Northwest Atlantic Fisheries Organization

Serial No. N5253 **NAFO SCR Doc. 06/32**

SCIENTIFIC COUNCIL MEETING – JUNE 2006

A Survey-based Assessment of Cod in Division 3M

by

H. Murua[1], S. Cerviño[2] and A. Vázquez[3]

[1] AZTI Tecnalia, Herrera Kaia, Portualde z/g, 20 110 Pasaia (Basque Country), Spain. E-mail: hmurua@pas.azti.es
[2] Instituto Español de Oceanografía, Vigo, Spain. E-mail: santiago.cerviño@vi.ieo.es
[3] Instituto de Investigaciones Marinas, Eduardo Cabello 6, 36208 Vigo, Spain. E-mail: avazquez@iim.csic.es

Abstract

The cod stock in NAFO Division 3M is in moratorium since 1999. The low catches collected since then make it difficult to apply a VPA based assessment to evaluate the current stock status. Therefore, a survey-based assessment method was used to evaluate the present status in a stochastic way; a method that takes into account uncertainties in survey sampling as well as in catchability estimates. The results show that the spawning stock biomass is at very low level in comparison to the time series levels and all survey stochastic estimates are under B_{lim}. Although abundance at age 1 in the survey is the highest observed since 1993, the current abundances at age of pre-mature year-classes are at very historic low levels and, consequently, a recovery of the stock is not expected in a sort or medium term.

Introduction

The stock is under moratoria since 1999 due to the collapse of the stock; which has been attributed to three possible factors: a stock decline due to overfishing, an increase in catchability at low abundance levels and a very poor recruitment since 1993. Last recent year assessment confirmed the poor situation of the stock with the spawning stock biomass at its lowest levels and well below B_{lim} (Vázquez and Cerviño, 2005). Moreover, the recovery of the stock was not expected in the short or medium term time period (Vázquez and Cerviño, 2005).

Since 1974, when a TAC was established for the first time, catches ranged from 48 000 tons in 1989 to a minimum of 16 tons in 2003. Total estimated catch in 2005 was 19 tons. Annual catches were about 30 000 tons in the late 1980s, when the fishery was under moratoria in 1988-1990, and they diminished since then as a consequence of the stock decline. Since 1998 catches were less than 1 000 tons and since 2000 they were less than 100 tons, mainly attributed to by-catches in other fisheries. Historical catches are shown in Table 1, where decline of the fishery is clearly observed.

A VPA based assessment of the cod stock in Flemish Cap was approved in 1999 for the first time and it was annually updated until 2002. However, most recent catches were very small, under 100 tons, undermining the VPA based assessment as the results of VPA are based on catches and are quite sensitive to natural mortality (M) values when catches are at low levels. The F estimates from last analysis were at the same level than M in both 1998 and 1999 and lower than M in 2000 and 2001 (Vázquez and Cerviño, 2002). Therefore, as the XSA depends solely on the precision of M the quality of the result is not considered reliable.

The Cerviño and Vázquez (2003) method combines survey abundance indices at age with the estimated catchability at age, from last reliable accepted XSA, in order to estimate total abundance at age. Uncertainty in both parameters, survey abundance and catchability, are estimated from sampling theory and bootstrapping XSA, respectively. With this method, estimates of abundance at age from surveys, with its associated variability, are the basis to calculate the SSB distribution and the probability of being above or below any limit.

A B_{lim} of 14 000 tons was established in 2001 for this stock (Cerviño and Vázquez, 2000). Given the present moratorium, the fishery re-opening criterion may include a decision on the current SSB estimates being above that level in probabilistic terms. Once the re-opening criteria are achieved, this kind of analysis could also allow a stochastic analysis of catch options by projections of short or medium term. This method allow assessing stocks without catches provide that survey abundance indices and an estimate of catchability are available, as it is the case of Flemish Cap cod; but could also be useful if a VPA based assessment gives unrealistic results.

