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Assessment of Cod Stock in Divisions 3NO

by

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INTRODUCTION

The regressions of the c.p.u.e. on effort for this stock have not so far been clear at all. In recent years it has been concluded that the stock is in a very depleted state, owing to a strong overfishing. Nevertheless, figure 3 of Gavaris paper (1979) does not show any symptom of overfishing because almost all points lie on the left side of the optimum effort level. On the other hand a fit of the data using m=5 in the PRODFIT (Fox, 1975) model gives quite unrealistic curves because such a population would become easily extinguished by natural selection.

METHOD

Following the multiplicative model proposed by Gavaris (1979)

$$\overline{C}_{dgmy} = B_d * G_g * M_m * Y_y \qquad (1)$$

where, $\overline{C}_{dgmy}$ = average catch in Division $\underline{d}$, by country-gear $\underline{g}$, during month $\underline{m}$ of year $\underline{y}$.

B_d = constant of the model for Division $\underline{d}$.

G_g = country-gear $\underline{g}$ factor.

M_m = month $\underline{m}$ factor.

Y_y = year $\underline{y}$ factor.

A new model is proposed to resolve the above model by considering that the distribution of $\overline{C}_{dgmy}$ values, being each one a mean, will be close to the normal one.

Several authors have studied the daily catch distribution of a vessel (Taylor, 1953; Larrañeta, 1967) and they have found skew distributions with an intermediate variance between that which would correspond to a random destribution of the fishable stock ($\sigma_c^2 \sim \overline{c}$) and that of a homogeneous one ($\sigma_c^2 \sim \overline{c}^2$).

In this paper two cases have been considered,

1) the variance being proportional to the square of the mean values, as some authors have assumed (Stark, 1971; Brennan, 1977; Laurec, 1979)

2) the variance being proportional to the mean of catches raised to 1.5 power.

Lacking a greater evidence to fix the value of the exponent and taking into account the similarity of the results obtained in the two cases, we choose the second one (1.5). This exponent was found to be the most suitable one in other stocks we have studied.

Let $\underline{k}$ be the exponent

$$\sigma^2_{\bar{C}_{dgmy}} = \frac{\sigma^2_{c_{dgmy}}}{f_{dgmy}} = \frac{(\bar{C}_{dgmy})^k}{f_{dgmy}} * V_g \qquad (2)$$

where V_g is the constant of proportionality corresponding to each country-gear, and c_{dgmy} is the catch at every country-gear unit effort in division $\underline{d}$, month $\underline{m}$ and year $\underline{y}$. The value of every parameter can be obtained from (1). For instance, going to the year factor

$$Y_y = \frac{\bar{C}_{dgmy}}{B_d \cdot G_g \cdot M_m}$$

Assuming that $\bar{C}$ has a normal distribution, an unbiased estimator of Y_y will be the average of the values calculated from the previous formula. But, as every term has its proper variance, when the mean value is calculated each term is weighted by the reciprocal of its variance.

$$\sigma^2_{Y_y} = \frac{\sigma^2_{\bar{c}_{dgmy}}}{B_d^2 \cdot G_g^2 \cdot M_m^2} = \frac{(B_d \cdot G_g \cdot M_m)^{k-2} \cdot Y_y^k}{f_{dgmy}} * V_g$$

$$\hat{Y}_y = \frac{\displaystyle\sum_{dgm} \frac{C_{dgmy}}{(B_d \cdot G_g \cdot M_m)^{k-1} \cdot V_g}}{\displaystyle\sum_{dgm} \frac{f_{dgmy}}{(B_d \cdot G_g \cdot M_m)^{k-2} \cdot V_g}} \qquad (3)$$

where C_{dgmy} is the whole catch in division $\underline{d}$, with country-gear $\underline{g}$, during month $\underline{m}$ and year $\underline{y}$. Similar formulas are deduced for the other factors.

The V_g values are estimated from the equation (2)

$$V_g = \frac{\sigma^2_{\bar{C}_{dgmy}} * f_{dgmy}}{(\bar{c}_{dgmy})^k}$$

$$\hat{V}_g = \frac{\displaystyle\sum_{dmy} \left[\left(\frac{C_{dgmy}}{f_{dgmy}} - B_d \cdot G_g \cdot M_m \cdot Y_y \right)^2 * f_{dgmy} \Big/ (B_d \cdot G_g \cdot M_m \cdot Y_y)^k \right]}{d.f.} \qquad (4)$$

where N-2 are taken as degrees of freedom (d.f.) being N the number of the terms used in the calculus.

