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An assessment of the cod stock in NAFO Division 3M

by

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INTRODUCTION

The last year analysis of the cod stock in Division 3M for 1988 to 1995 (Vazquez et al. 1996) is reviewed and updated with 1996 data.

The 1996 cod fishery was almost residual: most of the fleets traditionally aimed to 3M cod didn't participate. Most of the catch was obtained by the Portuguese stern trawlers as a direct cod fishery concentrated in February-April and December. Portuguese gillnetters, Spanish pair-trawlers, Faroese longliners and Non-Contracting Party vessels reduced substantially their presence and catches. Cod by-catch in the shrimp fishery has been negligible.

MATERIAL AND METHODS

Commercial fishery data

The 3M catch and effort data series for Portugal and Spain have been reconstructed for the 1988-1994 period by an extended revision of skippers log-books from each component of the national fleets (Vazquez et al. 1995). Spanish catch and effort data for 1995 and 1996 was derived from STATLANT 21B. Portuguese catch and effort data for 1995 were derived the same way has in the previous period, and for 1996 were taken from Portuguese STATLANT 21B. The use of STATLANT data for the last couple of years is justified by the fact that all EU vessels fishing in NAFO Regulatory Area had an independent observer on board since May 1995.

The 1996 total cod catch is estimated to be around 2,600 tons (Table 1), which represents a drastic decline from the 1994 estimated level of 30,000 tons. Canadian Surveillance reports rises the total cod catch figure to 3,925 tons.

Sampling catch

Sampling of commercial catches was in 1996 only available for Portugal (Alpoim et al. 1997). Portuguese catches were sampled on board for trawl on March, May and December. Gillnets catches were not sampled, but catches for this fleet were very low.

For 1996 sampling included length frequencies of the total catch of the hauls and the stratified subsamples of otoliths. Mean weight in the catch and mean weight at age were calculated using 3M cod length-weight relationship obtained from EU bottom trawl survey on Flemish Cap in July 1996 (Vazquez 1997).

Data files for Extended Survivors Analysis (XSA)

The 1996 landing data file includes the STATLANT catches of Portugal, Spain and Faroe Islands (provisional) as well as the catch estimates for Non-Contracting Parties from Canadian Surveillance.

For 1996, length and age structure of the gillnet catches were considered identical to the length and age structure of the trawl catches from May since most of the gillnet catches were taken during the second quarter of the year.

The 1996 cod catch by Spanish pair-trawlers and Non-Contracting Parties were considered to have a length structure similar to the Portuguese trawl catch, and were broken down in numbers at age using the mean weight in the catch and the age composition of this catch fraction. The same rational was applied to the Faroese longline catch as regards gillnet catches. The total numbers for 1996 were then incorporated in the catch-at-age data file (Table 2).

The 1996 mean weights-at-age used to update the catch weights-at-age data file were derived from Portuguese trawl data. The stock weights-at-age were calculated using the EU survey data (Table 3).

Natural mortality was assumed at 0.2.

Abundance at age indices as calculated in the EU survey (Vazquez 1997) were used to tuning the Analysis (Table 4). Abundance in 1994 survey was recalculated excluding an out of norm haul where half of the total catch of the whole survey had been taken. The effect of this modification on total stock biomass estimate is to smooth its evolution from 1993 to 1995. Abundance at age indices from Russian trawl survey (Kiseleva 1997) (Table 5) were also used together with EU survey data in trial runs of the XSA program. However, the Russian survey was not incorporated in the final run due to the poor results of the catchability analysis.

No effort/catch at age matrices from commercial CPUE series were used in the present analysis due to the discrepancy observed between survey biomass and CPUE trends over the time period considered (Avila de Melo and Alpoim, 1996).

RESULTS AND DISCUSSION

An Extended Survivor Analysis (Darby and Flatman 1994) was carried out for ages 1 to 8+ and years 1988 to 1996 (Table 6). Due to high levels of catches at age 2 observed in some years, ages 1 and 2 were considered in the present analysis although an increase is generally observed in the survey abundance indices from ages 1 to 3 for most of the 1988/1993 cohorts. Due to low t values on the regression analysis of catchability for age 2 and older, catchability was considered independent of year-class strength from age 2 onwards, and was considered independent of age for age 5 and older.

