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Relative abundance of Atlantic mackerel in ICNAF Subarea 5 and Statistical Area 6[1]

by

E. D. Anderson

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

ABSTRACT

U. S. commercial landings/standardized day indices for 1964-1973 and distant water fleet landings/standardized hour indices for 1968-1972 were calculated for the mackerel fishery in ICNAF Subarea 5 and Statistical Area 6 utilizing an analysis of variance procedure. The distant water fleet indices were calculated with and without the application of a 2-year learning function. U. S. spring and fall research vessel survey indices, the U. S. commercial indices and the distant water fleet (with learning) indices showed close similarity throughout the period in measuring relative stock abundance. The expansion of the mackerel fishery resulted in landings increasing from 1,000 MT in 1962 to 387,400 MT in 1972 and was accompanied by a sharp decrease in relative abundance after 1968. The apparent lack of strong year-classes since 1966 and 1967 suggests a 1974 catch below the 1971-1972 level of landings unless fishing mortality is increased.

INTRODUCTION

Landings of Atlantic mackerel (Scomber scombrus) from ICNAF Subarea 5 and Statistical Area 6 increased dramatically from 1,000 MT in 1962 to nearly 387,400 MT in 1972. Prior to the arrival of distant water fleets in the early 1960's, the mackerel fishery was limited to U. S. vessels. An intensive mackerel fishery was begun by the U.S.S.R. in 1967, followed by Poland in 1968 and the German Democratic Republic (G.D.R.) and Bulgaria in 1971. This paper presents three independent measures of catch per unit effort that attempt to describe recent changes in relative stock abundance and draws implications for yield from current stock sizes.

LANDINGS

Anderson (1973) reviewed the history of mackerel landings off the New England shores from colonial days to 1971. Annual landings since 1964 virtually doubled each year (114 percent average increase) until 1970 (Table 1, Figure 1). The increase from 209,617 MT in 1971 to 348,744 MT in 1972 was over 139,000 MT or about a 66 percent increase. Landings in 1972 climbed to 387,364 MT, an increase of 38,620 MT (11.1 percent increase). Preliminary 1973 landings are about 360,000 MT.

From 1965 to 1971 landings by the U.S.S.R. exceeded those by any other nation and varied from 79 percent of the total in 1967 to 37 percent in 1971. Poland, with 141,999 MT, had the largest catch in 1972, while the U.S.S.R., the G.D.R., and Bulgaria landed 134,057, 80,537, and 23,556 MT, respectively. Eight other nations contributed the remaining 7,215 MT landed in 1972.

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U. S. landings of mackerel since 1961 (Table 1) increased each year from 938 MT in 1962 to 4,364 MT in 1969 and then declined each year thereafter. U. S. landings in 1972 were only 2,006 MT. Preliminary 1973 landings are about 1,933 MT.

Landings from Subarea 5 contributed 52-89 percent of the total from the combined area during 1961-1970. Statistical Area 6 provided 67 percent in 1971, but landings in 1972 were nearly the same from the two areas (52 percent from SA 5, 48 percent from SA 6).

U.S. COMMERCIAL CATCH/EFFORT INDEX

Data

Catch and effort statistics from U. S. fishing vessels landing in New England ports during 1964-1973 were used to calculate annual catch/effort values. Although statistics exist for years earlier than 1964, they have not been processed for computer analysis. The data were essentially derived from inshore operations and generally included all quarters of the year. All individual vessel trips in which mackerel comprised 50 percent or more of the total catch were included in the analysis. Fishing effort was reported as days fished.

Standardization of Fishing Effort

Different types of gear are used by U. S. fishermen to land mackerel including hand line, otter trawl, floating trap, sink gill net, drift gill net, purse seine, pound net, and midwater pair trawl. Purse seines generally account for the largest amount landed. Total fishing effort by these various types of gear was standardized by the use of relative catchability coefficients which were computed according to a method proposed by Robson (1966) which uses an analysis of variance procedure of Snedecor and Cochran (1967). This procedure was used by Brown et al. (1973) to standardize the total effort of the ICNAF member nations fishing in Subarea 5 and Statistical Area 6 and also by Anderson (1973) to standardize the mackerel effort by various member nations.

The two factors that were considered to have the most influence on catch rates of mackerel and which were used in the analysis of variance were gear and tonnage class. Gear types included the eight previously listed while tonnage classes included 0-50 gross tons, 51-150 tons, and 151-630 tons. A separate analysis was performed for each year with each trip constituting one observation. Relative catchability 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 observations from this category were present in all years and this gear-tonnage class had greater landings in the majority of years than any other category similarly having observations in all years.

Results

The analysis of variance indicated that gear differences in all 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.

Relative catchability coefficients are given in Table 2. Coefficients for the respective gear-tonnage class categories were reasonably consistent among years although several exceptions resulted from categories having few observations (trips) with small landings (e.g. purse seine 51-150 in 1972 had one trip and 600 lb. and purse seine 151-630 in 1968 had one trip and 495 lb.).

The annual days fished value for each gear-tonnage class category was multiplied by the appropriate catchability coefficient, summed for all categories, and divided into the summed landings from the effort used in the analysis to give the landings/U.S. standardized day. Effort in terms of U.S. standardized days fished required to produce the total mackerel landings (all nations) was calculated by dividing the latter value by the landings/U.S. standardized day. Results are given in Table 9 and Figure 1.

Landings/U.S. standardized day increased each year from 0.43 MT in 1964 to 2.80 MT in 1968 and then declined sharply to 0.53 MT in 1973. Total fishing effort in terms of U.S. standardized days increased exponentially from 5,281 days in 1964 to 461,148 days in 1972.

