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Relative abundance of Atlantic mackerel off the northeastern coast of the United States

by

E. D. Anderson
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543

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Abstract

The historical mackerel fishery off the northeastern US coast (ICNAF Subarea 5 and Statistical Area 6) from 1804 to 1973 was reviewed. A US commercial fishery standardized catch per effort index for 1964-1973, a distant water fleet standardized catch per effort index for 1968-1973, and US spring (1968-1974) and autumn (1963-1974) research vessel survey abundance indices were presented to describe recent changes in mackerel stock abundance. Results of analyses on the catch per effort data from the distant water fleet vessel classes suggested that both learning and technological improvements occurred in those fleets during the recent expansion of the mackerel fishery. The recent development of the fishery was characterized by a large increase in fishing effort and catch and a marked decline in stock abundance which was documented by four separate measures of catch per effort. It is not likely that the stock can support increases in catch without further increases in fishing mortality and a decrease in size until more abundant year-classes are recruited.

Introduction

The international commercial catch of Atlantic mackerel (*Scomber scombrus*) off the northeastern coast of the United States (ICNAF Subarea 5 and Statistical Area 6) (Figure 1) increased from 1,049 metric tons (MT) in 1962 to 387,364 MT in 1972. The mackerel fishery was confined to small catches by US vessels just prior to the arrival of distant water fleets in the early 1960's, but a heavy fishery had been conducted during most of the 1800's with a maximum catch of 81,300 MT in 1884 (Sette and Needler, 1934). Intensive fisheries were begun by the USSR in 1967, Poland in 1968, and the German Democratic Republic (GDR) and Bulgaria in 1971. A total of 12 different nations reported mackerel landings in 1972-1973. The population has contained two strong year-classes, 1967 and 1966, which provided a major portion of the recent increased landings (ICNAF, 1974). Total allowable catches with national allocations were established by ICNAF for mackerel in SA 5-6 at 450,000 MT for 1973, 304,000 MT for 1974, and 285,000 MT for 1975. This paper describes recent changes in stock abundance based on various independent measures of catch-per-unit-effort and draws inferences about future potential yields.

Historical fishery

Atlantic mackerel have been harvested off the northeastern US shores since the 1600's. Landings from 1804 (the first year statistics were available) to 1965 underwent considerable fluctuation (Hoy and Clark, 1967) in response to the interaction of a number of factors including changing economic conditions, improvement in fishing methods, shifting of the fishery from one region to another, and natural fluctuations in abundance (Sette and Needler, 1934) (Figure 2). During the period 1804-1818 catches were low averaging only 3,100 MT due to the fishery being restricted to coastal areas. Catches then increased sharply as a result of the expansion of the fishery to offshore waters and the development of a large salt mackerel industry. From 1819 to 1885 catches averaged 41,700 MT but fluctuated widely from 10,500 MT in 1840 to 81,300 MT in 1884. Fishing methods during the latter part of this period changed from the traditional hook and line to purse seines. Catches declined during 1886-1924 and averaged only 9,300 MT. During this time vessels switched from sail to motor power and a fresh mackerel market developed. Catches increased again to average 23,500 MT per year in 1925-1949, but dropped during 1950-1964 to average only 1,500 MT. International landings after 1964 virtually doubled each year (114% average annual increase) until 1970 (Table 1, Figure 3). They increased from 209,622 MT in 1970 to 348,744 MT in 1971 (66% increase) to 387,364 MT in 1972 (11% increase), and then decreased slightly to 381,164 MT in 1973.

Landings by the USSR exceeded those of any other nation from 1965 to 1971 (Table 1) but decreased from 79% of the total in 1967 to 37% in 1971. Poland reported the largest catch in 1972 (141,999 MT) while the USSR, GDR, and Bulgaria landed 134,057, 80,537, and 23,556 MT, respectively. The USSR catch increased to 145,796 MT in 1973 while Polish landings decreased to 117,254 MT. GDR and Bulgaria landed 76,758 and 31,743 MT, respectively, in 1973 with six other nations contributing the remaining 9,613 MT.

Subarea 5 provided 52-89% of the total landings from the combined area during 1961-1970. Statistical Area 6 produced 67% in 1971, whereas landings in 1972 were nearly the same from the two areas (SA 5 - 52%, SA 6 - 48%). However, Subarea 5 landings increased to 83% of the total in 1973.

US commercial landings of mackerel increased each year from 938 MT in 1962 to 4,364 MT in 1969 and then declined each year thereafter to only 1,336 MT in 1973. A substantial US sport fishery for mackerel exists from Maine to North Carolina. Since yearly sport fishery catches are not known, they are not included in the US landings shown in Table 1. Angler surveys conducted at 5-year intervals beginning in 1960 estimated the 1960, 1965, and 1970 mackerel catch to be 4,957, 8,583, and 32,078 MT, respectively (Clark, 1962; Deuel and Clark, 1968; Deuel, 1973). The 1970 sport catch constituted 13% of that year's total landings from the stock (32,078 + 209,622 MT). Even though current assessment studies have not included the ever-increasing sport fishery catches, it would appear that their magnitude necessitates such in future analyses.

US commercial fishery abundance index

Data

Catch and effort statistics from a variety of gear types fished by US vessels landing in New England ports during 1964-1973 were used to calculate annual standardized catch per effort. The catch-per-unit-effort is limited as an index of population size because the US fishery is conducted only in inshore waters whereas the bulk of the international catch is taken by distant water fleets which operate farther offshore. Furthermore, the landings used in the analysis varied from 46.1% of the international total at the start to only 0.1% in the latest years (Table 2). Catch and effort statistics from only those individual vessel trips in which mackerel landings comprised 50% or more of the total were included in the analysis. The effort unit used was a day fished. The proportion of the total US landings taken by such trips ranged from 15.3% in 1972 to 63.7% in 1964 (Table 2) and averaged 38.6% annually for the 10-year period.

Standardization of fishing effort

Types of gear used in the US fishery to catch mackerel included hand line, otter trawl, floating trap, sink gill net, drift gill net, purse seine, pound net, and midwater pair trawl. Pound nets, floating traps, and purse seines have accounted for the largest amount landed. Total annual fishing effort by all the various types of gear was standardized by the use of effort standardization coefficients which were computed using a two-factor analysis of variance procedure proposed by Robson (1966) /method summarized by Brown *et al.* (1975)/. The two factors used in the analysis of variance were gear type and vessel tonnage class. Gear types included the eight listed earlier and tonnage classes included 0-50, 51-150, and 151-630 gross tons. A separate analysis was performed for each year with data from a single trip constituting one observation. Effort standardization coefficients were computed for each gear-tonnage class in relation to a standard gear-tonnage class. The floating trap, 0-50 ton class was selected as the standard because it (1) contained observations in all years (Table 3), (2) contained a larger number of observations in all years than other categories also meeting the first criterion (Table 3), and (3) provided greater landings than other categories satisfying the previous criteria (Table 2).

Results

The analysis of variance indicated that gear differences in each of the ten years and tonnage class differences in six of the years were significant at the 0.05 probability level. A significant gear-tonnage class interaction was apparent in only one year and the interaction term was ignored in the analysis.

Effort standardization coefficients are given in Table 3. Coefficients were greatest for purse seines followed by midwater pair trawls, otter trawls, pound nets, floating traps, drift gill nets, and hand lines. Values for individual gear types increased with tonnage class. Coefficients for some categories were generally consistent over years whereas others exhibited considerable variation. Some of the larger deviations were associated with a small number of trips producing small landings.

Landings per standardized US day fished was determined for each year by multiplying the days fished used in the analysis for each gear-tonnage class category by the appropriate effort standardization coefficient and dividing the sum of the products into the summed annual US landings used in the analysis. Total international effort expressed as standardized US days fished was calculated by dividing the total international landings by the landings per standardized US day. Results are given in Table 10 and Figure 3.

Landings per standardized US day increased each year from 0.43 MT in 1964 to 2.80 MT in 1968. The index dropped to 1.92 MT in 1969, increased to 2.07 MT in 1970 and then declined steadily to 0.53 MT in 1973. Total international effort expressed as standardized US days fished increased exponentially from 5,281 days in 1964 to 719,177 days in 1973 at an average annual rate of 80%.

US research vessel survey abundance index

US *ALBATROSS IV* autumn and spring bottom trawl surveys (Grosslein, 1969) have been used to monitor fluctuations and trends in the relative abundance of demersal fish stocks as well as some semi-pelagic and pelagic stocks beginning in 1963 on Georges Bank and 1968 in SA 6. Data from the spring (March-April) surveys have provided evidence of the changes in population size of sea herring (*Clupea harengus*) (Schumacher and Anthony, 1972) which agrees well with other estimates based on fishery statistics. Spring surveys have produced greater mackerel catches than autumn (September-December) surveys since during the spring the fish occur in dense pre-spawning and spawning concentrations between Georges Bank and Cape Hatteras. The autumn catch per tow, in addition to being substantially less than that in the spring, also exhibits relatively greater statistical variance (Table 4). However, the autumn survey is of value in spite of these factors because it constitutes a longer series of observations (1963-1974) than the spring survey (1968-1974) and has depicted noticeable trends in abundance over the 12-year period (Figure 5).