Total biomass, spawning stock biomass (SSB) as biomass age 5+ and recruitment abundance from 1988 to 1996, all of them from XSA, are presented in Figure 1. According to most recent analysis, cod spawned at a younger age in the last years than in the past: age at first maturity traditionally occurs at age 5, but it was observed at age 4 and younger since 1994 (Saborido-Rey 1997). First maturity at younger ages, together with the relatively abundant survivors of the 1991 year-class, induced an increase of the spawning stock biomass level in 1994 and 1995. However this increase was not reflected in the strength of the 1994 and 1995 year-classes, which are the weakest in the time series, according to the EU survey. The available data suggests that the rejuvenation of the spawning stock biomass implied a decline on relative fecundity.

Total biomass from XSA results declines from the highest level between 65,000 and 110,000 tons recorded in 1988-1990 period to an intermediate level around 50,000 tons observed between 1991 and 1994. This decline seems to be related with the overexploitation of the abundant 1985 and 1986 cohorts. High fishing mortalities are observed throughout the age range of the exploited population during this period (Figure 2). In 1994 the population was already basically restrained to the survivors of the abundant 1991 and 1990 year-classes but fishing mortalities on the correspondent age groups were still kept greater than 1 in 1994 and 1995. This fishing strategy lead to a further decline of the biomass to a level of around 25,000 tons in 1995 and 13,000 tons in 1996, the lowest recorded in the time series.

Biomass indices from EU surveys generally agree with XSA results. The Canadian survey of Flemish Cap in 1996 estimated total cod biomass by swept area method as 9,300 tons (Brodie et al. 1997), so at the same level of both 1996 EU survey and XSA results. Russian survey results also show a sharp decline of stock biomass from 1995 (8,300 tons) to 1996 (700 tons). However this decline is too dramatic to be only explained by the present status of the 3M cod stock, taking into account the residual level of the fishery in 1996.

Acknowledgements

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Table 1 - Total cod catch on Flemish Cap. Reported nominal catches and actual estimations. (tons)

year	total estimated	reported									
		Faro.	Japan	Korea	Norw.	Port.	Russ.	Spain	UK	others	total
1988	28899	1100	5	6		421	39	141		6	1718
1989	48373		38	321		170	10	378			917
1990	40827	1262	24	815		551	22	87		1	2762
1991	16229	2472	54	82	795	2838	1	1416	26	1196	8980
1992	25089	747	2	18		2201	1	4215	5		7189
1993	15958	2075		3		3130		2249			7458
1994	29916					2587		1952			4539
1995	10372	1125	2		1	1670		563		445	3805
1996	2601	715	2			1284		176		49	2226

Table 2 - Catch in numbers. ('000)

year	age: 1	2	3	4	5	6	7	8+
1988	1	3500	25593	11161	1399	414	315	162
1989	0	52	15399	23233	9373	943	220	205
1990	7	254	2180	15740	10824	2286	378	117
1991	1	561	5196	1960	3151	1688	368	76
1992	0	15517	10180	4865	3399	2483	1106	472
1993	0	2657	14530	3547	931	284	426	213
1994	0	1219	25400	8273	386	185	14	182
1995	0	0	264	6553	2750	651	135	232
1996	0	81	714	311	1072	88	0	0

Table 3 - Weights at age in both catch and stock. (Kg)

catch

year	age: 1	2	3	4	5	6	7	8+
1988	0.058	0.198	0.442	0.821	2.190	3.386	5.274	7.969
1989	0.000	0.209	0.576	0.918	1.434	2.293	4.721	7.648
1990	0.080	0.153	0.500	0.890	1.606	2.518	3.554	7.166
1991	0.118	0.229	0.496	0.785	1.738	2.622	3.474	6.818
1992	0.000	0.298	0.414	0.592	1.093	1.704	2.619	3.865
1993	0.000	0.210	0.509	0.894	1.829	2.233	3.367	4.841
1994	0.142	0.289	0.497	0.792	1.916	2.719	2.158	4.239
1995	0.000	0.000	0.415	0.790	1.447	2.266	3.960	5.500
1996	0.000	0.286	0.789	1.051	1.543	2.429	4.000	5.025

stock

year	age: 1	2	3	4	5	6	7	8+
1988	0.031	0.103	0.308	0.678	1.973	3.594	5.772	6.926
1989	0.044	0.243	0.541	1.040	1.595	2.505	4.269	6.930
1990	0.039	0.170	0.342	0.846	1.501	2.426	4.083	5.635
1991	0.054	0.166	0.495	0.855	1.611	2.606	4.255	7.692
1992	0.054	0.246	0.490	1.377	1.702	2.633	3.133	6.685
1993	0.043	0.222	0.655	1.209	2.270	2.371	3.449	5.890
1994	0.060	0.207	0.591	1.323	2.261	4.031	4.034	6.715
1995	0.046	0.235	0.466	0.961	1.850	3.159	5.555	8.480
1996	0.041	0.251	0.531	0.804	1.324	2.267	4.000	5.025

