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**Full benchmark review of the 3M cod assessment**

by

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**Introduction**

The 3M Cod assessment model used since 2008 is an XSA Bayesian model developed by *Fernandez et al.* (2008). The Bayesian model has been developed in a way that maximizes the incorporation of catch information. For the years with catch-at-age data, it works starting from cohort survivors and reconstructing cohorts backwards in time using catch-at-age and the assumed mortality rate. For the rest of the years, if an estimate of total catch weight is available, this information can be incorporated in the model by means of an observation equation relating (stochastically) the estimated catch weight to the underlying population abundances (hence aiding in the estimation of fishing mortalities). An advantage of the model is that it allows to combine years for which catch-at-age is available with years where only estimates of total catch weight are available. Years with no information on commercial catch are also allowed.

In 2015, the NAFO Fisheries Commission (FC) agreed to carry out a 3M Cod full review benchmark (NAFO, 2015) to try to solve some of the uncertainties observed in the last 3M Cod SC approved assessment (Gonzalez-Troncoso, 2015). The FC proposed that “*Scientific Council organizes a full benchmark review of the 3M cod assessment in two stages: For 2016 SC will agree on a standardized approach and prepare a plan for the benchmark process at NAFO including required resources. For 2017 SC will review the benchmark assessment methodology for 3M cod.*” This request was included in the NAFO SC 2016 June meeting agenda. The NAFO Joint Fisheries Commission–Scientific Council Working Group on Risk-Based Management Strategies (FC-SC WG-RBMS) 2016 April meeting developed a detailed work plan for full benchmark assessment of this stock (NAFO, 2016). It was noted that the work plan was designed to interrelate the different processes affecting management of this stock: the MSE, the FC Request to SC to organize a full benchmark assessment and to revise the Flim value, and the PA Framework revision which is currently under discussion. The tentative timeline to the NAFO 3M Cod Benchmark and the NAFO 3M Cod MSE approved by the FC-SC WG-RBMS was the following:

*NAFO 3M Cod Benchmark calendar*

1. *The Scientific Council (SC), in June 2016, will approve the main assessment issues to be revised during the 3M Benchmark. Among those issues, there the FC request to the SC (request number 8, SC SCS Doc16/01) that the SC should, in 2016, analyse whether the current Flim value for 3M cod is currently underestimated and to revise, if required, the relevant fishing mortality and biomass reference points appropriately. The RBMS WG recognizes that the best forum to carry out the Flim review is the benchmark process, so it would be recommended to undertake this task during that process.*
2. *Before the end of 2016 all data needed for the NAFO 3M Cod assessment will be reviewed and compiled.*
3. *Between June 2016 and March 2017 different teams of SC scientists will be working on the issues identified in the 2016 June SC meeting.*

4. The benchmark will be carried out in April 2017. This may involve SC and external scientists.
5. The June 2017 SC meeting will carry out a new assessment taking into account the Benchmark conclusions. This assessment would inform the TAC decision for 2018 because the MSE may not be finalised before September 2017.

#### *NAFO 3M Cod MSE calendar*

*Little progress is expected here before June 2017: this is because the results of the 3M cod benchmark and the NAFO PAF review will be required prior to the resumption of the MSE process. This would be the expected steps:*

1. *In June 2017 a new 3M Cod assessment would be issued, according with the benchmark outputs as well as (ideally) the reference points arising from any revisions of the PAF, which at this stage would be tentative (not adopted by the FC).*
2. *After September 2017, if the FC adopts any relevant new elements of the PAF, the RBMS WG should revise the management objectives of the 3M cod MSE accordingly.*
3. *Between September 2017 and March 2018 different HCRs could be tested in order to see if they reach the established management objectives.*
4. *By June 2018 the RBMS WG and SC may revise the 3M Cod MSE to enable the proposal of a HCR. This HCR may be submitted for approval to FC in September, 2018.*

*If and as approved by the FC, this HCR will be applied to determine the TAC in 2019 and onward.*

The intent of this document is to present some information to help to address the FC request and the proposed FC-SC WG-RBMS work plan.

