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3M cod assessment input data

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ABSTRACT

The objective of this document is to present the results of the review of the available data of the NAFO Division 3M cod fishery. The aim of this review has been to make available the best possible data for the 3M cod assessment benchmark that will take place in April 2018.

In this review, different errors have been found and alternatives have been proposed to solve them. These alternatives have been discussed at a meeting of the NAFO Scientific Council (SC) that was held in March to decide the best data available to perform the benchmark. The final decisions of that NAFO SC meeting are included in this document.

1. Flemish Cap Area (Perez-Rodriguez *et al.*).

Flemish Cap is a deep water mountain located in the NAFO Division 3M (Figure 1). Two features provide high degree of isolation to the Flemish Cap ecosystem. First, the Cap is separated from the Newfoundland shelf by the Flemish Pass, a channel characterized by depths beyond 1100 m and 30 miles wide in the narrowest point at 400 m depth. This feature hinders the migration to and from surrounding areas for juvenile and adult stages of shallow demersal species, such as Atlantic cod (*Gadus morhua*) and American plaice (*Hippoglossoides platessoides*). Second, a quasi-permanent anti-cyclonic gyre dominates the oceanography over the Cap, producing a retention effect on eggs and larvae that would eventually stay over the Flemish Cap and recruit to the population. This isolation provides to the Flemish Cap a high degree of independence in the dynamic of its populations in relation to the Grand Banks.

2. Flemish Cap Fisheries

The Flemish Cap has been a traditional fishing ground for cod and redfish especially since mid 20th century. After a period of extreme high fishing pressure, the Flemish Cap cod experienced a sharp decline that ended up with the collapse of the stock by mid 1990s. In parallel, redfish catches also showed a steep decline, after a period of very high values. The declines of cod and redfish were followed by the increase of shrimp, Greenland halibut, wolffishes and other demersal stocks. New fisheries targeting shrimp and Greenland halibut started by mid 1990s and kept total landings from the area at similar levels than before the cod stock collapsed. The recovery of both redfish and cod stocks since 2000-2005 were followed by the decline and collapse of shrimp by 2010 when the cod fishery was reopened.

3. Flemish Cap Cod Fishery

Registered cod catches from Flemish Cap start in 1954, but reported total catch was incomplete in the initial years. In the period 1959-1973 the fishery was carried out mainly by trawlers from Portugal, URSS,

France, United Kingdom and Spain and in less degree by Spanish pair trawlers, Portuguese gillnetters and Norwegian longliners. In 1974 a TAC was established for the first time and in the period 1974-1995 the fishery was mainly carried out by Portuguese trawlers, Spanish pair trawlers, Faroese and Norwegian longliners and, to a lesser extent, Portuguese gillnetters. Since 1995 catches had fallen and NAFO decreed a moratorium on this stock between 1999 and 2009. In this period catches were by-catch of other trawl fisheries in Division 3M, mainly redfish and shrimp. In 2010 the 3M cod fishery was reopened and since then catches have been taken mainly by Portuguese, Spanish and Faeroes trawlers and Faeroes and Norwegian longliners. Figure 3 shows the distribution of the 3M cod catches by gear based on the NAFO STATLANT 21B information for the period 1960-2015.

4. NAFO 3M cod Assessment

A VPA based assessment of the cod stock in Flemish Cap was approved by NAFO Scientific Council (SC) in 1999 for the first time and had been annually updated until 2002 with the catch data from 1972 and tuning with EU survey from 1988 and ages 1 to 7 (A. Vázquez and S. Cerviño, 2002).

However, catches between 2002 and 2005 were very small, undermining the VPA based assessment. Cerviño and Vázquez (2003) developed an assessment method which combines survey abundance indices at age with catchability at age, the latter estimated from the last reliable accepted XSA for the survey period from 1988. This new method had been used in the period 2003-2007.

In 2007 results from an alternative Bayesian model were also presented and in 2008 this Bayesian model was further developed and approved by the NAFO SC (Fernández *et al.*, 2008), with the catch data from 1988 and tuning with EU survey from 1988 and ages 1 to 7.

In 2013 the same Bayesian model structure was approved by the NAFO SC but with catch data from 1972 and tuning with Canadian survey for the period 1978-1985 and EU survey from 1988 (ages 1 to 7). The last approved 3M cod assessment was presented by González-Troncoso in 2017.

5. Assessment Input Data

5.1. Total Catch

Registered cod catches from Flemish Cap started in 1954, but reported total catch was incomplete in the initial years. In 1974 a TAC was established for the first time. The reduction of the TAC in 1980 produced an immediate decrease in reported catches. Confidence in reported fisheries data was raised in 1986 (NAFO SC Rep., 1986) due to large discrepancies observed between reported catches from member countries and Canadian surveillance estimates. Prior to 1988 total catches come from NAFO Statistical Bulletin. The figures were highly inaccurate, probably overestimated before 1974 (when ICNAF set a 40,000 t TAC distributed according historical catch by country) and underestimated after 1980 (when TAC dropped from 40,000 to 12,000 t). Catches before 1988 were not considered in the assessment until 1999 because it was generally assumed that reported catches were inaccurate.

A moratorium was agreed by the Fisheries Commission for the period 1988-1990. Despite the moratorium, cod catches were estimated at around 40,000 tonnes in 1989. Independent estimates of total annual catches for the period 1988-1994 were made by Vázquez *et al.* (1995) and substantially differ from total reported catches in the same period.

Catches from 1988 until 2010 were estimated for Spain and Portugal based in the information collecting by the "NAFO Observers" and the "Scientific Observers" and for the other fleets based on the STATLANT 21A data or Canadian Surveillance (if available and differing from reported catch).

In the period 2011-2012 catches were estimated by the Bayesian VPA model.

In 2013 and 2015 the base information to estimate the catches was the Daily Catch Reports (DCRs).

In 2014, for countries that submitted the STATLANT 21A data before June, catches were based on this information. For the rest of the countries, catches were based on the DCR's data.

From 2016, catches are estimated according to a method developed by the WG CDAG (Catch Data Advisory Group, NAFO 2016).

Figure 4 presents the 1959-2016 3M cod catches and TACs approved by the NAFO Fisheries Commission.

5.2. Catch-at-Age

Catch at age matrix for the period 1972-1983 was taken from the analyses made by Wells *et al.* (1984).

Catch at age for 1984 was calculated by Baird and Wells (1986). Catch at age for the period 1985-1987 was determined using sampling results for Portuguese otter trawl catch and Spanish pair-trawl catch.

Catch at age for the period 1988-1998 was calculated using sampling results for Portuguese gillnets and otter trawl catch and Spanish pair-trawl catch (Vazquez *et al*., 1999).

Catch at age for the period 1999-2016 was estimated using the Flemish Cap (FC) survey ALKs to the commercial length distributions. In the period 2002-2005 there was neither length distributions information nor age distributions in the catch. Depending on the type of model used in the assessment this could be a problem and how to solve it should be decided during the Benchmark. It is likely that some of the models that will be presented in the Benchmark can deal with this handicap.

Figure 5 presents the observed proportion of the catch numbers at age by year for the period 1972-2016 and Figure 6 shows the standardized proportion of the catch numbers at age by year for the same period. The standardization was made to the mean of the period for each age. Black bubbles indicate values less than the mean and grey bubbles indicate values bigger than the mean.

Figure 7 presents the ratio between the sum of the product of the catch at age numbers by the mean weights-at-age in catch (Sum Of Products: SOP) and the total catches used in the SC assessment. It can observed that before 1988 (green vertical line) the inconsistencies between the total catches and the catch at age assessment information are quite large in many years and it should be very difficult to solve due to the lack of information. Since 1987 these discrepancies are less and smaller. There is more information in this period and it would be possible to resolve these discrepancies.