This assessment updates the status of the stock using the methodology proposed by Cerviño and Vázquez (2003) based primarily on the Flemish Cap Survey indices at age and the catchability estimates from the 1999 accepted XSA. Indices and catchability uncertainty are used to calculate the statistical distribution of SSB estimates and its probability of being below or above B_{lim}.

Material and Methods

Data

Survey indices of abundance at age and their errors, survey catchability at age and their errors, weight at age and maturity at age are the inputs used to carry out a survey-based assessment. Errors in the maturity and weight at age were not taken into account. An estimate of total mortality is also used to transform the abundance at survey time (in summer) to the beginning of the year.

The EU bottom trawl survey of Flemish Cap was carried out since 1988 targeting the main commercial species down to 730. The surveyed zone includes the complete area distribution for cod, which rarely occurs deeper than 500 meters. The sampling procedure did not change along the series, although the research vessel used in 1989 and 1990 was not the same as used for the rest of the series. From 2003 onwards the survey was carried out with the new R/V *Vizconde de Eza* (Casas, 2004) keeping the same gear and survey procedure. Comparative fishing trials with the former vessel, R/V *Cornide de Saavedra*, were performed in 2003 and 2004 in order to make the series comparable (Casas and González-Troncoso, 2005). In total, 130 paired hauls with *Cornide de Saavedra* and *Vizconde de Eza* were carried out (in which 68 of them cod appeared) and the conversion factors to transform the *Cornide de Saavedra* values to *Vizconde de Eza* equivalents were estimated (González-Troncoso and Casas, 2005). The transformed data of cod abundance at age and their standard errors calculated following Cerviño (2002) are presented in Table 2. Weight and maturity ate at age are presented in Table 3.

Catchability at age was derived using a XSA based on catch data until 1999 because since then annual catches are very low introducing high uncertainty on XSA results (Cerviño and Vázquez, 2003). However, as the surveys indices were transformed to the new vessel R/V *Vizconde de Eza*, the XSA was re-run again with the new survey indices and using the same setting of 1999 XSA assessment. In summary, age 1 was calibrated with a two-parameter model or dependence on stock abundance, catchability for ages 2, 3 and 4 were estimated as independent of stock size from a one-parameter model, and catchability for older ages was considered constant and equal to age 4 catchability in the settings. Variance of catchability estimates from XSA has two components: one due to the survey sampling variability and other due to the year to year catchability variability. Therefore, a *bootstrap*-subtracting algorithm based on the XSA model was defined to quantify the second component of variance, i.e. due to inter-annual variability, assuming additivity and independence among both components. This algorithm has three steeps:

1. Total error in catchability parameters is estimated by *conditioned bootstrap*. Covariance matrix is presented in Table 4 (upper panel).
2. Partial errors due to indices variability are estimated by *unconditioned bootstrap*. 3000 XSA were run with different survey indices estimated from Montecarlo simulation assuming a log-normal error in the survey abundances in order to estimate the q error due to survey. Covariance matrix is presented in Table 4 (intermediate panel).
3. Catchability covariance matrix is calculated by subtracting the two previous matrices: the one due to survey variability from the one due to total variability. The result is presented in Table 4 (lower panel)

The values, standard errors and correlation matrix of the catchability used for simulation are presented in Table 5.

The stochastic model

The model follows the catchability equation, which relates the true abundance (N) to an abundance index (I):

$$I_{y,a} = q_a * N_{y,a} * \varepsilon_{y,a}$$

where q is the catchability and ε an error factor; the sub-index y relates to the year and a to age. Based on that, N is estimated from abundance index and estimated catchability according to:

$$\boldsymbol{N_{y,a} = I^*_{y,a} / q^*_a}$$

where the super-index * indicates stochastic values. I and q are assumed to follow a lognormal distribution with expected value and standard errors as described before. q covariances were included in the model, but I covariances were not included because they are low in the last years.

