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The effect of a combined assessment for mackerel in ICNAF Subareas 3, 4, and 5, and Statistical Area 6

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ABSTRACT

The migration patterns, including spawning, of the proposed two mackerel contingents in ICNAF Subareas 3, 4, and 5 and Statistical Area 6 were reviewed. Commercial landings from SA 3-6 were summarized showing an increase from 6,831 MT in 1961 to 419,306 MT in 1973. Analysis of the pattern and magnitude of monthly commercial catches from Division 6C to SA 3 offered insight into the question regarding the proportion of mackerel migrating from overwintering grounds in SA 5-6 to SA 3-4 and the contribution of the northern contingent to SA 5-6 landings. In order to perform a combined assessment of SA 3-6 mackerel, numbers of fish landed at age from SA 3-4 in 1968-1973 were estimated. An assessment of the SA 3-6 mackerel population was performed utilizing the same methods and assumptions previously agreed to and employed for SA 5-6 mackerel. Results indicated that an increase in fishing mortality from the 1973 level would be necessary to take the TAC's set separately for SA 5-6 and SA 3-4 for 1974 and 1975 resulting in a continued decrease in stock size. Predictions for the 1976 SA 3-6 catch ranged from 345,000 MT to 277,000 MT depending if F was maintained at the estimated 1975 level or reduced back to the 1973 level. Results showed that the TAC's set separately for SA 5-6 and SA 3-4 greatly exceed the suggested TAC for the combined SA 3-6 stock.

INTRODUCTION

Commercial landings of Atlantic mackerel (*Scomber scombrus*) from ICNAF Subareas 3, 4, and 5 and Statistical Area 6 increased from 6,831 MT in 1961 to 419,306 MT in 1973 (Table 1). Although landings from both SA 3-4 and SA 5-6 increased during this period as the result of improved stock abundance and developing distant water fleet fisheries, the bulk of the increase occurred in the southern area (Figure 1). Data suggest that SA 3-4 mackerel are either a migrating component of the SA 5-6 mackerel or, if they do comprise a separate stock, their distribution and the fisheries on the two stocks overlap in SA 5-6 during part of the year. Concern has been expressed relative to this problem and the possible consequences of setting separate TAC's for SA 3-4 and SA 5-6 (ICNAF, 1974a, 1974b). STACRES, therefore, recommended at the 1974 Annual Meeting that an overall assessment for mackerel in SA 3-6 be carried out for the 1975 Annual Meeting.

Nationally-allocated total allowable catches (TAC's) were established for mackerel by ICNAF at 450,000 MT, 304,000 MT, and 285,000 MT for 1973, 1974, and 1975, respectively, in SA 5-6; 55,000 MT for 1974 in Division 4VWX; and 70,000 MT for 1975 in SA 3-4. The 1973 TAC for SA 5-6 was not based on a firm assessment of maximum sustainable yield (MSY) but was set to limit the rapidly developing distant water fleet fisheries until an adequate assessment could be completed. The 1974 and 1975 TAC's for SA 5-6 were, however, established from scientific advice to stabilize fishing mortality at the 1973 level, which was near the point of maximum yield per recruit (ICNAF, 1974a, 1974b). The 1974 TAC for Divisions 4VWX was set at a level to permit a reasonable but limited expansion of that fishery and the 1975 SA 3-4 TAC was established to stabilize the fishery at the 1974 expected level of catch because of possible relationships with the SA 5-6 stock. Data were not available to assess the status of the fisheries for use in recommending either of the SA 3-4 TAC's.

Earlier work by Sette (1950) indicated that the mackerel in the Northwest Atlantic consist of a northern and southern contingent, one spawning in the Gulf of St. Lawrence and the other spawning south of Cape Cod, both overwintering offshore between Sable Island and Cape Hatteras. Sette concluded that during a brief period in both the spring and fall the two contingents are mixed in the Southern New England waters. Recent tagging experiments (Beckett *et al.*, 1974; Moores *et al.*, 1974; Parsons and Moores, 1974) have confirmed that some fish present in SA 3-4 in the summer and fall migrate as far south as Division 6A.

Recent assessments for mackerel in SA 5-6 have been based on stock analyses utilizing estimates of numbers of fish landed at age and current levels of fishing mortality derived from commercial catch-per-effort statistics. Comparable data for SA 3-4 have not been available to facilitate such analyses for that portion of the overall population. The purpose of this paper is to review the available information concerning stock migrations and historical landings, present estimates of numbers of fish landed at age from SA 3-4, and provide a combined assessment for SA 3-6 using these new data together with the data available and assumptions made at the 1974 Annual Meeting.

STOCK MIGRATIONS AND SPAWNING AREAS

Various authors (MacKay, 1967, 1973; Anderson, 1973; Paciorkowski *et al.*, 1973; Beckett *et al.*, 1974; Moores *et al.*, 1974; Stobo and Hunt, 1974) have reviewed and discussed Sette's (1950) hypothesis advocating the existence of northern and southern contingents of the overall mackerel population in the Northwest Atlantic which undergo a northerly migration in the spring and summer and a southerly migration in the fall and which overwinter in deep, offshore waters within a broad area extending from Sable Island (Division 4W) to Cape Hatteras (Division 6C). Sette's work was based on analyses of commercial length samples and substantiated by tagging results. The more recent studies all accepted Sette's conclusions.

Several aspects of the following migration pattern proposed by Sette (1950) for the northern contingent merit consideration in relation to the question of mixing in SA 5-6. This contingent moves inshore in late May, following the overwintering period in deep water, along a broad area from Hudson Canyon to Sable Island. The western portion of the northern contingent comes inshore off Southern New England (Divisions 6A, 5Zw) where it mixes only for several weeks with the southern contingent before continuing to the northeast; the middle portion moves inshore off Southern Nova Scotia (Division 4X); and the eastern portion moves shoreward in the Sable Island area (Division 4W). The approximate reverse of this movement occurs in the fall. The southern contingent, which in the summer moves only as far north as the Gulf of Maine, migrates back to the southwest in October followed by all or a portion of the northern contingent which passes through the Gulf of Maine in November and December. The bulk of the northern contingent moves through the Gulf of Maine and past Cape Cod in late fall enroute to its overwintering grounds offshore from Georges Bank to Hudson Canyon. Mackerel prefer temperatures above 8°C but are frequently tolerant of temperatures down to 7°C (Sette, 1950). Suitable water temperatures along the edge of the Scotian Shelf (Sette, 1950; Moores *et al.*, 1974) coupled with the fact that mackerel have been caught on the Scotian banks in the winter, indicate that the overwintering grounds possibly extend as far to the northeast as Sable Island. Even though it is uncertain how much of the northern contingent overwinters in SA 5-6, whatever portion does move that far south is vulnerable to the SA 5-6 fishery from November to the following May or June or 7-8 months of the year.

