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Update of the Flemish Cap Cod Stock Assessment

by

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INTRODUCTION

The total cod catch from Flemish Cap has shown considerable variation in the years 1960-77. This has been due to variations in the strength of year-classes as well as in effort expended. In 1978 the TAC was set at 40,000 tons, 15,000 tons higher than the value based on a general production analysis, because of indications that a strong year-class (1973 class) was entering the fishery. The effect of that year-class can now be objectively assessed by including the recent catch-rates in the general production analysis.

Practically all of the catch-effort data was incorporated in the analysis by use of a standardization technique based on a multiplicative model for catch-rate. Similar models have been used in fishery analyses previously (Gulland, 1956; Robson, 1966).

METHOD

The following model was postulated for catch-rate.

$$C/f = B\ G\ M\ Y$$

where C/f = catch-rate
B = basic catch-rate
G = country-gear
M = month
Y = year

The model states that any particular catch-rate is the result of a basic catch-rate modified by "power factors" to take into account the efficiency of the gear and country operating it (G), the seasonal concentrations (M), and variations in year-class strength (Y). Now let

$$X_o = 1$$

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

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

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

then the model can be written

$$C/f = B^{X_0} G_i^{X_i} M_j^{X_j} Y_k^{X_k} \quad e_{ijk}$$

where e_{ijk} is the error term for the ijk'th observation. Taking logarithms of both sides we have:

$$\log (C/f) = (\log B)\ X_0 + (\log G_i)\ X_i + (\log M_j)\ X_j + (\log Y_k)\ X_k + \log (e_{ijk})$$

let EXPRESSION$'$= log (EXPRESSION)

We can then express the relationship as a model which is linear in the parameters.

$$(C/f)' = B'X_0 + G_i'\ X_i + M_j'\ X_j + Y_k'\ X_k + e_{ijk}'$$

The estimators $\hat{b}'$, $\hat{g}_i'$, $\hat{m}_j'$ and $\hat{y}_k'$ obtained by fitting a line using least squares are minimum variance unbiased estimators of B', G_i', M_j' and Y_k'. If references concerning these estimates are to be made the assumption on normality and constant variance of the errors must be satisfied; ie: $e_{ijk}' \sim N\ (0, \sigma^2)$. The The corresponding estimators $\hat{b}$, $\hat{g}_i$, $\hat{m}_j$ and $\hat{y}_k$, obtained by taking the antilog of the former estimators, are not least squares estimators, however they are good estimators for predicting the mean catch-rate for a given vector X.

It should be noted that additional linear constraints are needed to solve the normal equations. The following were used in this analysis:

$$G_0' = 0$$
$$M_0' = 0$$
$$Y_0' = 0$$

This is equivalent to

$$G_0 = 1$$
$$M_0 = 1$$
$$Y_0 = 1$$

Consequently, all the power factors obtained are relative to G_0, M_0, and Y_0.

Many of the estimates for the power factors had wide confidence intervals which were overlapping. To reduce the large variances the treatments, within categories, which did not have significantly different power factors were grouped. There were three categories, country-gears, months and years. Kramer's (1956) modification of Duncan's multiple range test, taking into account unequal numbers of replications, was used to group the treatment means of catch-rates within each category. A group was considered homogeneous if

$$\{(\overline{C/f})_i' - (\overline{C/f})_j'\} \sqrt{\frac{2n_i\ n_j}{n_i+n_j}} < z\sqrt{MSR}$$

for all i and j in the group

where $(\overline{C/f})'$ = mean of log catch-rates for a treatment ie: March
n = number of replications
MSR = mean square of residuals from complete model
z = appropriate value from studentized range table

The above formula is based on the assumption that the means are uncorrelated and their respective variances are MSR/n. Since we do not have true replications (we have a three-way incomplete block design) this may not be exactly true. Use of the exact formula, in Kramer (1957), however would involve excessive computation.

