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Re-opening Criteria for Flemish Cap Cod: a Survey-based Method

by

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Abstract

One of the main difficulties in the assessment of closed fisheries is the lack of catch data needed to perform a VPA; nevertheless, assessment is necessary in order to advise for re-opening in the framework of the Precautionary Approach. In this situation, advise is usually based on survey trends, and the problem of not knowing the true abundance is translated to the advise as an increase of uncertainty. Nevertheless, when there was a calibration by a VPA assessment in the past, those catchability figures can be used to scale the current survey results and obtaining an estimation of the true abundance, more convenient for a precautionary advise. This paper proposes a way to manage survey information, using the Flemish Cap cod stock as an example. A stochastic simulation including estimates of errors in survey abundance and catchability at age is presented. The method, based in a stochastic design, yields a spawning stock biomass cumulative distribution ready to compare with B_{lim} in probabilistic terms. Some weaknesses of the method as well as the quality of VPA-based assessment with low catches are discussed.

Introduction

NAFO Scientific Council has implemented the Precautionary Approach (PA) on Fisheries Management in late 90s based on several international agreements, such as the Code of Conduct for Responsible Fisheries (FAO, 1995) or the Agreement on the Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (UN, 1995). Implementation includes recommendations on limit and target reference points, medium term considerations and risk, long-term requirements and criteria for re-opening fisheries. Scientific Council developed a PA framework in 1997 (Serchuck *et al.*, 1997) to include definitions of limit, buffer and target reference points for biomass and fishing mortality. A review of progress on PA was recently developed in the Scientific Council Workshop on that issue (NAFO, 2003); the workshop included an evaluation of present framework as well as a review of methods for determining PA reference points and their application to NAFO stocks.

Several fish stocks in the NAFO area are currently recognized as depleted, including some of them for cod supporting traditional fisheries, such as the northern stock and those of Div. 3NO and Flemish Cap. Evaluation of these stocks may include determination of their condition, classification of their stock status in relation to biomass limits and buffers, where available, and description and characterization of uncertainty and risk of the assessment. Taking into account that catches are, or should be, negligible in closed to fishing stocks, estimates of the fishing mortality (F) they support are not of main interest. The main concern for these stocks is the possibility of re-opening once they achieved some objective criteria related with the stock status. Those criteria should be stock specific.

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 (3 000 t in last year assessment), well bellow B_{lim}, which was estimated as 14 000 tons (Cerviño and Vázquez, 2000). Fish older than 7 years makes more than 90% of the spawning biomass in 2002. Since cod of 1 to 6 years old is scarce, the recovery of the stock is not expected in a short or medium term (Vázquez and Cerviño, 2002).

VPA based assessment has been applied to Flemish Cap cod stock since 1995, and it was accepted by the Scientific Council since 1999 (Vázquez *et al.*, 1999). The method used is a XSA calibrated with the EU Flemish Cap survey results since 1988. Main problem in this assessment is the decline in recent catches, which are necessary to promote VPA cohort convergence. Catches fall under 10,000 tons since 1996, and the estimated Fs that match those catches are at a similar level or below natural mortality (M = 0.2) since 1999. This implies that the quality of XSA results depends on precision of M, and given that reliability of M is unknown, the uncertainty of abundance estimates is ignored.

For some closed to fishing stocks, re-opening criteria depends on the probability that current SSB could be above a predefined level (B_{lim}). This level is 14 000 tons for the Flemish Cap cod stock. The main assessment task in this situation is to calculate this probability in order to give advise in a precautionary management framework. Since catches are expected to be low in the next future, VPA based advice probably will not work, and objective criteria for re-opening need alternative methods.

The proposed method combines survey abundance indices at age with the estimated catchability at age from past XSA in order to estimate total abundance at age. Uncertainty in both parameters, survey abundance and catchability, were estimated from sampling theory and bootstrapping XSA respectively. Estimates of abundance at age with its associated variability are necessary to calculate the SSB distribution and the probability of being above B_{lim}. Once the re-opening is advised, this kind of analysis also allows a stochastic analysis of catch options by projections of short or medium term although this option was not explored now. The method let assess stocks without catches if we have an indices of abundance and an estimate of catchability, as it happens with Flemish Cap cod; but also could be useful if a VPA based assessment gives unrealistic results.

