An evaluation of the reliability of electronic monitoring and logbook data for informing fisheries science and management

Eastern Tuna and Billfish Fishery

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Acknowledgement of Country

We acknowledge the Traditional Custodians of Australia and their continuing connection to land and sea, waters, environment and community. We pay our respects to the Traditional Custodians of the lands we live and work on, their culture, and their Elders past and present.

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Executive Summary

Background

Electronic monitoring (EM) is a tool used to collect fisheries-dependent data to support fisheries scientific analyses and assessments and subsequent fisheries management decision-making.

A key objective of the Australian Fishery Management Authority (AFMA) EM program is to improve the accuracy of logbook data, which in turn improves data for scientific assessments and supports fishery management decision-making (AFMA, 2020). Accurate logbook data is required for fishery stock assessments, ecological risk assessments (ERAs) and threatened, endangered, and protected (TEP) species analyses. A lack of accuracy and precision in logbook data can impact management decisions and the achievement of legislative or management objectives.

EM can help improve logbook data through independent validation. It can allow AFMA to take education or compliance-based action if biases are identified and for AFMA and scientists using logbook data to correct for logbook biases or screen out poorly reported logbook data. EM data can also be used directly as a source of scientific data, provided the coverage is representative of the fleet and audit rates are sufficient.

AFMA introduced EM into the Eastern Tuna and Billfish Fishery (ETBF) and the Gillnet, Hook and Trap (GHAT) sector of the Southern and Eastern Scalefish and Shark Fishery (SESSF) in 2015. The AFMA EM program audits a minimum 10% of shots from each vessel and a minimum of one shot per hard drive for each vessel for analysis of catch composition, discards, and interactions with TEP species (AFMA, 2020).

A previous comparative analysis of ETBF logbook and EM data (Emery et al., 2019a) looked at congruence in reporting of both retained and discarded species and interactions with TEP species, for the years 2015/16 to 2016/17. Congruence is defined here as the level of similarity between logbook and EM counts of individuals retained, discarded, or interacted with during a shot. It identified a higher level of congruence for retained than discarded species, with a greater proportion of discarded species in the ETBF not able to be identified to a species level by the EM analyst. The study also identified clear taxonomic issues in the reporting of rudderfish and escolar by both fishers and EM analysts. While reporting of seabird interactions was congruent, there were clear issues with the reporting of other TEP groups (sharks and turtles) by the EM analyst, with fishers reporting these in greater numbers in their logbook.

Objectives

The objective of this study is to provide an updated and expanded evaluation of the reliability of electronic monitoring and logbook data for informing fisheries science and management in the ETBF. Specifically, the analysis aims to:

- Compare both fishery level and individual vessel level congruence between logbook and EM data for commercial, bycatch and TEP species;
- Determine if congruence has changed through time;
- Identify, where possible, factors contributing to any differences between EM and logbook data; and

- Inform recommendations for i) the use of ETBF logbook and EM data in scientific analyses/assessments and ii) management actions to further improve, where necessary, future logbook and EM data collection/reporting.

Methods

This study compares EM and logbook reporting of catch numbers per fishing activity (e.g., set or shot) for both key retained and discarded species, as well as interactions with TEP species, by year, in the ETBF.

A range of indicators are calculated to compare reporting between EM and logbooks. This includes basic differences in counts of fish between logbooks and EM, as well as more sophisticated indicators such as frequency distributions and probability density functions of shot-level differences in counts. Importantly, many of the indicators, such as differences in counts of fish between logbooks and EM, are also expressed as a proportion of average catch per shot. This is important because, for example, a difference of five between EM and logbooks when 100 fish have been caught reflects good congruence, whereas a difference of five when only 10 fish are caught reflects poor congruence.

This analysis updates and expands on the previous study of Emery et al. (2019a), utilising five financial years of EM data (2015/2016 to 2019/2020) compared to two years in the previous study.

Results and Discussion

The analyses presented in this report indicate that the overall level of congruence (similarity between EM and logbook data) for the ETBF was:

- superior for key commercial species compared to byproduct/bycatch species,
- higher for retained than discarded catch; and
- higher for TEP groups (i.e., seabirds, marine turtles, and marine mammals) than at a species taxonomic level.

Importantly, fleet-wide estimates across the period analysed, concealed significant inter-annual and inter-vessel variation in congruence for some species. Consequently, whether ETBF logbook data can be used for scientific analysis and management decisions for any given species (or group of species) will depend on the findings from the comparative analysis at both fleet and individual vessel levels and the type of analysis being undertaken and/or management process to be informed. It may also be possible for the EM data itself to be used:

- directly in the analyses as a replacement for logbook data;
- as a source of information to help correct for logbook biases; or
- to identify and screen out biased or non-representative logbook data.

Retained key commercial species

Except for skipjack tuna, retained tuna and billfish were reported in similar numbers by logbook and EM, with the mean difference in counts as a proportion of the average catch low (<15%). On average, congruence improved for albacore, yellowfin tuna, swordfish between 2015/2016 to 2017/2018 but declined in the following two years. However, for other stocks such as bigeye tuna, southern bluefin tuna, striped marlin and mahi mahi after an initial improvement, the level of congruence has remained stable through time. Tuna and billfish were not unobserved often with <10% of shots containing a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool. There was some inter-vessel variation for albacore, bigeye tuna and mahi mahi but this was negligible for all other species.

In contrast, retained skipjack tuna was reported more by EM than in logbooks across all shots audited, with a mean difference in counts of 1.0 ± 0.2 individuals across the time period examined, with small numbers commonly being reported by EM that were not being reported in logbook. Like the previous study, there continues to be taxonomic issues in the reporting of retained escolar and rudderfish, with the EM analyst predominately recording them as the former and fishers the latter. Although there has been some improvement through time in the overall congruence of escolar.

Discarded key commercial species

For most species, reported discarding was less congruent than retained reporting. There were higher instances of zero reporting on one data collection tool where discarding was reported by the other and generally both the variation in the mean difference in counts and those expressed as a proportion of the average catch were higher than for retained catch of the same species. There was also significant inter-annual variation in discarding. Except for snake mackerel and escolar, discards were reported in greater numbers at the species level by logbook than EM across the time period. There was also significant inter-vessel and inter-annual variability for all tuna and billfish species discards. For example, there were several vessels not reporting any discarded catch of tuna and billfish in their logbooks, despite individuals being reported by EM. There were also vessels where EM was clearly having some issues either correctly identifying species or observing individuals being discarded. This result is not surprising when studies have highlighted the heterogeneity among fishers in respect to identification skill and diligence in logbook reporting (Macbeth et al., 2018). There is also likely disparity in the experience, skill and local knowledge of EM analysts reviewing footage (Piasente et al., 2012). Furthermore, many of the discarded species are released without being brought on board the boat, often to maximise the survivability of the animal being released. This means that it is often impossible for the EM analyst to observe the distinguishing features of the animal being release to the species level. These identification issues can be exacerbated due to poor image quality caused by external factors such as weather, waves and lighting, or the quality of the camera systems (Evans and Molony, 2011; Mangi et al., 2015; van Helmond et al. 2015; Wallace et al., 2013).

To investigate this further, the tuna, shark and oilfish species were grouped at a higher taxonomic level for analysis. When examining both tuna (grouped) and oilfishes (grouped) at a higher taxonomic level, overall congruence improved and in general, were reported in greater numbers by EM than logbook. This suggests the EM analyst was having difficulties in identifying discarded tuna to a species taxonomic level but was still observing tuna being discarded. Furthermore, escolar and rudderfish are potentially identified to species level differently on logbooks and EM. When examining sharks (grouped) it was evident that the EM analyst was still having issues in observing all discarding events, with greater numbers still reported by logbook than EM.

Threatened endangered and protected species

Reporting of TEP groups (seabirds, marine mammals and marine turtles) displayed some congruence. Where there were differences in counts observed, these were low in terms of absolute number (i.e., ±1-2 individuals), with no clear skew towards EM or logbook reporting more individuals than the other. A total of 45%, 59% and 55% of shots had no difference in counts for seabirds, marine mammals, and marine turtles respectively. Concerningly, there were a minority of shots where more than one interaction with either a seabird (5%) or marine mammal (6%) was not reported by one data collection tool. There was inter-vessel variation in reporting, with some vessels having perfect congruence (i.e., no difference in counts) and others where EM was reporting more individuals than the logbook. While it is possible these differences may be caused by missed observations, they could also be a result of incomplete or inaccurate logbook reporting, which has previously been shown to be an issue for TEP species (e.g., Goldsworthy et al., 2010; Brown et al., 2021; Basran et al., 2021). There was also evidence for occasional instances where fishers reported TEP interactions that were missed by the EM analyst. This can occur for a range of reasons, including vessels not maintaining and cleaning cameras, gaps in data for key camera views due to system functionality issues, as well as short term weather conditions that prevented clear EM views.

Reporting of TEPS at the species level was mixed and it was evident that the EM analyst was having difficulty in identifying all interactions to a species level. For example, while it seemed that the EM analyst could identify leatherback turtles, there were more issues identifying other marine turtles to a species level, resulting in them being classified as marine turtles (mixed). This was also apparent for specific shark species (shortfin, longfin mako, silky and porbeagle shark), where the EM analyst was not able to identify these to a species level, with significantly higher numbers being reported by fishers to the species level in their logbook across the time period. This was likely due to the 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 either detection or identification by the EM analyst. Unobserved discards of shark species were also observed during the integrated EM system pilot study in the ETBF and the Alaskan Pacific halibut longline fishery (Ames et al., 2005, 2007; Larcombe et al., 2016).

Table 1: Summary of overall congruence results for the ETBF sector of the SESSF

Target species	Fate	Mean difference in reporting across time period	Mean difference in reporting as a proportion of average catch across time period	Year-level differences	Inter-vessel variability
Albacore	Retained	EM~Logbook	Low (<15%)	Variable	Medium
	Discarded	EM<Logbook	Moderate (15-50%)	Variable	High
Yellowfin tuna	Retained	EM~Logbook	Low (<15%)	Variable	Negligible
	Discarded	EM<Logbook	High (>50%)	Variable	High
Southern bluefin tuna	Retained	EM~Logbook	Low (<15%)	Improving	Negligible
	Discarded	EM<Logbook	Moderate (15-50%)	Variable	High
Swordfish	Retained	EM~Logbook	Low (<15%)	Stable	Negligible
	Discarded	EM~Logbook	Low (<15%)	Declining	Medium
Bigeye tuna	Retained	EM~Logbook	Low (<15%)	Improving	Low
	Discarded	EM<Logbook	High (>50%)	Variable	Medium
Mahi mahi	Retained	EM~Logbook	Low (<15%)	Stable	Medium
	Discarded	EM~Logbook	Low (<15%)	Variable	Medium

Recommendations

The following recommendations aim to assist AFMA to identify and prioritise actions to further improve their EM program, to increase the benefits of the EM and logbook data collection programs for science and management decisions. More detail on these recommendations is provided in the main body of this report.

General recommendations

- **Review feedback processes and resourcing** – Several potential issues driving a lack of congruence between logbook and EM data in the ETBF (such as species identification issues for escolar/rudderfish and sharks) have persisted for over five years (i.e., between studies). It is recommended that AFMA ensure there are sufficient resources and processes in place to implement education, feedback and compliance processes that will improve congruence in the future.
- **Confirm key drivers for a lack of congruence through outreach** – It is recommended that AFMA investigate further, where required and identified in this report, key drivers of instances of low congruence. This will help inform the management actions needed to improve logbook reporting (and EM data collection) in the future, for each sector/species considered. Depending on the key drivers confirmed in each case, the specific recommendations below then apply.
- **Utilise a vessel specific approach to management** – There is variability between vessels in logbook reporting performance, hence investigations and management solutions required to improve logbook reporting, will in many cases need to be focussed on the individual vessel level. Furthermore, examination of the reporting practices and specific configuration of EM systems found on vessels with high congruence, might in some cases inform advice and solutions for vessels with low congruence.

Improving EM data

- **Periodically review and seek to improve individual vessel EM systems where required** – It is recommended that AFMA seek to improve EM systems on vessels whose systems are identified as hindering or not sufficiently enabling EM analysts a clear view of catch, discard, or interaction events. Solutions may include adding/moving/modifying camera positions and angles on those vessels, requiring vessels to remove objects obstructing camera views, or requiring fishers to only discard fish within view of the camera, or while cameras are recording during the haul.
- **Improve/maintain EM system/analyst capability to identify species** – It is recommended that AFMA and the EM service provider ensure EM analysts continue to be provided sufficient training, including from qualified experts (e.g., at sea observers, scientists) to accurately identify species, particularly for species for which identification is more difficult and that periodic audits are conducted on EM analyst reports to ensure consistency and maintenance of high-quality EM data through time (this is particularly needed for various discarded shark species and blue and black marlin species). The capability of EM analysts to accurately identify and determine the fate of species (retained/discarded) could also be improved if the crew adopted practices that increased their visibility to the camera (e.g., placing an individual in close view of the camera prior to discarding).
- **Remove duplicate CAAB codes -** Future EM-logbook congruence analyses would benefit through the removal by AFMA and the EM service provider of duplicate species fields for the same species (or taxa) (i.e., CAAB codes) in the database (Appendix A).

Improving logbook reporting

- **Improve the capability of fishers to identify and report species** – It is recommended that AFMA conduct further outreach activities to inform fishers about their reporting responsibilities and/or educate them in species identification/taxonomy. For example, this study identified this may be occurring for retained skipjack tuna, escolar/rudderfish and TEP species (seabirds, marine mammals and marine turtles).
- **Strengthen feedback and education mechanisms** – It is recommended that AFMA resource and implement direct feedback/education (and where necessary compliance) processes between AFMA managers and vessel skippers (and/or crew) whose logbook reporting needs improvement. It is clear from this report that a small number of boats are persistently under reporting bycatch and discards on their logbooks. The potential role of stronger incentives and/or compliance responses in ensuring improved reporting over time should be considered.
- **Prescribe clear tolerance levels for logbook reporting** – It is recommended that AFMA, in partnership with scientists and industry stakeholders, determine prescribed tolerance levels for logbook reporting of retained, discarded catch and TEP interactions through the development of quantitative evaluation standards. These can then be used to trigger strengthened vessel-specific feedback, education, and compliance responses (as recommended above).

Considering scientific analyses using logbook data

- **Use of fishery level congruent data** - Where congruence between EM and logbook data for a given species is high at both the fleet and individual vessel level, the data can generally be considered representative of the actual catch/discards in that fishery and used directly for analysis/assessment and management purposes. Examples include, retained tuna and billfish species and mahi mahi.
- **Accounting for under-reporting in logbooks –** For some species, where logbook data at a vessel level identifies either missed observations, misidentification, or misreporting (against EM data), scientists should carefully consider whether to include and how to adjust/account for logbook data from these vessels for scientific assessments/analyses. For example, for CPUE standardisations, it might be necessary to exclude data from under-reporting vessels. For total discard estimates, EM to logbook ratios might need to be used to correct for logbook under-reporting.
- **Use of EM data directly in scientific analyses** – For some species/vessels where logbook data is considered unreliable, EM data might be used directly to derive estimates of overall catches, catch rates or other parameters of interest to scientists and managers, providing the assumptions being applied in using the data in that way, are appropriately recognised. For some taxa, especially for discarded catch, species level identification may be an issue in such analyses.

Further research

- **Analyses of factors driving differences in EM and logbook reports** – It may be worth further exploring model-based approaches (such as generalised linear models) to identify factors driving differences in EM and logbook reporting over time, such as time of haul (i.e., lighting), sea/weather conditions, number of crew onboard to inform future management responses.
- **Congruence of byproduct and bycatch species of interest** – The approaches used to determine congruence in this report for key commercial species could in future be also applied to byproduct and bycatch species of interest.
- **At-sea observer and EM analyst comparative analyses** – AFMA may wish to consider conducting a small trial using at-sea observers, to help validate some aspects of EM data

collection in the ETBF and identify on board mechanisms to optimise EM data collection in the future.

1 Introduction

Electronic monitoring (EM) technologies were introduced into several Australian Commonwealth fisheries in 2015, including the Eastern Tuna and Billfish Fishery (ETBF) and the Gillnet, Hook and Trap (GHAT) sector of the Southern and Eastern Scalefish and Shark Fishery (SESSF). Under the current program, the Australian Fisheries Management Authority (AFMA) aims to use EM to validate fishery logbook information through auditing a minimum 10% of shots from each vessel. This includes an analysis of catch composition, discards, and interactions with threatened, endangered, and protected (TEP) species (AFMA, 2020).

It is important that the operation of the Australian Fisheries Management Authority (AFMA) electronic monitoring (EM) program is regularly reviewed to facilitate its development and refinement through time and to inform the implementation of EM as a data collection tool in other commercial fisheries.

One of the key objectives of the AFMA EM program is "increased accuracy of data – continual feedback on logbook reporting through e-monitoring will lead to higher quality self-reported logbook data. Improved quality data will lead to better fisheries management decisions". (AFMA, 2020). To assess whether this objective is being met there is a need to review the level of congruence between EM analyst and fisher logbook reporting. This allows an assessment to be made of whether:

- the EM analyst can accurately record all retained and discarded catch, as well as interactions with threatened, endangered, and protected (TEP) species; and
- the level of reporting of all catch and interactions by fishers in their logbook is similar to the EM analyst.

Congruence is defined here as the level of similarity between logbook and EM counts of individuals retained, discarded, or interacted with during a shot. Congruence can be determined through an examination of, *inter alia*, mean differences in counts (at the shot level) and frequency histograms of these differences. If there is a high level of congruence, there can be some confidence that logbook records provide a sufficiently precise and accurate account of retained and discarded catch, as well as interactions with TEP species. Where there is not high congruence, it is also important to understand why, to provide information that might assist in improving logbook (and EM) reporting in the future.

The aim of this study was to:

(i) compare the level congruence (i.e., similarity) between EM and logbook data for commercial, bycatch and protected species in the Eastern Tuna and Billfish Fishery (ETBF).

(ii) determine if the level of congruence has changed over time since the implementation of EM.

(iii) provide some metrics to compare the level of congruence among individual vessels in the ETBF.

(iv) identify what factors might be contributing to or explain differences in EM/logbook count reporting.

2 Methods

2.1 Data collation and review

All logbook and EM data from the ETBF were collated and aggregated by shot and the total number of species (either retained or discarded) for the period 1 July 2015 to 30 June 2020. Additional processing of the data sets was required before it could be used in the analyses. This included:

- The removal of a total of 27 audited EM shots that could not be linked, via the operation numbers provided by Archipelago Asia Pacific (AAP), to a corresponding logbook shot. All logbook and EM shots that were able to be linked by a common operation number (which are assigned to EM shots by AAP based on the logbook database), were assumed to be correctly paired.

- The manual combining of species codes. As identified in the previous analysis (2018), there were issues with species CAAB codes used in both the EM and logbook databases, with multiple codes being used by the EM analyst for similar species and species groups used in the logbook. For example, the EM analyst used thresher shark (37012001), thresher sharks mixed (37012901) and thresher sharks (37012000), while the logbook only used thresher shark (37012001) in the database. This required manual correction prior to analysis. Using the example above, the data for all three species groups were allocated to thresher shark (37012001), as it was considered the "primary" species CAAB code. The full list of multiple CAAB codes and their respective "primary" CAAB code that were used in the analysis can be found in Appendix B.

- The removal of shots with zero (i.e., 0,0) EM and logbook observations, for either retained, discarded, or interacted with species. This decision is aligned with other studies that have investigated the congruence between EM and at-sea observer data (e.g., Briand et al. 2017; Ruiz et al. 2015; Forget et al. 2021) as retaining them in the dataset can inflate and consequently bias the congruence estimate (Burch pers. comm. 2021).

Following processing of the data there remained a total of 2,226 shots (Table 2).

Table 2: Number of audited linked shots by financial year in the ETBF

Fishery	Financial year	Number of linked audited shots
ETBF	2015/2016	248
	2016/2017	495
	2017/2018	525
	2018/2019	486
	2019/2020	472

2.2 Data analysis

Several approaches were applied to explore congruence between ETBF EM and logbook data for both retained and discarded catch. This included basic differences in counts of fish between logbooks and EM, as well as more sophisticated indicators such as frequency distributions and probability density functions of shot-level differences in counts. These are described below with example plots shown in Box 1. Importantly, many of the indicators are expressed as a proportion of average catch per shot. This is important because, for example, a difference of five between EM and logbooks when 100 fish have been caught reflects good congruence, whereas a difference of five when only 10 fish are caught reflects poor congruence.

Mean Differences in counts

This calculates the difference in EM and logbook counts for each shot for a particular species of interest. This is summed across the fleet and the mean differences for each financial year calculated along with the 95% confidence intervals (see example (a) in Box 1). As the count data collected from either EM or logbook does not represent a "reference" or "true value" (Ames et al., 2007; Ruize et al., 2015), congruence is evaluated comparing the mean difference in counts. Calculating a proportional difference (e.g., absolute difference in counts divided by the average of counts) was not possible because a downward bias is created when there is a zero in the count data. For example, the proportional difference of two shots where EM reported zero individuals, but the logbook reported three and 200 individuals is identical ($\frac{0-3}{3} = \frac{0-200}{200} = -1$) but their level of congruence is significantly different.

The mean difference in counts for a particular species was also analysed relative to their average catch per shot across the entire time period (see example (b) in Box 1). Average catch per shot was calculated as the average of the reported EM and logbook counts for each shot. Further, differences as a proportion of total catch by species were also investigated (see example (c) in Box 1).

Frequency distributions of differences in counts

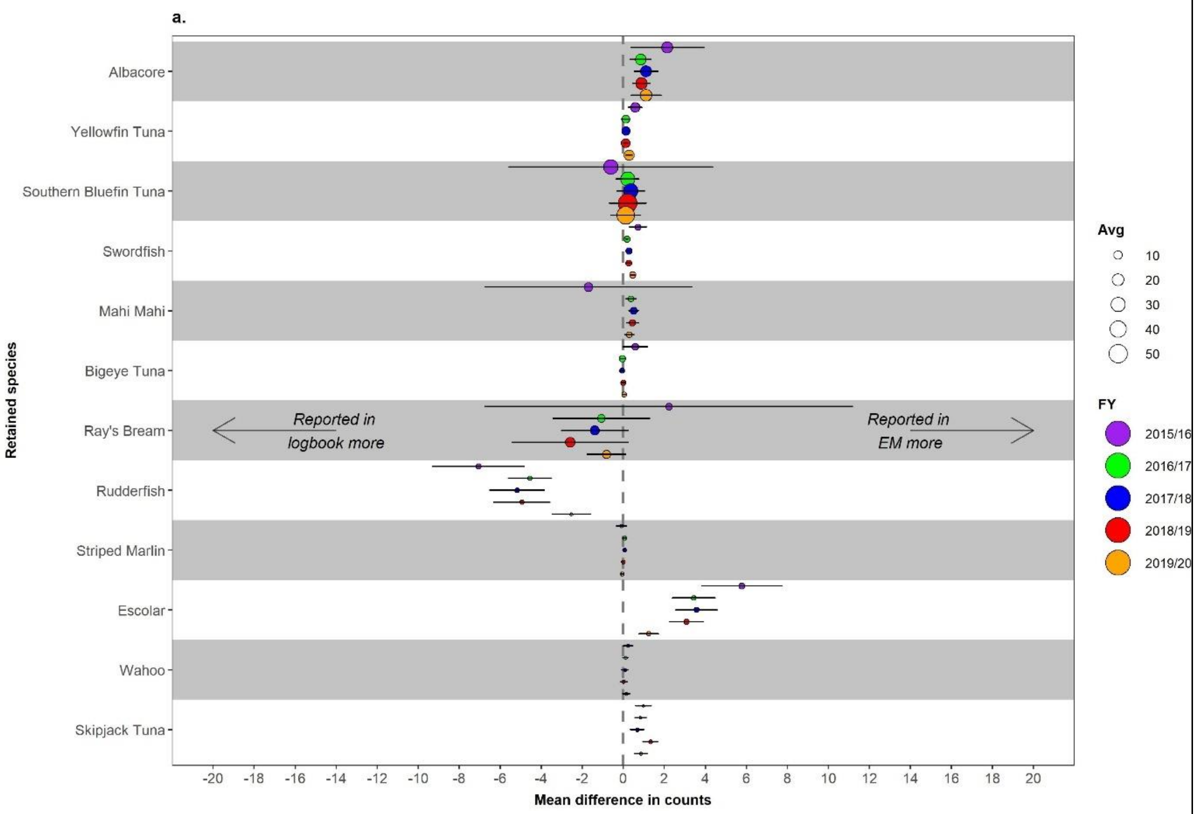
This calculates the proportional differences in counts between EM and logbook at an individual shot level by financial year (see example (d) in Box 1). This analysis identifies whether individual shots were clustered around zero (i.e., EM and logbooks counts were identical) or skewed either left or right (i.e., EM or logbook reported a greater number than the other data collection tool). A second analysis identified whether or not any of the differences in counts were the result of a zero being recorded in either EM or logbooks when ≥1 individual was reported by the other data collection tool (see example (e) in Box 1).

Vessel level differences

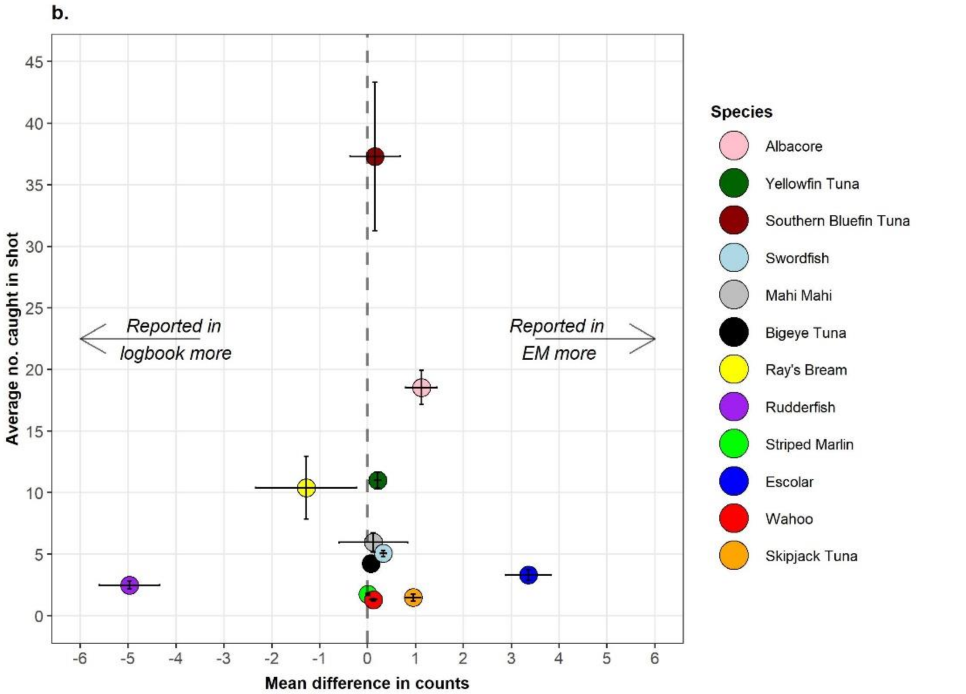
Given the heterogeneity in logbook reporting across vessels, analysis of shot-level differences in counts was undertaken and presented as kernel probability density functions (see example (f) in Box 1). This shows the shot-level differences in counts for a specific species, mean difference in counts and average catch per shot by individual vessel. Vessels were only included in the analysis where the selected species was recorded as either retained or discarded in ≥5 shots audited.

Box 1: Examples of the types of analyses undertaken to assess congruence between EM and logbook data in the ETBF

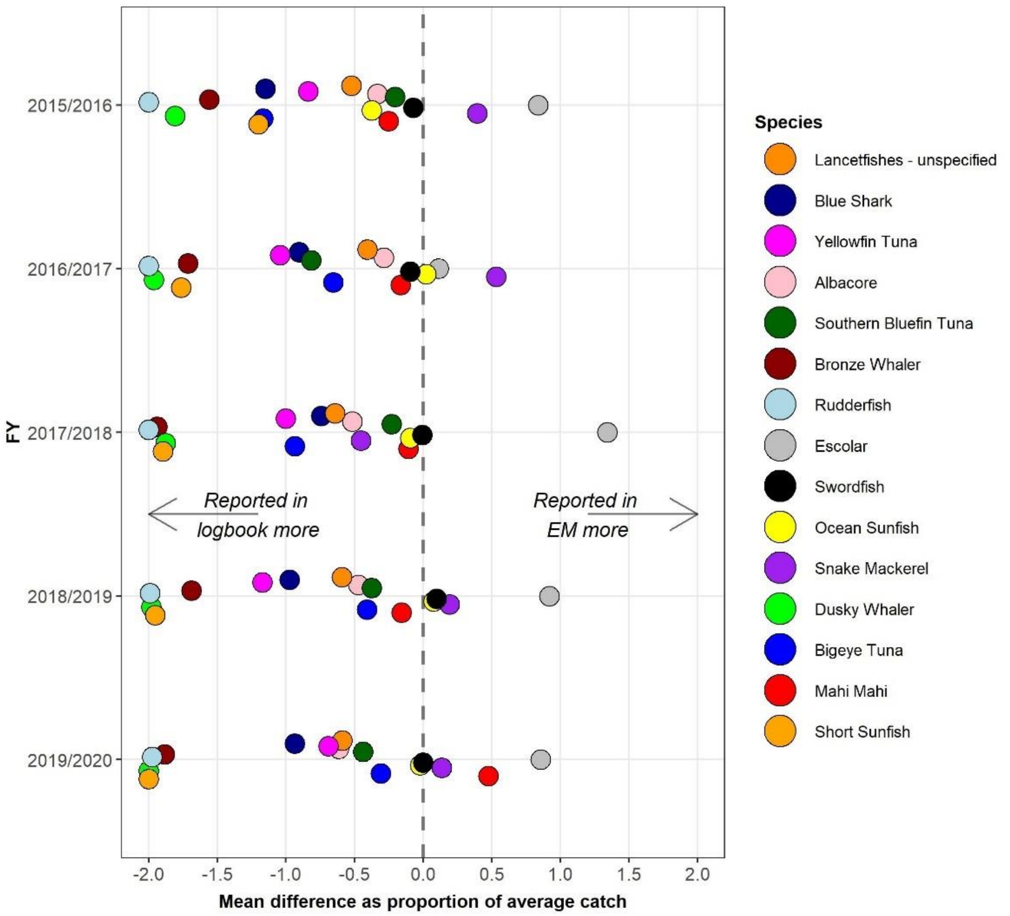
a. mean difference in counts



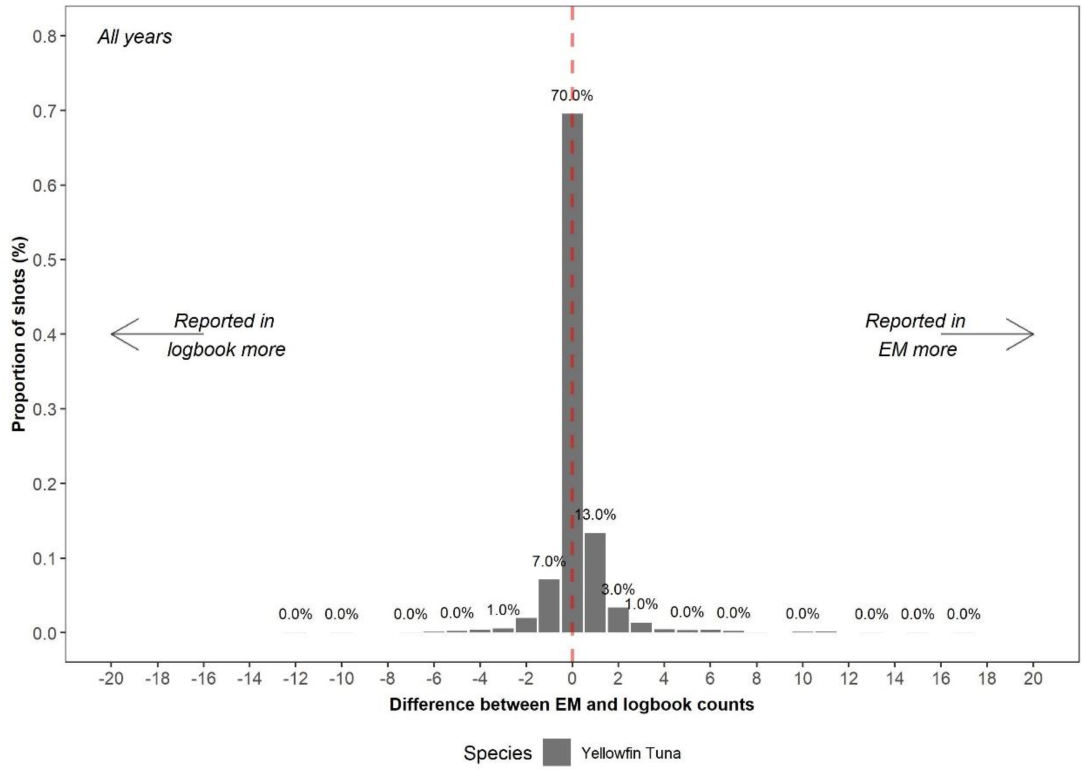
b. mean difference in counts relative to average catch no. of the shot



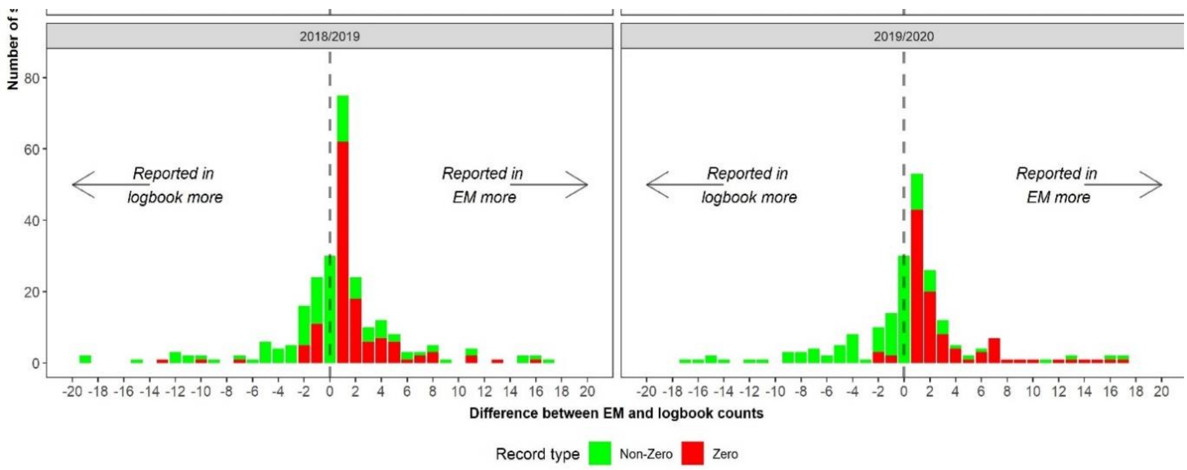
c. mean difference in counts as proportion of average catch no. of the shot



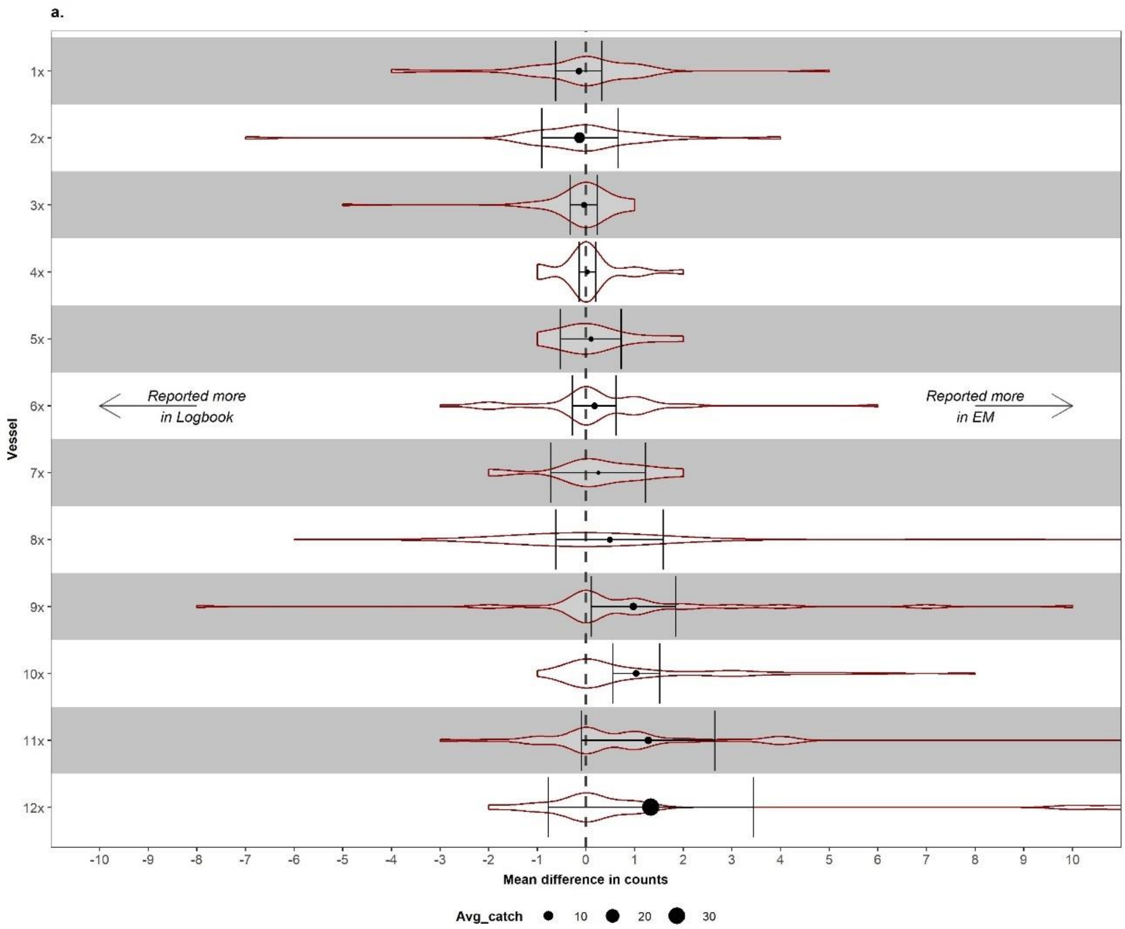
d. frequency histogram of shot level differences in counts as a proportion of total shots



e. frequency histogram of shot level differences including whether a record from either EM or logbook contained a zero



f. kernel probability density of differences in counts and mean difference at vessel level



Not all analyses were possible at a species, vessel or TEP level. This was due to limitations in the data (i.e., not enough audited interactions for TEP species at the vessel level). Box 2 below indicates what analyses were undertaken at each level.

Box 2: Coverage of analyses by species, vessel and TEP level in the ETBF

Analysis	Key commercial species (retained and discarded)	Vessel-level	TEPs
Mean differences in counts between EM and logbook (collated shots)	✓	✓	✓
Average catch no. per shot from EM and logbook (collated shots)	✓	✓	✗
Proportional differences in counts between EM and logbook (individual shots)	✓	✗	✗
Actual differences in counts between EM and logbook (individual shots)	✓	✗	✓

3 Results

3.1 Retained catch

In the ETBF, there were a total of 12 species that represented the main retained species in the fishery and were analysed herein (Table 3).

Except for skipjack tuna, retained catches of tuna and billfish species were reported in similar numbers by logbook and EM in the ETBF (Figure 1a, b and Table 3). For example, retained catch of yellowfin tuna had a mean difference in counts of 0.2 ± 0.1 individuals across the time period examined and the average number recorded as retained by both EM and logbook in a shot was 11.0 ± 0.6 individuals (Table 3). As a proportion of the average catch, the mean difference for yellowfin tuna was only 2% (Figure 2). Furthermore, there were only a negligible 1% of shots containing a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool (Table 3). Similar results were reflected in other tuna and billfish species (Table 3). Conversely, skipjack tuna was reported more by EM than logbook, with a mean difference in counts of 1.0 ± 0.2 individuals across the time period examined with small numbers being reported by EM that were not being reported in logbook most of the time (71%) (Table 3). Lastly, like the previous study (Emery et al, 2019a), there continues to be taxonomic issues in the reporting of escolar and rudderfish, with the EM analyst predominately recording them as escolar and fishers as rudderfish. Although there has been some improvement through time in the logbook reporting of escolar (Figure 1a).

Table 3: The mean difference in counts between EM and logbook, average number (from both EM and logbook) reported caught per shot, mean difference in counts as a proportion of average catch and proportion of zeroes reported by either EM or logbook across the time period examined for retained species in the ETBF.