DISTANT WATER FLEET CATCH/EFFORT INDEX

Data

Catch and effort statistics reported to ICNAF by Poland, Romania, the U.S.S.R., the G.D.R., and Bulgaria for 1968-1972 were utilized to calculate annual catch/effort values. Most of the data were obtained from STANA 1W or STATLANT 21B forms. The G.D.R. data for 1969-1971 and Bulgarian data for 1969 and 1970 were taken from Part IV of ICNAF Statistical Bulletin, Vol. 22. Hours fished was used as the fishing effort measure.

Most mackerel landings were reported to ICNAF with the main species sought specified as mixed. Effort was considered to be directed towards mackerel if in any given country-tonnage class-ICNAF division category the monthly catch of mackerel was greater than any other species. Only otter trawl data were utilized. The average annual catch/effort values by tonnage class and country determined from the summed monthly catch and effort data (Σ catch/Σ effort) are given in Table 3.

Standardization of Fishing Effort

Total fishing effort by the various vessel tonnage classes from the five nations listed earlier was standardized by utilizing relative catchability coefficients which were computed by the same procedure descried earlier for U.S. vessels but using quarterly Σ catch/Σ effort for all vessels in a given category instead of individual trips.

Factors used in the analysis of variance were country and tonnage class. Tonnage classes included 151-500 gross tons, 501-900 tons, 901-1800 tons, and > 1800 tons. A separate analysis was performed for each year.

Most of the data for this analysis were reported for various vessel types within a given country-tonnage class (Table 4). Monthly data from these within-class categories, as determined by the previously-mentioned criterion, were summed by quarters and division (or sub-division) to constitute observations in the analysis of variance.

Relative catchability coefficients were expressed for each country-tonnage class in relation to a standard which was selected as the U.S.S.R. 151-500 ton class. This category contained observations in all of the years and also contributed a higher proportion of the total mackerel landings in 1968 (74 percent - 10,690 MT), 1969 (51 percent - 28,240 MT), and 1970 (29 percent - 48,018 MT) than any other class (Table 5). Even though landings by this class were exceeded by the Polish, U.S.S.R., and G.D.R. > 1800 ton class categories in 1971 and 1972, it still contributed about 10 percent of the total in each of those years (31,148 MT and 31,544 MT, respectively). Mackerel comprised a substantial proportion of the landings made by this category in 1968-1972. The percentage of mackerel in the total landings of all fish made by this class increased from 17 percent in 1968 to 63 percent in 1970 and decreased slightly to 55 percent in 1972 (Table 6). The percentage of mackerel in the total landings by this class from effort considered to be directed towards mackerel increased from 49 percent in 1968 to 80 percent in 1970 and decreased to 67 percent in 1972. Therefore, it was assumed that the most realistic measure of relative stock abundance as determined by landings/hour, at least in 1968-1970, was provided by the U.S.S.R. 151-500 ton class and that this class was sufficiently involved in the directed mackerel fishery in each of the years to justify its selection as the standard.

Adjustment for Learning

A directed mackerel fishery by the distant water fleets began in Subarea 5 and Statistical Area 6 in 1968. It is assumed that a learning period is required for the participants of any new

fishery to attain top efficiency. The disparity between the catch/effort indices for the distant water fleets in the initial years of their fishery (1968-1969) and the corresponding U.S. commercial indices (Figure I) indicated that learning occurred in the mackerel fishery In order to utilize all available data to estimate trends throughout the entire period of the fishery, it was decided to adjust effort by new entrants for learning. Brown et al. (1973) suggested that learning required 2 years in the major distant water fleet fisheries that developed in Subarea 5 and Statistical Area 6 in the 1960's. Borkowska-Kwinta (1964, 1970) and Schumacher and Anthony (1972) also suggested that learning requires 2 years. Brown et al. (1973) developed a learning function that was exponential with approximately a 50 percent increase in efficiency in each of the two years. Since a learning function has not yet been determined specifically for the mackerel fishery, the function reported by Brown et al. (1973) was used in this paper. The function was applied over 2 years to each country-tonnage class with Subarea 5 and Statistical Area 6 data treated separately (Table 7). The adjustment for learning resulted in dividing the effort of each country-tonnage class in its first year in the fishery by 4 and the effort in its second year by 2. The first year in the directed mackerel fishery for each country-tonnage class was defined to be the first year in which effort was directed towards mackerel as described earlier. The first and second years in the fishery for each country-tonnage class are given in Table 7.

Results

Analysis of variance was computed without and with fishing effort adjusted for learning. Tonnage class differences in both cases in four of the five years were significant at the 0.05 probability level, while country differences were signficant in three years. Although significant country-tonnage interactions occurred in two years without the learning adjustment and in three years with the learning adjustment, examination of observation values indicated that they were generally caused by single country-tonnage class categories in each of the years (not the same in each year). Since the catch and effort contribution of these categories was judged to be minimal (less than 5 percent of the totals), the interactions were ignored.

Relative catchability coefficients are given in Table 8. The coefficients obtained from the analyses using effort adjusted for learning were generally larger than those obtained without the learning adjustment. This was due primarily to the fact that the learning adjustment was not applied to all the country-tonnage classes in the same years.

The relative catchability coefficients (Table 8) indicate that the catchability or efficiency of the various country-tonnage class categories has not remained constant throughout the 5-year period of analysis relative to that of the standard category (U.S.S.R. 151-500 ton class). The coefficients for some of the categories have merely fluctuated from year to year, but for other categories definite trends are evident (Figure 2). The Polish, U.S.S.R., and G.D.R > 1800 ton classes have apparently undergone an increase in efficiency throughout the period relative to that of the standard, particularly from 1970 to 1972. This trend is likely due to technological advances as well as increased knowledge and skills associated with catching mackerel that have continued beyond the assumed 2-year learning period.