### **Main assessment issues**

Table 1 presents some assessments characteristics of the North Atlantic cod management units. The main assessment issues that should be reviewed before and during the benchmark according to our opinion are presented below:

#### **Assessment model:**

The assessment model used in the 3M cod is coding in R. It should be necessary a depth review and debug of the R code used. This revision could be made by an independent expert in R and Bayesian assessment models with the assistance of the 3M Designated Expert (DE). This revision would be carried out during 2016.

The FC spotted an inconsistency in 3M cod risk advice table in 2015. The SC analysed this inconsistency in September 2015 and concluded that there are different ways to estimate the risk depending in the type of assessment results and it was demonstrated that the risk will differ to significant extent from one option to the other. This initiative is also in line with the setting of a technical subgroup in charge of revising the PAF (NAFO/FC Doc 15/19), where one of the ToR is dedicated to the standard risk computation. It will be necessary to review and debug the projections R code used till now in the 3M cod taking into account the conclusion of the technical subgroup in charge of revising the PAF.

The model estimates the natural mortality (M). M is constant for all ages and years. The last year estimation was  $M=0.16$ . Revision of North Atlantic cod assessment shows that this value of M is quite low compared with of other cod stocks (Table 1). It would be recommended to study other ways to estimate M (Lorenzen, 1996) or assume M. These scenarios could be presented during the benchmark.

#### **Assessment Input Data:**

It would be necessary to review the available assessment input data to try to improve the quality of them.

It should be explored the possibility of expanding the input data arrays in more ages. Table 2 and 3 show the otoliths collected in the EU-FC survey and in the Spanish commercial fleet. The current plus group used in the assessment is 8+ and it seems quite appropriated till 2010 based on the otoliths collected in the EU FC survey (Table 2) and in the age composition presented by Vazquez (1991) for the Spanish pair

trawlers fishery in the period 1988-1990. From the revision of other cod stocks (Table 1) it seems that this plus group could be appropriated, but it can be observed that in the last years the age composition has been expanded in the case of the 3M Cod. It will be good to make a study to see the possibility of increase the age of the plus group. To carry out this study it will be necessary to expand all the assessment inputs data as much as possible during 2016 to decide in the benchmark what should be the most appropriate plus group.

**Aging and Age-Length Keys (ALKs):**

The 3M cod is at present determined by the traditional method of annual ring interpretation. Some inconsistencies in age readings between readers and institutes have existed for age determination for this stock. In 2010, two commercial fisheries ALKs were available, one for the Portuguese data from the 3M FC survey data reader (IIM), and another one for the commercial Spanish data from a new reader (IEO). It was observed some differences between both ALKs. In order to maintain the consistency of the series, it was decided to use the survey reader ALK (IIM) for all the commercial catch because it comes from the same reader as the previous years for commercial and EU survey data (Vazquez, 2011 and Gonzalez-Troncoso and Vazquez, 2011). This problem has been exacerbated in recent years since there are three different ALKs (IIM survey, IEO commercial and IPMA commercial). The commercial ALKs (IEO and IPMA) are quite similar between them and have some differences compare with the survey ALK (IIM). In order to maintain the consistency of the series, it was decided to use the IIM ALK (IIM) for all the commercial and EU survey data because comes from the same institution as the previous years.

To solve this problem an otolith exchange should be recommended and it should take place well before the benchmark to try to solve the inconsistencies between the different institutions ALKs and to prepare the assessment data using the new commercial ALKs to be used during the benchmark.

**Review of the Limit Reference Points:**

$B_{lim}$  has been established by eye with a value of 14 000 tons. Probably this value could be reviewed with the new data points. It seems to be low compared with the current levels of SSB.