5.3. Catch Mean Weights-at-age

3M cod catch mean weight-at-age is presented in Figure 8. There are available data of mean weight-at-age in catch for years 1972-1987 from the 1999 assessment (Vázquez *et al.*, 1999). Mean weight the period 1973 to 1985 was calculated by Baird and Wells (1986) based on survey results and they are the same as the Stock Mean weights at Age. For the rest of the years mean weights-at-age have been computed using length-weight relationships and ALKs from the commercial sampling or from the EU survey depending on the information available each year.

5.4. Stock Mean Weights-at-Age

3M cod mean weight-at-age in the stock is presented in Figure 9. For the period 1972-1987 it was decided to apply the weight-at-age for catch presented in the 1999 assessment (Vázquez *et al.*, 1999). Mean weights-at-age for the period 1973 to 1985 were calculated by Baird and Wells (1986) based on Canadian survey results. As catch has no weight-at-age information for the youngest ages (1 and 2), the mean of the EU survey weight-at-age between years 1988-1995 for those ages was taken. The reason for taking the average of this period is that the mean weights seem to be stables during these years and they increased suddenly in 1996. From 1988 to 2016, mean weight-at-age in the stock is available from the Flemish Cap EU survey.

5.5. Maturity at age

Maturity ogives from the Canadian survey are available for all the years of the period 1978-1985 and from the EU survey for years 1990-1998, 2001-2006 and 2008-2016. For those years Bayesian logistic regression models for proportion mature at age have been fitted independently for each year. For 1972 to 1977, the 1978 maturity ogive was applied. For years 1983-1985 the fit was no consistent, so those years were omitted for the fit. The 1982 maturity ogive was taken for 1983 to 1987. For 1988 and 1989 the 1990 maturity ogive was applied. Maturity data for 1991 were of poor quality and did not allow a good fit, so a mixture of the ogives for 1990 and 1992 was used. For 1999 and 2000 maturity ogive was computed as a mixture of 1998 and 2001 data, and for 2007 as a mixed of 2006 and 2008 maturity ogive. The median of the maturity ogives by age for the whole period is presented in Figure 10.

5.6. Survey Data

5.6.1. Canadian survey

Canada conducted research vessel surveys on Flemish Cap from 1978 to1985. Surveys were conducted by the R/V *Gadus Atlantica*, a stern trawler of 74 m in length, fishing with a lined Engels 145 otter trawl. The surveys were conducted in January-February each year from 1978 to 1985, using a stratified random design. Fishing sets were usually of 30 minutes duration, over a distance of 1.75 nautical miles, and covered depths between 130 and 728 m. All strata were surveyed each year, with the exception of 1982, when 4 deeper strata were omitted (Brodie and Bowering, 1992). The indices of abundance of this survey for 3M cod were presented by Wells and Baird in 1985.

Figure 11 presents the 3M cod standardized proportion of the catch numbers at age in logarithm scale by year for the Canadian survey on Flemish Cap for the period 1978-1985. Black bubbles indicate values less than the mean and grey bubbles indicate values bigger than the mean.

5.6.2. EU (Spain and Portugal) Flemish Cap survey

The EU bottom trawl survey on Flemish Cap has been carried out since 1988 using a Lofoten type gear, targeting the main commercial species down to 730 m of depth. The surveyed zone includes the complete distribution area for cod, which rarely occurs deeper than 500 m. The survey procedures presented by Vázquez *et al.* (2013) have been kept constant throughout the entire period, although in 1989 and 1990 different research vessels were used. Since 2004, the survey has been carried out with a new research vessel (R/V *Vizconde de Eza*, replacing R/V *Cornide de Saavedra*) covered depths to 1430 m, and conversion factors to transform the values from the years before 2004 have been implemented for the assessed species by NAFO SC (González-Troncoso and Casas, 2005).

The surveys are conducted in June-July, using a stratified random design. Fishing sets are usually of 30 minutes duration, over a distance of 1.75 nautical miles, and covered depths between 130 and 730 m until 2003 and between 130 and 1430 m since 2004.

Figure 12 presents the 3M cod standardized proportion of the catch numbers at age in logarithm scale by year for the EU survey on Flemish Cap for the period 1988-2016. Black bubbles indicate values less than the mean and grey bubbles indicate values bigger than the mean.

Figure 13 presents the ratio between the sum of the product of the surveys abundance at age used as tuning in the 2017 assessment by the mean weights-at-age in the stock (Sum Of Products: SOP) and the surveys total biomass indices. It can be observed that for the Canadian survey (red points) the inconsistencies between the SOP and the total biomass index used in the 2017 assessment are quite large in many years and it should be very difficult to solve due to the lack of information. For the FC survey these

inconsistencies can be observed practically every year in the period 1988-2000, being much more punctual since then. There is more information for this survey and it would be possible to resolve these discrepancies.

6. Possible Benchmark discussions related to the input data:

6.1. Assessment Time Series

In the 2013 assessment the catch data set was extended from 1988 to 1972 and a new tuning survey started to be used, the Canadian survey during 1978-1985. Most of the input data prior to 1988 were taken from Vázquez *et al.* (1999) and there is some information about the quality of this data. Catches before 1988 were not considered in previous sequential population analysis till 1999 because it was generally assumed that reported catches were inaccurate.

The discrepancies between the information provided by the total catches and the information by age of the catches are quite large in the period before 1988, as indicated above (Figure 7). Similar problem has the Canadian survey information in the period 1978-1985 (Figure 13). The information available nowadays to improve the data before 1988 is very limited.

Table 1 presents a summary of the available information of the 1972-2016 time series. It can be observed that in the period 1972-1987 the available information is quite limited and the catch and survey information quality could be considered poor.

It would be suitable to discuss what would be the best time period in order to carry out the assessment and which should be the appropriated information to actualize the reference points.

6.2. How to deal with the periods without catch or CAA information.

In the period 2011-2012 total catches were estimated by the Bayesian model. We could estimate the catches of these years with the available information or, on the contrary, these years could continue to be estimated by the assessment models. Table 2 shows the estimated catches based on different information for the 2011-2016 period.

In the period 2002-2005 there was neither length distributions information nor age distributions in the catch. Depending on the type of model used in the assessment this could be a problem and how to solve it should be decided during the benchmark. It is likely that some of the models that will be presented in the benchmark can deal with this handicap.

An estimate of the abundance by age for this period has been calculated using the following method. An average ratio was estimated between abundances by age in the catches and that observed in the FC survey for the period 1988-2008. This period has been chosen because the observed catches have been less than 1000 tons and it has been thought that the catchabilities at low abundances could be similar. The average observed ratio in this period has been used to estimate catch abundances by age from the abundances by age in the FC survey. A similar method applied to sizes was used by Avila de Melo *et al.* (2009) in the 3M redfish. The new estimated abundances were used to run an XSA similar to that approved in the year 2017. The preliminary results presented convergence problems in the years 2002-2003. In these years enormous abundances were estimated in the plus group due to the lack of convergence.

6.3. CAA and Catch mean weights.

Before 1988 the inconsistencies between the total catches and the catch-at-age assessment information are abundant and it should be very difficult to solve due to the lack of information.

The majority of discrepancies in the SOP in the period 1988-2016 are from 1994 to 2007. For the years 1994 and 1995 it is not clear which could be the information with better quality. But it is quite clear that for the period 1996-2007 the information with more quality is the Total Catch due to the very low level of

commercial sampling information with which the CAA was built in this period, which means that probably the CAA does not represent the real catch at age composition.

It was decided to review all the years with SOP discrepancies more than 10%. The proposals to solve the discrepancies are summarized below:

Year 1994; SOP=0.72: It is proposed to use the SMW for this year. New SOP=0.98

Year 1995; SOP=1.21: Using the SMW the SOP is worse (1.57). It is proposed to raise the catch at age numbers to the total catches. New SOP=1.00. This measure is not recommended to be used regularly by Lewy and Lassen (1997). But we believe that it can be recommended to solve a specific problem such as this case.

