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Reassessment of mackerel in ICNAF Subareas 3, 4, and 5, and

Statistical Area 6

by

E. D. Anderson

National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543 USA

Introduction

Since the April Mid-Term Meeting of the Assessments Subcommittee, additional information concerning mackerel catches in 1974 and 1975 has become available. The 1974 catch in SA 3-6 was greater than previously assumed which therefore influences VPA calculations of fishing mortality and stock size. Estimates of the age composition of the catches by several countries in January-February 1975 are now available which indicates that the age composition of the 1975 catch will differ considerably from that assumed by the Working Group in its assessment. In view of this new data, this paper presents a reassessment of the mackerel stock in SA 3-6 and suggests alternatives to the 1976 TAC of 310,000 MT recommended by the Assessments Subcommittee at its Mid-Term Meeting.

Catch in 1974

The 1974 nominal catch of mackerel from SA 3-6 used by the Mackerel Working Group in its assessment of the stock at the April 1975 Mid-Term Meeting of the Assessments Subcommittee at Woods Hole, Mass. was 336,231 MT.

However, the 1974 catch appears to have been greater than this amount. The USSR catch, as reported in Working Paper No. 6 (Addendum 1), was 24,961 MT from SA 3-4 and 108,618 MT from SA 5-6 giving a total of 133,579 MT from the combined areas. The USSR catch, as reported in the USSR Research Report, 1974 (ICNAF Summ. Doc. 75/30), was 27,461 MT from SA 3-4 and 118,140 MT from SA 5-6 for a total of 145,601 MT. If the latter USSR catch is used, the international total for 1974 is 348,255 MT (Table 1). This total was used in this reassessment of the stock.

The numbers at age data for 1974 catches by Bulgaria, GDR, Poland, and USSR (ICNAF Res. Doc. 75/40) were modified to take into account the larger USSR catch. The revised numbers caught at age for 1974 are given in Table 2.

Virtual population analysis

Virtual population analysis was performed on the 1959-1972 year-classes using the 1968-1974 catch in numbers at age, $M = 0.3$, $F = 0.6$ for ages 4 and older in 1974, and partial recruitment of 42% at age 2 and 82% at age 3. These values, with the exception of the 1974 catch in numbers, are the same as accepted and used by the Mackerel Working Group (ICNAF Summ. Doc. 75/18). The results of the VPA are given in Table 2. The calculated F's and stock sizes vary only slightly from those obtained by the Working Group (ICNAF Summ. Doc. 75/18). The new F's are slightly smaller and the new stock sizes are slightly larger than the values obtained previously. These changes result from using a larger 1974 catch than before and assuming that the F in 1974 was the same as assumed for

the smaller 1974 catch. Using the assumed F's in 1974 and the calculated 1974 stock size, the size of the year-classes in 1975 was determined by the following equation: $N_{n+1} = N_n e^{-Z_n}$ where N = year-class size in numbers, n = 1974, and $Z = F + 0.3$.

The size of the 1973 year-class at age 1 was assumed to be 50% of the 1967 year-class or approximately $3,700 \times 10^6$ and the size of the 1974 and 1975 year-classes at age 1 was assumed to be equal to the median of the 1967-1972 year-classes or approximately $2,500 \times 10^6$.

The stock size in 1975 of age 1 and older fish was calculated to be $6,845.4 \times 10^6$ fish or $1,103.0 \times 10^3$ MT, in contrast to $6,780.8 \times 10^6$ fish and $1,084.6 \times 10^3$ MT calculated by the Working Group.

Catch in 1975

The assessment by the Working Group at the Mid-Term Meeting assumed that the 1975 catch would equal the TAC's, which total 355,000 MT for SA 3-6. The age composition of the 1975 catch in numbers was calculated by applying an F of 0.7 for ages 4 and older to the year-class sizes calculated to be present at the beginning of 1975 and assuming partial recruitment coefficients of 90% at age 3, 50% at age 2, and 18% at age 1. The estimated 1975 catch included 256.5×10^6 fish at age 1, 680.5×10^6 fish at age 2, 317.6×10^6 fish at age 3, 158.7×10^6 fish at age 4, and 222.8×10^6 fish at ages 5 and older for a total of $1,636.1 \times 10^6$ fish.

A revised estimate of the 1975 age composition is presented in this report. As the result of a recent ICNAF resolution, monthly catch statistics for 1975 are being reported to the Secretariat within 30 days following the month in which the catches were made. Catches through March 1975 are given in Table 3. Assuming each country takes its allocation of the TAC, the catch for April-December was estimated as the balance of the TAC not taken in January-March.

