Northwest Atlantic Fisheries Organization

Serial No. N3043 NAFO SCR Doc. 98/52

SCIENTIFIC COUNCIL MEETING - JUNE 1998

An Assessment of the Cod Stock in NAFO Division 3M

by

A. Vázquez[1] and L. Motos[2]

[1] Instituto de Investigaciones Marinas, Eduardo Cabello 6, Vigo, Spain
[2] Instituto Tecnológico Pesquero y Alimentario, San Sebastián, Spain

INTRODUCTION

The last year analysis of the cod stock in Division 3M for 1988 to 1996 (Vázquez et al. 1997) is reviewed and updated with 1997 data.

The 1997 cod fishery was at the same low level as in 1996: most of the fleets traditionally aimed to 3M cod didn't participate, particularly Portuguese gillnetters and Faroese longliners. One Spanish pair-trawler that came to the fishery moved to fish for Greenland halibut.

MATERIAL AND METHODS

Commercial fishery data

The 3M cod 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 (Vázquez et al. 1995). Spanish catch and effort data from 1995 onwards was derived from STATLANT 21B. Portuguese catch and effort data for 1995 were derived the same way as in the previous period, and since 1996 they were taken from Portuguese STATLANT 21B. The use of STATLANT data for those 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 1997 total cod catch is estimated to be around 2,933 tons (Table 1), including 1,500 tons attributed to vessels from Non-Contracting Parties, according to Canadian Surveillance reports.

Sampling catch

One only sample from commercial catches was available in 1997, coming from a Portuguese stern trawler (Alpoim et al. 1998). All those fish were aged.

Mean weight-at-age in the catch were calculated using the length-weight relationship obtained during EU bottom-trawl survey on Flemish Cap in July 1997 (Vázquez et al. 1998).

Data files for Extended Survivors Analysis (XSA)

The 1997 landing data file includes the STATLANT catches of Portugal and Spain (provisional) as well as the catch estimates for Non-Contracting Parties from Canadian Surveillance.

The 1997 cod catch by Non-Contracting Parties were considered to have a length and age structure similar to the Portuguese trawl catch. The total numbers for 1997 were then incorporated in the catch-at-age data file (Table 2).

The 1997 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 (Vázquez et al 1998) were used for tuning the Analysis (Table 4). The Russian survey was not used due to their poor results in previous 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 (Ávila de Melo and Alpoim, 1996). The series was discontinued in 1997.

RESULTS AND DISCUSSION

An Extended Survivor Analysis (Darby and Flatman 1994) was carried out for ages 1 to 7 and years 1988 to 1997 (Table 5). A first analysis was carried out with the same conditions that in the last year (Vázquez et al. 1997). The analysis was repeated setting catchability independent of year-class strength from age 3 onwards (instead of 2 onwards), because slopes of catchability regression were significantly dependent of stock abundance at younger ages. Catchability was also considered independent of age for age 4 and older (instead of 5 and older), because age 4 was observed as the oldest of the best estimated fully-recruited ages. Residuals of catchability regressions for the EU survey are presented in Figure 1. Results from the retrospective analysis appear consistent (Figure 2).

Spawning stock biomass (SSB) was calculated from XSA results on abundance-at-age, mean weights-at-age in stock and percentages of maturity-at-age according to Saborido-Rey (1997). Maturity data cover the 1992 to 1996 period. The maturity-at-age series was extended to the 1988 to 1997 period of the current analysis assuming the same values of 1992 for years 1988 to 1991, and accepting for 1997 the same value than in 1996. This extension is justified by the similarity of the stock biomass level in 1996 and 1997, and by the assumed greater stability of the stock before 1992. The deepest changes in this cod stock occurred during the period studied. According to most recent analysis, cod spawned at a younger age in the last years than in the past: age at first maturity traditionally occurred at age 5, but it was observed at age 4 and younger since 1994.

Total biomass and recruitment abundance from 1988 to 1997, all of them from XSA, and spawning stock biomass, calculated as described above, are presented in Figure 3. First maturity at younger ages, together with the relatively abundant survivors of the 1991 year-class, allowed for a maintenance of the spawning stock biomass level in 1994 and 1995, although total biomass sharply decreased. However, this relatively high level of spawning stock was not reflected in the strength of the 1994 and 1995 year-classes, which are among the weakest in the time series, according to the EU survey results. Spawning stock decreased after 1995, and the recruitment further decreased in 1996.

Total biomass, according XSA results, declined from the highest level between 70,000 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 those years (Figure 4). Fishing mortality (F 3-5) was around 1 or higher from 1992 to 1995. 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 27,000 tons in 1995 and 13,000/15,000 tons in 1996/1997, the lowest recorded in the time series. The last decline of the stock biomass is also related to a continuing failure of recruitment since 1992.