The spring index was calculated from catches in sampling strata 1-14, 61-76 (Figure 4) and the autumn index from strata 1-2, 5-6, 9-10, 13, 16, 19-21, 23, 25-26. These strata sets comprise the areas where mackerel have consistently been caught during past surveys. The spring set includes all strata from the southwest part of Georges Bank to Cape Hatteras and the autumn set includes all strata 60 fathoms and less from Hudson Canyon to east of Cape Cod including Georges Bank.

The 1973 and 1974 spring surveys employed a modified Yankee No. 41 high-opening bottom trawl in place of the previously used Yankee No. 36 trawl. In order to maintain continuity with the 1968-1972 catch per tow series, the 1973 and 1974 station catches were adjusted to equivalent No. 36 catches utilizing a catch ratio of 3.25:1 between the No. 41 and No. 36 trawls (unpublished NMFS data).

Survey catches of mackerel have generally been highly variable due to the distributional characteristics of mackerel. During the 1968-1974 spring surveys, mackerel in amounts of 0.45 kg per tow or more were taken on the average in 23.6% of the tows in each survey in strata 1-14, 61-76 in which the average catch per tow was 11.8 kg (does not include an unusually large 5,176 kg catch in 1973). Daylight tows accounted for slightly more than half the total (55.4%) each spring, and on the average 26.8% of those tows yielded mackerel, whereas 19.5% of the tows during hours of darkness caught mackerel. For those tows producing mackerel, the kg per tow ratio between daylight and darkness averaged 4:1 over the 7-year period. The spring stratified mean catch per tow (in weight) exhibited a large standard deviation (Table 4) with coefficients of variation ranging from 31.1 to 95.7 and averaging 54.7. A $\log_e (x+1)$ transformation, where x is the individual tow catch, was used to normalize the distribution of individual catches which reduced the standard deviation of the mean to give coefficients of variation averaging 24.8%. Changes in stock abundance from year to year which are represented as ratios in mean catch per tow on a linear scale are expressed as differences on the $\log_e$ scale.

The spring abundance index ($\log_e$ scale) decreased from a high of 0.73 in 1968 to 0.25 in 1973 (Table 4, Figure 5). The extremely low value of 0.03 in 1969 is probably not indicative of actual abundance but rather that the mackerel were outside the survey area. Nearly all of the mackerel were caught during that survey in stratum 62 (Figure 4) off Cape Hatteras indicating that the inshore, northerly migration had just begun. Water temperatures did not appear to differ from those in adjacent years. Spring indices for other pelagic species (*e.g.* sea herring) did not exhibit a similar drop in 1969 suggesting that the survey trawl and operation functioned normally. The high 1968 value resulted primarily from age 1 fish (1967 year-class) which comprised 80-90% of the total survey catch. The index decreased from 0.42 in 1972 to 0.25 in 1973, a 17% decline in terms of weight per tow, but increased 6% to 0.31 in 1974. The overall decline from 1968 to 1974, in terms of weight per tow, was 42%.

The autumn $\log_e$ index improved from <0.01 in 1964 to 0.32 in 1967 and then underwent a decline to 0.11 in 1970. Following a slight decrease to 0.09 in 1971 and a small improvement back to 0.11 in 1972, the index diminished further to 0.06 in 1973 and remained at that level in 1974. The decrease in weight per tow from 1967 to 1973-1974 was 26%.

Distant water fleet abundance index

Data

Catch and effort statistics reported to ICNAF (FAO STANA 1W or STATLANT 21B forms) by Bulgaria, GDR, Poland, Romania, and the USSR for 1968-1973 were utilized to calculate annual standardized catch per effort. Otter trawl effort was examined by country, tonnage class (including several vessel classes for some countries), ICNAF division or subdivision, and month and was defined as directed towards mackerel if the mackerel catch reported within these categories exceeded that of any other species. All mackerel landed by Bulgaria, GDR, Poland, and Romania during 1968-1973 were taken entirely by otter trawls, whereas the USSR otter trawl catch averaged 97% during 1968-1972 but dropped to 75% in 1973. The remainder of the USSR mackerel catch was taken by purse seines with a small amount landed by pair trawls in 1970. Hours fished was used as the measure of fishing effort. The proportion of landings used in the analysis to calculate standardized catch per effort varied from 24.2% of the international total in 1968 to 85.9% in 1971 (Table 5) and averaged 66.5% annually for 1968-1973.

Standardization of fishing effort

Total annual fishing effort by the various otter trawler tonnage classes from the five countries was standardized by calculating effort standardization coefficients using the same analysis of variance procedure as cited earlier. Factors considered in the analysis were country and tonnage class as reported to ICNAF: 151-500, 501-900, 901-1800, and >1800 gross tons. A separate analysis was performed for each year. Data were generally available from several vessel classes within each tonnage class (Table 6). Monthly data by vessel class within tonnage class and by ICNAF division or subdivision constituted observations in the analysis of variance.

Effort standardization coefficients were computed for each country-tonnage class in relation to the USSR 151-500 ton class as a standard. This category contained observations in all years and produced the highest proportion of mackerel landings of any class in 1968 (74% - 10,690 MT), 1969 (51% - 28,240 MT), and 1970 (29% - 48,018 MT) (Table 5). Landings were 31,148 MT in 1971 and 31,544 MT in 1972, which amounted to 10% of the total in each year, but dropped to 6,249 MT (2%) in 1973. In 1973 only 35% of the USSR mackerel catch by 151-500 ton vessels (all gears) was taken by otter trawls, whereas during 1968-1972 otter trawls averaged 97% of the total. The remainder in 1973 was taken by purse seines. The percentage of mackerel in total otter trawl landings by this class rose from 15% in 1968 to 63% in 1970, averaged 53% in 1971-1972, and declined to 32% in 1973 (Table 7). The percentage of mackerel in total otter trawl landings from directed mackerel effort by this class varied from 49% in 1968 to 80% in 1970 and averaged 68% per year during 1968-1973 (Table 7). The above data suggest that this class was substantially involved in the mackerel fishery throughout the period and that the catch per effort by this class was a realistic measure of relative stock abundance. Further justification for using this class as the standard is given in the following section relative to the concept of learning.

Adjustment for learning

A directed mackerel fishery by distant water fleets commenced in 1968 in Subarea 5 and Statistical Area 6. The development of this fishery, as with any new fishery, logically required a period of learning by the participants to attain top fishing efficiency and, hence, for catch per effort to become commensurate with stock abundance. The learning process involves acquiring knowledge pertaining to the seasonal and areal distribution of the fish and expertise necessary to effectively catch the fish and is separate from technological improvements made to vessels to improve catches. Comparison of annual catch per effort of fishing vessels with an independent measure of stock abundance should define the magnitude and extent of such a learning period. In this paper learning was expressed in terms of increases in annual catch per effort which were independent of actual changes in stock abundance. The learning model used, taken from Brown *et al.* (1975), was

$$\ell_i = \frac{X_i}{Y_i}$$

where ℓ_i = learning achieved by a country-tonnage class in its i^{th} year in the fishery,
X_i = observed catch per effort by a country-tonnage class in its i^{th} year in the fishery, and
Y_i = predicted catch per effort by a country-tonnage class in its i^{th} year in the fishery assuming no learning.

Observed annual catch per effort was determined as the mean of the monthly landings per hour by vessel class within tonnage class by ICNAF division or subdivision (Table 8). Predicted catch per effort was calculated as

$$Y_i = \frac{Z_i}{Z_1} \times Y_1$$

where $i = 2,3,\ldots$ and

Z_i = the independent measure of stock abundance in the i^{th} year of the fishery.

Observed catch per effort in the first year of the fishery was used as the predicted catch per effort. The measure of stock abundance independent of catch per effort was provided by the stock size (MT)of age 1 and older fish as calculated by virtual population analysis by the *ad hoc* Mackerel Working Group of the Assessment Subcommittee at the 1974 ICNAF Annual Meeting (ICNAF, 1974). The first year in the fishery for each country-tonnage class was considered to be the first year for which there was directed mackerel effort.