The annual hours fished value for each country-tonnage class category was multiplied by the appropriate catchability coefficient, summed for all categories, and divided into the total landings from the effort used in the analysis to give the landings/distant water fleet standardized hour. Effort in terms of distant water fleet standardized hours fished was determined by dividing total landings (from Table 1) by the landings/standardized hour. The results are shown in Table 9 and Figure 1.

Landings/standardized hour adjusted for learning decreased steadily from 1.96 MT in 1968 to 0.54 MT in 1972, a total decrease of 72 percent and an average annual decrease of 27 percent. Landings/standardized hour without the learning adjustment improved form 0.49 MT in 1968 to 1.20 MT in 1970 and then dropped to 0.54 MT in 1972. Standardized hours adjusted for learning increased from 30,598 hours in 1968 to 717,341 in 1972, a 22-fold increase. Standardized hours with no learning adjustment rose from 122,394 hours in 1968 to 717,341 in 1972, a 5-fold increase.

The relative catchability coefficients (Table 8), which indicate improved efficiency during the period for particular country-tonnage class categories relative to that of the standard category, suggest then that the recent increases in landings/hour (Table 3) exhibited by

these country-tonnage class categories were achieved only through improvements in technology, knowledge, skill, etc., that increased their ability to catch mackerel and did not reflect any increase in overall stock abundance.

U.S. RESEARCH VESSEL SURVEY INDEX

U.S. Albatross IV groundfish survey cruises (Grosslein, 1969) have been effective in monitoring fluctuations and trends in the relative abundance of demersal fish stocks as well as some semi-pelagic and pelagic stocks. Anderson (1973) concluded that the spring groundfish survey appeared to provide a good indication of the trend in mackerel abundance. Good mackerel catches have been achieved during the spring Albatross IV cruises, which began in 1968. Catches during fall cruises have generally been low with catch/tow values exhibiting greater statistical variance relative to spring values. Nevertheless, the fall survey has provided a longer series of relative abundance indices (1963-1973) than the spring survey (1968-1973) and in spite of its lower catches has depicted gross changes in abundance over the 11-year period.

The spring abundance index (stratified mean catch/tow in pounds, $\log_e$ scale) was calculated from catches in sampling strata 1-14, 61-76 (Figure 3) and the fall index from strata 1-2, 5-6, 9-10, 13, 16, 19-21, 23, 25-26. These strata sets comprise areas where mackerel have generally been caught during surveys, the spring set including all strata from the southwest part of Georges Bank to Cape Hatteras and the fall set including the strata 60 fathoms and less from Hudson Canyon around Cape Cod and including Georges Bank.

Prior to 1973, a No. 36 Yankee trawl was used on the surveys. However, the 1973 spring survey employed a modified high-opening No. 41. trawl. In order to relate the relative abundance that year. The fall index improved from a low in 1964 of < 0.01 to a high of 0.32 in 1967 and then decreased gradually to 0.06 in 1973.

DISCUSSION

The recent increase in mackerel landings in Subarea 5 and Statistical Area 6 resulted from a marked improvement in stock size which attracted substantial fishing effort, much of which was diverted from the declining sea herring stocks. Percentage age composition data in recent U.S.S.R. and Polish ICNAF Research Reports (summarized by Anderson, 1973) indicated strong 1967 and 1966 year-classes which provided the bulk of the landings through 1971. The 1969 year-class comprised an important part of the 1971 and 1972 landings (Report of the ad hoc Mackerel Working Group, ICNAF Redbook 1973, Part I). Length Compositions indicate that any year-classes in following years were of comparable strength (Anderson, 1973). The survey data suggested that the 1971 year-class was the largest after 1967.

The expansion of the mackerel fishery was accompanied by marked declines in relative abundance as measured by the U.S. commercial landings/standardized day index, the distant water fleet landings/standardized hour index, and the U.S. research vessel survey index. The U.S. commercial index improved rapidly from 1964 to 1968 in response to the recruitment of the 1966 and 1967 year-classes to the fishable stock, but declined equally rapidly following the intensification of the fishery after 1968 by the distant water fleets. Even though the U.S. commercial indices in 1972 and 1973 were comparable to the 1966 and 1964-1965 levels, respectively (Table 9, Figure 1), total landings differed markedly. Landings were 9,400 MT in 1966 and averaged 3,400 MT in 1964-1965 but were 387,000 MT and 360,000 MT in 1972 and 1973, respectively.

The distant water fleet index (with effort adjusted for learning) increased from 1968 to a peak in 1970 and then declined each year thereafter. This would imply that stock abundance was greatest in 1970, in contrast with the other indices which indicate that this occurred in 1968. The close similarity between the U.S. commercial index and the distant water fleet index with effort adjusted for learning (Figure 1) strongly supports the assumed concept of learning.

The unanimity indicated in the continued downward trend of all of the various relative abundance indices provides strong evidence for the validity of the trend. These results document the fact that the mackerel stock continued to decline even though catch/effort by certain country-tonnage class categories (Table 3) increased from 1971 to 1972. The huge landings of mackerel in 1971 and 1972 resulted from a tremendous increase in standardized effort (Table 9, Figure 1) emanating from an actual rise in hours fished by the distant water fleets coupled with an apparent improvement in vessel efficiency by various country-tonnage class categories. The expanded effort produced a greater fishing mortality which was directed

not only at the 1966 and 1967 year-classes, but also at the more recent and less formidable year-classes. The Report of the ad hoc Mackerel Working Group (ICNAF Redbook 1973, Part I) showed that 52 percent of the 1972 landings was comprised of fish from the 1968-1972 year-classes. It is not likely that these less substantial year-classes can support future landings comparable to those in 1971-1972 which were achieved when the stock was dominated by the strong 1966-1967 year-classes. It appears that landings in 1974 could be maintained at the 1971-1972 level only by a further increase in fishing mortality which would result in the continued reduction in the adult stock abundance.

