Fishing mortality based reference point estimates for Skipjack

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1 Introduction

This document details estimation of the annual fishing mortality from tag based estimates of the harvest rate detailed in IOTC-10-WPTT-26 and IOTC-10-WPTT-31. These are compared to the reference points F^{MAX} and $F^{0.1}$.

2 Methods

2.1 Fishing mortality

Annual harvest rates at age (H_a) estimated from IOTC-10-WPTT-26 and IOTC-10-WPTT-31 are given in Table 1. From these we were able to use the Baranov catch equation to numerically estimate $\hat{F}_a$:

$$H_a = \frac{F_a}{F_a + M_a}(1 - e^{-F_a - M_a}) \tag{1}$$

where M_a is the natural mortality at age a.

From $\hat{F}_a$ we obtain the mean across age groups: $\bar{F}$. This corresponds to age groups 2 to 5 (for years 2006 and 2007) or 3 to 5 (for 2008).

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2.2 Selectivity

Catches at size data from all fleets across years 2000 to 2008 were first collated into age classes 0 to 7, using the von Bertalanffy growth curve (see IOTC-10-WPTT-26). The mean catch proportion at age across years is given in Figure 1. This was used to estimate the selectivity at age (S_a), by standardising so that the mean across ages used to esimate $\bar{F}$ was equal to one.

2.3 Reference points

2.3.1 F^{MAX} and $F^{0.1}$

The age structure assuming mortality $Z_a = M_a + FS_a$ is given by

$$P_a^F = \begin{cases} 1 & \text{for } a = 0 \\ P_{(a-1)}^F e^{-Z_{(a-1)}} & \text{for } 0 < a < a^{++} \\ \frac{P_{(a-1)}^F e^{-Z_{(a-1)}}}{1-e^{-Z_a}} & \text{for } a = a^{++} \end{cases} \tag{2}$$

from which we obtain the yield per recruit $Y = \sum_a w_a P_a^F$. The yield per recuit curve (Y against F) is typically dome shaped. F^{MAX} is the fishing mortality associated with the maximum of this curve. $F^{0.1}$ is the F associated with a gradient of the curve that is 10% of the gradient at the origin.

Note that since the selectivity curve has a mean of one across age groups used to calculate $\bar{F}$, the reference point estimates also correspond to a mean value across these age groups.

2.3.2 Spawning potential ratio

The spawning poential ratio (SPR) is the ratio of the number of spawners per recruit, given fishing mortality, over the number of spawners per recruit without fishing. As such, it measures the proportional reduction in total productivity attributable to fishing. After

specifying an appropriate SPR, the fishing mortality that achieves that SPR (F^{SPR}) can be calculated.

Appropriate values for SPR can be derived from life history parameters (Brooks et al., 2010). Specifically, given steepness of the stock recuitment relationship h, we obtain the SPR associated with maximum excess recruitment (MER) :

$$SPR_{MER} = \frac{\sqrt{1-h}}{2\sqrt{h}} \tag{3}$$

MER is analogous to the MSY, but is based on numbers rather than biomass, with the 'excess' refering to the recruits that can be caught whilst maintaining the stock in stable condition. Simulations have shown that $F^{SPR}_{MER} > F^{MSY}$ (Brooks et al., 2010), but F^{SPR}_{MER} nevertheless provides an indication of whether overfishing is being experienced by the stock. Assuming $h = 0.9$, we obtain $SPR_{MER} = 0.15$. From this we are able to numerically estimate the reference point F^{SPR}_{MER}.

3 Results and Discussions

Estimated fishing mortalities at age are given in Figures 2 to 4 and Table 2, alongside $\bar{F}$ and its comparison to F based reference points. Note that there is marked change in 2008 due to the change in the age range used for estimating the selectivity. The analysis was therefore repeated using only ages 3 to 5 for all years (Table 3).

We are able to conclude fishing mortality has increased from 2006 to 2008 and for ages 3 to 5 at least is currently much higher than that associated with the maximum yield. Nevertheless it is still not clear that the stock is experiencing overfishing, although this result is dependent on our assumption concerning h.