Results of the application of the learning model to the distant water fleets are given in Table 8. Learning was assumed to cease if ℓ_i decreased from year i to year i+1. Learning for some of the country-tonnage classes decreased in the fourth year (USSR 151-500, GDR 501-900, and Bulgarian and USSR >1800) indicating that learning was completed by the third year in the fishery. The GDR 901-1800 and Romanian >1800 ton classes showed learning to be completed by the second year. The Polish and USSR 501-900 and (in the second year) Polish >1800 ton classes were characterized by ℓ_i less than 1.0 (ℓ_1 = 1.0) which would indicate negative or no learning. The most plausible explanation was that either the observed catch per effort in the first year was much higher than would have been expected, catch per effort in the following years was much lower than expected, or that the original data were poor. Even though the values were less than 1.0, both the Polish and USSR 501-900 ton classes showed an eventual increase in ℓ_i in the fifth year. The Polish 901-1800 and GDR and Polish >1800 ton classes generally exhibited a continuous increase in ℓ_i indicating perhaps that technological improvements occurred both during and following the learning period resulting in observed catch per effort increasing in spite of predicted catch per effort decreasing (*i.e.* decreasing stock abundance). Increases in ℓ_i in the fifth and sixth years in the fishery were evident for virtually all of the country-tonnage classes further supporting the belief that widespread improvements occurred in the distant water fleet operations enabling catch per effort to increase despite other evidence which indicates that stock abundance decreased. These improvements may have been accomplished in various ways such as by the conversion from bottom to more efficient midwater trawls, introduction of larger and/or more efficient nets, implementation of better electronic fish-finding gear, or further acquisition of knowledge relating to locating and capturing fish schools. Such improvements in the fishery are poorly documented although it is known that a conversion from bottom to midwater trawls did occur. GDR catch and effort statistics have been reported to ICNAF by bottom or midwater trawl whereas those from the other four nations have not been separated. GDR data indicated better catch per effort of mackerel with midwater than with bottom trawls. Some observations indicate that the Polish fleet underwent a gradual transition from bottom to midwater trawling and introduced larger and more efficient nets in the last several years. It must be concluded, therefore, that such changes invalidate the usefulness of unadjusted catch per effort by most country-tonnage classes as year to year indicators of mackerel stock abundance.

Close examination of the data for the USSR 151-500 ton class indicates that following an initial 2-year learning period, during which ℓ_i increased from 1.00 to 1.33, ℓ_i declined in the fourth and fifth years and then increased slightly in the sixth year. In none of the 5 years following year 1 did ℓ_i deviate markedly from 1.0 (mean = 1.12; range = 0.82-1.33) demonstrating the close similarity of the observed catch per effort of this fleet with the independent estimate of stock abundance. The learning that did occur in the first two years appears to have been minimal. The lack of a marked decrease in ℓ_i after 1970 suggests that technological improvements, evident in most other fleets, were not introduced. USSR 151-500 ton class vessels are generally incapable of satisfactorily employing midwater trawls; hence, conversion from bottom trawls did not occur as in the case of the larger vessels. The increase in observed catch per effort from 0.50 MT per hour in 1972 to 0.58 in 1973, even though stock abundance continued to decline (ICNAF, 1974), coincided with a marked drop in otter trawl-caught mackerel by this vessel class brought about in part by a major shift to purse seines. It is possible that the most efficient otter trawlers were not converted which may have resulted in the increased catch per effort in 1973. In summary, it was concluded that the catch per effort of the USSR 151-500 ton class, following slight adjustment of the first two years in the fishery (1968 and 1969) for learning, typified more closely accepted estimates of stock abundance than any other country-tonnage class.

Since changes in observed catch per effort due to both learning and technological improvements could not easily be quantified for other country-tonnage classes, the observed data for only the standard class were adjusted to compensate for learning. The object of this adjustment was to bring the fleet used as the standard in its first and second years in the fishery to the same level of knowledge or efficiency as in the third year when its learning was assumed to have been completed. This was accomplished using

$$f_{i,adj} = f_i \times \frac{\ell_i}{\ell_3}$$

where $f_{i,adj}$ = adjusted hours fished by month and ICNAF area,

f_i = original hours fished by month and ICNAF area, and

ℓ_i and ℓ_3 are as defined previously. It was not necessary to adjust the original effort data of the country-tonnage classes for learning and technological improvements because such adjustments were essentially achieved through the effort standardization coefficients.

The assumption of a 2-year learning period for the standard class agrees with results of previous

A 6 studies. Brown *et al.* (1975) suggested that learning required 2 years in the major distant water fleet fisheries for all species combined that developed off the northeastern coast of the US in the 1960's. Borkowska-Kwinta (1964, 1970) and Schumacher and Anthony (1972) also proposed that learning requires 2 years for new fisheries.

Results

Analyses of variance were computed for 1968-1973 without effort adjusted for learning and for 1968-1969 with the effort of the standard USSR 151-500 ton class adjusted for learning. Tonnage class differences were significant at the 0.05 probability level both without and with the learning adjustment in 1969-1973, whereas country differences were significant only in 1971-1973. Significant country-tonnage class interactions occurred in 1971-1973. Detailed examination of the data indicated that the interactions were caused mainly by the GDR 501-900 and 901-1800 ton classes in 1972 and the GDR 501-900 ton class in 1973. Since those classes contributed only a small amount to the catch and effort used in the 1972-1973 analyses (average of 0.7% of the catch and 1.4% of the effort), the interaction was ignored. The interaction F value for the 1971 analysis, although significant at the 0.05 level, was only 10% and 21% of the magnitude of the tonnage class and country F values, respectively, and therefore was assumed less important and ignored.

Effort standardization coefficients are given in Table 9. The coefficients increased with vessel size and showed a definite increase over time especially with the 901-1800 and >1800 ton classes. The 1968-1973 mean value over all countries obtained without learning adjustments increased from the standard of 1.00 to 1.43 for the 501-900 ton class to 5.28 for the 901-1800 ton class (only GDR and Poland) and to 5.85 for the >1800 ton class (GDR and Poland only; 4.83 for all countries). GDR, Poland and USSR had vessels in three different classes, with GDR having the highest mean coefficients, whereas Bulgaria and Romania had vessels only in the >1800 ton class. GDR increased from a mean of 1.59 for the 501-900 ton class to 5.33 for the 901-1800 ton class to 6.84 for the >1800 ton class; Poland increased from 1.57 for the 501-900 ton class to 5.25 for the 901-1800 ton class but decreased to 5.02 for the >1800 ton class. In three of the six years, the coefficient was greater for the Polish >1800 ton class than the 901-1800 ton class, but the lower overall mean resulted from a lower value in 1968 and two low values in 1969-1970 when there were no 901-1800 ton class coefficients. USSR increased from 1.00 for the 151-500 ton class to 1.06 for the 501-900 ton class to 3.32 for the >1800 ton class. The country means in the >1800 ton class were 6.84 for GDR, 5.02 for Poland, 3.94 for Bulgaria, 3.32 for USSR, and 2.14 for Romania.

The 501-900 ton class vessels, on the average, showed no definite increase in coefficients over years but varied from 1.12 to 1.66 with a mean of 1.43 (Table 9, Figure 6). GDR increased from 0.90 in 1968 to 2.71 in 1971, decreased to 1.55 in 1972, and then increased to 2.22 in 1973. Poland decreased from 2.29 in 1968 to 1.21 in 1970 and then increased to 1.73 in 1973. USSR declined from 1.40 in 1969 to 0.90 in 1971 and then improved to 1.02 in 1973.

The 901-1800 and >1800 ton classes generally exhibited an increasing trend in coefficients over years. In the 901-1800 ton class, Poland improved from 3.67 in 1968 to 4.00 in 1971 to 6.01 in 1972 and to 7.33 in 1973. GDR had values only for 3 years which changed from 2.01 in 1970 to 8.26 in 1971 to 5.71 in 1972. The most evident improvements were in the >1800 ton class where the overall country mean climbed steadily from 1.49 in 1969 to 7.27 in 1973. Nearly all countries experienced increases each year except Poland which decreased from 1968 to 1969, Bulgaria and GDR which declined from 1971 to 1972, and Poland and the USSR which dropped moderately from 1972 to 1973. Individual country coefficients ranged from 0.92 for Romania in 1970 to 11.34 for GDR in 1973.

Adjustment of the effort of the USSR 151-500 ton class for learning in 1968 and 1969 resulted in all coefficients being 25% and 5% smaller in those 2 years, respectively, than with the effort unadjusted. These percentage decreases equalled the adjustments initially made to the effort of the standard class to compensate for learning.

The effort standardization coefficients indicate that the fishing ability or efficiency of most of the country-tonnage class categories, particularly the 901-1800 and >1800 ton classes, did not remain constant throughout 1968-1973 relative to the standard class but rather exhibited a definite marked increase. These results support further the belief that widespread technological improvements occurred in the distant water fleets other than the USSR 151-500 ton class following an initial learning period.

Landings per standardized hour fished were calculated for each year by multiplying the hours fished used in the analysis for each country-tonnage class by the appropriate effort standardization coefficient and dividing the sum of the products into the summed annual landings used in the analysis. Total international effort expressed as standardized hours fished was determined by dividing the total international landings by the landings per standardized hour. Results are given in Table 10 and Figure 3.

