How much sampling coverage affects bycatch estimates in purse seine fisheries ?

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Abstract

IOTC-2010-WPEB-20 presents the results of a simulation approach conducted to evaluate the biases and uncertainties associated with the use of a ratio estimator method to estimate bycatch in tropical tuna purse seine (PS) fisheries. Simulations were based on a set of observer data collected in the Eastern Pacific Ocean by IATTC in 2000 and focused on fishing sets made on floating objects and on 4 major bycatch species: mahi mahi (*Coryphaena hippurus*), silky shark (*Carcharhinus falciformis*), swordfish (*Xiphias gladius*), and blue marlin (*Makaira nigricans*). Results mainly showed that biases and uncertainties were strongly dependent on the percentage of coverage as well as on the fish species considered. The current 10% sampling coverage rate of the European PS fishery of the Indian Ocean would lead to positives biases (< 5%) and large uncertainties (> 20%) in bycatch estimates for the 4 species when caught on log-associated schools. The importance of the fishery, i.e. total number of trips, was also shown to affect bycatch estimates for a specific level of sampling coverage. The use of unbiased ratio estimators was found to be particularly useful when sampling coverage is low (< 10%).

Keywords: Bycatch, simulation, ratio estimator, bias, uncertainty

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1. Introduction

Incidental catch of non target marine animals is a general and increasing concern in world marine fisheries (Hall 1998, Gaertner et al. 2002, Kelleher 2005, Minami et al. 2007, Soykan et al. 2008). One common and simple approach to compare the magnitude of bycatch within or between fisheries is to express their bycatch as a function of target species catch or the fishing effort (Hall 1999). Bycatch rate could be an important indicator to evaluate the relative impact of each fishery on a given non target species (Watson et al. 2008). Unfortunately this indicator is in general not calculable from usual fishery data (logbook) because information about non target species is not available or poorly mentioned by fishing masters (Gaertner et al. 2002).

Observer data have been shown to be a unique opportunity for scientists to learn more about species that are incidentally caught by fishermen (e.g. Amandè et al. 2009). Then, the expression of bycatch over catch or effort, called ratio is in general calculated from observer data and generalized to the whole fisheries from which the observer data are supposed to derive (De Pascual 1961, Rochet and Trenkel 2001, Kadilar and Cingi 2003, Borges et al. 2005, Sims et al. 2008) because of its simplicity and practical use. However, bycatch estimation remains still problematic in fisheries in which observer data represent a small part of the total fishing activities (Tsitsika and Maravelias 2008, Hall 1999, Lawson 2001) because of the the skewness and/or high variability in bycatch distribution. While the magnitude of bias and uncertainty in bycatch estimates could seriously impact decisions for fishery management, these notions are rarely mentioned in reviewed papers on bycatch estimation (Babcock et al. 2003).

The purpose of this paper is to analyze the effects of sample size in terms of bias and uncertainty on bycatch estimates in purse seine fisheries using a simulation approach.

2. Materials and methods

Data

Data were collected by observers aboard tuna purse seiners within the framework of the observer programme conducted in the eastern Pacific Ocean (EPO) by the Inter-American Tropical Tuna Commission (IATTC). IATTC data used here are only from floating objects sets collected in 2001 and represent 449 observed trips and 5,613 sets. Nearly 100% of the trips were observed in the IATTC observer programmme of which floating objects sets represented almost 85%. The term "bycatch" herein refers to incidental species caught during purse seine operations and the "catch" will refer to the retained catch of target tuna species, i.e yellowfin *Thunnus albacares*, skipjack *Katsuwonus pelamis*, and bigeye *Thunnus obesus*. Four species with different characteristics were selected for this study (Table 1). Details about the IATTC observer programme can be found in Hall (1995), Lennert-Cody et al. (2004), Watson et al. (2008), Lennert-Cody et al. (2008).

Approach

The fishing trip has been shown to be the best sampling unit for bycatch estimation Borges et al. (2005) and represents the real statistical unit on which sampling design could be made in purse seine fisheries. Simulations were then conducted at the trip level. For simulation purpose, the total observed data was considered as the fishery universe, i.e logbook data and simulation consisted in simple resampling without replacement in that population universe. It means that observer data were created by simple random sampling in the population trips. Ratio estimator was based on tuna catch and effort as auxiliary variables because such informations is always available in logbook data and generally used for raising procedures.

Bias in bycatch estimate

The simulation approach used here for quantifying bias and uncertainty in bycatch estimate was proposed by Babcock et al. (2003) and formulas mentioned in this section could be found in Thompson (2002).

