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A Review of the Status of the Cod Stock in NAFO Division 3M

by

Antonio Vázquez[1] and Santiago Cerviño[2]

[1]Instituto de Investigaciones Marinas
Eduardo Cabello 6, 36208 Vigo, Spain
e-mail: avazquez@iim.csic.es

[2]Instituto Español de Oceanografía, Centro Oceanográfico de Vigo
Cabo Estai – Canido, 36200 Vigo, Spain
e-mail: santiago.cervino@vi.ieo.es

Abstract

The cod stock on Flemish Cap (NAFO Division 3M) is collapsed, and a fishing moratorium was in force since 1999. Cod catches were reduced since then to the by-catch taken by other fisheries in the area, but the stock did not recover. Current spawning stock biomass is at a very low level, well below the B_{lim}, which was established in 14 000 tons for this stock, and recruitments since 1995 have been very poor. The lack of a directed fishery impedes to carry out a sequential population analysis, consequently the survey results are the only reference for the status of the stock.

EU Survey results in 2004 indicate an insignificant 2003 year-class at age 1. The stock was dominated by the 2002 year-class at age 2, even it is also considered very poor, well below the level required to rebuild the stock.

Growth of cod at the youngest ages in 2004 has been the highest ever observed.

Introduction

Flemish Cap cod is at present a collapsed stock; the reasons for this collapse are unclear, but there were three elements that had contributed to this situation: overfishing, a probable increase in catchability at low abundance levels, and a very poor recruitment since 1995. The stock is under fishing moratorium since 1999, although Scientific Council recommended its closure for fishing several years before. The current SSB is at its lowest level in the series and well bellow B_{lim}, which was estimated as 14 000 tons (Cerviño and Vázquez, 2000). The recovery of the stock is not expected in a short or medium term time period (Cerviño and Vázquez, 2004).

For those stocks in moratorium, such as Flemish Cap cod, the main concern is the possibility of re-opening once they achieved some objective criteria. Re-opening criteria on a Precautionary Approach framework depend on the probability that current SSB could be above B_{lim}. The SSB levels of the Flemish Cap cod were annually calculated by analytical methods since 1995, using a XSA calibrated with the EU survey abundance indices. After declining of catches, the precision of XSA results became poor and, consequently, the uncertainty of abundance estimates is too high. Lacking a reliable stock estimates, a method was developed to estimate the current SSB level based on survey results and previous estimates of the catchability coefficients.

Material and Methods

The EU Flemish Cap bottom trawl survey was carried out since 1988 targeting the main commercial species inside the 730 m (400 fathoms) bathymetric contour. The surveyed zone includes the complete area distribution for cod, which rarely occurs deeper than 500 m. The survey is being carried out by RV *Vizconde de Eza* since 2003 using the same gear and procedures, but increasing sampling depth to 1 460 m (800 fathoms) (Casas and Gonzalez, 2005). A calibration trail between these two vessels was made in 2003 and 2004 (Gonzalez and Casas, 2005).

Taking into account the results of the calibration, the former data series (1988-2002) based on RV *Cornide de Saavedra* catchability were converted to the scale of RV *Vizconde de Eza* catchability as follows:

- catches were multiplied by 1.1, the correction factor
- length frequency and abundance at age data were also multiplied by 1.1 (differences in catchability between both survey vessels were considered independent of length and age, taking into account the poor fit of calibration's ratios at length to a Warren's function).

For 2003 and 2004, those years when the calibration took place, the whole set of hauls of both vessels were used to calculate abundance indices in order to reduce estimates variance: catches in weigh and number as well as frequencies at length were taken as they were in RV *Vizconde de Eza's* hauls, and data from RV *Cornide de Saavedra's* hauls were converted according the criterion already said. Length distributions calculated in this way as well as those only based on RV *Vizconde de Eza* or RV *Cornide de Saavedra* data are presented in Fig. 1. The main effect of this procedure was noted on the abundance at age 1, the left most modal group, but abundance of larger size groups is roughly the same. It is necessary to point out that R/V *Cornide de Saavedra's* hauls did not cover the whole strata where cod is found and abundance in there was not estimated, so its result is a sub-estimation of the stock.

