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The effect of fishing on the marine finfish biomass in the Northwest Atlantic from the eastern edge of the Gulf of Maine to Cape Hatteras

by

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Abstract

Relationships between fishing intensity, total finfish community biomass, and yield are examined in terms of (1) finfish biomass as measured by research vessel surveys, (2) combined individual species stock assessments, and (3) the Schaefer (1954) equilibrium yield model. Multiple gear types are combined to provide a standardization index of fishing intensity in terms of days fished as reported to ICNAF. A multiplicative learning function is applied as a correction factor for developing fisheries deployed in areas and on stocks not previously fished, to bring all entering fleets to the equivalent level of efficiency by the third year in the fishery. These analyses demonstrate a rapid increase (a factor of 6) in fishing intensity, and a concurrent decline in finfish abundance (≈ 55 percent) during the period 1961-1972. Plots of yield versus standardized fishing intensity indicate that fishing mortality since 1968 has exceeded that level which would result in sustaining a maximum yield for the fishery under equilibrium conditions. The projected Maximum Sustainable Yield (MSY) from Schaefer yield curves approximates 900,000 MT, while the composite MSY from individual assessment studies totals ≈ 1,300,000 MT. It is suggested that because of species interactions the MSY obtained by summing the individual assessments may be an overestimate. If mackerel and herring MSYs are discounted to allow for interspecific competition then the composite MSY of individual assessments is ≈ 1,100,000.

Introduction

Historically, fisheries management has been stimulated by changes in the development of the fishery. New participants increase competition and may force changes in the distribution of the catches among countries. New fisheries develop in areas and on species theretofore not fished. New gear is employed that may cause conflicts in operations of other gear. In the face of marked and rapid increases in fishing effort, serious doubts are often raised about the ability of the fish stocks to sustain their full potential productivity, especially when the catch per fishing unit begins to drop.

Such has been the case in the Northwest Atlantic fishery south of Nova Scotia. Prior to 1960, almost all of the fishing on the continental shelf off New England and the Mid-Atlantic (ICNAF Subarea 5 and Statistical Area 6 (Figure 1) was done by United States vessels. This fleet developed on the basis of a coastal fishery (the fishing grounds close to home port and landing and processing facilities), and was composed of vessels under 300 GRT. After 1960, the distant water fleets of USSR, Poland, Federal Republic of Germany, Japan, and other countries entered this area. These fleets of large, highly mobile vessels steadily increased both in number and total tonnage (Table 1). The increase in the number of vessels resulted in enlarging the scope of this fishery with respect to species and area fished, as well as intensity. While historically, the US fishery had concentrated on selected groundfish species (cod, haddock, redfish, flounders), the present-day fishery heavily exploits all of the major species of fish found in the area (ICNAF Statistical Bulletins 1-23) (Table 2).

The Research and Statistics Committee of ICNAF (STACRES), which has been evaluating the effects of fishing on the fisheries resources in this area (*cf.* Assessment Subcommittee Reports, ICNAF Redbook, Part I, Vols. 1953-1974), has on several occasions advised the Commission that the overall fishing effort was fast approaching that which could not be supported by the stocks (ICNAF Redbook, Part I, 1961). For certain species (*e.g.* haddock and herring) concern that fishing mortality on the given stock was approaching a greater value than that which would maximize the long-term yield or yield-per-recruit was first expressed prior to severe overfishing (ICNAF Redbook, Part I, 1963 and 1968). As a consequence, the Commission had, by the end of the June 1972 Commission meeting, set quotas on many of the heavily fished species-stocks1/. The stock size had been so severely reduced on some that large reductions in the catch were necessary in order to begin to rebuild the stocks to achieve their full potential productivity. STACRES also recognized that the rapid expansion of fishing activity all but precluded timely and complete assessments of the effects of fishing, particularly when a multitude of species-stocks was being harvested.

More importantly, STACRES began considering in the late 1960's the larger question of whether the goals of management could be achieved based on independent assessment and regulation of each stock of fish. The difficulty in achieving these goals stems in good part from the lack of resources committed to collect the necessary data and make the required assessments within the required time period. In addition, the mixed-species nature of the current fisheries in ICNAF, which is most severe in Subarea 5 and Statistical Area 6, has led to the difficult but necessary consideration of the fishing mortality caused by the by-catch, *i.e.* the catch of species other than that which is the main object of the fishery. The mixed-species catches result primarily from the extensive use of the bottom tending otter trawl gear which is quite unselective.

In ICNAF SA 5 and 6 (Figure 2) numerous species make up significant portions of the biomass, and hence, the otter trawl fishery catch. The species mixture is illustrated by the catches in the 1971 USA and USSR joint bottom trawl survey in Southern New England, where the mean number of species caught per tow was 12 for the USA vessel and 11 for the USSR vessel (Grosslein, 1973). The inevitable incidental catches in species-directed fisheries may be great enough to harvest the total surplus production of some stocks, and this creates conflicts in objectives of conserving stocks which are at low abundance levels or maintaining an existing directed fishery without overfishing, *e.g.* haddock and yellowtail flounder (Brown *et al.*, 1973). The Assessment Subcommittee of ICNAF estimated that in 1971, 33 percent of the total fishing mortality in SA's 5 and 6 was generated as by-catch of the major species-directed fisheries (ICNAF Redbook, Part I, 1973). Finally, the current generation of fishery yield models do not directly incorporate terms which describe the effects of species interactions on long-term biological productivity. The interrelationships among species are not well understood, and considerable research is needed on this subject. However, consideration of basic ecological concepts such as prey-predator and competitive relationships underscores the need to examine the yield of this total ecosystem as an integrated whole rather than as just the sum of the individual components. In this paper, the interspecific effects of the finfish component of the ecosystem are included implicitly in analysis of the total sustainable yield of the finfish biomass to the extent they have been significant in affecting total yield as measured over the period 1962-1972.

The description of the status of the finfish biomass in Subarea 5 and Statistical Area 6 is based on analyses of total finfish catch and fishing activity and of research vessel surveys. The finfish biomass was defined as all species reported to ICNAF, except lobsters, shrimp, scallops, other shellfish (but including squids), menhaden (which are captured close to shore and primarily in a single-species fishery in the most southerly part of Statistical Area 6), and large pelagic species, *i.e.* swordfish, sharks other than dogfish, and tuna. The large pelagics contribute minimally to the total catch in a quantitative sense, and hence would not affect the calculations significantly. This is not to say, however, that the interactions of other fish with this component are not important, but that the results we present are provisional with respect to them. Species assessments based on analysis of commercial catch and effort data are combined to give one estimate of overall maximum sustainable yield. A Schaefer yield model for total finfish and squid, using commercial catch effort data, is also used to

1/ A species-stock refers to an ICNAF regulatory management unit; i.e., some regulations apply to a single population that is a self-contained component of one species considered to have uniform growth and mortality rates, others apply to convenient geographical groups of such stocks, while still others to even a combination of species.

estimate a total maximum sustainable yield. The relationship of current effort levels relative to that providing maximum sustainable yield is discussed.

Standardization of fishing units

Indices of fishing effort which purport to measure the relative fishing mortality (F, the coefficient of instantaneous fishing mortality) exerted on fishery resources over some time period have traditionally been used to determine the status of fisheries. For this study, because of the diversity of gear employed and the availability of comprehensive statistics reported to ICNAF for the New England-Mid-Atlantic offshore fishery, multiple gears have been standardized in terms of fishing mortality generated per unit activity based on factors which are demonstrably related to rates of catch. Catch and effort data from 1961-1972 were obtained from Tables 4 and 5 of the ICNAF Statistical Bulletins (Nos. 10-22), supplemented with additional data: German Democratic Republic catch and effort data, 1969 and 1970 (ICNAF Summ. Doc. 73/3); amended catch and effort data for Bulgaria, 1969-1970; and for Japan, 1967-1969 (ICNAF Summ. Doc. 74/3); and USA catch data for Statistical Area 6, 1961-1962 from National statistics, and 1963-1967 from ICNAF Summ. Doc. 74/4.

Days on grounds, days fished, hours fished, number of sets (trawl hauls or lines) and hooks, have all been reported with varying degrees of completeness to ICNAF. The latter two units were a very minor part of the fishing effort in the area concerned. Hours fished is probably the best of the effort units reported, in that it is a more accurate measure of F than a day's fishing activity. However, member countries have reported days fished to ICNAF more consistently through the years than hours fished. Days fished is considered more closely related to fishing intensity than days on grounds. It also appears to be a more standard measure of fishing activity over all types of vessels and gear; for example, "hours fished" definitions may differ greatly for purse seines depending on how searching time was recorded. Hence, days fished, as reported to ICNAF, was chosen as the basic unit of fishing effort for analysis.

In order to measure total fishing intensity in standard units, catchability coefficients relative to an arbitrarily chosen standard class of vessel and gear were estimated for the various other classes, and used to convert the reported days fished for each respective category to the standard equivalent. In all cases, the yearly total of catch and effort data for each class was the basic variable in analysis.

Robson (1966) proposed a method for determining effort standardization coefficients using an analysis of variance model assuming no interaction. This model was selected for the present study, and is defined as follows:

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

Y_{ijk} = catch per day of all fish for the i^{th} country, jth gear-tonnage class, and kth year, *i.e.* Σ catch/Σ days where the sum is of the appropriate Tables 4, 5 (of ICNAF Statistical Bulletins) entries over each month of the year and each area (SA 5 and SA 6),

m = the mean catch per day over all categories,

a_i = the i^{th} country effect,

b_j = the jth gear-tonnage class category effect, and

e_{ijk} = the error for testing significance and precision if the kth observation at the i-j level is such that the $\ln(e_{ijk})$ has a $N(0,\sigma^2)$ distribution.

Sampling error was measured on a year to year basis, and a natural logarithmic transformation of the observations, Y_{ijk}, was used to achieve linearity of the model. The cell coefficients (a_ib_j) were estimated using an analysis of variance procedure outlined by Snedecor and Cochran (1967) for a row x column design with unequal cell frequencies and missing observations. In order to express these coefficients in terms of a standard cell (gear tonnage class-country category), the value a_ib_j for the i-j cell was divided by the value of the standard cell (after anti-logging). Since the a_ib_j values are all estimated from the row and column totals, it is immaterial which cell is selected as the standard. To illustrate this fact, the results using both USA side trawler 0-50 GRT and USSR trawler 1800+ GRT categories as standard cells are presented. The latter are given in Appendix Tables 1-3.