Landings per standardized distant water fleet hour unadjusted for learning increased from 0.49 MT in 1968 to 0.77 MT in 1969 to a high of 0.99 MT in 1970. It then declined to 0.77 MT in 1971 and to 0.53 MT in 1972 followed by a slight improvement to 0.55 MT in 1973. With effort by the standard class adjusted for learning in 1968-1969, the landings per hour were 0.65 MT and 0.81 MT in those years, respectively, instead of 0.49 MT and 0.77 MT. Total international effort expressed as standardized distant water fleet hours fished increased by a factor of 6 from 122,394 hours in 1968 (unadjusted for learning) to 730,875 hours in 1972 and then decreased slightly (5%) to 693,025 hours in 1973. Total hours fished with the learning adjustment increased by a factor of 8 from 92,266 hours in 1968 to 730,875 hours in 1972 and then decreased 5% to 693,025 hours in 1973.

Discussion

The recent expansion of the mackerel fishery in Subarea 5 and Statistical Area 6 was characterized by a large increase in effort and catch and a marked decline in stock abundance. This decline has been documented by four separate independent measures of catch-per-unit-effort. US commercial fishery landings per standardized day, US research vessel spring and autumn bottom trawl survey catch per tow ($\log_e$ scale), and distant water fleet landings per standardized hour all declined following the intensification of the fishery after 1968 by the distant water fleet. It is interesting that relative stock abundance in 1972 and 1973 as measured by US commercial landings per day was similar to that in 1966 and 1964-1965, respectively (Table 10, Figure 3), but that total international landings differed substantially. In 1964-1965 when landings averaged only 3,400 MT and in 1966 when the catch was 9,431 MT, the stock was increasing in abundance but was only lightly exploited. However, in 1972 and 1973 with landings at 387,364 MT and 381,164 MT, respectively, stock abundance was decreasing and exploitation was heavy. The peak exhibited by each of the abundance indices did not occur in the same year. US commercial landings per day peaked in 1968, US autumn and spring survey catch per tow in 1967 and 1968, respectively, and distant water fleet landings per hour in 1970. The important fact is not that all of the indices failed to agree on the same year for greatest stock abundance but rather that there was agreement in indicating declining stock abundance following the peak year. US survey and distant water fleet landings per hour indices indicated a stabilization in the decline in 1973-1974 and a possible modest improvement in stock abundance, whereas US commercial landings per day showed a continued decline in 1973.

The rapid increase in landings which began in the 1960's required substantial fishing effort, much of which was diverted after 1971 from declining sea herring stocks. International mackerel effort, expressed as standardized US days fished, underwent a 135-fold growth from 1964 to 1973 and a 33-fold rise from 1968 to 1973 and, expressed as standardized distant water fleet hours fished (with adjustment for learning), increased 7-fold from 1968 to a peak in 1972.

The expansion in fishing effort resulted in an estimated increase in instantaneous fishing mortality on age 4 and older mackerel from 0.06 in 1969 to 0.60 in 1973 (ICNAF, 1974). The strong 1967 and 1966 year-classes provided a major part of the landings during 1968-1972. Age compositions of commercial landings show that 80% of the estimated number landed in 1973, however, consisted of the smaller 1968-1972 year-classes (ICNAF, 1974). It is not likely that these less abundant year-classes can support future landings comparable to those in 1971-1973 without further increases in fishing mortality and a further reduction in stock abundance. Nationally-allocated total allowable catches were established by ICNAF at 304,000 MT for 1974 and 285,000 MT for 1975 based on assessment advice that these TAC's would stabilize fishing mortality at a level no greater than in 1973. Future increases in landings can be justified only if year-classes more abundant than those now entering the fishery are recruited.

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Table 1. Mackerel landings (MT) from ICNAF Subarea 5 and Statistical Area 6 in 1961-1973.

Year	Bulgaria	Canada	Cuba	FRG	GDR	Italy	Japan	Poland	Romania	Spain	USSR	US	Other	Total
							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	59,074	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	2,747	47	68,754	813	----	232,304
1972	16,104	----	----	13	55,165	800	895	80,513	2,004	----	30,371	981	----	186,846
1973	7,374	----	----	267	21,884	375	296	16,525	4,971	----	13,461	715	----	65,868
							Total							
1961	----	----	----	----	----	----	----	----	----	----	----	1,361	----	1,361
1962	----	----	----	----	----	----	----	111	----	----	----	938	----	1,049
1963	----	----	----	----	----	----	----	----	----	----	1,189	1,320	----	2,509
1964	----	----	----	----	----	----	----	----	----	----	627	1,644	----	2,271
1965	----	----	----	----	----	----	----	1	----	----	2,528	1,998	11	4,538
1966	----	----	----	----	----	----	----	6	3	----	6,698	2,724	----	9,431
1967	----	----	----	90	211	----	46	507	138	----	17,994	3,891	----	22,877
1968	----	16	----	121	3,342	----	312	10,608	283	----	41,294	3,929	68	59,973
1969	2,083	----	----	99	2,214	----	523	18,398	151	----	85,110	4,364	253	113,195
1970	4,007	----	----	1,054	5,631	----	1,500	68,140	758	----	124,483	4,049	----	209,622
1971	28,507	----	145	2,795	69,173	----	1,025	112,294	4,521	50	127,828	2,406	----	348,744
1972	23,556	1	9	770	80,537	800	1,104	141,999	2,519	6	134,057	2,006	----	387,364
1973	31.743	53	----	1,527	76,758	375	446	117,254	5,876	----	145,796	1,336	----	381,164

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Table 2. Mackerel landings (MT) from directed mackerel effort by US gear-tonnage class categories used in the analysis of variance procedure for calculating effort standardization coefficients in ICNAF Subarea 5 and Statistical Area 6. Annual proportion of these landings compared to the total US and international landings is shown.

Gear	Tonnage class	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Hand line	0-50	----	0.2	----	----	4.8	----	----	----	0.4	----
Otter trawl	0-50	----	3.2	7.3	0.5	12.3	16.3	49.8	23.1	32.4	94.1
	51-150	11.2	----	----	0.1	7.3	199.6	10.3	62.7	----	30.4
Floating trap	0-50	109.1	106.9	145.0	206.6	278.2	278.5	410.6	133.4	184.8	133.9
	51-150	----	----	----	----	----	----	----	85.0	----	----
Sink gill net	0-50	----	0.7	----	----	----	----	----	----	----	6.1
	51-150	42.2	----	----	----	----	----	----	----	----	----
Drift gill net	0-50	39.6	13.2	27.0	59.7	85.6	28.2	18.2	20.1	7.4	11.9
Purse seine	0-50	21.9	0.7	2.5	----	----	----	12.4	338.6	15.4	20.5
	51-150	463.7	383.5	301.9	1,289.4	460.0	1,457.0	682.7	249.0	0.3	4.7
	151-630	----	----	----	362.8	0.2	----	----	----	----	----
Pound net	0-50	359.4	77.8	518.7	72.0	528.0	461.8	164.2	19.6	65.5	59.6
Midwater pair trawl	0-50	----	----	----	----	----	----	----	----	----	1.0
	51-150	----	----	----	----	----	----	----	----	----	1.0
Total		1,047.1	586.2	1,002.4	1,991.1	1,376.4	2,441.4	1,348.2	931.5	306.2	363.2
US total		1,644	1,998	2,724	3,891	3,929	4,364	4,049	2,406	2,006	1,336
Total/US total		.637	.293	.368	.512	.350	.559	.333	.387	.153	.272
International total		2,271	4,538	9,431	22,877	59,973	113,195	209,622	348,744	387,364	381,164
Total/International total		.461	.129	.106	.087	.023	.022	.006	.003	.001	.001

Table 3. Effort standardization coefficients calculated for US gear-tonnage class categories with the number of trips in parentheses.