Cod abundance estimates are presented in Table 1, where data are presented in the new standard index: catch per standard haul in the *Vizconde de Eza's* scale. Weight and maturity at age results are presented in Table 2.

Even *Vizconde de Eza's* surveys in 2003 and 2004 cover most of strata to the 1 460 m depth, the change in depth do not affect total biomass survey estimates for cod because this species is not found deeper that 730 m. However, the abundance indices expressed in catch per standard haul could change if new strata are considered; even their catch contribution is always cero. So, in order to maintain the uniformity of the series, mean catches per standard haul remain referred to the former 19 strata, all of them less than 730 metres depth. Obviously these two indices are proportional between them:

$$\text{Mean-catch-per-standard-haul} = 0.0012435 * \text{Total-biomass-swept-area-estimated}$$

according to Saborido and Vázquez (2003). This transformation is independent of the scale being used: Cornide or Vizconde, because gear and other characteristics of the haul remained the same.

The method described by Cerviño and Vázquez (2004) was applied to evaluate the level of the SSB in relationship to B_{lim}. SSB is currently estimated as a sum of products of abundance at age, weight at age and maturity at age. When survey abundances at age are used, the result is a SSB-survey estimate. An absolute SSB value is based on total stock abundances at age. The relationships between survey abundance and stock abundance at age are said catchability coefficients. Catchability at age values, which have been derived from last XSA assessment (Vázquez and Cerviño, 2002), as well their errors, calculated by bootstrapping the XSA residuals, were already used as in last analysis (Cerviño and Vázquez, 2004). It is important to note that these catchability values were calculated using survey indices expressed in the scale of RV *Cornide de Saavedra* and in units of swept area totals. Current survey indices were appropriately transformed to that scale to calculate SSB. The results are absolute figures in any case.

Errors in abundances at age and catchability at age are used to calculate the probability distribution of SSB estimates. It was calculated by bootstrapping, re-sampling abundance indices and catchability coefficients independently 2 000 times.

Results and Discussion

Probability distribution of survey abundance at age, as calculated by bootstrap, is presented in Table 3. All means are lightly above their deterministic values due to bias in a range between 3.2 % and 31.6%. Coefficient of variation varies from 0.1 at age 2 to 0.8 at age 1, being inversely proportional to abundance. All values have positive skewness.

Distribution statistics for SSB estimates are presented in Table 4. Their means are also lightly over their deterministic values, and their biases are about 1.5 % in the whole series. Coefficients of variation range from 0.14 in 2004 to 0.25 in 1992. All the skewness are positive. The 2003 SSB figure of 846 tons in last year assessment (Cerviño and Vázquez, 2004) was now calculated as 1416 tons (Table 4) due to some mistakes detected: age 8 had been used instead age 8+.

The SSB 2004 figure: 2265 tons, is well below the level observed before 1996, when the stock was not yet collapsed. Figure 2 shows the trend in SSB with the 90 % percentiles as well as the values derived from last XSA (Vázquez and Cerviño, 2002). 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 1996.

Figure 3 shows the most important result for reopening fishery advice: the cumulative SSB distribution that shows the probability of being over B_{lim}, which is 14 000 tons for this stock. Every SSB estimate in the 2000 runs bootstrap is below B_{lim}.

The observed trends in the EU survey abundance at age are clear enough to realize that the stock continues collapsed. All year-classes are at similar low level than in previous years, and no signal of recovery is observed. Abundance at age 1 in 2003 has been the highest since 1995 and its abundance was also observed at age 2 in 2004, however it remains at a low level in relation to those year-classes before 1995. The abundance at age 1 in the EU survey in 2004 is very poor as well as the abundance at older age groups, so a stock recovery is not expected in a short or medium term.