Size compositions (% at length) of mackerel catches in SA 5-6 by Bulgaria in January 1975 and Poland and USSR in January-February 1975 were presented in graphical form in ICNAF Res. Doc. 75/40. The percentage of the catch at each length (cm) was determined graphically for each country for each month indicated. An age-length key constructed from samples taken aboard *ALBATROSS IV*, *WIECZNO*, and *WALTHER HERWIG* during 1975 spring surveys (Table 4) was used to determine the percentage age composition of the length compositions. The results indicated that the catches by the three countries in January-February consisted entirely of age 1-3 mackerel (Table 5) with age 1 being predominant. The composition of the combined catches weighted by each country's monthly catch was 68% age 1, 30.6% age 2, and 1.4% age 3. In order to convert the catches in MT to numbers at age, mean weights at age determined from weights taken from the fish used to construct the age-length key (Table 4) were utilized. These values were 0.070 kg at age 1, 0.149 kg at age 2, and 0.242 kg at age 3. The numbers at age and MT at age for each of the countries each month are given in Table 5. The total catch converted to numbers at age was 82,826 MT, 23.3% of the TAC of 355,000 MT for 1975. Age 1 mackerel were 40,873 MT or 583.9×10^6 fish and age 2 were 39,171 MT or 262.9×10^6 fish.

Catches of 6,983 MT in January and 17,658 MT in February were taken by countries for which age or length compositions were not available. Numbers at age comprising these catches were estimated by the following procedure. Taking the stock size at the beginning of January 1975, as calculated from the VPA, and assuming partial recruitment coefficients of 18%, 50%, and 90% at ages 1, 2, and 3, respectively, and $M = 0.025$ (1/12 of 0.3 for one month), an F was applied (approximately 0.0097) which would produce the catch of 6,983 MT in January (Table 7). The mean weights at age given in Table 6 were used.

Previously, the Working Group used an agreed set of mean weights at age (*Redbook* 1974, p. 32) and then adjusted the summed annual weight of all ages by a procedure described in *Redbook* 1974, p. 34. The use of the agreed mean weights and the adjustment procedure was not possible when dealing with a fraction of the annual catch (or stock) so the mean weights at age were corrected to eliminate the need for an adjustment of the total weight. Using the previously-agreed set of mean weights at age, the unadjusted total weight of the 1975 stock (age 1+) was $1,327.7 \times 10^3$ MT. Following adjustment by the accepted procedure, the total weight was $1,103.0 \times 10^3$ MT. The ratio of the adjusted weight to the unadjusted weight was 0.831. Each of the mean weights at age was multiplied by this ratio to obtain the mean weights at age used in the present analysis (Table 6).

The stock at the beginning of January of $6,845.4 \times 10^6$ fish or $1,103.0 \times 10^3$ MT was reduced by the catch at age in numbers totalling 6,983 MT, 1/12 of M , and the catch at age in numbers estimated previously for Bulgaria, Poland, and USSR leaving a stock at the beginning of

February of $6,156.1 \times 10^6$ fish or $1,018.1 \times 10^3$ MT. The same procedure as performed for January was then done for the February catch. An F of about 0.0262 was applied to the February stock (and an M of 0.025) to produce a catch of 17,658 MT (Table 7). Reducing the stock by that amount plus that due to 1/12 of the annual natural mortality, and then deducting the numbers at age caught by Poland and USSR resulted in a stock at the beginning of March of $5,554.5 \times 10^6$ fish or 938.8×10^3 MT. An F of about 0.5275 and an M of 0.25 (10/12 of 0.3) was applied to the March stock size to produce the estimated March-December catch of 247,533 MT. The total catch for 1975 included 741.6×10^6 fish at age 1, 764.2×10^6 fish at age 2, $2,281.9 \times 10^6$ fish at age 3, 137.8×10^6 fish at age 4, and 193.5×10^6 fish at ages 5 and older for total of $2,119.0 \times 10^6$ fish.

The revised estimate of the 1975 catch includes 482.9×10^6 more fish than calculated by the Working Group at the Mid-Term Meeting (Table 8). The catch of young fish was greater in the revised estimate, with a 189% increase in numbers at age 1 and a 12% increase in numbers at age 2. The catch of age 3 and older fish was less in the revised estimate due to a greater portion of the TAC accounted for by age 1 and 2 fish.

