strength.

Age Composition of Commercial Catches

Age compositions (numbers at age) of the 1968-1973 SA 5-6 international catch which were calculated from Bulgarian, GDR, Polish, and USSR sampling data were initially presented by Paciorkowski et al. (1973). Numbers at age for the 1968-1973 SA 3-4 catches were initially reported by Anderson (1975) to facilitate a combined assessment for the SA 3-6 stock. Data for 1974 and 1975 for SA 3-6 were presented in research documents and working papers and adjusted at the respective Assessment Subcommittee meetings to account for revised catch totals. Although the sampling data used to calculate the numbers at age for the bulk of the SA 3-6 catch in 1968-1975 have been reported to ICNAF, the majority of the estimates have not been examined or recalculated to verify

methodology and accuracy. Furthermore, numbers at age from third and fourth quarters in recent years were frequently based on estimated catches and incomplete sampling but were never corrected later with final statistics. Consequently, it was decided to recalculate the numbers at age for 1968-1975 using the commercial sampling data reported to ICNAF. Canadian sampling data not reported to ICNAF were also obtained to improve the 1968-1972 estimates for SA 3-4 made by Anderson (1975). In addition, Canadian length frequencies and age-length data were obtained and used to estimate the numbers at age for the 1962-1967 total catch.

The 1968-1975 numbers at age for SA 3-6 were calculated separately for two groups of countries. Sampling data reported by USSR, Poland, GDR, Bulgaria, and Romania were applied to the catches of all countries in SA 3-6 except Canada and France (St. Pierre et Miquelon) in SA 3-4 for which group Canadian data were used to determine numbers at age. The mean weight reported with each monthly length frequency was divided into the applicable catch weight to obtain a total number of fish which was aportioned to lengths based on the percentages at length from the length frequency. For length frequencies (except Canadian) lacking an accompanying mean weight, a value or an average of several values from other length frequencies having the same or a similar mean length was used. Since many of the Canadian length frequencies which were used were without mean weights, a length-weight equation calculated by MacKay (personal communication): $W = .0059\ L^{3.154}$, where W = weight in gm and L = fork length in cm, was used to calculate mean weight from mean length. In calculating numbers at age using the distant water fleet data, each length frequency was applied to the catch of the reporting country in the appropriate month and subarea, division, or subdivision. That length frequency was also applied to any other catches in that month from other areas or by other countries lacking sampling data. If length frequencies were available for several areas in a particular month, the sum of the resulting numbers at length was prorated upwards to include any unsampled catches (other areas or countries) that month. The appropriate country quarterly age-length key was applied to the monthly numbers at length to obtain numbers at age. If length frequencies from several countries were available in a particular month, numbers at age were first determined for each country's catch for the entire area using the appropriate age-length key, and then the sum of the resulting numbers at age from the several countries was prorated upwards to include any unsampled catches by other countries. If length frequencies were not available from any country for one or two months in a particular quarter, the total numbers at age (all countries and areas) from the other month or months in the quarter were prorated upwards to include the unsampled catch. If length frequencies were lacking for an entire quarter, the total numbers at age (all countries and areas) from the remainder of the year were prorated upwards to include the unsampled catch.

The 1968-1975 numbers at age for Canada and France in SA 3-4 were obtained from various sources. The 1968-1969 SA 3-4 and the 1970-1972 SA 4 numbers at age were calculated using sampling data obtained from J. S. Hunt[1] (personal communication) and K. T. MacKay[2] (personal communication). Numbers at age were determined in a manner similar to that described for the distant water fleets. The 1970-1973 SA 3 numbers at age were calculated using data from the Newfoundland fishery provided by G. H. Winters[3] (personal communication) and as described by Anderson (1975). The 1973 SA 4 numbers at age were obtained by adjusting the preliminary estimates made by Stobo and Hunt (1974) to include final catch figures. The 1974 and 1975 SA 4 numbers at age were taken from Hunt (1975) and Hunt (1976), respectively. The 1974 and 1975 SA 3 numbers at age were obtained from Winters (personal communication) and are the same as used in past assessments.

The sampling data used to calculate the 1962-1967 numbers at age for the SA 3-6 catch were limited primarily to SA 4; several samples were from Div. 5Y. It was assumed that all catches in SA 3-6 were similar in age composition to those sampled in SA 4, even though that may not have been true. The length frequency data used were obtained from MacKay (1967, personal communication) and also obtained from J. J. Hunt (personal communication). Age-length keys were also supplied by MacKay (personal communication) and supplemented as necessary with appropriate age-length keys from later years. Numbers at age were calculated for those months with sampling data, summed for the year, and then prorated upwards to include the remaining SA 3-6 catches.

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The numbers at age for the 1962-1975 total international catch in SA 3-6 are presented in Table 1. Table 2 lists these numbers by age as well as the numbers at age used in past assessments (ICNAF 1976), and Table 3 shows the percentages at age for the two sets of data. Examination of these results (Tables 2-3) indicates obvious differences between the two sets of numbers at age. The most significant differences were generally at the younger ages (i.e. 4 years and less). The most striking difference was at age 1 in 1969; according to the old data there were 139.5 x 10^6 fish caught (28.1%), but only 6.5 x 10^6 (1.4%) based on the new results. It is not possible at this point to explain the causes for the major differences between the two sets of numbers other than to attribute them to markedly different methodology and assumptions used in calculating the numbers. If the same sampling data as reported to ICNAF and used in this paper were utilized to calculate the initial set of numbers, the results should not have differed so much. Minor differences, however, could easily be the result of having used preliminary or incomplete statistics to calculate the old set of numbers.

The mean weights at age used in past mackerel assessments (Table 4) were applied to the numbers at age in Table 1 to obtain calculated catches (tons) for 1962-1975 for comparison with the observed catches (tons). Ratios between observed and calculated catches ranged from 0.936 in 1964 to 1.301 in 1968 for an average of 1.025 over all years. Except for the ratios of 1.301 in 1968 and 1.141 in 1969, values ranged between 0.936 and 1.088 and averaged 0.992. The general close agreement in most years between calculated and observed catch tends to support the use of the new numbers at age in the assessment.

Survey Abundance Indices

Stratified mean catch per tow was calculated from USA research vessel spring (1968-1976) and autumn (1963-1976) bottom trawl surveys in SA 5-6. Survey methods, procedures, and gear were described by Grosslein (1974). Spring indices were calculated from catches in strata 1-25 and 61-76 and autumn indices from catches in strata 1-2, 5-6, 9-10, 13, 16, 19-21, 23, and 25-26 (Figure 1). All autumn catches and the 1968-1972 spring catches were made with a No. 36 Yankee trawl, and the 1973-1976 spring catches were with a No. 41 trawl. The 1968-1972 spring catches were adjusted upwards to equivalent No. 41 trawl catches using a 3.25:1 ratio between the No. 41 and No. 36 trawls (Anderson 1976a) to establish a standardized time-series of catches. A $\log_e$ (x+1) transformation of the station catches (in kg) was made before calculation of the mean catch per tow indices. The $\log_e$ indices were then retransformed to the linear scale in order to be compatible with other data on the linear scale. Retransformation was accomplished by the method described by Finney (1941) using the equation

$$\bar{y} = e^{(\bar{x} + \frac{S^2}{2})} - 1$$

where $\bar{y}$ = linear catch per tow, $\bar{x}$ = $\log_e$ catch per tow, and S^2 = population variance ($\log_e$ scale).

Results are given in Table 5, and the retransformed indices are plotted in Figure 2. The trends in abundance for both the spring and autumn data are downward after the 1968-1969 period and have been discussed in earlier papers (e.g. Anderson 1976a). A reason for the aberrant low 1969 spring value was suggested by Anderson and Almeida (1976) based on low water temperatures that year influencing mackerel availability. Both survey indices increased slightly in 1976 from 1975. Since both time-series have experienced year-to-year fluctuations in past years, it is uncertain whether the slight increases in catch per tow reflect a slight improvement in stock abundance or are merely the result of the normally high variance associated with each yearly value. Nevertheless, the 1976 indices are still substantially lower than those observed in the late 1960s and early 1970s. The spring index (linear scale) in 1976 was only 8% of the peak 1968 index, and the 1976 autumn index was only 14% of the peak 1969 index.

Fishing Mortality

The estimation of fishing mortality (F) in the most recent year of the fishery is an extremely important and critical parameter in assessing the state of the mackerel stock. Survey and commercial catch data were both examined to obtain estimates of F.