Gear	Tonnage class	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	Mean
Hand line	0-50	----	0.30 (1)	----	----	0.08 (2)	----	----	----	0.35 (1)	----	0.24
Otter trawl	0-50	----	3.78 (10)	2.61 (19)	0.89 (3)	4.36 (4)	1.34 (18)	1.61 (31)	3.24 (7)	28.50 (5)	14.99 (13)	6.81
	51-150	26.53 (2)	----	----	1.20 (1)	3.38 (1)	17.29 (5)	4.45 (10)	7.10 (3)	----	19.96 (6)	11.42
Floating trap	0-50	1.00 (12)	1.00 (12)	1.00 (10)	1.00 (9)	1.00 (23)	1.00 (9)	1.00 (9)	1.00 (5)	1.00 (9)	1.00 (16)	1.00
	51-150	----	----	----	----	----	----	----	2.19 (3)	----	----	2.19
Sink gill net	0-50	----	1.60 (3)	----	----	----	----	----	----	----	0.42 (2)	1.01
	51-150	31.97 (7)	----	----	----	----	----	----	----	----	----	31.97
Drift gill net	0-50	1.43 (28)	0.39 (18)	0.43 (6)	0.21 (4)	0.16 (5)	0.10 (3)	0.39 (2)	0.24 (2)	0.23 (3)	0.61 (9)	0.42
Purse seine	0-50	6.83 (6)	20.20 (1)	2.74 (2)	----	----	----	17.11 (4)	26.51 (7)	30.75 (6)	3.97 (4)	15.44
	51-150	79.62 (32)	52.28 (38)	34.24 (23)	81.89 (27)	35.17 (12)	150.92 (18)	47.22 (14)	58.01 (5)	0.43 (1)	5.29 (1)	54.51
	151-630	----	----	----	126.68 (1)	0.28 (1)	----	----	----	----	----	63.48
Pound net	0-50	5.29 (7)	3.18 (1)	2.16 (9)	0.64 (3)	0.87 (5)	1.95 (4)	1.75 (3)	1.20 (1)	2.88 (2)	0.25 (3)	2.02
Midwater pair trawl	0-50	----	----	----	----	----	----	----	----	----	18.32 (1)	18.32
	51-150	----	----	----	----	----	----	----	----	----	24.39 (1)	24.39
Mean1/		25.28	11.68	8.44	35.25	6.33	34.32	12.09	14.07	10.52	9.80	

1/ Excludes standard category: floating trap 0-50 ton class.

Table 4. Stratified mean catch per tow (pounds) of mackerel from US bottom trawl surveys in the spring (strata 1-14, 61-76) and fall (strata 1-2, 5-6, 9-10, 13, 16, 19-21, 23, 25-26) expressed on linear (spring only) and $\log_e$ scales with standard deviation and coefficient of variation.

Year	Spring							Fall		
	Date	Linear			$\log_e$			Date	$\log_e$	
		Mean	S.D.	C.V.	Mean	S.D.	C.V.		Mean	S.D.
1963	----	----	----	----	----	----	----	13 Nov -14 Dec	0.02	0.02
1964	----	----	----	----	----	----	----	22 Oct - 4 Dec	<0.01	<0.01
1965	----	----	----	----	----	----	----	6 Oct.- 9 Nov	0.07	0.03
1966	----	----	----	----	----	----	----	13 Oct -13 Nov	0.09	0.03
1967	----	----	----	----	----	----	----	25 Oct - 9 Dec	0.32	0.07
1968	2 Mar -14 Mar	17.28	8.04	46.5	0.73	0.12	16.4	10 Oct -20 Nov	0.17	0.06
1969	5 Mar -22 Mar	0.17	0.11	64.7	0.03	0.01	33.3	8 Oct -22 Nov	0.21	0.08
1970	18 Mar -29 Apr	6.75	2.10	31.1	0.56	0.09	16.1	15 Oct -20 Nov	0.11	0.04
1971	9 Mar -12 Apr	9.68	4.51	46.6	0.52	0.09	17.3	29 Sep -19 Nov	0.09	0.03
1972	8 Mar -25 Mar	4.82	2.33	48.3	0.42	0.09	21.4	28 Sep -19 Nov	0.11	0.04
1973	16 Mar -17 Apr	20.36	19.48	95.7	0.25	0.10	40.0	26 Sep -19 Nov	0.06	0.02
1974	13 Mar - 7 Apr	2.00	1.00	50.0	0.31	0.09	29.0	23 Sep -25 Oct	0.06	0.04

Table 5. Mackerel landings (MT) from directed mackerel effort by distant water fleet country-tonnage class categories used in the analysis of variance procedure for calculating effort standardization coefficients in ICNAF Subarea 5 and Statistical Area 6. Annual proportion of these landings compared to the total international landings is shown.

Country	Tonnage class	1968	1969	1970	1971	1972	1973
Bulgaria	>1800	----	1,966	4,007	27,269	23,395	30,702
GDR	501-900	104	347	912	1,624	879	1,550
	901-1800	----	----	216	441	1,881	----
	>1800	----	499	3,238	65,269	73,889	74,491
Poland	501-900	756	5,108	7,771	7,868	16,317	10,911
	901-1800	108	----	----	30,868	37,478	45,123
	>1800	1,272	2,936	49,690	56,826	76,600	49,198
Romania	>1800	----	----	444	4,043	2,213	5,876
USSR	151-500	10,690	28,240	48,018	31,148	31,544	6,249
	501-900	----	7,020	25,553	15,761	7,375	8,619
	>1800	1,569	9,136	26,065	58,593	44,527	68,519
Total		14,499	55,252	165,914	299,710	316,098	301,238
International total		59,973	113,195	209,622	348,744	387,364	381,164
Total/International total		.242	.488	.792	.859	.816	.790

Table 6. Vessel classes within country-tonnage class categories from which data for 1968-1973 were used in the analysis of variance procedure for calculating effort standardization coefficients.

Tonnage class	Bulgaria	GDR	Poland	Romania	USSR
151-500	----	----	----	----	OTSI, SRT
501-900	----	OTSI MTSI OTSN MTSN	OTSI, B-10/14 OTSI, B-20	----	OTSI, SRTM OTSI, SRTR
901-1800	----	OT MT OTSI MTSN	OTSN, B-29 OTSN, B-29s	----	----
1800	OTSN, BMRT OTSN, Atlantic	OTSN MTSN	OTSN, B-15/22 OTSN, B-418 OTSN, B-18	OTSN	OTSN, BMRT OTSN, RTM Tropi OTSN, RTM Atlanti OTSN, PPR

OT = Otter trawl (Not specified)
MT = Midwater trawl (Not specified)
OTSI = Otter trawl side
OTSN = Otter trawl stern
MTSI = Midwater trawl side
MTSN = Midwater trawl stern

Table 7. Percentage of mackerel in the otter trawl landings of the USSR 151-500 ton class from ICNAF Subarea 5 and Statistical Area 6 in 1968-1973

Year	% mackerel in total landings	% mackerel in landings from directed effort
1968	15.1	48.6
1969	32.9	67.7
1970	63.2	80.3
1971	52.6	74.3
1972	54.0	66.9
1973	32.2	70.4

Table 8. Data used to examine learning and technological improvements by the distant water fleets in the mackerel fishery in ICNAF Subarea 5 and Statistical Area 6.

Tonnage class	Country	Year	Observed C/E[1]	Abundance index[2]	Predicted C/E[3]	ℓ[4]
151-500	USSR	1968	0.52	1,161	0.52	1.00
		1969	0.84	1,482	0.66	1.27
		1970	1.01	1,705	0.76	1.33
		1971	0.73	1,607	0.72	1.01
		1972	0.50	1,360	0.61	0.82
		1973	0.58	1,117	0.50	1.16
501-900	GDR	1968	0.46	1,161	0.46	1.00
		1969	0.63	1,482	0.59	1.07
		1970	2.44	1,705	0.68	3.59
		1971	1.58	1,607	0.64	2.47
		1972	0.68	1,360	0.54	1.26
		1973	1.33	1,117	0.44	3.02
	Poland	1968	1.28	1,161	1.28	1.00
		1969	0.96	1,482	1.63	0.59
		1970	1.02	1,705	1.88	0.54
		1971	0.88	1,607	1.77	0.50
		1972	0.82	1,360	1.50	0.55
		1973	1.19	1,117	1.23	0.97
	USSR	1969	1.17	1,482	1.17	1.00
		1970	1.18	1,705	1.35	0.87
		1971	0.81	1,607	1.27	0.64
		1972	0.68	1,360	1.07	0.64
		1973	0.74	1,117	0.88	0.84
901-1800	GDR	1970	2.39	1,705	2.39	1.00
		1971	5.80	1,607	2.25	2.58
		1972	4.02	1,360	1.91	2.10
901-1800	Poland	1968	1.86	1,161	1.86	1.00
		1971	3.00	1,607	2.57	1.17
		1972	3.51	1,360	2.18	1.61
		1973	4.15	1,117	1.79	2.32
>1800	Bulgaria	1969	1.12	1,482	1.12	1.00
		1970	2.69	1,705	1.29	2.09
		1971	4.02	1,607	1.21	3.32
		1972	2.09	1,360	1.03	2.03
		1973	4.37	1,117	0.84	5.20
	GDR	1969	1.59	1,482	1.59	1.00
		1970	2.67	1,705	1.83	1.46
		1971	8.87	1,607	1.72	5.16
		1972	7.90	1,360	1.46	5.41
		1973	8.84	1,117	1.20	7.37
	Poland	1968	1.25	1,161	1.25	1.00
		1969	1.12	1,482	1.60	0.70
		1970	3.71	1,705	1.84	2.02
		1971	4.42	1,607	1.73	2.55
		1972	5.02	1,360	1.46	3.44
		1973	5.00	1,117	1.20	4.17
	Romania	1970	1.16	1,705	1.16	1.00
		1971	2.08	1,607	1.09	1.91
		1972	1.15	1,360	0.93	1.24
		1973	1.96	1,117	0.76	2.58
	USSR	1968	0.84	1,161	0.84	1.00
		1969	1.24	1,482	1.07	1.16
		1970	3.51	1,705	1.23	2.85
		1971	2.44	1,607	1.16	2.10
		1972	2.46	1,360	0.98	2.51
		1973	2.91	1,117	0.81	3.59

[1]Mean of monthly vessel class-area catch per effort used in analysis of variance in metric tons per hour.
[2]Stock size (age 1+) in thousands of metric tons calculated by *ad hoc* Mackerel Working Group at 1974 ICNAF Annual Meeting.
[3]See text for explanation.
[4]Ratio of observed C/E to predicted C/E.

