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Surplus Production Analysis for the Cod Stock in NAFO Divisions 2J+3KL

by

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DATA

Catch and effort data for 1959-78 was obtained from ICNAF Statistical Bulletins. For 1979, data from some countries was available in preliminary form from NAFO. Data for 1980 came from the Economics Branch and from the Foreign Observer Program. Preliminary reports from the Economics Branch provided the information for 1981.

ANALYSIS

The catch rates were standardized through the use of a multiplicative model (Gavaris 1980). The individual data points were weighted by (Catch X Effort)$^{0.25}$. The model indicated distinct seasonal and spatial heterogeneity, high catch rates being associated with the winter months and with Div. 2J respectively (Table 1). In general, country-gear categories showed greater fishing power for larger vessels.

The standardized catch rates show a definite stabilization followed by an increasing trend in the last few years (Fig. 1). The corresponding effort series is provided in Table 2 with an indication of the proportion of the total catch which was used in standardization. As standards Can (N) OT-5, Div. 2J and February were selected because they represent the bulk of the fishery in recent years.

The catch and effort data for 1959-80 were fit to a nonequilibrium surplus production model. The 1981 datum point was excluded because of its preliminary nature and its extreme value. The model formulation presented by Fletcher (1978) was employed. The difficulty in estimating all five parameters of the nonlinear model using least squares dictated that another tact be used. The parameters of the model are maximum sustainable yield (MSY), catchability coefficient (q), shape parameter (n), unfished biomass (B_α) and biomass at the beginning of the year in the first year of the data series (B_0).

Given q, parameter Bo can be effectively approximated using the formula:

$$B_0 = 1.5\ \bar{B}_0 - 0.5\ \bar{B}_1$$

where $\bar{B}_i = Y_i/q\ E_i$

Y_i = yield in year i

E_i = effort in year i

An estimate of q was obtained using the mean exploitable biomass from cohort analysis for the years 1962-77 in the estimator;

$$q = \Sigma y_i / \Sigma B_i^* \ E_i$$

where B_i^* = exploitable biomass

This formula was used because the variance was expected to increase as B_i and E_i increased. The shape parameter was not very well determined, therefore MSY and B_α were estimated using a nonlinear least squares algorithm for a range of fixed values of n. The smallest sums of squares for biologically reasonable results were obtained with a shape parameter of 3.75.

Examination of the predicted and observed yield (Fig. 2) indicated that there was substantial serial correlation which implies that the variance estimates of the parameters are not reliable (Ostrom 1978). The model, however, tracks the observed yield fairly well. Fishing mortality during 1968-74 was sufficiently high to bring the stock to extinction had it been sustained at that level indefinitely (Fig. 3). The equilibrium curves show that the stock has been overfished but that there is good evidence of recovery. The equilibrium sustainable yield at 2/3 effort MSY was about 488,000 t. The predicted catch rates for 1981 and 1982 were 2.58 and 3.02 t/hr respectively with projected yields at 2/3 effort MSY of 306,000 and 359,000 t.

REFERENCES

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

Gavaris, S. 1980. Use of a multiplicative model to estimate catch rate and effort from commercial data. Can. J. Fish. Aquat. Sci. 37: 2272-2275.

Ostrom, C. W. 1978. Time series analysis: Regression techniques. Sage Univ. Paper Series on Quantitative Applications in the Social Sciences, 07-009. Beverley Hills and London Sage Publications.

Table 1. Regression coefficients for grouped categories and the analysis of variance from the regression.

