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Assessment of the Yellowtail flounder fishery in Subarea 5

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Summary

Catch, effort and abundance indices

Total US landings (Fig. 7, Table 1) rose from about 5,000 metric tons in 1955 to about 38,000 in 1963, 1964 and 1965, declined to 27,000 in 1967, and then rose again to 33,000 in 1969. Discards of small fish have been heavy, upwards of 50% of landings, in some years (Tables I and II).

US effort rose almost continuously from 1,400 days fished in 1955 to 14,800 in 1966, declined to 10,600 in 1968, and then rose to 13,600 in 1969 (Fig. 2). In 1969, landings of other countries became important for the first time amounting to about 19,300 tons, bringing the total catch to 57,000 tons.

Landings per unit of effort have been somewhat more erratic than either catch or effort. From about 2.0 tons per day in 1955, they rose to about 2.7 in 1958, dropped to 2.0 in 1960, rose to a peak of 4.3 in 1963, declined sharply to 2.0 in 1966, rose to 3.0 in 1968, and then dropped to 2.7 in 1969 (Fig. 3). Estimates of relative abundance derived from groundfish surveys support these trends and also indicate a rather low recruitment for 1970 and 1971.

Length and age compositions

These are available from 1960 to 1968 and show that about 47 percent of the landings are age 3, 22 percent are age 4, and 20 percent are age 2 (Table IV). Adding the estimated age composition of the discards makes age 2, the predominant age of the catches at 41 percent, age 3, 35 percent, and age 4, 15 percent (Table V).

Estimates of total mortality rate (Z)

Z has been estimated from catch curves for the years 1943-1947 at 0.78, when the landings were about 18,000 tons annually, and of the years 1960-1965 as 1.02. From some rather small tagging studies, estimates have ranged from 1.14 to 1.99 for the 1957-62 period. An estimate based on a study of virtual population estimates gives a value of 1.26 for the 1960-67 period.

Estimates of fishing mortality rate (F)

The tagging studies gave estimates ranging from 0.08 to 2.55 but there are no hard data on tagging mortality or unreported tags. Analysis of the virtual population estimates gives a value of about 1.05 assuming a natural mortality rate of 0.2.

Estimate of the exploitation rate (E)

Using $F = 1.05$ and $Z = 1.26$ gives $E = 0.83$.

Estimate of population size

Using the E, F and M values by year-classes (Tables VII, VIII, IX) and the virtual population values, it is estimated that the overall average population

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size for the 1958-61 year-classes was about 231×10^6 fish of age 2 and older (Table X).

Yield per recruit

The Beverton and Holt model gives age 3 as the optimum age at first capture for values of $M = 0.2$ to 0.3 and $F = 0.5$ to 1.6. At $M = 0.2$ and 3 years as age of first capture, the optimum F occurs at 0.8 (Table XIII). This is estimated to be about 30 percent less than the current US effort.

Maximum yield

The estimated maximum equilibrium catch is estimated to be about 32,000 metric tons. This corresponds to about 7,000 standard US days fishing. Since some discard is inevitable, a quota of about 26,000 tons of landed fish would be required to produce the desired catch.

Change in mesh size

The present mesh is 114 mm (4 1/2 inches). A 129 mm (5.1 inches) mesh would result in a 27 percent decrease in discards, a 4 percent immediate loss, and a 10 percent long-term gain. A 145 mm mesh (5.7 inches) would result in a 51 percent decrease in discards, a 21 percent immediate loss, and a 17 percent long-term gain at current rates of fishing.

Introduction

The yellowtail flounder (*Limanda ferruginea*) fishery has been exploited since the late 1930's. In recent years fishing effort has increased. This document reports on attempts to determine the current level of fishing and its effects on the stocks. Estimates are presented of the optimum level of fishing in terms of yield and yield per recruit. Possible mesh regulations are reviewed and a quota suggested.

Status of the Fishery

Harvest, effort and indices of abundance

Lux (1964) discussed the landings, fishing effort, and apparent abundance of yellowtail flounder. In Figures 1, 2, and 3 are presented values for these items through 1969 separately for Georges Bank and the southern New England ground. The procedure for computation of days fished and catch per day is given by Lux (1964). The catch per day is based on the effort of trips of those vessels for which 50 percent or more of their landings were yellowtail flounder. The sampling areas referred to are shown in Figure 4. Lux (1963) and Royce et al. (1959) discuss the evidence for the separation of the stocks on these areas. In Figure 1 the total landings included food plus industrial landings while the subtotals for the separate areas refer only to food landings. The southern New England and Georges Bank food landings constituted 93 percent of all United States food landings (The remainder were caught primarily off Cape Cod.) and 86 percent of the overall total in the period 1963 to 1969. Almost all of the industrial fishery was located on the southern New England ground.

The total landings have dropped since the peak year of 1963. Effort continued upward to a peak in 1966, but decreased in 1967. Landings per day have decreased from the peak in 1963, showed some recovery in 1967, but dropped again in 1969. Estimates of abundance based on trawl survey cruise data for the year 1963 to 1969 corroborate the trends observed in the landings per day (Table IA).

The landings per day of 2-year-olds is given in Figure 5 for southern New England and in Figure 6 for Georges Bank. This index of the fish just entering the fishery dropped in 1968 on both grounds. However, the index for southern New England has been decreasing since 1965, while for Georges Bank, the index increased sharply in 1967. The trawl survey data allows the examination of catch per tow for fish of the I+ age group in the summer and autumn before they enter the fishery at age two the following year, a lead time of 6 to 12 months. This is evidence to suggest less than average entering year classes in 1969 and 1970.

In the yellowtail flounder food fishery, fish too small to be processed are discarded. Thus the catch as well as the landings need consideration. The figures for total catch are presented in Figure 7 and Table I. Discard as a percent of the food fish landings has ranged from 18 to 54 percent since 1963 (Table II). The lowest figure was in 1969. The average weight per fish in the discards was estimated to be 270 gms, while the average in the food landings in 1969 was 495 gms.

The industrial fish landings of yellowtail have increased recently (Figure 7 and Table I). This has been primarily a result of an increasing percentage of yellowtail flounder in the industrial catch (Table III). The average size of yellowtail in our 1969 samples of the industrial catch was 210 gms, even smaller than that of the discard.

The catch of yellowtail flounder in subarea 5 by countries other than the United States was estimated by applying the proportion of yellowtail flounder to overall flounder landings where species were known to the landings classified just as flounders. The non-United States catch was still less than 10 percent of the total catch (Table I) in 1968. However, it increased greatly in 1967 and 1968 over previous levels. Preliminary figures for 1969 indicate 19,300 M.T. were landed by nations other than the United States, 70 percent of a reported 27,600 M.T. of mixed flounders.

Length and age composition

Scale samples from fish in the food landings have been taken since 1960 for assessment of age composition. Lux (1969) has presented the age composition in number landed per day from 1960 to 1965. In Table IV those values are repeated along with the age composition for 1966 through 1968. For comparative purposes the percentage age composition in the landings for the years 1943-47 estimated by Royce et al. (1959) is given in Figure 8.

Changes in year class strength are evident. Yet in all cases the fishery is dependent on 2, 3, and 4-year-old fish. Even strong year classes are not heavy contributors beyond the latter age. The food landings between 1960 and 1969 consisted of an average of 89 percent in these age groups from southern New England and 87 percent from Georges Bank.

If the estimated numbers per day of the discard are added to the age composition of the landings a shift of the predominant age from 3 years to 2 is the result (Table V). Samples to estimate the amount of discard have been collected since 1963, but only in 1963 were scale samples for aging available. The amount of discard in 1960, 1961 and 1962 was estimated from the average of the percent discard from 1963 to 1969. During 1961-62, an average of 92 percent of the catch from southern New England and 88 percent from Georges Bank consisted of 2, 3, and 4-year-old fish.

The estimated length frequency distribution of the 1963 catch showing the discard is presented in Figure 9.

Assessment of the Stock

Virtual population study

Virtual population. Gulland's (1965) model of the virtual population estimate was used to study this fishery. This analysis was performed on the 1958 to 1961 year classes separately for the southern New England and Georges Bank grounds using the age compositions of the catch. Virtual population estimates are given in Table VI.

Estimate of Z. Estimates of total instantaneous mortality rates (Z) from these data are presented in Table VII.

The average values of Z for ages 4 to 7+ were 1.36 for southern New England and 1.26 for Georges Bank. If age 3 to 7+ are averaged for southern New England the value is 1.26. A Z of 1.26 corresponds to an annual survival rate of .28. The consistently lower mortality rate for Georges Bank may reflect the lesser fishing pressure on that area during the period that the age data were collected. However, the ratio of the mortality rate of southern New England and Georges Bank was less than the corresponding ratio for days fished. The effort on Georges Bank has been increasing and almost equaled that on the southern New England grounds in 1968, and surpassed it in 1969.

The low values for 2-year-old fish are undoubtedly a result of the fish being incompletely vulnerable to the gear. The greater catch (mainly discarded) of smaller fish on the southern New England ground results in a much higher estimate of Z at age 3 than the corresponding value from Georges Bank. Whether the different mortality rates of the younger fish reflect reality or are just an artifact of the virtual population estimate depends in part on how greatly the natural mortality rate varies with age.

The mortality rates estimated from the virtual population are considerably greater than those estimated by Lux (1969), from catch curve survival ratios for the period 1960 through 1965 using the same age composition data from the New England landings. The geometric mean of these ratios for the southern New England grounds was .36 and for Georges Bank, .37, for fish in age groups 4 through 7. These give an instantaneous mortality rate (Z) of 1.02. The corresponding value estimated by Lux (1969) for the data given by Royce et al. (1959) for fish ages 4 to 6 on the southern New England ground was 0.78 per the period 1943 to 1947.