Material and Methods

Data

Data needed are survey abundances at age and their associated errors, and estimates of catchability at age and their errors. Data used for the Flemish Cap cod stock assessment are abundances from the EU bottom trawl survey and catchability at age from past XSA assessments.

The EU Flemish Cap survey was carried out since 1988 targeting the main commercial species inside the 730 m bathymetric contour. The survey includes the complete area distribution for cod, which rarely occurs deeper than 500 meters in Flemish Cap. The sampling procedure did not change, although the research vessel used in 1989 and 1990 was not the same as those used for the rest of the series. Sampling of main species includes age, length, weight and maturity. Cod abundance estimates and their standard errors were calculated by bootstrap following Cerviño (2002) and are presented in Table 1; weight and maturity at age are presented in Table 2.

Catchability at age values for the Flemish Cap cod stock were derived from XSA, according to last year assessment (Vázquez and Cerviño, 2002) and are presented in Table 3. Age 1 was calibrated with a two-parameters model although this class is not a mature class and does not contribute to SSB. Catchability for ages 2, 3 and 4 are estimated from a one-parameter model, and catchability for older ages was considered constant and equal to age-4 catchability. Estimates of catchability for ages 3 and 4 as well as their associated errors are needed to estimate SSB from survey abundance indices, and catchabilities at all ages are needed for a complete estimate of abundance at the oldest ages. Catchability errors were calculated bootstrapping the XSA residuals. The XSA assumes that catchability is constant in the range of years where abundance indices are used for calibration. The choice of the best XSA to calculate catchability and its errors is an important issue. Year for catchability selection depends on a balance between precision and bias; precision is dependent on de numbers of survey years used to calibrate the XSA and bias can be due to catchability changes or problems in fitting the XSA.

The stochastic model

Abundance in year *y* at age *a* was calculated dividing the abundance index *I* by the catchability *q*

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

where *I* and *q* are stochastic variables lognormal distributed

$$I^*_{y,a} = I_{y,a} * \exp(\varepsilon_I)$$

being I^* the observed value and I the parametric value, and being ε a normal distributed variable with mean 0 and standard error estimated from sampling and corrected to log distribution ($s.e. = \sqrt{\ln(1+cv^2)}$).

Similarly,

$$q^*_a = q * \exp(\varepsilon_q)$$

where ε is a normal distributed variable, with mean equal 0, and standard deviation being estimated by conditioned resampling of XSA.

SSB is calculated from survey results, denoted SSB–survey, as the sum of products of abundance at age (*N*), mean weight (*W*) and maturity rate (*Mat*). However, this value needs to be corrected to the beginning of the year because B_{lim} is in that scale. Abundances at age (N) are so transformed to the beginning of the year (N^0). Since the UE survey is carried out in the middle of the year, an estimate of total mortality (Z) is necessary for that transformation. Natural mortality could be a good proxy for total mortality at low fishing levels.

$$N^0_{y,a} = N_{y,a} * \exp\left[Z * (t - t_0)\right]$$

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

Uncertainty in SSB–survey could be calculated by bootstrapping, resampling 2 000 times *I* and *q* independently. This procedure lets to know SSB distribution and then, the probability that the current value be below B_{lim}. A more complete evaluation of SSB distribution should include weight and maturity variability, but that is not essential for the comparative proposal of this example.

For comparative purposes, SSB for 1988 to 2002 were also estimated from XSA results on abundance at age, denoted as SSB–XSA, and taking into account the errors of those estimates. Weight at age and maturity at age were the same as the former calculations. Distribution of XSA abundances at age was estimated in two different ways: first, by bootstrapping residuals of XSA fits, and second, using Monte Carlo indices of abundance at age with lognormal distribution (Cerviño and Vázquez, 2001). To compare SSB-XSA and SSB–survey series, this last series was transformed to values at the beginning of each year applying a fishing mortality equal to the mean F at ages 3 to 5 from the XSA results, as shown in Table 4, and using M equal to 0.2.