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Table 1. Mackerel landings (MT) from ICNAF Subarea 5 and Statistical Area 6 during 1961-1972.

Year	U.S.	U.S.S.R.	Poland	Romania	Bulgaria	F.R.G.	G.D.R.	Japan	Canada	Italy	Spain	Cuba	Non-member	Total
						Subarea 5								
1961	1,027	-	-	-	-	-	-	-	-	-	-	-	-	1,027
1962	822	-	111	-	-	-	-	-	-	-	-	-	-	933
1963	1,202	896	-	-	-	-	-	-	-	-	-	-	-	2,098
1964	1,264	533	-	-	-	-	-	-	-	-	-	-	-	1,797
1965	1,467	2,475	1	-	-	-	-	-	-	-	-	-	11	3,954
1966	1,903	5,446	6	3	-	-	-	-	-	-	-	-	-	7,358
1967	3,216	11,907	507	138	-	90	48	1	-	-	-	-	-	15,907
1968	3,001	33,961	10,160	283	-	119	3,184	1	-	-	-	-	68	50,777
1969	3,873	47,547	13,421	140	1,966	89	2,021	197	-	-	-	-	253	69,507
1970	3,092	56,457	40,987	758	1,949	1,004	2,920	463	-	-	-	-	-	107,630
1971	1,593	59,074	43,682	1,774	1,632	1,175	7,090	272	-	-	3	145	-	116,440
1972	1,025	103,686	61,486	515	7,452	757	25,372	209	1	-	6	9	-	200,518
1973	941*													
						Statistical Area 6								
1961	334	-	-	-	-	-	-	-	-	-	-	-	-	334
1962	116	-	-	-	-	-	-	-	-	-	-	-	-	116
1963	118	293	-	-	-	-	-	-	-	-	-	-	-	411
1964	380	94	-	-	-	-	-	-	-	-	-	-	-	474
1965	531	53	-	-	-	-	-	-	-	-	-	-	-	584
1966	821	1,252	-	-	-	-	-	-	-	-	-	-	-	2,073
1967	675	6,087	-	-	-	-	163	45	-	-	-	-	-	6,970
1968	928	7,333	448	-	-	2	158	311	16	-	-	-	-	9,196
1969	491	37,563	4,977	-	117	-	193	326	-	-	-	-	-	43,667
1970	957	68,026	27,153	-	2,058	45	2,711	1,037	-	-	-	-	-	101,987
1971	813	68,754	68,612	2,747	26,875	1,620	62,083	753	-	-	47	-	-	232,304
1972	981	30,371	80,513	2,004	16,104	13	55,165	895	-	800	-	-	-	186,846
1973	992*													
						Total								
1961	1,361	-	-	-	-	-	-	-	-	-	-	-	-	1,361
1962	938	-	111	-	-	-	-	-	-	-	-	-	-	1,049
1963	1,320	1,189	-	-	-	-	-	-	-	-	-	-	-	2,509
1964	1,644	627	-	-	-	-	-	-	-	-	-	-	-	2,271
1965	1,998	2,528	1	-	-	-	-	-	-	-	-	-	11	4,538
1966	2,724	6,698	6	3	-	-	-	-	-	-	-	-	-	9,431
1967	3,891	17,994	507	138	-	90	211	46	-	-	-	-	-	22,877
1968	3,929	41,294	10,608	283	-	121	3,342	312	16	-	-	-	68	59,973
1969	4,364	85,110	18,398	140	2,083	89	2,214	523	-	-	-	-	253	113,174
1970	4,049	124,483	68,140	758	4,007	1,049	5,631	1,500	-	-	-	-	-	209,617
1971	2,406	127,828	112,294	4,521	28,507	2,795	69,173	1,025	-	-	50	145	-	348,744
1972	2,006	134,057	141,999	2,519	23,556	770	80,537	1,104	1	800	6	9	-	387,364
1973	1,933*													

*Preliminary estimate.

Table 2. Estimates of relative catchability coefficients for U. S. gear-tonnage class categories with the number of trips in parentheses.

Gear	Tonnage Class	Year									
		1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Hand line	0-50	-	0.30 (1)	-	-	0.08 (2)	-	-	-	0.35 (1)	-
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)
	51-150	26.53 (2)	-	-	1.20 (1)	3.38 (1)	17.29 (5)	4.45 (10)	7.10 (3)	-	19.96 (6)
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)
	51-150	-	-	-	-	-	-	-	2.19 (3)	-	-
Sink gill net	0-50	-	1.60 (3)	-	-	-	-	-	-	-	0.42 (2)
	51-150	31.97 (7)	-	-	-	-	-	-	-	-	-
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)
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)
	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)
	151-630	-	-	-	126.68 (1)	0.28 (1)	-	-	-	-	-
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)
Midwater pair trawl	0-50	-	-	-	-	-	-	-	-	-	18.32 (1)
	51-150	-	-	-	-	-	-	-	-	-	24.39 (1)

Table 3. Mackerel landings/hour (in MT) by distant water fleets in ICNAF Subarea 5 and Statistical Area 6.