Figure 4 shows growth in weight at age for several cohorts in comparison to Wells (1983) results from the 1949-1950 period and two dates: July-September 1964 and July-August 1968. Those previous results had been interpreted as indicative of an increase in growth at age from 1949-50 to 1964-68. Growth at age observed in the 1964-1968 period is similar to the one observed for the 1993 and 1994 cohorts, the last two year-classes with a low but still important abundance when recruited. The growth of the 1993 and 1994 year-classes was similar to the previously observed even the stock biomass was at very low level after 1995. The growth of the 1999 to 2002 cohorts was much higher, and they also lived at a very low stock biomass level. Apparently, the main difference between the 1993-1994 and 1999-2002 year-classes is not the low stock biomass level they lived with, but their different abundance when they recruited to the stock, one being low and the other being extremely poor. Growth rate related to cohort abundance has been described by Pérez-Gándaras and Zamarro (1990), who found a negative relationship between cohort abundance and growth.

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Table 1 – Survey abundance at age (mean number per RV *Vizconde de Eza* standard haul – 19 strata).

Abundance	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	6.35	28.46	3.41	188.51	97.38	5.97	4.30	2.11	0.05	0.05	0.03	0.01	0.24	0.62	0.00	0.67	0.01
2	98.60	15.08	16.33	35.02	50.69	180.88	5.25	15.55	4.05	0.19	0.10	0.11	0.02	2.26	1.58	0.05	2.47
3	54.47	115.28	6.50	21.04	6.49	38.85	33.65	1.69	8.39	4.30	0.12	0.14	0.38	0.01	0.76	0.64	0.02
4	14.48	67.23	21.16	2.64	2.78	1.38	6.24	4.92	1.12	5.96	1.56	0.14	0.23	0.15	0.04	0.19	0.61
5	1.60	25.40	20.05	8.59	0.45	1.74	0.16	1.21	3.07	0.49	1.98	0.90	0.11	0.10	0.09	0.04	0.17
6	0.24	1.74	5.88	2.29	1.72	0.23	0.09	0.05	0.26	1.23	0.10	0.57	0.55	0.01	0.04	0.05	0.01
7	0.31	0.21	0.48	0.40	0.30	0.67	0.01	0.03	0.01	0.03	0.20	0.03	0.22	0.20	0.04	0.01	0.01
8+	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09

Table 2 - Weight (kg) and maturity at age rate.

Weight at age	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
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
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
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	0.92	1.42
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	1.60	2.07
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	2.77	3.22
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	3.53	5.31
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	5.63	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	6.63	7.84

Maturity at age	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	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
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
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
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
6	0.75	0.75	0.5	0.91	0.86	1	1	1	1	0.96	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
8+	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 3 - *Bootstrap* statistics for the 2004 abundance at age absolute total estimates ('000).

	1	2	3	4	5	6	7	8	9	10
Mean	51	1952	21	696	199	7	17	9	4	16
Standard Deviation	41	196	8	99	36	6	8	6	4	7
cv	0.80	0.10	0.37	0.14	0.18	0.79	0.49	0.68	0.93	0.48
Skewness	2.3	0.3	1.2	0.5	0.5	2.9	1.5	2.2	3.7	1.4
Bias	13.3	3.2	5.7	3.7	3.5	18.5	6.4	11.4	31.6	6.2
5%	10	1644	11	548	146	2	7	3	1	7
10%	14	1707	12	576	156	2	8	3	1	8
50%	39	1944	19	691	195	6	15	7	3	14
90%	101	2195	30	825	247	13	28	15	8	25
95%	127	2289	35	865	261	17	33	19	11	30

Table 4 - *Bootstrap* statistics for the SSB absolute total estimates (tons).