The movement of mackerel from as far north as Division 3K south to Division 6A has been confirmed by recent tagging experiments. Parsons and Moores (1974) reported the recapture in Division 6A in December 1972 of a mackerel tagged in Division 3K in September 1972. Moores *et al.* (1974) reported two recaptures in Division 6A in January 1974 of fish tagged in Division 3K in September 1973. Beckett *et al.* (1974) indicated 6 recaptures during November 1973 - March 1974 in Division 5Z and Division 6A of fish tagged in Division 4X in October 1973, and a single recapture in Division 6A in January 1974 of a mackerel tagged in Division 4T in October 1973. Although these results document the migration of mackerel from SA 3-4 into SA 5-6 in the fall and the presence of some northern contingent fish in SA 5-6 catches, data are presently lacking to quantify what proportion of the SA 5-6 catch is comprised of northern fish. No tagging experiments have been designed to estimate the proportion of mackerel overwintering in SA 5-6 that actually migrate to SA 3-4 in the spring and summer.

Sette (1943) reported that spawning takes place over most of the spring and summer range from Cape Hatteras to Newfoundland. He concluded from estimates of egg abundance derived from plankton tows that the most important spawning area is located between Cape Cod and Cape Hatteras followed by the southern half of the Gulf of St. Lawrence with only about 10% as much spawning. Additional, but probably negligible, amounts of spawning occur in the

Gulf of Maine (except for Cape Cod Bay where eggs were only slightly less abundant than south of Cape Cod), along the Scotian Shelf, in the northern part of the Gulf of St. Lawrence, and in waters around Newfoundland. Various other investigations have shown the distribution and abundance of mackerel eggs and larvae to be generally similar to that concluded by Sette (Bigelow, 1917; Dannevig, 1919; Colton and St. Onge, 1974; Berrien, 1975). MacKay (1973), using Arnold's (1970) data on mackerel egg distribution and abundance in the Gulf of St. Lawrence, estimated the size of the northern spawning stock (age 2+) to be between 900,000 and 1,700,000 MT in 1968. This estimate is greater than the 675,000 MT calculated as the size of the 1968 SA 5-6 age 2+ stock (from data used by the *ad hoc* Mackerel Working Group at the 1974 Annual Meeting). Although mackerel eggs have been collected from ichthyoplankton sampling conducted during numerous surveys throughout SA 5-6, egg abundance data or other types of useful data have not as yet been processed to permit an estimate of the size of the southern contingent spawning stock for comparison with MacKay's estimate of the northern contingent. Therefore, any legitimate comparison of the size of the two contingents is impossible at the present time.

HISTORICAL LANDINGS

Commercial landings of mackerel from the Northwest Atlantic have increased sharply in recent years (Table 1, Figure 1). Anderson (1975) reviewed SA 5-6 landings, Stobo and Hunt (1974) described the SA 4 fishery, and Moores *et al.* (1974) briefly discussed the SA 3 fishery. Thirteen nations reported landings from the SA 3-6 area since 1961. Total landings increased from 6,831 MT in 1961 to 419,306 MT in 1973, with most of the increase coming from SA 5-6.

The SA 3 fishery has been conducted primarily by Canada with small landings reported in 1961-1966 and 1972-1973 by France and in 1968-1970 by several other nations including USSR, Poland, and GDR. Total landings varied from 54 MT in 1967 to 2,503 MT in 1973 and averaged only 780 MT during 1961-1973.

SA 4 landings have increased steadily from 4,449 MT in 1961 to 35,639 MT in 1973. Landings averaged 5,600 MT in 1961-1963, 11,400 MT in 1964-1967, and 20,500 MT in 1968-1972. Prior to 1968, the fishery was virtually all Canadian as USSR catches, which began in 1963, varied from only 11 MT to 1,234 MT. USSR landings increased from 62 MT in 1967 to 16,766 MT in 1973. Since 1968, seven distant water fleets have caught mackerel in SA 4. The sharp rise in landings from 1972 to 1973 resulted primarily from improved USSR and, to a lesser extent, Canadian catches.

The greatest increase in catches occurred in SA 5 rising from 933 MT in 1962 to 315,296 MT in 1973. Catches in SA 6 climbed from 116 MT in 1962 to 232,304 MT in 1972 but then dropped sharply to 65,868 MT in 1973.

The SA 3-4 fishery contributed the majority of the landings (76.3%) from the total area during 1961-1966. As SA 5-6 catches increased, mackerel catches from SA 3-4 averaged only 7.6% annually in 1970-1973.

A monthly breakdown of mackerel landings from SA 3-6 during 1968-1973 is provided in Table 2. These data reflect the annual fishing pattern as influenced by the migration pattern of the population. This pattern is vividly illustrated in Figure 2. The general pattern of landings indicates the summer-fall fishery in SA 3-4 contrasted to the predominantly winter-spring fishery in SA 5-6. A small US inshore summer fishery exists in Division 5Y. The distribution of catches by month and area generally remained constant during 1968-1973 although some deviations did occur.

Catches have usually been heaviest in Division 6ABC during January-April while the fish were overwintering and concentrated in deep, offshore waters. Catches virtually cease in SA 6 after May as the mackerel migrate northeasterly and do not occur again in comparable size until December when the fish reappear. The spring migration is easily followed by the rise and fall of monthly landings from Division 6C to Subdivision 5Ze and then northward through SA 4 into SA 3. Landings in January-April from Division 6C to Subdivision 5Ze and even as far north as Division 4W and Division 4V in some years support the belief that the entire area from Cape Hatteras to Sable Island constitutes potential overwintering grounds. The southwesterly fall migration out of the Gulf of St. Lawrence (Division 4RST) and Newfoundland waters (SA 3) is illustrated by the declining catches in those areas and the subsequent increases in Division 4V, 4W, and other areas to the southwest.

Data from Table 2 indicate a general northeasterly shift after 1969 of spring catches in SA 5-6. Catches in Division 6C gradually diminished after 1969 but increased in Division 6B and 6A; Division 6B landings decreased after 1971 with further increases in Division 6A; and Division 6A landings ultimately declined after 1972. Catches in both Subdivisions 5Zw and 5Ze underwent increases while SA 6 decreased. This northeasterly shift in landings within SA 5-6 has obviously reflected changes in the location of the fishing fleets, but it is likely that the fleets followed the fish. These changes may depict an actual relocation of the overwintering grounds brought about by modified environmental conditions, possibly including water temperatures, to the north and east of where the major overwintering grounds were previously determined to be. US spring survey mackerel catches have also evidenced a northeasterly shift in recent years.

