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Assessment of the Yellowtail Flounder Fishery in Subarea 5

by

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ABSTRACT

During the 1960's the catch of yellowtail has been very high, ranging from 19,000 to 58,000 MT. Effort has increased even more rapidly resulting in a drop in the catch per day fished in recent years. Survey cruise data also indicates a current decrease in stocks. Length samples from the survey cruises and age frequency distribution of the commercial catch indicate a strong trend towards a narrow population structure. This situation is most critical for the Southern New England stocks.

Evidence from application of Beverton and Holt yield models, Ricker simulation model and a mesh selection study, all indicate that yield per recruit would increase with either a decrease in effort or an increase in age at first capture.

The evidence at hand indicates that the year classes which will enter the fishery in 1970 and 1971 are below average, and continuing the fishery at the current high level of fishing will result in severly reduced stocks. The generalized production models indicate maximum sustainable yields of 16,000 tons for Southern New England and from 9,000 to 18,000 tons for Georges Bank, with the lower range more probable. At the 1968 stock level, a fishery rate of 0.8

would yield 18,000 MT from Southern New England and 12,000 MT from Georges Bank. Quotas to reduce the effort thus should be in the range from 25,000 to 30,000 MT.

INTRODUCTION

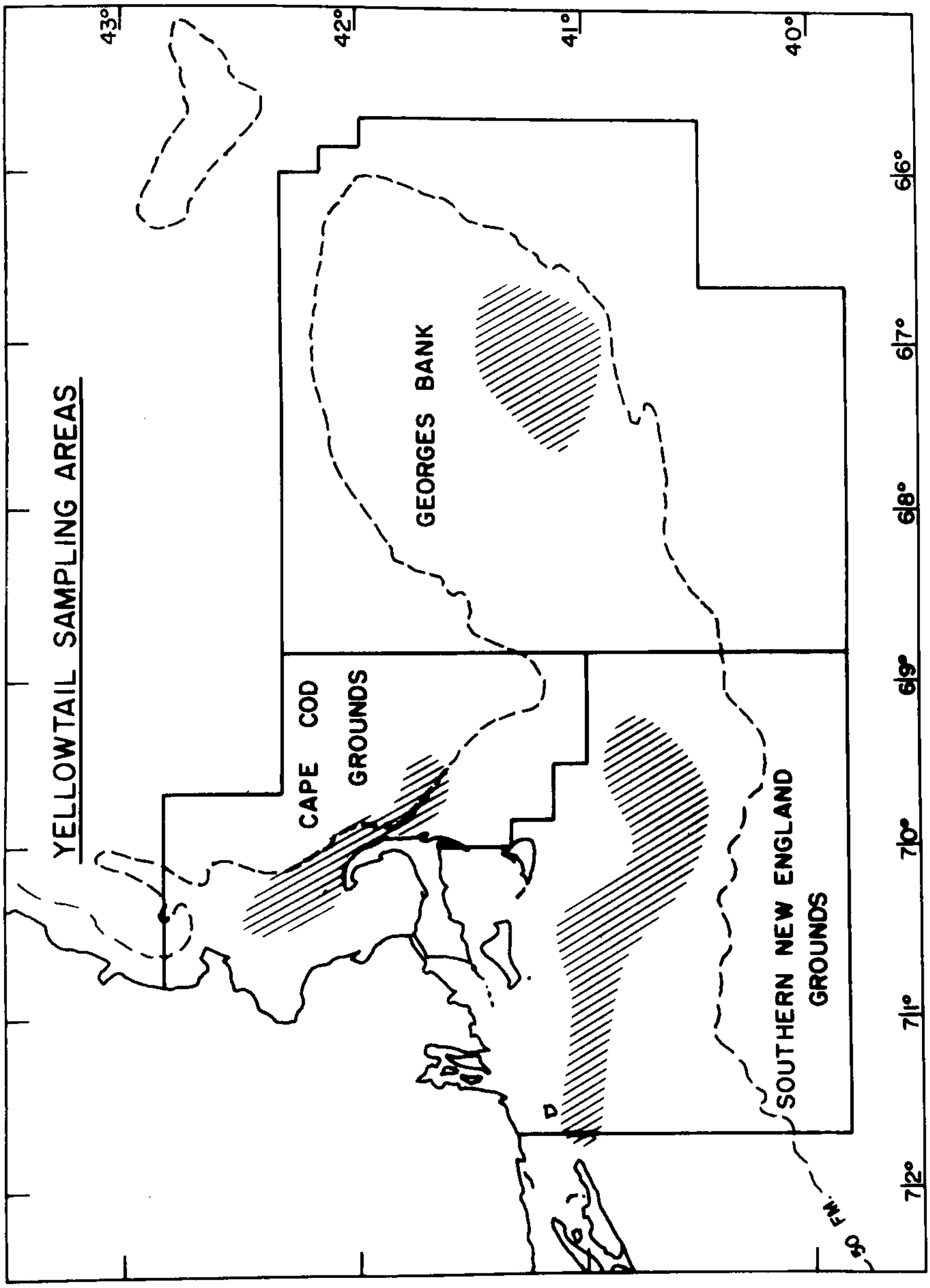
The yellowtail flounder (Limanda ferruginea) fishery in ICNAF Subarea 5 has been exploited since the late 1930's. In recent years fishing effort has increased. This document reports on attempts to determine the current level of fishing and its effects on the stocks. Estimates are presented of the optimum level of fishing in terms of yield and yield per recruit. Possible mesh regulations are reviewed and quota suggested.

REVIEW OF BIOLOGY

Spawning of yellowtail flounder in New England waters begins in March and extends through June. Peak spawning in Southern New England occurs in May. Males and females begin to mature at age 2 and by age 4 all fish are mature (Royce et al., 1959).

Studies by Royce et al. (1959) and Lux (1963) indicate there are two major populations in Subarea 5, one in the waters off Southern New England and the other on Georges Bank (Figure 1). The two stocks are roughly separated by the 69°W meridian. There is a small degree of inter-mixing of adults between these two groups; tagging studies indicate less than 5%. A third, much smaller group occupies the waters just off Cape Cod, but apparently does not interchange at all with the other two. Some fish exist in the northern Gulf of Maine but they are too few to support any fishery. The present study deals primarily with the two major stocks.

Figure 1.


YELLOWTAIL SAMPLING AREAS
GEORGES BANK
CAPE COD
GROUNDS
SOUTHERN NEW ENGLAND
GROUNDS
43°
42°
41°
40°
66°
67°
68°
69°
70°
71°
72°
50 FM.
D

17

Growth rates differ for the three areas (Lux and Nichy 1969). The Southern New England fish grow fastest for the first 2-1/2 years of age but after that, Georges Bank fish are largest per given age. Fish from the Cape Cod grounds grow slowest of all. However, the differences are not great enough to influence later calculations of yield, and a single combined growth curve has been used. Sexual difference in growth are apparent after age 3. A differential of about ten percent in length at age in favor of females is present from age 5 on. Females appear to live slightly longer than males. Beyond age 5 females greatly outnumber males. The former have been aged as old as 11+ and the latter as 9+. However very few yellowtail older than 7+ are captured. Growth rates determined from a Von Bertalanfy equation fitted to length at age data (Lux and Nichy 1969) are presented in Table 1. The equation is $l_t = 500 \; 1\text{-}e^{-0.335(t+0.26)}$, where l_t = length and t = age in years. Weights were estimated from the length weight equation given by Lux (1969): $\ln W = 12.96813 + 3.233 \ln L$, where W = weight in gm. and L = length in mm.

DESCRIPTION OF THE FISHERY

Harvest, Effort and Indices of Abundance

The United States yellowtail flounder fleet operates primarily out of the port of New Bedford, Massachusetts, but small amounts are landed at Provincetown, Massachusetts and Point Judith, Rhode Island. The fishing is conducted by otter trawlers ranging in size from 5 to 215 tons. Currently most of the food catch is landed by vessels 50 and 100 tons although in the past smaller vessels were more important. The smaller boats are limited to the inshore areas. Somewhat over 100 boats constituted the bulk of the fleet directing its effort primarily towards yellowtail flounder during the last five years or so.

Table 1.--Growth of yellowtail flounder estimated from a Von Bertalanfy growth equation.

Age-Years	Length in mm.	Weights in Grams	g*
2	265	159	0.71
3	330	324	0.45
4	380	510	0.29
5	415	679	0.19
6	440	812	0.12
7	455	915	0.09
8	470	1006	0.09

*g = instantaneous growth rate = $\log_e (W_{t+1}/W_t)$
where W = weight; t = age

Non-U.S. vessels began catching yellowtail in small amounts in 1963; catches have increased significantly in recent years. Most are caught by large (over 1800 gross ton) stern trawlers, fishing in the same general areas as the U.S. fleet (Table 2 and Figures 2 and 3).

Lux (1964) developed procedures for analyzing data of commercial landings and fishing effort in order to provide an index of apparent abundance based on landings per standardized days fished. He selected only those trips containing 50 percent or more of yellowtail flounder in the total landing. Days fished were standardized to the 26-50 gross ton class of vessel by first computing the ratio of annual mean landing per day of the larger and smaller classes to the standard class over the 1943-1961 period, and then multiplying each year the observed number of fishing days of the non-standard classes by this ratio. The total days fished for each year was estimated by dividing the total landings by the landings per standardized days-fished of the selected trips, the latter being used as the index of abundance. In the current stocks Lux's procedures have been followed except that catch per day (landings plus discard) were used rather than landings per day.

Table 2.--Yellowtail flounder catch statistics in Subarea 5

(catch in MT x 10^{-3}) - Southern New England

Year	Food landings	Discard	Indus-trial	Foreign	Total	Days fished in 1000's	Catch per day in MT
1935	6.0	2.4			8.4		
1936	6.8	2.7			9.5		
1937	7.6	3.0			10.6		
1938	7.7	3.1			10.8		
1939	9.5	3.8			13.3		
1940	14.2	5.7			19.9		
1941	19.3	7.7			27.0		
1942	28.4	9.9			38.3		
1943	18.0	7.3			25.3	5.75	4.4
1944	10.6	4.8			14.9	4.13	3.6
1945	10.4	4.2			14.6	2.86	5.1
1946	10.8	4.4			15.2	3.64	4.2
1947	12.1	4.9			17.0	4.59	3.7
1948	9.9	4.0			13.9	5.14	2.7
1949	4.7	1.9	0.2		6.8	3.40	2.0
1950	4.7	1.9	0.2		6.8	3.23	2.1
1951	2.8	1.1	0.1		4.0	2.00	2.0
1952	3.0	1.2	0.2		4.4	2.44	1.8
1953	2.0	0.8	0.3		3.1	1.63	1.9
1954	1.5	0.6	0.2		2.3	1.35	1.7
1955	2.2	0.9	0.3		3.4	1.70	2.0
1956	3.5	1.4	0.6		5.5	2.61	2.1
1957	5.5	2.2	0.7		8.4	2.62	3.2
1958	8.9	3.6	0.6		13.1	3.85	3.4
1959	7.7	3.1	0.5		11.3	5.13	2.2
1960	7.8	3.2	0.5		11.5	4.60	2.5
1961	11.6	4.7	0.7		17.0	4.85	3.5
1962	13.1	5.3	0.2		18.6	4.04	4.6
1963	22.0	5.4	0.3	0.2	27.9	5.47	5.1
1964	19.0	9.5	0.5	-	29.0	5.08	5.6
1965	18.9	7.0	1.0	1.4	27.8	6.61	4.2
1966	19.9	5.3	2.7	0.7	23.6	8.42	2.8
1967	10.8	7.7	4.5	2.8	25.8	6.51	4.0
1968	14.3	6.3	3.9	3.5	28.0	6.66	4.2
1969	11.4	2.4	4.2	17.6	35.6	10.78	3.3

Table 2.--Yellowtail flounder catch statistics in Subarea 5

(catch in MT x 10^{-3}) - Georges Bank

Year	Food landings	Discard	Industrial	Foreign	Total	Days fished in 1000's	Catch per day in MT
1935	0.3	0.1			0.4		
1936	0.3	0.1			0.4		
1937	0.3	0.1			0.4		
1938	0.3	0.1			0.4		
1939	0.4	0.1			0.5		
1940	0.6	0.2			0.8		
1941	0.9	0.3			1.2		
1942	1.6	0.5			2.1		
1943	1.3	0.4			1.7	0.20	8.6
1944	1.7	0.6			2.2	0.22	10.0
1945	1.4	0.5			1.9	0.28	6.7
1946	0.9	0.3			1.2	0.23	5.2
1947	2.3	0.8			3.1	0.48	6.5
1948	5.7	2.0			7.7	1.12	6.8
1949	7.3	2.5			9.8	2.49	3.9
1950	3.9	1.4			5.3	1.64	3.2
1951	4.3	1.5			5.8	1.61	3.6
1952	3.7	1.3			5.0	1.60	3.1
1953	2.9	1.0			3.9	1.24	3.1
1954	2.9	1.0			3.9	1.38	2.8
1955	2.9	1.0			3.9	1.23	3.2
1956	1.6	0.6			2.1	0.79	2.7
1957	2.3	0.8			3.1	0.82	3.8
1958	4.5	1.6			6.1	1.40	4.4
1959	4.1	1.4			5.5	1.97	2.8
1960	4.4	1.5			5.9	2.02	2.9
1961	4.2	1.5			5.7	1.82	3.1
1962	7.7	2.7			10.3	2.35	4.4
1963	11.0	5.6		0.1	16.7	3.63	4.6
1964	14.9	4.9		-	19.8	3.53	5.6
1965	14.2	4.2		0.8	19.2	4.68	4.1
1966	11.3	2.1		0.3	13.7	5.71	2.4
1967	8.4	5.5		1.4	15.3	4.13	3.7
1968	12.8	3.6		1.8	18.2	4.66	3.9
1969	15.9	2.6		2.4	20.9	6.71	3.1