The fishing mortality in 1975 at each age was determined from the equation: $C_n = N_n \frac{F}{Z} (1 - e^{-Z})$ where C_n is the catch in numbers in 1975 and N_n is the year-class size in numbers at the beginning of 1975. The results indicated a mean F (weighted by year-class size) for ages 4 and older (fully-recruited ages) of 0.55 (Table 7). This is less than the F of 0.7 calculated by the Working Group. However, the F's at ages 3, 2, and 1 of 0.513, 0.401, and 0.415, respectively, indicated much greater fishing mortality on the

younger ages than was previously assumed. The F's at ages 1 and 2 assumed by the Working Group were 0.126 and 0.350, respectively. The partial recruitment coefficients in 1975 resulting from the present analysis are 93% at age 3, 73% at age 2, and 75% at age 1 (Table 7). These are all greater than the coefficients of 90%, 50%, and 18% assumed for ages 3, 2, and 1, respectively, by the Working Group.

TAC for 1976

The stock size at the beginning of 1976 was calculated in the present assessment to be $3,323.1 \times 10^6$ fish or 744.8×10^3 MT of age 2 and older. Assuming the 1975 year-class at age 1 to be $2,500.0 \times 10^6$ fish, the stock size at age 1 and older was calculated to be $5,823.1 \times 10^6$ fish or 942.3×10^3 MT (Table 7). This is a smaller stock size than the $6,135.8 \times 10^6$ fish or 971.0×10^3 MT calculated by the Working Group (Table 8). The greatest difference between the present stock size and that calculated by the Working Group is that the 1974 year-class at age 2 and, to a lesser extent, the 1973 year-class at age 3 are smaller due to the catches of age 1 and 2 fish in 1975 which were greater than previously assumed.

Four hypotheses concerning the partial recruitment pattern in 1976 were considered in calculating possible catches for 1976 (Table 9). The first hypothesis was that accepted by the Working Group which assumed 18% recruitment at age 1, 57% at age 2, and 96% at age 3. The second hypothesis was the recruitment pattern indicated by the revised catches and F's at age in 1975 which assumed 75% recruitment at age 1, 73% at age 2, and 93% at age 3. The third and fourth hypotheses were options of the first two

hypotheses which assumed that age 1 fish would not be caught as the result of a recommended 25 cm total length minimum size limit.

Depending on the management objective desired, whether it be a particular level of F in 1976 or a particular stock size in 1977, the 1976 catch would vary considerably. The TAC of 310,000 MT recommended by the Assessments Subcommittee would generate an F of 0.6, which is very near the level of fishing mortality providing maximum yield per recruit. An F of 0.6 would produce a catch of 282,000 MT under the first hypothesis concerning partial recruitment and 335,000 MT under the second hypothesis (Table 9). However, both of these catches would result in a 1977 stock size smaller than that assumed by the Working Group. In order to keep the 1977 stock at the level of about 710×10^3 MT assumed by the Working Group which provided maximum recruitment during the past 10 years, adjusting for environmental variations, the 1976 catch would have to be about 250,000 MT (F of about 0.51) under the first hypothesis and about 237,000 MT (F of about 0.39) under the second hypothesis. If the management objective is to maintain the same stock size in 1977 as in 1976, then a catch of 220,000 MT (F = 0.44) should be taken in 1976 under the first hypothesis and 208,000 MT (F = 0.335) under the second hypothesis.

Assuming the exclusion of age 1 fish from the catch, an F of 0.6 would produce a catch of 265,000 MT under hypothesis 1a and 272,000 MT under hypothesis 2a. To maintain the 1977 stock size at 710×10^3 MT, the catch would need to be about 258,000 MT under hypothesis 1a and 255,000 MT under hypothesis 2a. To maintain the same stock size in 1977 as in 1976, a catch of 225,000 MT under hypothesis 1a and 224,000 MT under hypothesis 2a should be taken.

Discussion

The revised estimate of the age composition of the 1975 catch based on reported monthly catches and the reported size composition of those catches differs significantly from the estimated age composition assumed in the Working Group's assessment. The present estimate indicates much greater numbers of age 1 and 2 fish. These estimates of the catch of younger fish, though higher than previously estimated, may still be lower than actual if the catches for which size composition data are presently unavailable are, in fact, similar to those for which such information was known. The absence of fish older than age 3 in the known size compositions may indicate very low abundance of these fish. This, in fact, appears to be the case as indicated by 1975 spring survey catches by research vessels from FRG, GDR, Poland and USA (Working Paper No. 60). The estimates of fishing mortality in 1974 on age 3 and older fish may have been greatly underestimated if the catches from those year-classes in 1974 reduced their size to very low abundance. In view of the absence of older fish in the January-February 1975 commercial samples as well as in the survey catches, the large catches of age 1 and 2 fish would appear to suggest that only young fish are currently present in commercially-abundant quantities. There does not appear to be sufficient information to justify the hypothesis that the 1973 and 1974 year-classes are much greater in size than previously assumed.

