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External analysis of skipjack 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 natural mortality rates for skipjack 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. The initial plan was to use the length-based form of the model for skipjack, given the difficulties in obtaining the age-related growth parameters. However, the tagging data do not cover the recruiting ages of this stock and this proves a problem when wishing to apply a length-based model as abundance in length classes we have no initial observations on will move through the tagging data range over time. With an age-based model this issue is not such a problem. By using the tagging data-derived estimates of growth (assuming a von Bertalanffy growth curve, we used $k = 0.288$, $L_\infty = 74.8cm$ and $t_0 = -0.5$) we constructed catch, reference catch and tagging release and recapture data-at-age for ages

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2 to 5 for 2006 and 2007. No recruitment dynamics are included in this approach for obvious reasons and all that is done is that each cohort is simply modelled through the quarters in each year, according to the population, tag and recapture models.

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 to total stock abundance (particularly in relation to the younger fish). The data cover ages 2 to 5 and, given 3 release events and 24 recapture events in 2006 and 2 major release events and 12 recapture events in 2007 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.

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. 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

For estimating natural mortality 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

Recruitment dynamics are not considered for skipjack given our data cover ages 2 to 5 so we estimate only initial abundance and exploitation rate as well as natural mortality later on.

3.1 Estimates of exploitation rate and abundance only

For 2006, the estimates of abundance for age 2 were around 8×10^8 fish, age 3 around 3.7×10^8, age 4 around 8×10^7 and for age 5 around 7×10^7. Exploitation rates varied by quarter given fishing trends and for age 2 ranged from 2 to 7%, for age 3 from 2 to 6%, for age 4 from 3 to 8% and for age 5 from 1 to 4%. See Figure 1 for a summary plot of the numbers and exploitation rates.

In terms of fits to the tagging recaptures see Figure 2. The major recapture events are fitted fairly will but with some indication of differences between release (and subsequent recapture) events and the abundance of age 4 and 5 fish in 2006.

For 2007 the estimates of abundance of age 2 fish were around 6×10^8 fish, age 3 around 1.3×10^8, age 4 around 4×10^7 and for age 5 around 2.8×10^7. All these are slightly lower than those seen in 2006. Exploitation rates again varied by quarter given fishing trends ranging from 2-4% on age 2, 4-10% on age 3, 5-17% on age 4 and 2-6% on age 5. Exploitation rates on ages 3-4 were higher than those seen in 2006 but similar for ages 2 and 5. See Figure 3 for a summary plot of the numbers and exploitation rates.

Fits to the 2007 recapture data can be seen in Figure 4. For ages 2 and 3 the fits to the recaptures are OK and are largely driven by the much larger recapture events in quarter 4 from quarter 3 releases. As with 2006 there was apparent mismatched information in the age 4 and 5 data for the two release events.

3.2 Estimating natural mortality

When estimating M for the skipjack data we assumed no changes in M by age largely because we had no such information as was available for yellowfin and bigeye. For both years the estimate of M yielded a significant improvement in the fits to the data As with the other two species we estimated M for each year and Figures 5 and 6 show the summary plots for the two estimates. For 2006 we estimated an M with a median and 95% credible interval of 0.012 (0.001-0.045) which clearly updated the assumed prior of a mean and CV of 0.2 and 1. For 2007 we estimated an M with a median and 95% credible interval of 0.016 (0.001-0.065). These values are clearly much smaller than the prior and are surprising - even though these data do not cover the youngest/smallest ages these estimates of M, although consistent across the two years, do seem very low.

4 Discussion

For both 2006 and 2007 estimated abundances of skipjack are large and are larger than estimates of recruits of both bigeye and yellowfin even though they cover older ages suggesting substantially larger numbers of skipjack than both yellowfin and bigeye tuna in the Indian Ocean. Exploitation rates are generally fairly low - never exceeding 20% even over the most selected age-range of the stock. Abundances in 2006 are predicted to be higher than those in 2007 and it is worth noting the stable age-structure apparent in both years - there is a very similar decrease in relative abundance from ages 2 to 5. This hints at a reasonably stable year-class regime at least for the cohorts that encompass these data (2000-2005). Also, the numbers at the start of 2007 as predicted by the 2006 abundances and exploitation rates are all higher (and by a similar fraction of about 10-15%) than what we estimate using the 2007 data suggesting a potential for a slight decrease in availability (and therefore the exploitable stock size) of skipjack in 2007, when compared with 2006. It should be noted also that this was not an artefact of using the low estimates of - M this observation was made using the base-case estimate of $M = 0.2$ per quarter.

The estimates of M by quarter (around 0.015) are very low, even if they seem consistent over the two years, and are hard to explain given what we know about the fish.

