RESTRICTED

INTERNATIONAL COMMISSION FOR THE NORTHWEST ATLANTIC FISHERIES

Serial No. 2910
(D.c.9)

ICNAF Res.Doc. 73/8

ANNUAL MEETING - JUNE 1973

An Evaluation of the Effect of Fishing on the Total Finfish Biomass in ICNAF Subarea 5 and Statistical Area 6[1]

by

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Published in ICNAF RES. BULL. NO. 12: 49-68

Introduction

Prior to 1960 almost all of the fishing in ICNAF Subarea 5 and Statistical Area 6 was done by United States vessels. This fleet was developed on the basis of a coastal fishery and was composed of vessels under 300 GRT. Since 1960 the fleets of other countries, such as U.S.S.R., Poland, West Germany, and Japan among others have entered this area. These fleets are primarily composed of larger and highly mobile vessels and have steadily increased both in number and total tonnage (ICNAF List of Fishing Vessels, 1971) while the United States fleet has gradually declined. This increase in number of vessels has resulted in enlarging the scope of the fishery which previously had concentreted on selected groundfish species such that now all of the major species of fish in the entire area from Nova Scotia to Cape Hatteras are heavily fished (ICNAF Statistical Bulletins 1-20).

The Research and Statistics Committee of ICNAF which has been evaluating the effects of fishing on stocks in this area (ICNAF Redbooks, Vols. 1953-1972) has from time to time advised the Commission that certain stocks (e.g. haddock and herring) were demonstrably overfished; i.e., the fishing mortality was at or beyond the level which maximized the yield and yield-per-recruit. The Commission has set quotas on some species, but often only after the stock size had been severely reduced to the point requiring large reductions in the catch. The Research and Statistics Committee has recognized that the rapid expansion of fishing activity almost precludes the ability to assess the effects of fishing on each of the many stocks before they are subjected to heavy fishing.

There is grave doubt that management based on assessing the status of each stock, is capable of producing a management regime that will result in obtaining a sustainable yield at or near the maximum for the total biomass. This is not only because of the inability of scientists to collect the necessary data and make the required assessments in a short enough period of time , but because of the mixed nature of the fisheries in ICNAF Subarea 5 and Statistical Area 6, and the intricacies of

[1] Revision of Sp.Mtg.Res.Doc.73/8 presented to Special Commission Meeting, FAO, Rome, January 1973

ecological relationships. The mixed nature of the fishery results from the economic desirability of harvesting several species at one time, the extensive use of otter trawl gear which is quite unselective and the species composition in this ecosystem in which numerous species contribute significantly to the biomass. The latter can be illustrated by the 1971 U.S.A. and U.S.S.R. joint fall groundfish surveys where the mean number of species per tow was 12 for the U.S.A. vessel and 11 for the U.S.S.R. Incidental catches of regulated species in this situation may be enough to harvest the total production in the case of those such as haddock which are at low abundance levels. The interrelationship of different species is not well understood, and considerable research is needed on this subject. However, simple basic ecological concepts are enough to underscore the need to examine the yield of this total ecosystem as a whole rather than as just the sum of individual components. Certain single species regulations may play a vital part under a total biomass yield management regime but alone they are unsatisfactory under the heavy fishing pressures existing in the area under discussion.

In this paper the status of the fishery is evaluated in terms of total biomass and total fishing intensity. This approach offers a first approximation to including interspecific relations in the estimation of sustainable yield. They are included implicitly to the extent they have been significant in affecting production over the last 10 years. Declines in total stock abundance are examined for commercial catch/effort and survey cruise data. A Schaefer yield model for total biomass is examined and the relationship of current effort levels to those relative to maximum yield are discussed.

Standardization of Fishing Units

The diversity of types of vessels, fishing gear and fishing practices has always caused problems when commercial fishery data has been used to estimate fishing mortality. Indeed, only a few of the attempts to define an explicit relationship between effort and fishing mortality have been successful. However, indices of fishing intensity which purport to measure the relative fishing mortality exerted over some time period have commonly been used to determine the status of fisheries. In some cases, a single type of gear has been used and in other cases the gear has been classified by categories of size and type based on factors which are demonstrably related to the rate of harvest. We have chosen the latter approach as most applicable to the statistics reported to ICNAF. Catch and effort data from 1961-1971 were obtained from Tables 4 and 5 of the ICNAF Statistical Bulletins (Nos. 10-21). Effort data for the German Democratic Republic was obtained from ICNAF Summary Document 73/3 for 1969-1970.

We chose days fished as reported to ICNAF as the basic unit of effort for analysis. This has been reported by member countries more consistently than hours fished. We considered days fished to more closely relate to fishing intensity than days on ground and also to be a more standard measure of fishing activity for all types of vessels and gears.

In order to express total effort on a standardized basis, relative catchability coefficients must be estimated which can be applied to the various categories of vessels. Robson (1966) proposed determining relative catchability coefficients using an analysis of variance technique with a logarithmic linear hypothesis model. In the present study, the following model was utilized:

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$$Y_{ijk} = m * a_i * b_j * e_{ijk}, \quad \text{where}$$

Y_{ijk} is the catch per day of all species of fish for the ith country for the jth gear-tonnage class category and for the kth year, that is, the sum of the appropriate Table 4 entries for each year, m is the overall mean catch per day, a_i is the country effect, b_j is the gear-tonnage class category effect, and e_{ijk} is the error of the kth observation at the i-j level such that $\ln(e_{ijk})$ has a $N(o, \sigma^2)$ distribution. Sampling error is measured on a year to year basis.

A natural logarithmic transformation of the observations was used to achieve linearity of the model. The coefficients were then estimated using the analysis of variance procedure outlined by Snedecor and Cochran (1967) for a row x column design with unequal frequencies and missing observations.

This procedure computed fishing relative catchability coefficients a_ib_j in relation to the overall mean m. The relative catchability coefficients were then expressed for each cell (a country, gear-tonnage class combination) in relation to a standard cell by dividing the ratio of a_ib_j for the ith, jth cell to the a_ib_j value for the selected standard cell. Since the a_ib_j are all estimated by the row and column totals in the analysis, it is immaterial which cell is selected as standard. The U.S.A. side trawler 0-50 GRT class was used in this analysis.

Gears included in the analysis of variance were stern trawls, side trawls, pair and midwater trawls, purse seines, drift gill nets, long lines and hand lines. The resultant data accounted for approximately 83% of the total catch considered relevant to this study of the offshore mixed fishery in ICNAF Subarea 5 and Statistical Area 6. The remaining 17% of the total catch consisted of species caught by other lines and other seines, as well as catch data for which days fished were not recorded. Excluded from the study were several kinds of catch not concerned with finfish. Catch and effort data for lobsters, shrimp, scallop and miscellaneous shellfish were not considered. In addition, U.S.A. menhaden landings, which are captured close to shore, were excluded from the analysis. Eels, white perch and large pelagics, i.e. swordfish, sharks, and tuna were also eliminated. The large pelagics contribute minimally to the total catch. Certain small effort category entries, e.g. "by hand" were not analyzed. Catch of fixed gear along shore, i.e. pound nets, stop seines, etc., were omitted. The latter type of gear tends to harvest at a fixed rate as the total number of sites are limited. They also are difficult to analyze as equivalent to mobile gear. Table 1 lists the catch by country not included in the analysis of variance. The bulk of the catch for the U.S.A. and the U.S.S.R. in Table 1 was taken from Statistical Area 6 when there was no required reporting of statistics to ICNAF for that area.

