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Estimation of Indian Ocean skipjack fisheries' productivity using a catch based method

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Summary

Fisheries are managed using biological information of fish stocks, historical catch data and complex numerical models. However, the availability of reliable and complete information of both biological characteristics and fisheries yield is often incomplete, inaccurate or non-available. Therefore, there is a need for simple methods that allow estimating fish stocks productivity using limited data. In this study we use a simple method to investigate the productivity and historical harvest rates applied to Indian Ocean skipjack, a species exploited by several nations and a diversity of gears and managed by the Indian Ocean Tuna Commission (IOTC). Our results suggest that current and recent catch is within the estimated limits of the capacities of these stocks to replace the amount of biomass harvested except for the year 2008, where these limits were exceeded. We discuss that these results need to be supported by deeper studies and new data due to the limitations of catch based methods.

Keywords: Indian Ocean tropical tunas, skipjack, data-poor stocks, maximum sustainable yield, stock assessment

1. Introduction

The Indian Ocean Tuna Commission (IOTC) is responsible for the management of tuna and tuna-like species in the Indian Ocean. IOTC aims for the optimum utilisation of fish stocks and encouraging the sustainable development of fisheries. The maximum output that fisheries can produce while maintaining biomass within safe limits is the Maximum Sustainable Yield (MSY). Generally, stocks' MSY and their level of exploitation is estimated using complex stock assessment models fed with comprehensive fishery and fishery-independent data, collected through substantial international effort. However, in some cases, these data are not available or informative and simpler methods that do not require catch rate information are needed. Here, we estimate the productivity of the Indian Ocean skipjack (*Katsuomus pelamis*) using only historical catch series provided by IOTC and a method for estimating MSY from catch and resilience (Martell and Froese, 2012). This method is not proposed as a definitive stock assessment procedure but it can yield useful information on stocks' productivity and prior information for more complex stock assessment models.

2. Material and Methods

The simplest model-based methods for estimating MSY are production models such as that of Schaefer (1954), only require a time series of relative or absolute abundance and of removals to estimate two model parameters: the carrying capacity, *K*, and the maximum rate of population increase, *r*, for a stock (Martell and Froese, 2012). Abundance estimates can be difficult and costly to obtain and therefore, methods that require only a time series of removals are sometimes necessary. Without abundance estimates, Schaefer models output a range of *r*-*K* combinations which can be used to approximate MSY (Martell and Froese, 2012). We applied this method to obtain plausible MSY estimates and other biological parameters from catch only data, based on assumptions on resilience (corresponding to the intrinsic growth rate *r* in the stock production model) (Martell and Froese 2012). We used a medium resilience range as defined by Martell and Froese (2012), *i.e*. medium resilience of $0.2<r<1$ (Fishbase estimate for skipjack), and an initial (in 1948) relative stock size range of 50 to 90% of carrying capacity *K* or pristine biomass. The identification of pairs of *r*-*K* values compatible with the catch time series and the above assumptions was performed using the R-code for batch processing made publicly available in http://www.fishbase.de/rfroese/CatchMSY_2.r. For each plausible *r*-*K* pair, an estimate is obtained as MSY=1/4 *r K*. This MSY estimation algorithm has been validated against analytical fish stock assessment estimates of MSY (Martell & Froese, 2012). We used updated catch information from the IOTC Secretariat.

3. Results

Figure 1 shows the graphical output of the catch-MSY method as applied to the Indian Ocean stock of skipjack. Table 1 shows the output MSY, intrinsic growth parameter (r) and carrying capacity (K). The catch based model outputs a probabilistic estimation of the maximum sustainable yield and the intrinsic growth rate (*r*) and carrying capacity (*K*) parameters of the logistic surplus production model. Figure 1 shows the estimated MSY (median and upper-lower confidence intervals) together with historical catches and the probabilistic distribution of the estimated parameters MSY, *r* and *K*. In this figure, recent catch is below the median until 2013 and within the confidence intervals of the estimated MSY. At the right side of the historical catch and MSY boundaries, the posterior densities of *r*, *K* and MSY are shown.

In order to investigate if the catch increase observed in the last years of the series could bias the MSY estimates, we tried the catch-based method retrospectively: We ran the model for this stock for alternative data series starting in 1950 and ending in 2000, 2005, 2008-2011, and compared the resulting parameters with those estimated using the complete catch data until 2013.

Figure 2 shows that the estimates with data series ending at different years would produce variations on the MSY (from nearby 350-470 th t if estimated all final years, including the estimate with data series until 2013. Therefore, we consider that the MSY estimations were consistent regardless the length of the data series.