The abundance (N) needs to be corrected to the beginning of the year (N^0) because that is the scale for B_{lim}. Since the EU survey is carried out in the middle of the year, the assumed total mortality (Z) included natural mortality (M) equal 0.2, and fishing mortality (F) from 2002 assessment, which was considered negligible.

$$N^0_{y,a} = N_{y,a} * \exp(t * Z)$$

SSB was calculated from survey results as the sum of products of abundance at age (N), mean weight (W) and maturity rate (Mat) at age.

$$\boldsymbol{SSB = \sum_{a=1}^{n} N^0_{y,a} * W_{y,a} * Mat_{y,a}}$$

SSB distribution was calculated by a bootstrap where I and q were re-sampled independently 2000 times. The method allows estimating the *bootstrap* statistical properties of abundance at age and SSB: mean, standard deviation, coefficient of variance, skewness, statistical bias and percentiles.

Results

The mean catch per tow and the mean numbers per tow in the Flemish Cap survey decreased continuously from 1989 to the lowest observed level in 2003. They increased slightly in 2004 and 2005 but still remained at the lowest historic levels (Fig. 1). The abundance at age 1 in the EU survey in 2005 is the highest observed since 1993, nevertheless it is well below of the values observed before 1993, when the population was healthy (Table 2).

Deterministic results for abundance at age and for SSB are presented in Table 6. Abundances at age for each year were estimated independently using the results; which imply that cohort abundances are not forced to decrease from year to year necessarily as in the VPA. Although the 2005 SSB slightly increased (5 044 tons) from the lowest historic observed level of 2003 (1 372 tons), it is well below the values observed in the historic time series. Abundance at ages 4 to 8+ in 2005 are at the lowest observed level. Abundance at age 1 in 2005 is the highest since 1993, however it remains at a low level in relation to the abundance at age 1 before 1993.

Probability distributions of abundance at age, calculated by bootstrap, are presented in Tables 7 and 8, and in Fig. 2 and 3. Table 7 shows the *bootstrap* statistics for abundance at age. All the means are slightly above their deterministic values due to bias in the range between 1.2 % and 3.2 %, except for age 1, which had a bias of 53.6 %. Abundance at age 1 was estimated with the two parameter model and it is likely that its distribution doesn't match properly with the assumed lognormal distribution. Coefficients of variation range from 0.25 for age 3 to 0.62 for age 2.

Stochastic SSB estimates are showed in Table 8. The stochastic SSB means are also slightly above the deterministic values and their bias are around 2.7 % in the whole series. Coefficients of variation range from 0.18 in 1990 to 0.27 in 1993, being 0.22 in 2005. Figure 1 shows the trend in SSB with 90 % percentiles as well as the values derived form the last two XSAs carried out in 1999 and 2002, respectively (Vázquez and Cerviño, 2002; Cerviño and Vázquez, 2003). Although XSA values are in some cases outside the confidence margins of survey-based values, both series show similar trends and both XSA and survey-based SSB are under B_{lim} since 1998. Moreover, the cumulative SSB distribution shows the probability of being over B_{lim}, which was set at 14 000 tons for 3M cod, is 0% (Fig. 3). All the 3000 *bootstrap* values of SSB are below B_{lim}.

Discussion

Based on the observed trends of the EU bottom trawl survey abundance at age it could be concluded that cod 3M population continues collapsed. All year-classes are at similar or lower level than in previous years, and no signal of recovery is observed. The abundance at age 1 in the EU survey in 2005 was the highest observed since 1993, nevertheless it was well below in comparison to the values observed before 1993, when the population was healthy, and it is not expected that the stock will recover based on the observed low level of all cohorts.

Moreover, the proposed survey-based method reinforced the perception of the state of the stock. Moreover, it has other advantages with respect to traditional VPA based assessment in a situation of no catches. Particularly because this method presents the probability distribution of the SSB which fit within the NAFO PA framework and, thus, it can be used by Scientific Council to advice about re-opening the fishery and the risk associated with that decision.

