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External analysis of bigeye tagging data

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1 Introduction

This document details exploratory analyses using the tagging and catch data and employing the age-structured models detailed in document IOTC-08-WPTT-16. The work looks to estimate abundance, exploitation and where feasible natural mortality rates for bigeye tuna in the Indian Ocean. The work in this paper is more an investigation of the information content within the tagging data themselves, looking at consistency between release and subsequent recapture events, potential availability changes of the population over time and whether information on natural mortality might be extracted from these data.

2 Data & Methods

Tagging (Seychelles and PS at sea recaptures), associated reference catch (catch information directly associated to the recapture data used) and catch-by-gear data for each quarter of 2006 and 2007 were used in these analyses. Although the models detailed in

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paper WPTT-08-IOTC-16 can deal with multiple years of releases and recaptures, to address the issue of potential environmentally-driven changes in the ratio of exploitable to total stock abundance (particularly in relation to the younger fish). The data cover ages 0 to 3 and, given 2 major release events per year and 12 recapture events this also gives us enough information to look at estimating a natural mortality multiplier, for a given ogive defining how M changes with age. Catch-at-age by gear type was extracted from the catch data as calculated by the Secretariat for the given growth curve and the reference catch-at-age and tagging data (in terms of releases and recaptures) by age were calculated in the same manner, using the inverse growth curve and the error distribution-by-length.

Tag shedding parameters used were those calculated by WPTDA. As for the differing dispersal time of the tagged animals into the gear types, after some discussions with the Secretariat, the following approach was adopted:

- **PS fleets**: immediately available.
- **Artisanal**: fully available after 6 months-at-liberty.
- **Long-line gears**: fully available after a 3/4 of a year.

Within season recaptures were not used in the model (an assumption of 3 months mixing time of tags into the PS fleet) and in the tag dynamics the detection-rate adjusted recaptures were simply removed from the tagged population. In all cases the tag release and subsequent recapture events are considered separately in the likelihood function - they are not pooled together.

Parameters estimated were the initial abundance values for the first quarter of the year and the yearly recruitment value. A simulated annealing-type algorithm was used to obtain point estimates of the parameters to be used both to assess model choice questions and as the starting values in the MCMC algorithm used to draw from the parameters' posterior distribution. Priors for all abundance indices were improper uniform in the sense that any value of the abundance parameters would have the same prior density.

2.1 Model choice criteria

There are two instances when we have to decide whether a particular model structure is appropriate: (1) the recruitment model and (2) whether to estimate natural mortality. For the first case this requires no added parameters and a simple comparison of the posterior values of the models at the posterior mode (whichever is higher) will suffice. For the second case we have to decide whether the inclusion of another parameter has sufficiently increased our explanation of the data. To do this we use a simple chi-squared test: minus twice the difference in the log-posterior (at the mode) of the simpler and more complex model is assumed to be a chi-squared variable with degrees of freedom equal to the extra number of parameters in the more complex model. This makes it very simple to assess the significance of any potential better fit to the data with the more complex model.

3 Results

The first case to consider was the appropriate recruitment model to assume - do we have a single recruitment at the start of the year or a more continual phased recruitment spread over the year. In all cases it was clear that the evidence in the data suggested the phased-recruitment was a much better model in terms of explaining the data as posterior values at the mode were always higher with this recruitment model.

3.1 Estimates of exploitation rate and abundance only

For this case the quarterly M-vector was assumed to be that used previously: $M_q(0, 1+) = 0.2, 0.15$. Figure 1 shows the numbers and exploitation rates-at-age for 2006. In terms of numbers-at-age recruitment for 2006 is estimated to be 8×10^6 fish. While we cannot directly address recruitment size of the years preceding this we can an least make some inferences about these year classes relative to 2006. Given that the numbers of 1 year old fish (2005 year-class) is greater than the 0 group in 2006 and the number of 2 year old fish (2004 year-class) are higher still we can suggest that the 2006 year class was smaller than that of 2005 which was smaller than that of 2004. This trend is similar to that seen for yellowfin tuna. The age 3 numbers are estimated to be much lower than the age 2 fish.

In terms of total exploitation rates (aggregated across all gear types) we see that estimates of exploitation rates are low on age 0 ($\leq 2\%$), for age 1 they are also low ($\leq 3\%$), and equally low for age 2 ($\leq 2.5\%$). The situation is different for age 3 as we have a range of values of around 10-30% very likely due to the much smaller size of the this age class in comparison with age 2.

