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Catch reporting under E-Monitoring in the Australian Pacific longline fishery.

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Introduction

The Australian Fisheries Management Authority (AFMA) collects a range of data to aid in the assessment of fish stocks, assessment of the impacts of fishing on the environment, monitor compliance and to comply with Western Central Pacific Fisheries Commission (WCPFC) conservation measures. AFMA has relied on logbooks, at-sea observers, catch disposal records (landings) and port inspections as primary data sources. From 2009 AFMA commenced the trialling of electronic monitoring (EM) in a range of commercial fisheries under its management (Piasente et al. 2012). Subsequently, from July 2015 electronic monitoring was introduced to all vessels in Australia's Pacific tuna fishery (the Eastern Tuna and Billfish Fishery) with a phase-out of at-sea observers for fishing within the Australian exclusive economic zone (EEZ).

Electonic monitoring, as defined in Dunn & Knuckey (2013), is a combination of hardware (including cameras, gear sensors and GPS) and software that collects and transmits fisheries information in an automated manner that is closed to external or manual input or data manipulation. Because it is an automated operation and closed system, EM data are a significant tool for compliance purposes.

Piasente *et al*. (2012) identified the primary short-comings of the at-sea observer system in the Australian context. These included high cost (recovered from the fishing industry), high occupational health and safety risks, observer data quality/consistency control, difficulty in ensuring appropriate spatial and temporal coverage, limited pool of potential observers and problems with observer logistics (see also Dunn & Knuckey 2013). Further, it was recognised that the at-sea observer system was relatively ineffective at improving the quality of fishery dependant data across the whole fishery due to its relatively low coverage (around 5 per cent of hooks). There was also concern that the fishing behaviour while observers were on board may not have been reflective of "normal" activity and so there was potential for at-sea observer data to present a biased picture of the entire fleet. In the Australian context, EM was identified as a system that could address these short-comings and allow for greater (or effectively complete) coverage level with resulting increased compliance with management arrangements.

This study aims to share Australia's experience with EM implementation in Australia's Pacific longline fishery. Specifically, the objectives of this paper are to:

1) Describe the EM system used in the Australian Eastern Tuna and Billfish Fishery (ETBF).

2) Characterise the early performance of the EM system during its first eight months of operation.

The study focuses on the reporting and accurate estimation of retained catch and discards across the full suite of target, byproduct, bycatch and wildlife species categories. First, the design objectives and operating principles of the EM system are described. Second, we provide a brief summary of results from a trial of EM in Australia's ETBF previously reported in Piasente et al. (2012). Finally, we present some analysis of the initial eight months of the systems operation (July 2015–Feb 2016). This includes a comparison of catches derived from EM with the same catches derived from logbooks and an examination of the changes in the nature of logbook catch and discard reporting following the introduction of EM.

The Eastern Tuna and Billfish Fishery

The ETBF operates in the Australian Fishing Zone (AFZ) from Cape York to the South Australian-Victorian border and includes waters around Tasmania (Patterson et al. 2015). It can also operate on the high seas area of the Western and Central Pacific Fisheries Commission (WCPFC). However, fishing outside of the Australian EEZ has been very low in recent years.

The ETBF is mostly a pelagic longline fishery, although a small catch is taken using minor-line methods such as trolling, polling or hand-lining (AFMA 2015). The five key target species are yellowfin tuna, bigeye tuna, albacore, swordfish and striped marlin (AFMA 2015) which are each managed under a total allowable commercial catch. Other management arrangements include limited entry, zoning, spatial closures, bycatch provisions and gear restrictions (Piasente et al. 2012).

Some key monitoring concerns for the ETBF are (AFMA 2015):

- Interactions with protected species such as seabirds, turtles and some sharks
- Compliance with bycatch mitigation measures such as tori lines and a prohibition on the finning of sharks
- Discarding of the quota species (permitted but must be recorded)
- Accuracy of the recording of bycatch species.

EM System Objectives and Design

The overall objective of the ETBF EM system is to improve the quality and coverage of the data and information that is provided by vessels—essentially to improve the logbook data and to improve compliance with management measures. In this context, the following objectives and outcomes are pursued by the ETBF EM system:

- Verify the reporting of amount and type of fish
- Verify the reporting of interactions with protected species
- Reduce the costs in comparison to on-board observers
- Better target compliance and enforcement actions where they are needed without penalising responsible fishers (risk-based approach).

A critical aspect of the EM system is its 'always-on' nature, where close to 100 per cent of operations are recorded and may be subject to later analysis, feedback and compliance action—the ETBF target sample size for analysis of the EM data is 10 per cent. This contrasts with traditional on-board observers which, in the case of the ETBF, covered approximately 5 per cent of hooks. These on-board observer data are subject to the 'observer effect' where behaviour of vessels and the accuracy of reporting changes in the presence of the observer (demonstrated in Campbell 2013). However, the at-sea observer program may have little influence on vessel behaviour and reporting in the un-observed 95 per cent of hooks.

Figure 1 illustrates the functioning of the EM system for longline fishing in the Australian ETBF. Time-stamped video, sensor and GPS EM data are recorded and stored on hard drive during all longline setting and hauling operations (see Figure 2 for a diagram of the on-board EM components). Raw EM data are provided to the management agency (and its contractor

Archipelago Asia Pacific) for analysis. Analysis involves deriving data from events in the EM data streams and then alignment with the data provided in the vessels logbooks for the purpose of verifying those logbooks for accuracy of, for example, catch/discard reporting, reporting of protected species and use of bycatch mitigation measures (see Figure 3 for some screenshots of the EM data analysis environment).

Vessels are provided with regular feedback reports on their performance with respect to the accuracy of their logbooks (see example feedback in Table 1), as well as the operation and maintenance of the on-board EM system (on issues such as operational status, camera obstruction and cleaning). The final step in the cycle is an improvement in the compliance of vessels with data reporting and fishing practice requirements through the feedback process and, if necessary, through enforcement actions. In cases where catches are recorded in the log but not in the EM data, there is also a feedback process to modify the camera views or change deck handling practices to improve EM accuracy.