The meaning of V_g is clarified by expression (4); that is, V_g is an estimator of the deviation between the nominal catches of country--gear $\underline{g}$ and those expected from the model. In other words, it determines what country-gear gives rise to more accurate c.p.u.e. values of the density of the stock.

The equation system of factors and V_g is solved by iteration, fixing previously

$$G_1 = M_1 = Y_1 = 1.$$

and using $\hat{V}_g/\hat{V}_1$ instead of V_g.

As these factors are means weighted by the reciprocal of the variance, the parametric variance of the estimation will be

$$\sigma_{\hat{p}}^2 = \frac{1}{\sum \frac{1}{\sigma_p^2}}$$

The factor values obtained by this system of equations using monthly nominal data on catch and effort of all countries in 3NO during 1954-1977 and also those of Spain for 1978 are shown in Table 1.

There is not a significant difference between Div. 3N and 3O (Table 1). So, the year factor can be considered as an index of abundance of the fishable stock in 3NO together.

The years factors, which are derived from all the fleets in the fishery, will be a more accurate abundance index than those based on c.p.u.e. of a particular country-gear.

A value of the total annual effort being proportional to the fishing mortality is estimated as the ratio between the total catch in that year and the year factor.

The values of the factor corresponding to each country-gear show an apparent discrepancy. Normally, the nominal effort is measured in hours fished but the unit for Canada (MQ)-Dory vessel is measured in 1000 hooks, for Portugal-GNS that listed in Statistical Bulletin and for France OT 6 day fished. For Portugal-Dory vessel the hour fished is not referred to the whole fishing unit but to each dory.

Country-gear factors are not quite true fishing power ones but also an index of the directness to the cod fishery. Unexpected low values in this factor are associated to high by-catch values. In order to clarify this point the same analysis has been carried out by using total catch instead of cod catch. The new factor of country-gear ("total" colum in Table 1) would be more realistic about the fishing power although unexplained situations persist.

On applying the Pella-Tomlinson production model to this stock, the annual effort data were weighted after Fox (1975) method, being the maximum factor 8.33 because a period of 9 years is taken and in the lowest age (4 years) recruitment factor is 0.33. The computer program PRODFIT (Fox, 1975) was used to calculate the regression between the Y_y values and the average fishing effort from 1954 to 1977.

An estimation of the density of the stock in 1979 (Y_{1979}) was calculated from the catch and effort data of Spanish fleet, using equation (3) and factors listed in table 1.

RESULTS

The computer program PRODFIT gives the regression lines that are shown in figure 1, line 1 for the not weighting option and line 2 for the weighting option of the program. Points in figure 1 are very dispersed around these regression lines. An eye-fitted line would have a greater slope and perhaps it will be a more realistic fit. When m is calculated a value of 5 is obtained in the PRODFIT model, as Gavaris does, giving curve 3, but we think that it is quite unrealistic because of natural selection, as pointed out in the introduction .

A new approach is given in figure 2 where 10 points (63-72) are associated to regression line 1 and 5 points (62 and 73-76) to regression line 2. The lowest point (77) is not taken into account. The point series begins with a point (62) on regression 2 and inmediately leaps to regression 1 and, finally, there are 4 points , the series ending on regression 2 again. Least-square fitted line cuts effort scale at 256,295 units when regression 1 and at 268,933 units when regression 2, but 260,000 has been chosen as a common point for both regressions. Point (72) could be considered as a transitional one not belonging to any regression, but then regression 1 would cross effort scale at 316,000 units and we have been afraid to exagerate the optimum effort.

These two regressions lead to curves 1 and 2, respectively, in figure 3. Using provisional data on total catches and the Spanish data on catch and effort for 1978 point (78) is obtained; its position so distant from the cloud of points what leads us to suspect that something is wrong.