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 (Kiseleva 1997) 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.

The evolution of fishing mortality and spawning stock biomass from 1988 to 1997 period deduced from XSA results are presented in Figure 5. The series of XSA results is too short to be adequately fitted to most common analytical methods, so only a tentative approach was aimed for precautionary reference points.

The F0.1 and F_{max} reference points for the current exploitation pattern were calculated with partial recruitment, calculated by averaging fishing mortalities at ages for all years in XSA results and scaling to a flat-top for ages 4 onwards; mean weights at age, calculated as mean weight at age in the EU survey (weighted by abundance at age in the survey), and natural mortality equal 0.2 (Table 6). It is clear from Figure 5 that fishing mortality has been well above the F 0.1 level for the current exploitation pattern at least since 1988.

The stock-recruitment relationship for this stock was explored using the XSA results for spawning stock biomass and abundance at age 1 (Figure 6). The low numbers of data points and their scattering did not allow to get any significant fit to the usual S-R models.

ACKNOWLEDGEMENTS

This study was supported by the European Commission (DG XIV, Study 96-030), CSIC, IEO, IPIMAR and the Basque Government.

REFERENCES

Alpoim, R., M.L. Godinho, E. Santos and A.M. Ávila de Melo - 1998. Portuguese Research Report for 1997. *NAFO SCS Doc.* 98/13, 38 pp.

Ávila de Melo, A. and R. Alpoim - 1996. Catch rate versus biomass trends for 3M cod, 1988-95: why they don't match?. *NAFO SCR Doc.* 96/32, 15 pp.

Brodie, W.B., M.J. Morgan and E.F. Murphy - 1997. Results for selected species from a Canadian research vessel survey on Flemish Cap, NAFO Div. 3M, in 1996. *NAFO SCR Doc.* 97/42, 15 pp.

Darby, C. and S. Flatman - 1994. Virtual population analysis: version 3.1 (Windows/DOS) user guide. *Min. Agric. Fish. & Food*, Lowestoft, 77 pp.

Kiseleva, V.M.- 1997. Assessment of cod stock on the Flemish Cap from data of trawl survey in 1996. *NAFO SCR Doc.* 97/7, 9 pp.

Saborido-Rey, F.- 1997. Sexual maturity and spawning biomass of the cod stock on Flemish Cap (Division 3M). *NAFO SCR Doc.* 97/18, 9 pp.

Vázquez, A., A. Ávila de Melo, E. de Cárdenas and R. Alpoim - 1995. An assessment of the cod stock in NAFO Division 3M. *NAFO SCR Doc.* 95/73, 8 pp

Vázquez, A., A. Ávila de Melo and F. Saborido-Rey - 1998. Results from bottom trawl survey of Flemish Cap in July 1997. *NAFO SCR Doc.* 98/30, 38 pp.

Vázquez, A., A. Ávila de Melo, R. Alpoim, E. de Cárdenas and L. Motos- 1997. An assessment of the cod stock in NAFO Division 3M. *NAFO SCR Doc.* 97/50, 10 pp.

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

	total	reported								
year	estimated	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
1997	2933					1432		1			1433

Table 2 - Catch in numbers. ('000)

	age:							
year	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
1997	0	0	810	762	143	286	48	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
1997	0.000	0.000	0.402	0.640	0.869	1.197	1.339	0.000

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
1997	0.077	0.324	0.636	1.004	1.309	2.097	2.001	9.573

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	1997
1 :	458	2418	237	13780	7118	438	315	155	4	4
2 :	7196	6062	1179	2560	3706	13274	385	1137	297	14
3 :	4037	6964	467	1538	475	2852	2459	123	613	315
4 :	1085	2819	1588	193	203	102	456	361	82	436
5 :	128	227	1453	628	33	127	12	90	225	36
6 :	22	33	394	168	127	17	6	1	19	90
7 :	28	12	32	31	21	50	0	2	1	2
8 :	11	8	24	6	2	10	13	2	1	1
B 1+	33038	88301	51155	37230	22780	55170	22942	8763	8161	8924
B 2+	32896	87237	51063	29789	18937	54982	22753	8692	8160	8920
B 3+	25484	72507	49059	25539	9820	25513	21956	6020	7414	8875
B 4+	13050	34832	47461	17926	7493	6833	7423	5447	4159	6872
B 5+	5694	5514	34027	16276	4697	5599	1390	1977	3500	2494
B 6+	3169	1893	12217	6159	4136	2717	1119	312	521	2023
B 7+	2378	1067	2659	1781	792	2314	877	281	90	136
B 8+	762	554	1352	462	134	589	873	170	50	96

Table 5 - Results of the Extended Survivors Analysis.