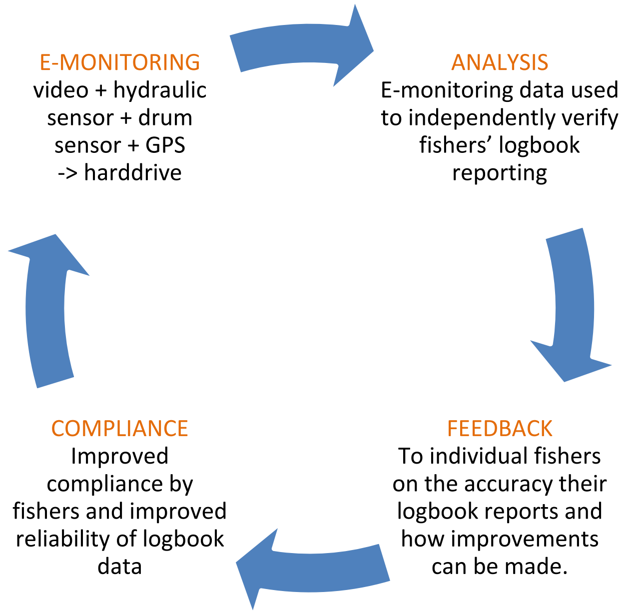


Figure 1: E-monitoring system for improving the quality and coverage of fishery-dependant data in the Australian ETBF.

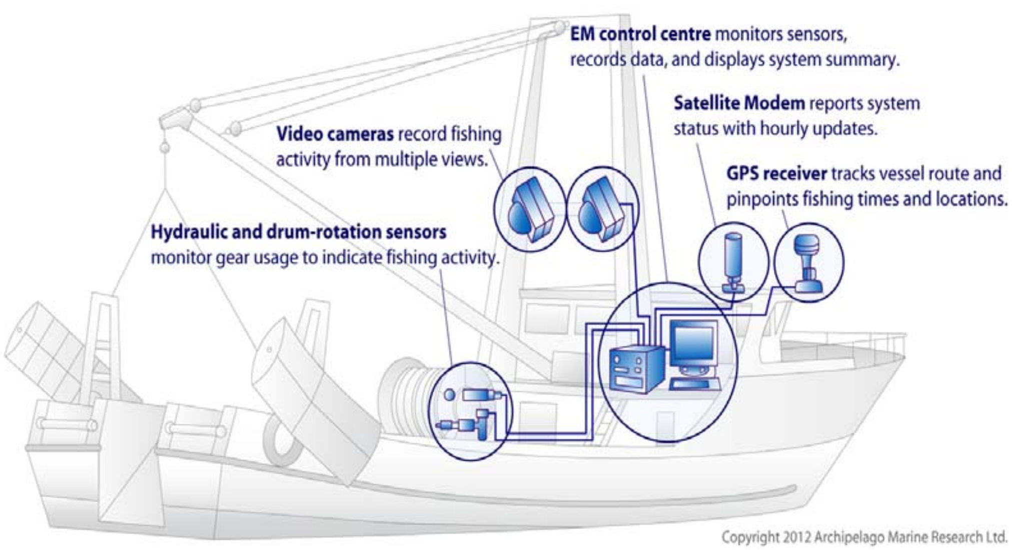


Figure 2: Typical e-monitoring hardware components (Source: Archipelago Marine Research)

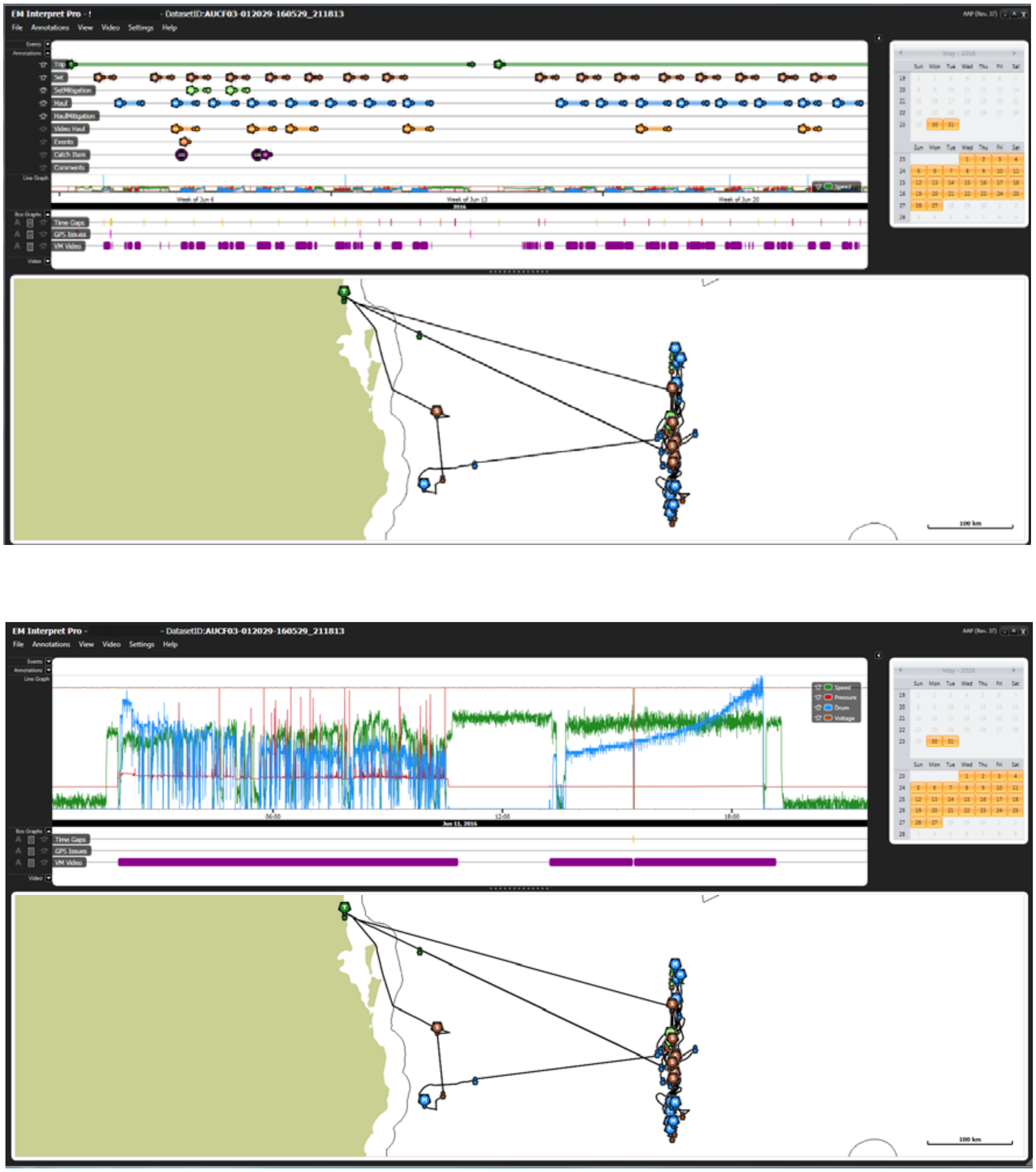


Figure 3: EM data analysis environment for deriving tabular/numerical data from events in the e-monitoring data streams which are then aligned with logbook data for the purpose of verifying logs.