Species	Scientific name	Mean difference in counts	Average number reported caught	Mean difference in counts as proportion of average catch	Proportion of 0s reported by either logbook or EM
Albacore tuna	*Thunnus alalunga*	1.1 (±0.3)	18.5 (±1.4)	6%	5%
Yellowfin tuna	*Thunnus albacares*	0.2 (±0.1)	11.0 (±0.6)	2%	1%
Southern bluefin tuna	*Thunnus maccoyii*	0.2 (±0.5)	37.3 (±6.0)	<1%	2%
Swordfish	*Xiphias gladius*	0.3 (±0.1)	5.0 (±0.2)	6%	5%
Mahi mahi	*Coryphaena hippurus*	0.1 (±0.7)	5.9 (±0.8)	2%	13%
Bigeye tuna	*Thunnus obesus*	0.1 (±0.1)	4.2 (±0.3)	1%	5%
Ray's bream	*Brama brama*	-1.3 (±1.0)	10.4 (±2.5)	-12%	35%

Rudderfish	*Centrolophus niger*	-5.0 (±0.6)	2.5 (±0.3)	-199%	>99%
Striped marlin	*Kajikia audax*	0.0 (±0.0)	1.7 (±0.1)	<1%	6%
Escolar	*Lepidocybium flavobrunneum*	3.4 (±0.5)	3.3 (±0.4)	101%	74%
Wahoo	*Acanthocybium solandri*	0.1 (±0.1)	1.3 (±0.1)	9%	19%
Skipjack tuna	*Katsuwonus pelamis*	1.0 (±0.2)	1.5 (±0.3)	64%	71%

Figure 1: Reporting of retained catches of species in the ETBF (a) mean difference in counts (mean ± 95% CI) (between EM and logbook) across individual financial years and (b) mean difference in counts (between EM and logbook) compared to the average number reported

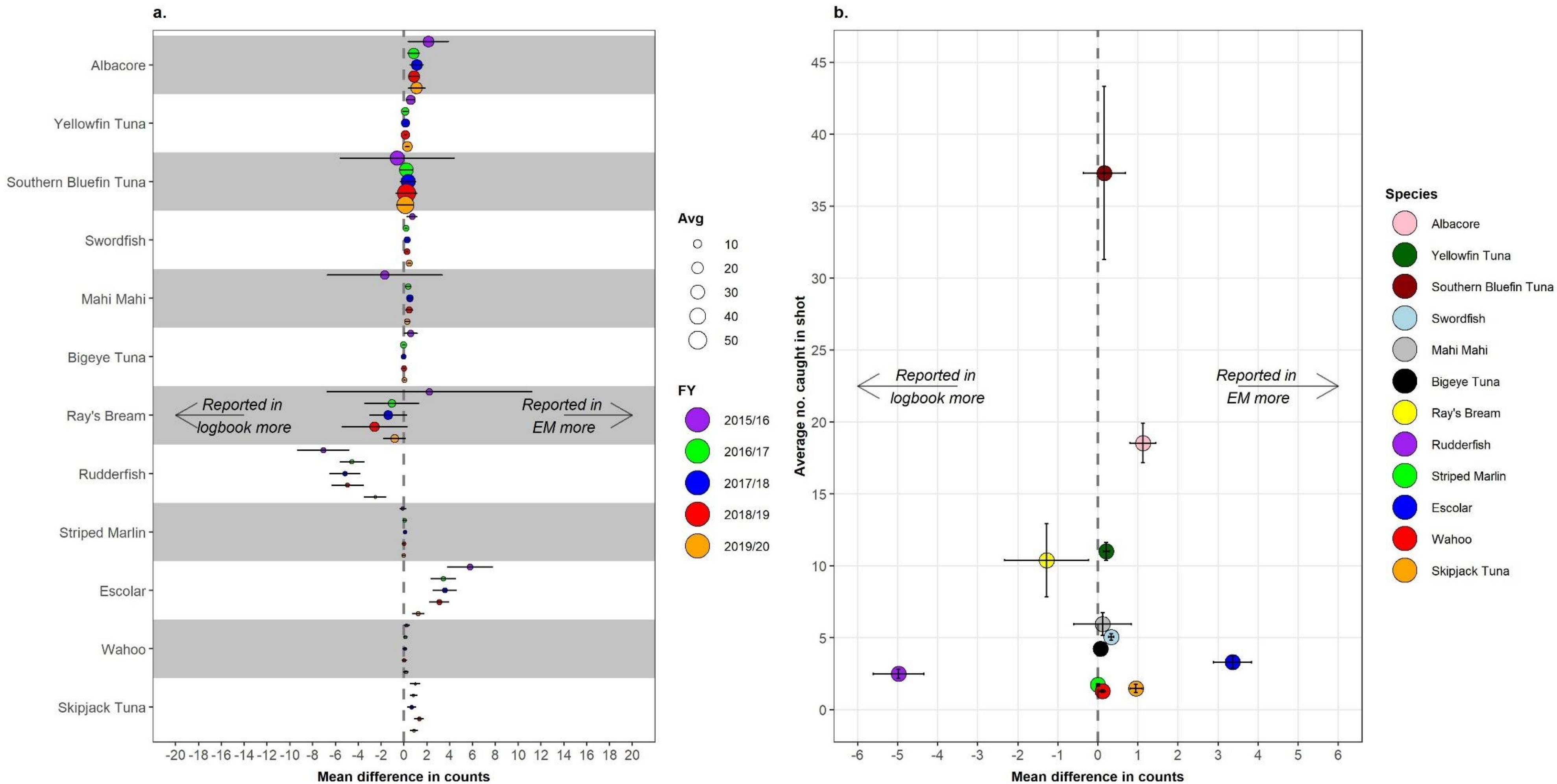
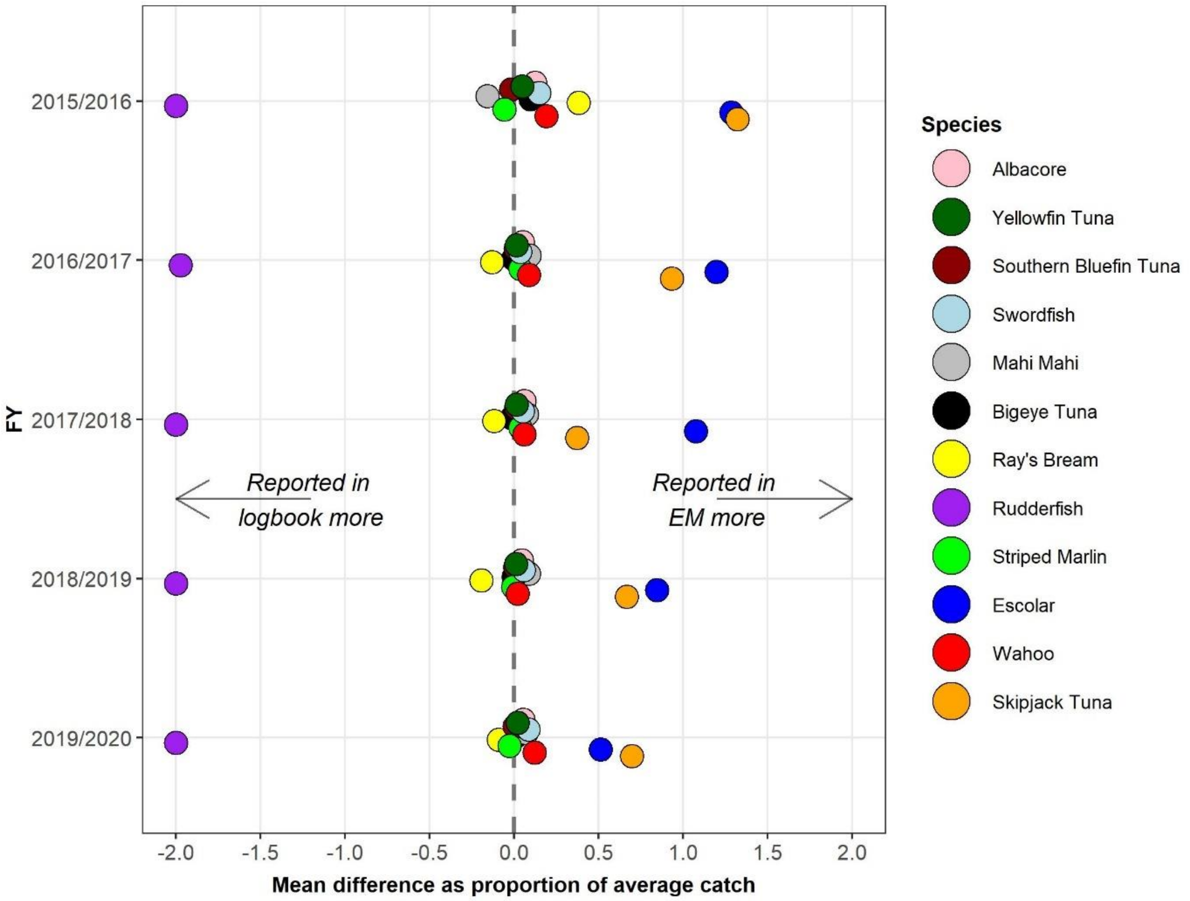


Figure 2: The mean difference in retained fish counts as a proportion of the average retained catch (average of EM and logbook reported) per shot for retained species in the ETBF



3.1.1 Albacore tuna

Across the time period examined, 42% of shots audited that contained retained albacore tuna had no difference in logbook and EM counts, 36% had higher counts reported by EM and 21% had higher counts reported by logbook. When differences in counts between logbook and EM were observed in a single shot these were mainly ~1-3 individuals (Figure 3 and Figure 4). There was evidence of some improvement in congruence through time with 38% of shots in 2015/16 having no difference in logbook and EM counts, increasing to 48% by 2017/18. However, since 2017/18 this declined back to 38% by 2019/20 (Figure 5). While albacore tuna was reported slightly more by EM (1.1 ± 0.3 individuals) across the time period examined, the average number recorded by both EM and logbook in a single shot was high (18.5 ± 1.4 individuals), so as a proportion of the average catch this difference was only 6% (Table 3). So, for every 10 individuals reported by EM, the logbook is reporting 9.4 individuals. Furthermore, there were only 5% of shots containing a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool (Figure 6). So, with typically higher average catches for this species, fishers or the EM analyst are only slightly under-counting relative to the other, rather than not reporting any individuals.

There was a total of 41 vessels that had greater than four audited shots with albacore tuna reported as retained across the time period examined. The average number of albacore tuna recorded as retained for each shot ranged from 3 to 44 individuals for each vessel. An examination of the data at an individual vessel level revealed that for 28 of the 41 vessels, the confidence intervals for the mean difference in counts encompassed zero (Figure 7).

As a proportion of the average catch, the difference in counts across all vessels was variable, with some vessels having very small average catches and therefore higher proportional differences (Figure 7). However, there were several vessels for which EM counts of retained albacore were, on average, significantly higher than retained counts reported on logbooks, especially relative to the rest of the fleet (Figure 7). These vessels included x10, x11, x30 and x31. There was also one fishing vessel – x32, which had higher numbers being reported by logbook relative to the rest of the fleet, however there was only a total of seven shots audited from this vessel.

Figure 3: Logbook and EM reported counts from individual shots containing retained albacore tuna across time period examined. Red dashed line is the 1:1 line.

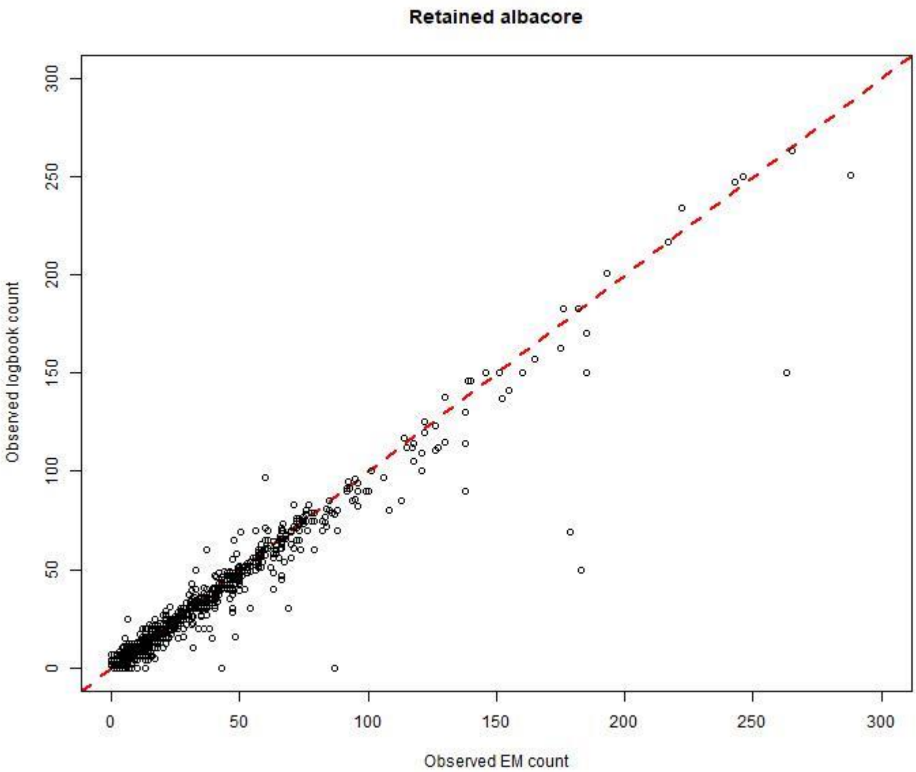


Figure 4: Proportion of shots with specific differences between EM and logbook counts for retained albacore tuna across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

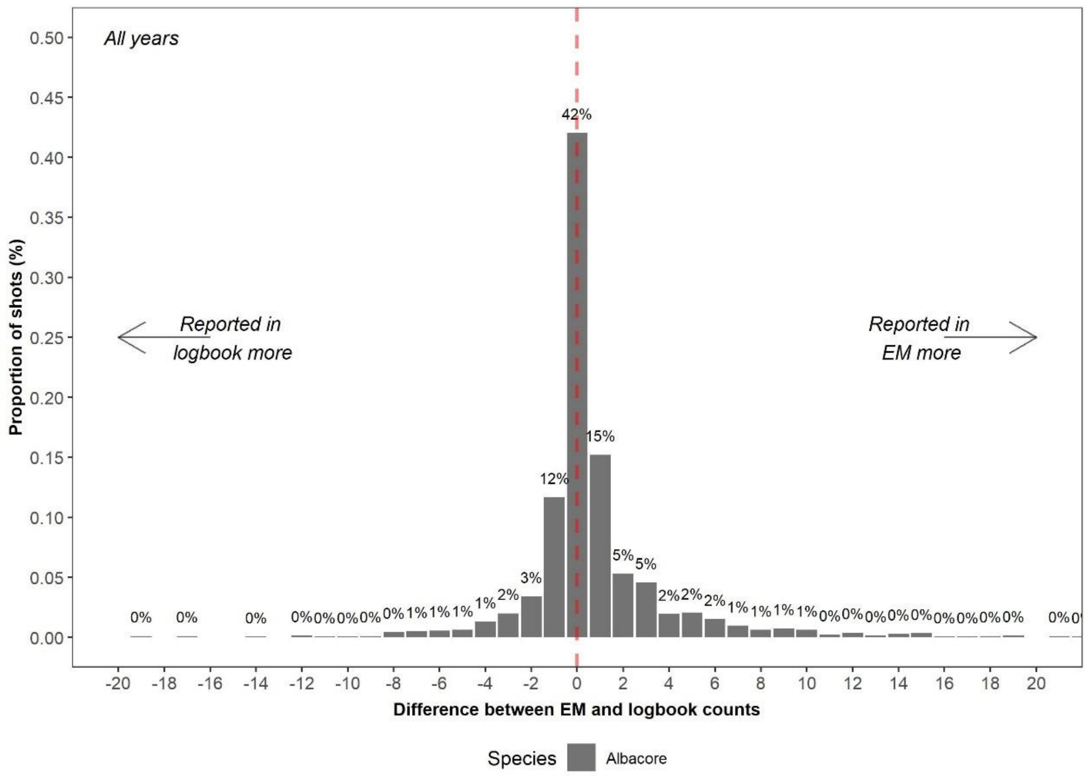


Figure 5: Proportion of shots with specific differences between EM and logbook counts for retained albacore tuna for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

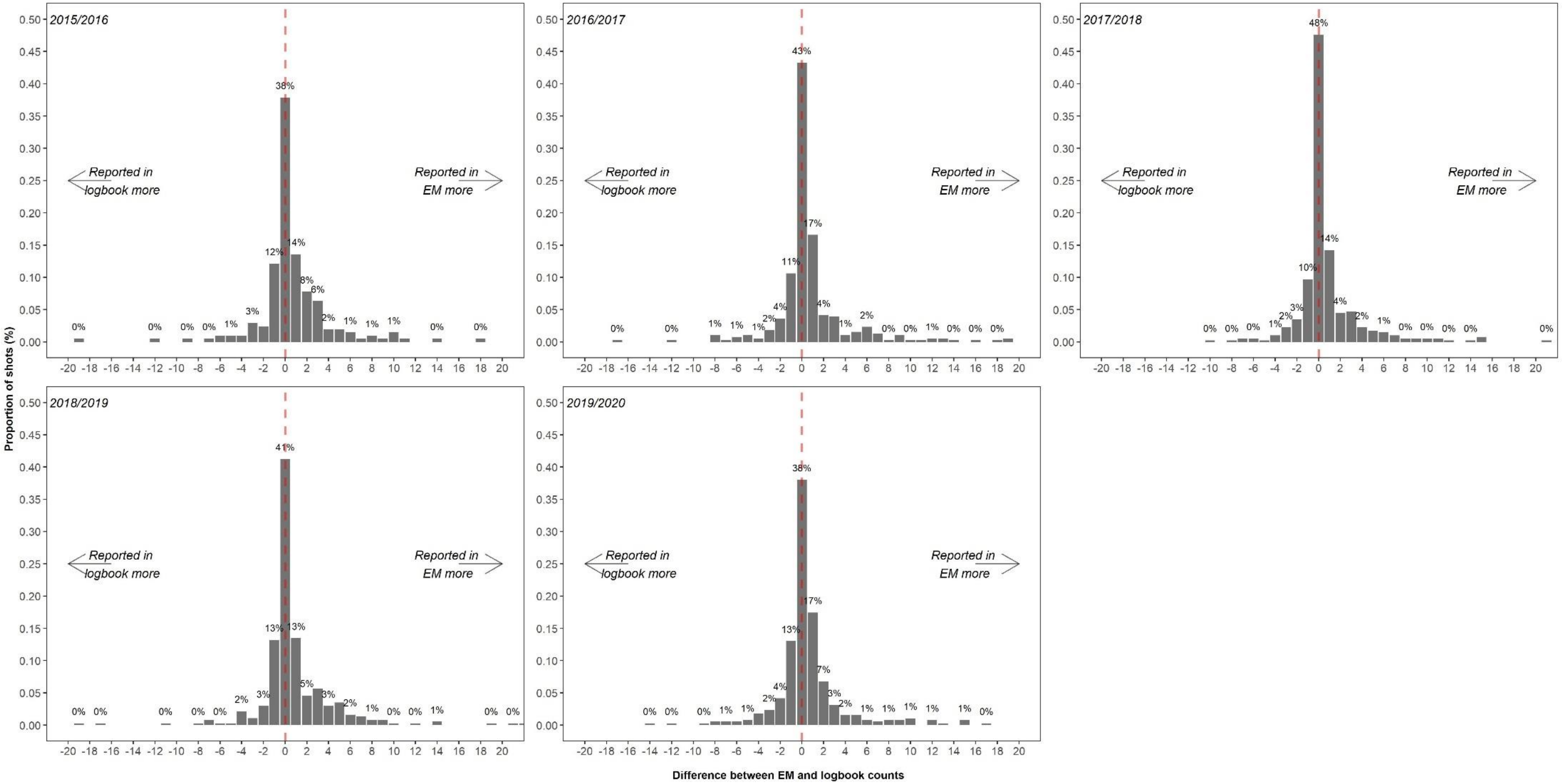


Figure 6: Number of shots with specific differences between EM and logbook counts for retained albacore tuna across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

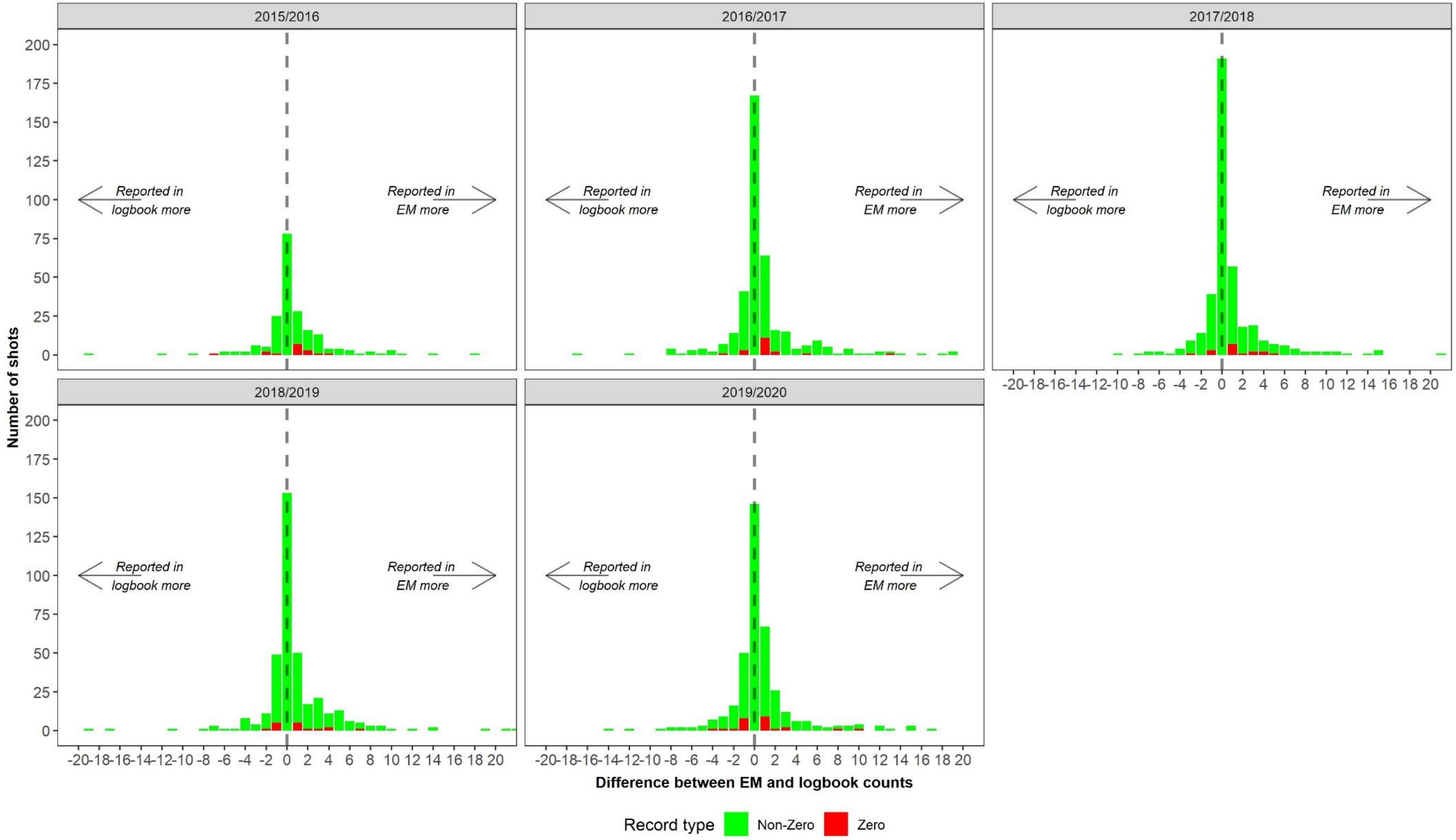
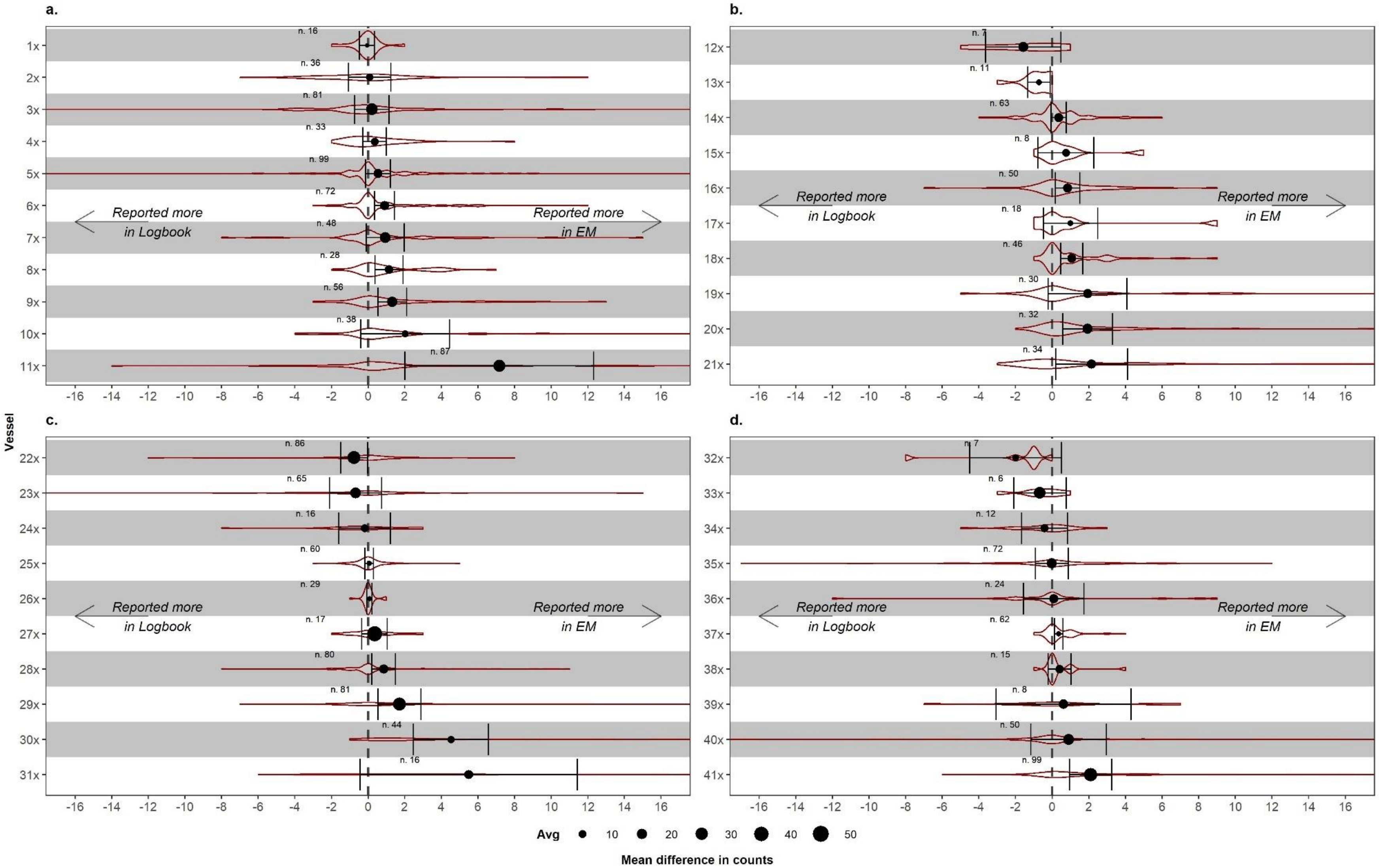


Figure 7: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing retained albacore tuna across the time period. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



3.1.2 Yellowfin tuna

Across the time period examined, 70% of shots audited that contained retained yellowfin tuna had no difference in logbook and EM counts, 20% had higher counts reported by EM and 10% had higher counts reported by logbook. When differences in counts between logbook and EM were observed in a single shot these were mainly only ~1 individual (Figure 8 and Figure 9). There was evidence of an initial improvement in congruence from 50% of shots having no difference in logbook and EM counts in 2015/16 to a total of 78% in 2016/17, which remained steady until 2019/20 when it declined to 59% (Figure 10). The mean difference in counts was negligible across the time period examined (0.2 ± 0.1 individuals) with the average number recorded by both EM and logbook relatively high (11.0 ± 0.6 individuals), so as a proportion of the average catch this difference was 2% (Table 3). So, for every 10 individuals reported by EM, the logbook is reporting 9.8 individuals. Furthermore, there were only 1% of shots containing a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool (Figure 11). So, with typically higher average catches for this species, fishers or the EM analyst are only slightly under-counting relative to the other, rather than not reporting any individuals.

There was a total of 41 vessels that had greater than four audited shots with yellowfin tuna reported as retained across the time period examined (Figure 12). The average number of yellowfin tuna recorded as retained for each shot ranged from 4 to 25 individuals for each vessel. An examination of the data at an individual vessel level revealed that for 36 of the 41 vessels, the confidence intervals for the mean difference in counts encompassed zero (Figure 12).

As a proportion of the average catch, the difference in counts across all vessels was <9%, with most vessels <5%, signifying high congruence across the fleet.

Figure 8: Logbook and EM reported counts from individual shots containing retained yellowfin tuna across time period examined. Red dashed line is the 1:1 line.

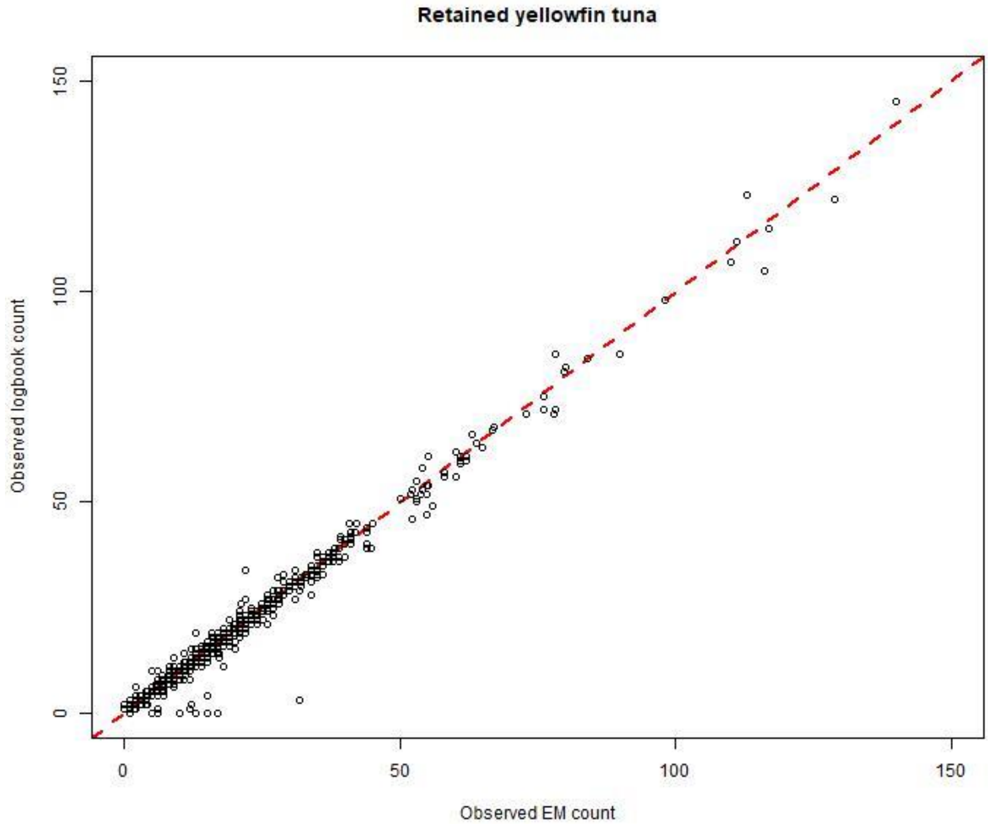


Figure 9: Proportion of shots with specific differences between EM and logbook counts for retained yellowfin tuna across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

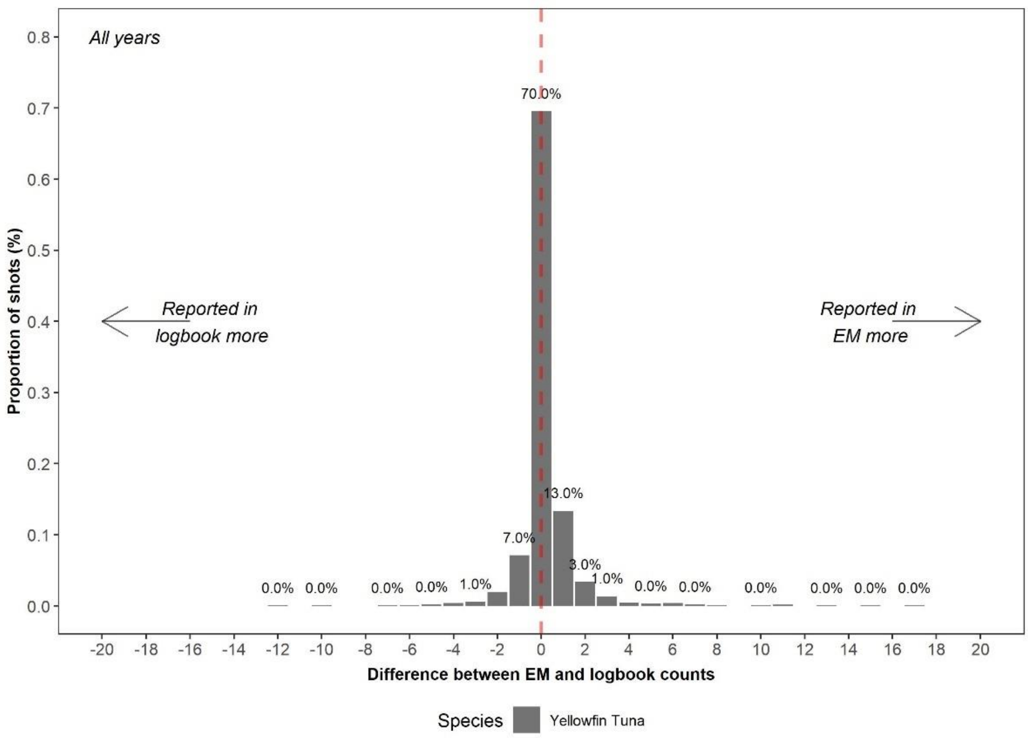


Figure 10: Proportion of shots with specific differences between EM and logbook counts for retained yellowfin tuna for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

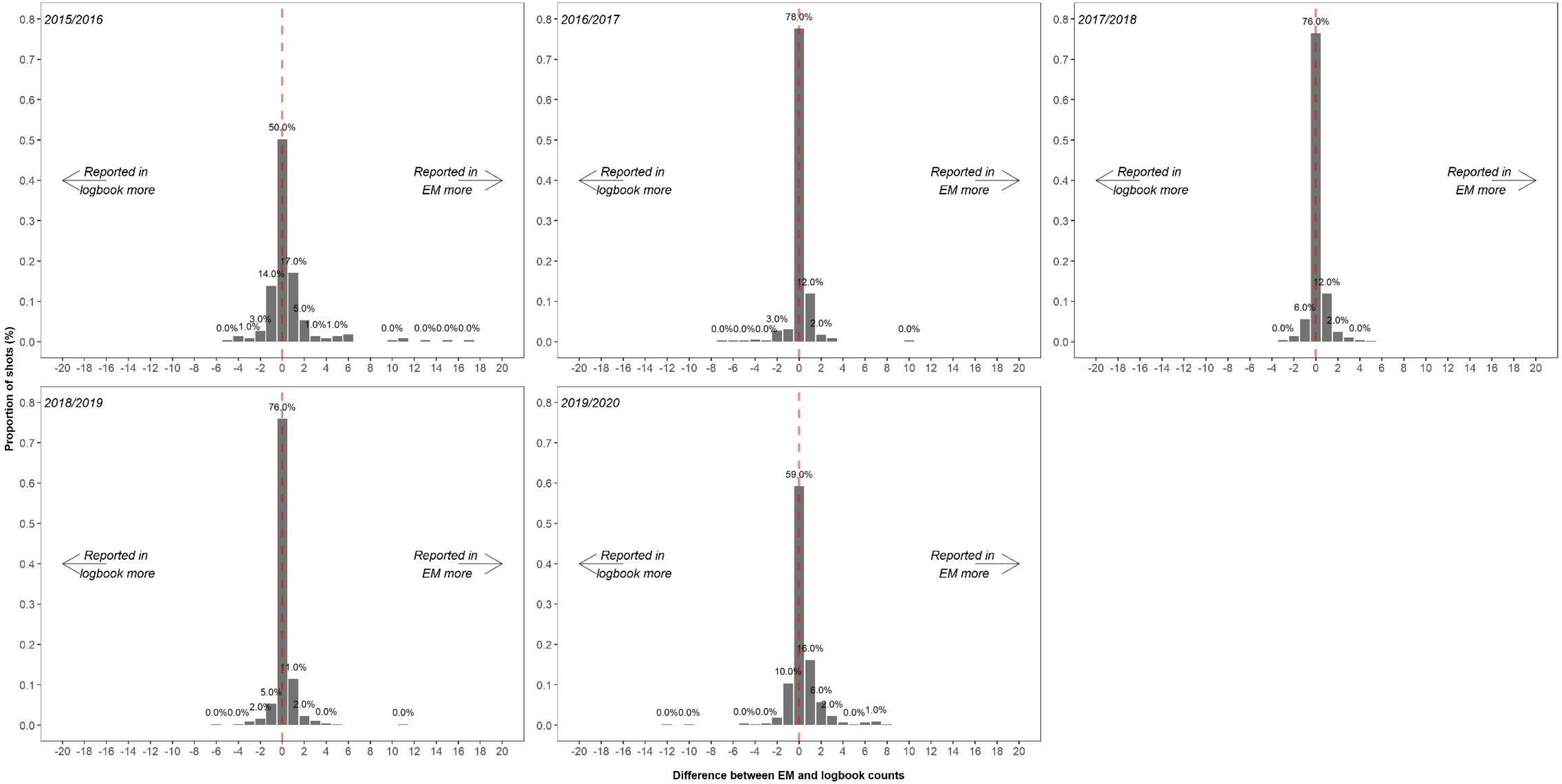


Figure 11: Number of shots with specific differences between EM and logbook counts for retained yellowfin tuna across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

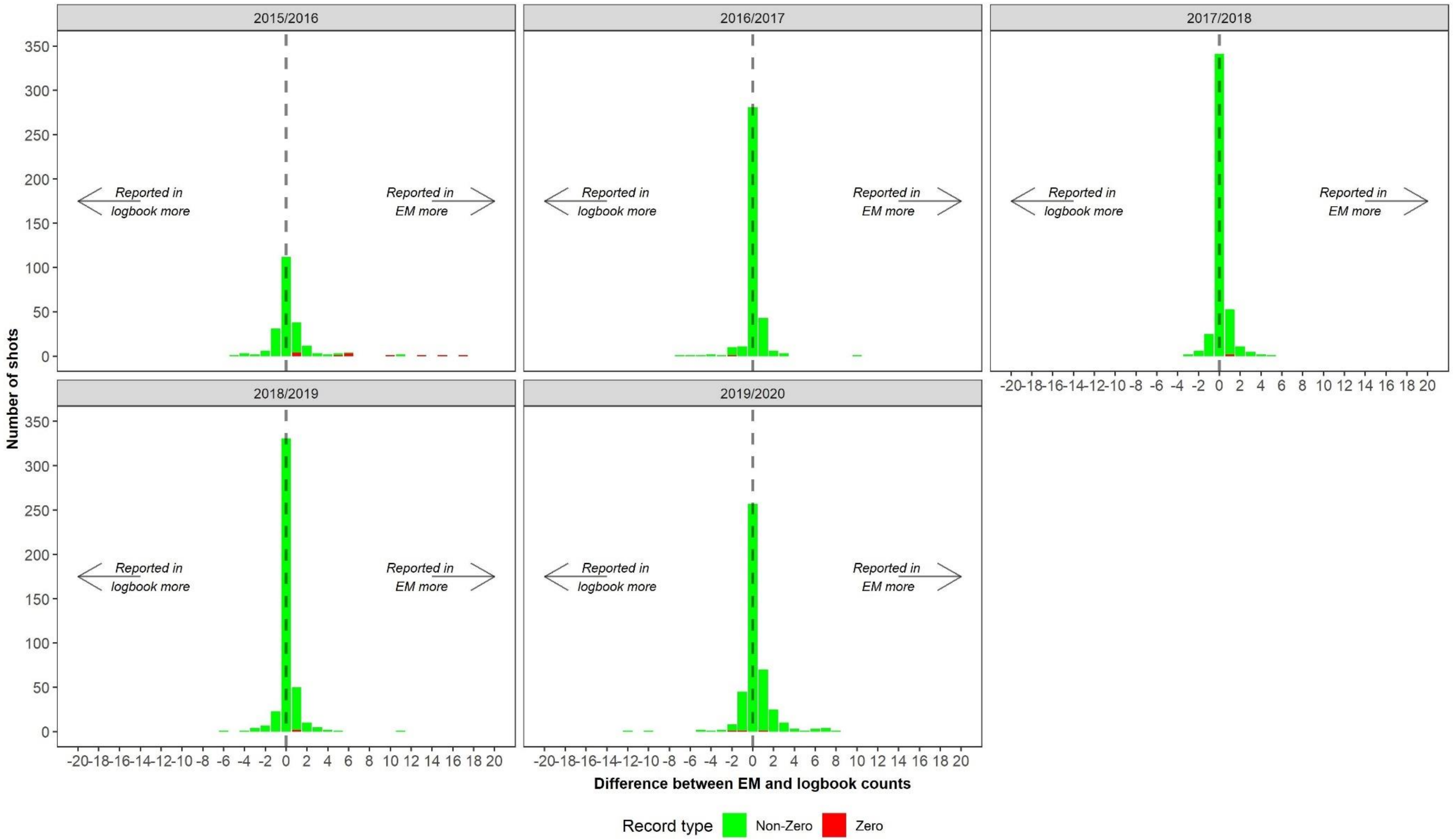
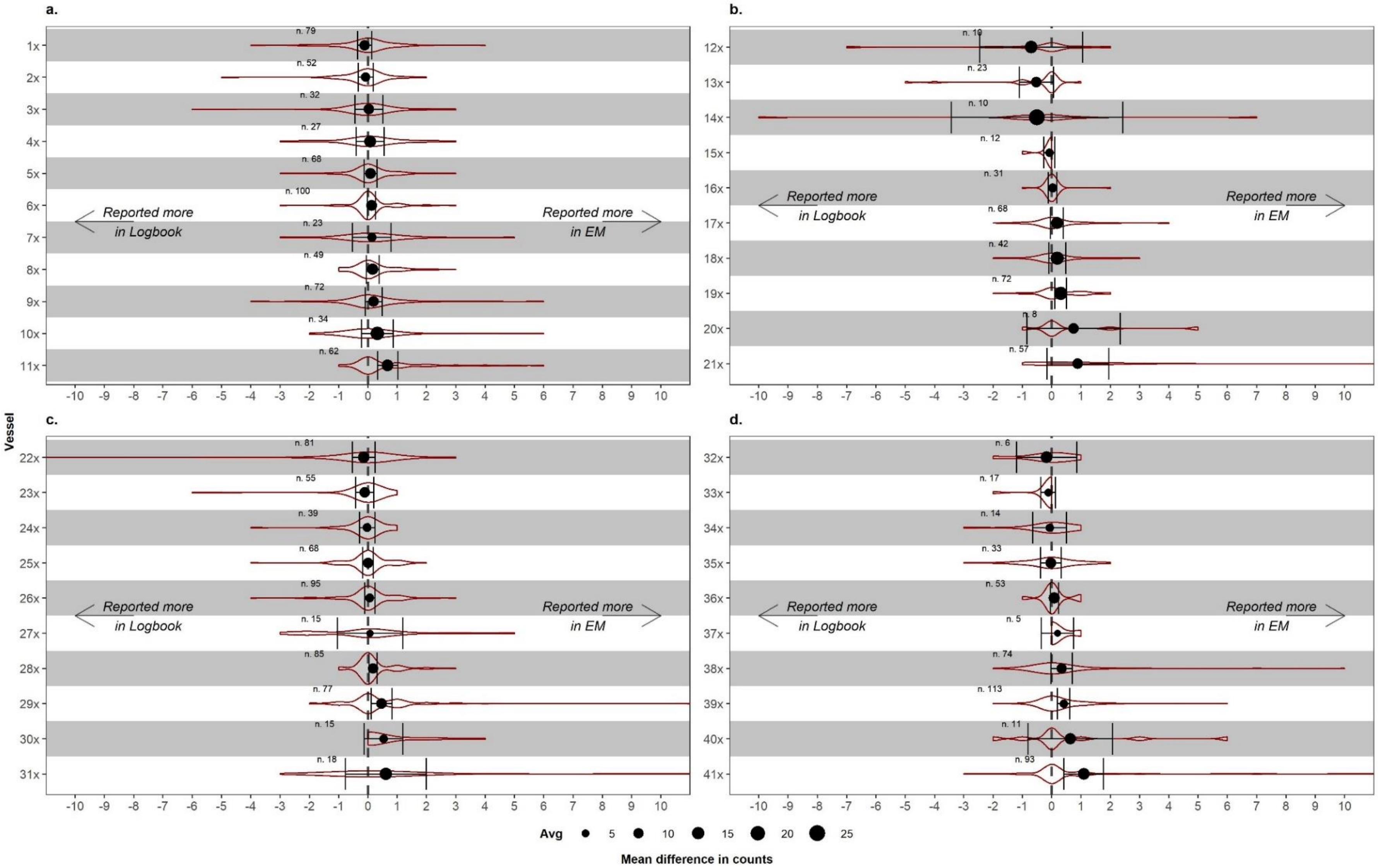


Figure 12: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing retained yellowfin tuna across the time period. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



3.1.3 Southern bluefin tuna

Across the time period examined, 46% of shots audited that contained retained southern bluefin tuna had no difference in logbook and EM counts, 34% had higher counts reported by EM and 19% had higher counts reported by logbook. When differences in counts between logbook and EM were observed in a single shot these were only ~1-2 individuals (Figure 13 and Figure 14). There was evidence of an initial improvement in congruence from 30% of shots having no difference in logbook and EM counts in 2015/16 to a total of 43% in 2016/17, which has remained steady at around 50% up to 2019/20 (Figure 15). The mean difference in counts across the time period was negligible across the time period examined (0.2 ± 0.5 individuals) with the average number recorded by both EM and logbook relatively high (37.3 ± 6.0 individuals), so as a proportion of the average catch this difference was <1%. So, for every 10 individuals reported by EM, the logbook is reporting ~9.9-10 individuals. Furthermore, there were only 2% of shots containing a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool (Figure 16). So, with typically higher average catches for this species, fishers or the EM analyst are only slightly under-counting relative to the other, rather than not reporting any individuals.

There was a total of 14 vessels that had greater than four audited shots with SBT reported as retained across the time period examined (Figure 17). The average number of SBT recorded as retained for each shot ranged from 6 to 67 individuals for each vessel. An examination of the data at an individual vessel level revealed that for 12 of the 14 vessels, the confidence intervals for the mean difference in counts encompassed zero (Figure 17).

As a proportion of the average catch, the difference in counts across 12 of the 14 vessels was <3%, signifying high congruence. For the remaining two vessels – x2 and x1, this was -5% and -11% respectively, which still indicates high congruence, but that EM was having some issues reporting all retained SBT relative to the rest of the fleet.

Figure 13: Logbook and EM reported counts from individual shots containing retained southern bluefin tuna across time period examined. Red dashed line is the 1:1 line.