Table 9. Effort standardization coefficients calculated for distant water fleet country-tonnage class categories without adjustments for learning and with the standard USSR 151-500 ton class adjusted for learning in 1968-1969.

Tonnage class	Country	Without learning 1968	1969	1970	1971	1972	1973	Mean	With learning 1968	1969	1970	1971	1972	1973	Mean
151-500	USSR	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
501-900	GDR	0.90	1.03	1.13	2.71	1.55	2.22	1.59	0.68	0.98	1.13	2.71	1.55	2.22	1.54
	Poland	2.29	1.25	1.21	1.31	1.63	1.73	1.57	1.72	1.20	1.21	1.31	1.63	1.73	1.47
	USSR	-	1.40	1.03	0.90	0.95	1.02	1.06	-	1.34	1.03	0.90	0.95	1.02	1.05
	Mean	1.60	1.23	1.12	1.64	1.38	1.66	1.43[1]	1.20	1.17	1.12	1.64	1.38	1.66	1.37
901-1800	GDR	-	-	2.01	8.26	5.71	-	5.33	-	-	2.01	8.26	5.71	-	5.33
	Poland	3.67	-	-	4.00	6.01	7.33	5.25	2.76	-	-	4.00	6.01	7.33	5.02
	Mean	3.67	-	2.01	6.13	5.86	7.33	5.28[1]	2.76	-	2.01	6.13	5.86	7.33	5.15
>1800	Bulgaria	-	1.54	2.21	4.82	3.59	7.55	3.94	-	1.47	2.21	4.82	3.59	7.55	3.93
	GDR	-	1.23	2.87	9.63	9.13	11.34	6.84	-	1.17	2.87	9.63	9.13	11.34	6.83
	Poland	2.45	1.50	3.07	4.66	9.60	8.84	5.02	1.84	1.43	3.07	4.66	9.60	8.84	4.91
	Romania	-	-	0.92	1.89	2.31	3.42	2.14	-	-	0.92	1.89	2.31	3.42	2.14
	USSR	1.63	1.68	2.60	3.19	5.61	5.21	3.32	1.22	1.60	2.60	3.19	5.61	5.21	3.24
	Mean	2.04	1.49	2.33	4.84	6.05	7.27	4.33[1]	1.53	1.42	2.33	4.84	6.05	7.27	4.28
Mean[2]		2.19	1.38	1.89	4.14	4.61	5.41		1.64	1.31	1.89	4.14	4.61	5.41	

[1] Mean of country-year values.
[2] Excludes USSR 151-500 ton class.

Table 10. International mackerel landings and measures of standardized catch per effort and fishing effort in ICNAF Subarea 5 and Statistical Area 6.

Year	International landings (MT)	Landings per std. US day	Landings per std. DWF hour: Without learning	Landings per std. DWF hour: With learning	International effort: Std. US Days	International effort std. DWF hours: Without learning	International effort std. DWF hours: With learning
1964	2,271	0.43	-	-	5,281	-	-
1965	4,538	0.49	-	-	9,261	-	-
1966	9,431	0.84	-	-	11,227	-	-
1967	22,877	1.75	-	-	13,073	-	-
1968	59,973	2.80	0.49	0.65	21,419	122,394	92,266
1969	113,195	1.92	0.77	0.81	58,956	147,006	139,747
1970	209,622	2.07	0.99	0.99	101,267	211,739	211,739
1971	348,744	1.29	0.77	0.77	270,344	452,914	452,914
1972	387,364	0.84	0.53	0.53	461,148	730,875	730,875
1973	381,164	0.53	0.55	0.55	719,177	693,025	693,025

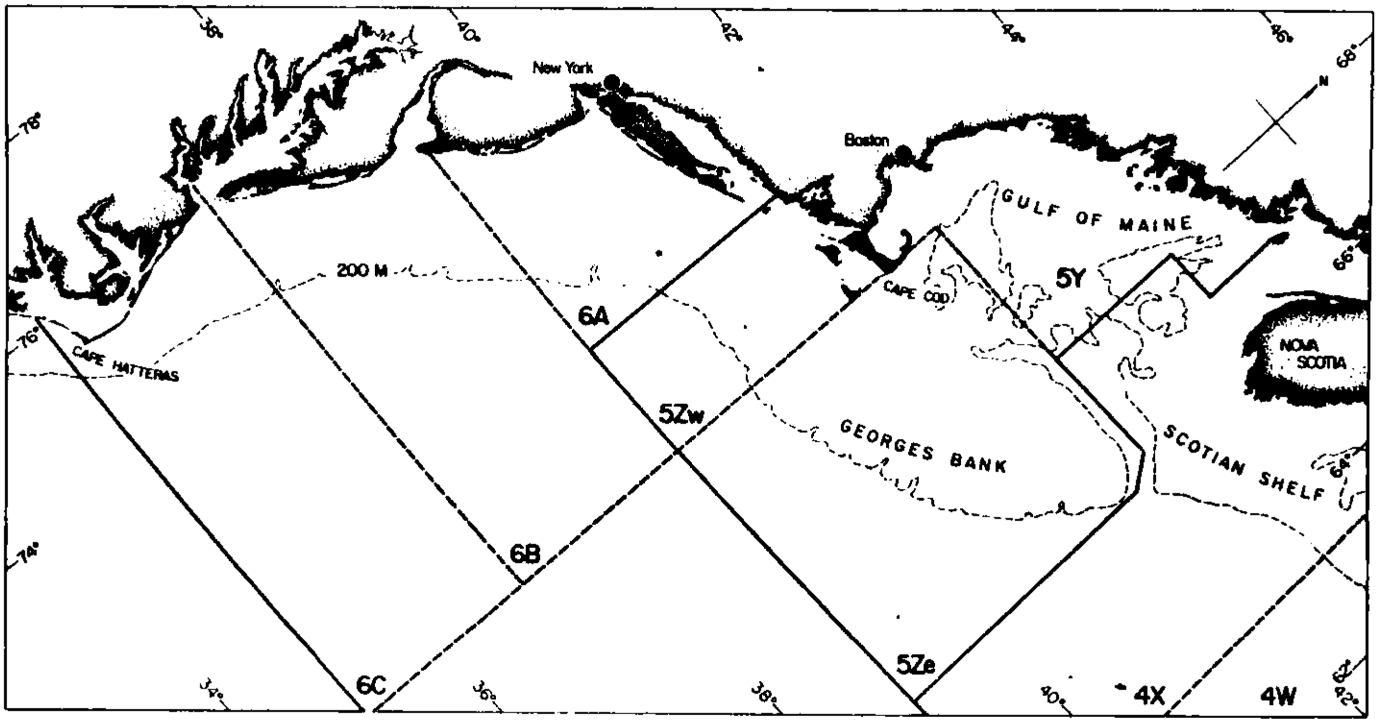

Fig. 1. Area off the northeastern coast of the United States as defined by Divisions and Subdivisions of ICNAF Subarea 5 and Statistical Area 6.