Year 1997; SOP=0.46: It is proposed to take the SMW at age and the catch at age abundance presented. With this change the SOP improves (0.7) but it is still quite bad. We propose that the new numbers are weighted to the total catch. New SOP=1.00

Year 2000; SOP=1.11: It is detected an error in the CAA. Age 2 should be 0 individuals. With this change the new SOP=1.00.

Years 2002-2005: For this period we don't understand why if we have not available commercial length distributions, we have catches mean weight at age different from the survey mean weights at age.

Year 2014; SOP=1.09. It is proposed to take the "*a*" and "*b*" of the survey for calculating the catch mean weights-at-age. With these values the new SOP is 1.00.

As a result of the review of the CAA data for the period 2010-2016, it has been detected that the length samples taken by UK have been measured from 2011 to the fork length instead of to the total length as they are for the rest of the countries. To solve this problem, in the 2017 EU FC survey samples were taken to estimate a relationship between the total length and the fork length. The estimated relationship (Figure 14) has been used to transform all the available UK samples since 2011 from the fork length to the total length and then estimate the new CAA and the new mean weights at age in the catches.

New longline catches length distribution samples collected by Norway in years 2013, 2014 and 2016 have been made available to the DE. These data have been included to estimate the new CAA and CMW. In years 2013-2014, with these new data the SOP was getting worse using parameters *a* and *b* of the Portuguese commercial fleet. So it has been decided to use the parameters from the FC survey for these years, resulting in a much better SOP. Figure 15 presents the SOP resulting from the input used in the 2017 assessment (points) and the new SOP resulting from the above proposals for updating the CAA and Catch Mean Weights inputs (line).

6.4. How to deal with the surveys SOP inconsistencies.

It can be observed in Figure 13 the inconsistencies between the SOP and the Canadian biomass index used in the 2017 assessment. It should be very difficult to solve these inconsistencies due to the lack of information.

For the FC survey these inconsistencies can be observed practically every year in the period 1988-2000, being much more punctual since then. The available data for this survey was reviewed and it was found that these discrepancies are due to the fact that the data used in the last assessments were not the correct one. The problem is that the data that have been being used in the assessments since 2007 for the period prior to 2004 were not well calibrated due to a software problem. The SC approved figures for the period 1988-2003 (as published by González-Troncoso and Casas in 2005) have been included and the new SOP has improved substantially (Figure 16).

For the period 2005-2016, all the FC survey input data have been revised and small differences have been found, mainly due to the data base debug that has been made during these years. Only a big change was made in the 2011 survey data, because the *a* and *b* Length-Weight relationship parameters used to estimate the 2011 data were poorly calculated.

Figure 16 presents the SOP resulting of the surveys indices input used in the 2017 assessment (points) and the new SOP resulting from the above proposals for updating the inputs (line).

6.5. Plus group composition

Currently the plus group is 8+, but in the last years the numbers and the ages presented in the 8+ have increased. Figure 17 shows the 3M cod plus group (8+) ratio of the total abundance and biomass in the last approved assessment (2017).

The 2017 Workshop concluded that with the current stock assessment model (essentially a VPA) the change of the plus group is difficult to implement because it requires having the historical catch disaggregated until age 11+ and it is not clear that it is worth to spend so much effort in this issue at this moment.

The 2017 Workshop recommends that the benchmark process considers alternative ways of extending the plus group (via disaggregation of historical data or by using alternative stock assessment models).

All the input data related with catches have been estimated for individual ages till 16+ for the period 2008-2016 and the survey data for the period 1998-2016. We will try to use these new disaggregated data until age 16 in any of the new assessment models to be presented in the Benchmark whenever time permits.

6.6. Maturity at age

Maturity ogives are based on survey information. The best samples to make the maturity ogives are those collected during the spawning season, which is in spring, and the surveys are carried out in July. It is possible that new maturity ogives are presented before the benchmark based on samples collected throughout the year by the commercial fleet to validate the ogives resulting from the surveys for the period 2010-2016.

The analysis of the samples for the period 2010-2016 revealed that there are only enough samples available for spring for the years 2012 and 2014. In the rest of the years the commercial samples were collected in summer or in autumn. So the comparison between the survey maturity ogives, which are those that are being used in the assessments, and the spring commercial maturity ogives, which is the 3M Cod spawning time, could only be done for the years 2012 and 2014.

The preliminary results show that for the years 2012 and 2014 the survey maturity ogives and the spring commercial ones are quite consistent (Figure 18). The differences in the L_{50} between the commercial ogives (spring) and the survey ogives are around 6 cm in both years. These differences are quite consistent with the observed growth pattern in 3M cod. The final results of the maturity studies of 3M cod will be presented in a SCR, hopefully during the benchmark.

7. Possible Benchmark discussions related to model configuration:

7.1. The Workshop recommends that the benchmark process will explore the possibility of using the plus group indices in the tuning.

7.2. There is a potential inconsistency between the plus group abundance estimation in the assessment (VPA) and in the projections (dynamic pool). The Workshop recommends that the benchmark process will explore the possibility of using models different from the VPA to solve this inconsistency.

7.3. It is recommended that the appropriateness of the use of the catchability depending on abundance in the current model should be studied more in-depth during the benchmark.

7.4. The Workshop recommended exploring the option to estimate M outside the stock assessment model.

One solution could be to take a M value (0.2) or the last assessment estimated median M constant for all ages and years. Results show with certain clarity that the assumption of constant mortality in all years and ages probably does not occur in this case. It seems quite clear in these results that at least ages 1 and 2 and possibly age 3 have a higher natural mortality than the other ages.

Other solution could be to build a vector of natural mortalities by age constant for all years based on the results obtained by Size-dependent models. One option is take the median M by age of all Size-dependent methods.

But this solution seems to be not very appropriate based on the Gadget results. The Gadget results show a very large M variability at age in the time series for ages younger than 4 years.

One of the possible solutions could be the use of GADGET results as source of annual values of natural mortality by age and years, used as input for single species models. This way to estimate M was used in different ICES assessment. To carry out this scenario it would be necessary to assume a value for the residual M.

8. **Conclusions of the NAFO meeting to review Input data for 3M Cod Benchmark Assessment.**

It was agreed that the best time period to run the assessment is the 1988-2016 due to the quality problems of the input data before 1988. It was also agreed that for some of the assessment models that will be presented during the Benchmark at least the base case will run with both time series (from 1972 and from 1988) to analyse the sensibility of the results to change the time series.

It was agreed that the best way to solve the SC Cod 3M total catches and the catch at age abundance for 2011-2012 was to take the prior for these years catches used in the last year assessment as the SC approved catches for these years. The reason to use the prior is that the prior was made with the best catch information available.

For the benchmark, it is not necessary to have a completed catch at age abundance matrix at this point. Solutions to problems of missing data in this matrix, where they occur, will be tackled during the process of developing the models. For the model that need the catch at age abundance for the whole period the numbers at age estimated with the method proposed in this document will be used.

For the years 1994, 1995 and 1997 it was decided a common method to estimated the mean weights at age in the catches and the catch at age abundance. The method was to use mean weights at age of the years before and after in these years and estimated the SOP with the old abundance at age. If the SOP is more than 1.10 or less than 0.90, the old numbers will be raised to the approved total catches for these years. The reason to apply this method was that in the old catch at age in the stock figures it can be observed and big year effect in some of these years. For the year 1994 y 1995, the weights at age was the mean of the years 1993 and 2006 and for 1997, the mean of the years 996-1998. For the three years the old abundance figures were raised to the total catches because the new SOP estimated with this method was more than 10%.
For 2014, it was decided to maintain the old mean weights at age and numbers estimated with the Portuguese commercial information with a SOP=1.09.
In the period 2013-2016, it was agreed to update the abundance and the mean weights at age with this modification of the UK samples and the inclusion of the new available Norway samples.

The corrected transform values for the stock mean weights at age and for survey abundance at age in 1988 to 2004 2016 will be used.

The default approach for the plus group will be to use the actual 8+. The study of an older plus group is considered a secondary problem and will be carried out if there is time.