Age-length keys from samples collected during the 1973-1976 spring bottom trawl surveys in SA 5-6 were applied to the length frequencies of the stratified mean catch (number) per tow from those surveys to obtain numbers at age per tow (Tables 6-9). These values were summarized in Table 10 indicating a marked reduction in number per tow (all ages) from 68.1 in 1973 to 7.3 in 1974 and a continued, but less pronounced, decline to 6.8 in 1975 and 5.8 in 1976. Decreases in number per tow of the various year-classes in successive years were very evident. This information was used to calculate total mortality rates (Z) by age for 1973-1975 (Table 11). Mean Z for ages 2 and older was 2.60 in 1973, 3.13 in 1974, and 1.34 in 1975. Subtracting M = 0.3, mean F was 2.30 in 1973, 2.83 in 1974, and 1.04 in 1975. These estimates suggest that fishing mortality was excessively high in those years.

Cohort analysis (Pope 1972) was used on the commercial numbers at age data for 1962-1975 (Table 1) to estimate age-specific fishing mortality. Terminal F in 1975 was assumed to be 1.00 based, to some extent, on the independent estimate of F = 1.04 in 1975 from the survey data; M was assumed to be 0.3 at all age groups. Partial recruitment was assumed to be 25% at age 1 and 100% at ages 2 and older in 1975 (ICNAF 1976). Terminal F in years earlier than 1975 for those year-classes having passed through the fishery was assumed to be the mean F (weighted by N at age - Table 14) for ages 3 and older that year.

Estimates of fishing mortality for 1962-1975 from the cohort analysis are given in Table 12. Results indicate, based on patterns of fishing mortality at age, that full recruitment to the fishery generally occurred by about age 3. Mean F values for ages 3 and older (weighted by N at age - Table 14) showed a continuous increase from very low levels in 1962-1964 (0.024-0.029) to 0.131-0.132 in 1968-1969 and to 0.545 and 0.707 in 1973 and 1974. Examination of fishing mortality by age in 1974 indicates full recruitment at age 2 in that year, and in view of the increased proportion of the catch being age 1 and 2 fish in 1975, there is strong support for assuming 100% recruitment at age 2 and older in 1975.

In order to check the estimate of F = 1.00 in 1975 determined from the analysis of survey catch per tow data, another estimation procedure was employed. Assuming that fishing effort is proportional to fishing mortality, a mathematical relationship between the two parameters can be defined which will allow fishing mortality to be predicted if fishing effort is known. Although commercial catch-per-unit-effort data are available from the international mackerel fishery for use in calculating fishing effort, analyses have indicated that vessel efficiency in the mackerel fishery has increased in recent years (Anderson 1976a) thus invalidating and confounding the determination of an accurate time-series of fishing effort. Therefore, instead of using commercial catch per effort data to calculate fishing effort, survey catch per tow data were used. The survey data are not subject to the biases inherent to commercial data, and they represent a standardized time-series of stock abundance measures. Fishing effort indices (Table 13) were calculated for 1968-1975 by dividing the SA 3-6 catch in each year by the appropriate USA spring survey catch (kg) per tow (linear scale) value. The survey values for 1969 and 1974 were replaced by the means of the 1968-1970 and 1973-1975 values, respectively, in order to establish a smooth time-series of values. The calculated fishing effort indices for 1968-1973 were plotted (Figure 3) against the respective mean F values for ages 3 and older obtained from the cohort analysis. A linear regression of fishing mortality on fishing effort was calculated, with r = 0.996. The values of F predicted from this relationship for 1974 and 1975 were 0.641 and 0.995, respectively (Table 13). Fishing mortality estimated for 1975 by this procedure is essentially the same as that estimated from the analysis of survey catch at age data (Table 11). The estimated F of 0.641 for 1974 is quite close to the F of 0.707 calculated for 1974 by cohort analysis. These results tend to support the estimate of F = 1.00 in 1975.

Stock Size

Population numbers (N) by year-class and age were calculated by cohort analysis. The results given in Table 14 show the calculated numbers of fish available at the beginning of the years, 1962-1976. Yearly stock biomass estimates were obtained by applying mean weights at age (Table 4) to the numbers at age and then correcting the summed weights by the ratio between observed and calculated catch (Table 1). Total number and weight was calculated for both the age 1 and older population and for the spawning population which was defined as 50% of the age 2 fish and 100% of the age 3 and older fish (ICNAF 1976).

Results indicate that the mackerel stock (age 1+) in SA 3-6 was stabilized at about 480,000 tons during 1962-1965 (Figure 4). Biomass then increased sharply to 2.1 million tons in 1969 following improved recruitment, especially from the 1967 year-class, after which it declined to an estimated 625,000 tons in 1975. The spawning stock biomass was about 410,000 tons during 1962-1967 before climbing to and maintaining a peak level of 1.6 million tons during 1970-1972. The spawners then decreased sharply to an estimated 247,000 tons at the beginning of 1976.

The USA survey abundance indices show general agreement with the changes in mackerel biomass described by the results of the cohort analysis (Figure 5). The autumn index was very low in the early 1960s but increased, as did stock biomass, to a peak in 1969. After 1969 the autumn index dropped sharply, again showing general agreement with the trend observed for stock biomass. The spring index peaked in 1968, its first point, and also decreased in subsequent years, showing agreement with both the autumn survey and stock biomass.

Year-Class Size and Recruitment

Results of the cohort analysis provide estimates of the sizes of the 1961-1974 year-classes at age 1 (Table 14). The year-classes produced in the early 1960s were quite poor, ranging from 365 million (1962 and 1963) to 775 million (1961). Recruitment improved to about 1 billion for the 1965 year-class, and the 1966, 1968, and 1969 year-classes were all about equal in strength with 2.7 billion fish at age 1. The 1967 year-class was very strong, containing 7 billion fish at age 1. The 1970 and 1971 year-classes each contained about 1.4 billion fish. The 1972 year-class, with an estimated 920 million fish at age 1, appears to be the poorest year-class since 1964. The 1973 and 1974 year-classes contained an estimated 1.1 and 1.9 billion fish, respectively, at age 1, thus making the 1974 year-class the strongest observed since 1969. The estimates for the more recent year-classes are highly dependent on the terminal F assumed in the cohort analysis, but will improve with the addition of subsequent years of catch data. The mean size of the 1961-1974 year-classes at age 1 was 1.785 billion fish; only five of the 14 year-classes were above-average. The median year-class size was 1.278 billion fish.

USA spring and autumn survey data were utilized in a manner similar to that described by Anderson (1976b) to estimate the approximate sizes of the 1975 and 1976 year-classes. Mean numbers per tow at ages 1 and 2 were determined from the 1968-1976 spring surveys (Table 15) and at age 0 from the 1963-1976 autumn surveys (Table 16) using the length frequencies of the stratified mean catch (numbers) per tow calculated from the appropriate sets of strata. The data for the 1973-1976 spring surveys were taken from Tables 6-9. Since age samples were not taken during the 1968-1972 spring surveys, age 1 fish were defined as those measuring 22 cm and less (fork length) and age 2 fish were defined as those measuring 23-29 cm. Age 0 fish for the autumn surveys were defined as those measuring 23 cm or less.

The spring survey numbers per tow at age 1 (1967-1974 year-classes) and the autumn survey numbers per tow at age 0 (1963-1974 year classes) were plotted against year-class size at age 1 calculated from cohort analysis. A power curve appeared to best describe the relationship between the year-class size and the survey catch per tow at age. The calculated curve using the spring survey data at age 1 (Figure 6) had a correlation coefficient (r) of 0.908, and the curve using the autumn survey data at age 0 (Figure 7) had an r of 0.755.

The size of the 1975 year-class at age 1 was predicted from the curves to be 640 million fish based on the spring catch per tow at age 1 (Table 15) and 490 million fish based on the autumn catch per tow at age 0 (Table 16). The mean of these two estimates is 565 million. The autumn survey index for the 1975 year-class was the lowest on record (1963-1976), suggesting that the 1975 year-class may be as poor as any observed (365 million - 1962-1963 year-classes). Anderson and McBride (1976) suggest, based on environmental conditions in 1975, that the 1975 year-class may be very poor.

The 1976 year-class at age 1 was predicted from the autumn survey data (Table 16, Figure 7) to contain about 1.2 billion fish, which is about the median size observed during 1961-1974.

The spring survey numbers per tow at age 2 (1966-1973 year-classes) were plotted against year-class size at age 2 calculated from cohort analysis (Figure 8). A power curve ($r = 0.950$) was fitted to the plotted points. The size of the 1974 year-class at age 2 was predicted from this relationship to contain 1156.7×10^6 fish (Table 15). The estimate based on the cohort analysis (Table 14) was 1101.5×10^6 fish indicating very close correspondence between the two estimates which suggests that the estimates may be reasonably accurate.

Catch and Stock Size Predictions

Assuming that (1) the stock size of age 2 and older fish at the beginning of 1976 was as estimated in Table 14, (2) the 1975 year-class at age 1 equalled 500 million fish, and (3) there was 25% recruitment at age 1 and 100% at ages 2 and older in 1976-1977, then the anticipated catch in 1976, ranging between 220,000 and 260,000 tons, would generate levels of fishing mortality from 1.20 to 1.67 compared to 1.00 in 1975. Assuming these ranges of catch and F in 1976 and assuming that the 1976 year-class at age 1 equalled 1.2 billion fish, fishing mortality reduced to $F_{0.1} = 0.35$ would generate a 1977 catch of between 46,000 and 35,000 tons.