References

Brooks, E. N., J. E. Powers, and E. Cortes. 2010. Analytical reference points for age-structured models: application to data-poor fisheries. ICES J. Mar. Sci. **67**:165–175.

Year	Age							
	2	*cv*	3	*cv*	4	*cv*	5	*cv*
2006	0.13	(0.071)	0.14	(0.023)	0.10	(0.046)	0.04	(0.139)
2007	0.08	(0.094)	0.21	(0.029)	0.28	(0.05)	0.05	(0.225)
2008	-	-	0.20	(0.05)	0.37	(0.045)	0.06	(0.165)

Table 1: Annual harvest rates-at-age estimated in IOTC-10-WPTT-26 (Option 3) and IOTC-10-WPTT-31

		Year					
		2006	*cv*	2007	*cv*	2008	*cv*
Age	2	0.16	(0.077)	0.1	(0.099)	-	-
	3	0.17	(0.025)	0.26	(0.033)	0.27	(0.057)
	4	0.12	(0.049)	0.36	(0.06)	0.5	(0.057)
	5	0.04	(0.142)	0.06	(0.232)	0.06	(0.171)
$\bar{F}$		0.12	(0.031)	0.19	(0.036)	0.27	(0.04)
$\bar{F}/F^{MAX}$		0.4	(0.031)	0.64	(0.036)	1.52	(0.04)
$\bar{F}/F^{0.1}$		0.56	(0.031)	0.9	(0.036)	2.14	(0.04)
$\bar{F}/F^{SPR}_{MER}$		0.17	(0.031)	0.27	(0.036)	0.65	(0.04)

Table 2: Estimates of fishing mortality and comparison of the mean across ages 2 to 5 (2006 and 2007) and 3 to 5 (2008) to F-based reference points

	Year					
	2006	*cv*	2007	*cv*	2008	*cv*
$\bar{F}$	0.11	(0.028)	0.23	(0.04)	0.27	(0.04)
$\bar{F}/F^{MAX}$	0.61	(0.028)	1.26	(0.04)	1.52	(0.04)
$\bar{F}/F^{0.1}$	0.85	(0.028)	1.77	(0.04)	2.14	(0.04)
$\bar{F}/F^{SPR}_{MER}$	0.26	(0.028)	0.54	(0.04)	0.65	(0.04)

Table 3: Estimates of fishing mortality and comparison of the mean across ages 3 to 5 (all years) to F-based reference points