It was agreed to use the actual FC survey maturity ogives. But it was raised in the meeting that could be more import the way as the actual maturity ogives are calculated more than the data (commercial or survey) to calculate them. It was discussed during the meeting that probably it would be necessary to make a research recommendation in the Benchmark to study how to estimate the maturity ogives in this case.

The conclusion of the Mars SC meeting was that it would be necessary to present three different scenarios for a base case of at least one model that it will be presented in the Benchmark to study the sensibility of the results. The three scenarios are:

1. Constant for all ages and years.
2. The median vector estimated of all Size-dependent methods varying by age and constant in time.
3. The age/year matrix of M estimated in the update GADGET model.

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TABLES

Table 1. Catches, catch-at-age (CAA), catch mean weights-at-age (CMW), stock mean weights-at-age (SMW), maturity information (MO) and tuning information by year available to assess the 3M cod. White blocks mean no information, light grey blocks mean limited information and dark grey blocks mean good information.

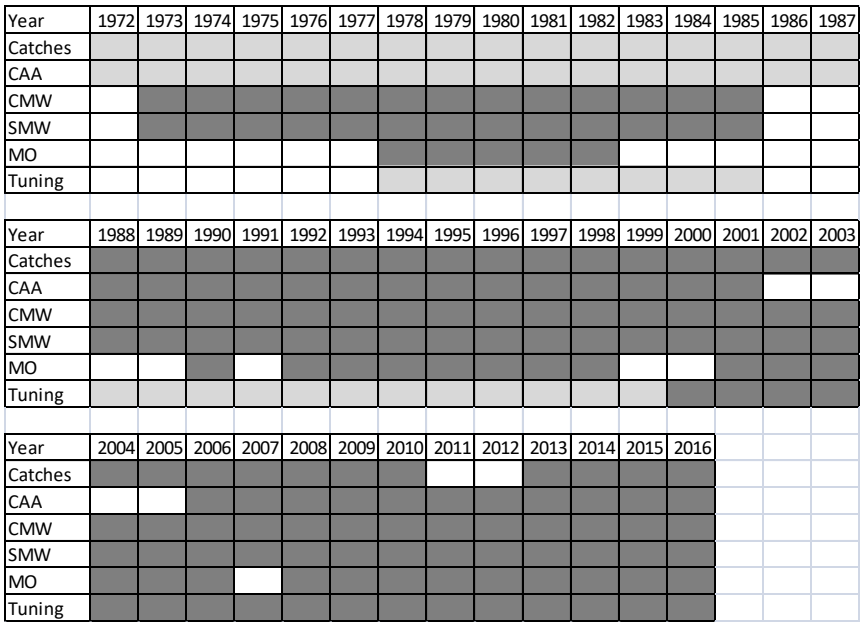

Table 2. Estimated NAFO 3M cod catches based on the Daily Catch Reports (DCR), SC assessment approved catches (STACFIS) and the NAFO official catch information (STATLANT 21A) for the period 2011-2016.

Data	2011	2012	2013	2014	2015	2016
DCR	9546	10166	14078	13431	13477	13915
STACFIS	13600	13230	13985	14290	13785	14023
STATLANT 21A	9977	9068	13521	14356	12828	13339

FIGURES

Fig. 1. The Flemish Cap is located within the regulatory area of the Northwest Atlantic Fisheries Organization (NAFO) corresponding to the Division 3M.

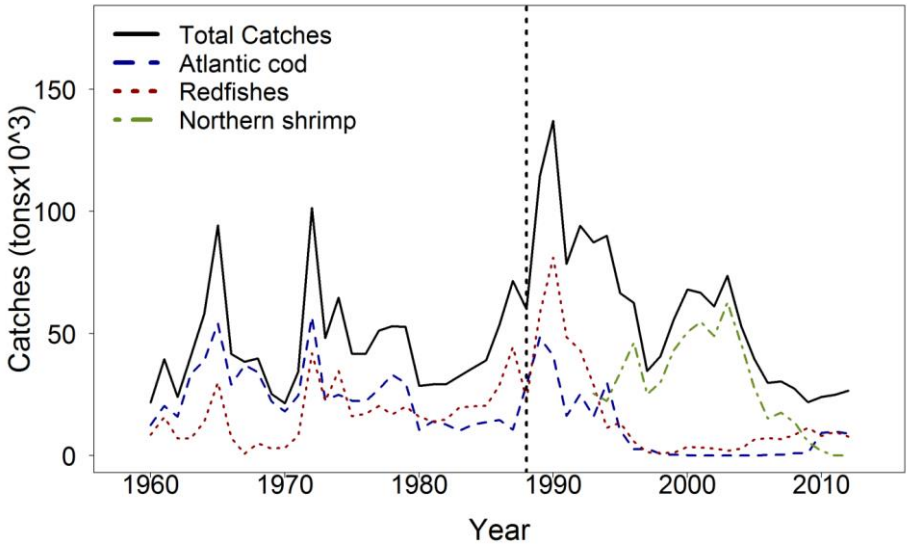

Fig.2. Total catches and catches of the main targeted species in the Division 3M. These species accounted for 94% of total catches since 1960. From Pérez-Rodríguez *et al.* (2016). The vertical dotted line indicates the start of the study period (year 1988).

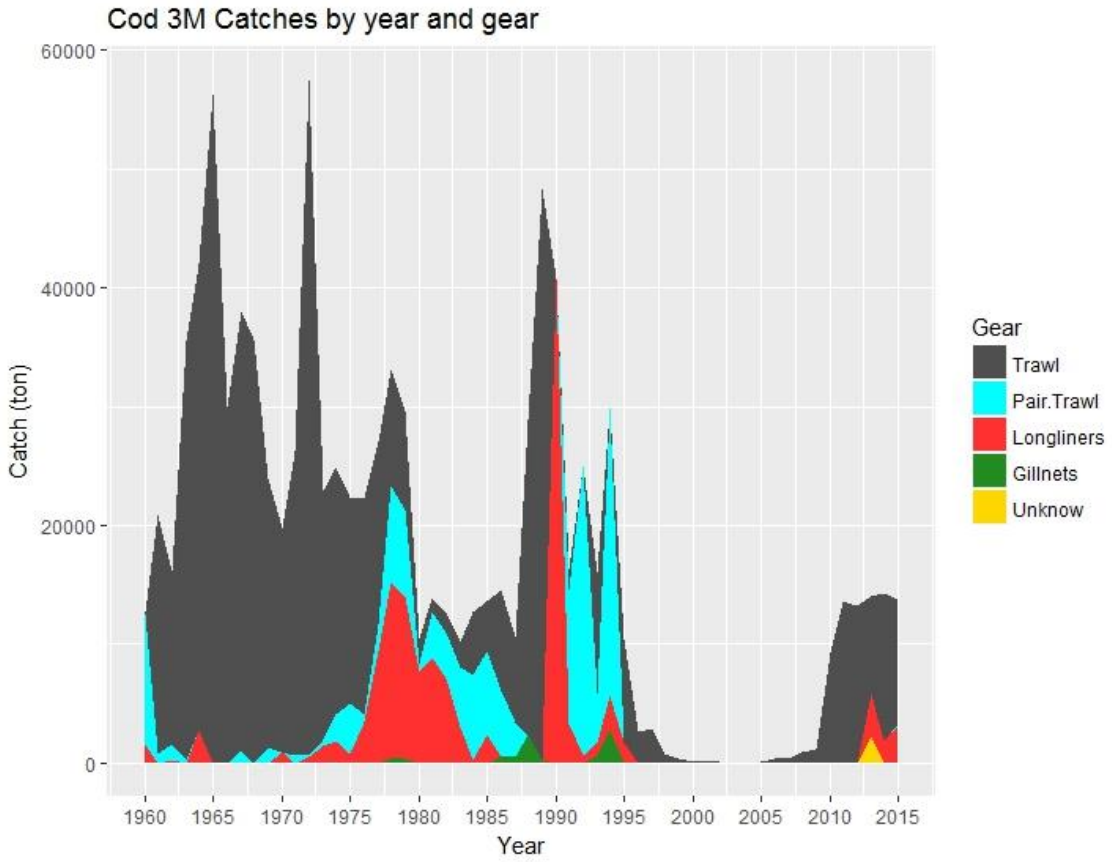

Fig. 3. 3M cod catches in tons by year and gear for the period 1960-2015. Proportion by gear was based on the STATLANT 21B information.