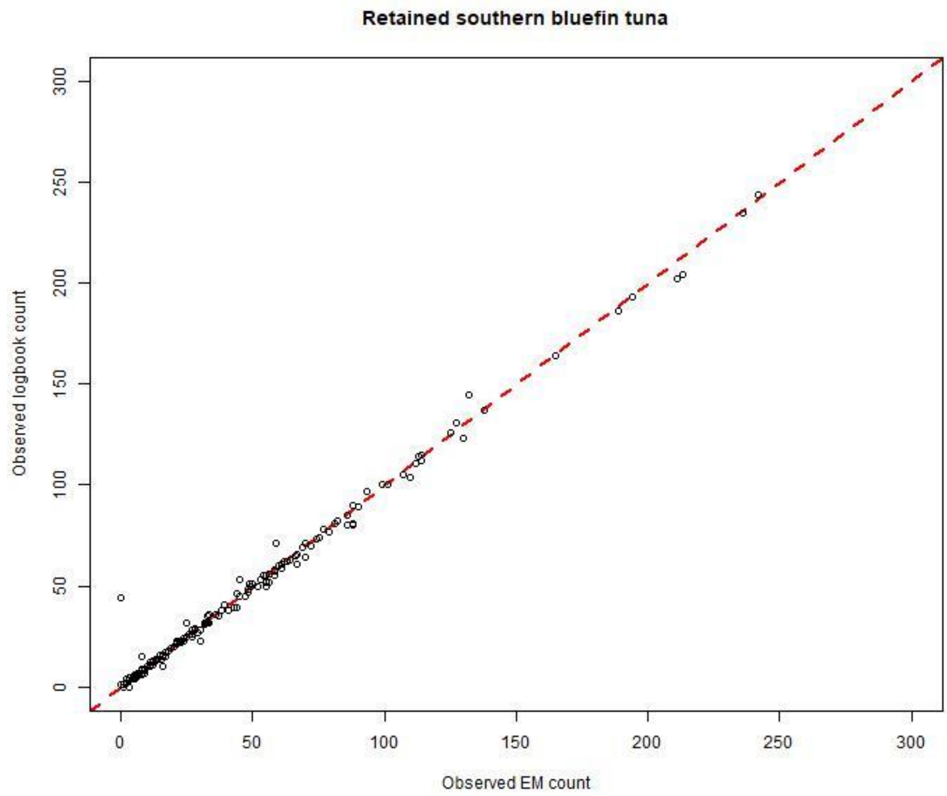


Figure 14: Proportion of shots with specific differences between EM and logbook counts for retained southern bluefin tuna across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

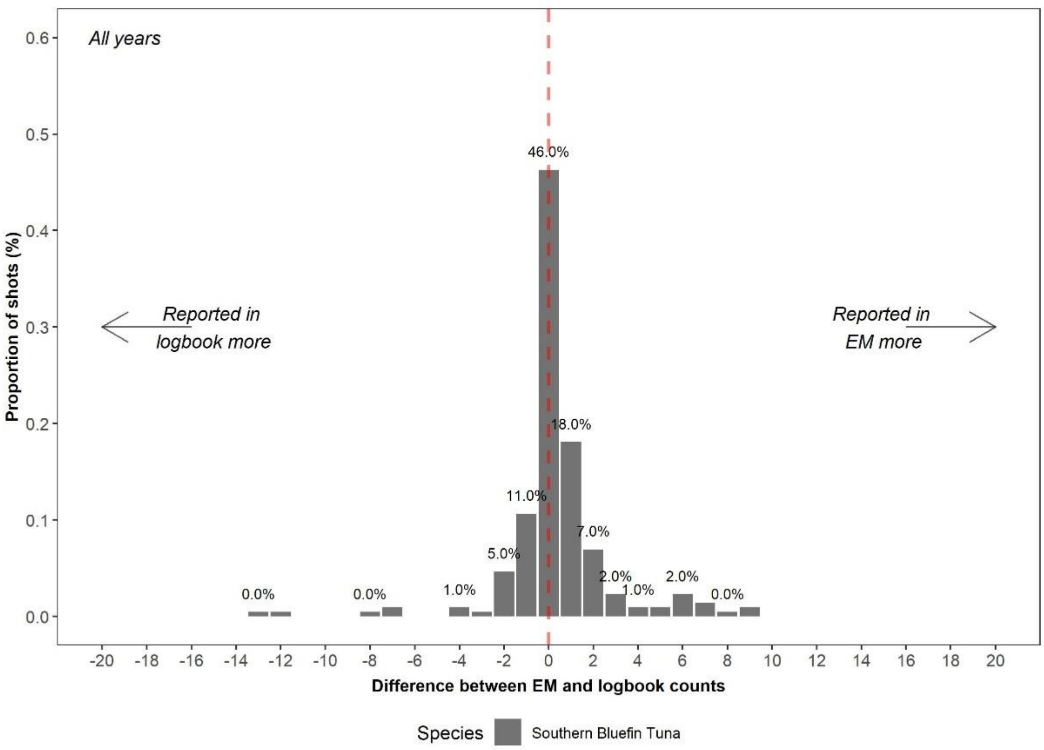


Figure 15: Proportion of shots with specific differences between EM and logbook counts for retained southern bluefin tuna for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

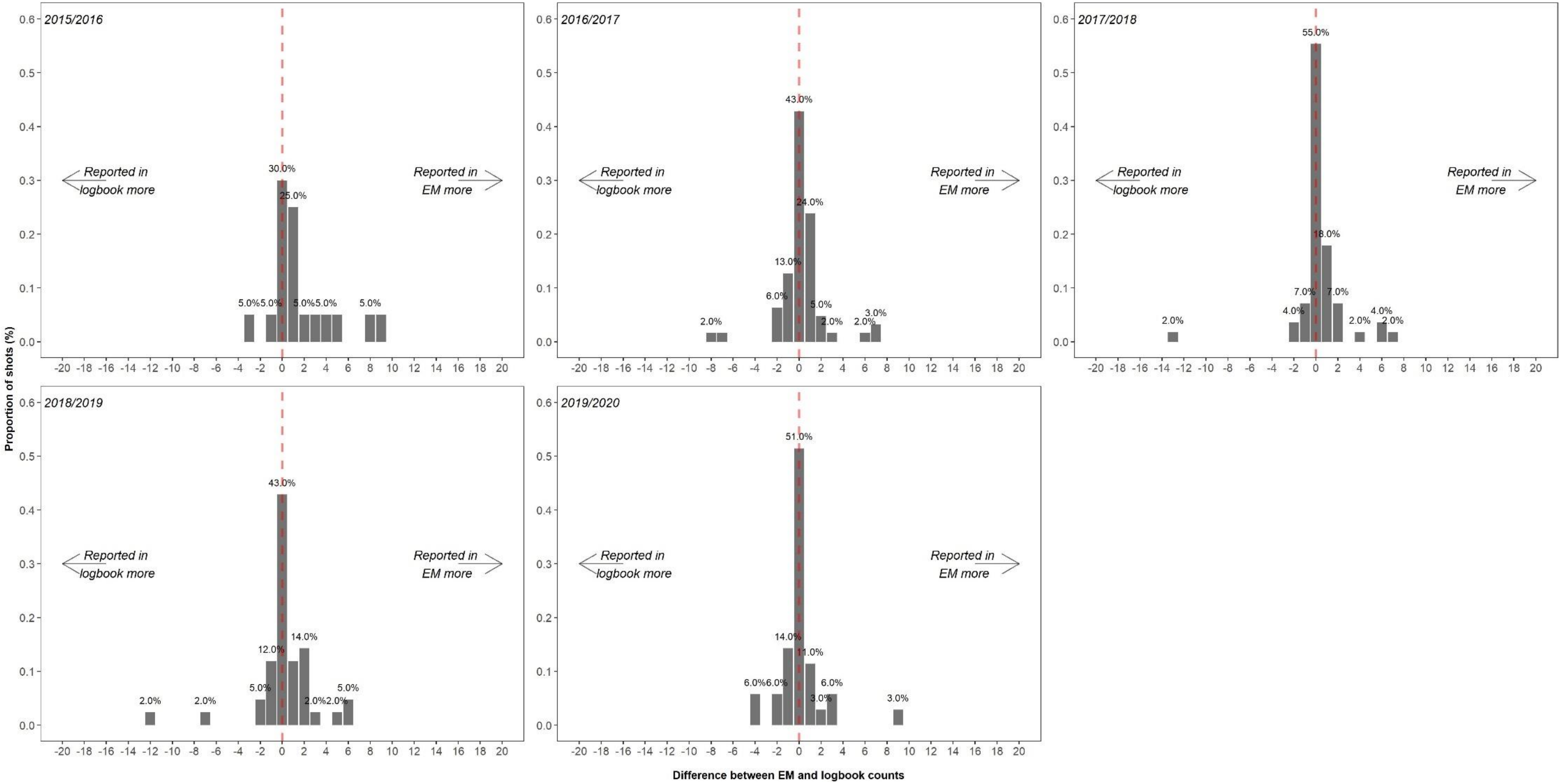


Figure 16: Number of shots with specific differences between EM and logbook counts for retained southern bluefin tuna across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

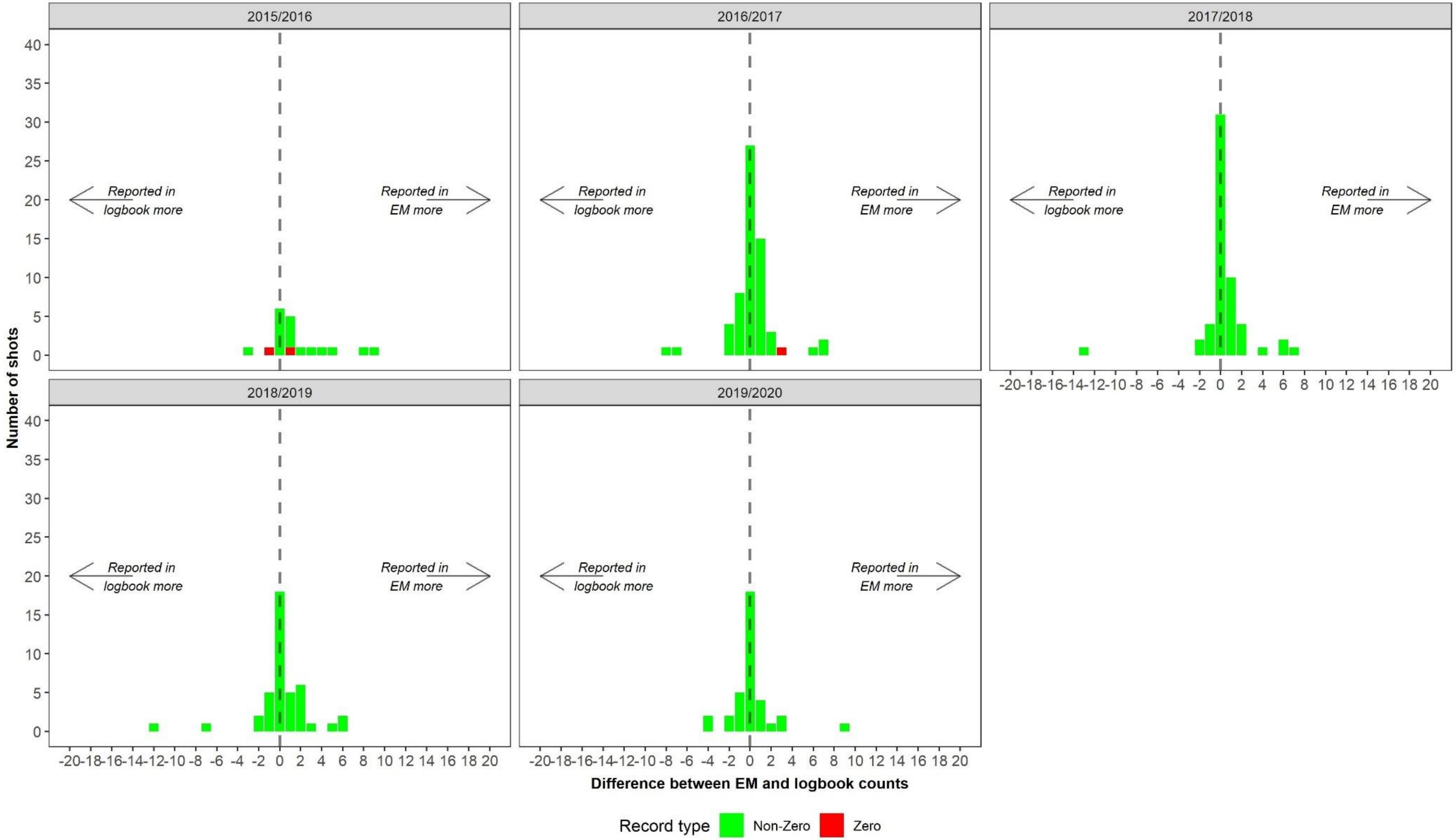
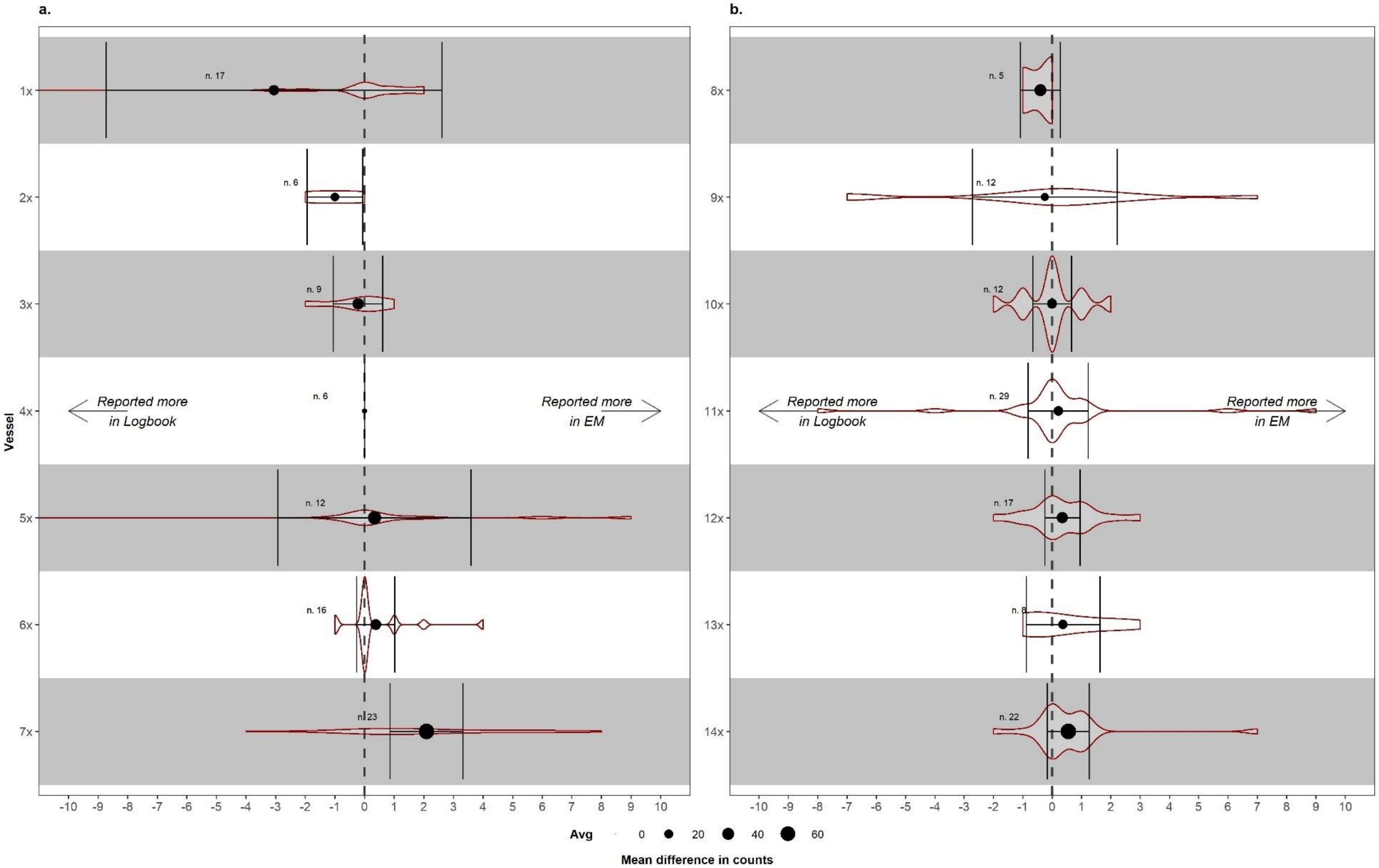


Figure 17: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing retained SBT across the time period. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



3.1.4 Swordfish

Across the time period examined, 69% of shots audited that contained retained swordfish had no difference in logbook and EM counts, 25% had higher counts reported by EM and 6% had higher counts reported by logbook. When differences in counts between logbook and EM were observed in a single shot these were typically around ~1-2 individuals (Figure 18 and Figure 19). Up until 2019/20, congruence was stable through time, ranging from 67-77% of shots having no difference in logbook and EM counts, but this declined to 62% in 2019/20 (Figure 20). The mean difference in counts across the time period was negligible at 0.3 ± 0.1 individuals, suggesting both data collections tools are reporting similar numbers of individuals. The average number recorded by both EM and logbook in a single shot was 5.0 ± 0.2 individuals, so as a proportion of the average catch this difference was 6% (Table 3). So, for every 10 individuals reported by EM, the logbook is reporting 9.4 individuals. Furthermore, there were only 5% of shots containing a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool (Figure 21).

There was a total of 38 vessels that had greater than four audited shots with swordfish reported as retained across the time period examined (Figure 22). The average number of swordfish recorded as retained for each shot from 4 to 25 individuals for each vessel. An examination of the data at an individual vessel level revealed that for 24 of the 38 vessels, the confidence intervals for the mean difference in counts encompassed zero.

As a proportion of the average catch, the difference in counts across all vessels was variable, with some vessels having very small average catches and therefore higher proportional differences (Figure 22). Three vessels in particular –x10, x27 and x29 had higher retained swordfish numbers being reported by EM (compared to logbook) relative to the rest of the fleet, but their average number reported retained were all less than two individuals. Three vessels (x14, x30 and x31) had perfect congruence, with all audited shots having no difference between EM and logbook reported numbers (Figure 22).

Figure 18: Logbook and EM reported counts from individual shots containing retained swordfish across time period examined. Red dashed line is the 1:1 line.

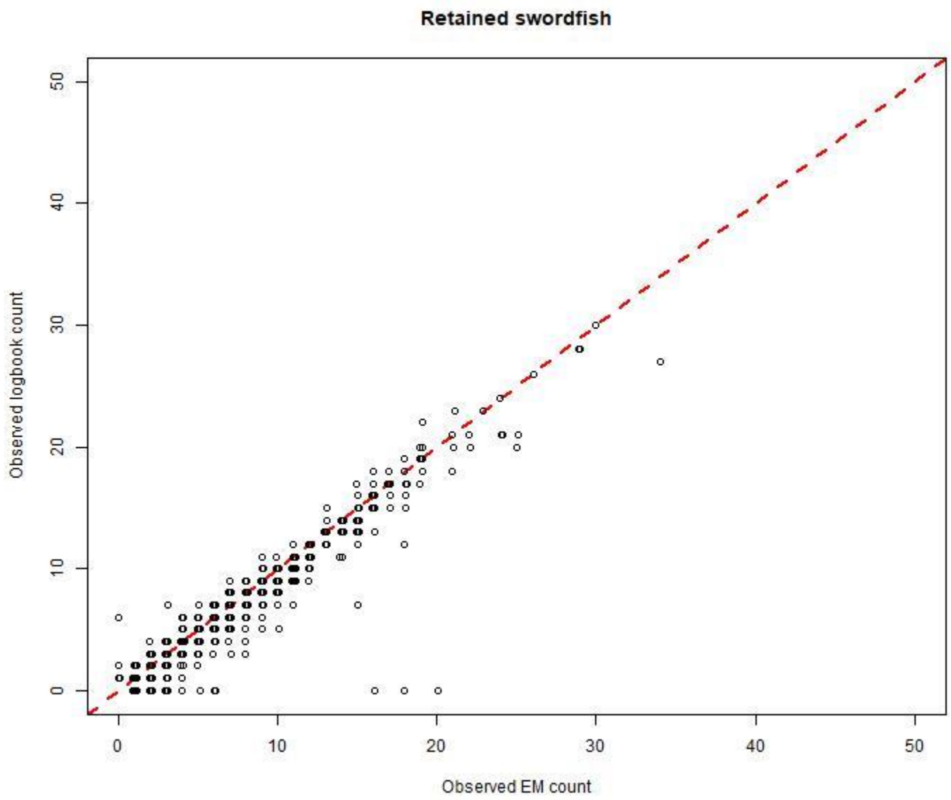


Figure 19: Proportion of shots with specific differences between EM and logbook counts for retained swordfish across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

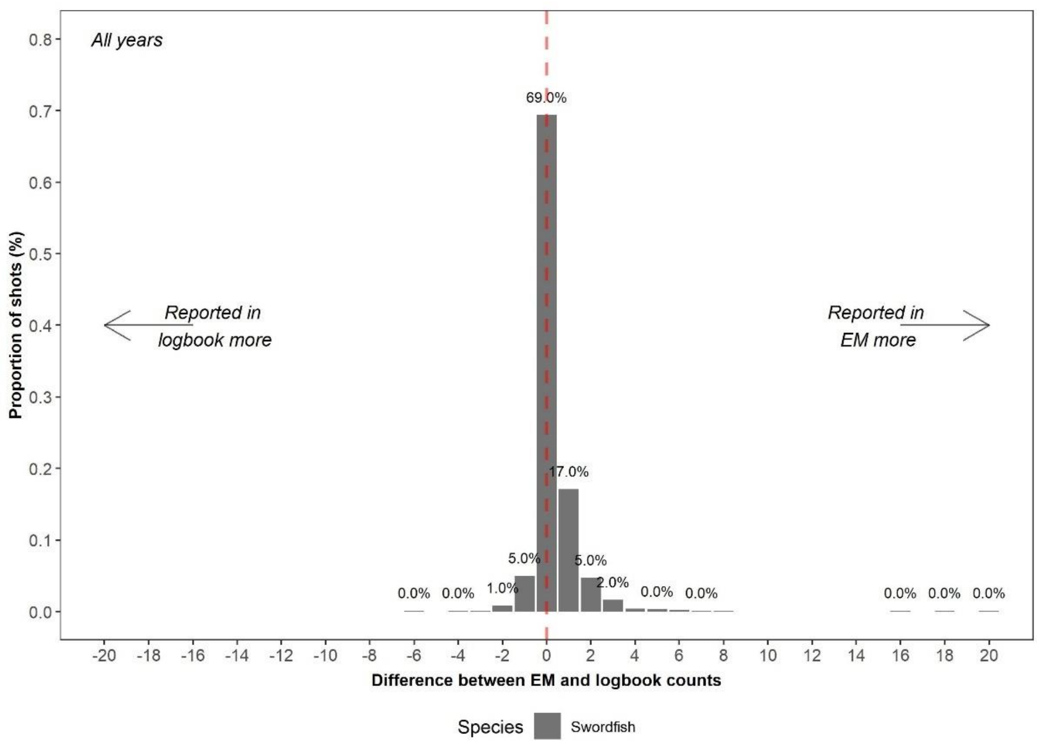


Figure 20: Proportion of shots with specific differences between EM and logbook counts for retained swordfish for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

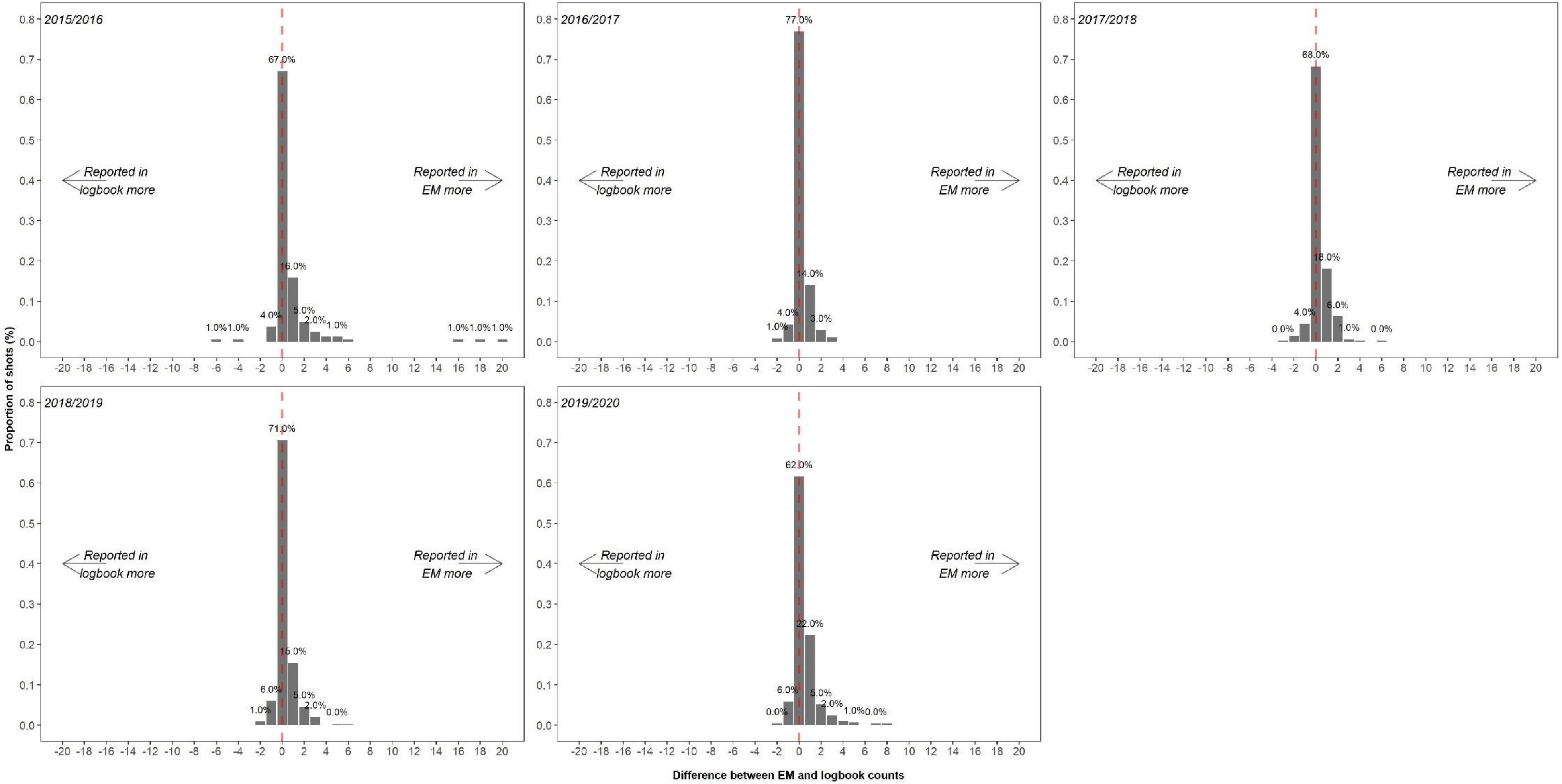


Figure 21: Number of shots with specific differences between EM and logbook counts for retained swordfish across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

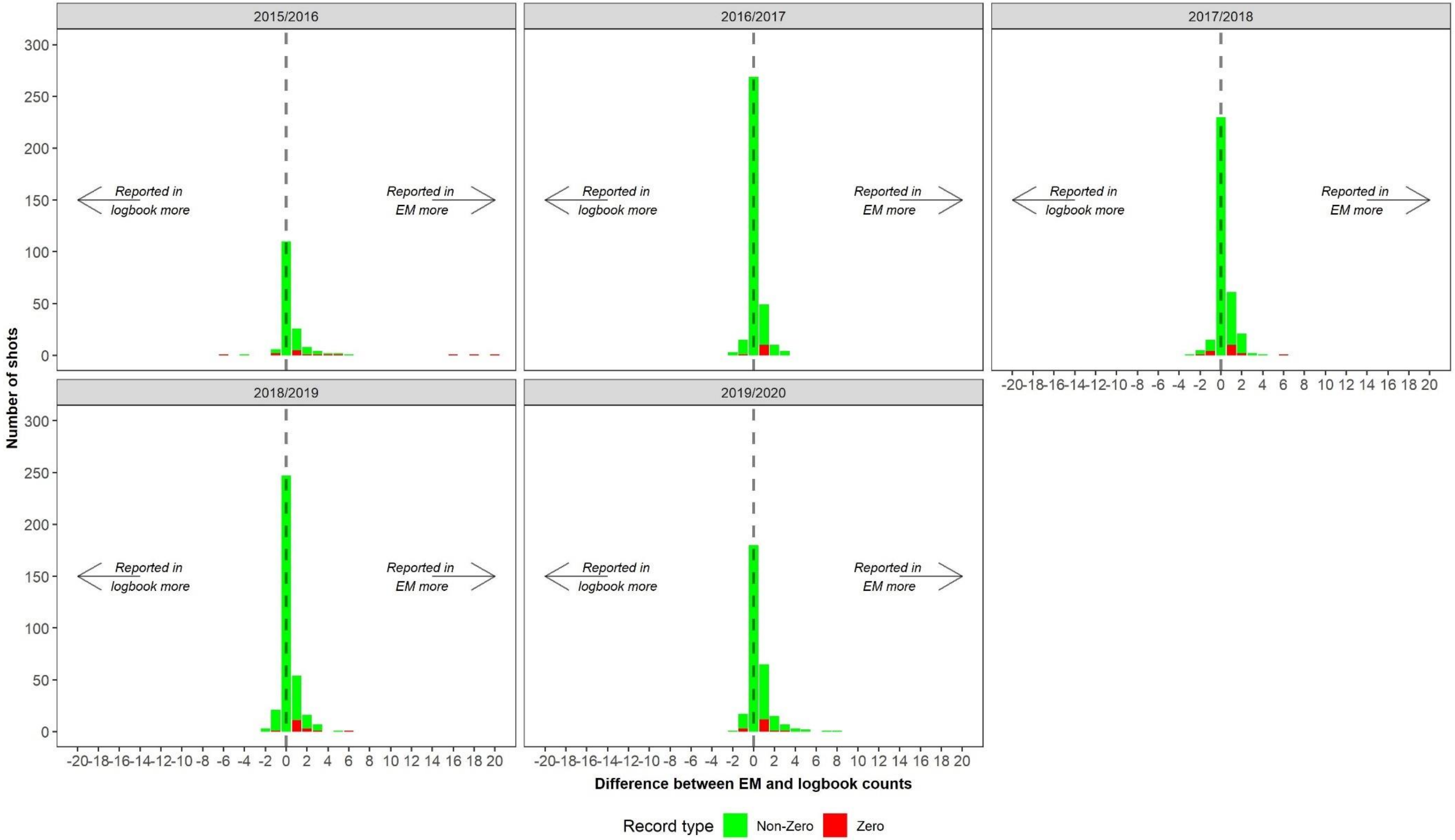
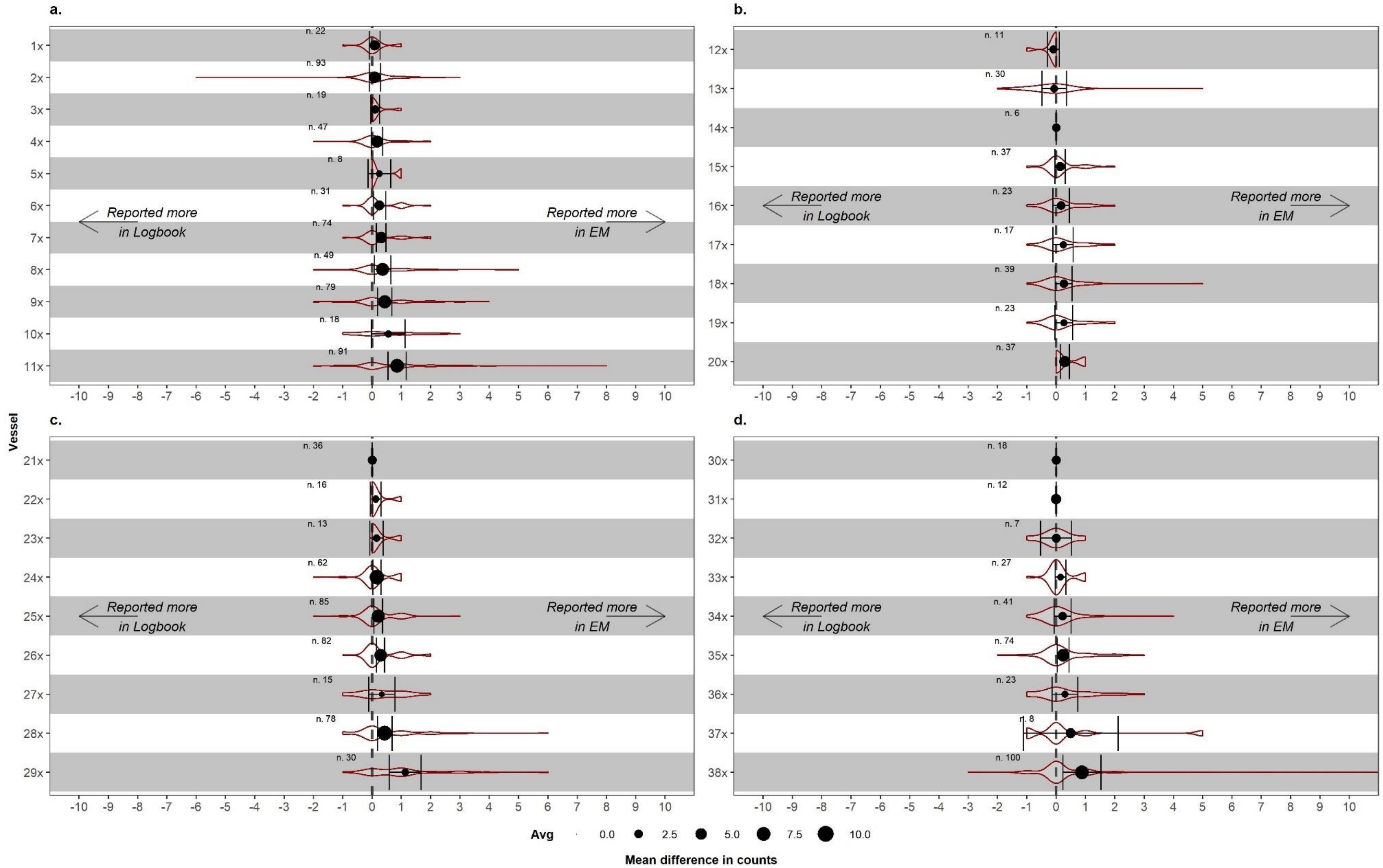


Figure 22: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing retained swordfish across the time period. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



3.1.5 Mahi mahi

Across the time period examined, 58% of shots audited that contained retained mahi mahi had no difference in logbook and EM counts, 30% had higher counts reported by EM and 12% had higher counts reported by logbook. When differences in counts between logbook and EM were observed in a single shot these were only ~1-2 individuals (Figure 23 and Figure 24). There was evidence of an initial improvement in congruence from 49% of shots having no difference in logbook and EM counts in 2015/16 to a total of 62% in 2016/17, which has remained steady around 60% up to 2019/20 (Figure 25). The mean difference in counts across the time period was negligible at 0.1 ± 0.7 individuals, suggesting both data collections tools are reporting similar numbers of individuals. The average number recorded by both EM and logbook in a single shot was 5.9 ± 0.8 individuals, so as a proportion of the average catch this difference was 2% (Table 3). So, for every 10 individuals reported by EM, the logbook is reporting 9.8 individuals. Around 13% of total shots contained a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool (Figure 26).

There was a total of 38 vessels that had greater than four audited shots with mahi mahi reported as retained across the time period examined (Figure 27). The average number of mahi mahi recorded as retained for each shot ranged from 1 to 19 individuals for each vessel. An examination of the data at an individual vessel level revealed that for 29 of the 38 vessels, the confidence intervals for the mean difference in counts encompassed zero (Figure 27).

As a proportion of the average catch, the difference in counts across all vessels was variable (but less than other retained species such as albacore tuna). There were a few vessels with higher proportional differences in counts. The fishing vessel x1 had higher numbers being reported by logbook relative to EM with clear reporting issues, suggesting EM may be having some issues either correctly identifying mahi mahi or observing it being retained. Fishing vessels x9, x20, x29, x30 and x38 all had significantly higher numbers being reported by EM compared to logbook, which may warrant further investigation (Figure 27).

Figure 23: Logbook and EM reported counts from individual shots containing retained mahi mahi across time period examined. Red dashed line is the 1:1 line.

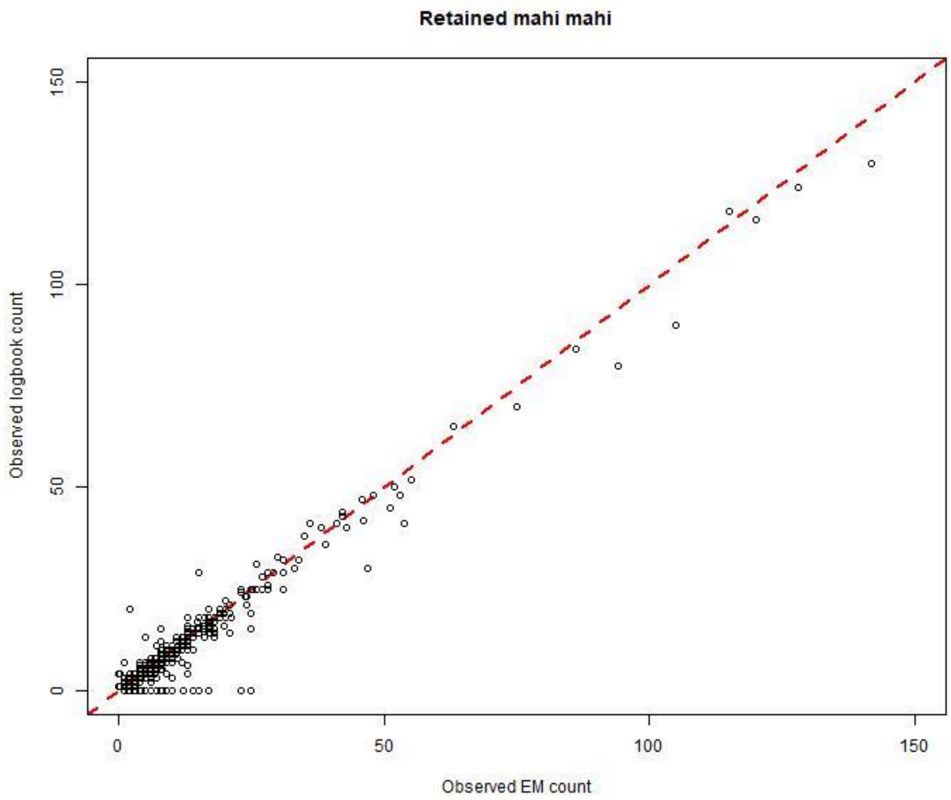


Figure 24: Proportion of shots with specific differences between EM and logbook counts for retained mahi mahi across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

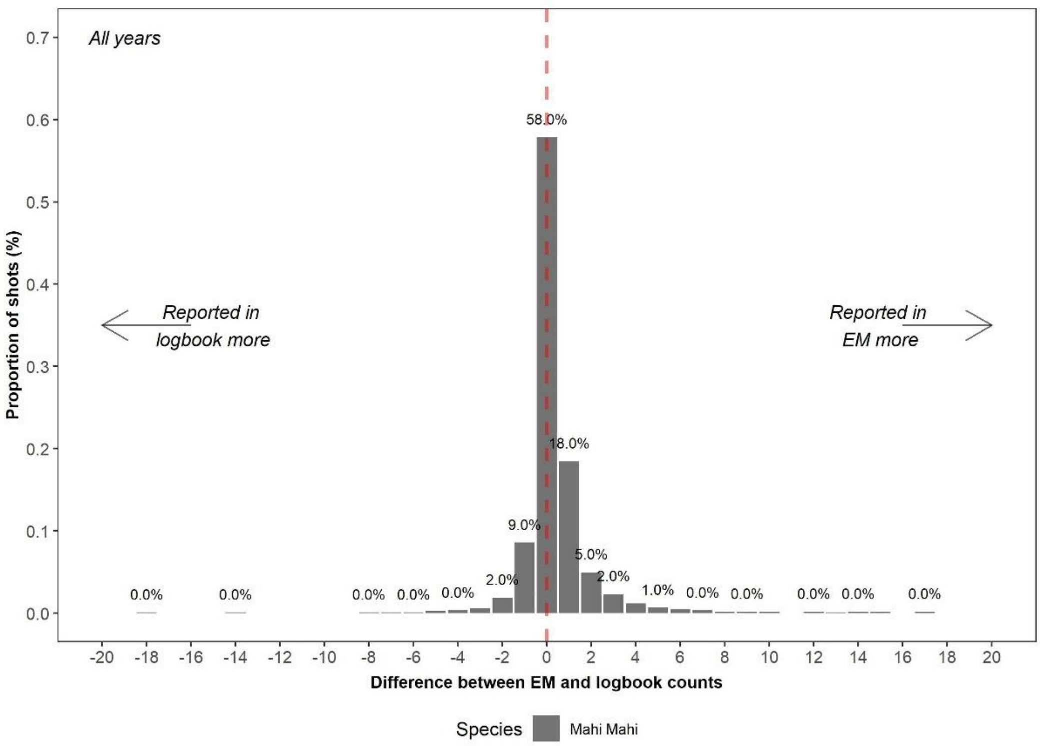


Figure 25: Proportion of shots with specific differences between EM and logbook counts for retained mahi mahi for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

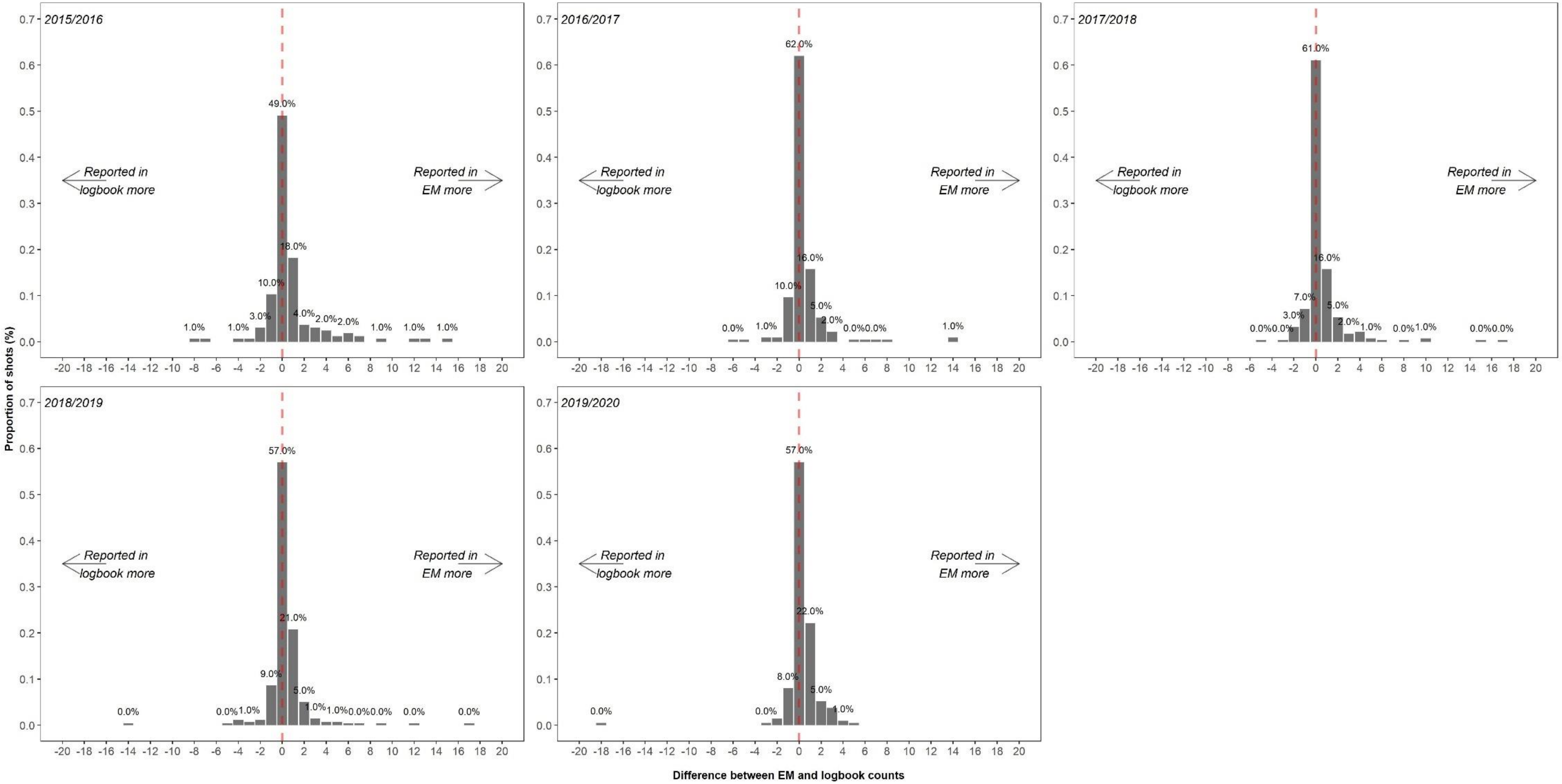


Figure 26: Number of shots with specific differences between EM and logbook counts for retained mahi mahi across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