Table 4 - EU survey abundance at age used for tuning XSA
(8+ group not used). ('0000).
B n+ = biomass of fish age n and older (tons)

age	year : 1988	1989	1990	1991	1992	1993	1994	1995	1996
1 :	458	2418	237	13780	7118	438	315	155	4
2 :	7196	6062	1179	2560	3706	13274	385	1137	297
3 :	4037	6964	467	1548	475	2852	2459	123	613
4 :	1085	2819	1588	192	203	102	456	361	82
5 :	128	227	1453	622	33	127	12	90	225
6 :	22	33	394	173	127	17	6	1	19
7 :	28	12	32	25	21	50	0	2	1
8+:	11	8	24	6	2	10	13	2	1
B 1+ :	33038	88301	51155	37049	22780	55170	22942	8763	8161
B 2+ :	32896	87237	51063	29608	18937	54982	22753	8692	8160
B 3+ :	25484	72507	49059	25358	9820	25513	21956	6020	7414
B 4+ :	13050	34832	47461	17696	7493	6833	7423	5447	4159
B 5+ :	5694	5514	34027	16054	4697	5599	1390	1977	3500
B 6+ :	3169	1893	12217	6034	4136	2717	1119	312	521
B 7+ :	2378	1067	2659	1525	792	2314	877	281	90
B 8+ :	762	554	1352	462	134	589	873	170	50

Table 5 - Russian trawl survey abundance at age according to Kiseleva (1997).
('000)

year	age 1	2	3	4	5	6	7	8+	abundance	biomass (tons)
1990	26	82	803	3052	294	30	0.1	22	4308.1	3921.7
1991	336	556	3874	3759	1459	483	42	0.1	10509.5	6738.9
1992	419	3730	3686	550	245	70	26	9	8734.6	2487.3
1993	0.1	9779	7474	3424	1275	269	90	67	22376.9	8986.9
1994										
1995	0.1	4775	5311	5437	2057	179	54	54	17865.5	8262.2
1996	0.1	132	500	187	245	10	0.1	20	1094.2	729.7

Table 6 - Results of the Extended Survivors Analysis.

Extended Survivors Analysis

BACALAO 3M 1997, 8+

CPUE data from file \VPA\data\COD97q.Tun

Catch data for 9 years. 1988 to 1996. Ages 1 to 8.

Fleet,		First,	Last,	First,	Last,	Alpha,	Beta
	,	year,	year,	age ,	age		
EU-SURV	,	1988,	1996,	1,	7,	.500,	.600

Time series weights :

Tapered time weighting applied
Power = 3 over 10 years

Catchability analysis :

Catchability dependent on stock size for ages < 2

Regression type = C
Minimum of 5 points used for regression
Survivor estimates not shrunk to the population mean

Catchability independent of age for ages >= 5

Terminal population estimation :

Final estimates not shrunk towards mean F

Minimum standard error for population
estimates derived from each fleet = .300

Prior weighting not applied

Tuning converged after 29 iterations

Regression weights
, .116, .284, .482, .670, .820, .921, .976, .997, 1.000

Fishing Mortalities and F(ages 3-5)

year :	1988	1989	1990	1991	1992	1993	1994	1995	1996
1 :	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2 :	0.060	0.004	0.016	0.028	0.358	0.054	0.408	0.000	0.037
3 :	0.411	0.404	0.241	0.501	0.978	0.677	1.026	0.143	0.124
4 :	0.527	0.829	0.971	0.355	1.361	1.226	1.120	0.831	0.250
5 :	0.475	1.246	1.327	0.513	2.325	1.133	0.386	1.820	0.300
6 :	0.680	0.696	1.340	0.750	1.034	2.849	0.715	3.495	0.226
7 :	0.638	1.001	0.677	0.808	2.247	0.478	3.898	2.677	0.000
F 3-5:	0.443	0.688	0.927	0.470	1.263	0.771	1.033	0.943	0.202