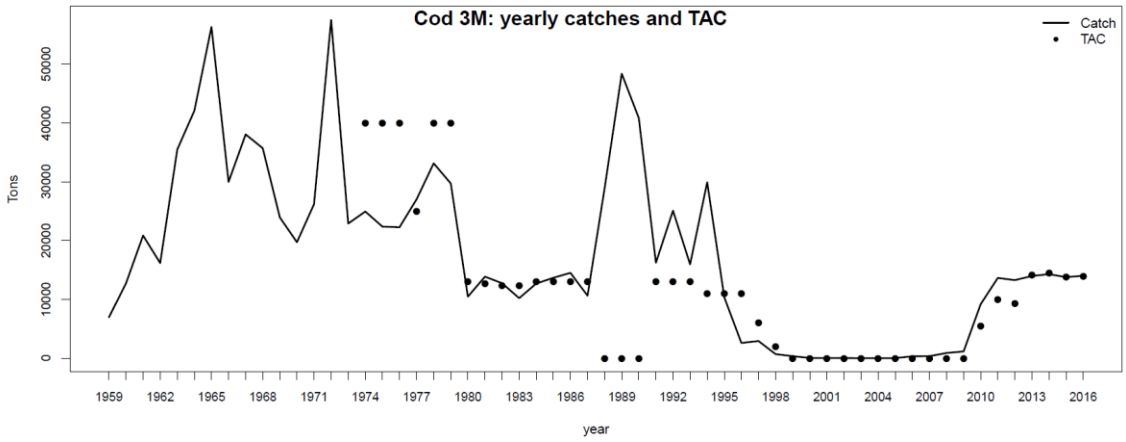

Fig. 4. 3M cod catches and TACs in tons by year for the period 1959-2016. Catches for 2011 and 2012 are the median results of the 2017 assessment.

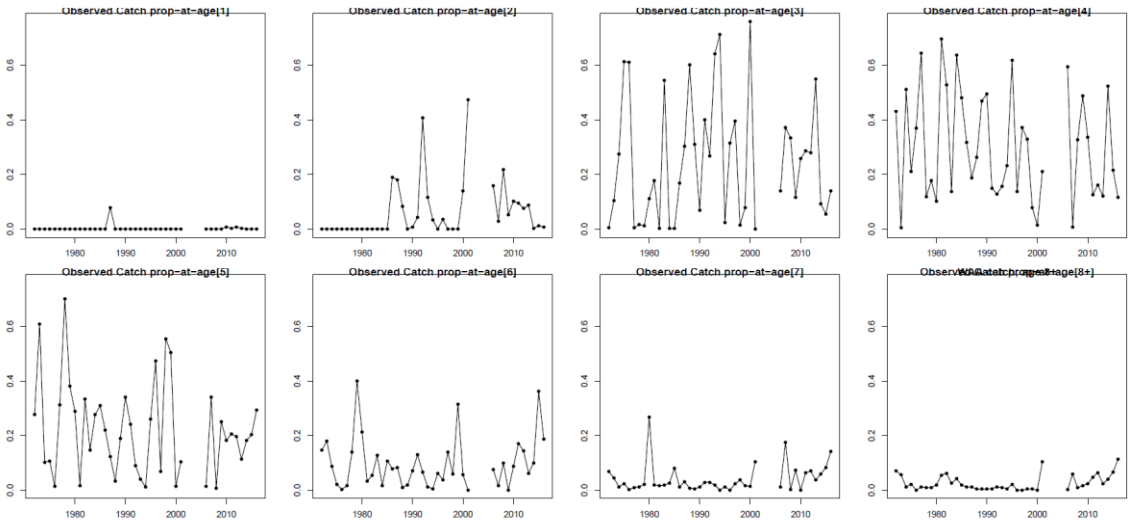

Fig. 5. 3M cod observed proportion of the catch numbers at age by year for the period 1972-2016.

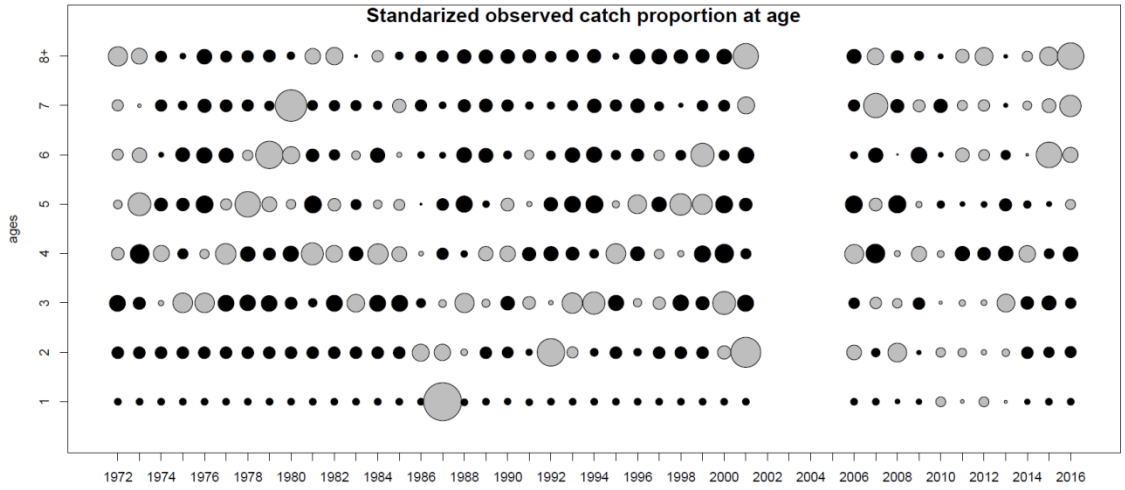

Fig. 6. 3M cod standardized proportion of the catch numbers at age by year for the period 1972-2016. Black bubbles indicate values less than the mean and grey bubbles indicate values bigger than the mean.

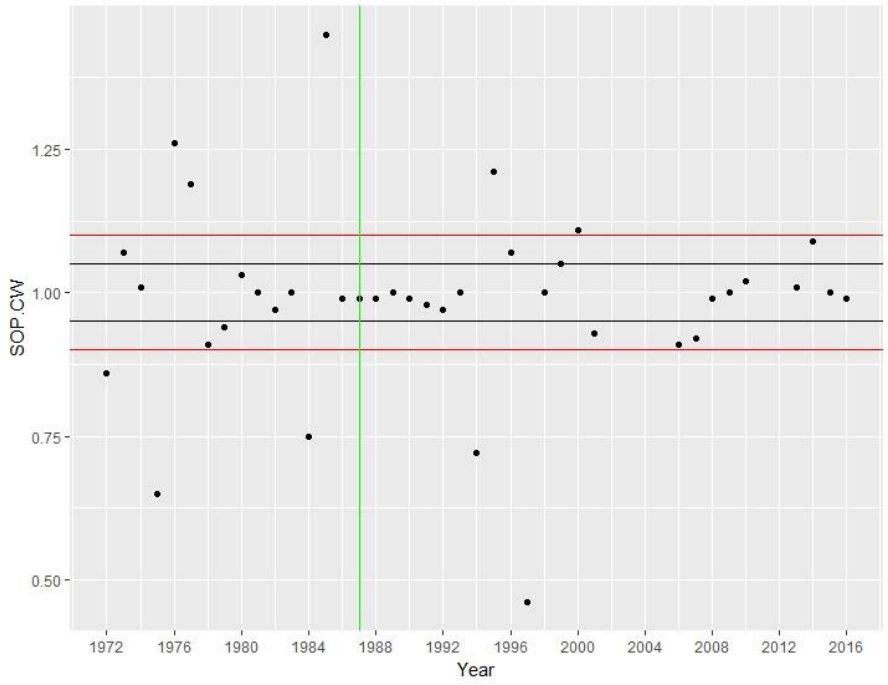

Fig. 7. 3M cod ratio between the sum of the product of the catch at age numbers by the mean weights-at-age in catches (Sum Of Products: SOP) and the total catches used in the SC assessment. Green vertical line = 1987. Red horizontal lines = 0.90-1.10. Black horizontal lines = 0.95-1.05.