Flemish Cap cod stock: results and discussion

Catchability trends in the EU survey on Flemish Cap

Catchability for ages 2, 3 and 4 are presented in Fig. 1. The reference year, in X-axis corresponds to the last year used for the XSA in a similar way as in a retrospective analysis. Values for the first year, 1993, corresponds to the results of a XSA calibrated with indices from 1988 to 1993 (6 years); in the other side, values for 2001 were calculated with survey indices from 1988 to 2001 (14 years). The plots show a general decrease of the estimated catchability with age along the whole series; values for ages 2, 3 and 4 are higher than 1, around 1, and below 1, respectively. Trends in catchability with time show a period of instability during the first three years; a period of relative stability from 1996 to 1999, and a general increase since 1999.

For the Flemish Cap cod stock example, the catchabilities at age from the last XSA were chosen as the reference. The advantages of selecting this option are that, first, it includes the longest series of abundance index (14 years), probably having the lowest error, and second, these catchabilities probably show the smallest bias regarding future years. A problem with these catchabilities is the increasing trend they show in last years; catchability at age 4 increased from 0.7 in 1998 to 1.2 in 2001. Taking into account that sampling procedure did not change in this period, the observed increase is probably due to a bad fit of the model to data, given the decrease of catches in most recent years.

Time series of SSB from XSA and survey

SSB–survey and SSB–XSA series show a similar trend, with an initial increase from 1988 to 1989 where both SSBs peak, even SSB–survey peaks higher than SSB–XSA. There was a continuous SSB decline after 1989, ending in the current collapsed situation, when the estimated level is 2-3 thousands tons. This declining trend has a similar pattern in both methods, although there are some exceptions: SSB–XSA shows a clear overestimation for 1989, 1990 and 1997 in relation to SSB–survey. However, the reverse is observed in most recent years: 2000 and 2001, with SSB–survey at the half level than SSB–XSA. Changes in both trends regarding to B_{lim} are quite similar, and very different management decisions should not be expected from adopting one or another option.

Values of SSB–XSA series in Fig. 2 were estimated from the last XSA; past SSB in this series are less prone to bias and variance than recent values as it was observed by the retrospective pattern, where a clear trend to overestimate current SSB exists (Vázquez and Cerviño, 2002). When comparing SSB–survey with SSB–XSA it is necessary to take into account the risk of XSA abundance overestimation.

Coefficients of variation (cv) for SSB–survey and SSB–XSA are shown in Fig. 3. Those from XSA were calculated by two different methods: conditional bootstrap of residuals and bootstrap of abundance indices with log-normal distribution

Coefficients of variation for SSB–survey show a quite stable trend, with a range between 0.23 in 1989 and 2002, and 0.33 in 1992. Those for SSB-XSA show a near cero value before 1996 for both methods, since 1996 errors increases until 2001 and then they shows a small decrease. This behaviour is typical of XSA results, since survivors (abundance in 2002) are estimated as a geometric mean of all cohort values projected forward, which gives a superior robustness against model assumptions.

The results from both methods to estimate SSB–XSA error distribution are very informative. In recent years, from 1998 to 2002, CVs from conditional bootstrap are three times higher than those observed in unconditional bootstrap. Conditional bootstrap assumptions are only that residuals are independent among them and are equally distributed. Unconditional lognormal bootstrap assumptions are that all the error occurs just in indices of abundance that are lognormal distributed. XSA model assumptions are a mixture of both methods: indices of abundance are the only source of errors (natural mortality and catches have no error), they are lognormal distributed (log transformation is made before catchability fitting), and errors are homocedastic and independent among them. Furthermore, the model assumes that there is not process error, i.e. catchability at age is constant in time. If these conditions are true, both methods should provide similar results; nevertheless, error from abundance indices just explains one third of total error. Differences in the estimated error from both methods are explained as violations of the XSA model assumptions: errors in catches, errors in natural mortality or temporal changes in catchability. This kind of violations of the model assumptions can lead to bias in the XSA parameters estimation; their occurrence in the Flemish Cap cod XSA are analysed.