5,000 observer samples were randomly drawn from logbook data under various levels of coverage (sequential from 5% to 100%). Let,

y_t, and x_t denote observer bycatch and tuna catch values per trip, respectively;

μ_y, μ_x, the population mean bycatch and mean catch (or number of sets), respectively;

N and n, the number of trips in logbook and observer data, respectively.

The population ratio R calculated from logbook data and the sample ratio r from each simulated data were defined as:

$$R = \frac{\mu_y}{\mu_x} \quad \text{and} \quad r = \frac{\sum_{t=1}^{n} y_t}{\sum_{t=1}^{n} x_t} \tag{1}$$

The relatives bias ($relB$) and root mean square error ($relRMSE$) were calculated for each coverage level and each bycatch species using equation 2 and equation 3; where $E(r)$ is the expectation of the ratio obtained from the 5,000 bootstrap samples.

$$relB = \frac{E(r) - R}{R} \tag{2}$$

$$relRMSE(r) = \frac{\sqrt{E(r - R)^2}}{R} \tag{3}$$

The relative values of bias and root mean square error are preferred to the absolute values in order to compare results obtained on the basis of the effort and the catch taken as auxiliary variables.

Uncertainty in bycatch estimates

Using a Taylor series expansion of this simple ratio, i.e r around μ_y and μ_x, van Kempen and van Vliet (2000) demonstrated that the ratio used above is only asymptotically unbiased and proposed an approximate expression of the unbiased ratio as follows:

$$r_v = \frac{\bar{y}}{\bar{x}} - \frac{1}{n}\left(\frac{\mu_y}{\mu_x^3} var(x) - \frac{cov(y,x)}{\mu_x^2}\right) \tag{4}$$

Bootstrap approximation of r_v

Ratio is used in general as raising procedure because the amount of non target species is only known at the sample level. In fishery real-life data, the population total bycatch is not available. This means that in practice, Equation 4 is not directly calculable because μ_y is unknown. We used bootstrap approach to derive an unbiased estimation (μ_y^*) of the bycatch average per trip using observer data. Equation 4 becomes 5.

$$r_v^* = \frac{\bar{y}}{\bar{x}} - \frac{1}{n}\left(\frac{\mu_y^*}{\mu_y^3} var(x) - \frac{cov(y,x)}{\mu_y^2}\right) \tag{5}$$

We finally compare the performance of the three ratio estimators (r, r_v and r_v^*) to the real ratio (R) on the basis of their average value estimated from the 5,000 samples.

3. Results

Magnitude of bias and uncertainty in bycatch estimates

The results obtained by using the effort as auxiliary variable were similar to those obtained by using the catch, for all species. Only the relative bias of the mahi-mahi was different with a correlation of 0.4 (Table 2). The simple ratio estimator induced bias and uncertainty in bycatch estimates. The magnitude of bias and variability were strongly dependent on the bycatch species and the sampling coverage (Figures 1-2). Swordfish was the less predictable bycatch with the highest bias and uncertainty on the estimates. Both bias and uncertainty were shown to be inversely proportional to the sampling coverage with a logarithmic trend for uncertainty (Figure 1). While the magnitude of bias seemed relatively low (less than $\pm$ 5%) for all species, the error on the estimates were relatively high, particularly for low sampling. This uncertainty on bycatch estimates was between 10 and 50% when coverage rate was smaller than 20% for silky, mahi-mahi and blue marlin; however swordfish estimates was highly unprecise whatever the level of sampling coverage.

The bias and precision in bycatch estimates depended on the sampling coverage and the importance of the fishery (Figure 3). For the same sampling coverage, estimates were less precise in small fisheries, i.e with the lowest number of trips. This means the coverage rate is not a sufficient factor that impacts the precision in bycatch estimates. The absolute number of observed trips also matters.

Comparison of estimators

The expectation of the simple ratio estimator was distinct to the true value of the ratio R when sampling coverage was less than 30%. The bias induced by this ratio estimator was positive in general, meaning that the biased ratio r overestimated bycatch. The expection of the simple ratio was different to the others (r_v, r_v^*) which were very close (Figure 4). Howerer the three estimators (r, r_v, r_v^*) described above seemed very similar when the sampling coverage was less than 30%. The bootstrap approximation of the unbiased ratio estimator (r_v^*) seems comparable to r_v when sampling coverage reaches 5%.

