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On 3M cod natural mortality: a proposal for a separable approach over recent years (2005-2017)

By

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Introduction

During the past 30 years (1988-2017) four stages can be set on 3M cod dynamics: sharp decline (1988-1995), stability at a very low level (1996-2004), recovery to the former early nineties level (2005-2013) and a gradual but consistent decline either on total abundance or total biomass (2014-2017) (González-Troncoso, 2017). Throughout these almost three decades the assessments have considered a natural mortality constant at age and time. Until 2007 M was an assessment input, assumed at 0.2, a natural mortality value historically adopted on many cod stocks from either side of North Atlantic. Since 2008 a Bayesian XSA was implemented on this assessment (Fernández *et al*, 2008). Natural mortality continued to be constant over time and ages but it has been estimated by the model since then on every assessment from a prior distribution around 0.2.

Background rational

At least from 2011 till 2017 the Bayesian assessments arrived to best median M's estimates always bellow 0.2, but gradually approaching again this reference level (from 75% to 95%). It is expected that these relatively low (at least for cod) and constant natural mortalities, despite being in place for the whole assessment interval and age spectrum, should basically reflect the average level of mortality other than fishing on most recent years along the existing cohorts. And in fact one should expect that lower natural mortalities gave room to the observed fast recovery of the stock since the mid 2000's, allowing high survival rates on increasingly abundant year classes entering the stock four-five years in a row.

However what is likely to have occurred since 2005 is unlikely to be valid backwards, at least with the same extent. In other words the order of magnitude of variability on natural mortality would not be the same over the whole assessment period, and at least two periods may be considered as regards M. On a former period, between 1988 and 2004, natural mortality can be assumed as constant: this period started with an abrupt stock decline caused by very high fishing mortalities, the stock collapsed on 1995-1996 but remained stable at a very low level till 2004. It is not difficult to accept that natural mortality had little impact on the stock dynamics over these years: the stock collapsed because it has been overfish and major changes in M since then would not allow the flat low level to be kept till 2004. The second and more recent period started in 2005, when M may vary through time and ages in line with the fast increase of stock size.

A separable approach to the computation of M

On the approach to estimate 2005-2017 natural mortalities varying simultaneously with time and age, the principle is the same as assumed on the computation of separable fishing mortalities and catch/stock projections under several average F options:

1. For practical purposes average natural mortality (ages 1-7) should be allowed to vary every two years (there is no evidence of inter annual changes on environmental conditions so dramatic to justify the need of M fit on an annual basis).

2. Relative M (proportion of average M at each true age) is age dependent but is constant with time. According to the results of all size dependent methods, M is expected to be higher on the very young ages, basically justified by predation, including cannibalism, and gradually decline with individual growth. This variation of M with age is obviously also reflected in the relative M at age vector.

3. On each year and age M at age is the product of the relative M for that age and the average M for that year. Fish stock assessments lived for immemorial times assuming a level of natural mortality constant over time and age, regardless the number of years of the assessment or the longevity of the species. But that assumption is difficult to hold, just common sense will tell that is highly unlikely to occur at least for long periods of time or/and trough life span. However a quantitative approach to natural mortality varying with time and age simultaneously still need the making of assumptions, closer to reality hopefully. The assumption in this case is that the average level of natural mortality will vary over time but its distribution over ages remains the same. In our perspective there is no greater discomfort dealing with this assumption in the case of natural mortality than in the case of fishing mortality, namely on younger ages: in both cases this assumption is jeopardized if major differences occur on individual growth and/or size between cohorts, since both predation and fishing are related with the speed of growth in length and in weight of the fish within each cohort namely during very young ages and are usually density dependent as well.

4. M at the plus group is kept from the last true age.

In order to get the average natural mortalities since 2005 a sequence of reruns of the Bayesian XSA model should be performed on alternate years, starting with a 2006 last year run and ending with a 2017 last year run. All reruns using the same input data and assessment settings approved on the SC Cod Benchmark WebEx Preparatory Meeting March 2018 (NAFO 2018), and M constant at 0.2 for ages 1-8+ over the 1988-2004 interval. This set of runs would allow the step by step search for a best fit average M, from 2005-2006 till 2015-2017 (in order to include last assessment year). The approach is very similar to the one implemented on the 3M beaked redfish stock unit from 2011 assessment onwards as regards the search for variability on the average level of natural mortality over time (Ávila de Melo et al, 2017). Each run should keep constant the natural mortalities already estimated on previous runs and the M optimization should focus just on the last years. At the end of this sequence of runs an average M would be available every two years (three years for the last interval), covering the dynamics of the stock on recent times.

As for the relative M at age, first get an average M at age vector from the results at age by the all natural mortality size dependent methods applied to 3M cod. Or, get a relative M at age vector straight from the Gad Cap results (Pérez-Rodríguez *et al*, 2017). Regardless the option when you standardize the chosen vector to its mean you will end up with a relative M at age vector.

If one fears that the observed declines in mean weights at age, namely for ages 6 and younger, namely within the 2007-2015 period (NAFO, 2017) , could have a significant impact on relative M at age over time, the process summarized above can also be replicated every two years, based on the growth model results taken from the correspondent bi annual ALK's (predation should play a main role on natural mortality at young ages, and so changes in growth rate are expected to reflect in M at age).

Final comments

This approach to quantify natural mortality over time and age, incorporate information both from survey (on the fit of an average M for each couple of years by the Bayesian XSA) and biology (on the average relative M@age given by size dependent methods). There is no need to remind that if the model is fixing one natural mortality value throughout the whole assessment matrix any change in the settings or any next year in time will change that one natural mortality value that in turn will impact all total mortalities throughout the whole matrix and will rescale the results to a new level. So, each run should keep constant the natural mortalities estimated on previous runs and the M optimization should focus just on the last couple of years. At end of this process an average M would be available every two years, covering the dynamics of the stock other than from fishing on recent times.

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