Lowestoft VPA Version 3.1

8/06/1998 13:00

Extended Survivors Analysis

Cod 3M 1998, 8+

CPUE data from file \VPA\data\COD98a.Tun

Catch data for 10 years. 1988 to 1997. Ages 1 to 8.

Fleet,	First year,	Last year,	First age ,	Last age	Alpha,	Beta
EU-SURV	1988,	1997,	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 < 3

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

Catchability independent of age for ages >= 4

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 had not converged after 30 iterations

Total absolute residual between iterations
29 and 30 = .00269

Final year F values

Age	1,	2,	3,	4,	5,	6,	7
Iteration 29,	.0000,	.0000,	.3204,	.1353,	.1709,	.1537,	1.2649
Iteration 30,	.0000,	.0000,	.3194,	.1351,	.1705,	.1535,	1.2640

Regression weights

,	.020,	.116,	.284,	.482,	.670,	.820,	.921,	.976,	.997,	1.000

Fishing mortalities

Age,	1988,	1989,	1990,	1991,	1992,	1993,	1994,	1995,	1996,	1997
1,	.000,	.000,	.000,	.000,	.000,	.000,	.000,	.000,	.000,	.000
2,	.060,	.004,	.016,	.028,	.363,	.055,	.404,	.000,	.022,	.000
3,	.411,	.405,	.241,	.501,	.979,	.694,	1.070,	.141,	.093,	.319
4,	.524,	.830,	.975,	.355,	1.362,	1.227,	1.191,	.925,	.246,	.135

5,	.479,	1.225,	1.330,	.517,	2.326,	1.135,	.386,	2.658,	.362,	.170
6,	.689,	.706,	1.260,	.754,	1.055,	2.850,	.718,	3.530,	.731,	.154
7,	.660,	1.031,	.697,	.686,	2.312,	.498,	3.963,	2.740,	.000,	1.264
3-5	.471,	.820,	.849,	.458,	1.555,	1.018,	.882,	1.241,	.234,	.208

XSA population numbers (thousands), Btot and SSB in tons

age / year :	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	term
1 :	16900	22100	27700	68800	67300	4950	13300	4990	279	274	0
2 :	66300	13800	18100	22600	56400	55100	4050	10900	4090	229	227
3 :	83900	51100	11300	14600	18000	32100	42700	2220	8930	3270	189
4 :	30200	45500	27900	7250	7230	5550	13100	12000	1580	6660	1950
5 :	4060	14700	16300	8620	4160	1520	1330	3270	3900	1010	4770
6 :	919	2060	3530	3520	4210	333	399	741	188	2220	698
7 :	721	378	832	819	1360	1200	16	159	18	74	1560
8+	366	346	254	167	558	594	194	263	0	0	17
Btot	71718	111914	69434	48731	62439	52055	50259	26862	12702	14993	
SSB	14355	27508	28106	19525	18548	9786	17030	18499	6549	9886	

Taper weighted geometric mean of the VPA populations:

, 4.13E+03, 7.02E+03, 1.07E+04, 7.06E+03, 2.70E+03, 8.67E+02, 1.45E+02,

Standard error of the weighted Log(VPA populations) :

, 2.2325, 1.9424, 1.1679, .8598, .8589, 1.2159, 1.8893,

Log catchability residuals.

Fleet : EU-SURV

Age ,	1988,	1989,	1990,	1991,	1992,	1993,	1994,	1995,	1996,	1997
1 ,	-.51,	.48,	-1.50,	.67,	.19,	.68,	-.56,	-.12,	-.01,	.01
2 ,	-.22,	1.17,	-.51,	-.05,	-.49,	.49,	.20,	-.04,	-.21,	.02
3 ,	-.35,	.69,	-.59,	.48,	-.64,	.42,	.19,	-.36,	-.17,	.29
4 ,	-.15,	.56,	.55,	-.54,	.06,	-.44,	.18,	-.11,	.07,	.23
5 ,	-.31,	-.61,	1.20,	.55,	-.67,	1.03,	-1.61,	.75,	.23,	-.35
6 ,	-.47,	-.86,	1.39,	.26,	-.03,	1.47,	-.92,	-1.79,	1.00,	-.24
7 ,	.00,	.00,	.01,	-.01,	-.01,	-.02,	.00,	.01,	.01,	-.03