4. Discussion

Only observer data collected in 2000 on fishing sets made on floating objects were used in the present analysis for reasons of homogeneity. Hence, we expected to avoid temporal (i.e. annual) and fishing mode effects within the simulation procedure. Simulation results could then differ if they were based on another dataset. The magnitude of bias and uncertainty in bycatch estimates would certainly be higher than those obtained here had we considered sets made on free swimming schools because bycatch tends to be rare in free swimming schools sets (e.g. Amandè et al. 2009).

Our results showed that using the catch or the effort as auxiliary variable did not affect the precision and bias in bycatch estimates. This is due to the fact that total tuna catch per trip was proportional to the number of sets per trip in the data considered in this analysis. Our results differ to those obtained by Amandè et al. (in press) in which raising procedure was done at the set level. However, the true statistical unit is the trip (Borges et al. 2005). Conducting the analysis at trip level (re-sampling trips rather than sets) is also consistent with the practical aspects of observer sampling design in purse seine fisheries.

The ratio proposed by van Kempen and van Vliet (2000) is an "unbiased" expression of the simple ratio obtained by using a second order of Taylor series expansion. This estimator remains still quite biased for a low coverage rate because it remains a mathematical approximation. However this approximate ratio gave best results compared to the simple ratio estimator. In practice the formula proposed by van Kempen and van Vliet (2000) is not directly useful for estimate bycatch. Bootstrap approach could be used to obtain similar results as what was expected when using the unbiased ratio estimator.

5. Conclusion

We showed that bias and uncertainty in bycatch estimates depend on the species, sampling coverage, and the absolute number of trips made at the level of the whole fishery. The fishery importance combined with the sampling coverage represents the absolute number of observed data that will be considered when planning observer programme for bycatch assessment. In our case, tuna catch used as auxiliary variable gave similar results in terms of bias and uncertainty as the fishing effort expressed in numbers of sets. Because bycatch estimates highly depend on the species distribution, it is of major importance to correct for bias and provide precisions associated with bycatch estimates.

6. Acknowledgments

We thank IATTC administrators and scientists, particularly Nick Vogel for his wonderful work on observer database management. We are grateful to Laurent Dagorn (IRD) for his collaboration. This work was financially supported by the IRD-DSF (http://www.ird.fr/les-partenariats/soutien-et-formation-des-communautes-scientifiques-du-sud) and the European project MADE (http://www.made-project.eu).

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Table 1: Characteristics of non target species selected for the simulation tests

Specie scientific name	Common name	Characteristics
Coryphaena hipurus	Mahi mahi	One of the most species in tuna fisheries with common characteristics between fisheries. Mahi mahi occurs in 85% of sets but the number of individuals caught is highly dispersed and can vary from 1 to more than 2000 individuals.
Carcharhinus falciformis	Silky shark	The most frequent species of elasmobranches in purse seine fisheries with about 1/3 of positive occurrence in their catch per set. The distribution of silky shark per set is skewed and overdispersed. (*See Minami et al. (2007), Amandè et al. (2008), Watson et al. (2008), Romanov (2008)* for more details).
Xiphias gladius	Swordfish	Rare in purse fisheries (> 99% of zeros) with low variance. The number of swordfish observed per set is always low (more than 99% of observations don't exceed 3 individuals) when positive occurrence.
Makaira nigricans	Blue marlin	The blue marlin could be considered as middle occurrence specie in purse seine fisheries i.e more frequent than swordfish and less than silky shark. But in contrary to swordfish the number of individuals can attend 10 invididuals.

Table 2: Correlation between results obtained using effort or using the catch as auxiliary variable.

Specie	Relative Bias	Relative mean square error
Mahi mahi	0.4	1.0
Silky shark	0.9	1.0
Blue marlin	0.8	1.0
Swordfish	0.9	1.0