Fishing gear for which data was used in the analysis of variance included stern, side and pair trawls, purse seines, drift gill nets, long lines, and hand lines. These gears accounted for approximately 80 percent of the total catch of the species considered. The remaining 20 percent of this catch included catch by the other gear categories (other lines, fixed gear, and other seines) and catch for which days fished were not recorded. The standard effort associated with this catch was estimated in the last stages of analysis.

Adjustment for learning

It may be logically asserted that the development of new fisheries in areas and on stocks not previously fished involves learning: how to conduct and distribute the fishing fleet over the grounds, particularly in relation to seasonal changes; how to deploy the different kinds of gear in relation to depth or bottom types, current, and weather patterns; and how best to utilize spawning or feeding concentrations (time and space) and migratory patterns. All these factors affect the efficiency of operations (for further discussion see ICNAF Report of Special Meeting of Experts on Effort Limitation, ICNAF Summ. Doc. 73/3). Such must certainly have been the case for the distant water fleets that began fishing the New England and Mid-Atlantic banks after 1960. The magnitude of this learning would be reflected in the catch/effort statistics for the various countries, but not clearly separated from other causes of variation in catch. There undoubtedly are many other components of success involved with the development of a fishery. In this study no attempt was made to define the learning factors in terms of explicit causes. Rather, the problem was approached by assuming that learning could be expressed as a monotonic increase in catch per unit effort through a continuous time period, which was not caused by changes in stock abundance. In order to estimate the magnitude of learning, a multiplicative learning function was hypothesized for a given fleet in a fishery. The model for learning was:

$$l_i = \frac{0_i}{P_i}$$

where l_i = learning gained by a fleet in the i^{th} year in a fishery,
0_i = observed catch per effort by the fleet in the i^{th} year in the fishery,
P_i = predicted catch per effort for the fleet in the i^{th} year in the fishery assuming no learning,
$P_1 = 0_1$
$l_1 = 1$
$i = 1,2,3,\ldots$

The predicted catch per effort, P_i, was defined algebraically to be:

$$P_i = \frac{(Z_i)}{(Z_{i-1})} * P_{i-1}$$

where Z_i is an independent estimate of the abundance of the species in the i^{th} year in the fishery.

By recursion

$$P_i = \prod_{j=2}^{i} \frac{(Z_j)}{(Z_{j-1})} * P_{i-1}$$

$$= \frac{(Z_i)}{(Z_1)} * P_1 \qquad (2)$$

$$P_i = \frac{(Z_i)}{(Z_1)} * 0_1$$

as $P_1 = 0_1$

The observed catch per effort in the first year in the fishery, 0_1, was taken to be the predicted catch per effort, P_1. The first year of presence in a fishery was taken as that year in which a fleet first caught 20 percent of its total catch in a particular fishery, *i.e.* 20 percent of the total catch of a fleet was of the species by which the fishery is identified.

It was assumed that if the catch of a single species exceeded 80 percent of the total catch by the fleet in an area for a particular year, a "directed fishing" effort had taken place, and all days fished for the fleet during the year were assigned to the species. If the catch of the species was between 20 and 80 percent of the total catch, the directed effort was estimated as proportional to the species catch in the nominal landings.

A further assumption made in applying a learning function was that learning ceased when the ratio (1) decreased from year i to year i+1, *i.e.* when $l_{i+1} < l_t$.

An independent measure of the abundance of a species was provided by the catch (pounds per tow) of the US *ALBATROSS IV* bottom trawl during its annual surveys. Fisheries were selected for analyses of the learning factor for which survey cruise indices of the species sought had been developed.

Certain "sets" of data were incomplete and could not be used to estimate a learning factor, *e.g.* no fishing effort (in "days fished" units) was recorded by the USSR for 1962, although there was fishing before, during, and after 1962. Therefore, only selected sets of complete data could be used (Table 3). A learning function derived from situations where statistics are available can then be used to adjust reported units for other fisheries where the data were not available.

In most cases where l_i could be estimated for 4-5 successive years, l_i declined in the fourth year in the fishery (Table 3). We concluded, therefore, that in general the learning process was completed by the end of the third year in the fishery.

An exponential curve was fit to a fleet's data for the first three years in the fishery (see Figure 3).

$$l_i = \frac{0_i}{P_i} = [\exp(a(i-1))]e_i, \text{ where}$$

$$P_i = 0_1 * \frac{Z_i}{Z_1}$$

0_i = the observed commercial catch per unit effort in the i^{th} year in the fishery after entrance, where i = 1,2,3...

Z_i = the stock abundance in the same year

e_i = the residual error, where $\ln(e_i)$ has a $N(0,\sigma^2)$ distribution, and

a = constant

This curve was selected since the ideas underlying the model seemed to coincide with the underlying notion of learning: that the learning gained by time t_i was dependent on the learning gained by time t_{i-1} as well as the time interval t_i-t_{i-1}. Since there was no trend to the differences in the values of l_i for the different fleets, pooled data were used to fit the curve. A least squares linear fit of $\ln l_i$ on i yielded the curve

$$l_i = .48 \exp(.735i), \quad i = 1...3$$

with a coefficient of determination of .82.

From this equation

$l_1 = 1.00$
$l_2 = 2.09$
$l_3 = 4.35$

This is approximately equivalent to having the effort on that species halved and quartered during this learning period.

The effort data was adjusted so that a unit of effort in the years prior to full learning experience was made equivalent in this respect to a unit of effort in later years. The adjustment involved is:

$$X_i, \text{adj.} = \frac{0_i}{l_i} * l_3$$

for i = 1...3

where X_i, adj. = adjusted catch/effort for the i^{th} year in a fishery by a fleet, and 0_i, l_i, and l_3 are as defined previously.

The values of 1, 2 and 4 were used for l_1, l_2 and l_3, respectively. Adjusting data according to (4) essentially brings all entering fleets to the equivalent of the level of knowledge of the third year in the fishery. The data adjusted by (4) included data used in the development of the model (Table 3), as well as sets of data excluded because they were incomplete, *e.g.* where there was no index of abundance available, etc. Table 4 lists these sets of data.

Application of fishing effort standardization

Analysis of variance results

Standardizations of effort were calculated with and without adjustments for learning. Both vessel class and country effects showed significance at the .01 probability level (Table 5).

Inspection of the data to determine which levels of the two factors contributed most to the interaction sum of squares revealed that departures from main effect trends could be attributed mainly to the USSR drift gill nets. Considering the relatively minor contribution of this category to both total catch (0.08 percent) and effort (0.3 percent), the consequence of ignoring the interaction term was considered to be minimal. Relative catchability coefficients are therefore presented in Table 6 for the US standard and Appendix Table 1 for the USSR for all country gear-tonnage class categories which were present in the fishery during the years under consideration.

Estimation of total fishing intensity

Total fishing effort in standard days fished directed at finfish was estimated for 1961-1972 for each country and gear combination, by multiplying the reported days fished by the relative catchability coefficients, with and without learning. Finfish catch per standard day was then estimated for each year by dividing the total annual catch of the categories associated with this effort by the adjusted effort thus obtained. Finally, the total annual finfish catch over all categories, including those catches from gear-country combinations which were excluded from the analysis of variance (Table 7), was divided by the catch per standard day to obtain the total fishing intensity per year for Subarea 5 and Statistical Area 6 combined.

Effort for Statistical Area 6 prior to 1968 for countries other than the US was estimated by dividing that area's catch by the corresponding Subarea 5 catch per unit effort for that year. This was judged adequate because these countries fished primarily on stocks which migrate between this area and Subarea 5. The effort for the USA in Statistical Area 6 for 1961-1967 was estimated by dividing the yearly catches by the 1968-1970 average USA catch per standard day for SA 6. The stocks fished primarily by the USA in this area are different from those in the major fisheries in Division 5Z. If these stocks had been decreasing over this period, an overestimate of effort would result. This would have a minor effect on overall results, because the USA catches in SA 6 were always small (between 75,000 and 124,000 MT) relative to the total.

The combined results of the above computations are presented in Table 8 and Figure 4.

Relationships between fishing intensity and yield

The relationships between fishing intensity and yield have been examined in three ways. First, relative changes in finfish biomass measured by research vessel surveys are related to relative changes in total fishing intensity estimated in this paper. Second, data from individual species assessments (based on commercial catch and effort data and research vessel survey data) are combined to estimate the total potential yield. Third, annual total catch and total effort as estimated herein are used in an equilibrium yield model to describe the equilibrium relationship between catch and effort.

Changes in biomass as estimated from *ALBATROSS IV* survey data cruise

Estimates of relative change in biomass of groundfish and flounder species for Georges Bank and Southern New England areas were calculated by comparing mean catch per haul for United States autumn research surveys in 1963-1965 with the mean for 1970-1972 (see Grosslein, 1972, for 1963-1971 detailed statistics). With few exceptions there were substantial declines in the abundance of groundfish in both areas (Table 9).

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 1). This set of sampling strata covered almost all of Division 5Z but only Subdivision A of SA 6; however, since the bulk of the major stocks are found east of Hudson Canyon in the autumn, the data are considered adequate to represent changes in the whole of SA 6. The pooled mean catch per haul of all but four of the species or species groups declined from 10 to 90 percent (Table 10). The four exceptions are the catches of white hake (no change), yellowtail flounder (6% increase), sculpins (45% increase), and squids (186% increase). The drastic decline (over 90%) in haddock may have contributed to increased survival of longhorn sculpins since both species depend heavily on crustacea for food[1/]. The small increase in yellowtail is due to a large catch in the 1972 survey. This may be anomalous since it was not consistent with commercial yellowtail catches nor with previous and subsequent survey abundance indices of the year classes involved (see Parrack, 1974). Silver and red hake, skates, and miscellaneous flounders all declined about 40 percent and cod and winter flounder dropped about 10 percent. Ocean pout showed a decline of 80 percent, and anglers and miscellaneous groundfish declined approximately by one third. The overall decline of all of these species pooled was 49 percent. The squid abundance indices have not been analyzed in detail; not surprisingly there is no evidence of a trend during this period since directed fisheries for squid did not begin until 1970.