The estimated spawning stock biomass of 247,000 tons at the beginning of 1976 is lower than ever observed (1962-1976) and will be further reduced to between 125,000 and 85,000 tons in 1977 depending on whether catch was 220,000 or 260,000 tons in 1976. With fishing mortality reduced to the $F_{0.1}$ level in 1977, the spawning stock biomass would improve in 1978 to between 170,000 and 142,000 tons. Figure 9 shows the relationship between recruitment at age 1 and spawning stock biomass. Although the strong 1967 year-class was produced from a spawning biomass of only about 435,000 tons, the poor 1962-1965 year-classes were produced from spawning stocks only slightly smaller (average of 393,000 tons) in size. The 1975 year-class, estimated to be as poor as the 1962-1964 year-classes, was produced from a spawning stock estimated to be of the approximate same size that produced the 1962-1964 year-classes. The 1976 year-class estimated as below-average, came from a spawning stock estimated to be even smaller. Considering the adversely low level of the spawning stock biomass estimated to be present in 1977 and anticipating a decreased probability of strong recruitment from such a small spawning stock, a major reduction in catch in 1977 to the level of 35,000-46,000 tons appears justified.

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Table 1. Mackerel catch (millions of fish) from SA 3-6 during 1962-75.

	Year													
Year-class	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
1951	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-
1952	0.1	0.1	-	-	-	-	-	-	-	-	-	-	-	-
1953	0.3	0.1	-	-	-	-	-	-	-	-	-	-	-	-
1954	0.5	0.1	0.2	-	-	-	-	-	-	-	-	-	-	-
1955	1.0	0.1	0.6	-	-	-	-	-	-	-	-	-	-	-
1956	1.1	0.1	0.5	0.6	-	-	-	-	-	-	-	-	-	-
1957	0.8	0.2	2.9	3.1	0.1	-	-	-	-	-	-	-	-	-
1958	2.6	4.2	3.1	3.3	0.4	0.3	0.1	-	-	-	-	-	-	-
1959	10.5	18.3	14.6	15.4	18.1	28.5	5.6	7.6	2.6	-	-	-	-	-
1960	1.9	0.9	3.0	4.1	6.6	5.4	0.9	2.0	3.5	6.9	-	-	-	-
1961	11.1	2.9	3.1	3.2	3.9	4.5	0.6	2.8	9.3	7.8	5.4	-	-	-
1962	-	0.8	5.2	2.3	2.2	2.9	6.0	1.8	9.2	4.1	3.6	1.6	-	-
1963	-	-	9.7	2.8	4.4	3.1	13.1	2.7	4.9	3.4	7.9	3.7	0.8	
1964	-	-	-	7.1	9.5	17.5	34.8	5.2	6.6	8.5	4.1	4.0	2.4	1.0
1965	-	-	-	-	19.9	23.6	54.1	59.9	25.8	33.1	23.2	10.6	6.3	2.2
1966	-	-	-	-	-	0.7	56.1	146.2	152.3	194.8	84.2	30.4	25.1	12.2
1967	-	-	-	-	-	1.6	129.0	238.5	488.0	535.1	376.5	192.2	105.9	49.6
1968	-	-	-	-	-	-	1.0	6.5	51.0	122.0	176.1	187.5	109.4	50.9
1969	-	-	-	-	-	-	-	3.6	180.9	281.7	247.0	227.5	111.8	66.6
1970	-	-	-	-	-	-	-	-	4.5	71.4	82.7	277.6	99.3	57.6
1971	-	-	-	-	-	-	-	-	-	2.3	21.3	275.8	258.6	99.1
1972	-	-	-	-	-	-	-	-	-	-	3.4	157.7	236.9	111.7
1973	-	-	-	-	-	-	-	-	-	-	-	3.9	93.8	423.7
1974	-	-	-	-	-	-	-	-	-	-	-	-	2.0	367.1
1975	-	-	-	-	-	-	-	-	-	-	-	-	-	3.6
1976	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	30.1	27.8	42.9	41.9	65.1	88.1	301.3	476.8	938.6	1271.1	1035.4	1372.5	1052.3	1245.3
Obs.wt.(10^3tons)	7.9	9.0	13.2	16.1	22.3	34.1	80.8	131.8	230.6	373.0	409.7	419.3	339.6	287.1
Calc. wt[1]	7.3	9.5	14.1	16.6	21.0	34.4	62.1	115.5	242.9	396.7	376.5	425.3	339.3	301.8
Obs./calc.	1.082	0.947	0.936	0.970	1.062	0.991	1.301	1.141	0.949	0.940	1.088	0.986	1.001	0.951

[1] Using mean weights at age from Table 4.

Table 2. Comparison between the numbers at age (10^6) used previously (Old) (ICNAF, 1976a) and those presented in this paper (New) for the 1968-75 mackerel catch in SA 3-6.

Age	Numbers at age (10^6)															
	1968		1969		1970		1971		1972		1973		1974		1975	
	Old	New	Old	New	Old	New	Old	New	Old	New	Old	New	Old	New	Old[1]	New
0	2.2	1.0	3.2	3.6	3.2	4.5	1.1	2.3	11.0	3.4	0.3	3.9	5.2	2.0	2.1	3.6
1	94.5	129.0	139.5	6.5	143.0	180.9	101.2	71.4	41.8	21.3	95.3	157.7	102.9	93.8	336.8	367.1
2	99.0	56.1	189.9	238.5	34.7	51.0	288.7	281.7	76.3	82.7	356.3	275.8	260.7	236.9	476.9	423.7
3	57.4	54.1	99.9	146.2	408.9	488.0	110.7	122.0	287.7	247.0	237.1	277.6	270.4	258.6	111.1	111.7
4	15.3	34.8	26.1	59.9	190.2	152.3	566.2	535.1	226.5	176.1	261.3	227.5	104.3	99.3	87.5	99.1
5	14.3	13.1	7.8	5.2	43.6	25.8	234.7	194.8	432.7	376.5	182.9	187.5	118.5	111.8	54.5	57.6
6	9.2	6.0	6.8	2.7	15.2	6.6	48.6	33.1	114.2	84.2	217.1	192.2	117.2	109.4	57.8	66.6
7	1.3	0.6	6.3	1.8	14.1	4.9	14.1	8.5	37.2	23.2	41.6	30.4	117.3	105.9	49.0	50.9
8	8.3	0.9	3.1	2.8	21.7	9.2	11.1	3.4	8.6	4.1	15.3	10.6	26.3	25.1	42.3	49.6
9	0.1	5.6	13.3	2.0	19.3	9.3	9.8	4.1	13.5	7.9	7.4	4.0	8.3	6.3	10.7	12.2
10	-	0.1	0.9	7.6	12.9	3.5	5.1	7.8	9.4	3.6	4.9	3.7	2.0	2.4	3.4	2.2
11+	-	-	-	-	-	2.6	4.6	6.9	4.0	5.4	1.8	1.6	1.3	0.8	1.6	1.0
Total	301.6	301.3	496.8	476.8	906.8	938.6	1395.9	1271.1	1262.9	1035.4	1421.3	1372.5	1134.4	1052.3	1233.7	1245.3

[1]Adjusted from 283.4 X 10^3 tons as in ICNAF (1976a) to 287.1 X 10^3 tons.

Table 3. Percentage age compositions of the 1968-75 SA 3-6 mackerel catch based on the numbers at age used previously (Old) (ICNAF, 1976a) and those presented in this paper (New).

Age	Percent at Age															
	1968		1969		1970		1971		1972		1973		1974		1975	
	Old	New	Old	New	Old	New	Old	New	Old	New	Old	New	Old	New	Old	New
0	0.7	0.3	0.6	0.8	0.3	0.5	0.1	0.2	0.9	0.3	+	0.3	0.5	0.2	0.2	0.3
1	31.3	42.8	28.1	1.4	15.8	19.3	7.2	5.6	3.3	2.1	6.7	11.5	9.1	8.9	27.3	29.5
2	32.8	18.6	38.2	50.0	3.8	5.4	20.7	22.2	6.0	8.0	25.1	20.1	23.0	22.5	38.6	34.0
3	19.0	18.0	20.1	30.7	45.1	52.0	7.9	9.6	22.8	23.9	16.7	20.2	23.8	24.6	9.0	9.0
4	5.1	11.5	5.3	12.5	21.0	16.2	40.6	42.1	17.9	17.0	18.4	16.6	9.2	9.4	7.1	7.9
5	4.7	4.3	1.6	1.1	4.8	2.7	16.8	15.3	34.3	36.4	12.9	13.6	10.5	10.6	4.4	4.6
6	3.1	2.0	1.4	0.5	1.7	0.7	3.5	2.6	9.0	8.1	15.3	14.0	10.3	10.4	4.7	5.3
7	0.4	0.2	1.3	0.4	1.6	0.5	1.0	0.7	3.0	2.2	2.9	2.2	10.3	10.1	4.0	4.1
8	2.8	0.3	0.6	0.6	2.4	1.0	0.8	0.3	0.7	0.4	1.1	0.8	2.3	2.4	3.4	4.0
9	0.1	1.9	2.7	0.4	2.1	1.0	0.7	0.3	1.1	0.8	0.5	0.3	0.7	0.6	0.9	1.0
10	-	0.1	0.1	1.6	1.4	0.4	0.4	0.6	0.7	0.3	0.3	0.3	0.2	0.2	0.3	0.2
11+	-	-	-	-	-	0.3	0.3	0.5	0.3	0.5	0.1	0.1	0.1	0.1	0.1	0.1

Table 4. Mean weights at age (kg) for mackerel (ICNAF 1974).