Estimate of F. Gulland (1965) proposed estimating F at each age by the following equation:

$$E_{x\,n} = \frac{F_{t\,n}}{F_{t\,n} + M} \left(1 - e^{-(F_{t\,n} + M)}\right) + \left(e^{-(F_{t\,n} + M)}\right) \cdot {}_{x}E_{n+1}$$

where, F = instantaneous rate of fishing mortality,

M = instantaneous rate of natural mortality,

$E = \frac{F}{F+M}$, rate of exploitations,

x = year class,

n = year,

and t = age.

If a value for M and a value for E at the upper age of the fish being exploited are assumed, the above equation can be solved successively to obtain estimates of F for each year class for every year in the fishery. This procedure was applied to the 1958 through 1961 year classes for M ranging from .1 to .3 and for E at age 7+ of .8 and .9.

These values for F are presented in Table VIII for an M of .2 and an E at age 7+ of .8 separately for Georges Bank and for the southern New England grounds. The higher values of F, for the southern New England grounds probably reflect the greater fishing effort in that area in the early 1960's. The average F for ages 4 through 6 was 1.15 for southern New England and .96 for Georges Bank. The higher value at age 3 (.79 versus .43) for southern New England probably also reflects their earlier age of recruitment.

Estimates of E. The assumption of a low natural mortality rate combined with a high total mortality rate implies a high rate of exploitation or E value. Gulland's (1965) procedure allows estimates of E to be refined. These values are presented in Table IX for ages from 2 through 6. These were computed on a basis of M of .2 and an E for fish of 7+ of .8. The values of E are slightly higher for fish on the southern New England grounds. The average values of E for ages 4 through 6+ were .83 for Georges and .84 for southern New England.

Population size. Using the E, F, and M values discussed previously with the virtual population values an estimate of the total population can be made as follows:

$$Pm_{(ik)} = VP_{(i,k)}/[(1-e^{-Z(i,k)}) \cdot E_{(i,k)}]$$

where Pm = population number,
VP = virtual population (=catch),
i = year class,
k = age, and
Z = virtual population estimate of F +0.2.

These values are presented in Table X. The overall average for the 1958-61 year classes is 230, 637 x 10^3 fish age 2 years and older. These year classes supported the fishery during the first half of the 1960's when very heavy catches were made on the southern New England grounds. There was little industrial catch during these years but discard amounts were large.

Analysis of Tagging Studies

Fishing Mortality Rate. Several tagging studies were conducted between 1957 and 1959 to determine the degree of interchange between yellowtail flounder stocks (Lux, 1963). Three lots had enough releases to enable an analysis of fishing mortality to be made (Table XI).

These data were fitted to the model of tag returns described by Gulland (1963) and Fink (1965). This model is:

$$R_t = cqfKTe^{-Z't}$$

where R_t = the number of recaptures per unit time,
c = proportion of recaptured tags that are reported,
q = instantaneous rate of fishing per standard days fished,
f = number of standard days fished in time period t,
K = proportion of tagged fish surviving initial tagging mortality,
T = number of fish tagged,
e = 2.71828,
Z' = instantaneous rate of loss of fish to the tagged population, and
t = time since tagging.

The actual equation solved was:

$$\ln \left(\frac{Rt}{cfKt} \right) = \ln q - Z't.$$

To solve this equation it was necessary to assume various values of c and k as these were not known. The proportion of recaptured tags reported is believed to be quite high as a $1.00 reward was paid, and port agents of the U.S. Bureau of Commercial Fisheries were actively interviewing vessels' captains in the ports.

Measures of fishing effort were not available on any finer time basis than one month. When fractions of a month were used, at the initial period after tagging, effort was prorated on a basis of equal effort each day of the month. As time from tagging increased it was necessary to consider periods longer than a month in order to have recaptured tags in each period. A standard day fished, as described by Lux (1964), was used as the measure of effort.

This tagging model assumes that the instantaneous rate of fishing (q), the total loss of fish from the tagged populations and the proportion of tags reported are constant throughout the time of study. It is conceivable that this did not occur. The most likely period for a difference would be the initial period after tagging. Therefore, regression lines were fitted to these data using all points and then sequentially eliminating the first and second point.

The results of these calculations are presented in Table XI. The value for F was computed by multiplying q times the days fished during the entire period and then dividing by the appropriate time factor to convert this to a yearly value. These values are difficult to interpret. The values of Z' appear reasonable when compared with the values of Z discussed in the previous section. On the 1957 tagged fish, high initial losses and/or poor tag reporting would have to be assumed in order for the fishing rate to be as high as indicated in previous results.

A considerable change in fishing effort occurred during the period of this study. The number of standard days fished on Georges Bank was 821 in 1957 and 1816 in 1961. On the southern New England grounds the value in 1957 was 2396, in 1959 it was 4904, and in 1961 it was 4686. This increase in effort may well have caused an increasing Z' during this period of this study and thus hampered the correct fitting of the tag return model.

The most reasonable estimates of q from these data are judged by the author to be the last one given under for each lot of tagged fish. The overall average of these values is $.3249 \times 10^{-3}$.

If this value is multiplied times the days fished for southern New England and Georges Bank, (Table XII), the F values seem unreasonably high in recent years. It is possible that q has decreased with the increasing effort and that it may be different for the two areas. The measure of standard days fished may be biased, because only boats with 50 percent yellowtail landings were used. In all cases, however, the level of F since the late 1950's on the southern New England grounds and the mid-1960's on Georges Bank has been very high.

Evaluation of Effects of Fishing

Yield-per-Recruit

The Beverton and Holt (1957) yield model was applied to the yellowtail flounder. The values of growth rate K (-.335), arbitrary age at origin of growth, t_o (-.26) and asymptotic length, L_{∞} used were those from the Von Bertalanfy growth equation fitted by Lux and Nichy (1969). The value of W_{∞} (1.2 Kg) was estimated from L_{∞} using the length weight relationship given by Lux (1969).

A series of computations using the Beverton and Holt model were made for M varying from .2 to .3 with increments of .05. For each M, F was varied from 0.5 to 1.6 by increments of .05 and for each F, the age at entry to the exploited phase was varied from 1.75 to 3.00 years by increments of .25.

For all combinations of M and F the maximum yield occurred at an age of entry of 3.00. The average length of yellowtail flounder at this age is 33 cm.

The yield isopleth for M = .2 is shown in Table XIII. At this level of M the maximum yield per recruit is obtained from an F of .75 - .8. This is a 20 to 40 percent reduction in effort below the present level. If the present age of entry is assumed to be 2 years and the level of F set at 1.0, then raising the age at entry to 3 and reducing F to .8 results in a 26 percent gain. If the present F is 1.1 the gain would be 28 percent, if F is 1.2, 31 percent and if F is 1.3, 33 percent. The corresponding gains from a reduction in effort alone would be 4, 6, 8, and 9 percent. The actual percentage gain in landings would be greater than the above values which are figures for catch, because of the greater proportion of discards in the present situation compared with what would be expected if effort were reduced and age at entry level increased.

Determination of Maximum Yield

Shaefer (1954 and 1957) has proposed a logistic model of fishing relating fishing effort to catch. This model was applied to the southern New England and Georges Bank stocks to estimate the maximum sustainable yield. Landings per day in M.T. were plotted against a moving average of 3 of days fished (Figures 10 and 12) and the linear regression,

$X = a(b-\bar{u})$

where X = effort in standard days fished,

$\bar{u}$ = landings per day, and

a&b = constants,

estimated for the recent years in these fisheries. This can be converted to a curve for equilibrium catch, $Ce = a(b-\bar{u})\bar{u}$.

The major effect on yield is variation in recruitment. Recruitment is assumed to be higher in the past decade than in the 1950's. For this reason only the recent points from 1961 for southern New England and from 1963 for Georges Bank were considered when estimating the equations. Unfortunately, good measures of recruitment are not available. The maximum estimated equilibrium yield in landings for southern New England was 12,400 M.T. and with an effort between 3,250 and 4,000 standard days fished. The corresponding values for Georges Bank were 10,900 M.T. with 3,250 standard days fished. This is a reduction of 15 percent below the average level of fishing pressure for the last three years for southern New England and 23 percent for Georges Bank. The amount of landings have exceeded these figures seven times for southern New England and six times for Georges Bank since 1943. The effort exceeded these values 15 and 6 times respectively. However, the effort corresponding to maximum equilibrium catch has been consistently exceeded in the last few years.

Simulated Ricker Model

Ricker (1958) outlined a yield model to study changes in mortality rates. His procedure was followed in this study to estimate the number of fish that would be caught in each of the six years following a change in the fishing rate. At the end of six years the fishery would be stabilized at the new rate. This procedure was applied separately to the southern New England grounds and to Georges Bank. The size of the entering year class of 2-year-olds was taken as the average of the values for the year classes estimated by the virtual population estimates. The Z and F values used to compute the initial population size and catch are given in Table XIV and were adopted from the virtual populations estimate. The fishing mortality coefficient was reduced to 0.8 (a 30 percent reduction for southern New England and 20 percent for Georges Bank) for the fish age 4 and older and correspondingly reduced for the younger ages. These values and their accompanying Z's are also given in Table XIV. The weight of the catch was computed by multiplying the average weight at each age times the number caught. The average weights were computed from the overall length-weight equations given by Lux (1969) and lengths at age were estimated from the Von Bertalanfy equations given by Lux and Nichy (1969) (Table XV).

The changes in weight of catch (yield per recruit) are given in Table XVI. On the southern New England grounds there is an immediate loss of 19.7 percent that is recovered in the following year and a substantial gain of 9.0 percent is achieved in the third year. Almost all of the eventual gain of 29.8 percent is achieved in the fourth year after the decrease in F.

On Georges Bank the long term gain is only 5.4 percent after an initial loss of 16 percent. However, at the present levels of fishing Georges Bank values may be more comparable to southern New England. The percentage gain in landing- would be greater than the values for the catch because of the decreasing contribution to the catch of the smaller fish which are discarded.

Effects of Changes in Mesh Size

Hennemuth and Lux (Res.Doc.70/86) have analyzed mesh selection data for yellowtail flounder. They concluded that discards would be reduced 27 percent by weight by a 129 mm mesh and 51 percent by a 145 mm mesh when compared with the present 114 mm mesh. The resulting immediate losses to the fishery would be 4 and 21 percent respectively with the corresponding long-term gains being 10 and 17 percent. The gains predicted from the use of a larger mesh size corroborates the results given earlier of the analyses of the yield per recruit.

