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Assessment of the Cod Stock in Division 3M

by

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Introduction

The cod stock in ICNAF division 3M has experienced a wide range of fishing effort between the years 1960 and 1979. Catches were at their peak in the late 1960's and early 70's. Over the years Portugal and Spain have been the primary exploiters of this stock with the U.S.S.R. entering significantly into the fishery in the late 60's.

Methods

In order to standardize the effort the following multiplicative modal was postulated

$$U = U_R \prod_{ij} (P_{ij}^{X_{ij}}) \exp(\varepsilon)$$

where U = catch rate for a particular combination of categories

U_R = Catch rate for the combination of categories chosen as the reference

P_{ij} = relative power of category j in category type i

$$X_{ij} = \begin{cases} 1 & \text{when category j occurs} \\ 0 & \text{otherwise} \end{cases}$$

$\varepsilon \sim N(0, \sigma^2)$ and independent of each other

The category types used in this analysis were country-gear combinations, months and years. This is the same model that Gavaris (1979) used previously but the notation has been generalized. An improved method of using the model to obtain estimates of catch rate and standardized effort was applied. An unbiased estimator of the dependent variable and its standard error was derived for lognormal models by Bradu and Mundlak (1970).

$$\hat{U} = \exp(\widehat{\ell n\, U})\, g_m\left\{\frac{m+1}{2m}(\hat{\sigma}^2 - \hat{\sigma}^2_{\widehat{\ell n\, U}})\right\}$$

$$\hat{\sigma}^2_{\hat{U}} = \exp(2\,\widehat{\ell n\, U})\left[g_m{}^2\left\{\frac{m+1}{2m}(\hat{\sigma}^2 - \hat{\sigma}^2_{\widehat{\ell n\, U}})\right\} - g_m\left\{\frac{m+1}{m}(\hat{\sigma}^2 - \hat{2\sigma}^2_{\widehat{\ell n\, U}})\right\}\right]$$

where $\ell n\, U$, $\hat{\sigma}^2$ and $\hat{\sigma}^2_{\widehat{\ell n\, U}}$ are obtained from the regression of the ℓn transformed model, m is the degrees of freedom for the residuals and $g_m(t)$ is a function (see Bradu and Muudlak 1970) which corrects for the bias of $\exp(\widehat{\ell n\, U})$.

The standard effort is computed using the relationship

$$\hat{E} = C/\hat{U}$$

where C is the total annual catch

Since the regression of C vs $\hat{U}$ must go through the origin by definition, $\hat{E}$ should be unbiased.

A time dependent formulation of the generalized production model (Fletcher 1978) was used to estimate the important management parameters by applying an algorith similar to that of Rivard and Bledsoe (1978).

Results

The regression of the ℓn transformation was significant (Table 1) however not all of te regression coefficient are significantly different from each other. The regression coefficients can be advantageously grouped to obtain more precise estimates of $\hat{U}$. There is no single satisfactory test for doing this so the grouping was accomplished by examining the results of the ANOVA, a cluster analysis and Duncan's range test. Table 2 summarizes how the country-gear combinations were grouped and Fig. 1 shows the trend in ℓn P during the year and how the months were grouped. The results from the regression with these grouped categories is given in Table 3. The regression was significant as was the inclusion of each of the category types. The summary of the estimation of catch rate and standardized effort along with the catch and directed catch are presented in Table 4. For the estimation purpose the second group in Table 1 was used as the standard country-gear and the third group from the top in Fig. 1 was used as the standard month category. A clearer apprecation of the trend in catch rate is obtained by examining Fig. 2. The pattern that has evolved since 1969 is very discouraging, partcularly the trend which began in 1974.