XSA population numbers (Thousands)
term = Estimated population abundance at 1st Jan 1997

year :	1988	1989	1990	1991	1992	1993	1994	1995	1996	term
1 :	16900	22100	27700	69600	68800	4910	10100	3000	159	0
2 :	66400	13800	18100	22600	57000	56400	4020	8290	2450	130
3 :	83900	51200	11300	14600	18000	32600	43700	2190	6790	1940
4 :	30100	45600	28000	7250	7230	5550	13600	12800	1550	4910
5 :	4090	14500	16300	8680	4160	1520	1330	3630	4580	989
6 :	927	2080	3420	3540	4260	333	400	742	481	2780
7 :	738	384	849	734	1370	1240	16	160	18	314
8 :	0	0	0	0	0	0	0	0	0	0
B 1+ :	69273	109426	67940	47268	59102	49312	49941	25356	12701	
B 2+ :	68749	108454	66859	43509	55387	49100	49335	25218	12695	13878
B 3+ :	61910	105100	63782	39758	41365	36580	48503	23270	12080	13845
B 4+ :	36069	77401	59918	32531	32545	15227	22676	22249	8474	12815
B 5+ :	15661	29977	36230	26332	22589	8517	4683	9948	7228	8868
B 6+ :	7591	6850	11763	12348	15509	5066	1676	3233	1164	7558
B 7+ :	4260	1639	3466	3123	4292	4277	64	889	74	1256
B 8+ :	0	0	0	0	0	0	0	0	0	0

AGE

,	1,	2,	3,	4,	5,	6,	7,

Estimated population abundance at 1st Jan 1997

,	0.00E+00,	1.30E+02,	1.94E+03,	4.91E+03,	9.89E+02,	2.78E+03,	3.14E+02,

Taper weighted geometric mean of the VPA populations:

,	6.90E+03,	1.31E+04,	1.41E+04,	8.14E+03,	3.79E+03,	9.83E+02,	2.02E+02,

Standard error of the weighted Log(VPA populations) :

,	2.1565,	1.2832,	1.1375,	.9881,	.8584,	1.0873,	1.9768,

Log catchability residuals.

Fleet : EU-SURV

Age	1988	1989	1990	1991	1992	1993	1994	1995	1996
1	-.69	.44	-1.73	.75	.21	.51	-.49	.13	.00
2	-.15	1.22	-.68	-.13	-.50	.62	-.08	.05	-.05
3	-.34	.69	-.59	.50	-.63	.40	.15	-.33	.13
4	-.09	.62	.61	-.49	.12	-.38	.16	-.17	.14
5	-.28	-.55	1.23	.57	-.64	1.06	-1.58	.22	.07
6	-.45	-.84	1.50	.32	-.02	1.51	-.89	-1.77	-.19
7	.00	.01	.02	-.01	-.02	-.03	.00	.01	.01

Mean log catchability and standard error of ages with catchability independent of year class strength and constant w.r.t. time

Age	2	3	4	5	6	7
Mean Log q	-1.9290	-2.3554	-2.8324	-2.8118	-2.8118	-2.8118
S.E(Log q)	.4832	.4586	.3563	.9651	1.1849	.0161

Regression statistics :

Ages with q dependent on year class strength

Age	Slope	t-value	Intercept	RSquare	No Pts	Reg s.e	Mean Log q
1,	.84,	1.052,	3.82,	.91,	9,	.76,	-2.85,

Ages with q independent of year class strength and constant w.r.t. time.

Age	Slope	t-value	Intercept	RSquare	No Pts	Reg s.e	Mean Q
2,	.97,	.147,	2.13,	.88,	9,	.52,	-1.93,
3,	.86,	.933,	3.38,	.91,	9,	.40,	-2.36,
4,	.90,	.681,	3.46,	.91,	9,	.34,	-2.83,
5,	.70,	.835,	4.42,	.65,	9,	.70,	-2.81,
6,	.88,	.269,	3.42,	.53,	9,	1.14,	-2.94,
7,	1.00,	-1.383,	2.81,	1.00,	9,	.01,	-2.82,

Terminal year survivor and F summaries :

Age 1 Catchability dependent on age and year class strength

Year class = 1995

Fleet,	Estimated, Survivors,	Int, s.e,	Ext, s.e,	Var, Ratio,	N,	Scaled, Weights,	Estimated F
EU-SURV ,	130.,	.987,	.000,	.00,	1,	1.000,	.000
P shrinkage mean ,	13081.,	1.28,,,,				.000,	.000

Weighted prediction :

Survivors, at end of year,	Int, s.e,	Ext, s.e,	N,	Var, Ratio,	F
130.,	.99,	.00,	1,	.000,	.000