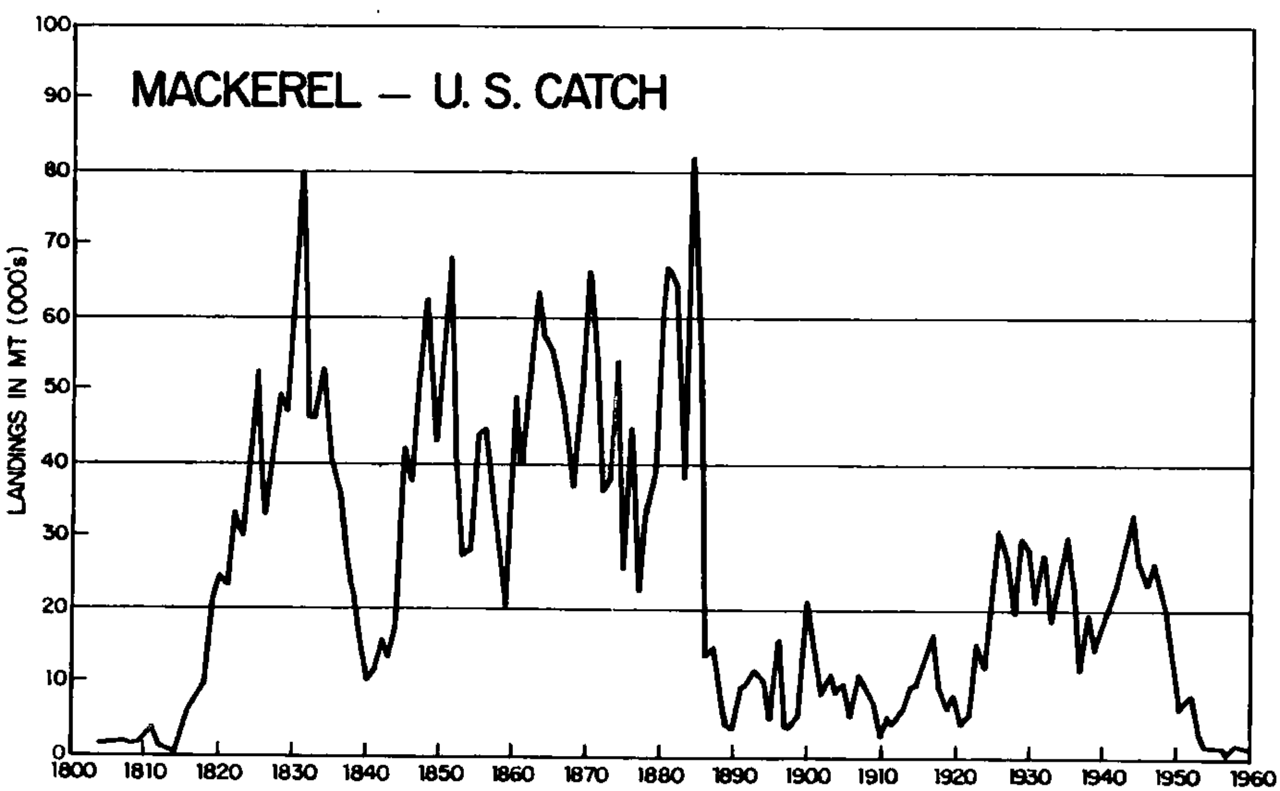

Fig. 2. US mackerel catch, 1804-1960. Most of the catch is from US waters, although a small amount is Canadian waters. Data were taken from Table 25 in Sette and Needler (1934) and from Hoy and Clark (1967).

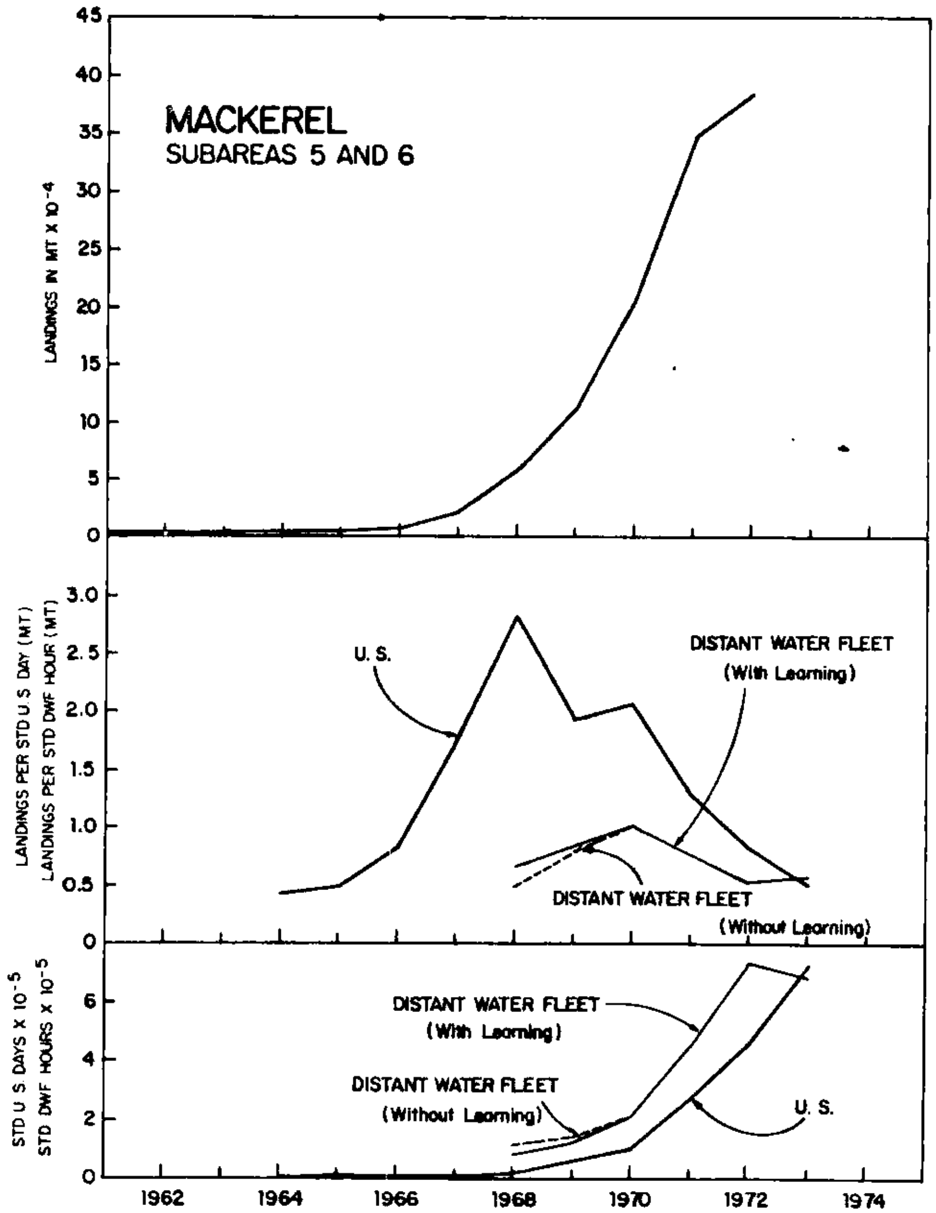

Fig. 3. International landings, US commercial and distant-water fleet landings per standardized effort, and international effort expressed as standardized US days and distant-water fleet hours for the ICNAF Subarea 5 and Statistical Area 6 mackerel stock.

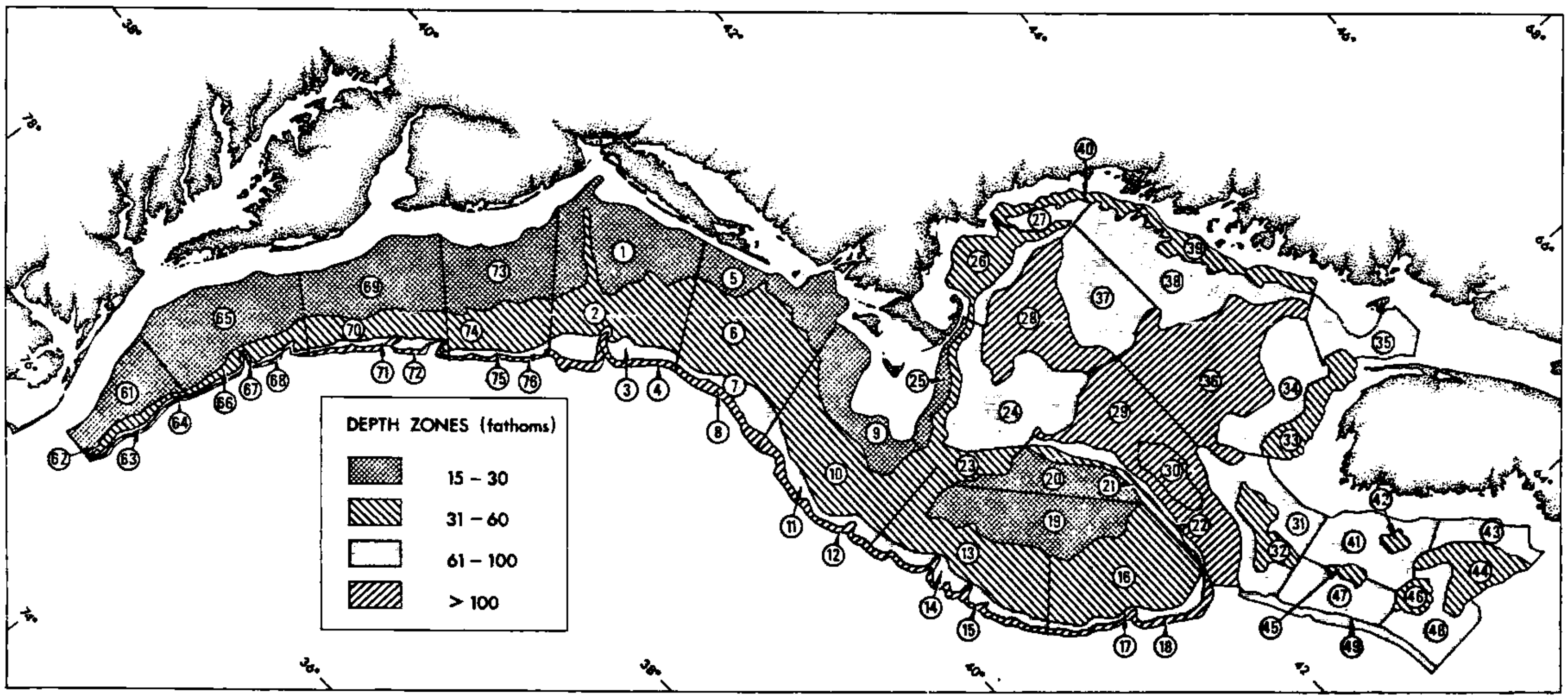

Fig. 4. US groundfish survey sampling strata.