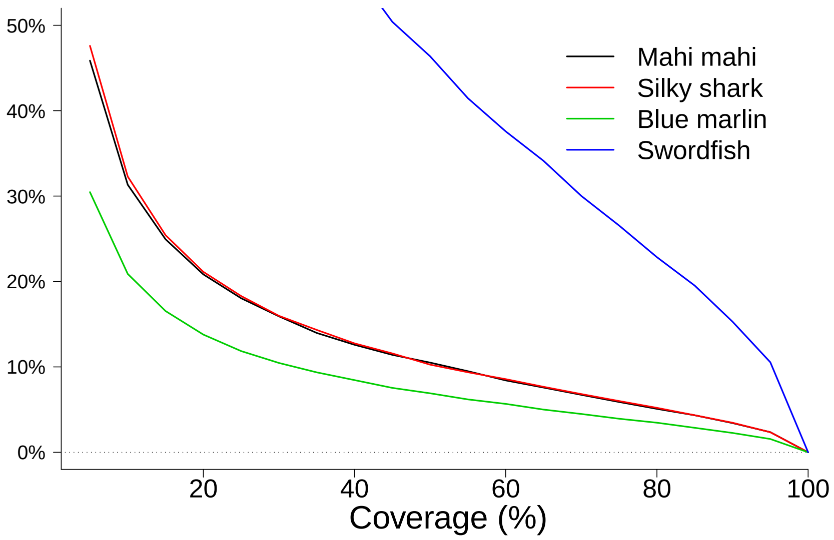

Figure 1: Uncertainty in bycatch estimate as a function of sampling coverage

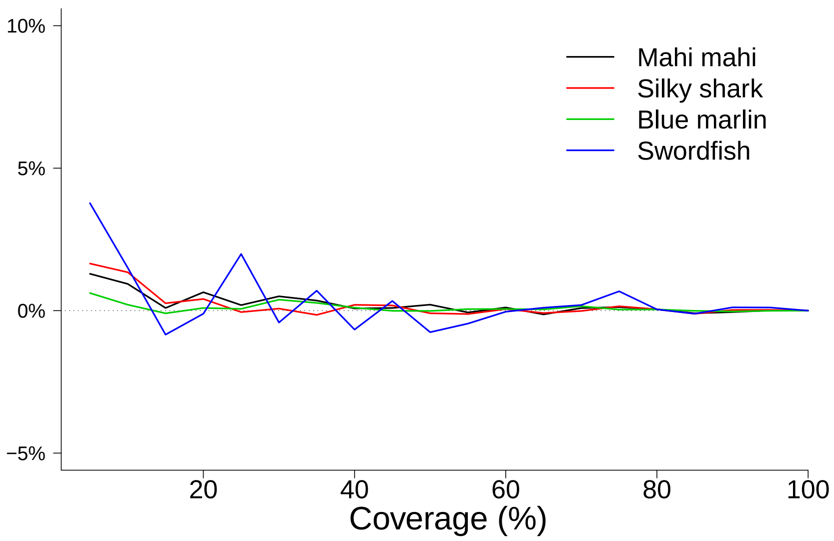

Figure 2: Bias in bycatch estimate as a function of sampling coverage

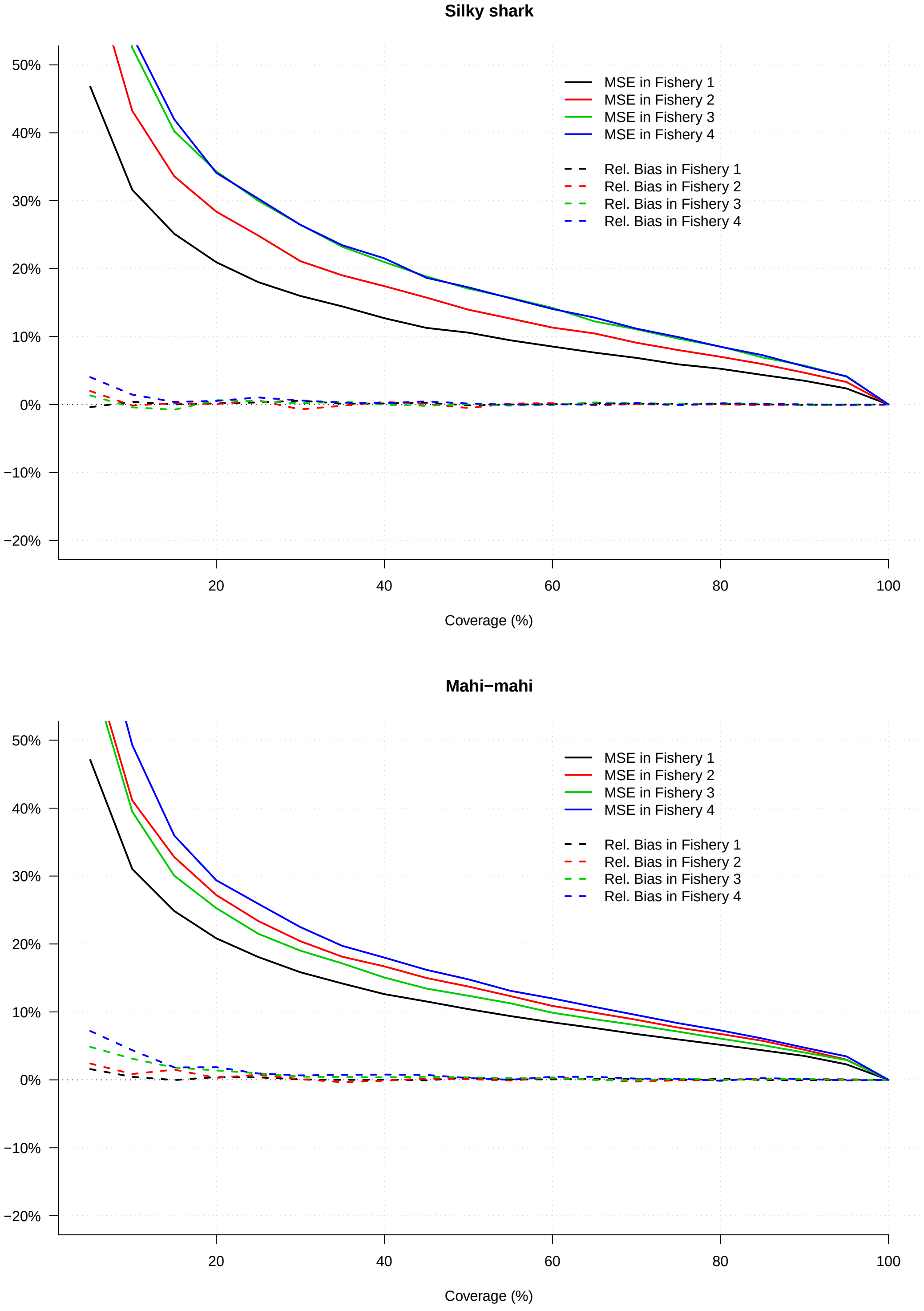

Figure 3: Bias and uncertainty as a function of observer