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Can length-based selectivity explain the two stage growth curve observed in Indian Ocean YFT and BET?

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Summary

Indian Ocean yellowfin (YFT) and bigeye (BET) tuna populations appear to follow a 2 stage growth curve. Relative to a classic von Bertalanffy function, growth appears to be slower than expected until length ~60cm, and faster than expected for lengths ~60-100 cm (fig. 1). Recent growth estimates are derived from growth increment observations from the RTTP tagging programme, and supported by direct ageing of otoliths. It has generally been assumed that the change in growth rate is associated with some unknown ontogenetic shift in the population (which in turn is probably also related to the change in selectivity). This paper describes a quick simulation to see if the effect might instead be an artefact of size selectivity in the fisheries.

The simulation used the following assumptions:

- The mean length-at-age of a hypothetical population follows a standard von Bertalanffy growth curve with parameters loosely derived from the (2 stage) Eveson and Million (2008, IOTC-2008-WPTT-09) YFT analysis:
    - mean L(a) = Linf(1 – exp(-k(t-t0)))
    - Linf = 146 cm
    - t0 = 0; L(a=0.5 y) ~ 33 cm
    - k = 0.5(k1+k2) = 0.5(0.133+0.905) = 0.519
    - length-at-age of individuals is assumed to be normally distributed (σ_L = 12 cm).
- Gaussian functions were used to define the selectivity (probabilitiy of capture as a function of length, independent of age) for 2 fisheries, loosely corresponding to the modes of the catch in the log set and free school PS fisheries:
    - Small mode mean = 55 cm, SD = 10 cm
    - Large mode mean = 125 cm, SD = 15 cm

Fig. 2 shows the assumed selectivity curves, and a simulated growth curve estimated from the size-selected population (fit with a LOWESS smoother assuming that the fish are aged without error). The estimated growth curve shows similar 2 stage growth characteristics to those of fig. 1. It suggests that size-at-age biases may occur at several points in the estimated function, and there is a potential for bias in the L(inf) estimate (exaggerated in fig. 3 when the 'true' L(inf) is increased to 160cm). This suggests that the actual YFT population in the Indian Ocean might not deviate substantially from a traditional von Bertalanffy growth curve, and the estimated growth curves in fig. 1 could (at least partly) represent the effect of size-based selectivity.

This concept has undoubtedly been examined elsewhere in more detail. John Hampton and Alejandro Anganuzzi (pers. comm.) did a similar simulation and reached a different conclusion (presumably because they used a single fishery). There is also an important element missing in this simulation. It is based purely on direct age estimates, rather than tag growth increments. Different individual growth rates may also mean that slower growing individuals are vulnerable to fisheries with dome-shaped selectivity for a longer period of time, and might further exaggerate the biases. This simulation is not intended as evidence, but merely points out that this mechanism for producing biases in the length-at-age estimates is plausible, and might be worth some discussion in the WPTT, and further investigation.

Implications?

1. Length-at-age distributions of the general population might be considerably different from the length-at-age distributions observed in the catch (due to size selectivity in the fishery that is independent of age).

2. Even if all of the data and analyses are perfect, we should not be surprised if an integrated assessment model (MFCL) estimates a different growth curve than an analysis based on tag recoveries, if the tag recoveries are not representative of all fisheries. Similarly, evidence for differential growth by area or over time might be misleading if it is based on samples/tag recoveries from different fleets.

3. What growth curve would be best to use in an assessment model? Length distributions are essentially being used to provide information about the age structure of the population. So the catch-at-length distributions derived from a particular fleet should be the most appropriate for that fleet even if they are not representative of the whole population. In contrast, if growth curves are derived primarily from PS fisheries, this could be very misleading for the longline fisheries (e.g. particularly for BET, which is predominantly longline caught).

4. Rather than searching for the definitive ‘best’ growth curve it may be better to:
    - Estimate alternative growth curves from different sources.
    - Examine the sensitivity to the alternative growth curves, and represent this uncertainty in the assessment.
    - If necessary/feasible, use different length-at-age functions for different regions/fisheries.

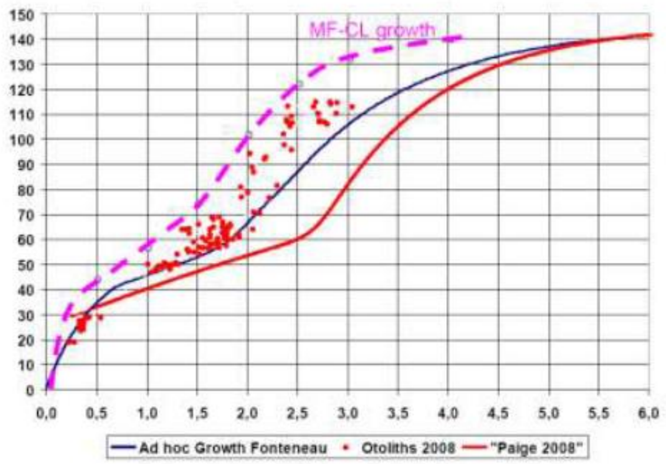

Figure 46. Estimated growth of yellowfin derived from (a) the base-case assessment model (MFCL derived purple line) (b) the estimated mean length at age from the tag analysis (LEP derived red line) and (c) an alternative curve tabled at the meeting (blue curve).

Fig. 1. Estimated growth curves for IO YFT from WPTT final report 2008.

