An assessment of electronic monitoring in Australian tuna longline fisheries

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ABSTRACT

Electronic monitoring (EM) has the capacity to collect fisheries-dependent data to support fisheries management decision-making. In Australia, an integrated EM system was implemented as a replacement for at-sea observers in several managed fisheries, including the tuna longline fisheries from 1 July 2015. In these fisheries, EM is used as an audit tool to independently validate fisheries logbook information. To assess whether the Australian EM system was meeting key objectives we: (i) compared EM analyst and fisher-reported logbook data to examine the level of congruence in reporting of both retained and discarded catch and protected species interactions and; (ii) analysed changes in logbook reported nominal catch and discard per unit effort (CPUE and DPUE) and interactions with protected species per-unit-effort (IPUE) post EM implementation. In general, congruence between fisher-reported logbook and EM analyst data for the tuna longline fishery was higher for retained than discarded catch. However, there was variability among individual species and species groups. Data reported for some species were highly congruent (e.g. tuna, swordfish) but for others there were taxonomic (e.g. escolar and rudderfish), identification (e.g. sharks, marlins) and reporting (e.g. marine turtles, sharks and marlins) issues, which reduced overall congruence. For many species that were discarded, the number reported in the logbook was higher than that reported by the EM analyst due either to species being grouped into a mixed category or individuals not being observed. Our analysis of logbook changes in the tuna longline fishery identified significant increases in fisher-reported logbook DPUE for target, byproduct and bycatch species and IPUE for marine seabirds, mammals and turtles in the two years following the implementation of EM relative to the previous six years. Not discounting possible environmentally-driven shifts in availability and abundance, as well as individual vessel effects, weight of evidence suggests the use of EM as an audit tool has led to significant changes in logbook reporting. We contend that both analyses provide an important insight into the ability of the EM, when used as an audit tool, to lead to improvements in logbook reporting behaviour and to record and report the capture of all species in tuna longline fisheries.

INTRODUCTION

Over the last two decades, technological advancements in fisheries monitoring have led to the implementation of electronic monitoring (EM) in a variety of fisheries as both a replacement and supplement to at-sea observers (Larcombe et al., 2016; NMFS, 2017; Ruiz et al., 2015). Following successful pilot studies and trials, an EM system was introduced in several managed fisheries, including tuna longline fisheries by the Australian Fisheries Management Authority (AFMA) as a replacement for at-sea observers from 1 July 2015. Under the current program, AFMA uses the integrated EM system to validate fisher-reported logbook information with an audit target of 10% of sets (fishing events) from each vessel. This audit includes an analysis of catch composition, discards and interactions with protected species (i.e. species of special interest) (AFMA, 2015). Through the auditing and accompanying feedback process to fishers, AFMA aims to independently evaluate the veracity of fisheries logbook information as a source of data for assessing and managing fisheries.

One of the key objectives of the AFMA EM program in all fisheries is "increased confidence in data quality achieved through cross validation with data captured in logbooks and observer records" (AFMA, 2015). In order for this objective to be achievable, the EM system would need to be able to accurately record all retained and discarded catch and all interactions with protected species. Furthermore, fishers would need to be responsive to the feedback mechanism instituted by AFMA (i.e. audit report sent to fishers) by improving their logbook reporting. In order to assess this, we conducted two studies examining (i) the level of congruence between fisher logbook and EM analyst reporting and; (ii) changes in nominal catch and discard per unit effort (CPUE and DPUE) and interactions with protected species per-unit-effort (IPUE) post EM implementation.

METHODS

Congruence analysis

EM analyst and fisher-reported logbook data from the first two financial years of EM operation (1 July 2015 to 30 June 2017) were collated and aggregated by set to examine the level of congruence in data for retained and discarded catch and interactions with protected species. Species were classified based on their role in the fishery (see Table 1). This analysis was undertaken using two separate methods: (i) generalised linear model (GLM) analysis and; (ii) percentage difference analysis.

Similar to Briand et al. (2017), we fitted GLMs to catch data (counts of individuals) reported for each set, in each year, to evaluate the variability between EM and logbooks in reporting retained and discarded catch. The form of the GLM was as follows:

$$EM \sim L * Y + \varepsilon$$

Where EM is the count of individuals in each set from electronic monitoring, L is the count of individuals in each set from fisher logbooks, Y is the year and ε is the model error assumed to be normally distributed. Only sets where catches were observed (number >0) from either EM analyst or logbook data were included in the analysis.