Age group	1	2	3	4	5	6	7	8	9	10+
Kg	.095	.175	.266	.350	.432	.506	.564	.615	.659	.693

Table 5. Stratified mean catch (kg) per tow ($\log_e$ and retransformed) of mackerel from USA bottom trawl surveys in the spring (strata 1-25, 61-76) and autumn (strata 1-2, 5-6, 9-10, 13, 16, 19-21, 23, 25-26).

Year	Spring[1]		Autumn[2]	
	$\log_e$	retransformed	$\log_e$	retransformed
1963	-	-	.013	.016
1964	-	-	<.001	<.001
1965	-	-	.046	.073
1966	-	-	.057	.085
1967	-	-	.195	.372
1968	.575	3.998	.117	.217
1969	.029	.065	.154	.459
1970	.471	2.039	.068	.099
1971	.425	1.969	.052	.073
1972	.354	1.332	.070	.107
1973	.228	.748	.034	.043
1974	.277	.769	.046	.108
1975	.121	.255	.010	.016
1976	.144	.317	.043	.062

[1]Based on catches with No. 41 trawls; 1968-72 catches were with No. 36 trawl and were adjusted to equivalent No. 41 catches using a 3.25:1 ratio (41/36).

[2]Based on catches with No. 36 trawl.

Table 6. Age composition and length frequency of the stratified mean catch (number) per tow of mackerel from the 1973 USA spring bottom trawl survey in SA 5-6, strata 1-25, 61-76.

Fork length (cm)	Number by age and year-class										
	1 1972	2 1971	3 1970	4 1969	5 1968	6 1967	7 1966	8 1965	9 1964	10+ 1963	Total
13	.012	-	-	-	-	-	-	-	-	-	.012
14	.093	-	-	-	-	-	-	-	-	-	.093
15	.365	-	-	-	-	-	-	-	-	-	.365
16	.518	-	-	-	-	-	-	-	-	-	.518
17	.323	-	-	-	-	-	-	-	-	-	.323
18	.178	-	-	-	-	-	-	-	-	-	.178
19	.069	-	-	-	-	-	-	-	-	-	.069
20	.070	-	-	-	-	-	-	-	-	-	.070
21	.135	-	-	-	-	-	-	-	-	-	.135
22	.109	.024	-	-	-	-	-	-	-	-	.133
23	.060	.020	-	-	-	-	-	-	-	-	.080
24	.017	.215	-	-	-	-	-	-	-	-	.232
25	-	.766	-	-	-	-	-	-	-	-	.766
26	-	.735	.023	-	-	-	-	-	-	-	.758
27	-	.486	-	-	-	-	-	-	-	-	.486
28	-	2.503	-	-	-	-	-	-	-	-	2.503
29	-	.808	.269	-	-	-	-	-	-	-	1.077
30	-	.925	1.849	1.156	-	-	-	-	-	-	3.930
31	-	.201	4.025	4.830	.805	.805	-	-	-	-	10.666
32	-	-	1.540	7.316	.770	6.546	1.155	-	-	-	17.327
33	-	-	.330	2.309	.989	8.245	1.979	.330	-	-	14.182
34	-	-	.152	.152	.911	3.795	1.366	1.213	-	-	7.589
35	-	-	-	.194	.194	1.360	.971	.680	.097	-	3.496
36	-	-	-	-	-	.293	.584	.730	.219	-	1.826
37	-	-	-	-	-	-	.254	.254	-	-	.508
38	-	-	-	-	-	.037	-	.112	.037	.262	.448
39	-	-	-	-	-	-	-	-	.012	.074	.086
40	-	-	-	-	-	-	-	-	-	.019	.019
41	-	-	-	-	-	-	-	-	-	.202	.202
42	-	-	-	-	-	-	-	-	-	.005	.005
43	-	-	-	-	-	-	-	-	-	.008	.008
44	-	-	-	-	-	-	-	-	-	-	-
45	-	-	-	-	-	-	-	-	.004	.004	.004
Total	1.949	6.683	8.188	15.957	3.669	21.081	6.309	3.319	.365	.574	68.094
%	2.9	9.8	12.0	23.4	5.4	31.0	9.3	4.9	0.5	0.8	100.0

Table 7. Age composition and length frequency of the stratified mean catch (number) per tow of mackerel from the 1974 USA spring bottom trawl survey in SA 5-6, strata 1-25, 61-76.

Fork length (cm)	Number by age and year-class 1 1973	2 1972	3 1971	4 1970	5 1969	6 1968	7 1967	8 1966	9 1965	10+ 1964	Total
15	.061	-	-	-	-	-	-	-	-	-	.061
16	.298	-	-	-	-	-	-	-	-	-	.298
17	.582	-	-	-	-	-	-	-	-	-	.582
18	.571	-	-	-	-	-	-	-	-	-	.571
19	.265	-	-	-	-	-	-	-	-	-	.265
20	.137	-	-	-	-	-	-	-	-	-	.137
21	.061	.015	-	-	-	-	-	-	-	-	.076
22	.063	.012	-	-	-	-	-	-	-	-	.076
23	.008	.015	-	-	-	-	-	-	-	-	.023
24	.021	.073	-	-	-	-	-	-	-	-	.094
25	-	.225	-	-	-	-	-	-	-	-	.225
26	-	.205	.008	-	-	-	-	-	-	-	.213
27	-	.122	.010	-	-	-	-	-	-	-	.132
28	-	.049	.046	-	-	-	-	-	-	-	.095
29	-	.019	.210	-	-	-	-	-	-	-	.229
30	-	.009	.511	.022	.004	-	-	-	-	-	.546
31	-	.005	.422	.016	.016	.005	-	-	-	-	.464
32	-	-	.115	.030	.080	.015	.020	.004	-	-	.264
33	-	-	.018	.055	.146	.018	.177	.012	.013	-	.439
34	-	-	.007	.052	.124	.039	.333	.098	.013	-	.666
35	-	-	-	-	.083	.114	.478	.114	.073	.001	.863
36	-	-	-	.010	.029	.048	.209	.047	.085	-	.428
37	-	-	-	-	.010	.010	.089	.089	.050	.020	.268
38	-	-	-	-	-	-	.088	.044	-	.029	.161
39	-	-	-	-	-	-	.007	.003	.003	.018	.031
40	-	-	-	-	-	-	-	.006	-	.028	.034
41	-	-	-	-	-	-	-	-	-	.011	.011
42	-	-	-	-	-	-	-	.023	-	-	.023
Total	2.067	.749	1.347	.185	.492	.249	1.401	.440	.237	.107	7.274
%	28.4	10.3	18.5	2.5	6.8	3.4	19.3	6.0	3.3	1.5	100.0

Table 8. Age composition and length frequency of the stratified mean catch (number) per tow of mackerel from the 1975 USA spring bottom trawl survey in SA 5-6, strata 1-25, 61-76.