Effects of Reduction of Fishing Effort on Yield

The estimate of current population size can be made from recent catch data. If the 1968[1] catch in weight (Table I) is converted to numbers by dividing the United States food fishery plus the non-United States catch by the average size of food fish (495 gms) and added to the discard weight divided by 273 gms (the average weight of discard) and to the industrial landings divided by 209 gms (the average weight in that fishery), the resulting value is 115,827 x 10^3 fish. To obtain an estimate of population size a rate of fishing (F) must be assumed. For a first trial value of F, I chose 1.1. This is the value for the southern New England fishery estimated from the virtual population model for age groups 3+ and older. The increasing fishery on Georges Bank since that time would indicate a similar level for that area. The greater industrial catch has increased the rate applying to 2 and 3-year-olds. The mean population size,

$$\bar{P} = \frac{\text{catch}}{F}.$$

The estimate of mean population size is 105,297 x 10^3. If an F value of 1.15 is assumed, then the resulting estimate is 100,719 x 10^3 fish. The estimated population at the start of each year is equal to the catch/($E \cdot 1\text{-}e^{-Z}$). If E is 0.8 and Z is 1.38 the estimated population is 181,266. This is less than the average strength of the 1958 to 1961 year classes estimated from Gulland's (1965) virtual population procedure. Part of the difference is undoubtedly caused by assuming a constant F as opposed to the variable F used in the virtual population estimate. A smaller F for the younger aged fish would result in a higher estimate of population size.

The values estimated for the 1968 population size can be utilized to estimate the effect of a reduction in fishing rate (F) to 0.8, the optimum value from the yield per recruit model, on the actual yield. Using a mean population size computed from an F of 1.1 of 105,297 x 10^3 fish weighing an average of 387 gms (the product of these two values is the weight of the 1968 catch) then the catch with an F of 0.8 would be 32,600 M.T. If the population size computed from an F of 1.15 is used then the catch would be 31,200 M.T. with landings of 25,100 M.T.

Conclusions and Management Recommendations

All indications are that the yellowtail flounder stocks are being exploited at a level greater than that which will result in a maximum sustainable yield. There is no indication of strong entering year classes which would sustain this high level of effort. In addition, trends point towards continued increasing effort which could be disastrous to the fishery, and if combined with poor recruitment could spell disaster. The reliance primarily on two year classes for spawning means that if there is any stock-recruitment relationship, heavy fishing on poor year classes could cause a virtual disappearance of the commercial fishery. On the other hand predictions are that if the fishery was regulated with a mesh regulation and a quota, it is quite possible that the build-up of the spawning stock would occur which would result in greater stability in the fishery from spreading the harvest more evenly over several year classes, an improvement in the landings because of reduced discard as a result of harvesting more older fish, and a greater likelihood of more stronger year classes resulting from the larger spawning stocks.

To manage for an F reduced to 0.8 it is necessary to determine a quota that would effect this change. In addition, the quota should be compatible with the maximum equilibrium estimated from the Shaefer model. The latter estimates a value for landings of 12,400 M.T. for southern New England and 10,900 M.T. for Georges Bank. A small additional amount should be added to account for minor fisheries outside these two areas such as the grounds off Cape Cod. In addition, although the quota must be set in terms of landings, it is the total catch including discard which is important.

The predicted catch with an F of 0.8 is between 31,200 and 32,600 M.T. A landings quota that would achieve this catch would be between 25,100 and 26,000 M.T. depending on the population base used.

[1] Values of 1969 catch were not available at the time these calculations were made.

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Table I.--Yellowtail flounder removals in metric tons $X10^{-3}$.

	SUBAREA 5					
	U.S. Landings					
Year	Food	Industrial	Discards from food fish	Total U.S.	Estimated Foreign & Unspecified	Total
1963	35.1	0.3	12.4	47.8	0.3	48.1
1964	35.7	0.4	10.9	47.0	1.0	48.0
1965	36.2	1.0	10.0	47.2	1.6	48.8
1966	28.1	2.4	13.1	43.6	0.7	44.3
1967	20.8	4.5	11.3	36.6	2.4	39.0
1968	28.6	3.9	8.8	41.3	3.6	44.9
1969	28.7	4.3	5.1	38.0	19.3	57.3

Table IA. Numbers of fish caught per tow by Albatross IV in autumn surveys of Subarea 5Z

Year	Total all ages	Age-group I	Age-groups II+
1963	36.0	13.3	22.7
1964	33.1	8.1	25.0
1965	28.2	11.6	16.6
1966	31.2	17.8	13.4
1967	41.1	11.4	29.7
1968	40.6	9.3	31.3
1969	37.7	4.3	33.4

Table II.--Yellowtail flounder discard as a percent of food landings.

Year	Southern New England Grounds	Georges Bank	Total
1963	24.6	51.5	35.2
1964	50.0	33.4	30.4
1965	38.2	30.1	27.5
1966	35.8	18.6	46.8
1967	71.5	66.2	54.2
1968	44.1	28.4	30.6
1969	21.1	16.2	17.7
Average	40.7	34.9	34.6

Table III.--Percentage of Yellowtail flounder in the industrial fishing landings.

Year	Percent
1963	1.2
1964	1.6
1965	2.9
1966	8.7
1967	12.0
1968	11.2
1969	16.0

Table IV .--Numbers of yellowtail flounder landed per day.

Year	Age 1	2	3	4	5	6	7+
			Southern New England Ground				
1960	6	3199	927	859	623	88	34
1961	-	2279	4998	536	345	172	40
1962	-	1385	5436	1492	172	48	25
1963	5	1145	5051	3067	593	77	21
1964	6	1501	2045	2397	1603	229	31
1965	-	1650	2743	1180	953	437	74
1966	-	1092	2027	861	318	236	78
1967	-	1262	3480	914	153	54	61
1968	-	798	3868	2050	128	31	13
			Georges Bank				
1960	-	1425	1260	593	428	37	20
1961	-	1430	4491	732	351	199	110
1962	-	1264	3444	1245	334	164	92
1963	-	579	3176	1754	549	102	57
1964	-	490	2514	3497	754	153	81
1965	1	548	2433	1403	1098	269	93
1966	-	434	1795	837	475	226	62
1967	-	1563	1616	941	299	138	64
1968	-	1356	3323	916	279	115	60

TABLE V.--Numbers of Yellowtail flounder caught per day.
(landings plus discard)

Year	Age 1	2	3	4	5	6	7+
			Southern New England Ground				
1960	103	4708	1546	918	623	88	34
1961	143	4327	5830	606	345	172	40
1962	190	4639	6530	1577	172	48	25
1963	168	3560	4938	3154	593	77	21
1964	316	6005	3915	2570	1603	229	31
1965	196	4465	3911	1282	953	437	74
1966	115	2877	2776	1000	318	236	77
1967	276	5208	5092	1044	153	54	61
1968	218	3875	5014	2085	128	31	13
			Georges Bank				
1960	152	3610	2168	674	428	37	20
1961	159	3723	5471	818	351	199	110
1962	227	4542	507	1388	334	164	92
1963	400	6313	1388	1960	549	102	57
1964	234	3840	3867	3560	754	153	81
1965	161	4188	3375	1479	1098	269	93
1966	62	1319	2156	864	475	226	62
1967	255	5228	3138	1618	299	138	64
1968	144	3412	4147	978	279	115	60

Table VI. --Virtual population estimate of yellowtail flounder in numbers X10^{-3} .

Year Class	2	3	4	5	6	7+	Total
Southern New England Grounds							
1958	58,284	37,568	10,168	3,861	1,632	465	111,513
1959	74,860	54,523	28,404	11,374	3,157	535	147,253
1960	66,043	47,488	20,823	7,718	2,010	305	144,387
1961	49,505	30,281	10,315	2,621	3,150	660	96,538
Average	51,023	42,465	17,487	6,393	2,487	491	124,921
Georges Bank							
1958	22,517	15,297	5,449	2,227	952	420	46,862
1959	16,732	10,037	8,864	4,161	1,543	337	41,674
1960	33,028	22,581	19,249	6,432	1,504	224	81,668
1961	39,209	24,057	10,137	3,483	794	277	77,957
Average	27,871	17,993	10,924	4,076	1,198	314	62,040

Table VII.--Estimates of total instantaneous mortality ratio (Z) for yellowtail flounder.

Year class	2-3	3-4	4-5	5-6	6-7
Southern New England Ground					
1958	0.44	1.30	0.97	0.86	1.26
1959	0.32	0.65	0.92	1.28	1.77
1960	0.33	0.82	0.99	1.34	1.88
1961	0.49	1.07	1.37	2.12	1.56
Average	0.40	0.96	1.06	1.40	1.62
Georges Bank					
1958	0.38	1.03	0.88	0.87	0.82
1959	0.51	0.12	0.76	0.99	1.52
1960	0.38	0.16	1.00	1.45	1.90
1961	0.49	0.86	1.07	1.48	1.05
Average	0.44	0.54	0.95	1.20	1.32

Table VIII.--Estimates of instantaneous rates of fishing from virtual population estimates.

Year Class	2-3	3-4	Age 4-5	5-6	6-7
Southern New England Grounds					
1958	0.35	1.06	0.78	0.69	1.03
1959	0.22	0.52	0.75	1.09	1.50
1960	0.24	0.66	0.84	1.17	1.59
1961	0.38	0.92	1.21	1.86	1.31
Average	0.30	0.79	0.90	1.20	1.36
Georges Bank					
1958	0.28	0.80	0.60	0.67	0.65
1959	0.34	0.08	0.61	0.82	1.27
1960	0.25	0.13	0.94	1.27	1.62
1961	0.38	0.71	0.90	1.22	0.84
Average	0.31	0.43	0.78	1.00	1.09

Table IX.--Virtual population estimate of exploitation ratio (E) for yellowtail flounder.