From our point of view both curves show a double equilibrium relationship between the fishing effort and the yield. These two equilibrium curves will occur if there are two stock-recruitment curves, as proposed by Larrañeta (1978) to occur when a general ecological change has taken place. From Larrañeta's analysis about the biological meaning of the parameters of the Ricker model R=APexp(-BP) in a stock(P)-recruitment(R) relationship, it results than parameter A is related to the ecological niche, and if parameter A changes the stock-recruitment curve also changes producing a new effort-yield relationship as between curves 1 and 2 in figure 3, or, more precisely, curve 2 would cross the effort scale at a lower level than curve 1.

The curves of figure 3 are parabolic, as a result of applying the model of Pella and Tomlinson when m=2. The distribution of the points does not invite to use a coefficient lesser than 2.

Parameters of both curves are shown in table 2, where c.p.u.e. of the Spanish fleet in 1979 is an estimation of the annual factor Y_{1979}, as described previously. This value is the angular coefficient of the straight line in figure 3, crossing the 2/3 optimum effort level at a yield of 68,500 tons.

DISCUSSION

If points in figure 2 are really belonging to two regression lines, two hypothesis seem to be reasonable.

a) Ecological hypothesis. The leap from one regression to another is exclusively caused by ecological factors. In fact, all points of line 2 are below points of line 1, both series between the same effort range. The "crisis" from 1958 to 1962 took place when there was a relatively small level of fishing effort and the recovery at equal or greater efforts (figure 4). Nevertheless, when the stock is in state "2" it will be more sensitive to a danger of overfishing because optimum effort is minor than when in state "1" (In figure 2 both lines, as a simplification, cross effort scale at the same point , but if point (72) is not included in regression 1 the maximum effort will be greater).

b) Fishing-ecological hypothesis. When fishing increases then spawning stock is reduced and, therefore, the egg-stock. On arriving at a threshold zone of minimum egg-stock some adverse ecological event, as the increase of a competitor species, creates a new ecological state that persists until the spawning cod stock arises till a new upper threshold zone and with favorable conditions "switches" from state "2" to state "1" again.

It seems that fishing will play some rôle, as a component of the factor complex of the environment (hypothesis b), so that the crisis will not be a purely ecological question (hypothesis a), but it also seems that in the range of the historical data the fishing mortality has been a minor factor leading the population by regression 1 or regression 2.

We realise that a cod stock consists normally of a number of recruited age-groups as to reflect suddenly changes of the stock-recruitment relationship and that the detected periods are rather too short. Usually natural periods of high and low density are explained through good or poor annual classes belonging to the same stock-recruitment curve; however in this case points would lie only around a single regression line, and this is not the matter if the picture of the figure 2 is not an artifact. We mean that good and poor annual classes are organized around two possible levels of stock-recruitment relationship, the difference of both curves to be reflected in parameter A (that related to density-independent mortality), giving the normal and critical periods. In any case, the low periods detected in this stock have been not "collapses", to mean a very great depletion, but merely "crisis".

CONCLUSIONS

From empirical data ot seems that in this fishery a real overfising never took place; on the contrary low catch per unit effort levels could be associated with periods of low recruitment, and that to recover the stock to the highest yield it seems not necessary to reduce the fishing from the normal levels of effort.

According to the catch per unit effort of the Spanish fleet in 1979 a TAC of 68,500 tons will be advisable for 1980. If the theory of two levels of stock-recruitment relationship is to be not ignored, it will be prudent to consider that nowadays the equilibrium yield at 2/3 of the optimum effort is around 65,000 tons rather than 85,000 tons as previously has been portulated (Gavaris, 1979).