$F_{30\%SPR}$  has been established as the best  $F_{lim}$  proxy and has been estimated with all the series parameters values due to the observed big trend in these parameters and the estimated low M values. If these situations change it will be necessary to estimate new values. The FC requested the SC for 2016 to analyse whether the current  $F_{lim}$  value for 3M cod is currently underestimated and to revise, if required, the relevant fishing mortality and biomass reference points appropriately. The best forum to carry out these reviews is the benchmark, so it would be recommended to take this task during the benchmark as was proposed by the FC-SC WG-RBMS.

**Proposed timetable:**

Table 4 shows the proposed timetable to carry out the benchmark and the main tasks described above. It is proposed to perform the benchmark in April 2017 to allow having time to prepare the assessment to be held in the Scientific Council of June 2017 with the conclusions of the benchmark. It would be appropriate that the SC nominate responsible for each task of the benchmark and that at least two external experts with experience in the cod stocks assessment and benchmark processes participate in NAFO 3M cod Benchmark.

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Table 1. Information about the models assessment, plus group and  $F_{msy}$  of the different North Atlantic cod management units. The year column shows the last assessment consulted.

Area	Management Unit	Model	Plus Group	M	Fmsy	Year
NAFO	Northern Labrador Cod (NAFO Div 2GH)	Not information				
NAFO	Labrador / Grand Bank (NAFO 2J+3KL)	SURBA	2-12	Z=0.5		2013
NAFO	Flemish Cap (NAFO 3M)	Bayesian XSA	1-8+	0.16	F30%=0.131	2015
NAFO	Southern Grand Bank (NAFO 3NO)	ADAPT	2-12	0.2	0.3	2015
NAFO	Southern Newfoundland (NAFO 3Ps)	SURBA	1-10	Z=0.5		2014
NAFO	northern Gulf of St. Lawrence (3Pn, 4R5)	ADAPT	1-13	Time V 0.3-0.5		2014
NAFO	S. Gulf of St Lawrence (NAFO 4TVn)	VPA (ADAPT)		Age Var		2009
NAFO	Sydney Bight (NAFO Subdivisions 4Vn)	Surveys				2015
NAFO	Eastern Scotian Shelf (4VsW)	VPA (ADAPT)	1-15	Age Var 1-4, 5+		2011
NAFO	Southern Scotian Shelf and Bay of Fundy (NAFO 4X5Yb)	VPA		1.5?		2011
NAFO	Gulf of Maine (NAFO Division 5Y)	ASAP (Age Structured Assessment Program)	1-9+	0.2	F40%=0.185	2014-2015
NAFO	Georges Bank (NAFO 5Z)	ASAP (Age Structured Assessment Program)	1-10+	0.2	F40%=0.169	2012-2015
AFWG	Northeast Arctic (ICES Subareas I and II)	XSA	3-13+	0.2		2015
AFWG	Norwegian coastal waters (ICES Subareas I and II)	XSA	2-10+	0.2		2015
NWWG	Offshore West Greenland (NAFO Subdivisions 1A-1E)	Surveys	1-10+			2015
NWWG	in inshore (NAFO Subarea 1)	Surveys	3-10+			2015
NWWG	ICES Subarea XIV and NAFO subarea 1 (offshore waters)	Surveys	3-10+			2015
NWWG	Iceland (ICES Va)	statistical catch-at-age (ADCAM)	3-14+	0.2		2015
NWWG	Faeroe Bank (ICES Vb2)	ASPIC/Surveys				2015
NWWG	Faeroe Plateau (ICES Vb1)	XSA	2-10+	0.2		2015
WGCE	West of Scotland (ICES VIa)	Analytical age-based assessment (TSA)	1-7+	Lorenzen (1996)		2015
WGCE	Rockall (ICES VIb)	data-limited stocks (Only landings)				2012
WGCE	Eastern Channel and Southern Celtic Seas (ICES VIIe-k)	XSA	1-7+	0.2		2015
WGCE	Irish Sea Cod in (ICES VIIa)	SAM (State-space assessment model)	1-6+	0.2		2015
WGNSSK	North Sea, Skagerrak (Subarea IV and Divisions VIId and IIIa West)	Age-based analytical assessment (SAM)	1-11+	Var age 1-3, older Cons=0.2		2015
WGBFAS	Eastern Baltic Sea (ICES Subdivisions 25-32 and Subdivision 24)	Surveys				2015
WGBFAS	Western Baltic Sea (ICES Subdivisions 22-24)	Age-based analytical assessment (SAM)	1-7+	0.8,0.24,0.2		2015
WGBFAS	Kattegat (ICES IIIa East)	stochastic state-space model (SAM)	1-6+	0.2		2015

Table 2. Number of collected otoliths in the Flemish Cap survey by year and age.

