Received: 15 November 2013

IOTC–2013–SC16–INF06

On the growth of bigeye tuna in the Indian Ocean and what is the real age of a 50 cm/2.6kg Bigeye?

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Summary

All stock assessment done by the IOTC WG in 2013 on the Bigeye stock were done using the Eveson & al 2012 growth curve. This growth curve estimates that 50 cm bigeye are fished at an age of 2 years, suffering a high natural mortality of 0.8 during each of these 2 years. However, the analysis of the bigeye growth rates between 37 and 50 cm, based on 930 mell measured recoveries, strongly indicates that the real age of a 50 cm bigeye would be close to only 1 year (then with only 1 year class suffering a high natural mortality of 0.8). The paper tries to estimates the consequences of this misspecification of the growth model in the stock assessment work: there is no doubt that a corrected growth should be used in future model, but based on the present results, this improved growth should not deeply alter the main conclusion of the 2013 assessment models, for instance the trajectories in the Kobe plot).

1- Introduction

Recent stock assessment work on the Indian Ocean tuna stocks have been using the VB log k growth model proposed by Eveson & al 2012, and the use of this new growth curve was not really questioned by the IOTC scientists. The relationship between sizes and ages estimated by this model is shown by figure 1.

Figure 1: Relationship between sizes and ages of Indian Ocean Bigeye estimated by the Eveson & al model 2012.

Following this growth curve: a slow growth is observed/estimated between 35 and 50 cm: subsequently a 50 cm bigeye is fished at an age of 2 years (when bigeye is caught between 30 and 40 cm at age 0). Total numbers of these small bigeye less than 50 cm are always significant because of the PS FAD fisheries: 30% of the total catches of bigeye (in numbers) have been caught at sizes <50 cm during the average period 1990-2012.
As a consequence the catch at size of juvenile bigeye of the typical mode of juvenile bigeye, between 30 & 74 cm, are classified in 3 age classes: 0, 1 & 2, as shown by figure 2

