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An Assessment of the Georges Bank Cod Stock (Div. 5Z)

by

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Abstract

Cod landings from Subarea 5 increased markedly during the mid-1960's concurrent with increased effort, but had declined again by 1970 as effort declined. Abundance has remained stable since 1963. First recruitment occurred between ages 2 and 3, and fish were fully recruited by age 6. Yield per recruit studies indicate that the maximum occurs with an F of 0.3 for a length of first capture of 55 cm. The generalized production model indicates the maximum sustained yield for the Georges Bank stock is about 35,000 MT. Average fishing intensity over the past four years was slightly above that required for a maximum sustained yield.

Introduction

Cod has been exploited off New England since the seventeenth century (Jensen and Murray, 1965). Landings statistics are available since 1893. Until 1960, the stock was exploited entirely by U.S. vessels. After 1960, nations other than the U.S. began significant exploitation and landings increased threefold. The following report represents an assessment of the status of the stocks in the area.

Stock Structure

Wise (1962) proposed three or possibly four separate groups of cod in ICNAF Subareas 5 and 6. The areas inhabited by these groups were defined as (1) Georges Bank, east of the 68th meridian, (2) Gulf of Maine, north of Provincetown, Massachusetts, (3) southern New England, south and west of Nantucket Shoals, and (4) a New Jersey coastal group which spends part of the year mingled with a group in the southern New England area. Historically, the majority of the commercial landings have come from Georges Bank and hence this is the group discussed in this paper.

Landings Data

The cod fishery since 1893 may be classified into three periods: The early period from 1893-1910 in which years of record high landings in 1895 and 1907 were followed by much reduced catches; the middle period from 1910-1950 during which landings remained fairly steady; and the latest period from 1950-1972 when landings again rose to near record high levels and then returned to the long term average levels (Table 1, Figure 1).

The mean annual catch for the fishery since 1893 is 32,000 MT. Approximately 80 percent of the catch is taken from the Georges Bank stock. The catch from the Gulf of Maine stock (ICNAF Area 5Y) has remained between 2,800-8,100 MT from 1952-1971. Annual removals above 40,000 MT were not maintained for more than a few years in any period.

Abundance

Landings-per-day-fished have been estimated since 1931 from the catch statistics of a selected set of large otter trawlers fishing out of Boston (Hennemuth, 1969). These vessels have primarily sought to catch haddock. Thus, landings-per-day-fished reflects the relative abundance of cod in those areas

where haddock were caught. However, these areas encompass the major portion of the cod stock or Georges Bank (ICNAF Area 5Z), and although the availability of haddock may well have influenced the landings of cod, the fishery was quite stable from 1935 to 1960. In contrast, during the recent years, particularly after 1967, the much reduced abundance of haddock has undoubtedly affected the fishing patterns, and hence, the relationship between abundance and landings-per-day-fished of cod.

The standard days fished were estimated by dividing total catch by the landings-per-day-fished of the selected vessels. The data are presented in Figure 2.

Since 1963 the data from Albatross IV groundfish surveys has also been used to estimate the relative abundance of cod stocks. These estimates are probably a more reliable index because they are independent of irrelevant factors such as changes in fishing practices which may effect commercial effort. The numbers and pounds caught per tow are plotted in Figures 3 and 4. Both indices are relatively stable, with only a slight decrease evident in the figure for pounds per tow. The high indices in 1963 and 1964 are coincident with the increase in the early 1960's of the commercial landings/day. The survey abundance index has remained level since 1964 despite the rise in U.S. commercial landings per day.

Because the survey data was believed to be free of the effect of changing fishing practices described earlier, the data from Georges Bank was used to adjust the commercial landings-per-day-fished and subsequent calculation of standard days fished for the 1963-71 period to eliminate the bias.

After adjusting the pounds per tow to include only those fish large enough to be commercially available, the adjusted pounds per tow for fall surveys was plotted along with the annual commercial landings-per-day-fished in the form of natural logs

111

(Figure 5). From 1963-1967 the two indices are seen to fluctuate together but following 1967 the commercial landings-per-day-fished increased while the survey pounds-per-tow remained level. Using 1963-1967 as a base period, the commercial landings-per-day-fished from 1968-1971 were adjusted to vary together with the survey index in the same proportion as the average difference calculated for the base period (Figure 5). This adjusted landings-per-day-fished was then used to recompute the standard days fished (Figure 2).

It is evident from these graphs that the increased catch in recent years has resulted primarily from increased effort. Landings-per-day have fluctuated markedly in some short term of years, but have trended downward over the period from 1932-1967. Landings also decreased steadily from 1932-1960 so that effort remained rather steady.

Abundance indices were also compiled from data in ICNAF Statistical Bulletin Table 4 for Spanish paired trawlers, Canadian side trawlers of 151-500 GRT, Canadian stern trawlers of 151-500 GRT, and Canadian trawlers over 500 GRT. Some of these groups have entered the fishery only recently. The results are presented in Table 2. Over all these data support the evidence presented above of a stable or slightly decreasing level of abundance for cod stocks in Subarea 5Z.

Length Frequency Studies

Examination of length frequency curves derived from samples collected on research vessel survey cruises does not indicate any noticeable trends from 1963 to 1970. A typical curve is shown in Figure 6. The mean lengths of fish in the samples (Table 3) do indicate some decrease in the later years. However, it is difficult to say how meaningful this trend is.

Sample data of length frequencies from U.S. commercial landings are not very representative of the true length frequency

composition of landings due to varying market size categories between ports and limited sampling effort. No changes in the frequencies of the first quarter landings were evident in the period 1956-1970. The value for 1970 is given in Figure 7. The mean weight of these samples is presented in Table 4 and no trends are indicated. Samples from other countries are too infrequent to indicate trends.

Age and Growth

Collections of otoliths for 325 fish from the research vessel surveys of Georges Bank during the Spring of 1971 were used to construct an age length key. Because the spring capture time minimized new seasonal growth, the length at capture for each age group was computed and the growth curve plotted in Figure 8. Applying the curve to the length frequency for commercial landings shows cod to begin to be recruited to the fishery between age 2 and 3, with full recruitment by age 6.

Using the method of Tomlinson and Abramson (1961) and Abramson (1964), the age at length data was fitted to the Von Bertalanffy growth equation Table 5. When we compare the growth rate as computed for Georges Bank with that reported by Schroeder (1930) we see very little difference between the two (Table 6).

Sustainable Yields

Plots of landings-per-day against effort have been fitted with a yield function in order to estimate the current status of the fishery for the Georges Bank stock. The basic data points for Subarea 5Z are given in Figure 9 and 11. From the plots, the data can be grouped into two periods: (1) 1932-1959 which shows very little change in effort but considerable fluctuation in landings-per-day, and (2) 1960-1971 which shows large fluctuations in effort together with fluctuations in landings-per-day. The latter group of data was used to fit the yield function utilizing a 4-year moving average procedure with the

data referring to the terminal year. This procedure allows the effect of effort in any given year to be felt in subsequent years, and also serves as a smoothing of the data. A 4-year average of effort was selected as the best fit from a series of plots using the actual data points as well as a series of different moving averages.

Using a generalized production model developed from the Schaefer (1954) model by Pella and Tomlinson (1969), a stock production curve was estimated for the period 1963-1971. The curve based on the 4-year moving average and the logistic assumption of m = 2.00 was chosen, as the degree of fit was no better for curves other than m = 2.00 (Table 7). The equilibrium curves are given in Figures 10 and 11.

For m = 2.00 the estimate of maximum equilibrium yield is 34,600 MT with an optimum fishing effort of 29,900 fishing days for the same period (1963-1971) for Subarea 5Z.