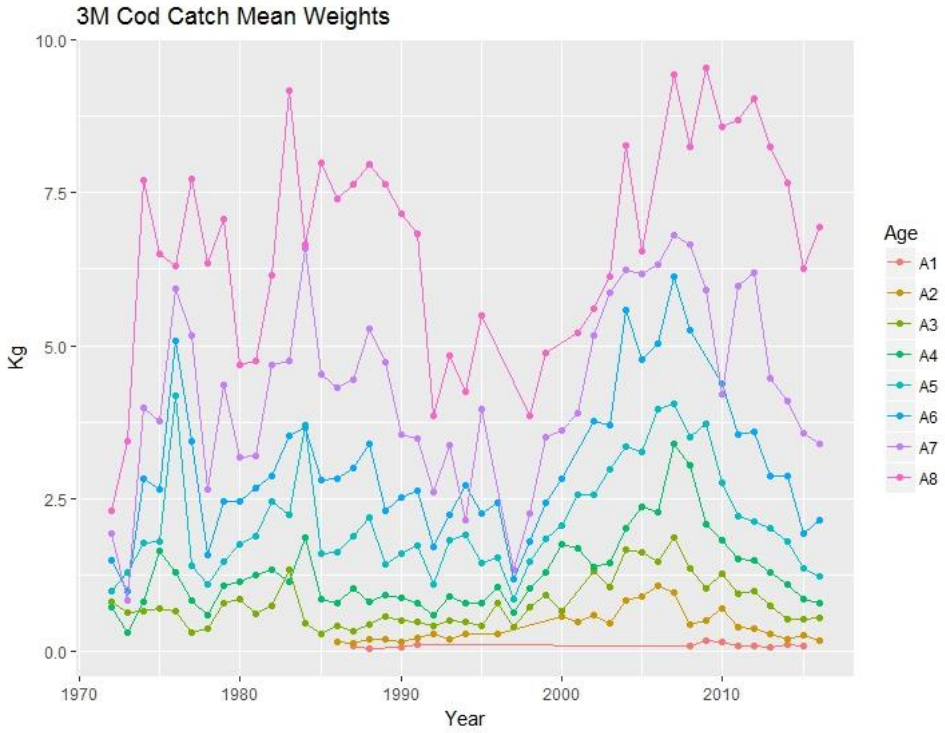

Fig. 8. 3M cod catch mean weights-at-age (kg).

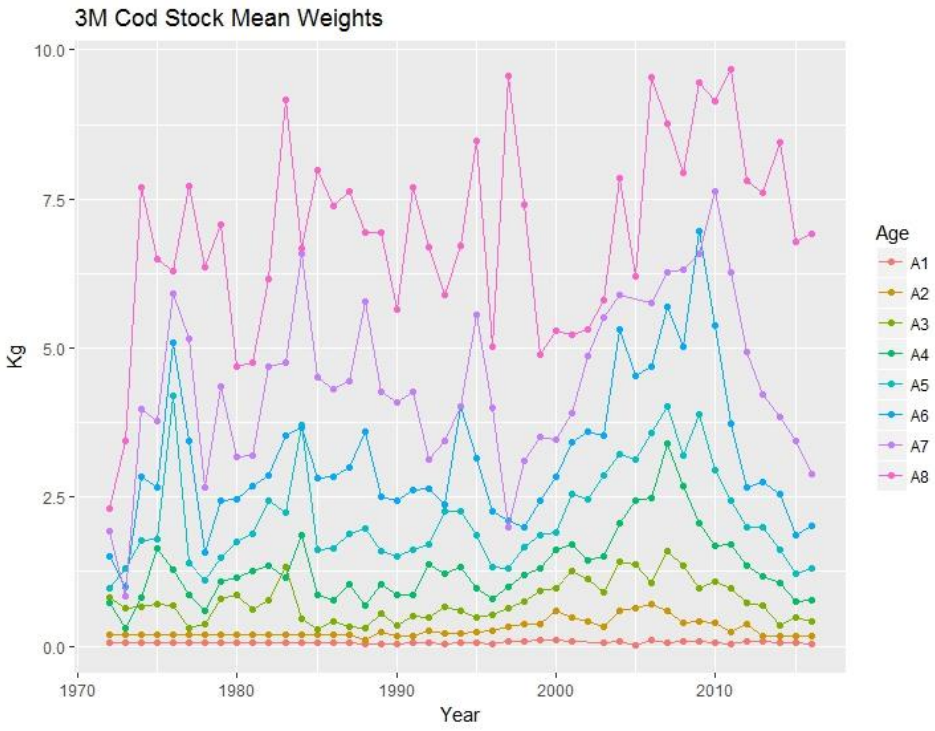

Fig. 9. 3M cod stock mean weights-at-age (kg).

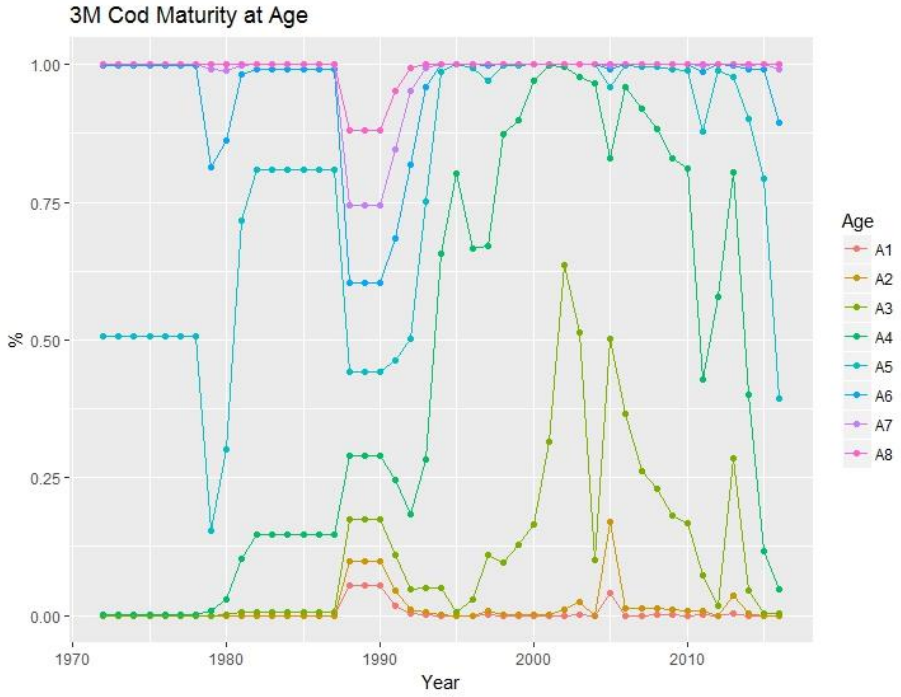

Fig. 10. 3M cod median of the Bayesian logistic regression models for proportion mature at age.