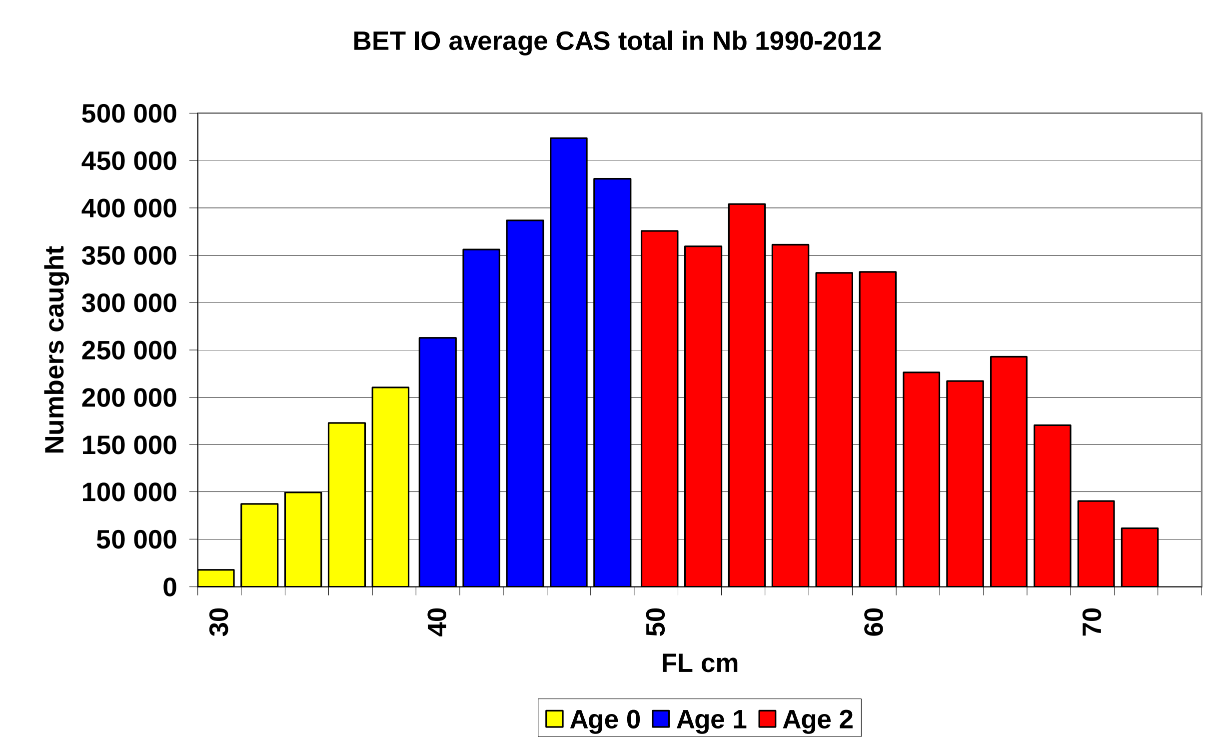

Figure 2: Average bigeye catch at size during the 1990-2012 period stratified by age classes in the Eveson's 2012 growth curve.

The main goal of this paper will be to discuss the validity of this age-length relationship of juvenile bigeye.

2) A basic biological problem: the VB log k model used by Eveson et al 2012 cannot describe the growth during the early life of bigeye

This fundamental problem has been already discussed by Fonteneau 2008 for the growth of yellowfin. When the VB log k model used by Eveson et al 2012 for yellowfin & bigeye is very consistent to model the complex growth observed between 50 cm and L infinity, this model appears to be fairly/totally unrealistic to model the vary fast growth estimated for yellowfin & for bigeye between their post larval stages and the sizes at early recruitments in a size range between 30 and 50 cm. Such very fast growth is needed to allow the survival of bigeye & yellowfin populations: smaller individuals at sizes less than 2.5 kg have to grow very quickly in order to avoid the large numbers of predators in these highly vulnerable sizes. This very fast growth has been well demonstrated in this size range for yellowfin (by tagging & age readings) but not yet for bigeye.
On the opposite, the flat & slow growth estimated at these post larval stages by the VB log K model appears to be highly questionable: this working paper will discuss this question.

3- Growth of early bigeye recruits as estimated by the Fonteneau & Gascuel 2008 growth rates:

The observed growth rates between tagging & recoveries provide a very simple but quite strong & direct way to estimate the observed growth rates at size in this size range. This conclusion is of special interest to analyse the growth rates of juvenile tunas (when this method tend to provide biased growth rates at large sizes and after long durations). The recovery data set of all the small bigeye recoveries has been analysed in the following way:

1) selecting only tunas tagged and recovered as bigeye
2) selecting all bigeye with known date at tagging and at recovery
3) selecting all recoveries showing at least 1 month at liberty
4) eliminating the 1 percentile of higher and of lower growth rates (assumed to be due to errors)
5) calculating the average growth rate of each tuna between its tagging & recovery, this growth rate being assigned to the average size (by 1 cm class) between tagging and recovery.
6) the uncertainty in the average growth rates estimated in each 1 cm class are estimated assuming a normal distribution of growth rates in each size interval

As a result, a total of 4355 selected recoveries have been entered in this analysis. Figure 3 shows the average growth rates estimated by this method, and they are shown in comparison with the growth rates estimated by the model proposed by Eveson et al 2012, and also by the VB growth model of Stequert & Conand 2004.