Changes in survey catchability can be attributed to modifications in survey procedure or in fish behaviour. The EU Flemish Cap survey procedure did not change in all the series in such a way that could explain this observed deep change. In regards to fishing behaviour, it was observed a trend of cod to concentrate in the shallowest waters of Flemish Cap in most recent years. Trawl gear performance can change with depth, with smaller lateral opening at shallower waters (Godø and Engås, 1989), which means smaller catchability. However, the estimated catchability increased in recent years (Fig. 1), and that possible relationship to cod behaviour must be discarded.

Catchability estimates depend not only on its true value, but also depends on the abundances estimated by VPA, which also depend on estimated catches and estimated natural mortality; underestimation of VPA abundance in most recent years may produce a overestimation of the catchability for the last year. Misreported catches (or by-catches) can explain the increase in catchability estimates. Flemish Cap cod catches were review from 1988 to 1994 based on skippers' logbooks (Vázquez *et al.*, 1995); if catches were misreported since then, it could explain the observed increase in XSA catchability. Another possible reason to underestimate true abundances is the underestimation of natural mortality. Natural mortality is not a parameter easy to estimate, but its errors are negligible if fishing mortality is big enough as to hide them, nevertheless its importance increases at low F levels. Last year assessment shows the trend of estimated F (Table 4). Mean F is similar or lower than estimated M since 1999, and in such cases, the bias in estimated M can yields biased results.

A comparison between the cumulative distributions of the SSB in 2002 calculated from survey and XSA results is shown in Fig. 4. Cumulative distribution is the best way to present results to be compared with management reference points and obtaining a conclusion in probabilistic terms. B_{lim} was accepted as 14 000 tons for Flemish Cap cod, a level that is very far from the current situation. Survey based assessment shows SSBs in 2002 lower than XSA SSB and survey SSB are more precise than XSA.

Discussion and Conclusions

Although the current level of SSB in regards to B_{lim} for Flemish Cap cod does not allow doubts about its status, Fig. 4 illustrates the problem of which assessment method produce the most realistic results. Although is accepted that VPA based assessment gives more precise results than survey estimates, it is also accepted that survey results are less biased. Abundance estimates from XSA are more dependent on assumptions than survey abundance; nevertheless, there is a level of assumption violations that makes the survey results better than the XSA. Recent XSA retrospective pattern for Flemish Cap cod shows a trend to overestimate SSB and, furthermore, as the caches decline, the error in XSA abundance estimates becomes highly dependent on M. In such circumstances, a survey-based assessment seems to be more robust than a VPA–based assessment. Even more, it is expected than future catches will not be enough as to support an advice based on VPA. The main weakness of the SSB–survey estimates is the choice of the appropriate catchability given the observed trends by most recent XSA. In this case, we used the catchability estimated in the last year assessment, but a more complete analysis of catchability including uncertainty in every year would be useful to clarify this question.

One of the main criticisms of direct use of survey results for assessment proposes is their inefficacy to provide useful results in a precautionary framework given that survey results are abundance indices. The method described allows knowing the SSB in absence of catches, as well as the probability that SSB is over the limit reference point; so the risk of re-opening can be evaluated. The method can also provide estimates of abundance at age with their respective errors, as necessary to make projections and evaluate alternative catch options. The method is particularly useful for collapsed fisheries that were assessed by survey calibrated VPA, so there is an estimation of catchability at age, but also is useful for stocks where VPA based assessment are unrealistic, for example, when there is a clear retrospective patter. The assumption that catchability will remain constant needs to be evaluated, but the inclusion of catchability errors in the simulation minimizes its impact on management decisions.

NAFO precautionary framework regarding to biomass sets B_{buf} as a spawning stock biomass above B_{lim} that gives very low probability for any biomass estimated above B_{buf} will actually be below B_{lim} (probability less or equal 5 to 10%). Nevertheless, if stock assessment generates an estimate of the current biomass and its probability distribution, that biomass estimate could be directly evaluated against B_{lim}, so B_{buf} would be not necessary. The described method allows to compare directly the estimated biomass distribution against B_{lim} in poor catch data situations, and without a previous definition of B_{buf}.

