WOODS HOLE LABORATORY REFERENCE DOCUMENT NO. 82-44

STATUS OF THE NORTHWEST ATLANTIC MACKEREL STOCK - 1982

by

Emory D. Anderson

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

TABLE OF CONTENTS

SUMMARY

The international catch of Atlantic mackerel (Scomber scombrus) in the Northwest Atlantic increased from about 29,300 metric tons (tons) in 1980 to 31,600 tons in 1981. Canada and the US accounted for 61% and 22% of the 1981 total, respectively. The international catch in 1982 was estimated to be about 25,000 tons.

The 1974 year class was the predominant year class in the 1981 catch and comprised 21% of the total catch in numbers. The 1980, 1978, and 1975 year classes accounted for 17%, 14%, and 13%, respectively. Mean weights at age have increased substantially since the mid 1970's.

Catch per tow (kg) from NEFC bottom trawl surveys (spring and autumn) and catch per day (tons) from the US commercial fishery continue to reflect an increasing trend in mackerel stock biomass.

Natural mortality (M) was estimated to be 0.20 in the present assessment, instead of 0.30 as used previously, based on analysis of catch and effort data. Fishing mortality (F) was estimated to be 0.15 in 1981 compared to an average of 0.12 in 1978-80 and a high of 0.74 in 1976. A catch of 25,000 tons in 1982 would generate an F of about 0.11.

The 1975-81 year classes are all estimated to be below average in strength, with the 1980 year class appearing to be the strongest among these. The 1978 year class appears to be weaker than estimated in the 1981 assessment. The 1982 year class appears to be above average in strength based on results from the 1982 NEFC autumn survey. However, the autumn age 0 indices by themselves are insufficient to reliably predict year-class size, and furthermore, the 1982 index was felt to be biased upwards because of an unusually early southerly migration of mackerel which considerably increased their availability at the time of the autumn survey. The 1982 year class was, therefore, assumed to be equal to the median of the 1977-81 year classes.

Total stock biomass increased from a low of 323,000 tons in 1978 to a projected level of 561,000 tons in 1983. Spawning stock biomass improved from 288,000 tons in 1980 to an estimated 472,000 tons in 1983.

Yield-per-recruit calculations using M = 0.20 indicate an $F_{0.1}$ of 0.28 applicable to average long-term (1962-81) conditions in the fishery and an $F_{0.1}$ of 0.40 applicable to present conditions in the fishery.

Catch and stock biomass projections indicate that the catch in 1983 can be increased considerably above the level taken during 1978-82 (25,000-35,000 tons) without incurring a decrease in spawning stock biomass from 1983 to 1984. A minimum spawning stock biomass constraint of 360,000 tons (using an M of 0.20) is suggested as an equivalent to the 600,000-ton constraint (using an M of 0.30) currently in the pending management regulations prepared by the Mid-Atlantic Fishery Management Council. The further constraint that fishing mortality should not exceed $F_{0.1}$ = 0.40 would suggest a 1983 catch of about 104,000 tons.

INTRODUCTION

Atlantic mackerel (*Scomber scombrus*) in the Northwest Atlantic are distributed between Labrador and North Carolina. The population consists of two major spawning components, a southern group which spawns primarily in the Mid-Atlantic Bight during April-May and a northern group which spawns in the Gulf of St. Lawrence in June-July. Overwintering of both groups occurs in waters generally southward from Georges Bank along the continental shelf, with extensive northerly (spring) and southerly (autumn) migrations to and from spawning and summering grounds.

Mackerel are subjected to seasonal fisheries, both commercially and recreationally, throughout most of their distributional range. Catches from 1978 to the present have been fairly constant at about 30,000-35,000 metric tons (tons), taken largely by fishermen from Canada and the United States (US). The recent fishery is in sharp contrast to the intensive international fishery conducted during 1968-77 by vessels from as many as 13-14 nations when reported catches peaked at 430,400 tons in 1973. After being heavily fished in the 1970's and declining sharply in abundance, the mackerel resource has exhibited some recovery in the last several years.

Even though there are two spawning groups of mackerel in the Northwest Atlantic, biochemical (MacKay 1967) and meristic (MacKay and Garside 1969) studies have not established that genetic differences exist between them. Furthermore, the bulk of the catch during the intensive international fishery in the late 1960's and 1970's occurred during the winter and early spring while both groups were overwintering in US waters, thus making it impossible to assign catches to northern or southern groups. Since 1975, all mackerel in the Northwest Atlantic have been assessed as a unit stock.

This report assesses the current and projected status of mackerel in Subareas 2, 3, 4, 5, and 6 (SA 2-6) of the Northwest Atlantic Fisheries Organization (NAFO) (Figure 1). This assessment is based on catch, effort, and sampling data from fisheries conducted by the US, Canada, and other countries, and from Northeast Fisheries Center (NEFC) spring and autumn bottom trawl survey data. Data and analyses presented herein represent an update of the previous assessment (Anderson 1981). However, significant changes in estimates of fishing mortality rates and stock size determined from virtual population analysis occurred as a consequence of a new estimate of instantaneous natural mortality (M). Appropriate comparisons are provided between results obtained with the new estimate of M versus the previous estimate.

MANAGEMENT

Atlantic mackerel in the Northwest Atlantic were managed by means of nationally-allocated catch quotas from 1973 until 1977 by the International Commission for the Northwest Atlantic Fisheries (ICNAF). Following implementation of the Magnuson Fishery Conservation and Management Act (MFCMA) on 1 March 1977, mackerel in US waters were managed by the Preliminary Management Plan (PMP) for the Atlantic Mackerel Fishery of the Northwestern Atlantic until 21 February 1980. Optimum yield (OY) under the PMP was set at 88,000 tons in 1977 (19,000 tons for US harvest) and 15,500 tons in both 1978 and 1979 (14,300 tons for US harvest).

The Fishery Management Plan (FMP) for the Atlantic Mackerel Fishery of the Northwest Atlantic Ocean was developed by the Mid-Atlantic Fishery Management Council and implemented on 21 February 1980. The FMP specified an OY of 30,000 tons for a 1 April 1979 - 31 March 1980 fishing year, a domestic annual harvest (DAH) of 20,000 tons, a total allowable level of foreign fishing (TALFF) of 4,000 tons, and a reserve of 6,000 tons which can be allocated during the fishing year to the domestic fishery and/or the foreign fishery. Amendments #1 and #2 extended the FMP through the 1980-81 and 1981-82 fishing years and a Secretarial Amendment extended the FMP through the 1982-83 fishing year, with OY, DAH, TALFF, and the reserve all retained at the 1979-80 levels.

Since the implementation of the MFCMA, the domestic commercial and recreational fisheries have been unconstrained as actual catches have been considerably below the projected DAH for each calendar or fishing year.

All foreign fishing for mackerel has been regulated by the NOAA Foreign Fishing Regulations. Consequently, all activities, unless given special dispensation, have been confined to the foreign fishing areas (windows) and subject to national catch allocations and seasonal, area, gear, and by-catch restrictions.

Amendment #3 to the Fishery Management Plan for the Atlantic Mackerel, Squid, and Butterfish Fisheries, which merges the three separate FMPs for the above species and extends them for a 3-year period beyond the 1981-82 fishing year, will, when approved and implemented, establish mechanisms for determining annual OY, DAH, and TALFF. At present, Amendment #3 specifies two basic options based on a minimum spawning stock biomass constraint of 600,000 tons [assuming a natural mortality rate (M) of 0.30].

If spawning stock biomass for the year in question is less than or equal to 600,000 tons after discounting anticipated US and Canadian catches, TALFF will be no greater than 2% of the allocated silver hake TALFF plus 1% of the allocated TALFFs for red hake, Illex squid, and Loligo squid. DAH will equal actual US catch up to 30,000 tons minus TALFF, and OY will equal DAH plus TALFF but not exceed 30,000 tons.

If spawning stock biomass is greater than 600,000 tons after discounting anticipated US and Canadian catches, OY will equal the catch which, in conjunction with the anticipated Canadian catch, will reduce the spawning stock biomass to 600,000 tons at the beginning of the following year. A further constraint is that the total catch (OY and Canadian) not generate a fishing mortality rate in excess of $F_{0.1}$. TALFF will equal OY minus DAH (which will be no less than 30,000 tons), but will not be less than the TALFF derived under the first option. If the amount available for TALFF is greater than 10,000 tons, half will be assigned to TALFF and half placed in reserve for allocation later in the year to DAH and/or TALFF.

As indicated in the INTRODUCTION, a new estimate of natural mortality (M) is used in this assessment. Since the minimum spawning stock biomass constraint of 600,000 tons ceases to be applicable when an M other than 0.30 is used, an equivalent biomass value based on the new estimate of M is suggested in the DISCUSSION.

CATCH

Commercial

The international commercial catch in SA 2-6 increased from 25,385 tons in 1980 to 27,603 tons in 1981 (Table 1). Apart from 1980, the 1981 catch was the lowest since 1966 (22,252 tons) and was only 7% of the peak commercial catch taken in 1973 (419,714 tons).

The US commercial catch increased 10% from 2,683 tons in 1980 to 2,951 tons in 1981, the highest reported since 1970 (4,049 tons) (Table 1). The US catch has increased every year since 1977 (1,377 tons). About 67% of the 1981 catch was from SA 6, principally Div. 6B (between Delaware Bay and Chesapeake Bay), with the remainder from SA 5 (Table 2).

The Canadian catch decreased from 22,136 tons in 1980 to 19,284 tons in 1981, continuing a decline from the record high of 30,244 tons in 1979 (Table 1). About 64% of the total Canadian catch in 1981 was from SA 4, 35% from SA 3, and the balance from SA 5 (26 tons) and SA 2 (1 ton) (Table 2).

Catches by countries other than the US and Canada increased sharply from 566 tons in 1980 to 5,368 tons in 1981 (Table 1). The 1981 catch was the highest since 1977 (56,067 tons), but only 1.4% of the peak of 396,759 tons reported in 1973. Of the 5,368 tons taken in 1981, 96% (5,163 tons) came from SA 6, 3% (144 tons) from SA 5, and 1% (61 tons) from SA 4. A total of seven countries (other than the US and Canada) accounted for this total in 1981, with 74% (3,979 tons) taken by Poland and 19% (1,039 tons) by Italy.

International commercial catches in 1982 are estimated to total about 21,000 - 22,000 tons based on projections of available statistics. The US catch is estimated to be about the same as in 1981 or about 3,000 tons. The Canadian catch is estimated at about 12,000 - 13,000 tons, a considerable drop from the 19,284 tons reported for 1981. Most of the Canadian decrease is in the Newfoundland area, where availability of mackerel has been markedly less than in previous years. It is possible that reduced water temperatures in that area have affected the usual seasonal distribution patterns of mackerel. Poland caught 4,364 tons in a research fishery in SA 6 during January-April 1982 and Italy and Japan took a total of about 2,000 tons in SA 6.

Recreational

Estimates of the annual US recreational catch of mackerel between Maine and North Carolina for 1960-80, as reported by Anderson (1981), are given in Table 1. The 1980 estimate of 3,900 tons was determined from a predictive linear regression between spawning stock biomass and recreational catch estimates from previous years as results from the NMFS 1980 Marine Recreational Fishery Statistics Survey (MRFSS) were not available.

Results from neither the 1980 nor 1981 MRFSS are available at the present time. In addition, the estimate of 3,315 tons in 1979, based on results from the 1979 MRFSS, is subject to revision (Holliday[1]). In the absence of 1981 data, the recreational catch was assumed to be 4,000 tons, a slight increase from the 3,900 tons predicted for 1980, as a reflection of the increase in stock biomass from 1980 to 1981.

For the purpose of providing catch and stock biomass projections in this assessment, a 1982 recreational catch of 4,000 tons was assumed.

[1]Mark Holliday, National Marine Fisheries Service, Resource Statistics Division, Washington, DC, personal communication.

Total

The total international catch in SA 2-6 increased from 29,285 tons in 1980 to 31,603 tons in 1981 (Table 1), an increase of 8%. The 1981 level was the second lowest (next to 1980) since 1966 (26,787 tons) and only about 7% of the peak harvest of 430,437 tons reported in 1973. Total catches during 1978-81 have remained relatively constant, averaging 32,800 tons per year. The Canadian catch comprised 61% (19,284 tons) of the total in 1981, while the US catch (commercial and estimated recreational) accounted for 22% (6,951 tons).

The international catch in 1982 is projected to include 21,000-22,000 tons from the commercial fisheries and 4,000 tons from the US recreational fishery for a total of 25,000-26,000 tons.

CATCH COMPOSITION

Length frequency samples from US commercial catches in 1981 were obtained during January (3), March (8), April (10), and May (1) from SA 6 (primarily Div. 6B), during July (2) and August (1) from Div. 5Y, and during November (1) from Subdiv. 5Zw. A total of 3,162 lengths was represented in these 26 samples. Five samples were collected by US foreign fisheries observers aboard Italian and Spanish vessels during March in SA 5-6 representing a total of 359 fish. A total of 65 samples (11,281 lengths) was collected by US observers and Polish scientists aboard Polish vessels during January-March in SA 6.

Age/length keys were prepared for the first and second quarters combined (little or no growth during these months), third quarter, and fourth quarter of 1981 using samples from Polish, US commercial, and NEFC bottom trawl survey catches. These keys were applied to the available length frequency data in the various months from both US and distant-water-fleet (DWF) catches to estimate numbers at age.

