Exploratory growth analyses for Indian Ocean tuna spp.

R. Hillary, J. Million & A. Anganuzzi

Imperial College, IOTC Secretariat

Data available

- Otolith data (bigeye and yellowfin only):
  1. Stequert data (*ca* 1980s; ages 0-4, lengths 20-150)
  2. Indonesian otolith data (OTC validated; yellowfin only; ages 0-2.5, lengths 20-60)
- Length increment and time-at-liberty data for yellowfin (1461), bigeye (836) and skipjack (1713) from the tagging program

Background

- Historically, at least for the purposes of stock assessment, a von Bertalanffy growth function was applied to otolith data for yellowfin and bigeye
- As the tagging data became available initial analyses suggested more complex, two-stage growth dynamics for yellowfin and bigeye
- This takes us outside the von Bertalanffy growth paradigm so other more flexible growth models needed to be explored
- From a data perspective, for yellowfin and bigeye we wanted to integrate the otolith data and the tagging data into a single estimation scheme; for the skipjack we only have the tagging data so we can estimate only a subset of the growth parameters

Candidate growth models

- von Bertalanffy: $l(a) = L_\infty(1 - \exp(-k(a - t_0)))$
- Richards/logistic growth model, able to accomodate a two-stage growth behaviour:

(1) $$l(a) = L_0 + \frac{L_\infty - L_0}{(1 + \beta(-k(a - t_{\max})))^{1/\beta}}$$

- Another potential sigmoidal growth model with one less parameter than the Richards model which can also accomodate two-stage growth