In terms of the fits to the 2006 tagging data (Figure 2) it is clear they are not so good. For age 0 they are not so bad but there seems to be a clear difference between the information in the two release events:

For age 1 the quarter 2 release event predicts a smaller abundance than the quarter 3 releases; for age 2 it is the other way round with quarter 2 releases suggesting a larger abundance than quarter 3, which is true to a lesser degree for age 3.

For 2007 we see the numbers and exploitation rates-at-age in Figure 3. In terms of numbers the recruitment in 2007 was around 7.5×10^6 fish, only a little smaller than that of 2006 - as was the case with the yellowfin analyses the suggestion being we have had four successively lower recruitments in 2004, 2005, 2006 and 2007. As for age 3 fish in 2006 the number of age 3 fish in 2007 is estimated to be much lower than their age 2 counterparts.

Exploitation rates for age 0 are low but more wide-ranging than in 2006 (1-5%), the same is true for age 1 (1-6%), being a little higher for age 2 (3-10%). Exploitation rates for age3 in quarters 1 to 3 are fairly high ranging from about 20-40% but what is worrying is the very high exploitation rate predicted in quarter 4 of 2007 which is almost 80%. This is clearly driven by the low abundance of age 3 fish which is in turn driven by the high number of recaptures of age 3 fish for both release events in 2007.

With respect to the fits to the 2007 tagging recaptures we see a very similar trend to that seen in 2006. The fits to age 0 are arguably the best but are not great. For age 1 the abundance predicted by the quarter 2 releases is lower than for quarter 3, while for age

2 the opposite is again true with quarter 2 releases predicting a larger abundance than quarter 3. For age 3 both release events predict a smaller population than the model, with the harvest rate penalty acting to discourage the model from going to regions where the compound harvest rate approaches 1.

In brief summary, for 2006 and 2007 the model predicts low to fairly low exploitation rates for ages 0, 1 and 2 but both higher exploitation rates and noticeably lower abundances for age 3 fish with a 2007 quarter 4 exploitation rate of almost 0.8 on age 3 fish.

In terms of potential year-to-year changes in availability there appears to be more of a within-year potential for this kind of phenomenon and perhaps changing with age. For both 2006 and 2007 there was a clear pattern of higher/lower abundance predictions by age and by release event. For age 1 quarter 2 releases predicted lower abundance than quarter 3. The opposite was true of age 2 with quarter 2 releases predicting higher abundance than quarter 3 releases. For age 3 we saw a general over-estimation of abundance by the model - particularly in 2007 and largely driven by the penalties in the model discouraging extremely high exploitation rates. These differences in recapture numbers could well be a complex interaction between release location, migration patterns-at-age and potentially age-related availability changes throughout the year.

3.2 Estimating natural mortality

While having less recapture events and general recapture numbers than yellowfin and even with some apparent trends in the fits to the differing release recaptures we looked to estimating natural mortality. We chose to estimate a simple single natural mortality multiplier, such that:

$$M_{q,a} = M \times \chi_{q,a}, \tag{1}$$

so that the natural mortality ogive $\chi_{q,a}$ mimicked the current assumed ogive: $\chi_{\cdots,0,1+} = 1, 0.75$. A weakly informative prior was set on M with a mean of 0.2 and CV of 1 (prior mean being the present assumed value) so that if the data do possess information in M they would likely update this prior.

We only estimated a significant estimate of M for 2006 - the M estimated in 2007 was very close to the prior and was not significant in the chi-squared test we applied in the yellowfin case. Figure 5 shows the summary plot for the 2006 estimate of M. The mean and CV were 0.176 and 0.59 which clearly updated the prior and in terms of the significance probability it was less than 0.05. The estimate is slightly lower than that currently assumed and quite a lot lower than the two yellowfin estimates. It is also less precise and this is to be expected - for bigeye we have less recaptures and recapture events used in the modelling and this would always be expected to increase our uncertainty in this parameter.

4 Discussion

The tagging data considered (2006 and 2007) clearly possess information on exploitation rate and abundance (when combined with the catch data). In terms of abundance estimates the numbers were smaller than those estimated for yellowfin as might be expected but we did see a similar indication of successively smaller year classes form 2004 to 2007. For both years estimates of age 3 fish were noticeably low.

Exploitation rates were low on ages 0 to 2 but high in both years and sometimes very high on age 3 fish in 2007. The fits to the tagging data held a common trend across years related to both age and release time suggesting potential for a complex relationship between age, migration pattern, release location and availability.