A statisfactory fit was obtained with the generalized production model (Fig. 3). The analysis produced a maximum sustainable yield of 33,000 tonnes. Fig. 4 shows the changes in biomass from 1960 to 1979. The equilibrium biomass is that biomass which the population would attain if the effort of that year was sustained for a long time. The graph indicates that the population was in good shape in the early sixties but excess fishing effort during most of the remaining history has reduced the population biomass. Only short respites were offered in 1968, 1969 and 1974 where the effort was low enough to allow an equilibrium biomass larger than the actual biomass, thus creating periods of growth. The equilibrium biomass for maximum sustainable yield is approximately 175,000 tons. The equilibrium yield curves are presented in Fig. 5 and 6. Examination of the paths shows a general decline in biomass subseqeunt to yields above equilibrium curve and similar declines in yield following excessive fishing effort.

Discussion

The catch rate remained at farily respectable levels during the sixties even though the fishing pressure was too high and the population biomass was steadily decreasing. In the 1970's however the first signs of a faltering stock were reflected in the lower catch rates. The high fishing pressure was maintained and the biomass continued to decrease. This trend has not changed, and in fact has accelerated since 1976. This result makes it clear that taking even half the MSY from this stock in its present condition is dangerous. The recommendation therefore is to reduce the allowable catch to the lowest possible level and at least less than 10,000 tonnes. This last figure is approximately the smallest catch that would not lead to extinction if next year's catch rate is the same as this years. It should be stressed that the catch should be less than 10,000 tonnes if possible.

References

Bradu, D. and Y. Mundlak. 1970. Estimation in lognormal linear models. J. Amer. Stat. Assoc. 65: 198-211.

Fletcher, R. I. 1978. Time-dependent solutions and efficient parameters for stock-production models. Fish. Bull. 76: 377-388.

Gavaris, S. 1979. Update of the Flemish Cap cod stock. ICNAF Res. Doc. 79/VI/46, Ser. No., 5385.

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Table 1. Results from the regression of ℓu catch rate against dummy variables for the cod stock in ICNAF Division 3M.

Multiple R = 0.65
Multiple R^2 = 0.42

Source	d.f.	Analysis of Variance Sum of Squares	Mean squares	F-values	P
C-Gears*	16	89.09	5.57	10.59	<.001
Months*	11	13.97	1.27	2.41	<.005
Years*	19	79.89	4.20	7.99	<.001
Regression	4	206.85	4.49	8.55	<.001
Residual	551	289.64	0.52		
Total	597	496.50			

* These sums of squares are conditional on the other category tpes being included in the model.

Table 2. Grouping of the regression coefficients for country-gear categories. The column labled ℓn P_g contains the regression coefficients obtained after grouping.

Country-gear		ℓn P	ℓn P_g
FRG	OT-7	0.51	0.44
Port	OT-6	0.00	
Port	OT-7	0.15	0.00
USSR	OT-7	0.09	
Pold	OT-7	0.16	
Spain	PT-4	-0.46	
Norw	OT-4	-0.34	
USSR	OT-5	-0.40	-0.48
Icel	OT-5	-0.42	
CauN	OT-4	-0.37	
Spain	OT-6	-0.54	
Norw	LL-4	-0.68	-0.62
USSR	OT-6	-0.65	
Spain	PT-5	-1.02	
UK	OT-5	-1.14	-1.02
UK	OT-6	-0.85	
CauN	OT-5	-0.87	

Table 3. Results of the regression for grouped categories.

Multiple R = 0.64
Multiple R^2 = 0.41

Source	d.f.	Analysis of Variance Sum of squares	Mean squares	F-values	P
C-gears*	4	86.68	21.67	42.21	<.001
Months*	3	14.11	4.70	9.18	<.001
Years*	19	85.05	4.47	8.73	<.001
Regression	26	203.92	7.84	15.30	<.001
Residuals	571	292.57	0.51		
Total	597	496.50			

*Same note as in Table 1.

Table 4. Summary of catch, effort and catch rate for cod in Division 3M.