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

Age ,	3,	4,	5,	6,	7
Mean Log q,	-2.3474,	-2.7765,	-2.7765,	-2.7765,	-2.7765,
S.E(Log q),	.4261,	.3155,	.9625,	1.1824,	.0169,

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,	.76,	2.026,	4.49,	.94,	10,	.61,	-3.27,
2,	.87,	1.508,	3.07,	.97,	10,	.40,	-2.17,

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
3,	.90,	.662,	3.04,	.91,	10,	.41,	-2.35,
4,	.92,	.517,	3.27,	.90,	10,	.31,	-2.78,
5,	.69,	.897,	4.35,	.66,	10,	.68,	-2.77,
6,	1.21,	-.380,	1.97,	.43,	10,	1.57,	-2.81,
7,	1.00,	-.640,	2.78,	1.00,	10,	.02,	-2.78,

Terminal year survivor and F summaries :

Age 1 Catchability dependent on age and year class strength

Year class = 1996

Fleet,	Estimated, Survivors,	Int, s.e,	Ext, s.e,	Var, Ratio,	N, Scaled, Weights,	Estimated F
EU-SURV ,	227.,	.727,	.000,	.00,	1, 1.000,	.000
P shrinkage mean ,	7022.,	1.94,,,,			.000,	.000

Weighted prediction :

Survivors, at end of year,	Int, s.e,	Ext, s.e,	N, ,	Var, Ratio,	F
227.,	.73,	.00,	1,	.000,	.000

Age 2 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 ,	189.,	.424,	.013,	.03,	2, 1.000,	.000
P shrinkage mean ,	10717.,	1.17,,,,			.000,	.000

Weighted prediction :

Survivors, at end of year,	Int, s.e,	Ext, s.e,	N, ,	Var, Ratio,	F
189.,	.42,	.01,	2,	.031,	.000

Age 3 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 ,	1954.,	.285,	.165,	.58,	3, 1.000,	.319

Weighted prediction :

Survivors, at end of year,	Int, s.e,	Ext, s.e,	N, ,	Var, Ratio,	F
1954.,	.28,	.17,	3,	.580,	.319

Age 4 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	4773.,	.219,	.143,	.65,	4,	1.000,	.135

Weighted prediction :

Survivors, at end of year,	Int, s.e,	Ext, s.e,	N,	Var, Ratio,	F
4773.,	.22,	.14,	4,	.651,	.135

Age 5 Catchability constant w.r.t. time and age (fixed at the value for age) 4

Year class = 1992

Fleet,	Estimated, Survivors,	Int, s.e,	Ext, s.e,	Var, Ratio,	N,	Scaled, Weights,	Estimated F
EU-SURV	698.,	.224,	.136,	.61,	5,	1.000,	.170

Weighted prediction :

Survivors, at end of year,	Int, s.e,	Ext, s.e,	N,	Var, Ratio,	F
698.,	.22,	.14,	5,	.607,	.170

Age 6 Catchability constant w.r.t. time and age (fixed at the value for age) 4

Year class = 1991

Fleet,	Estimated, Survivors,	Int, s.e,	Ext, s.e,	Var, Ratio,	N,	Scaled, Weights,	Estimated F
EU-SURV	1561.,	.301,	.093,	.31,	6,	1.000,	.153

Weighted prediction :

Survivors, at end of year,	Int, s.e,	Ext, s.e,	N,	Var, Ratio,	F
1561.,	.30,	.09,	6,	.309,	.154

Age 7 Catchability constant w.r.t. time and age (fixed at the value for age) 4

Year class = 1990

Fleet,	Estimated, Survivors,	Int, s.e,	Ext, s.e,	Var, Ratio,	N,	Scaled, Weights,	Estimated F
EU-SURV	17.,	.290,	.069,	.24,	7,	1.000,	1.263

Weighted prediction :

Survivors, at end of year,	Int, s.e,	Ext, s.e,	N,	Var, Ratio,	F
17.,	.29,	.07,	7,	.238,	1.264

Table 6 - F 0.1 input parameters and results

age	mean weight	partial R
1	0.052	0.000
2	0.199	0.158
3	0.507	0.638
4	0.960	1.000
5	1.585	1.000
6	2.496	1.000
7	4.094	1.000
8	6.578	1.000