The estimation of values of M was considered significant only for 2006 and a mean and CV of 0.176 and 0.59 was estimated which is slightly lower than the current assumed value of 0.2.

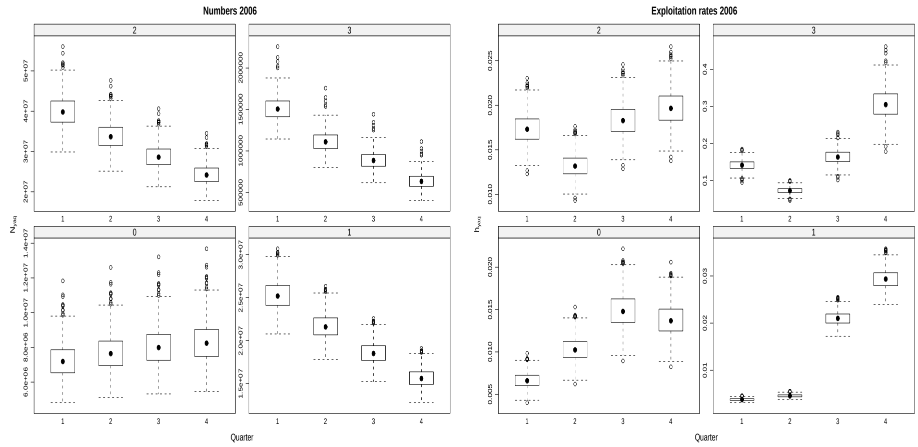

Figure 1: *Numbers and exploitation rates-at-age by quarter for 2006.*

5 Acknowledgements

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6 Figures

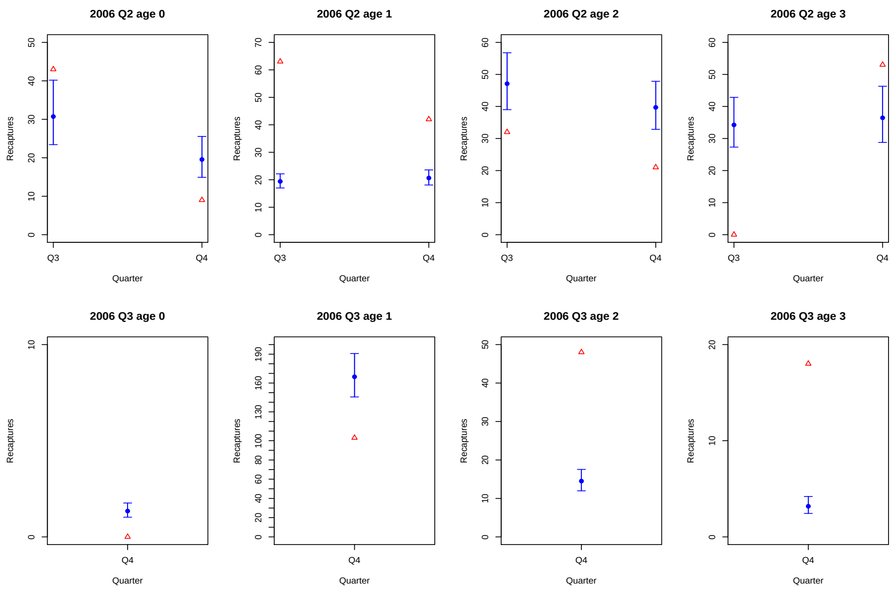

Figure 2: *Fits to the tag recapture events by release events for 2006. Red triangles denote the observed recaptures and the blue circles and bars represent the median and 95% credible interval for the model-predicted recaptures.*