Yield per Recruit

Using the Beverton and Holt (1957) model and the results of the Von Bertalantly fit of the growth information, a yield per recruit curve was plotted where:

W_∞ = 30.345 kg

K = 0.116

t_o = 1.2772

l_r = 45 cm

l_c = 55 cm

L_∞ = 142.47 cm

Assuming natural mortality to approximate 0.2 (Haliday, ICNAF Res. Doc. 71/12), a yield per recuit curve was plotted from the tables of yield functions given in Beverton and Holt (1966) (Figure 12). The curve shows maximum equilibrium yield per recruit to occur at F = 0.3 which agrees well with the value of

F = 0.35 calculated for cod stocks in the 4X area (Haliday, ICNAF Res. Doc. 71/12).

Discussion

This assessment of the cod stock in Subarea 5 indicates that the high levels of effort observed from 1965-1969 were considerably in excess of those estimated to maintain maximum equilibrium conditions. While the results of the production model cannot be used as a precise estimate of the actual equilibrium effort, they do indicate that levels approximating 29,900 days fished should be considered as an upper limit. Actual effort for the period 1962-1971 averaged 31,300 days fished.

At current levels of abundance, a fishing effort of 29,900 days on the Georges Bank stock would result in a catch of 33,000 MT which is very close to the 1970 and 1971 catches. The average 1964-1971 abundance indexes (1.1) is lower than that for the period 1931 to 1963 (average 1.8). Thus it is likely that the relatively high catches in recent years have generated a level of fishing mortality exceeding both that which would give maximum yield per recruit and that which would generate a maximum sustained yield.

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Table 1. -- Recent cod landings (metric tons X 10^{-3}) from Subarea 5.

Year	United States		Canada		Spain		U.S.S.R.		Poland		Total	
	5Z	5Y	5Z	5Y	5Z	5Y	5Z	5Y	5Z	5Y	5Z	5Y
1960	10.8	3.4	-	.1	-	-	-	-	-	-	10.9	3.6
1961	14.0	3.2	.2	-	-	-	.1	-	-	-	14.3	3.2
1962	15.2	3.0	2.4	-	-	-	5.3	-	.1	-	23.1	3.1
1963	13.9	2.6	7.8	-	-	-	5.2	.1	-	-	27.0	2.7
1964	12.3	3.2	7.1	-	-	-	5.4	-	-	-	25.2	3.2
1965	11.4	3.8	10.6	-	.1	-	14.4	-	1.9	-	38.3	3.9
1966	11.8	4.0	15.6	-	8.4	-	16.8	-	.3	-	52.9	4.4
1967	12.7	5.5	8.2	-	14.7	-	.5	-	-	-	36.2	5.8
1968	15.0	6.4	9.1	-	14.6	-	1.5	-	2.5	-	42.8	6.4
1969	16.4	8.2	6.0	-	13.6	.2	.6	-	.6	-	37.4	8.5
1970	14.5	7.8	2.6	-	6.9	.4	.4	-	.6	-	25.1	8.2
1971*	15.8	7.2			7.5	.2						

* Preliminary

Table 2. -- Abundance indices for Subarea 5Z cod

Year	Country	Gear	Catch/day in MT
1966	Spain	Paired trawlers	19.2
1967		151-500 MT	16.2
1968			16.0
1969			13.9
1970			15.5
1962	Canada	151-500 MT	3.2
1963		Side trawler	4.3
1964			3.2
1965			3.2
1966			3.5
1967			2.1
1968			2.7
1969			2.7
1970			2.6
1966	Canada	151-500 MT	3.3
1967		Stern trawler	2.7
1968			3.5
1969			2.0
1970			1.7
1966	Canada	500+ MT	2.4
1967		Stern trawler	3.1
1968			4.8
1969			3.7
1970			2.9

Table 3 -- Mean size of cod captured in research survey cruises in Subarea 5.

Year	Country	Mean lengths in mm			
		Autumn	Winter	Spring	Summer
1963	U.S.	-	-	-	627
1963	U.S.	700	-	-	-
1964	U.S.	-	766	-	-
1964	U.S.	-	-	-	646
1964	U.S.	753	-	-	-
1965	U.S.	-	639	-	-
1965	U.S.	-	-	-	702
1965	U.S.	628	-	-	-
1966	U.S.	-	624	-	-
1966	U.S.	612	-	-	-
1967	U.S.	578	-	-	-
1968	U.S.	-	-	616	-
1968	U.S.	650	-	-	-
1968	USSR	568	-	-	-
1969	U.S.	-	-	600	-
1969	U.S.	-	-	-	632
1969	U.S.	683	-	-	-
1969	USSR	612	-	-	-
1970	U.S.	-	-	672	672
1970	U.S.	646	-	-	-
1970	U.S.	639	-	-	-
1971	U.S.	545	-	698	-

Table 4 -- Mean weight of U.S. first quarter cod sample in area 5Z U.S. Commercial catch.

Year	Weight (kg.)
1957	4.03
1958	2.25
1959	2.12
1960	3.29
1961	2.32
1962	2.80
1963	3.93
1964	3.32
1965	3.75
1966	6.21
1967	2.50
1968	2.91
1969	2.04
1970	4.59
1971	4.61

Table 5 -- Length at capture, by age, for cod sampled from Georges Bank by U.S. spring 1971 survey cruise - sample data fit to the Von Bertalanffy growth equation.

Age	Sample Size	Sample Mean Length (cm)	Std. Error Sample Mean	Fitted Length (cm)
.0	0	-	-	19.64
1.0	9	26.00	.833	33.10
2.0	105	45.02	.515	45.09
3.0	70	58.30	.655	55.77
4.0	23	63.17	1.607	65.27
5.0	47	74.06	.876	73.74
6.0	11	79.36	1.718	81.27
7.0	24	84.87	1.926	87.98
8.0	21	93.48	1.674	93.96
9.0	4	93.25	4.553	99.27
10.0	4	105.50	1.936	104.01
11.0	3	121.67	1.764	108.23
12.0	1	123.00	.000	111.98
13.0	0	-	-	-
14.0	3	131.33	-	-

	Estimated Parameters and Standard Errors		
	L Infinity	K	T Sub-Zero
Estimates	142.47	.116117	-1.2772
Std. Error	10.91	.017947	.234239

Table 6 -- Growth rates for cod from area 5Z.

	Georges Bank		Nantucket Shoals *	
	Length (cm)	Sample Size	Length (cm)	Sample Size
I	26.0	9	17.0	573
II	45.0	105	38.4	573
III	54.3	70	52.8	557
IV	63.2	23	63.0	450
V	74.1	47	70.4	113
VI	79.4	11	80.0	36
VII	84.9	24	85.3	13
VIII	93.5	21	91.7	6
IX	93.2	4	98.3	4
X	105.5	4	104.1	1
XI	121.7	3		
XII	123.0	1		
XIII	-	-		
XIV	131.3	3		

* Computed from Schroeder (1930)

Table 7 -- Estimates of equilibrium yield for cod in Area 5Z from the generalized production model with M varying between 0.4 and 3.2.