An estimate of the decline for sea herring was made using herring abundance indices from USA spring surveys which first began in 1968 (Figure 5). The spring surveys begin in March when sea herring are concentrated south of Cape Cod, and the $\log_e$ abundance indices shown in Figure 5 represent sampling strata 1-12 and 61-76 combined (Nantucket to Cape Hatteras). The slope (estimated by least squares linear regression) of the line was -2.95 ($\log_e$ scale) which gave a decline of about 93 percent in the period 1963-1972. This estimate corresponds closely to that based on other data (see Assessment Report, ICNAF Redbook, 1972). An estimate of the decline of mackerel was based on the US spring surveys of 1967-1974 as analyzed by Anderson (1974a). A least squares linear regression through stratified means of $\log_e$ (lbs/tow) (Figure 6), eliminating the outlier value for 1969, gave a slope of -0.078 which means a decline of 37 percent since 1967. There was no observed decline in the mackerel population until after 1967 (Anderson, 1974a).

The decline in total biomass of finfish in Divisions 5Z and 6A was calculated by weighting the percent decline of groundfish, herring, squid, and mackerel shown in Table 10 in proportion to the total landings of those species groups in the 11-year period 1962-1972. The resulting weighted change indicates about a 56 percent drop in total biomass of these species during the last decade (Table 10). The landings are not necessarily proportional to size of the biomass of every species but they were considered the best available proportional measure of the biomass. The estimate of the overall decline thus derived may be less than the true decline because landings of some miscellaneous groundfish species (particularly ocean pout, angler and skates) were not adequately reported in earlier years, and these species showed major declines. The percentage declines are measured from an initial point of time (1963-1965) prior to which many of the stocks concerned had already been harvested in moderate to severe degrees. Thus, the overall decline from unfished abundance levels is greater than the 1963-1972 decline.

Dogfish were not included in these calculations. There has been no discernible trend in their abundance in the survey cruises and there was essantially no directed exploitation of this resource in the years under discussion.

It has been postulated, based on the Schaefer yield model (Schaefer, 1954) that maximum average yields are obtained at stock sizes about one-half the maximum. The estimated decline of 56 percent since 1963 thus implies a significant degree of overfishing.

This decline is plotted in Figure 7. The average standard effort estimates for 1963-1965 and 1970-1972 were used to position end points of the line with respect to the abscissa, and the line was fitted through the mean of commercial catch/effort and effort for the decade, to position it with respect to the ordinate. This implies a 65 percent decline in catch/effort between 1963 and 1972, relative to the change in effort during the period.

An even greater rate of decline in biomass since 1967 is indicated by USSR autumn research surveys in Southern New England (strata 1-12), and by both USA and USSR autumn surveys since 1967 for the Mid-Atlantic area to the south (strata 61-76). These data were reported at the 1973 annual meeting (ICNAF Redbook 1973, Part I, Annex 3A, Appendix I), and provide further evidence of overfishing. USSR and USA autumn survey indices for all finfish for SA 6 declined about 80 and 70 percent, respectively, in this later period of years.

Individual stock assessments and total yield

Results from individual species assessment studies and review of historic catches were used to estimate a composite MSY for the combined finfish stocks in Subarea 5 and Statistical Area 6. The Assessment Subcommittee reports in the ICNAF Redbooks 1962-74 provide the source for the estimates given in Table 11 except for other flounder and other finfish which are based on the average of the last ten

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1/ Based on unpublished data in files of M.D. Grosslein, Northeast Fisheries Center, Woods Hole, Massachusetts, 02543.

years catches (1963-1972). As there are some disagreements between scientists in their estimates of specific MSY's for all stocks of such species as silver and red hake, in order to have a single figure the present authors exercised their interpretive judgment using the Assessment Reports and the documents of Anderson (1972 and 1974b) and Rikhter (1974 a and b). The silver hake MSY was taken to be equal to the recommended total allowable catches (TAC's) for the 5Z-6 stocks in 1973 and 1974 plus the estimate of MSY for the Gulf of Maine stock given in the 1972 Assessment Report. The red hake MSY is the TAC recommended for 1973. For pollock, cod (see also Brown and Heyerdahl 1972) and redfish, estimates of MSY's correspond to the recommended TAC values for 1973. Estimates of MSY's for haddock and yellowtail flounder are given in the 1973 ICNAF Redbook (page 20). The ICNAF Assessment Subcommittee provided a preliminary assessment of squid (*Loligo*) in 1972 and estimated an MSY of 50-80,000 MT. In order to include the yield of *Illex* squid a value of 80,000 MT for the two genera combined was assumed (ICNAF Redbook 1973, Part I). Individual assessments for herring in 5Z and 6 (Schumacher and Anthony, 1972) and mackerel in 5Z-6 (Anderson, 1973) indicated MSY's of 285,000 and 310,000 MT, respectively. The herring stock in 5Y was estimated to have an MSY value of 50,000 MT (ICNAF Redbook 1973, Part I) (see also Anthony and Brown 1972). Combining all MSY estimates for the entire species complement gives a total of 1,352,000 metric tons as a projected MSY value for the total finfish biomass.

Considering that MSY is a long-term, average yield, the MSY estimates probably are too high for many of the species in this area which have been subjected to heavy fishing mortality only recently. A high proportion of the available data represent an expanding fishery which was harvesting accumulative biomass rather than only yearly productivity. In addition, these single species assessment models do not explicitly account for species interactions.

These principles are perhaps of most significance in terms of the total biomass for herring and mackerel, where the assessed MSY values were estimated during a time period when there were two extremely good year classes in the fishery, and when a rapid monotonic increase in fishing effort occurred. Furthermore, herring and mackerel, at least in recent history, have not maintained a high biomass concurrently, but rather have fluctuated inversely, with the mackerel showing an increase in abundance while the herring declined. The strong herring year classes were 1960 and 1961, while those for mackerel were 1967 and 1968. Consequently, a more accurate description of the potential yield for the two species might be estimated by looking at their average combined landings. Table 12 presents the metric tons of herring and mackerel landed by all countries over the period of the analysis. The average annual landings figure for the two species combined (1961-1972) is 336,000 metric tons. Substituting this combined figure for the individual assessment estimates results in reducing the projected MSY value for the total biomass to 1,043,000 metric tons.

Surplus yield modeling

An estimate of maximum sustained yield (MSY) was calculated for the above selected finfish community as a whole, using the generalized stock production model approach discussed by Schaefer (1954). Schaefer's model assumes logistic growth and symmetric yield curves with the MSY value occurring at 50 percent of the maximum stock size. Because this model considers the combined effect of recruitment, growth, and natural mortality parameters as a single term, only catch and fishing effort statistics are needed to estimate the parameters of the curve.

Fitted curves derived from this type of analysis are considered to represent the equilibrium, or long-term average, expected yields. However, in the Northwest Atlantic a rather consistent and rapid increase in effort has been demonstrated, particularly during the first part of the 1960's. When such large and consistent increases, or decreases, in fishing effort exist, the fitted curves will tend to over- or underestimate the true situation unless the population can react instantaneously in adjusting its productivity to the new density structure. When it cannot, the effects of fishing effort in any given year will be dependent upon the cumulative effect of previous years' effort. Gulland (1961) has suggested that in order to account for this effect, an average of effort over previous years should be taken as the effort applicable to any year where the averaging occurs over the mean number of years that a year class contributes significantly to the catch. The number of years to be averaged is, therefore, a function of the total mortality rate.

For the fish stocks of the Northwest Atlantic in an equilibrium state providing maximum yields, an average year class contributes significantly to the catch over about a 3-year period. However, for the period covered, 1961-1972, some significant non-normal events should be considered. 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; and Assessment Report, ICNAF Redbook 1972-1974, Part I). The mackerel fishery has been harvesting principally the same two year classes, 1966 and 1967, since the fishery began to increase in 1968 through 1972 (ICNAF Redbook, 1974, Part I). 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 lag or delay-time periods to cover the possible range of this effect.

Solutions of the Schaefer model were obtained by computing least squares linear regressions of catch/effort in year i on an averaged effort as defined above (both with and without learning), terminating with year i. A series of regression lines were calculated corresponding to data sets beginning with 1968-1972 and successively adding earlier years' data back to 1961 (Figure 7). Each linear solution was then expressed as a yield versus effort parabola to obtain the equilibrium catches and corresponding effort in terms of the US 0-50 OT standard days fished (Table 13 and Figure 8). Similar analyses, using the USSR 1800+ category as the standard, are given in Appendix Tables 3, 4. Coefficients of determination for all data sets adjusted for learning ranged from .57 to .99 with 15 of the 17 values being above .9; for data sets not adjusted for learning the coefficients ranged from .42 to .97 with 3 above .9 and 11 above 0.8. The range of parameter estimates derived from the yield/effort parabolas was less for data sets adjusted for learning than for those sets that had not been adjusted. However, this would be expected as learning accounted for a major source of variation or bias in estimating population size. For both data sets, *i.e.* with and without a learning adjustment, the best fit to the Schaefer model occurred when data for the years 1965-1972 and later were used. The years prior to 1965 were those for which data were proportionally more incomplete, and for which the consequential changes associated with learning had their greatest effect. In addition, in those years effort was directed towards fewer species than in later years.

Discussion

Results of these analyses have demonstrated a rapid and substantial increase in fishing intensity (a factor of 6), and a concurrent marked decline in abundance (about 56 percent) for the offshore finfish community in ICNAF Subarea 5 and Statistical Area 6 during the period 1961-1972. Yield versus standardized fishing intensity parabolas, estimated using the Schaefer approach, indicate that fishing mortality since 1968 has exceeded that level which would result in sustaining a maximum yield for the fishery under equilibrium conditions. The average MSY for the data sets for 1965-1972, using 3-year, 4-year, and 5-year averaging methods for fishing effort, was 898,329 MT for data adjusted for learning and 938,000 MT for data without adjustment for learning (Table 12).

The projected MSY value from the Schaefer model, approximately 900,000 MT, is somewhat lower than the composite MSY estimated earlier from single assessment summations of ≈1,300,000 MT, but as discussed in that section it may not be reasonable to assume that these individual assessments can be summed for the total biomass yield. It is similar to the ≈1,000,000 estimated from assessment summations after discounting for a hypothesized mackerel-herring interaction.

The estimated MSY values are for long-term equilibrium yields. Because the fishery had been subject to overfishing (as indicated in this case by the Schaefer model), the sustainable yield at this time would be considerably less than the estimated MSY value.

