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Assessment of the Cod Stock in Subdivision 3Ps

by

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INTRODUCTION

Cod of the St. Pierre Bank form a distinct stock which supports an active inshore fishery in southern Newfoundland. The catch reached a peak in 1961 when 83,620 tons were taken. During the sixties the catch fluctuated about the 55,000 ton point but in the seventies a marked decline was evident (Fig. 1a). The corresponding catch rates showed a similar decline (Fig. 1c). There appears to be an upward trend in the catch rates starting in 1976.

A surplus yield analysis was performed to assess the condition of the stock and to obtain an updated prediction for the catch at 2/3 effort MSY. The results were compared to the cohort analysis presented at this meeting.

MATERIALS AND METHODS

The following model was postulated for the fishery (Gavaris, 1979):

$$(C/f)_{ijk} = B^{X_0} G_i^{X_i} M_j^{X_j} Y_k^{X_k} e_{ijk}$$

where C/f = catch rate

B = basic catch rate

G_i = country-gear class i

M_j = month j

Y_k = year k

X_0 = 1

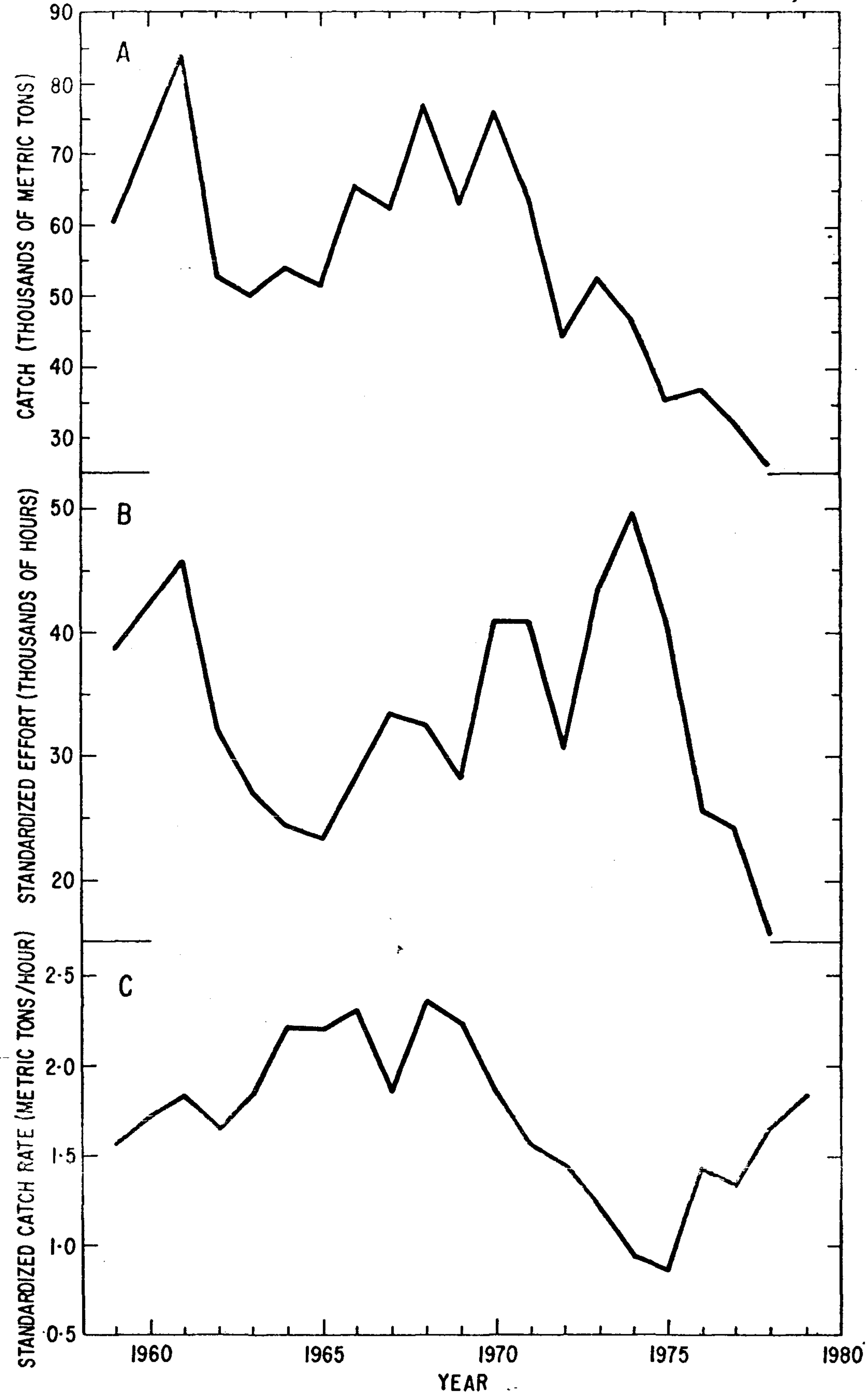

Fig. 1. Catch-effort history for cod in ICNAF Subdivision 3Ps.