Moores *et al.* (1974), on the basis of similarities in growth and year-class composition, migration patterns supported by tagging evidence, and the pattern of landings by area, suggested that the northern contingent of the population contributes to the bulk of the catches in SA 5-6 and that, accordingly, the southern contingent is small or underexploited. Examination of the monthly landings in SA 5 (Table 2, Figure 2) indicates that even though catches peak in May and then decrease sharply suggesting a possible movement into SA 4, catches in SA 5 remain at a substantial level throughout the summer totaling considerably more than the SA 3-4 landings. Therefore, a sizable portion of the population necessarily remains in SA 5 in order to support the summer landings. There is no doubt that some proportion of the overwintering population in SA 5-6 does migrate to SA 3-4. However, since landings have been reported during winter and spring months from SA 4, some proportion of the northern contingent apparently overwinters along the Scotian Shelf. The decline in catches in SA 5 after May could result merely from reduced availability of fish to the fishing fleets caused by dispersal of schools following spawning or by movement to coastal areas. Sette (1950) reported that the southern contingent summered primarily in coastal areas in the Gulf of Maine (Division 5Y). If the population remained in dense schools during the summer in Division 5Z where they would be available to the distant water fleets, this fact would be expected to be reflected by continued high landings. On the other hand, if most of the schools continued migrating into SA 4 it seems logical that the distant water fleets would follow and that substantial catches would be taken in Division 4X, then Division 4W, and so on. However, the latter has not been the case. This suggests that the mackerel concentrations in SA 4 have not been sufficient to support catches larger than what have historically been taken or that other factors have prevented the fleets from following the schools out of SA 5. An additional consideration concerns the distant water fleet mackerel fishery in SA 4, which has been conducted primarily by the USSR. USSR landings have been taken mainly from Division 4W during most months of the year with only small catches in Division 4X. Even though mackerel may constitute a by-catch of the large USSR silver hake fishery in Division 4W, landings from that area during nearly all months of the year and the general lack of significant catches in Division 4X prior to May suggests that the fishery may be supported to a large extent by fish overwintering in SA 4 waters. If the SA 4 fishery was supported primarily by fish migrating up from SA 5-6, one would expect the pattern of large spring catches in SA 5-6 to continue in Division 4X.

Until such time as tagging or other studies provide estimates of the magnitude of the migration from SA 5-6 to SA 3-4, one can only surmise based on the pattern of landings. Irrespective of this uncertainty, it is apparent from presently-available evidence that both population contingents contribute to SA 5-6 landings and that catches in one area may ultimately exercise some degree of influence upon the stock in the other area. This being so, a combined assessment of the stocks in the entire SA 3-6 area appears necessary.

AGE COMPOSITION OF LANDINGS

Age compositions of the SA 5-6 international landings for 1968-1973, which have been accepted and utilized in past assessments by the *ad hoc* Mackerel Working Group (ICNAF, 1974a, 1974b), were initially prepared by scientists from Bulgaria, GDR, Poland, and USSR using sampling data from their respective fisheries (ICNAF, 1974c, 1975). These results were initially presented at the 1973 Annual Meeting by Paciorkowski *et al.* (1973), with a subsequent modification taking into account revised catch totals (Paciorkowski, Working Paper No. 5, January 1974 Special Meeting). Numbers landed at age in SA 5-6, corrected for more recent reported landings for 1973, are presented in Table 3.

Commercial age composition data are available for SA 3-4 catches only from samples by Canada. Stobo and Hunt (1974) presented preliminary estimates of the numbers landed at age in the 1973 Canadian fishery in Division 4T, 4VW, and 4X. Moores *et al.* (1974) provided graphical illustrations of the age composition of Canadian catches in SA 3 waters in 1970-1973. MacKay (1973) reported 1965-1972 Canadian age compositions for certain months and areas, but only in graphical form. Tabular age composition data were kindly supplied by the authors of the latter two papers for use in place of the graphical data to facilitate estimation of numbers landed at age.

Canadian mackerel catches are taken primarily from inshore waters by purse seines, gill nets, traps, and weirs (Stobo and Hunt, 1974) which are generally size-selective gears. The distant water fleet catches, however, are from farther offshore by non-selective small-mesh otter trawls. It seems likely that Canadian and distant water fleet catch age compositions are not necessarily similar. Therefore, it was decided that Canadian age compositions should be applied only to Canadian landings. No length or age data are presently available from distant water fleet catches in SA 3-4. It was assumed that the distant water fleet landings from Division 5Z were similar in length and age composition to the distant water fleet landings from SA 3-4. Therefore, USSR length frequencies and age-length keys from Division 5Z (or SA 6 if 5Z data were lacking) for 1968-1973 (ICNAF, 1974c, 1975) were applied to the distant water fleet landings in SA 3-4 on a monthly basis. Mean weights accompanying the length data were used to convert landed weight to numbers landed.

Numbers landed at age by Canada from SA 4 in 1973 were determined by correcting the preliminary estimates submitted by Stobo and Hunt (1974) to include final catch figures. The 1968-1972 numbers at age from Canadian landings from SA 4 were determined from data supplied by MacKay (personal communication). These data included percentage age compositions, mean lengths at age (mainly for June) for the 1959 and 1967 year-classes and for all other year-classes combined, and length-weight equations. MacKay (1967) indicated that 1959 produced a dominate year-class and that the 1960 year-class was probably poor. However, difficulties occurred in differentiating between the ages of the slow-growing 1959 year-class and the 1960 year-class in later years. Therefore, the age compositions supplied by MacKay for the present analysis were combined for the 1959 and 1960 year-classes and designated as belonging to the 1960+ year-class. MacKay's data were available only from May-June and July-August in 1968, 1970, and 1971 and from May-June in 1969 and 1972 and from Divisions 4X, 4Vn, and 4T. Consequently, May-June data were applied to total Canadian SA 4 landings in May-June (there were no landings prior to May in any year) and July-August data were applied to July-December for 1968, 1970, and 1971; May-June data were applied to May-December landings for 1969 and 1972. First, a mean length was assigned to each age represented in the percentage age compositions. Secondly, mean weight for each age was calculated using the provided length-weight equations. Lastly, a weighted (by the percentage at each age) mean weight was determined which was then used to convert the weight of the landings to numbers landed. The given percentages at age were then applied to the total number landed to obtain numbers landed at age.

The number landed at age from SA 3 by Canada and France (St. Pierre et Miquelon) in 1970-1973 were estimated from data from the Canadian fishery provided by Winters (personal communication). These data included percentage age compositions and mean weight for certain months Landed weight was converted to numbers landed using the mean weight; the given percentages were applied to that total to estimate numbers landed at age. Numbers landed at age for months lacking age data were determined using data from the nearest adjacent month. Estimates for 1968-1969, for which SA 3 age data were not available, were obtained by prorating the overall annual numbers at age determined for Canadian SA 4 landings.

The combined SA 3-4 estimated numbers landed at age for 1968-1973 are presented in Table 3.

ASSESSMENT

An assessment of the SA 3-6 mackerel stock was performed utilizing the same methodology and assumptions pertaining to the recruitment pattern, mortality, and estimates of year-class strength as agreed to and employed by the *ad hoc* Mackerel Working Group at the 1974 Annual Meeting in its assessment of SA 5-6 mackerel (ICNAF, 1974b). The assumptions included partial recruitment of 25% at age 1, 50% at age 2, 90% at age 3, and 100% at ages 4 and older; a total mortality rate (Z) of 0.9 in 1973 with M = 0.3; and, concerning the strength of incoming year-classes at age 1, the 1972 year-class equal to the 1971 year-class and the 1973, 1974, and 1975 year-classes equal to 1.6 times the 1972 (or 1971) year-class.

A virtual population analysis was performed using numbers landed at age from SA 3-6 in 1968-1973. Calculated instantaneous fishing mortality rates (F) by age and calendar year for each year-class are given in Table 4. Annual fishing mortality on fully-recruited ages was determined by weighing F at ages 4 and older by the calculated stock sizes at age. The results indicate that mean annual F increased from 0.08 in 1968 to 0.48 in 1972 (F = 0.60 was assumed for 1973).