coverage and importance of fisheries. Fisheries 1,2,3 and 4 have 449, 225, 150 and 113 trips, respectively.

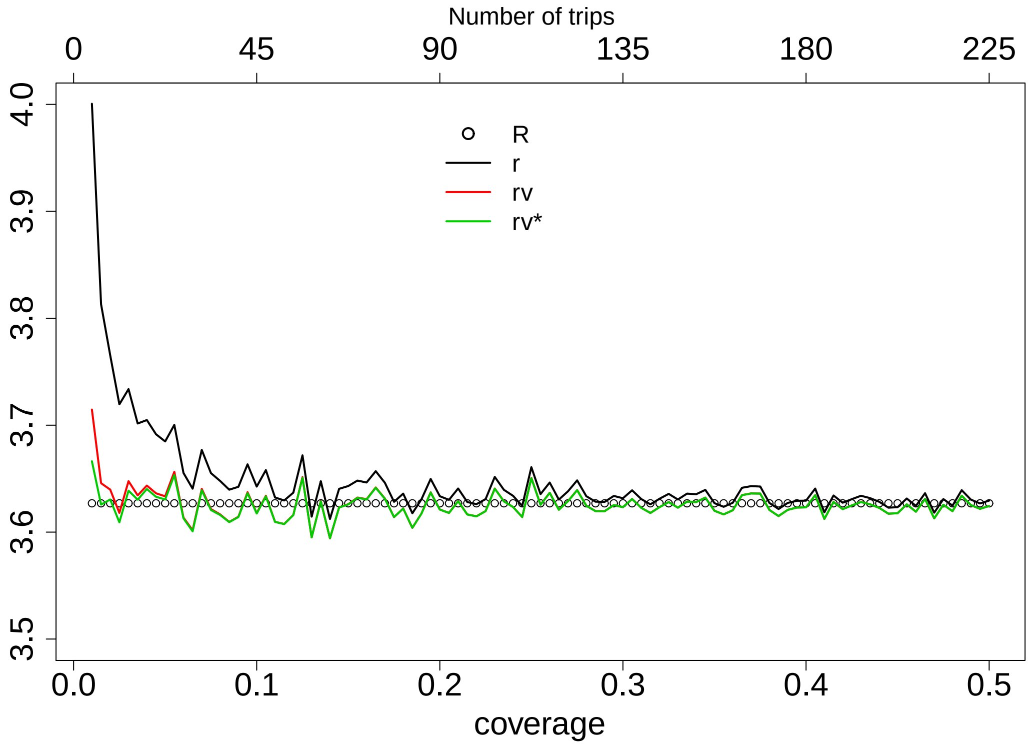

Figure 4: Comparison between the simple ratio (r), the unbiased ratio (r_v) proposed by van Kempen and van Vliet (2000) and the bootstrap approximation of the unbiased ratio (r_v^*)