- The method avoids the use of a VPA based method, which results became unrealistic year after year given the low catch levels that occurred since 2000.
- The method uses abundance indices and catchability at age from VPA as input variables to produce an absolute SSB estimate, the same scale used to set B_{lim} (14 000 tons for 3M cod).
- The method provides the error distribution of state variables, SSB and abundance at age, taking into account the survey sampling errors and the survey catchability errors.
- The method provides the distribution SSB estimates, which allows calculating the probability of being below or above B_{lim}, avoiding the need of setting B_{buff} as a precautionary reference.
- The abundance at age distribution allows the use of stochastic projections as a tool to advice on the fishing mortality that could be applied after re-opening.
- The method can be applied to other stocks in a situation similar to Flemish Cap cod. A survey with estimated errors of abundance at age and estimates of catchability at age are only needed.

In summary, the current SSB, being estimated around 5 000 tons, is at historic low levels in the whole series and, although recruitment at age 1 shows a lightly increase respect to previous years, it is unlikely to expect a stock recovery in a short or medium term.

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Table 1 – Total cod catch in Flemish Cap. Reported nominal catches since 1959 and estimated total catch since 1988 in tons.

Year	Estimated	Faroes	Japan	Korea	Norway	Portugal	Russia	Spain	UK	France	Poland	Others	Total
1959					11		6470	466				2	6949
1960		260			166	9	11595	607			2	96	12735
1961		246			116	2155	12379	851	600	2626	336	1548	20857
1962		188	1		95	2032	11282	1234	93		888	363	16176
1963		969	35		212	7028	8528	4005	2476	9501	1875	853	35482
1964		1518	333		1009	3668	26643	862	2185	3966	718	1172	42074
1965		1561			713	1480	37047	1530	6104	2039	5073	771	56318
1966		891			125	7336	5138	4268	7259	4603	93	259	29972
1967		775			200	10728	5886	3012	5732	6757	4152	802	38044
1968		852	223		697	10917	3872	4045	1466	13321	71	235	35699
1969		750	30		1047	7276	283	2681		11831		42	23940
1970		379	34		1347	9847	494	1324	3	6239	53	1	19721
1971		708	6		926	7272	5536	1063		9006	19	1647	26183
1972		6902			952	32052	5030	5020	4126	2693	35	693	57503
1973		7754			417	11129	1145	620	1183	132	481	39	22900
1974		1872			383	10015	5998	2619	3093		700	258	24938
1975		3288			111	10430	5446	2022	265		677	136	22375
1976		2139			1188	10120	4831	2502		229	898	359	22266
1977		5664	24		867	6652	2982	1315	1269	5827	843	1576	27019
1978		7922	22		1584	10157	3779	2510	207	5096	615	1239	33131
1979		7484	74		1310	9636	4743	4907		1525	5	26	29710
1980		3259	37		1080	3615	1056	706		301	33	381	10468
1981		3874	9		1154	3727	927	4100		79		3	13873
1982		3121	10	4	375	3316	1262	4513	33	119			12753
1983		1499	1		111	2930	1264	4407				3	10215
1984		3058	9		47	3474	910	4745				459	12702
1985		2266	5		405	4376	1271	4914				438	13675
1986		2192	6			6350	1231	4384				355	14518
1987		916	269			2802	706	3639		2300			10632
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	897	2838	1	1416	26			1203	8989
1992	25089	747	2	18		2201	1	4215	5			6	7226
1993	15958	2931		3		3132		2249				1	8316
1994	29916	2249			1	2590		1952					6885
1995	10372	1016				1641		564					3221
1996	2601	700				1284		176	129			16	2305
1997	2933					1433		1	23				1475
1998	705					456							456
1999	353					3							3
2000	55					30	6						36
2001	37					54							54
2002	33					32	1						33
2003	16					7						9	16
2004	5						2					3	5
2005	19					16							3

Table 2 - EU bottom trawl survey abundance indices (in '000) for ages 1 to 14 and years 1988 to 2005 transformed to *Vizconde de Eza* equivalents (upper panel); corresponding standard errors (lower panel).