5 Acknowledgements

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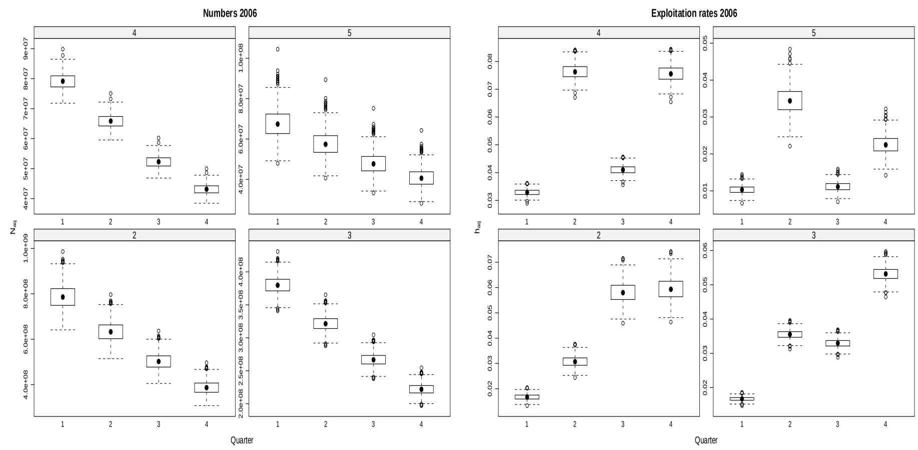

Figure 1: *Numbers and exploitation rates-at-age by quarter for 2006.*

6 Figures

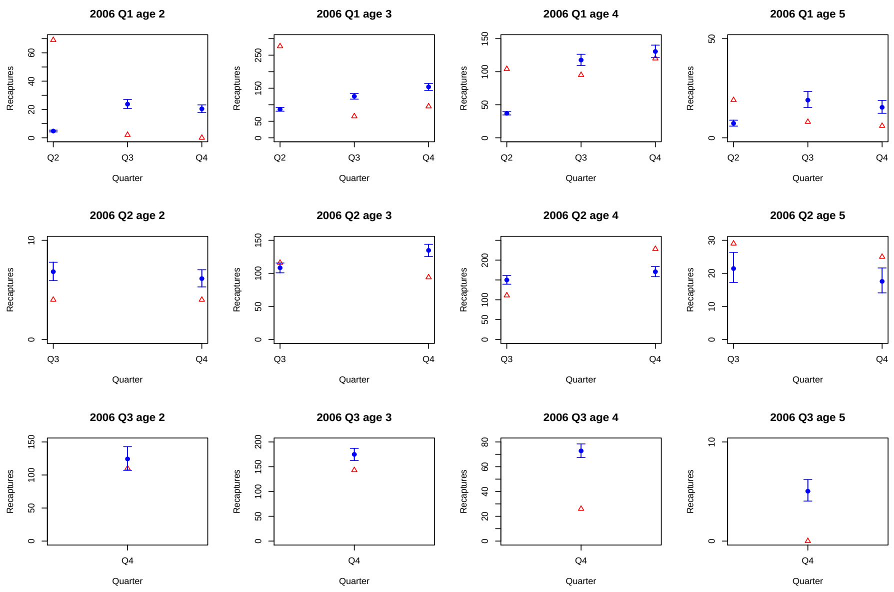

Figure 2: *Fits to the tag recapture events by release events for 2006. Red triangles denote the observed recaptures and the blue circles and bars represent the median and 95% credible interval for the model-predicted recaptures.*