F 0.1 =	0.141
Y 0.1 =	0.653
F max =	0.220
Y max =	0.691

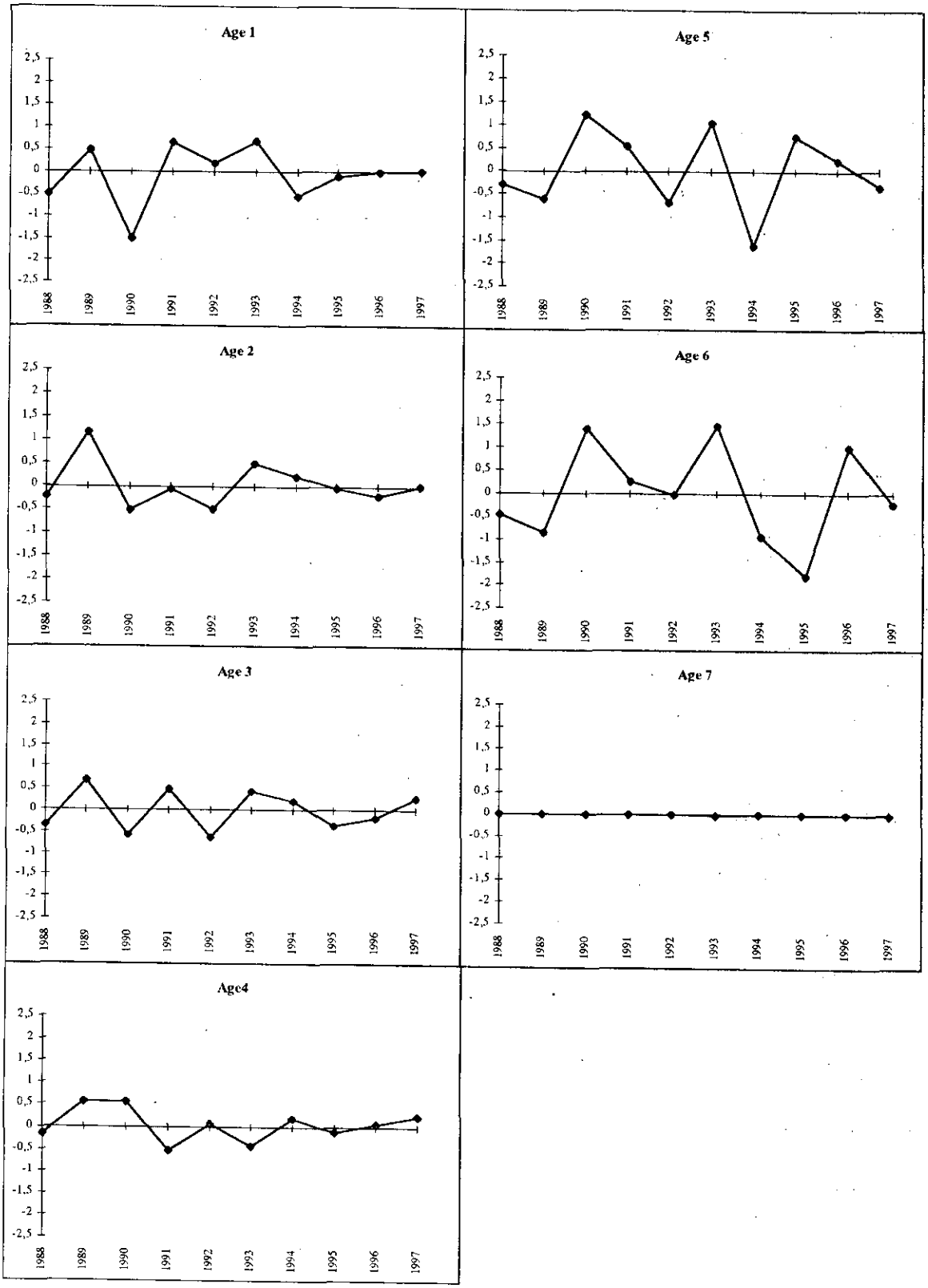

Figure 1 - Residuals of the catchability regression for ages 1 to 7.