Table 2.--Yellowtail flounder catch statistics in Subarea 5

(catch in MT x 10^{-3}) - Cape Cod Grounds

Year	Food landings	Discard	Indus-trial	Foreign	Total	Days fished in 1000's	Catch per day in MT
1935	0.4	0.1					
1936	0.4	0.1					
1937	0.5	0.2					
1938	0.5	0.2					
1939	0.6	0.2					
1940	0.9	0.3					
1941	1.3	0.4					
1942	1.5	0.5					
1943	1.3	0.4			1.7	0.53	3.2
1944	1.5	0.5			2.0	1.01	2.0
1945	1.2	0.4			1.6	0.61	2.6
1946	1.2	0.4			1.6	0.62	2.6
1947	1.1	0.3			1.4	0.75	1.9
1948	0.7	0.2			0.9	0.47	1.9
1949	1.2	0.4			1.6	0.68	2.4
1950	1.3	0.4			1.7	0.95	1.8
1951	0.8	0.2			1.0	0.79	1.3
1952	0.8	0.2			1.0	0.76	1.3
1953	0.8	0.2			1.0	0.78	1.3
1954	1.1	0.3			1.4	0.89	1.6
1955	1.3	0.4			1.7	1.00	1.7
1956	1.4	0.4			1.8	1.34	1.3
1957	2.4	0.7			3.1	1.44	2.2
1958	1.6	0.5			2.1	0.92	2.3
1959	1.5	0.5			2.0	0.76	2.6
1960	1.5	0.5			2.0	1.12	1.8
1961	1.8	0.6			2.4	0.91	2.6
1962	1.9	0.6			2.5	1.01	2.5
1963	3.6	1.0			4.6	1.00	4.6
1964	1.8	0.6			2.4	0.71	3.4
1965	1.5	0.5			2.0	0.70	2.8
1966	1.8	0.3			2.1	1.37	1.6
1967	1.5	0.8			2.3	1.69	1.4
1968	1.6	0.6			2.2	0.99	2.3
1969	1.3	0.3			1.6	0.68	2.5

Table 2.--Yellowtail flounder catch statistics in Subarea 5

(catch MT x 10^{-3})

Year	Food landings	Discard	Indus-trial	Foreign	Total	Days fished in 1000's	Catch per day in MT
1935	6.7	2.6			9.3		
1936	7.5	2.9			10.4		
1937	8.4	3.3			11.7		
1938	8.5	3.4			11.9		
1939	10.5	4.1			14.6		
1940	15.2	6.2			21.4		
1941	21.5	8.4			29.9		
1942	31.5	10.9			42.4		
1943	20.6	8.1			28.7	6.52	4.4
1944	12.8	11.9			24.7	5.36	4.6
1945	13.0	5.1			18.1	3.75	4.8
1946	12.9	5.1			18.0	4.49	4.0
1947	15.5	6.0			21.5	5.82	3.7
1948	16.3	6.2			22.5	6.73	3.3
1949	13.2	4.8	0.2		18.2	6.57	2.8
1950	9.9	3.7	0.2		13.8	6.32	2.2
1951	7.9	2.8	0.1		10.8	4.40	2.5
1952	7.5	2.7	0.2		10.4	4.83	2.2
1953	5.7	2.0	0.3		8.0	3.65	2.2
1954	5.5	1.9	0.2		7.6	3.62	2.1
1955	6.4	2.3	0.3		9.0	3.93	2.3
1956	6.5	2.4	0.6		9.5	4.74	2.0
1957	10.2	3.7	0.7		14.6	4.88	3.0
1958	15.0	5.7	0.6		21.3	6.17	3.5
1959	13.3	5.0	0.5		18.8	7.86	2.4
1960	13.7	5.2	0.5		19.4	7.74	2.5
1961	17.6	6.8	0.7		25.1	7.58	3.3
1962	22.7	8.6	0.2		31.5	7.40	4.3
1963	36.6	12.0	0.3	6.3	55.2	10.10	5.5
1964	35.7	15.0	0.5	-	51.2	9.32	5.0
1965	34.6	11.7	1.0	2.2	49.5	11.99	4.1
1966	28.0	7.7	2.7	1.0	39.4	15.50	2.5
1967	20.7	14.0	4.5	4.2	43.4	12.33	3.5
1968	28.7	10.5	3.9	5.3	48.4	12.31	3.9
1969	28.6	5.3	4.2	20.0	58.1	18.17	3.2

Figure 2.--Trends in the yellowtail fishery of Southern New England.

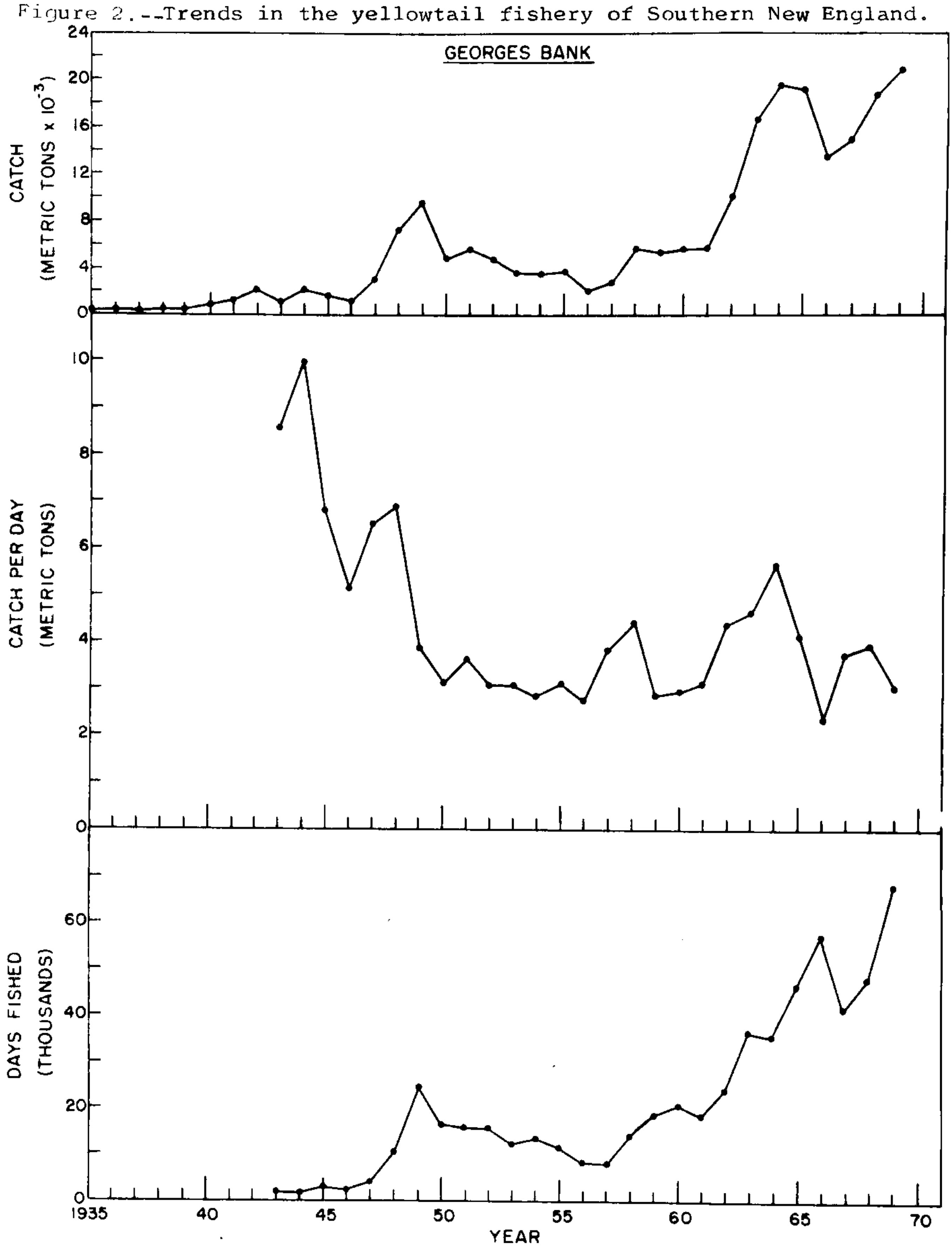
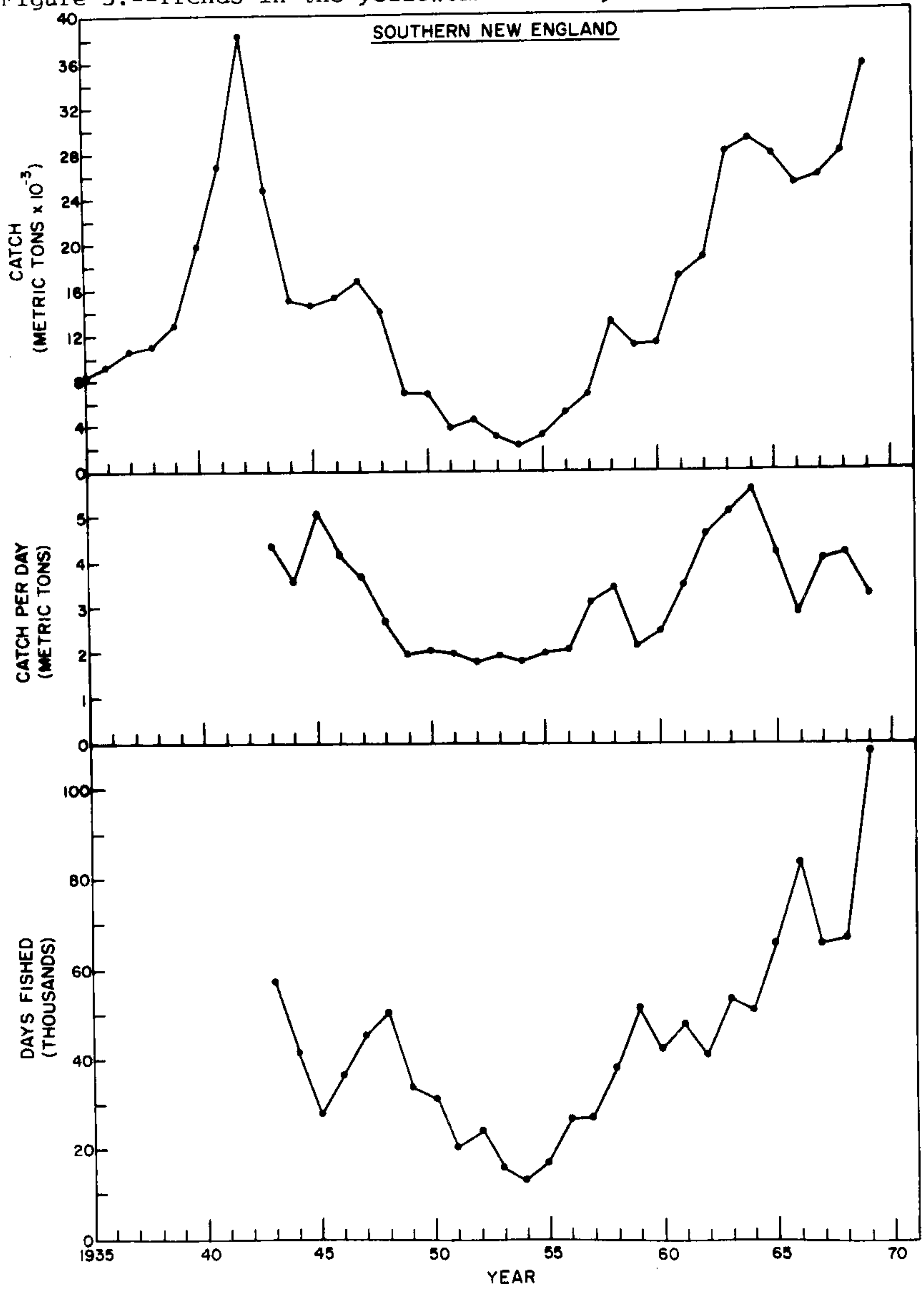


Figure 3.--Trends in the yellowtail fishery of Southern New England.



The landings which are used for food have been the major part of the total landings up to 1968. Small fish are discarded at sea before landing and records of discard were not available prior to 1963. Since then estimates of the amount of discards have been made based on information obtained from interviews with vessel captains. Discard has varied from 19 to 68 percent of the food fish landings during this period (Table 3). In 1963 length and age samples of retained and discarded portions of the catch were taken at sea aboard commercial trawlers (Figure 4). The average weight per fish in discards was 273 gm. compared to 495 gm. for the landed portion. The average percent discard relative to landings for 1963-1969 was used to calculate catch from the landings data prior to 1963 (Table 2).

The amount of yellowtail included in industrial fishery catches has increased in recent years (Table 2). This is primarily due to an increased percentage in the catches because total industrial catches have declined (Table 4). The length frequency of yellowtail in the industrial catch in 1969 is given in Figure 5. The average weight per fish was 209 gm., which is less than that in the discarded fish.

Table 3.--Yellowtail flounder discard as a percent of food landings.

Year	Southern New England Grounds	Georges Bank	Total
1963	24.5	50.9	32.8
1964	50.0	32.9	42.0
1965	38.0	29.6	33.3
1966	35.6	18.6	27.5
1967	71.2	65.5	67.6
1968	40.0	28.1	36.6
1969	21.0	16.4	1.85

Figure 4.--Length frequency of yellowtail flounder in the 1963 food fishery catch showing discards.