Results of the overall assessment are presented in Table 5. Following calculation of stock sizes by the virtual population analysis and having assumed both F in 1973 and the size of the 1972-1975 year-classes at age 1, the stock size at the beginning of 1974 was determined as 1,070,000 MT. The catch in 1974 was estimated to be 374,000 MT which assumed complete removal of the SA 5-6 TAC of 304,000 MT and the Division 4VWX TAC of 55,000 MT plus an additional 15,000 MT estimated to be taken from Division 4RST and SA 3 (ICNAF, 1974b). The fishing mortality required to take the estimated 1974 catch was calculated to be 0.725 with the resulting stock size at the beginning of 1975 being 1,008,000 MT. Assuming that the 1975 catch will equal 355,000 MT (the SA 5-6 TAC of 285,000 MT plus the SA 3-4 TAC of 70,000

MT), an F of 0.817 will be required to generate that catch, leaving a stock size at the beginning of 1976 of 989,000 MT. The stock sizes at the beginning of 1975 and 1976 and the fishing mortality necessary in 1975 to take the estimated catch are highly dependent on the size of the 1974 and 1975 year-classes at age 1, actual estimates of which are not available

The estimated catch in 1976 and the stock size at the beginning of 1977 were calculated assuming various levels of fishing mortality (Table 6). The 1976 year-class at age 1 was assumed to be the same as the 1973-1975 year-classes. If fishing mortality in 1976 is retained at the estimated 1975 level of 0.817, the 1976 catch will be 345,000 MT, a reductio of 10,000 MT from the 1975 combined TAC's, leaving a 1977 stock size of 987,000 MT, which is nearly the same as estimated for the beginning of 1976. If fishing mortality in 1976 is reduced to the 1974 level of 0.725, the 1976 catch will be 317,000 MT, a 38,000 MT decrease from the 1975 TAC's, and the 1977 stock size will be 1,020,000 MT. If the 1976 fishing mortality is reduced to the assumed 1973 level of 0.60, the catch will be 277,000 MT, 78,000 MT less than in 1975 and the 1977 stock size will be 1,067,000 MT, which is equal to the 1974 stock size. In order to increase the stock size in 1977 to the 1973 level of 1,221,000 MT, the catch in 1976 will need to be reduced to 144,000 MT with an F of 0.25.

The results of the SA 5-6 assessment conducted at the 1974 Annual Meeting indicated that the 1974 TAC of 304,000 MT would be obtained at F = 0.60, the same level as estimated for 1973, and that the 1975 catch would be 285,000 MT if F is maintained at 0.60. This catch was proposed by ICNAF as the 1975 TAC and implies agreement not to increase F beyond the 1973 level. The combined assessment of SA 3-6 stocks indicates, however, that an increase in F to 0.725 would be necessary to take the 1974 catch of 374,000 MT including set TAC's for two areas plus the estimated catch from the unregulated portion of SA 3-4. An additional increase in F to 0.817 was determined as the level necessary to take the TAC's set for 1975 totaling 355,000 MT. Therefore, the objective of not increasing F beyond the 1973 level cannot be achieved by the 1974 and 1975 TAC's. If F had been maintained at the 1973 level of 0.60 in 1974, the catch would have been 327,000 MT, 47,000 MT less than the estimated catch of 374,000 MT. A 1975 catch of 304,000 MT would result if F was maintained at 0.60, constituting a 51,000 MT decrease form the combined TAC's already set. The 1976 catch, assuming F = 0.60, would be 316,000 MT with a 1977 stock size of 1,128,000 MT.

Assuming that the catch in 1975 equals the TAC's now set and the assumptions of incoming year-class strength and fishing mortality in 1973 and 1974 are reasonably correct, then predictions for the 1976 catch range from 345,000 MT if F is maintained at the presumed 1975 level to 277,000 MT if F is reduced back to the 1973 level. Under the first option the stock size would continue to diminish in 1977 but under the other option the reduced catch would initiate an increase in stock size. Even though the estimated level of F in 1975 of 0.817 is less than F_{max} (0.9) (ICNAF, 1974b), it far exceeds $F_{0.1}$ (0.3) and if maintained in the absence of continued strong recruitment would insure future low levels of stock size and catch. The results also indicate that the TAC's set separately for SA 5-6 and SA 3-4 for 1974 and 1975 greatly exceed the suggested TAC for the combined SA 3-6 stock.

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Table 1. Mackerel landings (MT) from Subareas 3,4, and 5 and Statistical Area 6 in 1961-1973.