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Mean	11128	82914	64758	29041	15812	13638	13408	21405	8984	11644	7439	3923	3430	2175	1854	1416	2265
s.d.	2077	12749	9538	5580	3977	3045	3225	4144	1642	1965	1153	677	615	455	314	330	319
cv	0.19	0.15	0.15	0.19	0.25	0.22	0.24	0.19	0.18	0.17	0.15	0.17	0.18	0.21	0.17	0.23	0.14
Skewness	0.60	0.45	0.37	0.62	0.82	0.81	1.09	0.56	0.67	0.64	0.48	0.52	0.79	0.65	0.58	1.18	0.48
bias	1.6%	1.5%	1.5%	1.5%	1.5%	1.6%	1.5%	1.6%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.6%	1.5%	
5%	8070	63681	50072	21025	10254	9342	9028	15252	6541	8778	5718	2900	2533	1522	1386	955	1778
10%	8592	67364	53217	22422	11232	10030	9805	16478	7021	9314	5999	3119	2706	1628	1470	1031	1873
50%	10961	82172	63919	28398	15272	13280	12979	20991	8848	11449	7359	3877	3372	2135	1832	1378	2249
90%	13866	99404	77150	36523	21108	17484	17372	27015	11089	14149	8894	4817	4223	2765	2255	1843	2667
95%	14793	105279	81451	39051	23148	19140	19270	28795	11867	14909	9429	5132	4489	2996	2404	1979	2810

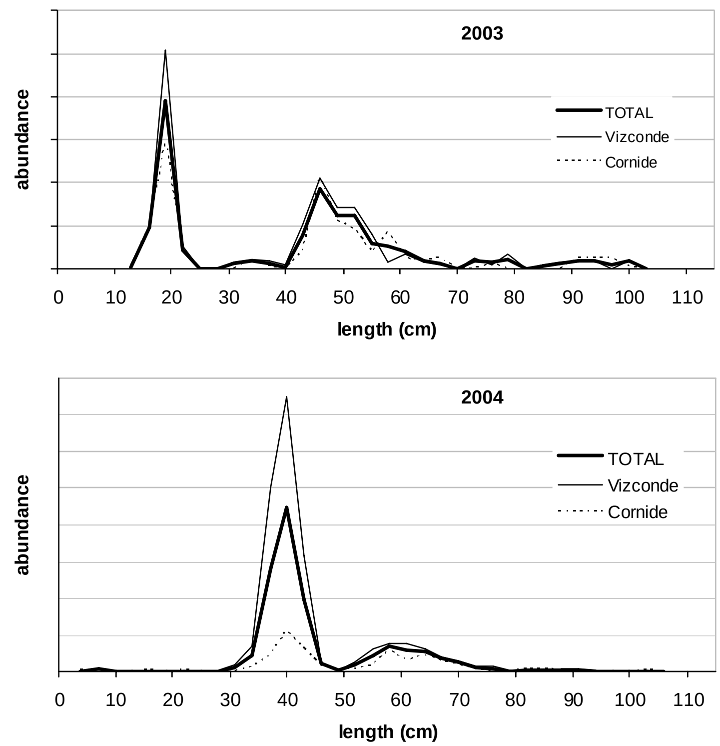

Fig. 1. Survey's abundance at age calculated with RV *Vizconde's* results, *Cornide's* results, or both.

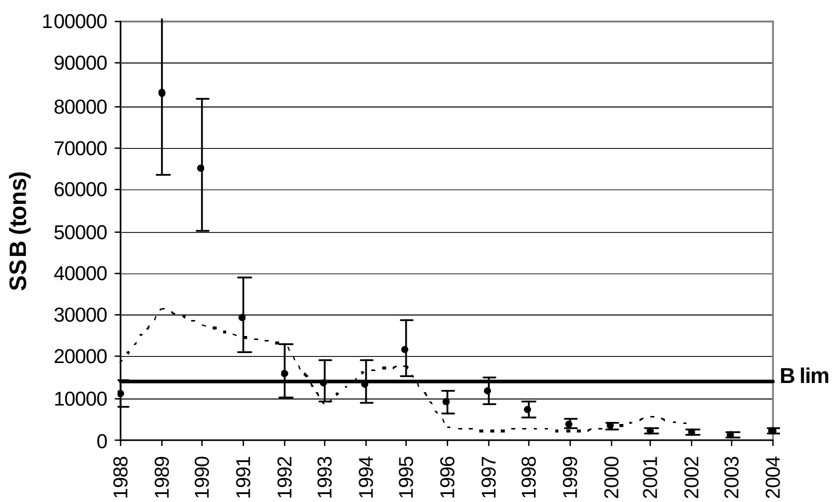

Fig. 2. SSB values and confidence intervals [0.05-0.95] for years 1988 to 2004 estimated with the stochastic survey-based method. The broken line represents the SSB values estimated in last XSA (Vázquez and Cerviño, 2002). The thick line is the B_{lim} level at 14 000 tons.