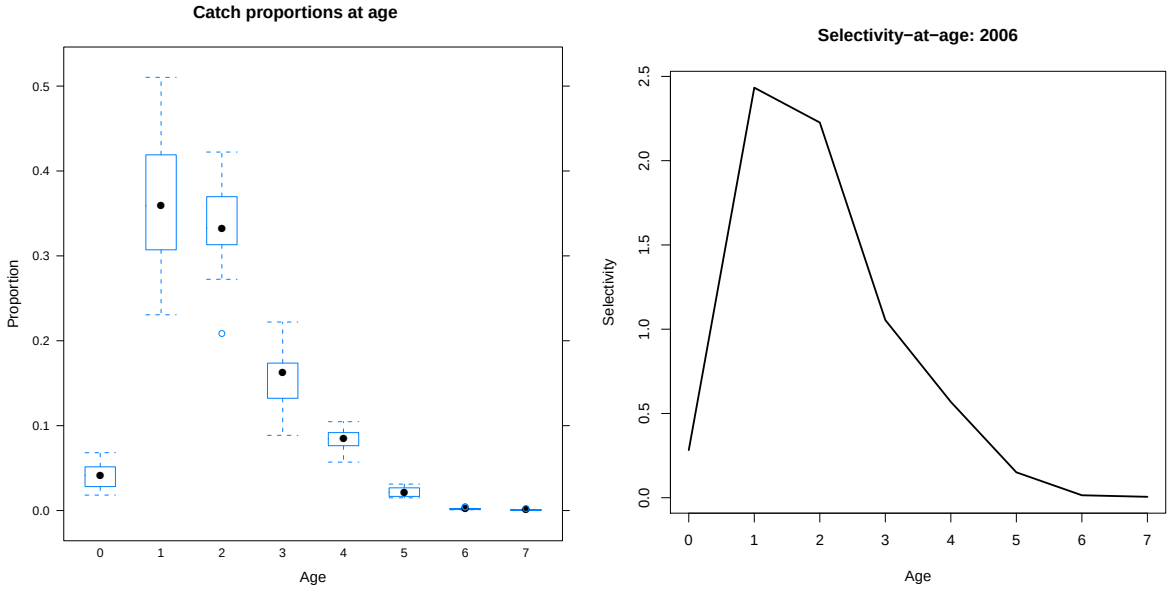

Figure 1: Mean catch proportions at age and selectivity for 2006

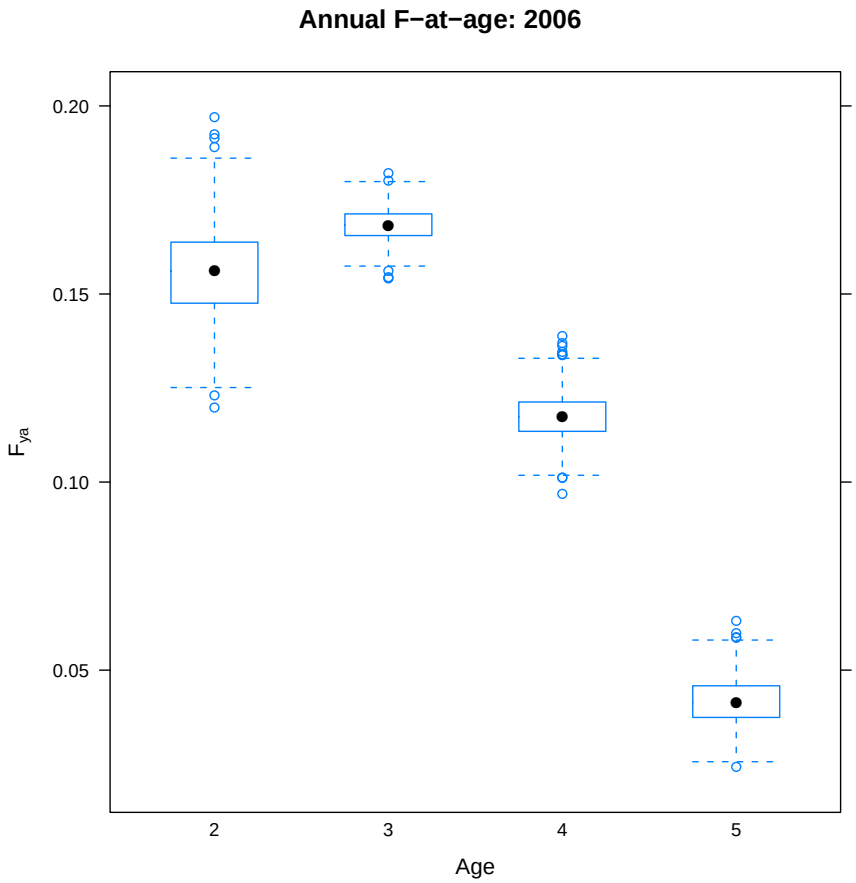

Figure 2: Estimated annual fishing mortalities at age F_a for 2006