Adjustment for Learning

It may be expected that the development of fisheries in areas and on stocks not previously fished involves a degree of learning.how the fish are distributed over the grounds, particularly in relation to seasonal changes, how best to deploy the different kinds of gear in relation to types of bottom or current patterns and how the fish themselves behave and respond to the gear. There may be additional reasons involved. We have not attempted to define the learning factors in terms of explicit causes, but have approached the problem by assuming that it would be expressed as a consistent increase in catch per unit effort through time that is not related to changes in stock abundance.

An exponential learning model was assumed thus,

$$\frac{Xi}{Zi} = \left[\exp(a(i-1))\right] e_i, \text{ where}$$

$$Zi = X_1 \left(\frac{Yi}{Y_1}\right)$$

Xi = the observed commercial catch per unit effort in the ith year in the fishery after entrance,

Yi = the stock abundance in the same year, and

e_i = residual error, where $\ln(e_i)$ has a $N(o, \sigma^2)$ distribution.

Stock abundance was estimated from the catch per tow of the autumn groundfish surveys on the U.S.A. research vessel, Albatross IV. Catch per unit effort of certain fisheries were selected to estimate the parameter a of the function. These fisheries were chosen to reflect a representative set of the major fisheries for which the requisite data were complete: U.S.S.R. 500-900 GRT side trawlers in the 5Z silver hake fishery, Spanish pair trawlers in the 5Z herring fishery, and Romanian 1800+ GRT stern trawlers in the herring fishery. The first year of the fishery was defined as that year when the catch of the defined species in the fleet considered first exceeded 20% of its total catch. Where the catch of a given species was between 20 and 80%, effort was prorated on the basis of the catch and when the catch exceeded 80% the entire effort was considered to be directed towards that species. The curve was fitted to the $\log_e$ data by least squares (see Figure 1). It is apparent that learning has been completed by the third year in the fishery. The parameter a was estimated from all data combined to be 0.71 with an index of determination of 0.80 (proportion of the variation accounted for by the model.

The learning function was applied to each case where new species fisheries were developed in the period 1961-1971 (Table 2). Division 5Y, 5Z and Statistical Area 6 were treated separately. The amount of effort for a particular species for a gear-tonnage class-country to be adjusted was determined from the proportion of catch of that species to total catch by the category. The catch per effort was then adjusted according to model, and subsequently divided into the catch of the species to get the adjusted effort. This adjusted effort was then substituted in the total effort for a particular gear-tonnage class-country combination for the original effort before proceeding with the analysis of variance. The adjustment amounted to substituting 1/4 of the recorded effort for the first year of a new fishery, and halving of the recorded effort in the second year. Effort related to 11% of the total catch was adjusted for learning.

Results of Analyses Variance

Standardizations of effort were calculated with and without the data adjusted for learning. The results of the analyses of variance are presented in Table 3. Both vessel class and country effects were significant at the .01 probability level. The former showed the greatest differences. With missing cells the presence of a significant interaction, as is the case in theory, sum of squares invalidates the assumption of additivity and the use of the row and column coefficients to adjust effort. The cell values were examined to determine the source of the interaction. Departures from main effect trends could be attributed mainly to the following country and gear-tonnage class combinations: drift gill nets, U.S.S.R.; and stern trawls, U.S.A., tonnage class 1800+ GRT. Considering the relatively minor contribution of these categories to the total catch (0.5%) and effort (0.02%), the effect of ignoring the interaction would be minimal, and we proceeded with the analysis assuming additivity. Relative catchability coefficients are presented in Table 4 for all country gear-tonnage categories which were present in the fishery over the years. It must be understood that these coefficients do not measure strict technical fishing power because they reflect patterns of fishing as well as vessel capabilities. However, they are appropriate for standardizing the effort as reported to ICNAF so that the change in standard effort reflects the change in fishing mortality.

Estimation of Total Effort

Total effort in standard-days-fished directed at finfish was estimated for each year from 1961 to 1971 by multiplying the raw days fished by the relative catchability coefficient relative to the standard (U.S.A otter trawlers) and summing over all categories. Catch per standard day of finfish was estimated each year by dividing the total catch represented by these categories by the effort thus obtained. The total annual finfish catch for Subarea 5 and 6, including those catches from gear-country combinations discussed earlier which were excluded from the analysis of variance, was divided by the standardized catch per day to obtain the total effort. The only exception to this procedure was data of U.S.A. catches, 1961-1971, Statistical Area 6. The use of a 1968-1970 average catch per standard day was applied here because the inshore stocks fished by the U.S. in that area are generally separate from stocks in 5Z, and would be lower if anything than that earlier in the period as overall stock abundance had declined based on reported U.S.A. statistics and species assessments reported in ICNAF Redbooks. This procedure was followed both with and without adjustments for learning. The results are presented in Table 5 and Figure 2.

These values clearly illustrate the importance of standardizing effort in estimating the relative fishing mortality exerted on the fisheries in a particular area. The raw effort approximately doubled during the period 1961 to 1971, while the standardized effort quadrupled during the same period. When the effect of learning is considered the standardized effort increased by a factor of six.

Yield-Effort Relations of the Finfish Stocks.

In calculating a maximum sustained yield for the finfish community as a whole (excluding large pelagic species and menhaden), the approach discussed by Schaefer (1954) was used. Schaefer's model assumes logistic growth and symmetric yield curves with the MSY value occurring at 50% of the maximum stock size. Because this model considers only the combined effect of recruitment, growth, and natural mortality parameters, only catch and fishing effort statistics are needed to make the calculations of MSY.

The fitted curves purport to represent the equilibrium or long-term average expected yields. In the Northwest Atlantic, we have demonstrated a rather consistent and rapid increase in effort, particularly in the first part of the decade covered. When there are large and consistent increases or decreases in fishing effort, the fitted curves tend to overestimate or underestimate the true situations unless the population reacts instantaneously in adjusting its productivity to the new structure. When this is not so, the effects of fishing effort in any given year are dependent upon the cumulative effect of previous years' effort. Gulland (1961) suggests that in order to account for this effect, the average effort over the previous number of years equal to the mean number of years that a year class contributes significantly to the catch, taken as the effort applicable to any year. The number of years to be averaged is a function of the total mortality rate.

For the fish stocks of the Northwest Atlantic one might, under normal conditions, assume that a given year class contributes significantly over a 3-year period. However, the period covered by our calculations shows some significant non-normal events. For herring, two very good year classes were spawned in 1960 and 1961, and these fish carried a major share of the fishery for 5-6 years (Schumacher and Anthony (1972);;Anthony and Brown (1972)). Haddock have existed virtually without any significant recruitment since the 1962 and 1963 year classes and thus these year classes contributed significantly over 7-8 years (Hennemuth, 1969). The mackerel fishery has been harvesting principally the same 2-year classes, 1966 and 1967, since the fishery began to increase in 1968 and probably will continue to do so in 1972 and 1973 (U.S.S.R. and Polish Research Reports, ICNAF Redbook, 1972). Silver hake, with a more stable age distribution, shows a 3-4 year pattern of contribution (Anderson, 1972), as do yellowtail flounder (Brown and Hennemuth,(1971). Consequently, running averages of total effort were made over 3, 4, and 5-year periods to cover the possible range of this effect.

The parameters of the Schaefer model were estimated by computing least squares linear regressions of catch/effort in year i on a running average of effort over the previous 2 to 4 years and in year i. For each method of averaging effort, several regression lines were calculated corresponding to data sets beginning with 1968-1971 data and successively adding data to earlier years back to 1961. In each case the parameters of the predicted linear equations were converted to parameters of the yield versus effort parabolas (Table 6).