Year	Reported directed catch (t)	Total Catch (t)	Estimated Catch Rate (t/hr)	Standardized effort (hr)
1960	662	5,573	2.7357	2,037
1961	3,006	22,996	3.3746	6,814
1962	3,640	16,175	1.5290	10,579
1963	11,033	38,216	1.8936	20,182
1964	6,856	47,819	1.3054	36,632
1965	32,175	60,313	1.5058	40,054
1966	12,263	33,834	1.3554	24,962
1967	19,671	42,163	1.5263	27,624
1968	15,148	40,385	1.9221	21,011
1969	9,977	31,845	1.9832	16,057
1970	10,918	26,529	1.0897	24,345
1971	8,335	33,692	1.2801	26,320
1972	41,177	57,691	1.3465	42,845
1973	12,932	22,900	0.8683	26,373
1974	12,620	24,941	1.2484	19,978
1975	13,234	22,375	0.9670	23,139
1976	13,760	22,266	0.7660	29,068
1977	10,195	27,239	0.5928	45,950
1978	18,233	32,992	0.7578	43,537
1979	388	25,000	0.3985	62,735

Note: The data for 1960-77 were obtained from ICNAF files, for 1978 from Statlant reports and for 1979 from the Foreign Observer Program.

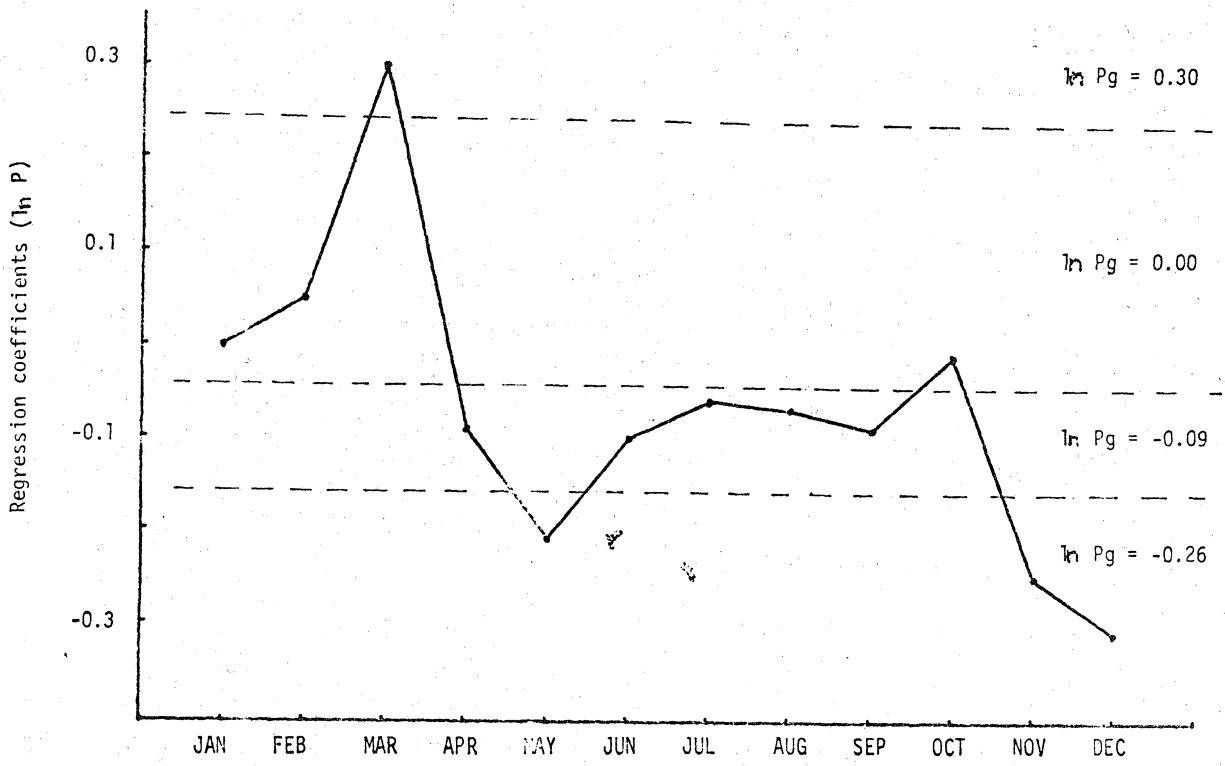

Fig. 1. The annual trend in ln power showing how the months were grouped for the cod stock in ICNAF division 3M. The value ln Pg is the resulting grouped regression coefficient.