Numbers-at-age data from the 1981 SA 3-4 Canadian Newfoundland catch were obtained from Moores[2], and comparable data from the SA 4 Canadian Maritime catch were provided by Hunt[3]. Comparison of US and Canadian Maritime age/length keys for 1980 indicated considerable discrepancy (Anderson 1981), particularly with respect to the 1977 and 1978 year classes. The age composition of US catches in SA 5-6 indicated a 0.03:1 ratio between numbers of 1977 and 1978 year-class fish. In contrast, the age composition of Canadian Maritime SA 4 catches indicated a 1.58:1 ratio between 1977 and 1978 year-class fish. This marked disparity was due to differences in age interpretation and not to dissimilar length compositions of the respective catches. In the absence of a resolution of differences in otolith interpretation between US and Canadian Maritime age readers, US age/length keys were applied to the 1980 Maritime length frequency data for the purposes of the previous assessment (Anderson 1981).

Aging differences have not been totally resolved as evidenced by aging results from 1981 samples, although the disparity observed in the 1981 aging was not as pronounced as in 1980. US commercial catch age compositions in SA 5-6 in 1981 indicated a 0.04:1 ratio between numbers of 1977 and 1978 year-class fish, compared to a ratio of 0.03:1 in 1980. Canadian Maritime age compositions for the 1981 SA 4 catch indicated a 0.44:1 ratio between 1977 and 1978 year-class fish (compared to 1.58:1 in 1980). Canadian Newfoundland aging indicated a 0.14:1 ratio between 1977 and 1978 year-class fish in both 1980 and 1981, which is more in agreement with US than Canadian Maritime age

---

[2] John A. Moores, Fisheries and Oceans Canada, Research and Resource Services, Northwest Atlantic Fisheries Center, St.Johns, Newfoundland, personal communication.

[3] Joseph J. Hunt, Fisheries and Oceans Canada, Marine Fish Division, St. Andrews, New Brunswick, personal communication.

interpretation. Since 1981 US age/length keys for the various months corresponding to Maritime length samples contained insufficient numbers of age-at-length observations to provide adequate coverage for the lengths represented in the Maritime samples, Canadian Maritime aging was used for 1981. The overall effect of the aging disparity on the age composition of the total catch in 1981 and on the results of subsequent analyses of that data is not quantifiable, given the available information, but should not appreciably alter the outcome of this assessment.

The age composition of the US recreational catch was not estimated for 1981 because MRFSS length frequency sampling data were not available for analysis. Consequently, the recreational catch in 1981 was assumed to have an age composition equivalent to that of the combined commercial catch in SA 2-6.

Numbers at age for the 1981 international catch are given in Table 3. The 1974 year class at age 7 comprised 21% of the total catch in numbers, followed by the 1980 year class (age 1) with 17%, the 1978 year class (age 3) with 14%, and the 1975 year class (age 6) with 13%. The 1974 year class has been the dominant year class (in terms of numbers) in the catch every year since 1976 (Table 4). The 1978 year class accounted for 22% of the catch in 1980, but only 14% in 1981. The percentage contribution of age 1 fish (1980 year class) in 1981 (17%) was the highest since 1975 (29% - 1974 year class). Mean age of the total catch was 5.1 years, compared to 5.8 years in 1980 and a 1962-81 high of 6.2 years in 1977 (Table 4).

The US commercial catch in 1981 was dominated by 1980 year class (age 1) fish (61%), followed by the 1979 year class (24%) (Table 3). The non-US catch in SA 5-6 (principally Polish) consisted primarily of the 1974 (28%) and 1978 (27%) year classes. The Canadian Newfoundland catch from SA 3-4 was dominated by the 1974 year class (35%), followed by the 1975 (19%) and 1973 (15%) year classes. The Maritime catch from SA 4 contained 25% 1974 year-class, 21% 1975 year-class, and 18% 1978 year-class fish.

The January-April 1982 Polish research catch from SA 6 (4,364 tons) was comprised primarily of the 1974 (23%) and 1978 (22%) year classes, followed by the 1980 (13%), 1981 (9%), and 1973 (8%) year classes. If these catches are indicative of the rest of the international catch in 1982, it suggests that the 1974 year class at age 8 was again the dominant year class in the 1982 catch (for the 7th consecutive year), and that the 1978, 1980, and 1981 year classes also contributed significantly.

The international numbers-at-age catch data for mackerel during 1962-81 for SA 2-6 are given in Table 4.

MEAN WEIGHT AT AGE

Estimated mean weights for ages 1-14 for the international catch from NAFO SA 2-6 during 1962-81 are given in Table 5. The 1962-77 values were calculated using von Bertalanffy growth parameters and length-weight parameters, as reported in previous assessments (Anderson 1981), and raised proportionately to correspond to the approximate calendar date by which 50% of the catch each year was taken. The resulting weights were then corrected so that the sum of products (mean weights times numbers at age) equalled the actual catch.

The mean weights at age for the 1978-81 catch were derived by utilizing reported mean weights at age from the Canadian catch and mean lengths at age from the remaining portions of the sampled catch which were converted to weights by use of the length-weight equation given by Anderson (1981). The various weights for each age were weighted by catch in numbers to obtain a yearly value for each age.

Mean weights at age used for calculating stock biomass as of 1 January for each year are given in Table 6. The weights at age derived using the von Bertalanffy growth parameters and length-weight parameters reported previously (Anderson 1981) were used each year during 1962-77. The 1978-81 mean weights were determined by adjusting the catch mean weights at age for those years to 1 January assuming within-year growth at age proportional to that described by the von Bertalanffy growth curve.

Results (Tables 5-6) indicate that mean weight at age has increased significantly since 1977, although some of the increase is perhaps due to the different methods used to calculate mean weights for the 1962-77 and 1978-81 periods. The increase is also a reflection of increased mean length at age which has been observed for some recent year classes and appears to be a function of density-dependent growth (Dery and Anderson in preparation).

The 1980-81 average mean weights at age for catch (Table 5) and stock (Table 6) were used in calculating projected catch in 1982-83 and stock biomass in 1982-84.

STOCK BIOMASS INDICES

Research Vessel Survey Catch Per Tow

Indices of mackerel stock biomass have been calculated from data obtained from NMFS, NEFC spring and autumn bottom trawl surveys. Spring catch-per-tow indices based on catches in sampling strata 1-25 and 61-76 (Figure 2) during 1968-82 and autumn indices based on catches in strata 1-42 and 49 during 1963-82 are given in Table 7. Analysis of the data involves ln transformation of the catch (kg) at each trawl station, computation of stratified mean catch per tow (ln scale), and retransformation of the results to the linear scale (Anderson 1979, Anderson and Paciorkowski 1980).

Spring catch per tow underwent a pronounced drop from highs in the late 1960's-early 1970's to a low level during 1975-1980. The index increased sharply from 0.22 kg in 1979 to 1.84 kg in 1981, the highest index observed since 1971 (1.97 kg), followed by a drop to 0.88 kg in 1982 (Table 7, Figure 3). Even though catch per tow decreased by over 50% from 1981 to 1982, the 1982 value is the second highest (after 1981) since 1972. The high indices in 1981 and 1982 reflect an increasing trend in stock biomass in recent years.

Autumn catch per tow has exhibited the same general trends over time as spring catch per tow, but the numerical values averaged about 20 times smaller and showed greater within-year statistical variance (Anderson 1976) and somewhat greater between-year variability. The 1982 autumn index was the highest observed (0.13 kg per tow) since 1979 (0.19 kg) (Table 7, Figure 3), and is consistent, as are the recent spring indices, with an increasing trend in stock biomass. A possible reason for the unusually high catch-per-tow value in 1982 could be increased availability of mackerel at the time of the survey relative to previous years as a result of an early southerly migration induced by lower-than-normal water temperatures. Several unusually large survey catches of mackerel were taken in early October from stratum 1 (south of Long Island in vicinity of Hudson Canyon with depth range of 27-55 meters) and stratum 7 (along edge of continental shelf from south of Nantucket to south of Block Island in depth of 111-185 meters). Mackerel are usually not found that far south in October.

US Commercial CPUE

The standardized US commercial catch-per-day index (all ages) (Anderson 1976), derived by standardizing effort from various gear-tonnage categories to that of the floating trap, increased steadily from 0.48 tons in 1978 to 1.42 tons in 1980, the highest value since 1970 (2.07 tons) (Table 8, Figure 4). Catch per day declined to 1.09 tons in 1981, but was still the second highest (next to 1980) since 1971 (1.29 tons). As was the case with both the spring and autumn trawl survey catch-per-tow indices, the increase in the last several years is indicative of an increasing trend in mackerel stock biomass.

Standardized US catch per day for ages 3 and older (Table 9, Figure 4) declined from 0.65 tons in 1979 to 0.42 tons in 1981 after having increased rather steadily from 0.14 tons in 1974. This index (Anderson 1982) has generally followed the pattern of catch per day for all ages, except in years when ages 1-2 comprised a significant portion of the catch and resulted in higher total CPUE. In both 1980 and 1981, about 60% of the CPUE for ages 1 and older was due to ages 1-2. Comparison of the upward trend in stock biomass in the last several years as indicated by survey catch per tow (all ages) and US commercial CPUE for all ages with the slightly downward trend in CPUE for ages 3 and older indicates that the increasing trend is due to the improvement in abundance of recent year classes recruiting to the stock.

Polish Commercial CPUE

Catch per day of mackerel by two different Polish stern trawler tonnage classes during 1970-77 and 1981-82 in SA 5-6 has been examined as an index of stock biomass (Anderson 1981, 1982). Various factors influenced by the schooling behavior of mackerel tend to introduce unmeasurable biases into CPUE from mobile gear such as the Polish stern trawlers and render it invalid as an indicator of stock biomass. Consequently it is concluded that the Polish CPUE is not reliable as a measure of mackerel stock biomass in the Northwest Atlantic.

NATURAL MORTALITY

Instantaneous natural mortality (M) for mackerel in SA 2-6 was assumed to be 0.30 for all ages and years in all previous assessments done since 1974, when this value was adopted by scientists in the ICNAF Assessments Subcommittee (ICNAF 1974, Anderson and Paciorkowski 1980).

The value of M for mackerel in the Northeast Atlantic (same species as in the Northwest Atlantic) was assumed to be 0.20 when the first assessment was done in 1970, and since 1978 has been assumed to be 0.15, based on estimates derived from an extensive analysis of tag return data (Hamre 1980). In 1973, the ICNAF Mackerel Working Group (ICNAF 1973) concluded that the life span of mackerel was similar in the Northeast and Northwest Atlantic, but that growth parameters were sufficiently different to justify a higher M for the Northwest Atlantic mackerel.

The conclusion on growth differences was based primarily on a comparison between values for the von Bertalanffy growth parameter K of 0.408 estimated by Castello and Hamre (1969) and 0.57 estimated by Postuma (1969) for the

North Sea stock compared to 0.25 adopted by the ICNAF Mackerel Working Group for Northwest Atlantic mackerel (ICNAF 1973). Various growth studies of Northwest Atlantic mackerel in the early and mid 1970's summarized by Anderson and Paciorkowski (1980) provided estimates of K varying between 0.221 and 0.360. Recent age and growth studies of Northeast Atlantic mackerel (Kastner 1977, Corten and van de Kamp 1978, Eltink and Gerritsen 1982, and Gordo et al. 1982) provided estimates of K ranging from 0.14 to 0.27. Although growth rates of Northwest Atlantic mackerel have not been re-calculated in the last several years, the observed increase in length at age for recent year classes implies an increase in K over the value of 0.25 determined earlier. It is apparent that growth rates of both Northeast and Northwest Atlantic mackerel have fluctuated during the past 10-15 years. However, the general similarity in K values between the two areas at various time intervals in the past decade tends to imply some similarity in natural mortality rates.

Age analysis of current catches indicates similar life spans for Northeast and Northwest Atlantic mackerel. Mackerel as old as 20 years have been aged at the NEFC from otolith samples taken from recent catches in the Northwest Atlantic, and numbers-at-age data since 1979 have been reported for ages 1-14+ (Table 4). For the North Sea stock, results from Norwegian ageing are reported for ages 1-15+ (Anon. 1982).

Revised estimates of M have been calculated (Anderson unpublished data), from linear regressions between estimates of instantaneous total mortality (Z) derived from numbers-at-age catch data (Table 4), and fishing effort (Table 9). The five estimates obtained ranged from 0.145 to 0.222 (average = 0.195). Further refinement of the estimates may prove to be necessary, but since the results obtained for M averaged 0.195, a value of 0.20 was used for this assessment.

DISEASE AND PARASITES

As part of a major NEFC attempt to investigate the effects of disease on fish populations, intensive sampling of mackerel was done aboard the Polish F/V ADMIRAL ARCISZEWSKI in SA 6 during February-April 1982. Sampling aboard the Polish vessel included blood smears and kidney and spleen tissue imprints for cytogenetic and hematozoan studies, gonadal and somatic tissues for contaminants analysis, ectoparasites for identification of potential disease vectors, and observations of external and internal lesions.

Analysis of the collected samples is still ongoing, although some preliminary results are available. The prevalence of a blood parasite, *Haematractidium scombri*, was found to be 23% from fish sampled in SA 6, and 38% from fish sampled during the summer in SA 4 (MacLean[4]). These values are close to or within the range of infection rates found during 1974-76 in mackerel sampled off Virginia (SA 6) (MacLean 1980).

Preliminary results from analysis of 1982 samples by Polish scientists suggest a very high incidence (95%) of the systemic fungus pathogen, *Ichthyophonus hoferi*, in mackerel sampled in SA 6 during March-April (MacLean[4]). This pathogen has been responsible for previous mass mortalities of both sea herring (*Clupea harengus*) and mackerel in the Gulf of Maine and the Gulf of St. Lawrence as recent as the 1940's and 1950's (Sindermann 1963). Further analysis and monitoring will be necessary to ascertain the full extent and possible implications of this infection in the population.