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TABLE 1

Division	B_d	Country-gear	G_g	"total"	Month	M_m	year	Y_y
3N	1.126	SPA PT 4	1.00	1.00	JAN	1.00	1954	1.00
30	1.163	SPA PT 5	1.56	1.46	FEB	1.05	1955	.86
		SPA PT 6	1.44	2.05	MAR	.77	1956	1.45
		SPA OT 6	1.05	1.05	APR	.87	1957	1.28
		POR DV 3	.025	.022	MAY	1.00	1958	.74
		POR DV 4	.028	.025	JUN	1.14	1959	.89
		POR DV 5	.028	.026	JUL	1.12	1960	.86
		POR DV 6	.034	.030	AUG	.98	1961	.97
		POR GNS 5	.21	.25	SEP	.89	1962	.82
		POR GNS 6	.35	.35	OCT	.76	1963	1.50
		POR OT 6	1.38	1.33	NOV	.95	1964	1.21
		POR OT 7	1.29	1.31	DEC	1.08	1965	1.34
		FRA-M OT 6	18.44	18.54			1966	1.23
		CAN-MQ DV 3	.44	.41			1967	1.46
		CAN-MQ DV 4	.77	.71			1968	1.23
		CAN-MQ OT 4	.51	.79			1969	1.08
		CAN-MQ St 5	.69	1.04			1970	.97
		CAN-N OT 4	.43	.73			1971	1.09
		CAN-N OT 5	.50	.76			1972	.77
		UK OT 5	.48	.53			1973	.58
		UK OT 6	.76	.79			1974	.60
		UK OT 7	.95	1.09			1975	.63
		USSR OT 5	.31	.62			1976	.72
		USSR OT 6	.34	.40			1977	.49
		USSR OT 7	.86	1.47			1978	.11

TABLE 2

	Curve 1	Curve 2	units
Maximum effort (X_{max})	260 000	260 000	SPA PT 4/hour,JAN,1954
Optimum effort (X_{MSY})	130 000	130 000	" " " "
MSY	117 000	72 800	tons
Effort at 2/3 MSY	86 667	86 667	SPA PT 4/hour,JAN,1954
Yield at $X_{2/3\ MSY}$	104 000	64 711	tons
Abundance estimation for 1979 from spanish fleet (Y_{1979})	0.796	0.796	tons p.u.e.