Fork length (cm)	Number by age and year-class 1 1974	2 1973	3 1972	4 1971	5 1970	6 1969	7 1968	8 1967	9 1966	Total
6	.003	-	-	-	-	-	-	-	-	.003
7	.003	-	-	-	-	-	-	-	-	.003
8	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-
10	.035	-	-	-	-	-	-	-	-	.035
11	.009	-	-	-	-	-	-	-	-	.009
12	.013	-	-	-	-	-	-	-	-	.013
13	.006	-	-	-	-	-	-	-	-	.006
14	.003	-	-	-	-	-	-	-	-	.003
15	.144	-	-	-	-	-	-	-	-	.144
16	1.380	-	-	-	-	-	-	-	-	1.380
17	2.262	-	-	-	-	-	-	-	-	2.262
18	1.039	-	-	-	-	-	-	-	-	1.039
19	.234	-	-	-	-	-	-	-	-	.234
20	.115	-	-	-	-	-	-	-	-	.115
21	.051	-	-	-	-	-	-	-	-	.051
22	.028	-	-	-	-	-	-	-	-	.028
23	.005	.043	-	-	-	-	-	-	-	.048
24	-	.168	-	-	-	-	-	-	-	.168
25	-	.452	-	-	-	-	-	-	-	.452
26	-	.227	-	-	-	-	-	-	-	.227
27	-	.125	-	-	-	-	-	-	-	.125
28	-	.064	.013	-	-	-	-	-	-	.076
29	-	.022	.032	-	-	-	-	-	-	.054
30	-	-	.052	.023	-	-	-	-	-	.075
31	-	-	.029	.028	-	-	-	-	-	.057
32	-	-	.015	.044	-	-	-	-	-	.058
33	-	-	-	.017	-	-	.011	-	-	.028
34	-	-	-	.006	.009	.008	-	.006	-	.029
35	-	-	-	-	.005	.014	.009	.008	-	.036
36	-	-	-	.010	.010	-	-	-	-	.020
37	-	-	-	-	-	.006	-	-	-	.006
38	-	-	-	-	.006	-	-	-	-	.006
39	-	-	-	-	-	-	-	-	.001	.001
Total	5.330	1.101	.141	.128	.030	.028	.020	.014	.001	6.793
%	78.5	16.2	2.1	1.9	0.4	0.4	0.3	0.2	<0.1	100.0

Table 9. Age composition and length frequency of the stratified mean catch (number) per tow of mackerel from the 1976 USA spring bottom trawl survey in SA 5-6, strata 1-25, 61-76.

Fork length (cm)	Number by age and year-class									
	1 1975	2 1974	3 1973	4 1972	5 1971	6 1970	7 1969	8 1968	9 1967	Total
15	.037	-	-	-	-	-	-	-	-	.037
16	.079	-	-	-	-	-	-	-	-	.079
17	.061	-	-	-	-	-	-	-	-	.061
18	.045	-	-	-	-	-	-	-	-	.045
19	.077	-	-	-	-	-	-	-	-	.077
20	.060	-	-	-	-	-	-	-	-	.060
21	.043	-	-	-	-	-	-	-	-	.043
22	.004	-	-	-	-	-	-	-	-	.004
23	.022	.032	-	-	-	-	-	-	-	.054
24	.019	.818	-	-	-	-	-	-	-	.837
25	-	1.856	.029	-	-	-	-	-	-	1.885
26	-	1.588	-	-	-	-	-	-	-	1.588
27	-	.484	.026	-	-	-	-	-	-	.510
28	-	.131	.015	-	-	-	-	-	-	.146
29	-	.009	.070	-	-	-	-	-	-	.079
30	-	-	.098	.010	-	-	-	-	-	.108
31	-	.010	.088	.016	-	-	-	-	-	.114
32	-	-	.032	.019	-	-	-	-	-	.051
33	-	-	.003	.008	.004	-	-	-	-	.015
34	-	-	.004	.012	.008	-	.009	-	-	.033
35	-	-	-	.005	.002	.002	-	-	-	.009
36	-	-	-	-	-	-	-	-	-	-
37	-	-	-	-	-	-	-	-	-	-
38	-	-	-	-	-	.004	-	-	.004	.008
Total	.447	4.928	.365	.070	.014	.006	.009	-	.004	5.843
%	7.7	84.3	6.2	1.2	0.2	0.1	0.2	-	0.1	100.0

Table 10. Stratified mean catch (number) per tow of mackerel by year-class from the 1973-76 USA spring bottom trawl surveys in SA 5-6, strata 1-25, 61-76.

Year	Number by year-class													
	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963+	Total
1973	-	-	-	1.949	6.683	8.188	15.957	3.669	21.081	6.309	3.319	.365	.574	68.094
1974	-	-	2.067	.749	1.347	.185	.492	.249	1.401	.440	.237	.107	-	7.274
1975	-	5.330	1.101	.141	.128	.030	.028	.020	.014	.001	-	-	-	6.793
1976	.447	4.928	.365	.070	.014	.006	.009	-	.004	-	-	-	-	5.843

Table 11. Total mortality (Z) of mackerel during 1973-76 determined from stratified mean catch (number) per tow of year-classes in successive years from USA spring bottom trawl surveys in SA 5-6, strata 1-25, 61-76.

Year	Age								Mean	
	2	3	4	5	6	7	8	9	Z	F
1973	1.60	3.79	3.48	2.69	2.71	2.66	2.64	1.23	2.60	2.30
1974	1.67	2.35	1.82	2.87	2.52	4.61	6.09	-	3.13	2.83
1975	1.10	.70	2.21	1.61	1.14	-	1.25	-	1.34	1.04

Table 12 . Estimates of fishing mortality rates (F) for mackerel in SA 3-6 derived from cohort analysis.

Year-class	Year													
	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
1951	(.024)	-	-	-	-	-	-	-	-	-	-	-	-	-
1952	.020	(.027)	-	-	-	-	-	-	-	-	-	-	-	-
1953	.058	(.027)	-	-	-	-	-	-	-	-	-	-	-	-
1954	.038	.011	(.029)	-	-	-	-	-	-	-	-	-	-	-
1955	.026	.004	(.029)	-	-	-	-	-	-	-	-	-	-	-
1956	.028	.004	.024	(.040)	-	-	-	-	-	-	-	-	-	-
1957	.039	.013	.308	.733	(.048)	-	-	-	-	-	-	-	-	-
1958	.092	.236	.308	.729	.193	.243	(.131)	-	-	-	-	-	-	-
1959	.019	.046	.052	.080	.141	.389	.135	.307	(.180)	-	-	-	-	-
1960	.004	.002	.010	.019	.043	.049	.011	.035	.088	(.279)	-	-	-	-
1961	.017	.006	.009	.012	.020	.033	.006	.039	.194	.278	(.351)	-	-	-
1962	-	.003	.023	.014	.018	.033	.098	.043	.359	.301	.538	(.545)	-	-
1963	-	-	.031	.012	.027	.026	.165	.051	.138	.149	.699	1.020	(.707)	-
1964	-	-	-	.019	.035	.093	.302	.074	.141	.305	.264	.508	.768	1.000
1965	-	-	-	-	.023	.038	.127	.226	.160	.356	.519	.544	.867	1.000
1966	-	-	-	-	-	<.001	.033	.125	.208	.510	.491	.369	.689	1.000
1967	-	-	-	-	-	<.001	.022	.056	.174	.329	.463	.520	.707	1.000
1968	-	-	-	-	-	-	<.001	.003	.030	.104	.241	.498	.711	1.000
1969	-	-	-	-	-	-	-	.001	.078	.188	.281	.515	.593	1.000
1970	-	-	-	-	-	-	-	-	.003	.060	.102	.662	.604	1.000
1971	-	-	-	-	-	-	-	-	-	.001	.017	.365	.814	1.000
1972	-	-	-	-	-	-	-	-	-	-	.003	.223	.704	1.000
1973	-	-	-	-	-	-	-	-	-	-	-	.003	.101	1.000
1974	-	-	-	-	-	-	-	-	-	-	-	-	.001	.250
Wtd $\bar{F}$ (age 3+)	.024	.027	.029	.040	.048	.093	.131	.132	.180	.279	.351	.545	.707	1.000

Table 13. Estimation of F in 1974-75 for SA 3-6 mackerel fishery.

Year	Spring survey catch/tow	International catch SA 3-6	Fishing effort index[1]	Wtd. $\bar{F}$ (age 3+)
1968	3.998	80,810	20,213	.131
1969	(3.019)[2]	131,810	43,660	.132
1970	2.039	230,603	113,096	.180
1971	1.969	373,033	189,453	.279
1972	1.332	409,724	307,601	.351
1973	.748	419,306	560,570	.545
1974	(.502)[3]	339,580	676,454	(.641)[4]
1975	.255	287,138	1,126,031	(.995)[4]
1976	.317			

[1]International catch divided by survey catch/tow.
[2]Mean of 1968 and 1970 values.
[3]Mean of 1973 and 1975 values.
[4]Calculated from regression of fishing effort index on $\bar{F}$ for 1968-73:
$Y = .108 + .00000079\ X$, $r = .996$.

Table 14. Estimates of mackerel stock size in SA 3-6 (millions of fish) derived from cohort analysis assuming M = 0.3 and F = 0.25 at age 1 and 1.00 at ages 2 and older in 1975.