Model fit was determined using the pseudo R^2 measure for estimating the deviance explained by the model (D^2) following Guisan and Zimmermann (2000). The regression slope, y-intercept and standard deviation of the residuals were estimated and the fitted model was compared to the expected 1:1 relationship (slope of 1, y-intercept of 0). Where the confidence intervals encompassed or approached 0 for the intercept and 1 for the slope, the data reported from EM and logbooks were considered to be congruent (Pineiro et al., 2008). The main effect of Y and the interaction between L and Y were used to evaluate whether the intercept and/or the slope of the relationship between EM and logbook data varied between years (i.e. 2015/16 and 2016/17) respectively.

To explore the difference in reporting for individual species and interactions with protected species (i.e. species of special interest), we calculated the percentage difference in reported catches from fishers in their logbook and EM analysts rather than use GLMs, because the number of observations were too low and variance too high. The percentage difference was calculated as the difference between the number of individuals reported by the EM analyst and by fishers in logbooks divided by the number of individuals reported by the method with the greatest number. For this analysis, protected species were combined into groups including: marine seabirds, turtles, mammals and sharks.

Further information on the methods employed can be found in the accompanying IOTC information paper IOTC-2018-WPDCS14-INF04 (Emery et al. in press).

Table 1. List of species that were classified as either target or byproduct (i.e. retained more than discarded) for Australian tuna longline. All other species were classified as bycatch (i.e. discarded more than retained)

Fishery	**Target**	**Byproduct**
Tuna longline	Albacore tuna (*Thunnus alalunga*)	Mahi mahi (*Coryphaena hippurus*)
	Broadbill swordfish (*Xiphias gladius*)	Moonfish (mixed) (Lampridae)
	Yellowfin tuna (*Thunnus albacares*)	Ray's bream (*Brama australis*)
	Striped marlin (*Kajikia audax*)	Shortbill spearfish (*Tetrapturus angustirostris*)
	Bigeye tuna (*Thunnus obesus*)	Shortfin mako (*Isurus oxyrinchus*)
		Wahoo (*Acanthocybium solandri*)
		Rudderfish (*Centrolophus niger*)
		Southern bluefin tuna (*Thunnus maccoyii*)

Logbook reporting analysis

Logbook data from the first two financial years of EM operation (1 July 2015 to 30 June 2017) were collated and compared to the previous six financial years without EM to examine changes in logbook reported nominal CPUE, DPUE and IPUE in the tuna longline fishery.

Retained and discarded species were classified based on their role in the fishery – target, byproduct and bycatch (see Table 1). Protected species were combined into groups for analysis including: marine seabirds, turtles, mammals and sharks.

Nominal CPUE, DPUE and IPUE were calculated by dividing the total number of species retained, discarded or interacted with by the unit of effort (1,000 hooks). We calculated nominal CPUE, DPUE and IPUE for vessels that had fished in every year during the selected period (2009/10 to 2016/17) to reduce the overall variability caused by different vessels entering and exiting the fishery.

Initial linear regression showed serious violations of homogeneity, so we applied a generalised least squares (GLS) approach following Zuur et al. (2009). Using GLS, we defined a variance structure that allowed for modelling different residual variation for CPUE, DPUE and IPUE per EM and non-EM year. The Akaike information criterion (AIC) was lower for the model using the different variances per EM and non-EM years.

Further information on the methods employed can be found in the accompanying IOTC information paper IOTC-2018-WPDCS14-INF05 (Emery et al. in review).

RESULTS & DISCUSSION

Congruence analysis

In general, congruence was higher for retained than discarded catch in the tuna longline fishery, however fishery-wide estimates of congruence concealed a large amount of variation among individual and groups of species. While the reporting of retained target species were equivalent (Figure 1a, Figure 2a), there were large discrepancies for other byproduct and bycatch species (Figure 1b, 1c and Figure 2a), particularly those discarded (Figures 1b, 1d, 1f and Figure 2b). Furthermore, with the exception of marine seabirds, it was evident that protected species interactions were being missed by the EM analyst, with fishers consistently reporting higher numbers across both years in their logbooks (Figure 3).