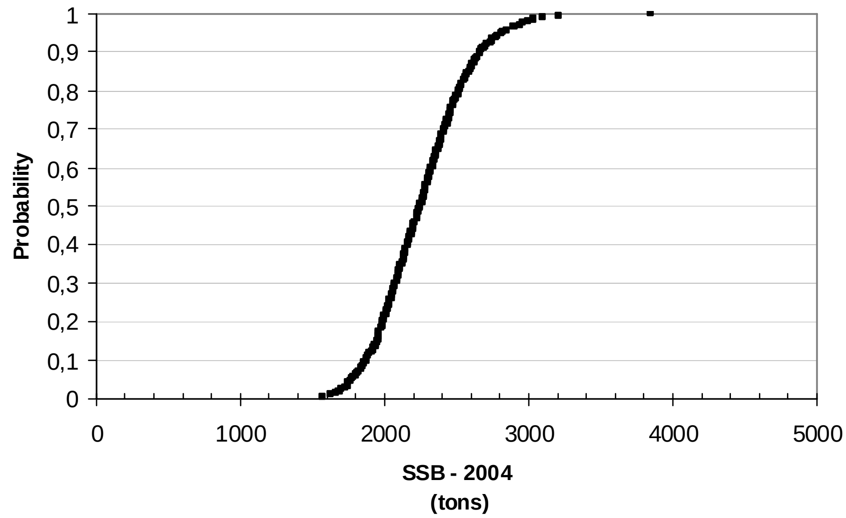

Fig. 3. Cumulative distribution of the 2004 SSB estimates.

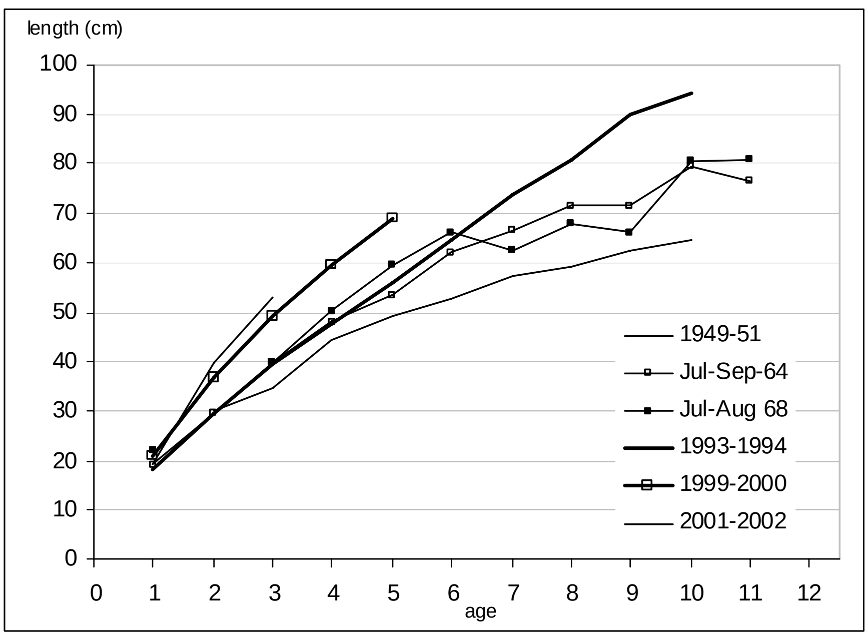

Fig. 4. Growth in size of cod at different years and cohorts:

1949-1950	- Wells (1983)
Jul-Sep-64	- Wells (1983)
Jul-Aug 68	- Wells (1983)
1993-1994	- cohorts 1993 and 1994
1999-2000	- cohorts 1999 and 2000
2001-2002	- cohorts 2001 and 2003