External analysis of yellowfin tagging data

R.M. Hillary[1]
Division of Biology,
Imperial College London, SW7 2AZ, UK.
J. Million
IOTC Secretariat,
Victoria, Seychelles.

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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 natural mortality rates for yellowfin 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 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

[1]E-mail: `r.hillary@imperial.ac.uk`

to total stock abundance (particularly in relation to the younger fish). The data cover ages 0 to 3 and, given 3 release events and 24 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.
- **Baitboat, gillnet and line fisheries**: 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 1.5×10^7 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.

In terms of total exploitation rates (aggregated across all gear types) we see that estimates of exploitation rates are low on age 0 ($\leq 3\%$), for age 1 they are also fairly low ($\leq 7\%$), for age 2 we see they are increasing to a peak of almost 9%. The situation is different for age 3 as we have a range of values of around 10-25%.

Looking at the fits to the tagging data in Figure 2 the least number of releases were seen in in the quarter 1 release event, and we see an associated low number of recaptures for this release event. Also it is these data that are fitted the worst and it is worth bearing in mind that the recapture events with the largest number of recaptures will dominate the estimates and will usually be fitted closer than the small recapture events. Fits to ages 0 and 1 are generally good but looking at the fits to ages 2 and 3 we see some potential differential information on abundance in the different release events. In terms of uncertainty the estimates of abundance are (given the high number of recaptures which strongly drives the level uncertainty in the abundance estimates) quite accurate (with CVs between 5-15%).

For 2007 we see the numbers and exploitation rates-at-age in Figure 3. In terms of numbers the recruitment in 2007 was around 1×10^7 fish, 33% smaller than that of 2006 - the suggestion being we have had four successively lower recruitments in 2004, 2005, 2006 and 2007. In terms of exploitation rates as was the case with 2006 we see low exploitation rates on age 0 fish ($\leq 5\%$), for age 1 a little higher than those seen in 2006 (3-12%), for age 2 between 5% and 13% but somewhat lower for age 3 for 2007 (6-12%) than those seen in 2006.

With respect to the fits to the 2007 recapture data they are again reasonably good. The fits to age 0 are good for the quarter 1 releases with a slight under/estimation of recaptures for quarter 2/3 which would suggest that the quarter 2/3 data suggest lower/higher abundances. For age 1 the major recapture event in quarter 4 from the quarter 3 releases is fitted well and this is the same for age 2, with the second largest recapture series (quarter 2 releases) also fitted fairly well. For age 3 we fit well the largest recapture series from the quarter 1 and 2 release events.

In brief summary, the models suggest low exploitation rates for age 0 but with an increasing trend in exploitation rate as we ascend the age classes in the study with the highest observed exploitation rates being on age 3 fish in 2006 (approaching 25%). There was evidence also of a strictly decreasing recruitment trend from 2004 to 2007. The fits to the data, in particular the major recapture events, was fairly good suggesting little information of any within-year information differences between the three release events considered.

In terms of potential year-to-year changes in availability we can look at the 2006 predictions of the next age classes in 2007 and the actual estimates from the 2007 data. For the predicted age 1 fish in quarter 1 of 2007 (age 0 from 2006 at the end of quarter 4) this is actually slightly lower than the estimated exploitable abundance of age 1 quarter 1 fish in 2007 but for the 2006-predicted age 2 and 3 fish it is higher. It could be that there are some potential changes in the available populations-by-age but also given this result it is just as likely to be the result of using different data to estimate the same thing.

3.2 Estimating natural mortality

Given we have a high number of releases and recaptures as well as 24 recapture events for the three release events considered in each year we also look at the information each yearly data set holds on 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.

For 2006 Figure 5 shows the summary plot of the estimate of M. As can be seen from the figure the posterior clearly updates the prior for M giving a mean and CV of 0.32

and 0.19. Figure 6 shows the summary plot for M_{2007} and this updating is even more apparent with a mean and CV of 0.59 and 0.142. In terms of whether the estimation of M significantly increased the explanation of the data in both cases the significance level for the estimation of M using the chi-squared likelihood ration test was less than 0.01 so fairly significant.