The indices of determination (proportion of total variation accounted for by the regression line) of all data sets ranged from .64 to .97 for data adjusted for learning, and from .39 to .89 for data not adjusted for learning. The range of the estimates of the parameters on the yield versus effort parabolas

(MSY, optimum effort, and catch/effort) was smaller for data adjusted for learning. This trend, i.e. data adjusted for learning determining parametric estimates with narrower ranges, seems reasonable; these data, having been adjusted for a major source of annual variation - learning, should be more consistent over the number of years for which effort is averaged (3-5 years) and the number of years included in the regression analysis.

In both data sets, i.e. where there was a learning adjustment, and where there was not, the best fits to the Schaefer model occurred when data sets for the years 1965-1971 were fit. The years prior to 1965 were those at the beginning of the distant water fleet fishery, when statistics were perhaps not as complete, e.g. no U.S.S.R. effort in 1962, and also that period when the effects of learning would be expected to be greatest as entirely new fisheries were being developed by these fleets. The percentage reductions in standardized effort from the 1971 levels to reach the MSY level resulting from these fits are as follows:

Averaging Period	No Learning Adjustment	Learning Adjustment
3 years	23%	34%
4 years	30.5%	40%
5 years	34.5%	42%

The average MSY for the three 1965-1971 data sets using the 3-year, 4-year and 5-year averaging method for effort was 810,267 MT for data adjusted for learning and 823,902 MT for data without adjustment for learning. Both these values are close to the 1968 total catch figure of 856,098 MT. The corresponding optimum effort values, ranging from 148,624-169,572 standard days fished for data adjusted for learning and 138,410-162,621 standard days fished for data without learning adjustment, likewise are in the vicinity of the 1968 level.

Other Estimates of Sustainable Yield

Data for research surveys and individual species assessments were also used to estimate the MSY value for the entire finfish stocks in Subarea 5 and 6. Grosslein (1972) estimated that the MSY for all groundfish (except hakes), flounders, dogfish, and skates approximated 200,000 metric tons for Subarea 5Z. Based on historical catches, a value of 185,000 metric tons does not seem unreasonable for the same group of species in Subarea 5Y and Statistical Area 6. Anderson (1972) and Anderson and Au (1972) in assessment working papers presented at the 1972 ICNAF Annual Meeting indicated a MSY for red and silver hake in Divisions 5 and 6 to be around 240,000 metric tons. Individual assessments indicated MSY values of 285,000 metric and 300,000 metric tons for herring and mackerel, respectively. These total to 1,210,000 metric tons. However, in both cases, the MSY values were each dependent upon two extremely good year classes within each fishery during this time. Furthermore, herring and mackerel have not maintained a high biomass concurrently, but rather the latter increased after the former declined.

Consequently, it may be that a more accurate description of the potential yield for the two species might be estimated by looking at the average combined landings for the two. Table 7 presents the metric tons landed by all countries of herring and mackerel over the period of analysis. The average annual landings figure for the two species combined over the 11-year period (1961-1971) is 303,000 metric tons. Summing all of the above estimates of potential MSY values give a total stock of 927,000 metric tons which is very close to the estimates calculated from the surplus yield model.

Decline in Biomass as Estimated from Albatross IV Survey Data Cruise

Estimates of relative change in biomass for groundfish and flounders on Georges Bank and southern New England were calculated by comparing mean catch per haul figures for United States autumn surveys in 1963-1965 with the mean values for 1969-1971. With few exceptions there were substantial declines in the abundance of groundfish in both areas (Table 8).

An estimate of the relative change in biomass for the whole of 5Z and 6 was made by pooling the survey results for southern New England (strata 1-12) and Georges Bank (strata 13-23, 25; see Figure 5). This set of sampling strata covered only DIV 5Z, but since the bulk of the major groundfish stocks are found east of Hudson Canyon, the data are considered adequate for a first approximation for SA6. The pooled mean catch per haul data shows declines ranging from about 20-90% for nearly every species or species group within the groundfish and flounder category, and a decline of 62% for skates (Table 9). The only exceptions are white hake and sculpins. White hake showed no change, and longhorn sculpins showed a 45% increase. In the case of sculpins, it seems likely that the drastic decline (over 90%) in haddock may have contributed to increased survival of sculpins since haddock prey heavily on sculpin eggs which adhere to the sea bed. Cod, silver and red hake, and miscellaneous flounders all declined about 45%, and yellowtail and winter flounder dropped about 20% (Table 9). Ocean pout and angler showed greater declines of 85 and 65%, respectively, and miscellaneous groundfish declined approximately by one third.

An estimate of the decline for sea herring was made using herring abundance indices for 1968-1971 based on U.S.A. spring surveys (Figure 6). Spring surveys are conducted in March when sea herring are concentrated south of Cape Cod, and the abundance indices shown in Figure 6 represent sampling strata 1-12 and 61-76 combined (area south of Cape Hatteras). The extrapolated $\log_e$ value for 1964 is 2.7 (vs 0.3 for 1971) which corresponds to a decline of about 90%. This value corresponds well with the estimated reduction in the sea herring stock based on assessment studies (ICNAF Redbook, 1972). A first approximation to the decline in total biomass of finfish in Divisions 5Z and 6A was calculated by weighting the decline of each species (or group) shown in Table 8, in proportion to the cumulative landings of that species over the decade 1962-1971. The resulting weighted change indicates about a 65% drop in total biomass of the principal finfish species under exploitation the last decade; if we exclude sea herring from consideration the weighted mean decline of groundfish alone is 49% (Table 9). This estimate is based on the assumption that landings are approximately proportional to size of the biomass of each species. The decline including sea sea herring is plotted in Figure 3 through the mean of catch/effort and effort for the decade. The average effort of the starting and ending three year periods were used as the beginning and ending points for the line representing this decline. The MSY for this curve is 860,000 MT at 120,000 days fished.

The estimate of the decline may be on the conservative side because landings of some miscellaneous groundfish species (particularly pout, angler and skates) were not adequately reported in earlier years, and these species showed average declines. Significant known biomass components not included in these calculations are dogfish and mackerel. In the case of dogfish, there has been no abundance trend observed and there is essentially no exploitation of this resource. With respect to mackerel, no trends have been observed in the overall survey abundance indices.(computed overall strata on a weight basis). Significant removals did not begin until 1968.

It should be noted that the percentage declines are taken from a point of time (1963-1965) when most of the stocks concerned had already been harvested to some significant degree. Thus, the decline from unfished abundance levels is greater than indicated, and if one accepts that the maximum yields that can be sustained occur at stock sizes about one-half the maximum, the decline of 64% implies a significant degree of overfishing. This decline is plotted in Figure 3. The average efforts for 1963-1965 and 1969-1971 were used to position the decline on the x-axis, and a line was fitted through the mean of commercial catch/effort and effort for the decade to represent a 65% decline in catch/effort between the two end points on the x-axis.

Considering this information along with current assessment studies (ICNAF Redbook, 1972) it is logical to assume that the current sustainable yield is considerably less than the maximum values estimated in this paper. A value of 650,000 MT does not seem unreasonable as a first approximation. This is approximately 55% of the highest MSY estimate (the sum of individual species or species group assessments) and 80% of the average of the production curves (adjusted for learning).

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Table 1. Catch data (MT) for which days fished was estimated.