M	Maximum Equilibrium Yield	Optimum Effort	R
0.40	34.1	49.1	.699
0.80	33.8	39.9	.708
1.20	33.6	34.0	.708
1.60	34.0	31.3	.704
2.00	34.6	29.9	.698
2.40	35.6	29.3	.692
2.80	35.4	29.1	.686
3.20	36.1	29.1	.680

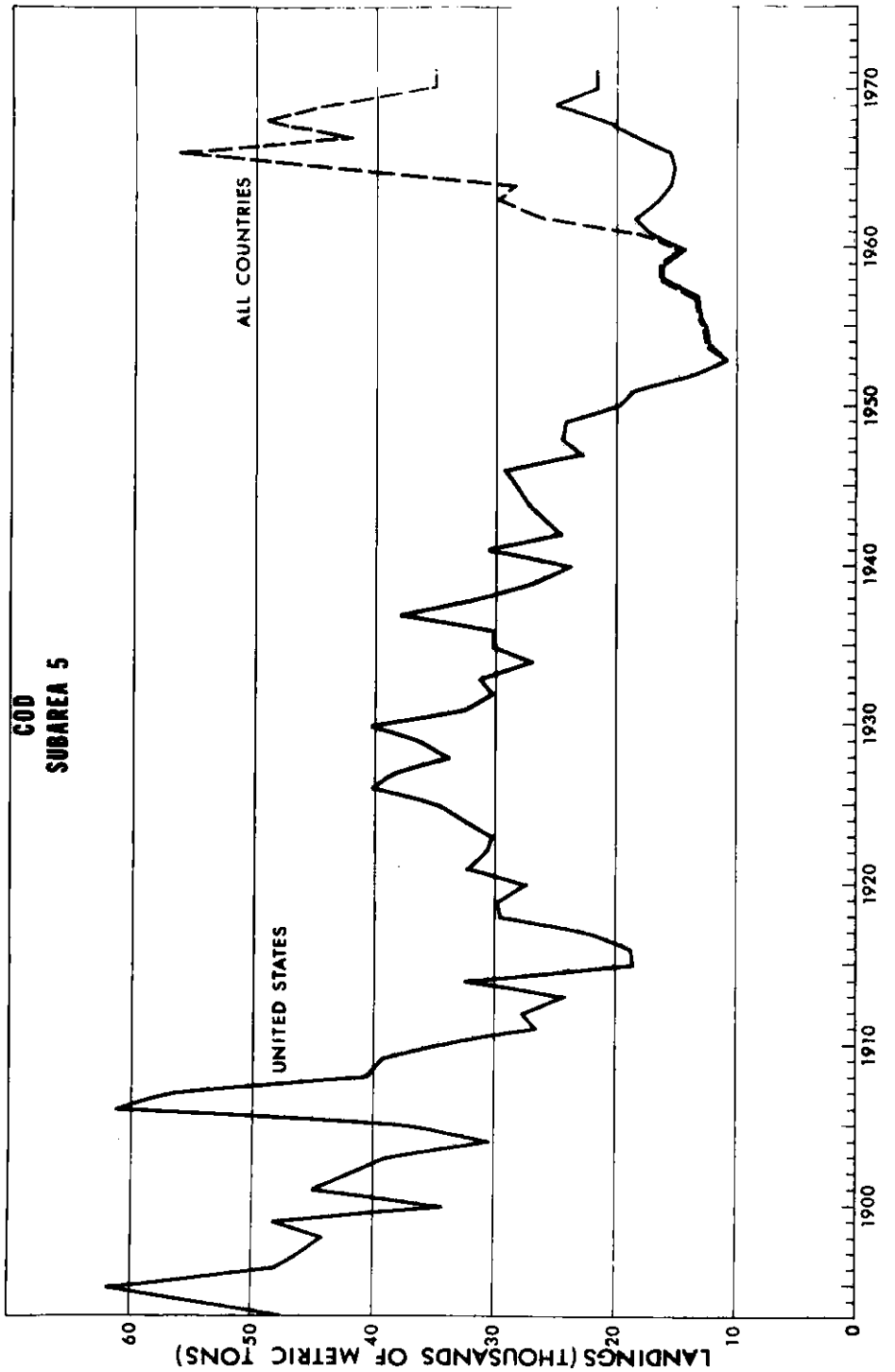

Figure 1. -- Landings of Cod since 1893.

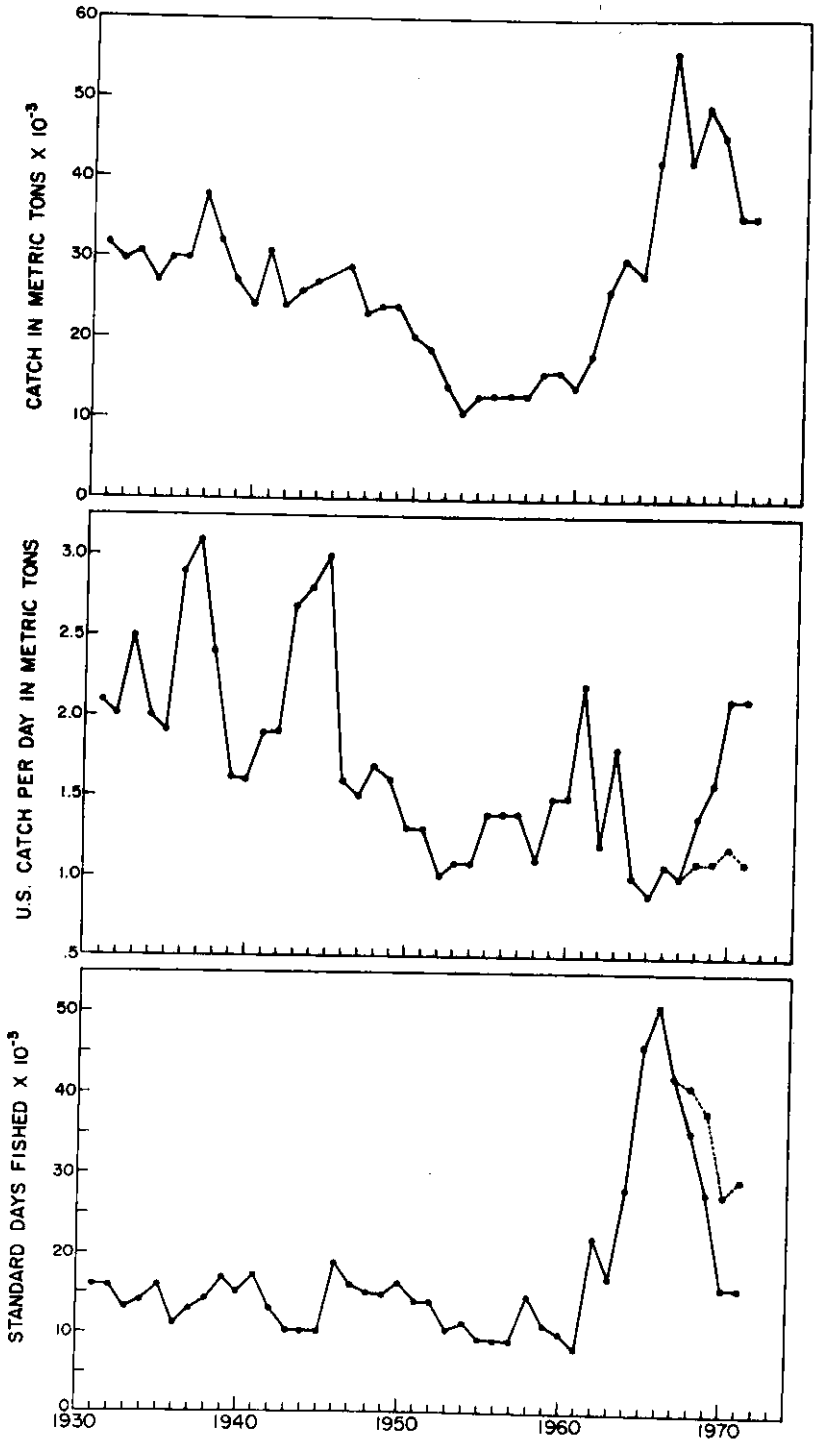

Figure 2. -- Landings, catch per day and standard days fished for Subarea 5 Cod since 1932 (dashed line indicates adjusted values).