For 2006 these values are higher than the currently assumed values and for 2007 they are considerably higher. Further work would be required to investigate the influence of the ogive assumed (stronger decreases in M-at-age for example might be expected) and also what happened if we integrate the two years of data (assuming M to be a fixed quantity over years).

4 Discussion

The tagging data considered (2006 and 2007) clearly possess information on exploitation rate and abundance (when combined with the catch data). Estimates of exploitation rates on age 0 animals were seen to be low but also exhibited an increasing trend as we ascended the age classes. In terms of year-class information there were clear indications of successively smaller year-classes from 2004 to 2007. There was little indication of obvious within-year inconsistencies between the relevant release events. In terms of information on natural mortality there was a clear updating of the weak prior distribution set for this parameter with suggestions of higher levels of M in 2006 and considerably higher levels of M in 2007 than have been assumed previously.

5 Acknowledgements

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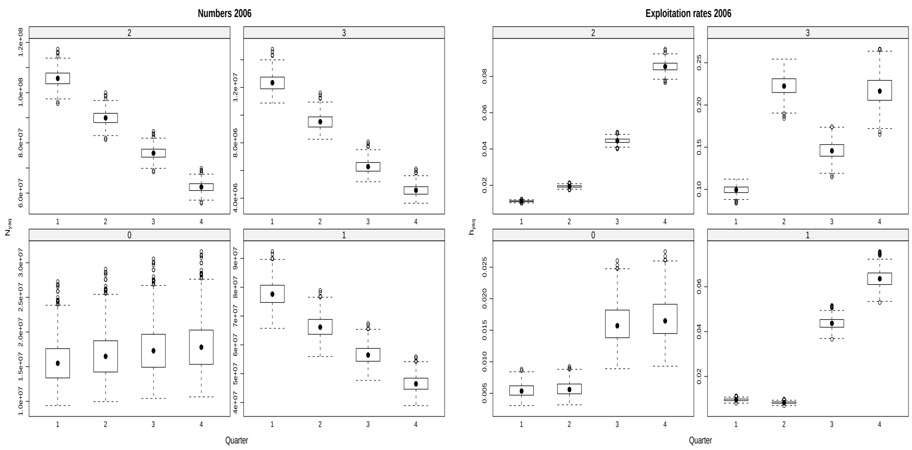

Figure 1: *Numbers and exploitation rates-at-age by quarter for 2006.*

mented by the Indian Ocean Commission under the technical supervision of the Indian Ocean Tuna Commission. We wish to acknowledge the contributions of the project staff and all the technicians, recovery officers and fishers that have been involved in the RTTP-IO.