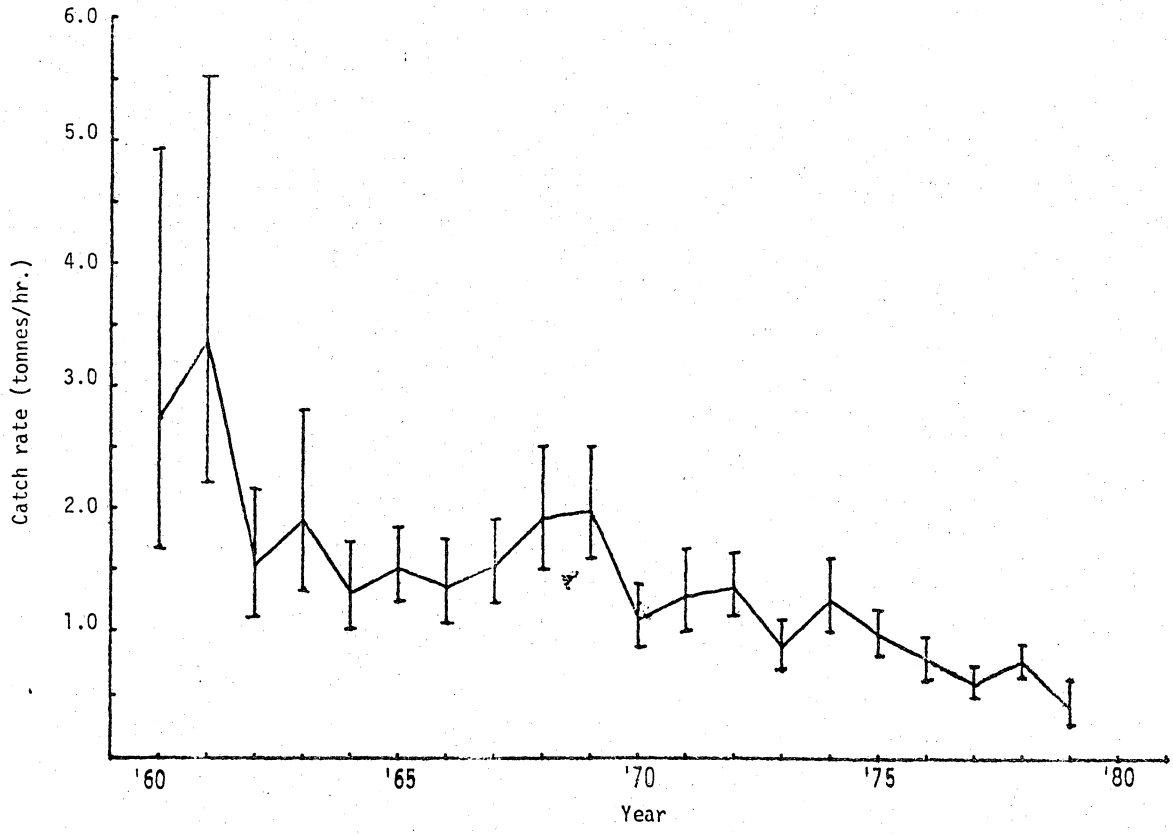

Fig. 2. Standardized catch rate for cod in ICNAF division 3M with approximate 90% confidence intervals (Land, 1972).