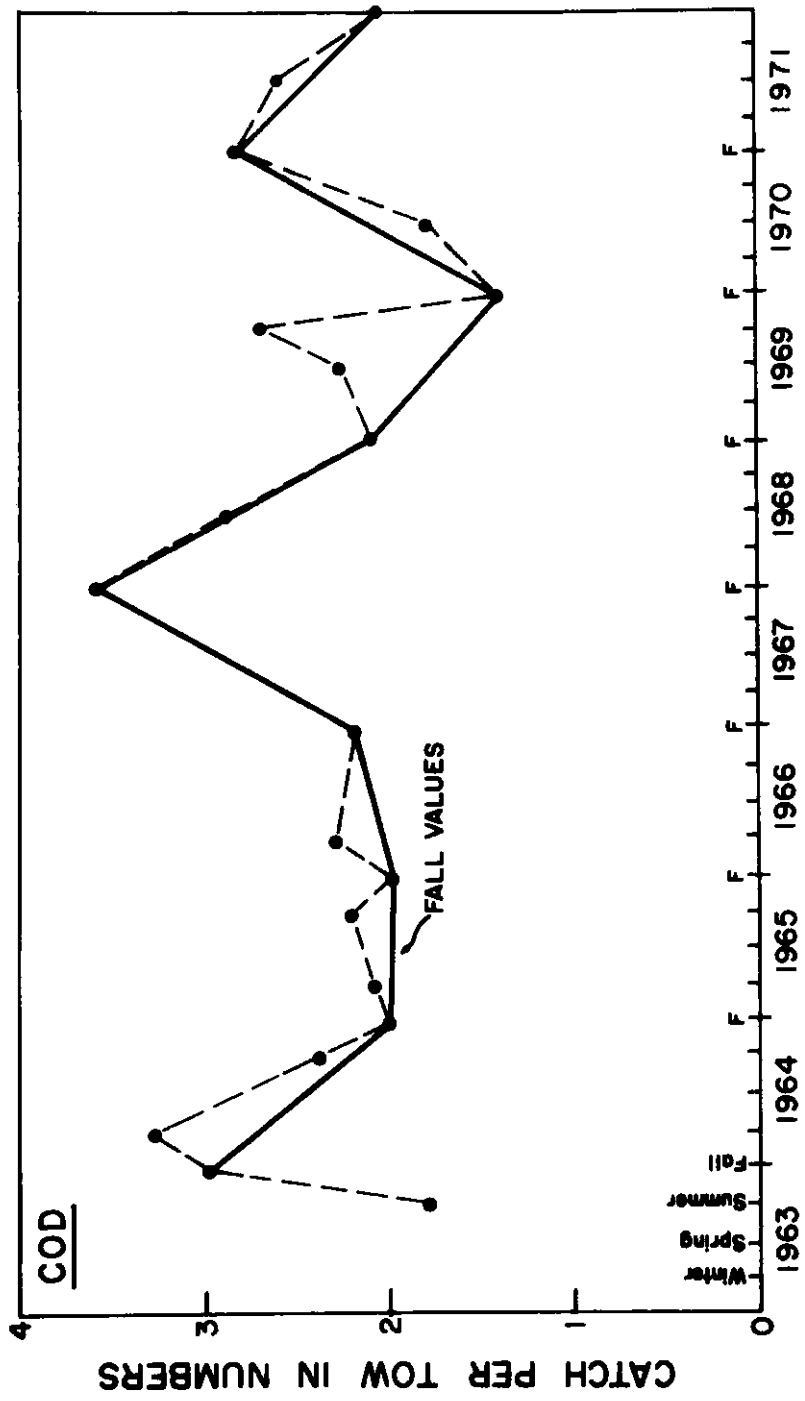

Figure 3. -- Numbers per tow of Cod from U.S. survey cruises in Subarea 5.

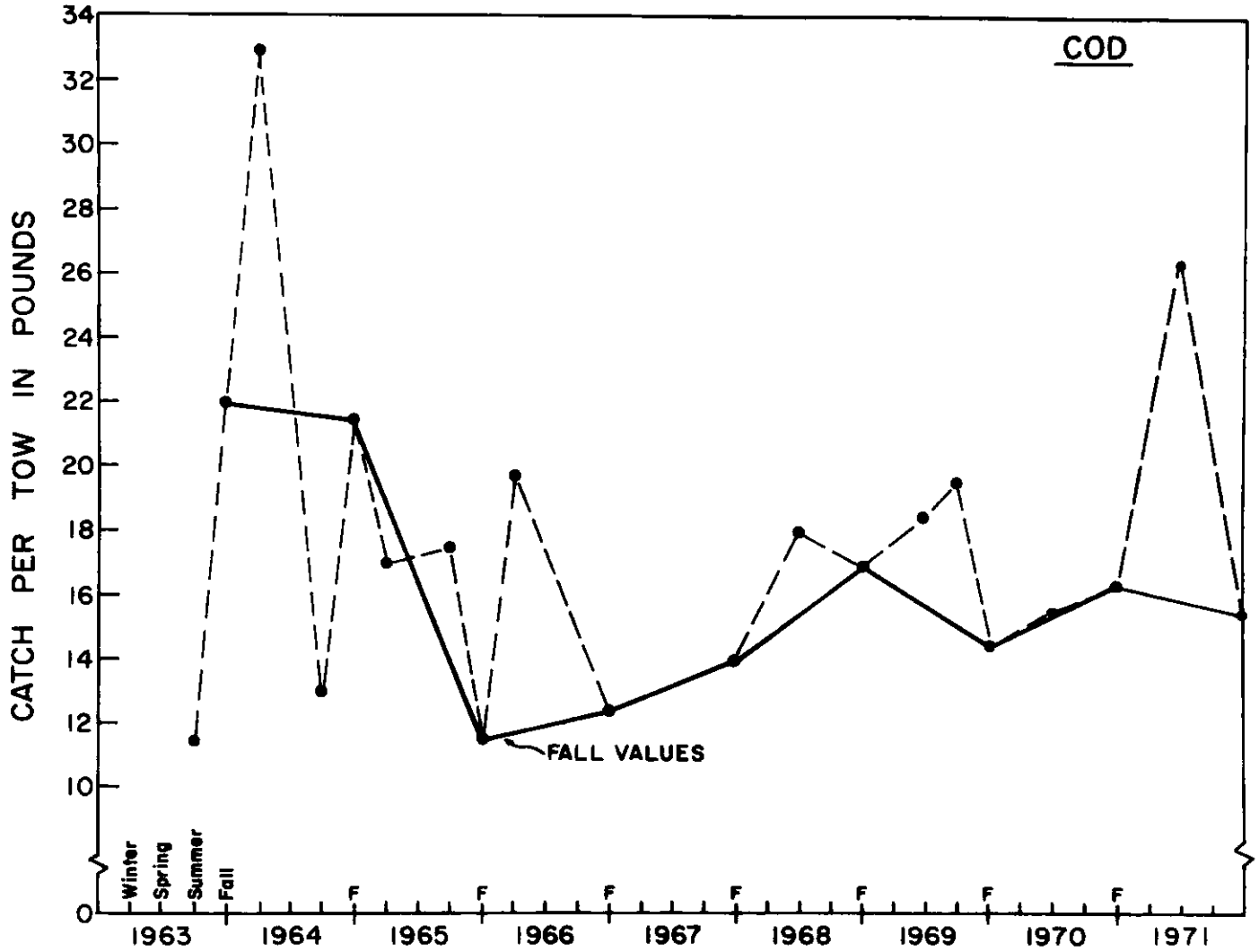

Figure 4. -- Pounds per tow of Cod from U.S. survey cruises in Subarea 5.