Abundance Indices	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1	4850	22100	2660	46100	75480	4600	3340	1640	41	42	27	7	186	487	0	665	0	8069
2	78920	12100	14020	29400	44280	56100	4550	13670	3580	171	94	96	16	2048	1340	53	3379	16
3	49050	06400	5920	20600	6290	35400	31580	1540	7649	3931	106	128	343	15	609	610	25	1118
4	13370	63400	19970	2500	2540	1300	5760	4490	1020	5430	1408	129	207	125	24	131	602	78
5	1450	23800	18420	7800	410	1500	150	1070	2766	442	1763	792	100	81	68	22	168	708
6	210	1600	5090	2100	1500	200	70	40	221	1078	87	491	467	15	36	47	5	136
7	220	200	390	300	270	600	10	30	9	24	165	21	180	146	28	7	10	
8	60	100	170	100	10	100	120	0	6	0	0	7	11	101	96	8	3	17
9	0	0	90	0	0	0	0	20	0	0	6	0	17	6	33	37	5	8
10	0	0	30	0	0	0	10	10	0	0	0	0	0	6	0	25	16	8
11	0	0	0	0	10	0	0	0	0	0	0	0	0	6	6	0	0	0
12	0	0	0	0	0	0	0	0	0	6	0	0	5	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0

Standard Error	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1	1575	3358	590	49587	16130	2307	707	407	22	25	17	9	46	149	0	360	0	727
2	12388	1973	1676	5178	10717	60189	1712	5547	426	57	35	36	15	199	89	29	320	10
3	5903	12593	728	3614	1746	7422	8003	319	1411	870	31	50	145	9	62	90	10	204
4	2357	6035	2636	397	934	348	1416	837	187	906	145	43	52	44	14	41	95	36
5	399	2871	2373	1692	190	558	50	232	424	81	229	140	31	30	22	18	38	151
6	64	264	689	424	499	88	33	19	53	138	28	76	87	6	14	24	5	53
7	77	54	99	74	89	151	9	18	10	13	48	14	45	47	13	10	7	0
8	37	75	72	33	13	39	44	0	9	0	0	9	11	32	24	10	3	14
9	0	10	50	22	0	0	0	18	0	0	10	0	14	12	14	23	5	7
10	0	9	23	9	0	0	10	9	0	0	0	0	0	10	0	19	10	7
11	0	0	0	14	10	0	0	0	0	0	0	0	0	9	6	0	0	0
12	0	0	0	0	0	0	0	0	0	9	0	0	10	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0

Table 3 - Weight and maturity at age estimated from EU bottom trawl survey.

Weight at age	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
1	0.03	0.04	0.04	0.05	0.05	0.04	0.06	0.05	0.04	0.08	0.07	0.10	0.10	0.08	0.00	0.05	0.07	0.02
2	0.10	0.24	0.17	0.17	0.25	0.22	0.21	0.24	0.25	0.32	0.36	0.37	0.58	0.48	0.42	0.33	0.60	0.64
3	0.31	0.54	0.34	0.50	0.49	0.66	0.59	0.47	0.53	0.64	0.75	0.92	0.96	1.25	1.12	0.90	1.42	1.37
4	0.68	1.04	0.85	0.86	1.38	1.21	1.32	0.96	0.80	1.00	1.19	1.30	1.61	1.70	1.43	1.50	2.07	2.44
5	1.97	1.60	1.50	1.61	1.70	2.27	2.26	1.85	1.32	1.31	1.66	1.85	1.91	2.56	2.47	2.86	3.22	3.13
6	3.59	2.51	2.43	2.61	2.63	2.37	4.03	3.16	2.27	2.10	1.99	2.44	2.83	3.42	3.59	3.52	5.31	4.54
7	5.77	4.27	4.08	4.26	3.13	3.45	4.03	5.56	4.00	2.00	3.10	3.51	3.47	3.91	4.86	5.52	5.88	
8+	6.93	6.93	5.64	7.69	6.69	5.89	6.72	8.48	5.03	9.57	7.40	4.89	5.28	5.22	5.31	5.80	7.84	6.21