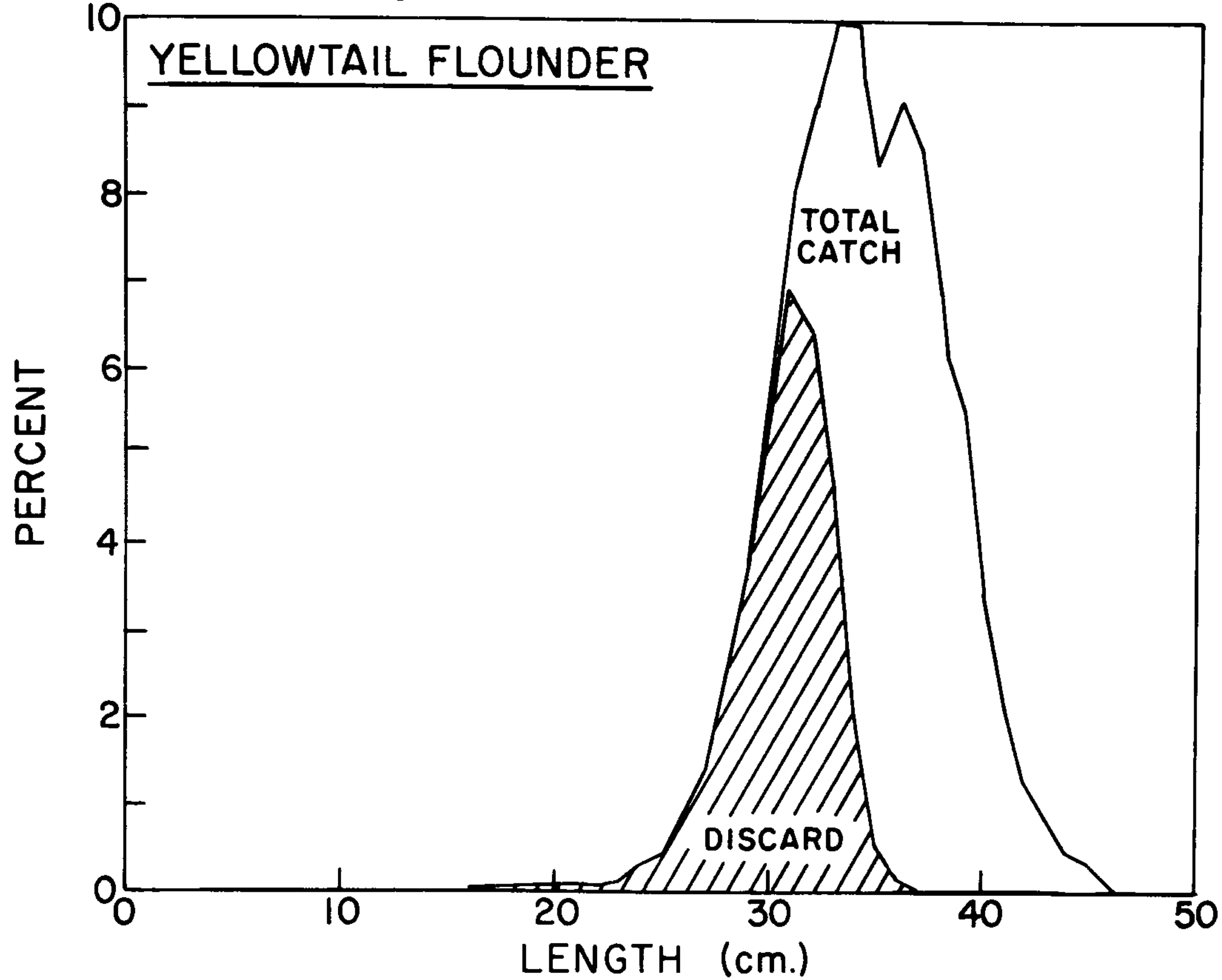
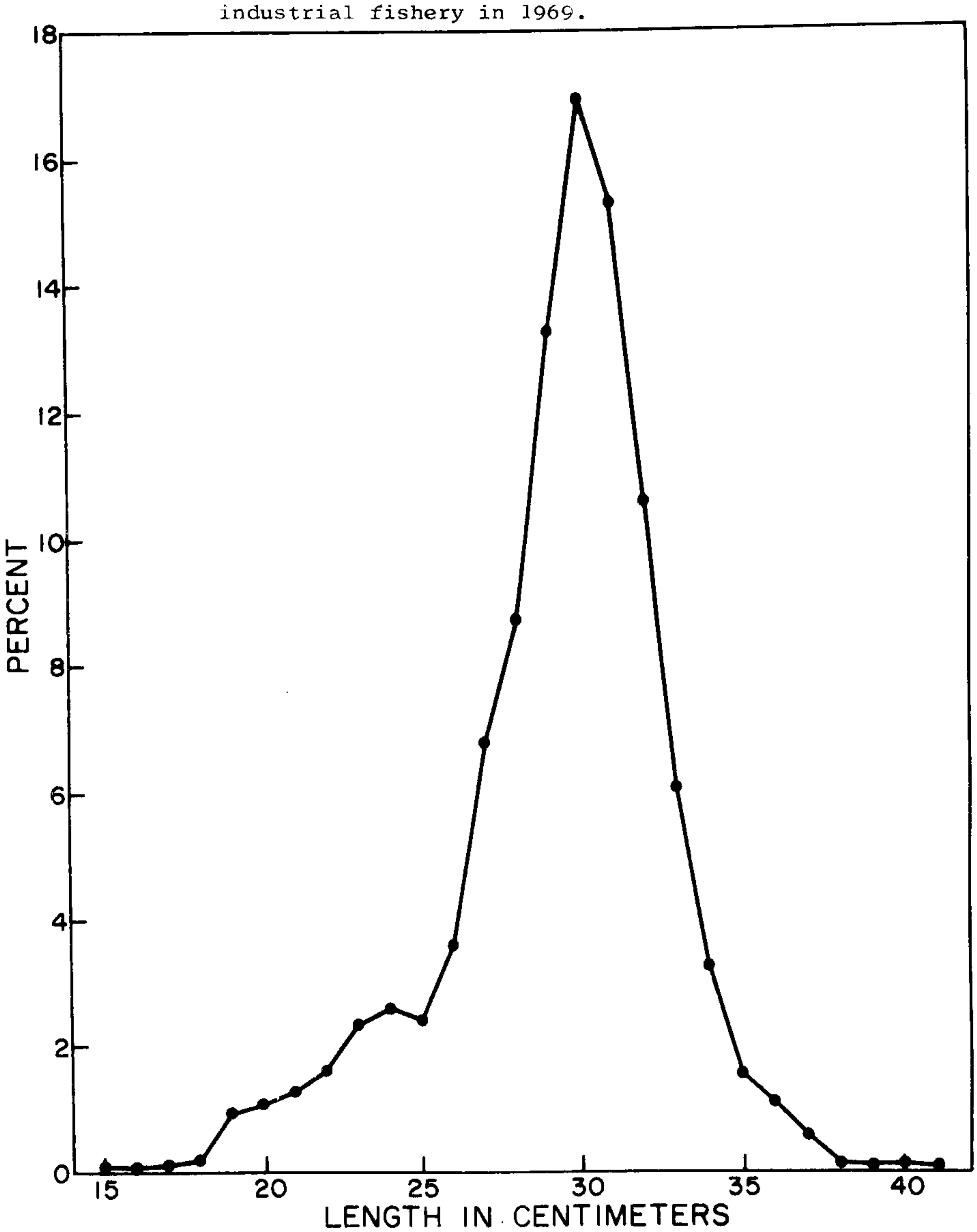


Table 4.--Percentage of yellowtail flounder in the industrial fishing landings.

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

Figure 5.--Length frequency of the yellowtail flounder in the industrial fishery in 1969.



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The industrial fishery uses a very small mesh size in the trawls - about 25 mm.

The total catch, effort and catch per unit effort is summarized in Table 2. The fishery in Southern New England started in the early 1930's. Catch peaked at 38,000 tons in 1942, decreased to a low of 2,300 tons in 1954 and since then has increased to 35,600 tons in 1969 (Figure 2). The 1969 catch contains an estimated 17,600 tons which was caught by foreign fisheries - chiefly the USSR. Effort data is not available prior to 1934. Catch per unit effort decreased markedly from 1943 to 1948, and remained low until 1959. The same trend was more or less true for fishing effort. Fishing effort has increased steadily and rapidly since the late 1950's. Catch per day increased during the 1960-64 period, but has decreased since then.

The fishery on Georges Bank was very small until 1948 when catches jumped to 7,700 tons. The catches peaked at 9,800 tons in 1949, declined again to 2,400 tons in 1956, and have increased since to a peak of 20,800 tons in 1969. Effort has followed a similar trend. Catch per day decreased from 1943 - the first year of effort data - to 1954. Since then it has increased and decreased three times, with the current trend downward.

The catch of yellowtail flounder in Subarea 5 by countries other than the U.S. was not reported separately from other flounders. It was estimated by assuming that the proportion of yellowtail flounder in the unspecified catch was the same as that in the specified landings of the U.S. The non-U.S. catch was still less than 10 percent of the total catch (Table 2) in 1968. However, it increased greatly in 1967 and 1968 over previous levels. Figures for 1969 indicate 20,300 MT were landed by nations other than the U.S. The distribution of foreign catch to areas prior to 1969 is based on the judgment of the authors.

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 5 those values are repeated along with the age composition for 1966 through 1968. For comparative purposes the age composition of fish in the landings from Southern New England for the years 1943-1947 estimated from data given by Royce et al. (1959) are also presented.

Table 5.--Numbers of yellowtail flounder landed per day.

	Age						
Year	1	2	3	4	5	6	7+
			Southern New England Ground				
1943-1947 Av*	83	1945	1456	1337	666	350	72
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
1969	-	624	2648	2647	624	78	25
			Georges Bank				
1960	-	1425	1260	593	428	37	20
1961	-	1430	1491	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
1969	-	507	2241	1412	420	127	91

* Calculated from Royce et al., 1959

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. Between 1960 and 1969 these age groups provided an average of 91 percent of the food fish landings from Southern New England and 88 percent from Georges Bank. The number caught per day fished may be estimated by adding the estimated numbers discarded per day, utilizing the 1963 age composition data (Table 6), to the numbers landed. During 1961-1969 an average of 92 percent of the catch per day from Southern New England and 90 percent from Georges Bank consisted of 2-, 3-, and 4-year old fish.

MEASURES OF MORTALITY RATES AND POPULATION NUMBERS

Virtual population

Gulland's (1965) model of the virtual population technique was used to estimate mortality and population size. This analysis was performed on the 1958 to 1962 year classes separately for the Southern New England and Georges Bank grounds using the age compositions of the catch. The virtual populations are given in Table 7.

Table 6.--Numbers of yellowtail flounder caught per day.

(landings plus discard)

Year	Age 1	2	3	4	5	6	7+
			Southern New England Ground				
1943-1947 Av*	262	4908	3664	1449	666	350	72
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	6409	3154	593	77	21
1964	316	6005	3915	2570	1603	229	31
1965	196	4465	2911	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
1969	97	2003	3217	2695	625	78	25
			Georges Bank				
1960	152	3610	2168	674	428	37	20
1961	159	3723	5471	818	351	199	110
1962	227	4542	4855	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
1969	76	1513	2689	1450	420	127	91

* Calculated from Royce et al., 1959

Table 7.--Virtual populations of yellowtail flounder in numbers X 10^{-3}

Year Class	AGE 2	3	4	5	6	7+
			Southern New England Ground			
1958	59254	38538	11138	4819	1613	440
1959	74908	54571	28445	11415	3192	567
1960	69867	53491	20826	7730	2006	299
1961	49474	30253	10299	2617	309	57
1962	61763	31130	7671	982	266	12
Average	63053	41597	15676	5513	1477	275
			Georges Bank			
1958	22529	15309	5461	2279	958	416
1959	26816	20115	8942	4236	1558	352
1960	43071	32620	19290	6446	1519	238
1961	39176	24201	10111	3454	765	249
1962	36058	22049	7051	2133	1019	541
Average	33530	22823	10171	3710	1164	359

Estimate of Z

Estimates of total instantaneous mortality coefficients (Z) from these data are presented in Table 8.

The average values of Z for ages 4 to 7 were 1.36 for Southern New England and 1.16 for Georges Bank. The average Z of ages 3 to 7 for Southern New England is 1.25. A Z of 1.25 corresponds to an annual survival rate of .29. The mortality rate for Georges Bank is lower for the older age groups than that for Southern New England and could reflect the lesser fishing pressure on that area during the period that the age data were collected.

The lower values for 2- and 3-year old fish are undoubtedly a result of the fish being incompletely vulnerable to the gear and to current fishing practices. However the actual accuracy and precision of these estimates could have been improved by a more adequate sampling procedure.

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 age composition data from the New England landings. The geometric mean of his ratios for the Southern New England ground was 0.36 and for Georges Bank 0.37, for fish in age group 4 through 7. These give an instantaneous mortality rate (Z) of 1.02. The corresponding value estimated by Lux (1969) for the period 1943 to 1947 using the data given by Royce et al. (1959) for fish ages 4 to 6 on the Southern New England ground was 0.78.

Table 8.--Estimates of total instantaneous mortality coefficient (Z) for yellowtail flounder.

	AGES				
Year class	2	3	4	5	6
		Southern New England Grounds			
1958	0.43	1.24	0.34	1.09	1.30
1959	0.32	0.65	0.91	1.27	1.73
1960	0.27	0.94	0.99	1.34	1.90
1961	0.49	1.07	1.37	2.14	1.69
1962	0.68	1.40	2.06	1.31	0.79
Average	0.44	0.86	1.23	1.43	1.48
		Georges Bank			
1958	0.39	1.03	0.87	0.87	0.83
1959	0.29	0.81	0.75	1.00	1.49
1960	0.28	0.52	1.10	1.44	1.85
1961	0.49	0.86	1.07	1.50	1.12
1962	0.68	1.40	2.06	1.31	0.79
Average	0.39	0.87	1.00	1.11	1.18

Estimates of Natural Mortality M

The magnitude of the natural mortality coefficient, M, may be inferred by comparing the change in estimates of Z with the corresponding change in effort, f, between two periods. This assumes that M and q, where F = qt, have not changed. If we let $Z = Z_2 - Z_1$, where the subscripts denote different time periods, and $k = F_2/F_1$, then $M = Z_1 - Z/(k-1)$.

Z_1 (0.78) has been taken from Royce et al. for the 1943-1947 period. Three estimates of Z_2 are available: Lux (1969) for the 1960-65 period (1.02); and the two derived in this paper for the 1960-68 (1.14) and 1960-69 (1.36) periods. The latter includes the heavy fishing of 1969.

The values of k have been determined for a range of M values for each of the three estimates of Z (Table 9). The ratio of f_2/f_1 may be taken as an estimate of k for the three sets of data outlined above, this ratio was 1.2, 1.4 and 1.5, respectively. Thus, by comparison to Table 9, the natural mortality coeficient is low, certainly less than 0.3.

Table 9.--Computation of M by comparison of periods with different fishing intensity.

M	F	K*	K**	K***
.7	.1	6.8	4.6	3.2
.6	.2	3.9	2.8	2.1
.5	.3	2.9	2.2	1.7
.4	.4	2.4	1.9	1.6
.3	.5	2.2	1.7	1.4
.2	.6	2.0	1.6	1.4
.1	.7	1.8	1.5	1.3
	.8	1.7	1.4	1.3
	.9	1.6	1.4	1.2
	1.0	1.6	1.4	1.2

Estimates of F

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

$$_xE_n = \frac{_tF_n}{_tF_n+M}\ (1-e^{-(_tF_n+M)})+(e^{-(_tF_n\ +M})\ _xE_{n+1}$$

where, F = instantaneous rate of fishing mortality,

M = instantaneous rate of natural mortality,

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

x = year class,

n = year,

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 by successive iterations over the age groups in the fishery to obtain estimates of F for each year class for every year in the fishery. This procedure was applied to the 1958 through 1962 year classes with an M of 0.1 and 0.2 and taking E at age 7+ equal to 0.8 and 0.9. The values differed only slightly (generally less than 10 percent) among the various combinations of parameters.