Table 1: An example of individual fisher feedback on the accuracy their logbooks. Data are counts of fish species retained, released and total. On the left are counts from analysis of e-monitoring data and on the right from the vessels logbook.

	EM catch Review			Vessel Logbook		
Species	**Retained (pcs)**	**Released (pcs)**	**Total (pcs)**	**Retained (pcs)**	**Released (pcs)**	**Total (pcs)**
Quota Species						
Albacore	1	0	1	0	0	0
Bigeye Tuna	1	0	1	1	0	1
Yellowfin Tuna	15	1	16	14	0	14
Swordfish	1	0	1	1	0	1
Striped Marlin	1	0	1	1	2	3
Non – Quota Species						
Bronze Whaler	0	0	0	0	2	2
Crocodile Shark	0	2	2	0	2	2
Sharks	0	1	1	0	0	0
Oceanic Whitetip Shark	0	1	1	0	0	0
Escolar	1	0	1	0	0	0
Lancetfishes	0	0	0	0	2	2
Mahi Mahi	40	3	43	45	0	45
Marlin species	0	3	3	0	0	0
Sailfishes	0	0	0	0	1	1
Wahoo	2	0	2	2	0	2

Trial EM in the ETBF

Piasente et al. (2012) reported on the results of an EM trial conducted to determine the viability of using EM in the ETBF. The trial examined the efficacy of EM for specific monitoring tasks, developed an approach to use EM data to audit logbooks and undertook a cost benefit analysis of EM compared with at-sea observers. Research was conducted on ten vessels between October 2009 and August 2010 and involved parallel data collection with both EM and at-sea observers.

During the design phase of the trial a review of the current ‘at-sea’ observer data collection practices was undertaken to determine how camera views could be installed to capture and compare the same data. Vessel logbook and at-sea observer data were supplied to data analysts during the trial to enable comparisons between the data sources.

Image data from a sample of fishing events were reviewed for catch interpretation, seabird abundance and mitigation device deployment, and some compliance performance. The raw image data from a fishing trip were sampled for audit-based analysis against the logbook data and comparisons with the observer data. These comparisons were used to assess the quality of data from the three sources and to provide insight into the causes of missed catch from any of the sources. To validate the accuracy of image analysis results, hook-by-hook comparisons between electronic monitoring and observer catch data were undertaken.

An assessment of the uses of EM for compliance monitoring was undertaken. Compliance issues monitored and assessed during the project included handling and reporting of protected species interactions, use of seabird mitigation measures, dropping of clips during hauling, and catch handling and processing.

Trial outcomes

Overall, the electronic monitoring hardware systems functioned and operated successfully during the trial. A number of system performance issues were identified relating to either installation or service of the hardware.

The trial EM provided accurate temporal and spatial information on gear setting and hauling activities, aligning very closely with observer data. Results suggested that sensor data could be used to monitor the temporal and spatial elements of fishing effort and to audit the accuracy of corresponding logbooks records.

A total of 3794 catch items were compared between EM and at-sea observer data. Catch identification was aligned for 70.2 per cent of items, 4.8 per cent of items were detected by EM viewers but not the observer and 25 per cent of the items were recorded by the observer but not by the EM analyst. Most (75.7 per cent) of the catch items that were absent from the EM data were recorded as *released.* Differentiating the species of tuna for smaller sized fish (southern bluefin tuna, bigeye tuna and albacore) from video footage was difficult. Also, it is likely that species such as blue shark and lancetfish were undercounted in the trial due to fish being cut free from the lines or released without coming on-board and therefore out of the field of view of the trials cameras.

Trial EM analysts were not familiar with ETBF species hence used more general species groupings than observers. Camera placements, the lack of high resolutions and poor image quality also impacted species identification of catch.

In general, the camera view of the vessels' setting operations was shown to be reliable for monitoring the use of tori-lines. However, in the trial it was not possible to determine whether tori lines have been correctly deployed in accordance with AFMA's regulations and requirements.

In comparison to observers, there are obvious limitations assessing the extent of injury and survivability of captured protected species from electronic monitoring imagery.

Full EM introduction in the ETBF

Following the lessons of the EM trial and with the subsequent improvements in technology in some areas, full coverage of EM was introduced to the Australian longline fleet from July 2015. A key improvement from the trial system was the use of better quality and higher definition cameras that should improve the capacity for EM analysts to detect and identify catch and which afford better view of gear and mitigation deployment. There was also substantial development of the onshore processing component of the system (Figure 3). The routine deployment of at-sea observers for fishing within the Australian EEZ ceased from July 2015 and was replaced by EM.

Below we further assess the performance of the EM system by comparing catches derived from EM with the same catches derived from logbooks during the initial eight months of the EM systems operation (July 2015–Feb 2016). In addition, we examined the change in the nature of logbook reporting following the introduction of EM by comparing reporting rates for this same eight months with reporting rates in earlier years.

Comparison between EM and logbook data—the first eight months

During the eight month period from 1 July 2015 to 29 February 2016 there were a total of 288 operations (longline sets) subject to review by EM analysts (8 per cent of the total 3447 operations). For these 288 operations, retained catch and discard amounts were calculated from both the EM data and the logbook data. For the purposes of this analysis, a subset of taxa were selected and grouped into four categories: target species; secondary commercial and byproduct species; common but generally discarded species; and a category for mixed taxa. The latter category is only relevant in the EM database and corresponds to instances where only partial identification was possible by EM analysts hence individuals where grouped into categories such as 'sharks' or 'tunas'.

For all target species, with the exception of striped marlin, the EM observed retained catch was slightly higher than vessel logbooks (Figure 4a). Retained catch differences between EM and vessel logbooks range between 2 per cent for bigeye tuna and 12 percent for swordfish and mahi mahi. A similar pattern was demonstrated for secondary and byproduct species with EM retained catch figures tending to be somewhat higher than logbook figures in some cases by a larger margin (EM 29 per cent higher for rays bream; 83 per cent higher for skipjack tuna). As expected, the retained catch figures for the common but discarded category where extremely low for both EM and logbooks.

The reason for the consistently slightly higher EM catches for the target and secondary species is not clear. It may be that EM is more accurate than the logbooks or it may be that the some of the EM retained catch was actually discarded (i.e. fate wrongly recorded).