Year-class	Year														
	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
1951	9.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1952	6.0	4.3	-	-	-	-	-	-	-	-	-	-	-	-	-
1953	6.2	4.3	-	-	-	-	-	-	-	-	-	-	-	-	-
1954	15.5	11.0	8.1	-	-	-	-	-	-	-	-	-	-	-	-
1955	45.6	32.9	24.3	-	-	-	-	-	-	-	-	-	-	-	-
1956	46.0	33.1	24.5	17.7	-	-	-	-	-	-	-	-	-	-	-
1957	24.4	17.4	12.7	6.9	2.5	-	-	-	-	-	-	-	-	-	-
1958	34.4	23.2	13.6	7.4	2.6	1.6	0.9	-	-	-	-	-	-	-	-
1959	646.0	469.5	332.1	233.4	159.7	102.7	51.6	33.4	18.2	-	-	-	-	-	-
1960	630.1	465.2	343.8	252.1	183.3	130.1	91.7	67.2	48.0	32.6	-	-	-	-	-
1961	776.8	565.9	416.7	306.1	224.0	162.6	116.6	85.8	61.2	37.3	20.9	-	-	-	-
1962	-	364.7	269.5	195.2	142.6	103.7	74.4	49.9	35.4	18.3	10.1	4.3	-	-	-
1963	-	-	366.3	263.0	192.4	138.8	100.1	62.9	44.3	28.6	18.3	6.7	1.8	-	-
1964		-	-	441.3	320.8	229.5	155.0	84.8	58.4	37.6	20.5	11.7	5.2	1.8	-
1965	-	-	-	-	1020.5	738.9	527.1	343.9	203.2	128.3	66.6	29.4	12.6	3.9	1.1
1966	-	-	-	-	-	2715.5	2011.1	1441.6	942.1	566.8	252.3	114.4	58.6	21.8	5.9
1967	-	-	-	-	-	-	7007.4	5080.2	3558.2	2216.0	1181.1	550.9	242.7	88.6	24.1
1968	-	-	-	-	-	-	-	2692.2	1988.9	1429.5	954.0	555.2	249.9	91.0	24.8
1969	-	-	-	-	-	-	-	-	2789.6	1910.9	1173.2	656.5	290.5	119.0	32.4
1970	-	-	-	-	-	-	-	-	-	1425.8	994.8	665.8	254.3	102.9	28.0
1971	-	-	-	-	-	-	-	-	-	-	1440.3	1048.7	539.5	177.1	48.3
1972	-	-	-	-	-	-	-	-	-	-	-	918.5	544.7	199.6	54.4
1973	-	-	-	-	-	-	-	-	-	-	-	-	1131.0	757.2	206.4
1974	-	-	-	-	-	-	-	-	-	-	-	-	-	1909.1	1101.5
Age 1+															
Total (10^6)	2240.8	1991.5	1811.6	1723.1	2248.4	4323.4	10135.9	9941.9	9747.5	7831.7	6132.1	4562.1	3330.8	3472.0	
Wt(10^3tons)	489.1	466.6	474.9	479.3	570.3	754.7	1886.2	2128.5	2030.5	1912.7	1826.2	1276.1	874.2	625.5	
Spawning stock (50% age 2, 100% age 3+)															
Total (10^6)	1149.0	1343.9	1310.6	1150.3	1067.5	1238.5	2123.0	4709.6	5963.5	5450.5	4194.4	3119.3	1927.5	1184.3	976.2
Wt(10^3tons)[1]	349.6	386.9	420.2	416.3	437.5	435.0	791.1	1329.4	1613.8	1628.2	1582.6	1099.6	718.9	390.0	246.9

[1]Adjusted using yearly ratios between observed and calculated catch (see Table).

Table 15. Mackerel year-class sizes at ages 1 and 2 estimated from USA spring bottom trawl survey catch per tow (number) (strata 1-26, 61-76) compared with those calculated by cohort analysis (millions of fish).

Year-class	Age 1		Age 2	
	Spring survey	Cohort analysis	Spring survey	Cohort analysis
1966	-	2715.5	21.661	2011.1
1967	197.993	7007.4	1.190[1]	5080.2
1968	.299[1]	2692.2	12.435	1988.9
1969	6.208	2789.6	13.390	1910.9
1970	2.954	1425.8	5.545	994.8
1971	12.093	1440.3	6.683	1048.7
1972	1.949	918.5	.749	544.7
1973	2.067	1131.0	1.101	757.2
1974	5.330	1909.1	4.928	(1156.7)[2]
1975	.447	(638.9)[2]	-	-

[1]Not used.
[2]Calculated.

Table 16. Catch per tow (number) of age 0 mackerel from USA autumn bottom trawl surveys (strata 1-2, 5-6, 9-10, 13, 16, 19-21, 23, 25-26) and year-class size (millions of fish) at age 1 derived from cohort analysis.

Year-class	Autumn survey age 0	Cohort analysis age 1
1963	.087	366.3
1964	.022	441.3
1965	.134	1020.5
1966	.170	2715.5
1967	15.709	7007.4
1968	.215	2692.2
1969	38.504	2789.6
1970	.027	1425.8
1971	.517	1440.3
1972	.119	918.5
1973	.339	1131.0
1974	.648	1909.1
1975	.012	(491.1)[1]
1976	.152	(1212.6)[1]

[1]Calculated.

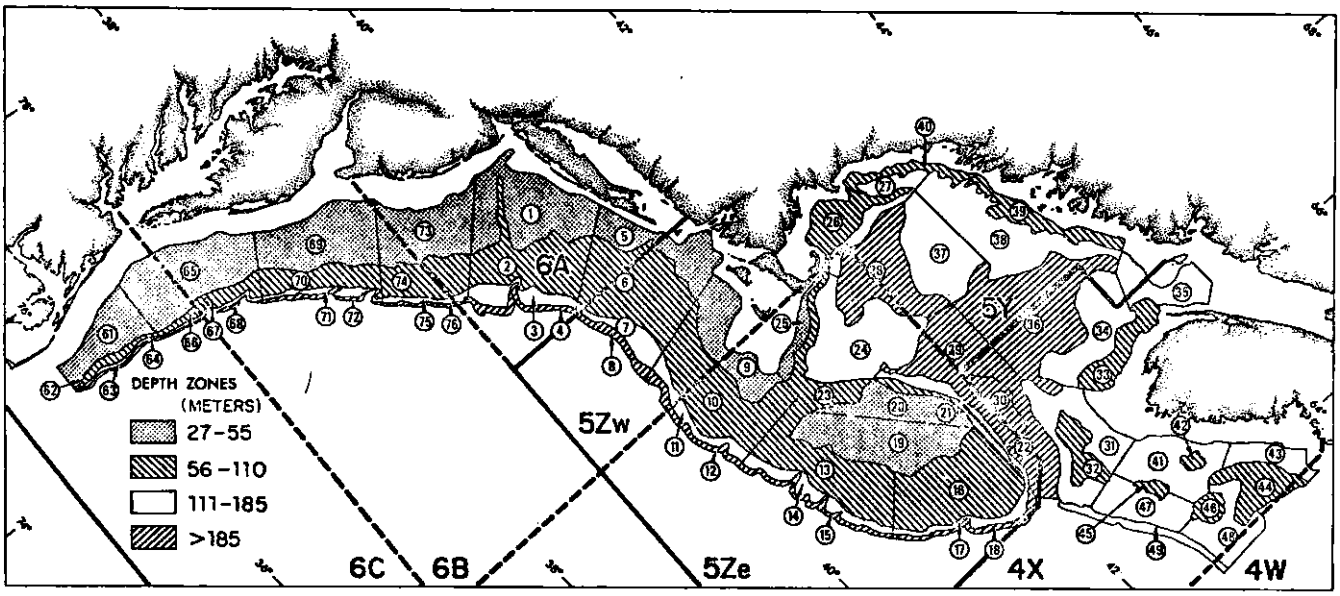

Fig. 1. US bottom trawl survey sampling strata in ICNAF SA 5-6.

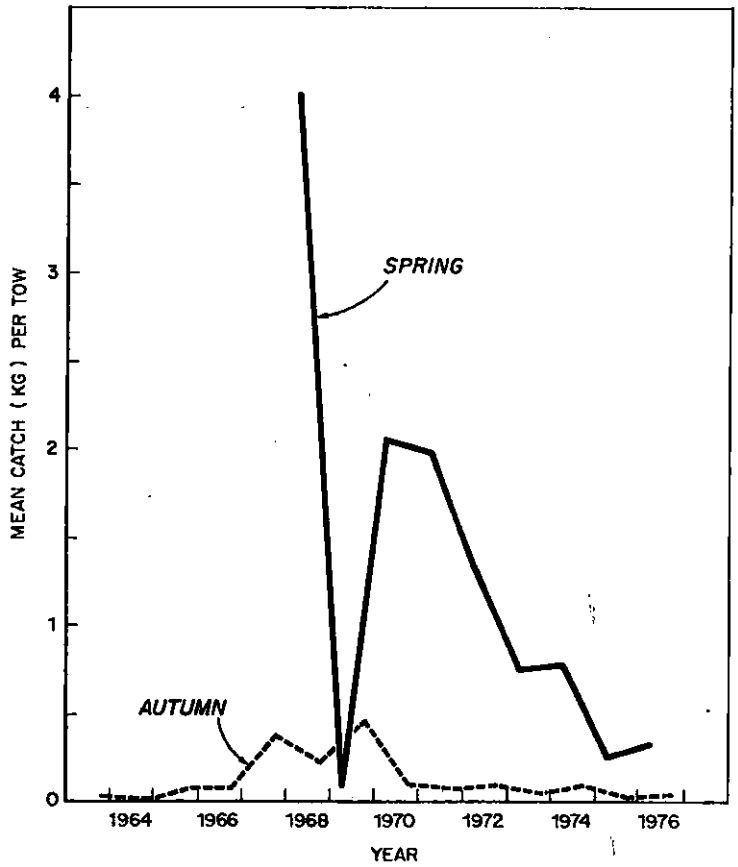

Fig. 2. Stratified mean catch (kg) per tow of mackerel (retransformed from $\log_e$ to linear scale from US spring (1968-1976) and autumn (1963-1976) bottom trawl surveys.