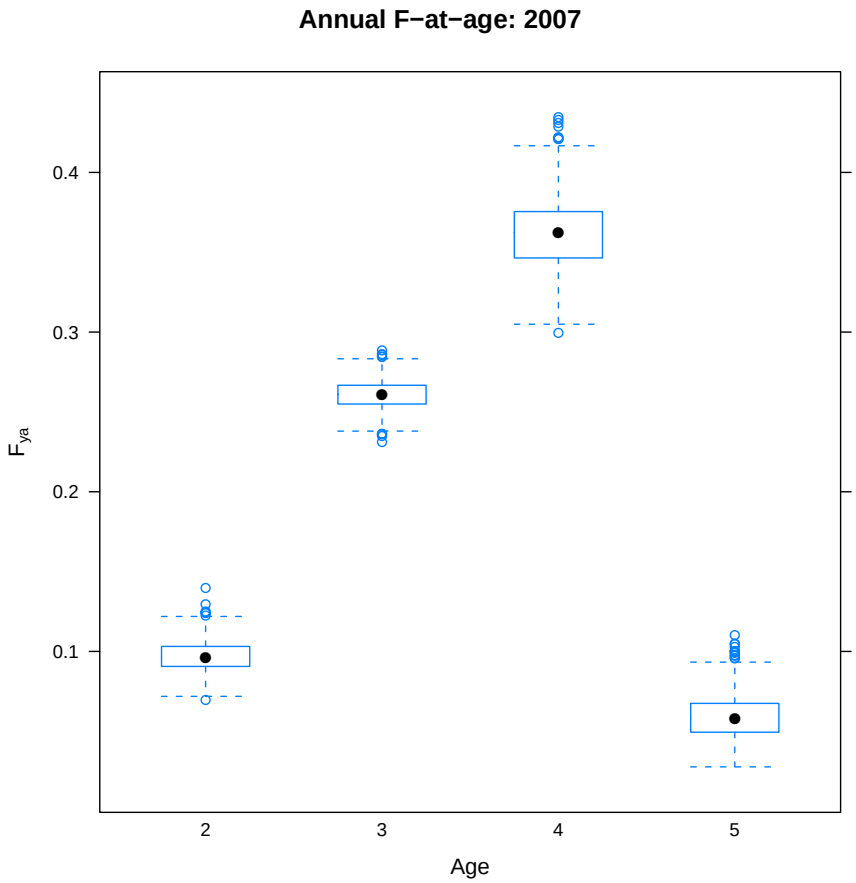

Figure 3: Estimated annual fishing mortalities at age F_a for 2007

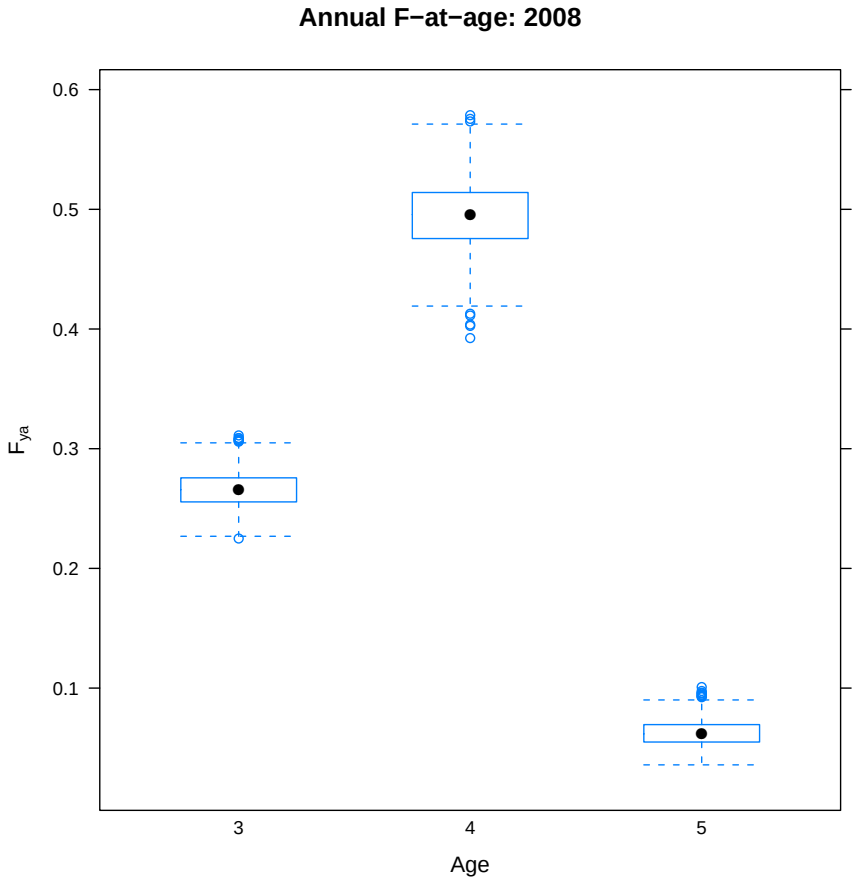

Figure 4: Estimated annual fishing mortalities at age F_a for 2008