The values for F are presented in Table 10 for an M of 0.2 and an E at age 7+ of 0.8 separately for Georges Bank and for the Southern New England ground. The higher values of F, for the Southern New England ground probably reflect the greater fishing effort in that area in the early 1960's. The average F for ages 4 through 7 was 1.17 for Southern New England and 0.90 for Georges Bank. There is an indication that F increased during the 1960's.

Table 10.--Estimates of instantaneous rates of fishing from virtual population estimates.

Year Class	Age 2-3	3-4	4-5	5-6	6-7
			Southern New England Grounds		
1958	0.34	1.00	0.67	0.91	1.07
1959	0.22	0.52	0.75	1.10	1.46
1960	0.21	0.76	0.84	1.16	1.62
1961	0.38	0.92	1.20	1.90	1.41
1962	0.56	1.23	1.77	1.04	0.62
Average	0.34	0.69	1.05	1.22	1.24
			Georges Bank		
1958	0.28	0.80	0.67	0.68	0.65
1959	0.20	0.62	0.59	0.84	1.24
1960	0.19	0.41	0.92	1.26	1.56
1961	0.38	0.71	0.91	1.27	0.90
1962	0.38	0.92	0.92	0.56	0.50
Average	0.29	0.69	0.80	0.92	0.97

Estimates of E

The assumption of low natural mortality rate combined with a high total mortality rate implies a high rate of exploitation or E value. These values are presented in Table 11 for ages 2 through 6. These were computed on a basis of M = 0.2 and E for fish of age 7-8 = 0.8. The values of E are slightly higher for fish on the Southern New England ground. The average values of E for ages 4 through 7 were 0.81 for Georges Bank and 0.84 for Southern New England.

Table 11.--Virtual population estimate of exploitation ratio (E) for yellowtail flounder.

	AGE				
Year Class	2-3	3-4	4-5	5-6	6-7
			Southern New England Grounds		
1958	0.74	0.82	0.79	0.82	0.83
1959	0.68	0.77	0.81	0.85	0.86
1960	0.71	0.80	0.82	0.86	0.88
1961	0.76	0.84	0.87	0.90	0.86
1962	0.80	0.87	0.89	0.82	0.78
Average	0.74	0.82	0.84	0.85	0.84
			Georges Bank		
1958	0.71	0.79	0.77	0.77	0.78
1959	0.68	0.77	0.78	0.82	0.85
1960	0.67	0.76	0.84	0.86	0.87
1961	0.74	0.80	0.83	0.85	0.81
1962	0.75	0.81	0.80	0.75	0.76
Average	0.71	0.79	0.80	0.81	0.81

Population size

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

$$Pn = VP_{(i,k)}/(1-e^{-Z(i,k)}) . E_{(i,k)}$$

where Pn = 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 12. The numbers average of fish age 2 and greater in the 1958-1962 year classes was 70×10^6 for Southern New England and 38×10^6 for Georges Bank. 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 ground. There was little industrial catch during these years but discard amounts were large. The average population present in the years 1960-1964 was 150 x 10^6 for Southern New England, 88 x 10^6 for Georges Bank, for a total of 238 x 10^6 fish.

Table 12.--Estimates of population numbers based on Gulland's (1965) virtual population model using variable E and F (numbers X 10^{-3})

Year Class	Ages 2	3	4	5	6	7	Year	Total
Southern New England Grounds								
1958	66,988	47,758	13,724	5,808	1,964	3,034	1960	139,280
1959	86,783	66,405	34,144	13,281	3,750	3,910	1961	208,270
1960	68,931	65,778	24,530	8,967	2,327	2,062	1962	172,600
1961	57,718	35,408	11,753	2,924	366	393	1963	108,560
1962	72,150	35,582	8,758	1,228	336	827	1964	118,880
Average	70,514	50,186	18,582	64,416	17,486	20,452		149,518
Georges Bank								
1958	26,633	19,724	7,090	2,910	1,214	2,869	1960	60,439
1959	29,938	26,035	11,037	5,042	1,867	2,427	1961	76,346
1960	48,118	38,360	22,814	7,419	1,775	1,641	1962	120,130
1961	46,755	29,086	11,957	4,098	952	1,717	1963	94,565
1962	42,186	27,733	9,160	2,804	1,255	3,731	1964	86,869
Average	38,726	28,188	12,286	4,455	1,413	2,477		87,670

YIELD PER RECRUIT STUDIES

Beverton and Holt Model

A series of computations using the Beverton and Holt (1957) model were made with M varying from 0.2 to 0.3 in increments of 0.05. For each M, F was varied from 0.5 to 1.6 by increments of 0.05 and for each F, the age at entry to the exploited phase was varied from 1.75 (245 mm in length) to 3.00 years (332 mm in length) by increments of 0.25. For all combinations of M and F the maximum yield per recruit occured at an age of entry of 3 years, the maximum age studied.

The yield isopleth for M = 0.2 is shown in Table 13. At this level of M the maximum yield (catch) per recruit is obtained with an F of 0.75 - 0.8. This is a 20 to 40 percent reduction in effort below the present level. If the age of entry is assumed to be 2 years (265 mm), the age at which they begin to be captured in large amounts at present, and the level of F set at 1.0, then raising the age at entry to 3 (332 mm) and reducing F to 0.8 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 in catch.

Increasing the age of entry to 2 1/2 years would reduce discards by about 25 percent under the current culling practice. An increase to age 3 would reduce discards by about 45 percent.

It is estimated from the curves given by Lux and Hennemuth (1969) that a mesh size of 129 mm synthetic would retain approximately 66 percent of the 2.5 year olds and 77 percent of the 3 year olds relative to presently used 114 mm mesh. The 145 mm mesh would retain 33 percent of the 2.5 year olds and 50 percent of the 3 year olds.

Table 13.--Yield per 1000 recruits in kg as estimated from the Beverton and Holt yield mode for M = 0.2.

Instantaneous Rate of Fishing (F)	Minimum age at first capture in years (length in mm in ())					
	1.75 (245)	2.00 (265)	2.25 (284)	2.50 (302)	2.75 (318)	3.00 (332)
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

Ricker Model

Ricker (1958) outlined a yield model to study changes in yield per recruit with varying mortality rates. His procedure was followed in this study to estimate the metric tons of fish that would be caught in each of the seven years following a change in the fishing rate. At the end of seven years the fishery would be stabilized at the new rate. This procedure was applied separately to the Southern New England ground and to Georges Bank with a 20 percent reduction in fishing mortality. The size of the entering year class of 2 year olds was taken as the average of the values for the year classes 1958-1961 estimated by the virtual population technique. The age specific Z and F values used to compute the initial population size and catch are given in Table 14 and are considered by the authors to represent current values. Discards were estimated at 60 percent of the catch for age group two and 30 percent for age group three.

On the Southern New England ground there is an immediate loss in landings of 13.0 percent which is almost recovered in the following year. A gain of 4.6 percent is achieved by the end of the third year (Table 14). Almost all of the eventual gain of 9.1 percent is achieved in the fifth year after the decrease in F. On Georges Bank the long term gain in landings is 7.9 percent after an initial loss of 13.8 percent. The percentage gain to landings are greater than that for the catch (4 percent for both areas) because of the decreased catch of the smaller fish which are mostly discarded. The year-by-year percentage changes are given in Table 15.

If an additional reduction of 0.1 is made in the fishing rate for age group 2 (42 percent both areas) and age group 3 (16 percent Southern New England and 21 percent Georges Bank), as might occur with an increase in mesh size to 129 mm.the gains in yield are greater (Table 16). There is an immediate loss of 23.0 percent in landings for Southern New England and 20.9 percent for Georges Bank (Table 15). However, the landings at the end of seven years are increased by 17.2 and 19.9 percent for Southern New England and Georges Bank, respectively.

Table 14.--Changes in population biomass and yield following a 20 percent reduction in fishing rate (in metric tons X 10^{-3})

Age	Old Mortality Rates Z	Old Mortality Rates F	Biomass	Discard	Landings	New Morality Rates Z	New Morality Rates F	Seven Years Later Biomass	Seven Years Later Discard	Seven Years Later Landings
				SOUTHERN NEW ENGLAND						
2	0.45	0.30	11147	2291	1527	0.39	0.24	11147	1892	1262
3	0.95	0.80	14457	2730	6371	0.79	0.64	15351	2498	5830
4	1.00	0.85	8768	-	5336	0.83	0.68	10926	-	5741
5	1.40	1.25	4311	-	3113	1.15	1.00	6367	-	4076
6	1.55	1.40	1273	-	948	1.27	1.12	2414	-	1606
7	1.55	1.40	304	-	224	1.27	1.12	764	-	502
8	1.55	1.40	70	-	52	1.27	1.12	235	-	154
Total			40330	5021	17571			47204	4390	19171
				22592					23561	
				GEORGES BANK						
2	0.45	0.30	6020	1237	825	0.39	0.24	6020	1022	681
3	0.75	0.60	7808	1214	2833	0.63	0.48	8290	1093	2549
4	0.95	0.80	5784	-	3387	0.79	0.64	6924	-	3487
5	1.15	1.00	2989	-	1913	0.95	0.80	4200	-	2343
6	1.25	1.10	1133	-	747	1.03	0.88	1945	-	1124
7	1.25	1.10	366	-	238	1.03	0.88	783	-	447
8	1.25	1.10	115	-	75	1.03	0.88	306	-	174
Total			24215	2451	10018			28448	2115	10805
				12469					12920	

Table 15.--Yearly changes in yield (MT) of yellowtail flounder following the reductions in fishing rate shown in Tables 14 and 16.

	TABLE 14				TABLE 16			
Year from Change	Catch	%	Landing	%	Catch	%	Landing	%
				Southern New England				
0	22592		17571		22592		17571	
1	19536	-13.5	15291	-13.0	16547	-26.8	13536	-23.0
2	21572	- 4.5	17182	- 2.2	19815	-12.3	16489	- 6.2
3	22769	0.8	18379	4.6	22125	- 2.1	18799	7.0
4	23118	3.2	18928	7.7	23339	3.3	20013	13.9
5	23502	4.0	19112	8.8	23769	5.2	20443	16.4
6	23552	4.4	19162	9.0	23897	5.8	20571	17.1
7	23561	4.5	19171	9.1	23925	5.9	20599	17.2
				Georges Bank				
0	12469		10018		12469		10018	
1	10689	-14.3	8638	-13.8	9409	-24.5	7925	-20.9
2	11724	- 6.0	9609	- 4.0	11123	-10.8	9490	- 5.3
3	12401	- 0.5	10286	2.7	12419	- 0.2	10816	3.0
4	12734	2.1	10619	6.0	13181	5.7	11548	15.3
5	12864	3.2	10749	7.3	13498	8.2	11865	18.4
6	12910	3.5	10795	7.8	13614	9.2	11981	19.6
7	12920	3.6	10805	7.9	13646	9.4	12013	19.9

Table 16.--Changes in population biomass and yield following a 20 percent reduction in fishing rate plus an additional reduction of .1 for age group 1 and 2

Age	Z	F	Seven Years Later		
			Biomass	Discard	Landings
			Southern New England		
2	0.29	0.14	11147	1164	776
3	0.69	0.54	16965	2162	5044
4	0.83	0.68	13345	-	7012
5	1.15	1.00	7777	-	4978
6	1.27	1.12	2977	-	1980
7	1.27	1.12	942	-	615
8	1.27	1.12	289	-	190
Total			53442	3326	20599
				23925	
			Georges Bank		
2	0.29	0.14	6020	629	419
3	0.53	0.38	9162	1004	2342
4	0.79	0.64	8458	-	4260
5	0.95	0.80	5130	-	2862
6	1.03	0.88	2375	-	1372
7	1.03	0.88	956	-	545
8	1.03	0.88	373	-	213
Total			32474	1633	12013
				13646	

The actual landings estimated by the model at year zero (i.e. prior to change in fishing) are 17,571 MT for Southern New England and 10,018 MT for Georges Bank, which are reasonable average values for recent years (Table 2). The estimated landings after a straight 20 percent reduction in effort were 19,171 MT for Southern New England and 10,795 MT for Georges Bank, compared with 20,599 MT and 12,013 MT for a reduction in effort which reflects also an increase in mesh size.

Effects of Changes in Mesh Size

Hennemuth and Lux (1970) have analyzed mesh selection data for yellowtail flounder utilizing length frequencies of catch and discard directly, and an 80 percent fishing rate (E). They estimated that discards would be reduced 27 percent by weight with a 129 mm mesh and by 56 percent with a 145 mm mesh, when compared with the present 114 mm mesh. The resulting immediate losses to the fishery (landings) would be 4 and 21 percent, respectively, with the corresponding long-term gains being 10 and 17 percent. These estimated gains agree closely with the results obtained from the Beverton-Holt yield per recruit function.

DETERMINATION OF MAXIMUM YIELD

Catch-Effort Model

Schaefer (1954 and 1957) developed a logistic model of fishing relating fishing effort to catch. Pella and Tomlinson (1969) extended this model with a generalized production model which permits skewness of the stock production curve. The computer program adapted from that of the latter authors was applied to the catch-effort data on yellowtail flounder.

The curves based on other than the logisitc assumption ($m = 2.0$, see Table 17) did not give substantially better fits to the data. For Southern New England, the Schaefer model ($m = 2.0$) will be discussed as all models gave basically the same estimate of maximum sustained yield. For Georges Bank the curve for $m = 3.2$ was also considered as it indicated a considerably larger maximum catch than the Schaefer model with the same degree of "fitness". In utilizing these programs it is necessary to put constraints on q, the catchability coefficients. In this study the limits were 0.01 and 0.4, Effort units were in 1000's of days and catch in 1000's of MT.

The graphs of catch per unit effort versus effort are given in Figures 6 and 7, and the equilibrium catch curves in Figures 8 and 9. The estimates of maximum equilibrium yields from the Schaefer model are 15.8 MT for Southern New England and 9.2 MT for Georges Bank. The corresponding effort values are 5,390 and 3,420 standard days fished. When compared with the number of standard days fished in recent years (10,780 and 6,710, Table 2) the current level of overfishing is obvious. In 1969 the effort was essentially double that which the fishery would sustain on a long term basis. If the curve for m $\doteq$ 3.2 is examined for Georges Bank (Figure 9) the maximum sustained yield is 18,500 MT with an effort of 6,780 days fished. Although these values are in line with the current fishing situation a drastic decline in yield is predicted from this model with even small increases in effort.