From the resulting homogeneous groups within each category a set of groups which were disjoint and suggested reasonable associations was selected. This set of groups was then subjected to backwards stepwise regression in order to remove those group powers which were not significantly different from the standard (the standard may be a group). The remaining power estimates were used to standardize the effort data in the manner shown below.

Let us concern ourselves with only one power factor, P_1. After having estimated P_1, we could write $(C/f)_1 = B\ P.$

$$\text{also } (C/f)_0 = B \quad \text{since } P_0 = 1$$

For a given catch, C_a we have

$$C_{a/f_1} = C_{a/f_0}\ P_1$$

If C_a is the catch that 1 obtained by applying effort f_1, then f_0 is the equivalent effort that the standard, 0, would have applied for the same catch, ie: the standardized effort f_s. After simplification we have

$$f_s = P_1\ f_1$$

It is clear then that to add the efforts of different country-gear treatments for different months within the same year the effort should be standardized using the formula

$$f_s = G_i\ M_j\ f_{ij}$$

Since G_i and M_j are unknown parameters the estimators $\hat{g}_i$ and $\hat{m}_j$ are used.

The catch and standardized effort data were used as input for the PRODFIT computer program (Fox, 1975). The formula used in this program is

$$C/f = (a + bf)^{\frac{1}{m-1}}$$

Here f is a weighted average given by

$$\frac{f_i\ (k) + f_{i-1}\ (k-1) + \ldots + f_{i-(k-1)}\ (1)}{k + (k-1) + \ldots + (1)}$$

where k = number of significant ages in the fishery various values of m were tried in the model. For the purpose of comparison the results obtained from a conventional analysis using a two-year running average are presented.

RESULTS

The gear-country category was partitioned into three groups. (See Table 1 below). The highest power was associated primarily with otter trawls in tonnage class 7 from various countries as well as Portuguese otter trawls in tonnage class 6 and Spanish pair trawls in tonnage class 4. One of the Canadian otter trawls and the two United Kingdom trawls were lowest in efficiency. The months category was partitioned into two groups. February and March showed significantly higher catch-rates than the rest of the year.

The regression from which the power factors were obtained was highly significant (P<.001) and had a multiple correlation coefficient of R=0.46. All of the power factors used were significantly different from the standard (P<.05). Examination of the residuals did not suggest serious violations of the assumptions for the model.

Figure 1 shows a plot of the standardized catch-rates and catch-rates for Portugal otter trawls in tonnage class 6. The trends are similar and the correlation between the two catch-rates is R=0.72. If 1960 is not considered then the correlation would be R=0.87.

The standardized data (Table 2) gave a satisfactory fit to the PRODFIT model when m was fixed at 2 ie: typical Schaeffer curve. The MSY obtained from this general production analysis was 38,931 tons, (See Fig. 2) with an error index of 7%. This error index can be thought of as a standard error although strictly speaking it is not.

The MSY obtained by using a two-year running average of effort and performing a linear regression of the catch-rate on that effort was 38,940 tons.

CONCLUSIONS

The multiplicative model for catch-rate gave results suggesting that the large tonnage class boats were more efficient in general. Experience in the fishery however must play a role since the Portuguese and Spanish small vessels were also very efficient. February and March were singled out as being better months for fishing. This is reasonable as these months coincide with pre-spawning and spawning concentrations.

The general production analysis gave an MSY of 38,931 tons and a catch for 2/3 effort MSY of approximately 34,000 tons. These results are in general agreement with previous assessments (Wells, 1978).

The information available to date for 1978 (foreign fleet observer reports, FLASH, and Newfoundland catch-effort data) gave a standardized catch-rate of 0.54 tons/hour (See Fig. 2). There is no sign that the stock density has increased substantially despite indications that a strong year-class should have entered the fishery.

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Table 1. Relative power factors for the gear-country and month categories, found by using a multiplicative model.