The effort giving MSY was 218,367 standard days fished when adjusted for learning and 223,145 standard days fished without the learning adjustment. These are in the same order of magnitude as the respective efforts estimated for 1969, which were 221,137 and 210,914 standard days fished (Table 8). The averages of catch and effort for the years following 1968 (except for 1970) exceed the projected allowable values for maximum sustained yield of the fishery and hence indicate a condition of overfishing. For example, the percentage reductions in standardized effort from the 1972 observed levels required to reach the average MSY level resulting from the above fits to the Schaefer model ranged from 30.7 percent to 27.7 percent for data with and without an adjustment for learning, respectively.

Using the survey cruise estimate of population decline of 8.8 percent per year for 1969-1971 and assuming that the 1969 effort was equal to that giving the MSY, then the 1972 fishing effort was 27 percent in excess of that needed for MSY.

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Table 1. Number of vessels (U.S., Others) fishing in ICNAF Subarea 5 (6) during 1959, 1965 and 1971 by tonnage class (A = less than 901 gross tonnage; B = 901 gross tonnage and above).

Year	NUMBER OF VESSELS[3]						
	U.S.		Others		Total		
	A	B	A	B	A	B	Total
1959[1]	301	-	26	-	327	-	327
1965[1]	323	-	244	110	567	110	677
1971[2]	463	-	493	220	956	220	1176

[1]Includes only Subarea 5 data.
[2]Includes both Subarea 5 and Subarea 6 data.
[3]Data from ICNAF List of Fishing Vessels, 1959, 1965 and 1971.

Table 2. Subarea 5 landings (greater than 3,000 tons). As reported in ICNAF Statistical Bulletins.

	1960	1972
Cod	14,430	31,357
Haddock	45,801	6,669
Redfish	11,375	19,095
Yellowtail flounder	13,581	29,620
Winter flounder	6,953	10,505
Witch flounder		5,454
Scup	3,779	
Pollock	10,397	12,989
Silver hake	46,688	107,113
Red hake	3,410	60,062
White hake		3,084
Food species	3,790	
Industrial species (primarily red and silver hakes)	15,320	
Herring	69,046	220,964
Mackerel		200,518
Alewife	8,669	8,656
Atlantic saury		3,429
Angler		4,332
Sculpins		4,862
Argentine		32,707
Sharks		12,798
Skates		8,735
Other fish		21,661
Squid		26,111

Table 3. Statistics used in development of learning model, by fleet, species and area.

Data set	Year	Observed catch/ effort	Research vessel abundance index1/	Predicted catch/ effort	i	I_i
Herring	1966	30.99	10.41	30.99	1	1.00
Area: 5Z	1967	20.98	3.26	9.70	2	2.16
Poland	1968	28.13	1.36	4.05	3	6.94
OtSt >1800	1969	22.96	1.14	3.39	4	6.77
	1970	27.21	.66	1.96	5	13.88
	1971	35.63	2.07	6.15	6	5.80
Cod	1964	6.00	7.62	6.00	1	1.00
Area: 5Z	1965	11.80	5.52	4.35	2	2.71
Spain	1966	19.25	4.84	3.81	3	5.05
P. trawl	1967	16.22	12.46	9.81	4	1.65
	1968	15.96	5.74	4.52	5	3.53
	1969	13.92	5.24	4.12	6	3.38
	1970	15.48	6.70	5.27	7	2.94
	1971	15.22	4.53	3.56	8	4.27
S. Hake	1963	6.13	9.90	6.13	1	1.00
Area: 5Z	1965	8.90	10.76	6.66	2	1.34
U.S.S.R.	1966	10.56	5.84	3.62	3	2.92
OtSI 151-500						
S. Hake	1964	8.65	8.16	8.65	1	1.00
Area: 5Z	1965	19.72	10.76	11.40	2	1.73
U.S.S.R.	1966	16.03	5.84	6.19	3	2.59
OTSI 501-900	1967	12.17	6.37	6.75	4	1.80
Herring	1968	12.20	17.40	17.40	1	1.00
Area: 6	1969	10.23	6.40	4.49	2	2.28
Poland	1970	12.02	1.20	.84	3	14.31
OtSt 501-900	1971	8.71	3.70	2.59	4	3.36
Herring	1967	19.19	3.26	19.19	1	1.00
Area 5Z	1968	22.42	1.36	8.01	2	2.80
Romania	1969	12.03	1.14	6.71	3	1.79
OtSt >1800	1970	13.95	.66	3.88	4	3.59
	1971	17.41	2.07	12.37	5	1.40

1/ lbs./tow index as recorded by U.S.A. research vessel Albatross IV groundfish surveys; all autumn surveys except for statistical area 6 where spring surveys were used.

Table 4. 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	5Y Country	5Y Gear	5Y Tonnage class	5Y Years adjusted	5Z Country	5Z Gear	5Z Tonnage class	5Z Years adjusted	6 Country	6 Gear	6 Tonnage class	6 Years adjusted
Herring	Germany(Fr)	OtSI	901-1800	1969, 70	Germany(Fr)	OtSt	901-1800	1967, 68	Poland	OtSi	501-900	1968, 69
		OtSt	1801+	1969, 70		OtSt	1801+	1967, 68		OtSt	1800+	1968, 69
	United States	Purse			Non-Mbr	OtSt	1801+	(1965), 66	USSR	OtSi	151-500	1967, 68
		seine	51+	1965, 66	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	51+	1968, 69				
						D. gill						
						Nets - All		1961, (62)				
						Pair						
	NonMbr A	OtSt	501-900	1968, 69					NonMbr A	OtSi	501-900	1968, 69
		OtSt	1801+	1968, 69								
Cod	Spain	Pair										
		trawl	151-500	1969, 70	Spain	Trawl	151-500	1964, 65				
Haddock					USSR	OtSi	501-900	1965, 66				
Silver hake					USSR	OtSi	151-900	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 5. 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	547.38	299		
Country (unadjusted)	174.18	9		
Gear-tonnage class (unadjusted)	477.53	18		
Country (adjusted)	15.58	9	1.73	4.08**
Gear-tonnage class (adjusted)	257.96	18	14.33	33.80**
Interaction	45.39	26	1.75	
Error	69.84	246	0.28	
Interaction plus error	115.23	272	.424	

**Significant at 0.01 level.

Table 5 (cont'd). Analysis of variance of ln (catch/effort) data for ICNAF Subareas 5 plus 6, not adjusted for learning.

Source of variation	Sums of squares	Degrees of freedom	Mean square	F
Total	473.42	299		
Country (unadjusted)	124.08	9		
Gear-tonnage class (unadjusted)	421.65	18		
Country (adjusted)	11.55	9	1.28	3.90**
Gear-tonnage class (adjusted)	260.21	18	14.46	44.09**
Interaction	37.35	26	1.44	
Error	51.78	246	0.21	
Interaction plus error	89.13	272	.328	

**Significant at 0.01 level.

Table 6. Estimates of fishing power factors for given country and gear-tonnage class combinations for ICNAF Subareas 5 plus 6 without adjustments for learning, 1961-1972.

COUNTRY	USA	CANADA	USSR	SPAIN	POLAND	GERMANY(FR)	NON-MEMBER A	ROMANIA	JAPAN	BULGARIA
Gear-tonnage class										
Otter trawl (side)										
0-50 MT	1.00	.67								
51-150 MT	1.30	.87								
151-500 MT	1.77	1.19	1.44			1.72				
501-900 MT		1.63	1.98		1.64	2.35	1.32			
901-1800 MT			3.16		2.62	3.76	2.11			
Otter trawl (stern)										
0-50 MT	3.33	2.24								
51-150 MT	0.94	.63								
151-500 MT	1.75	1.18								
501-900 MT	2.67	1.79	2.18			2.59	1.45			
901-1800 MT			5.54	4.38	4.59	6.59	3.70			
>1800 MT			7.65		6.34	9.09	5.10	3.53	3.19	6.47
Purse seine										
50 -058	7.35	4.93	5.99							
50 -052	0.95									
Pair trawl - All	4.36		3.56	2.81						
Line trawls - All	0.46	.31								
Hand lines - All	0.14									
Drift gill nets - All	0.11		.09							
Otter trawl (side-pelagic)										
501-900							0.82			
901-1800							0.29			

Table 7. Subarea 5 and Statistical Area 6 catch data (MT) for which days fished was not reported.

YEAR	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
CAN	27	137	93		1,091	2,997	9,564	36,341	10,309	7,496	30,999	14,718
FRA												296
ICE								292	12,786			
ITA												4,000
JAP							331	7,212	16,251	28,795	27,673	
NOR									1,224			
ROM					1,982	3,433						
SPA											4,197	7,546
USSR		201,224	7,960	22,393	34,464							75,704
USA	70,792	43,163	166,789	152,855	155,585	127,899	115,084	106,563	96,180	77,733	74,594	69,062
OTH + NONM			2	10,213	5,722		202	263	6,516	8,998	108,180	2,381
TOTAL(1)	70,819	244,524	174,844	185,461	198,844	134,329	125,181	150,671	143,266	123,022	245,643	173,707
1/ TOTAL CATCH(2)	344,286	472,263	650,825	786,346	954,808	988,568	759,881	942,762	1,029,391	840,267	1,124,872	1,144,597
PERCENT 2/ (1)/(2)	21%	52%	27%	24%	21%	14%	16%	16%	14%	15%	22%	15%

1/ Total catch = Catch of finfish (excluding sharks, billfishes, tunas, swordfish, menhaden) and squid.

2/ All years combined = 20%.

Table 8. ICNAF Subarea 5 and Statistical Area 6 total finfish plus squid catches, unadjusted effort, standardized effort with (without) learning, catch/effort and catch/ standardized effort with (without learning) for the years 1961-1972.