6 Figures

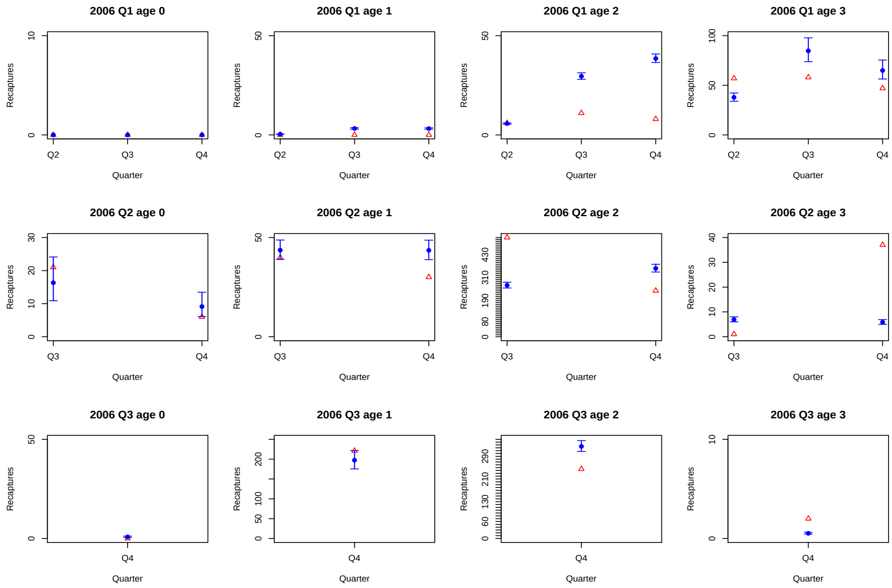

Figure 2: *Fits to the tag recapture events by release events for 2006. Red triangles denote the observed recaptures and the blue circles and bars represent the median and 95% credible interval for the model-predicted recaptures.*

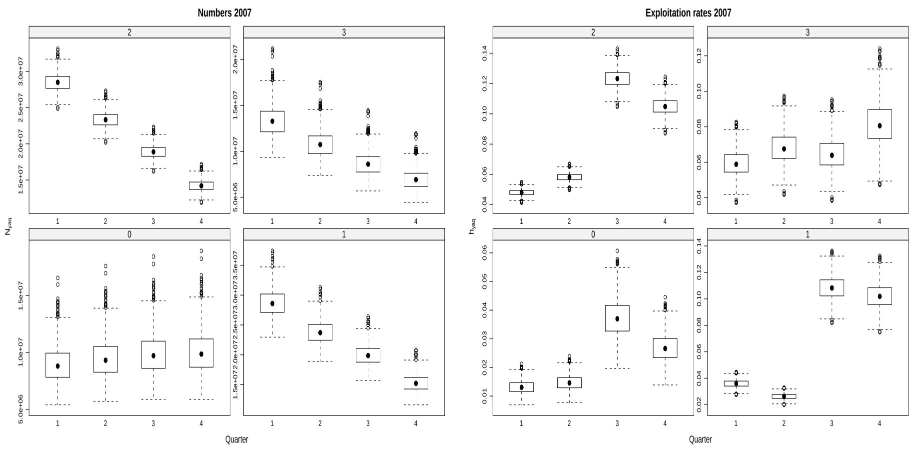

Figure 3: *Numbers and exploitation rates-at-age by quarter for 2007.*

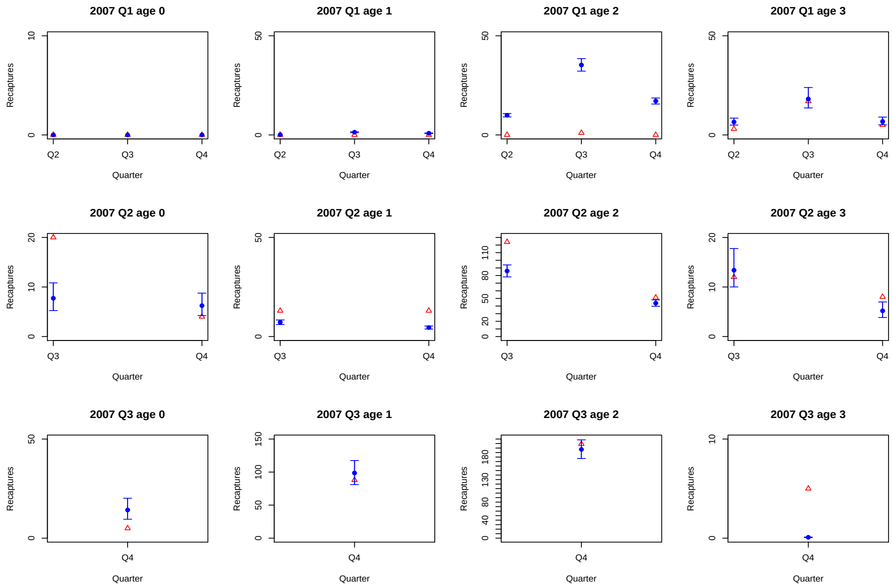

Figure 4: *Fits to the tag recapture events by release events for 2007. Red triangles denote the observed recaptures and the blue circles and bars represent the median and 95% credible interval for the model-predicted recaptures.*