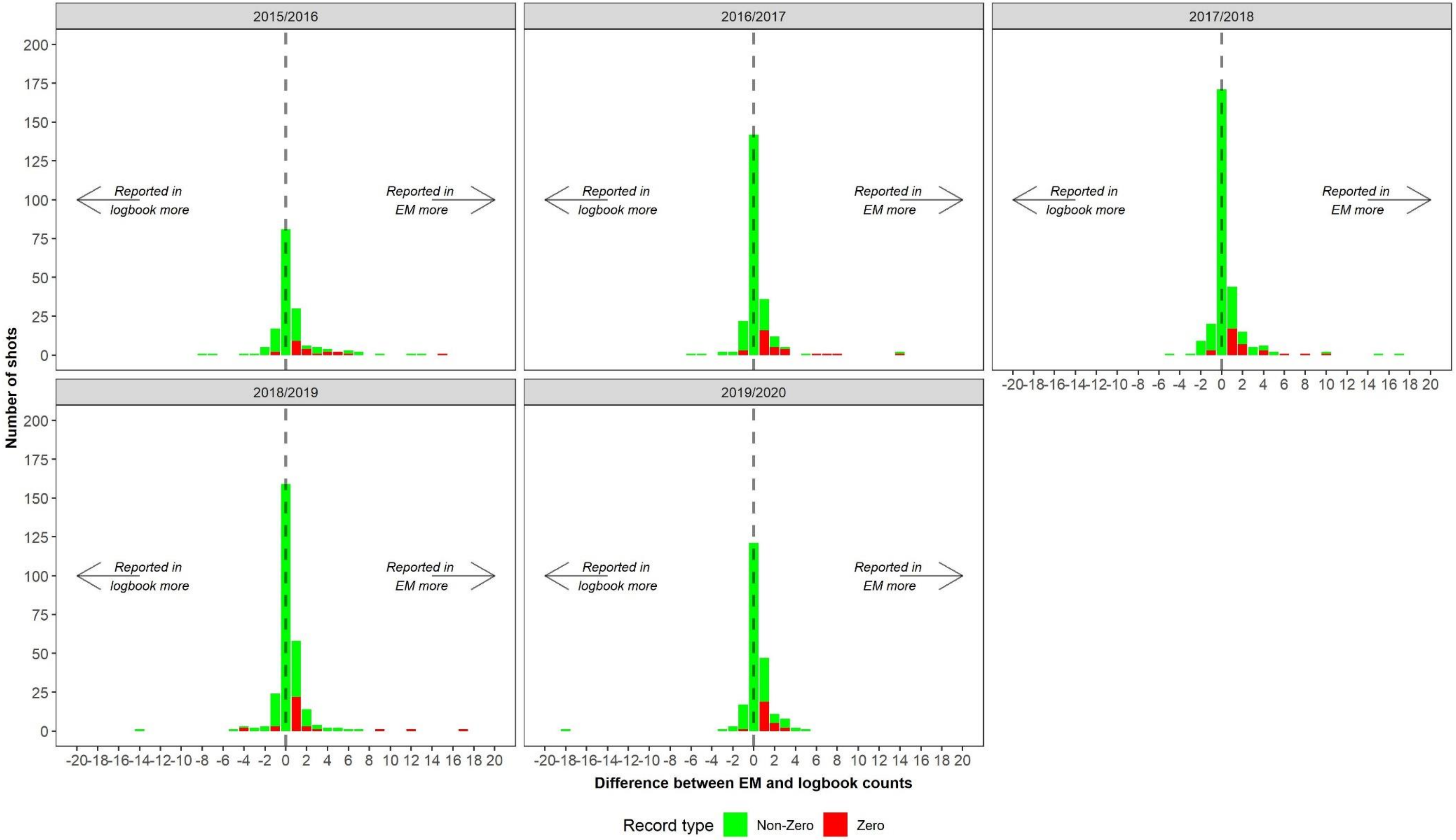
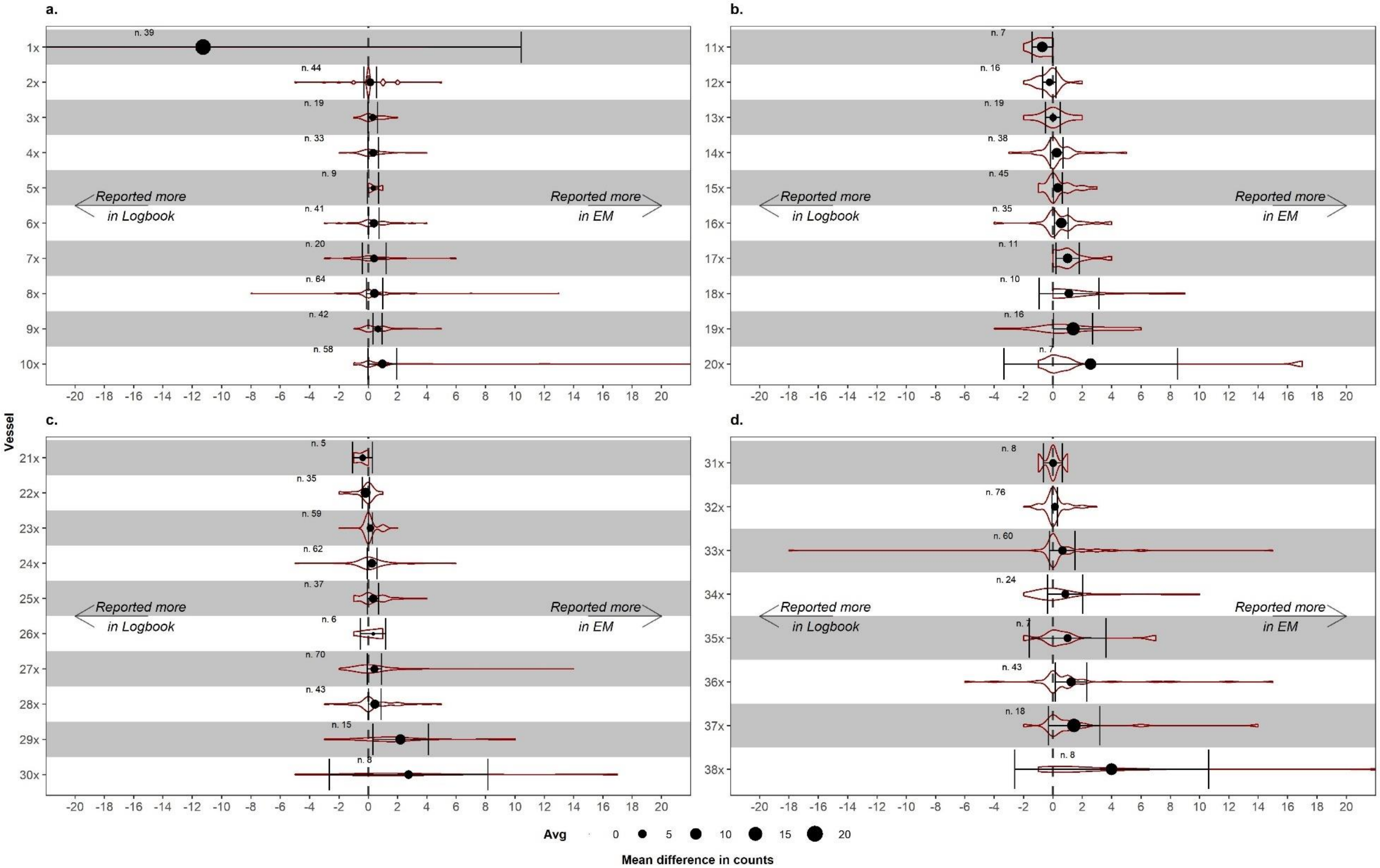


Figure 27: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing retained mahi mahi across the time period. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



3.1.6 Bigeye tuna

Across the time period examined, 74% of shots audited that contained retained bigeye tuna had no difference in logbook and EM counts, 14% had higher counts reported by EM and 12% had higher counts reported by logbook. When differences in counts between logbook and EM were observed in a single shot these were typically around ~1 individual (Figure 28 and Figure 29). There was evidence of an initial improvement in congruence from 49% of shots having no difference in logbook and EM counts in 2015/16 to a total of 75% in 2016/17, which has remained steady around 80% up to 2019/20 (Figure 30Figure 20). The mean difference in counts across the time period was negligible at 0.1 ± 0.1 individuals, suggesting both data collections tools are reporting similar numbers of individuals. The average number recorded by both EM and logbook in a single shot was 4.2 ± 0.3 individuals, so as a proportion of the average catch this difference was 1% (Table 3). So, for every 10 individuals reported by EM, the logbook is reporting 9.9 individuals. Furthermore, there was only 1% of shots containing a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool (Figure 31).

There was a total of 37 vessels that had greater than four audited shots with bigeye tuna reported as retained across the time period examined (Figure 32). The average number of bigeye tuna recorded as retained for each shot ranged from 1 to 8 individuals for each vessel. An examination of the data at an individual vessel level revealed that for 34 of the 37 vessels, the confidence intervals for the mean difference in counts encompassed zero (Figure 32).

As a proportion of the average catch, the difference in counts across all vessels was variable, with some vessels having very small average catches and therefore higher proportional differences. Two vessels – x11 and x19 had higher numbers being reported by EM relative to the rest of the fleet, while three vessels – x20, x12 and x30 had higher numbers being reported by logbook relative to the rest of the fleet (Figure 32).

Figure 28: Logbook and EM reported counts from individual shots containing retained bigeye tuna across time period examined. Red dashed line is the 1:1 line.

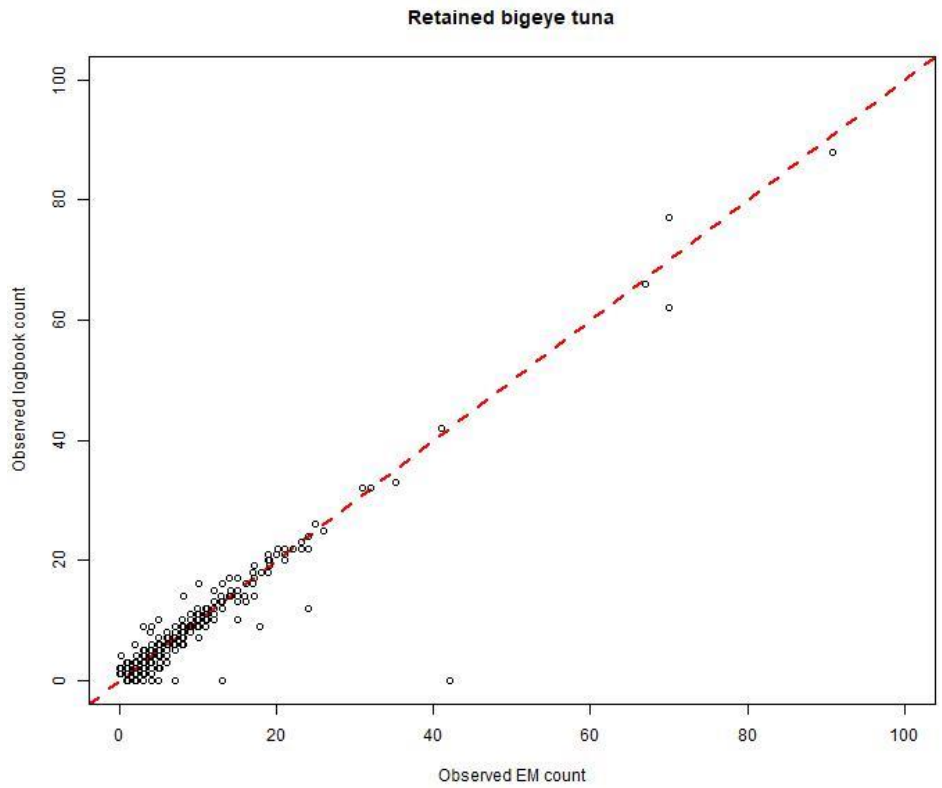


Figure 29: Proportion of shots with specific differences between EM and logbook counts for retained bigeye tuna across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

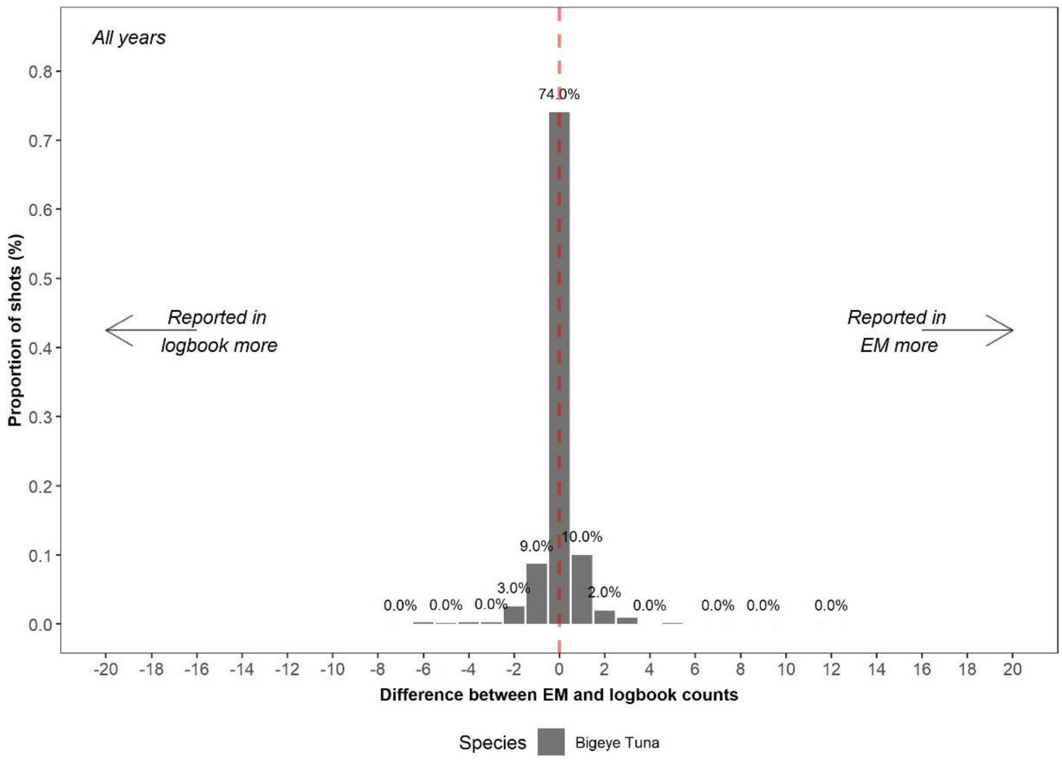


Figure 30: Proportion of shots with specific differences between EM and logbook counts for retained bigeye tuna for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

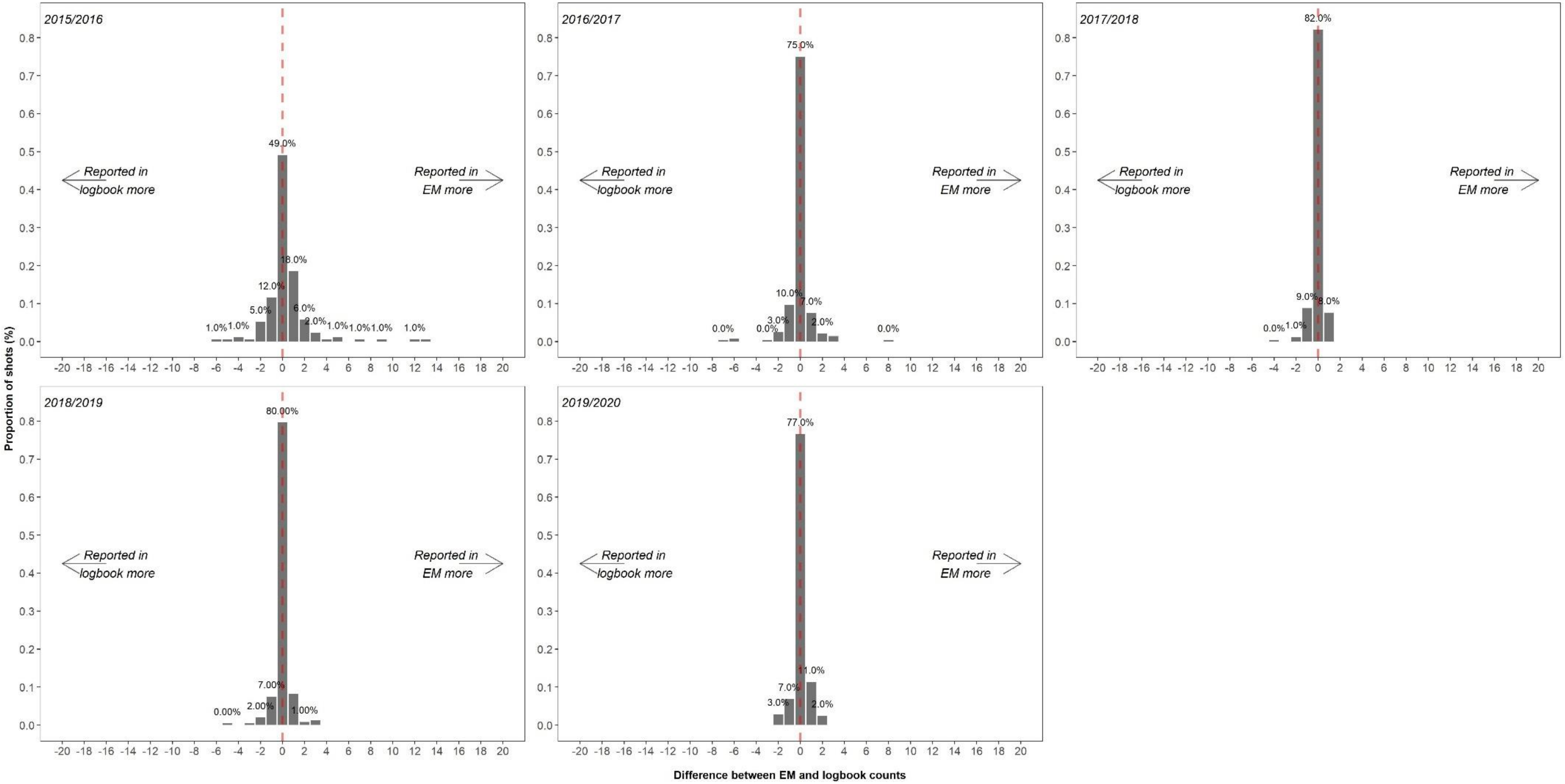


Figure 31: Number of shots with specific differences between EM and logbook counts for retained bigeye tuna across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

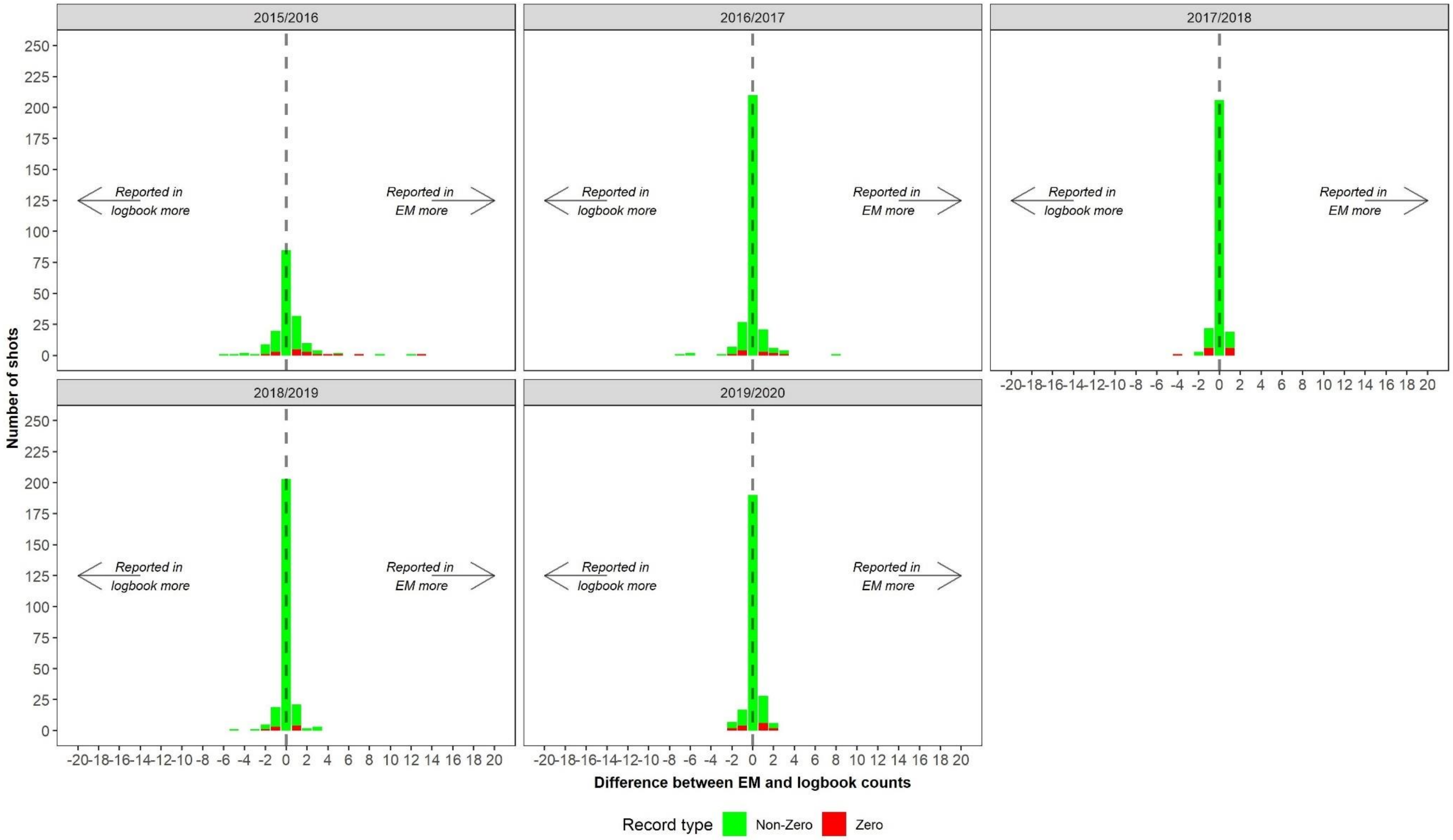
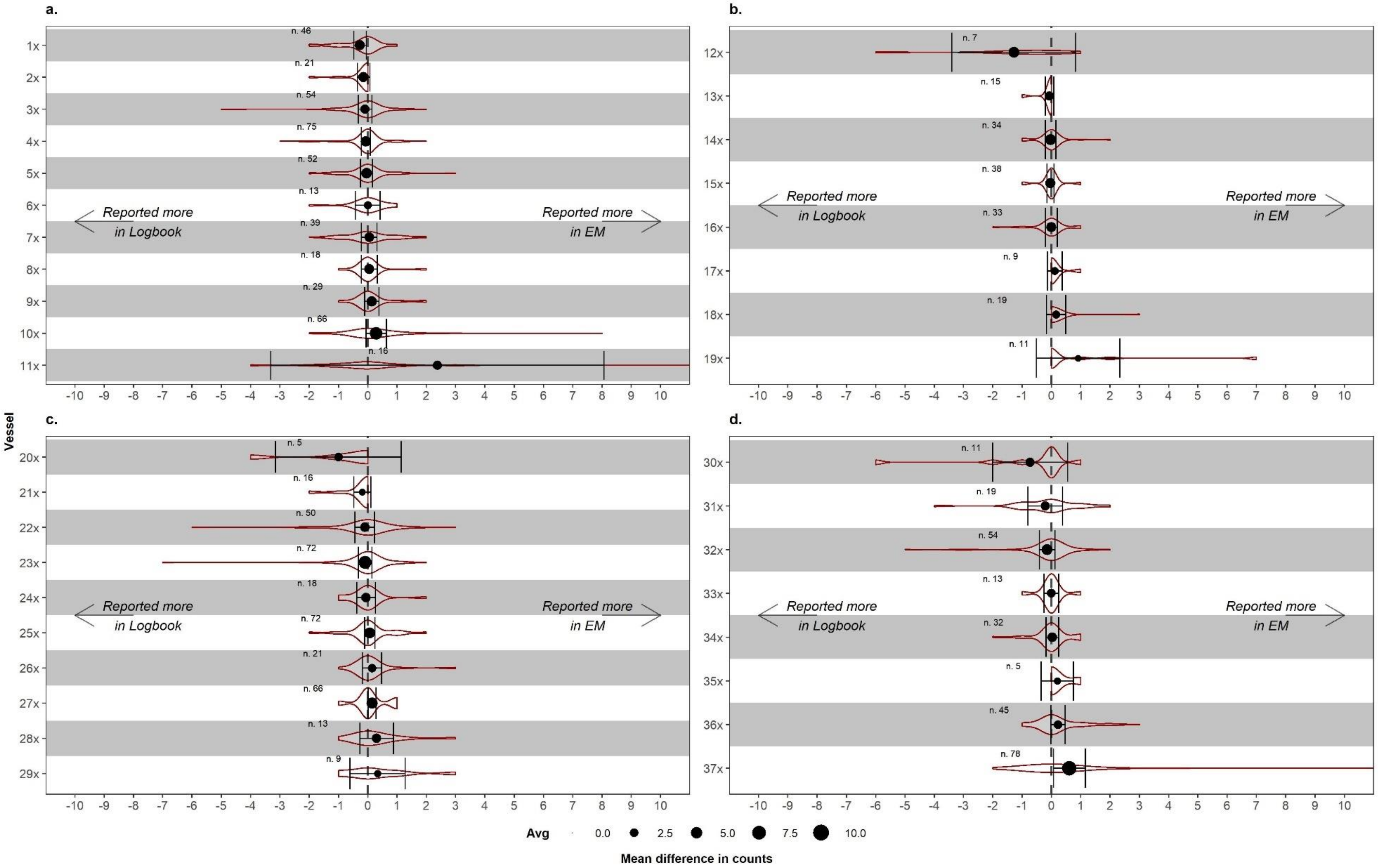


Figure 32: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing retained bigeye tuna across the time period. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



3.1.7 Striped marlin

Across the time period examined, 87% of shots audited that contained retained striped marlin had no difference in logbook and EM counts, 7% had higher counts reported by EM and 6% had higher counts reported by logbook. Out of all retained species, striped marlin had the highest congruence. When differences in counts between logbook and EM were observed in a single shot these were typically around ~1 individuals (Figure 33 and Figure 34). There was evidence of an initial improvement in congruence from 62% of shots having no difference in logbook and EM counts in 2015/16 to a total of 90% in 2016/17, which has remained steady around 90% up to 2019/20 (Figure 35Figure 20). The mean difference in counts across the time period was negligible at 0.0 ± 0.0 individuals, suggesting both data collections tools are reporting the same number of individuals. The average number recorded by both EM and logbook in a single shot was 1.7 ± 0.1 individuals, so as a proportion of the average catch this difference was <1% (Table 3). So, for every 10 individuals reported by EM, the logbook is reporting ~9.9-10 individuals. Furthermore, there were only 6% of shots containing a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool (Figure 36).

There was a total of 32 vessels that had greater than four audited shots with striped marlin reported as retained across the time period examined (Figure 37). The average number of striped marlin recorded as retained for each shot ranged from 1 to 2 individuals for each vessel. An examination of the data at an individual vessel level revealed that for 31 of the 32 vessels, the confidence intervals for the mean difference in counts encompassed zero (Figure 37).

As a proportion of the average catch, the difference in counts across all vessels was mainly <10%, signifying high congruence across the fleet. There were a couple of outliers, with x10, x17, x25 and x9 having higher numbers being reported by logbook compared to EM. Fishing vessel x24 had higher numbers being reported by EM, but the number of shots audited was low (n. 6) (Figure 37). Six vessels (X3, x4, x14, x18, x28, x30) had perfect congruence, with all audited shots having no difference between EM and logbook reported numbers (Figure 37).

Figure 33: Logbook and EM reported counts from individual shots containing retained striped marlin across time period examined. Red dashed line is the 1:1 line.

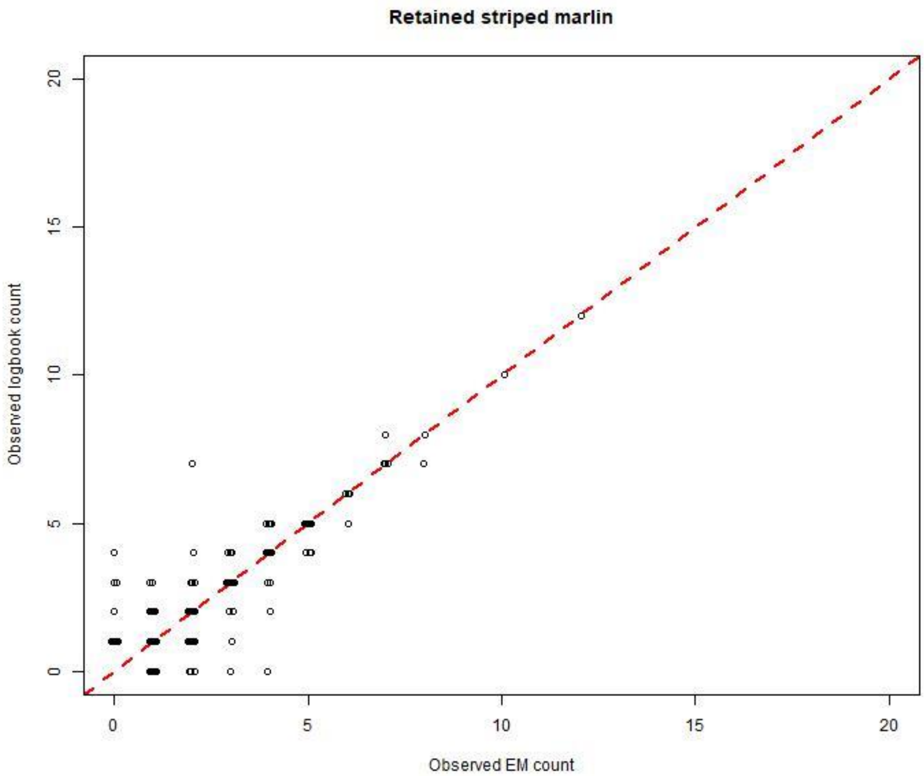


Figure 34: Proportion of shots with specific differences between EM and logbook counts for retained striped marlin across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

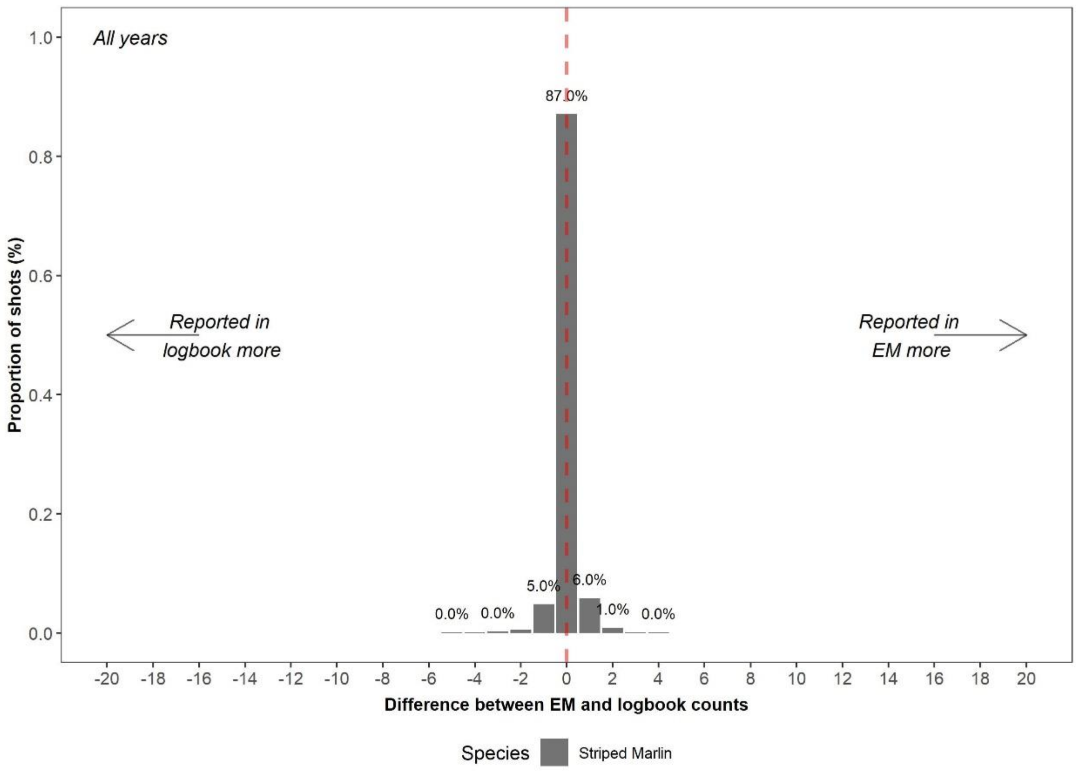


Figure 35: Proportion of shots with specific differences between EM and logbook counts for retained striped marlin for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

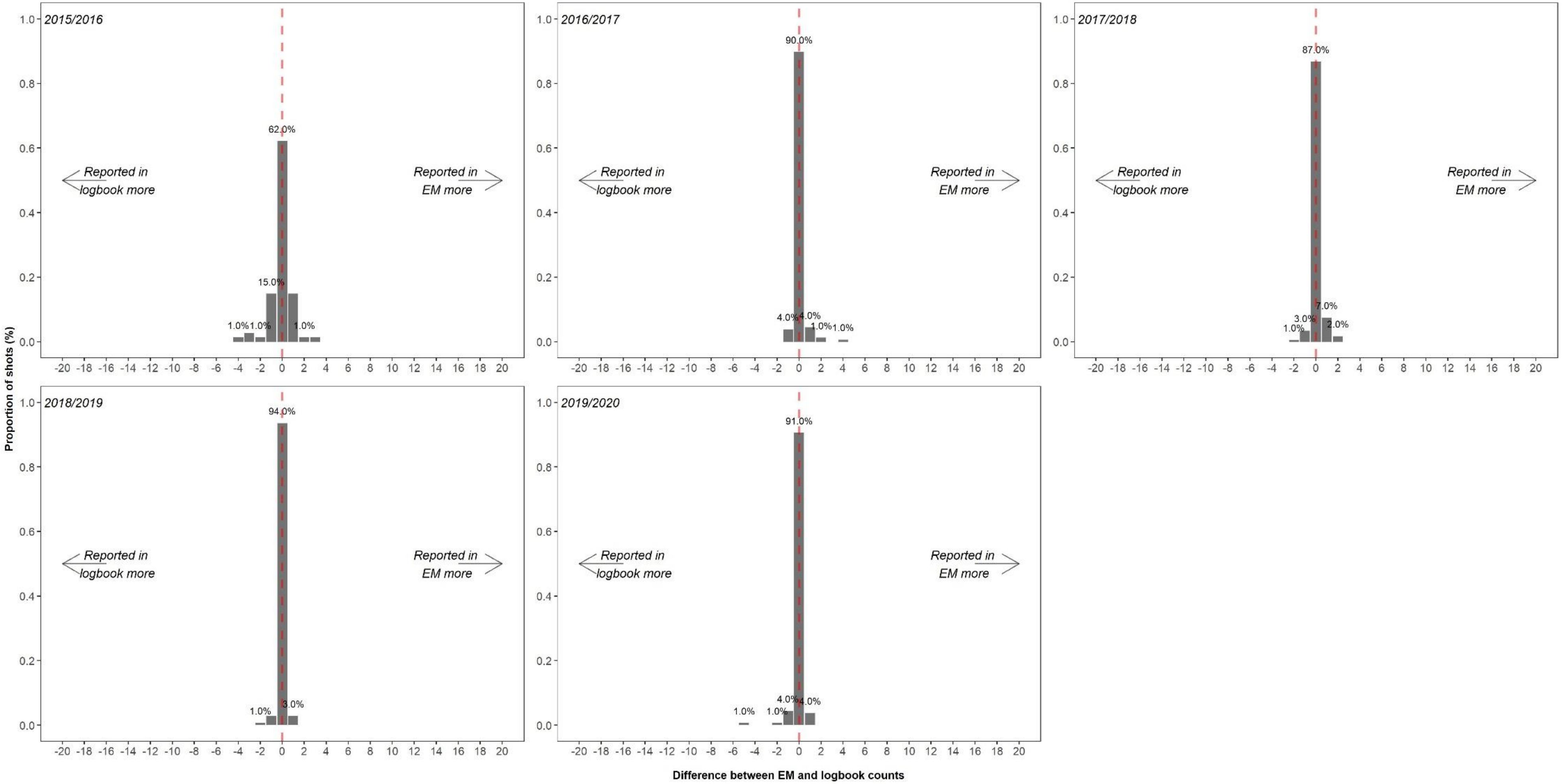


Figure 36: Number of shots with specific differences between EM and logbook counts for retained striped marlin across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

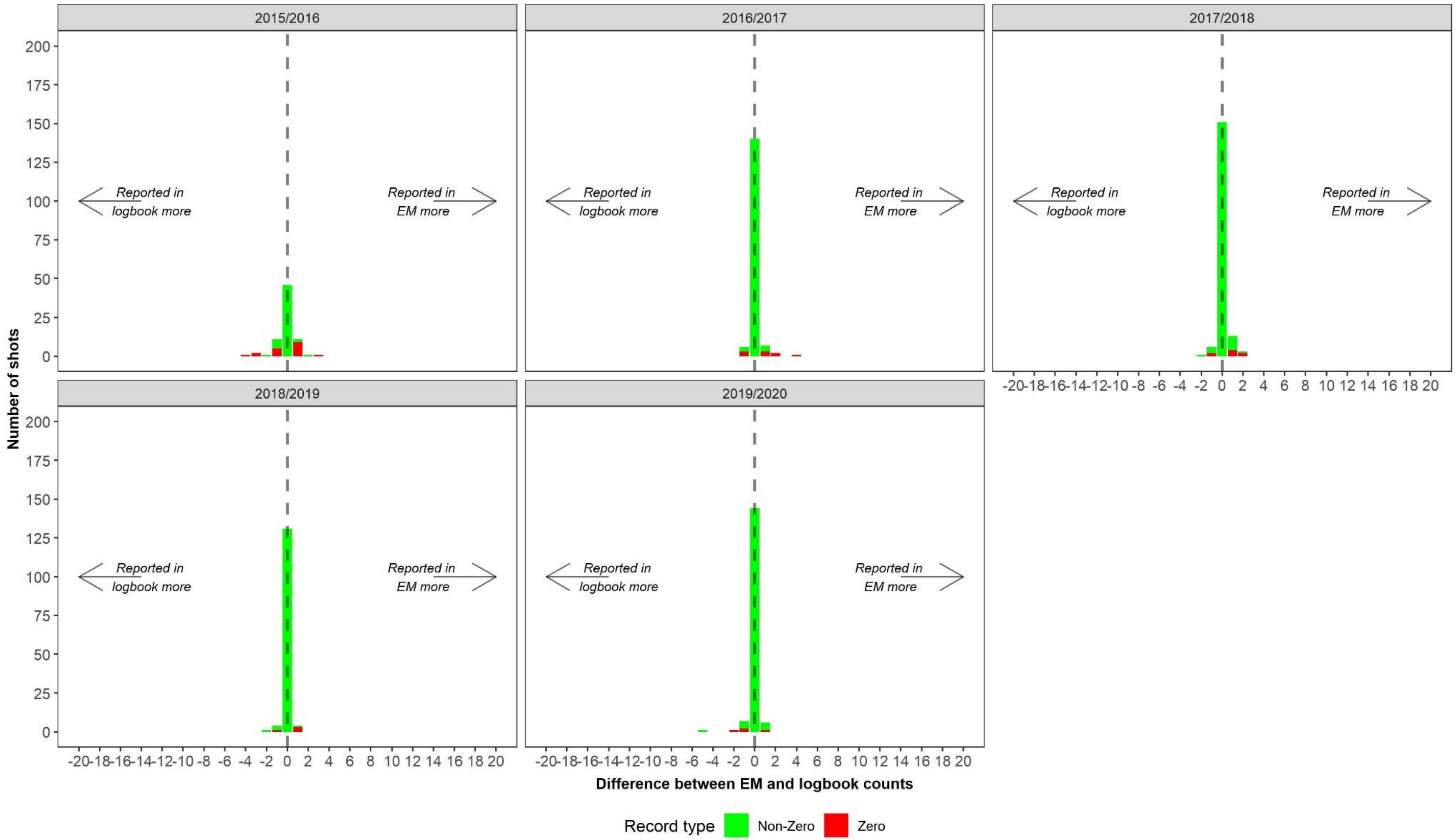
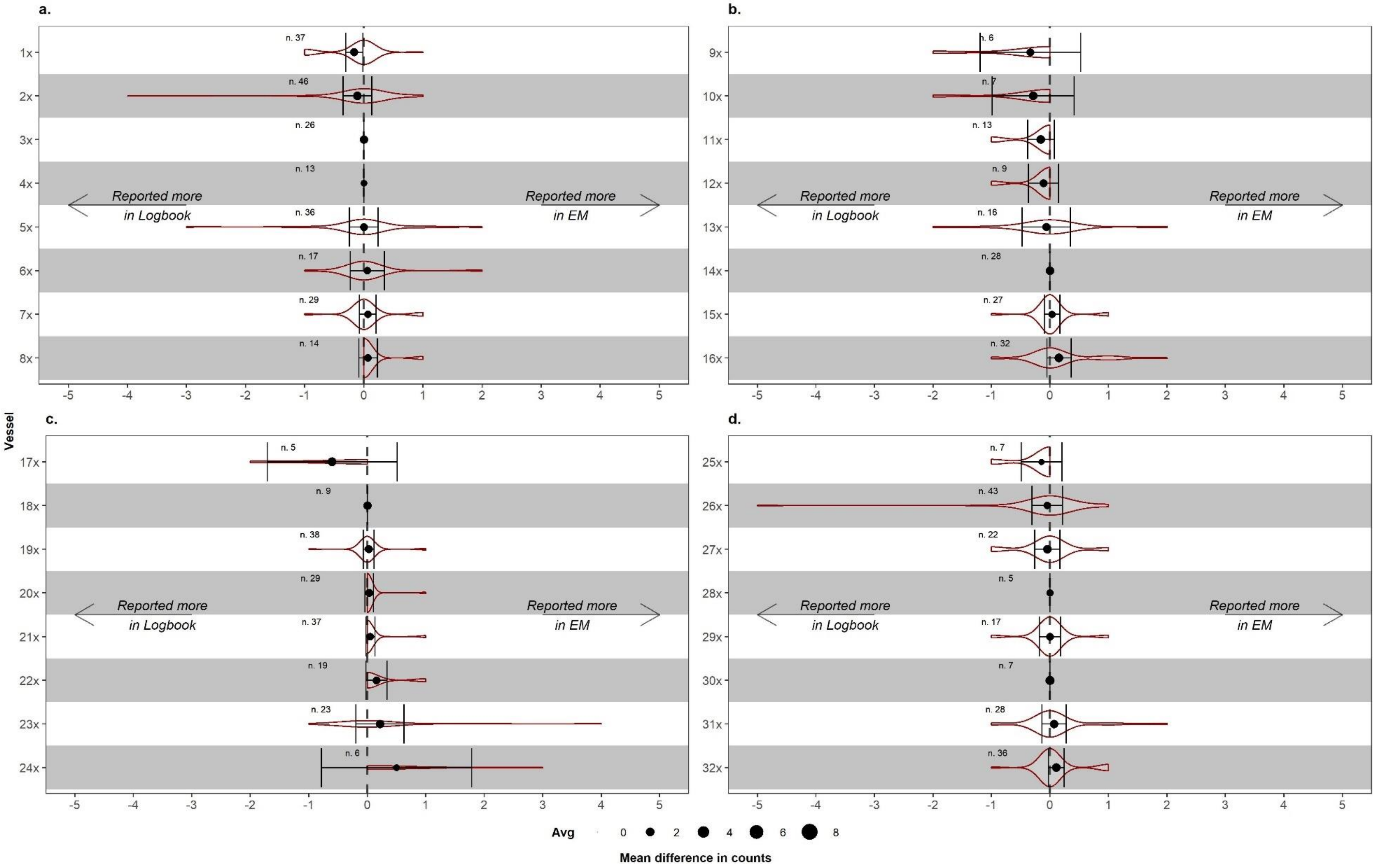


Figure 37: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing retained striped marlin across the time period. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



3.2 Discarded catch

In the ETBF, there were a total of 15 species that represented most of the discarded catch in the fishery and were analysed herein (Table 4).