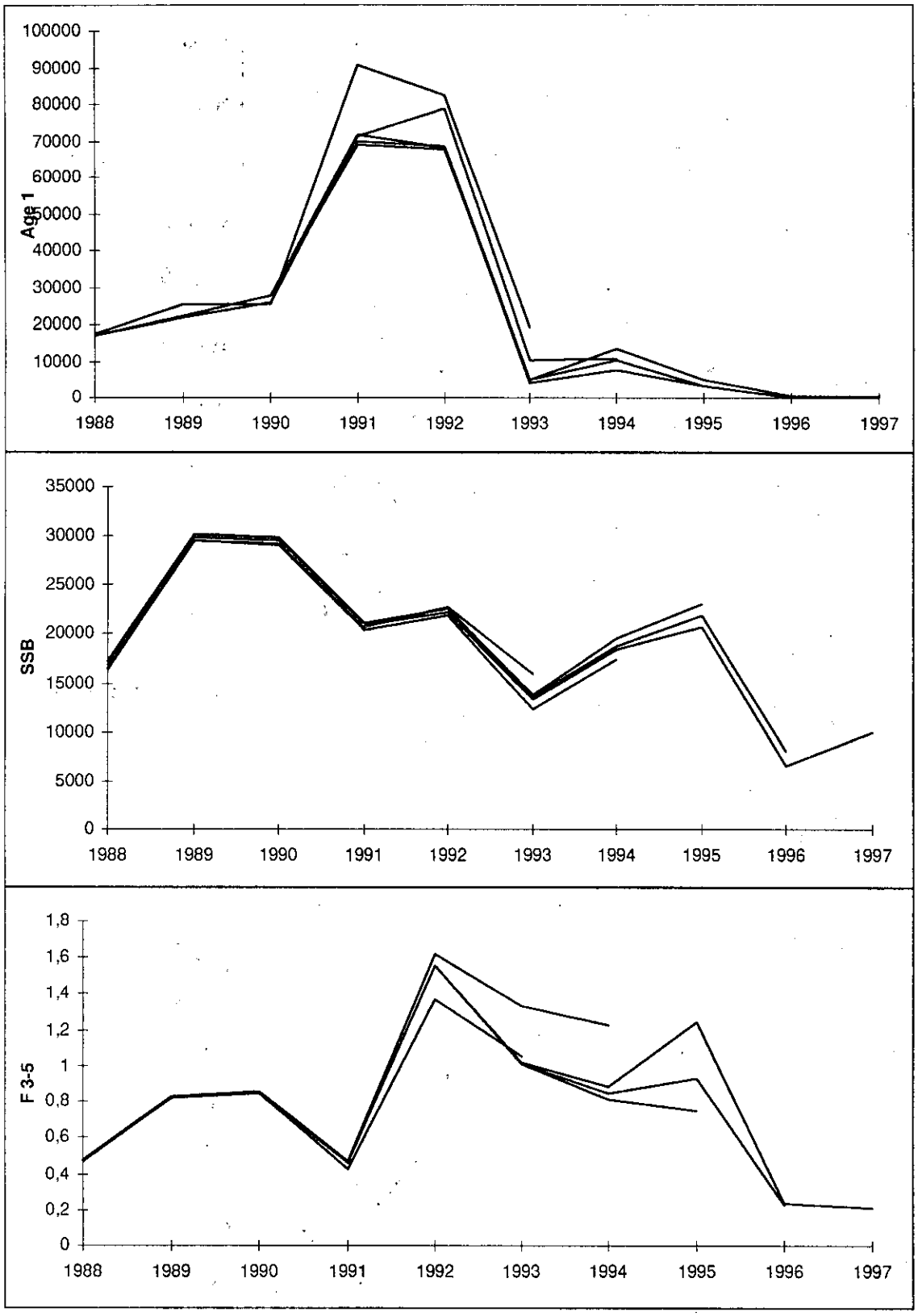

Figure 2 - Results of a retrospective analysis.