Year	Bulgaria	Canada	Cuba	FRG	France	GDR	Italy	Japan	Poland	Romania	Spain	USSR	US	Other	Total
								Subarea 3							
1961	-	1,010	-	-	11	-	-	-	-	-	-	-	-	-	1,021
1962	-	586	-	-	64	-	-	-	-	-	-	-	-	-	650
1963	-	274	-	-	99	-	-	-	-	-	-	-	-	-	373
1964	-	819	-	-	27	-	-	-	-	-	-	-	-	-	846
1965	-	184	-	-	3	-	-	-	-	-	-	-	-	-	187
1966	-	83	-	-	10	-	-	-	-	-	-	-	-	-	93
1967	-	54	-	-	-	-	-	-	-	-	-	-	-	-	54
1968	-	186	-	-	-	-	-	-	42	-	-	142	-	-	370
1969	-	311	-	-	-	6	-	-	-	-	-	-	-	2	319
1970	-	837	-	-	-	-	-	-	-	-	-	5	-	-	842
1971	-	1,299	-	-	-	-	-	-	-	-	-	-	-	-	1,299
1972	-	1,554	-	-	25	-	-	-	-	-	-	-	-	-	1,579
1973	-	2,339	-	-	164	-	-	-	-	-	-	-	-	-	2,503
								Subarea 4							
1961	-	4,449	-	-	-	-	-	-	-	-	-	-	-	-	4,449
1962	-	6,215	-	-	-	-	-	-	-	-	-	-	-	-	6,215
1963	-	6,089	-	-	-	-	-	-	-	-	-	11	-	-	6,100
1964	-	9,967	-	-	-	-	-	-	-	-	-	147	-	-	10,114
1965	-	11,001	-	-	-	-	-	-	-	-	-	402	-	-	11,403
1966	-	11,494	-	-	-	-	-	-	-	-	-	1,234	-	-	12,728
1967	-	11,127	-	-	-	-	-	-	-	-	-	62	-	-	11,189
1968	-	10,932	-	-	-	-	-	19	98	-	-	9,419	-	-	20,468
1969	-	12,946	-	2	-	1,265	-	1	27	-	-	4,075	-	-	18,316
1970	-	14,853	-	208	-	1,047	-	-	49	-	-	3,987	-	-	20,144
1971	-	13,436	-	32	-	10	-	-	2	18	-	9,492	-	-	22,990
1972	-	14,699	37	-	-	31	-	-	245	-	-	5,769	-	-	20,781
1973	-	18,885	-	-	-	-	-	18	-	-	-	16,766	-	-	35,639
								Subarea 5							
1961	-	-	-	-	-	-	-	-	-	-	-	-	1,027	-	1,027
1962	-	-	-	-	-	-	-	-	111	-	-	-	822	-	933
1963	-	-	-	-	-	-	-	-	-	-	-	896	1,202	-	2,098
1964	-	-	-	-	-	-	-	-	-	-	-	533	1,264	- -	1,797
1965	-	-	-	-	-	-	-	-	1	-	-	2,475	1,467	11	3,954
1966	-	-	-	-	-	-	-	-	6	3	-	5,446	1,903	-	7,358
1967	-	-	-	90	-	48	-	1	507	138	-	11,907	3,216	-	15,907
1968	-	-	-	119	-	3,184	-	1	10,160	283	-	33,961	3,001	68	50,777
1969	1,966	-	-	99	-	2,021	-	197	13,421	151	-	47,547	3,873	253	69,528
1970	1,949	-	-	1,009	-	2,920	-	463	40,987	758	-	56,457	3,092	-	107,635
1971	1,632	-	145	1,175	-	7,090	-	272	43,682	1,774	3	59,014	1,593	-	116,440
1972	7,452	1	9	757	-	25,372	-	209	61,486	515	6	103,686	1,025	-	200,518
1973	24,369	53	-	1,260	-	54,874	-	150	100,729	905	-	132,335	621	-	315,296
								Statistical Area 6							
1961	-	-	-	-	-	-	-	-	-	-	-	-	334	-	334
1962	-	-	-	-	-	-	-	-	-	-	-	-	116	-	116
1963	-	-	-	-	-	-	-	-	-	-	-	293	118	-	411
1964	-	-	-	-	-	-	-	-	-	-	-	94	380	-	474
1965	-	-	-	-	-	-	-	-	-	-	-	53	531	-	584
1966	-	-	-	-	-	-	-	-	-	-	-	1,252	821	-	2,073
1967	-	-	-	-	-	163	-	45	-	-	-	6,087	675	-	6,970
1968	-	16	-	2	-	158	-	311	448	-	-	7,333	928	-	9,196
1969	117	-	-	-	-	193	-	326	4,977	-	-	37,563	491	-	43,667
1970	2,058	-	-	45	-	2,711	-	1,037	27,153	-	-	68,026	957	-	101,987
1971	26,875	-	-	1,620	-	62,083	-	753	68,612	2747	47	68,754	813	-	232,304
1972	16,104	-	-	13	-	55,165	800	895	80,513	2004	-	30,371	981	-	186,846
1973	7,374	-	-	267	-	21,884	375	296	16,525	4971	-	13,461	715	-	65,668
								Total							
1961	-	5,459	-	-	11	-	-	-	-	-	-	-	1,361	-	6,831
1962	-	6,801	-	-	64	-	-	-	111	-	-	-	938	-	7,914
1963	-	6,363	-	-	99	-	-	-	-	-	-	1,200	1,320	-	8,982
1964	-	10,786	-	-	27	-	-	-	-	-	-	774	1,644	-	12,231
1965	-	11,185	-	-	3	-	-	-	1	-	-	2,930	1,998	11	16,128
1966	-	11,577	-	-	10	-	-	-	6	3	-	7,932	2,724	-	22,252
1967	-	11,181	-	90	-	211	-	46	507	138	-	18,056	3,891	-	34,120
1968	-	11,134	-	121	-	3,342	-	331	10,748	283	-	50,855	3,929	68	80,811
1969	2,083	13,257	-	101	-	3,485	-	524	18,425	151	-	89,185	4,364	255	131,830
1970	4,007	15,690	-	1,262	-	6,678	-	1,500	68,189	758	-	128,475	4,049	-	230,608
1971	28,507	14,735	145	2,827	-	69,183	-	1,025	112,296	4,539	50	137,320	2,406	-	373,033
1972	23,556	16,254	46	770	25	80,568	800	1,104	142,244	2,519	6	139,826	2,006	-	409,724
1973	31,743	21,247	-	1,527	164	76,758	375	464	117,254	5,876	-	162,562	1,336	-	419,306

Table 2. Mackerel landings (MT) by area and month from Subareas 3, 4, and 5 and Statistical Area 6 for 1968-1973.