The partial recruitment pattern indicated by the revised catch and fishing mortality estimates for 1975 shows quite clearly a shift in the fishing pattern from older fish in past years to very young fish at the present time. The coefficients for 1975 provide strong evidence of heavy fishing mortality at ages 1 and 2 with the result of nearly full recruitment to the fishery at those ages.

The revised estimate of the stock size at the beginning of 1976 is about 3% smaller by weight than that determined by the Working Group at the 1975 Mid-Term Meeting. Of greater significance is the fact that the 1973 and 1974 year-classes are smaller than previously assumed due to the large removals in 1975. If the presently-recommended TAC of 310,000 MT is taken in 1976, then the 1977 stock size will be much smaller than determined earlier. If 310,000 MT is taken under hypothesis 1 concerning partial recruitment (*i.e.*, 18% at age 1, 57% at age 2, and 96% at age 3), the 1977 stock will be about 10% smaller than assumed by the Working Group. Under hypothesis 2 (*i.e.*, 75% at age 1, 73% at age 2, and 93% at age 3), the 1977 stock will be 12% less than assumed before.

The partial recruitment pattern accepted by the Working Group as applicable to the 1976 fishery (hypothesis 1) appears now to be inaccurate, especially at age 1. Under hypothesis 2 which assumed a higher percentage of fishing mortality at ages 1 and 2, the catch at a given F would be much greater than under hypothesis 1. However, the resulting 1977 stock size would accordingly be much smaller. It would seem advisable, therefore, to

recommend a TAC based more on the resulting 1977 stock size than on a particular level of F in 1976. A meaningful management objective would be to regulate the 1976 catch so as to maintain the spawning stock (age 2+) in 1977 at the 1976 level of about 745×10^3 MT which is also close to the level which has provided maximum recruitment in past years (ICNAF Res. Doc. 75/33). Under such a management regime, the recommended 1976 TAC would vary from 220,000 MT (hypothesis 1) to 208,000 MT (hypothesis 2). Under the recommended provision of excluding age 1 fish from the catch, the TAC would be about 225,000 MT assuming either hypothesis concerning partial recruitment.

Table 1. Mackerel catch (MT) in 1974 from SA 3-6.

Country	SA3	SA4	SA5-6	Total
Bulgaria	---	---	20,723	20,723
Canada	1,845	14,790	---	16,635
FRG	---	383	386	769
GDR	---	---	59,976	59,976
Italy	---	---	420	420
Japan	---	---	67	67
Poland	---	1	96,103	96,104
Romania	---	---	6,967	6,967
USSR	---	27,461	118,140	145,601
USA	---	---	993	993
Total	1,845	42,635	303,775	348,255

Table 2. Catch of mackerel in numbers from SA3-6 and fishing mortalities (F) and stock sizes in numbers calculated from virtual population analysis.