(2) $$l(a) = L_0 + \frac{L_\infty - L_0}{\mu^\gamma + a^\gamma}$$

Probability models for the data

- **Otolith data**: we assume that the observed length-at-age is normally distributed around the corresponding model-predicted length-at-age. The error is assumed to be a composite of the measurement error of length-at-age/otolith reading and a process error term
- **Tagging data**: use the growth increment for a given time-at-liberty and assume that the observed growth increment is normally distributed about its model-predicted counterpart. The error term here was a little more complex:

$$\sigma^2_{\mathrm{tag}} = \sigma^2_l + \varphi \times l^{\mu}_{\mathrm{rel}} \times t^{\nu}_{\mathrm{lib}} \tag{3}$$

- This type of error term has been applied in many previous cases, allowing for variation in growth increment with both time-at-liberty and length-at-release

Model selection criteria

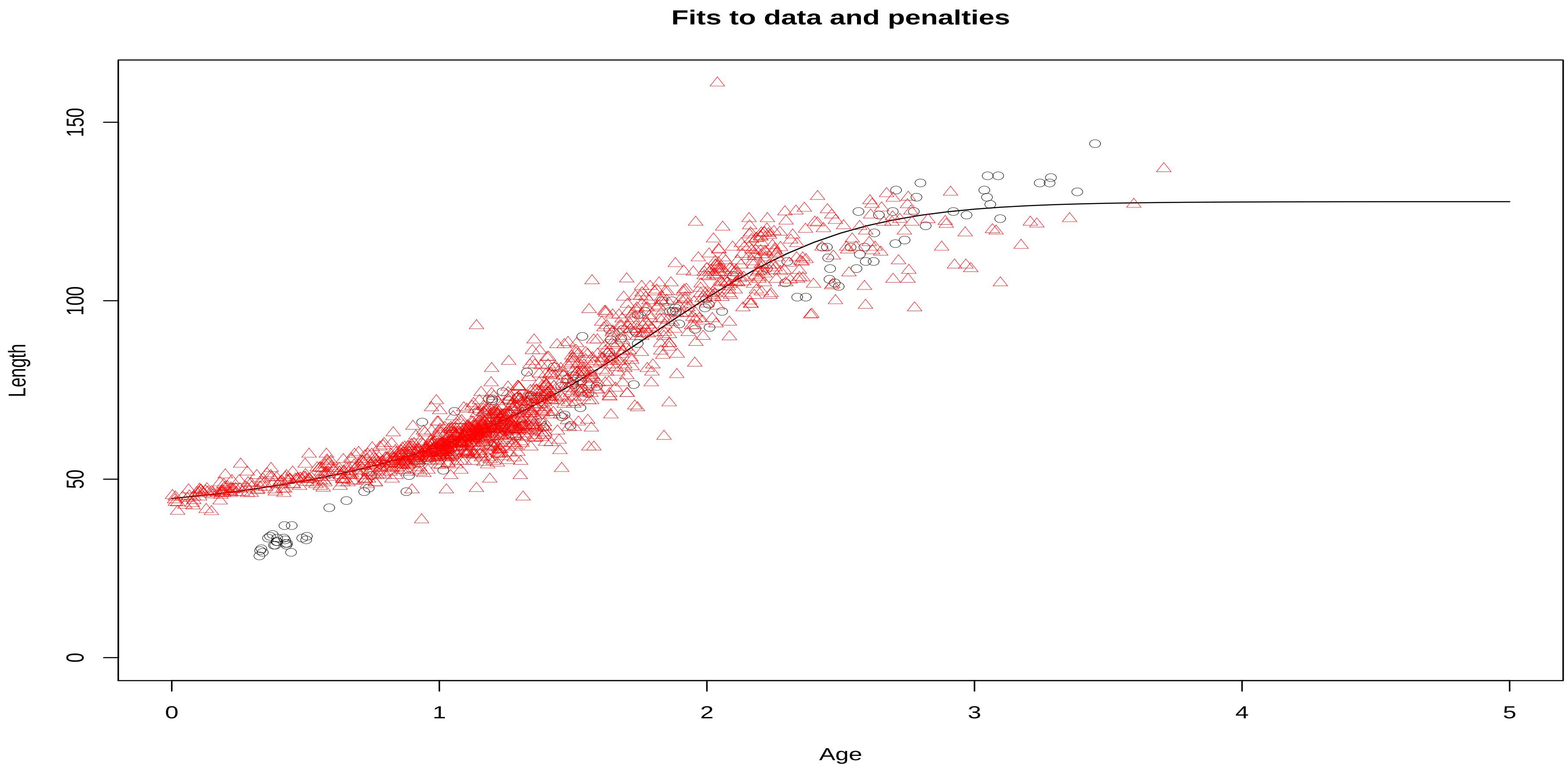
- We have three candidate growth models and we would ideally like to be able to use some sort of criteria with which to choose between the two models
- We use maximum likelihood techniques and, although the models are not nested models, we use a simple chi-squared likelihood ratio model selection criteria
- Accounts for models with different numbers of parameters and gives us a simple significance probability with which to choose between growth hypotheses