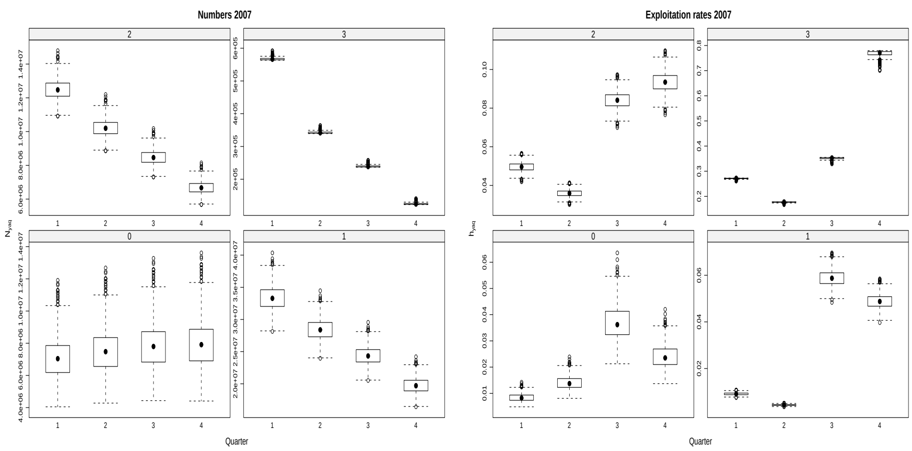

Figure 3: *Numbers and exploitation rates-at-age by quarter for 2007.*

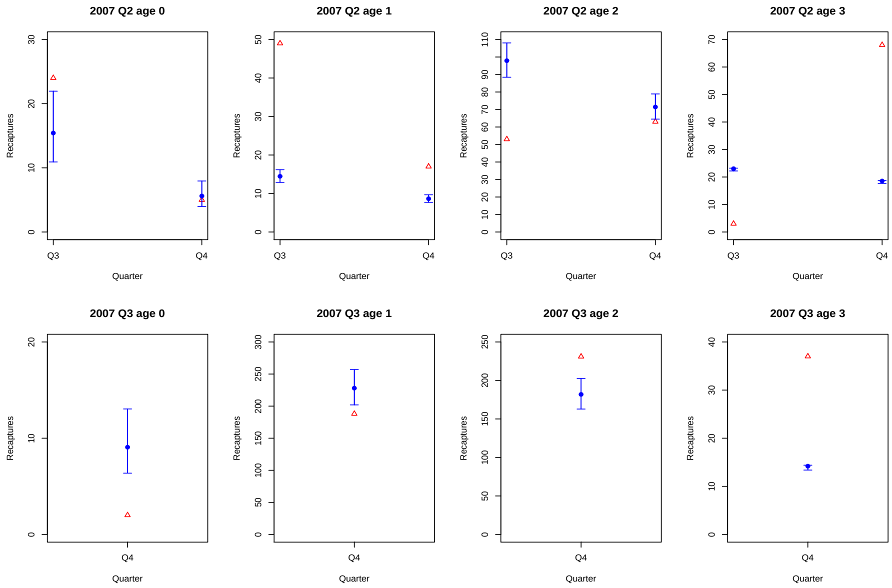

Figure 4: *Fits to the tag recapture events by release events for 2007. Red triangles denote the observed recaptures and the blue circles and bars represent the median and 95% credible interval for the model-predicted recaptures.*

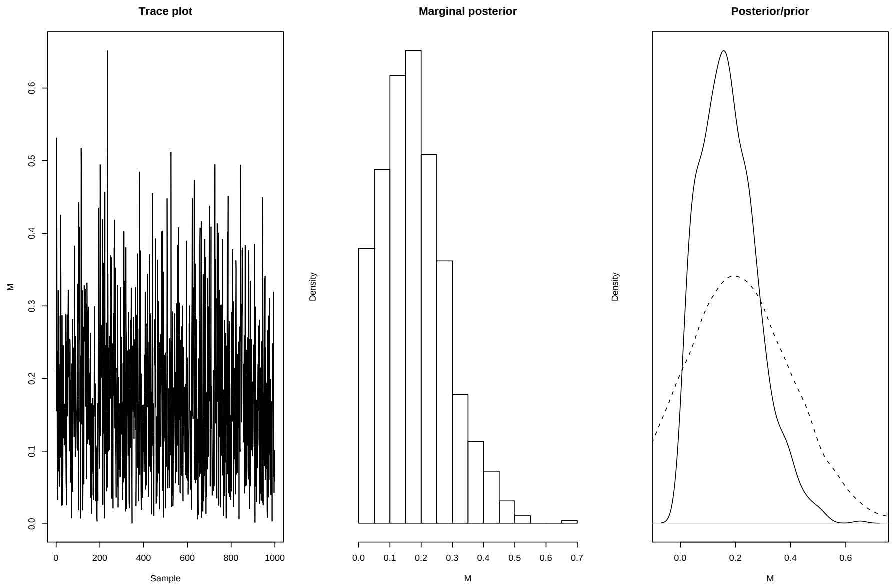

Figure 5: *Summary of the posterior estimates of M using the 2006 data.*