Tonnage class	Year	Poland			Romania			U.S.S.R.			G.D.R.			Bulgaria		
		SA5	SA6	SA5&6	SA5	SA6	SA5&6	SA5	SA6	SA5&6	SA5	SA6	SA5&6	SA5	SA6	SA5&6
151-500	1968	--	--	--	--	--	--	0.48	0.63	0.49	--	--	--	--	--	--
	1969	--	--	--	--	--	--	0.63	1.05	0.87	--	--	--	--	--	--
	1970	--	--	--	--	--	--	0.92	1.13	1.03	--	--	--	--	--	--
	1971	--	--	--	--	--	--	0.52	0.69	0.62	--	--	--	--	--	--
	1972	--	--	--	--	--	--	0.46	0.38	0.45	--	--	--	--	--	--
501-900	1968	1.24	--	1.24	--	--	--	--	--	--	--	0.46	0.46	--	--	--
	1969	0.77	1.34	0.88	--	--	--	0.95	1.16	1.06	0.43	0.69	0.50	--	--	--
	1970	0.62	1.37	0.84	--	--	--	0.87	1.63	1.16	0.80	2.91	1.29	--	--	--
	1971	0.68	1.03	0.89	--	--	--	0.58	0.87	0.71	0.57	1.89	1.81	--	--	--
	1972	0.55	0.95	0.82	--	--	--	0.70	0.31	0.58	0.36	0.54	0.44	--	--	--
901-1800	1968	1.86	--	1.86	--	--	--	--	--	--	--	--	--	--	--	--
	1969	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	1970	--	--	--	--	--	--	--	--	--	1.57	1.56	1.56	--	--	--
	1971	2.81	3.50	3.26	--	--	--	--	--	--	--	5.80	5.80	--	--	--
	1972	2.54	3.84	2.99	--	--	--	--	--	--	5.26	4.89	5.00	--	--	--
>1800	1968	1.28	--	1.28	--	--	--	0.69	0.99	0.73	--	--	--	--	--	--
	1969	0.94	--	0.94	--	--	--	1.04	1.39	1.11	1.59	--	1.59	1.07	--	1.07
	1970	2.51	4.11	2.98	0.80	--	0.80	1.00	3.65	2.50	2.05	2.58	2.38	1.11	2.57	1.57
	1971	4.65	4.68	4.67	0.62	1.89	1.10	1.24	2.53	1.89	4.31	11.73	10.06	1.17	3.41	3.32
	1972	3.36	6.04	4.69	0.48	1.31	0.89	2.28	2.12	2.21	5.52	8.99	7.59	0.84	3.17	..69

Table 4. Vessel types within country-tonnage class categories from which data for 1968-1972 were used in the analysis of variance procedure for estimating relative catchability coefficients.

Tonnage class	Poland	Romania	U.S.S.R.	G.D.R.	Bulgaria
151-500	---	---	OTSI, SRT	---	---
501-900	OTSI, B-10/14 OTSI, B-20	---	OTSI, SRTM OTSI, SRTR	OTSI MTSI OTSN MTSN	---
901-1800	OTSN, B-29	---	---	OT MT OTSI MTSN	---
>1800	OTSN, B-15/22 OTSN, B-418 OTSN, B-18	OTSN	OTSN, BMRT OTSN, RTM Tropic OTSN, RTM Atlantic	OTSN MTSN	OTSN, BMRT OTSN, Atlantic

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 5. Mackerel landings (MT) from directed mackerel effort by distant water fleets used in the analysis of variance procedure for estimating relative catchability coefficients in ICNAF Subarea 5 and Statistical Area 6.

Tonnage class	Year	Poland	Romania	U.S.S.R.	G.D.R.	Bulgaria
151-500	1968	--	--	10,690	--	--
	1969	--	--	28,240	--	--
	1970	--	--	48,018	--	--
	1971	--	--	31,148	--	--
	1972	--	--	31,544	--	--
501-900	1968	756	--	--	104	--
	1969	5,108	--	7,020	347	--
	1970	7,771	--	25,553	912	--
	1971	7,868	--	15,761	1,624	--
	1972	16,317	--	7,375	879	--
901-1800	1968	108	--	--	--	--
	1969	--	--	--	--	--
	1970	--	--	--	216	--
	1971	30,868	--	--	441	--
	1972	37,478	--	--	1,881	--
>1800	1968	1,272	--	1,506	--	--
	1969	2,936	--	9,136	499	1,966
	1970	47,690	444	26,065	3,238	4,007
	1971	56,816	4,243	88,608	65,269	27,269
	1972	76,600	2,061	44,527	72,363	23,556

Table 6. Percentage of mackerel in the landings of the U.S.S.R. 151-500 ton class in ICNAF Subarea 5 and Statistical Area 6 in 1968-1972.

Year	Percentage of total catch	Percentage of catch taken by effort considered directed towards mackerel
1968	16.9	48.6
1969	32.9	67.7
1970	63.2	80.3
1971	54.8	74.3
1972	54.6	66.9

Table 7. Country-tonnage class categories indicating years for which effort was adjusted for learning.

Country	Tonnage class	Years adjusted	
		Subarea 5	Statistical Area 6
Poland	501-900	1968, 1969	1969, 1970
	901-1800	1968, 1971[1]	1971, 1972
	>1800	1968, 1969	1970, 1971
Romania	>1800	1970, 1971	1971, 1972
U.S.S.R.	151-500	1968, 1969	1968, 1969
	501-900	1969, 1970	1969, 1970
	>1800	1968, 1969	1968, 1969
G.D.R.	501-900	1969, 1970	1968, 1969
	901-1800	1970, 1972[2]	1970, 1971
	>1800	1969, 1970	1970, 1971
Bulgaria	>1800	1969, 1970	1970, 1971

[1]No directed mackerel effort by this class in 1969 and 1970.

[2]No directed mackerel effort by this class in 1971.

Table 8. Estimates of relative catchability coefficients for country-tonnage class categories obtained with and without adjustments for learning.