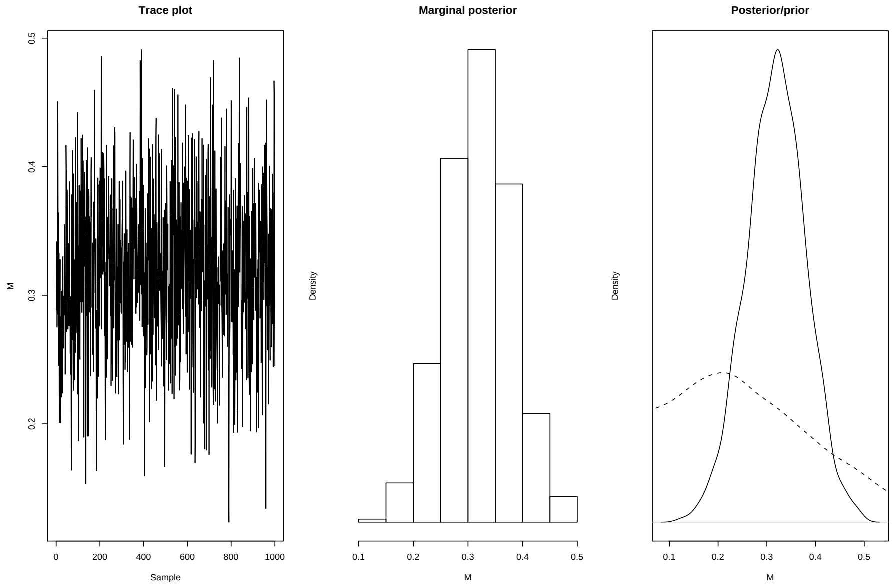

Figure 5: *Summary of the posterior estimates of M using the 2006 data.*

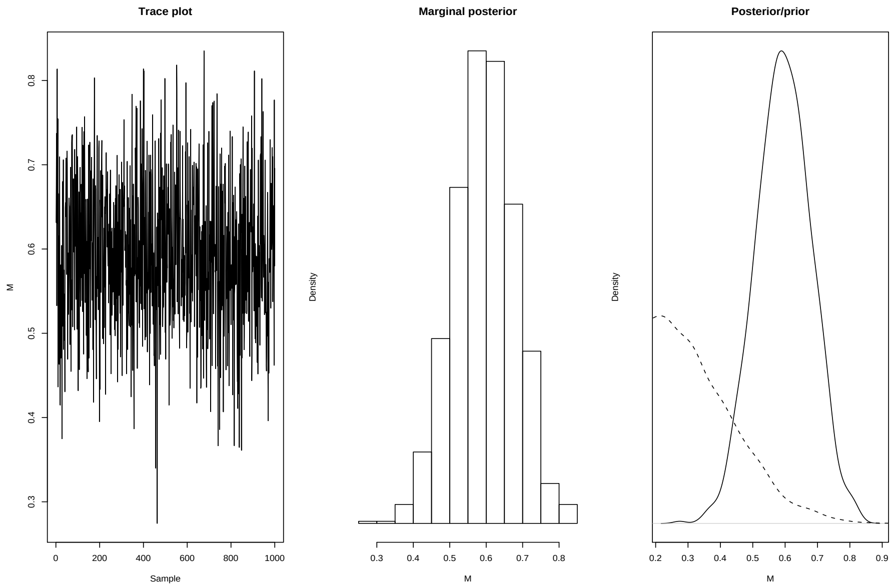

Figure 6: *Summary of the posterior estimates of M using the 2007 data.*