The method provides a complete set of assessment tools in absence of VPA based assessment: it provides a determination of the stock status, it allows to classify the stock status in relation to biomass precautionary areas (B_{lim}), and it describes and characterizes uncertainty as necessary to conduct risk assessment. These are the roles of scientist as defined by NAFO Working Group on Precautionary Approach (NAFO, 1998). Data needed for this kind of assessment are a survey abundance indices and an estimation of catchability at age. The method is especially useful when VPA based assessment become unrealistic due to absence of catches, but a survey is carrying on. Its main weakness is the catchability selection when they show a trend; a retrospective analysis of catchability can be a useful tool to detect this problem. If the survey is performed in middle of the year, SSB survey estimates underestimate their value at the beginning of the year, where biomass references are defined; their values need to be corrected with an estimate of total mortality (Z). In absence of fishing, 0.2 can be a proxy; otherwise, Z must be estimated from a catch curve analysis.

Survey based assessment for Flemish Cap cod with data up to 2002 shows higher precision than XSA based assessment. The lack of catches in recent years undermines the performance of XSA, which results are highly dependent from the value attributed to natural mortality, highly uncertain. The selection of catchability from the last XSA to estimate SSB from survey abundance needs a more complete analysis since recent trends in XSA catchability could be due to a bad performance of the last XSA and an overestimation of the current SSB.

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Table 1 – Survey abundance indices and the standard errors in lognormal scale, by years.

Survey abundance indices

age	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
1	4644	20803	2492	137814	71190	4364	3147	1546	39	39	25	6	172	452	
2	72082	11028	11937	25600	37060	132237	3835	11365	2964	139	76	78	13	1651	1154
3	39819	84280	4755	15381	4748	28403	24599	1238	6131	3146	85	102	276	6	557
4	10585	49149	15469	1928	2033	1010	4562	3595	820	4360	1137	105	170	108	26
5	1171	18571	14660	6283	332	1269	120	885	2247	358	1449	655	84	70	65
6	177	1270	4298	1674	1255	168	66	33	187	902	73	415	405	4	32
7	224	157	350	296	222	491	7	25	8	20	144	19	161	148	26
8	65	140	159	71	12	100	118		6			6	11	86	97
9		8	88	35				23			7		17	12	32
10		6	29	7			7	7						7	
11				13	7									7	6
12										6			6		
14													6		

Standard error (logN scale)

age	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
1	0.28	0.16	0.22	0.36	0.22	0.50	0.21	0.26	0.54	0.61	0.60	1.04	0.26	0.33	
2	0.16	0.18	0.14	0.21	0.28	0.45	0.43	0.45	0.14	0.40	0.43	0.43	0.93	0.12	0.07
3	0.15	0.14	0.15	0.24	0.36	0.25	0.30	0.25	0.23	0.27	0.33	0.45	0.51	1.07	0.1
4	0.22	0.12	0.17	0.20	0.41	0.32	0.29	0.23	0.22	0.20	0.13	0.39	0.30	0.38	0.49
5	0.30	0.15	0.16	0.25	0.50	0.40	0.39	0.26	0.18	0.22	0.15	0.21	0.36	0.40	0.3
6	0.32	0.20	0.16	0.24	0.36	0.47	0.47	0.52	0.27	0.15	0.36	0.18	0.21	0.96	0.42
7	0.31	0.32	0.27	0.24	0.37	0.30	0.97	0.63	0.99	0.59	0.32	0.65	0.27	0.31	0.48
8	0.52	0.47	0.42	0.43	0.92	0.37	0.35		1.04			1.01	0.87	0.35	0.23
9		0.97	0.51	0.56				0.65			1.04		0.70	0.83	0.42
10		1.05	0.69	1.05			1.07	0.98						1.05	
11				0.87	1.04									0.97	0.82
12										1.06			1.94		
14													1.94		

Table 2 – Weight at age and maturity at age from Flemish Cap cod stock.