Maturity at age	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0.04	0.04	0.07	0	0	0.02	0.02	0	0.02	0.08	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
4	0.18	0.18	0.34	0.23	0.23	0.16	0.57	0.77	0.56	0.69	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
5	0.63	0.63	0.52	0.78	0.79	0.73	0.97	1	1	0.91	1	1	1	1	1	1	1	1
6	0.75	0.75	0.5	0.91	0.86	1	1	1	1	0.96	1	1	1	1	1	1	1	1
7	0.85	0.85	0.71	0.84	0.74	0.95	1	1	1	1	1	1	1	1	1	1	1	1
8+	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 4 - Variance-covariance matrix for catchability parameters from XSA with calibration data from 1988 to 1999. Upper panel shows covariance estimated by conditioned *bootstrap*. Intermediate panel shows covariance estimated by unconditioned *bootstrap*. And the lower panel shows the difference among conditioned and unconditioned covariance.

Conditioned	***q' 1***	***exp 1***	***q 2***	***q 3***	***q 4***
q' 1	0.021				
exp 1	-0.013	0.011			
q 2	0.005	-0.003	0.029		
q 3	0.002	-0.001	0.006	0.039	
q 4	0.002	-0.001	0.004	0.004	0.022

Unconditioned	***q' 1***	***exp 1***	***q 2***	***q 3***	***q 4***
q' 1	0.007				
exp 1	-0.005	0.005			
q 2	0.001	-0.001	0.011		
q 3	0.001	-0.001	0.000	0.008	
q 4	0.001	0.000	0.001	0.001	0.005

Con.-Uncon.	***q' 1***	***exp 1***	***q 2***	***q 3***	***q 4***
q' 1	0.014				
exp 1	-0.008	0.007			
q 2	0.004	-0.002	0.018		
q 3	0.001	-0.001	0.005	0.031	
q 4	0.001	0.000	0.004	0.003	0.017

Table 5 - Catchability parameters applied in the simulation. Expected values were estimated from XSA with calibration data from 1988 to 1999. Standard errors and correlation were estimated from the *bootstrap*-subtracting algorithm.

Q	***Mean***	***S.E.***	***cv***	***corr***	***q' 1***	***exp 1***	***q 2***	***q 3***	***q 4***
q' 1	0.11	0.12	1.07	***q' 1***	1.00				
exp 1	1.17	0.08	0.07	***exp 1***	-0.81	1.00			
q 2	1.13	0.13	0.12	***q 2***	0.23	-0.19	1.00		
q 3	1.04	0.18	0.17	***q 3***	0.05	-0.05	0.23	1.00	
q 4	0.79	0.13	0.16	***q 4***	0.07	-0.05	0.21	0.14	1.00

Table 6.- Abundance at age and spawning stock biomass (SSB) estimated from the deterministic algorithm.

Abundance	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
1	10171	37145	6090	186415	106050	9721	7396	4029	173	176	121	36	629	1428	0	1862	0	15710
2	79337	11822	13776	29064	51764	156736	6339	13327	3561	167	92	94	22	2010	1306	51	3294	16
3	64144	139331	7106	28174	10931	53314	62223	1926	9487	5929	119	147	471	16	648	649	27	1190
4	24392	134359	46608	4171	7026	3368	14626	12940	2118	10392	2285	207	291	182	34	184	841	109
5	2651	63186	50470	14534	1824	3718	255	5856	6534	1090	3184	1270	142	115	95	30	235	989
6	437	3477	15082	4336	4186	1072	141	501	466	2399	180	754	657	21	50	65	7	190
7	610	615	987	750	1638	1372	33	241	13	87	246	32	253	205	39	10	14	0
8+	166	308	734	250	121	229	435	241	8	22	9	10	55	167	189	98	34	46
SSB (tons)	12390	102558	78259	33969	18765	15893	15953	25369	10854	14008	8878	4627	3857	2316	1888	1372	2667	5044

Table 7 - *Bootstrap* statistics for abundance at age in 2005.