4. Discussion

We present an estimation of this fishery's productivity and estimation of MSY obtained through a catch-only based methodThis method allows a very simple estimation of the productivity of fish stocks and is similar to that previously used by the ICCAT Skipjack Working Group (after Vasconcellos and Cochrane, 2005; see Rosenberg *et al*, 2014 and Merino et *al*., 2014). However, the key question is how well this method compares with the estimates yielded by full stock assessments. In the paper by Martell and Froese (2012), a comparison using stocks evaluated within the International Commission for the Exploration of the Sea (ICES) and from the RAM legacy database (Ricard et al., 2011) shows that the results obtained with this method are not significantly different to those obtained from full stock assessments (R^2=0.986). In addition, the RAM legacy database contains information from many tuna and tuna-type stocks that were used for the comparison, including bigeye, yellowfin, skipjack, swordfish, albacore stocks from the Atlantic, Indian and Pacific Oceans. However, this method does have limitations and caveats that need to be discussed.

A key assumption in this approach is the ability to define reasonable prior ranges for the parameters of the Schaefer model. For example, in developing fisheries, or fisheries that have not reached or exceeded their MSY and have not gone through overexploitation phases, the time series of catches do not contain sufficient information about productivity (Martell and Froese, 2012).

The Schaefer model used in this study does not consider environmental effects on the productivity of the stocks, as it does not allow for change in the parameters over time. Fish stocks, especially pelagic fish, can be highly vulnerable to environmental variability (Barange et al., 2009; Hsieh et al., 2009), which are hypotheses that are generally considered in IOTC and other Tuna Regional Management Organizations full stock assessments. Future evaluations could take on such hypotheses, if supporting evidence for such systematic change can be identified.

These types of simple methods are suitable for data poor fisheries only if additional data are not available. For the cases where more complex methods are used, this method can be used to generate priors or provide robustness tests in support of the overall stock assessment.

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Figures

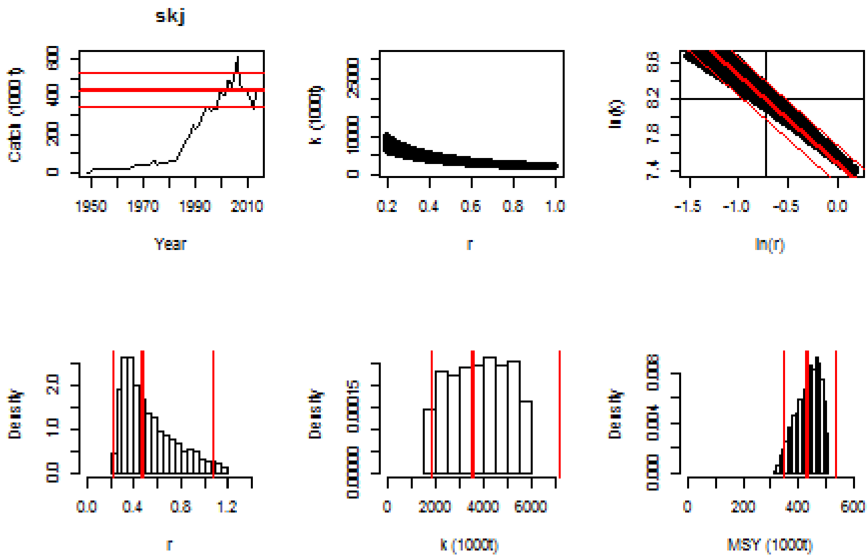

Figure 1. Graphical results of the catch only model.

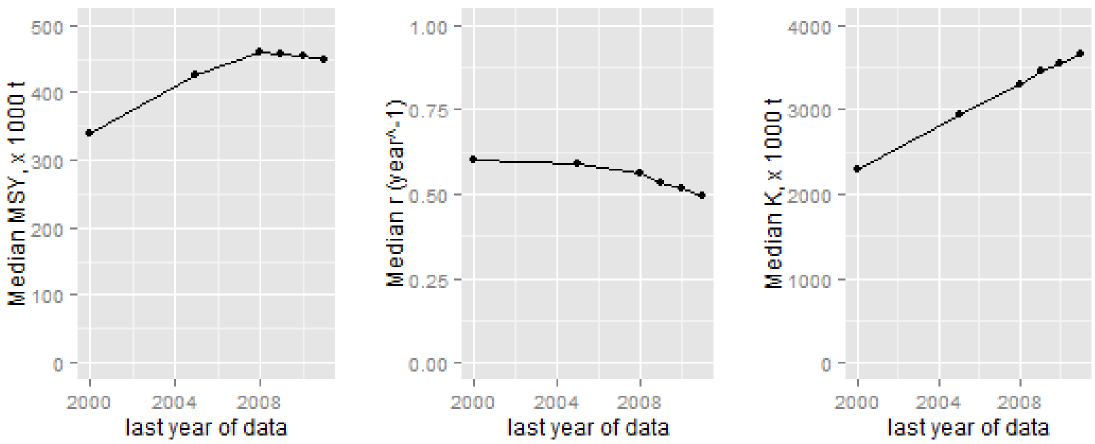

Figure 2. Estimates of MSY, r and K for the catch only models run retrospectively.

Tables

Table 1

MSY (th tonnes)			r			*K*		
Median	q05	q95	Median	q05	q95	Median	q05	q95
441.23	354.27	486.134	0.4581	0.2672	0.9818	3847.15	1845.69	5625.99