Year Class	2-3	3-4	4-5	5-6	6-7
	Southern New England Grounds Age				
1958	0.75	0.83	0.80	0.80	0.83
1959	0.68	0.77	0.81	0.85	0.87
1960	0.70	0.79	0.82	0.86	0.87
1961	0.76	0.84	0.87	0.90	0.85
Average	0.73	0.81	0.83	0.85	0.86
	Georges Bank				
1958	0.71	0.79	0.77	0.77	0.78
1959	0.65	0.66	0.78	0.82	0.85
1960	0.66	0.71	0.84	0.87	0.88
1961	0.74	0.80	0.83	0.85	0.80
Average	0.69	0.74	0.80	0.83	0.83

Table X.--Gulland's (1965) estimate of population numbers based on virtual population model using variable E and Z (numbers $X10^{-3}$).

Year Class	2	3	4	5	6	7+	Total
	Southern New England Grounds Age						
1958	65,537	46,170	12,683	4,750	1,995	3,207	134,340
1959	86,783	66,387	34,144	13,321	3,699	3,689	208,020
1960	74,008	58,356	24,544	8,909	2,343	2,103	170,260
1961	57,727	35,429	11,734	2,948	3,748	455	108,670
Average	71,014	51,586	20,776	7,482	2,103	2,363	155,322
	Georges Bank						
1958	26,638	19,730	7,089	2,930	1,192	2,896	60,474
1959	24,775	7,223	10,820	4,992	1,844	2,324	51,978
1960	43,943	16,622	22,486	7,384	1,744	1,545	93,725
1961	46,788	29,150	12,054	4,191	973	1,910	95,087
Average	35,536	18,181	13,112	4,874	1,443	2,169	75,316

Table XI.--Estimated mortality rates from tagging studies.

Fishing Grounds	Year of Tagging	Last Year in which tags were Recovered	Number of fish Tagged	C.k	Time Periods Used	q	F	Z
Georges Bank	1957	1961	430	1	all	$.1678 \times 10^{-3}$	0.31	1.27
				1	-1	$.1234 \times 10^{-3}$	0.23	1.14
				.5	all	$.3357 \times 10^{-3}$	0.62	1.27
				.5	-1	$.2469 \times 10^{-3}$	0.46	1.14
				.3	all	$.5595 \times 10^{-3}$	1.04	1.27
				.3	-1	$.4115 \times 10^{-3}$	0.76	1.14
So.New Eng.	1957	1961	447	1	all	$.2317 \times 10^{-4}$	0.09	1.41
				1	-1	$.1978 \times 10^{-4}$	0.08	1.35
				.3	all	$.7725 \times 10^{-4}$	0.32	1.41
				.3	-1	$.6593 \times 10^{-4}$	0.27	1.35
				.1	-1	$.1978 \times 10^{-3}$	0.81	1.35
So. New Eng.	1959	1962	2150	1	all	$.5722 \times 10^{-3}$	2.55	1.99
				1	-1	$.4569 \times 10^{-3}$	2.03	1.88
				1	-2	$.3655 \times 10^{-3}$	1.62	1.78

Table XII.--Estimates of instantaneous rates of fishing (F) from yellowtail flounder.

Year	Southern New England Ground	Georges Banks
1943	1.851	0.064
1944	1.364	0.064
1945	0.940	0.102
1946	1.179	0.064
1947	1.494	0.162
1948	1.624	0.367
1949	1.049	0.812
1950	1.017	0.529
1951	0.027	0.529
1952	0.789	0.529
1953	0.459	0.399
1954	0.389	0.454
1955	0.491	0.399
1956	0.757	0.269
1957	0.789	0.269
1958	1.202	0.454
1959	1.592	0.659
1960	1.439	0.659
1961	1.537	0.584
1962	1.309	0.142
1963	1.754	0.189
1964	1.666	1.178
1965	1.959	1.472
1966	1.349	1.851
1967	1.537	1.202
1968	1.608	1.264
1969	1.364	1.494

Table XIII.--Yield per 1000 recruits in kg as estimated from the Beverton and Holt yield mode.

Instantaneous Rate of Fishing (F)	Minimum age at first capture in years: 1.75	2.00	2.25	2.50	2.75	3.00
0.6	256	273	288	300	309	317
0.7	250	269	285	299	311	320
0.8	244	264	282	297	310	321
0.9	238	259	278	294	308	320
1.0	232	254	274	291	306	319
1.1	227	250	270	288	304	317
1.2	222	245	267	286	302	316
1.3	218	242	263	283	300	314
1.4	214	238	260	280	298	313
1.5	210	235	258	278	296	311

Table XIV.--Changes in population numbers and yield following a reduction in fishing rate (number x 10^{-3}).

Southern New England Ground

Age	Old Mortality Rates Z	Old Mortality Rates F	Population Number	Yield	New Mortality Rates Z	New Mortality Rates F	Population Number 6 Years later	Yield 6 Years Later
2			71,104				71,104	
	0.40	0.30		17,581	0.30	0.20		12,285
3			47,662				52,675	
	0.96	0.80		24,514	0.75	0.55		22,282
4			18,249				24,882	
	1.36	1.15		11,741	1.00	0.80		15,309
5			4,684				9,154	
	1.36	1.15		2,944	1.00	0.80		4,629
6			1,202				3,368	
	1.36	1.15		755	1.00	0.80		1,703
7+			308				1,239	
	1.36	1.15		194	1.00	0.80		626
Total			143,209	58,360			162,422	56,834

Georges Banks

Age	Old Mortality Rates Z	Old Mortality Rates F	Population Number	Yield	New Mortality Rates Z	New Mortality Rates F	Population Number 6 Years later	Yield 6 Years Later
2			35,536				35,336	
	.44	0.30		8,624	0.34	0.20		6,025
3			22,886				25,299	
	.54	0.40		7,074	0.49	0.30		6,104
4			13,337				16,292	
	1.16	0.96		7,577	1.00	0.80		8,238
5			4,181				5,994	
	1.16	0.96		2,375	1.00	0.80		3,031
6			1,311				2,205	
	1.16	0.96		745	1.00	0.80		1,115
7+			411				811	
	1.16	0.96		234	1.00	0.80		410
Total			77,662	26,629			85,937	24,959

Table XV.--Average weights at age for yellowtail flounder estimated from a Von Bertalanfy growth equation.

Age-Years	Weights in Grams
2	159
3	324
4	510
5	679
6	849
7	929
8	1006

Table XVI.--Yearly change in weight of catch following the reduction in fishing rate shown in Table XI.

Year from Change	Southern New England Grounds		Georges Bank	
	Weight M.T.	% Change	Weight M.T.	% Change
0	19,429	-	9,990	-
1	15,606	-19.7	8,388	-16.0
2	19,489	+ 0.3	9,319	- 6.7
3	21,181	9.0	9,967	- 0.2
4	24,931	28.3	10,366	3.8
5	25,170	29.3	10,498	5.1
6	25,223	29.8	10,534	5.4

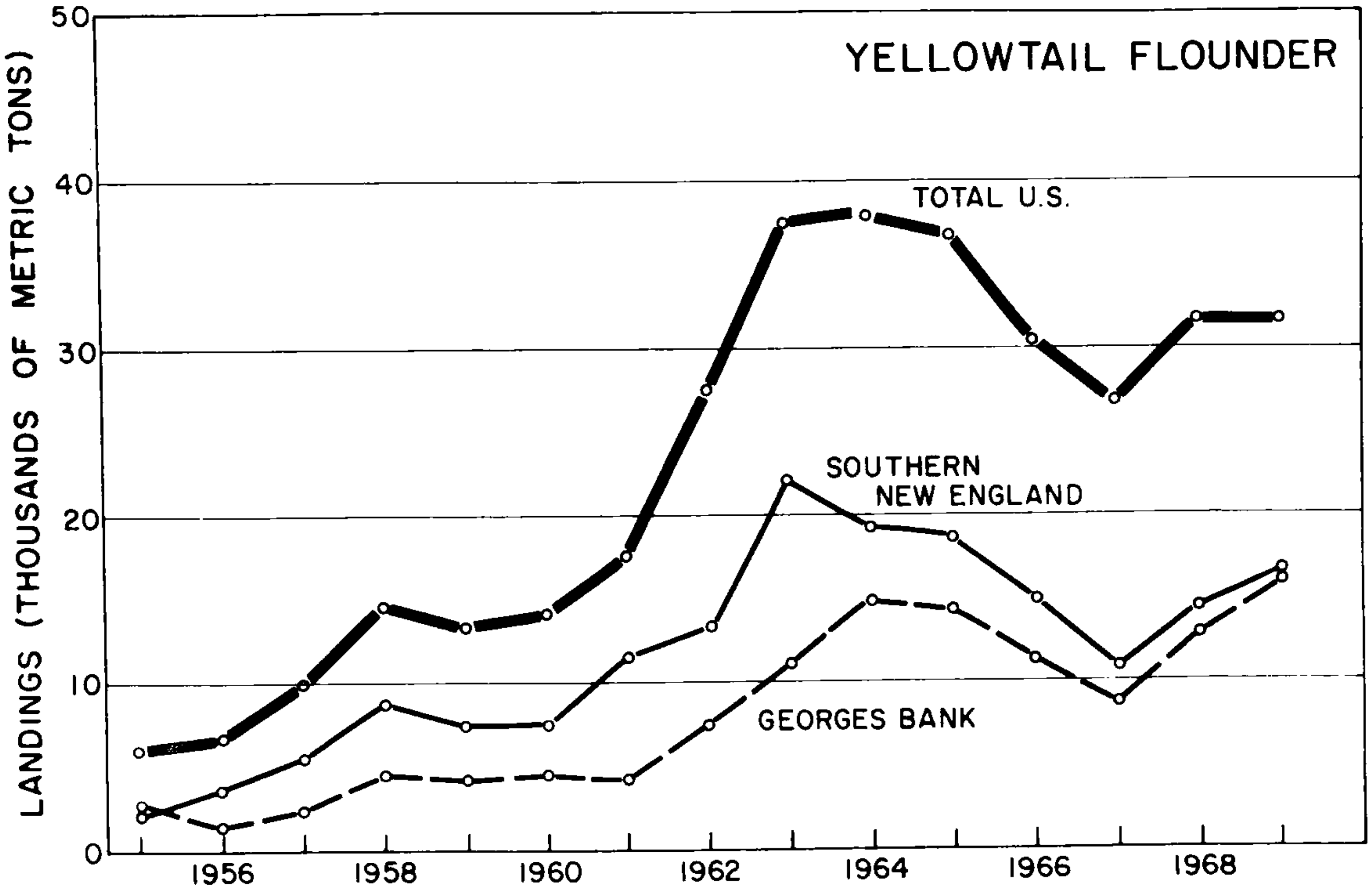

Fig. 1. United States yellowtail flounder landings.