Country	Tonnage class	Without learning					With learning				
		1968	1969	1970	1971	1972	1968	1969	1970	1971	1972
Poland	501-900	2.45	1.27	0.90	1.12	1.61	2.45	1.74	1.67	1.35	1.60
	901-1800	3.67	--	--	3.79	5.46	3.80	--	--	11.36	7.46
	>1800	2.45	1.62	2.29	4.47	9.72	2.45	1.41	3.66	6.60	9.70
Romania	>1800	--	--	0.74	1.91	1.37	--	--	2.97	5.14	2.17
U.S.S.R.	151-500	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	501-900	--	1.32	0.83	0.71	0.98	--	2.36	1.25	0.63	0.98
	>1800	1.43	1.68	2.10	2.85	5.91	1.43	1.92	2.75	3.07	5.91
G.D.R.	501-900	0.90	1.02	0.92	2.09	1.48	0.90	1.93	1.92	2.37	1.48
	901-1800	--	--	1.88	7.08	5.01	--	--	6.76	19.97	6.88
	>1800	--	1.30	2.35	8.35	8.92	--	1.57	4.22	11.59	8.95
Bulgaria	>1800	--	1.50	2.13	4.31	1.86	--	3.01	7.17	7.51	1.86

Table 9. Total mackerel landings and measures of standardized catch/effort and fishing effort.

Year	Total landings (MT)	U.S.		Distant Water Fleet			
				Landings/Hour		Hours Fished	
		Landings/Day	Days Fished	Without learning	With learning	Without learning	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	13,072	--	--	--	--
1968	59,973	2.80	21,419	0.49	1.96	122,394	30,598
1969	113,174	1.92	58,945	0.77	1.51	146,979	74,950
1970	209,617	2.07	101,264	1.20	1.07	174,681	195,904
1971	348,744	1.29	270,344	0.91	0.92	383,235	379,070
1972	387,364	0.84	461,148	0.54	0.54	717,341	717,341
1973		0.53					

Table 10. Stratified mean catch (pounds, $\log_e$ scale) of mackerel per tow from spring (strata 1-14, 61-76) and fall (strata 1-2, 5-6, 9-10, 13, 16, 19-21, 23, 25-26) U.S. groundfish survey cruises with $\pm$ 2 S.D. indicated.

Year	Spring	Fall
1963	-	0.02 $\pm$ 0.03
1964	-	<0.01 $\pm$ 0.00
1965	-	0.07 $\pm$ 0.06
1966	-	0.09 $\pm$ 0.07
1967	-	0.32 $\pm$ 0.14
1968	0.73 $\pm$ 0.24	0.17 $\pm$ 0.11
1969	0.03 $\pm$ 0.02	0.21 $\pm$ 0.16
1970	0.56 $\pm$ 0.18	0.11 $\pm$ 0.08
1971	0.52 $\pm$ 0.18	0.09 $\pm$ 0.06
1972	0.42 $\pm$ 0.18	0.11 $\pm$ 0.07
1973	0.20 $\pm$ 0.08	0.06 $\pm$ 0.02