The observed divergence between the EM analyst estimates and logbook reporting by fishers may have been due to one, or a combination of: (i) species identification issues; (ii) taxonomic issues or (iii) missed observations from both the EM analyst and/or fisher. For instance, there were clearly some taxonomic issues in regard to the reporting of escolar (*Lepidocybium flavobrunneum*) and rudderfish (*Centrolophus niger*), which led to the EM analyst reporting them as escolar and fishers reporting them as rudderfish in their logbook. Anecdotal evidence also points to similar issues in the logbook reporting of snake mackerel (*Gempylus serpens*) and escolar. There were also species identification issues, particularly among those discarded, leading to them being grouped into more general species categories (Table 2). For example, 46% of discarded tuna species were grouped into the tuna (mixed) category by the EM analyst, while this proportion was even higher (76%) for marlins, spearfish and sailfish species (Table 2). Furthermore, failure of the EM analyst and/or the fisher to detect the capture of some species likely contributed to their lack of congruence. For example, shark and marlin species, along with marine turtles, were reported in greater numbers by fishers in their logbooks than by the EM analyst. This could be due to these species being cut off (i.e. in the case of sharks to avoid potential injury to the crew) or dropping off the line before entering the camera's field of view, thus preventing detection by the EM analyst. This was observed during the integrated EM system pilot study in the Australian tuna longline and the Alaskan Pacific halibut longline fishery (Ames et al., 2007; Ames et al., 2005; Larcombe et al., 2016).

Table 2. Numbers of discarded individuals by species and species group (i.e. mixed species) reported by the EM analyst and in logbooks in the tuna longline fishery between 2015/16 and 2016/17

<table>
<tr><th>Species Group or Species</th><th>Electronic Monitoring</th><th>Logbook</th><th>Proportion grouped by EM analyst</th></tr>
<tr><td>Tuna (Mixed)</td><td>719</td><td>0</td><td rowspan="5">46%</td></tr>
<tr><td>Yellowfin tuna</td><td>298</td><td>788</td></tr>
<tr><td>Bigeye tuna</td><td>96</td><td>252</td></tr>
<tr><td>Albacore tuna</td><td>463</td><td>711</td></tr>
<tr><td>Total</td><td>1,576</td><td>1,751</td></tr>
<tr><td>Escolar and Oilfish</td><td>260</td><td>0</td><td rowspan="5">37%</td></tr>
<tr><td>Escolar</td><td>406</td><td>301</td></tr>
<tr><td>Oilfish</td><td>36</td><td>17</td></tr>
<tr><td>Rudderfish</td><td>0</td><td>362</td></tr>
<tr><td>Total</td><td>702</td><td>680</td></tr>
<tr><td>Marlins, Spearfishes, Sailfishes</td><td>261</td><td>3</td><td rowspan="7">75%</td></tr>
<tr><td>Blue Marlin</td><td>35</td><td>216</td></tr>
<tr><td>Black Marlin</td><td>18</td><td>128</td></tr>
<tr><td>Striped Marlin</td><td>16</td><td>54</td></tr>
<tr><td>Shortbill Spearfish</td><td>11</td><td>11</td></tr>
<tr><td>Sailfish</td><td>5</td><td>6</td></tr>
<tr><td>Total</td><td>346</td><td>418</td></tr>
</table>

The issues identified in this study could be addressed through more effective camera placement, changes to vessel operational practices, increased education of fishers or modification of the existing management incentives for logbook reporting. If not addressed, these deficiencies could create a disincentive for fishers to accurately report in their logbook if they believe the EM analyst is failing to observe all retained, discarded catch and protected species interactions during their audit. This could potentially result in the AFMA objective for the EM program (i.e. increased confidence in logbook reporting) not being attained. However, the AFMA EM program is still in its infancy and is flexible enough to continue to evolve in response to ongoing scientific review and feedback from stakeholders.

Logbook reporting analysis

There was no significant increase observed in the logbook-reported nominal CPUE for target, byproduct and bycatch species in the tuna longline fishery (Figure 4), which in the absence of shifts in environmental conditions and fleet behaviour would be expected, given that the number and weight of retained target, byproduct and bycatch species in both fisheries are independently verified upon landing (through catch disposal records).

Conversely, there was a significant increase in logbook reported nominal DPUE for target, byproduct and bycatch species (Figure 4). While it is possible that this could have been driven by shifting environmental conditions, (e.g. increasing total abundance or availability) or individual vessel effects (e.g. changes to targeting practices or catchability through time), it seems unlikely that availability and catchability would have increased for all these species groups simultaneously during the EM years. Furthermore, various studies have documented historical underreporting of discarded target, byproduct and bycatch species in logbooks in the tuna longline fishery (Campbell, 2013; AFMA, 2009, Bromhead et al. 2006).