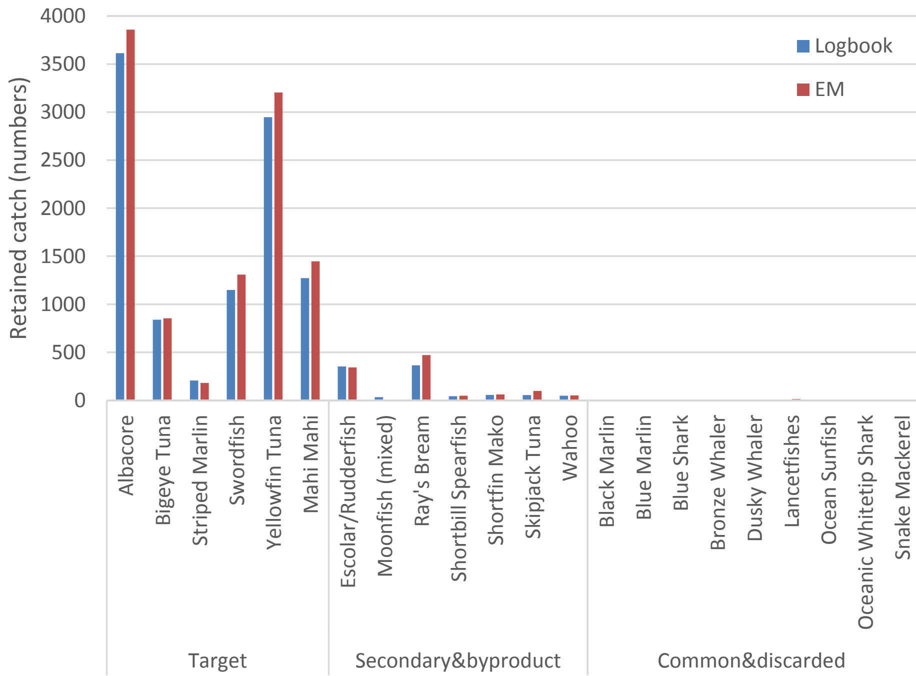
The overall pattern for the discarded catch (Figure 4b) appears to be reversed, with EM tending to report lower levels of fish discarded compared with the logbook data. For all target species, the number of EM observed discarded catch was lower in the EM figures compared to vessel logbooks (Figure 4b). Observed and reported discard differences ranged from 4 and 8 percent for mahi mahi and swordfish to 74 and 73 percent for striped marlin and yellowfin tuna. These large differences for the tuna species, particularly yellowfin, are partially explained by incomplete species identification by the EM analyst. There were some 220 mixed tuna recorded by EM that would account for most of the discrepancy in the EM discard figures. However, EM figures still remain lower than logbook records for tunas indicating some tuna discards were not detected by EM.

In the case of billfish discards, a similar partial identification issue was found where most of the apparent EM underestimates of black and blue marlin are accounted for in the mixed billfish category (Figure 4b). However, in the case of shark discards (blue, bronze whaler, dusky whaler and oceanic whitetip) EM figures are substantially lower than the log figures (Figure 4b) and most of this discrepancy is not explained by the addition of the mixed sharks category, suggesting that a large proportion of sharks (more than half) were not detected by EM.

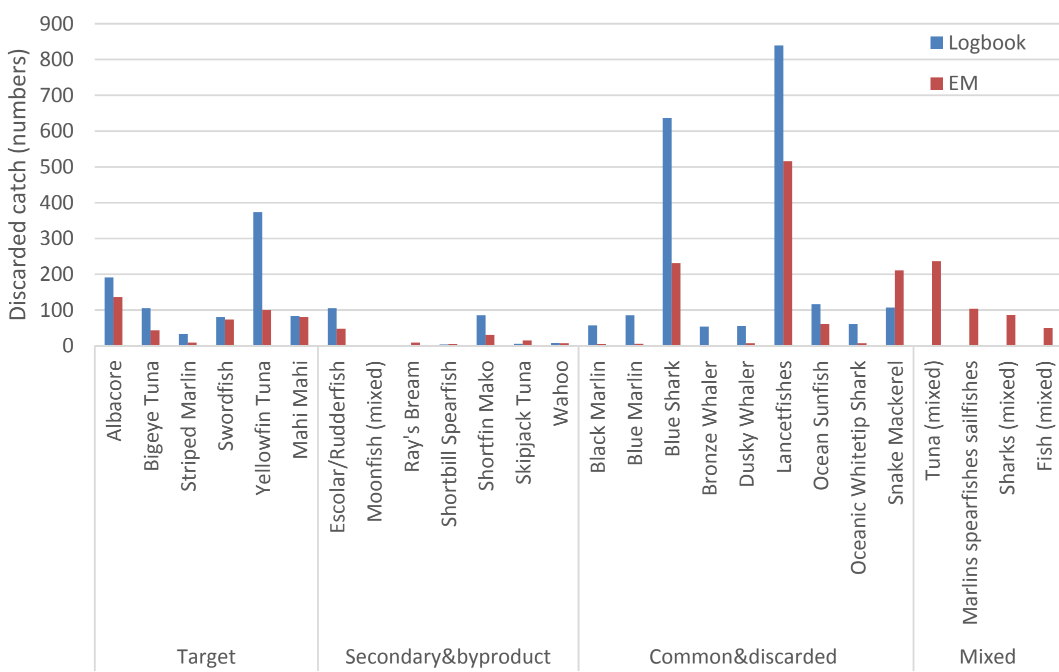
It is clear that the taxonomic resolution and the fish detection rate of EM is better for retained fish compared with discarded fish. This is likely explained by the on-board processes typical of Australian longliners where a large proportion of discarded fish are cut or jerked free of the line while in the water—a process that may go unobserved by the EM analyst (not detected by EM) or be poorly observed by the EM analyst (a mixed fish category).

Figure 4: Comparison between EM and logbook retained catch (n) reported in the Australian ETBF following the full introduction of e-monitoring (July 2015 to Feb 2016)

a) Retained



b) Discarded



Impact of EM on quality of logbook reporting—the first eight months

One the primary objectives of the Australian longline EM system is to improve quality and coverage of fishery logbook reporting. Conceptually, this would be achieved through the performance improvement cycle described in Figure 1. Here we seek to illustrate changes that have occurred in the logbook reporting during the first eight month period of EM operation when compared to an historical baseline. The unstandardized catch rates (fish per 1000 hooks) were calculated for the eight month EM period (1 July 2015 to 29 February 2016) and also for the same eight month period in each of the six earlier non-EM years commencing 2009. For ease of interpretation, the EM period year was then compared with a mean of the earlier non-EM baseline years to determine whether reporting rates had increased or decreased under EM. In addition to this comparison, individual annual catch rates for each species are also plotted in Appendix 1 to illustrate if there are any trends that predate the EM and may better explain differences between the EM period and the baseline. It is acknowledged that a comparison of the most recent EM period with a longer term baseline will be subject to changes in fishing practice and fish availability.