GEAR-COUNTRY			POWER	MONTH	POWER
FRG	OT	GT-1999		February	1.40
Poland	OT	GT-1999		March	
Portugal	OT	1000-1999	1.00		
Portugal	OT	GT-1999		January	
Spain	PT	IS0-499		April	1.00
USSR	OT	GT-1999		May	
				June	
Canada	OT	150-499		July	
Iceland	OT	500-999		August	
Norway	LL	150-499		September	1.00
Norway	OT	150-499		October	
Spain	OT	1000-1999	0.67	November	
Spain	PT	500-999		December	
USSR	OT	500-999			
USSR	OT	1000-999			
Canada	OT	500-999			
UK	OT	500-999	0.39		
UK	OT	1000-999			

Table 2. Directed and total catch and standardized directed and total effort for 1960-77.

Year	Directed Catch	Total Catch	Directed Effort	Total Effort
1960	662	5573	324.62	2732.79
1961	3006	22,996	1519.98	11,627.90
1962	3640	16,175	3174.60	14,106.91
1963	11,033	38,216	4295.33	14,878.12
1964	7181	47,819	5230.05	34,827.41
1965	37,248	60,313	27,613.20	44,712.06
1966	12,327	33,834	8,212.52	22,540.96
1967	19,671	42,163	11,697.04	25,071.55
1968	15,148	40,385	9,952.03	26,532.40
1969	9,977	31,845	5756.68	18,374.41
1970	10,918	26,529	9216.58	22,394.41
1971	8335	33,629	8443.51	34,066.80
1972	41,177	57,691	43,112.95	60.403.37
1973	12,932	22,900	16,198.09	28.683.60
1974	12,620	24,941	10,209.14	20,176.41
1975	13,234	22,375	17,897.88	30,260.32
1976	13,697	22,266	15,413.25	25,055.96
1977	7611	27,042	10,821.75	38,449.81

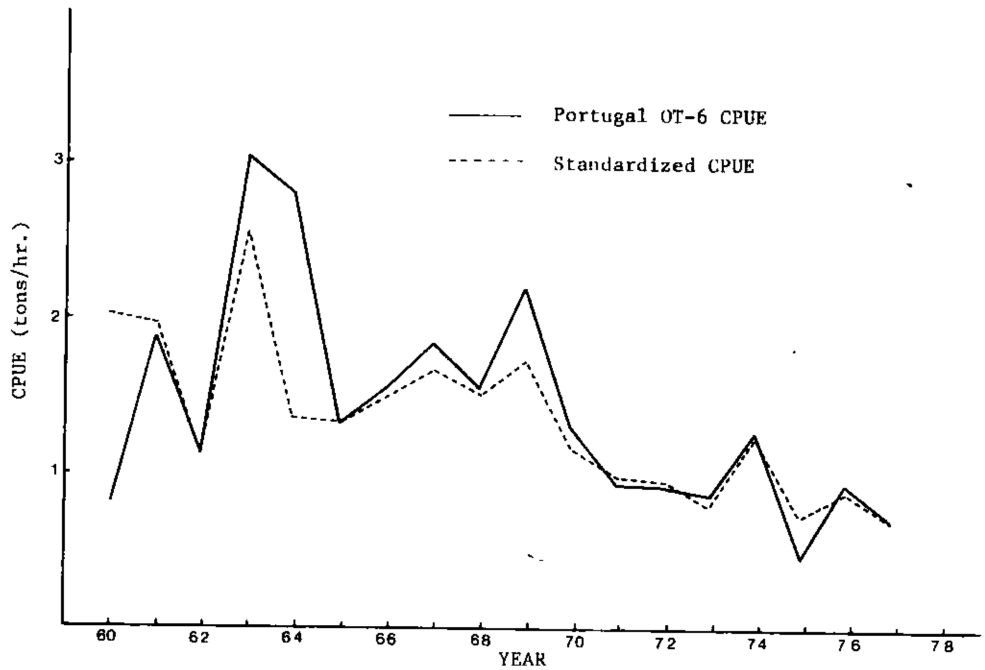

Fig. 1. Comparison of the standardized catch-rate and the catch-rate for Portuguese OT-6.