Year	Year-class										F
	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	
	<u>Catch (x10⁶)</u>										
1968	0.1	8.3	1.3	9.2	14.3	15.3	57.4	99.0	94.5	2.2	
1969	0.9	13.3	3.1	6.3	6.8	7.8	26.1	99.9	189.9	139.5	3.2
1970		12.9	19.3	21.7	14.1	15.2	43.6	190.2	408.9	34.7	143.0
1971		4.6	5.1	9.8	11.1	14.1	48.6	234.7	566.2	110.7	288.7
1972		3.8	0.2	9.4	13.5	8.6	37.2	114.2	432.7	226.5	287.7
1973		0.3	0.1	1.4	4.9	7.4	15.3	41.6	217.1	182.9	261.3
1974			0.1	0.5	0.8	2.0	8.5	26.8	120.2	120.2	121.7
1968	.037	.116	.024	.077	.099	.091	.102	.049	.015	.001	.001
1969	.600	.308	.083	.077	.069	.068	.068	.071	.041	.053	.057
1970		.632	1.213	.460	.222	.204	.172	.209	.130	.018	.174
1971		.554	1.785	.440	.306	.332	.331	.485	.299	.083	.295
1972		1.636	.317	1.215	.864	.392	.517	.528	.443	.271	.542
1973		.600	.290	.660	1.106	.802	.472	.419	.473	.413	.600
1974			.600	.600	.600	.600	.600	.600	.600	.600	.600
	<u>Stock (x10⁶)</u>										
1968	3.2	87.3	62.6	143.1	175.8	202.5	685.3	2385.4	7457.8	4317.3	3984.5
1969	2.3	57.6	45.3	98.2	118.0	136.9	458.6	1682.5	5445.4	3144.7	2972.0
1970		31.4	30.9	67.3	81.6	94.8	317.4	1161.1	3871.9	2210.3	2079.3
1971		12.3	6.8	31.5	48.4	57.2	197.9	698.0	2519.0	1608.4	1293.9
1972		5.3	0.8	15.0	26.4	30.4	105.3	318.2	1384.2	1096.9	713.7
1973		0.8	0.5	3.3	8.3	15.2	46.5	139.1	658.5	619.7	307.6
1974			0.3	1.3	2.0	5.1	21.5	67.7	303.8	303.8	125.1
1975			0.1	0.5	0.8	2.1	8.7	27.5	123.5	123.5	

¹50% of the 1967 year-class.

²Median of 1967-1972 year-classes.

³F required to catch 105.5x10⁶ fish from stock of 3700.0x10⁶ fish.

Table 3. Mackerel catch (MT) in 1975 from SA 3-6.

Country	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total	TAC
Bulgaria	5,737	3,794	4,435	←	←	←	←	4,784	←	←	←	←	18,750	18,750
Canada	---	---	---	←	←	←	←	46,500	←	←	←	←	46,500	46,500
FRG	---	---	---	←	←	←	←	1,400	←	←	←	←	1,400	1,400
GDR	6,945	13,790	8,585	←	←	←	←	26,930	←	←	←	←	56,250	56,250
Italy	---	10	---	←	←	←	←	---	←	←	←	←	10	---
Poland	18,554	8,944	7,659	←	←	←	←	54,843	←	←	←	←	90,000	90,000
Romania	---	---	---	←	←	←	←	3,750	←	←	←	←	3,750	3,750
Spain	1	19	14	←	←	←	←	---	←	←	←	←	34	---
USSR	23,768	25,823	33,334	←	←	←	←	40,325	←	←	←	←	123,250	123,250
USA	37	45	107	←	←	←	←	5,511	←	←	←	←	5,700	5,700
Others	---	---	---	←	←	←	←	9,356	←	←	←	←	9,356	9,400
Total	55,042	52,425	54,134	←	←	←	←	193,399	←	←	←	←	355,000	355,000

Table 4. Mackerel age-length key from *Albatross IV*, *Wieczno*, and *Walther Herwig* 1975 spring surveys in SA 5-6.

Total length (cm)	Number at age										Total
	1	2	3	4	5	6	7	8	9	10+	
17	25	1	--	--	--	--	--	--	--	--	26
18	58	--	--	--	--	--	--	--	--	--	58
19	33	--	--	--	--	--	--	--	--	--	33
20	20	--	--	--	--	--	--	--	--	--	20
21	18	--	--	--	--	--	--	--	--	--	18
22	12	--	--	--	--	--	--	--	--	--	12
23	16	--	--	--	--	--	--	--	--	--	16
24	6	--	--	--	--	--	--	--	--	--	6
25	5	3	--	--	--	--	--	--	--	--	8
26	--	16	--	--	--	--	--	--	--	--	16
27	--	32	1	--	--	--	--	--	--	--	33
28	--	26	--	--	--	--	--	--	--	--	26
29	--	13	--	--	--	--	--	--	--	--	13
30	--	10	--	--	--	--	--	--	--	--	10
31	--	2	8	1	--	--	--	--	--	--	11
32	--	2	7	--	--	--	--	--	--	--	9
33	--	--	12	5	--	--	--	--	--	--	17
34	--	--	7	4	--	--	--	--	--	--	11
35	--	1	2	4	1	--	--	--	--	--	8
36	--	--	--	4	--	--	1	--	--	--	5
37	--	--	--	3	2	5	1	1	--	--	12
38	--	--	--	--	3	1	2	2	--	--	8
39	--	--	--	--	--	3	1	2	--	--	6
40	--	--	--	--	1	1	--	--	1	--	3
41	--	--	--	--	--	--	--	--	1	--	1
42	--	--	--	--	--	--	--	--	--	1	1
Total	193	106	37	21	7	10	5	5	2	1	387

Table 5. Estimated age composition of mackerel catches in SA 3-6 by Bulgaria, Poland, and USSR in January-February 1975.