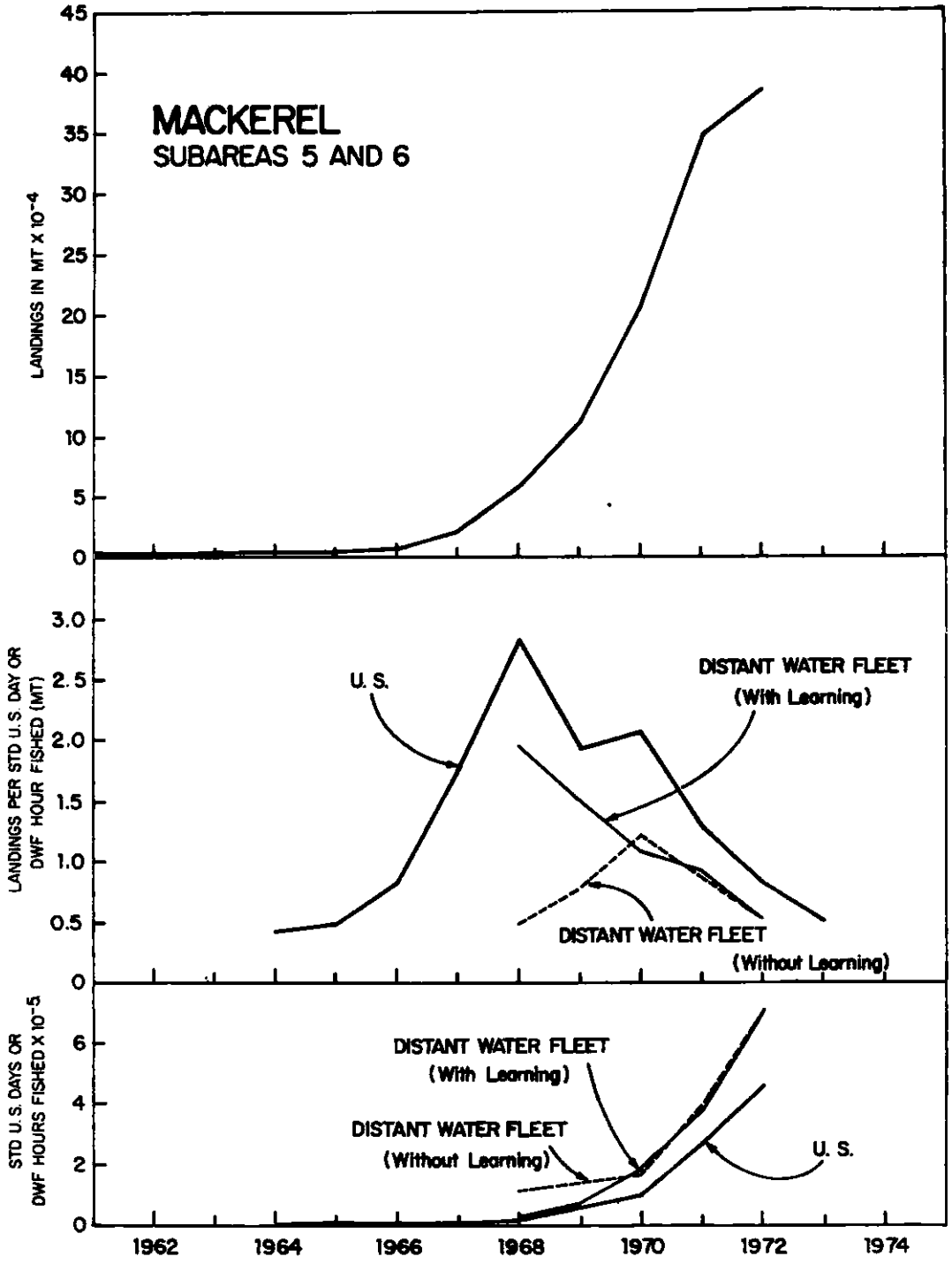

Fig. 1. Landings and US and distant-water fleet landings per standardized effort indices and total standardized effort for the ICNAF Subarea 5 and Statistical Area 6 mackerel stock.

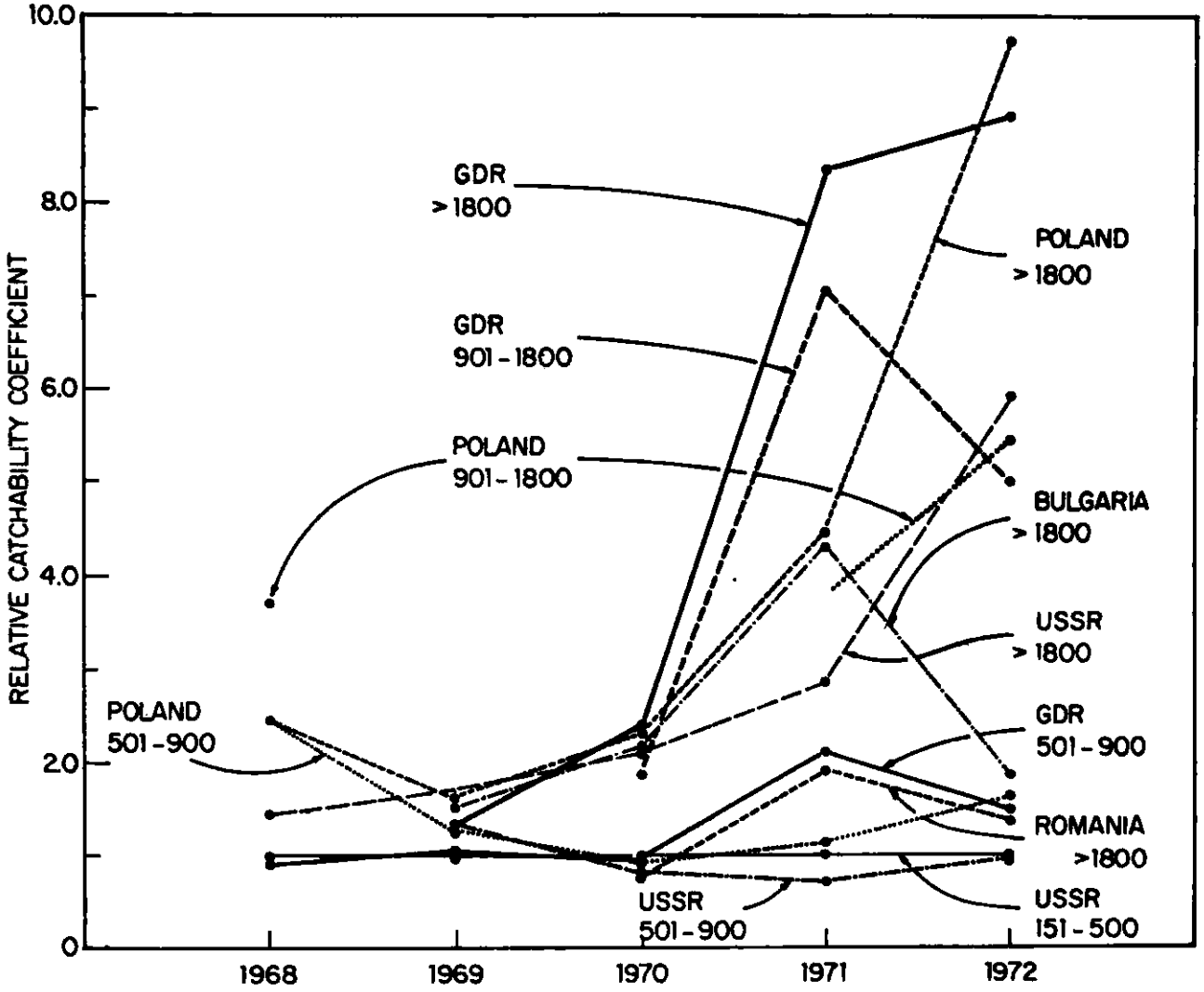

Fig. 2. Relative catchability coefficients for the distant-water fleet country-tonnage class categories obtained without adjustments for learning.