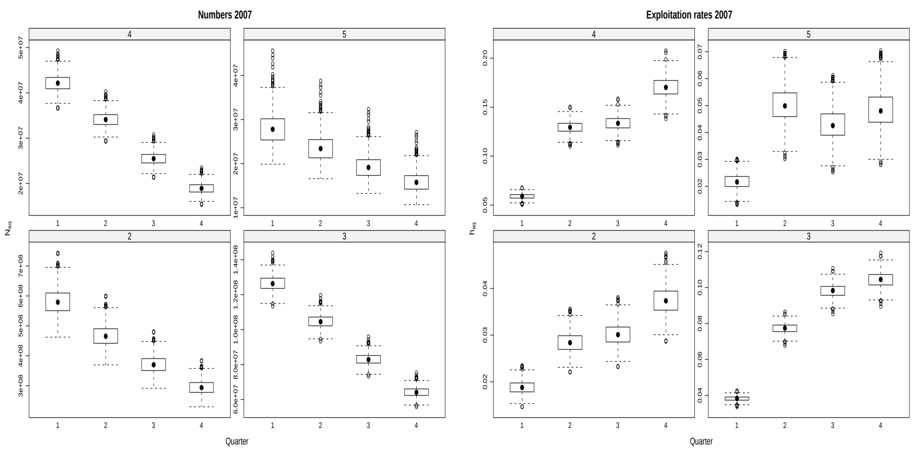

Figure 3: *Numbers and exploitation rates-at-age by quarter for 2007.*

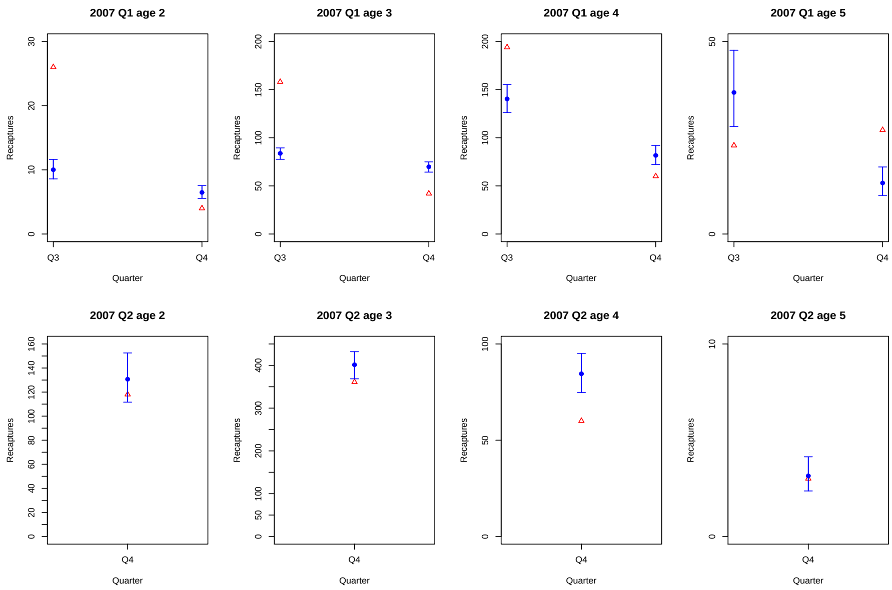

Figure 4: *Fits to the tag recapture events by release events for 2007. Red triangles denote the observed recaptures and the blue circles and bars represent the median and 95% credible interval for the model-predicted recaptures.*

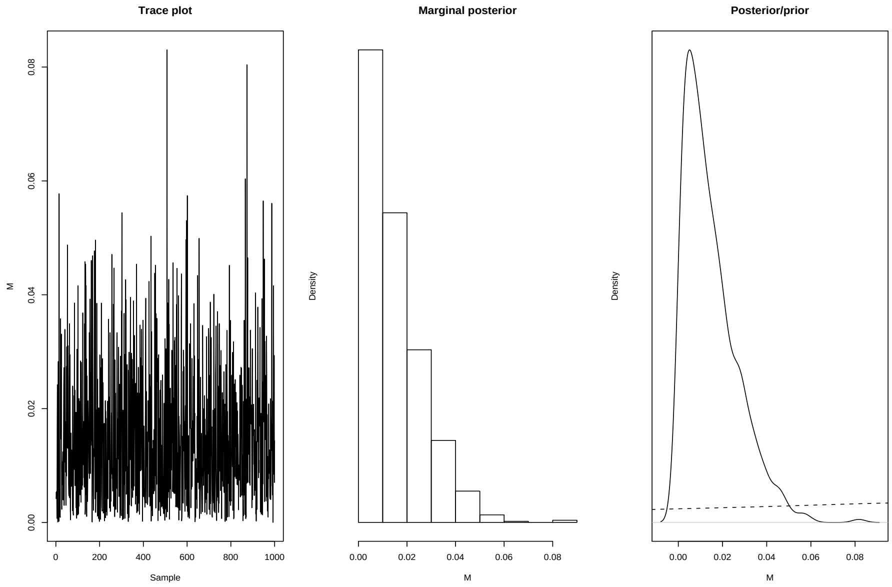

Figure 5: *Summary of the posterior estimates of M using the 2006 data.*

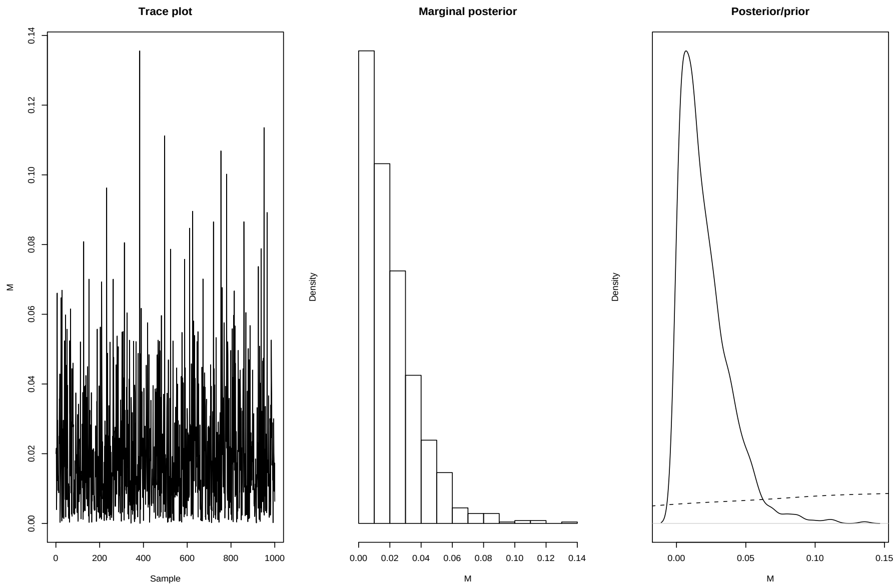

Figure 6: *Summary of the posterior estimates of M using the 2007 data.*