Month	Country	Age composition of catch											
		Percentage			Numbers (x10 ⁶)			MT					
		1	2	3	Total	1	2	3	Total	1	2	3	Total
January	Bulgaria	59.00	37.50	3.50	100.00	32.0	20.3	1.9	54.2	2,243	3,034	460	5,737
	Poland	66.25	33.75	-----	100.00	127.2	64.8	---	192.0	8,901	9,653	---	18,554
	USSR	66.55	31.55	1.90	100.00	161.1	76.4	4.6	242.1	11,276	11,379	1,113	23,768
	Total	---	---	-----	---	320.3	161.5	6.5	488.3	22,420	24,066	1,573	48,059
February	Poland	82.80	17.20	-----	100.00	88.6	18.4	---	107.0	6,202	2,742	---	8,944
	USSR	66.55	31.55	1.90	100.00	175.0	83.0	5.0	263.0	12,251	12,363	1,209	25,823
	Total	---	---	-----	---	263.6	101.4	5.0	370.0	18,453	15,105	1,209	34,767

Table 6. Mean weights (kg) at age of mackerel used in the assessment of the SA 3-6 stock.

Age	Mean weight (kg)
1	.079
2	.145
3	.221
4	.291
5	.359
6	.420
7	.469
8	.511
9	.547
10+	.576

Table 7. Mackerel catch in SA 3-6 in January, February, and March-December 1975, stock size at beginning of January, February, and March 1975 and January 1976, F in 1975 as determined from 1975 catch and stock size, and partial recruitment pattern in 1975 as indicated by fishing mortality at age.

Year	Month	Year-class												
		1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
1975	Jan.	0.1	0.5	0.8	2.1	8.7	27.5	123.5	123.5	125.1	109.9	371.7	802.6	2649.4
	Feb.	0.1	0.5	0.8	2.0	8.4	26.6	119.3	119.3	120.8	106.2	359.0	769.5	2409.9
	Mar.	0.1	0.5	0.7	1.9	8.0	25.2	113.3	113.3	114.8	100.9	341.1	728.0	2218.5
1976	Jan.		0.2	0.3	0.9	3.7	11.6	52.1	52.1	52.8	46.3	156.7	352.7	1327.2
1975	Jan.													
	Bul, Pol. USSR					0.1	0.3	1.2	1.2	1.2	1.0	3.5	6.5	161.5
	Others					0.1	0.3	1.2	1.2	1.2	1.0	3.5	6.9	12.7
	Total					0.2	0.7	2.4	2.4	2.4	2.0	7.0	13.4	174.2
1975	Feb.													
	Pol, USSR				0.1	0.2	0.7	3.0	3.1	3.1	2.7	9.2	17.7	101.4
	Others				0.1	0.2	0.7	3.0	3.1	3.1	2.7	9.2	17.7	31.0
	Total				0.2	0.7	1.4	6.0	6.2	6.2	5.4	18.4	35.4	132.4
1975	Mar.-Dec.		0.2	0.3	0.7	2.9	9.2	41.6	41.6	42.1	37.0	125.1	245.8	457.6
	Total		0.2	0.3	0.8	3.2	10.2	45.8	45.9	46.4	40.7	137.8	281.9	764.2
1975			.610	.559	.570	.545	.551	.550	.552	.551	.550	.551	.513	.401
1975		100	100	100	100	100	100	100	100	100	100	100	93	73
			<u>F</u>											
			<u>Partial recruitment coefficient</u>											

Table 8. Comparison of the 1975 mackerel catch and 1976 stock size from SA 3-6 in numbers ($\times 10^6$) at age determined by the Mackerel Working Group (ICNAF Summ. Doc. 75/18) and the present assessment.