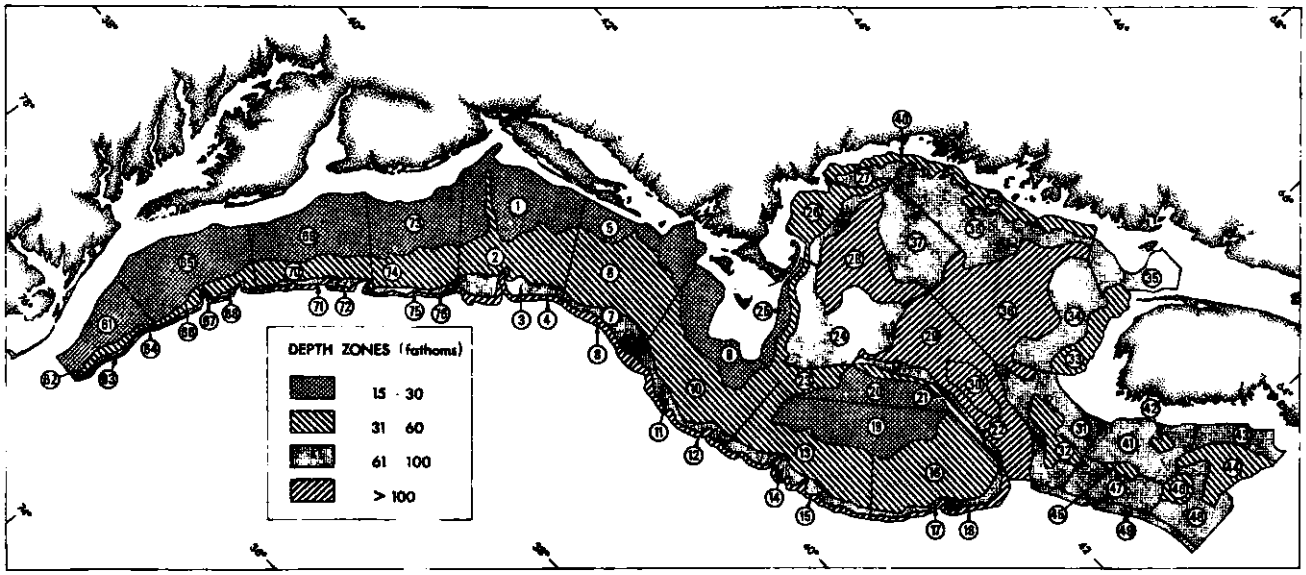

Fig. 3. US-USSR groundfish survey sampling strata.

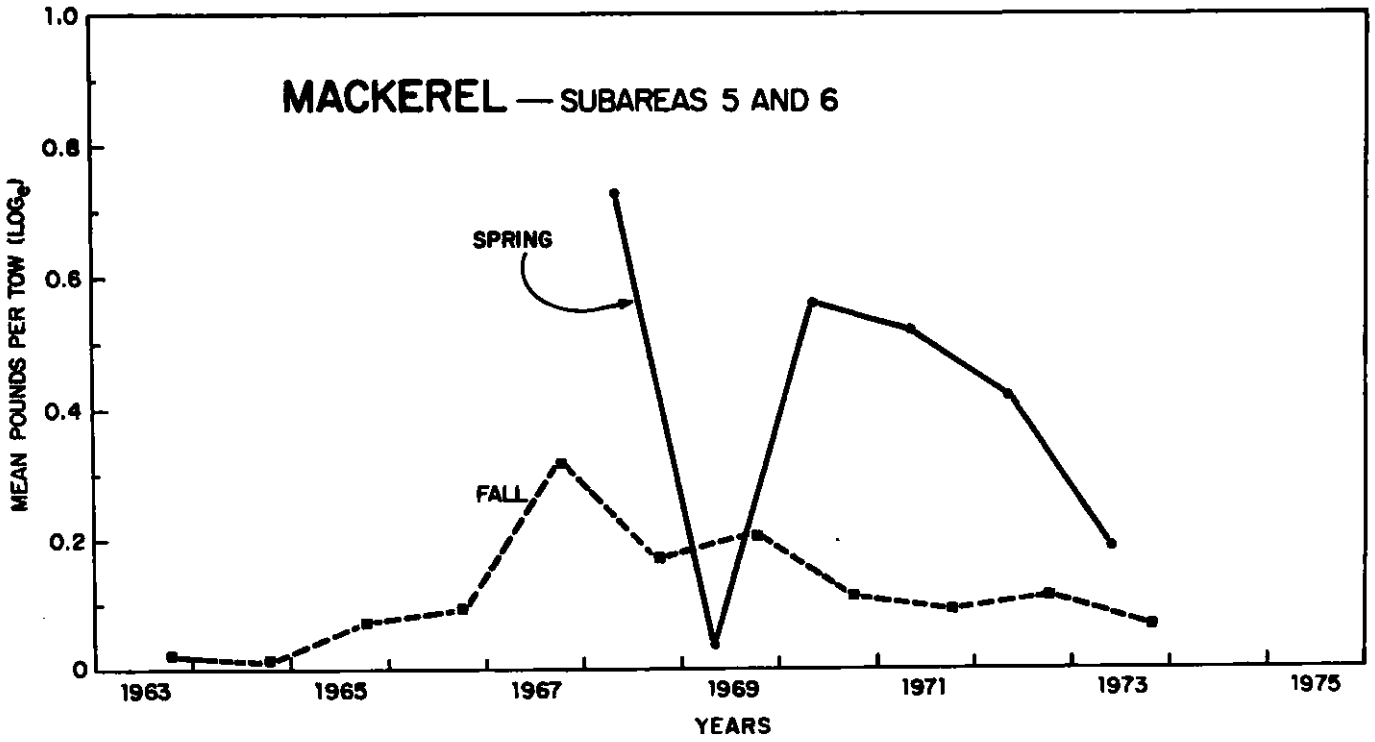

Fig. 4. Stratified mean pounds per tow ($\log_e$) of mackerel from US spring and fall groundfish survey cruises in ICNAF Subarea 5 and Statistical Area 6.