	USA	CANM	USSR	UK	ICEL	NONM	JAP	NORW	FRANCE	TOTAL	% annual catch
1961	69279	27						140		69446	21%
1962	98777	231	210090							309098	58%
1963	165313	392	7900							173605	27%
1964	149087	1188	28200	1050						179525	23%
1965	151423	1076	33400			3081				188980	20%
1966	81042	2537		111						83690	9%
1967	76475	9535		24			452			86486	12%
1968	13911	38424			292		7260		53	59940	7%
1969	6029	10225			12786	2102(B)	16922		5	48070	5%
1970	4754	7459				7338(B) 1549(C)	29659			50759	6.5%
1971	21046	32036	2144			106855(A) 1150(C)	54732			217993	20%
									TOTAL	1467592	17%

Table 2. Country gear-tonnage class categories where effort was adjusted for learning. Parenthesis indicates year in which greater than 20 percent of the total catch by a gear-tonnage class-country was taken in the given species, but for which days fished data was unavailable.

SPECIES	SUBAREAS 5Y				5Z				6			
	Country	Gear	Tonnage class	Years adjusted	Country	Gear	Tonnage class	Years adjusted	Country	Gear	Tonnage	Years adjusted
Herring	Germany (Fr)	OtSt	901-1800	1969, 70	Germany (Fr)	OtSt	901-1800	1967, 68	Poland	OtSt	501-900	1968, 69
		OtSt	1801+	1969, 70		OtSt	1801+	1967, 68		OtSt	1800+	1968, 69
	United States	Purse seine	51+	1965, 66	Non-Mbr	OtSt	1801+	(1965), 66	USSR	OtSi	151-500	1967, 68
					Poland	OtSi	501-900	1967, 68		OtSi	501-900	1969, 70
						OtSt	901-1800	1967, 68				
						OtSt	1801+	1966, 67				
					Romania	OtSt	1801+	1967, 68				
					USSR	OtSi	151-500	(1962), 63				
						OtSt	1801+	1961, (62)				
						Purse seine	50+	1968, 69				
						D. gill Nets - All		1961, (62)				
	NonMbr A	OtSt	501-900	1968, 69		Pair						
		OtSt	801+	1968, 69					NonMbr A	OtSi	501-900	1968, 69
Cod	Spain	Pair trawl	151-500	1969, 70								
Haddock					Spain	Trawl	151-500	1964, 65				
Silver hake					USSR	OtSi	501-900	1965, 66				
					USSR	OtSi	151-500	1963, 65				
						OtSi	501-900	1964, 65				
						OtSt	1800+	(1962), 63				
Mackerel					Poland	OtSi	501-900	1969, 70	Poland	OtSi	501-900	1969, 70
						OtSt	1800+	1968, 69		OtSt	1800+	1970, 71
					Romania	OtSt	1800+	1969, 70	USSR	OtSi	151-500	1968, 69
					USSR	OtSi	151-500	1969, 70		OtSi	501-900	1969, 70
						OtSi	501-900	1969, 70		OtSt	1800+	1970, 71

Table 3. Analysis of variance of ln (catch/effort) data for ICNAF Subareas 5 plus 6. No learning adjustment.

Source of variation	Sums of squares	Degrees of freedom	Mean square	F
Total	474.14	261		
Country (unadjusted)	97.49	8		
Gear-tonnage class (unadjusted)	371.14	16		
Country (adjusted)	12.38	8	1.547	4.05**
Gear-tonnage class (adjusted)	286.03	16	17.876	46.80**
Interaction	51.95	23	2.26	
Error	38.67	214	.181	
Interaction plus error	90.62	237	.382	

**Significant at 0.01 level.

Table 3 (contd). Analysis of variance of ln (catch/effort) data for ICNAF Subareas 5 plus 6, adjusted for learning.

Source of variation	Sums of squares	Degrees of freedom	Mean square	F
Total	546.65	261		
Country (unadjusted)	146.91	8		
Gear-tonnage class (unadjusted)	415.40	16		
Country (adjusted)	19.05	8	2.381	5.03**
Gear-tonnage class (adjusted)	287.54	16	17.97	37.99**
Interaction	57.74	23	2.51	
Error	54.46	214	.254	
Interaction plus error	112.20	237	.473	

**Significant at 0.01 level.

Table 4. Estimates of fishing power factors for given country and gear-tonnage class combinations for ICNAF Subareas 5 plus 6 without adjustments for learning.

COUNTRY	USA	CANADA	USSR	SPAIN	POLAND	GERMANY (FR)	NON-MEMBER A	ROMANIA	BULGARIA
Gear-tonnage class									
Otter trawl (side)									
0-50 MT	1.00	.63							
51-150 MT	1.265	.80							
151-500 MT	1.64	1.04	1.49			1.86			
501-900 MT		1.25	1.80		1.48	2.25	1.11		
901-1800 MT			2.85			3.57	1.77		
Otter trawl (stern)									
0-50 MT	3.37	2.14							
51-150 MT	.81	.51							
151-500 MT	1.72	1.09							
501-900 MT		1.74	2.51			3.14	1.55		
901-1800 MT			5.47		4.50	6.85	3.39		
>1800 MT	6.96		6.33		5.20	7.92	3.92	3.28	6.54
Purse seine									
>50	1.92								
<50	14.32	9.07	13.02						
Pair trawl - All			1.68	2.91					
Line trawls - All	.46	.29							
Hand lines - All	.13								
Drift gill nets - All	.098		.089						

Table 4 (contd). Estimates of fishing power factors for given country and gear-tonnage class combinations for ICNAF Subarea 5 plus 6 with adjustments for learning.

COUNTRY	USA	CANADA	USSR	SPAIN	POLAND	GERMANY (FR)	NON-MEMBER A	ROMANIA	BULGARIA
Otter-tonnage class									
Otter trawl (side)									
0-50 MT	1.00	.66							
51-150 MT	1.26	.83					1.17		
151-500 MT	1.58	1.04	1.88			3.06	1.92		
501-900 MT		1.19	2.16		2.17	3.51			
901-1800 MT			3.56			5.79			
Otter trawl (stern)									
0-50 MT	3.37	2.22							
51-150 MT	.80	.53							
151-500 MT	1.71	1.12							
501-900 MT		1.58	2.86			4.64	1.54		
901-1800 MT			6.92		6.93	11.24	3.74		
>1800 MT	6.50		7.72		7.73	12.55	4.17	5.01	6.62
Purse seine									
<50	1.94								
>50	15.76	10.37	18.72						
Pair trawl - All			1.70	3.79					
Line trawls - All	.45	.30							
Hand lines - All	.13								
Drift gill nets - All	.10		.13						

Table 5. Estimates of unadjusted effort, standardized effort without learning, standardized effort with learning, total catch, catch/unadjusted effort, catch/standardized effort without learning, and catch/standardized effort with learning for years 1961-1971, ICNAF Subarea 5 and Statistical Area 6.

Year	Unadjusted Effort	Standardized Effort No learning adjustment	Standardized Effort Learning adjustment	Catch	Catch / Effort	Catch / Standardized Effort-No Learning	Catch / Standardized Effort - Learning
1961	41,737	49,669	43,310	342,913	8.22	6.90	7.92
1962	69,331	103,934	101,544	536,841	7.74	5.16	5.29
1963	66,288	102,303	89,729	649,586	9.80	6.35	7.24
1964	72,429	119,931	136,201	782,519	10.80	6.52	5.74
1965	71,608	129,858	139,391	946,060	13.21	7.28	6.79
1966	65,865	142,060	159,362	949,017	14.41	6.68	5.96
1967	65,473	112,513	119,760	723,702	11.05	6.43	6.04
1968	76,102	146,978	156,551	856,098	11.25	5.82	5.50
1969	79,394	190,299	203,556	943,866	11.89	4.96	4.65
1970	69,851	150,048	166,999	773,818	11.08	5.16	4.64
1971	80,637	211,261	256,511	1,082,913	13.43	5.13	4.24

Table 6. Estimates of optimum effort*, MSY, catch/effort and coefficient determination for ICNAF Subarea 5 and Statiscal Area 6 catch and effort data applied to the Shaefer model. Gulland's averaging method to determine effort in year i was used on the basic data.