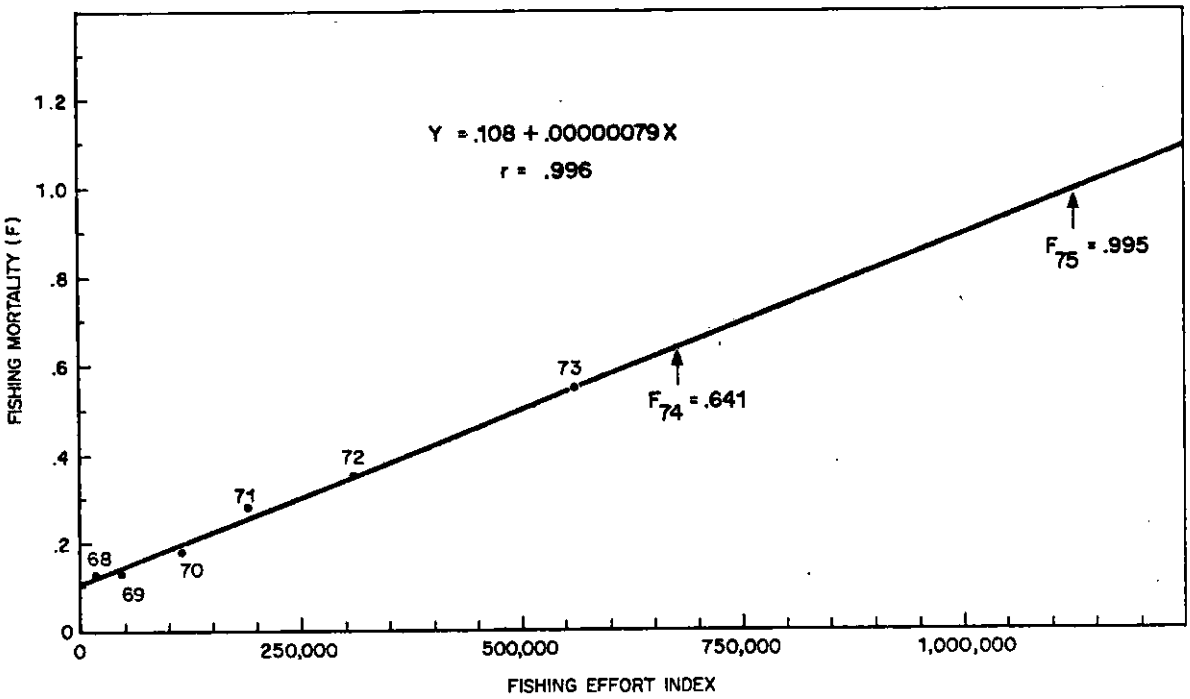

Fig. 3. Relationship between fishing mortality from cohort analysis and fishing effort indices derived from spring survey catch per tow and commercial catch.

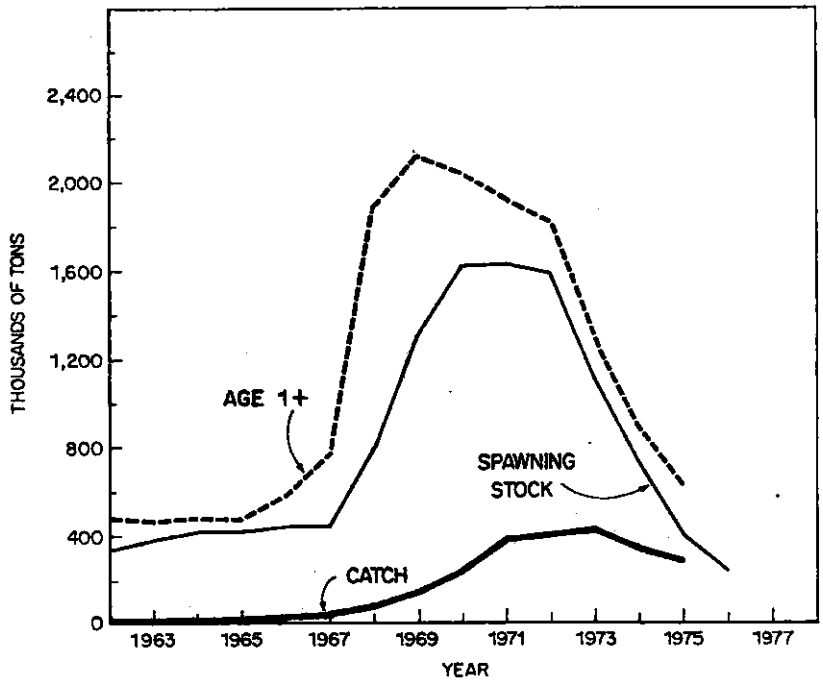

Fig. 4. Mackerel catch, spawning stock biomass, and total stock biomass (age 1+) for the SA 3-6 stock in 1962-1975.

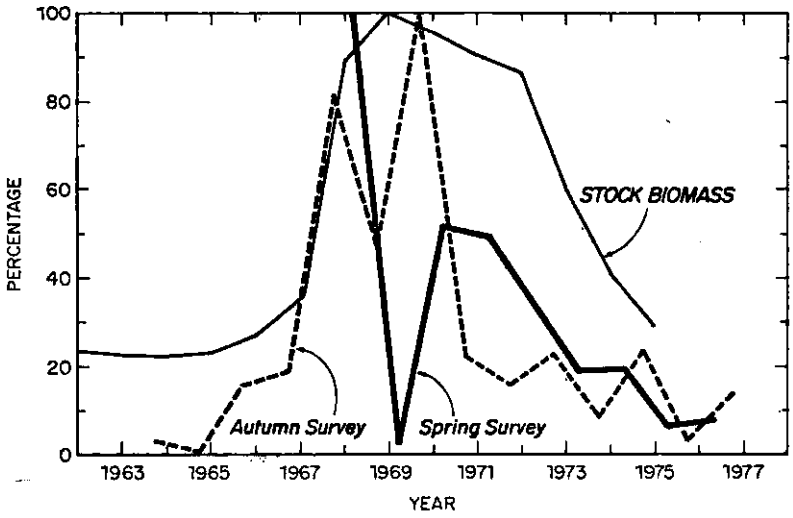

Fig. 5. Mackerel stock biomass (age 1+) and US spring and autumn survey catch per tow each plotted as a percentage of its maximum value.