Yellowfin growth

- Only the Richards and sigmoidal growth models were fitted to these data, given the clear two-stage growth of yellowfin, but some simple runs clearly show that the von Bertalanffy model is not appropriate
- For both models, very similar answers (for comparable parameters) and problems appeared
- Instability in the estimates of asymptotic length (and, consequently, in the other parameters highly correlated with this parameter) and for suitably high ageing error otolith data become ignored
- Quite 'high' initial length ($L_0 \approx 30 - 40$) and 'low' asymptotic length (*ca.* 120-150); clear two-stage growth behaviour and (statistically) significant evidence for increased variation in growth increment by both time-at-liberty and length-at-release

Yellowfin growth

Fits to otolith data (black circles) and, for graphical purposes, length-at-recapture (red triangles) for yellowfin:



Yellowfin growth

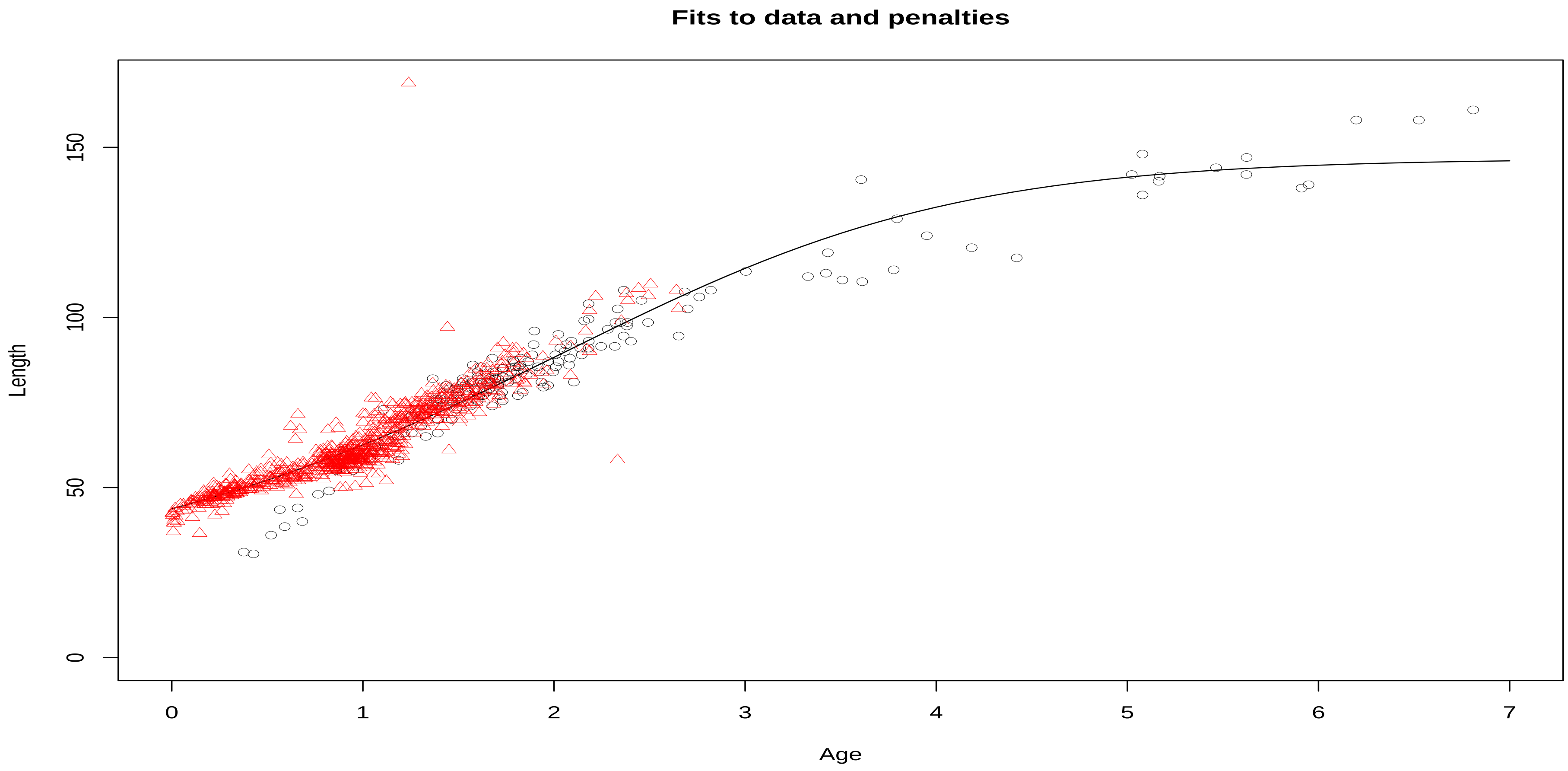
- Clear disparity between otolith-predicted younger ages and that preferred by the tagging data
- Two-stage growth clear from the fits to the tag data
- Clear increased variation in growth as the fish age and get longer (assuming that the increase in variation in time-at-liberty and length-at-release are proxies for this effect)
- Multiple modes in the likelihood (simulated annealing and simplex optimisation methods were both tried), with respect to asymptotic length and correlated parameters, making the identification of a single, unambiguous growth curve in this framework (integrating both otolith and tagging data) unlikely
- Simply not enough otolith readings/tag recaptures on longer/older fish to inform on the parameters sufficiently

Bigeye growth

- As with the yellowfin the von Bertalanffy model was clearly incapable of modelling the tagging data
- As with the yellowfin, the Richards and sigmoidal models gave very similar answers, but again we saw instability in the asymptotic length and the associated correlated parameters
- Higher/lower estimates of L_0/L_∞ than when using the otolith data alone, as with the yellowfin
- Mismatch between model and otolith-predicted length-at-age at the younger ages - again as we saw with the yellowfin

Bigeye growth

Fits to otolith data (black circles) and, for graphical purposes, length-at-recapture (red triangles) for bigeye:



'Realistic' L_∞?