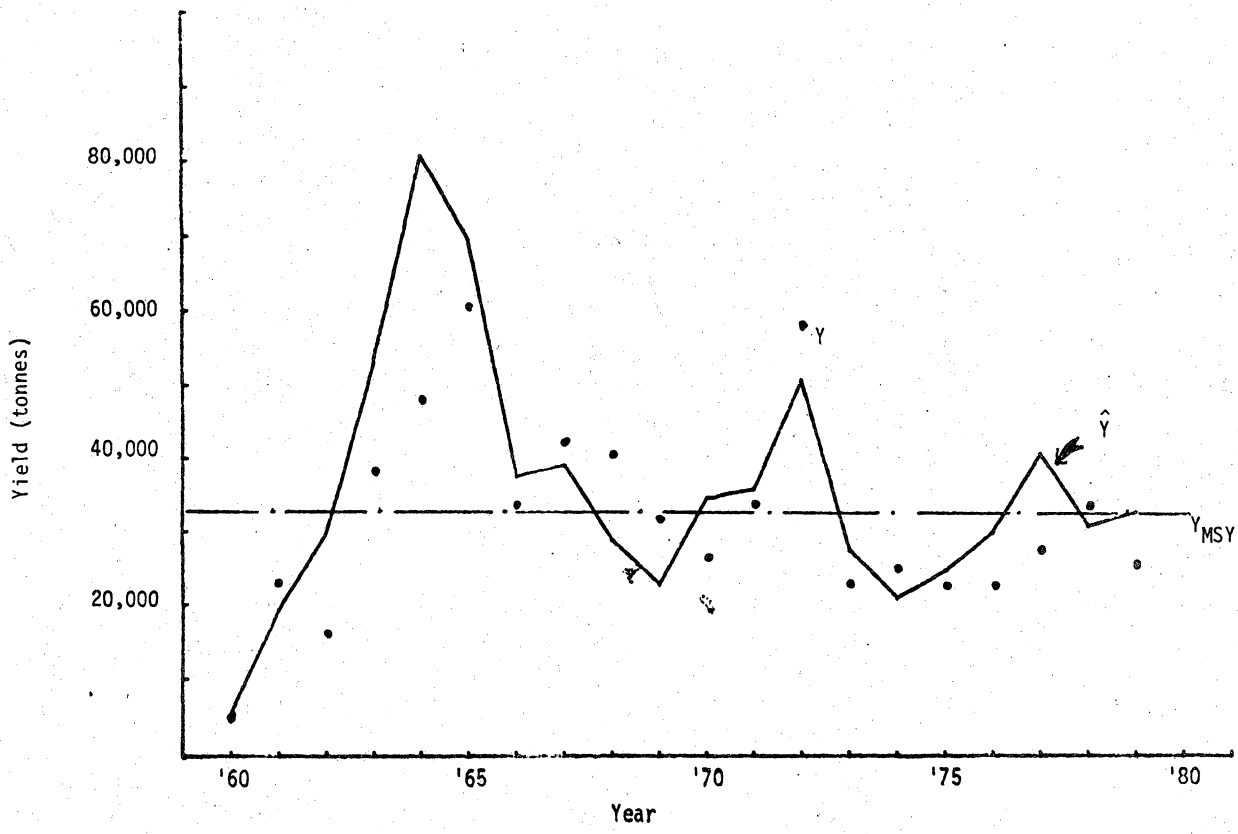

Fig. 3. The predicted and observed values of the dependent variable, yield, for cod in ICNAF divisions 3M. The equilibrium yield at MSY is shown.