---

[4] Sharon A. MacLean, National Marine Fisheries Service, Northeast Fisheries Center, Oxford Laboratory, Oxford, Maryland, personal communication.

Kidney tissues and blood smears collected both offshore in the Mid-Atlantic area during February-April 1982 and inshore from Hempstead Bay, Long Island in May 1982 are being analyzed to determine mutation frequencies in red blood cells. The mutation frequencies obtained from samples collected in various areas will be compared with respect to time and location of capture, age, length, sex, and maturity stage of the fish, body burden of contaminants, and water quality. Preliminary results indicate that mackerel collected in Hempstead Bay exhibited a higher mutation frequency than those sampled further offshore (Longwell[5]).

FISHING MORTALITY

Instantaneous fishing mortality (F) for ages 4 and older in 1981 was estimated from a power curve relationship between mean annual F derived from virtual population analysis (VPA) using M = 0.20 and fishing effort expressed as equivalent US standardized days fished. F values for ages 3 and older from VPA were weighted by stock size at age (numbers) to obtain an annual mean F. Annual fishing effort directed towards ages 3 and older was determined by dividing the international catch (tons) of ages 3 and older by US standardized catch per day for ages 3 and older (Table 9).

An adjustment was made to the US CPUE time-series before calculating effort. The observed 1974 value for ages 3 and older was 0.14 tons per day, compared to 0.44 in 1973 and 0.32 in 1975. This relatively low CPUE in 1974 was not felt to be representative of actual stock biomass in that year and would have implied a level of fishing effort vastly in excess of that in

---

[5]Arlene C. Longwell, National Marine Fisheries Service, Northeast Fisheries Center, Milford Laboratory, Milford, Connecticut, personal communication.

adjacent years and greatly disproportionate to fishing mortality estimated from VPA for 1974. Therefore, CPUE for ages 1 and older in 1974 was assumed the same as in 1973 and 1975 (0.53 tons per day) (Table 8), and a value of 0.44 tons per day for ages 3 and older was derived from that by assuming that the corrected CPUE for ages 3 and older was the same proportion of the CPUE at ages 1 and older as actually observed in 1974 (0.835).

Mean annual F values for ages 3 and older in 1964-79 were determined from a preliminary VPA, which assumed a trial value for F at ages 4 and older in 1981 of 0.10 and an M of 0.20 at all ages. These estimates of F were regressed (power curve) against fishing effort for those years. The F for 1981 predicted from this regression was used as the terminal F in a second VPA. The VPA-regression process was followed through several iterations until the F predicted by the regression for 1981 remained unchanged from the terminal F for 1981 used in the previous VPA. An F of 0.154 was thus estimated for ages 4 and older in 1981 from a power curve regression having a correlation coefficient (r) of 0.893 (Table 9, Figure 5).

Age-specific F values for 1962-80 estimated from VPA (using M = 0.20) are given in Table 10. Mean annual values for ages 3 and older increased from an average of 0.06 in 1962-64 to a high of 0.74 in 1976 and then dropped to an average of 0.12 during 1978-80 as a result of the sharp drop in international catch after 1977.

Since an M of 0.30 was used in previous assessments of this stock, the analysis described above was repeated using an M of 0.30 instead of 0.20 to provide a comparison of results. Mean annual F values based on the two values for M are given and compared in Table 14. Annual mean F values using M = 0.20 exhibited increases ranging from 36 to 106% above those obtained using M = 0.30. The increases averaged 68% for the 1962-82 period.

RECRUITMENT

The sizes of the 1961-77 year classes at age 1, estimated from VPA, ranged from 29 million (1977 year class) to 4,939 million fish (1967 year class) (Table 10), with a mean size of 1,150 million and a median size of 1,044 million. The estimates for the strongest (1967) and poorest (1977) year classes differed by a factor of 168.

Estimates of the sizes of the 1978-82 year classes at age 1 were based on catch-per-tow-at-age (numbers) data from NMFS, NEFC spring and autumn bottom trawl surveys. Catch-per-tow indices have been determined for age 0 from autumn surveys and for ages 1 and 2 from spring surveys (Table 11). A procedure was developed in the previous assessment (Anderson 1981) which combined the available age 0-2 indices for each year class into a single index which was regressed against year-class size at age 1 from VPA to provide a basis for predicting the sizes of the most recent year classes. This procedure was modified slightly, as described below, for use in the present assessment.

Mean catch per tow (numbers) for each year class at ages 0, 1, and 2 (Table 11) was adjusted twice before being combined into a single index. All indices were first expressed as equivalent age 1 values as of 1 January by decreasing the autumn age 0 values and increasing the spring age 1 and 2 values to account for natural and fishing mortality between the time of the respective survey and 1 January (age 1). Following this initial adjustment, it was observed that the three sets of indices (ages 0, 1, and 2) remained nonequivalent because of apparent differences in availability to and/or catchability by the survey trawl. Mackerel catches during autumn surveys (including age 0) are typically quite small due to reduced catchability/availability influenced by the apparent dispersion of schools at that time of year and also to the fact that many mackerel are located close inshore in areas inaccessible to the survey gear. During spring surveys, catch rates of age 2 mackerel have, on average, been slightly higher than for age 1, suggesting greater availability/catchability of age 2 versus age 1 fish. Ratios between the adjusted (to 1 January age 1) autumn age 0 and spring age 1 catch-per-tow values and between the spring age 2 and spring age 1 values were calculated. The geometric mean of the age 0/age 1 ratios was 0.106, whereas the geometric mean of the age 2/age 1 ratios was 1.241. Each age 0 value was divided by 0.106 and each age 2 value was divided by 1.241 as a means of adjusting for the availability/catchability differences between these age groups and age 1. The final adjusted mean catch-per-tow indices are given in Table 11.

The geometric mean of the various adjusted indices for each year class was used as a single index for that year class (Table 11). A geometric mean was used instead of an arithmetic mean to minimize the influence of exceptionally high or low values on the mean. The geometric mean (GM) survey index was regressed against year-class size at age 1 from VPA for the 1963-77 year classes employing a functional (GM) linear regression (r = 0.937) (Table 11, Figure 6). This relationship was used to predict the sizes at age 1 of the 1978 (412 million), 1979 (224 million), 1980 (607 million), 1981 (421 million), and 1982 (1,241 million) year classes.

The 1982 year class, based on the estimate of 1,241 million fish at age 1, would appear to be the strongest year class since 1974 (1,492 million). However, since that estimate was based on only one survey index value, which by itself is insufficient to reliably predict year-class size, and which, in the case of the 1982 age 0 value, is felt to be biased upwards due to apparent increased availability of mackerel (all ages) during the 1982 autumn survey, as indicated earlier, it was not used in this assessment. Therefore, for the purpose of catch and stock biomass projections, the 1982 year class (as well as the 1983 year class) was assumed to be 400 million fish at age 1, which is the median of the estimates for the previous five year classes (1977-81).

The 1978 year class was estimated to be 400 million fish at age 1 or about 27% of the size of the 1973-74 year classes. This represents a substantial decrease in the relative size of this year class, since it was estimated to be equal in size to the 1974 year class in the previous assessment (Anderson 1981). The estimated sizes of the 1979 (200 million at age 1) and 1980 (600 million) year classes remain relatively the same in proportion to the 1974 year class as in the previous assessment. The 1981 year class (400 million at age 1) is relatively stronger than assumed previously.

The change in M from that used previously (0.30) to 0.20 in the present assessment has had an accompanying effect on the absolute level of year-class size at age 1 estimated from VPA (Table 14). Year-class sizes based on an M of 0.20 are, on average, 45% smaller than those based on an M of 0.30.

PARTIAL RECRUITMENT COEFFICIENTS

Partial recruitment of an age group to the fishery in a given calendar year can be thought of as the fraction of that age group vulnerable to the fishery or the fraction of the fishing mortality (F) exerted on age groups fully vulnerable to the fishery which is directed towards that age group. In this paper, partial recruitment is defined as the ratio between F at the incompletely recruited age group and the mean F for ages 3 and older in that year.

Ratios between the F values at ages 1-6 and the mean F at ages 3 and older for the 1968-81 period (Table 12) exhibited considerable variability between years for a given age and between ages in a given year that are assumed to be fully recruited. This variability is due to differences in year-class strength and to changes in fishing patterns. F values alone do not provide an absolute indication of the degree of recruitment of an age group to the fishery. Mackerel are generally of sufficient size by age 3 to be fully vulnerable to the fishery, and by virtue of age 3 and older fish schooling together, these age groups should all be fully vulnerable to the fishery.

Examination of the partial recruitment ratios or coefficients for the period of heavy international fishing during 1968-77 indicated full recruitment to the fishery at age 3 in most years (Table 12). The geometric means of the 1968-77 values were 16% at age 1, 52% at age 2, 91% at age 3, 114% at age 4, 98% at age 5, and 90% at age 6. The values at ages 3-6 (90-114%) suggest full recruitment at those ages during 1968-77.

The pattern of exploitation after 1977 appears to have changed, with full recruitment occurring later than age 3. The geometric means of the 1978-81 values were 4% at age 1, 16% at age 2, 36% at age 3, 65% at age 4, 99% at age 5, and 125% at age 6. These values suggest full recruitment at ages 5 and older during the 1978-81 period.

For the purpose of making catch projections for 1983, the mean values for 1978-81 were used as a basis for approximating the exploitation pattern likely to occur during 1982-83. Partial recruitment coefficients chosen were 5% at age 1, 15% at age 2, 35% at age 3, 65% at age 4, and 100% at ages 5 and older.

STOCK BIOMASS

Age-specific stock size estimates from VPA are given in Table 10. Annual stock biomass estimates for 1962-82 were determined by applying mean weights at age from Table 6 to the stock size estimates.

Total stock biomass (ages 1 and older) increased from around 300,000 tons during 1962-65 to 1.8 million tons in 1970-71 and then decreased as rapidly to an estimated 323,000 tons in 1978 (Table 10, Figure 7). Since 1978, the total stock has increased nearly 50% to about 480,000 tons at the beginning of 1982.

Spawning stock biomass, defined as 50% of the age 2 and 100% of the age 3 and older fish, increased from an average of 263,000 tons per year during 1962-67 to 1.6 million tons in 1971 and then dropped to only 288,000 tons in 1980 (Table 10, Figure 7). Spawning biomass increased about 28% from 1980 to about 370,000 tons at the beginning of 1982.

As a consequence of using an M of 0.20 in the present assessment, instead of 0.30 as previously, present estimates of stock biomass are proportionately smaller than previously. Comparisons are provided in Table 14 and indicate that, on average, biomass estimates are about 40% less using an M of 0.20.

YIELD PER RECRUIT AND EQUILIBRIUM YIELD

Yield-per-recruit analyses employing the Thompson and Bell (1934) method (Rivard 1980) were performed to estimate the fishing mortality reference points of $F_{0.1}$ and F_{max} when $M = 0.20$. As mentioned previously in this report, conditions in both the stock and the fishery have varied over the 1962-81 period for which data are available. Mean weights at age have shown a marked increase since 1977, and the exploitation pattern of the fishery has also changed since 1977, based on the partial recruitment coefficients given in Table 12. Since the Thompson and Bell model uses mean weights at age and partial recruitment coefficients, calculations were performed to obtain $F_{0.1}$ and F_{max} values applicable to 1) the 1968-77 period of intensive fishing and high stock biomass, 2) the 1978-81 period of reduced fishing and low biomass (current conditions), and 3) the 1962-81 period to represent the average of both high and low levels of fishing and biomass.

Calculations for the 1968-77 period used average mean weights for those years (Table 5) and the exploitation pattern for those years as given in Table 12. Results indicated that $F_{0.1}$ = 0.26 and F_{max} = 0.60 for equilibrium conditions comparable to the 1968-77 period. Results for the 1978-81 period gave an $F_{0.1}$ of 0.40 and an F_{max} of 1.78; for the 1962-81 period, $F_{0.1}$ = 0.28 and F_{max} = 0.78. To illustrate the effect on the determination of $F_{0.1}$ and F_{max} of using M = 0.20 instead of M = 0.30, the above analyses were repeated for 1962-81 and 1978-81 using M = 0.30. Results indicated that $F_{0.1}$ = 0.40 and F_{max} = 1.20 for the 1962-81 period [same as estimated by Anderson (1980)], and $F_{0.1}$ = 0.60 and F_{max} = >2.00 for the 1978-81 period. The effect of using M = 0.20 instead of M = 0.30 is to reduce the $F_{0.1}$ and F_{max} values by 30-35%.

Results from the yield-per-recruit calculations indicate that the values for $F_{0.1}$ and F_{max} vary under the different options used for mean weight at age and partial recruitment coefficients. Values to be applied to the 1983 fishery must correspond with anticipated conditions in the stock and fishery in 1983. Since the exploitation pattern and mean weights at age of the catch observed for 1978-81 are not expected to change markedly in 1983, an $F_{0.1}$ of 0.40 would be appropriate for management purposes in 1983.

Equilibrium yield projections were simulated using the same mean weights at age and exploitation pattern as existed for the 1978-81 period assuming constant recruitment each year at age 1 equivalent to the median level (690 million fish) estimated for 1962-82 (1961-81 year classes). The simulated yield at this constant level of recruitment ranged from 152,000 tons at $F_{0.1}$ = 0.40 to 182,000 tons at F_{max} = 1.78.