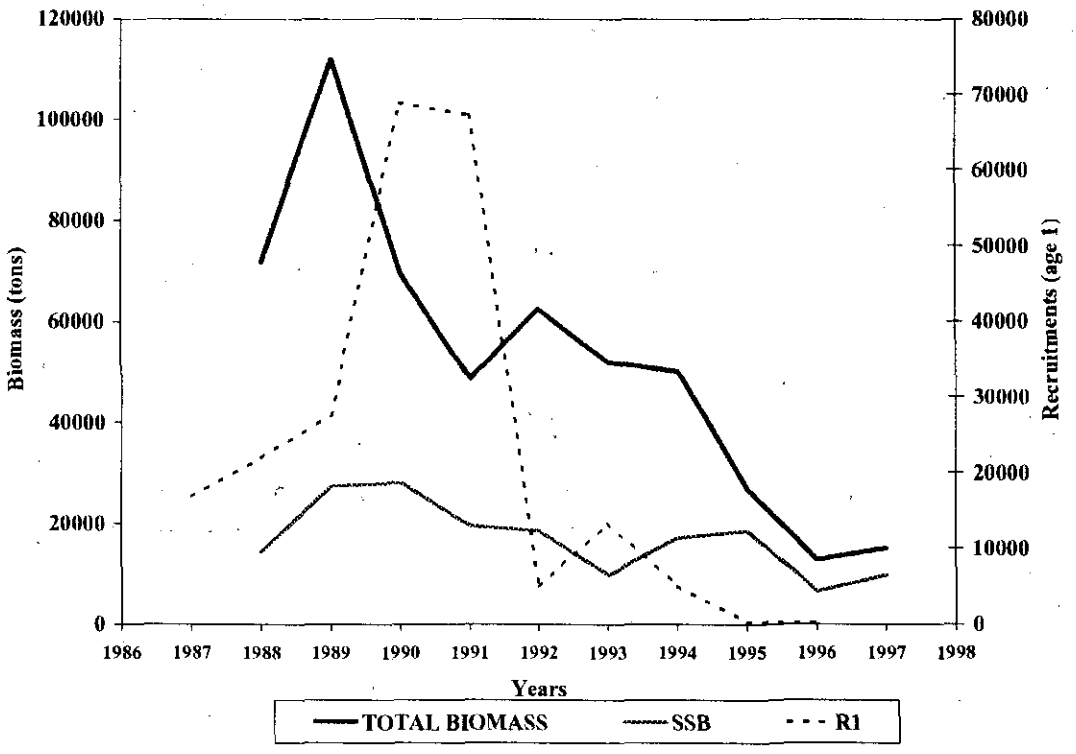

Figure 3 - 3M cod: total biomass, spawning stock biomass (SSB) and abundance of recruitment at age 1 according to XSA results.

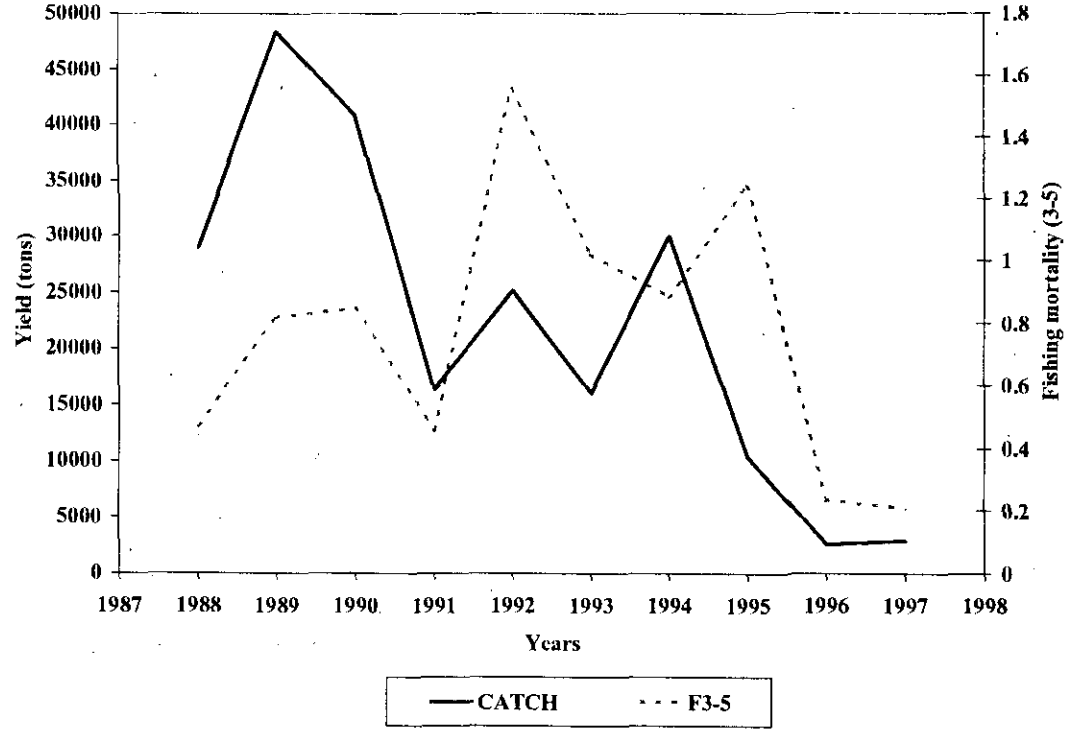

Figure 4 - 3M cod: total annual catch and fishing mortality (as F 3-5) according to XSA results.