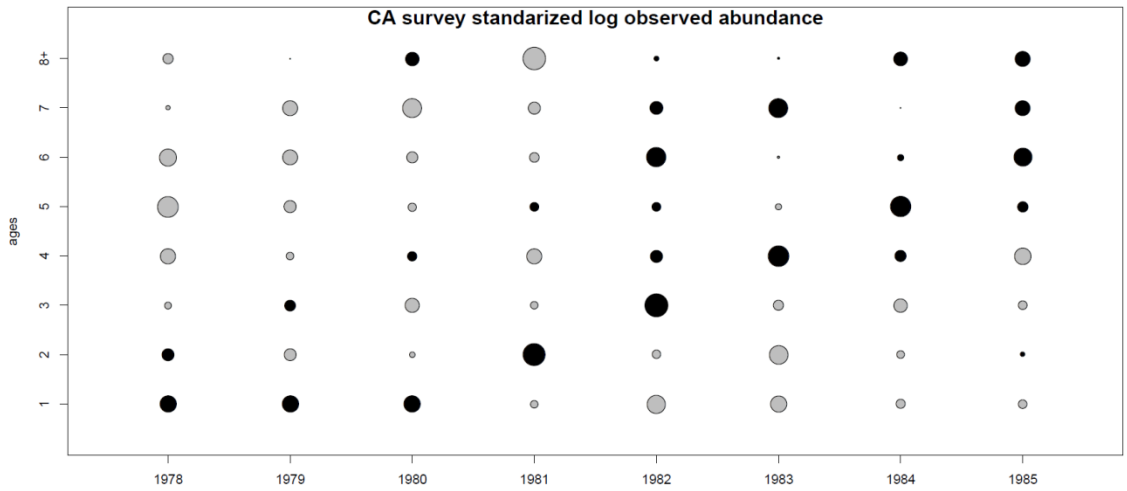

Fig. 11. 3M cod standardized proportion of the catch numbers at age by year for the Canadian survey on Flemish Cap for the period 1978-1985.

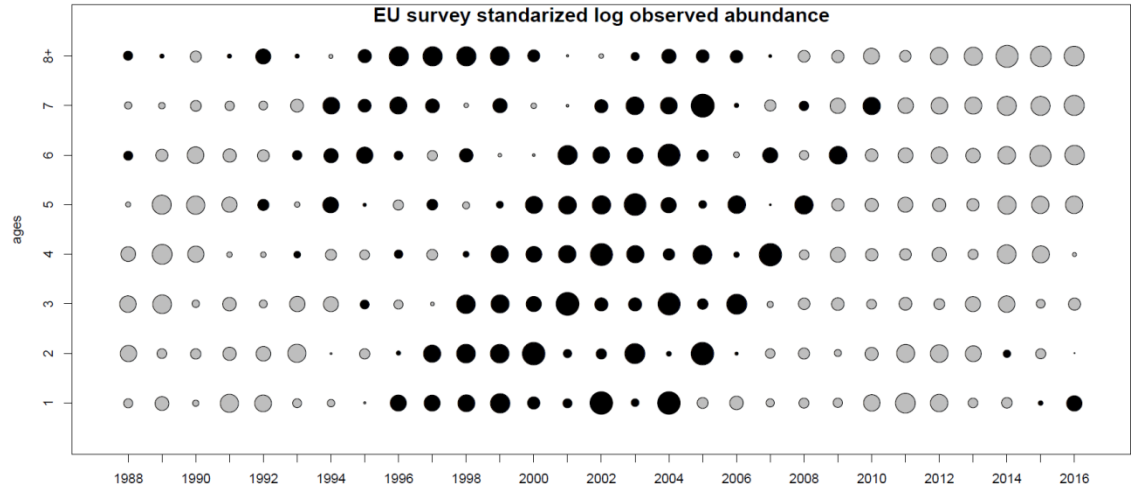

Fig. 12. 3M cod standardized proportion of the catch numbers at age in log scale by year for the EU survey on Flemish Cap for the period 1988-2016.

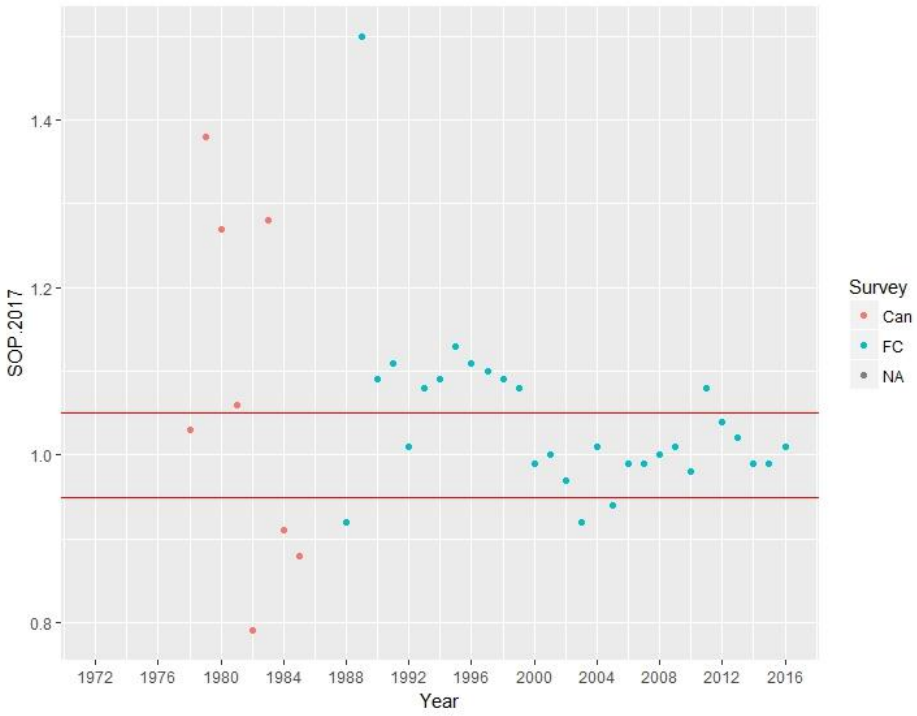

Fig. 13. Cod 3M ratio between the sum of the product of the surveys abundance at age numbers by the mean weights-at-age in the stock (Sum Of Products: SOP) and the surveys total biomass indices used in the SC assessment. Red points indicate Canadian survey. Blue points indicate EU Flemish Cap survey. Red horizontal lines = 0.95-1.05.

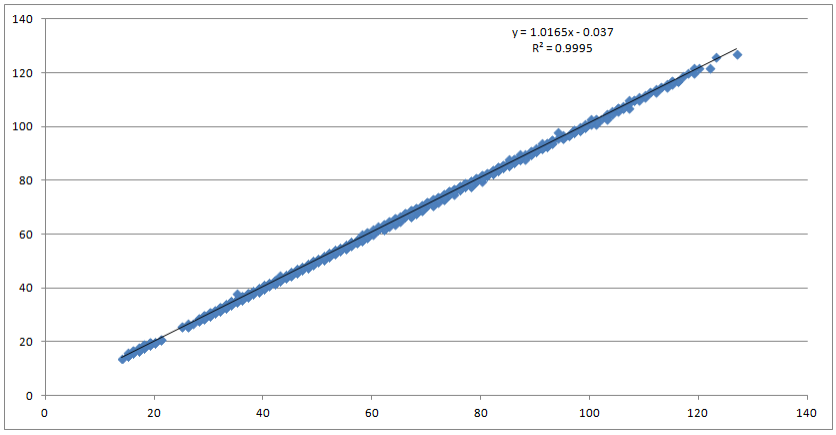

Fig. 14. Total length (y) and fork length (x) relationship for Cod 3M estimated with the samples collected during the 2017 FC survey.