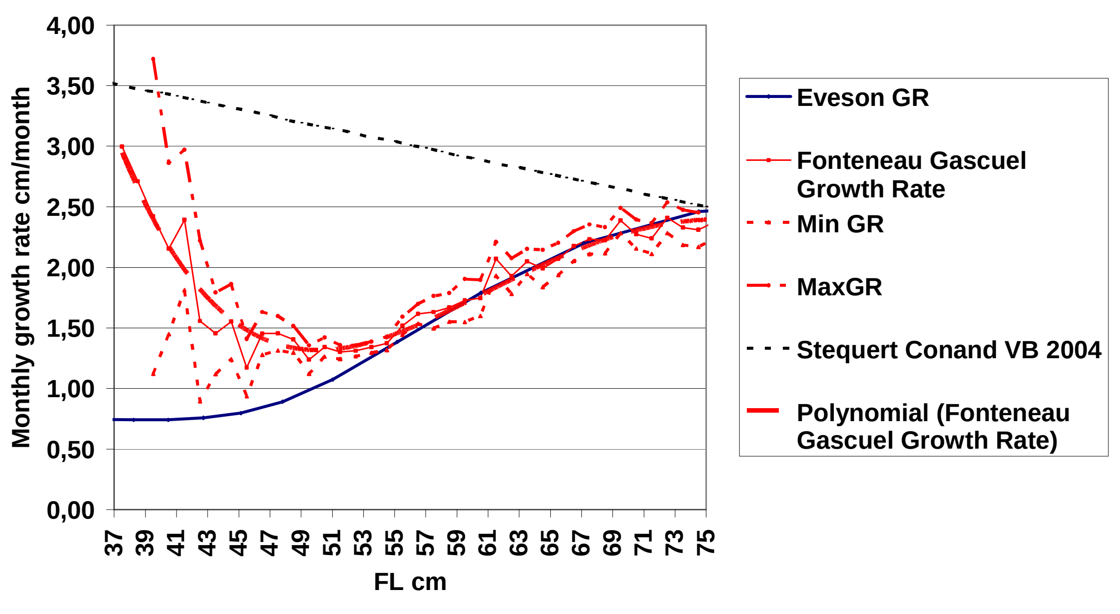

Figure 3: Growth rates at size estimated for bigeye by Eveson et al 2012 and growth rates of recovered bigeye estimated by the Fonteneau and Gascuel 2008 method, and by the Stéquert & Conand 2004 Von Bertalanffy growth.

This figure shows a logical & nearly perfect agreement of the theoretical and observed growth rates (as estimated by the 2 methods) at sizes between 51 and 75 cm. However they are showing marked & increasing divergences at decreasing sizes lower than 50 cm:

- modelled growth rates being flat and low between 37 and 50 cm: average 0.82 cm/month
- observed growth rates being 2 to 3 time faster : average 1.84 cm/month

- the growth rates at size estimated by the Von Bertalanffy model (Von Bertalanffy 1938) previously used in various IOTC bigeye stock assessments are much higher in this size range between 37 and 75 cm (when they are very similar at larger sizes over 75 cm) (Stequert & Conand 2004)

As a consequence there is a long duration (over 1 year) between 37 & 50 cm in the Eveson's theoretical growth curve but about only 6 months in the Fonteneau & Gascuel 2008 observed growth rates. Taking into account the trend in observed growth rates between 37 and 50 cm and considering the very growth presently estimated for early juvenile of yellowfin (Dortel et al, submitted 2013), it could easily be assumed that the real age of 50 cm bigeye would be at close to 1 year, and not to 2 years as in the Eveson & al 2012 model. It should also be kept in mind that the apparent growth rates at size of small yellowfin and small bigeye, as estimated by the Fonteneau & Gascuel method, are very similar or identical under 60 cm (when at larger sizes growth rates are much faster for yellowfin than for bigeye). Based on this similarity of their early growth rates, it could easily be assumed that the bigeye & yellowfin growth between birth and their full recruitment at 37 cm would also be very similar for the 2 species, i.e. showing a short duration of about 7 months as it was estimated for yellowfin by Dortel et al 2013.

4-Discussion

4-1- What growth curve for young juvenile bigeye?

Our conclusion is that the early growth pattern estimated in the Eveson's growth curve is unrealistic at sizes lower than 50 cm, when the growth curve observed from recoveries appears to be much more realistic. In this hypothesis, a 50 cm bigeye would not be a 2 years old tuna, but more probably a 1 year tuna (or close to this age) and this growth curve should not be used for small bigeye caught at sizes under 50 cm (25% of total recent catches). In this case, all bigeye tunas that are classified today in class 0 and class 1 in most of the 2013 stock assessments (figure 2), should in the future be assigned to the year class 0 (the same change being done directly or indirectly in all analytical stock assessment models).