STOCK-RECRUITMENT

An examination was made of the relationship between year-class size at age 1 and parental (spawning) stock biomass (Figure 8). The array of points reveals a range in spawning stock biomass between about 340,000 and 490,000 tons below which most of the year classes produced were poor and above which most of the year classes were strong. During 1962-81, the estimated spawning biomass was 341,000 tons or less during 11 of those 20 years (averaging 285,000 tons per year) and only 27% (3 of 11) of the year classes produced were above median size (690 million). In the remaining 9 years, spawning stock biomass was 488,000 tons or higher (averaging 1,013,000 tons per year) and 78% (7 of 9) of the year classes produced were above median size.

From the plot of points in Figure 8 and considering the outstanding 1967 year class to be an anomalous occurrence, a recognizable stock-recruitment relationship is evident. Even though environmental factors are instrumental in determining year-class size, as the series of above-average year classes during 1966-74 might suggest, the historical record tends to indicate a generalized stock-recruitment relationship which can perhaps provide some guidance for management purposes. At the very least, the data indicate an increased probability of poor recruitment when spawning biomass is below about 340,000 tons and an increased probability of strong recruitment when spawning biomass is above 490,000 tons.

CATCH AND STOCK BIOMASS PROJECTIONS

An estimated catch of 25,000 tons in 1982 will generate an F of 0.108 on fully-recruited ages (compared to 0.154 in 1981). Total stock biomass available at the beginning of 1983, given a 1982 year class of 400 million fish at age 1 (1978-81 median level), was estimated to be 561,000 tons, a 17% increase in stock biomass from 1982 (Table 14). Spawning stock biomass in 1983 was estimated to be 472,000 tons, a 28% increase from 369,000 tons in 1982.

Projected catches in 1983 ranging from 20,000 to 104,000 tons (Table 13) would generate fishing mortality rates ranging from 0.069 to 0.400 and leave estimated spawning stock biomass levels at the beginning of 1984 varying from 531,000 tons (12% increase from 1983) to 455,000 tons (4% decrease from 1983). Fishing at the $F_{0.1}$ level applicable to present conditions in the fishery (F = 0.40) would result in an estimated catch of 104,000 tons in 1983 and a spawning stock in 1984 of 455,000 tons (4% decrease from 1983). Fishing at the $F_{0.1}$ level applicable to average conditions in the stock and fishery during 1962-81 (F = 0.28) would result in a catch of 76,000 tons in 1983 and a spawning stock in 1984 of 481,000 tons (2% increase from 1983).

DISCUSSION

Evidence continues to indicate that the mackerel stock in SA 2-6 is maintaining the recovery trend begun after 1978 when total stock biomass reached a low of about 323,000 tons. Projections suggest that total stock biomass increased nearly 75% from 1978 to 1983 (561,000 tons). Spawning stock biomass also increased substantially from a low of 288,000 tons in 1980 to a projected 472,000 tons at the beginning of 1983 (64% increase). Recovery has been aided by the relatively low catches (average of 31,300 tons) and F levels (average of 0.12 using M = 0.20) during 1978-82, in contrast to the high catches (average of 340,000 tons) and F levels (average of 0.46) during 1970-76. Although the 1975-81 year classes are all estimated to be below average (1961-81), those since 1978 have been much better than the 1975-77 cohorts. This improvement in recruitment has also contributed to the increasing trend in stock biomass. In addition, the higher mean weights at age in recent years stemming from improved growth rates have also influenced the upward trend in stock biomass. Catch and stock projections indicate that the catch in 1983 can be increased above the level taken in recent years and still maintain the rebuilding trend in stock biomass.

Proposed management regulations for mackerel in US waters, as reviewed in the MANAGEMENT section of this paper, have incorporated a 600,000-ton minimum spawning stock biomass constraint and a ceiling on fishing mortality equivalent to $F_{0.1} = 0.40$. At the time these regulations were developed, the mackerel assessment was based on using a natural mortality rate of 0.30. However, new information and analyses have led to the adoption of a different M value (0.20) in the present assessment. Accordingly, the 600,000-ton spawning stock biomass constraint is not applicable to the results of the present assessment. As indicated earlier in this report, the consequence of changing M from 0.30 to 0.20 was to decrease the estimates of total and spawning stock biomass by about 40%. Applying this percentage decrease to the stock biomass constraint of 600,000 tons would result in 360,000 tons.

Stock-recruitment considerations, using an M of 0.20, indicate a range in spawning stock biomass of 340,000-490,000 tons, below which the probability of good recruitment is 27% and above which the probability of good recruitment is

78%. A minimum stock biomass constraint of 360,000 tons would, therefore, be consistent with stock-recruitment considerations and equivalent to the management strategy implied by the 600,000-ton value.

Since projected spawning stock biomass levels for 1984 resulting from the various catch options presented for 1983 (Table 13) remain considerably above the suggested minimum stock biomass constraint of 360,000 tons, proposed regulations by the Mid-Atlantic Fishery Management Council stipulate that fishing mortality in 1983 should not exceed $F_{0.1} = 0.40$. The projected catch at this level of F in 1983 would be about 104,000 tons.

LITERATURE CITED

Anderson, E. D. 1976. Measures of abundance of Atlantic mackerel off the northeastern coast of the United States. Int. Comm. Northw. Atlant. Fish., Res. Bull. 12:5-21.

____________. 1979. Assessment of the Northwest Atlantic mackerel, Scomber scombrus, stock. NOAA Tech. Rept. NMFS SSRF-732, 13 p.

____________. 1980. Status of the Northwest Atlantic mackerel stock-1980. NMFS, NEFC, Woods Hole Lab. Ref. Doc. No. 80-29, 43 p.

____________. 1981. Status of the Northwest Atlantic mackerel stock-1981. NMFS, NEFC, Woods Hole Lab. Ref. Doc. No. 81-38, 40 p.

____________. 1982. The use of commercial CPUE data in assessing the Northwest Atlantic mackerel stock. Int. Coun. Explor. Sea, C.M. 1982/H:34, 25 p.

____________, and A. J. Paciorkowski. 1980. A review of the Northwest Atlantic mackerel fishery. Rapp. P.-v. Reun. Cons. int. Explor. Mer, 177:175-211.

Anonymous. 1982. Report of the Mackerel Working Group. Int. Coun. Explor. Sea, C.M. 1982/Assess:11, 77 p.

von Bertalanffy, L. 1938. A quantitative theory of organic growth. Hum. Biol. 10:181-213.

Castello, J. P., and J. Hamre. 1969. Age and growth of mackerel from Skagerrak and the northern North Sea. Int. Coun. Explor. Sea, C.M. 1969/H:7, 12 p.

Corten, A., and G. van de Kamp. 1978. Different growth pattern in mackerel west of the British Isles. Int. Coun. Explor. Sea, C.M. 1978/H:8.

Eltink, A., and J. Gerritsen. 1982. Growth, spawaning and migration of Western mackerel. Int. Coun. Explor. Sea, C.M. 1982/H:31, 26 p.

Gordo, L. S., M. M. B. Martins, and I. M. Jorge. 1982. Preliminary study on the age and growth of mackerel (Scomber scombrus L.) in the ICES Sub-area IXa. Int. Coun. Explor. Sea, C.M. 1982/H:16, 26 p.

Hamre, J. 1980. Biology, exploitation, and management of the Northeast Atlantic mackerel. Rapp. P.-v. Reun. Cons. int. Explor. Mer, 177:212-242.

ICNAF. 1973. Report of Standing Committee on Research and Statistics - June 1973. App. I. Report of Assessments Subcommittee. Ann. I. Report of ad hoc Mackerel Working Group. Int. Comm. Northw. Atlant. Fish., Redbook 1973 (Part I):87-94.

_____. 1974. Report of Standing Committee on Research and Statistics-January 1974. App. I. Report of Assessments Subcommittee. Ann I. Report of the ad hoc Mackerel Working Group. Int. Comm. Northw. Atlant. Fish., Redbook 1974:31-36.

Kastner, D. 1977. Preliminary results of the occurrence of two mackerel groups (Scomber scombrus L.) with different growth pattern west of Britain. Int. Coun. Explor. Sea, C.M. 1977/H:38, 17 p.

MacKay, K. T. 1967. An ecological study of mackerel, Scomber scombrus (Linnaeus), in the coastal waters of Canada. Fish. Res. Bd. Can., Tech. Rept., 31, 127 p.

__________, and E. T. Garside. 1969. Meristic analysis of Atlantic mackerel, Scomber scombrus, from the North American coastal population. J. Fish. Res. Bd. Can., 26:2537-2540.

MacLean, S. A. 1980. Study of Haematractidium scombri in Atlantic mackerel, Scomber scombrus. Can. J. Fish. Aquat. Sci. 37:812-816.

Postuma, K. H. 1969. On the mackerel in the north-eastern North Sea. Int. Coun. Explor. Sea, C.M. 1969/H:21, 13 p.

Rivard, D. 1980. APL programs for stock assessment. Can. Tech. Rept. Fish. Aquat. Sci., 953, 103 p.

Sindermann, C. J. 1963. Disease in marine populations. Trans. N. Am. Wildl. Conf. 28:221-245.

Thompson, W. F., and F. H. Bell. 1934. Biological statistics of the Pacific halibut fisihery. 2. Effect of changes in intensity upon total yield and yield per unit of gear. Rep. Int. Fish. (Pacific Halibut) Comm. 8, 49 p.

Table 1. Mackerel catch (tons) from NAFO SA 2-6 during 1960-81.

Year	US		Canada	Other countries	Commercial total	Grand total
	Commercial	Recreational				
1960	1,396	2,478	5,957	-	7,353	9,831
1961	1.361	3,022	5,459	11	6,831	9,853
1962	938	3,565	6,801	175	7,914	11,479
1963	1,320	3,981	6,363	1,299	8,982	12,963
1964	1,644	4,343	10,786	801	13,231	17,574
1965	1,998	4,292	11,185	2,945	16,128	20,420
1966	2,724	4,535	11,577	7,951	22,252	26,787
1967	3,891	4,498	11,181	19,047	34,119	38,617
1968	3,929	7,781	11,134	65,747	80,810	38,591
1969	4,364	13,050	13,257	114,189	131,810	144,860
1970	4,049	16,039	15,710	210,864	230,623	246,662
1971	2,406	16,426	14,942	355,892	373,240	389,666
1972	2,006	15,588	16,254	391,464	409,724	425,312
1973	1,336	10,723	21,619	396,759	419,714	430,437
1974	1,042	7,640	16,701	321,337	339,580	347,220
1975	1,974	5,190	13,544	271,719	287,237	292,427
1976	2,712	4,202	15,746	223,275	241,733	245,935
1977	1,377	522	20,362	56,067	77,306	73,328
1978	1,605	6,571	25,429	841	27,875	34,446
1979	1,990	3,315	30,244	440	32,674	35,989
1980	2,683	3,900	22,136	566	25,385	29,285
1981	2 951	4,000	19,284	5,368	27,603	31,603

Table 2. Mackerel catch (tons) in 1981 by country and subarea from NAFO SA 2-6.

Country	Subarea					Total
	2	3	4	5	6	
Canada (N)	1	6,833	60	-	-	6,894
Canada (Q)	-	-	1,450	-	-	1,450
Canada (M)	-	-	10,914	26	-	10,940
Cuba	-	-	3	-	-	3
Italy	-	-	-	48	991	1,039
Japan	-	-	-	96	142	238
Poland	-	-	-	-	3,979	3,979
Romania	-	-	-	-	1	1
Spain	-	-	-	-	50	50
USSR	-	-	58	-	-	58
US (Comm)	-	-	-	970	1,981	2,951
Total	1	6,833	12,485	1,140	7,144	27,603
US (Rec)						4,000
Grand total						31,603

Table 3. Age composition (thousands of fish) of the 1981 mackerel catch from NAFO SA 2-6.

Age	US comm. SA 5-6	Non-US SA 5-6	Canada SA 2-4: New-foundland	Canada SA 2-4: Quebec[1]	Canada SA 2-4: Maritimes	Canada SA 2-4: Total	Total SA 2-4[2]	Grand total SA 2-6[3]
0	2.3	-	-	-	-	-	-	2.6
1	8,602.8	93.7	-	16.0	124.0	140.0	140.4	10,117.5
2	3,435.1	331.7	34.8	35.0	265.1	334.9	336.0	4,697.3
3	876.7	2,495.1	645.3	387.0	2,914.8	3,947.1	3,959.6	8,393.8
4	33.8	71.6	117.2	171.0	1,288.4	1,576.6	1,581.6	1,931.5
5	24.5	207.1	539.1	181.0	1,360.4	2,080.5	2,087.1	2,654.7
6	121.6	824.7	1,812.8	459.0	3,451.9	5,723.7	5,741.8	7,657.3
7	451.8	2,570.1	3,318.1	548.0	4,123.1	7,989.2	8,014.5	12,635.7
8	185.5	1,054.2	1,419.2	246.0	1,848.5	3,513.7	3,524.8	5,454.7
9	101.2	646.6	621.6	101.0	765.2	1,487.8	1,492.5	2,364.9
10	39.7	268.6	300.0	17.0	127.0	444.0	445.4	862.9
11	48.6	146.2	103.1	9.0	69.0	181.1	181.7	431.1
12	63.7	113.2	79.8	7.0	54.0	140.8	141.2	364.2
13	37.7	252.4	177.9	16.0	119.0	312.9	313.9	714.4
14+	102.3	265.4	187.1	17.0	126.0	330.1	331.1	800.1
Total	14,147.2	9,340.6	9,356.0	2,210.0	16,636.4	28,202.4	28,291.6	59,282.7
Tons	2,951	5,333	6,894	1,450	10,914	19,258	19,319	31,603

[1]Assumed same as for Maritimes.