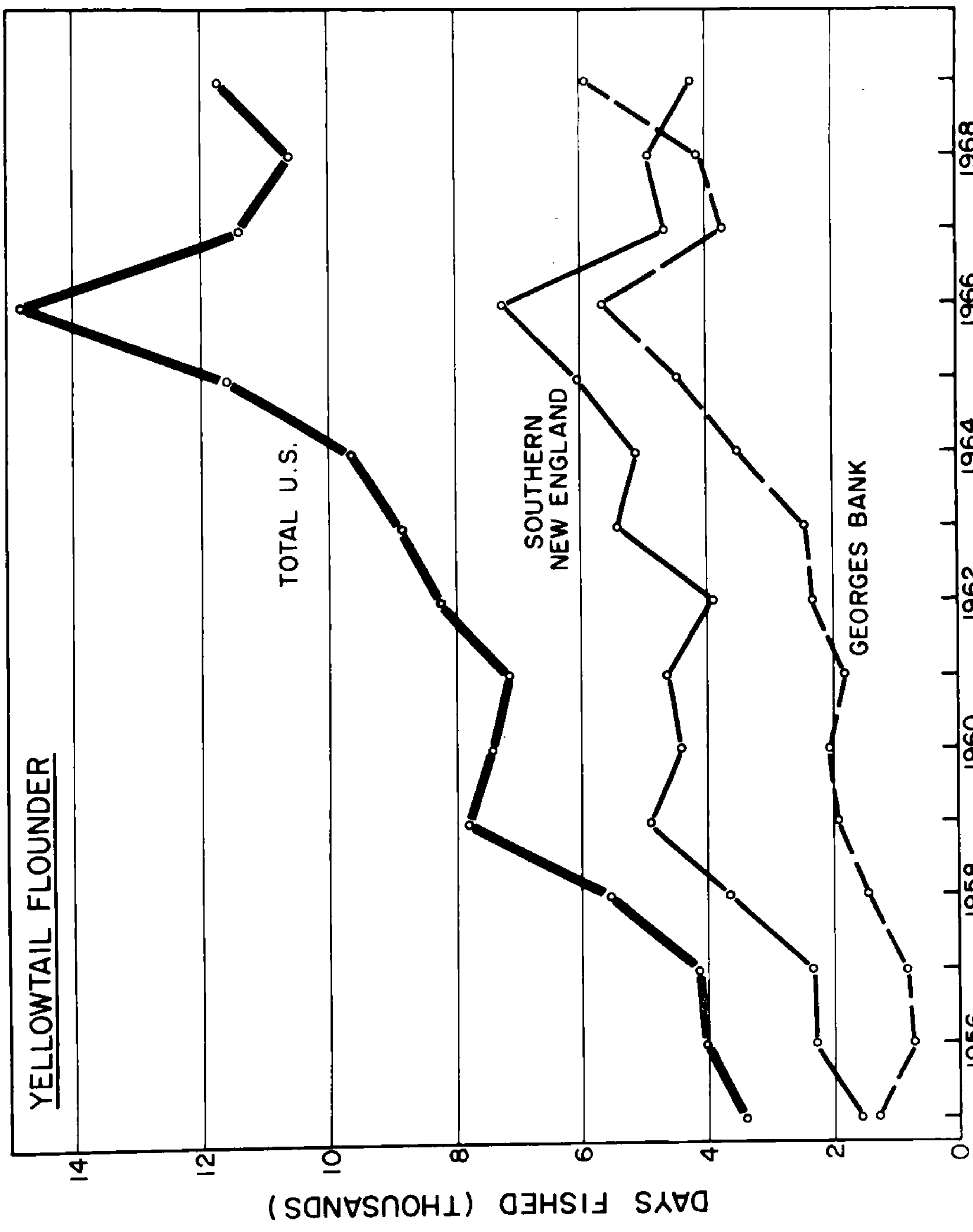

Fig. 2. United States fishing effort for yellowtail flounder.

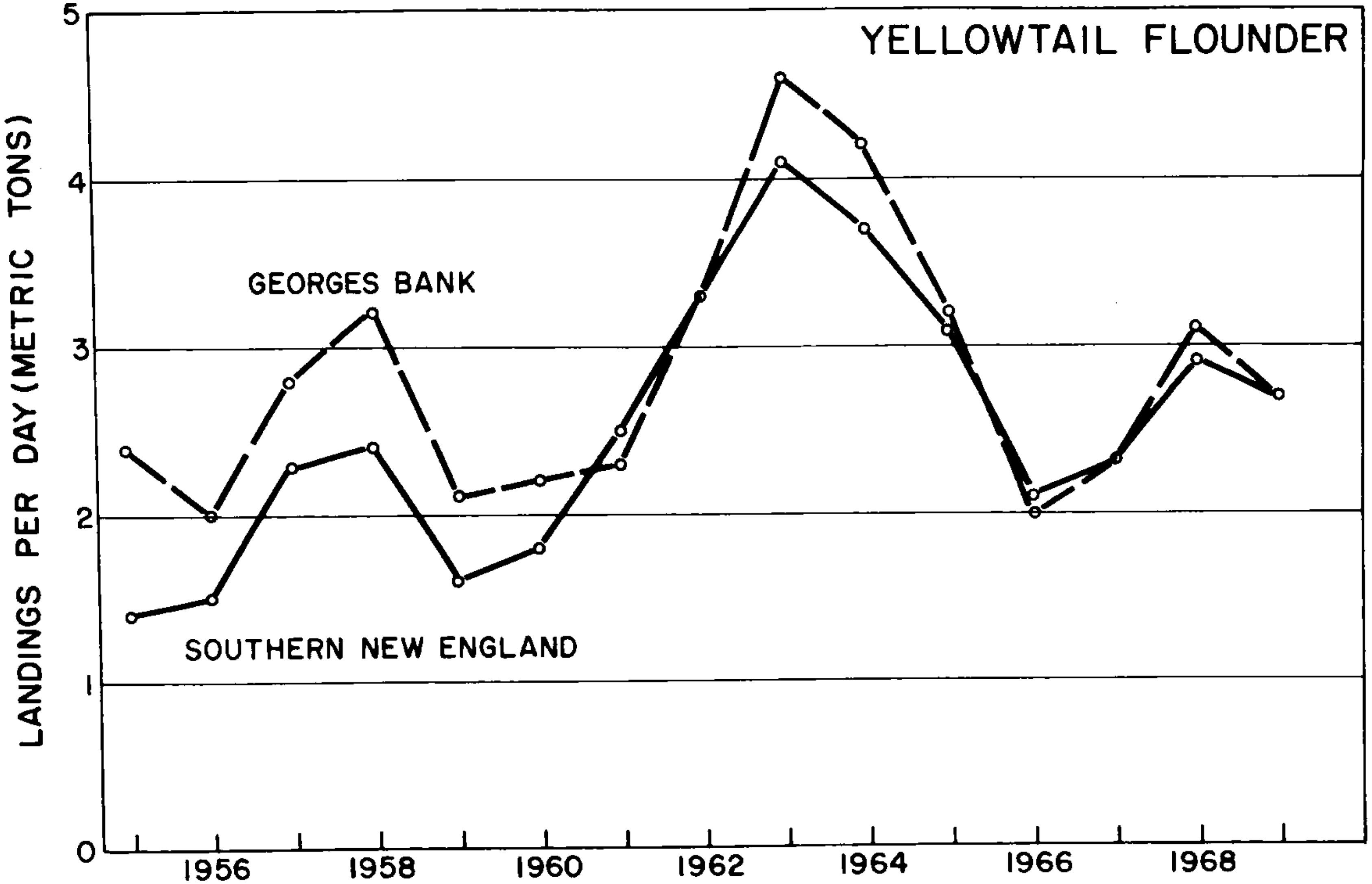

Figure 3.--Landings per day in the United States yellowtail flounder food fishery.