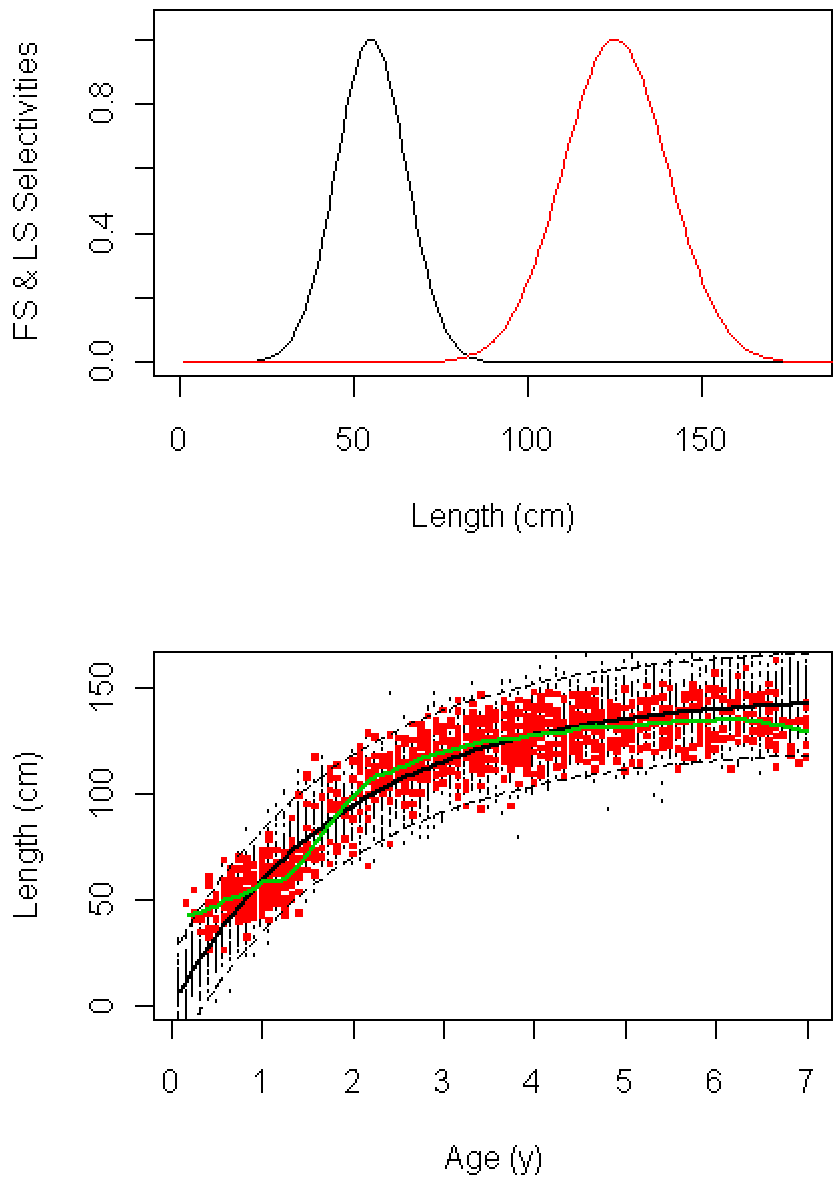

Fig. 2. Top panel – hypothetical selectivity curves resembling the small modes in the YFT log set and free school PS fisheries (black) and the large mode in the free school sets (red). Lower panel - hypothetical length-at-age curve (black line), with random deviates (black points), a random sample of fish caught using purely size-based selectivities from top panel (red points), and LOWESS smoother through the red points (green line).

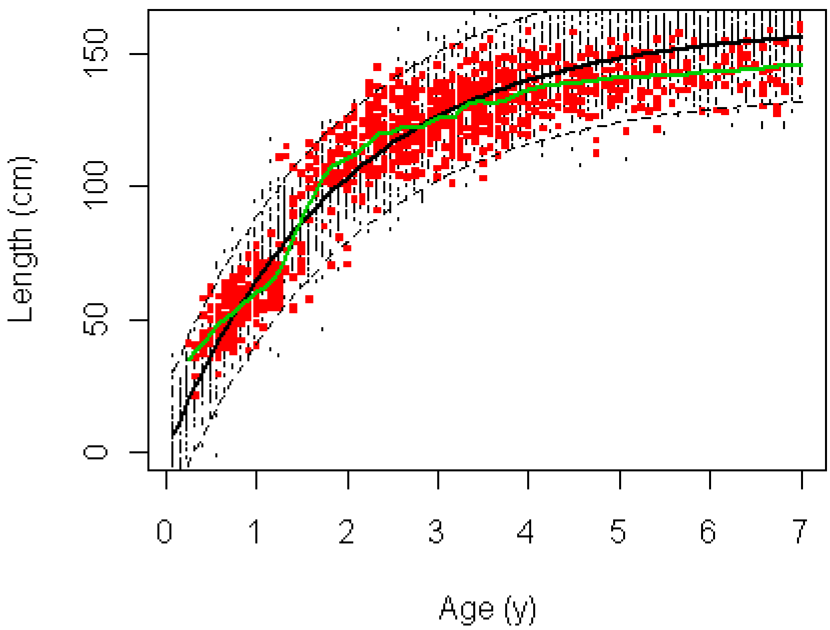

Fig. 3. Hypothetical length-at-age curve (black line), with random deviates (black points), a random sample of fish caught using purely size-based selectivities from fig. 2 (red points), and LOWESS smoother through the red points (green line), and a population L(inf) = 160cm.