Country	gear	ln power
Can(N) USSR USSR	OT-4 OT-5 OT-6	-0.232
UK	OT-6	-0.109
Can(M)	OT-4	0.000
Can(N)	OT-5	0.203
USSR	OT-7	0.294
Can(M) Span	OT-5 OT-6	0.375
Pold Port Span	OT-7 OT-6 PT-4	0.519
FRG GDR	OT-6 OT-5	0.744
Port Span FRG	OT-7 PT-5 OT-7	0.820
GDR	OT-6	1.014
Span	PT-6	1.117

Month	ln power
Aug. Sept. Oct. Nov.	-0.642
July	-0.529
June Dec.	-0.355
May	-0.187
Mar.	-0.116
Jan. Apr.	0.000
Feb.	0.160

Divs.	ln power
3L	-0.296
3K	-0.174
2J	0.000

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R..............0.735
MULTIPLE R SQUARED.....0.540

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
TYPE 1	10	1.58126E2	1.58126E1	76.790
TYPE 2	6	1.94596E2	3.24327E1	157.501
TYPE 3	2	3.98687E1	1.99344E1	96.806
TYPE 4	22	3.16079E2	1.43672E1	69.771
REGRESSION	40	6.88104E2	1.72026E1	83.540
RESIDUALS	2845	5.85842E2	2.05920E-1	
TOTAL	2885	1.27395E3		

Table 2. Historical catch, effort and catch rate for cod in Divisions 2J+3KL. The proportion indicates how much of the catch was used in estimating catch rate.

YEAR	TOTAL CATCH	PROP.	CATCH RATE MEAN	S.E.	EFFORT
1959	329572	0.251	2.441	0.193	134997
1960	393577	0.302	2.488	0.179	158177
1961	498078	0.306	2.553	0.179	195075
1962	502752	0.480	2.673	0.176	188089
1963	499904	0.491	2.779	0.180	179867
1964	603585	0.378	2.686	0.171	224748
1965	555654	0.452	2.275	0.138	244275
1966	522307	0.425	2.466	0.152	211795
1967	610535	0.416	2.540	0.153	240378
1968	807470	0.323	2.557	0.150	315791
1969	748433	0.303	2.179	0.131	343548
1970	516213	0.338	1.918	0.117	269089
1971	432496	0.382	1.607	0.099	269094
1972	458170	0.331	1.468	0.091	312041
1973	354509	0.424	1.263	0.079	280690
1974	372650	0.518	1.408	0.089	264754
1975	287508	0.477	1.313	0.083	219008
1976	214220	0.420	1.215	0.081	176331
1977	172720	0.293	0.766	0.049	225602
1978	138559	0.246	0.687	0.045	201678
1979	166743	0.330	1.311	0.087	127233
1980	169113	0.282	1.788	0.129	94578
1981	200000	0.173	4.833	0.590	41384