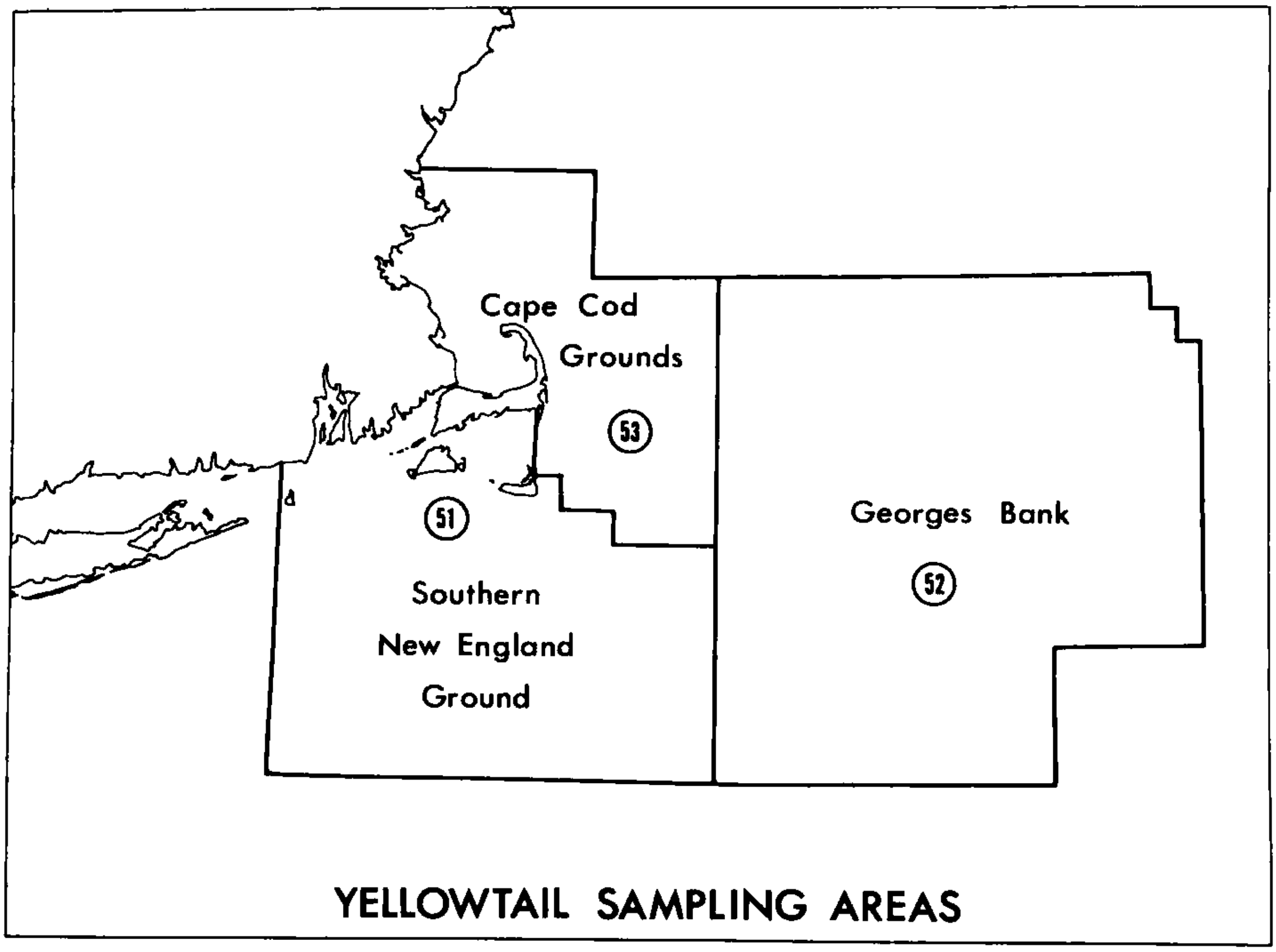

Figure 4.--Yellowtail flounder sampling areas.

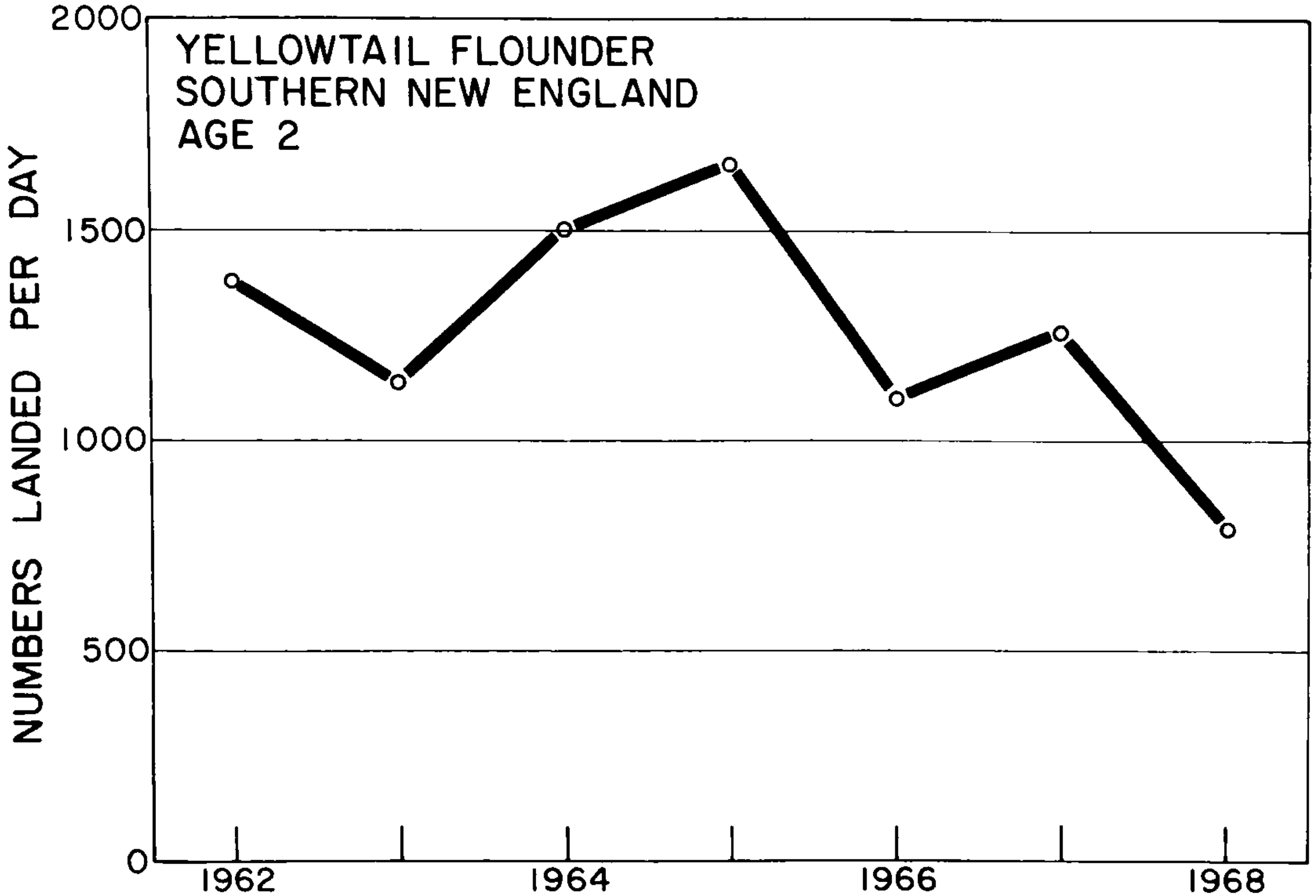

Figure 5.--Number of two-year-old yellowtail flounder landed per day in the food fishery from the southern New England ground.

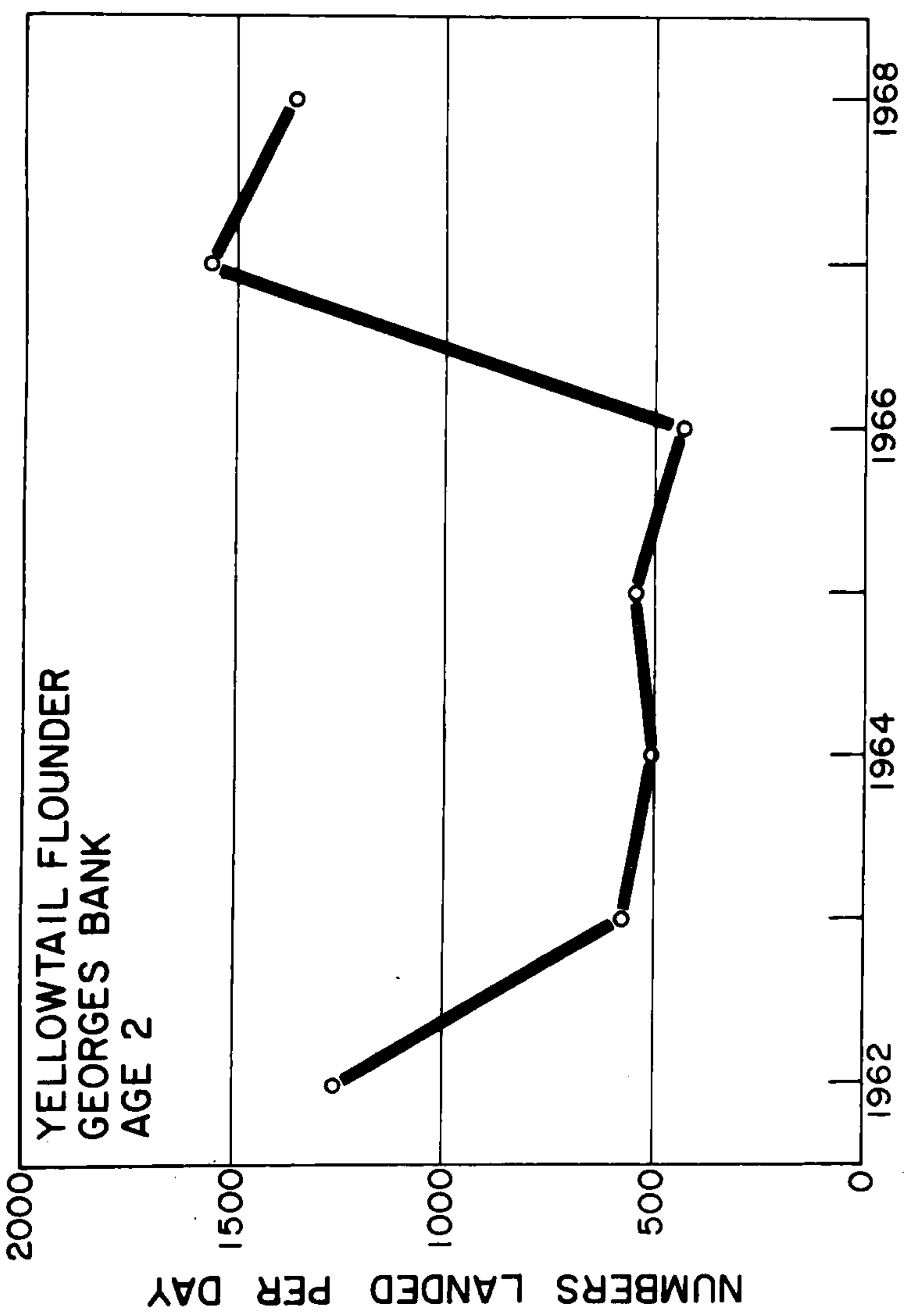

Figure 6.--Number of two-year-old yellowtail flounder landed per day in the food fishery from Georges Bank.