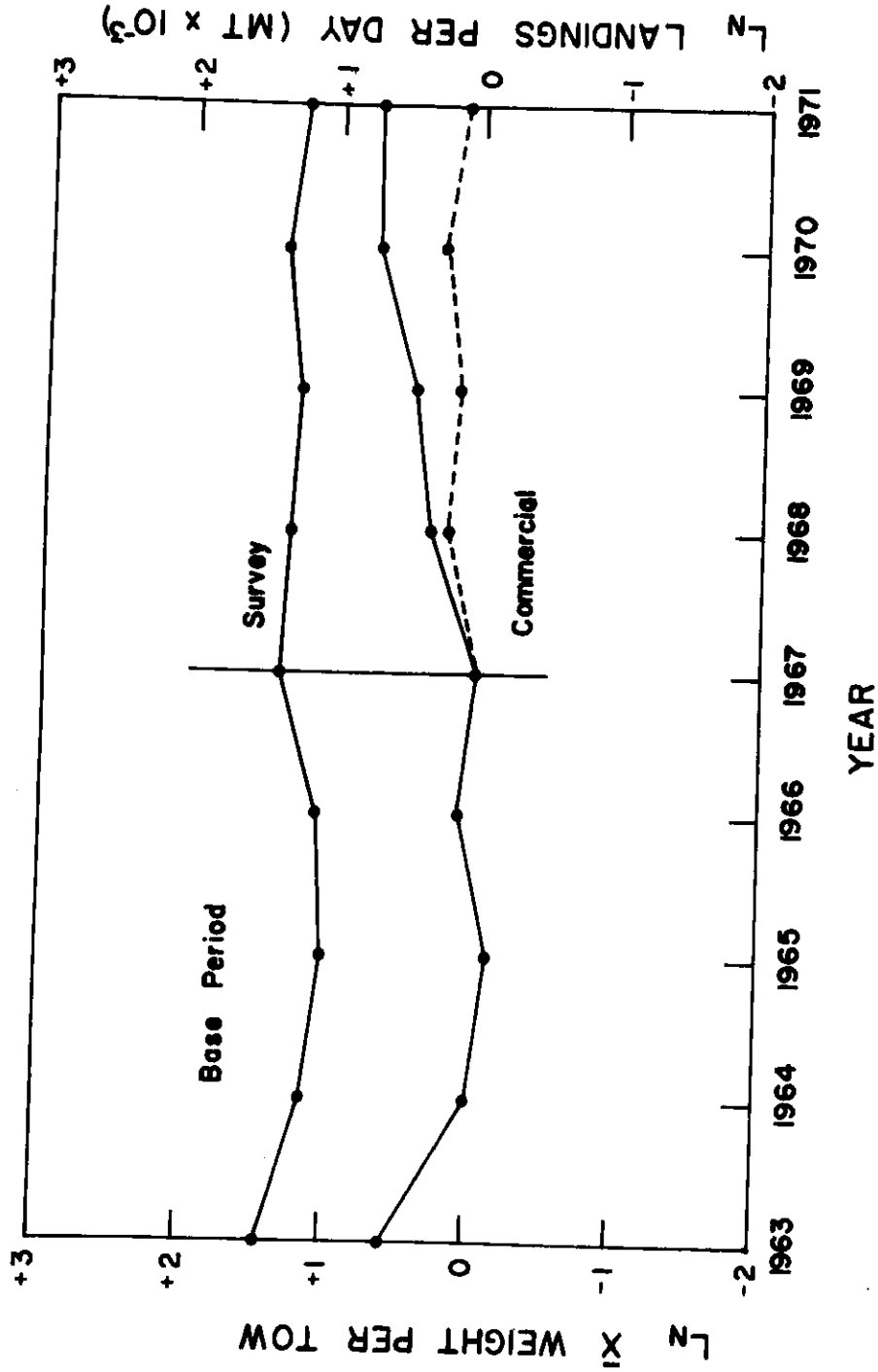

Figure 5. -- U.S. commercial landings per day for Cod in Area 5Z and pounds per tow of Cod from fall U.S. survey cruises in Subarea 5 - expressed in terms of natural logs (dashed line indicates adjusted values).

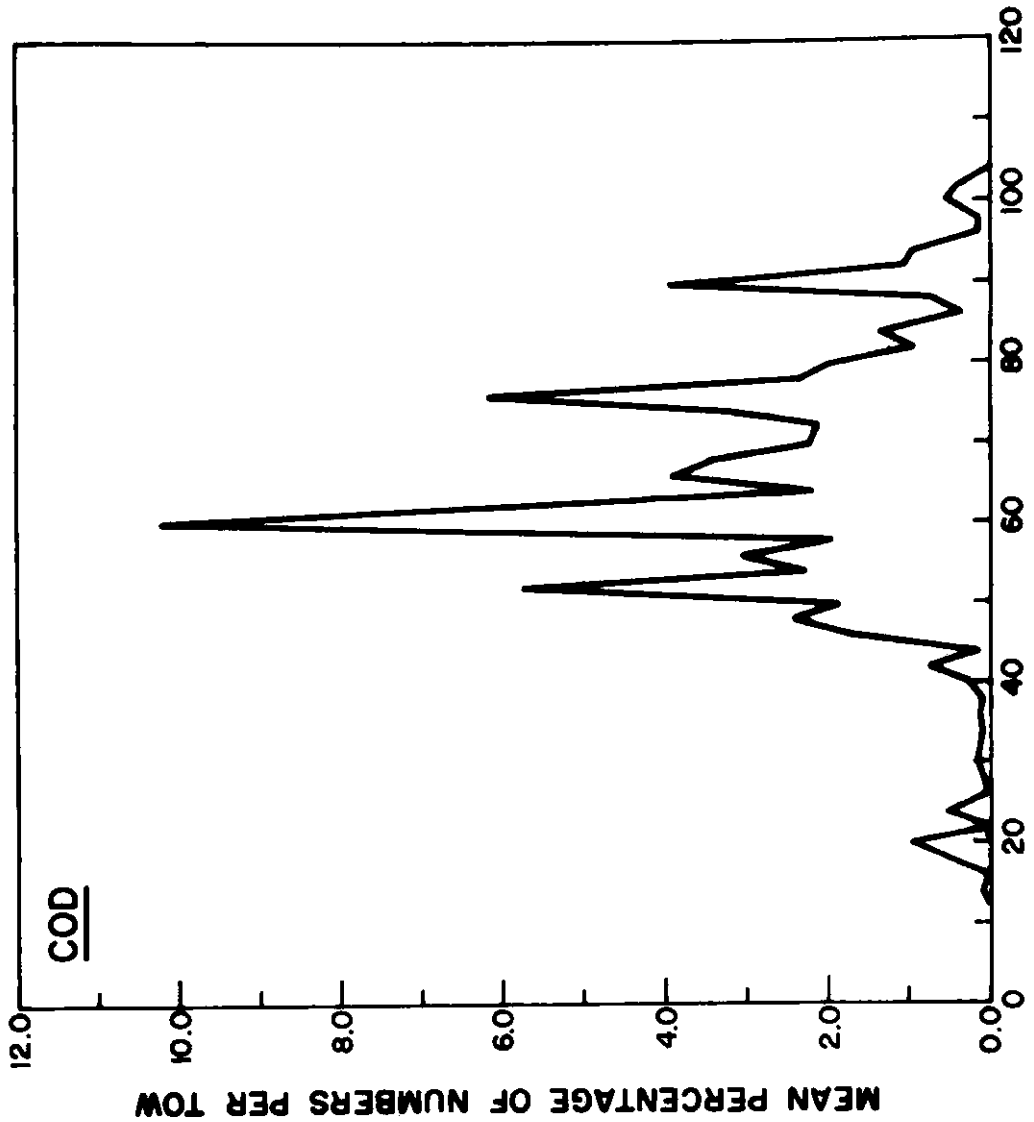

Figure 6. -- Mean of strata percent length frequency of Cod for Subarea 5 from autumn 1968 U.S. survey cruises