[2]Canadian SA 2-4 total raised to include 58 tons from USSR and 3 tons from Cuba.

[3]Sum of US comm. in SA 5-6, non-US in SA 5-6, and total in SA 2-4 raised to include 4,000 tons of US rec. in SA 5-6.

Table 4. Mackerel commercial and recreational catch at age (millions of fish) from NAFO SA 2-6 during 1962-81.

Year	Age 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14+	Total	Tons[1]	Mean age
1962	-	16.1	2.8	15.2	3.8	1.2	1.6	1.4	0.8	0.4	0.1	0.3	-	-	-	43.7	11.5	2.8
1963	-	1.1	4.2	1.3	26.3	6.0	0.3	0.2	0.2	0.2	0.1	0.1	-	-	-	40.0	13.0	4.1
1964	-	12.9	7.0	4.1	4.0	19.4	4.1	3.9	0.7	0.8	0.2	-	-	-	-	57.1	17.6	3.8
1965	-	9.0	3.6	2.9	4.0	5.2	19.5	4.2	4.0	0.7	-	-	-	-	-	53.1	20.4	4.7
1966	-	24.0	11.5	5.3	2.6	4.7	7.9	21.8	0.5	0.2	-	-	-	-	-	78.5	26.8	3.9
1967	1.8	0.8	26.7	19.8	3.5	3.3	5.1	6.1	32.3	0.3	-	-	-	-	-	99.7	38.6	4.3
1968	1.1	141.4	61.5	59.3	38.1	14.3	6.6	0.7	1.0	6.1	0.1	-	-	-	-	330.2	88.6	2.3
1969	4.0	7.1	262.1	160.7	65.8	5.7	3.0	2.0	3.1	2.2	8.3	-	-	-	-	524.0	144.9	2.8
1970	4.8	193.5	54.5	522.1	162.9	27.6	7.0	5.3	9.9	10.0	3.8	2.8	-	-	-	1,004.2	246.7	3.0
1971	2.4	74.6	294.2	127.4	558.9	203.5	34.6	8.9	3.6	4.3	8.1	7.2	-	-	-	1,327.7	389.7	3.6
1972	3.6	22.1	85.7	256.2	182.6	390.4	87.3	24.0	4.2	8.2	3.3	5.6	-	-	-	1,073.7	425.3	4.2
1973	4.0	161.8	283.2	285.1	233.6	192.4	197.2	31.2	11.0	4.1	3.8	1.6	-	-	-	1,409.0	430.1	3.6
1974	2.0	95.9	242.2	264.4	101.5	114.3	111.8	108.3	25.7	6.4	2.5	0.8	-	-	-	1,075.8	347.2	3.8
1975	3.7	373.7	431.4	113.7	100.8	58.6	67.8	51.9	50.5	12.5	2.3	1.0	-	-	-	1,267.9	292.4	2.8
1976	-	12.5	353.5	272.5	85.7	52.4	27.3	40.5	34.6	22.6	13.4	1.4	-	-	-	916.4	245.9	3.5
1977	-	2.0	27.0	101.0	54.0	12.0	9.9	5.6	6.3	3.8	3.6	0.3	0.3	-	-	225.8	78.3	3.8
1978	-	0.1	0.2	4.7	17.4	13.3	8.4	4.7	2.2	4.5	1.5	4.6	0.6	0.6	-	62.8	34.4	5.9
1979	-	0.4	0.6	1.3	7.1	18.6	13.1	6.2	2.6	2.2	2.2	0.6	1.8	0.5	0.9	58.1	36.0	6.2
1980	-	1.2	10.9	1.1	1.1	7.0	13.0	4.8	2.1	1.2	1.2	2.1	0.6	1.6	0.9	49.7	29.3	5.8
1981	+	10.1	4.7	8.4	1.9	2.7	7.6	12.6	5.4	2.6	0.9	0.4	0.4	0.7	0.8	59.2	31.6	5.1

[1]Thousands of tons.

Table 5. Mean weight at age (kg) of the international mackerel catch from NAFO SA 2-6 during 1962-81.

Year	Age 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14+
1962	-	.130	.208	.289	.365	.433	.491	.541	.581	.614	.641	.662	-	-	-
1963	-	.120	.192	.264	.334	.395	.448	.492	.529	.559	.583	.602	-	-	-
1964	-	.116	.188	.262	.332	.395	.450	.495	.533	.564	.588	-	-	-	-
1965	-	.123	.200	.278	.352	.419	.477	.525	.565	.598	-	-	-	-	-
1966	-	.128	.209	.294	.374	.447	.509	.562	.605	.641	-	-	-	-	-
1967	.057	.123	.202	.283	.360	.428	.489	.540	.581	.615	-	-	-	-	-
1968	.070	.148	.241	.335	.425	.506	.576	.634	.683	.722	.753	-	-	-	-
1969	.061	.131	.214	.300	.382	.456	.520	.574	.618	.654	.683	-	-	-	-
1970	.048	.107	.179	.253	.324	.389	.444	.491	.530	.562	.587	.608	-	-	-
1971	.050	.110	.181	.256	.327	.391	.446	.494	.532	.564	.589	.610	-	-	-
1972	.054	.123	.210	.300	.386	.464	.533	.590	.638	.677	.708	.733	-	-	-
1973	.051	.113	.189	.269	.345	.414	.473	.524	.565	.600	.628	.650	-	-	-
1974	.048	.111	.190	.273	.352	.425	.487	.541	.585	.621	.649	.673	-	-	-
1975	.045	.104	.176	.252	.326	.393	.451	.500	.540	.573	.600	.621	-	-	-
1976	-	.097	.168	.244	.316	.382	.440	.489	.530	.563	.590	.611	-	-	-
1977	-	.114	.198	.288	.375	.454	.524	.582	.631	.671	.703	.729	.749	-	-
1978	-	.192	.285	.425	.463	.509	.582	.625	.659	.673	.697	.717	.797	.705	-
1979	-	.190	.272	.531	.567	.579	.603	.652	.714	.752	.769	.822	.809	.842	.830
1980	-	.146	.376	.548	.609	.617	.635	.672	.705	.781	.743	.785	.773	.775	.778
1981	.072	.114	.315	.523	.577	.643	.660	.674	.707	.723	.756	.772	.812	.780	.801
1962-81[1]	.056	.127	.220	.323	.395	.457	.512	.560	.602	.636	.663	.685	.788	.776	.803
1968-77[1]	.072	.116	.195	.277	.356	.427	.489	.542	.585	.621	.649	.654	.749	-	-
1978-81[1]	.072	.161	.312	.507	.554	.587	.620	.656	.696	.732	.741	.774	.798	.776	.803
1980-81[1]	.072	.130	.346	.536	.593	.630	.648	.673	.706	.752	.750	.779	.793	.778	.790

[1] Arithmetic mean

Table 6. Mean weight at age (kg) of the mackerel stock on 1 January in NAFO SA 2-6 during 1962-81.

Year	Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14+
1962-77	.096	.177	.267	.355	.436	.508	.569	.620	.662	.696	.723	.745	-	-
1978	.141	.228	.359	.409	.462	.543	.594	.634	.657	.681	.706	.789	.699	-
1979	.132	.217	.438	.495	.527	.564	.619	.686	.730	.754	.809	.799	.834	.824
1980	.115	.307	.480	.545	.566	.596	.638	.679	.759	.729	.775	.766	.770	.774
1981	.093	.276	.461	.514	.589	.620	.645	.684	.706	.742	.762	.804	.774	.797
1980-81[1]	.104	.292	.471	.530	.578	.608	.642	.682	.733	.736	.769	.785	.772	.786
1962-81[1]	.101	.193	.301	.382	.456	.523	.580	.630	.672	.703	.734	.781	.769	.798

[1] Arithmetic mean

Table 7. Stratified mean catch (kg) per tow of mackerel from NMFS, NEFC bottom trawl surveys in the spring (strata 1-25, 61-76) and autumn (strata 1-42, 49). See Figure 2 for location of sampling strata.

Year	Spring[1]	Autumn[2]
1963	-	.02
1964	-	<.01
1965	-	.03
1966	-	.04
1967	-	.15
1968	4.00	.10
1969	.06	.19
1970	2.04	.05
1971	1.97	.04
1972	1.33	.11
1973	.75	.05
1974	.77	.05
1975	.26	.01
1976	.32	.04
1977	.20	.04
1978	.45	.10
1979	.22	.06
1980	.35	.06
1981	1.84	.02
1982	.88	.13

[1]Based on catches with No. 41 trawl; 1968-72 and 1982 catches were with No. 36 trawl and were adjusted to equivalent No. 41 catches using a 3.25:1 ratio (No. 41: No. 36).
[2]Based on catches with No. 36 trawl.

Table 8. Mackerel catch per standardized US day fished in NAFO SA 5-6.

Year	Catch per day (tons)
1964	.43
1965	.49
1966	.84
1967	1.75
1968	2.80
1969	1.92
1970	2.07
1971	1.29
1972	.84
1973	.53
1974	.17
1975	.53
1976	.59
1977	.52
1978	.48
1979	.69
1980	1.42
1981	1.09

Table 9. Data used in estimating fishing mortality (F) in 1981 for the NAFO SA 2-6 mackerel fishery. Catch per day, international catch, fishing effort, and F values apply to age 3 and older fish.

Year	US std. catch per day (tons)	International catch (thousands of tons)	Fishing effort[1] (thousands of tons)	F[2]
1964	.36	14.8	41.0	.064
1965	.45	18.6	41.6	.081
1966	.67	21.3	31.9	.085
1967	1.50	33.0	22.0	.146
1968	1.67	52.8	31.6	.169
1969	1.16	87.7	75.5	.159
1970	1.81	216.0	119.2	.214
1971	1.09	328.2	301.9	.309
1972	.80	404.4	506.1	.361
1973	.44	358.4	812.7	.509
1974	(.44)[3]	290.5	655.8	.559
1975	.32	177.5	553.0	.519
1976	.44	185.3	417.3	.740
1977	.48	72.7	150.5	.291
1978	.43	34.3	79.8	.112
1979	.65	35.7	55.1	.130
1980	.57	26.1	45.8	.114
1981	.42	29.0	69.4	(.154)[4]

[1]Expressed as equivalent US standardized days fished.

[2]Weighted mean fishing mortality for ages 3 and older obtained from virtual population analysis assuming F = 0.154 at ages 4 and older in 1981.

[3]Actual value of 0.14 replaced by 0.44 (see text for explanation).

[4]Predicted from regression of fishing effort (f) on F for 1964-79:

$$\ln F = -4.200 + 0.549 \ln f, \; r = 0.893.$$

Table 10. Fishing mortality (F) and stock size (millions of fish) by age and year for mackerel in NAFO SA 2-6 derived from virtual population analysis assuming M = 0.20 at all ages and F = 0.154 at ages 4 and older in 1981.

Fishing mortality

Year	Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14+	Mean[1]
1962	.054	.011	.042	.142	.062	.087	.069	.146	.188	.050	.054	-	-	-	.054
1963	.007	.018	.007	.094	.346	.020	.014	.013	.049	.065	.065	-	-	-	.065
1964	.074	.054	.022	.025	.093	.422	.377	.062	.064	.064	-	-	-	-	.064
1965	.036	.027	.028	.026	.041	.127	1.051	.843	.081	-	-	-	-	-	.081
1966	.035	.059	.050	.032	.039	.080	.205	.320	.085	-	-	-	-	-	.085
1967	<.001	.049	.137	.042	.052	.054	.082	.527	.324	-	-	-	-	-	.146
1968	.032	.043	.146	.422	.240	.139	.009	.017	.176	.169	-	-	-	-	.169
1969	.004	.077	.152	.239	.102	.072	.057	.052	.048	.383	-	-	-	-	.159
1970	.100	.040	.215	.227	.149	.174	.176	.434	.237	.109	.214	-	-	-	.214
1971	.074	.218	.122	.374	.490	.282	.350	.174	.341	.307	.309	-	-	-	.309
1972	.019	.113	.299	.258	.489	.404	.322	.277	.744	.574	.361	-	-	-	.361
1973	.187	.364	.658	.489	.473	.493	.245	.240	.476	.976	.509	-	-	-	.509
1974	.074	.468	.688	.521	.474	.561	.556	.328	.214	.603	.559	-	-	-	.559
1975	.321	.538	.420	.619	.655	.577	.556	.552	.262	.111	.519	-	-	-	.519
1976	.057	.573	.793	.651	.784	.746	.836	.920	.515	.496	.091	-	-	-	.740
1977	.042	.168	.316	.349	.172	.324	.328	.288	.229	.142	.018	.025	-	-	.291
1978	.004	.005	.040	.082	.135	.175	.251	.207	.345	.133	.270	.045	.065	-	.112
1979	(.001)[2]	.028	.043	.078	.118	.191	.189	.214	.328	.282	.072	.161	.048	.130	.130
1980	(.007)[2]	(.037)[2]	.066	.047	.102	.121	.099	.090	.145	.300	.476	.096	.210	.114	.114
1981	(.019)[2]	(.032)[2]	(.037)[2]	.154	.154	.154	.154	.154	.154	.154	.154	.154	.154	.154	.154