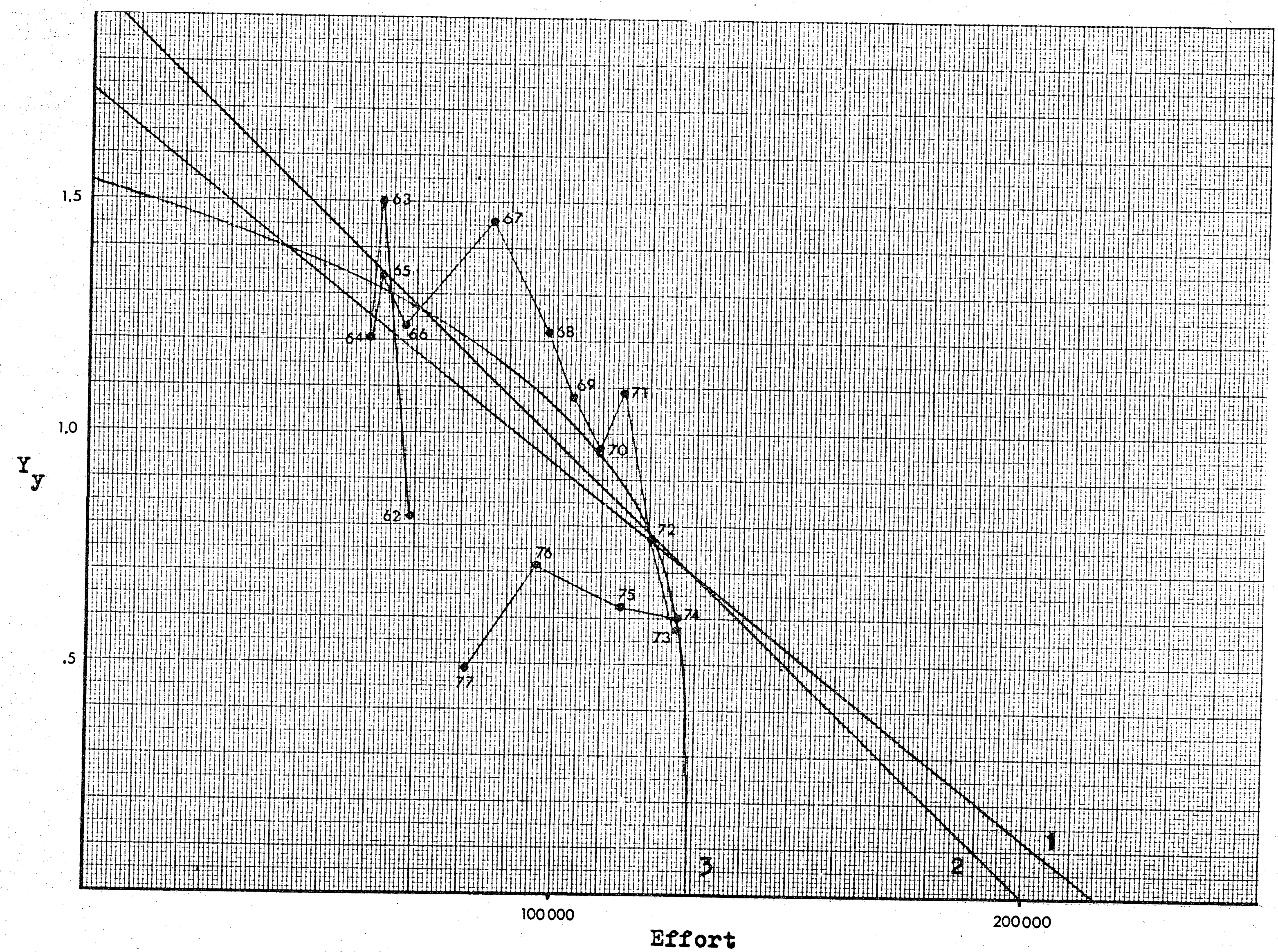

FIGURE 1.- Least squares lines using computer program PRODFIT

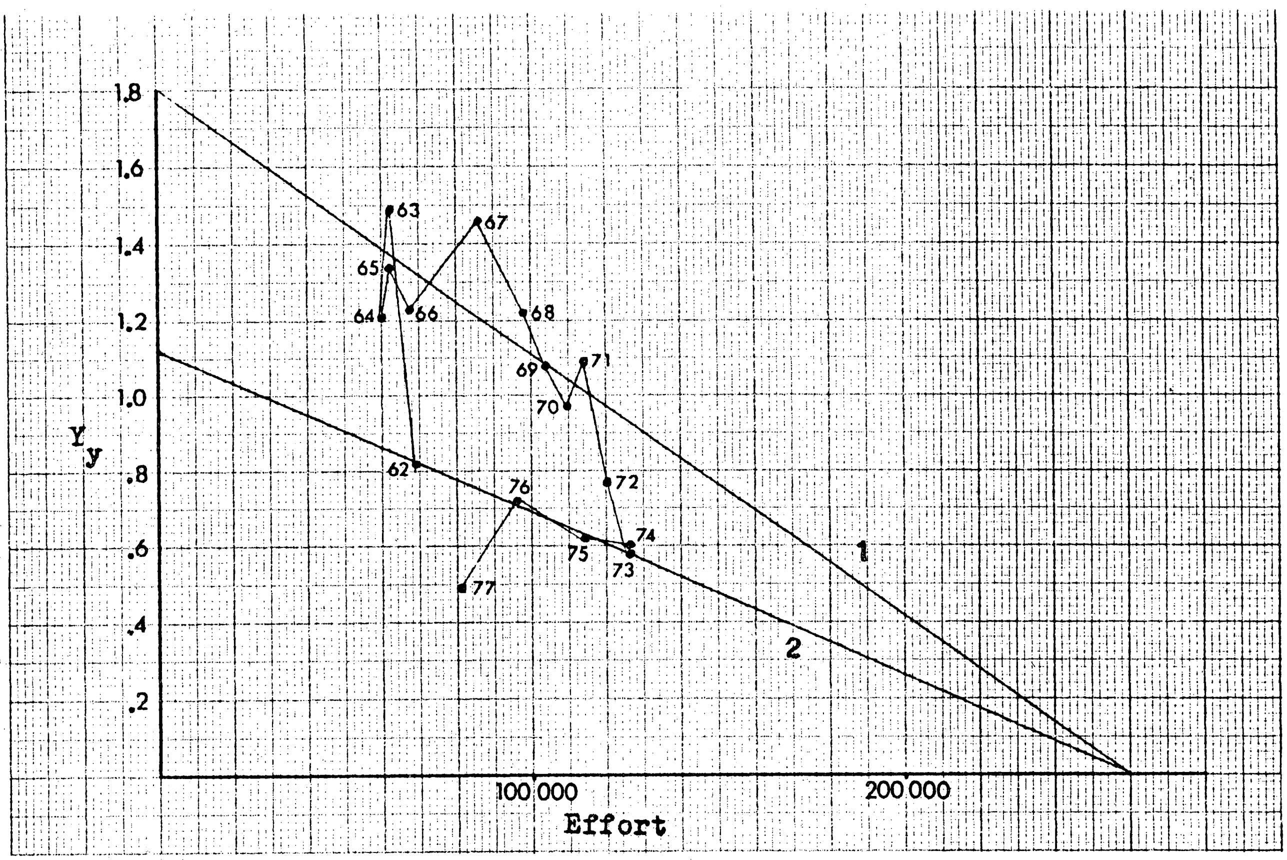

FIGURE 2.