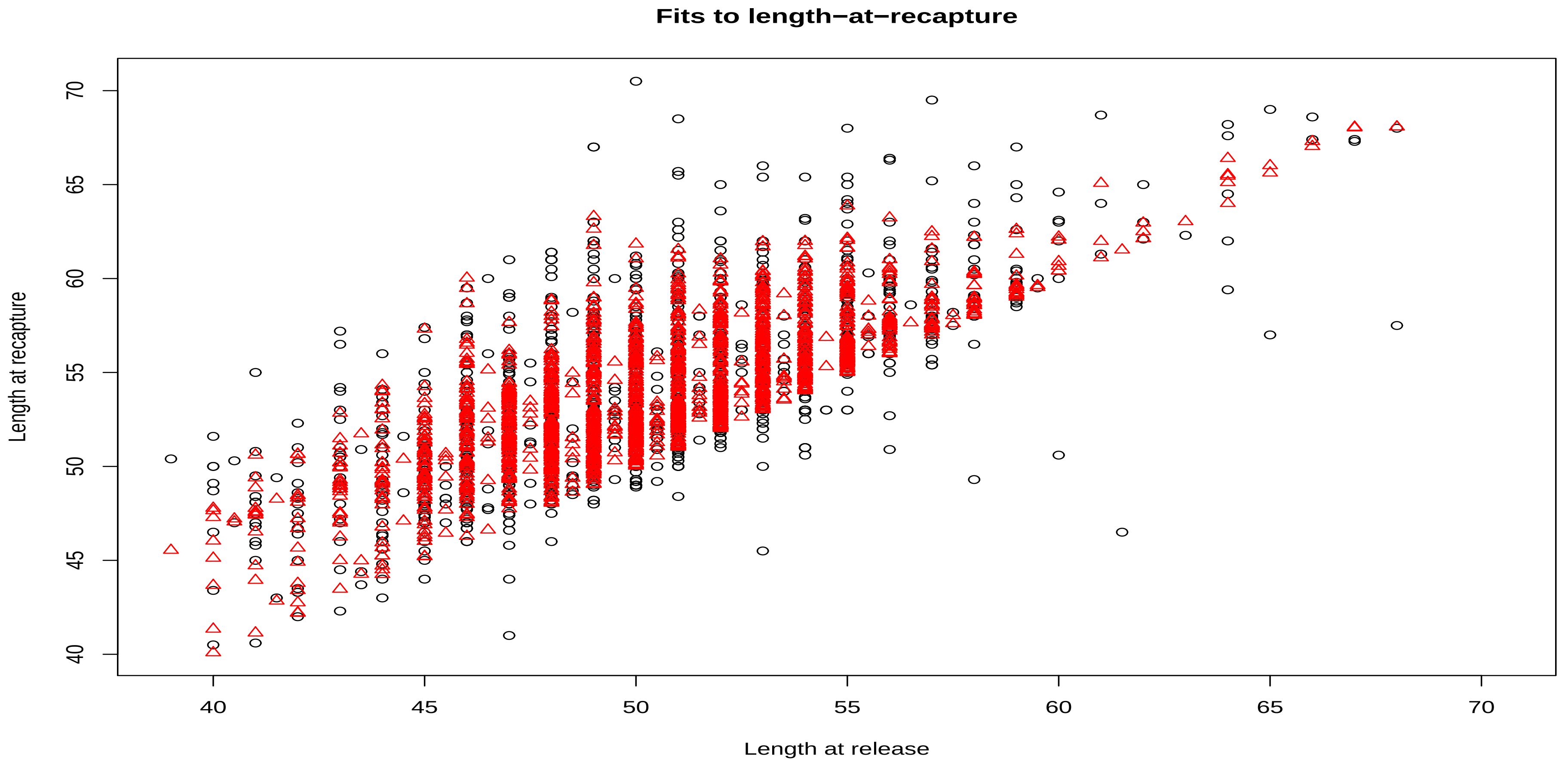
- This work, and other work incorporating the tagging data, came up with lower estimates of asymptotic length than seen before
- Some previous discussion as to whether these are realistic, given the observed maximum lengths seen in the fisheries
- Given strong evidence for increasing growth variation with time-at-liberty and length-at-release (proxies of a sort for older/longer fish) are long fish seen in the data merely plausible realisations from highly uncertain growth dynamics at the older ages/longer lengths?
- These fish are hardly ever aged so we do not know if we see similar aged fish of 'low' lengths and these would not give us concern as they fall within observed catch lengths

Skipjack growth

- Without otolith data we just estimated a reduced form of the von Bertalanffy model (k and L_∞ only) - more complex growth curves were fitted using similar methods in other work and seemed to confirm the von Bertalanffy growth behaviour of skipjack
- No problems with consistency at all, with very robust answers - $k = 0.289$ and $L_\infty = 76$cm, which was slightly slower growing than analyses of Maldavian skipjack and with a higher asymptotic length

Skipjack growth

Observed length-at-release and recapture (black circles) and model-predicted length-at-recapture form length-at-release (red triangles):



Yellowfin and bigeye summary

- Clear evidence for two-stage growth and increasing growth variation with time-at-liberty and length-at-release
- Estimation stability problems when integrating the otolith and the tagging data
- Clear disparity between tagging data and otoloth predictions of young length-at-age
- Lower estimates of asymptotic length than when using the otolith data alone
- Does it even make sense to integrate otolith data from 20 years ago with tagging data from at most 2-3 years ago?

Skipjack summary

- Fairly clear evidence for von Bertalanffy growth of skipjack and as with the other tuna spp. strong evidence of increasing growth variation with time-at-liberty and length-at-release
- In comparison with Maldavian skipjack growth analyses, we saw a slower growth rate and longer asymptotic length
- Unlike yellowfin and bigeye, we can probably use the von Bertalanffy estimates and the error model to define a suitable length-transition matrix for use in potential population models using the tagging data

Conclusions

- This work was unable to provide a consistent growth curve for yellowfin and bigeye that incorporates both the otolith data and the tagging data
- There is a paper detailing an alternative approach using only the tagging data and would likely provide a much better way to estimate growth of yellowfin and bigeye using the tagging data
- For skipjack this method seems to give a reasonable estimate of the growth parameters required to parameterise a length-based population/assessment model