The IPUE for marine seabirds, turtles and mammals also significantly increased in the EM years (Figure 5). While again it was not possible to discount possible increases in abundance, availability or catchability driving this change, it seems unlikely given the low productivity (e.g. slow growth, late maturation and low fecundity) of the protected species groups (Musick, 1999) and the documented historical underreporting of interactions in both fisheries (AFMA, 2009; Bromhead et al. 2006).

Taking a weight of evidence approach to the results suggest the use of EM as an audit tool in the tuna longline fishery has led to changes in logbook reporting. Assuming this supposition is valid, the success of the AFMA EM program, which is still in its infancy, is made even more significant considering the current lack of any evaluation standards for logbook reporting. Determining prescribed tolerances for logbook reporting, as similarly undertaken in Canadian fisheries (Stanley et al. 2011), may further increase logbook reporting performance through facilitating certainty among industry as to AFMA's expectations. This could lead to a permanent "observer effect", in which fishing and logbook reporting behaviour changes fleet-wide, instead of on individual vessels or trips that are randomly selected to carry an at-sea observer (Faunce et al. 2011; Benoit & Allard, 2009).

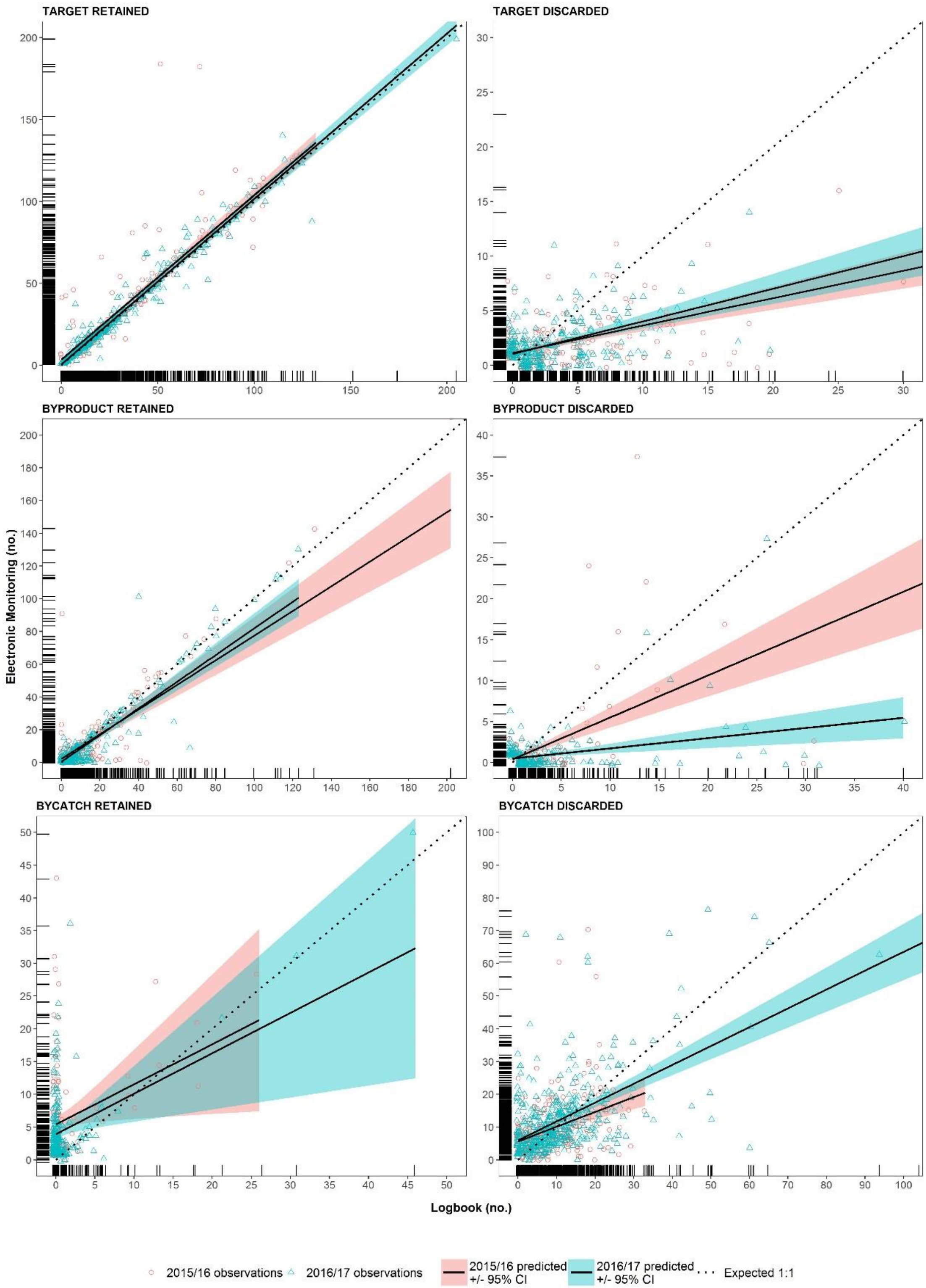
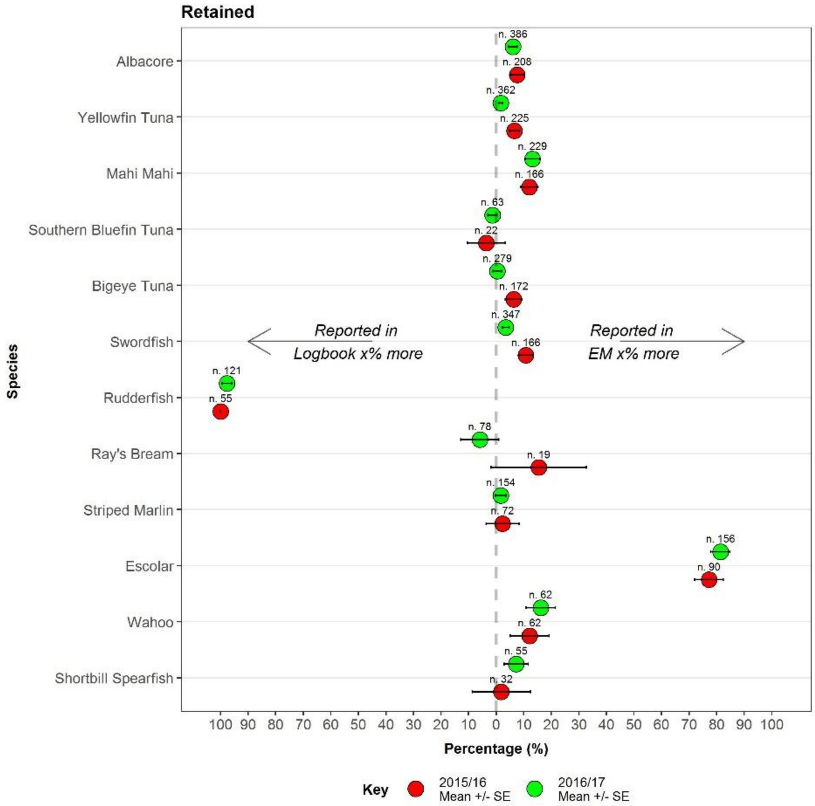


Figure 1. Estimated regression for 2015/2016 (solid black line with red shading) and 2016/2017 (solid black line with blue shading) and equal 1:1 relationship (dotted black line) between EM analyst and logbook reporting of species groups in the tuna longline fishery. Note some figures have been truncated to reveal patterns in data.