- Double regression using weighted efforts, with M=2

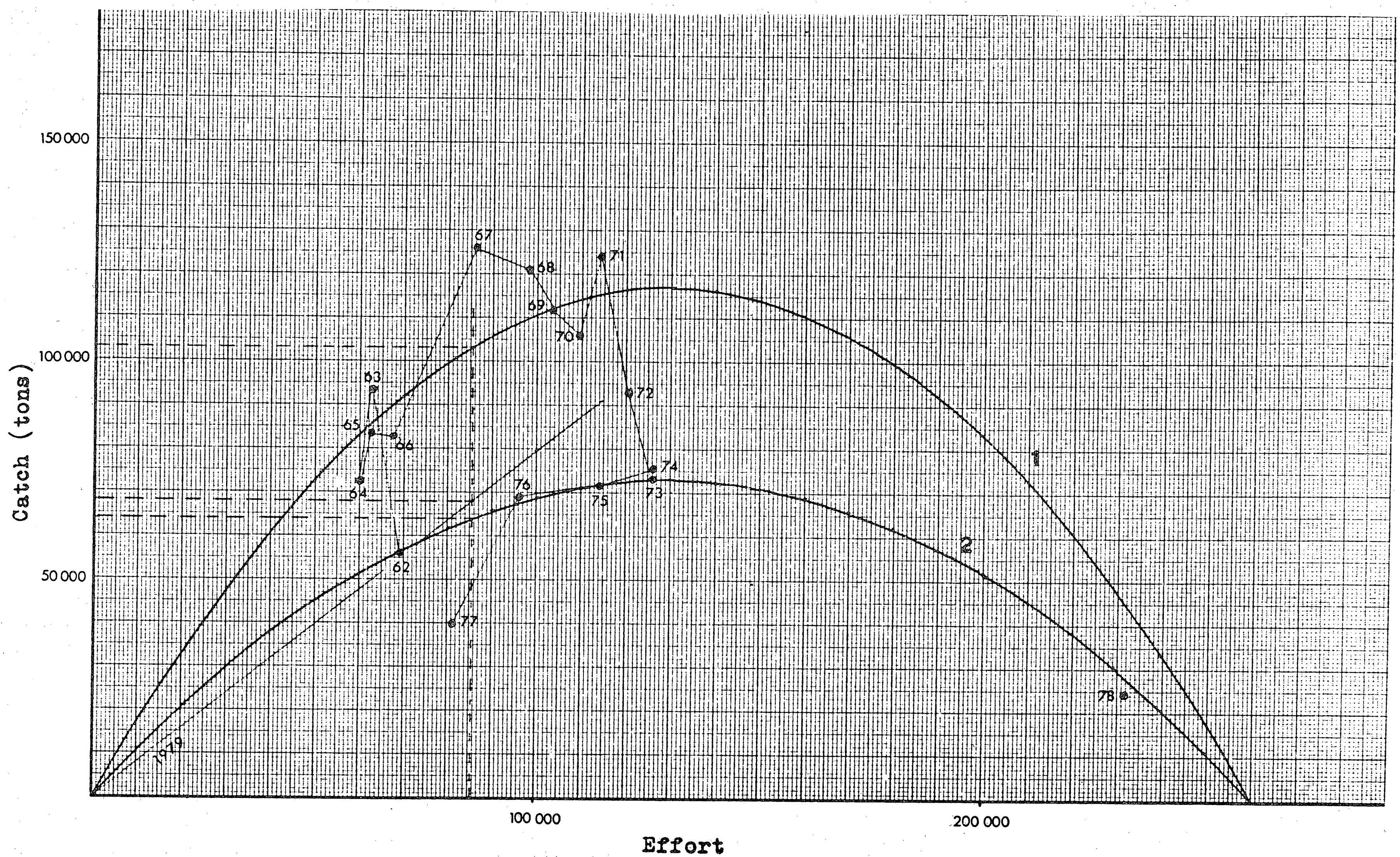

FIGURE 3.- Double yield curve for Divisions 3NO cod with M=2
1978 point is not an equilibrium one