Stock size

Year	Age 1	2	3	4	5	6	7	8	9	10	11	12	13	14+	Age 1+ Numbers	Age 1+ Weight[4]	Spawning stock Numbers	Spawning stock Weight[4]
1962	399.1	273.0	410.8	31.7	22.0	21.3	23.1	6.5	2.6	2.2	6.3	-	-	-	1138.6	247.2	663.0	190.5
1963	180.4	263.2	221.0	322.6	22.5	17.0	16.0	17.6	4.6	1.7	1.7	-	-	-	1068.3	281.4	756.3	240.8
1964	198.4	146.9	211.7	180.0	240.4	13.0	13.6	12.9	14.3	3.6	-	-	-	-	1034.8	304.6	763.0	272.6
1965	278.7	150.8	113.9	169.6	143.8	179.4	7.0	7.6	9.9	-	-	-	-	-	1060.8	313.2	706.7	273.1
1966	779.7	220.0	120.2	90.7	135.3	113.1	129.3	2.0	2.7	-	-	-	-	-	1593.0	371.1	703.3	276.8
1967	1919.3	616.9	169.8	93.7	71.9	106.5	85.4	86.2	1.2	-	-	-	-	-	3150.9	560.3	923.2	321.5
1968	4939.0	1597.6	481.0	121.2	73.5	55.9	82.6	64.5	41.7	0.7	-	-	-	-	7457.6	1103.9	1719.8	488.4
1969	1896.0	3917.2	1252.8	340.4	65.0	47.3	39.8	67.1	51.9	28.6	-	-	-	-	7706.0	1501.6	3851.4	972.9
1970	2231.7	1548.1	2970.5	880.8	219.5	48.1	36.1	30.8	52.1	40.5	16.0	-	-	-	8074.1	1828.1	5068.4	1476.8
1971	1159.9	1652.7	1218.3	1962.1	574.6	154.8	33.1	24.8	16.3	33.7	29.7	-	-	-	6860.0	1844.8	4873.8	1587.2
1972	1268.1	882.5	1088.3	882.7	1104.7	288.1	95.7	19.1	17.0	9.5	20.3	-	-	-	5675.9	1608.7	3966.6	1408.9
1973	1043.9	1018.5	645.3	660.8	558.4	554.6	157.5	56.8	11.9	6.6	4.4	-	-	-	4718.7	1353.0	3165.6	1162.6
1974	1490.5	709.0	579.6	273.6	331.7	284.8	277.4	100.9	36.6	6.0	2.0	-	-	-	4092.1	1060.0	2247.1	854.2
1975	1492.0	1133.9	363.4	238.4	133.1	169.1	133.1	130.2	59.5	24.2	2.7	-	-	-	3879.6	884.2	1820.7	640.6
1976	248.5	885.8	542.1	195.5	105.1	56.6	77.8	62.5	61.4	37.5	17.7	-	-	-	2290.5	631.9	1599.1	529.7
1977	53.1	192.2	408.9	200.9	83.5	39.3	22.0	27.6	20.4	30.0	18.7	13.2	-	-	1109.7	363.4	960.5	341.3
1978	29.4	41.7	133.0	244.0	116.0	57.5	23.3	13.0	16.9	13.3	21.3	15.0	10.6	-	735.0	322.5	684.8	313.6
1979	(400.0)[5]	24.0	34.0	104.7	184.1	83.0	39.5	14.8	8.6	9.8	9.5	13.3	11.8	8.1	945.2	351.7	533.2	296.3
1980	(200.0)[5]	327.1	19.1	26.6	79.3	134.0	56.1	26.8	9.8	5.1	6.1	7.3	9.3	9.2	915.8	361.6	552.3	288.4
1981	(600.0)[5]	162.7	258.0	14.7	20.8	58.6	97.2	41.6	20.0	6.9	3.1	3.1	5.4	6.2	1298.3	400.1	617.0	321.9
1982	(400.0)[5]	482.1	129.0	203.6	10.3	14.6	41.1	68.2	29.2	14.0	4.8	2.2	2.2	3.8	1405.1	480.6	764.1	368.6

[1]Weighted mean F at ages 3 and older, ages 4 and older in 1981.

[2]Determined from estimated stock size and known catch.

[3]50% age 2 and 100% age 3 and older.

[4]Thousands of tons.

[5]Predicted.

Table 11. Stratified mean catch (numbers) per tow of age 0, 1, and 2 mackerel from NMFS, NEFC autumn and spring bottom trawl surveys, survey values adjusted to equivalent age 1 values on 1 January (see text for explanation), the geometric mean of the adjusted values, and year-class size at age 1 (millions of fish) from virtual population analysis (VPA) assuming F = 0.154 at ages 4 and older in 1981.

Year class	Mean catch per tow: Autumn age 0	Mean catch per tow: Spring age 1	Mean catch per tow: Spring age 2	Adjusted mean catch per tow: Autumn age 0	Adjusted mean catch per tow: Spring age 1	Adjusted mean catch per tow: Spring age 2	Adjusted mean catch per tow: Geometric mean	VPA age 1
1963	.053	-	-	.491	-	-	.491	198.4
1964	.009	-	-	.085	-	-	.085	278.7
1965	.055	-	-	.500	-	-	.500	779.7
1966	.088	-	1.726	.802	-	1.786	1.197	1919.5
1967	.619	40.240	.198	5.689	42.292	.214	3.720	4939.0
1968	.039	.238	2.625	.358	.249	2.761	.627	1896.0
1969	.289	1.010	2.779	2.632	1.093	3.429	2.145	2231.7
1970	.023	.929	1.368	.208	1.004	1.605	.695	1159.9
1971	.068	1.894	.787	.613	2.008	.965	1.059	1268.1
1972	.076	.915	.383	.689	1.043	.623	.765	1043.9
1973	.236	.826	1.277	2.142	.908	1.944	1.558	1490.5
1974	.089	3.136	.787	.802	4.043	1.670	1.756	1492.0
1975	.009	.204	.109	.085	.224	.135	.137	248.5
1976	.012	.021	.221	.113	.023	.241	.086	53.1
1977	.045	.128	.009	.415	.136	.010	.083	29.4
1978	.264	.029	.406	2.387	.031	.423	.315	(412.5)[1]
1979	.028	.066	.243	.255	.070	.258	.166	(224.2)[1]
1980	.036	.647	.424	.330	.691	.451	.469	(606.6)[1]
1981	.013	.799	-	.123	.845	-	.322	(421.1)[1]
1982	.108	-	-	.972	-	-	.972	(1241.3)[1]

[1]Predicted from functional (geometric mean) regression between geometric mean of adjusted mean catch per tow and year-class size for the 1963-77 year classes: Y = 14.781 + 1261.841 X, r = 0.937.

Table 12. Percentage of fishing mortality (F) at ages 1-6 compared to the weighted mean F at ages 3 and older (ages 4 and older in 1981) for the mackerel fishery in NAFO SA 2-6 during 1968-81.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
1968	19	25	86	250	142	82
1969	3	48	96	150	64	45
1970	47	19	101	106	70	31
1971	24	71	39	121	159	91
1972	5	31	83	71	136	112
1973	37	72	129	96	93	97
1974	13	84	123	93	85	100
1975	62	104	81	119	126	111
1976	8	77	107	88	106	101
1977	14	58	109	120	59	111
1978	4	4	36	73	120	156
1979	1	22	33	60	91	147
1980	6	32	38	41	89	106
1981	12	21	24	100	100	100
1968-77[1]	16	52	91	114	98	90
1978-81[1]	4	16	36	65	99	125
1968-81[1]	11	37	70	97	99	99

[1]Geometric mean

Table 13. Various levels of projected catch of mackerel in 1983 in NAFO SA 2-6 and associated fishing mortality (F) at fully-recruited ages, with resulting spawning stock biomass in 1984 and the percentage change from 1983. These projections assume a 1982 catch of 25,000 tons (F = 0.108). Catch and stock biomass are expressed as thousands of tons.

Spawning stock in 1983	Catch in 1983	F in 1983	Spawning stock in 1984	% change in stock from 1983
472.0	20.0	.069	531.0	+12.5
472.0	25.0	.086	526.5	+11.5
472.0	30.0	.104	521.9	+10.6
472.0	31.1	.108[1]	520.9	+10.4
472.0	35.0	.122	517.4	+ 9.6
472.0	40.0	.141	512.9	+ 8.7
472.0	45.0	.159	508.4	+ 7.7
472.0	50.0	.178	503.9	+ 6.8
472.0	70.7	.260[2]	485.2	+ 2.3
472.0	75.7	.280[3]	480.7	+ 1.8
472.0	103.8	.400[4]	455.3	- 3.5

[1] Level of F projected for 1982.

[2] $F_{0.1}$ applicable to average 1968-77 conditions.

[3] $F_{0.1}$ applicable to average 1962-81 conditions.

[4] $F_{0.1}$ applicable to average 1978-81 (current) conditions.

Table 14. Comparison of estimates of total and spawning stock biomass of mackerel (thousands of tons), year-class size at age 1 (millions of fish), and mean fishing mortality (F) obtained with natural mortality (M) of 0.3 and 0.2.

	Total stock biomass			Spawning stock biomass			Year-class size at age 1			Mean F		
Year	M = 0.3	M = 0.2	% change	M = 0.3	M = 0.2	% change	M = 0.3	M = 0.2	% change	M = 0.3	M = 0.2	% change
1962	560.1	247.2	-56	397.4	190.5	-52	953.9	339.1	-64	.029	.054	+ 86
1963	608.2	231.4	-54	507.0	240.8	-53	415.3	180.4	-57	.032	.065	+103
1964	621.2	304.6	-51	555.0	272.6	-51	405.7	198.4	-51	.031	.064	+106
1965	599.6	313.2	-48	524.9	273.1	-48	511.4	278.7	-46	.041	.081	+ 98
1966	714.6	371.1	-48	498.1	276.8	-44	1913.3	779.7	-59	.048	.085	+ 77
1967	1066.3	560.3	-47	572.2	321.5	-44	3858.8	1919.3	-50	.088	.146	+ 66
1968	1907.3	1103.9	-42	875.8	488.4	-44	8097.0	4939.0	-39	.092	.169	+ 84
1969	2424.0	1501.6	-38	1585.2	972.9	-39	3317.7	1896.0	-43	.094	.159	+ 69
1970	2751.3	1828.1	-34	2217.4	1476.8	-33	3292.6	2231.7	-32	.148	.214	+ 45
1971	2643.4	1844.8	-30	2280.8	1587.2	-30	1681.4	1159.9	-31	.215	.309	+ 44
1972	2256.9	1608.7	-29	1978.8	1408.9	-29	1807.3	1268.1	-30	.260	.361	+ 39
1973	1870.9	1353.0	-28	1601.2	1162.6	-27	1592.0	1043.9	-34	.373	.509	+ 36
1974	1508.5	1060.0	-30	1199.1	854.2	-29	2263.0	1490.5	-34	.402	.559	+ 39
1975	1320.9	884.2	-33	945.6	640.6	-32	2439.7	1492.0	-39	.342	.519	+ 52
1976	1029.6	631.9	-39	841.7	529.7	-37	585.4	248.5	-58	.439	.740	+ 69
1977	711.1	363.4	-49	660.9	341.3	-48	133.2	53.1	-60	.148	.291	+ 97
1978	655.8	322.5	-51	635.2	313.6	-51	67.7	29.4	-57	.056	.112	+100
1979	676.5	351.7	-48	578.6	296.3	-49	700.0	400.0	-43	.067	.130	+ 94
1980	653.8	361.6	-45	528.2	288.4	-45	400.0	200.0	-50	.062	.114	+ 84
1981	680.9	400.1	-41	537.8	321.9	-40	1100.0	600.0	-45	.087	.154	+ 77
1982	777.9	480.6	-38	587.4	368.6	-37	700.0	400.0	-43	.070	.108	+ 54
1983	854.8	561.1	-34	706.6	472.0	-33	700.0	400.0	-43	-	-	-
Geometric mean			-41			-40			-45			+ 68