Year	Ages														Total	8+	%
	1	2	3	4	5	6	7	8	9	10	11	12	13	14			
1993	306	1234	1574	112	246	34	122	26							3654	26	0.71%
1994	293	159	785	384	15	10	1	16		1					1664	17	1.02%
1995	380	1068	278	996	264	10	8		6	2					3012	8	0.27%
1996	10	852	1276	204	672	58	2	2							3076	2	0.07%
1997	18	54	1383	1962	162	405	9					3			3996	3	0.08%
1998	4	12	13	172	219	11	22		1						454	1	0.22%
1999	1	38	23	22	121	70	3	2							280	2	0.71%
2000	39	2	47	29	15	73	32	3	3			1		1	245	8	3.27%
2001	107	274	2	18	13	3	23	18	1	1	1				461	21	4.56%
2002		173	85	4	9	5	4	15	5		1				301	21	6.98%
2003	138	9	110	32	6	7	1	1	7	6					317	14	4.42%
2004	2	420	9	187	51	2	4	2	1	3	1				682	7	1.03%
2005	368	2	145	10	89	17		2	1	1					635	4	0.63%
2006	390	347	7	197	11	79	16	1		1	2		1		1052	5	0.48%
2007	340	290	464	3	160	8	62	11	2	3					1343	16	1.19%
2008	243	454	448	328	6	113	7	30	10		2				1641	42	2.56%
2009	197	300	267	341	92	1	38		22			2			1260	24	1.90%
2010	222	237	86	66	132	137	1	45	6	27	3				962	81	8.42%
2011	315	599	257	104	155	155	92		17		8				1702	25	1.47%
2012	280	314	84	159	98	168	123	74	3	11	2	11		2	1329	103	7.75%
2013	153	262	338	101	191	178	186	135	42	6	5	4	1		1602	193	12.05%
2014	214	70	251	328	162	190	199	156	139	58	9	6	1		1783	369	20.70%
2015	89	207	150	190	135	317	196	120	88	47	27	3	3	3	1575	291	18.48%
Total	4109	7377	8082	5949	3024	2051	1151	659	354	167	61	30	6	6	33026	1283	3.88%

Table 3. Number of collected otoliths in the Spanish commercial fishery in the period 2006-2015 by year and age.

Year	Ages													Total	8+	%	
	2	3	4	5	6	7	8	9	10	11	12	13	17				
2006				3		1	1	1							6	2	33.33%
2007			1	5	26	3	16	2							53	18	33.96%
2010	33	97	168	130	191	70	65	32	35	12					833	144	17.29%
2011		8	53	168	102	107	18	37	5	13	1				512	74	14.45%
2012	1	72	59	65	137	135	107	19	16	11	17	3	1		643	174	27.06%
2013	11	123	341	96	55	29	10	5	1		1				672	17	2.53%
2014		62	113	303	178	136	166	91	27	2	1				1079	287	26.60%
2015	26	28	195	171	358	105	60	32	16						991	108	10.90%
Total	71	390	930	941	1047	586	443	219	100	38	20	3	1	4789			

Table 4. Proposed schedule to carry out the NAFO 3M cod Benchmark and related tasks.

Task	2016				2017			
	1st Q	2nd Q	3rd Q	4th Q	1st Q	2nd Q	3rd Q	4th Q
Review Assessment R code								
Review projectionst R code								
Assessment input data review								
M values								
Plus Group data								
Commercial ALKs								
Review Reference Points								
Benchmark						April		
SC meeting						June		