$X_i = \begin{cases} 1 & \text{if country-gear class } i \text{ is used} \\ 0 & \text{otherwise} \end{cases}$

$X_j = \begin{cases} 1 & \text{if month } j \text{ occurs} \\ 0 & \text{otherwise} \end{cases}$

$X_k = \begin{cases} 1 & \text{if year } k \text{ occurs} \\ 0 & \text{otherwise} \end{cases}$

$e_{ijk} \sim LN\ (0, \sigma^2)$ (LN = log - normal)

Letting EXPRESSION´ = log (EXPRESSION) we can rewrite the model as:

$$(C/f)'_{ijk} = B'X_o + G'_iX_i + M'_jX_j + Y'_kX_k + e'_{ijk}$$

The minimum variance unbiased estimators of B', G'_i, M'_j and Y'_k are obtained using the method of least squares. Within each of the three categories, country-gear class, month and year the estimated coefficients are not all appreciably different from each other. A graphical method for grouping similar coefficients was devised (Fig. 2). A description of the method follows.

The estimated mean of the coefficient is plotted in the lower part of the graph (symbol 'X'). A line representing plus and minus some specified proportion of the standard deviation is drawn through the mean. This is done for all coefficients within a category. After this has been done a vertical line is moved across the graph. The frequency of lines intersected by the vertical line is plotted in the upper part of the graph. The result is a sequence of histograms. Various values for the proportion of the standard deviation used are tried in order to explore how the histograms merge and separate.

The graphs must then be examined and one which gives a "satisfactory" grouping is selected. There are two types of errors that could be made:

1) coefficients which should be grouped are not
2) coefficients which shouldn't be grouped are

An appreciation of the severity of each of these errors is needed in selecting the graph considered "satisfactory".

The purpose of grouping the coefficients is twofold:

1) reduce the standard deviation of the estimate
2) simplify the model

Estimates of the new coefficients for the groups (some groups may remain with only one member) were obtained using the method of least squares. The antilog of the estimates for country-gear classes and months were used to standardize the effort data (Gavaris, 1979).