Age	1975 catch		1976 stock	
	Mackerel Working Group	Present assessment	Mackerel Working Group	Present assessment
1	256.5	741.6	2,500.0	2,500.0
2	680.5	764.2	1,632.8	1,266.5
3	317.6	281.9	1,380.3	1,327.2
4	158.7	137.8	305.5	352.7
5	47.0	40.7	131.9	156.7
6	53.3	46.4	39.1	46.3
7	52.7	45.9	44.3	52.8
8	52.8	45.8	43.9	52.1
9	11.8	10.2	43.9	52.1
10	3.7	3.2	9.8	11.6
11	0.9	0.8	3.1	3.7
12	0.4	0.3	0.8	0.9
13	0.2	0.2	0.3	0.3
14	---	---	0.1	0.2
Total ($\times 10^6$)	1,636.1	2,119.0	6,135.8	5,823.1
Weight ($\times 10^3$ MT)	355.1	355.0	971.0	942.3

Table 9. Mackerel catch and stock biomass in SA 3-6 for a range of F's with M = 0.30 under different hypotheses concerning the partial recruitment pattern.

Hypothesis	% recruitment to fishery by age			
	1	2	3	4+
1	18	57	96	100
1a	0	57	96	100
2	75	73	93	100
2a	0	73	93	100

F	Z	1976 Catch-Age 1+		1977 Stock-Age 2+		1976 Catch-Age 1+		1977 Stock-Age 2+	
		No. (x10 ⁶)	MT (x10 ³)	No. (x10 ⁶)	MT (x10 ³)	No. (x10 ⁶)	MT (x10 ³)	No. (x10 ⁶)	MT (x10 ³)
.05	.35	134.7	29.2	4198.3	958.2	115.3	27.7	4214.9	960.6
.10	.40	264.6	57.2	4087.3	926.8	226.0	54.1	4120.3	931.6
.15	.45	389.9	84.0	3980.4	896.6	332.3	79.5	4029.7	903.8
.20	.50	510.7	109.8	3877.5	867.7	434.3	103.8	3942.9	877.2
.25	.55	627.4	134.6	3788.3	840.0	532.2	127.0	3859.8	851.8
.30	.60	739.9	158.3	3682.8	813.4	626.3	149.3	3780.2	827.5
.35	.65	848.6	181.1	3590.8	787.9	716.6	170.7	3703.9	804.2
.40	.70	953.6	203.0	3502.2	763.4	803.3	191.2	3630.8	782.0
.45	.75	1055.0	224.1	3416.7	739.9	886.6	210.8	3560.8	760.8
.50	.80	1153.0	244.3	3334.3	717.3	966.6	229.6	3493.7	740.4
.55	.85	1247.6	263.7	3254.8	695.7	1043.6	247.6	3429.3	721.0
.60	.90	1339.2	282.4	3178.1	674.9	1117.5	264.9	3367.7	702.4
.65	.95	1427.7	300.3	3104.1	654.9	1188.5	281.4	3308.6	684.6
.70	1.00	1513.3	317.6	3032.7	635.7	1256.8	297.3	3252.0	667.5
.75	1.05	1596.1	334.2	2963.8	617.3	1322.4	312.5	3197.7	651.2
.80	1.10	1676.2	350.1	2897.2	599.6	1385.5	327.1	3145.6	635.6
.85	1.15	1753.8	365.5	2832.9	582.6	1446.2	341.2	3095.7	620.7
.90	1.20	1828.9	380.2	2770.8	566.2	1504.5	354.6	3047.8	606.4
.95	1.25	1901.6	394.4	2710.8	550.5	1560.7	367.5	3001.9	592.7
1.00	1.30	1972.1	408.1	2652.8	535.4	1614.7	379.9	2957.8	579.6

Hypothesis 1

Hypothesis 1a

TABLE 9 (continued)

Hypothesis 2		Hypothesis 2a						
.05	201.8	34.8	4140.9	949.5	122.2	28.5	4209.1	959.4
.10	395.7	68.2	3975.1	909.8	239.4	55.8	4108.9	929.2
.15	582.2	100.2	3816.1	871.8	351.7	82.0	4013.1	900.4
.20	761.5	130.9	3663.5	835.4	459.5	107.0	3921.5	872.8
.25	933.9	160.3	3517.1	800.5	562.9	131.0	3833.7	846.4
.30	1099.6	188.5	3376.6	767.1	662.0	153.9	3749.8	821.2
.35	1259.1	215.6	3241.9	735.2	757.2	175.9	3669.5	797.2
.40	1412.4	241.5	3112.6	704.5	848.4	197.0	3592.6	774.1
.45	1559.9	266.4	2988.5	675.2	936.0	217.1	3519.0	752.1
.50	1701.7	290.3	2869.5	647.1	1020.0	236.5	3448.6	731.1
.55	1838.2	313.2	2755.2	620.2	1100.7	255.0	3381.2	711.0
.60	1969.5	335.2	2645.6	594.5	1178.0	272.7	3316.7	691.8
.65	2095.8	356.4	2540.4	569.8	1252.3	289.7	3255.0	673.4
.70	2217.3	376.6	2439.5	546.2	1323.6	306.0	3195.9	655.9
.75	2334.3	396.1	2342.6	523.6	1392.1	321.6	3139.4	639.1
.80	2446.8	414.7	2249.6	501.9	1457.8	336.6	3085.2	623.0
.85	2555.1	432.6	2160.4	481.1	1520.9	350.9	3033.4	607.7
.90	2659.4	449.8	2074.7	461.2	1581.5	364.7	2983.8	593.0
.95	2759.7	466.4	1992.5	442.2	1639.6	377.9	2936.3	579.0
1.00	2856.3	482.2	1913.7	423.9	1695.5	390.5	2890.9	565.6