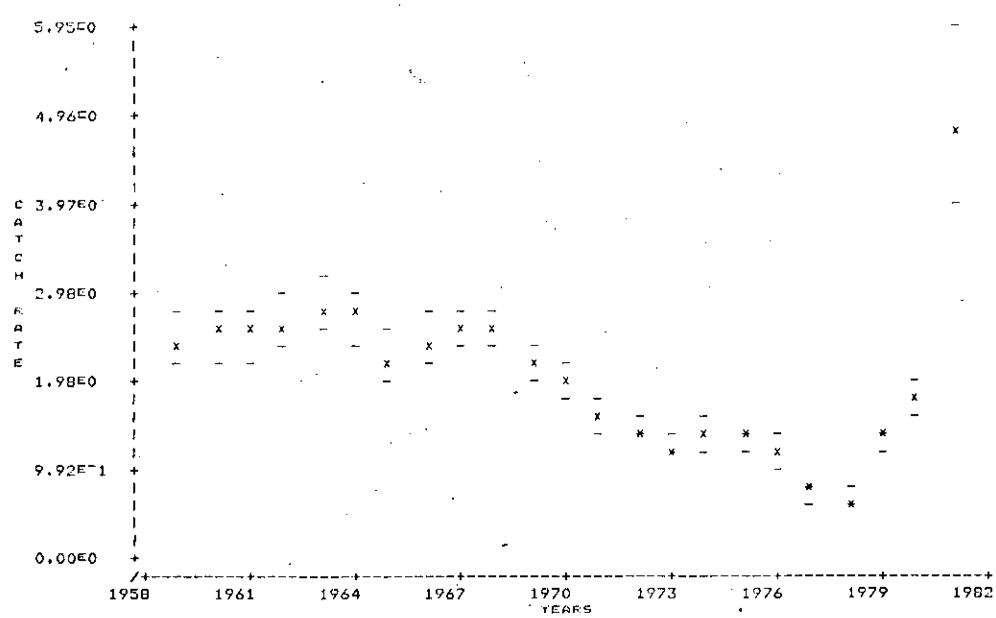

Fig. 1. Historical catch rates with approximate 90% confidence intervals.

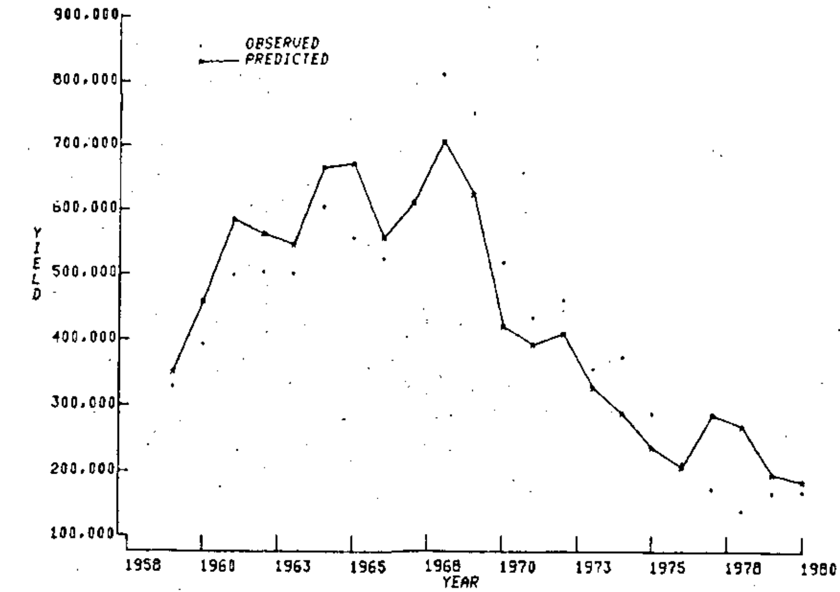

Fig. 2. Predicted and observed yield show that there is autocorrelation in the data.

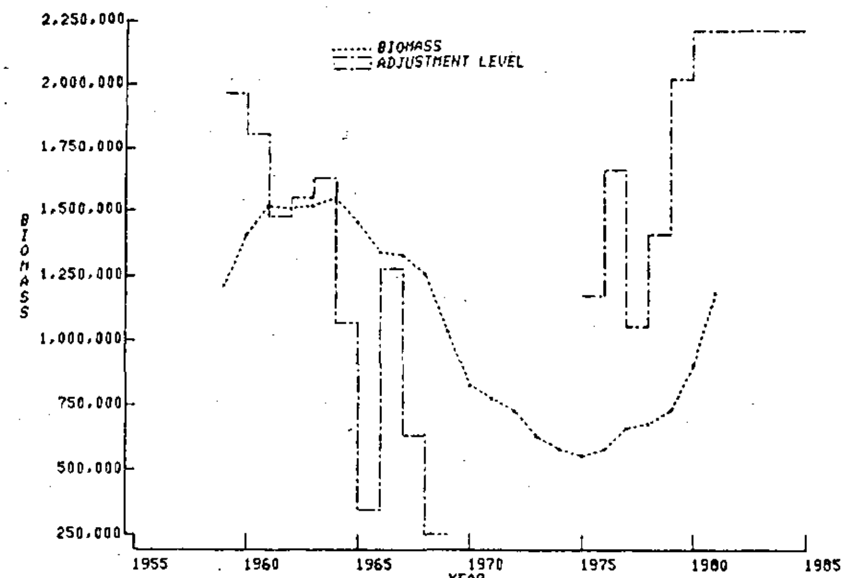

Fig. 3. The adjustment level for 1968-74 was negative meaning that the fishing pressure was too high in these years for the stock to sustain.