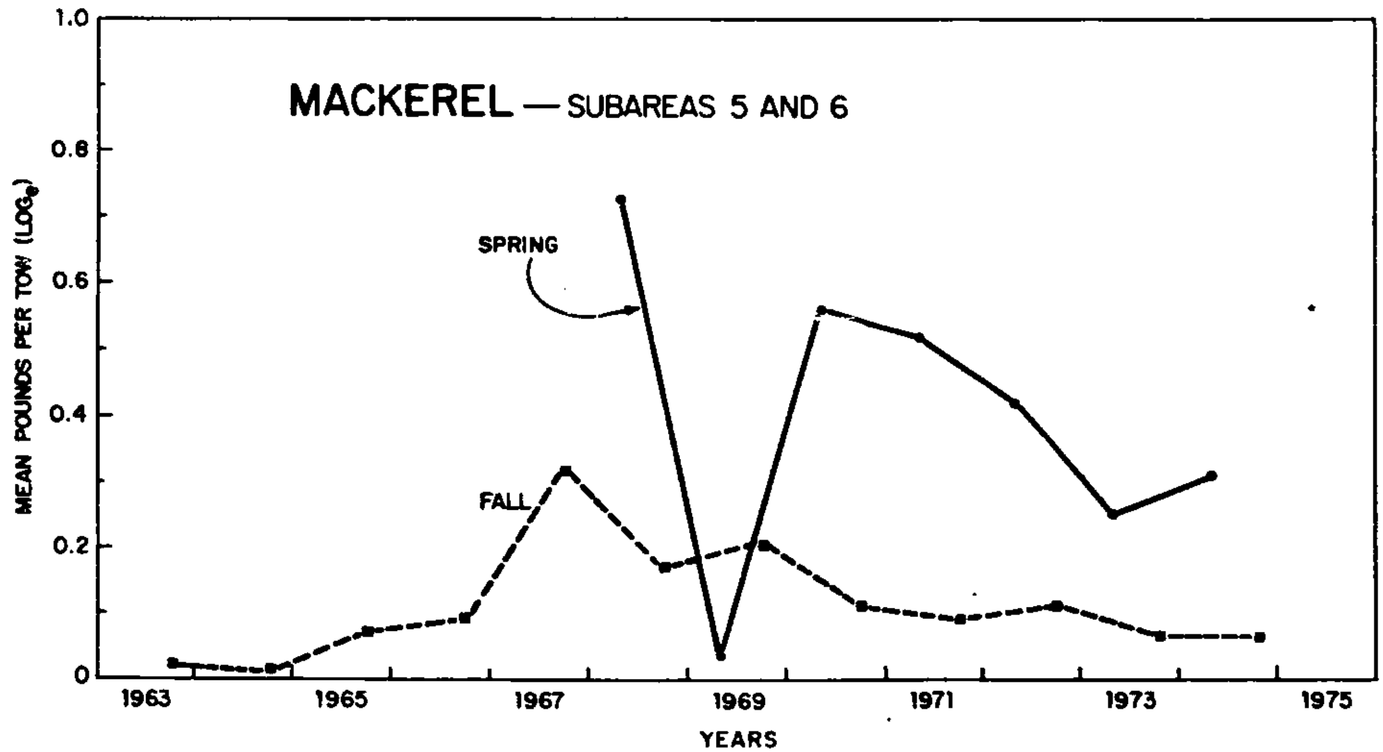

Fig. 5. Stratified mean pounds ($\log_e$) per tow of mackerel from US spring and autumn groundfish surveys in ICNAF Subarea 5 and Statistical Area 6.

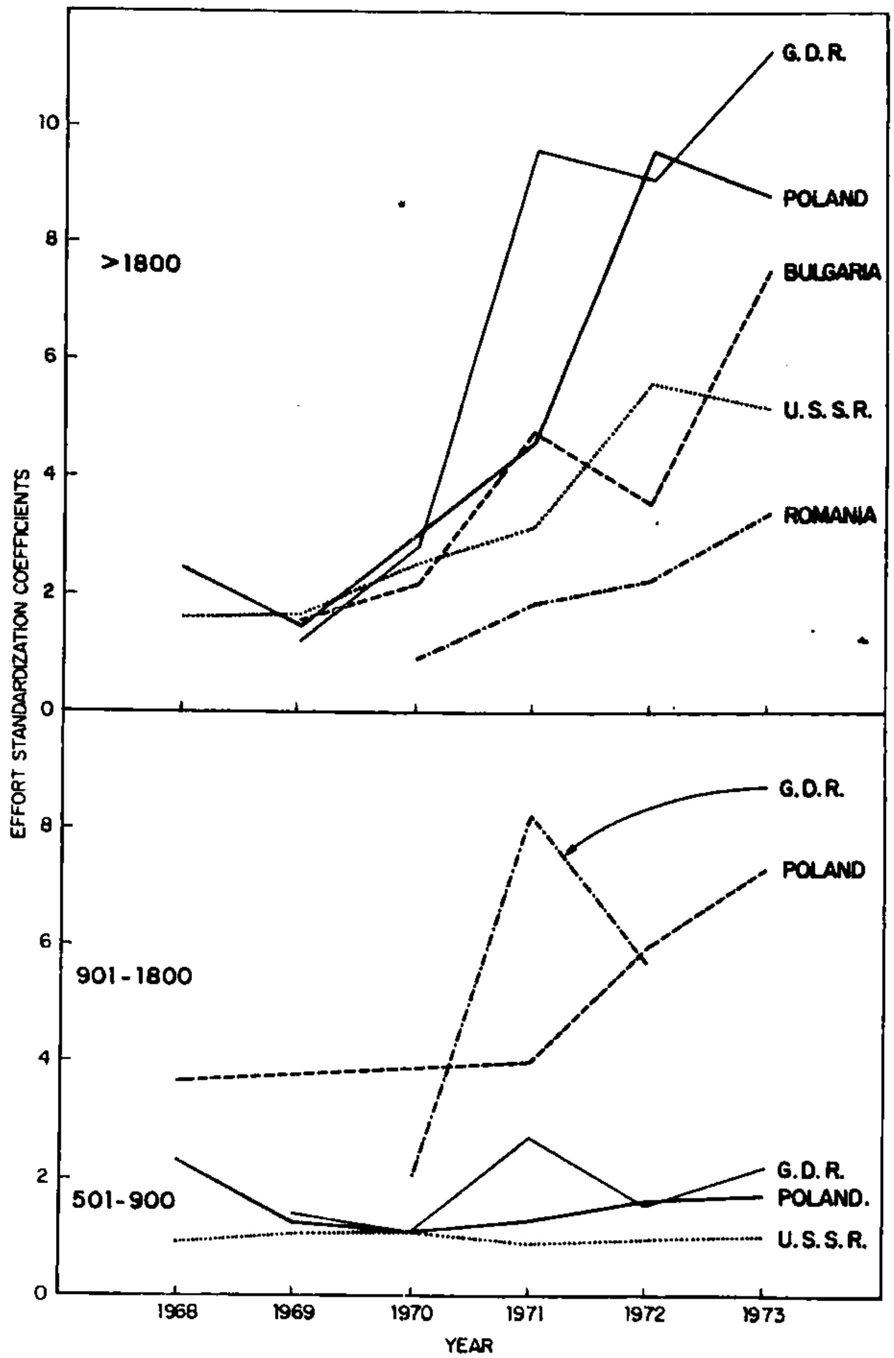

Fig. 6. Effort standardization coefficients for the distant-water fleet country-tonnage classes calculated without learning adjustments.