	No learning adjustment			Data adjusted for learning		
	Averaging period			Averaging period		
OPTIMUM EFFORT*	3 years	4 years	5 years	3 years	4 years	5 years
1963-1971	215,083			189,879		
1964-1971	174,072	173,066		192,966	194,079	
1965-1971	162,621	146,841	138,410	169,572	154,753	148,624
1966-1971	182,548	161,479	141,552	182,871	164,010	147,921
1967-1971	207,849	181,598	153,213	191,395	166,687	146,283
1968-1971	315,046	269,094	201,190	226,136	194,066	156,937
MSY						
1963-1971	940,885			858,148		
1964-1971	870,448	842,355		861,785	835,073	
1965-1971	863,015	822,634	786,058	851,039	809,570	770,192
1966-1971	874,999	823,188	784,983	850,532	804,845	770,648
1967-1971	899,851	836,255	781,923	846,778	803,415	772,953
1968-1971	1,106,334	986,029	832,619	869,515	804,076	761,363
CATCH/EFFORT						
1963-1971	4.37			4.52		
1964-1971	5.00	4.87		4.47	4.30	
1965-1971	5.31	5.60	5.68	5.02	5.23	5.18
1966-1971	4.79	5.10	5.55	4.65	4.91	5.21
1967-1971	4.33	4.60	5.10	4.42	4.82	5.28
1968-1971	3.51	3.66	4.14	3.85	4.14	4.85
COEFFICIENT OF DETERMINATION						
1963-1971	.54			.81		
1964-1971	.69	.66		.80	.64	
1965-1971	.71	.77	.89	.83	.88	.97
1966-1971	.62	.69	.81	.77	.83	.94
1967-1971	.58	.60	.75	.77	.78	.93
1968-1971	.39	.39	.51	.77	.78	.86

*The term optimum effort is used in association with MSY catch levels.

Table 7. Total annual landings from ICNAF Subareas 5 and 6 for herring and mackerel, 1961-1971, in metric tons $x10^{-3}$ (all countries).

Year	Herring	Mackerel	Total
1961	94	1	95
1962	224	1	225
1963	167	2	169
1964	159	2	161
1965	74	5	79
1966	172	9	181
1967	257	23	280
1968	436	60	496
1969	361	113	474
1970	303	210	513
1971	314	349	663
Average	233	70	303

Table 8. Mean catch per haul (lb) on Albatross IV Autumn surveys for 1963-65 and 1969-71 and percentage change from 1963-65 to 1969-71.1/

Species	Georges Bank 2/ 1963-65 mean	Georges Bank 2/ 1969-71 mean	Georges Bank 2/ % change	Southern New England 3/ 1963-65 mean	Southern New England 3/ 1969-71 mean	Southern New England 3/ % change
Haddock	147.6	11.3	-92	8.8	0.5	-94
Cod	16.0	9.6	-40	4.3	1.7	-60
Silver Hake	4.7	3.1	-34	13.6	7.0	-48
Red Hake	9.2	3.6	-61	12.9	8.8	-32
White Hake	1.5	2.3	+53	1.6	1.1	-31
Yellowtail flounder	19.5	10.7	-45	24.4	24.7	+01
Winter flounder	5.1	6.4	+26	6.7	3.4	-49
Other flounders	5.0	3.8	-24	8.1	3.4	-58
Longhorn sculpin	4.7	8.4	+79	2.1	1.9	-10
Ocean Pout	3.1	0.1	-97	1.0	0.4	-60
Angler	8.4	2.0	-76	11.8	4.9	-58
Other Groundfish	7.5	4.3	-43	8.4	6.1	-27
Total - all gndfish & fldrs	232.4	65.5	-72	103.8	63.9	-38
Skates	54.5	23.5	-57	26.0	8.0	-69

1/ The mean catch per haul figures in this table represent simple averages of the stratified mean values for individual years presented in Tables 1 and 2 of Res. Doc. 72/119 by Grosslein (1972).

2/(Strata 13-23,25)

3/(Strata 1-12)

Table 9. Comparison of mean catch per haul (lb) on Albatross IV autumn surveys in Divisions 5Z and 6A for the two periods 1963-1965 and 1969-1971, the percentage change relative to the earlier period, and cumulative landings from 1962-1971, for groundfish, skates and sea herring.

Species	63-65 1/ Mean catch/haul	69-71 1/ Mean catch/haul	% change	Cumulative landings for 1962-71 (metric tons x10^{-3})
Haddock	72.0	5.4	- 92	581
Cod	9.6	5.3	- 45	336
Silver hake	9.5	5.2	- 45	1,151
Red hake	11.2	6.4	- 43	347
White hake	1.6	1.6	0	6
Yellowtail	22.2	18.3	- 18	324
Winter fldr.	6.0	4.8	- 20	110
Other fldr.	6.7	3.6	- 46	64
Sculpin	3.3	4.8	+ 45	36
Ocean pout	2.0	0.3	- 85	74
Angler	10.2	3.6	- 65	10
All other groundfish	8.0	5.3	- 34	182
Total groundfish and flounders	162.3	64.4	- 60	3,220
Skates	39.0	15.0	- 62	37
Sea herring	-	-	"- 90"	1,666
	Weighted mean 2/ percentage change		- 64	

1/ Calculated by pooling the means shown in Table 8 for Georges Bank and southern New England into a single stratified mean representing Divisions 5Z and 6A.

2/ Weights equivalent to cumulative landings in 1962-71; weighted mean includes skates and sea herring as well as groundfish species indicated (but does not include percentage for total groundfish and flounders).

Table 10. Estimates of relative catchability coefficients for given country and gear-tonnage combinations for ICNAF Subarea 5 and Statistical Area 6, with adjustments for learning and standard vessel USSR OT ST, 1801+MT.

Gear	USA	CANADA	USSR	SPAIN	POLAND	GERMANY(FR)	NONMA	ROMANIA	BULGARIA
OT-SI									
<50 MT	.129	.085							
51-150 MT	.163	.107					.132		
151-500 MT	.205	.135	.244			.397	.151		
501-900 MT		.155	.280		.281	.455			
901-1800 MT			.461			.750			
OT-SI									
< 50 MT	.437	.288							
51-150 MT	.104	.068							
151-500 MT	.221	.146							
501-900 MT		.205	.370			.602	.200		
901-1800 MT			.896		.898	1.456	.484		
1800+ MT	.842		*1.000*		1.000	1.625	.540	.649	.857
P. SEINE									
0-50 MT	.251								
51+MT	2.040	1.343	2.423						
P. TRAWL									
All			.220	.492					
LINE TRAWLS									
ALL	.059	.039							
HAND LINES									
All	.017								
D. GILLNETS									
All	.014		.016						

Table 11. Estimates of standardized effort with learning (standard= USSR, OT ST, 1801+ MT) and catch/standardized effort for years 1961-1971, ICNAF Subarea 5 and Statistical Area 6.