It is unfortunate that effort values are not available for the late 1930's and early 1940's when the catch built up to a peak in Southern New England. The values in the mid-1940's for catch and effort may possibly represent the effects of overfishing (Figure 2).

Table 17.--Optimum catch in metric tons

Southern New England

m	Catch	R*
0.4	12,300	0.72
0.8	16,400	0.77
1.2	17,000	0.75
1.6	15,400	0.76
2.0	15,800	0.76
2.4	15,500	0.76
2.8	16,100	0.75
3.2	15,200	0.76

Georges Bank

m	Catch	R*
0.4	10,300	0.86
0.8	12,150	0.86
1.2	11,300	0.86
1.6	9,800	0.86
2.0	9,200	0.86
2.4	9,300	0.86
2.8	18,200	0.87
3.2	18,500	0.87

* R = Measure of fit where with perfect fit

R = 1.0.

Figure 6.--Relationship between fishing effort and catch-per-unit effort for yellowtail flounder from the Southern New England ground.

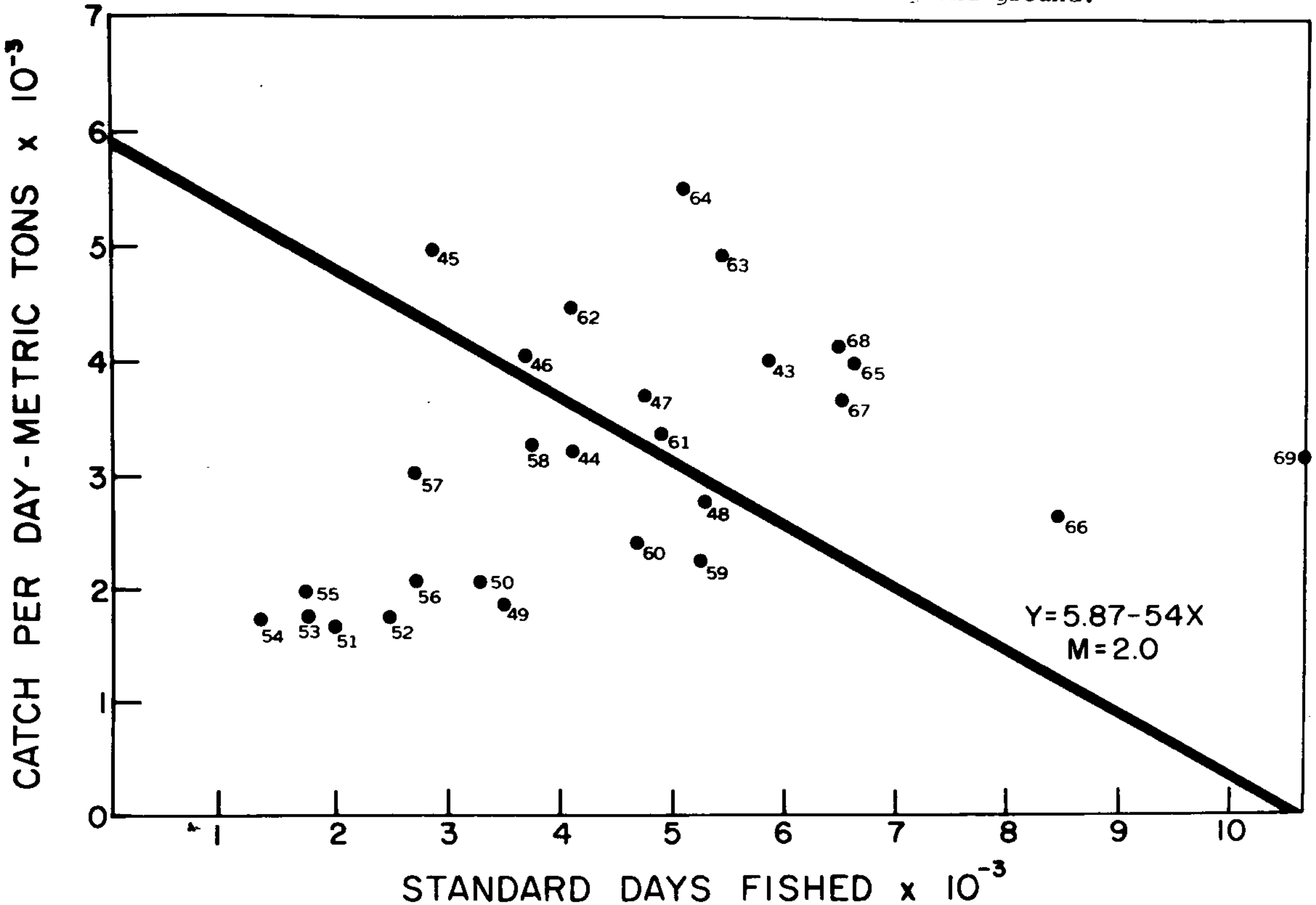


Figure 7.--Relationship between fishing effort and catch-per-unit effort for yellowtail flounder from Georges Bank.

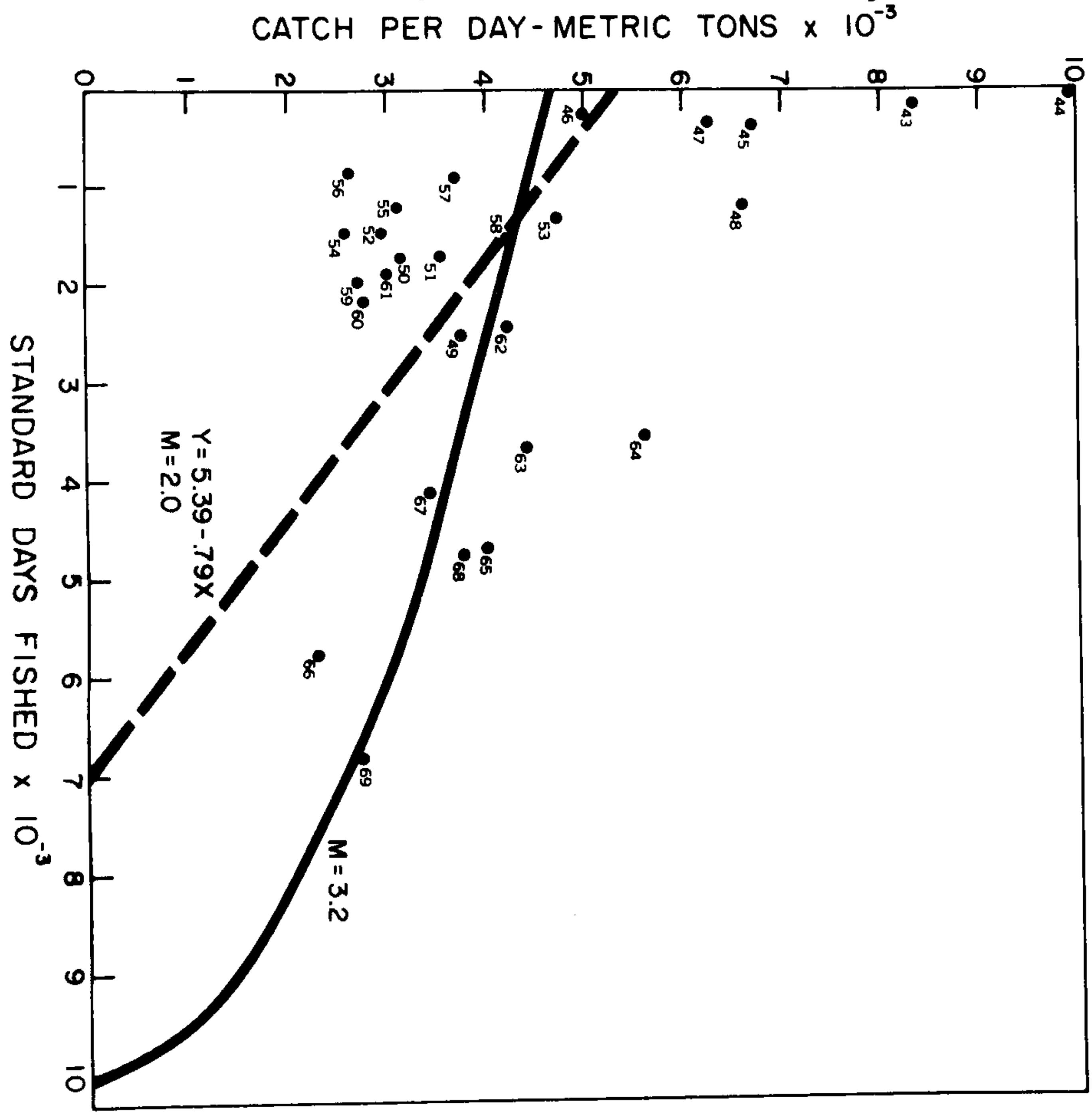


Figure 8.--Relationship between fishing intensity and landings for yellowtail flounder from Southern New England Ground.

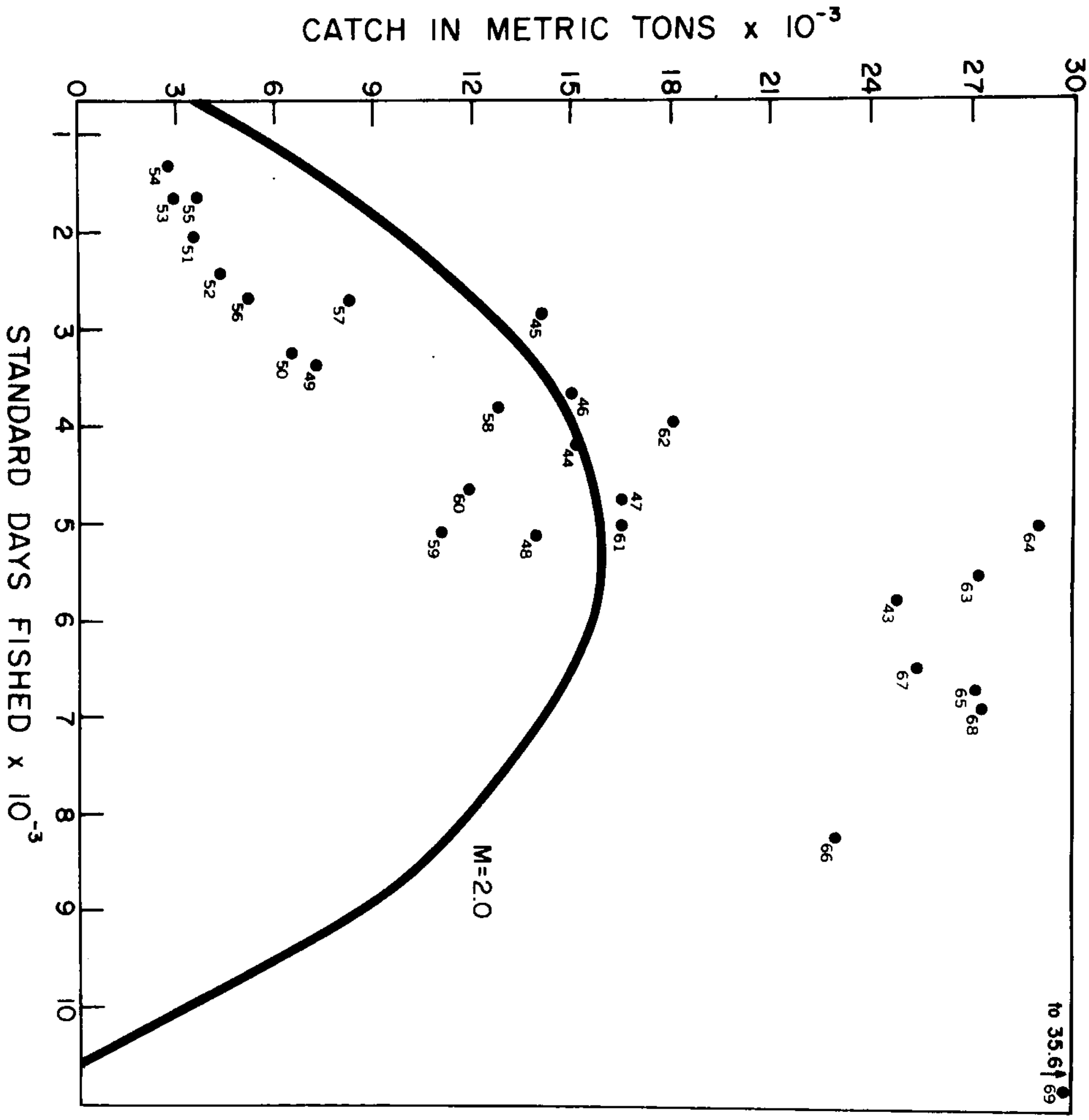
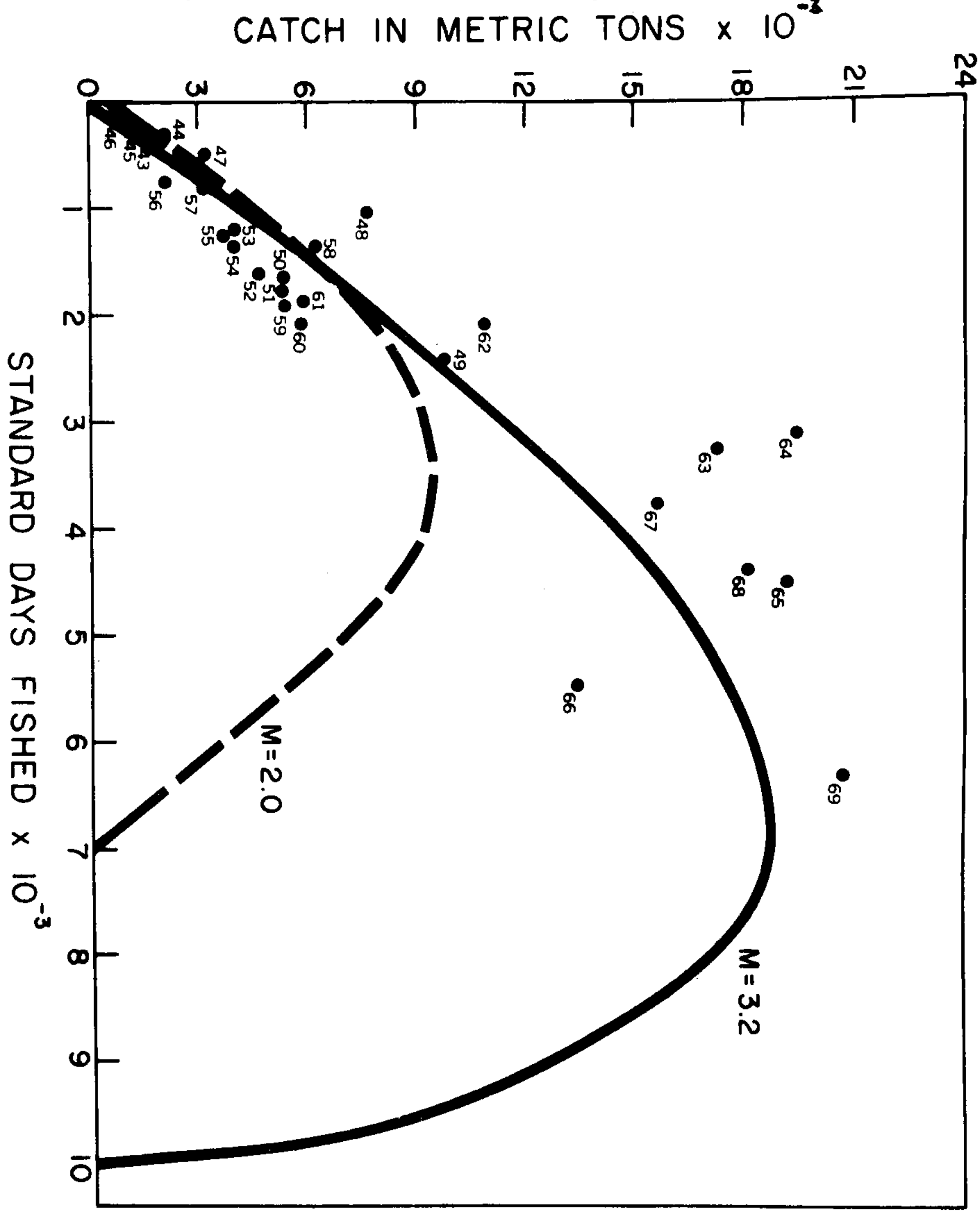