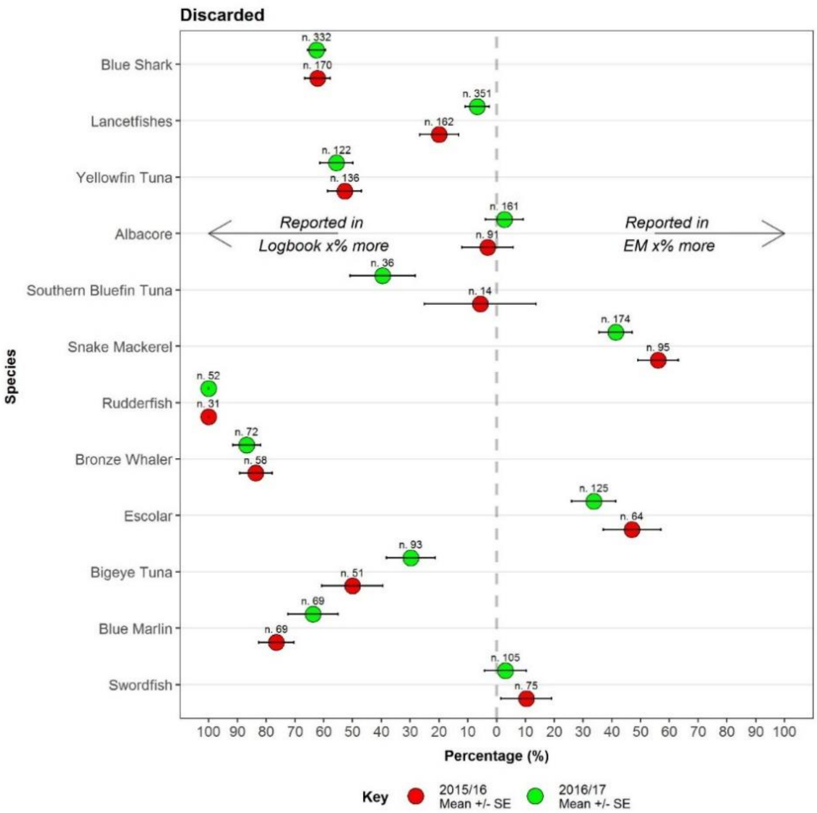


Figure 2. Proportional difference in individual species reported as retained and discarded in the ETBF logbooks and by EM analysts across all sets in 2015/16 and 2016/17 financial years. Species are ordered by top twelve reported species from 2015/16 and 2016/17 logbook data. The number above the mean is the total number of sets audited.

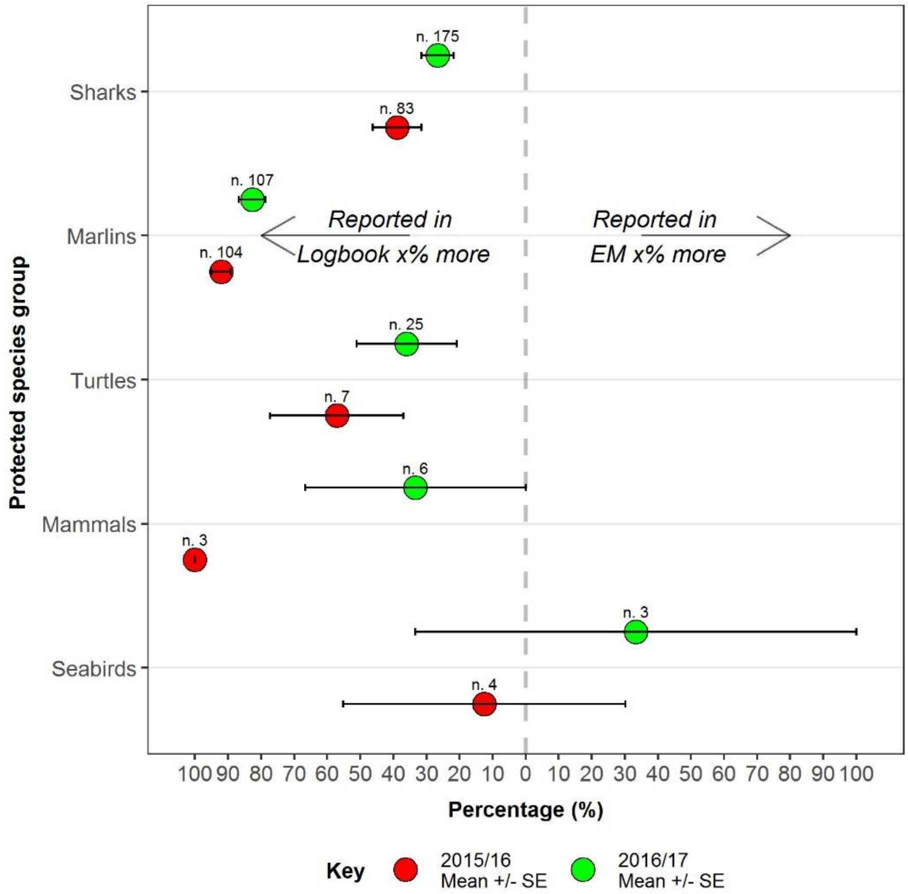


Figure 3. Comparison of logbook to EM analyst reporting in 2015/16 and 2016/17 by set for interactions with protected and no-take species in tuna longline.