For most discarded species, both the mean difference in discarded counts as a proportion of the average discarded catch and the proportion of zeros reporting by either logbook or EM when ≥1 discarded individual was reported by the other data collection tool was high and substantially greater than for retained catch (Table 4). This suggests discarded individuals are either being misreported or unreported by fishers or the EM analyst. Except for snake mackerel and escolar, most discarded species were reported in greater numbers by logbook than EM (Figure 38). Furthermore, the EM analyst reported discards of some grouped species (e.g., tuna species) more commonly than logbooks, suggesting that it is more difficult for EM to identify discarded individuals to the species level (see further discussion below). Swordfish was the exception, with a mean difference in counts of 0.0 ± 0.1 individuals across the time period examined and the average number recorded discarded by both EM and logbook in a shot was 1.5 ± 0.1 individuals. As a proportion of the average catch, the mean difference in counts for swordfish was <1% (Table 4 and Figure 39). However, there was over 50% of shots containing a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool. This suggests that both EM and logbook are sometimes missing small numbers of individuals being discarded.

Table 4: The mean difference in counts between EM and logbook, average number (from both EM and logbook) reported caught per shot, mean difference in counts as a proportion of average catch and proportion of zeroes reported by either EM or logbook across the time period examined for discarded species in the ETBF.

Species	Scientific name	Mean difference in counts	Average number reported discarded	Mean difference in counts as proportion of average discarded catch	Proportion of 0s reported by either logbook or EM
Lancetfishes - unspecified	*Alepisaurus spp.*	-2.4 (±0.4)	4.3 (±0.2)	-56%	47%
Blue shark	*Prionace glauca*	-3.2 (±0.4)	3.6 (±0.4)	-89%	54%
Yellowfin tuna	*Thunnus albacares*	-1.9 (±0.2)	2.1 (±0.1)	-90%	62%
Albacore tuna	*Thunnus alalunga*	-1.2 (±0.3)	2.6 (±0.5)	-44%	60%
Southern bluefin tuna	*Thunnus maccoyii*	-4.1 (±2.1)	10.9 (±3.3)	-37%	36%
Bronze whaler	*Carcharhinus brachyurus*	-3.1 (±0.3)	1.7 (±0.2)	-180%	92%
Rudderfish	*Centrolophus niger*	-4.4 (±0.7)	2.2 (±0.2)	-199%	99%
Escolar	*Lepidocybium flavobrunneum*	1.7 (±0.4)	2.3 (±0.4)	74%	82%

Swordfish	*Xiphias gladius*	0.0 (±0.1)	1.5 (±0.1)	<1%	50%
Ocean sunfish	*Mola mola*	-0.4 (±0.2)	1.4 (±0.1)	-3%	66%
Snake mackerel	*Gempylus serpens*	0.4 (±0.3)	1.8 (±0.2)	22%	75%
Dusky whaler	*Carcharhinus obscurus*	-3.2 (±0.4)	1.6 (±0.2)	-194%	99%
Bigeye tuna	*Thunnus obesus*	-0.8 (±0.2)	1.2 (±0.1)	-66%	75%
Mahi mahi	*Coryphaena hippurus*	-0.2 (±0.4)	1.5 (±0.2)	-10%	65%
Short sunfish	*Mola alexandrini*	-2.4 (±0.5)	1.3 (±0.2)	-188%	97%

Figure 38: Reporting of discarded catches of species in the ETBF (a) mean difference in counts (mean ± 95% CI) across individual financial years and (b) mean difference in counts as a factor of the average number (reported) discarded in a shot (mean ± 95% CI) across all financial years.

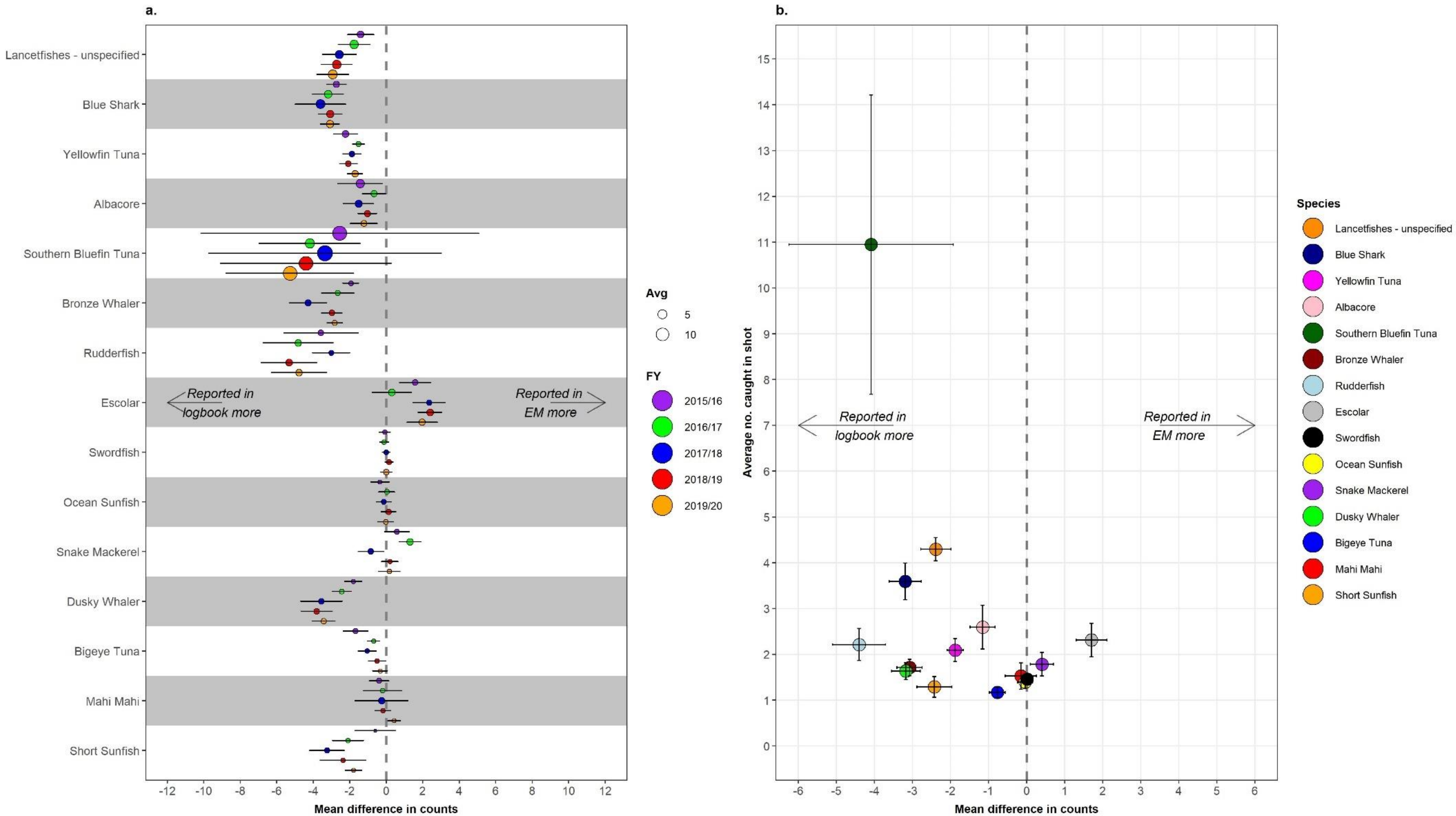
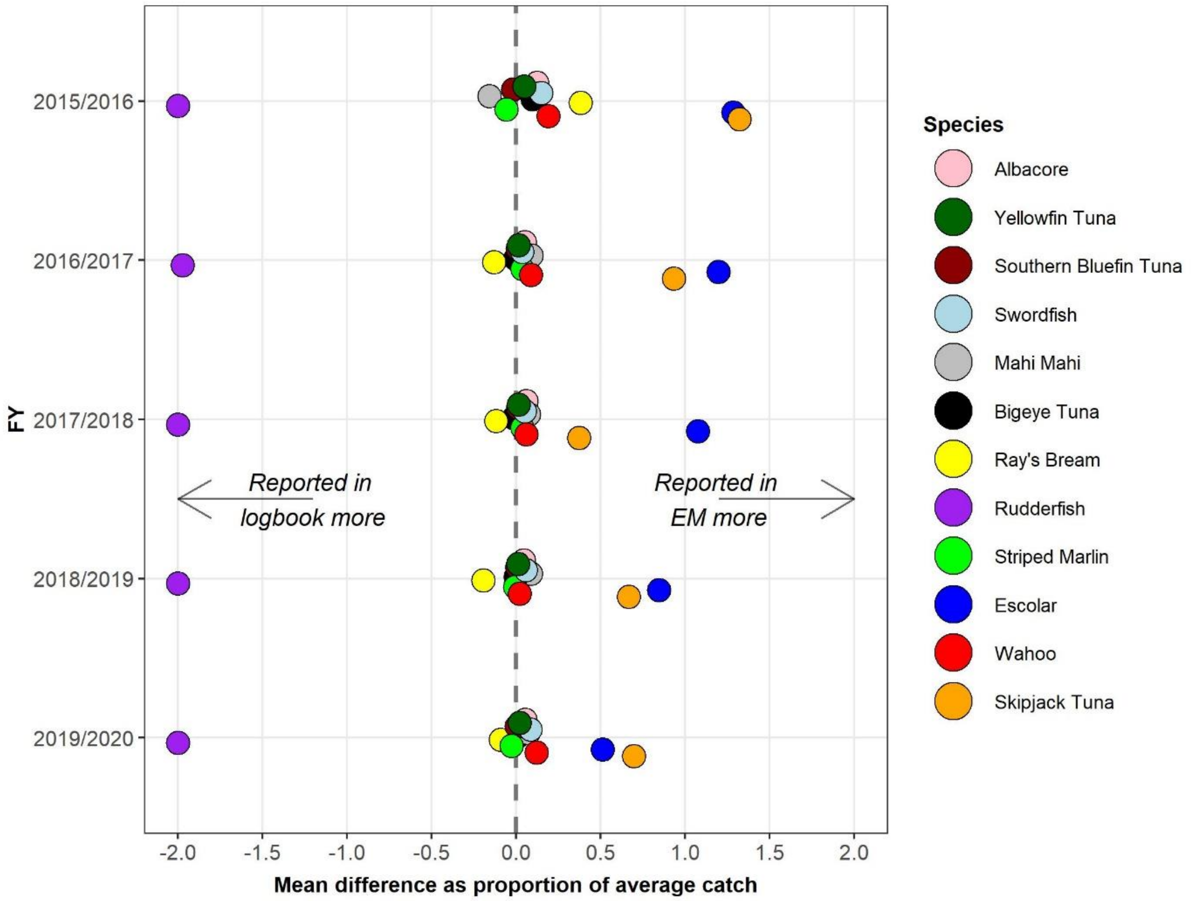


Figure 39: The mean difference in discarded fish counts as a proportion of the average discarded catch (average of EM and logbook reported) per shot for species in the ETBF.



The discarding results for some species possibly reflected the inability of the EM analyst to identify some individuals to a species taxonomic level (e.g., southern bluefin tuna for EM). Given there were some possible issues with identifying individuals to a species taxonomic level, some groups containing key target and byproduct species in the ETBF were-re-analysed to examine overall congruence (Table 5).

Table 5: Individual species that were assessed at a higher taxonomic group level

Tuna (grouped)	Oilfishes (grouped)	Sharks (grouped)	
Mackerel tuna	Oilfish	Dusky whaler	Smooth hammerhead
Yellowfin tuna	Escolar	Blue shark	Mackerel sharks
Bigeye tuna	Rudderfish	Bronze whaler	School shark
Albacore		Tiger shark	Whaler sharks (mixed)
Southern bluefin tuna		Shortfin mako	Bigeye thresher
Tuna (mixed)		Longfin mako	Scalloped hammerhead
Skipjack tuna		Whaler and weasel sharks	Whitetip reef shark
Northern bluefin tuna		Sharks (mixed)	Kitefin sharks (mixed)
		Thresher shark	Longfin mako
		Oceanic whitetip shark	Broadnose shark
		Crocodile shark	Bull shark
		Pelagic thresher	Blacktip sharks (mixed)
		Sandbar shark	Thresher sharks (mixed)
		Hammerhead sharks – unspecified	Gulper sharks, sleeper sharks, dogfishes

For discarded catch, there were improvements observed in the congruence for both tuna (grouped) and oilfishes (grouped) at the higher taxonomic level (Figure 40 and Figure 41), with evidence that EM reported a greater number of discarded individuals than the logbook. Sharks (grouped) were still reported in higher numbers by logbooks than EM (Figure 40 and Figure 41).

Across the time period examined, 10% of shots audited that contained discarded sharks (grouped) had no difference in logbook and EM counts, 15% had higher counts reported by EM and 75% had higher counts reported by logbook (Figure 42). Differences in counts were on average -3.1 individuals across all years and the mean difference as a proportion of average catch was -68% across all years, with a clear skew towards higher reporting in logbooks. In total, 21% of all shots across the time period contained a zero record for either EM or logbook when ≥1 individual was reported discarded by the other data collection tool, which was primarily driven by the EM analyst not observing individuals discarded (Figure 45).

Across the time period examined, 40% of shots audited that contained discarded tuna (grouped) had no difference in logbook and EM counts, 34% had higher counts reported by EM and 26% had higher counts reported by logbook (Figure 43). Differences in counts were on average <1 individual across all years and the mean difference as a proportion of average catch was less than 10% across all years indicating high congruence. In total, 24% of all shots across the time period contained a zero record for either EM or logbook when ≥1 individual was reported discarded by the other data collection tool, which was primarily driven by fishers not recording individuals in the logbook (Figure 46).

For oilfishes (grouped) 44% of shots audited had no difference in logbook and EM counts, 33% had higher counts reported by EM and 23% had higher counts reported by logbook. Differences in counts were on average <1 individual across all years and the mean difference as a proportion of average catch was less than 10% across more recent years (2018/19 and 2019/20) indicating high congruence (Figure 44). In total, 37% of all shots across the time period contained a zero record for either EM or logbook when ≥1 individual was reported discarded by the other data collection tool, which was primarily driven by fishers not recording individuals in the logbook (Figure 47).

The results for tuna (grouped) suggest that the EM analysts are observing the individuals being discarded but are having some issues identifying these individuals to the species level and therefore grouping them at a higher taxonomic level. While there seems to be issues with identifying to a species level for many discarded tunas, the overall total numbers seem to be more accurately reported at a higher taxonomic level and reported in greater numbers by EM than logbook. For oilfishes (grouped) EM analysts are mainly recording these individuals at the species level but are recording a different species than logbooks. For sharks (grouped) there continues to be issues with the EM analysts being able to observe all discarded individuals and when they do observe individual sharks, they can't identify them to a species level. Interestingly, if the "unknown or other" CAAB code is included in sharks (grouped) taxonomic level, the overall skew towards logbook reporting a higher number of individuals declines from 75% to 45% and the percentage of shots with no differences in counts increases from 10% to 14%, possibly indicative of the EM analyst using this CAAB code during instances of logbook recorded sharks being discarded.

Figure 40: Mean difference in counts (mean ± 95% CI) across individual financial years for discarded sharks (grouped), tuna (grouped) and oilfish (grouped) in the ETBF.

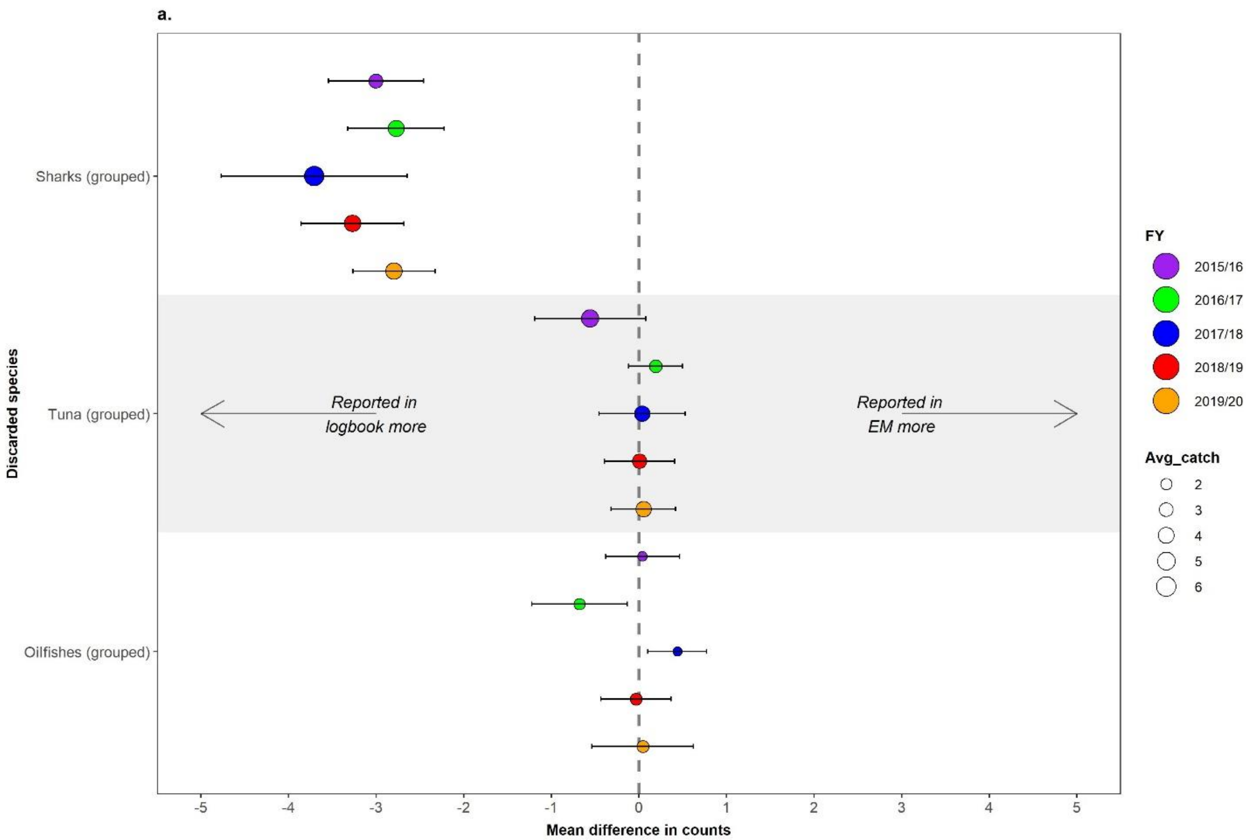


Figure 41: The mean difference in counts as a proportion of the average catch (average of EM and logbook reported) per shot for discarded sharks (grouped), tuna (grouped) and oilfish (grouped) in the ETBF

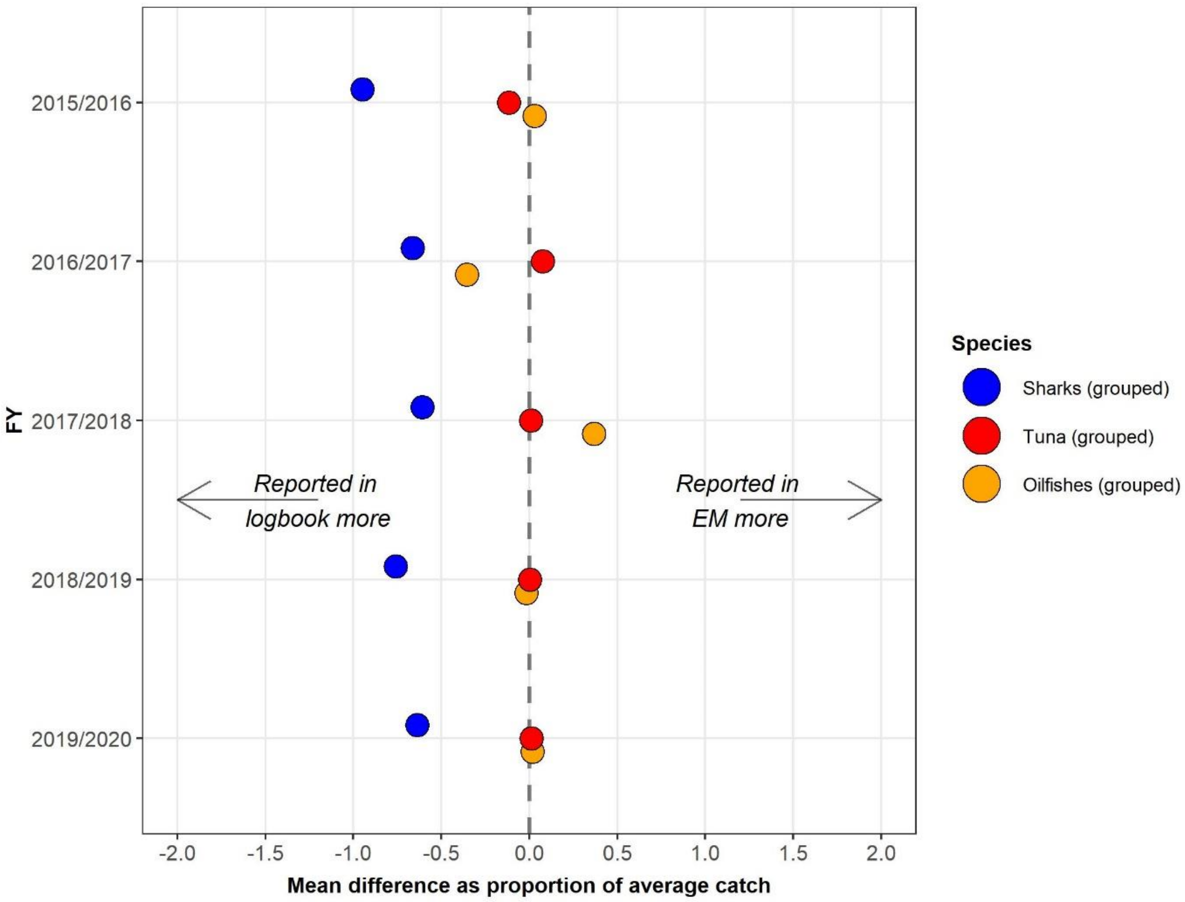


Figure 42: Proportion of shots with specific differences between EM and logbook counts for discarded sharks (grouped) for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

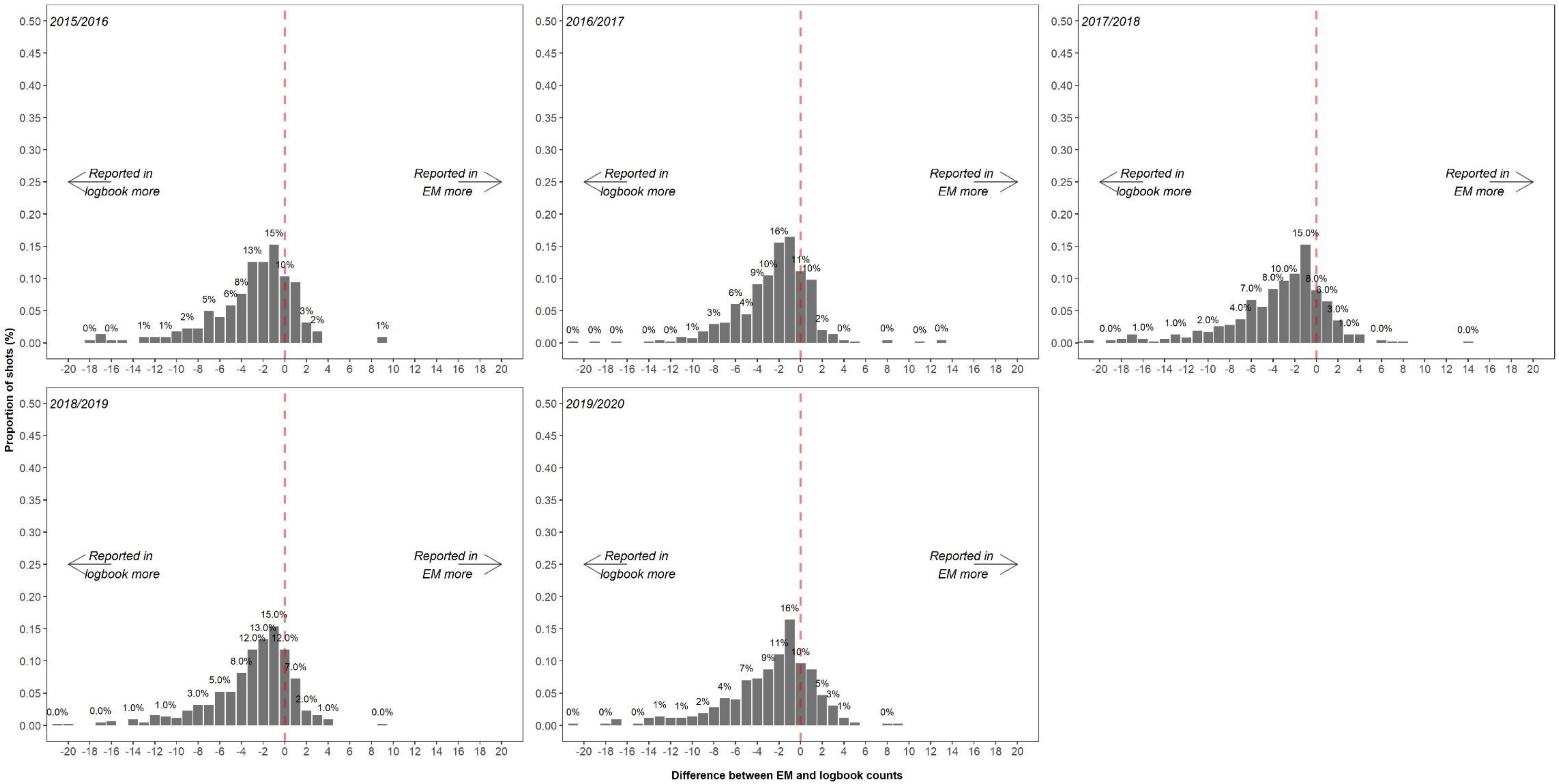


Figure 43: Proportion of shots with specific differences between EM and logbook counts for discarded tuna (grouped) for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

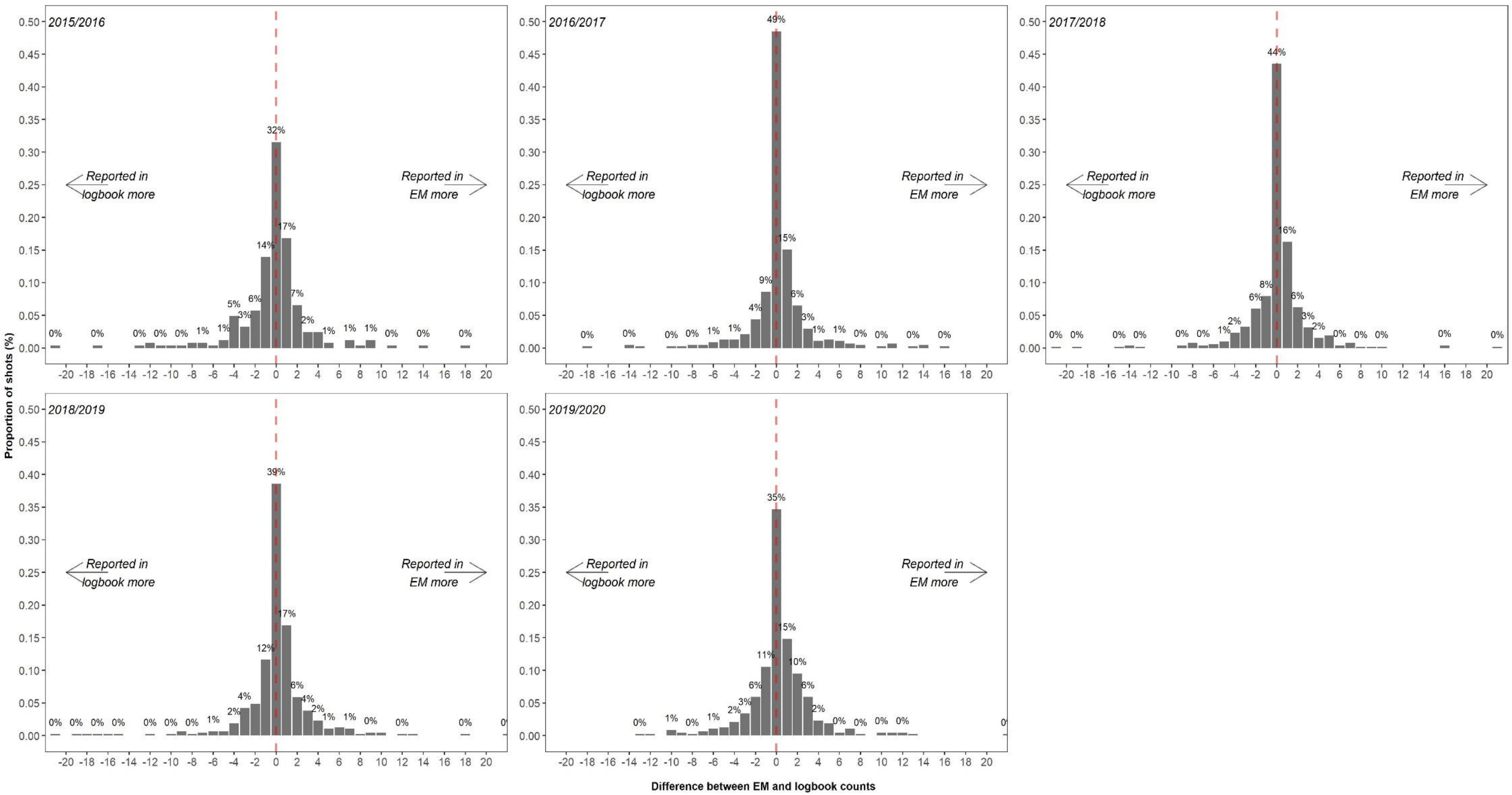


Figure 44: Proportion of shots with specific differences between EM and logbook counts for discarded oilfishes (grouped) for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

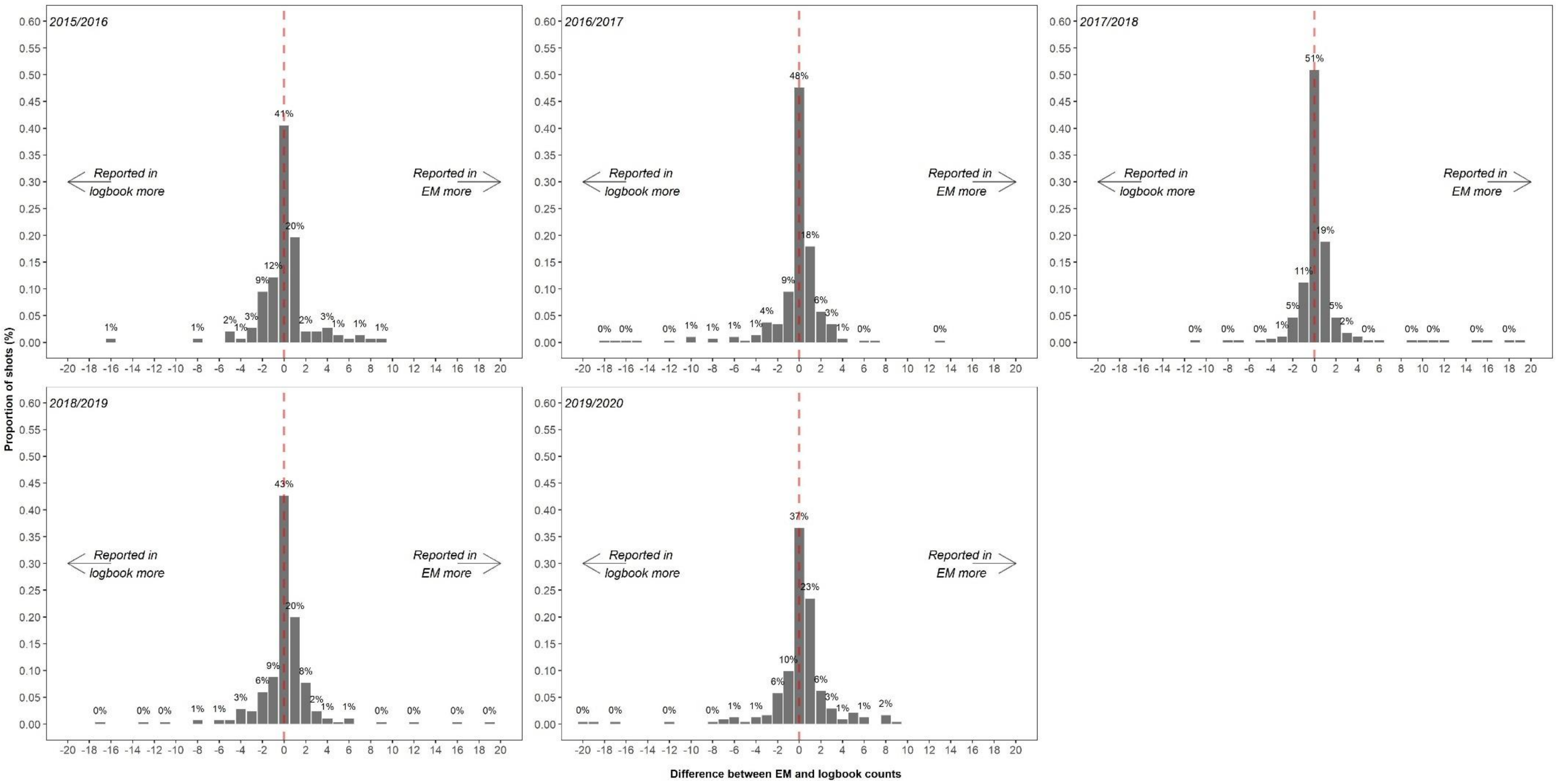


Figure 45: Number of shots with specific differences between EM and logbook counts for discarded sharks (grouped) across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

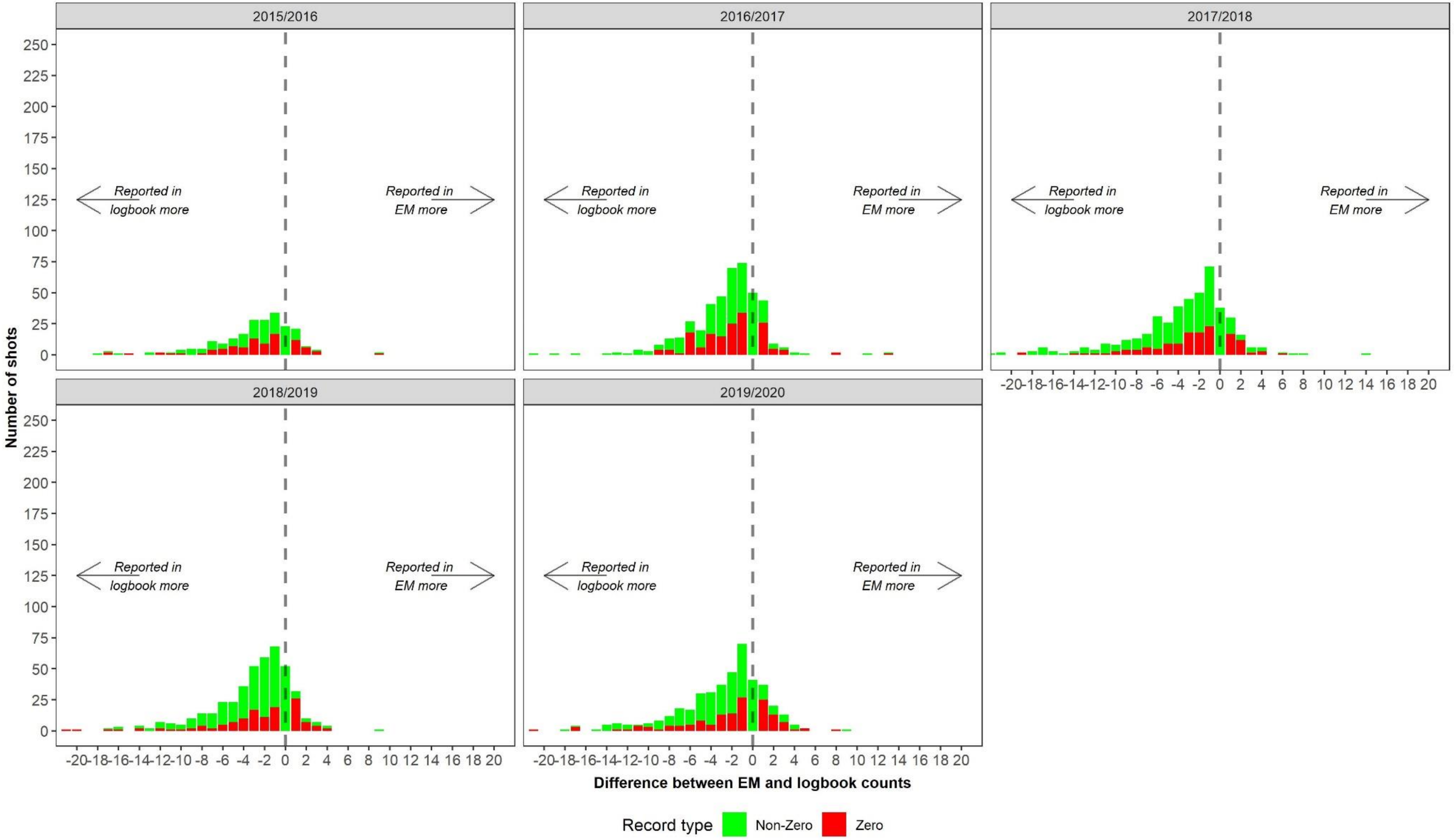


Figure 46: Number of shots with specific differences between EM and logbook counts for discarded tuna (grouped) across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

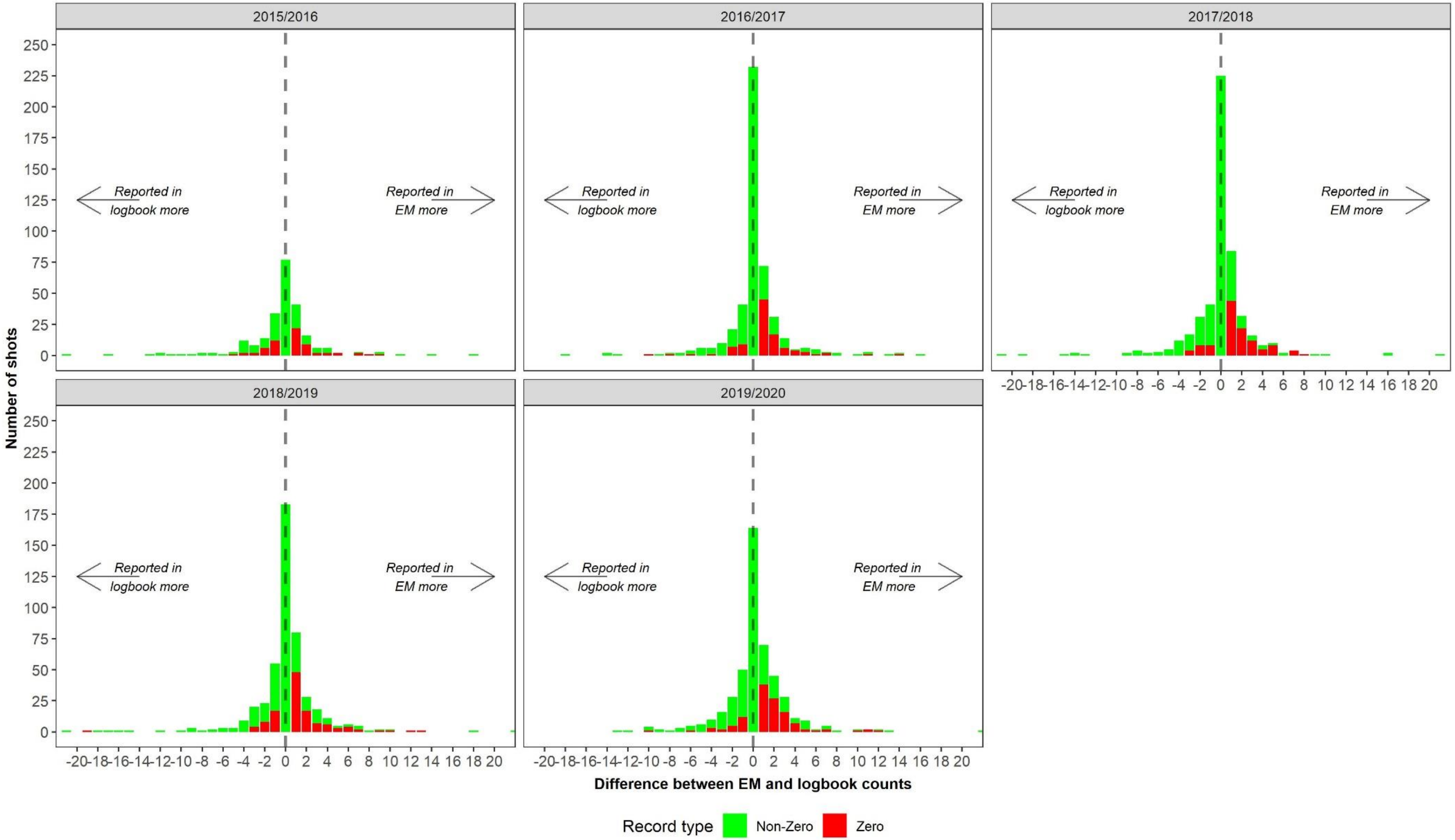
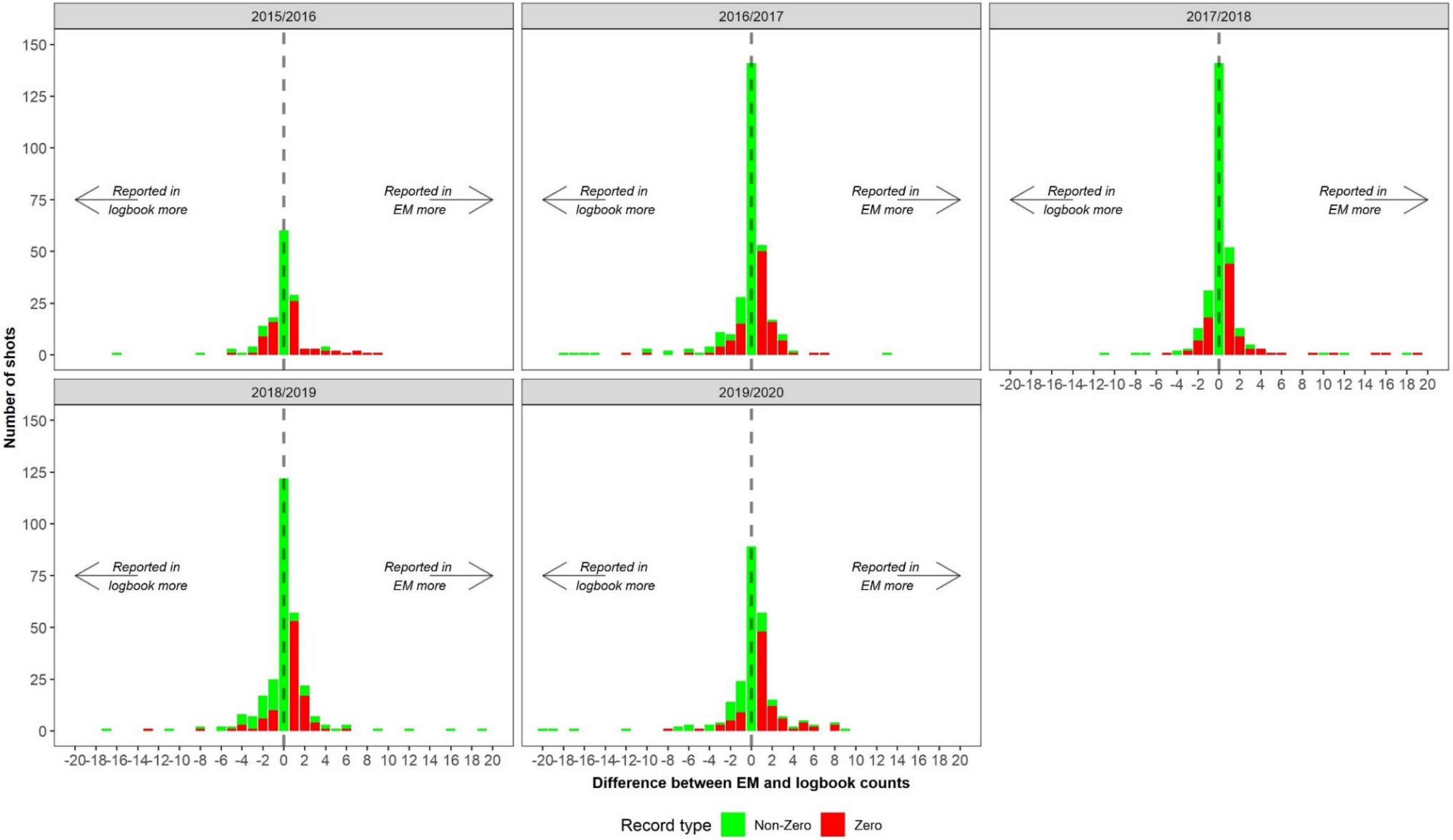


Figure 47: Number of shots with specific differences between EM and logbook counts for discarded oilfish (grouped) across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



3.2.1 Albacore tuna

Across the time period examined, 9% of shots audited that contained discarded albacore tuna had no difference in logbook and EM counts, 38% had higher counts reported by EM and 53% had higher counts reported by logbook. When differences in counts between logbook and EM were observed in a single shot these varied between 1-4 individuals (Figure 48 and Figure 49). There was no evidence of any improvement in congruence through time (Figure 50). Albacore tuna was reported discarded slightly more by logbook (-1.2 ± 0.3 individuals) across the time period examined, but the average number recorded discarded by both EM and logbook in a single shot was low (2.6 ± 0.5 individuals), so as a proportion of the average catch this difference was significant at -44% (Table 4) and led to a clear left-hand skew in the distribution of differences in counts. So, for every 10 individuals reported by EM, the logbook is reporting 14.4 individuals discarded. Furthermore, there were 60% of shots containing a zero record for either EM or logbook when ≥1 individual was reported discarded by the other data collection tool, suggesting there is numerous shots where ~1-4 individuals are being overlooked (Figure 51). This is somewhat driven by several vessels not reporting any discarded albacore tuna in their logbook (see below).