4-2- On the future impact of a revised growth in stock assessment

This accelerated growth rate of early juvenile bigeye between 30 and 50 cm should have some significant impact on stock assessment and these expected changes are quite easy to estimate and without using complex model. One of the major typical characteristics of the bigeye fisheries is the bimodal structure of their size distribution of catches, shown by figure 4: in this context, there is a typical clear potential yield per recruit interaction between fisheries catching bigeye at small sizes (mainly between 35 and 70 cm) and longline fisheries catching the adults.

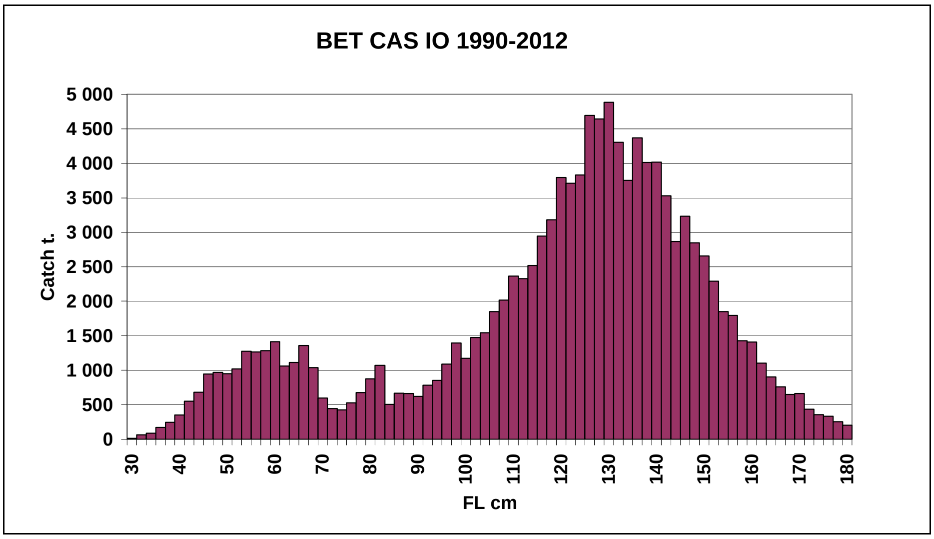

Figure 4: Average catch at size (in weight) of the bigeye IO fisheries (1990-2012)

In the Eveson et al 2012 growth model, the 1st mode of young juvenile bigeye catches contains 3 year classes (figure 2), but only 2 year classes when following the growth rates estimated by the Fonteneau & Gascuel method.

It is interesting to estimate the potential effects of this growth uncertainty/error in the stock assessment done by the IOTC in 2013. Simple VPA can easily allow estimating the potential changes in stock size and in fishing mortality due to this change. This result will be estimated in the following way:

1) VPA are first conducted on the average catch at age of the 1990-2012 period in order to estimate the average recruitment at age 0 that is necessary to explain a fully exploited adult stock of bigeye (assuming a constant M=0.8 during 2 years followed by a constant M=0.4): this number of recruits can be estimated by VPAs at about 100 millions individuals. The estimated recruitment and fishing mortality at age estimated by such simplified VPA are similar to the ones presently estimated in the stock assessment models (a total biomass of the bigeye stock during this period being estimated at an average of 800.000 tons). This VPA also allows estimating the number of pre-adult recruits at the beginning of age 4 (70 cm).
2) In a second stage: forward VPAs are ran on the same CAA of juvenile, but adding catches of age 0 & 1 in a new age 0, but now targeting at the end of age 3 the same number of survivors that was estimated in the first VPA. This VPA was done under the hypothesis of M= 0.8 at age 0 and M=0.4 at age 1, as a relatively low M of 0.4 should now be assumed at age 1 bigeye (average weight over 4 kg)

The main results of these ad hoc VPAs are given by figure 5a (population sizes) and 5b (F at age).