Year	Month	3	4RST	4Vn	4Vs	4W	4X	5Y	5Ze	5Zw	5NK	6A	6B	6C	6D	6NK	Total
1968	Jan	-	-	-	-	-	-	-	55	81	-	-	-	-	-	-	
	Feb	-	-	-	-	-	-	-	129	129	-	54	7	-	-	239	
	Mar	-	-	-	-	-	-	-	470	522	-	223	3	-	-	162	
	Apr	-	-	-	-	-	-	-	4714	688	-	146	7	-	-	4216	
	May	-	2	43	-	121	263	83	5171	5339	-	18	150	-	-	2160	
	Jun	-	772	774	-	690	939	463	2031	8604	-	-	-	-	-	82	
	Jul'	27	1981	191	2	108	332	698	2013	151	-	-	-	-	-	36	
	Aug.	106	828	8	11	134	213	155	5428	191	-	-	-	-	-	-	
	Sep	46	1025	144		64	286	53	2172	132	-	7	-	-	-	-	
	Oct	168	506	492	29	937	336	87	2155	225	-	-	-	-	-	281	
	Nov	23	-	113	-	2508	511	68	2705	3714	-	-	-	-	-	-	
	Dec	-	43	-	-	5995	48	59	10	1373	-	-	-	-	-	157	
	NK	-	-	-	-	-	19	641	68		-	327	-	-	-	921	
	Total	370	5157	1765	42	10557	2947	2307	27121	21349	-	775	167	-	-	8254	80811
1969	Jan	-	-	-	46	143	-	-	-	135	-	202	22	202	-	-	
	Feb	-	-	-	-	121	-	-	-	106	-	24	676	2204	-	-	
	Mar	-	-	-	1	121	-	-	4	47	-	347	2461	21604	-	-	
	Apr	-	-	-	24	56	1	-	191	2323	-	2693	5626	2746	-	-	
	May	-	5	12	-	619	837	1057	1788	5261	-	2075	776	-	-	-	
	Jun	-	568	749	-	1120	1646	873	2142	5990	-	-	132	-	-	-	
	Jul	16	1490	110	-	584	933	310	4744	3585	-	1	-	-	-	-	
	Aug	75	729	14	-	565	447	199	5293	3538	-	-	-	-	-	-	
	Sep	156	439	184	2	1568	458	218	4467	1083	-	14	-	-	-	-	
	Oct	24	433	927	93	343	283	49	5225	2444	-	-	-	-	-	-	
	Nov	39	108	88	23	1139	333	40	2002	9780	-	797	-	-	-	-	
	Dec	7	-	1	1	-	51	29	570	4897	-	212	39	-	-	-	
	NK	2	-	-	-	-	1	688	253	-	197	-	-	-	-	814	
	Total	319	3772	2085	1090	6379	4990	3463	26679	39189	197	5365	9732	26756	-	814	131830
1970	Jan	-	-	-	-	5	-	4	3746	102	-	158	1445	2597	-	-	
	Feb	-	-	-	90	-	-	-	4651	-	-	21	3953	12914	-	-	
	Mar	-	-	-	7	10	-	-	3278	393	-	4792	16843	7354	-	-	
	Apr	-	-	-	244	1067	-	-	2547	5211	-	13148	20767	209	-	-	
	May	3	-	8	107	553	353	515	10383	12413	-	6814	1574	-	-	-	
	Jun	3	983	1247	-	1013	612	443	6956	5480	-	402	-	-	-	-	
	Jul	54	1381	158	-	986	663	564	5654	1280	-	-	-	-	-	-	
	Aug	337	1273	13	-	473	1775	347	7190	335	-	1	-	-	-	-	
	Sep	324	1451	180	36	621	1229	153	4730	47	-	1	-	-	-	-	
	Oct	96	619	673	-	230	247	139	2462	1546	-	16	-	-	-	-	
	Nov	25	181	467	13	448	464	390	6476	5295	-	139	151	-	-	-	
	Dec	-	-	13	-	218	33	692	8317	4943	-	6701	-	-	-	-	
	NK	-	-	-	-	-		490	165	298	-	502	488	47	-	950	
	Total	842	5888	2759	497	5624	5376	3737	66555	37343	-	32695	45221	23121	-	950	230608
1971	Jan	-	-	32	-	-	-	170	165	214	-	14113	15880	6225	-	-	
	Feb	-	-	-	-	135	-	-	37	226	-	3696	22532	983	-	-	
	Mar	-	-	-	6	449	-	-	158	73	35	9030	45550	6325	-	-	
	Apr	-	-	-	-	45	-	-	8626	3183	2945	14075	27297	296	-	-	
	May	-	8	19	25	604	628	10	11058	7207	2330	8927	4983	100	-	792	
	Jun	1	942	834	12	1513	1409	67	7478	2307	410	577	62	-	-	1449	
	Jul	152	2860	86	5	1642	992	554	4785	1223	1195	3	-	-	-	-	
	Aug	412	944	29	-	2288	704	477	5486	434	1250	1	-	-	-	-	
	Sep	380	752	255	11	702	515	103	5923	682	367	-	-	-	-	-	
	Oct	324	513	538	12	1071	220	16	2257	1291	137	797	-	-	-	-	
	Nov	29	35	118	92	1625	198	97	10294	8379	253	3792	-	-	-	-	
	Dec	1	-	4	-	85	33	242	8211	13500	2248	43917	102	-	-	-	
	NK	-	-	-	-	-	-	192	145		-	2	-	-	-	798	
	Total	1299	6054	1915	163	10159	4699	1928	64623	38719	11170	98930	116406	13929	-	3039	373033
1972	Jan	-	-	-	-	243	-	9	7250	19675	-	49466	1838	4	-	-	
	Feb	-	-	-	-	9	-	405	3353	2508	-	29265	10521	794	-	-	
	Mar	-	-	-	-	-	-	424	5644	9173	-	41789	3992	465	-	-	
	Apr	-	-	-	-	61	24	497	7643	3385	-	18347	14373	371	-	-	
	May	-	7	19	-	2036	549	607	26634	5103	-	8132	1296	3	-	-	
	Jun	3	573	536	31	844	731	250	14437	9937	-	640	-	-	-	-	
	Jul	48	4495	111	4	913	760	288	11928	2109	-	250	-	5	-	-	
	Aug	515	1586	194	15	384	889	493	8102	1101	-	-	-	2	-	-	
	Sep	655	769	518	3	137	660	59	3354	316	-	-	-	-	-	-	
	Oct	343	295	614	11	1145	341	95	5048	1019	-	41	-	-	-	-	
	Nov	15	11	48	-	788	329	822	11614	4212	-	94	-	-	-	-	
	Dec	-	-	34	-	-	27	8	28855	4152	-	3181	4	-	212	-	
	NK	-	-	-	-	22	15	-	2	7	-	-	-	-		1761	
	Total	1579	7736	2074	64	6582	4325	3957	133864	62697	-	151205	32024	1644	212	1761	409724
1973	Jan	-	-	-	-	-	-	-	1985	35264	-	10048	989	97	-	90	
	Feb	-	-	-	-	-	-	-	14270	51801	-	2310	465	84	-	100	
	Mar	-	-	-	-	19	-	-	9512	23357	-	10587	1639	47	-	75	
	Apr	-	-	-	-	228	275	56	14541	13836	-	5207	13941	53	-	-	
	May	-	1	16	-	3920	645	44	41288	2753	-	1908	1338	-	-	-	
	Jun	5	751	512	80	7124	806	120	16783	3610	-	73	-	-	-	-	
	Jul	319	4160	1305	215	1269	531	92	10152	1028	-	-	-	-	-	-	
	Aug	509	2861	291	166	2269	729	52	5311	71	-	67	-	-	-	-	
	Sep	803	1754	447	148	241	1484	32	2778	119	-	2	-	-	-	-	
	Oct	665	391	1254	46	400	772	38	8545	30	-	5	-	-	-	-	
	Nov	202	14	71	-	239	129	181	23841	7725	-	-	-	3	-	55	
	Dec	-	4	-	-	43	29	242	6000	19839	-	14662	1282	-	-	55	
	NK	-	-	-	-	-	-	-		-	-	-	-	-	-	686	
	Total	2503	9936	3896	655	15752	5400	847	155006	159433	-	44869	19654	284	-	1061	419306

F 10

Table 3. Estimated number (millions) of mackerel landed during 1968-1973 from each year-class from Subareas 3-4 and Subarea 5 - Statistical Area 6.

Year	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	Total
							Year-class									
							SA 3-4									
1968	-	7.9	0.5	4.9	5.1	5.3	7.3	7.6	30.4	0.1	-	-	-	-	-	69.1
1969	-	11.6	0.5	1.3	1.1	1.3	5.2	13.6	10.9	0.1	0.4	-	-	-	-	46.0
1970	-	3.5	0.4	1.1	1.0	0.6	2.0	7.7	42.4	4.4	5.3	0.2	-	-	-	68.6
1971	-	4.6	0.3	0.7	0.4	0.4	3.1	6.9	35.6	6.5	10.7	0.8	-	-	-	70.0
1972	-	3.8	0.2	0.5	0.4	0.1	4.4	4.8	23.8	7.9	8.3	1.7	0.2	0.1	-	56.2
1973	-	0.3	0.1	0.2	0.5	0.5	1.7	5.5	22.9	18.4	17.6	14.5	14.4	6.8	0.3	103.7
							SA 5-6									
1968	0.1	0.4	0.8	4.3	9.2	10.0	50.1	91.4	64.1	2.1	-	-	-	-	-	232.5
1969	0.9	1.7	2.6	5.0	5.7	6.5	20.9	86.3	179.0	139.4	2.8	-	-	-	-	450.8
1970	-	9.4	18.9	20.6	13.1	14.6	41.6	182.5	366.5	30.3	137.7	3.0	-	-	-	838.2
1971	-	-	4.8	9.1	10.7	13.7	45.5	227.8	530.6	104.2	278.0	100.4	1.1	-	-	1325.9
1972	-	-	-	8.9	13.1	8.5	32.8	109.4	408.9	218.6	279.4	74.6	41.6	10.9	-	1206.7
1973	-	-	-	1.2	4.2	6.8	13.3	34.9	195.7	168.0	249.7	214.4	341.3	89.4	-	1318.9

Table 4. Instantaneous fishing mortality rates (F) for SA 3-6 mackerel estimated from virtual population analysis.