Weight															
age	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
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
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
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
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
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
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
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
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
Maturity															
age	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
1	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
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
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
5	0.63	0.63	0.52	0.78	0.79	0.73	0.97	1	1	0.91	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
7	0.85	0.85	0.71	0.84	0.74	0.95	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

Table 3 – Catchability parameters by age and its standard errors estimated by conditioned bootstrap of XSA.

Q	**mean**	**s.e.**
1	0.15	0.12
exp 1	1.19	0.10
2	1.33	0.23
3	1.38	0.23
4	1.25	0.27

Table 4 – XSA results. SSB estimated throughout XSA and coefficients of variation (cv) estimated by conditioned bootstrap and unconditioned bootstrap with lognormal distribution.

XSA results	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
SSB XSA	15443	30358	27396	22620	22698	9423	16490	18309	3150	2792	2857	1983	1921	2400	2977
cv XSA condicional	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.30	0.46	0.53	0.59	0.50
cv XSA unconditional	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.10	0.15	0.18	0.19	0.17
F 3-5	0.49	0.84	0.87	0.48	1.55	1.03	0.94	1.50	0.72	0.82	0.30	0.24	0.18	0.04	0.00

Table 5.- Results from SSB estimated by survey simulation with catchability estimated by XSA

SSB survey simulation	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Mean	8958	78924	56249	23093	23255	15576	13639	21133	8212	12628	5788	3242	2816	1543	1186
Standard Deviation	2212	18188	13509	6415	7809	4532	4123	5792	2121	3154	1417	838	717	444	274
cv	0.25	0.23	0.24	0.28	0.34	0.29	0.30	0.27	0.26	0.25	0.24	0.26	0.25	0.29	0.23
median	8686	76921	54314	22251	22136	15000	13003	20350	7913	12237	5653	3137	2700	1486	1149

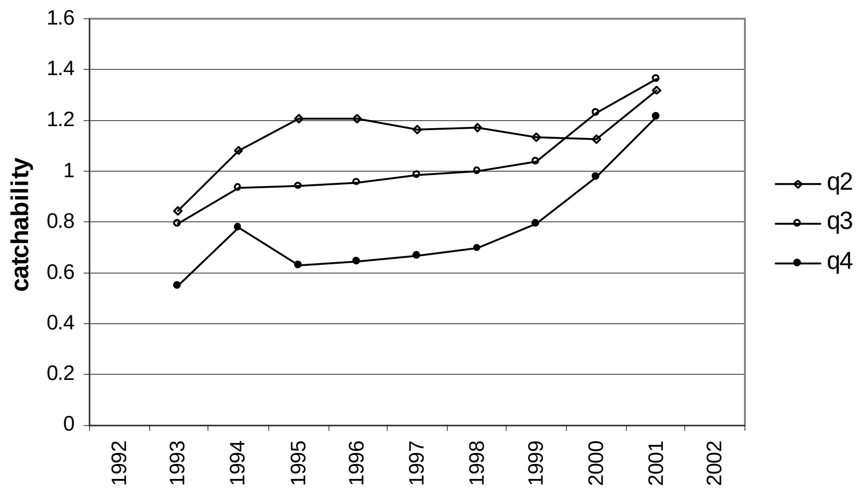

Fig. 1. Estimated catchability from XSA at ages 2, 3 and 4. The reference year (X axis) represents the last year included in the corresponding XSA.