There was a total of 28 vessels that had greater than four audited shots with albacore reported as discarded across the time period examined (Figure 52). The average number of albacore recorded as discarded for each shot ranged from 1 to 6 individuals for each vessel. An examination of the data at an individual vessel level revealed that for 15 of the 28 vessels, the confidence intervals for the mean difference in counts encompassed zero.

As a proportion of the average catch, the difference in counts across most vessels was greater than 15%, signifying poor congruence across the fleet. However, there was variation across individual vessels. For example, x21, x26 and x28 reported no discards across all audited shots, however some were reported by the EM analyst, which may warrant further investigation (Figure 52). Similarly, only one out of the seven audited shots from x7 had recorded discards in the logbook, where the EM analyst reported individuals discarded. For several other vessels, logbooks reported higher albacore discards, and clearly the EM analysts were having difficulty identifying albacore tuna on some vessels. This included x12, x22, x23, x15, x2 and x3 (Figure 52).

Figure 48: Logbook and EM reported counts from individual shots containing discarded albacore tuna across time period examined. Red dashed line is the 1:1 line.

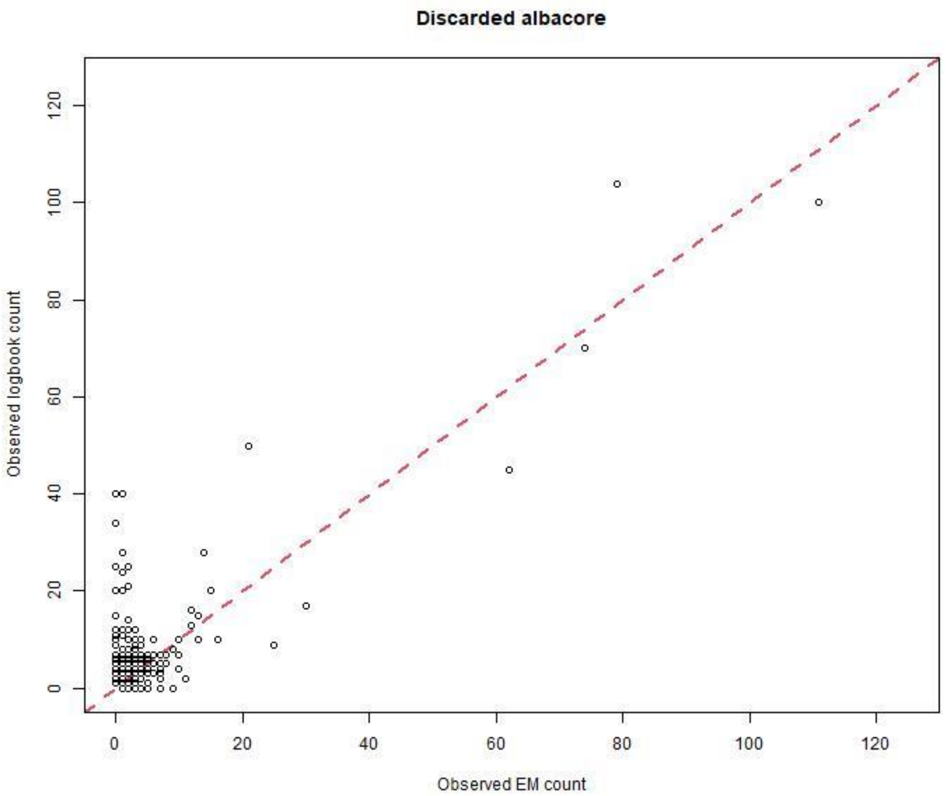


Figure 49: Proportion of shots with specific differences between EM and logbook counts for discarded albacore tuna across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

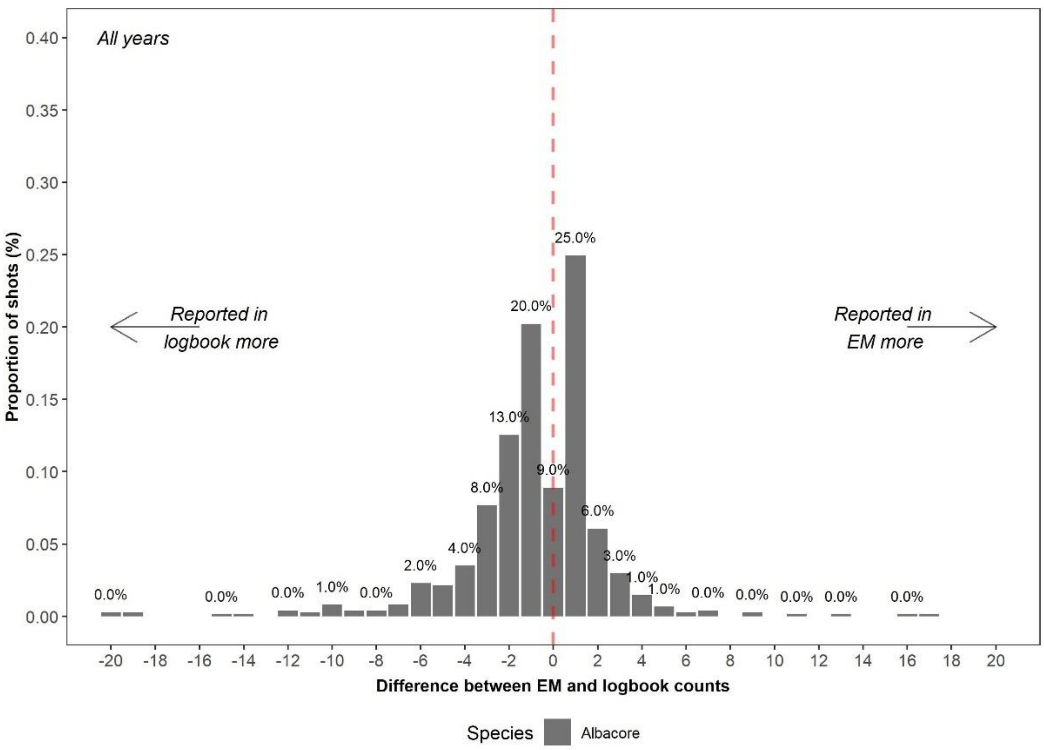


Figure 50: Proportion of shots with specific differences between EM and logbook counts for discarded albacore tuna for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

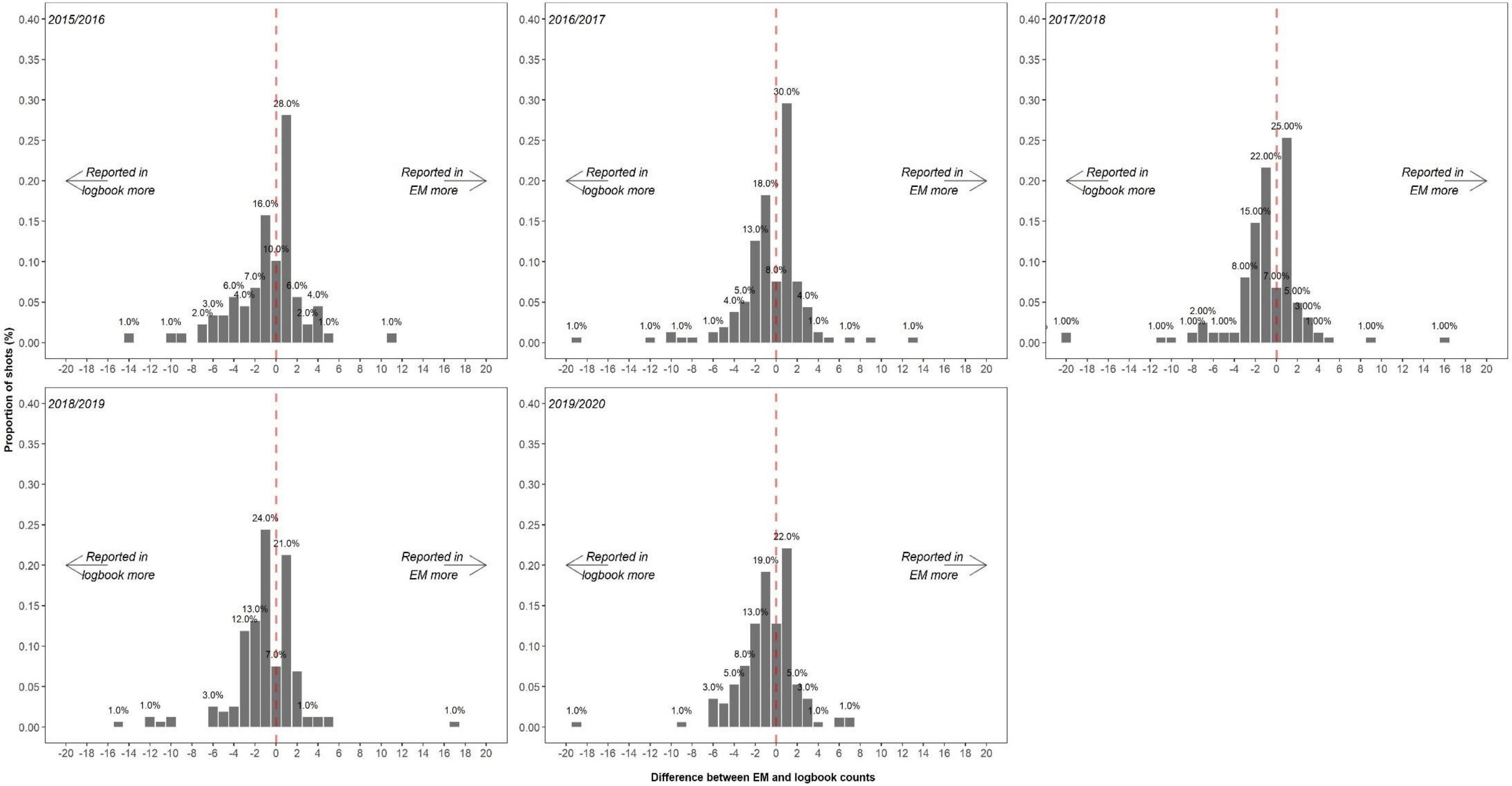


Figure 51: Number of shots with specific differences between EM and logbook counts for discarded albacore tuna across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

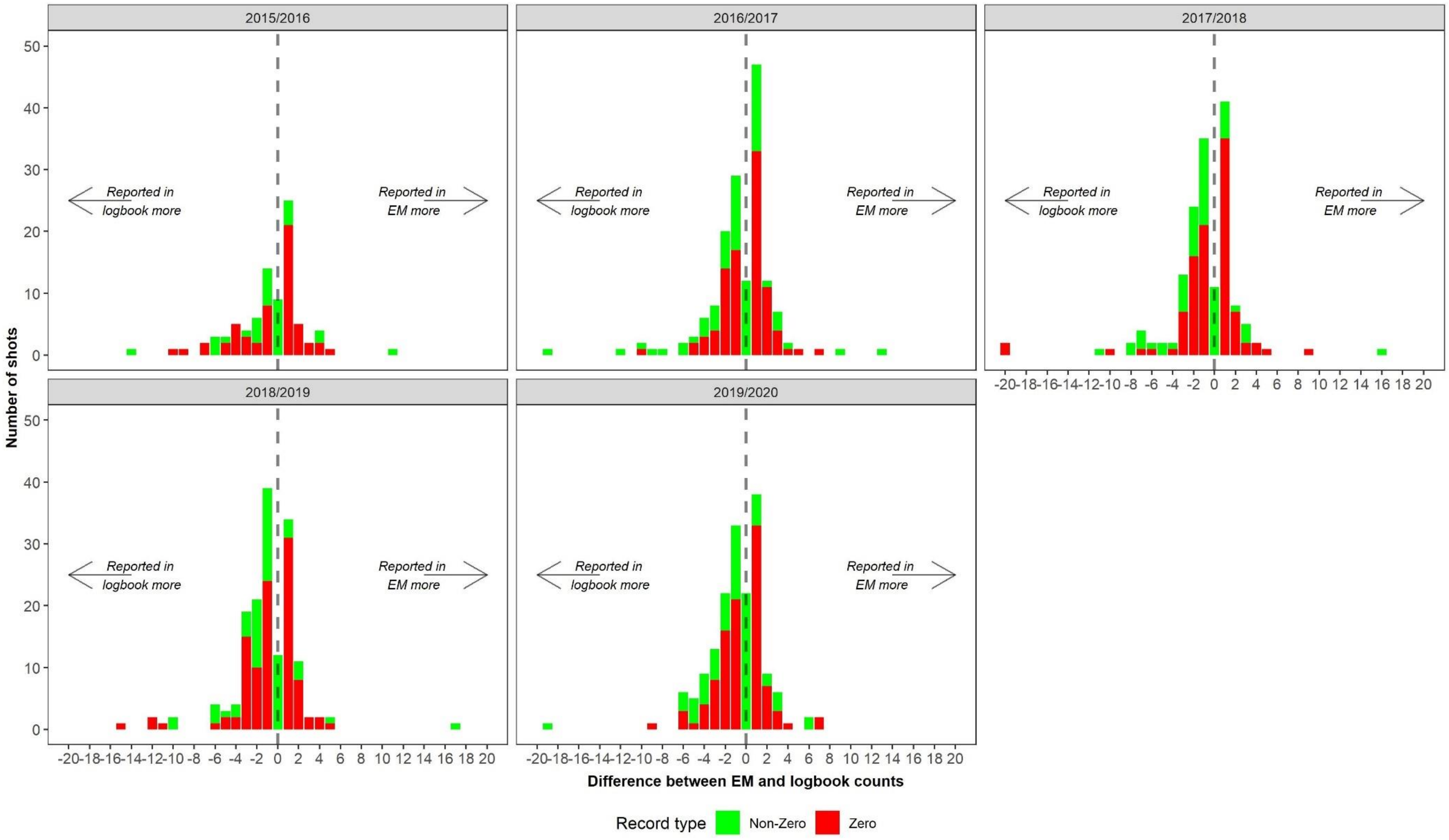
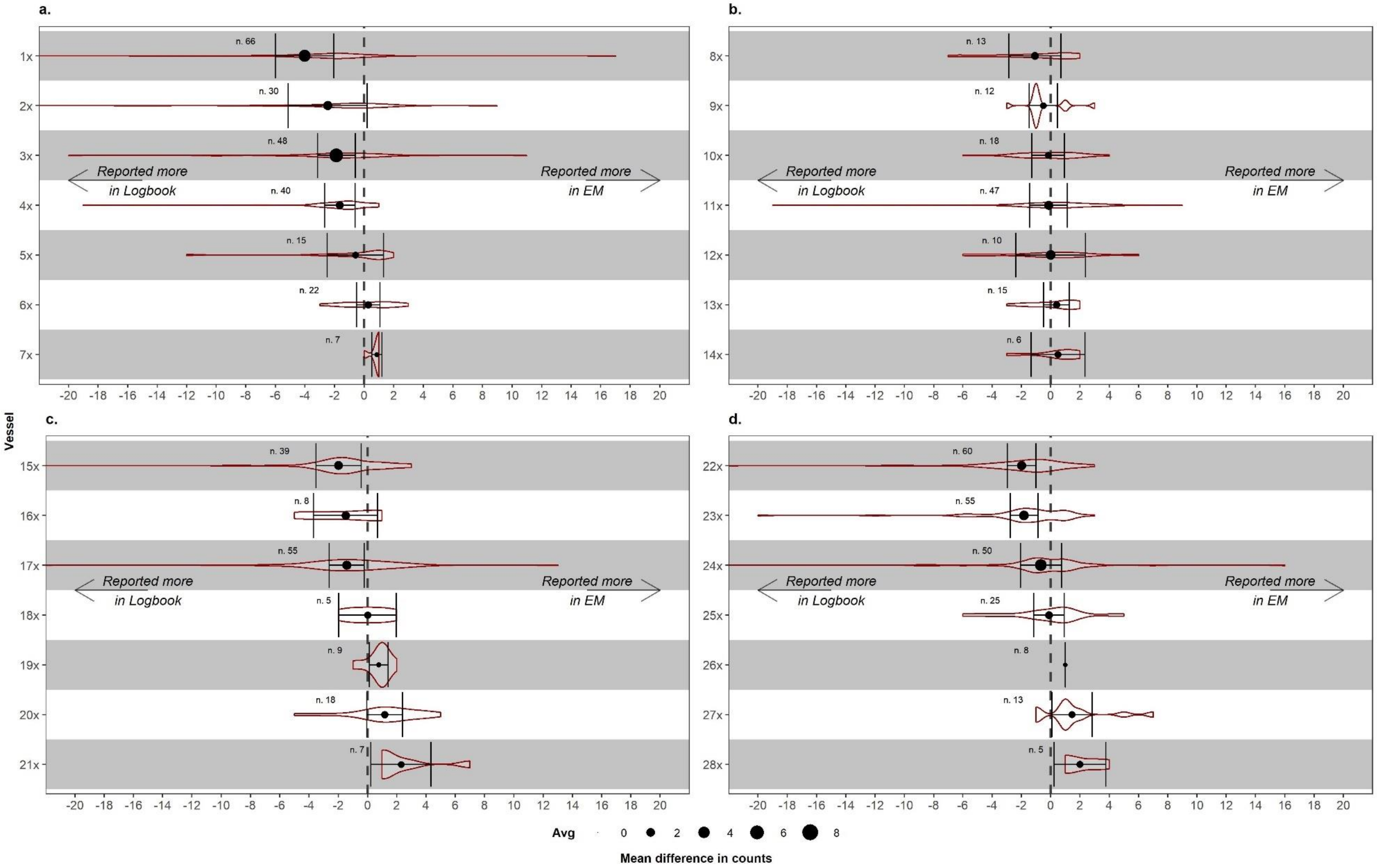


Figure 52: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing discarded albacore tuna across the time period. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



3.2.2 Yellowfin tuna

Across the time period examined, 10% of shots audited that contained discarded yellowfin tuna had no difference in logbook and EM counts, 32% had higher counts reported by EM and 45% had higher counts reported by logbook. When differences in counts between logbook and EM were observed in a single shot these were mainly between ~1-2 individuals (Figure 53 and Figure 54). There was no evidence of any improvement in congruence through time (Figure 55). Yellowfin tuna was reported discarded slightly more by logbook (-1.9 ± 0.2 individuals) with the average number recorded discarded by both EM and logbook in a single shot low (2.1 ± 0.1 individuals), so as a proportion of the average catch, this difference was significant at -90% (Table 4) and led to a clear left-hand skew in the distribution of differences in counts. So, for every 10 individuals reported by EM, the logbook is reporting 19 individuals. This suggests EM is having some issues correctly identifying yellowfin tuna. Furthermore, there were 62% of shots containing a zero record for either EM or logbook when ≥1 individual was reported discarded by the other data collection tool, suggesting there is numerous shots where ~1-2 individuals are being overlooked (Figure 56). This is somewhat driven by a single vessel reporting limited numbers as discarded in their logbook compared to EM (see below).

There was a total of 31 vessels that had greater than four audited shots with yellowfin tuna reported as discarded across the time period examined (Figure 57). The average number of yellowfin tuna recorded as discarded for each shot ranged from 1 to 10 individuals for each vessel. An examination of the data at an individual vessel level revealed that for most of the 31 vessels, the confidence intervals for the mean difference in counts did not encompass zero, with a clear skew towards more individuals being reported in the logbook (Figure 57).

As a proportion of the average catch, the difference in counts across most vessels was greater than 100%, signifying poor congruence across the fleet. It is important to note that the lack of logbook reporting of yellowfin tuna discards was particularly evident for one vessel, x31. This vessel had a total of 30 shots audited but in only one of those shots was an individual recorded in the logbook, with all others only recorded by EM, which may warrant further investigation.

Figure 53: Logbook and EM reported counts from individual shots containing discarded yellowfin tuna across time period examined. Red dashed line is the 1:1 line.

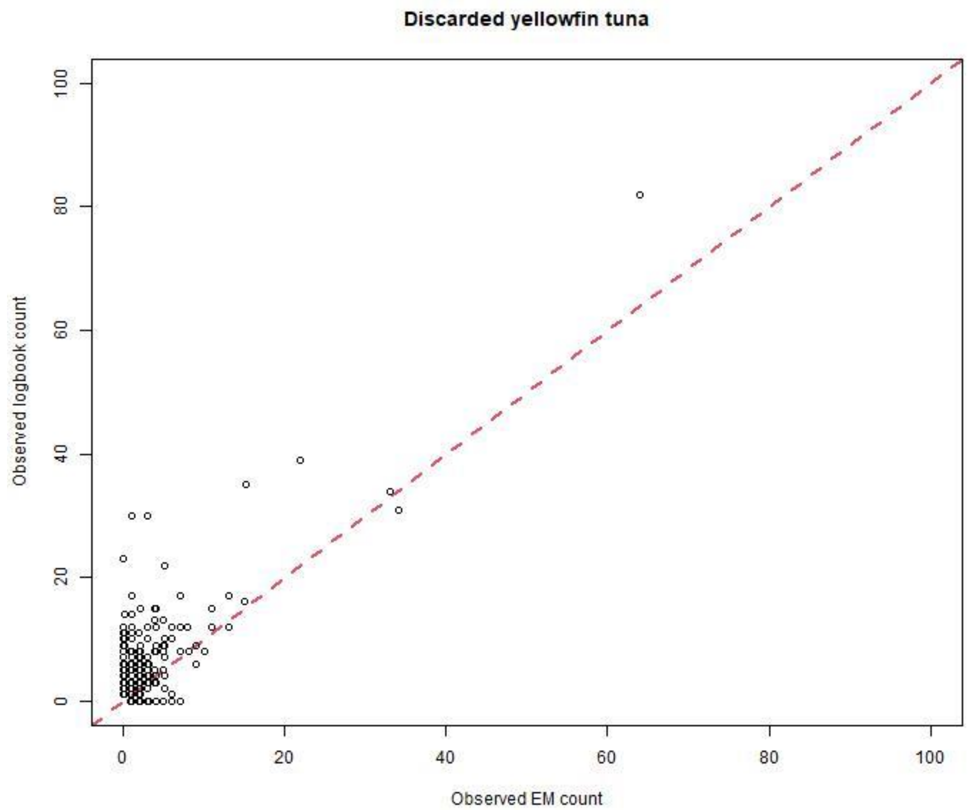


Figure 54: Proportion of shots with specific differences between EM and logbook counts for discarded yellowfin tuna across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

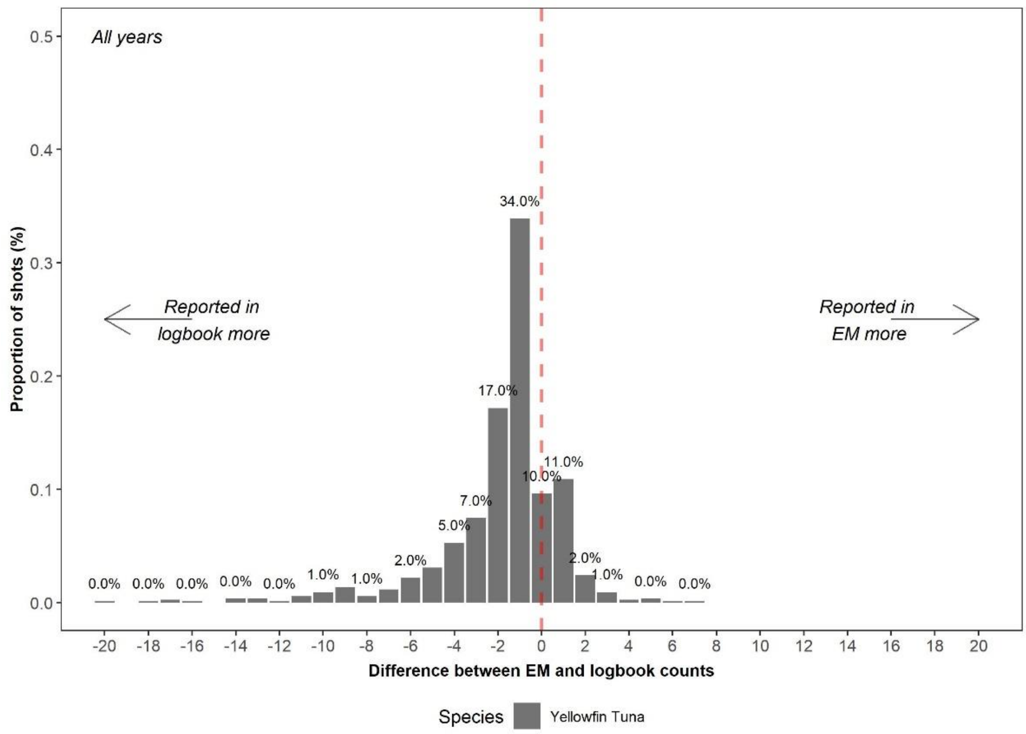


Figure 55: Proportion of shots with specific differences between EM and logbook counts for discarded yellowfin tuna for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

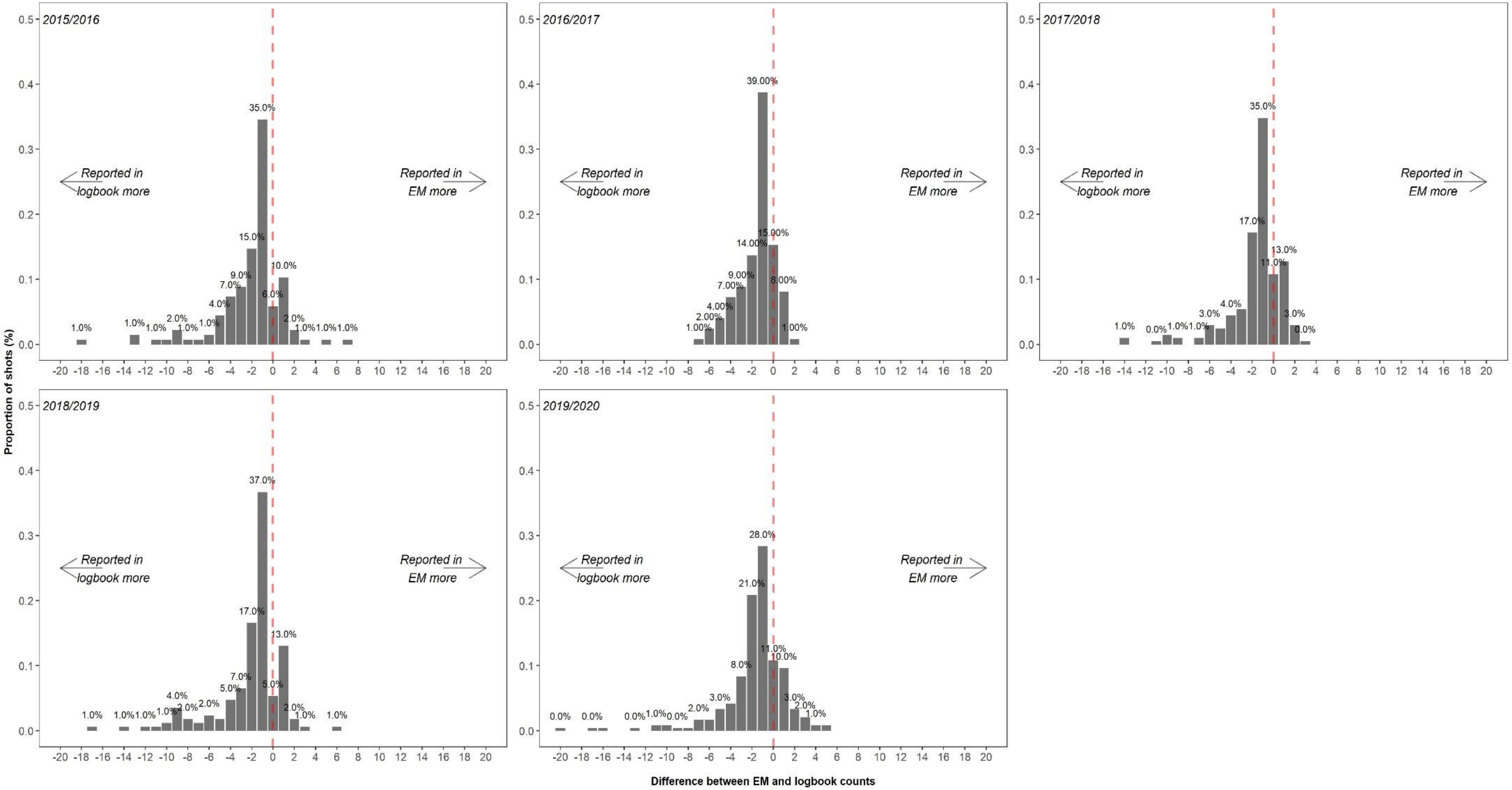


Figure 56: Number of shots with specific differences between EM and logbook counts for discarded yellowfin tuna across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

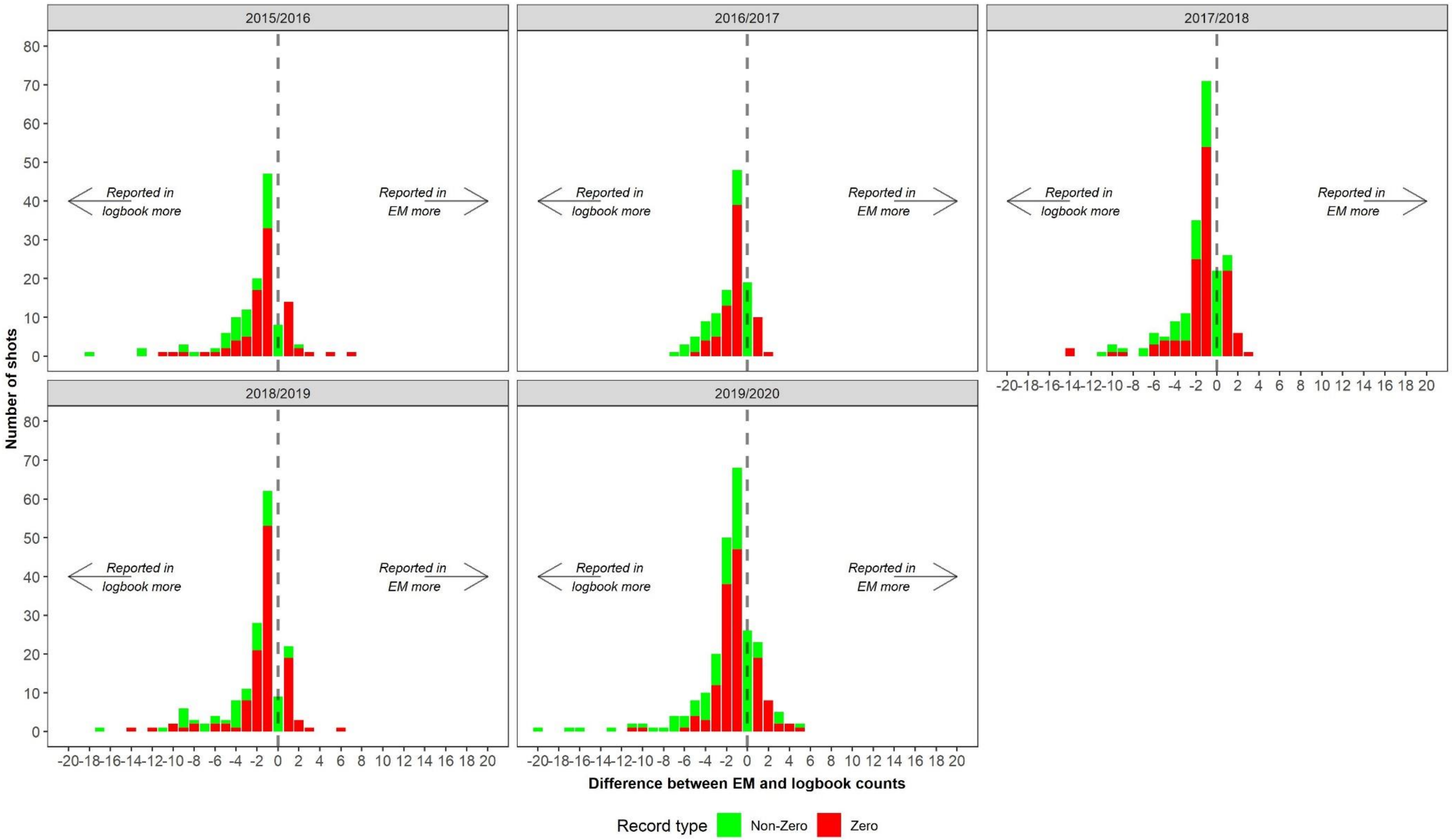
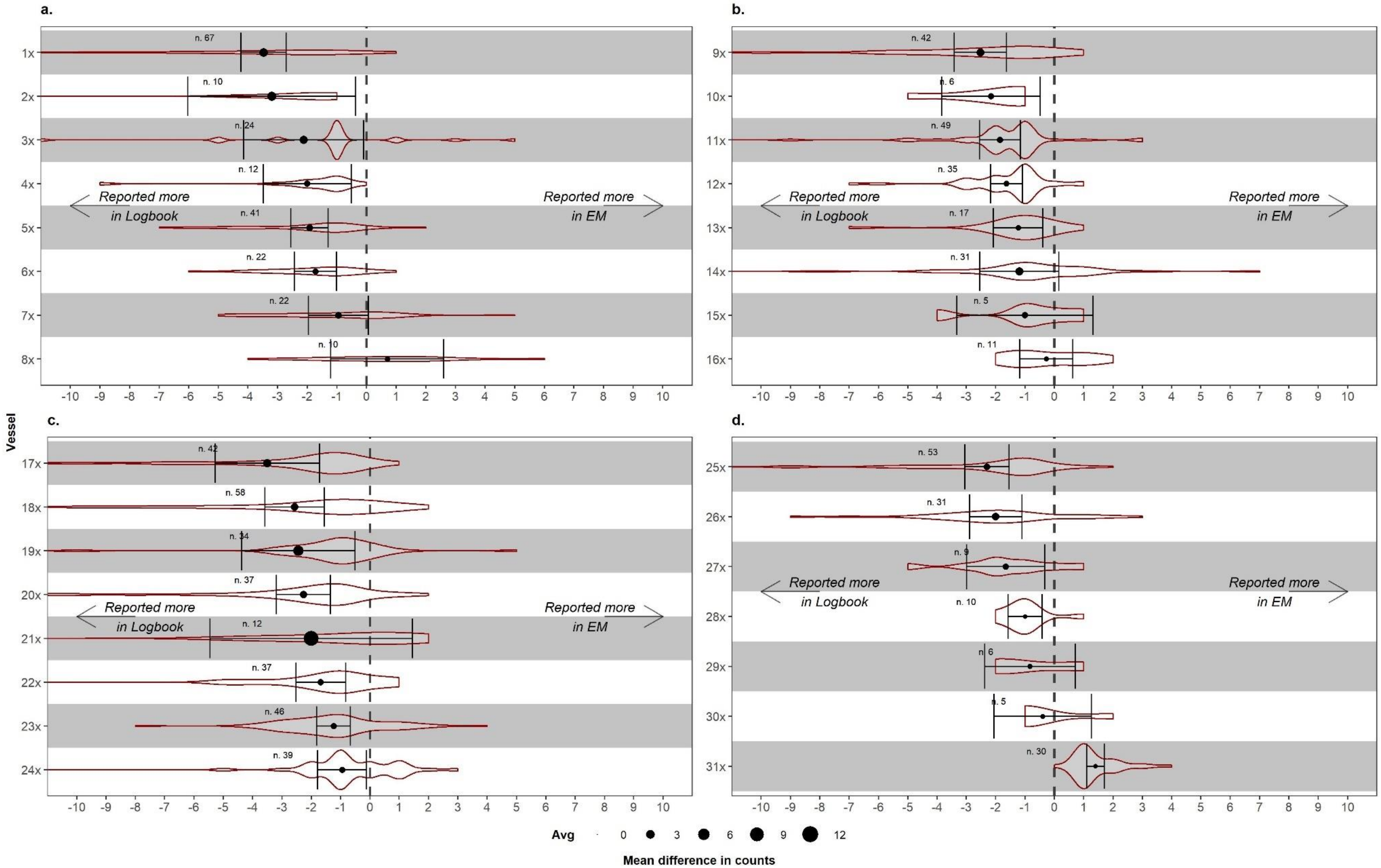


Figure 57: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing discarded yellowfin tuna across the time period. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



3.2.3 Southern bluefin tuna

Across the time period examined, 16% of shots audited that contained discarded southern bluefin tuna had no difference in logbook and EM counts, 21% had higher counts reported by EM and 62% had higher counts reported by logbook. When differences in counts between logbook and EM were observed in a single shot these were mainly between ~1-5 individuals but there was a large amount of variability, with numerous shots with higher differences in counts (Figure 58 and Figure 59). There was no evidence of improvement in congruence through time (Figure 60). Southern bluefin tuna was reported discarded more by logbook (-4.1 ± 2.1 individuals) across the time period examined, with the average number recorded discarded by both EM and logbook in a single shot also high (10.9 ± 3.3 individuals), so as a proportion of the average catch this difference was significant at -37% (Table 4) and led to a clear left-hand skew in the distribution of differences in counts. . So, for every 10 individuals reported by EM, the logbook is reporting 13.7 individuals. Furthermore, there were 36% of shots containing a zero record for either EM or logbook when ≥1 individual was reported discarded by the other data collection tool, suggesting there is numerous shots where ~1-5 individuals or more are being overlooked (Figure 61).

There was a total of 8 vessels that had greater than four audited shots with southern bluefin tuna reported as discarded across the time period examined (Figure 62). The average number of southern bluefin tuna recorded as discarded for each shot ranged from 1 to 20 individuals for each vessel. An examination of the data at an individual vessel level revealed that for 7 of the 8 vessels, the confidence intervals for the mean difference in counts encompassed zero.

As a proportion of the average catch, the difference in counts across vessels was disparate, with some less than 15% (e.g., x5 and x7) and others higher than 70% (e.g., x6 and x1). EM was likely having some issues correctly identifying southern bluefin tuna on some vessels (Figure 62). This included x1, which had a mean difference in counts of -8.4 ± 4.2 individuals (with more reported by logbooks), with an average 11.6 ± 9.9 individuals discarded per shot (Figure 62).

Figure 58: Logbook and EM reported counts from individual shots containing discarded southern bluefin tuna across time period examined. Red dashed line is the 1:1 line.