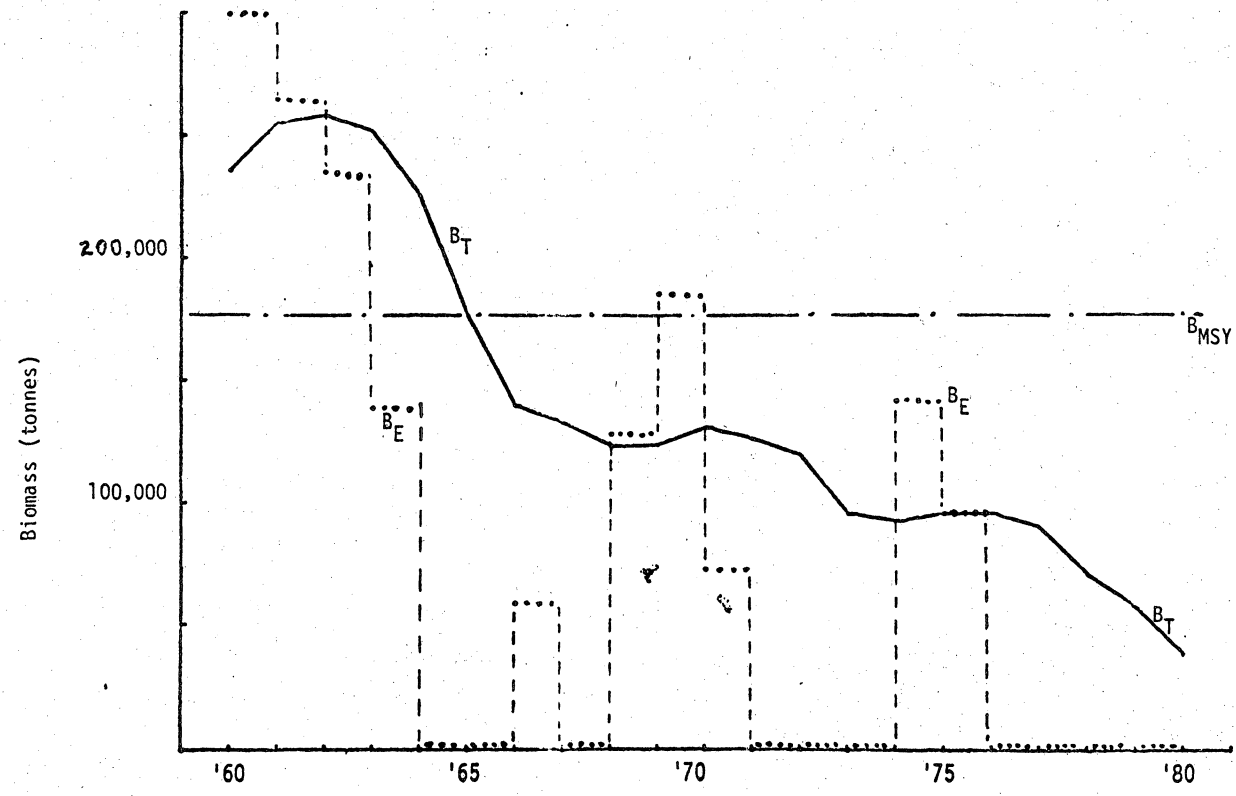

Fig. 4. Trend in biomass over time and the equilibrium biomass associated with the effort for that year for cod in ICNAF division 3M. The equilibrium biomass at MSY is also shown.