Abundance 2005	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Mean	24135	16	1224	112	1016	196	0	25	11	11
Standard Deviation	11610	10	307	56	274	85	0	22	10	10
CV	0.48	0.62	0.25	0.50	0.27	0.43	-	0.91	0.90	0.89
Skewness	1.6	2.1	0.8	1.7	0.8	1.4	-	4.3	3.0	2.9
Bias	53.6%	1.2%	2.9%	2.7%	2.7%	2.9%	-	3.2%	2.8%	2.6%
5%	10653	5	793	47	631	92	0	5	2	2
10%	12378	6	868	55	695	106	0	7	3	3
50%	21403	13	1187	100	977	180	0	18	8	9
90%	38960	28	1632	184	1379	305	0	48	23	23
95%	45671	35	1772	218	1513	357	0	63	30	30

Table 8 - *Bootstrap* statistics for Spawning Stock Biomass. Bias expressed as percentage $[100*(\bar{x}_{boot} - x_{obs})/x_{obs}]$.

SSB survey (bootstrap)	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Mean	12725	105378	80367	34910	19288	16325	16386	26044	11145	14394	9120	4749	3963	2377	1939	1409	2738	5182
Standard Deviation	2656	19305	14612	7645	5048	3943	3992	5441	2295	2799	1713	922	814	554	389	382	557	1135
CV	0.21	0.18	0.18	0.22	0.26	0.24	0.24	0.21	0.21	0.19	0.19	0.19	0.21	0.23	0.20	0.27	0.20	0.22
Skewness	0.73	0.57	0.53	0.90	0.79	0.78	0.86	0.62	0.66	0.70	0.53	0.52	0.72	0.60	0.68	1.37	0.62	0.72
Bias	2.7%	2.7%	2.7%	2.8%	2.8%	2.7%	2.7%	2.7%	2.7%	2.8%	2.7%	2.6%	2.8%	2.6%	2.7%	2.7%	2.7%	2.7%
5%	12559	102863	77118	34879	17111	14411	15988	24290	10325	13051	8630	4654	3725	2011	1912	1107	2776	4899
10%	8986	77503	58623	24093	12336	10796	10795	18229	7757	10441	6594	3405	2784	1577	1387	909	1926	3549
50%	12424	103445	79165	34066	18643	15821	15957	25553	10866	14095	8956	4661	3883	2315	1892	1354	2681	5056
90%	16241	131213	100061	44782	26139	21565	21521	33111	14194	18079	11404	6003	5022	3123	2452	1894	3455	6674
95%	17596	139671	106608	48643	28757	23483	23586	35924	15353	19418	12215	6406	5422	3388	2643	2096	3756	7243