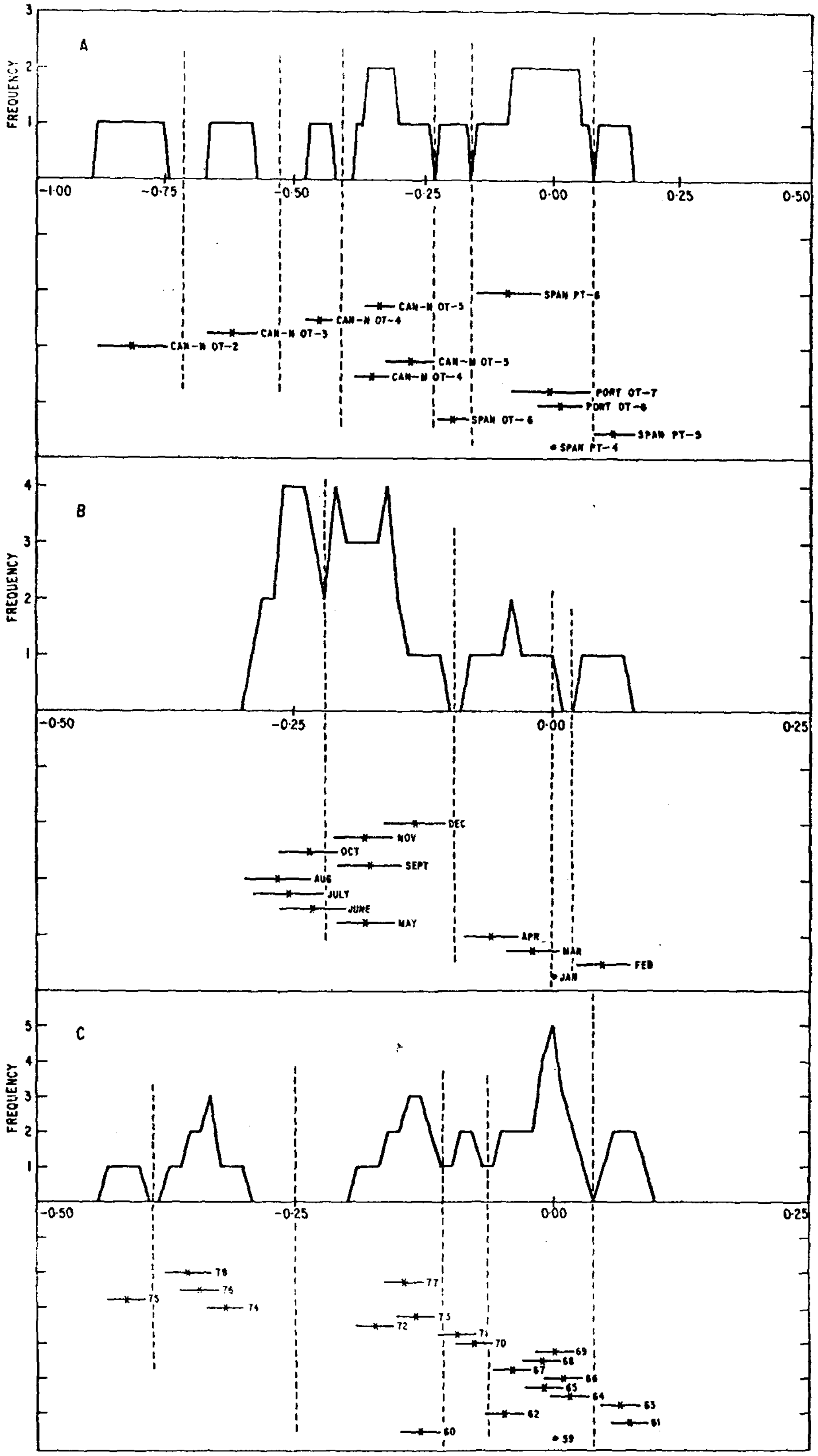

Fig. 2. Graphical grouping of the coefficients for a) the country-gear category using $\bar{x}\pm0.8s$, b) the month category using $\bar{x}\pm0.6s$, and c) the year category using $\bar{x}\pm0.25s$.

In order to apply the equilibrium surplus yield model the effort data needs to be transformed to equilibrium effort. The following weighted running average was used (Fox, 1975):

$$\bar{f}_i = \frac{kf_i + (k-1)\, f_{i-1} + \ldots + (1)\, f_{i-(k-1)}}{k + (k-1) + \ldots + 1}$$

where k is the number of significant year classes in the fishery during year i. The value for k was obtained by examining the catch at age records.

The catch and standardized equilibrium effort were fitted to the model:

$$C_i = a\bar{f}_i + b\bar{f}_i^2 + e_i$$

where C_i = catch in year i

$\bar{f}_i$ = standardized equilibrium effort in year i

$e_i \sim N\ (0, \sigma^2)$

RESULTS AND DISCUSSION

The power factors obtained from the standardization technique are presented in Tables 1 and 2. The multiple regression was very significant ($P<.001$) with a multiple R value of 0.72. The power factors for the country-gear classes show that in general power increases as tonnage class increases. The power factors for the months show an increase in catch rates during January through April with a peak in February. These high catch rates coincide with known seasonal concentrations.

The resulting standardized effort is tabulated in Table 3 along with directed catch, total catch and directed effort. Inshore catches were not classified as cod directed in this table. Table 4 gives the standardized equilibrium effort computed from the weighted running average. The corresponding number of years used for each particular average is shown.

The least squares regression line obtained for the surplus yield model was:

$$C = 3.638\ \bar{f} - 0.0000605\ \bar{f}^2 \qquad \text{(Fig. 3)}$$

The F-test showed the regression to be highly significant (P .001). Examination of the residuals showed that they were approximately normally distributed but they possessed a fairly high serial correlation (0.69). This indicates that observations are not independent of time, that is, the conditions causing the catch rates persist for several years.

The predicted catch at 2/3 effort MSY was 48,613 tons with a standard deviation of 6,664 tons. Assuming that the 1979 catch rate will persist in 1980 the suggested catch in order to attain 2/3 effort MSY was 37,069 tons with a standard deviation of 6,249 tons.