In the case of retained catch, we have no particular expectation of what effect EM will have on the reported catch rates—logbook reporting of retained catch is expected to be quite accurate because this catch is also subject to independent quantification upon landing.

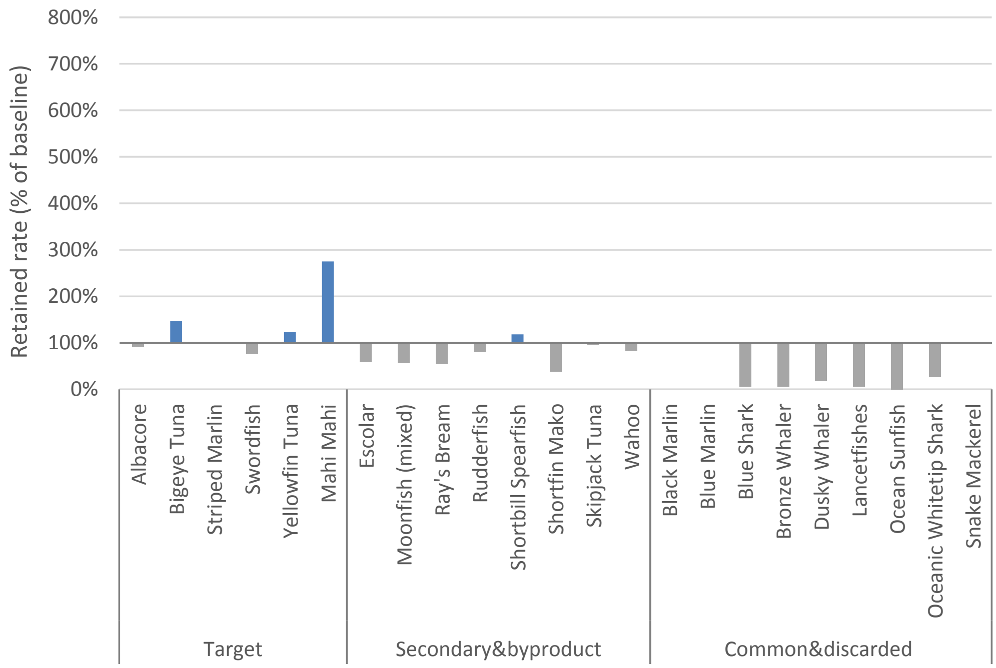
It is widely assumed that fish discards may be underreported in logbooks and this has previously been demonstrated in the Australian ETBF (e.g. blue shark, Campbell 2013). In the case of discarding, if the EM system was having its desired effect it would be expected that logbook discard per unit effort would be higher under EM as the quality of reporting improves.

For the retained catch, Figure 5a shows the percentage change in the catch rates reported following the full introduction of e-monitoring on 1 July 2016. Mahi mahi showed a significant increase in reported catch rates of some 2.8 times its pre-EM average and, anecdotally, this appears to be due to a targeting or retention shift in 2015–16 unrelated to EM. Conversely, most of the secondary catch and byproduct, as well as the common but discarded species, showed an apparent fall in retained catch rates under EM (Figure 5a). However, for many of these species this reflects a decline in retained catch rates that began prior to EM introduction (escolar, rays bream, rudderfish, shortfin mako, blue shark, bronze whaler, lancetfish and oceanic whitetip. See Appendix 1, Figure 6) and cannot be attributed to EM. For example, the retained catch of blue sharks is very low after in the EM period but it follows a trend that started around 2013–14 (Appendix 1, Figure 6c).

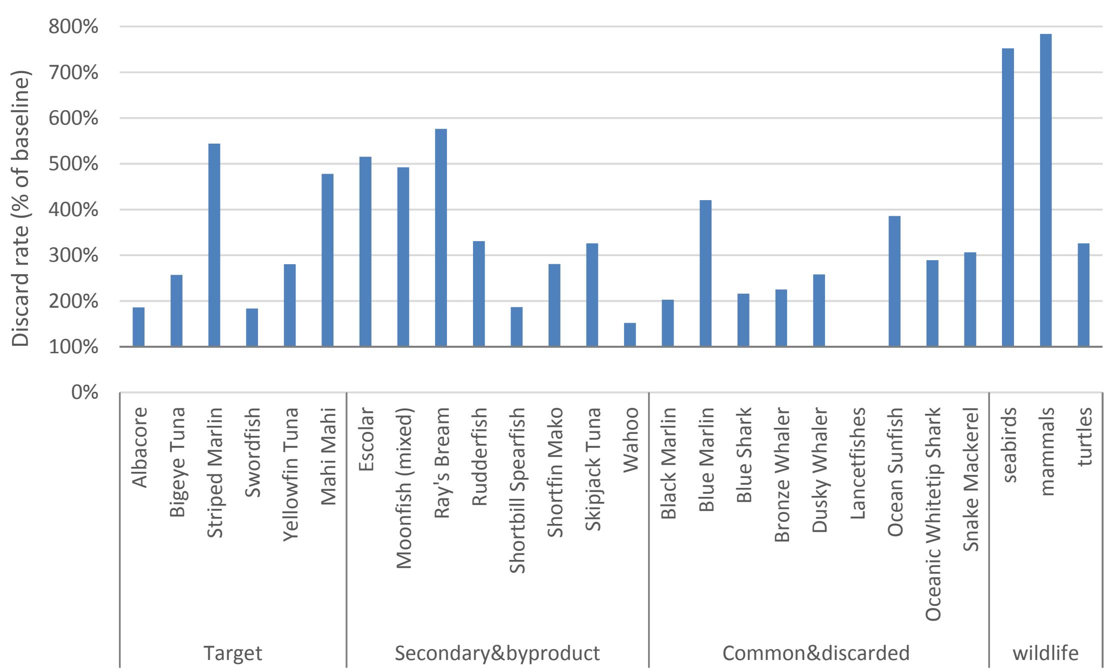
Turning to discarded catch, shown in Figure 5b, there was a clear and substantial increase in the reporting rates of discards for almost all species across all categories including wildlife. In all cases this appears to be quite unambiguously associated with the introduction of EM and not reflective of an earlier trend (Appendix 1, Figure 7). Logbook reported discard rates increased by a factor of 2 for most species and over a factor of 4 for some species across all four categories. The increased logbook reporting was most pronounced for seabird and mammal interactions which both increased by 7 fold.