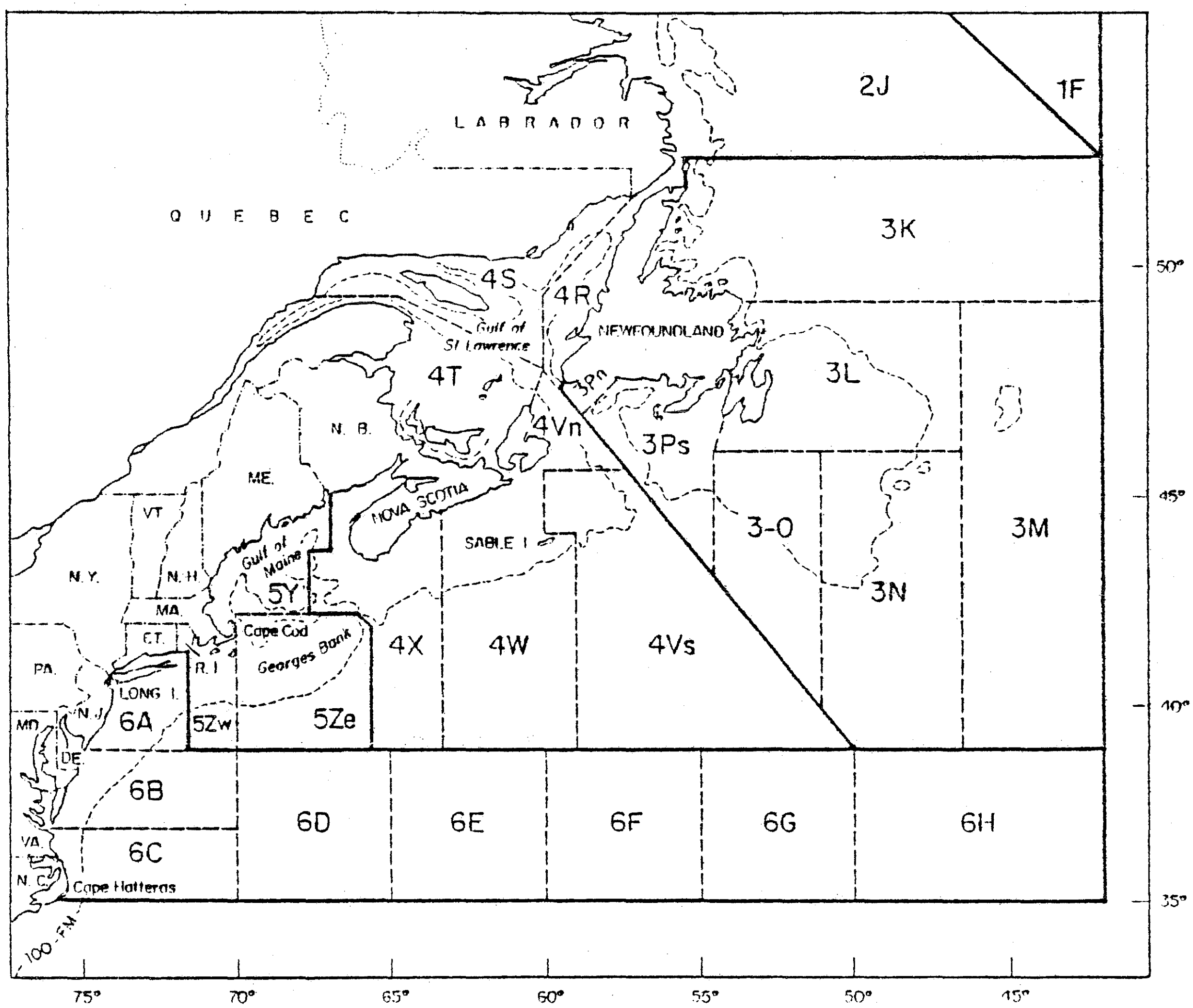

Figure 1. Northwest Atlantic from Labrador to North Carolina showing NAFO SA 2-6.

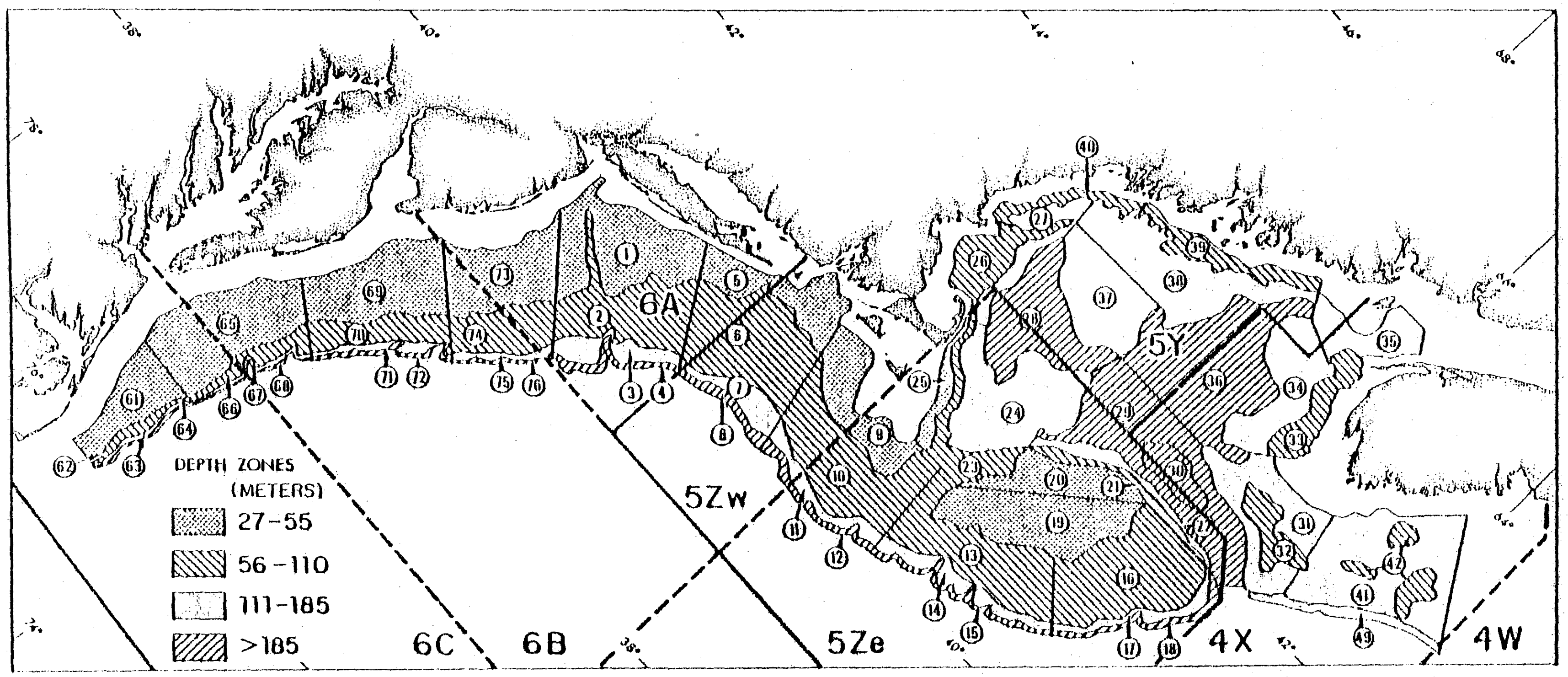

Figure 2. NMFS, NEFC bottom trawl survey sampling strata in the Northwest Atlantic between Cape Hatteras and Nova Scotia.

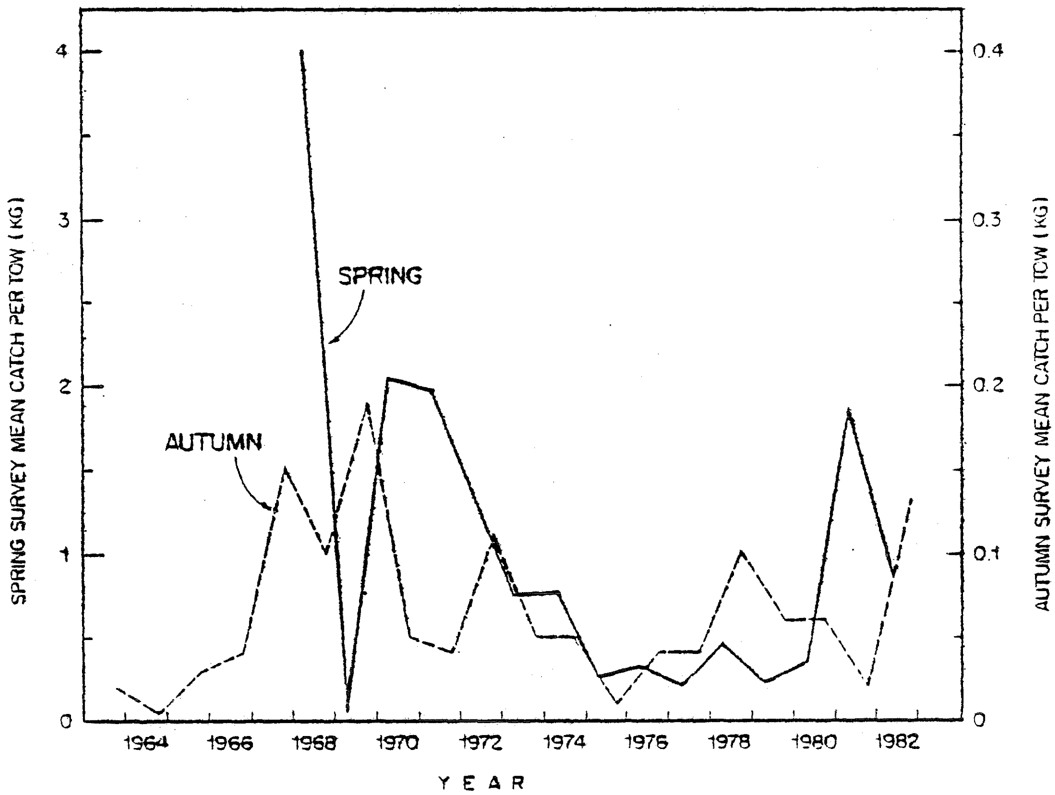

Figure 3. Mean catch per tow (kg) of mackerel from NMFS, NEFC spring (1968-82) and autumn (1963-82) bottom trawl surveys in NAFO SA 4-6.

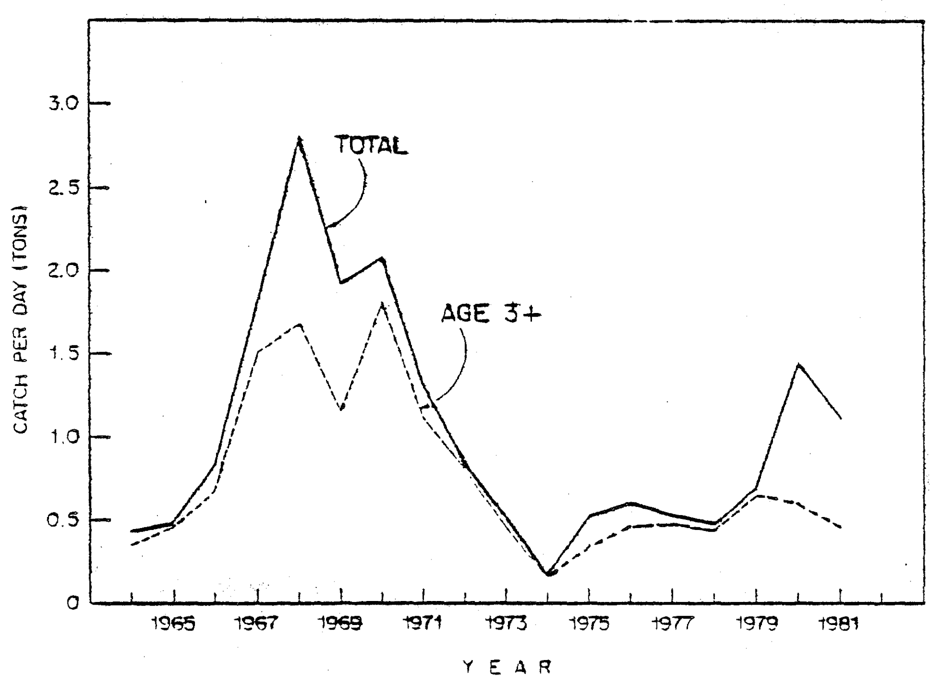

Figure 4. Catch per standardized day fished for (1) all ages (total), and (2) ages 3 and older in the US commercial mackerel fishery in NAFO SA 5-6.

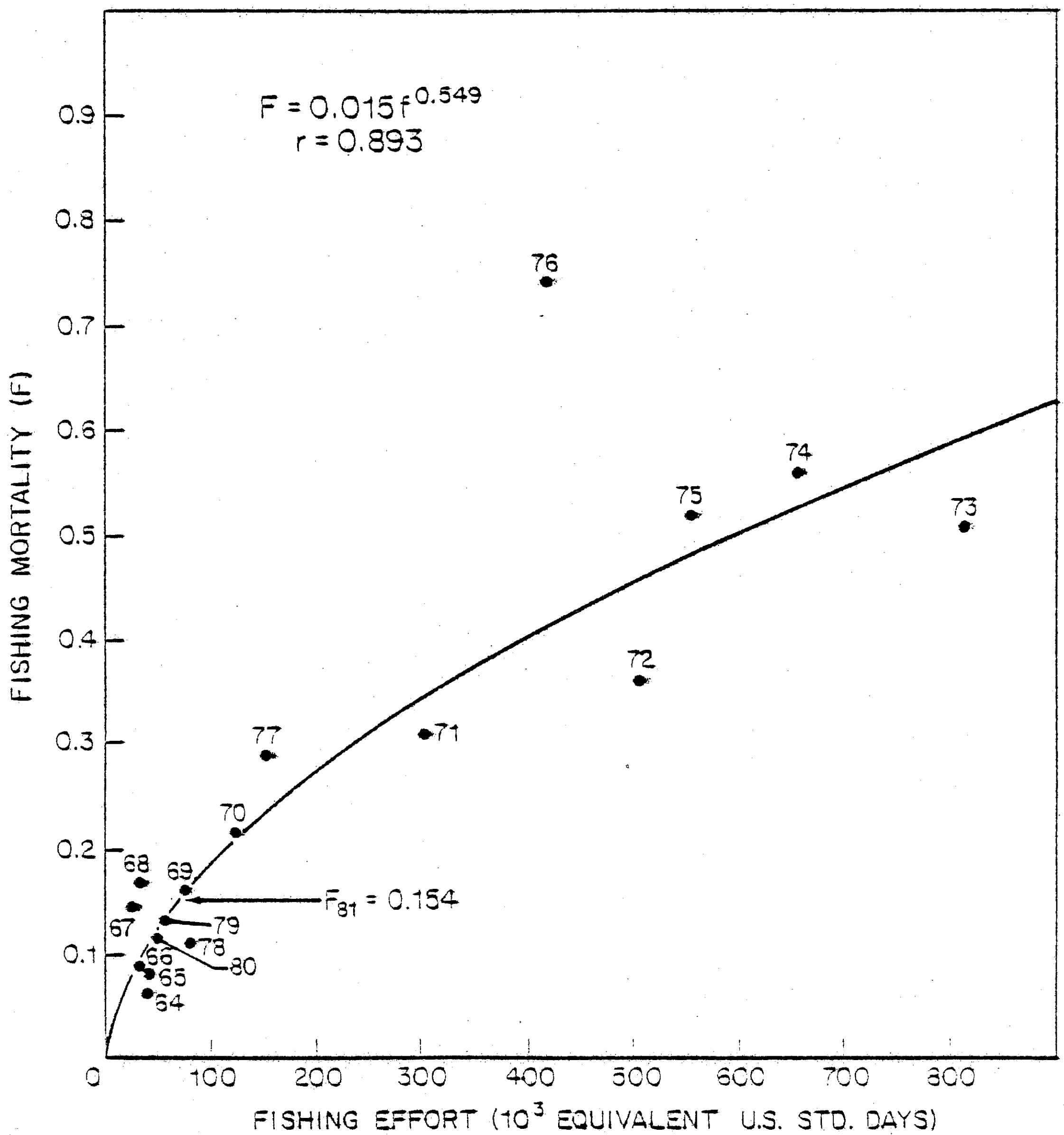

Figure 5. Relationship between mean fishing mortality for age 3 and older mackerel from VPA assuming F = 0.154 at ages 4 and older in 1981 (M = 0.20) and fishing effort directed towards ages 3 and older expressed as equivalent US standardized days fished.