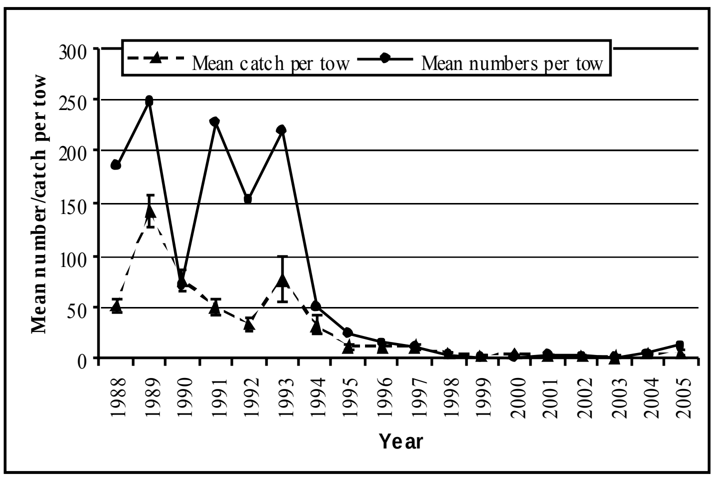

Figure 1. Mean catches per tow (Kg) with SD and mean number per tow of Atlantic cod in EU Flemish Cap survey (1988-2005). The values of the period 1998-2002 are transformed from R/V *Cornide de Saavedra* to R/V *Vizconde de Eza* equivalents. 2003-2005 data are original from R/V *Vizconde de Eza*.

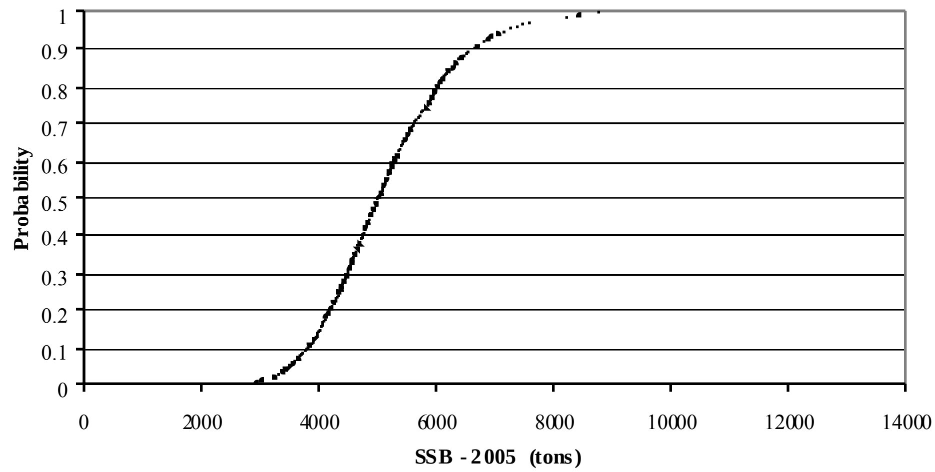

Figure 2 - SSB values and confidence intervals [0.05-0.95] for years 1988 to 2005 estimated with the stochastic survey-based method. The grey line and broken line represent the SSB values estimated from XSA in 1999 (for q estimation) and in the last assessment of 2002, respectively. The red thick line is the B_{lim} level at 14 000 tons.

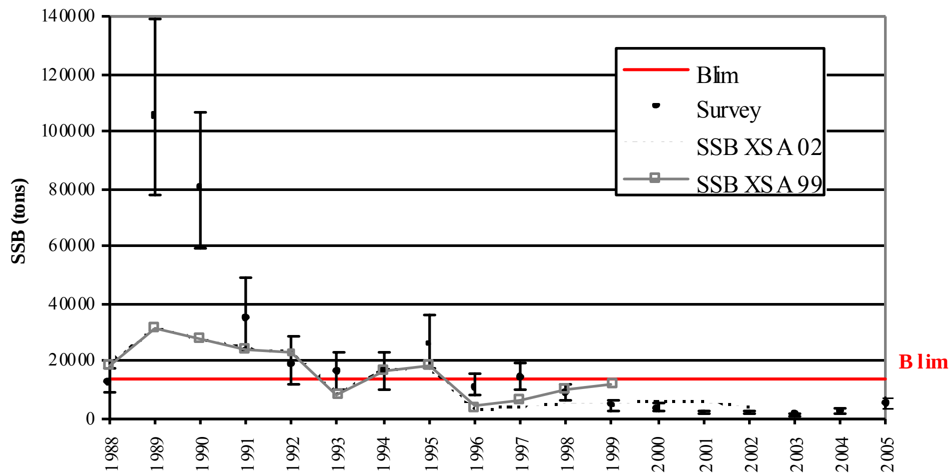

Figure 3 - Cumulative distribution of the 2005 SSB estimates.