Age 2 Catchability constant w.r.t. time and dependent on age

Year class = 1994

Fleet,	Estimated, Survivors,	Int, s.e,	Ext, s.e,	Var, Ratio,	N,	Scaled, Weights,	Estimated F
EU-SURV ,	1935.,	.440,	.083,	.19,	2,	1.000,	.037

Weighted prediction :

Survivors, at end of year,	Int, s.e,	Ext, s.e,	N,	Var, Ratio,	F
1935.,	.44,	.08,	2,	.188,	.037

Age 3 Catchability constant w.r.t. time and dependent on age

Year class = 1993

Fleet,	Estimated, Survivors,	Int, s.e,	Ext, s.e,	Var, Ratio,	N,	Scaled, Weights,	Estimated F
EU-SURV ,	4913.,	.329,	.153,	.46,	3,	1.000,	.124

Weighted prediction :

Survivors, at end of year,	Int, s.e,	Ext, s.e,	N,	Var, Ratio,	F
4913.,	.33,	.15,	3,	.464,	.124

Age 4 Catchability constant w.r.t. time and dependent on age

Year class = 1992

Fleet,		Estimated, Survivors,	Int, s.e,	Ext, s.e,	Var, Ratio,	N,	Scaled, Weights,	Estimated F
EU-SURV	,	989.,	.257,	.137,	.53,	4,	1.000,	.250

Weighted prediction :

Survivors, at end of year,	Int, s.e,	Ext, s.e,	N,	Var, Ratio,	F
989.,	.26,	.14,	4,	.534,	.250

Age 5 Catchability constant w.r.t. time and dependent on age

Year class = 1991

Fleet,		Estimated, Survivors,	Int, s.e,	Ext, s.e,	Var, Ratio,	N,	Scaled, Weights,	Estimated F
EU-SURV	,	2777.,	.301,	.122,	.41,	5,	1.000,	.300

Weighted prediction :

Survivors, at end of year,	Int, s.e,	Ext, s.e,	N,	Var, Ratio,	F
2777.,	.30,	.12,	5,	.406,	.300

Age 6 Catchability constant w.r.t. time and age (fixed at the value for age) 5

Year class = 1990

Fleet,		Estimated, Survivors,	Int, s.e,	Ext, s.e,	Var, Ratio,	N,	Scaled, Weights,	Estimated F
EU-SURV	,	314.,	.632,	.109,	.17,	6,	1.000,	.226

Weighted prediction :

Survivors, at end of year,	Int, s.e,	Ext, s.e,	N,	Var, Ratio,	F
314.,	.63,	.11,	6,	.173,	.226

Age 7 Catchability constant w.r.t. time and age (fixed at the value for age) 5

Year class = 1989

Fleet,		Estimated, Survivors,	Int, s.e,	Ext, s.e,	Var, Ratio,	N,	Scaled, Weights,	Estimated F
EU-SURV	,	15.,	.298,	.042,	.14,	7,	1.000,	.000

Weighted prediction :

Survivors, at end of year,	Int, s.e,	Ext, s.e,	N,	Var, Ratio,	F
15.,	.30,	.04,	7,	.141,	.000