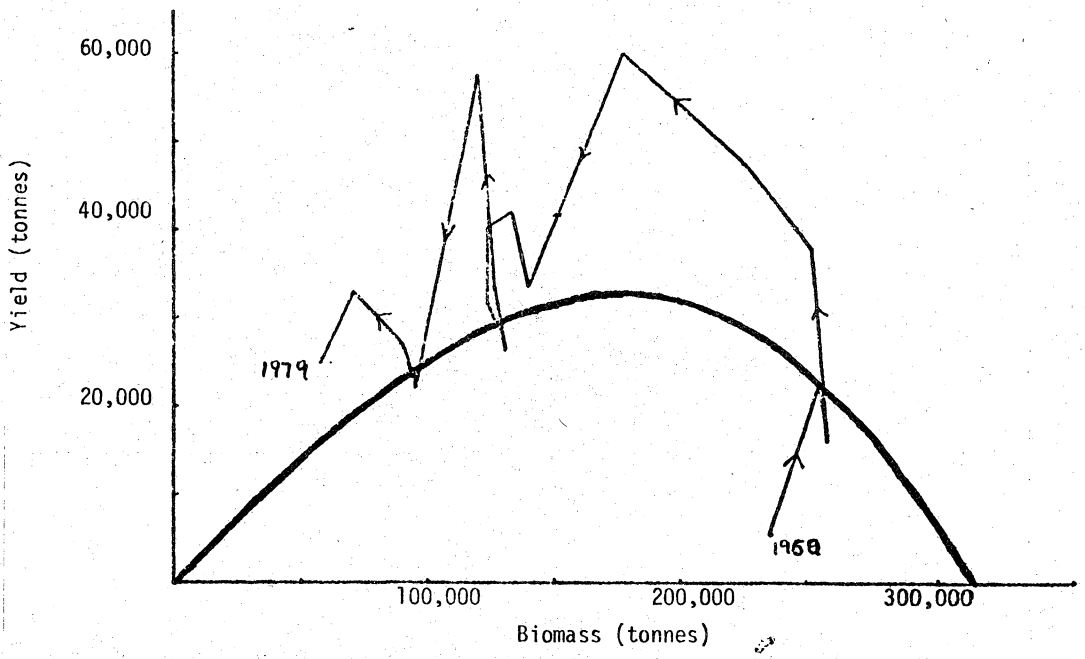

Fig. 5. Equilibrium curve of yield vs biomass and patch from 1960-1979.

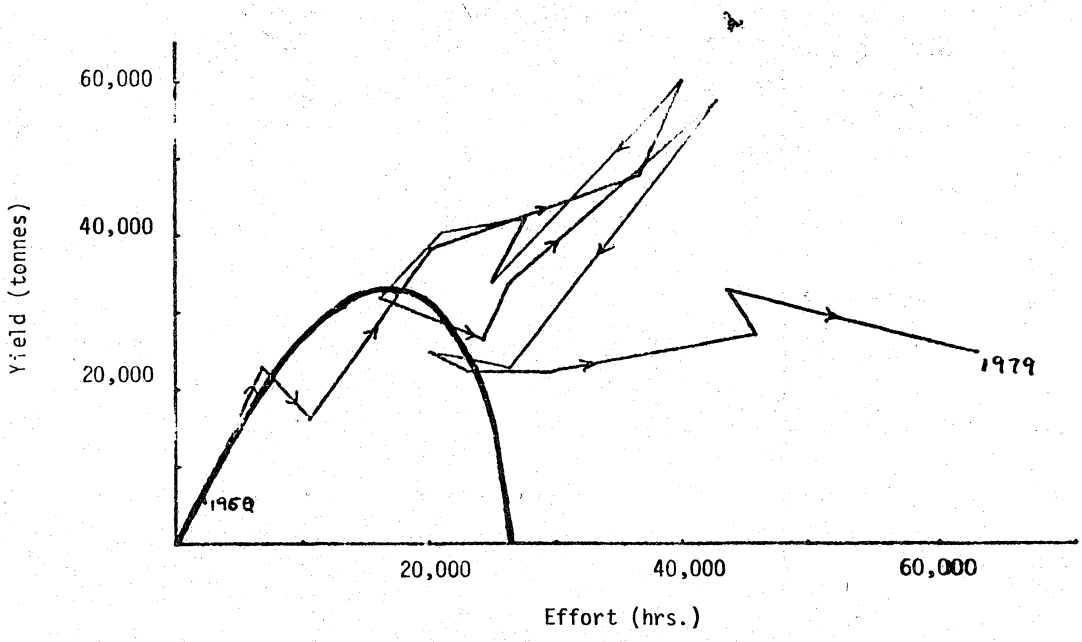

Fig. 6. Equilibrium curve of yield vs effort and path from 1960-1979.