Figure 5: Percentage change in the rates (per 1000 hooks) of a) retained and b) discards reported in the Australian ETBF following the full introduction of EM on 1 July 2015. The first 8 months of EM (July 2015 to Feb 2016) are compared with a mean of the same 8 month period for the previous six years prior to EM. Figures are percentages where 100 per cent would indicate no change.

a) Retained



b) Discarded



Discussion

Consistent with an earlier trial in the Australian ETBF, recent EM data appear to provide accurate estimates of retained catch by species that tend to be slightly higher than those recorded in logbooks. Also consistent with an earlier trial, EM data for discards appear to be underestimated to various degrees and subject to a higher taxonomic uncertainty when compared to the equivalent logbook reporting that has been subject to improvements through the EM feedback system. This study provides early evidence that the introduction of the EM system in the Australian ETBF has modified fisher behaviour and improved logbook reporting. This is most evident in the reporting of discarded catch where logbook reporting rates have increased substantially under EM.

Interestingly, the improvements in the logbook reporting of catch, particularly bycatch, have occurred even in cases where the EM system is not estimating catch levels well—such as for sharks. It is hoped that this improvement would be maintained despite this anomaly, but it would be desirable for the EM data collection and analysis system to undergo further development to improve accuracy for discards. This may involve repositioning or addition of cameras or modification of cameras field of view.

Discard estimation

The 2009–10 trial of EM on Australian longliners found that EM tended to underestimate discards when compared with an at-sea observer. This underestimate was, to some extent, related by to camera position and how discards are processed, particularly the practice of releasing fish in the water without them coming on-board. Following further development, technological improvements and full introduction of the EM system across the fleet, this same underestimation of discards is apparent through the comparison of EM with logbook. Again the EM underestimate is largest for species that are released in the water such as sharks (Figure 4b).

This raises the question of what constitutes the best source of total discard information for a species—raised estimates derived from the EM sample or the demonstrably improved recent logbook data. For example, in the case of yellowfin tuna discards, there appear to be substantial taxonomic issues in the EM data, with much of the catch flagged as mixed tuna (Figure 4b). In addition, the total numbers of all tuna discards are less in the EM compared with the logbook. Given that there is no incentive for fishers to over-report yellowfin tuna discards (noting this is a quota species), it is suggested that the logbooks would constitute a more accurate source of total yellowfin discards under the current EM system. In the case of blue shark, the reporting rate in logbooks is substantially higher than EM and, again noting the lack of fisher incentive to over-report, the logbooks would constitute a more accurate source of total discards for blue shark.

Further work

The feedback system design of the Australian longline EM system suggests that there should be ongoing improvements to the quality of the logbook data and the capabilities of the EM system. This should also manifest in better compliance with conservation and management measures. A future study could examine changes in EM performance across the first several years of implementation that would determine if this process of continuous improvement was occurring and perhaps illustrate where more focus is needed.

This paper has not examined the wider question of how EM may or may not provide the full range of data that at-sea observers have provided in the past. With respect to the WCPFC Regional Observer Program requirements, this issue has been explored in SPC (2016) and is currently being explored for Australia's observer/EM data. There are a range of 'data continuity' issues with potential impacts to science delivery and stock assessment that will require careful consideration.

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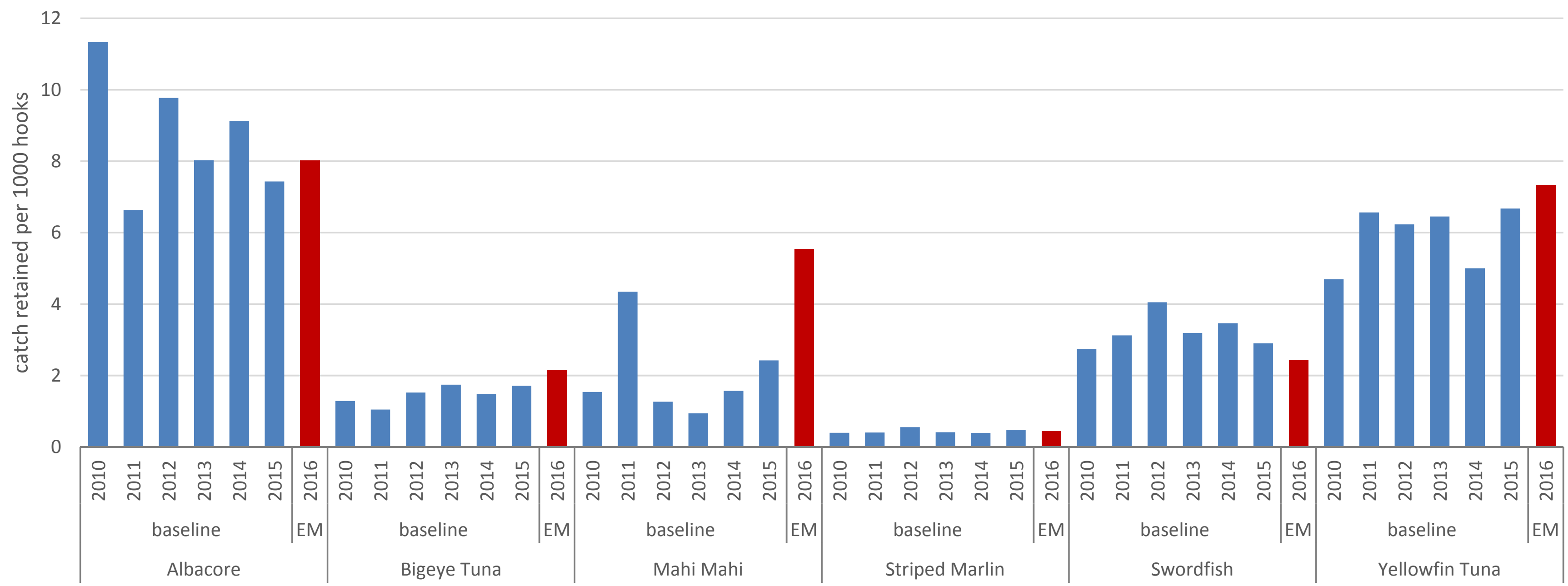
Appendix