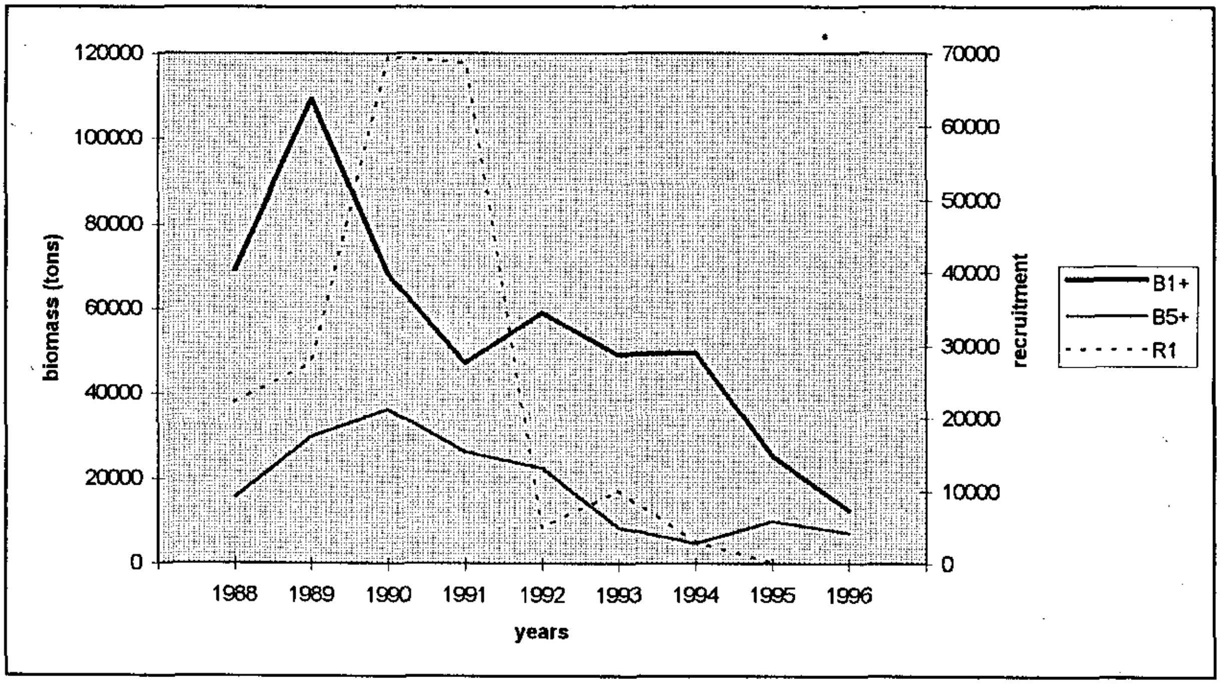

Figure 1 - 3M cod: total biomass, spawning stock biomass (5+ biomass) and abundance of recruitment at age 1 according to XSA results.

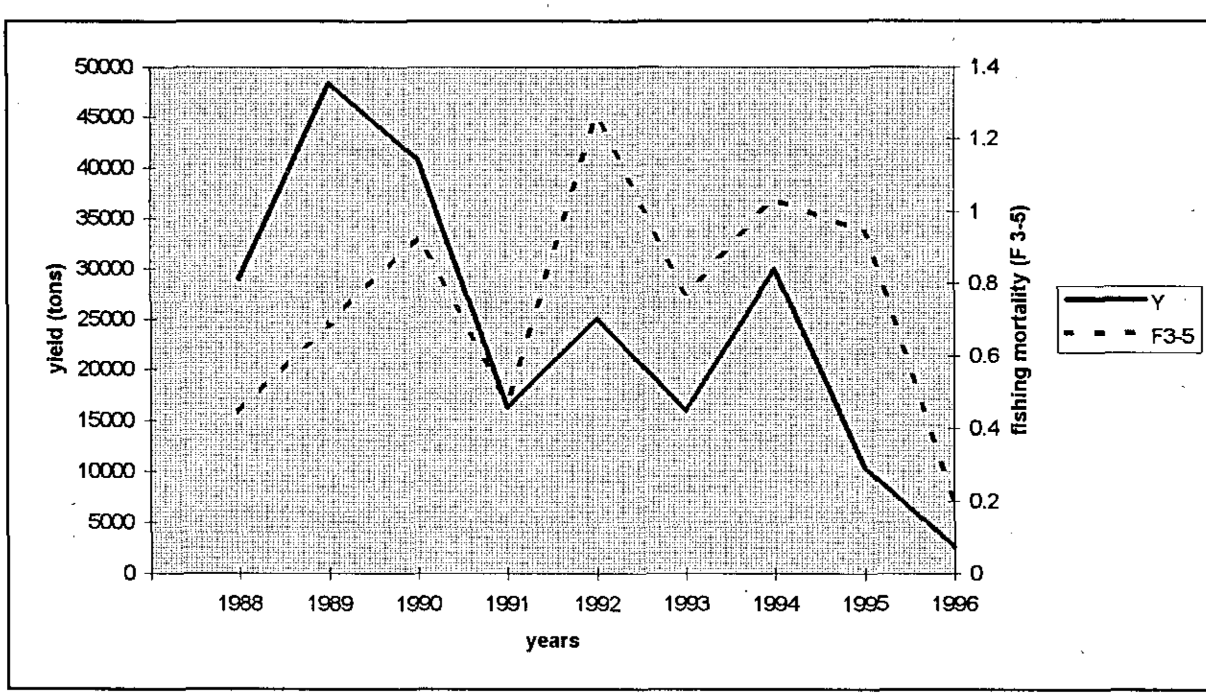

Figure 2 - 3M cod: total annual catch and fishing effort (as F 3-5) according to XSA results.