YEAR	UNADJUSTED EFFORT	TOTAL STAND-ARDIZED EFFORT	STANDARD EFFORT WITH LEARNING ADJUSTMENT	TOTAL CATCH	CATCH / EFFORT	CATCH / STANDARD EFFORT	CATCH / STANDARD EFFORT -LEARNING
1961	42,348	61,590	53,879	344,286	8.13	5.59	6.39
1962	60,780	110,342	108,816	472,263	7.77	4.28	4.34
1963	66,683	123,262	108,834	650,825	9.76	5.28	5.98
1964	71,812	150,353	165,896	786,346	10.95	5.23	4.74
1965	70,884	161,558	169,895	954,808	13.47	5.91	5.62
1966	68,698	175,278	191,583	988,568	14.39	5.64	5.16
1967	68,892	137,411	143,104	759,881	11.03	5.53	5.31
1968	84,100	171,723	180,260	942,762	11.21	5.49	5.23
1969	85,576	210,941	221,137	1,029,391	11.89	4.88	4.65
1970	75,905	171,834	182,667	840,267	11.07	4.89	4.60
1971	81,749	230,035	267,190	1,124,872	13.76	4.89	4.21
1972	91,203	263,126	315,316	1,144,597	12.55	4.35	3.63

Table 9. Mean catch per haul (lb) on Albatross IV autumn surveys for 1963-65 and 1970-72 and percentage change from 1963-65 to 1970-1972[1/]

Species	Georges Bank[2/] 1963-65 mean	Georges Bank[2/] 1970-72 mean	% change	Southern New England[3/] 1963-65 mean	Southern New England[3/] 1970-72 mean	% change
Haddock	147.6	12.3	-92	8.8	0.4	-95
Cod	16.0	16.4	+03	4.3	2.1	-51
Silver Hake	4.7	2.8	-32	13.6	8.2	-40
Red Hake	9.2	3.1	-66	12.9	10.2	-21
White Hake	1.5	2.4	+60	1.6	0.9	-44
Yellowtail flounder	19.5	9.4	-52	24.4	35.3	+45
Winter flounder	5.1	6.3	+24	6.7	4.7	-30
Other founders	5.0	3.8	-24	8.1	4.1	-49
Longhorn sculpin	4.7	7.8	+66	2.1	2.3	+10
Ocean pout	3.1	0.4	-87	1.0	0.3	-70
Angler	8.4	2.4	-71	11.8	10.2	-14
Other groundfish	7.5	3.6	-52	8.4	7.5	-14
Total - all gndfish & fldrs	232.4	70.8	-70	103.8	86.3	-17
Skates	54.5	27.7	-49	26.0	13.6	-48
Squid	7.0	3.0	+55	3.1	12.4	+243

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 10. Comparison of mean catch per haul (lb) on Albatross IV autumn surveys in Divisions 5Z and 6A for the two periods 1963-1965 and 1970-1972, the percentage change relative to the earlier period, and cumulative landings from 1962-1972, for groundfish, skates and sea herring.

Species	63-65[1/] mean catch/haul	70-72[1/] mean catch/haul	% change	Cumulative landings for 1962-72 (metric tons x10^3)
Haddock	72.0	5.8	-92	588
Cod	9.6	8.6	-10	368
Silver Hake	9.5	5.7	-40	1266
Red Hake	11.2	7.0	-38	423
White Hake	1.6	1.6	0	9
Yellowtail Flounder	22.2	23.5	+ 6	362
Winter Flounder	6.0	5.4	-10	121
Other Flounder	6.7	4.0	-40	76
Sculpin	3.3	4.8	+45	43
Ocean Pout	2.0	0.4	-80	77
Angler	10.2	6.6	-35	14
All other groundfish	8.0	5.7	-29	229
Skates	39.0	20.0	-49	46
Total groundfish, skates and flounders	201.3	92.3	-49	3672
Squid	2.9	8.3	+186	118
Sea Herring	-	-	"-93"	2007
Mackerel	-	-	"-37"	1162
	Weighted mean[2/] percentage change		"-56"	

1/ Calculated by pooling the means shown in Table 7 for Georges Bank and Southern New England into a single stratified mean representing Divisions 5Z and 6A.

2/ Weights equivalent to cumulative landings in 1962-72; weighted mean includes squid, mackerel, and sea herring as well as groundfish species (using the percentage for total groundfish and flounders).

Table 11. Individual Stock Assessments.

Species	Estimate of Maximum Sustainable Yield X $1{,}000^{-1}$ MT
Herring	335
Mackerel	310
Silver Hake	200
Squid	80
Red Hake	70
Haddock	50
Cod	45
Yellowtail Flounder	37
Redfish	30
Pollock	20*
Other flounder	25
Other finfish	150
Sum of species assessments	1,352

*MSY estimated to be 50,000 including Division 4VWX, 20,000 MT based on catch ratios assigned to SA 5.

Table 12. Total annual landings from ICNAF Subareas 5 and 6 for herring and mackerel, 1961-1972, 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
1972	237	387	624
Average	233	96	330

Table 13.
Estimate 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.[1]

		3 Years	4 Years	5 Years
Optimum effort	1963-1972	271,857		
	1964-1972	271,681	291,031	
	1965-1972	224,375	216,987	213,740
	1966-1972	225,709	217,342	202,690
	1967-1972	227,835	212,405	194,369
	1968-1972	235,535	220,108	193,089
	1969-1972	257,552	241,430	209,264
MSY	1963-1972	981,474		
	1964-1972	980,942	996,064	
	1965-1972	931,365	898,352	865,270
	1966-1972	931,772	898,458	859,465
	1967-1972	901,001	898,705	860,987
	1968-1972	931,451	896,762	861,988
	1969-1972	940,004	899,972	852,617
Catch/effort	1963-1972	3.61		
	1964-1972	3.61	3.42	
	1965-1972	4.15	4.14	4.05
	1966-1972	4.13	4.13	4.24
	1967-1972	4.09	4.23	4.43
	1968-1972	3.95	4.07	4.46
	1969-1972	3.65	3.73	4.07
Coefficient of determination	1963-1972	.77		
	1964-1972	.67	.57	
	1965-1972	.96	.95	.94
	1966-1972	.94	.93	.94
	1967-1972	.94	.93	.96
	1968-1972	.93	.93	.94
	1969-1972	.97	.99	.99

[1] Data adjusted for learning.

Appendix table 1. Estimates of fishing power factors for given country and gear-tonnage class combinations for ICNAF Subareas 5 plus 6 with adjustments for learning using USSR OtSt >1800 as standard gear.

COUNTRY	USA	CANADA	USSR	SPAIN	POLAND	GERMANY(FR)	GERMANY(DR)	ROMANIA	JAPAN	BULGARIA
Gear-tonnage class										
Otter trawl (side)										
0-50 MT	.110	.076								
51-150 MT	.142	.098	.195							
151-500 MT	.190	.132	.026			.296				
501-900 MT		.174	.411		.250	.390	.154			
901-1800 MT					.399	.622	.251			
Other trawl (stern)										
0-50 MT	.368	.254								
51-150 MT	.103	.071								
151-500 MT	.192	.133								
501-900 MT	.264	.183	.271			.411	.162			
901-1800 MT			.722	.619	.701	1.093	.431			
>1800			1.000		.972	1.514	.597	.554	.354	.719
Purse seine										
>50	.105									
<50	.876	.606	.898							
Pair Trawl - All	.434		.445	.381						
Line Trawls- All	.016									
Hand lines - All	.051	.035								
Drift gill nets - All	.014		.014							
Otter-trawl (side-pelagic)										
501-900							.092			
901-1800							.033			

Appendix table 2. ICNAF Subarea 5 and Statistical Area 6 total finfish plus squid catches, standardized effort with (without) learning, and catch/(standardized effort with (without) learning) for the years 1961-1972 using USSR OtSt >1800 as standard gear.

YEAR	TOTAL STANDARDIZED EFFORT	STANDARD EFFORT WITH LEARNING ADJUSTMENT	TOTAL CATCH	CATCH / STANDARD EFFORT	CATCH / STANDARD EFFORT-LEARNING
1961	8,051	5,925	344,286	42.76	58.10
1962	14,423	11,968	472,263	32.74	39.46
1963	16,113	11,969	650,825	40.39	54.37
1964	19,654	18,245	786,346	40.01	43.10
1965	21,119	18,684	954,808	45.21	51.10
1966	22,912	21,070	988,568	43.15	46.92
1967	17,962	15,738	759,881	42.30	48.28
1968	22,447	19,825	942,762	42.00	47.55
1969	27,574	24,321	1,029,391	37.33	42.28
1970	22,462	20,090	840,267	37.41	41.83
1971	30,070	29,385	1,124,872	37.41	38.28
1972	34,396	34,678	1,144,597	33.28	33.01

Appendix table 3. Estimate 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[1] using USSR OtSt >1800 as standard.

		3 Years	4 Years	5 Years
Optimum effort	1963-1972	29,899		
	1964-1972	29,879	32,007	
	1965-1972	24,677	23,864	23,507
	1966-1972	24,823	23,903	22,972
	1967-1972	25,057	23,360	21,377
	1968-1972	25,904	24,207	21,236
	1969-1972	28,325	26,552	23,015
MSY	1963-1972	981,474		
	1964-1972	980,942	996,064	
	1965-1972	931,365	898,352	865,270
	1966-1972	931,772	898,458	859,465
	1967-1972	901,001	898,705	860,987
	1968-1972	931,451	896,762	861,988
	1969-1972	940,004	899,972	852,617
Catch/effort	1963-1972	32.82		
	1964-1972	32.82	31.10	
	1965-1972	37.73	37.64	36.83
	1966-1972	37.55	37.55	38.55
	1967-1972	37.19	38.46	40.28
	1968-1972	35.92	37.01	40.55
	1969-1972	33.19	33.92	37.01
Coefficient of determination	1963-1972	.77		
	1964-1972	.67	.57	
	1965-1972	.96	.95	.94
	1966-1972	.94	.93	.94
	1967-1972	.94	.93	.96
	1968-1972	.93	.93	.94
	1969-1972	.97	.99	.99

[1]Data adjusted for learning.

Appendix table 3. (continued). Estimate 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. No learning. Standard is USSR, OtSn, 1801+ Gst.