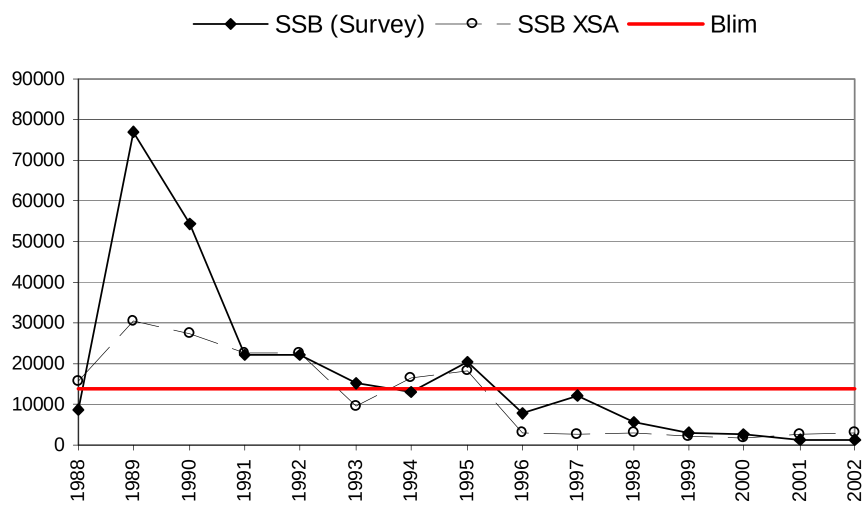

Fig. 2. SSB trends in years 1989 to 2002 as estimated from survey data or from XSA, where each year SSB corresponds to the survivors for a XSA until that year.

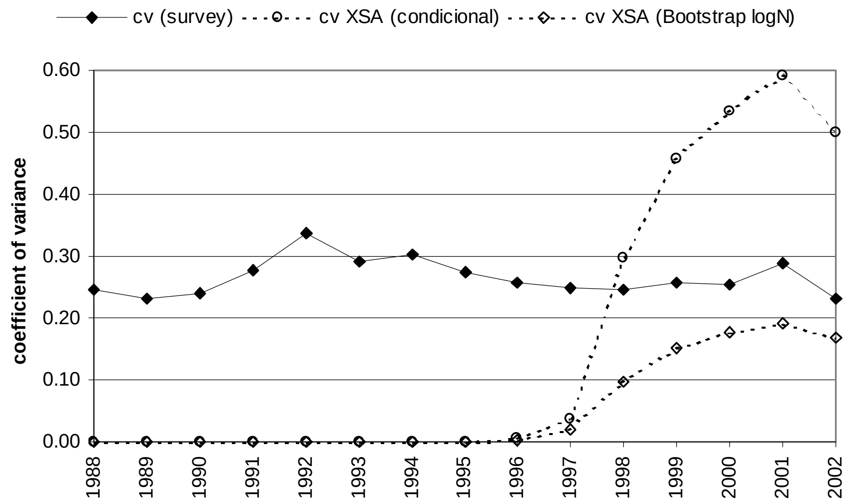

Fig. 3. Coefficient of variation (cv) for SSB. Those for SSB–survey (continuous line) were calculated considering errors in abundance indices and in catchabilities. Those for SSB–XSA errors (dotted line) were calculated by two methods: conditional bootstrap (circle) and unconditional bootstrap (diamond).

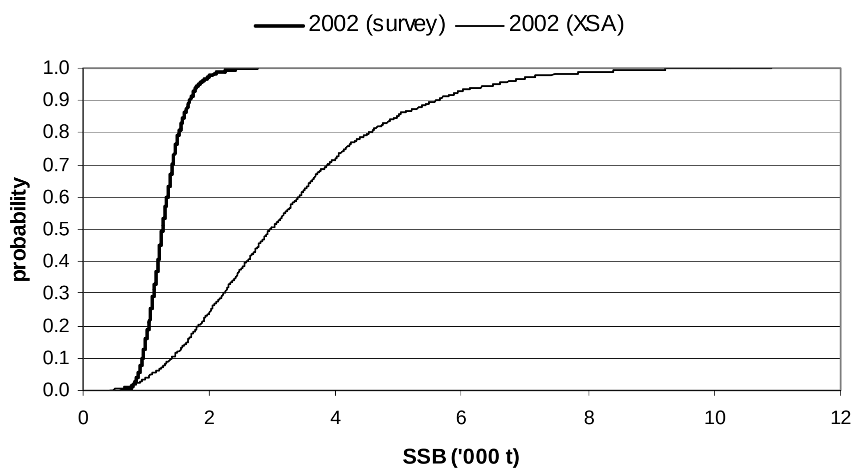

Fig. 4. SSB cumulative distribution for Flemish Cap cod based on 2002 EU–survey and 2002 XSA results.