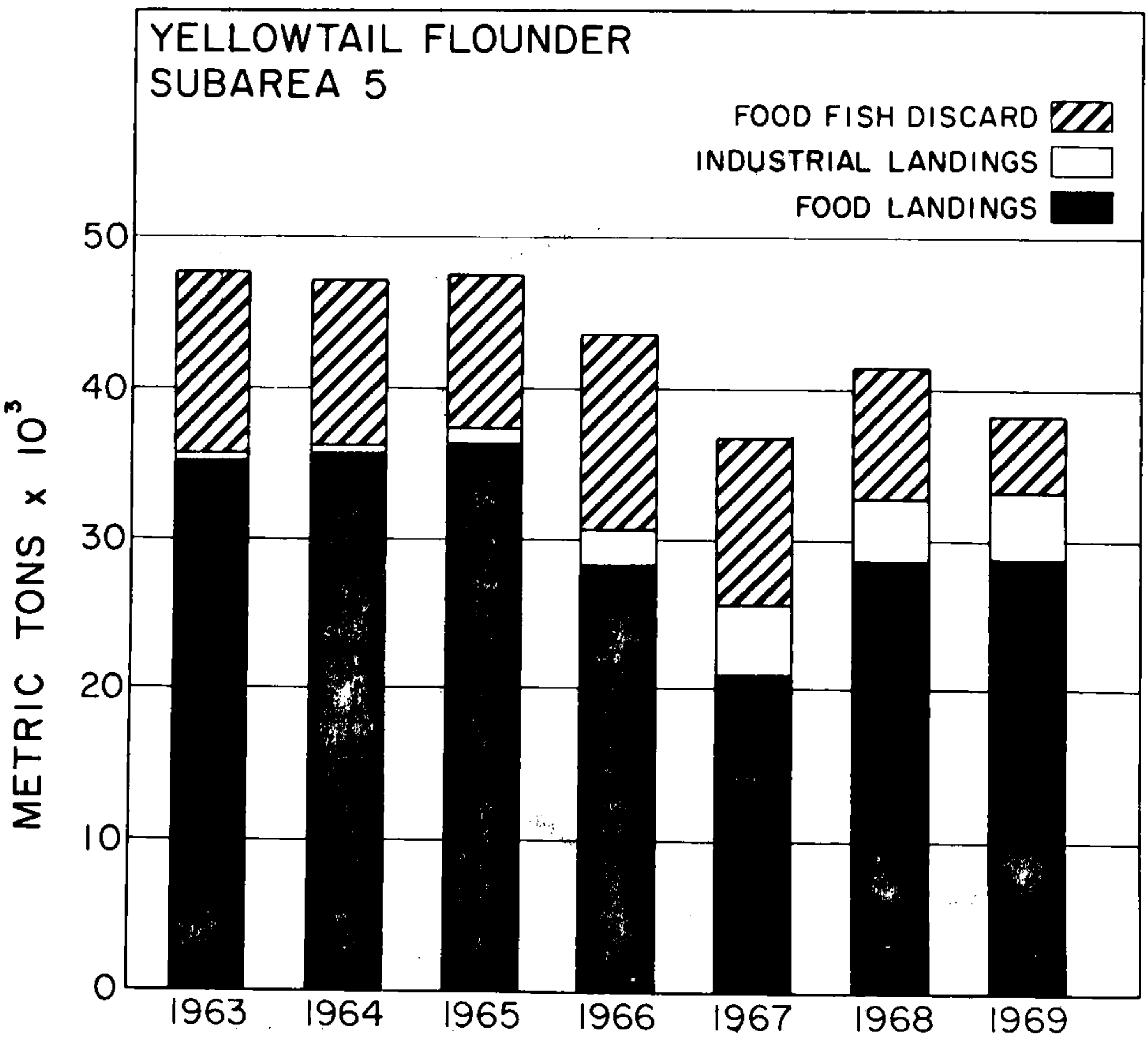

Figure 7.--United States yellowtail flounder catch.

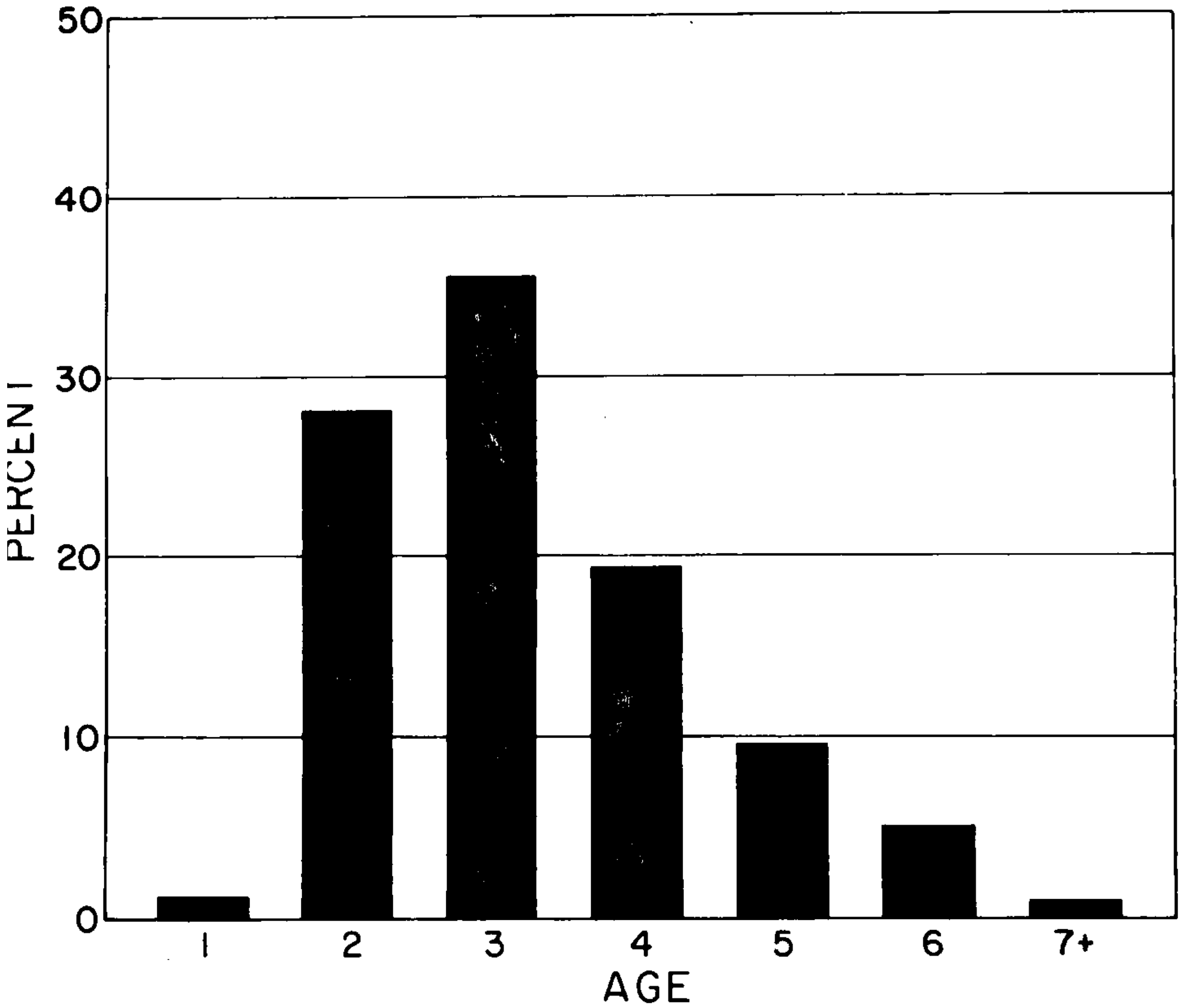

Figure 8.--Percentage age composition of 1943-1947 food landings of yellowtail flounder from the southern New England ground.