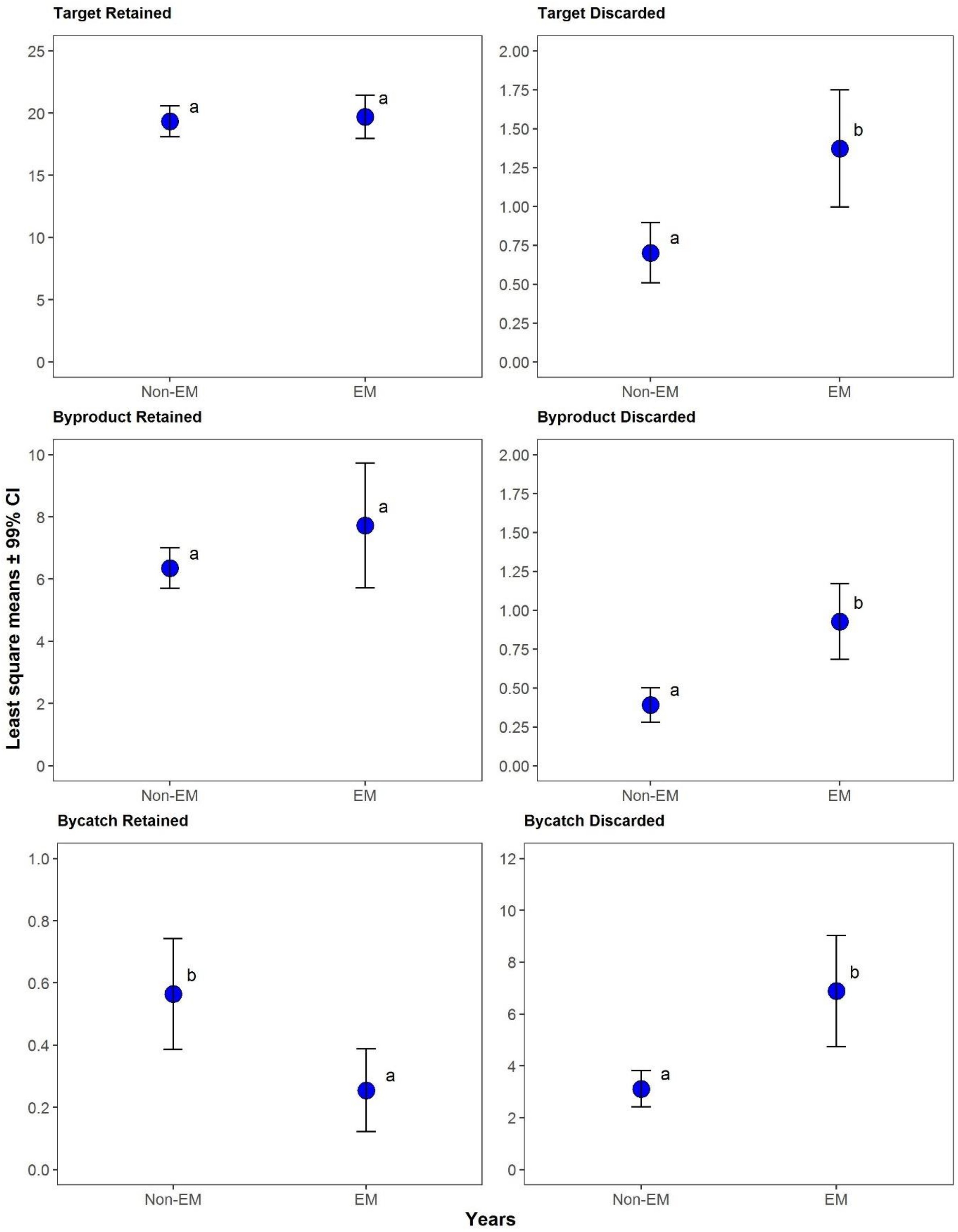


Figure 4. Least square means ± 99% CI of catch and discard per unit effort (CPUE and DPUE) (no. individuals retained and discarded per 1000 hooks) by tuna longline vessel that fished all years in EM (2015/16 and 2016/17) and non-EM (2009/10 to 2014/15) years for target and discarded species groups. Means not sharing a letter are significantly different at $p<0.01$ (Tukey-adjusted comparisons).