Year	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	Weighted mean age 4+[1]
							Year-class								
1968	0.037	0.116	0.025	0.077	0.090	0.085	0.108	0.053	0.016	0.001	-	-	-	-	0.083
1969	0.600[2]	0.308	0.084	0.076	0.062	0.063	0.073	0.077	0.044	0.063	0.001	-	-	-	0.086
1970	-	0.632	1.256	0.455	0.197	0.187	0.186	0.229	0.140	0.022	0.059	0.002	-	-	0.252
1971	-	0.554	2.118	0.433	0.263	0.296	0.365	0.554	0.328	0.100	0.181	0.089	<0.001	-	0.377
1972	-	1.636	0.513	1.168	0.672	0.334	0.604	0.664	0.509	0.343	0.309	0.099	0.022	0.012	0.477
1973	-	0.600[2]	0.600[2]	0.600[2]	0.600[2]	0.600[2]	0.600[2]	0.600[2]	0.600[2]	0.600[2]	0.600[2]	0.540[3]	0.300[3]	0.150[3]	0.600[2]

[1] F at each age is weighted by the stock size in number.
[2] Assumed F at age of full recruitment in 1973.
[3] Assumed F adjusted for partial recruitment.

Table 5. Results of mackerel assessment for Subareas 3, 4, and 5 and Statistical Area 6.

Age	Mean weight (kg)	Partial recruitment %	Age composition of stock and catch (millions) 1968	1969	1970	1971	1972	1973	1974	1975	1976
						Stock					
0	-	-	3538.0	3860.1	1863.0	2894.3	1086.9	-	-	-	-
1	0.095	25	6979.4	2652.3	2878.1	1377.4	2176.3	2176.3[2]	3482.1[3]	3482.1[3]	3482.1
2	0.175	50	2217.4	5090.5	1845.6	2009.9	933.9	1576.7	1387.7	2152.0	2103.0
3	0.266	90	646.3	1557.9	3609.3	1337.1	1242.5	626.6	865.3	715.4	1059.6
4	0.350	100	217.0	429.7	1068.7	2324.4	895.9	675.6	270.5	333.8	254.1
5	0.432	100	192.4	147.7	296.0	629.6	1240.4	471.2	274.7	97.1	109.2
6	0.506	100	144.3	130.3	102.8	182.1	267.9	552.6	191.7	98.6	31.8
7	0.564	100	61.5	99.0	90.7	63.1	93.6	102.1	224.7	68.8	32.3
8	0.615	100	87.3	44.5	68.0	55.2	34.8	37.9	41.6	80.6	22.5
9	0.659	100	3.2	57.6	30.3	31.9	31.4	18.5	15.4	14.9	26.4
10	0.693	100	-	2.3	31.4	6.4	15.4	11.9	7.5	5.5	4.9
11+	0.693	100	-	-	-	12.3	5.9	4.6	6.6	2.7	1.8
Number[4]			10548.8	10211.8	10020.9	8029.4	6938.0	6254.0	6767.8	7051.5	7127.7
Weight (ooo MT)[5]			1279.5	1615.2	1846.1	1744.3	1481.7	1221.1	1069.5	1007.8	989.0
						Catch					
0			2.2	3.2	3.2	1.1	11.0	0.3	-	-	
1			94.5	139.5	143.0	101.2	41.8	96.2	501.0	558.6	
2			99.0	189.9	34.7	288.7	76.3	355.7	367.8	629.8	
3			57.4	99.9	408.9	110.7	287.7	228.9	364.1	327.7	
4			15.3	26.1	190.2	566.2	226.5	267.3	122.7	164.3	
5			14.3	7.8	43.6	234.7	432.7	186.4	124.6	47.8	
6			9.2	6.8	15.2	48.6	114.2	218.6	86.9	48.5	
7			1.3	6.3	14.1	14.1	37.2	40.4	101.9	33.8	
8			8.3	3.1	21.7	11.1	8.6	15.0	18.9	39.7	
9			0.1[1]	13.3	19.3	9.8	13.5	7.3	7.0	7.3	
10			-	0.9	12.9	5.1	9.4	4.7	3.4	2.7	
11+			-	-	-	4.6	4.0	1.8	3.0	1.3	
Number			301.6	496.8	906.8	1395.9	1262.9	1422.6	1701.3	1861.5	
Weight (000 MT)			80.8	131.8	230.6	373.0	409.7	419.3	374.0[6]	355.0	
Fishing mortality ages 4+			0.083	0.086	0.252	0.377	0.477	0.600	0.725	0.817	
TAC			-	-	-	-	-	450[7]	359[8]	355[9]	

1 Provisional values requiring correction on estimated catches as in ICNAF (1974a), Fig. 1, p. 34.
2 Assumed equal to the 1971 year-class.
3 Assumed equal to 1.6 times the 1971 year-class.
4 Age 1 and older.
5 Age 1 and older and adjusted as in ICNAF (1974a), Fig. 1, p. 34.
6 Includes TAC's for SA 5-6 (304) and Div. 4VWX (55) and 15 for remainder of SA 3-4.
7 SA 5-6 only.
8 Includes 304 for SA 5-6 and 55 for Div. 4VWX.
9 Includes 285 for SA 5-6 and 70 for SA 3-4.

Table 6. Catch in 1973, estimated catches in 1974-1976, and stock sizes in 1973-1977 of mackerel in Subareas 3, 4, and 5 and Statistical Area 6 given various levels of fishing mortality (F).

Fishing mortality (F)				Catch (000's MT)				Stock size (000's MT)				
1973	1974	1975	1976	1973	1974	1975	1976	1973	1974	1975	1976	1977
0.600[1]	0.725[2]	0.817[3]	0.817	419.3	374.0	355.0	344.6	1221.1	1069.5	1007.8	989.0	986.8
0.600	0.725	0.817	0.725	419.3	374.0	355.0	316.9	1221.1	1069.5	1007.8	989.0	1019.6
0.600	0.725	0.817	0.600	419.3	374.0	355.0	276.7	1221.1	1069.5	1007.8	989.0	1067.4
0.600	0.725	0.817	0.250	419.3	374.0	355.0	143.8	1221.1	1069.5	1007.8	989.0	1224.7
0.600	0.600	0.600	0.600	419.3	327.0	303.8	316.4	1221.1	1069.5	1059.8	1099.1	1128.4