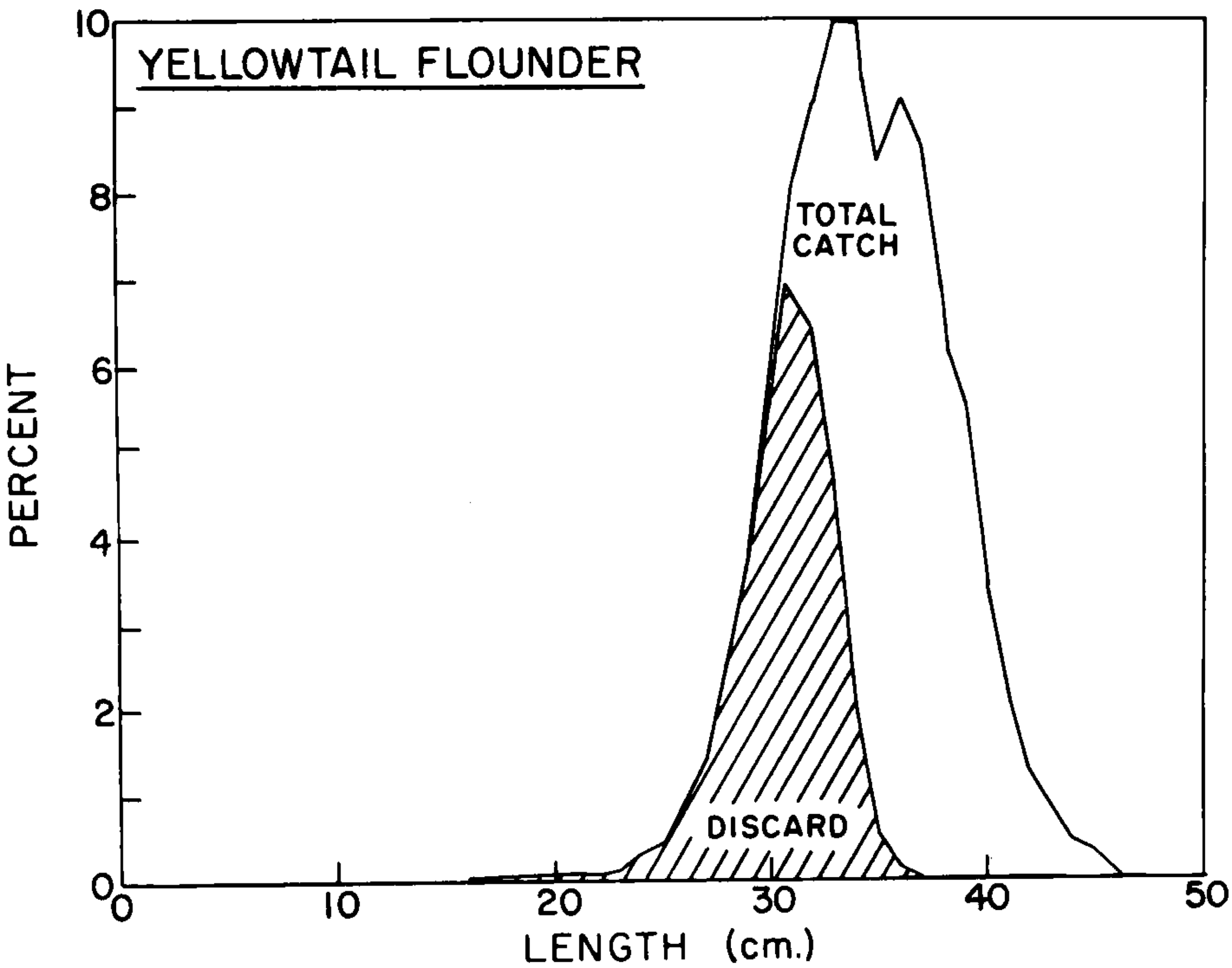

Figure 9.--Length frequency of yellowtail flounder 1963 food fishery catch showing discards.

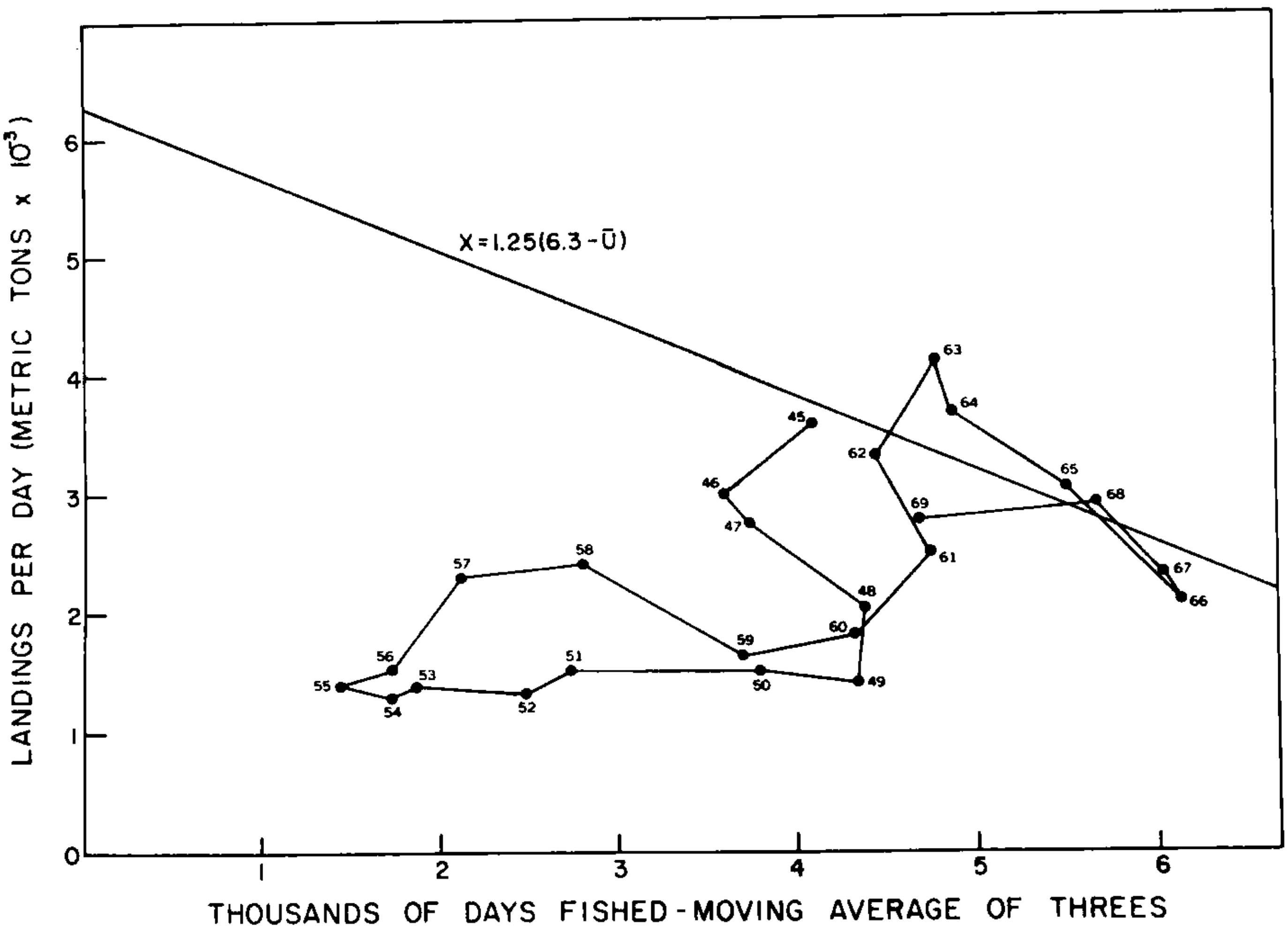

Figure 10.--Relationship between fishing effort and catch-per-effort for yellowtail flounder from the southern New England grounds.

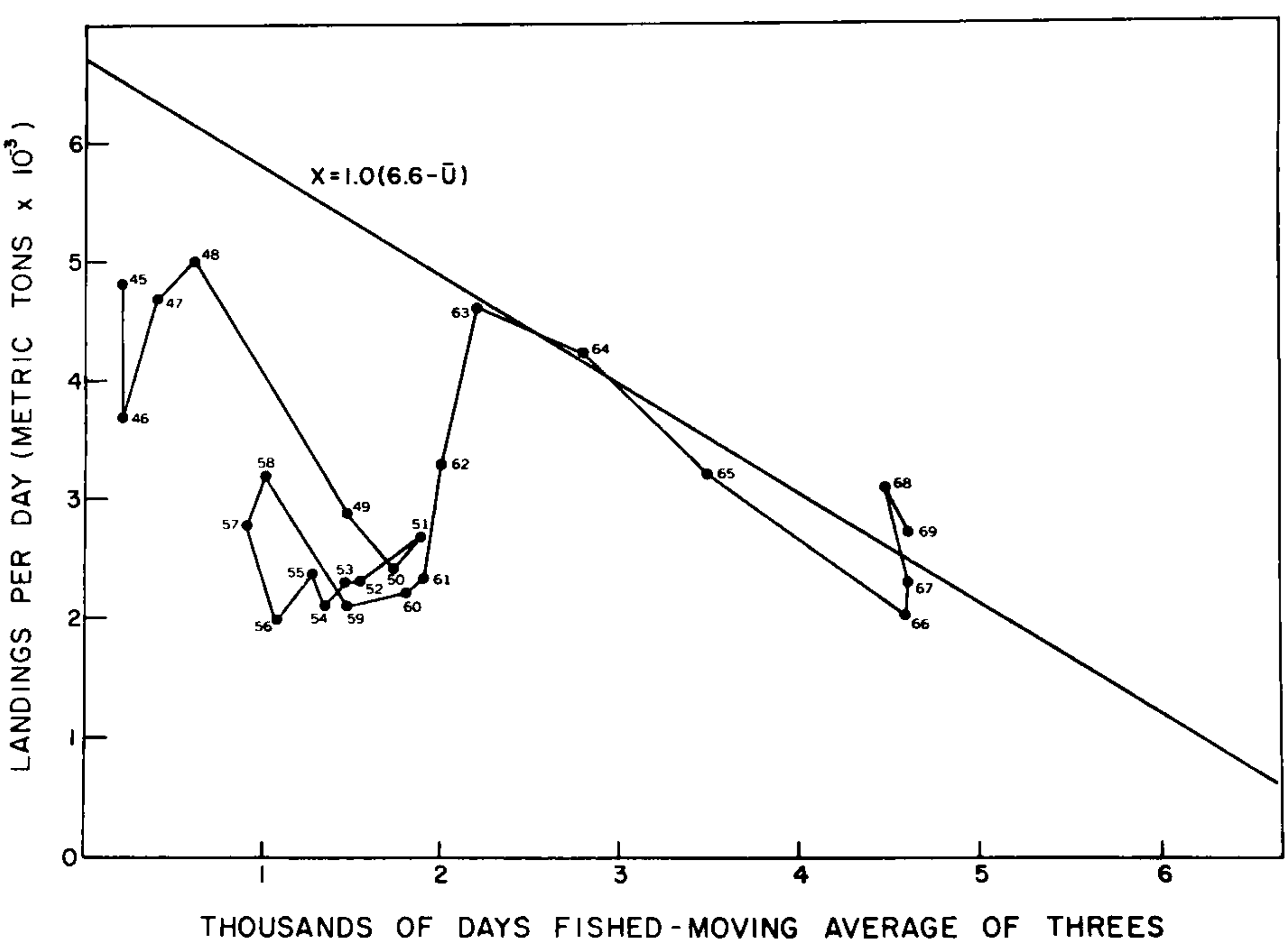

Figure 11.--Relationship between fishing effort and catch-per-effort for yellowtail flounder from Georges Bank.