Appendix

The revised age composition of the 1975 catch and the resulting F values determined from that catch and the 1975 stock size suggests high partial recruitment coefficients at ages 1-3 (hypothesis 2). In order for the previously-accepted partial recruitment coefficients of 18%, 50%, and 90% at ages 1, 2 and 3, respectively, to be applicable to the 1975 catch, the earlier estimates of the strength of the 1973 and 1974 year-classes would necessarily have to be greatly increased.

This possibility was examined by the following procedure. Fishing mortality in 1975 at ages 1-3 was determined assuming partial recruitment coefficients of 18%, 50%, and 90% at ages 1, 2, and 3, respectively, and $F = 0.551$ at ages 4 and older. The resulting F's at ages 1, 2, and 3 were 0.099, 0.276, and 0.496, respectively. These values were applied to the catch in numbers at the respective ages, using the equation: $C = N \frac{F}{Z}(1 - e^{-Z})$, to determine the size of each of the year-classes at the beginning of 1975. The results are given in Appendix Table 1. According to this procedure, the size of the 1974 year-class at age 1 would need to be $9,084.5 \times 10^6$ fish instead of $2,500.0 \times 10^6$, or 3.6 times larger. Also, the 1973 year-class at age 2 would be $3,642.4 \times 10^6$ instead of $2,649.4 \times 10^6$, or 1.4 times larger. Assuming that the F of 0.034 calculated in 1974 for the 1973 year-class at age 1 was correct, then the 1973 year-class at age 1 would have been $5,086.8 \times 10^6$, or 68% of the 1967 year-class instead of 50% as presently assumed. The total stock size at the beginning of 1975 would have been $14,444.5 \times 10^6$ fish, nearly 30% larger than the previous high of $11,203.0 \times 10^6$ in 1968 and twice as large as that calculated in the present

Appendix Table 1. Comparison of the 1975 mackerel stock size in SA 3-6 in numbers ($\times 10^6$) at age determined by two methods: (1) assuming that partial recruitment coefficients of 18%, 50%, and 90% at ages 1, 2, and 3, respectively, and an F of 0.551 for fully-recruited ages (4+) were applicable to the revised 1975 catch and (2) as presented in the present assessment.

Age	Method 1	Method 2
1	9,084.5	2,500.0
2	3,642.4	2,649.4
3	824.2	802.6
4	371.7	371.7
5	109.9	109.9
6	125.1	125.1
7	123.5	123.5
8	123.5	123.5
9	27.5	27.5
10	8.7	8.7
11	2.1	2.1
12	0.8	0.8
13	0.5	0.5
14	0.1	0.1
Total ($\times 10^6$)	14,444.5	6,845.4
Weight ($\times 10^3$ MT)	1,771.2	1,103.0

assessment. The stock weight would be $1,771.2 \times 10^3$ MT as compared to $1,103.0 \times 10^3$ MT determined by the present analysis.

Spring survey catch/tow values in recent years (ICNAF Res. Doc. 75/15 and Working Paper No. 60) have declined substantially as have commercial catch/effort indices indicating that stock abundance has declined instead of increasing. Furthermore, *ALBATROSS IV* spring survey catches, in terms of actual numbers of mackerel, have not indicated any strong incoming year-classes as was the case with the 1967 year-class when very large catches of that year-class were taken in the 1968 spring survey (ICNAF Res. Doc. 73/14).

Available evidence, therefore, suggests that the 1973 and 1974 year-classes are not stronger than previously assumed and that fishing mortality is, indeed, currently very heavy on age 1 and 2 mackerel.