CONCLUSION

The standardized CPUE from Table 3 agreed very well with the biomass obtained in cohort analysis indicating that the catch rate is a good indicator of stock size. The correlation was R=0.94.

This surplus yield analysis assumes that population growth follows the logistic model. Although the regression was significant the data range is too small to confirm that a parabola truly represents the surplus yield. Another implication of the model is that recruitment is density dependent. In view of these limitations the results can only be reliable within the range of the observed data and only as long as large fluctuations in recruitment do not occur.

The predicted catch given by the cohort analysis was 28,000 tons at $F_{0.1}$. This is somewhat lower than the catch at 2/3 effort MSY using the 1979 catch rate. Since the catch rate for 1979 is provisional and indications are that the stock is only now starting to recover, it would be more prudent to accept the catch prediction from the cohort analysis which is compatible with catch rates from previous years. As can be seen from Fig. 3 the catch rate associated with 28,000 tons catch is intermediate to the catch rates of 1977 and 1978.

It can be seen from Table 4 that the ratio of directed offshore cod catch to total cod catch has been decreasing in recent years. This has the effect of inflating the variance of the standardized effort estimate. To alleviate the problem methods of including inshore catch and effort should be explored. A further line of approach would be the use of weighted least squares in the regression of catch on standardized effort.

REFERENCES

Fox, W.W. 1975. Fitting the generalized stock production model by least squares and equilibrium approximation. Fish. Bull. 73(1): 23-36.

Gavaris, S. 1979. Update of the Flemish Cap cod stock assessment. Intern. Comm. for the Northw. Atlant. Fish. Res. Doc. 79/VI/46 Serial No. 5385.

Table 1 Power factors for the country-gear category obtained by taking the antilog of the estimated coefficients.

COUNTRY	GEAR	POWER
SPAN	PT-5	1.33
Port	OT-6	
Port	OT-7	1.00
Span	PT-4	
Span	PT-6	
Span	OT-6	.64
Can-m	OT-4	
Can-m	OT-5	.47
Can-n	OT-5	
Can-n	OT-4	.36
Can-n	OT-3	.24
Can-n	OT-2	.15

Table 2 Power factors for the months obtained by taking the antilog of the estimated coefficients.

MONTH	POWER
Feb	1.13
Jan	1.00
Mar Apr	.92
May Sept Nov Dec	.67
Jun Jul Aug Oct	.57

Table 3 Catch, standardized effort and standardized catch rate for Subdivision 3Ps cod during 1959-79.

YEAR	DIRECTED CATCH (tons)	TOTAL CATCH (tons)	STANDARDIZED DIRECTED EFFORT (hrs)	STANDARDIZED TOTAL EFFORT (hrs)	STANDARDIZED CPUE (tons/hr)
1959	13,000	60,170	8360.53	38694.53	1.56
60	18,921	72,636	11021.99	42312.40	1.72
61	30,477	83,620	16644.44	45667.48	1.83
62	13,101	52,639	8003.03	32155.69	1.64
63	11,625	50,051	6304.77	27144.93	1.84
64	16,908	53,956	7605.69	24270.91	2.22
65	15,367	51,400	6951.42	23251.32	2.21
66	28,816	65,749	12455.73	28420.03	2.31
67	24,903	62,393	13374.15	33508.13	1.86
68	32,718	77,217	13792.37	32551.06	2.37
69	31,780	63,103	14181.80	28159.67	2.24
70	40,566	76,161	21864.61	41049.91	1.86
71	27,179	63,967	17400.64	40953.98	1.56
72	21,068	44,323	14852.06	30677.83	1.44
73	21,778	52,641	18006.63	43524.98	1.21
74	18,928	46,712	20230.96	49927.54	0.94
75	13,929	35,373	16134.77	40974.60	0.86
76	10,383	37,133	7191.35	25718.62	1.44
77	3,021	32,376	2254.99	24166.73	1.34
78	1421	26,255	855.85	15813.03	1.66
79*					1.84

*Provisional for 1979.

Table 4 Standardized equilibrium effort obtained by a weighted running average.