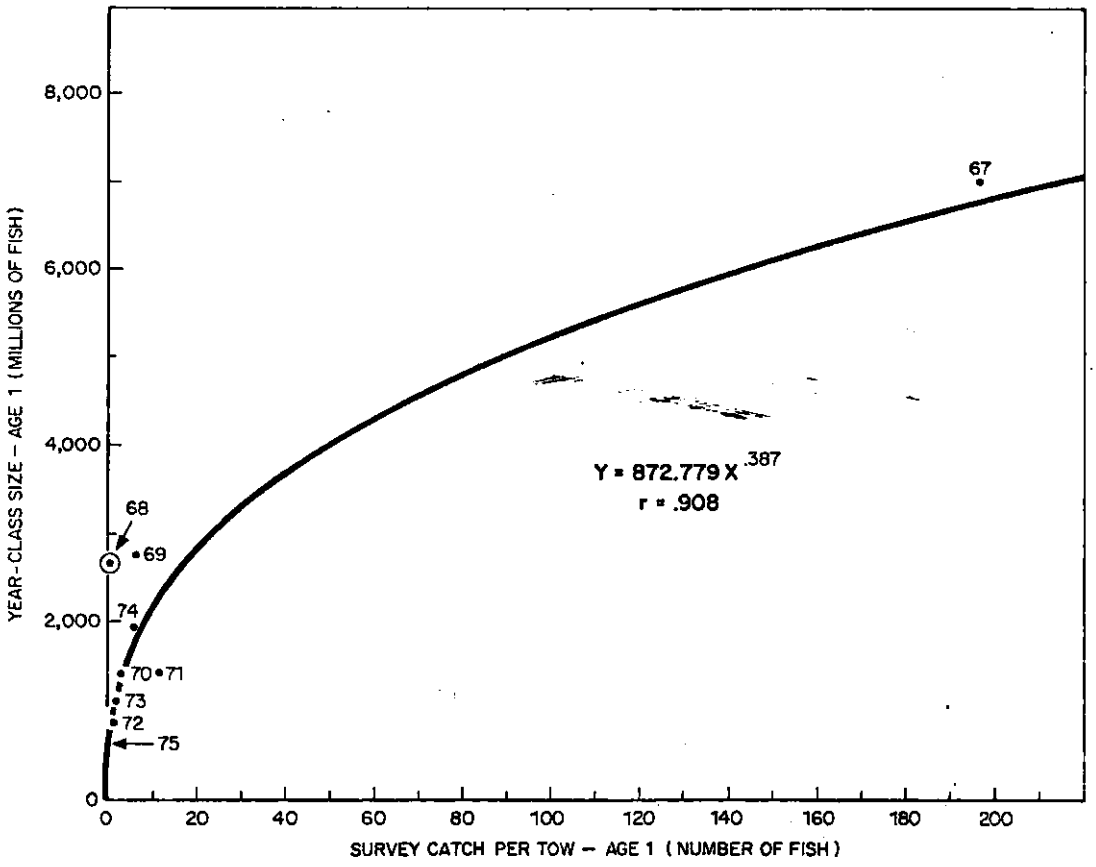

Fig. 6. Relationship between mackerel year-class size at age 1 and spring survey catch per tow at age 1. The 1968 point was not used in calculating the power curve.

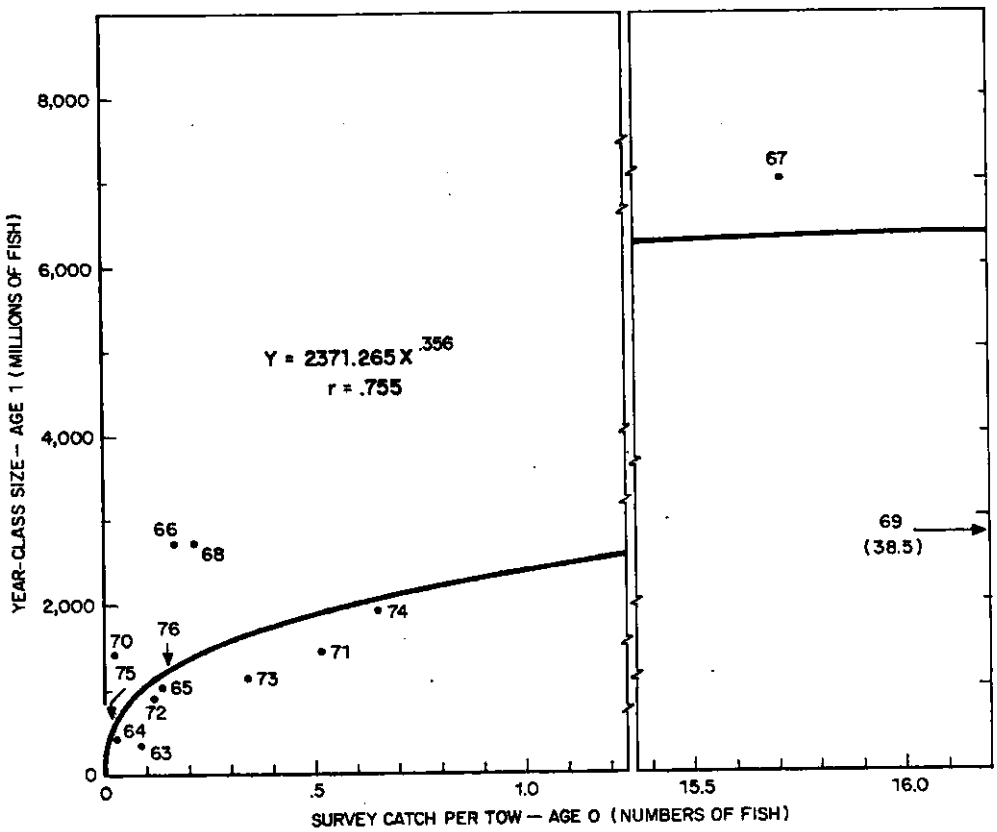

Fig. 7. Relationship between mackerel year-class size at age 1 and autumn survey catch per tow at age 0. The 1969 point was not used in calculating the power curve.

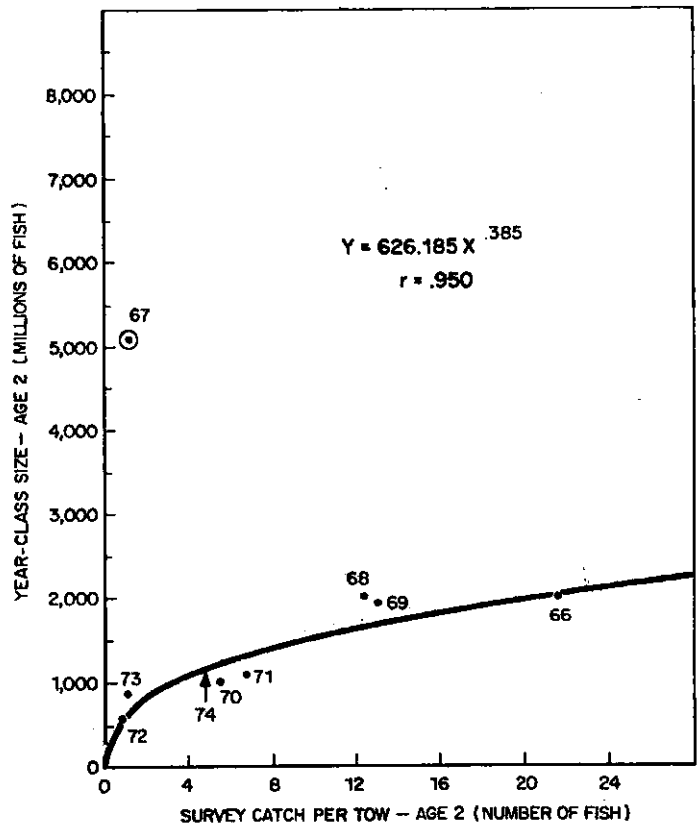

Fig. 8. Relationship between mackerel year-class size at age 2 and spring survey catch per tow at age 2. The 1967 point was not used in calculating the power curve.

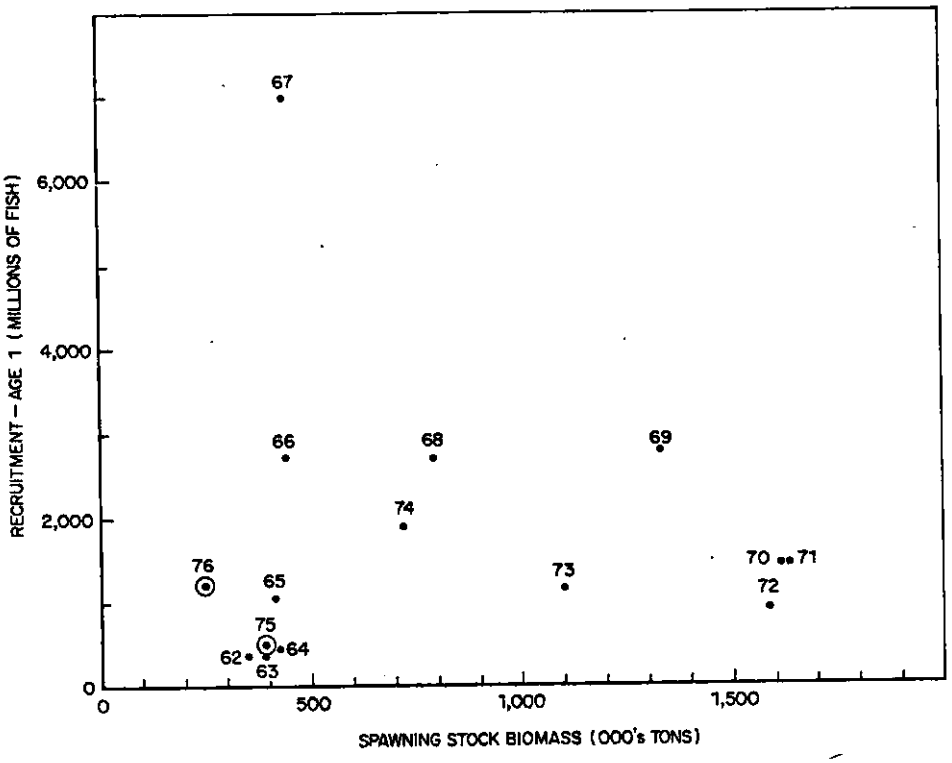

Fig. 9. Relationship between mackerel recruitment at age 1 and spawning stock biomass for 1962-1976.