		3 Years	4 Years	5 Years
Optimum Effort	1963-1972	50,362		
	1964-1972	35,326	39,600	
	1965-1972	29,771	29,140	28,597
	1966-1972	30,882	30,048	27,469
	1967-1972	32,464	31,159	27,876
	1968-1972	34,472	33,144	28,304
	1969-1972	44,261	42,187	34,073
MSY	1963-1972	1,274,828		
	1964-1972	998,504	1,081,719	
	1965-1972	964,367	939,613	910,024
	1966-1972	974,312	947,857	899,647
	1967-1972	986,631	957,489	902,401
	1968-1972	1,007,138	976,682	905,414
	1969-1972	1,117,381	1,088,310	959,131
Catch/Effort	1963-1972	25.31		
	1964-1972	28.26	27.32	
	1965-1972	32.39	32.24	31.82
	1966-1972	31.55	31.54	32.75
	1967-1972	30.39	30.73	32.37
	1968-1972	29.22	29.47	31.99
	1969-1972	25.24	25.80	28.15
Coefficient of determination	1963-1972	.42		
	1964-1972	.65	.56	
	1965-1972	.87	.89	.94
	1966-1972	.82	.85	.93
	1967-1972	.82	.82	.90
	1968-1972	.76	.76	.85
	1969-1972	.61	.74	.87

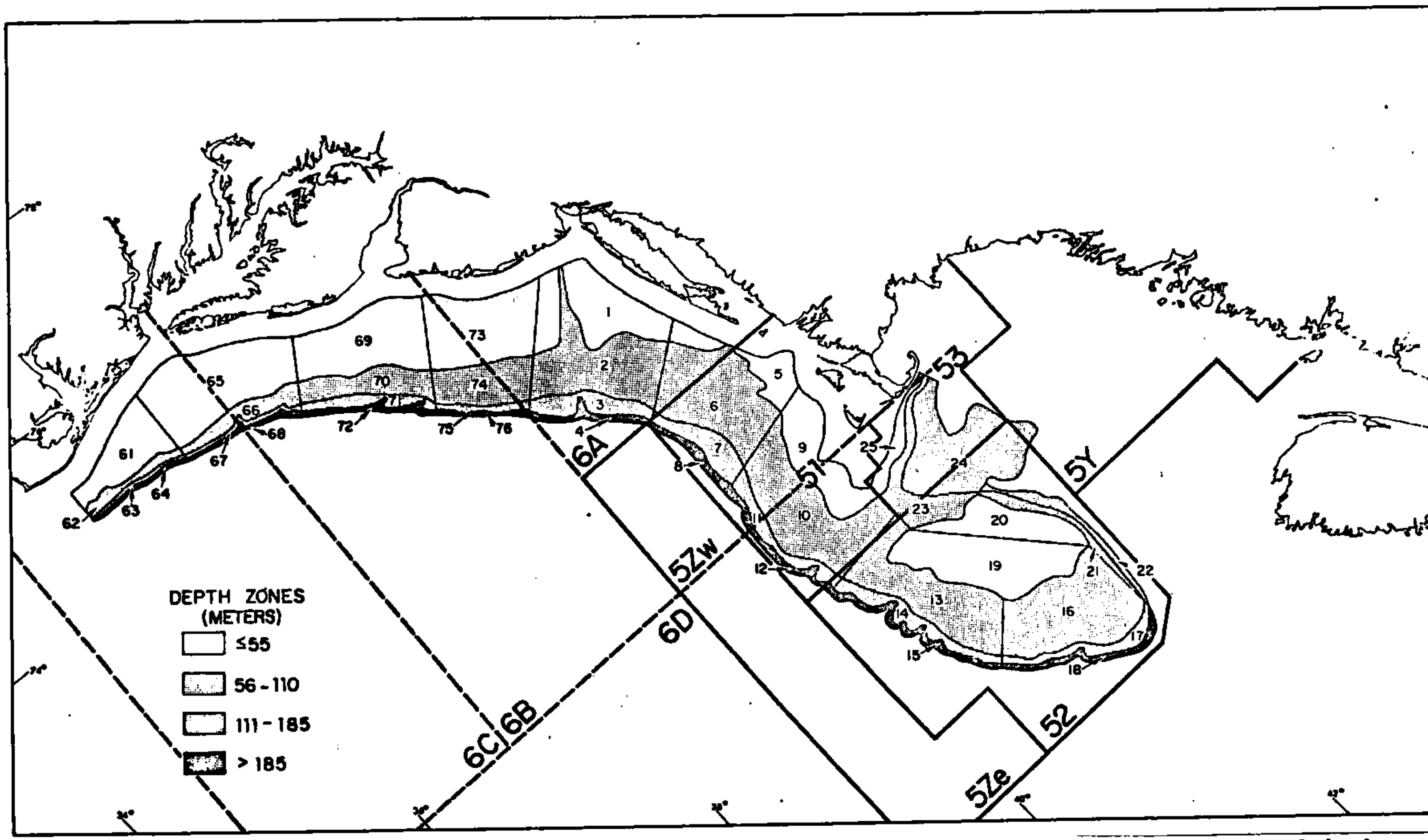


Figure 1. Sampling strata for US-USSR joint groundfish surveys. Strata 1-25 (less 24) were used for pooled estimates of abundance for 5Z; only US survey data used for estimating decline in biomass.

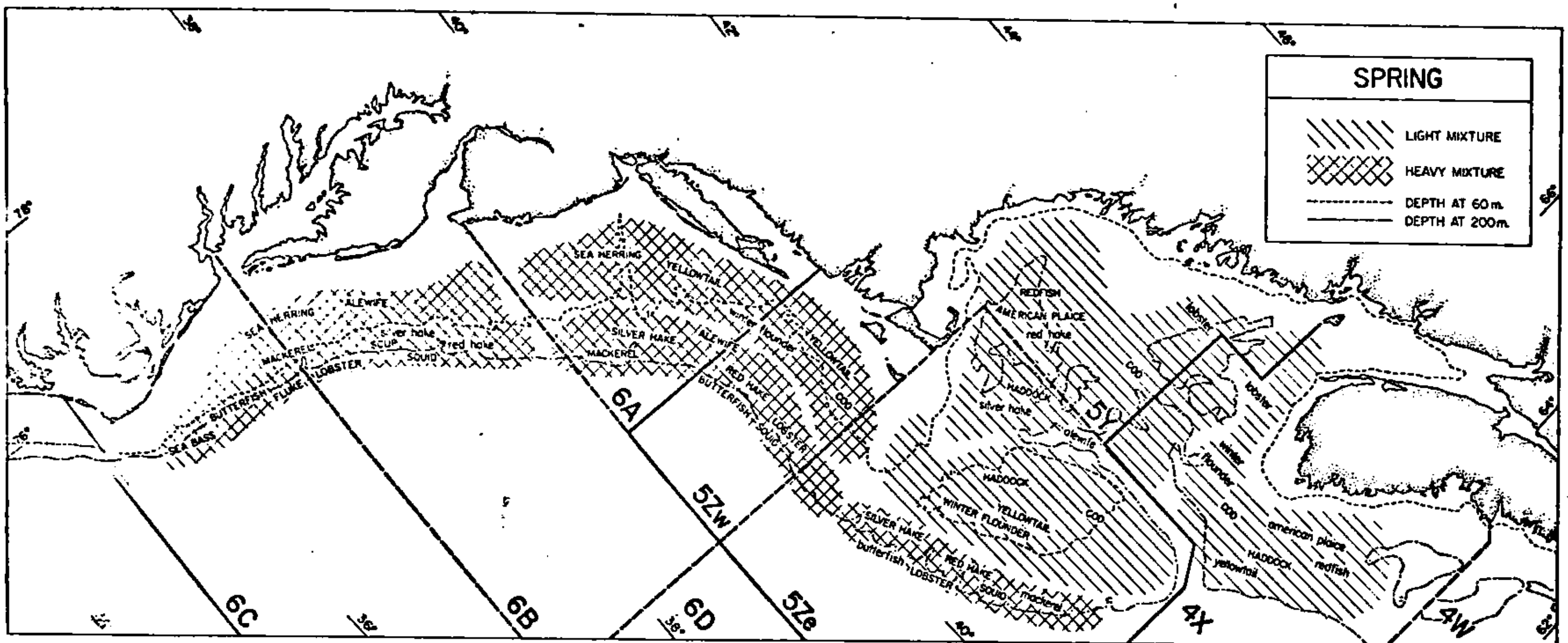
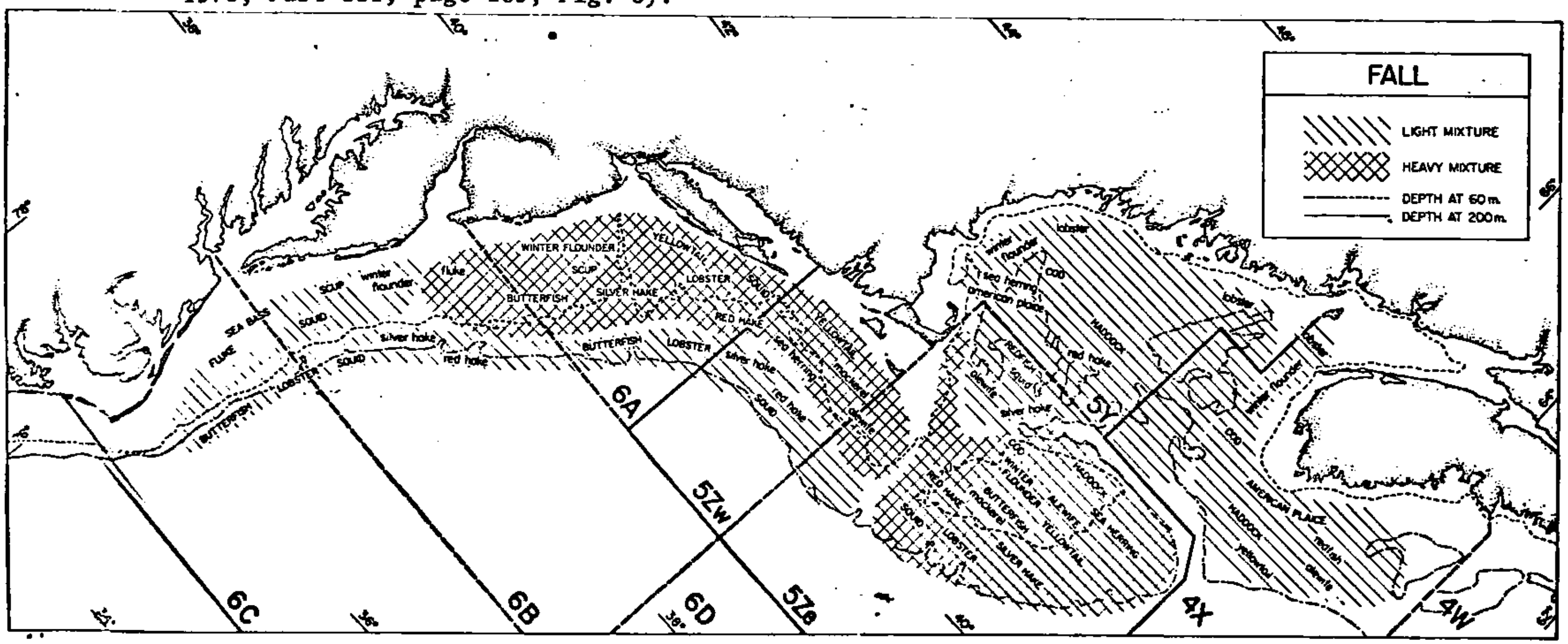


Figure 2. Generalized pattern of species mixture of ICNAF Subareas 5 and 6 (From Grosslein, M. D. and E. Bowman, Mixture of species in Subareas 5 and 6, ICNAF Redbook 1973, Part III, page 169, Fig. 6).