	Catch	Standardized Effort Learning Adjustment	Catch/Effort
1961	342,913	5,607	61.16
1962	536,841	13,146	40.84
1963	649,586	11,617	55.92
1964	782,519	17,633	44.38
1965	946,060	18,046	52.42
1966	949,017	20,631	46.00
1967	723,702	15,504	46.68
1968	856,098	20,268	42.24
1969	943,866	26,353	35.82
1970	773,818	21,620	35.79
1971	1,082,913	33,209	32.61

Table 12. Estimates of optimum effort*, MSY, catch/effort and coefficient of determination for ICNAF Subarea 5 and Statistical Area 6 catch and effort data applied to the Schaefer model. Gulland's averaging method to determine effort in year i was used on the basic data. Standard = USSR OTST, 1801+MT.

	Data adjusted for learning		
	Averaging period		
OPTIMUM EFFORT*	3 years	4 years	5 years
1963-1971	24,582		
1964-1971	24,982	25,126	
1965-1971	21,953	20,035	19,241
1966-1971	23,675	21,233	19,150
1967-1971	24,779	21,580	18,938
1968-1971	29,276	25,124	20,318
MSY			
1963-1971	858,148		
1964-1971	861,785	835,073	
1965-1971	851,039	809,570	770,192
1966-1971	850,532	804,845	770,648
1967-1971	846,778	803,415	772,953
1968-1971	869,515	804,076	761,363
CATCH/EFFORT			
1963-1971	34.91		
1964-1971	34.53	33.21	
1965-1971	38.78	40.40	40.01
1966-1971	35.92	37.93	40.24
1967-1971	34.14	37.23	40.78
1968-1971	29.74	31.98	37.46
COEFFICIENT OF DETERMINATION			
1963-1971	.81		
1964-1971	.80	.64	
1965-1971	.83	.88	.97
1966-1971	.77	.83	.94
1967-1971	.77	.78	.93
1968-1971	.77	.78	.86

*Optimum effort is defined as that corresponding to the MSY catch level.

Percentage reduction in standardized effort to achieve MSY. Standardized effort adjusted for learning.

	Effort Averaging Period		
	3 years	4 years	5 years
Reduction	34%	40%	42%

Table 13. Results of Analysis of Variance of ln (catch/effort) data of ICNAF Subarea 5 and Statistical Area 6. Data adjusted for learning. Gear-tonnage class was the only factor considered. Catch and effort data were summed over countries within a year. Observations were annual catch/annual effort logged to the base e. ** = significant at 0.01 level.

Source of variation		d.f.	Mean Square	F
Between S.S.	268.2	16	16.766	37.94**
Within S.S.	56.6	128	.442	
Total S.S.	324.8	144		

Table 14. Estimated Relative Catchability Coefficients of Gear-Tonnage Class combinations relative to OTST, 0-50 MT for ICNAF Subarea 5 and Statistical Area 6. Effort data adjusted for learning.

Gear - Tonnage Class	Coefficient
OTSI	
0-50 MT	1.00
51-150 MT	1.157
151-500 MT	1.432
501-900 MT	2.911
901-1800 MT	2.471
OTST	
0-50 MT	3.767
51-150 MT	1.181
151-500 MT	1.367
501-900 MT	1.812
901-1800 MT	7.944
1801+MT	7.331
PURSE SEINE	
0-50 MT	1.825
51+MT	14.002
PAIR TRAWL	
ALL	3.306
LINE TRAWL	
ALL	.383
HAND TRAWLS	
ALL	.126
D. GILL NETS	
ALL	.119

Table 15. Estimates of Optimum Effort*, MSY, Catch/Effort and Coefficient of Determination for ICNAF Subarea 5 and Statistical Area 6 catch and effort data applied to the Schaefer model. Gulland's averaging method to determine effort in year i was used on the basic data. Standardized effort based on relative catchability coefficients without country factor.

	Learning adjustment		
	Averaging period		
OPTIMUM EFFORT*	3 years	4 years	5 years
1961-1971			
1962-1971			
1963-1971	164,592		
1964-1971	167,702	163,170	
1965-1971	162,597	150,716	144,704
1966-1971	173,463	159,603	145,719
1967-1971	178,004	156,744	140,792
1968-1971	216,356	186,121	153,752
MSY			
1961-1971			
1962-1971			
1963-1971	843,548		
1964-1971	844,113	804,553	
1965-1971	842,625	799,286	759,401
1966-1971	844,531	798,327	759,226
1967-1971	843,743	799,270	763,946
1968-1971	869,612	803,943	754,556
CATCH/EFFORT			
1961-1971			
1962-1971			
1963-1971	5.13		
1964-1971	5.03	4.93	
1965-1971	5.18	5.30	5.25
1966-1971	4.87	5.00	5.21
1967-1971	4.74	5.10	5.43
1968-1971	4.02	4.32	4.91
COEFFICIENT OF DETERMINATION			
1961-1971			
1962-1971			
1963-1971	.94		
1964-1971	.88	.88	
1965-1971	.86	.89	.97
1966-1971	.79	.84	.95
1967-1971	.75	.81	.95
1968-1971	.79	.79	.92

*Optimum effort is defined as that corresponding to the MSY catch level.

Table 16. Percentage reduction in standardized effort to achieve MSY. Standardized effott adjusted for learning.