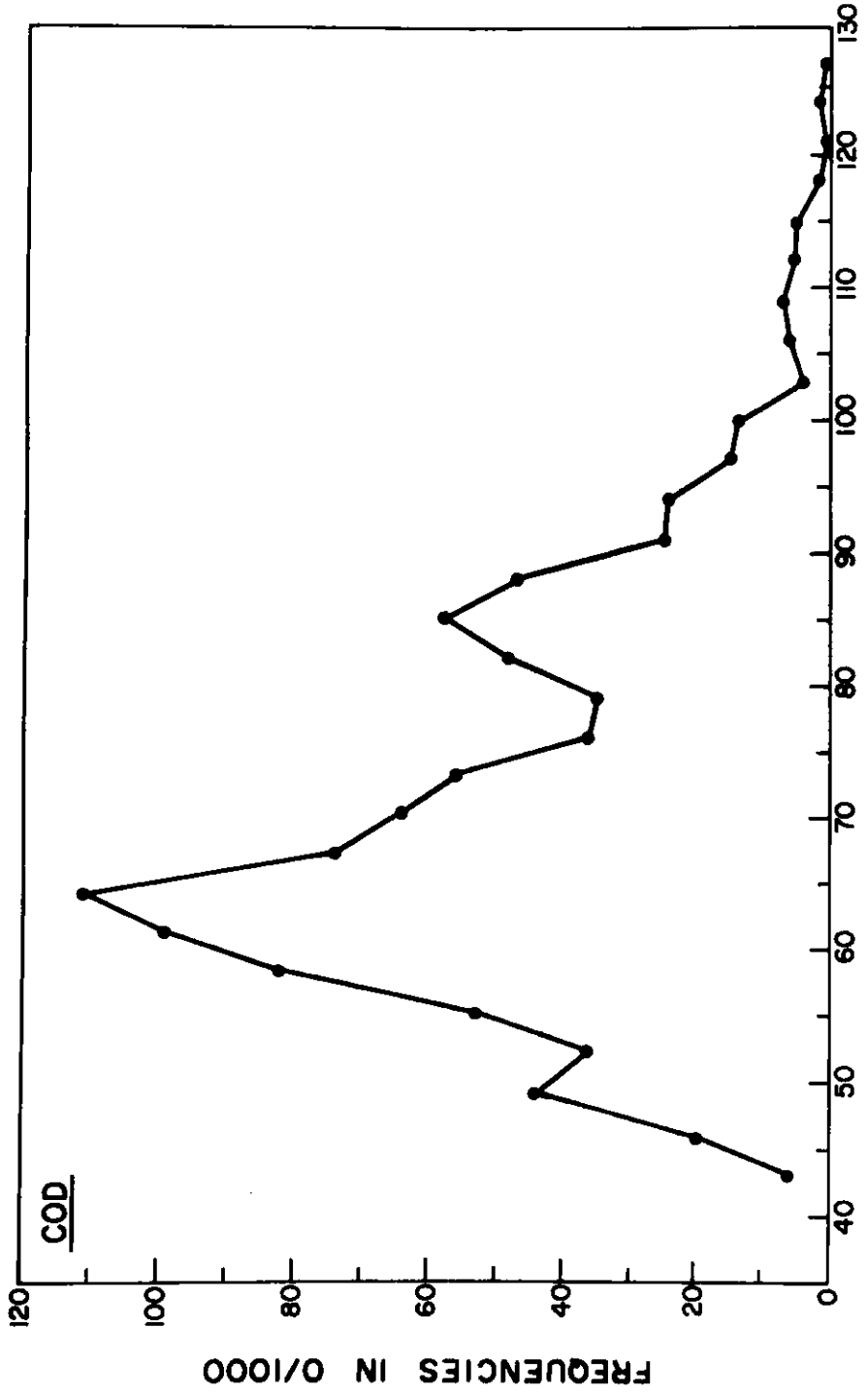

Figure 7. -- Length frequency of U.S. commercial Cod landings - January-March 1971 for Area 5Z.

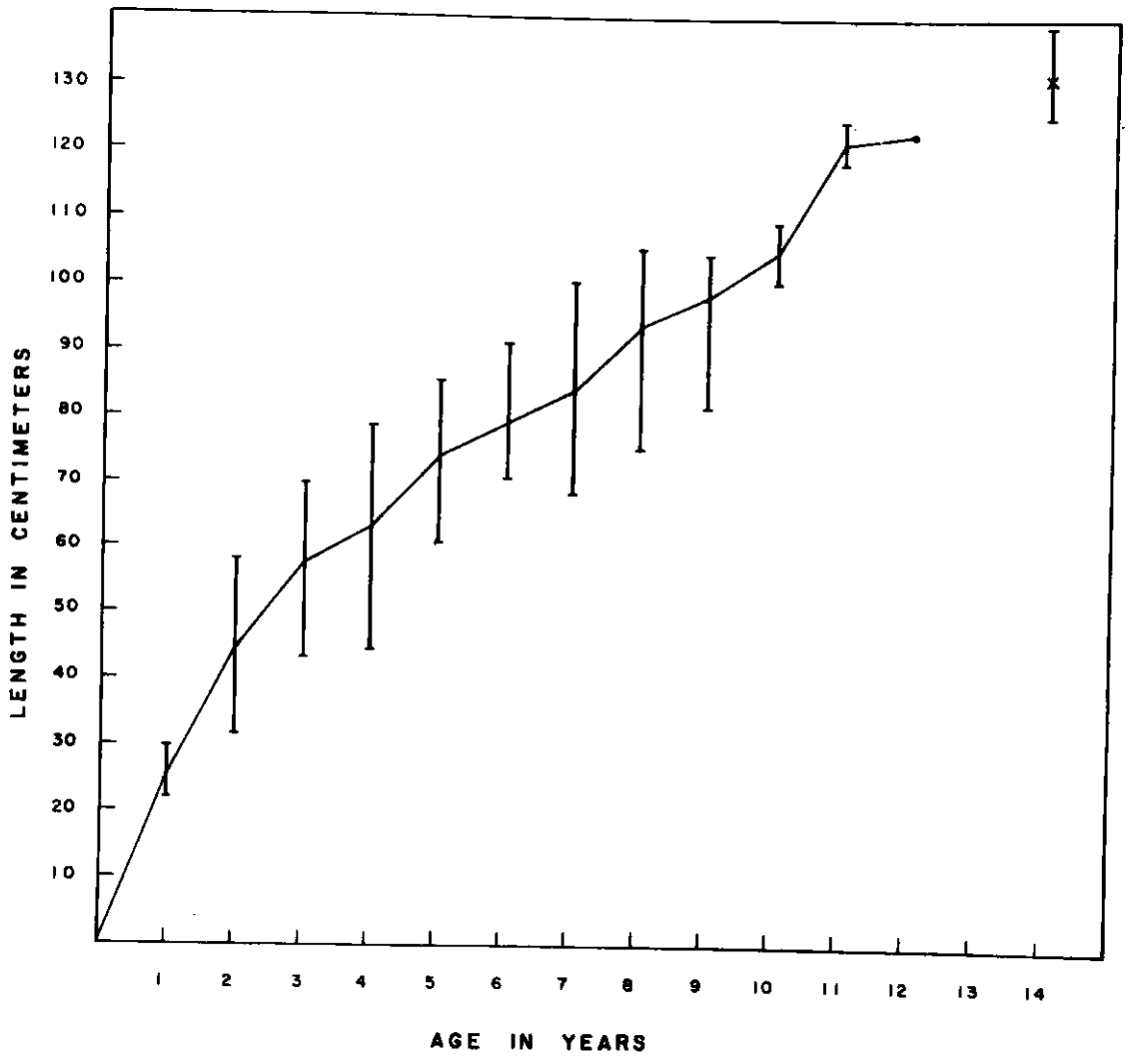

Figure 8. -- Length at capture by age group for Cod from Georges Bank - from spring 1971 U.S. survey cruises.