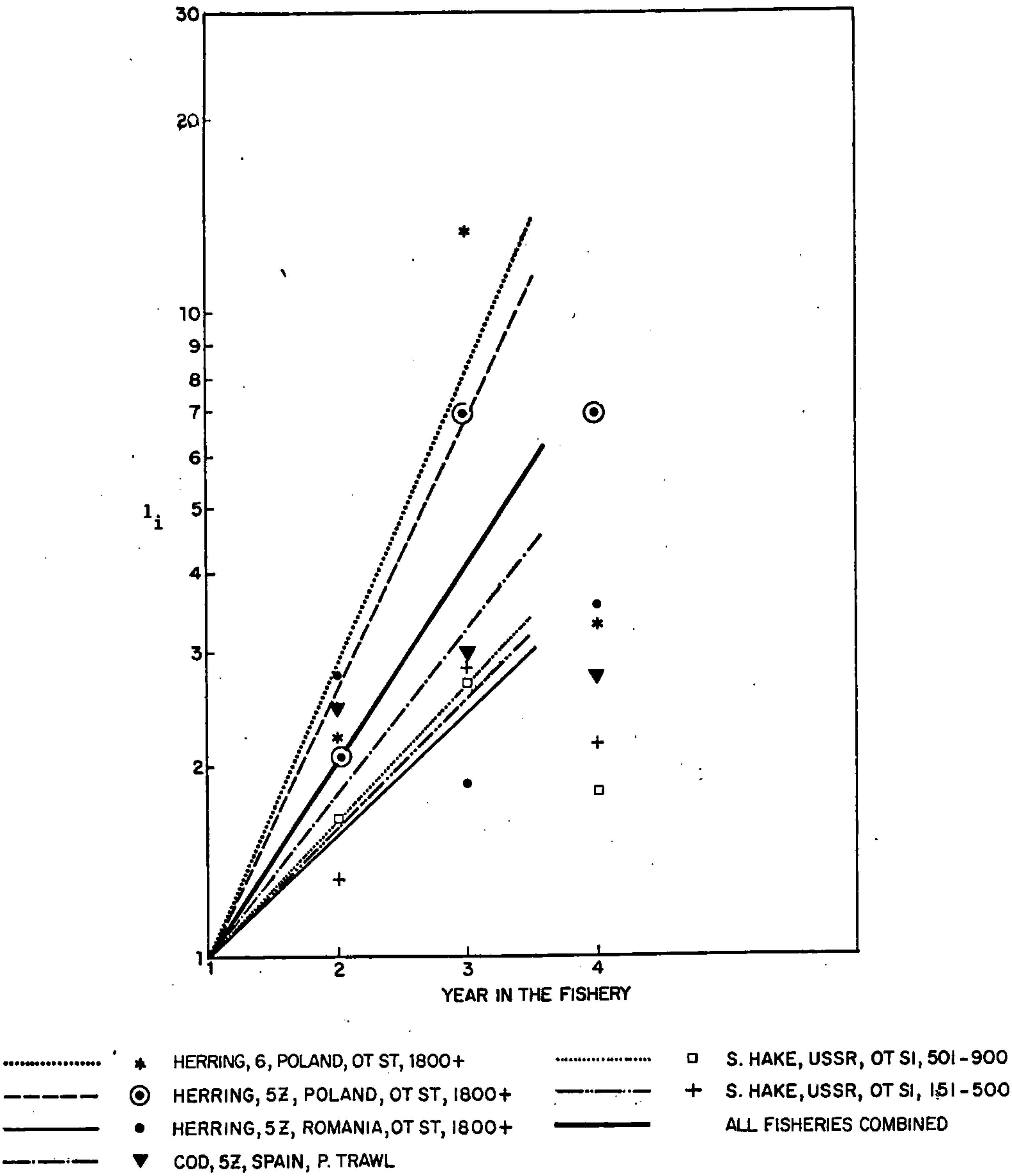


Fig. 3. Relationship of learning function (l_i) to year in the fishery (see text for explanation).

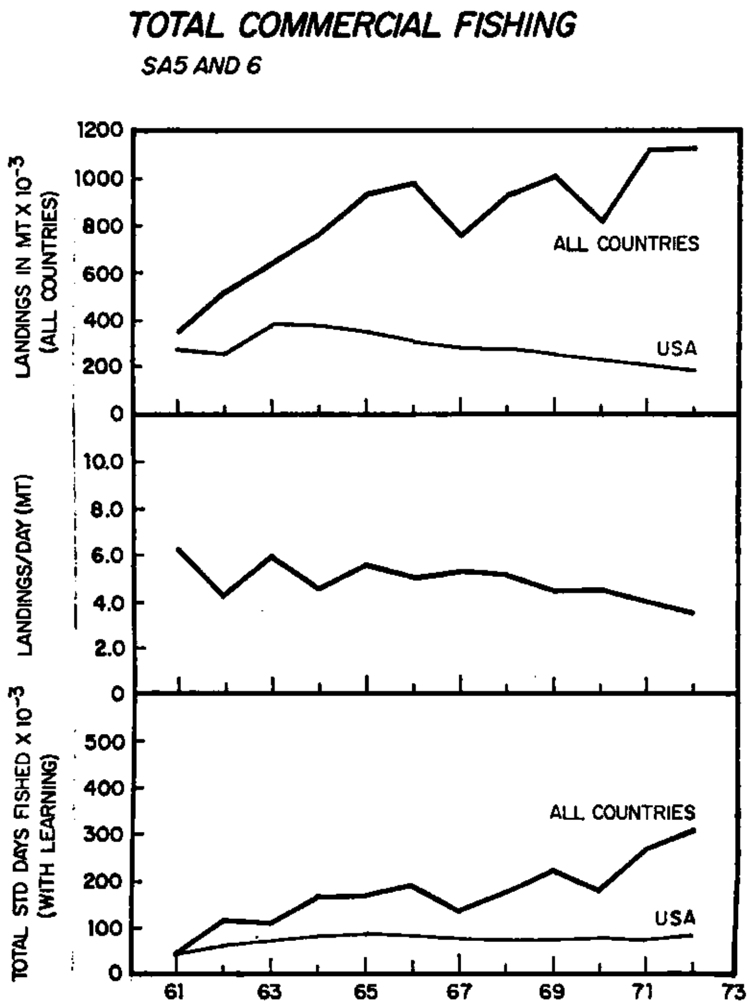


Fig. 4. Total commercial landings of finfish (excluding swordfish, tunas, billfishes, menhaden) plus squid, landings per day, and total standardized days fished (with learning) for ICNAF Subarea 5 and Statistical Area 6, plotted against time.

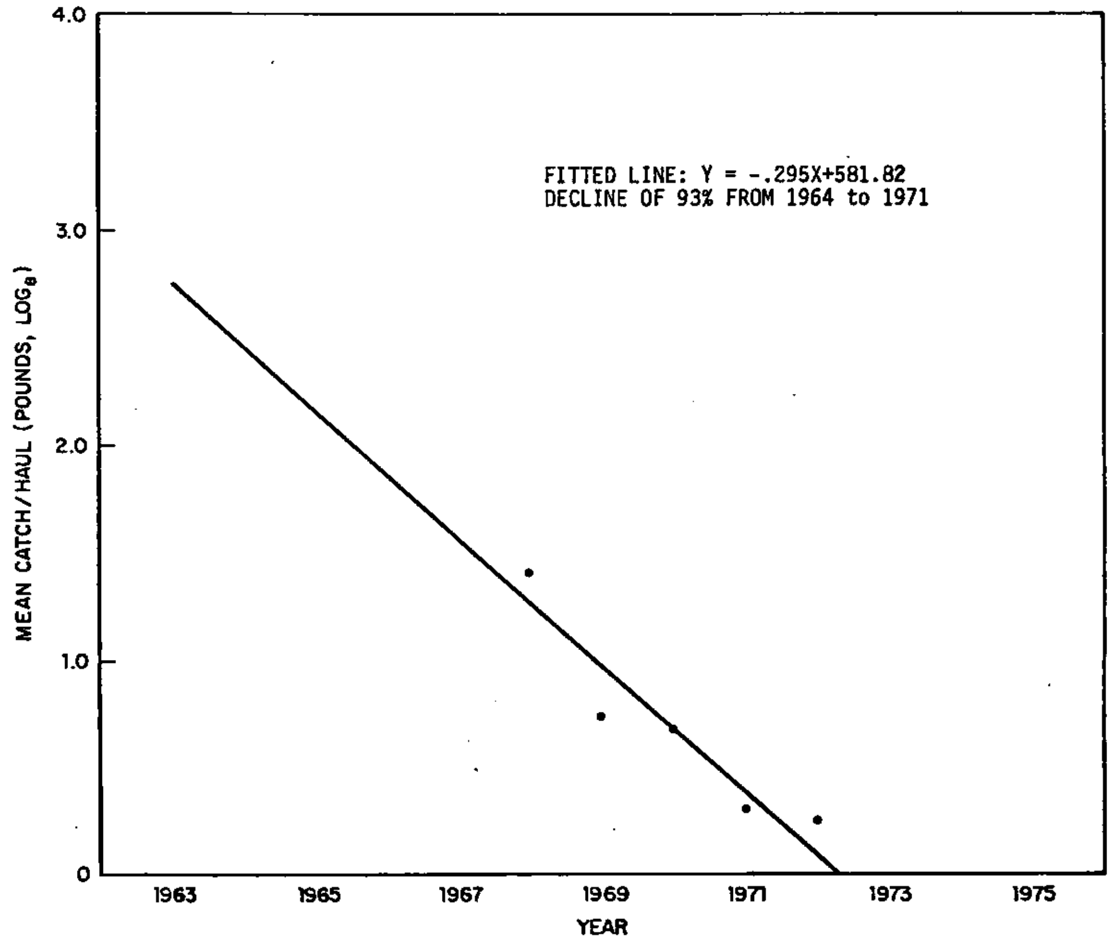


Fig. 5. Plot of sea herring abundance indices from Albatross IV spring surveys in Strata 1-12 and 61-76 (Nantucket to Cape Hatteras).