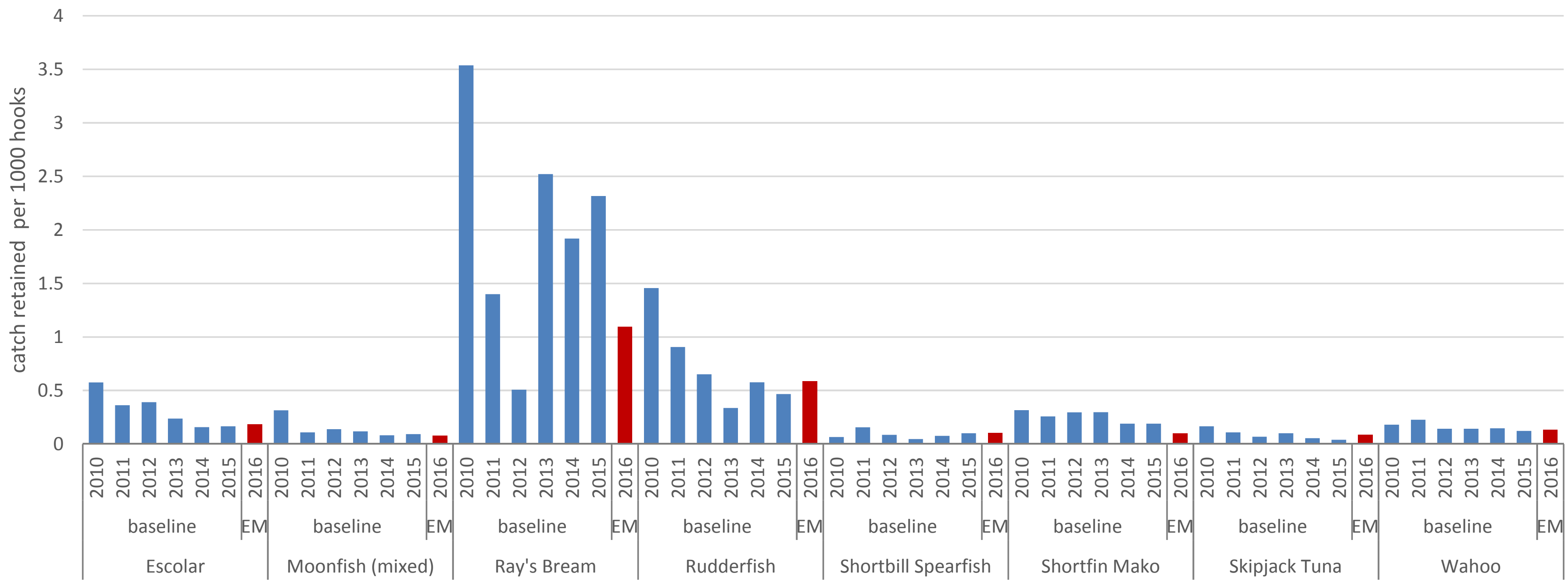
Appendix 1

Figure 6: Retained catch rates (per 1000 hooks) reported in logbooks in the Australian ETBF in the 8 months following the introduction of EM ("2016" = July 2015 to Feb 2016) and in the equivalent months for the six years prior to EM (2010 to 2015). Separate plots are provided for (a) target species, (b) secondary commercial and byproduct species, and (c) a selection of species that common in the catch but usually discarded.