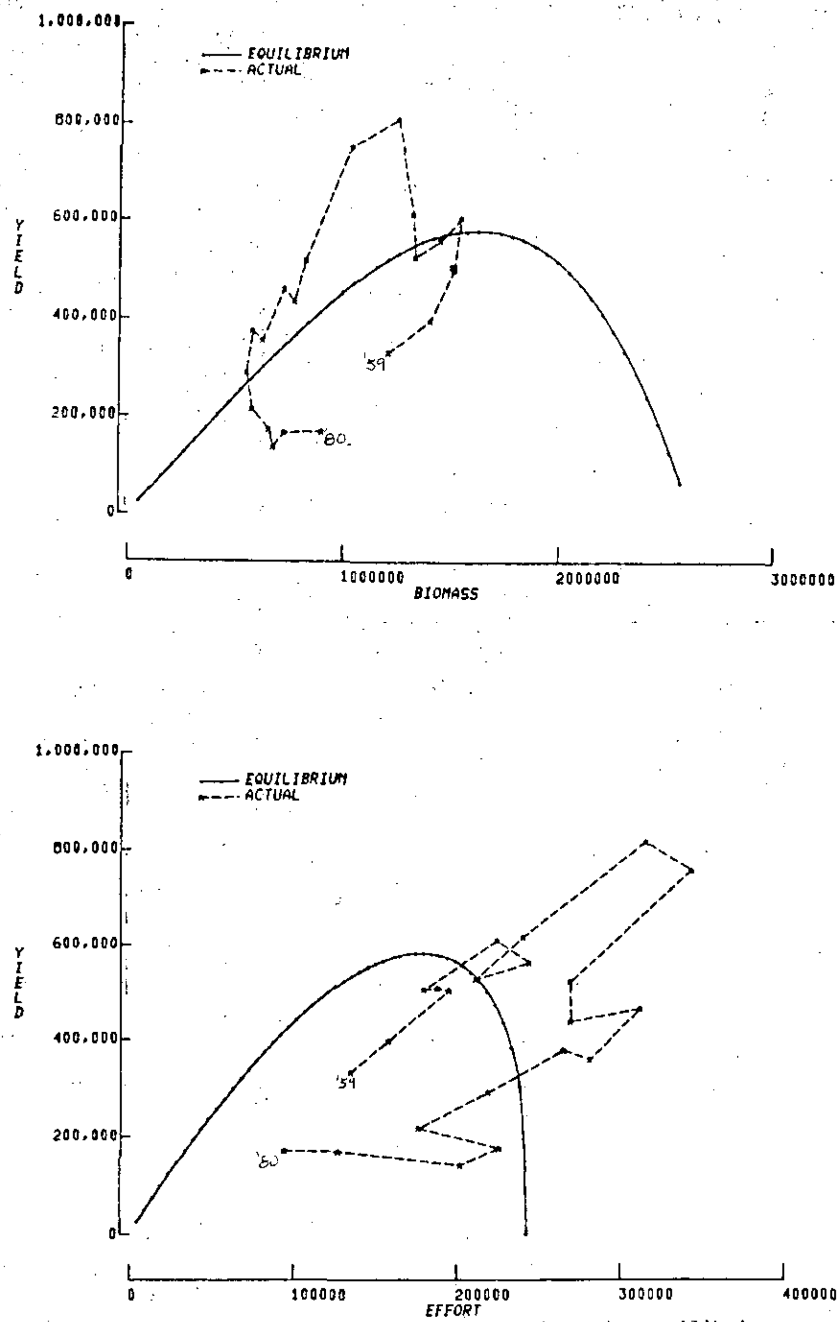

Fig. 4. The actual trajectory is superimposed on the equilibrium curves to elucidate the response to high fishing mortality.