1 F assumed for 1973.

2 F needed to take 1974 estimated catch.

3 F needed to take 1975 TAC's.

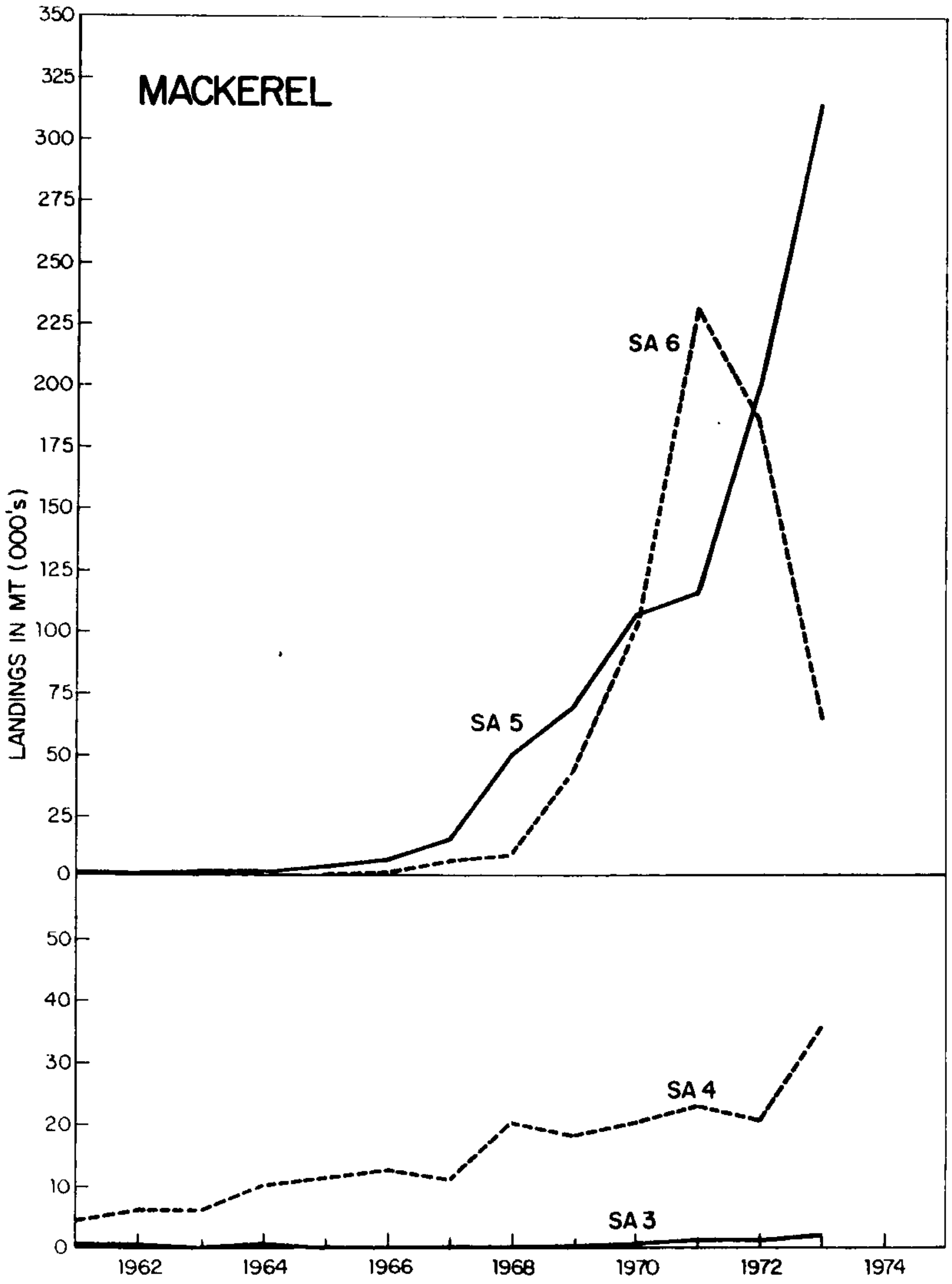
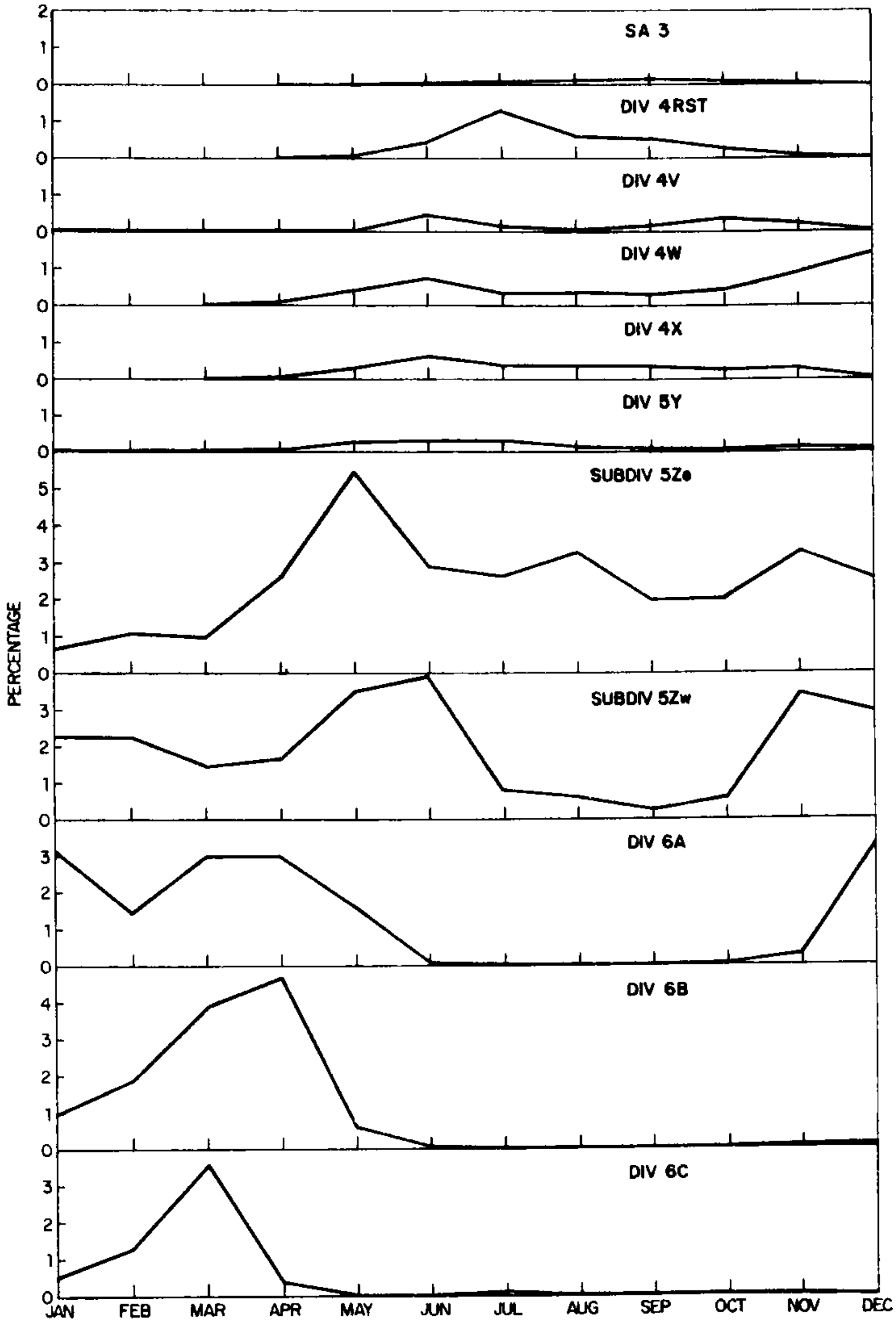


Fig. 1. International landings of mackerel from Subareas 3, 4, and 5, and Statistical Area 6, 1961-1973.

F 14



G 1

Fig. 2. Monthly pattern of mackerel landings from Subareas 3, 4, and 5, and Statistical Area 6, expressed for each month and Division or Subdivision as the percentage of the annual total SA 3-6