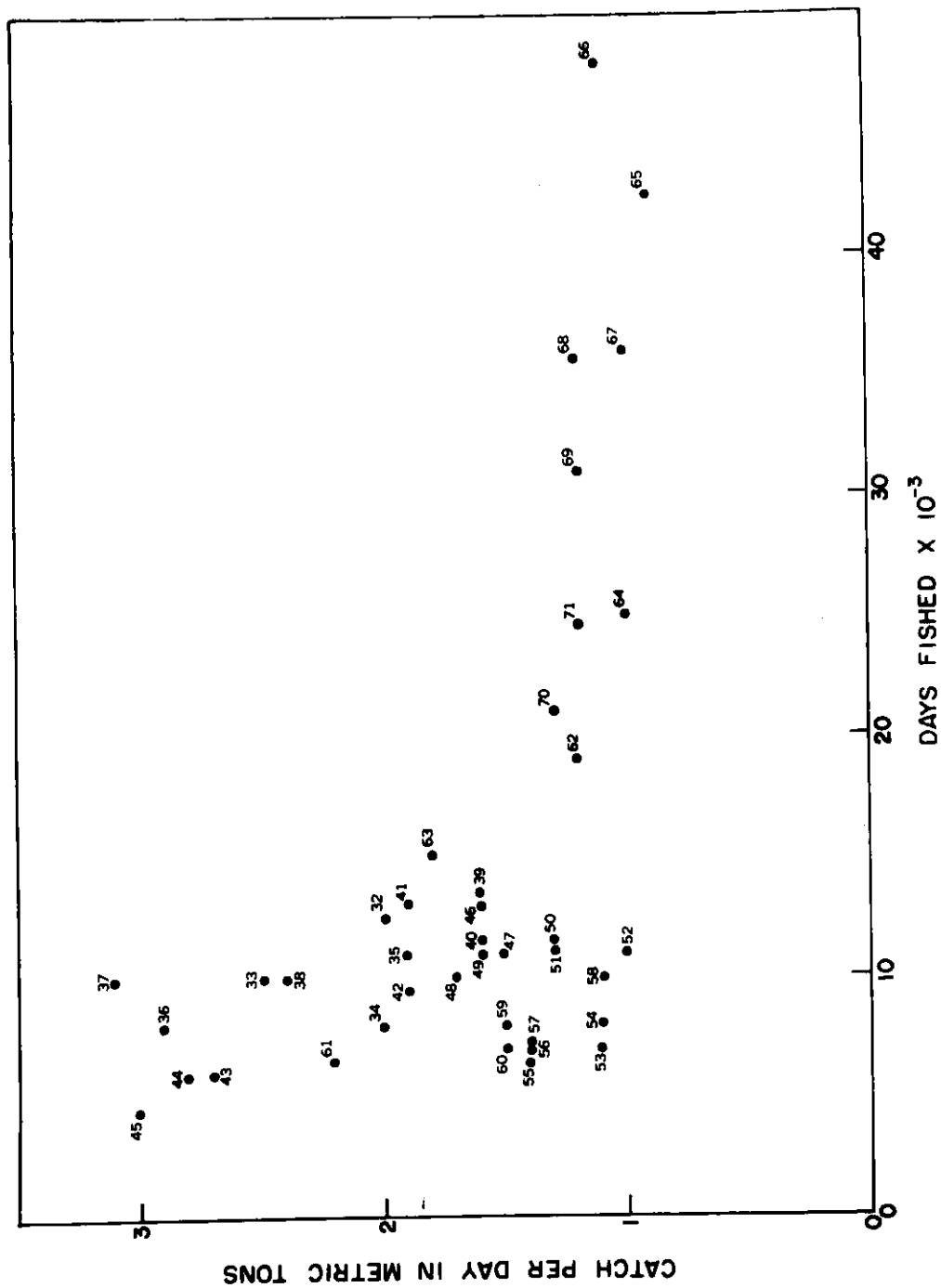

Figure 9. -- Catch per unit effort verses days fished for Cod in Area 5Z.

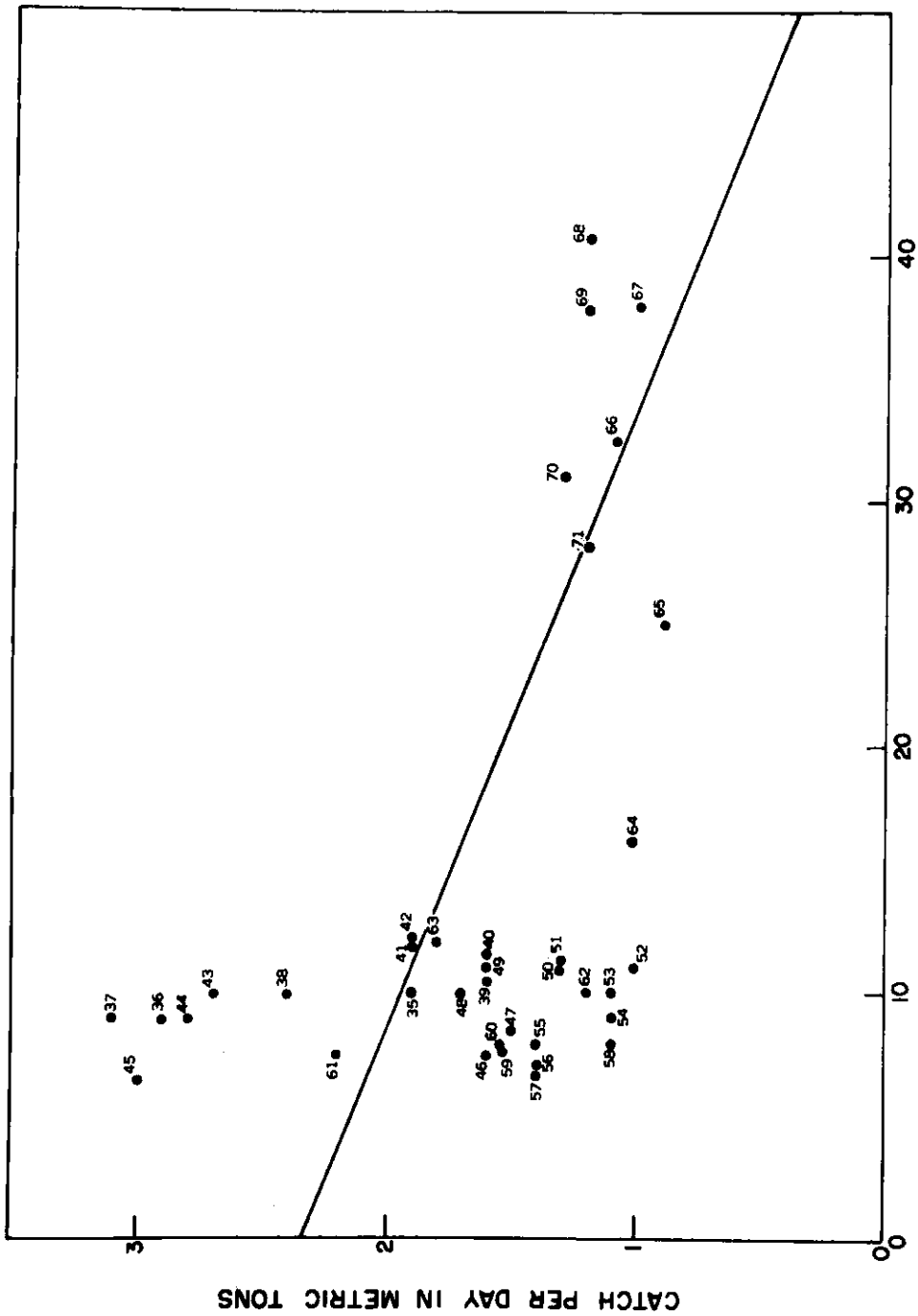

Figure 10. -- Catch per unit effort verses days fished (moving average of 4s) for Cod in Area 5Z.