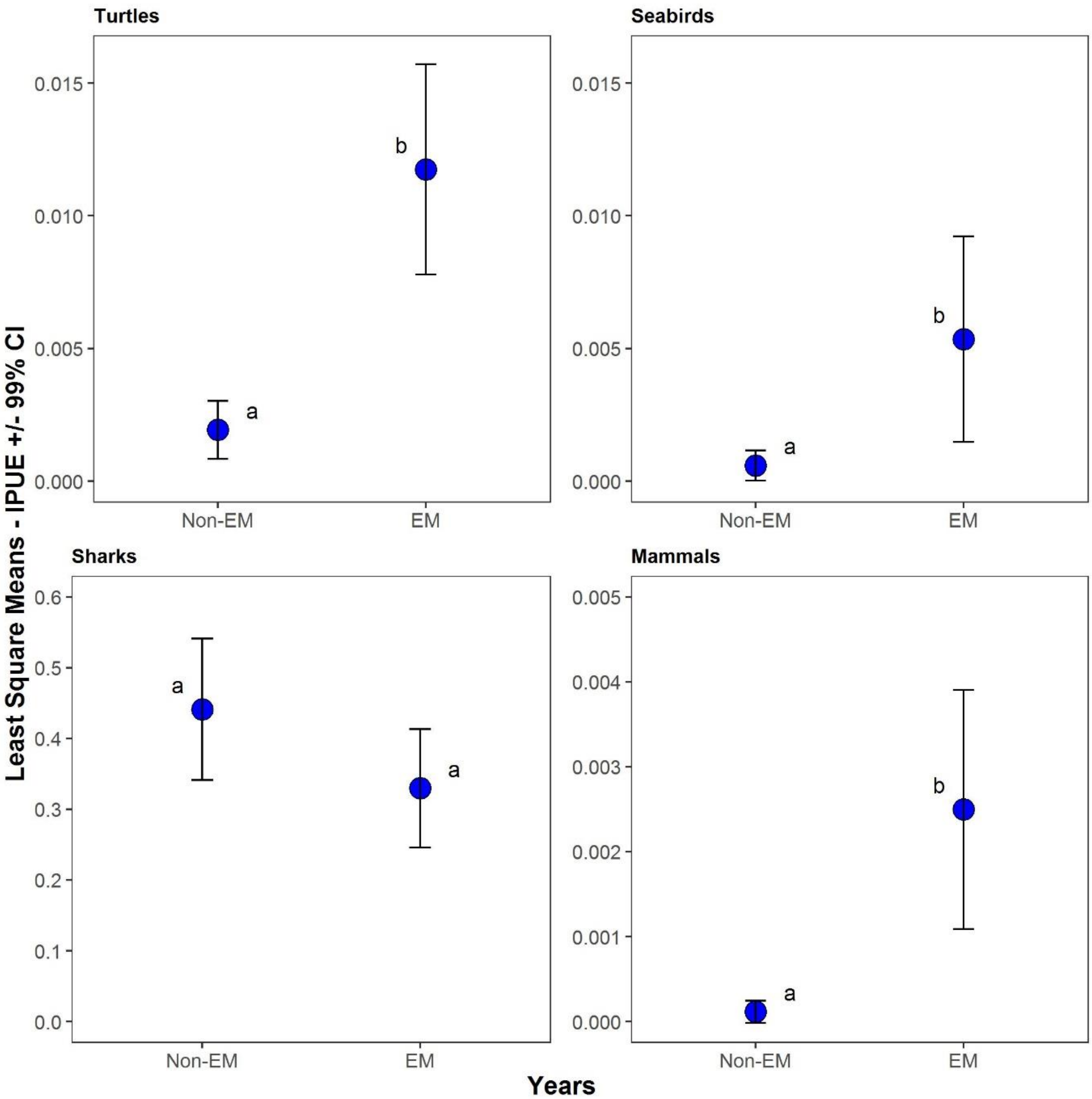


Figure 5. Least square means ± 99% CI of protected species interaction per unit effort (IPUE) (no. individuals interacted with per 1000 hooks) by tuna longline vessel that fished all years in EM (2015/16 and 2016/17) and non-EM (2009/10 to 2014/15) years for groups of protected species. Means not sharing a letter are significantly different at p<0.01 (Tukey-adjusted comparisons).

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