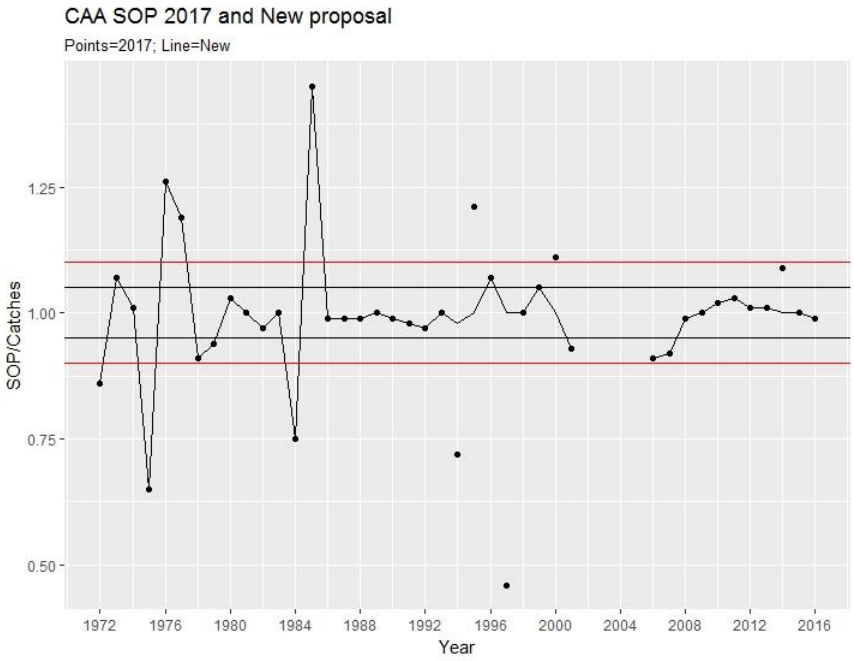

Fig.15. Cod 3M ratio between the sum of the product of the catch at age numbers by the mean weights-at-age in catches (Sum Of Products: SOP) and the total catches used in the 2017 SC assessment (points) and the new proposals for updating the 2017 inputs (line). Green vertical line = 1987. Red horizontal lines = 0.90-1.10. Black horizontal lines = 0.95-1.05.

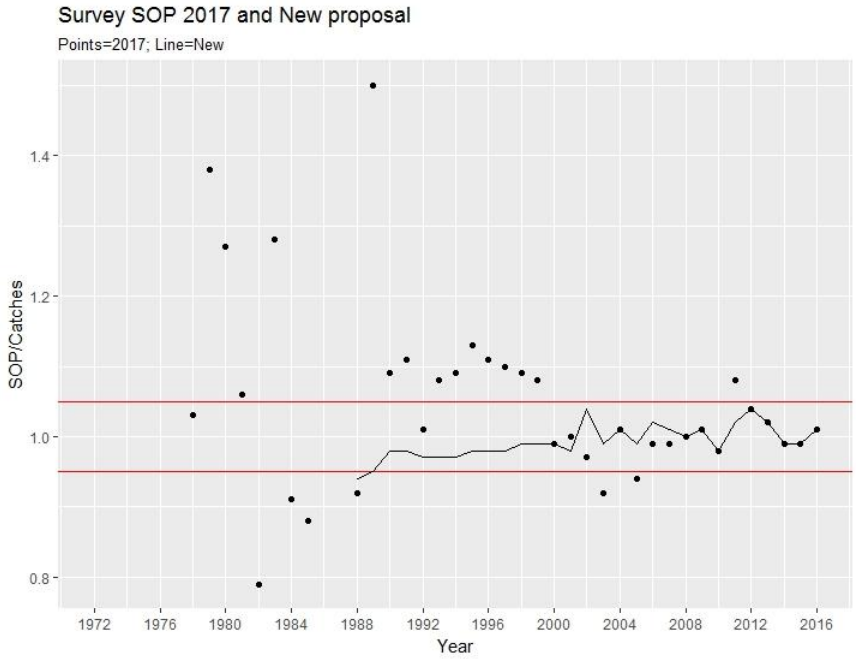

Fig. 16. Cod 3M ratio between the sum of the product of the survey at age numbers by the mean weights-at-age in stock (Sum Of Products: SOP) and the survey total biomass used in the 2017 SC assessment (points) and the new proposals to change the 2017 inputs (line). Red horizontal lines = 0.95-1.05.

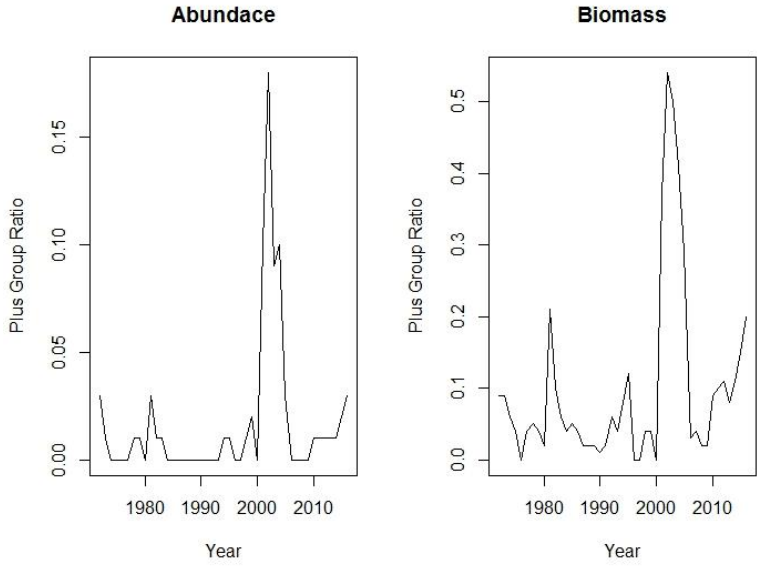

Fig. 17. 3M cod plus group (8+) ratio of the total abundance and biomass of the last approved assessment.

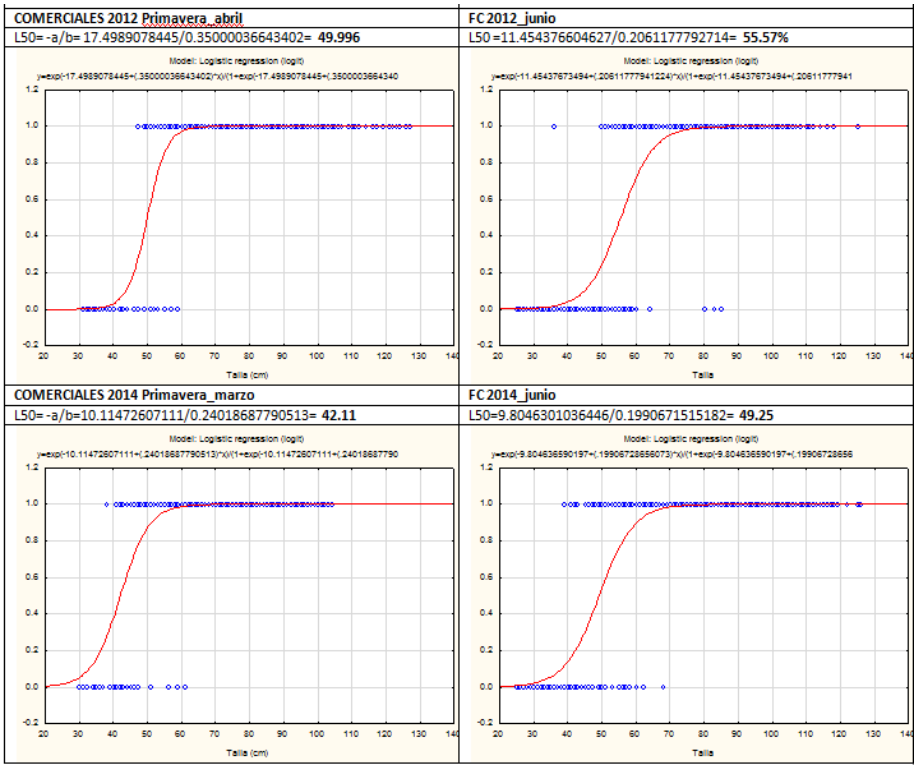

Fig. 18. Cod 3M 2012 (top row) and 2014 (bottom row) length maturity for the commercial (left plots) and the survey data (right plots) fitted with a logistic model.