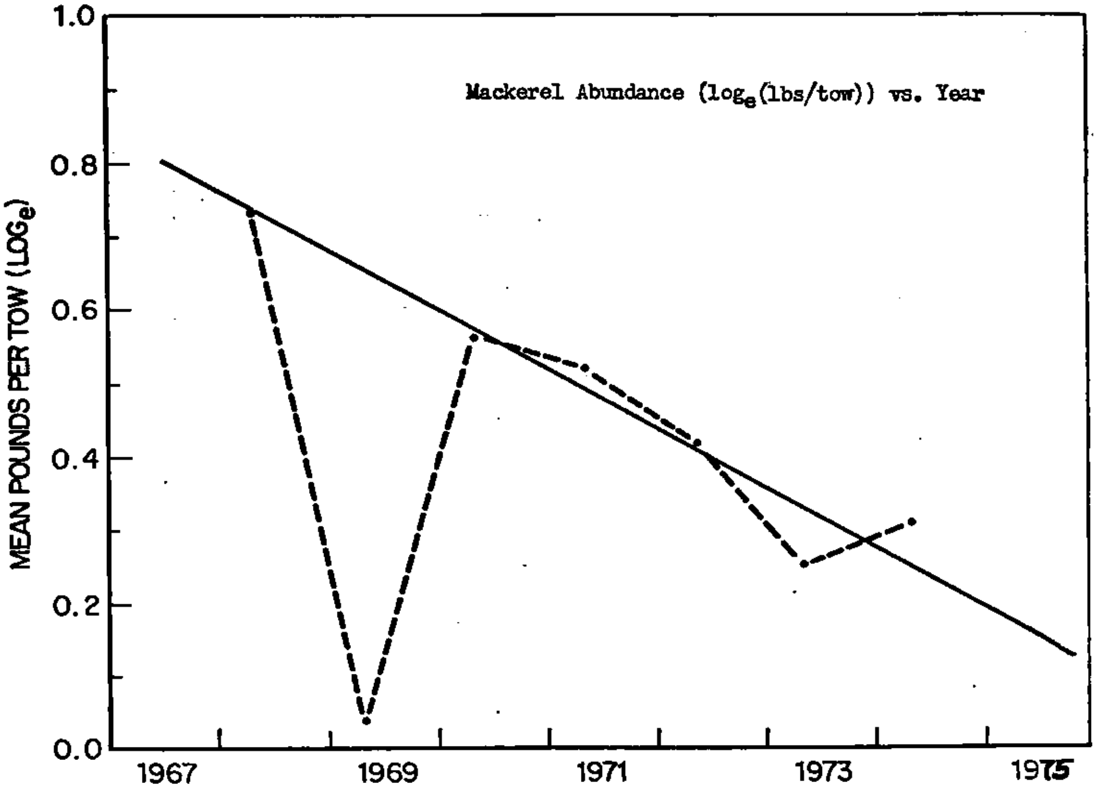


Fig. 6. Least squares regression fit of mean log$_e$ (lbs/tow) from Albratross IV spring surveys, through time. Data for 1969 was excluded from the calculations.

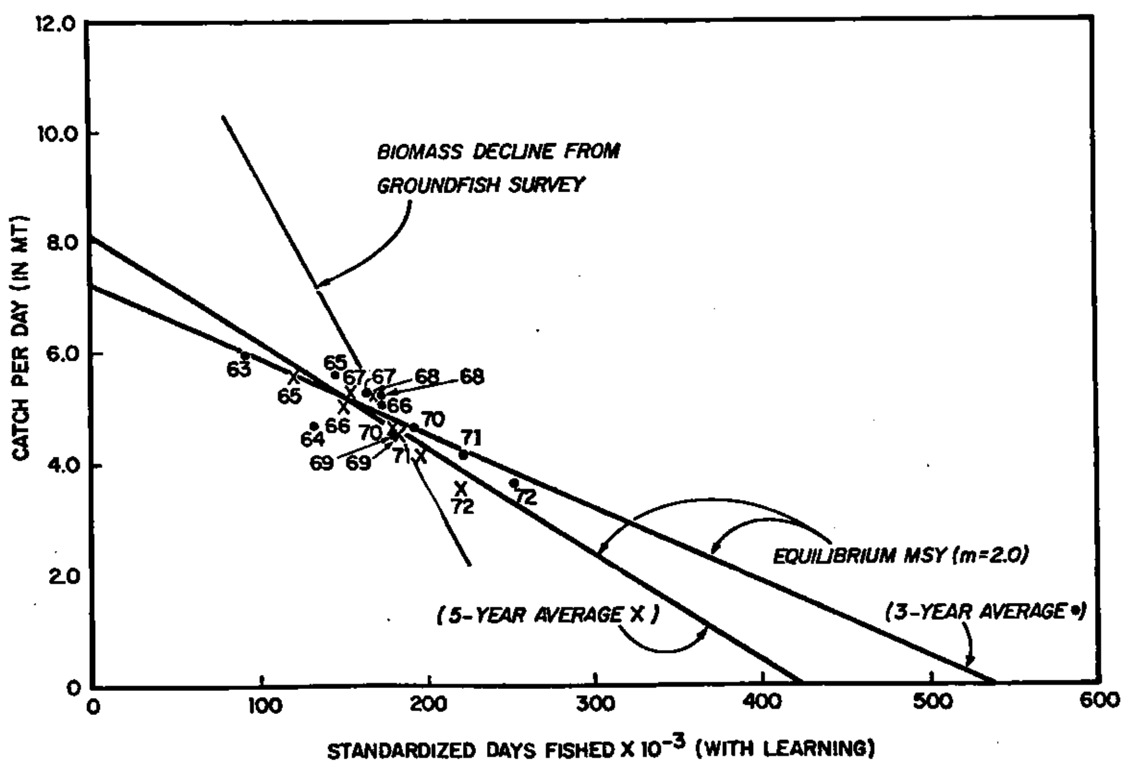


Fig. 7. Catch per day plotted against standardized days fished (with learning) for data from ICNAF Subarea 5 and Statistical Area 6, 1961-1972. Also, estimate of biomass decline of groundfish, skates and herring from groundfish survey (see Table 8).

C 1

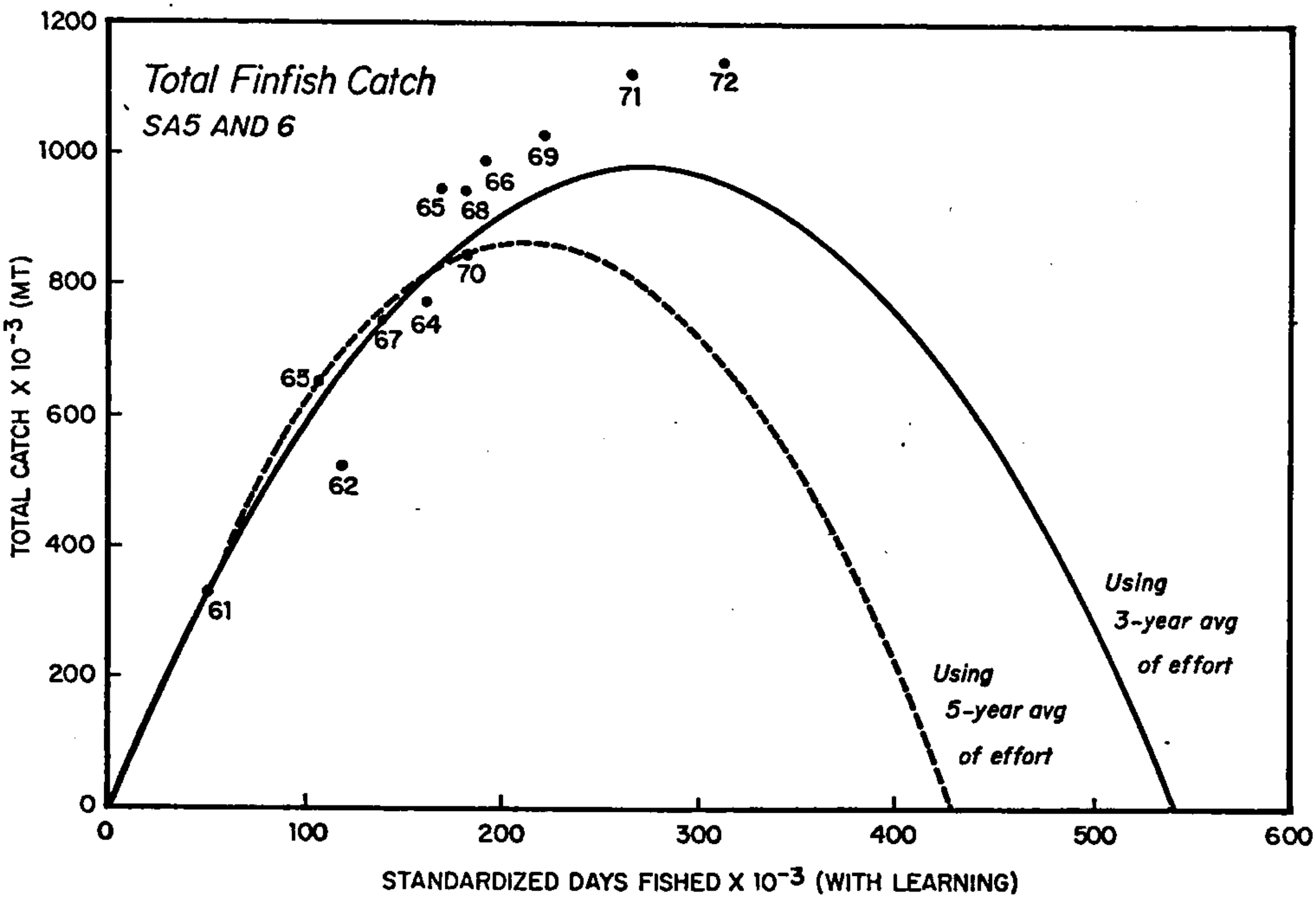


Fig. 8. Total catch (finfish plus squid) vs. standardized days fished (with learning) for Subarea 5 and Statistical Area 6, 1961-1972, using a three-year average over effort (days fished) and a five-year average over effort. Original data points (catch vs. standardized days fished) are plotted.