a) **Target species, retained**



b) Secondary commercial and byproduct species, retained



(c) Common but usually discarded species, retained

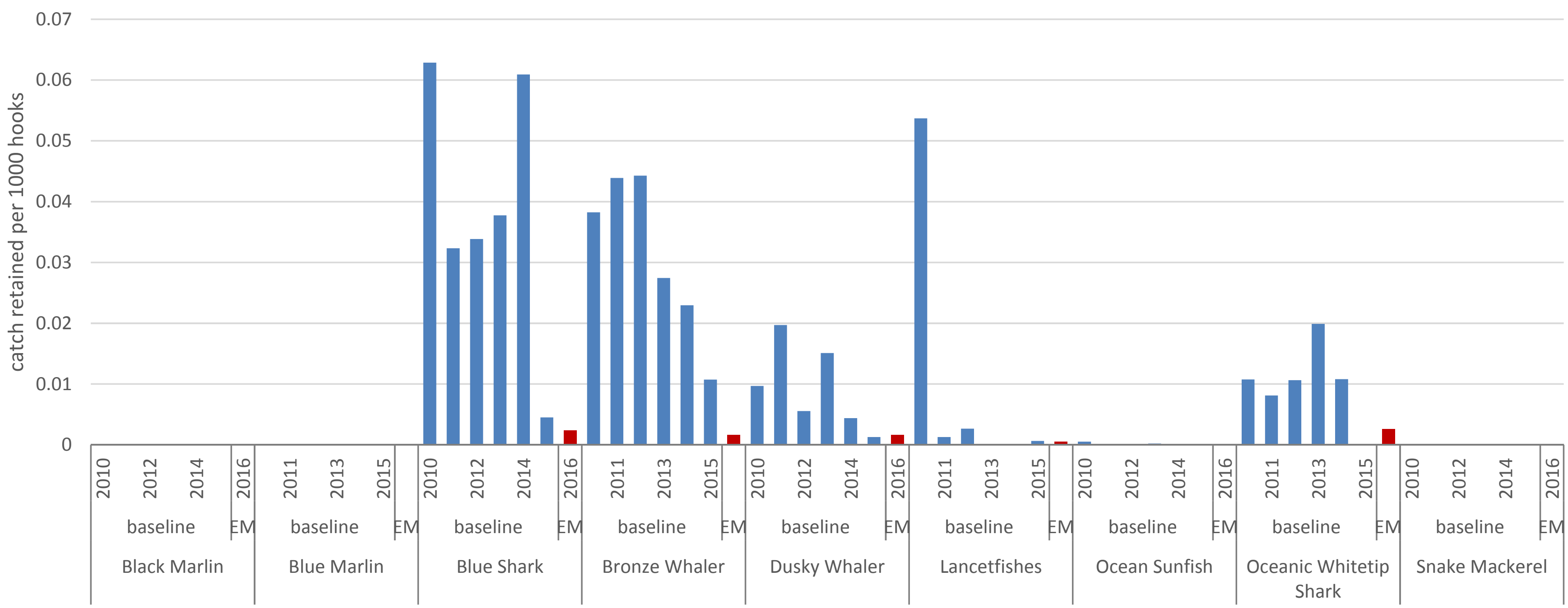
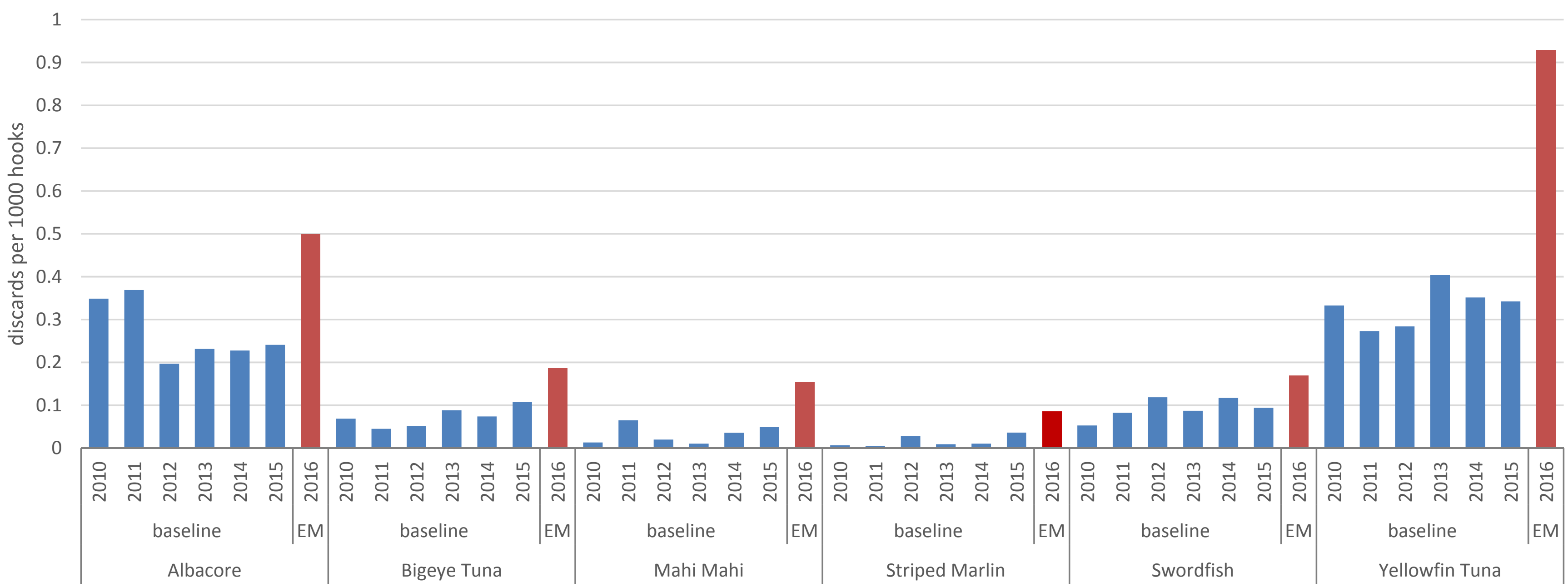
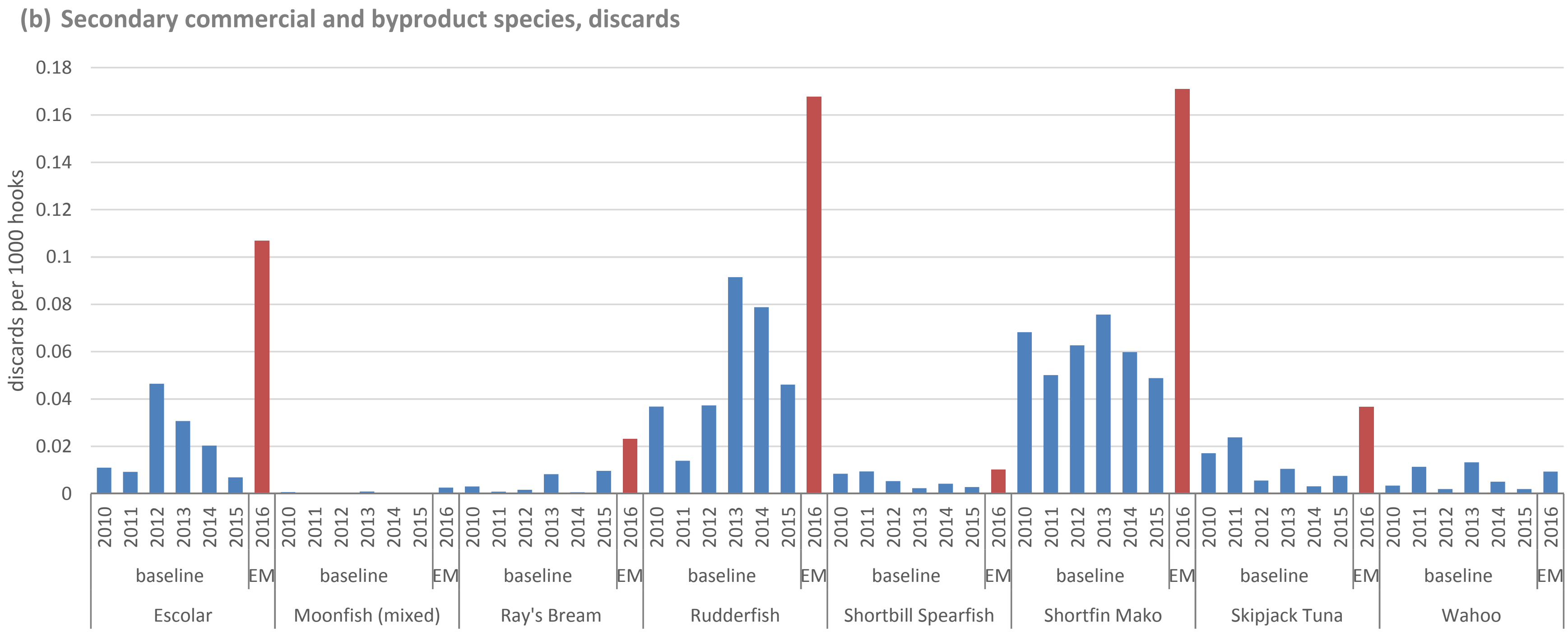


Figure 7: Discarding rates (per 1000 hooks) reported in logbooks in the Australian ETBF in the 8 months following the introduction of EM ("2016" = July 2015 to Feb 2016) and in the equivalent months for the six years prior to EM (2010 to 2015). Separate plots are provided for (a) target species, (b) secondary commercial and byproduct species, and (c) a selection of species that common in the catch but usually discarded.

(a) Target species, discards




(b) Secondary commercial and byproduct species, discards
discards per 1000 hooks
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
2010
2011
2012
2013
2014
2015
2016
baseline
EM
Escolar
Moonfish (mixed)
Ray's Bream
Rudderfish
Shortbill Spearfish
Shortfin Mako
Skipjack Tuna
Wahoo

(c) Common but usually discarded species, discards