YEAR	STANDARDIZED EQUILIBRIUM EFFORT (hrs.)	k (yrs.)
1963	34977.9	5
1964	31918.8	6
1965	28550.3	6
1966	27394.0	6
1967	28444.1	5
1968	31082.0	4
1969	30107.9	5
1970	34065.2	5
1971	36033.2	6
1972	35281.5	5
1973	37636.7	6
1974	40709.4	7
1975	42497.8	5
1976	36917.8	4
1977	27485.3	3
1978	22816.4	4

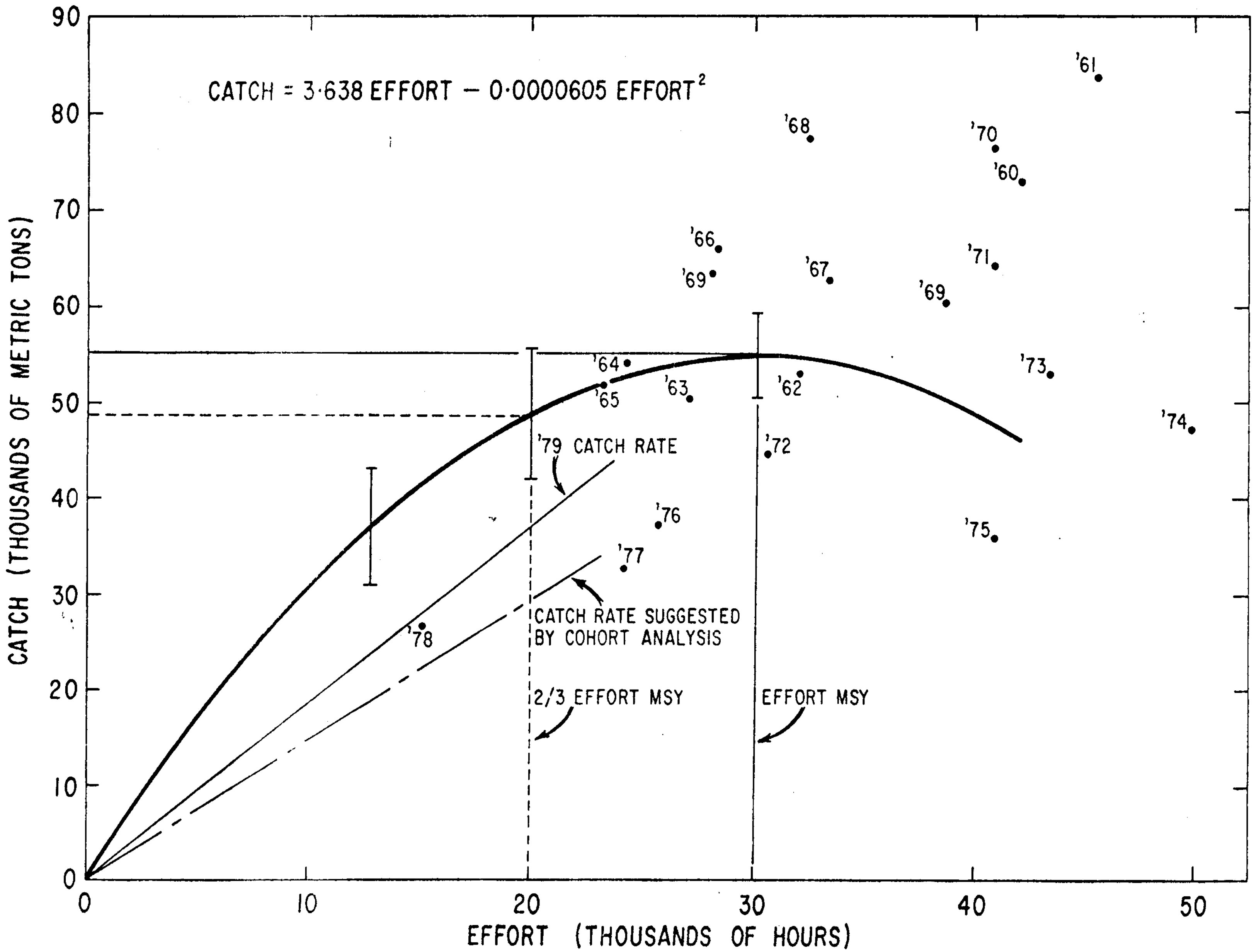

Fig. 3. Yield curve for cod in ICNAF Subdivision 3Ps showing the mean equilibrium catch at effort $_{MSY}$ and at 2/3 effort $_{MSY}$. The mean catch at 2/3 effort$_{MSY}$ using the 1979 catch rate is also shown. The vertical lines through the means represent plus and minus one standard deviation.