Figure 9.--Relationship between fishing intensity and landings for yellowtail flounder from Georges Bank.



EFFECTS OF REDUCTION OF FISHING EFFORT ON YIELD

The estimate of current population size can be made from recent catch data. The 1969 catch in weight (Table 2) was converted to numbers by dividing the total of the U.S. food fishery landings plus the non-U.S. catch by the average size of food fish in U.S. landings (495 gm), and adding it to the numbers in the discard and industrial landings obtained by using the mean weight per fish in those segments (273 and 209 gm respectively). The resulting values are 87 x 10^6 fish for Southern New England, and 46 x 10^6 for Georges Bank for a total of 138 x 10^6 fish. This is a conservative estimate because the average weight per fish of the foreign catch undoubtedly is less than 495 gm.

To obtain an estimate of population size, first trial values of F = 1.2, 1.0 and 1.1 were chosen for Southern New England, Georges Bank and combined areas, respectively estimated from the virtual population model for age groups 4 and older. The greater industrial catch has probably increased the rate estimated for 2- and 3- year olds on the Southern New England ground. The increasing fishery on Georges Bank in 1968 and 1969, the last two years used in the virtual population analysis, would indicate a similar level for that area. The mean population size,

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

The estimate of mean 1969 population size (age 2 and older) was 73 x 10^6 fish for Southern New England and 46 x 10^6 fish for Georges Bank. The overall total is 125 x 10^6. The estimated population at the start of each year is equal to the catch/($E \cdot 1 - e^{-Z}$). Assuming M = 0.2, , the corresponding estimates are 136 x 10^6, 68 x 10^6, and 224 x 10^6. These values are 17 to 19 percent less than the average year's population estimated by Gulland's (1965) virtual population method for the early 1960's (Table 12). Numbers can be converted to biomass by multiplying by the average weight of fish caught in the various areas, which are 409 gm for Southern New England and 454 gm for Georges Bank, and 421 gm total. The mean biomasses are 30,000 MT for Southern New England, 21,000 MT for Georges Bank, and 53,000 MT for Subarea 5.

The values for the 1969 population size can be utilized to estimate the effect of a reduction in fishing rate (F) to 0.8, the optimum value estimated from the yield per recruit model, on the actual yield. The catch (Fx mean population weight) under this condition would be 24,000 MT for Southern New England, 17,000 MT for Georges Bank and 42,000 MT overall. The value for Southern New England is higher than that previously estimated for a maximum sustained yield. It is quite likely that the heavy increase in fishing effort in 1969 compared with 1968 (62 percent Southern New England, 45 percent Georges Bank) caused the rate of fishing, F to increase beyond 1.2. If the 1968 catch is used, the estimated mean biomass is 23,000 MT Southern New England, 8,000 MT Georges Bank, and 44,000 MT total. The corresponding catches with an F of 0.8 would be 18,000, 14,000 and 35,000 MT. This compares with an estimated maximum yield of 16,000 MT for Southern New England and 9,000-18,000 MT for Georges Bank stocks from the production model.

ASSESSMENT OF POPULATION TRENDS FROM RESEARCH CRUISES

Total number of yellowtail was estimated from all research cruises for the Southern New England and Georges Bank areas. (See Grosslein 1969 for a description of the survey cruise sampling procedures.) The values estimated by directly weighting up the catches area sampled to total area seemed minimal, on the average less than half of the corresponding weight of the commercial catch. A comparison experiment with a USSR research trawler (Hennemuth 1968), indicated that the Soviet vessel caught 2.5 times as much flounder using a more efficient net than the 36 Yankee trawl. For an approximate population estimate the survey cruise totals were multiplied by 2.5. For the fall surveys the population numbers with one standard deviation are plotted in Figures 10 and 11 and population weights in Figures 12 and 13. The values for all surveys are given in Table 18. The trends for Georges Bank parallel those from the fishery, with abundance (Figure 3) dropping from 1963 to a low point in 1966, an upturn in 1967-1968, and a decrease in 1969. For Southern New England the trends were less marked, but with a slight long term decrease.

The ratio of the 1963-1969 average commercial catch to the overall survey cruise estimated population weight is 1.08. The corresponding value for Georges Bank is 0.95. If just the 1969 figures are compared the ratios are 1.27 and 0.81 for Georges Bank. Thus it is likely that the effects of fishing are greater on the Southern New England stocks than on those on Georges Bank.

Figure 10.--Survey cruise estimates of total numbers of yellowtail flounder on the Southern New England grounds.

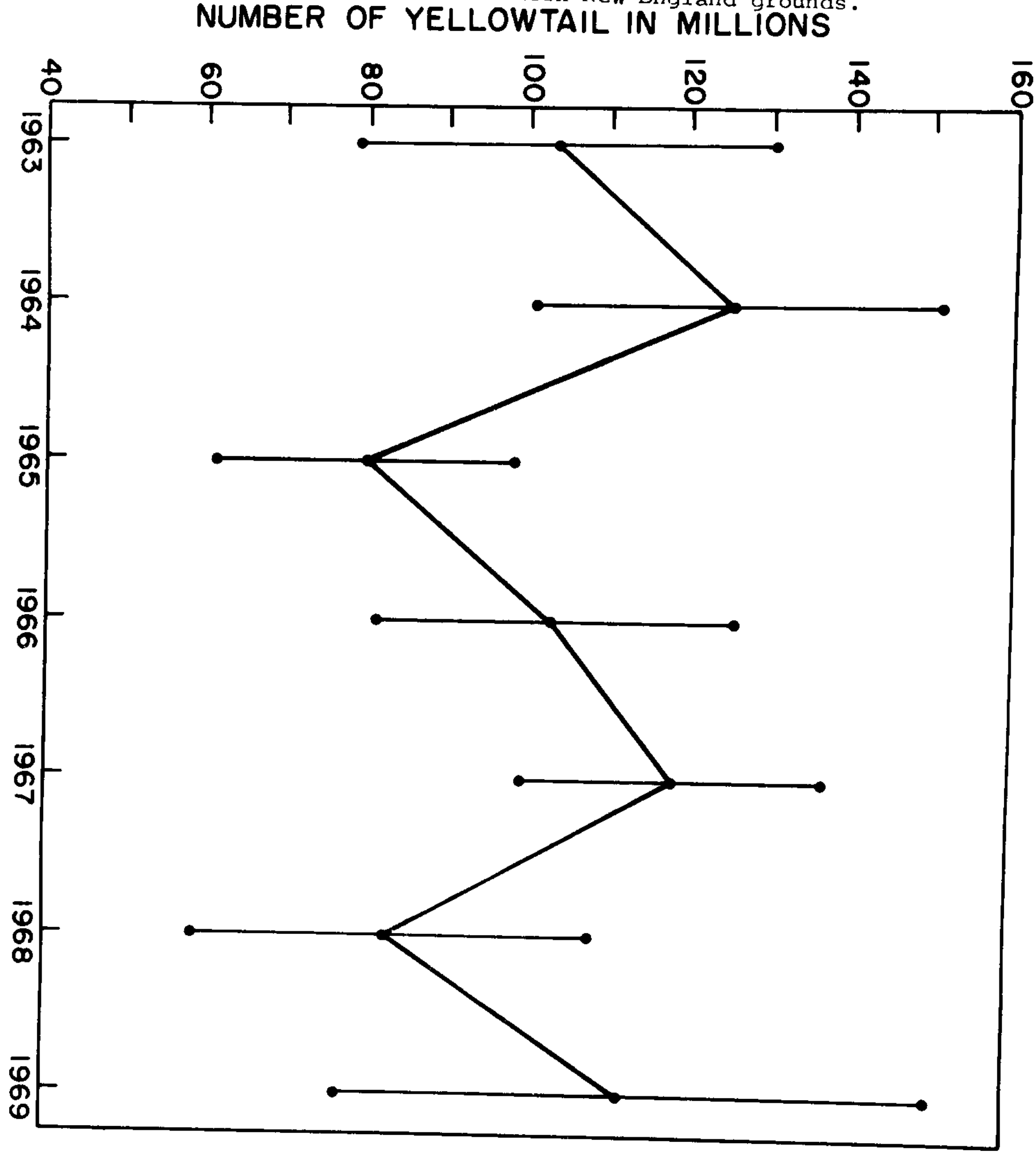


Figure 11.--Survey cruise estimates of total numbers of yellowtail flounder on Georges Bank.

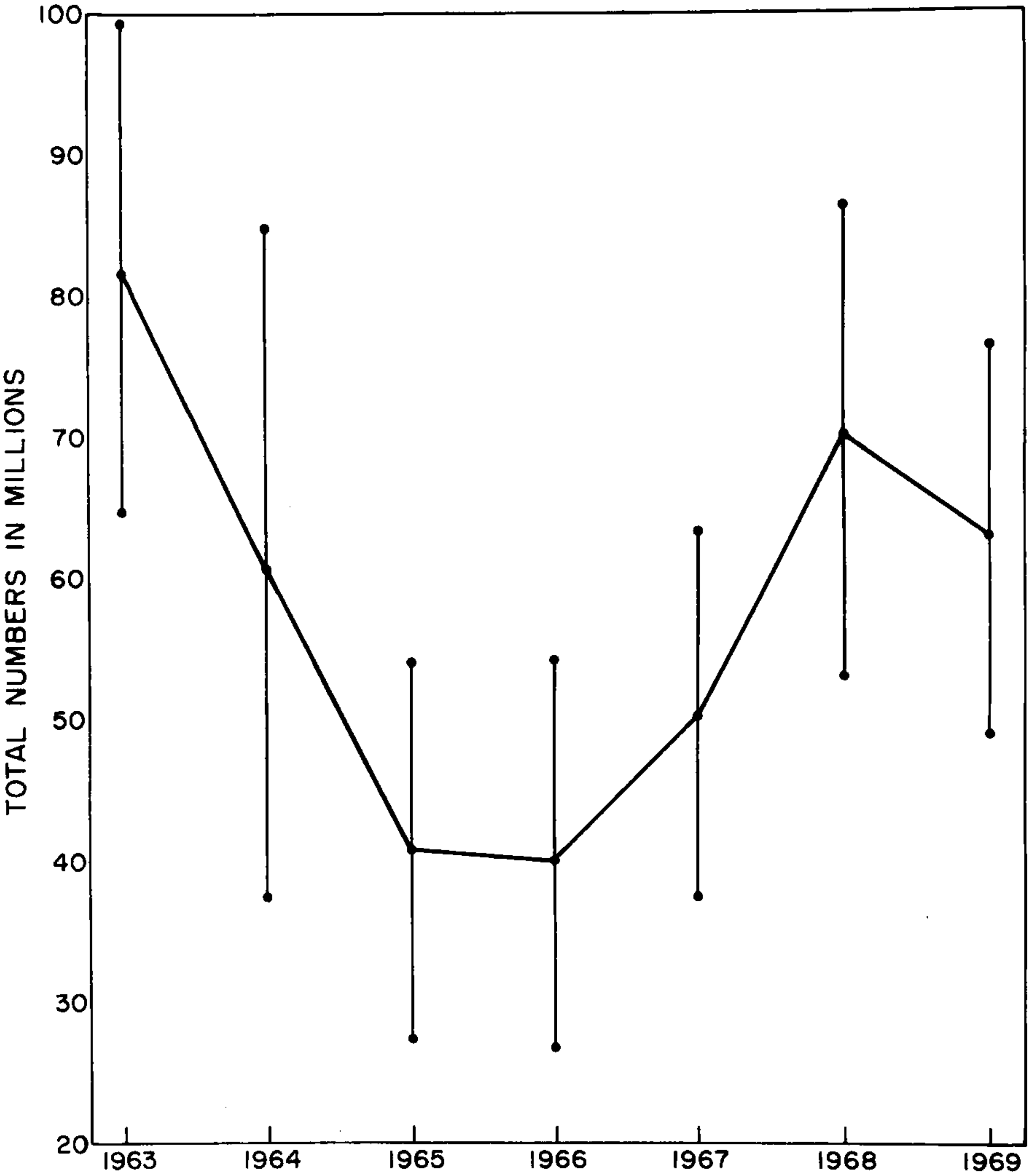


Figure 12.--Survey cruise estimates of total weight of yellowtail flounder on the Southern New England grounds.