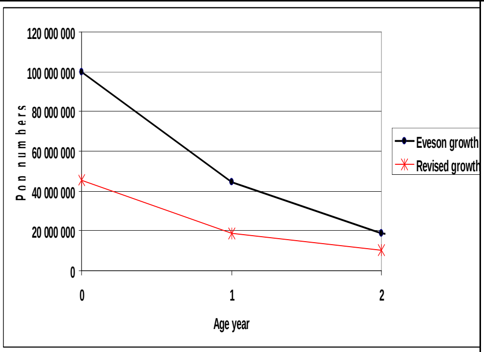

Figure 5a: Population size at age (beginning of time intervals) estimated by VPA in the Eveson and in the revised growth curve

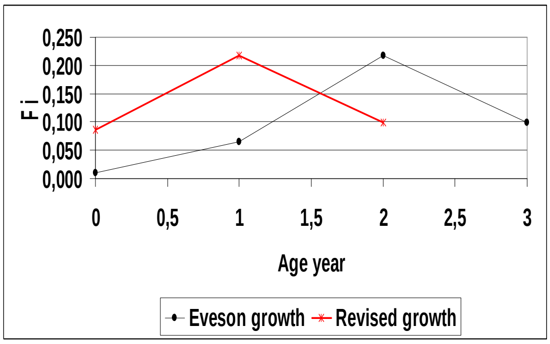

Figure 5b: Fishing mortality at age estimated by VPA in the Eveson and in the revised growth curve

These VPA results are mainly indicative, but they are logical ones and they strongly confirm that:

(1) the levels of initial recruitment of bigeye would be much lower combining age 0 and 1 time intervals (and having only 1 year class facing high natural mortality) and

(2) fishing mortality exerted on younger ages (classes 0+1 in the Eveson's growth vs class 0 in the corrected growth) tend to be higher (about 15% higher) in the new corrected growth hypothesis. Such increase of F should potentially increase the yield per recruit interaction between fisheries active on juveniles and on adults.

(3) Only 9 year classes are analyzed in the corrected growth, possibly a too short period for a bigeye stock, and then increasing the relative weight of the large & heterogeneous of the 8+ year class (when bigeye stocks appear to be exploited during a much longer period, probably well above 10 years). This duration of the exploited Bigeye life will be better estimated based on the long term recoveries of tagged Bigeye that are still surviving.

These VPA results are totally logical ones, and not at all surprising. They would indicate that a corrected growth curve would probably have limited consequences for the bigeye stock assessment, even if such corrected growth curve should necessarily be used in future stock assessments.

5-Conclusion

Our conclusion is that the Eveson 2012 growth model used in the bigeye stock assessment in 2013 is facing a serious bias in its aging of small bigeye caught at sizes under 50cm. This bias is structural to the model: simply due to its inability to handle the very fast growth of many tunas & billfishes observed between post larval stages and the young recruits. Such well known bias should have been identified before the bigeye stock assessment, but unfortunately this was not the case. This problem/error should be corrected as soon as possible in the future bigeye stock assessments, even if it appears, at least based on the present VPA calculations, that this corrected growth should not have a major impact on the stock assessment results. This use of a fully valid growth curve remains necessary because:

- It would allow to identify the real years of tuna birth, for instance in order to associate year class strength with environmental conditions or to compare year class strength between species
- It would allow to associate a realistic vector of natural mortality at age to a realistic growth curve,
- It would allow to compare stock assessment results between species, for instance the population sizes of young recruits, good & bad years for recruitments, etc.

In the long term, there is clearly a need to create for bigeye more realistic SA growth model that would need to be valid from birth to death, for instance based on a DEB model (Kooijman et al 2008) of based on a more flexible growth model (as in the Dortel et al 2013 yellowfin study). If necessary, stock assessment should be based using ad hoc growth model (for instance as in the Karlberg 1987 thesis in his study of human growth or the Fonteneau 2008 yellowfin ad hoc growth), that would be more realistic for stock assessment, but not necessarily the fancy growth models published in rank A Journals. When before the IOTTC tagging programme there was no choice but to use the Von Bertalanffy growth curve, a model that has been now proven to be inadequate, now the IOTC stock assessment of tropical tunas done by the IOTC should be fully based on the results of these tagging/recoveries.

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