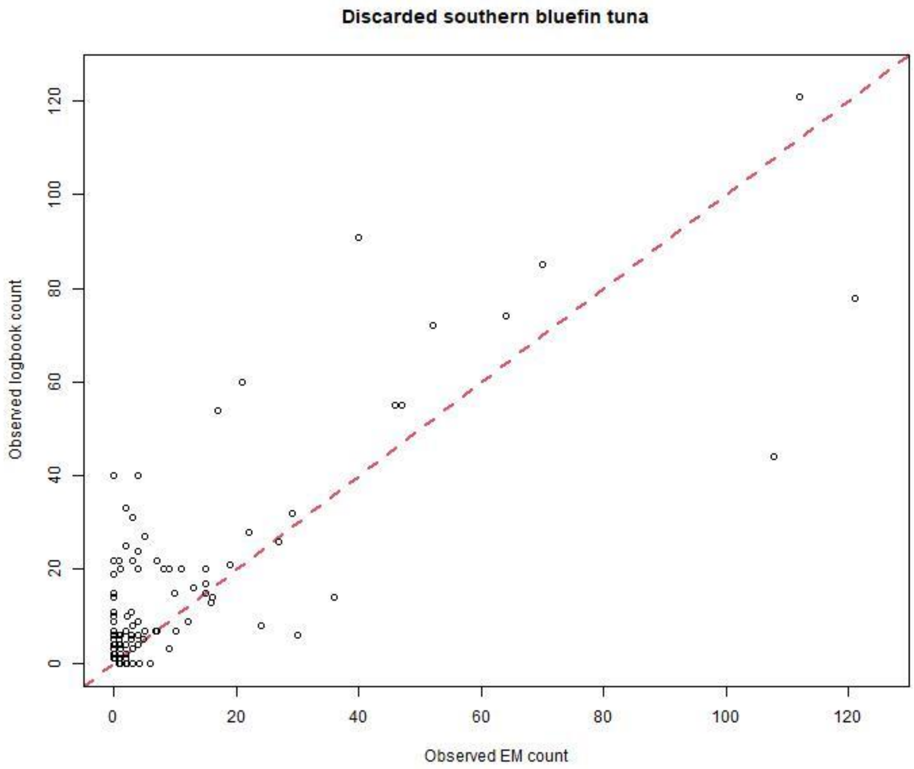


Figure 59: Proportion of shots with specific differences between EM and logbook counts for discarded southern bluefin tuna across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

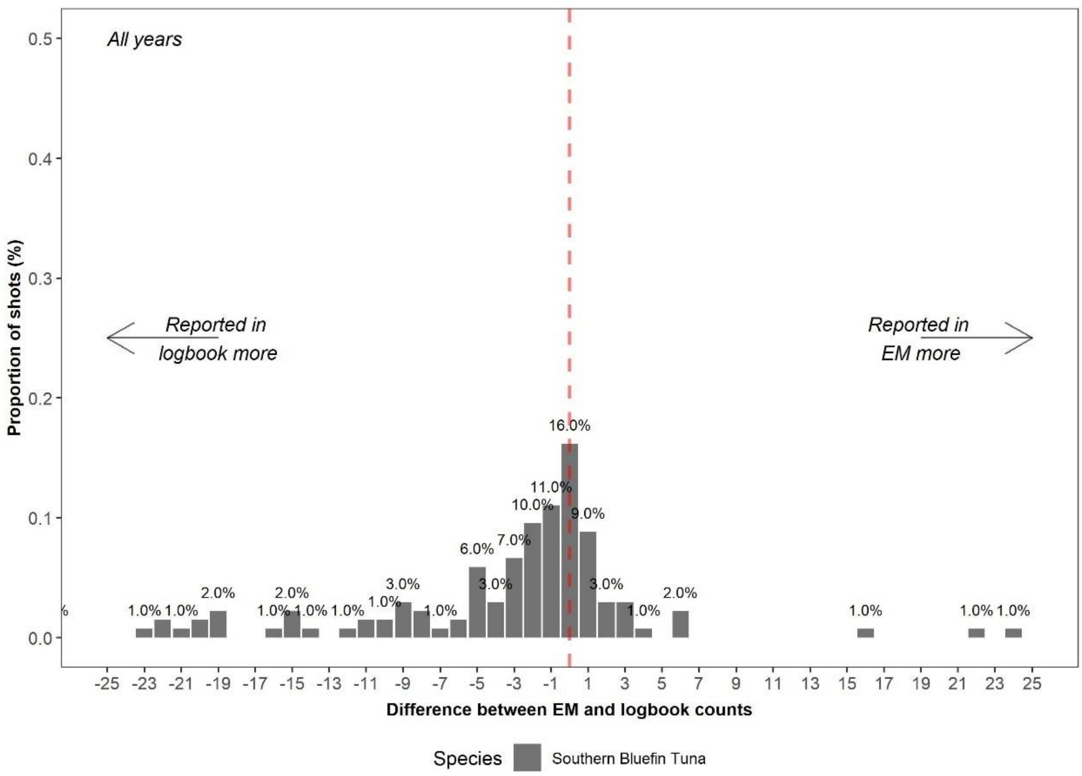


Figure 60: Proportion of shots with specific differences between EM and logbook counts for discarded southern bluefin tuna for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

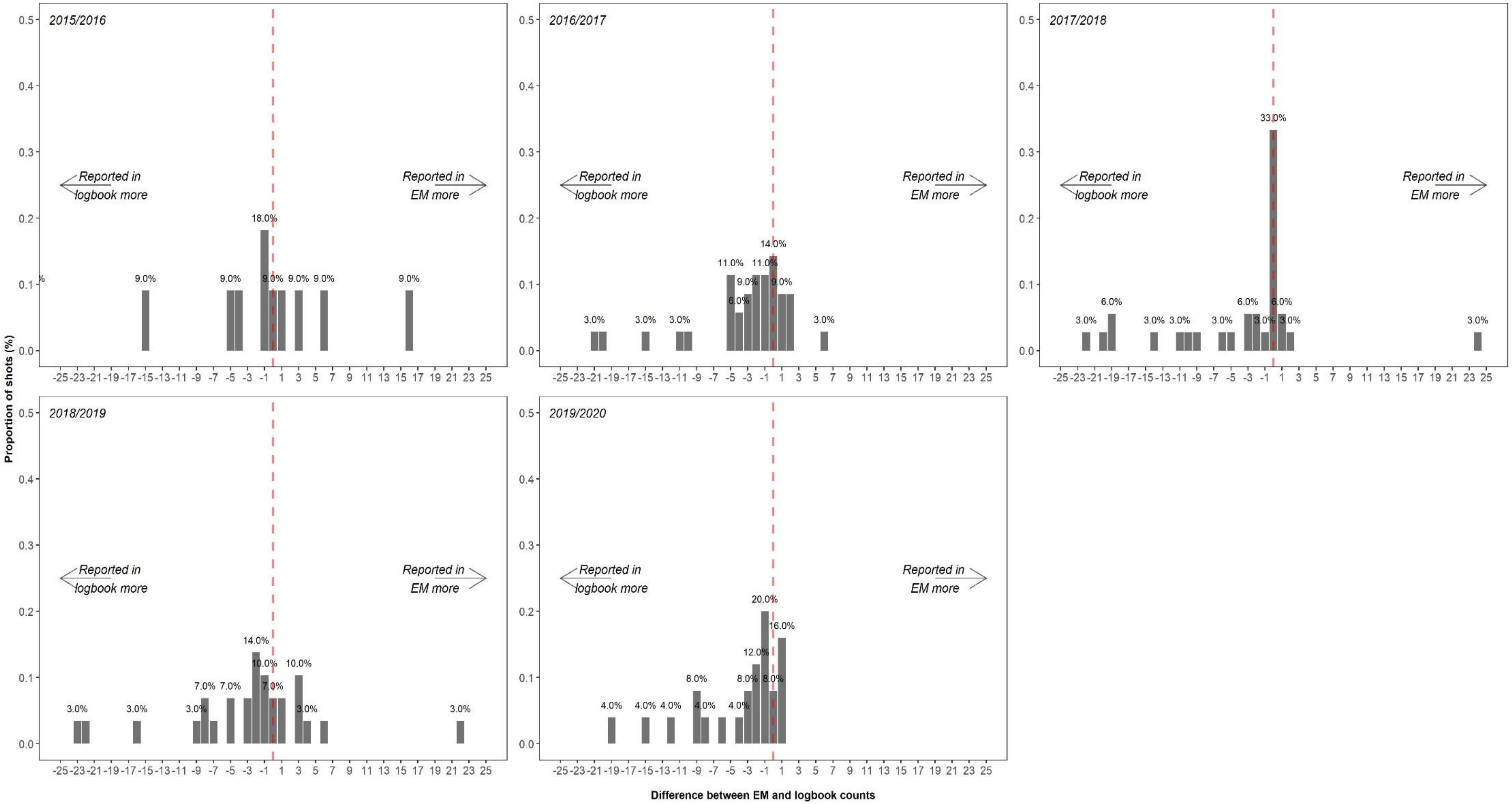


Figure 61: Number of shots with specific differences between EM and logbook counts for discarded southern bluefin tuna across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

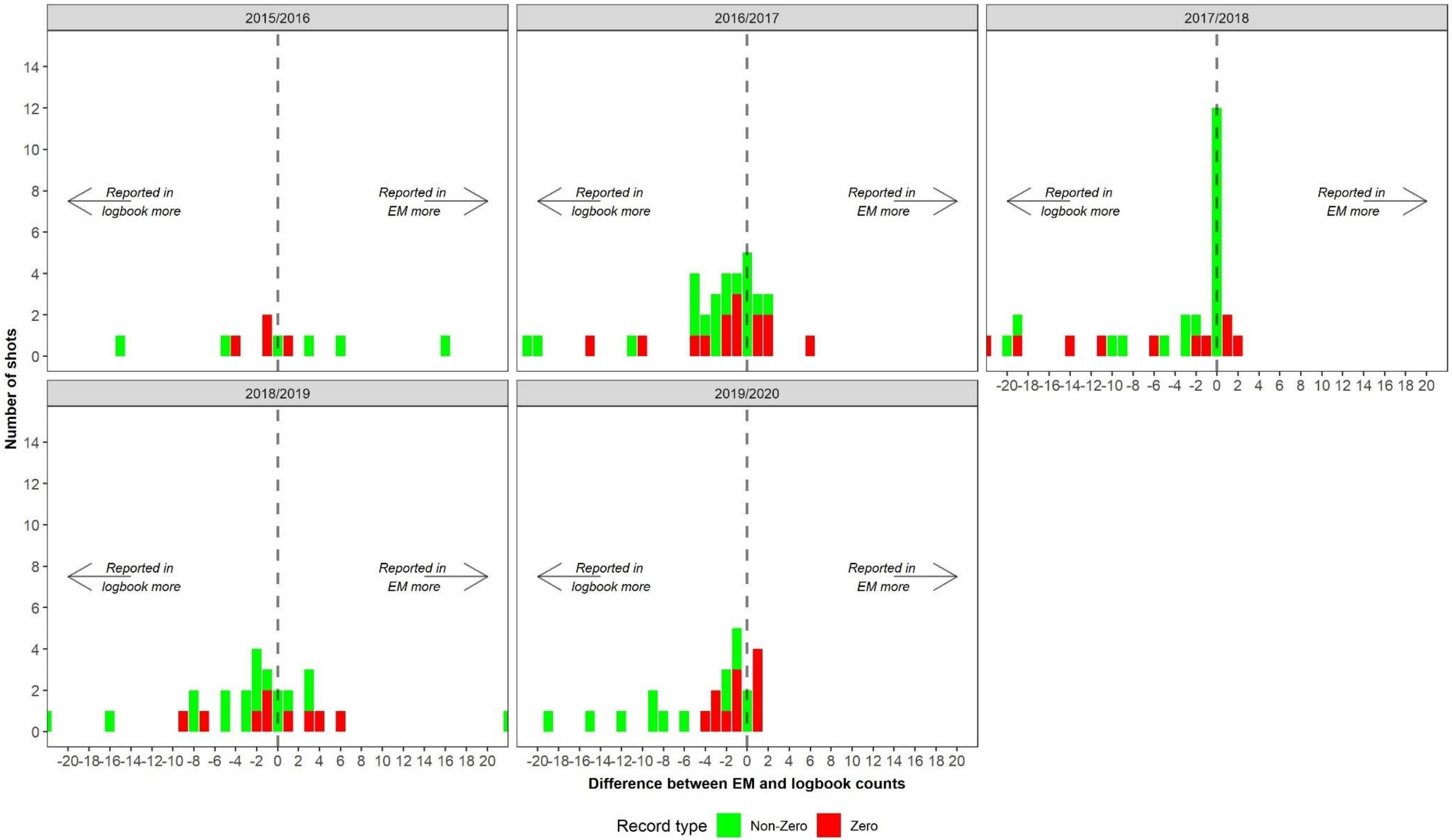
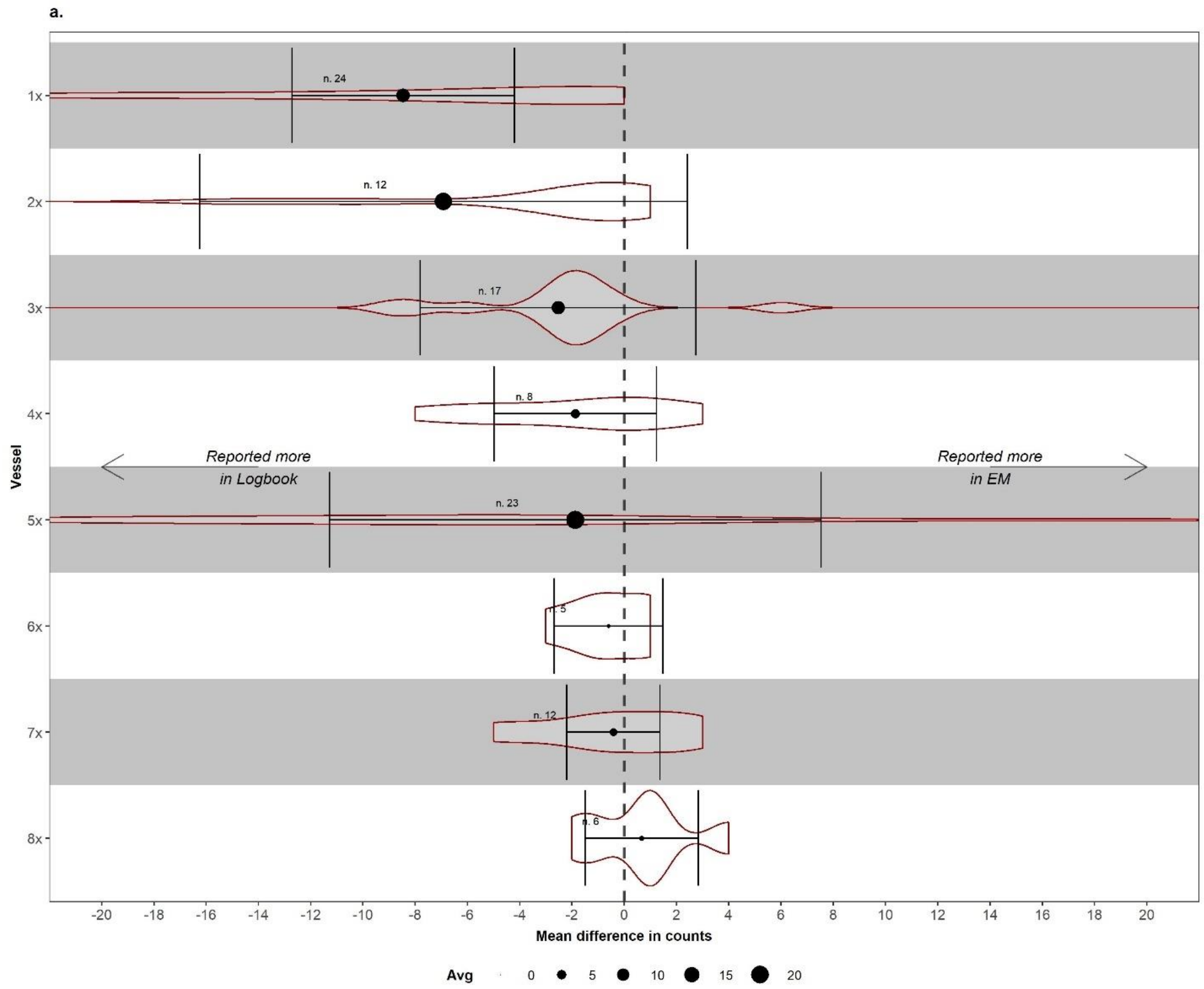


Figure 62: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing discarded southern bluefin tuna across the time period. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



3.2.4 Swordfish

Across the time period examined, 25% of shots audited that contained discarded swordfish had no difference in logbook and EM counts, 41% had higher counts reported by EM and 34% had higher counts reported by logbook. When differences in counts between logbook and EM were observed in a single shot these were around ~1-2 individuals (Figure 63 and Figure 64). There was overall a reduction in congruence through time with 33% of shots in 2016/17 having no difference in logbook and EM counts, decreasing to 20% by 2019/20 (Figure 65). The mean difference in counts was negligible across the time period examined (0.0 ± 0.1 individuals) with the average number recorded by both EM and logbook low (1.5 ± 0.1 individuals), so as a proportion of the average catch this difference was <1%. So, for every 10 individuals reported by EM, the logbook is reporting ~9.9-10 individuals. However, this conceals the fact that individuals were overlooked, with 50% of shots containing a zero record for either EM or logbook when ≥1 individual was reported discarded by the other data collection tool (Figure 66). This is somewhat driven by some vessels reporting no discards in their logbook despite EM reporting individuals (see below).

There was a total of 23 vessels that had greater than four audited shots with swordfish reported as discarded across the time period examined (Figure 67). The average number of swordfish recorded as discarded for each shot ranged from 1 to 3 individuals for each vessel. An examination of the data at an individual vessel level revealed that for 15 of the 23 vessels, the confidence intervals for the mean difference in counts encompassed zero.

As a proportion of the average catch, the difference in counts across most vessels was greater than 15%, signifying poor congruence across the fleet. However, there was variation across individual vessels. For example, x18 and x22 reported no discards across all audited shots, however some were reported by the EM analyst, which may warrant further investigation (Figure 67). Similarly, only two out of the eight audited shots from x23 had recorded discards in the logbook, where the EM analyst reported individuals discarded (Figure 67). Overall, for those vessels with a higher number of audited shots (>40) which reported discarded swordfish, congruence was improved relative to those with lower numbers of audited shots.

Figure 63: Logbook and EM reported counts from individual shots containing discarded swordfish across time period examined. Red dashed line is the 1:1 line.

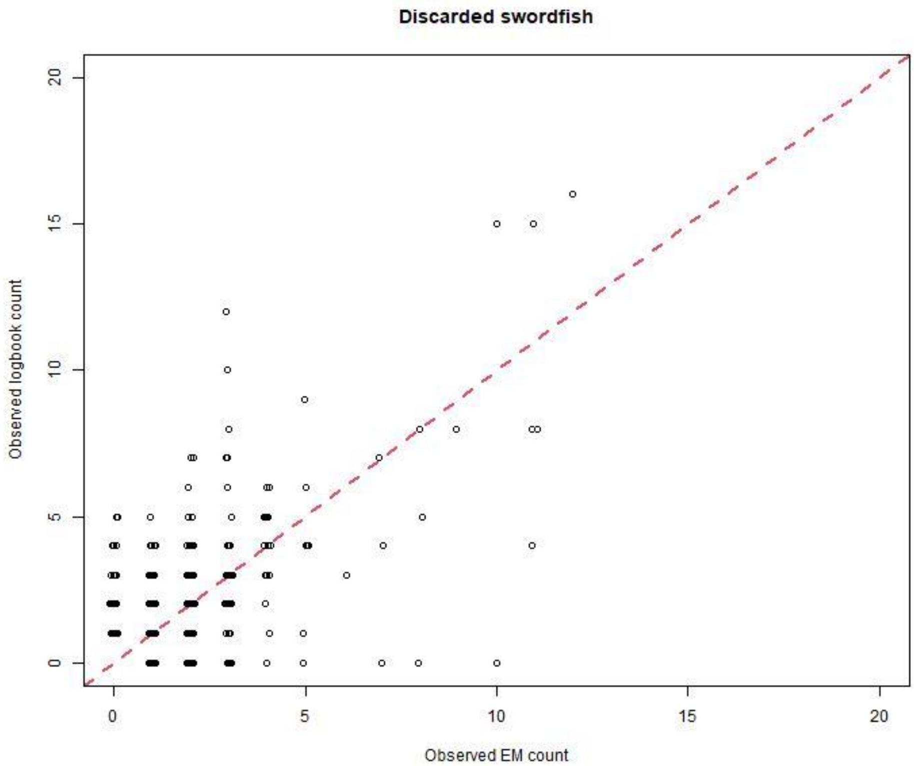


Figure 64: Proportion of shots with specific differences between EM and logbook counts for discarded swordfish across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

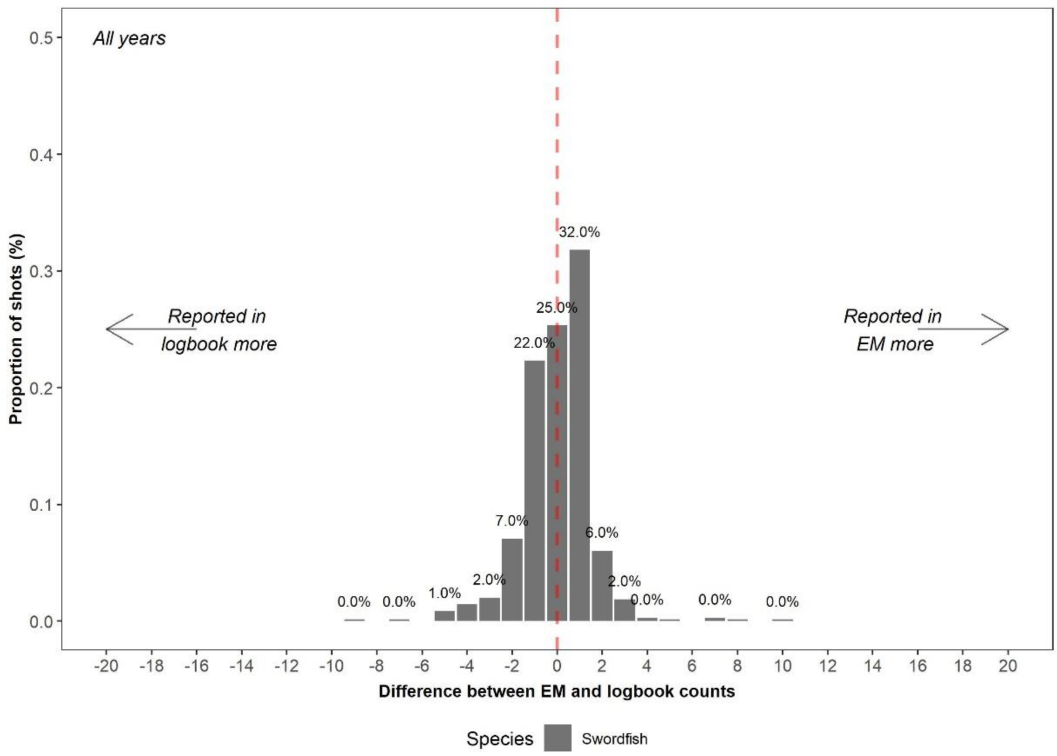


Figure 65: Proportion of shots with specific differences between EM and logbook counts for discarded swordfish for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

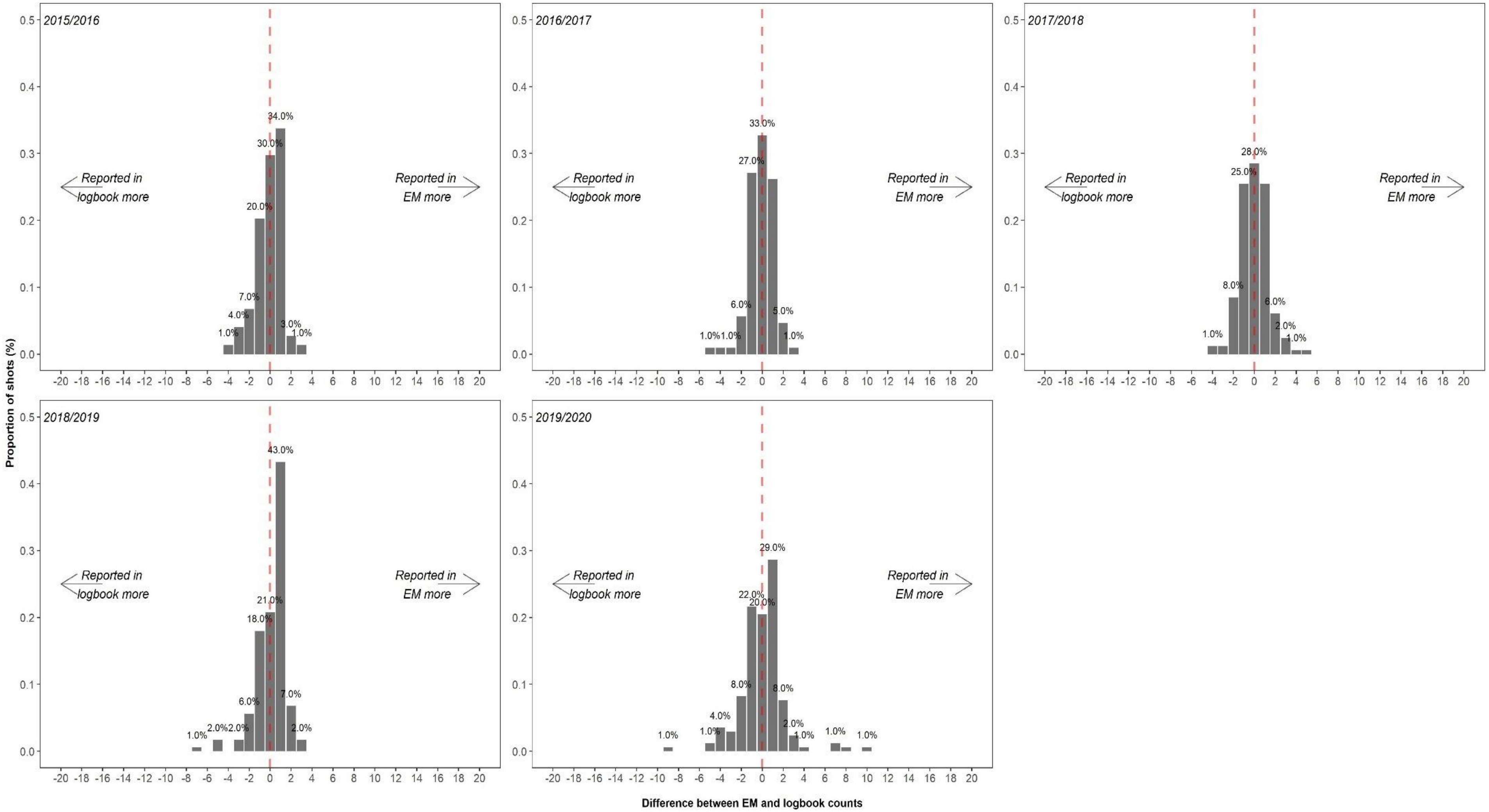


Figure 66: Number of shots with specific differences between EM and logbook counts for discarded swordfish across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

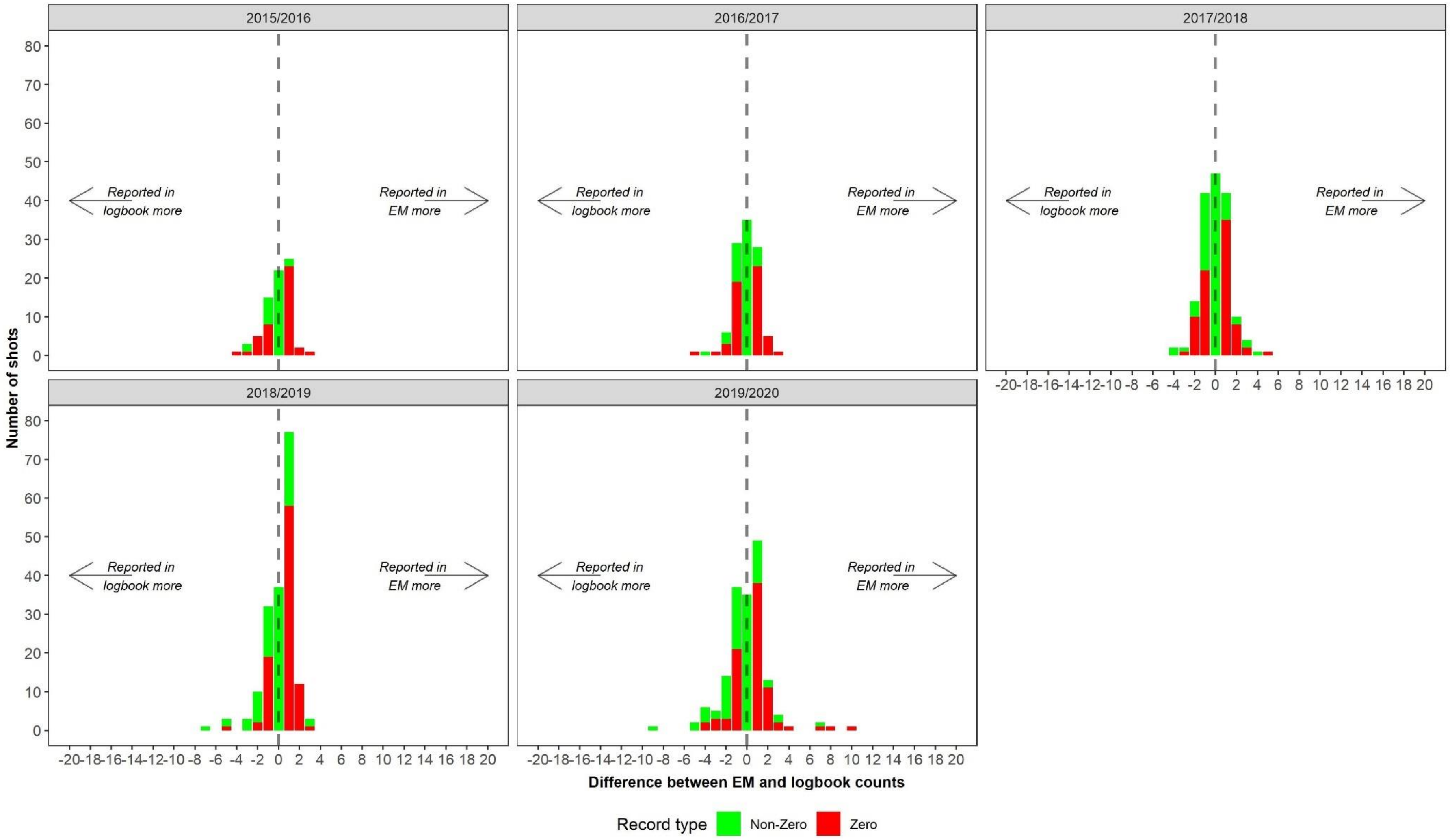
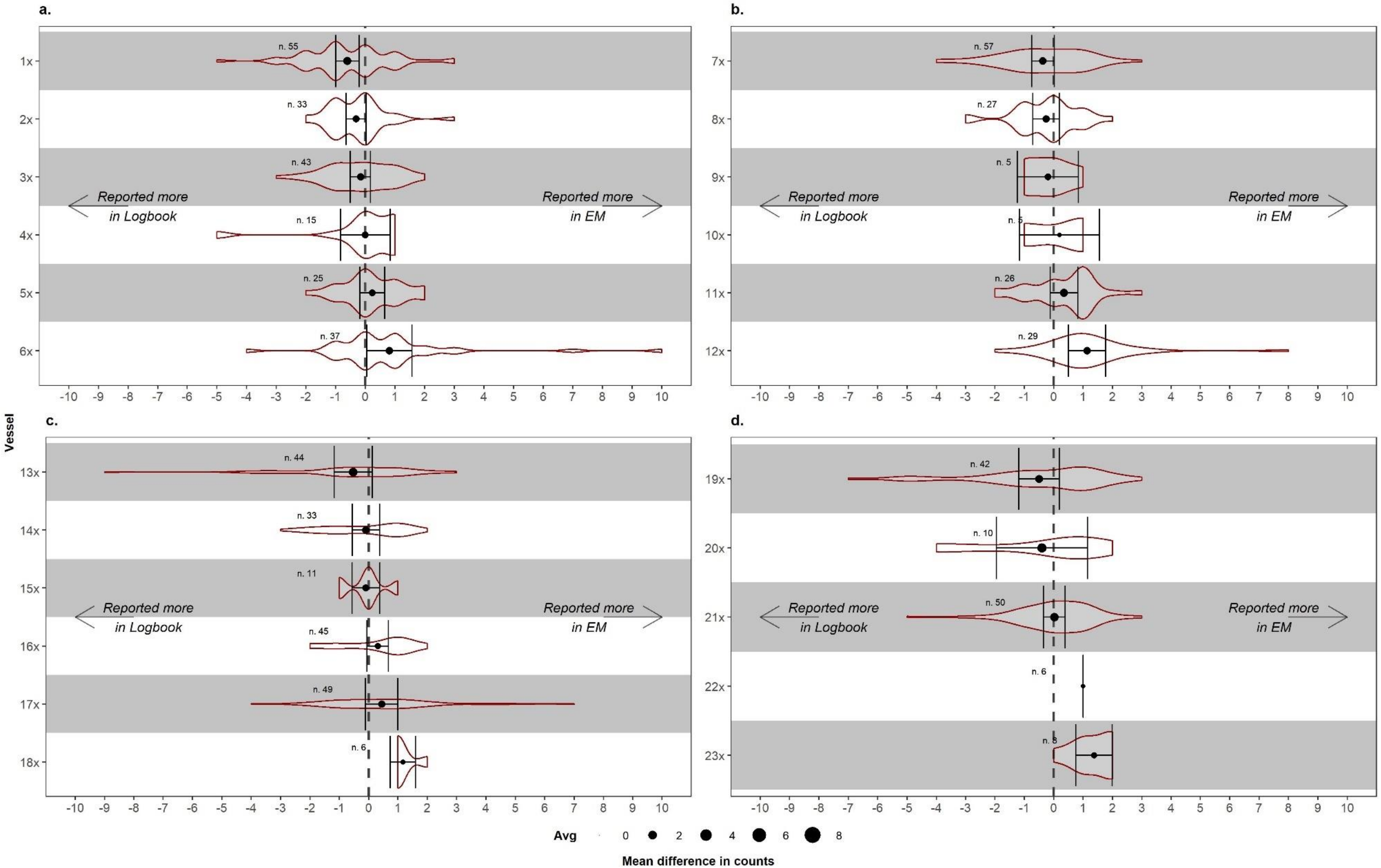


Figure 67: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing discarded swordfish across the time period. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



3.2.5 Mahi mahi

Across the time period examined, 18% of shots audited that contained discarded mahi mahi had no difference in logbook and EM counts, 48% had higher counts reported by EM and 34% had higher counts reported by logbook. When differences in counts between logbook and EM were observed in a single shot these were mainly between ~1-2 individuals (Figure 68 and Figure 69). There was inter-annual variation in congruence through time with no evidence of improvement (Figure 70). The mean difference in counts was negligible across the time period examined (-0.2 ± 0.4 individuals) with the average number recorded by both EM and logbook also low (1.5 ± 0.2 individuals), so as a proportion of the average catch this difference was low at -10%. So, for every 10 individuals reported by EM, the logbook is reporting 11 individuals. Furthermore, there were 65% of shots containing a zero record for either EM or logbook when ≥1 individual was reported discarded by the other data collection tool, suggesting there is numerous shots where ~1-2 individuals are being overlooked (Figure 71). This is somewhat driven by several vessels not reporting any discarded mahi mahi catch in their logbook (see below).

There was a total of 22 vessels that had greater than four audited shots with mahi mahi reported as discarded across the time period examined (Figure 72). The average number of mahi mahi recorded as discarded for each shot ranged from 1 to 4 individuals for each vessel. An examination of the data at an individual vessel level revealed that for 16 of the 22 vessels, the confidence intervals for the mean difference in counts encompassed zero (Figure 72).

As a proportion of the average catch, the difference in counts across most vessels was greater than 15%, signifying poor congruence across the fleet. However, there was variation across individual vessels. For example, x11, x17 and x21 reported no discards across all audited shots, however some were reported by the EM analyst, which may warrant further investigation (Figure 72). EM was clearly having some issues either correctly identifying mahi mahi or observing mahi mahi being discarded on some vessels. This included x1, which had a mean difference in counts of -3.5 ± 4.2 individuals, with an average 3.7 ± 3.4 individuals discarded per shot (Figure 72).

Figure 68: Logbook and EM reported counts from individual shots containing discarded mahi mahi across time period examined. Red dashed line is the 1:1 line.

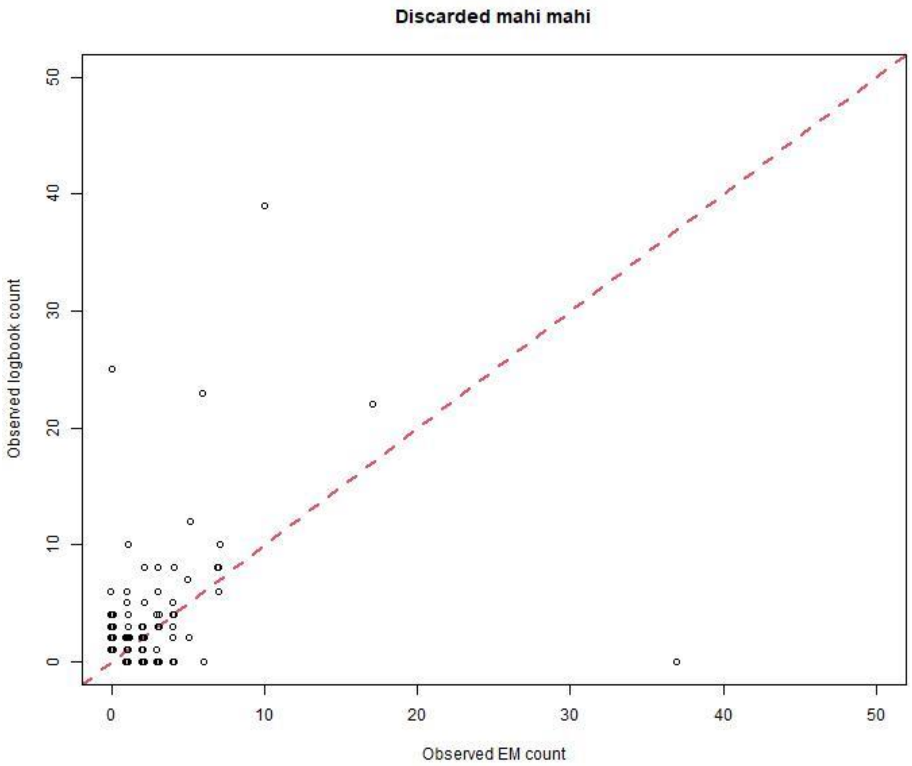


Figure 69: Proportion of shots with specific differences between EM and logbook counts for discarded mahi mahi across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

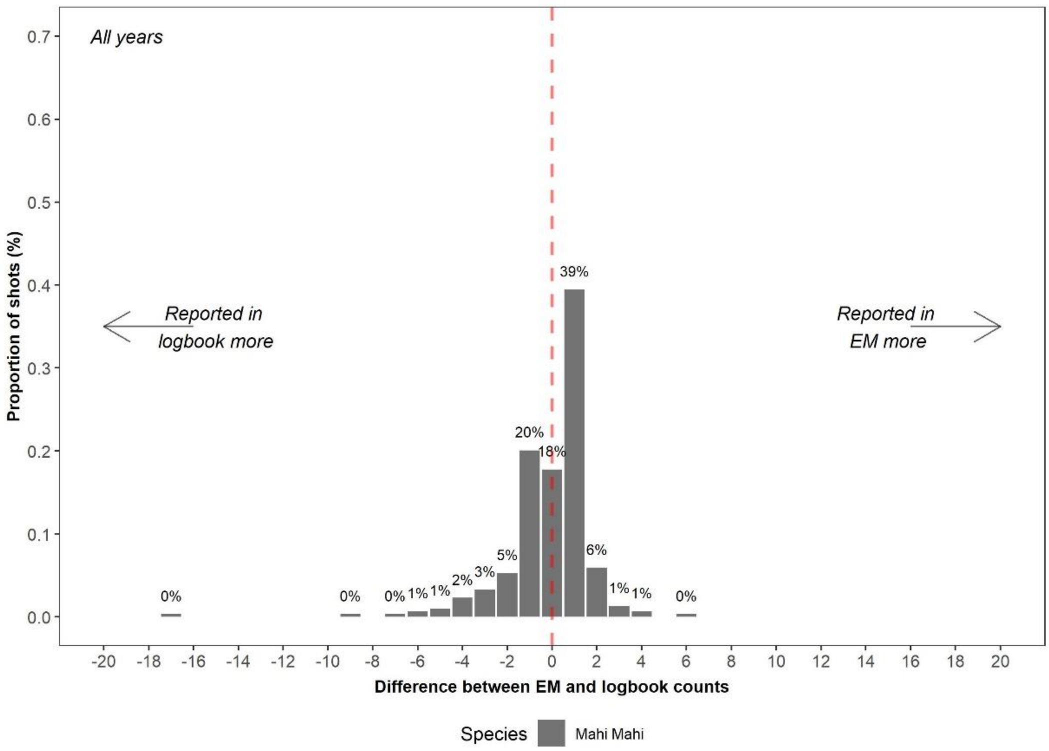


Figure 70: Proportion of shots with specific differences between EM and logbook counts for discarded mahi mahi for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

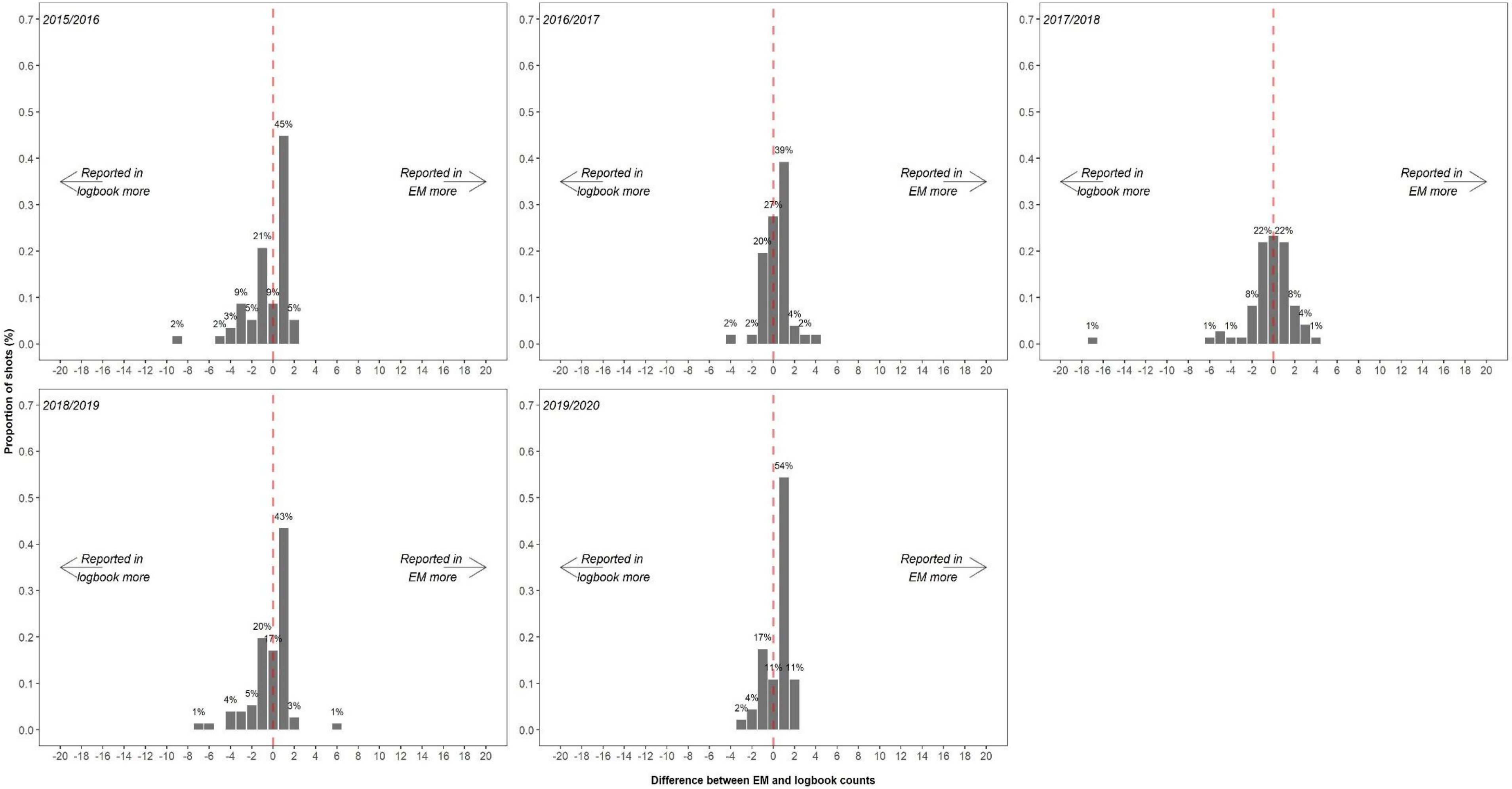


Figure 71: Number of shots with specific differences between EM and logbook counts for discarded mahi mahi across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

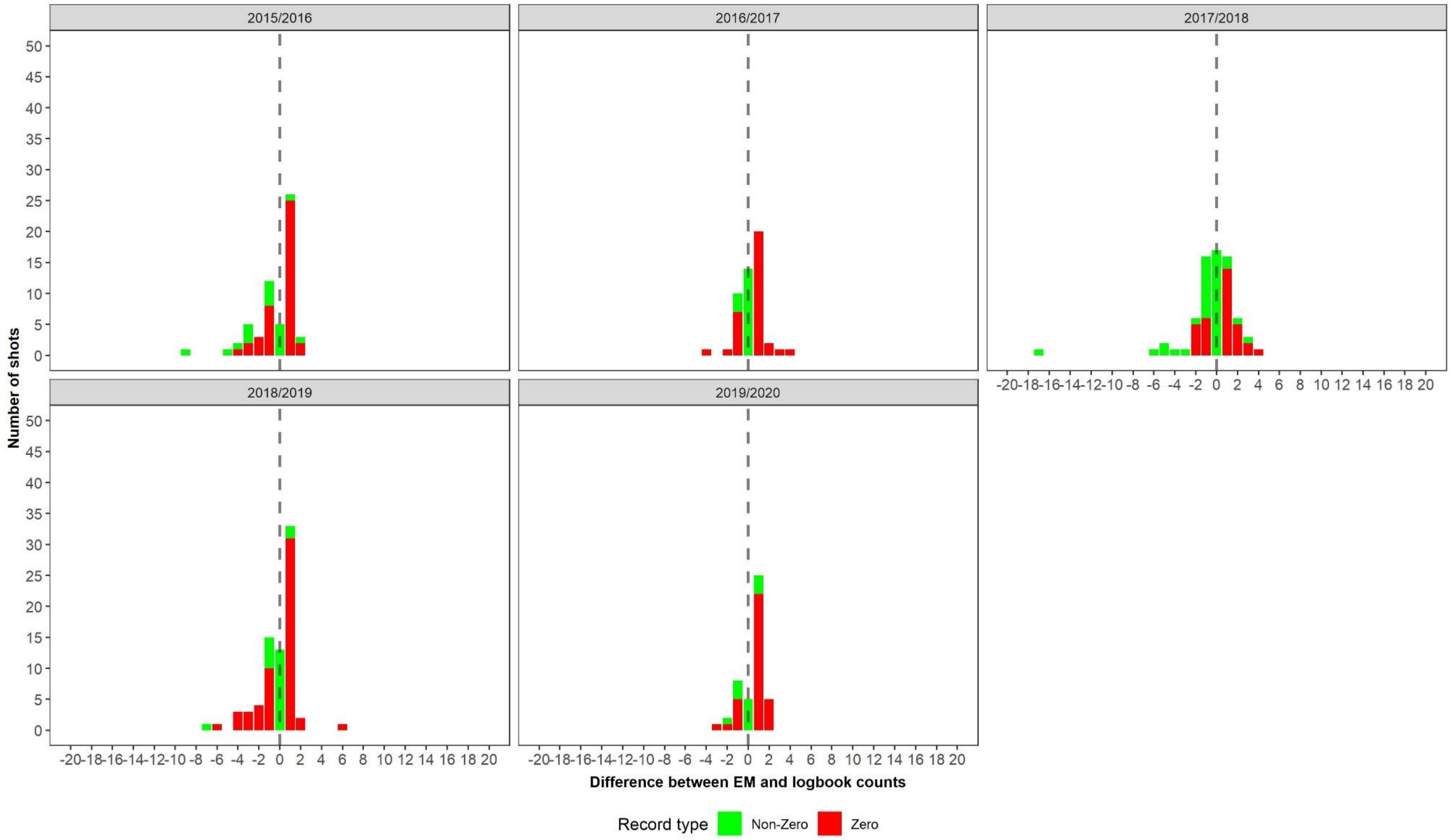
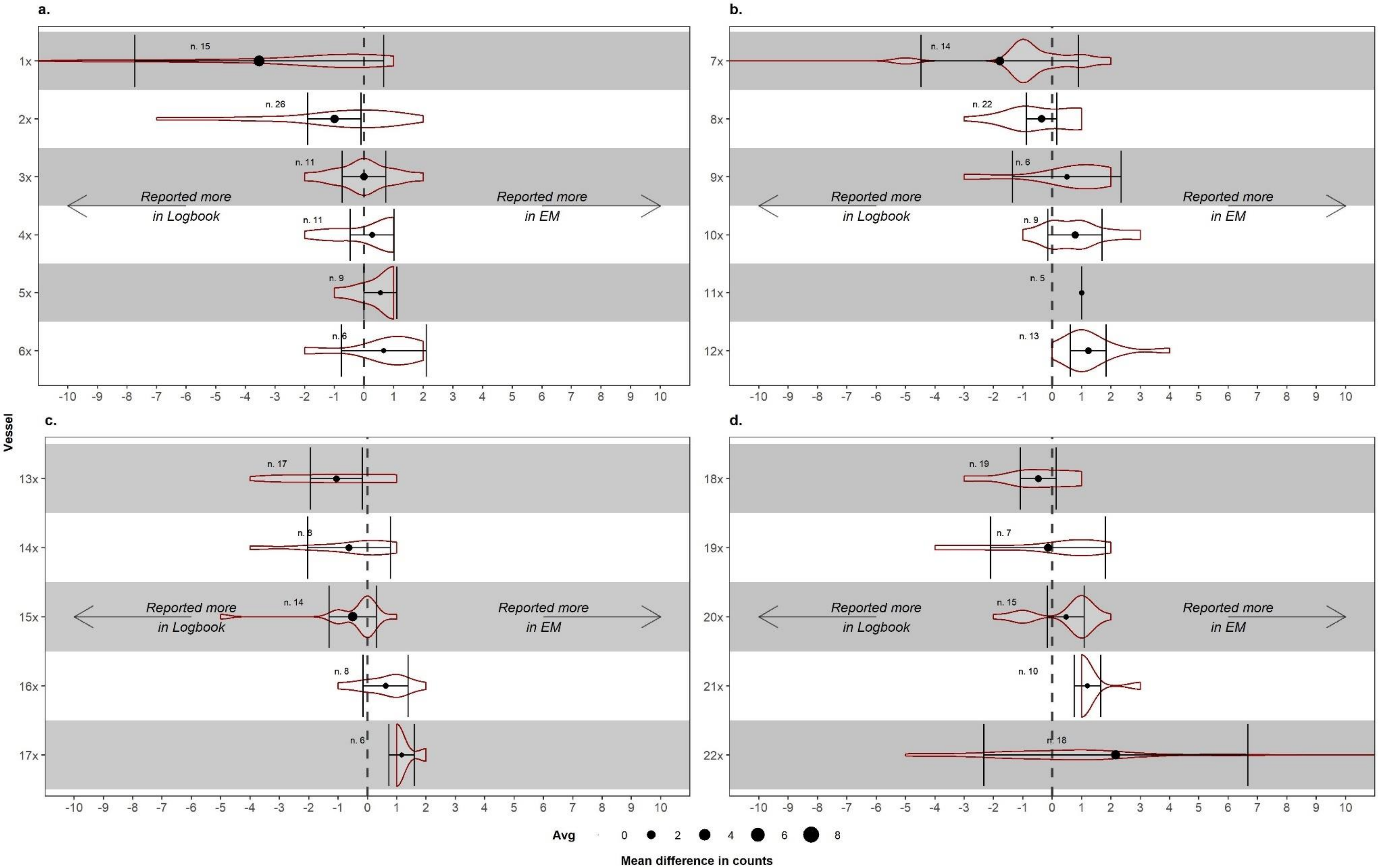


Figure 72: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing discarded mahi mahi across the time period. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



3.2.6 Bigeye tuna

Across the time period examined, 12% of shots audited that contained discarded bigeye tuna had no difference in logbook and EM counts, 29% had higher counts reported by EM and 59% had higher counts reported by logbook. When differences in counts between logbook and EM were observed in a single shot these were around ~1-2 individuals (Figure 73 and Figure 74). There was inter-annual variation in congruence through time with no evidence of improvement (Figure 75). The mean difference in counts was negligible across the time period examined (-0.8 ± 0.2 individuals) but the average number recorded by both EM and logbook was also low (1.2 ± 0.1 individuals), so as a proportion of the average catch this difference was significant at -66% and led to a clear left-hand skew in the distribution of differences in counts (Figure 75). This skew is more dominant in the earlier years (2015/16 to 2017/18). So, for every 10 individuals reported by EM, the logbook is reporting 16.6 individuals. Furthermore, there were 75% of shots containing a zero record for either EM or logbook when ≥1 individual was reported discarded by the other data collection tool, suggesting there are multiple shorts where ~1-2 individuals are being overlooked (Figure 76). This is somewhat driven by a couple of vessels reporting limited numbers as discarded in their logbook compared to EM (see below).