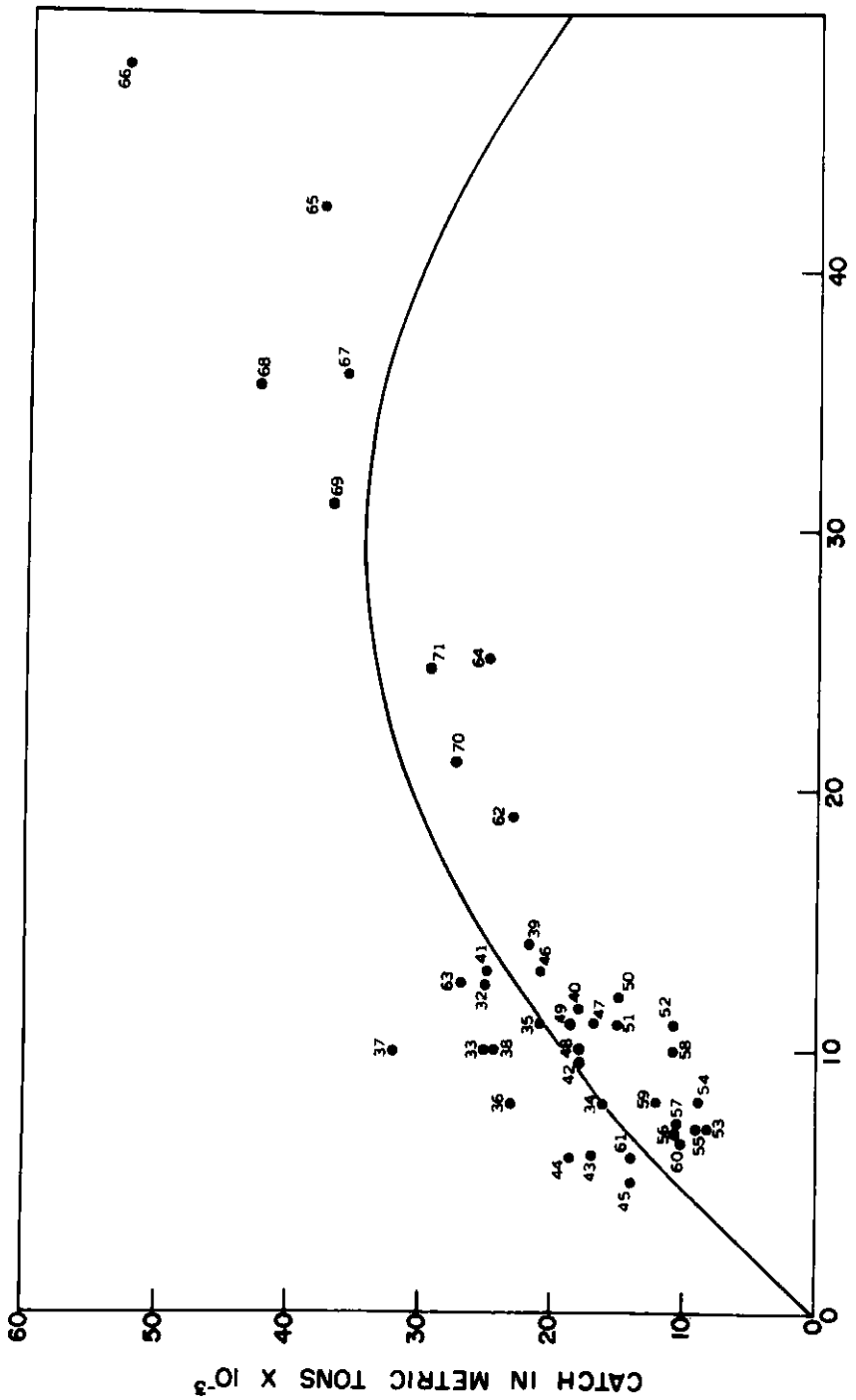

Figure 11.--- Catch verses days fished for Cod in Area 5Z.

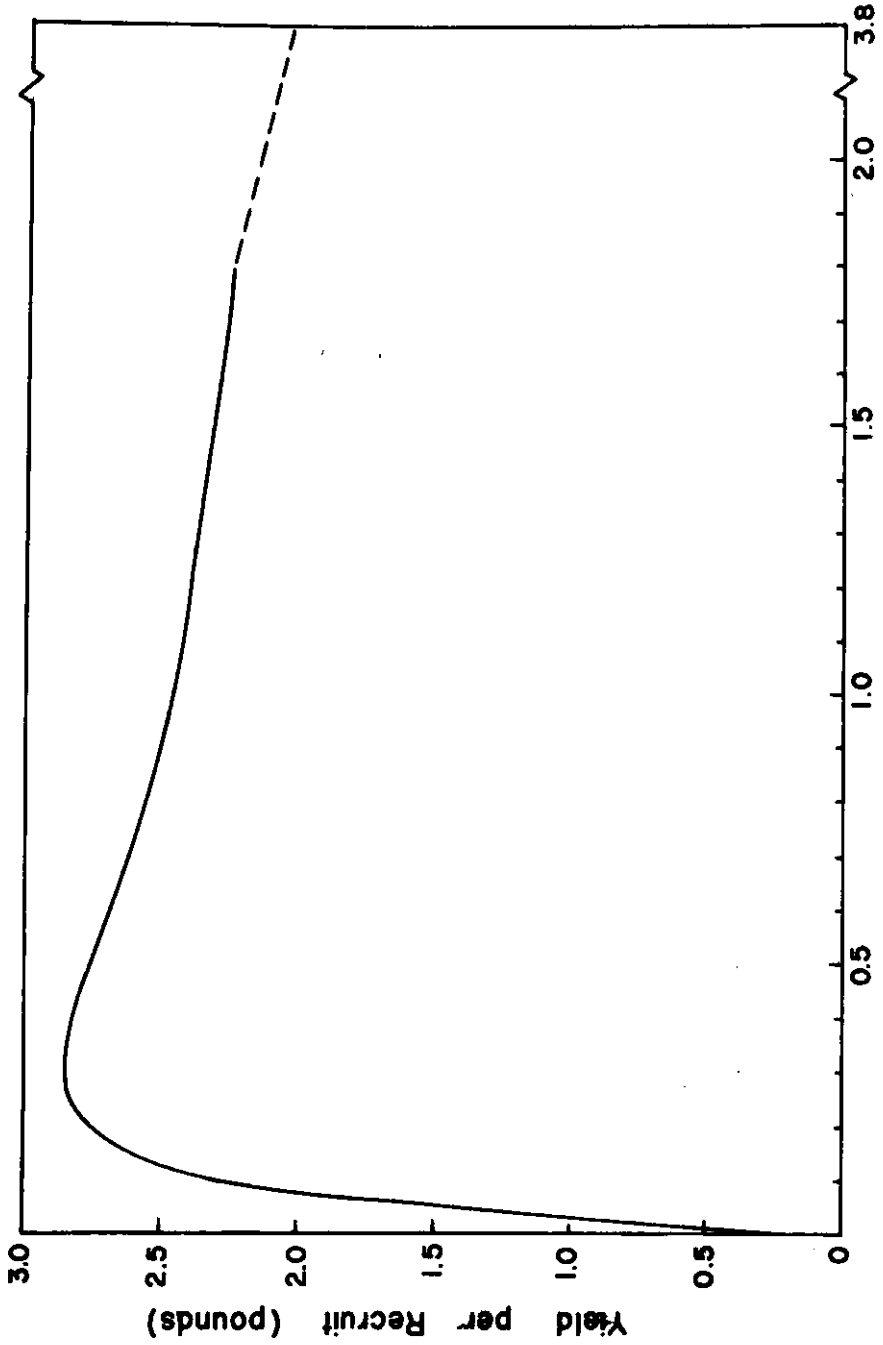

Figure 12. -- Yield per recruit curve (in pounds) for Cod in Area 5Z where: M = 0.2, F = 0.6, k = 0.116, L_∞ = 142.47 cm, l_c = 55 cm or 3.0 years, and l_r = 45 cm.