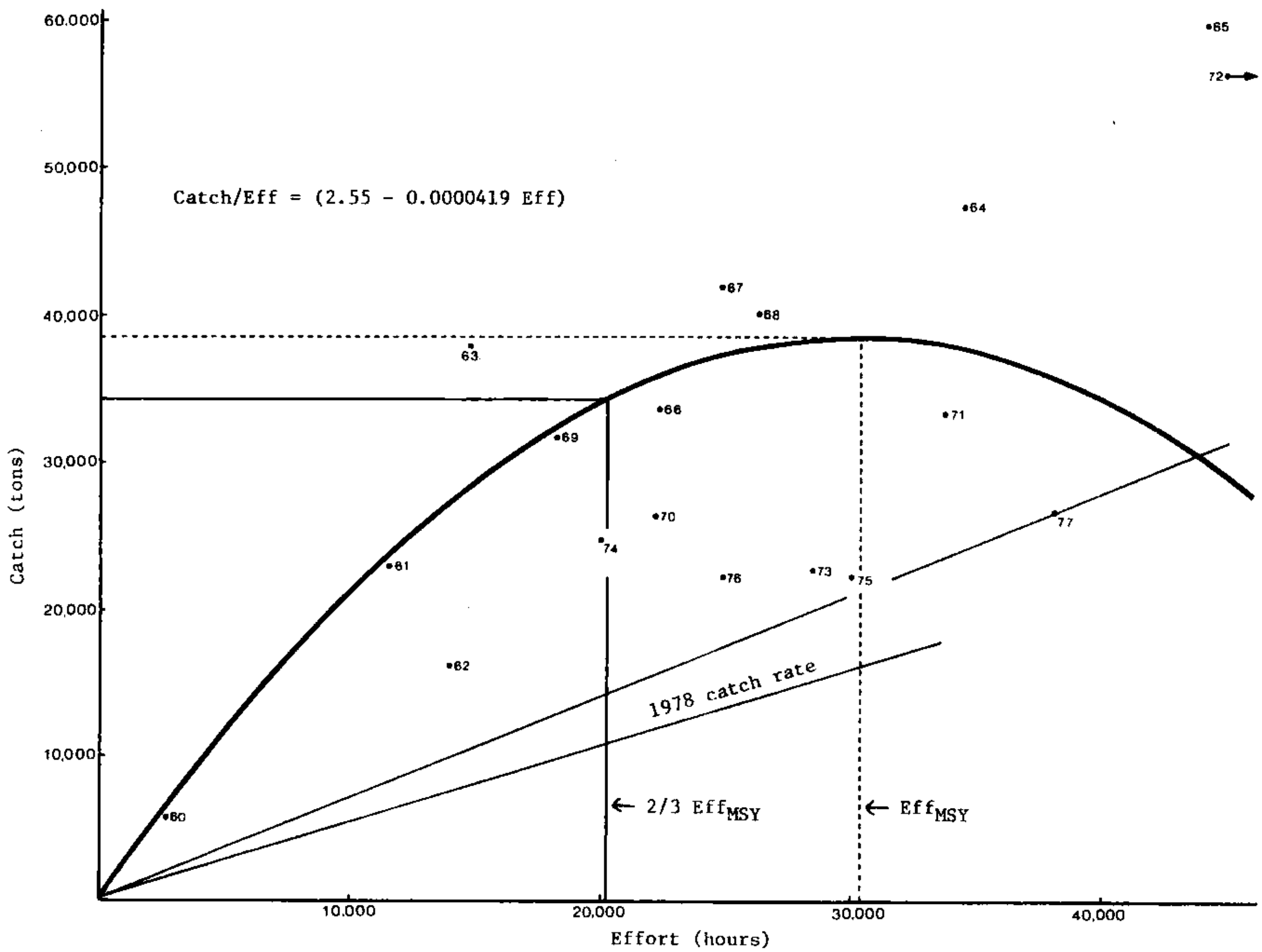

Fig. 2. General production curve obtained by using PRODFIT program with m = 2.