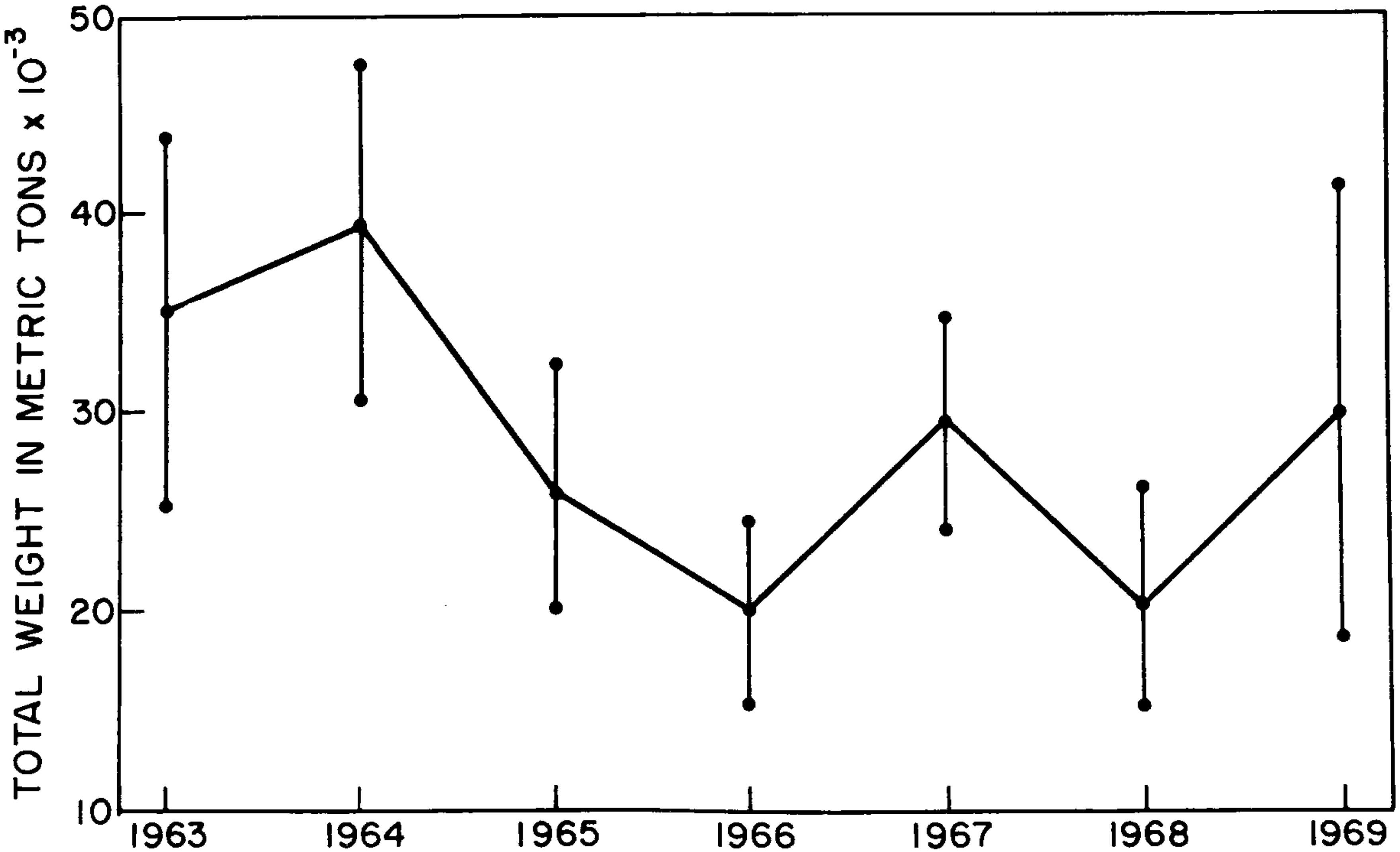


Figure 13.--Survey cruise estimates of total weight of yellowtail flounder on Georges Bank.

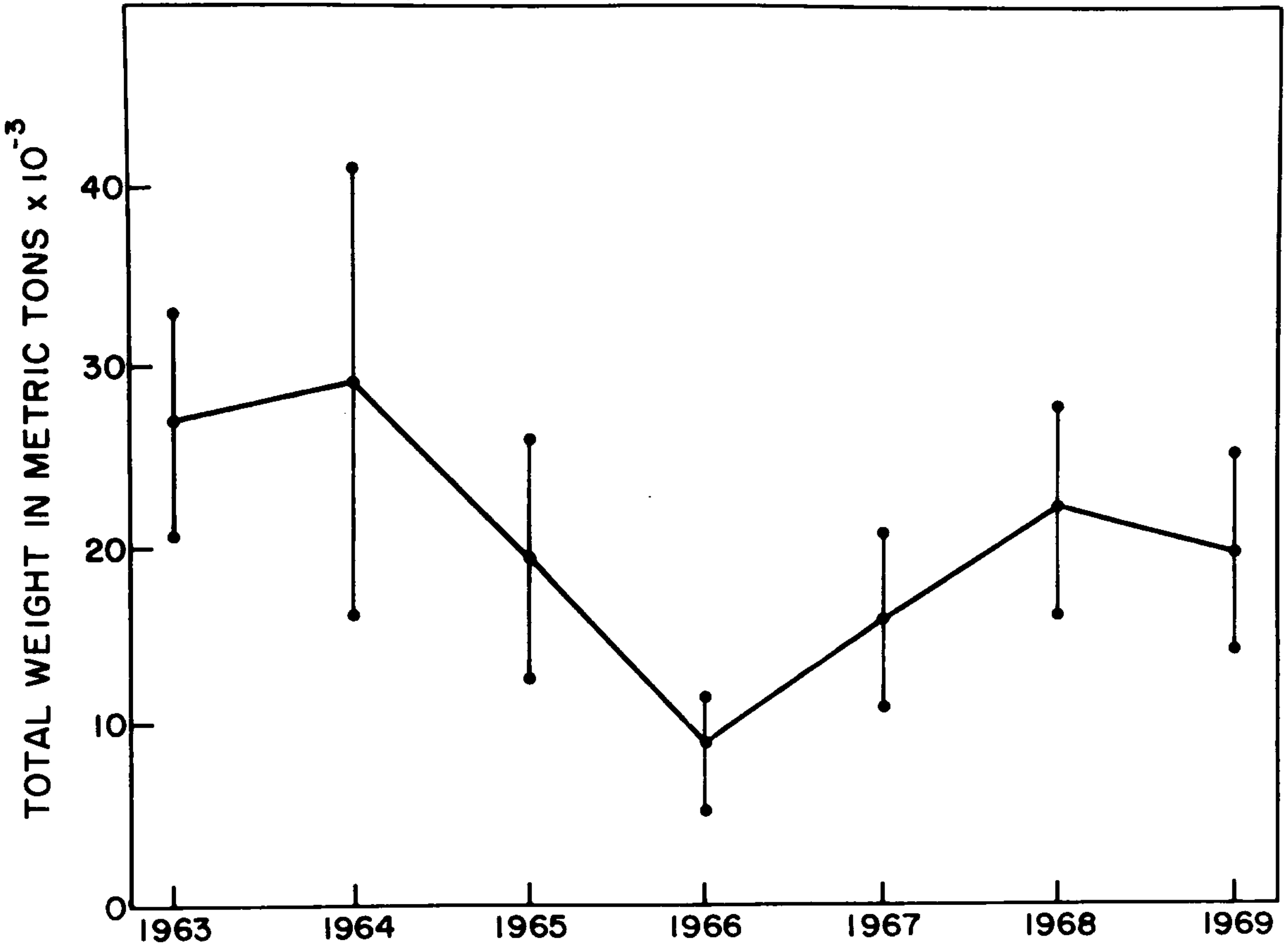


Table 18.--Estimates of population size from survey cruises yellowtail (metric tons)

	Southern New England		Georges Bank	
Cruise	Weight	No's x 10^5	Weight	No's x 10^5
1963 S*	18,535	582	16,553	440
1963 F	34,816	1046	27,148	819
1964 W	21,355	573	16,417	398
1964 S	23,109	507	9,088	265
1964 F	39,809	1257	28,913	612
1965 S	20,213	734	25,738	579
1965 F	20,677	796	14,227	422
1965 W	26,223	8011	19,311	429
1966 W	15,169	370	10,813	257
1966 F	19,507	1049	8,465	401
1967 F	29,061	1192	16,084	505
1968 S	43,595	1625	5,933	173
1968 F	20,811	832	22,345	696
1969 Sp	27,610	1182	24,262	618
1969 S	26,708	1230	33,235	1141
1969 F	29,772	1132	19,691	628
Av. all cruises	26,033	1382	18,639	523
Av. fall cruises	28,506	2074	20,280	581

* S = summer
W = winter
Sp= spring
F = fall

The yellowtail flounder length frequency of catch (numbers per tow) is given for all the survey cruises in Figures 14 and 15 for Southern New England and Georges Bank. The values are weighed by strata area and all fish 8 cm and smaller were combined in the computer program accounting for the occasional peaks at the point. Few young of year fish are captured. The fall survey is the first time that the 1+ year class is caught in enough numbers to estimate pre-recruit strength. The Georges Bank size distribution has not shown drastic changes throughout the years. However the Southern New England stock has moved towards a unimodal situation. In 1969 the first mode was essentially absent. In addition there are now fewer fish in the larger size groups causing the length range to be rather narrow.

RECRUITMENT

The catch per day of 2-year-olds is given in Figure 16 for Southern New England and in Figure 17 for Georges Bank. This index of the abundance of fish just entering the fishery dropped in 1968 and 1969 on both grounds. However, the index for Southern New England has been generally 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 autumn before they enter the fishery at age two the following year, a lead time of 6 to 12 months (Figure 18 and Table 19). The data suggest lower than normal entering year classes in 1969 on Georges Bank and rather low ones on Southern New England in 1968 and 1969. The current values for Southern New England are considerably below those for the early 1960's and thus indicate that the fishery will not be able to sustain the high catches of those years in 1971 and 1972. The preliminary estimates for 1970 are of the same magnitude as 1969 for both areas. The picture for Georges Bank is less clear, particularly because of the very low values in 1964 and 1965. These may be a result of the sample locations, as the Southern New England stock is more evenly distributed over its strata than is the Georges Bank stock (Figure 1). In addition since the interchange between the two populations is not well delineated for small fish it is possible that the pre-recruit individuals do move between the areas. The factors which control recruitment are not known.

The environment may well be a major contributing force. However it seems reasonable to suppose that population density has some effect, and that low levels would reduce the probability of good recruitment.

Figure 14.--Survey cruise length frequency distribution of yellowtail flounder in Southern New England.

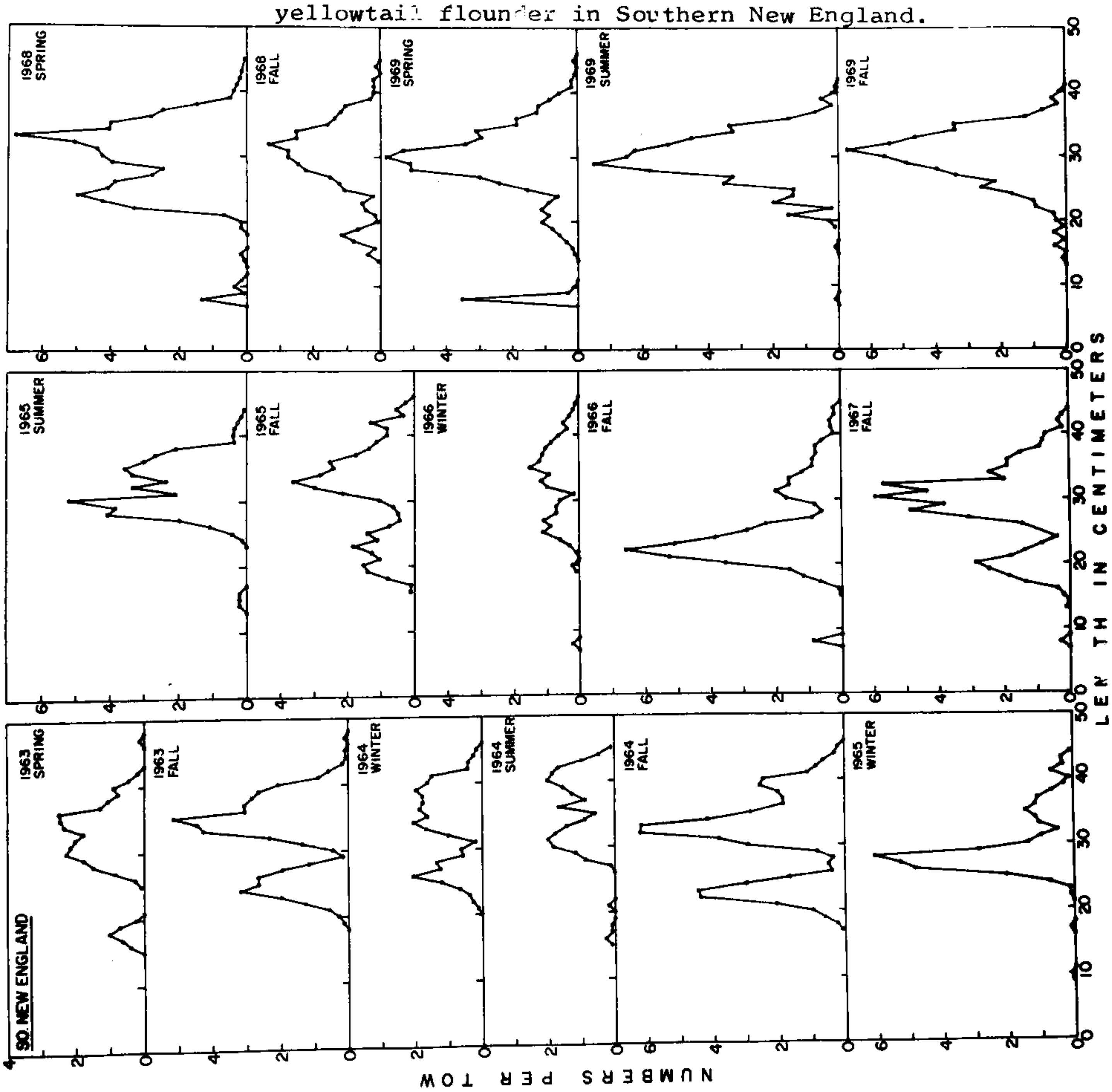


Figure 15.--Survey cruise length frequency distribution of yellowtail flounder in Georges Bank.