	Effort		
	Averaging period		
	3 years	4 years	5 years
Reduction	32%	38%	40%

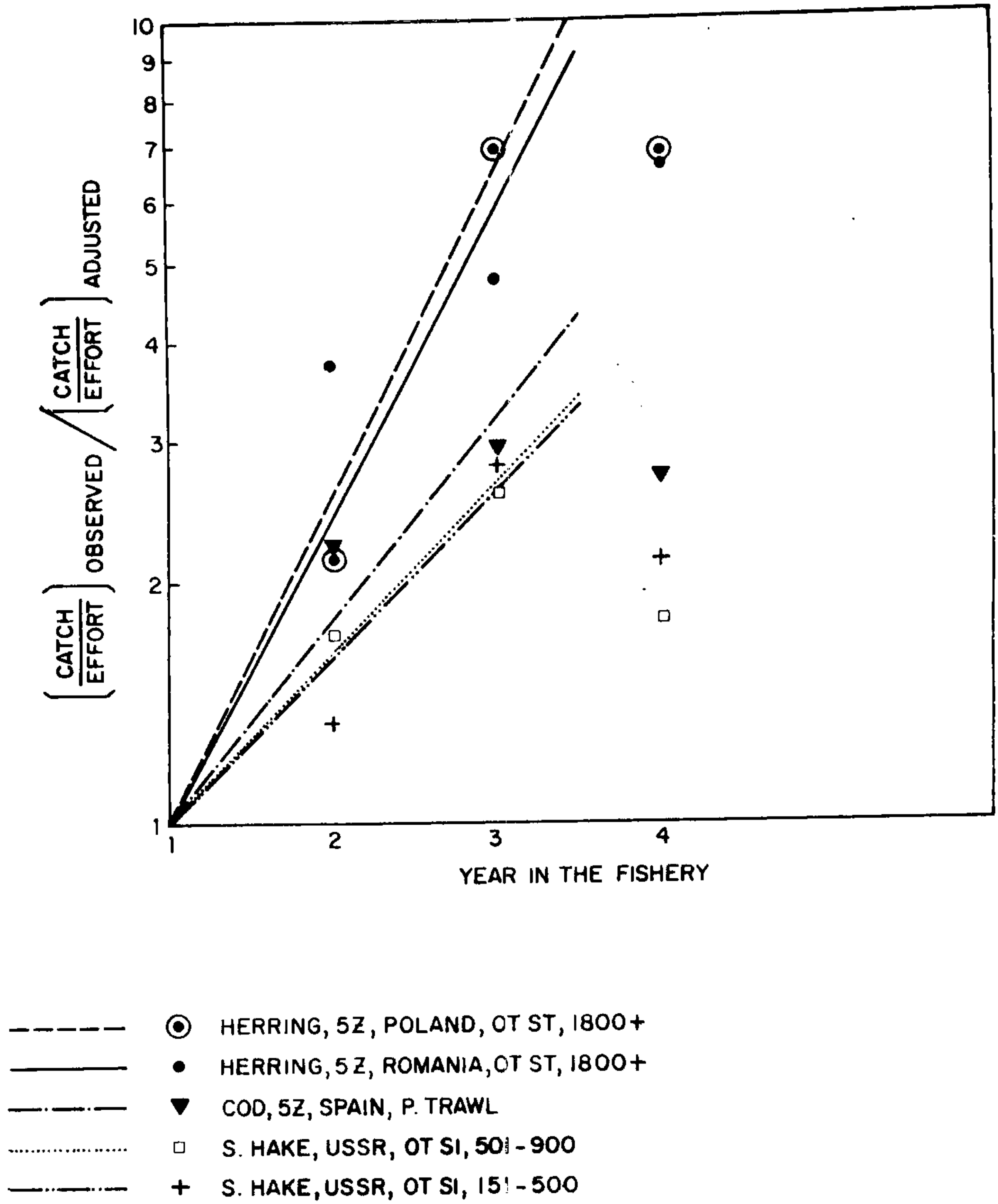
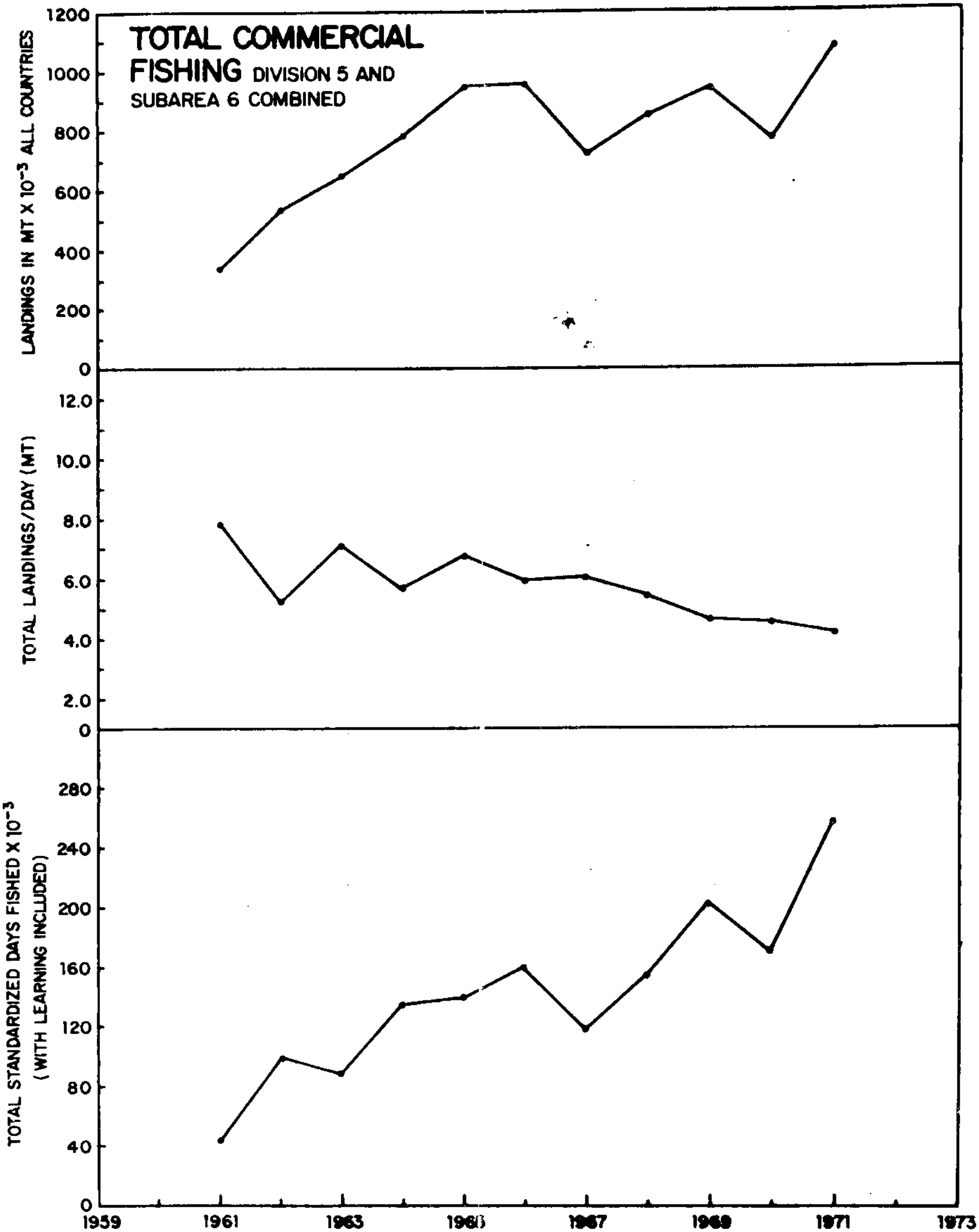


Figure 1. Relationship of commercial catch per effort to <u>Albatross IV</u> survey cruise abundance indices



Rigure 2. Trends in effort, catch and catch per unit effort in ICNAF Subarea 5 and Statistical Area 6.