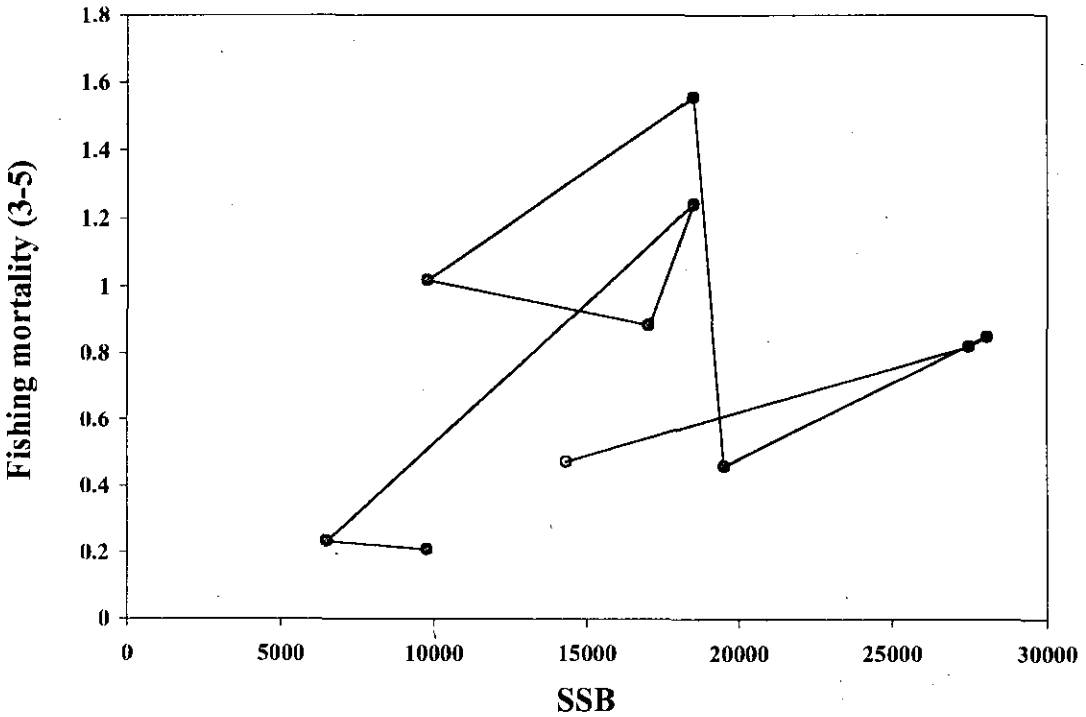

Figure 5 - Fishing mortality and spawning stock biomass (SSB) from 1988 to 1997 according to XSA results.

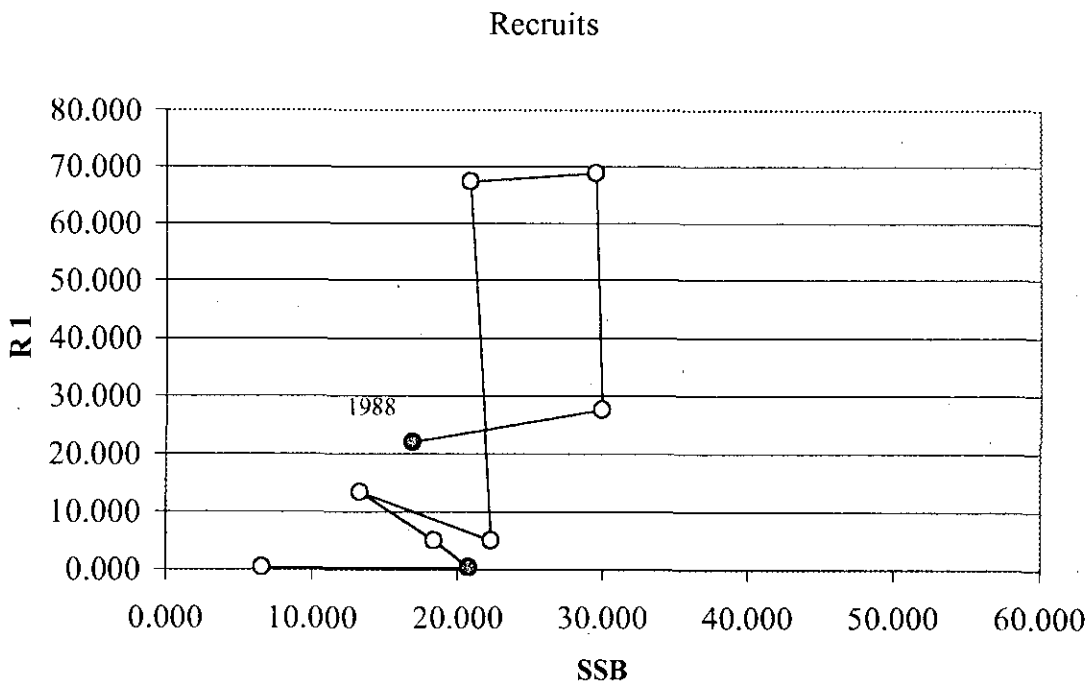

Figure 6 - Spawning stock biomass (SSB) and recritment at age 1 (R1) from 1988 to 1997 according to XSA results.