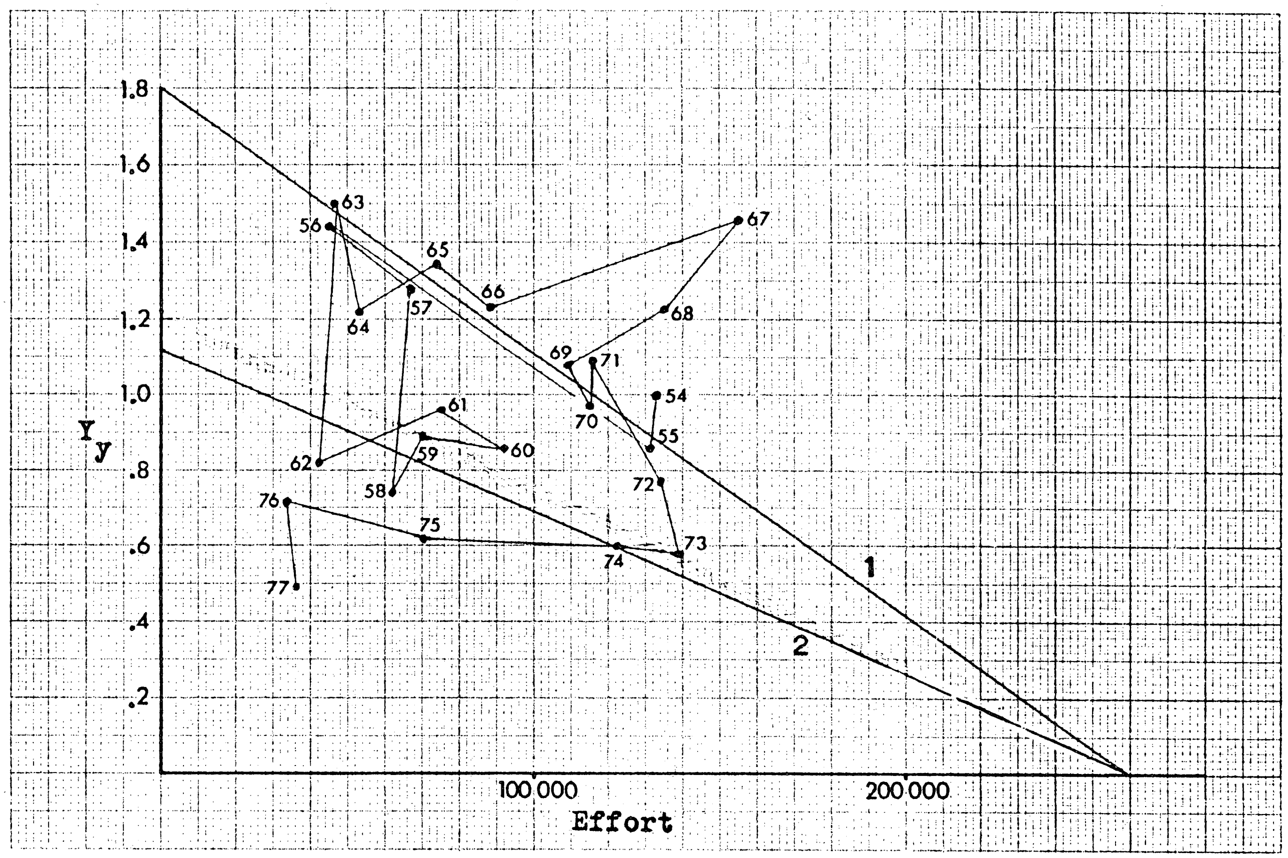

FIGURE 4.- Regression lines as in figure 2. Points with annual effort