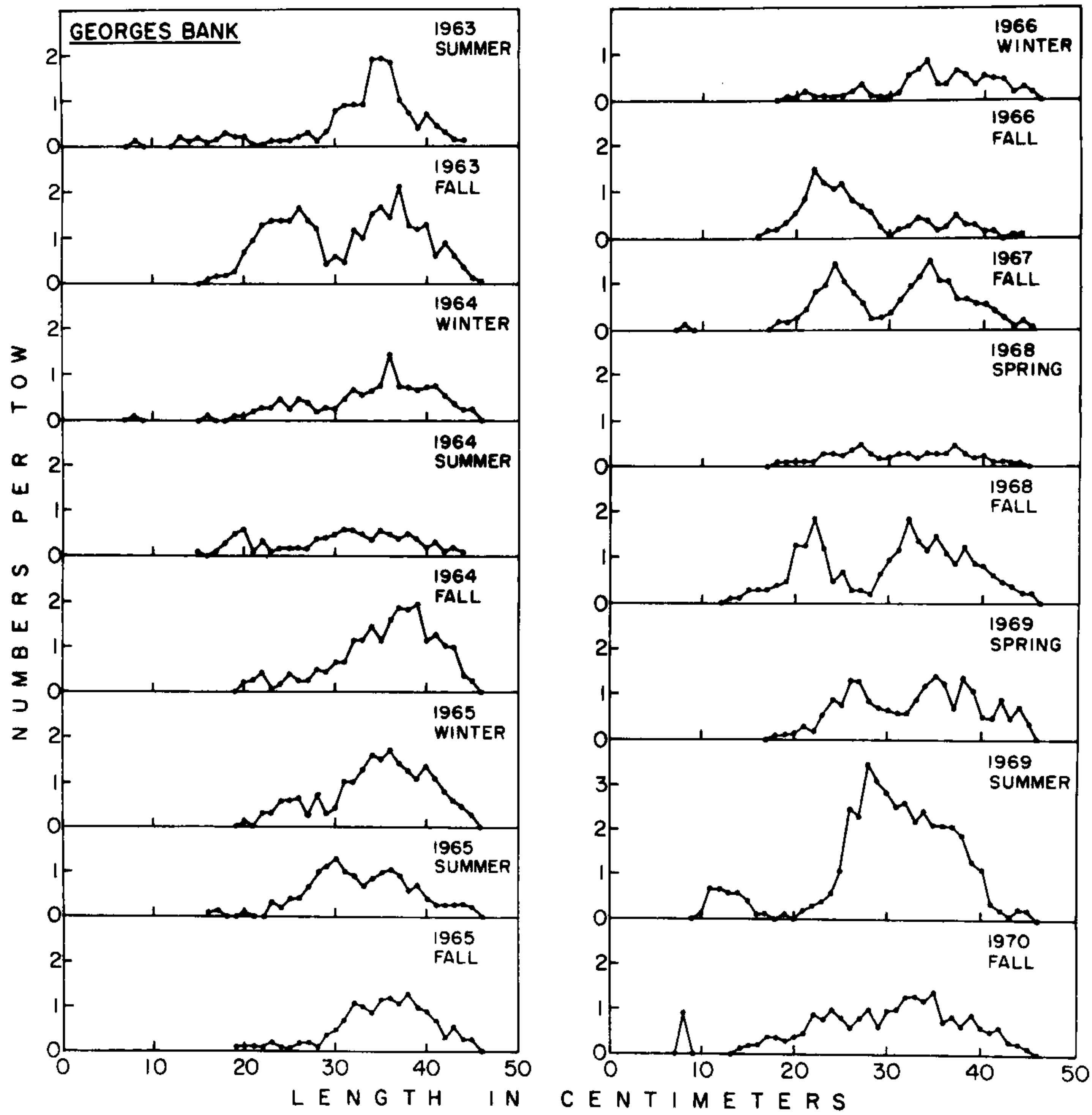


Figure 16.--Number of two-year old yellowtail flounder landed per day in the food fishery from Southern New England.

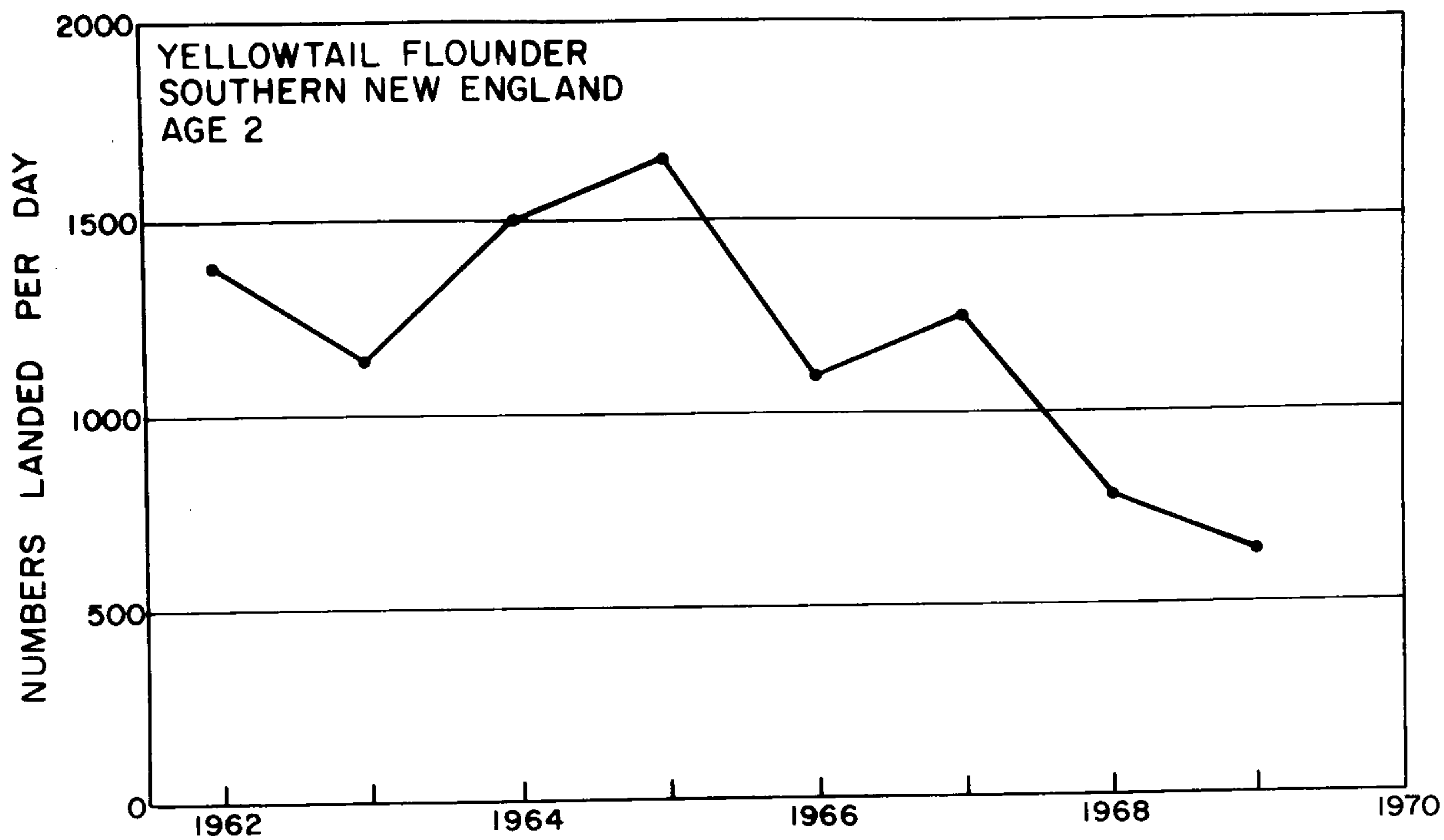


Figure 17.--Numbers of two-year-old yellowtail flounder landed per day in the food fishery from Georges Bank.

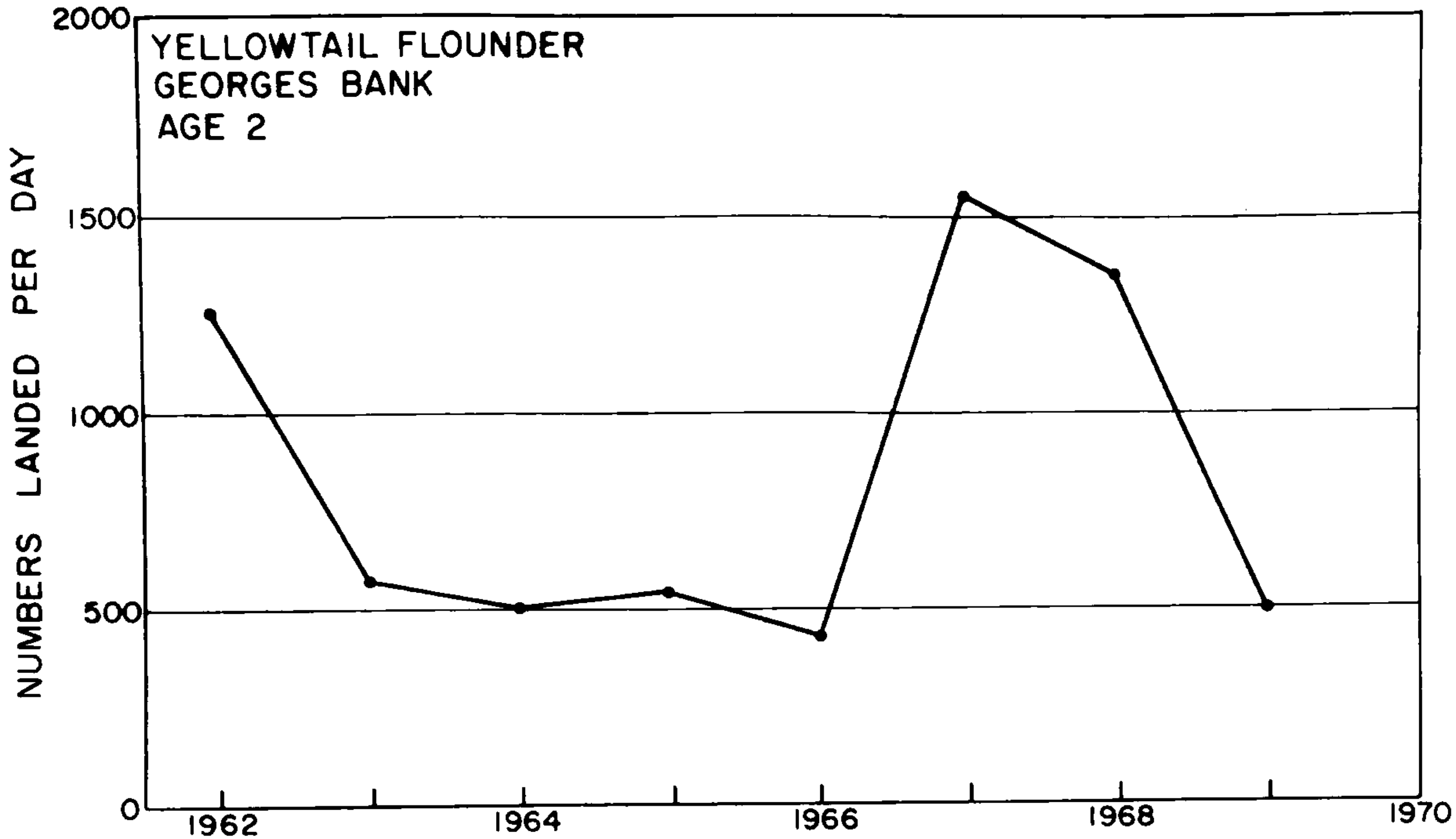


Figure 18.--Survey cruise abundance index for age group I yellowtail flounder.

Table 19 .--Abundance index for I^+ fish in fall survey cruises

Year	INDEX Southern New England	Georges Bank
1963	16.3	12.7
1964	18.5	2.2
1965	11.7	1.3
1966	34.4	9.9
1967	19.9	7.7
1968	9.0	9.7
1969	7.0	6.0

SUMMARY

Status of the Stocks

During the 1960's the catch of yellowtail has been very high, ranging from 19,000 to 58,000 MT. Effort has increased even more rapidly resulting in a drop in the catch per day fished in recent years. Survey cruise data also indicates a current decrease in stocks. Length samples from the survey cruises and age frequency distribution of the commercial catch indicate a strong trend towards a narrow population structure. This situation is most critical for the Southern New England stocks.

Yield per recruit

Evidence from application of Beverton and Holt yield models, Ricker simulation model and a mesh selection study, all indicate that yield per recruit would increase with either a decrease in effort or an increase in age at first capture. A combination of both measures gives the greatest improvement. Current United States fishing practices result in approximately 37 percent of the catch at present being discarded because the fish

are too small to market. A reduction in effort and an increase in mesh size will allow much of this discard to escape. With a low natural mortality rate a significant proportion will later enter the landings. Thus in addition to the expected catch benefits from measures to increase yield per recruit, the landings will increase by an even greater percentage because of reduced discards. Estimates of the percent long term gains to landings are given below:

Mesh (synthetic) in mm	1965-68 F = 1.2	33 percent red F = 0.8
	Percent long term gains	
114	-	8-12
129	10-25	17-31
145	17-40	57

Yield

The upper values came from the Beverton-Holt model and maybe high because of not accounting for discard sufficiently when assuming knife-edge selection.

The evidence at hand indicates that the year classes which will enter the fishery in 1970 and 1971 are below average, and continuing the fishery at the current high level of fishing will result in severly reduced stocks. This will lead to strong dependence on the recruiting year class, causing the yields to fluctuate directly with fluctuations in recruit year class strength. It is also probable that the reduced spawning stock will reduce the average level of recruitment. The generalized production models indicate maximum sustainable yields of 16,000 tons for Southern New England and from 9,000 to 18,000 tons for Georges Bank, with the lower range more probable. At the 1968 stock level, a fishery rate of 0.8 would yield 18,000 MT from Southern New England and 12,000 MT from Georges Bank. Quotas to reduce the effort thus should be in the range from 25,000 to 30,000 MT.

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