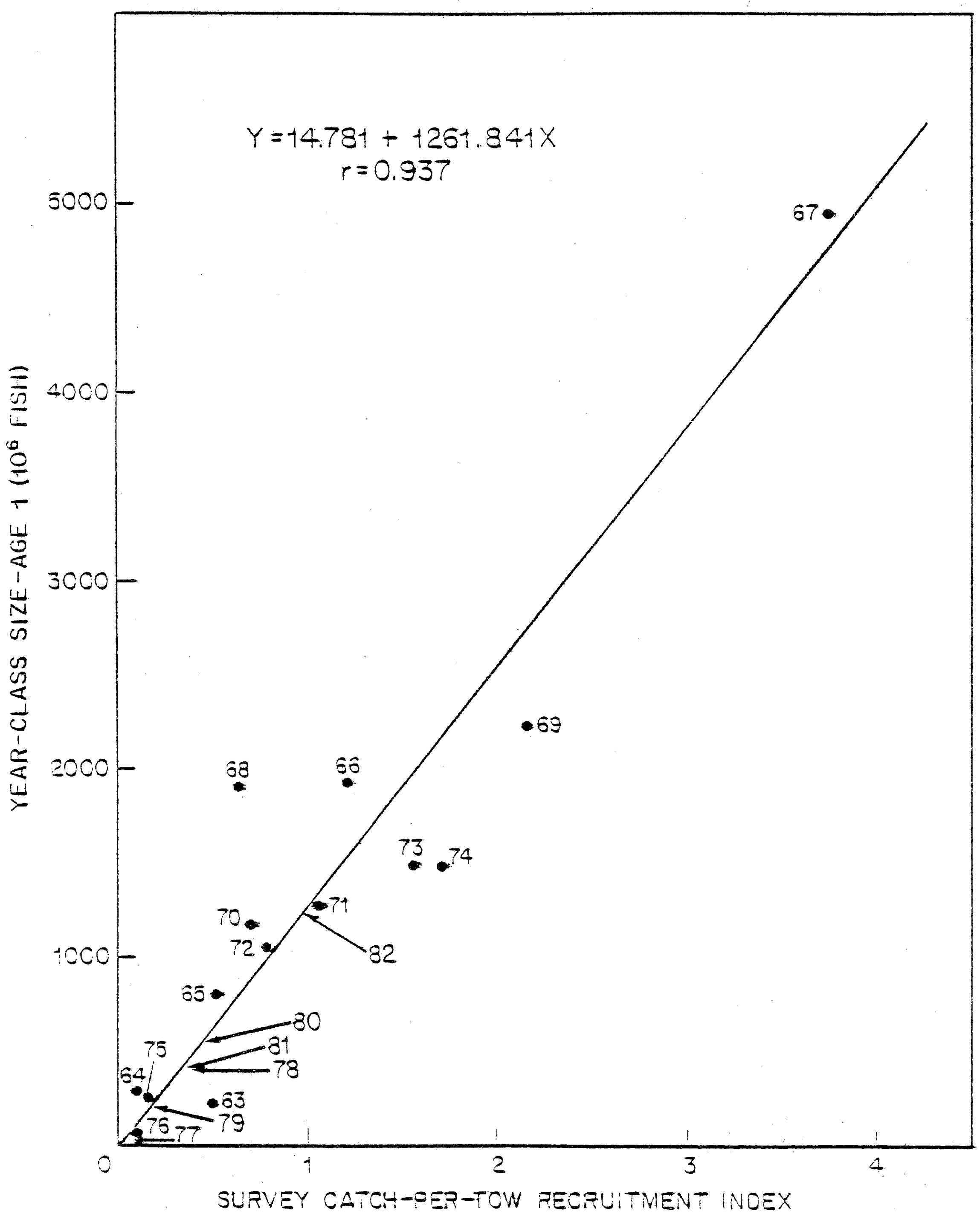

Figure 6. Relationship between mackerel year-class size at age 1 from VPA assuming F = 0.154 at ages 4 and older in 1981 (M = 0.20) and a catch-per-tow recruitment index from NMFS, NEFC autumn and spring bottom trawl surveys in NAFO SA 4-6.

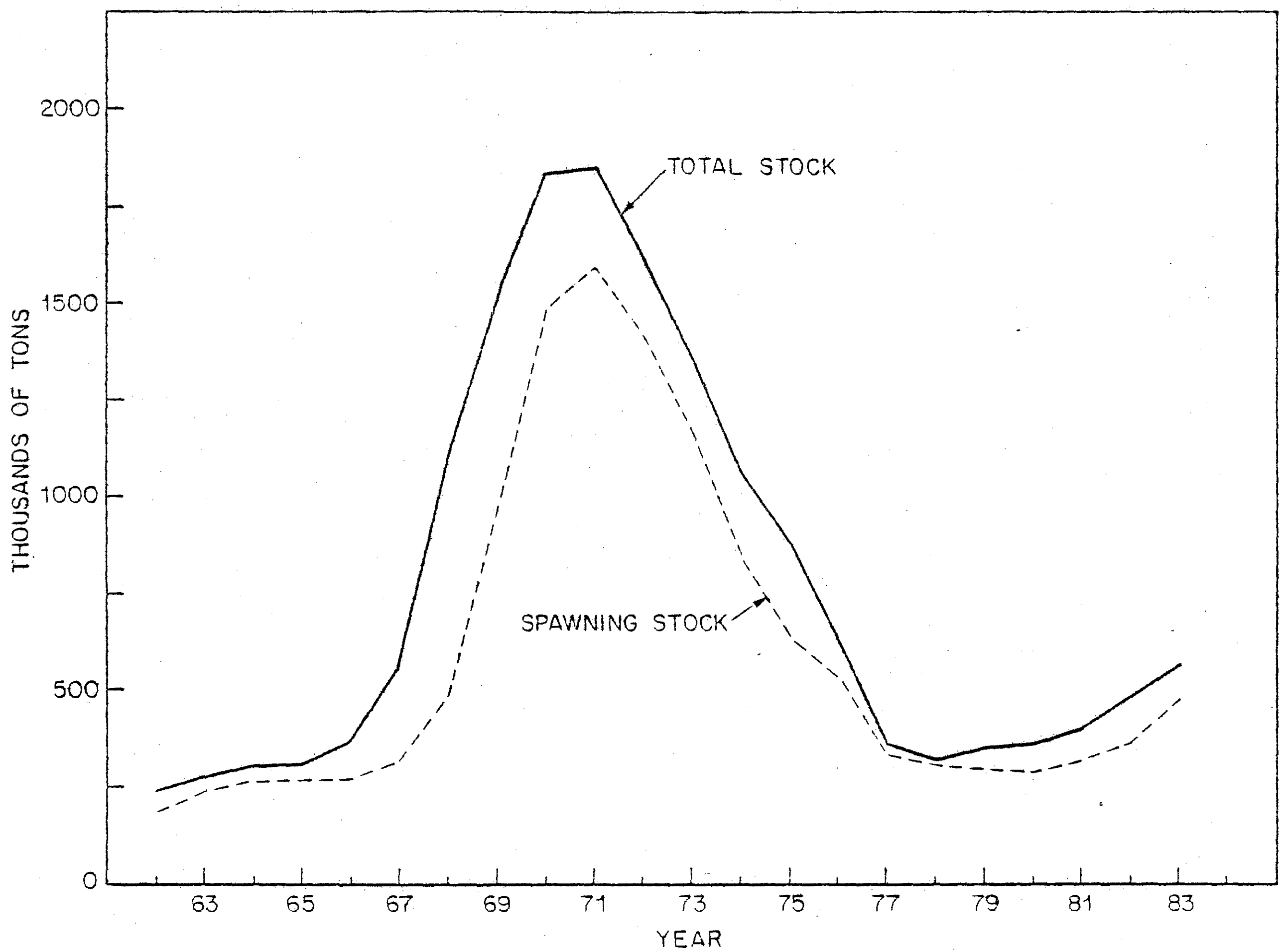

Figure 7. Total stock biomass (ages 1 and older) and spawning stock biomass (50% age 2 and 100% ages 3 and older) of mackerel in NAFO SA 2-6 during 1962-83 estimated from VPA and biomass projections.

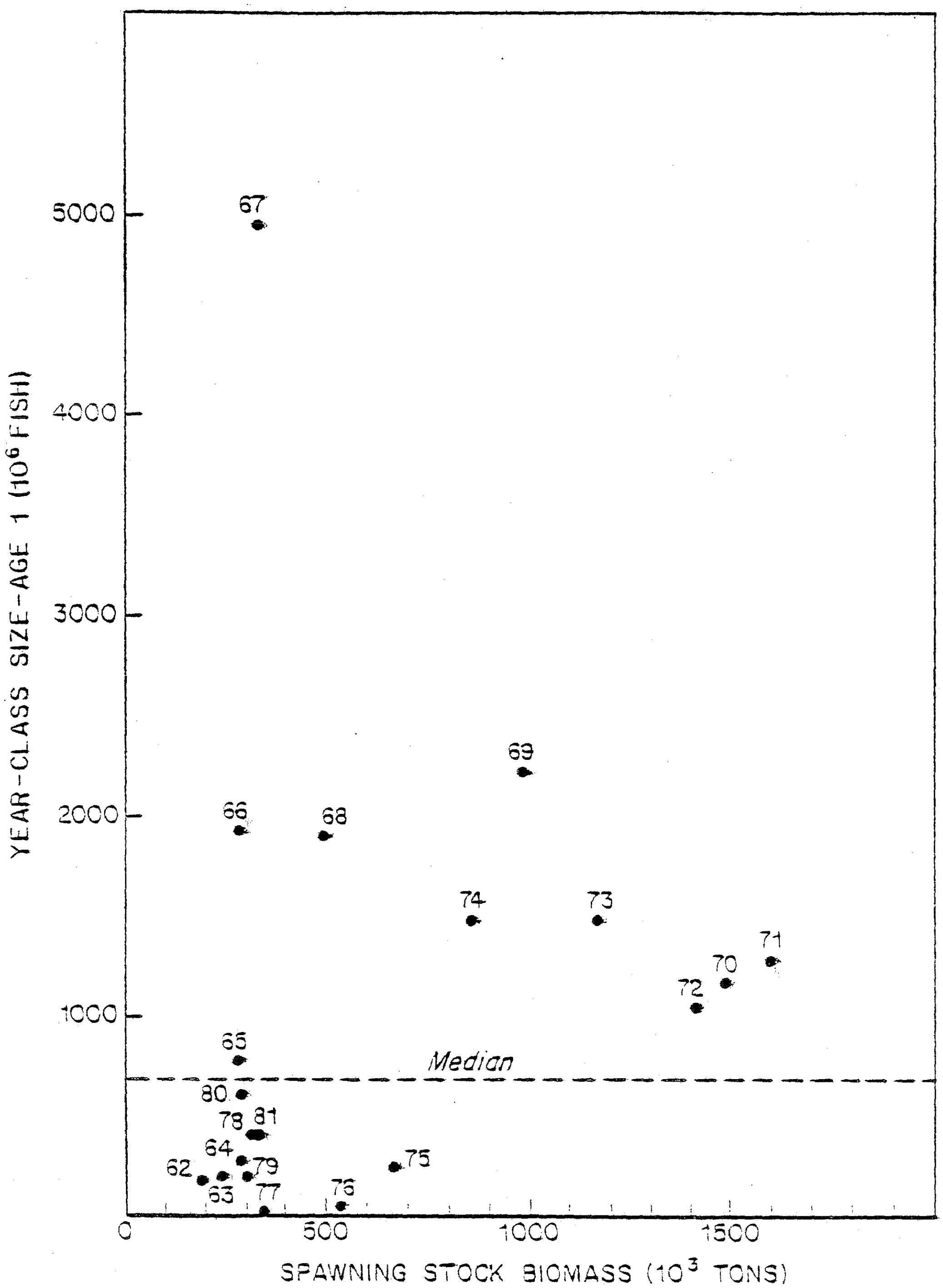

Figure 8. Relationship between mackerel year-class size at age 1 and the parental spawning stock biomass during 1962-81 in NAFO SA 2-6.