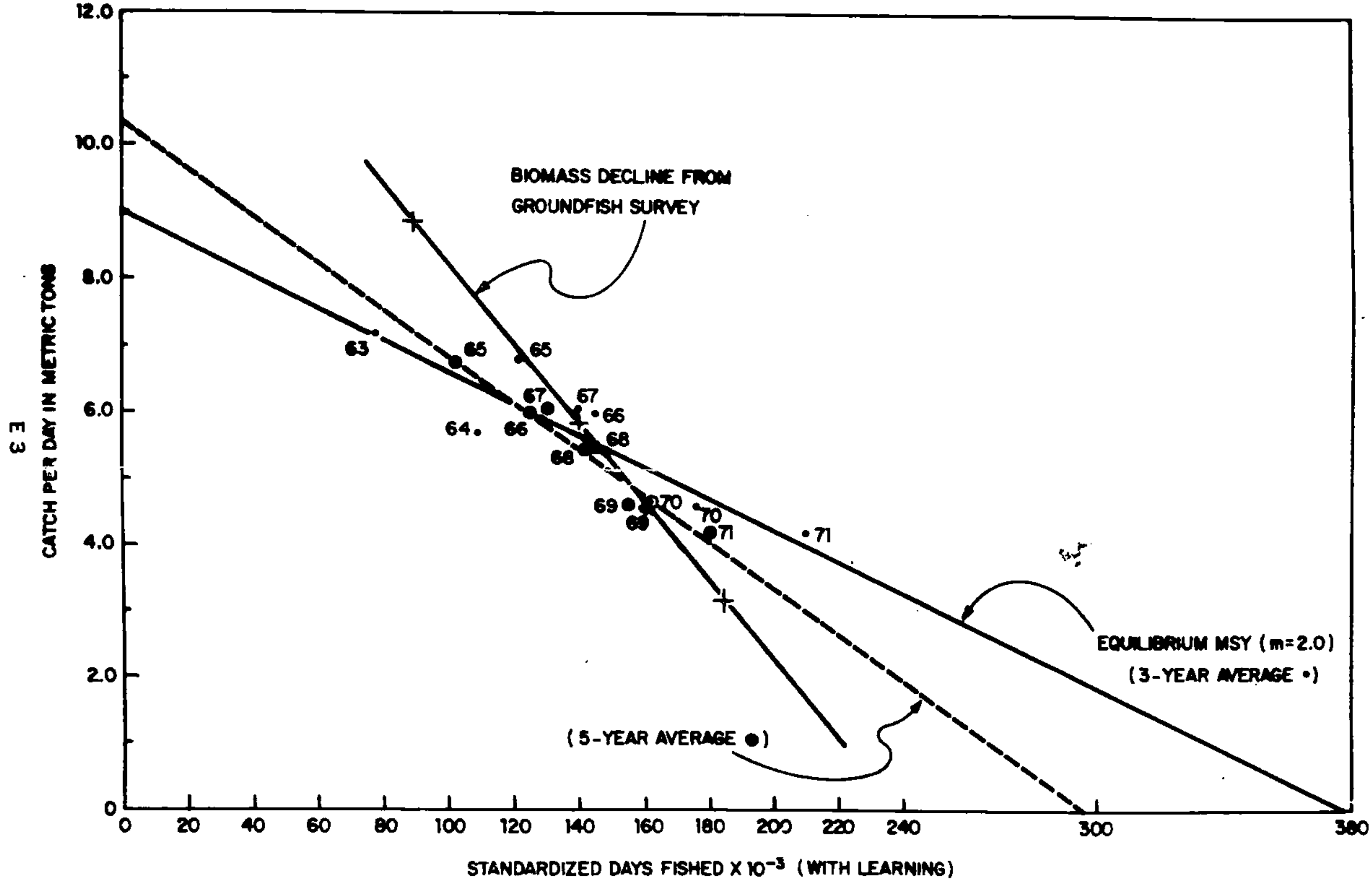


Figure 3. Abundance of finfish biomass versus total fishing effort in ICNAF Subarea 5 and Statistical Area 6. See text for explantaion.

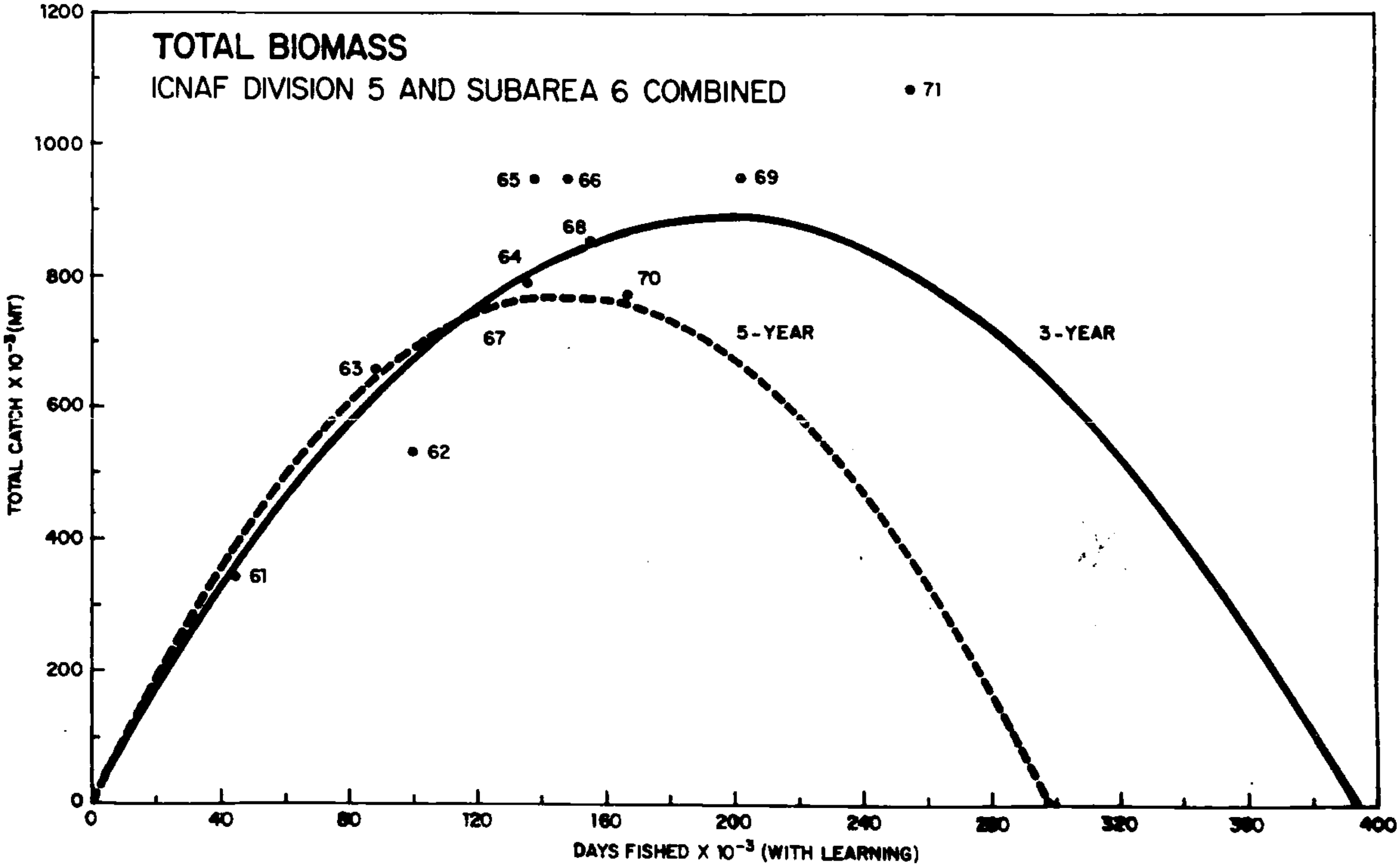


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Figure 4. Total finfish yield versus total fishing effort in ICNAF Subarea 5 and Statistical Area 6. See text for explanation.

Serial No. 2910
(D.c.9)

ICNAF Res.Doc.73/8
Appendix

INTRODUCTION

At the January 1973 ICNAF Assessment Subcommittee Meeting several suggestions were made relative to the analyses used in Doc. 73/8 entitled "An Evaluation of the Effect of Fishing on the Total Finfish Biomass in ICNAF Subarea 5 and Statistical Area 6." An attempt was made to investigate these suggestions and the results are reported here.

I. Expression of effort in different standard units.

The estimation of relative catchabilities, yearly effort values, and Schaefer yield-effort curves were calculated as in the original paper, using USSR stern trawler tonnage class 1801+ MT as a standard. This procedure does not produce changes in the maximum yield or in the relative changes in fishing effort. Tables 10-12 present these results.

II. Evaluation of Catch-Effort Relationships

Eliminating Country Factors

The analysis of variance used in Brown et al. (1973) considered country and vessel (gear-tonnage class) category. The mean square for the country factor was considerably smaller than that for vessel category. Therefore it was suggested that a one way analysis of variance using vessel factors only be tried. Adjustment for learning was utilized in this analysis. The appropriate data tabulations are presented in Table 13 to 16. The conclusions as to the MSY catch, the level of effort associated with it, and the extent the 1971 effort exceeds that level are essentially the same as in the earlier analysis.