There was a total of 20 vessels that had greater than four audited shots with bigeye tuna reported as discarded across the time period examined (Figure 77). The average number of bigeye tuna recorded as discarded for each shot ranged from 1 to 2 individuals for each vessel. An examination of the data at an individual vessel level revealed that for 9 of the 20 vessels, the confidence intervals for the mean difference in counts encompassed zero (Figure 77).

As a proportion of the average catch, the difference in counts across most vessels was greater than 15%, signifying poor congruence across the fleet, with a clear skew towards more individuals being reported in the logbook. This suggests EM may be having some issues either correctly identifying bigeye tuna or observing bigeye tuna being discarded on most vessels. However, there was variation across individual vessels. For example, x15 and x20 had greater numbers being reported by the EM analyst, which may warrant further investigation. x20 had a total of 13 shots audited and in all but one, there were no discarded individuals reported, despite up to four individuals being reported as discarded per shot by the EM analyst (Figure 77).

Figure 73: Logbook and EM reported counts from individual shots containing discarded bigeye tuna across time period examined. Red dashed line is the 1:1 line.

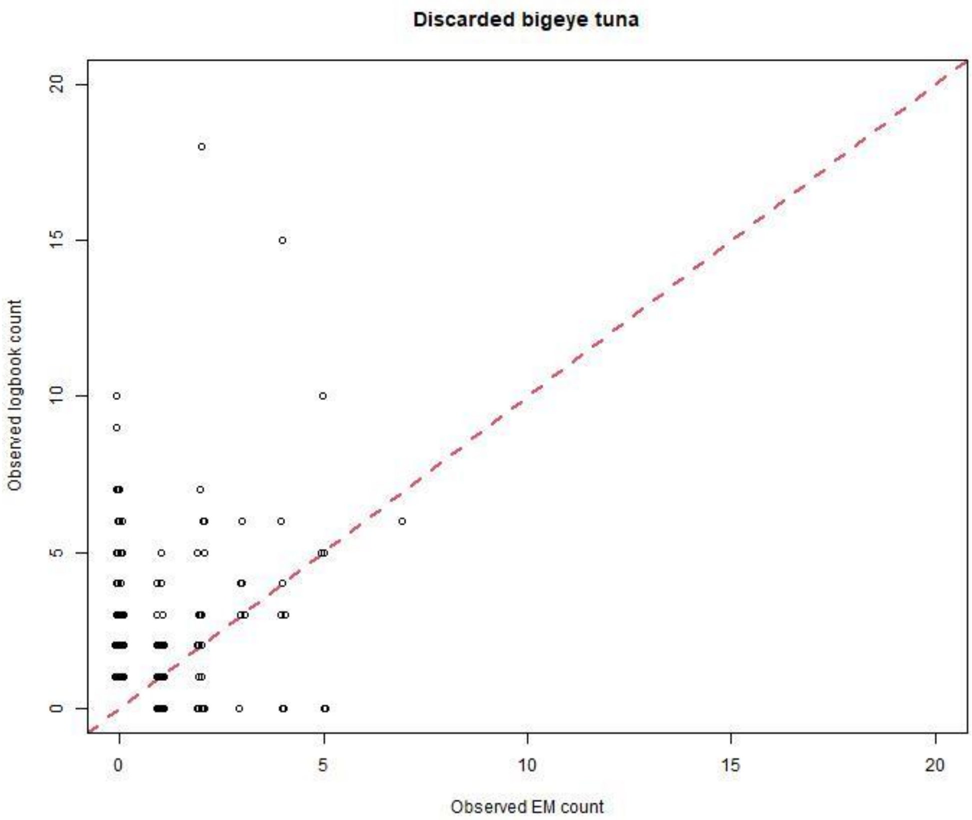


Figure 74: Proportion of shots with specific differences between EM and logbook counts for discarded bigeye tuna across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

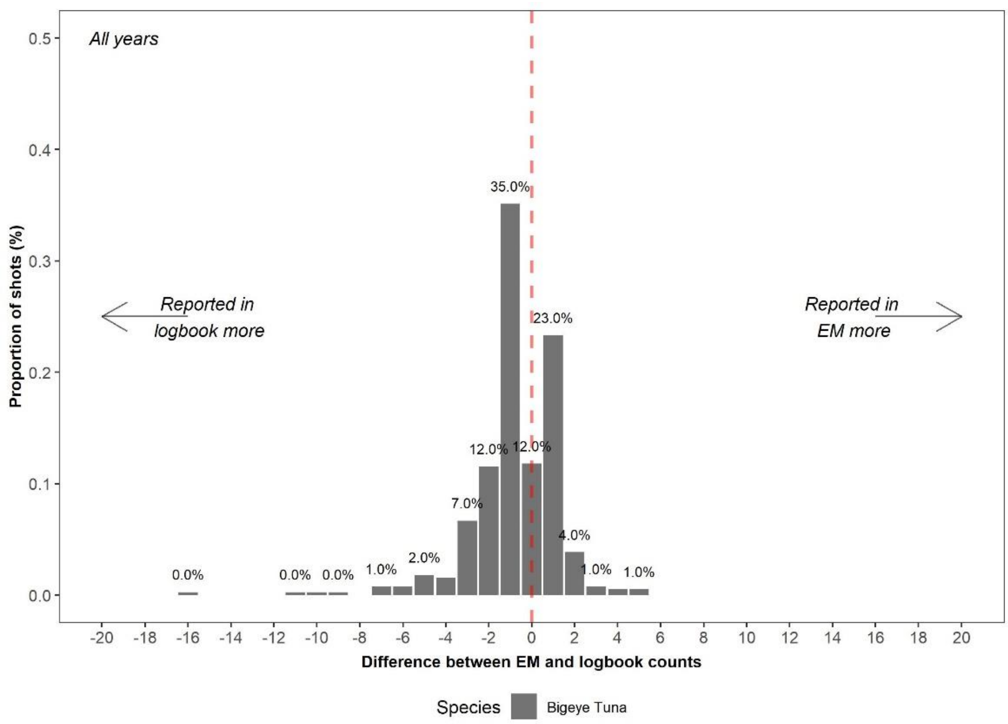


Figure 75: Proportion of shots with specific differences between EM and logbook counts for discarded bigeye tuna for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

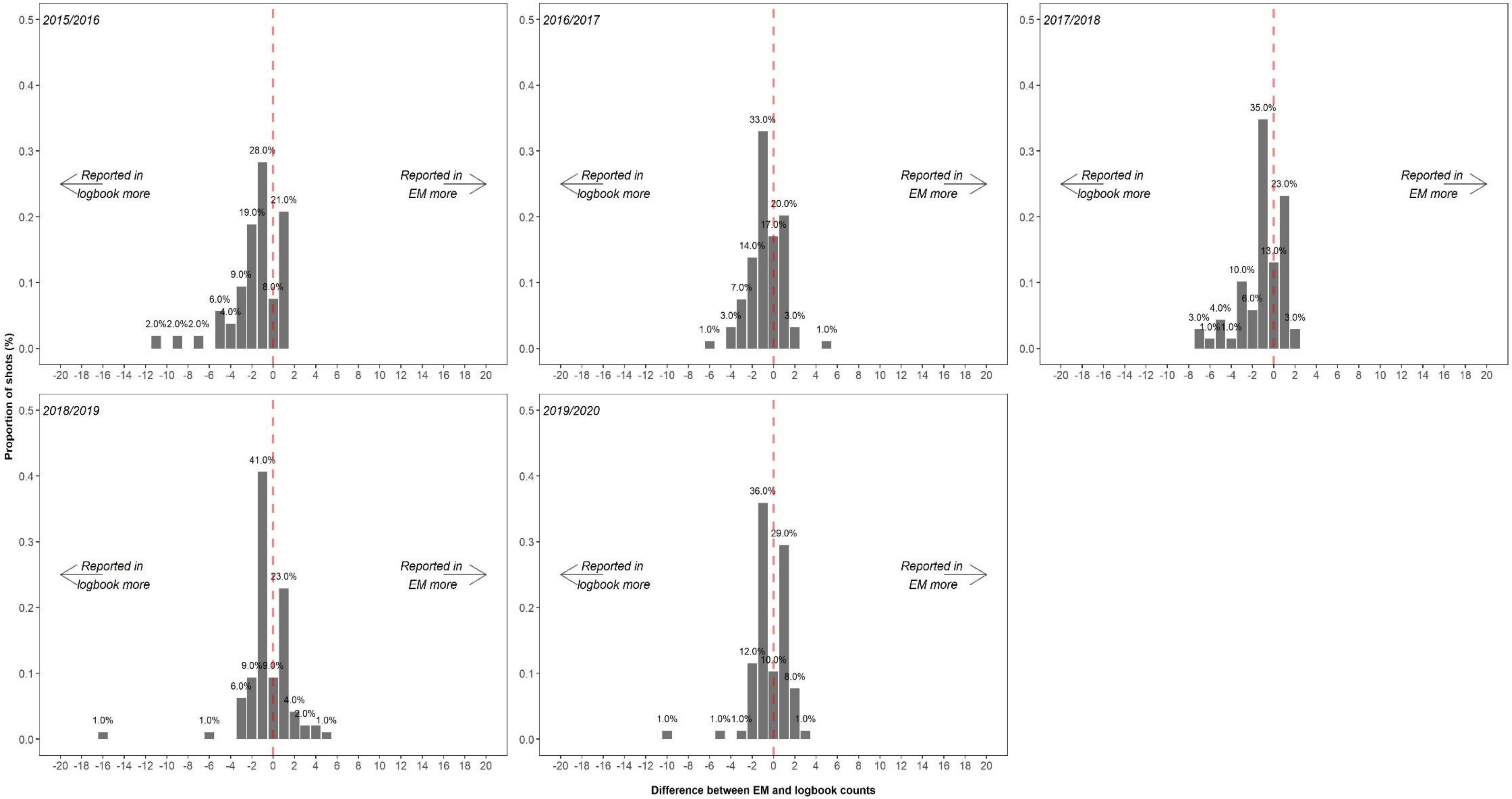


Figure 76: Number of shots with specific differences between EM and logbook counts for bigeye tuna across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

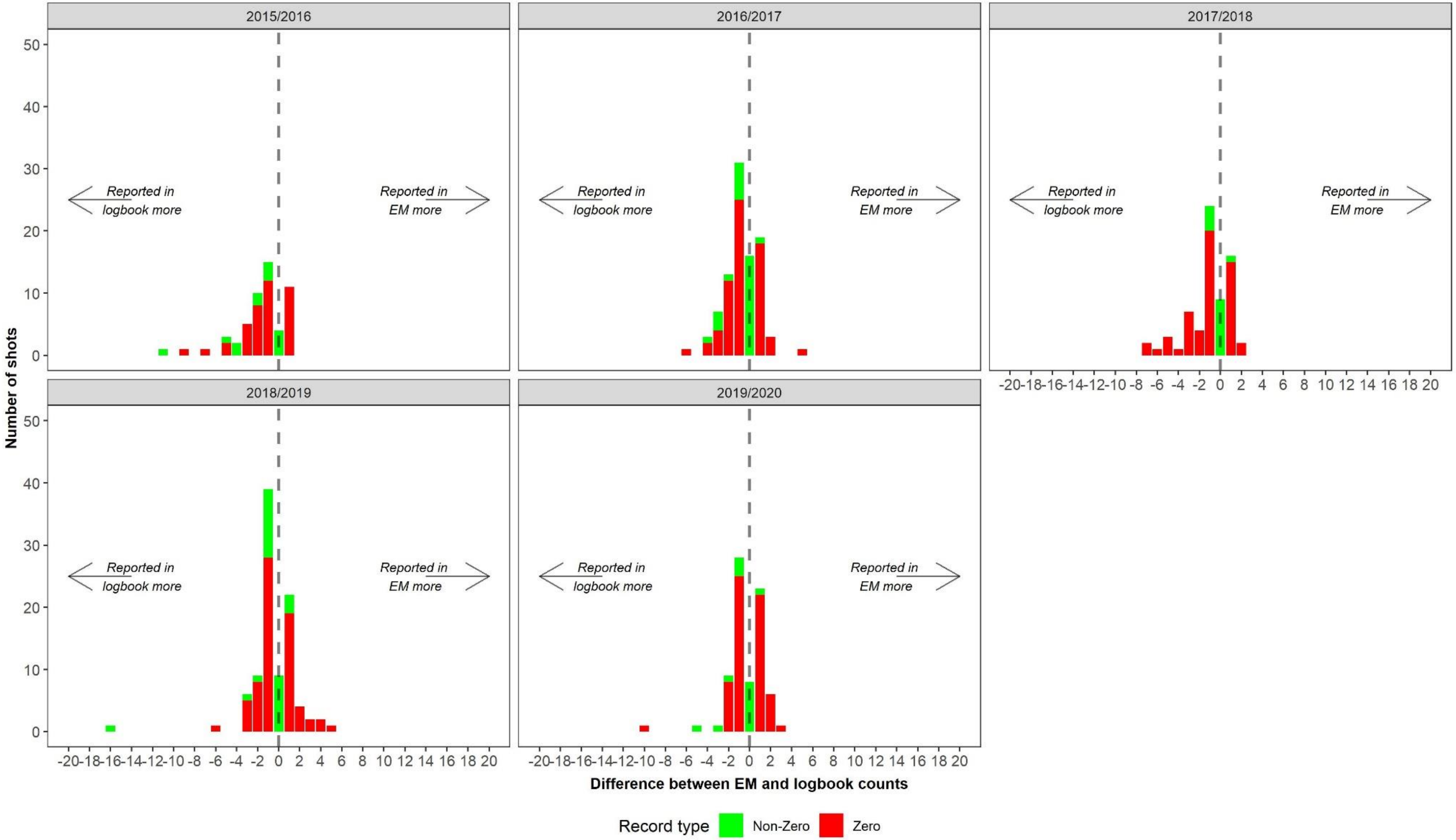
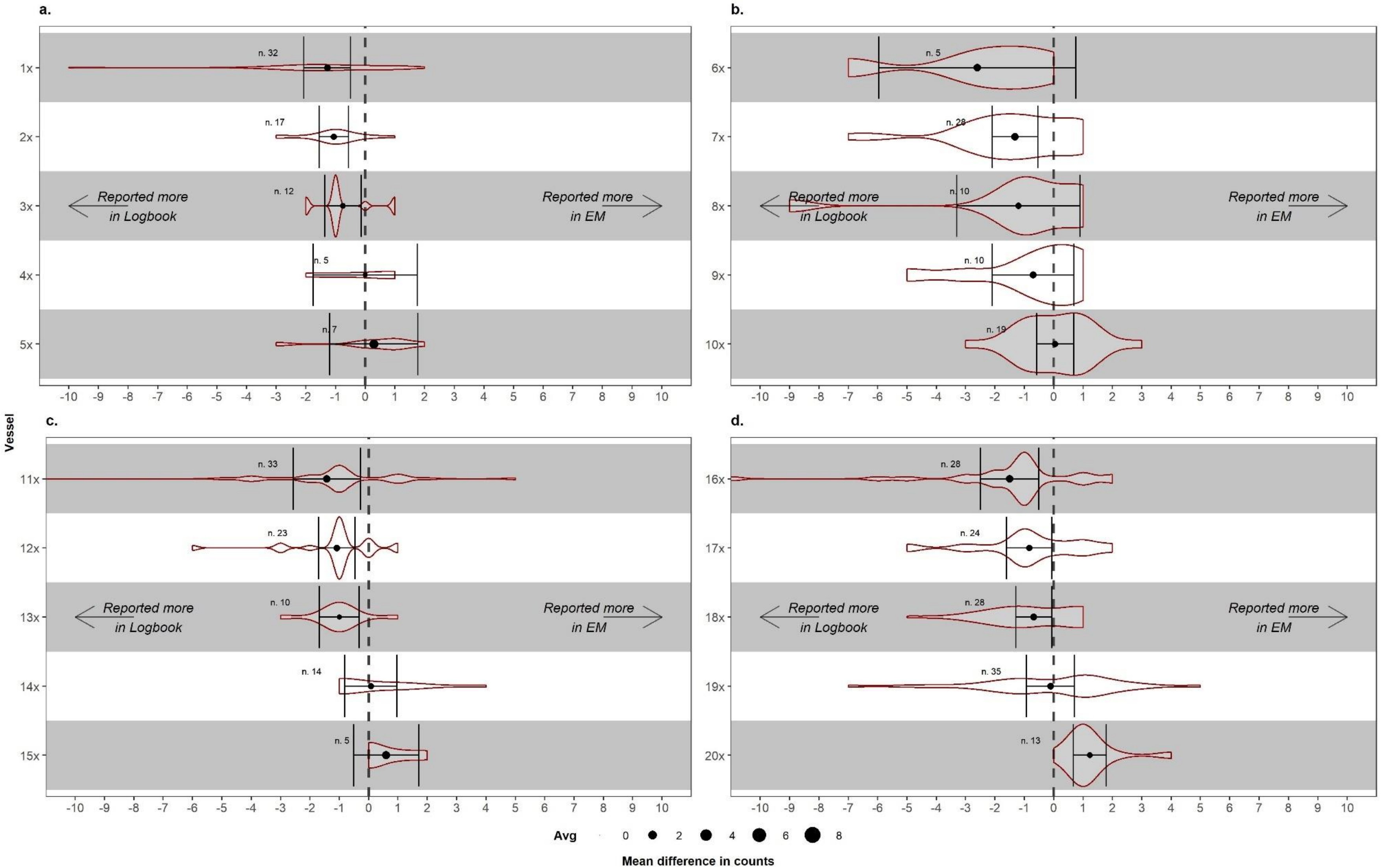


Figure 77: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing discarded bigeye tuna across the time period. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



3.2.7 Blue shark

Across the time period examined, 7% of shots audited that contained discarded blue shark had no difference in logbook and EM counts, 10% had higher counts reported by EM and 83% had higher counts reported by logbook. There is a clear left-hand skew in the distribution of differences in counts, with the logbook reporting significantly higher numbers of discarded blue shark compared to EM (Figure 78 and Figure 79). There was no evidence of improvement in congruence through time (Figure 80). Blue shark was reported discarded more by logbook (-3.2 ± 0.4 individuals) across the time period examined, with the average number recorded discarded by both EM and logbook in a single shot around 3.6 ± 0.4 individuals, so as a proportion of the average catch this difference was significant at -89% (Table 4) and led to a clear left hand skew in the distribution of differences in counts (Figure 80). So, for every 10 individuals reported by EM, the logbook is reporting 18.9 individuals. Furthermore, there were 54% of shots containing a zero record for either EM or logbook when ≥1 individual was reported discarded by the other data collection tool, suggesting there is numerous shots where individuals are being overlooked, predominately by EM (Figure 81).

There was a total of 38 vessels that had greater than four audited shots with blue shark reported as discarded across the time period examined (Figure 82). Apart from a single vessel (x11 whose average discarded catch in single shot was 22 individuals), the average number of blue shark recorded as discarded for each shot ranged from 1 to 7 individuals for each vessel. An examination of the data at an individual vessel level revealed that for 9 of the 38 vessels, the confidence intervals for the mean difference in counts encompassed zero (Figure 82).

As a proportion of the average catch, the difference in counts across most vessels was greater than -80%, signifying poor congruence across the fleet, with a clear skew towards more individuals being reported in the logbook. This suggests EM may be having some issues either correctly identifying blue shark or observing blue shark being discarded on most vessels. This trend was more extreme on some vessels than others but overall, it was evident that logbook reporting of this species was much higher than EM (Figure 82).

Figure 78: Logbook and EM reported counts from individual shots containing discarded blue shark across time period examined. Red dashed line is the 1:1 line.

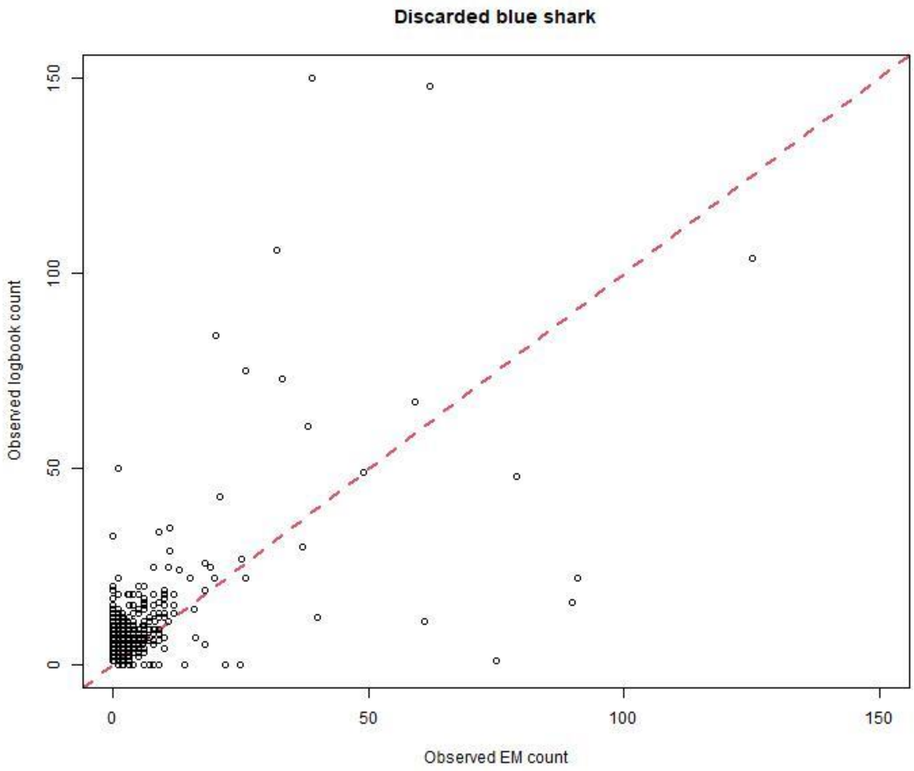


Figure 79: Proportion of shots with specific differences between EM and logbook counts for discarded blue shark across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

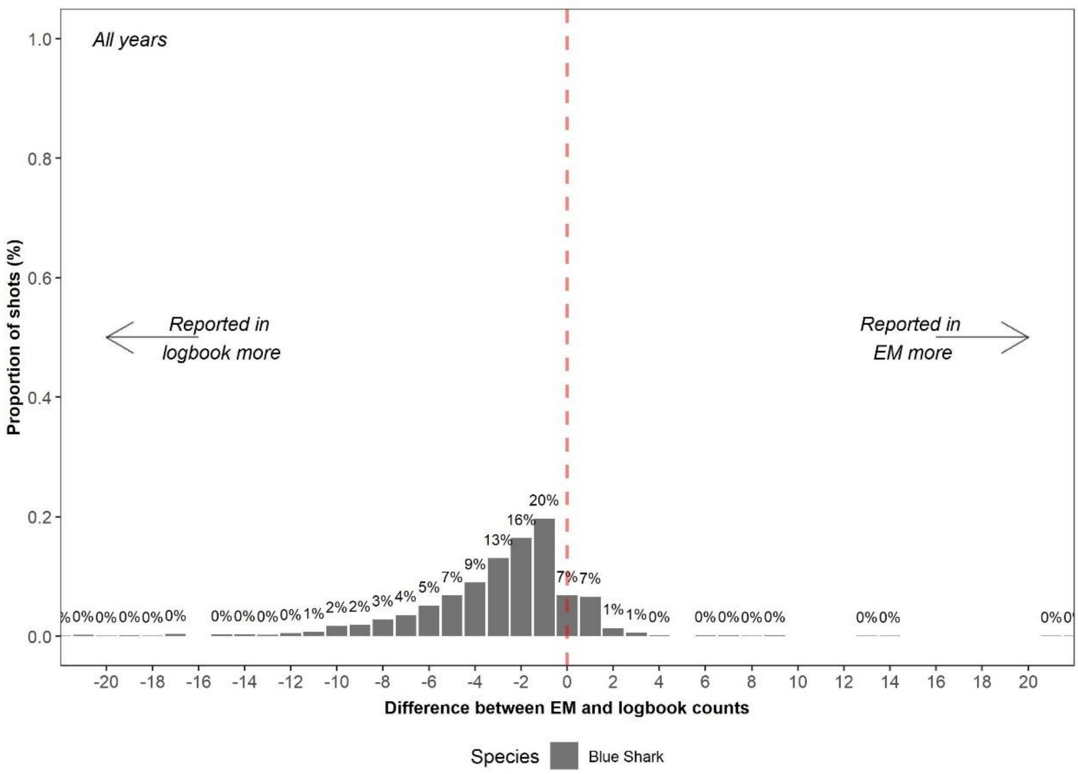


Figure 80: Proportion of shots with specific differences between EM and logbook counts for discarded blue shark for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

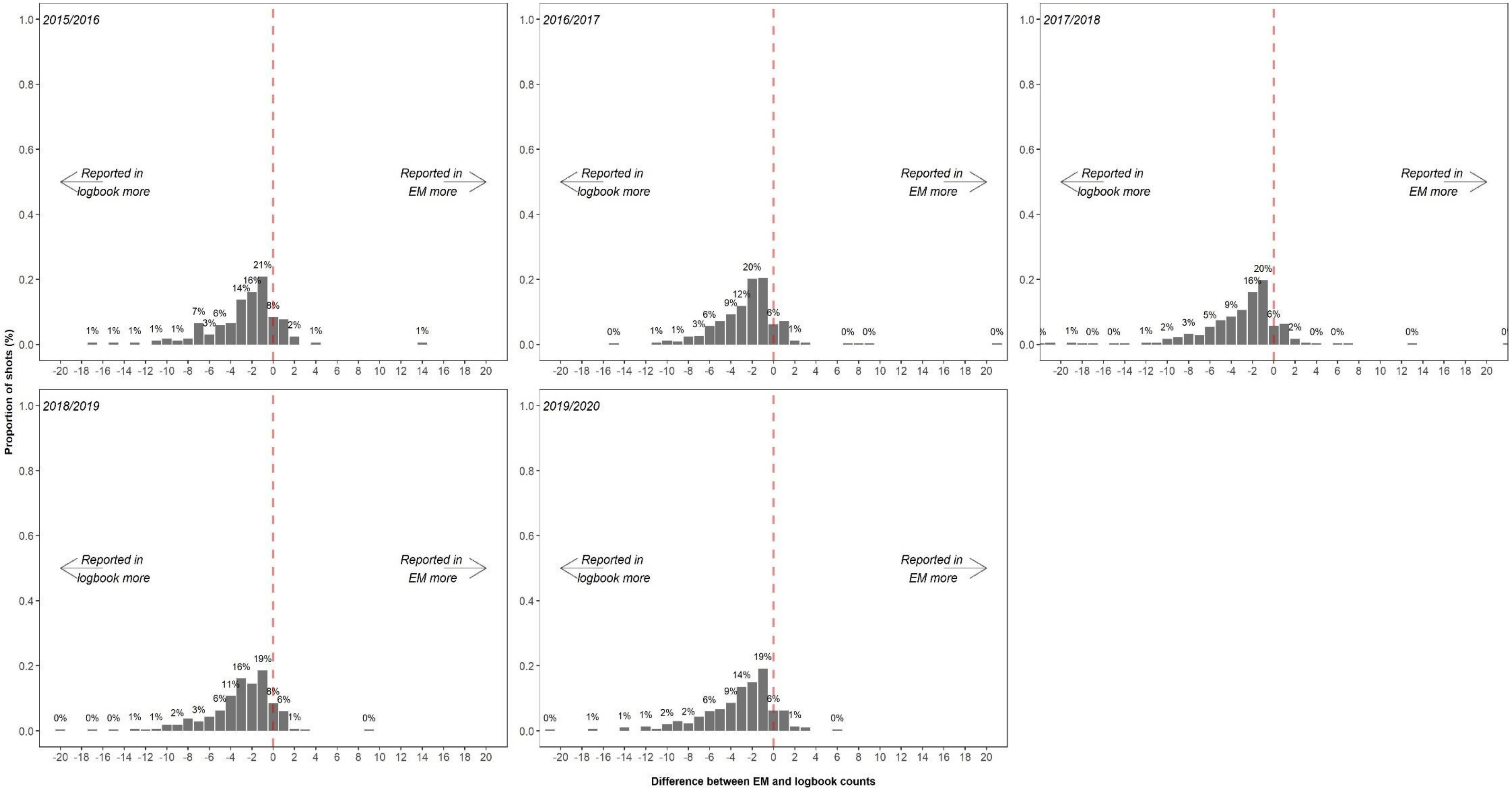


Figure 81: Number of shots with specific differences between EM and logbook counts for discarded blue shark across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

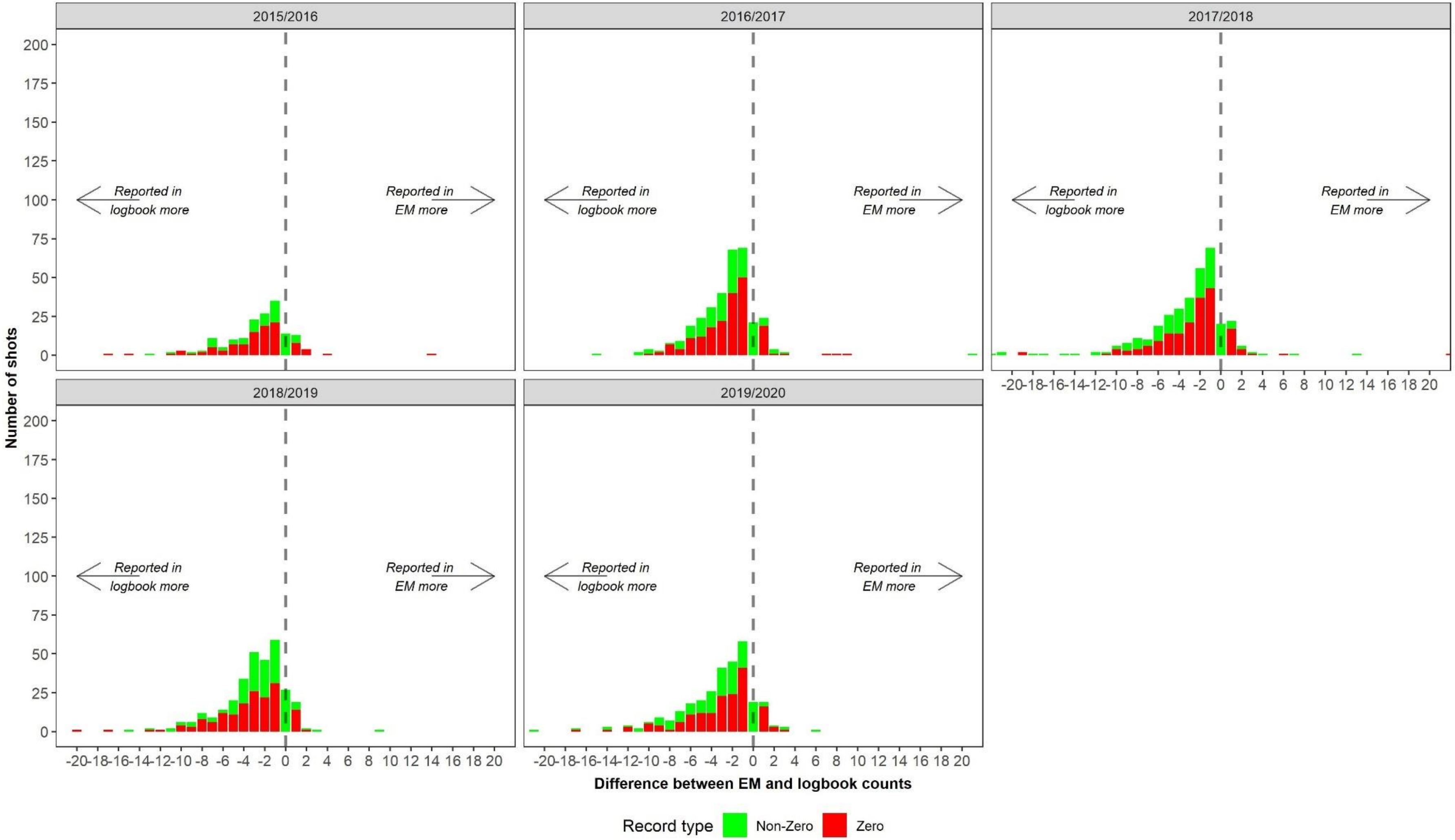
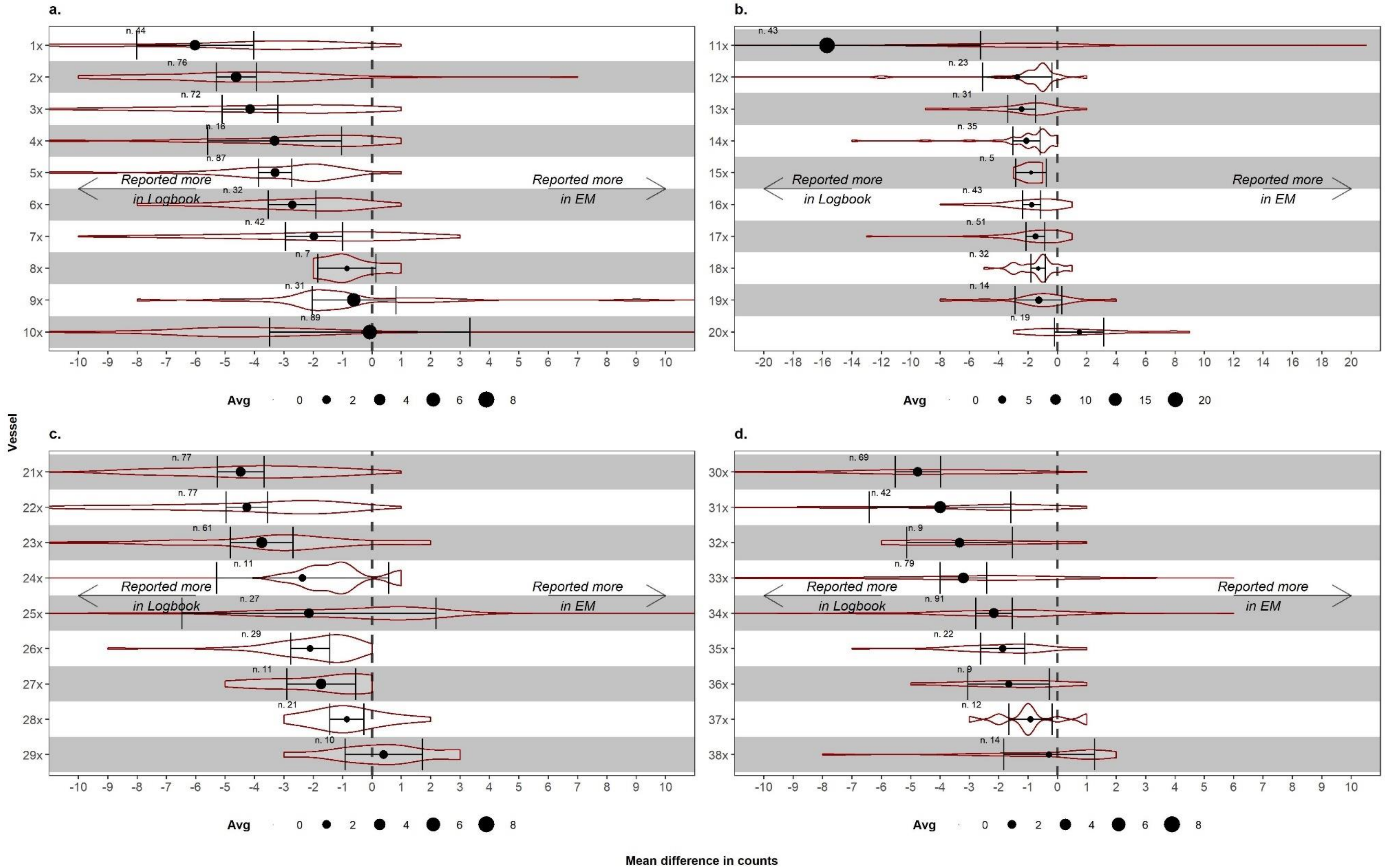


Figure 82: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing discarded blue shark across the time period. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



3.2.8 Lancetfishes – unspecified

Across the time period examined, 6% of shots audited that contained discarded lancetfishes – unspecified had no difference in logbook and EM counts, 37% had higher counts reported by EM and 57% had higher counts reported by logbook. There is a clear left-hand skew in the distribution of differences in counts, with the logbook reporting significantly higher numbers of discarded lancetfishes – unspecified compared to EM (Figure 83 and Figure 84). The spread of the differences in counts was also higher than many other discarded species in the ETBF. There was no evidence of improvement in congruence through time (Figure 85). Lancetfishes – unspecified were reported discarded more by logbook (-2.4 ± 0.4 individuals) across the time period examined, with the average number recorded discarded by both EM and logbook in a single shot around 4.3 ± 0.2 individuals, so as a proportion of the average catch this difference was significant at -56% (Table 4) and led to a clear left hand skew in the distribution of differences in counts (Figure 85). So, for every 10 individuals reported by EM, the logbook is reporting 15.6 individuals. Furthermore, there were 47% of shots containing a zero record for either EM or logbook when ≥1 individual was reported discarded by the other data collection tool, suggesting there is numerous shots where individuals are being overlooked, predominately by EM (Figure 86).

There was a total of 39 vessels that had greater than four audited shots with lancetfishes – unspecified reported as discarded across the time period examined (Figure 87). Apart from one vessel (x11 whose average discarded catch in single shot was 11 individuals), the average number of lancetfishes- unspecified recorded as discarded for each shot ranged from 1 to 8 individuals for each vessel. An examination of the data at an individual vessel level revealed that for 15 of the 39 vessels, the confidence intervals for the mean difference in counts encompassed zero (Figure 87).

As a proportion of the average catch, the difference in counts across most vessels was greater than -50%, signifying poor congruence across the fleet, with a clear skew towards more individuals being reported in the logbook. This suggests EM may be having some issues either correctly identifying lancetfishes – unspecified or observing lancetfishes – unspecified being discarded on most vessels. However, there was variation across individual vessels. For example, x20, x30 and x39 reported no discards across all audited shots, however some were reported by the EM analyst, which may warrant further investigation (Figure 87).

Figure 83: Logbook and EM reported counts from individual shots containing discarded lancetfishes across time period examined. Red dashed line is the 1:1 line.

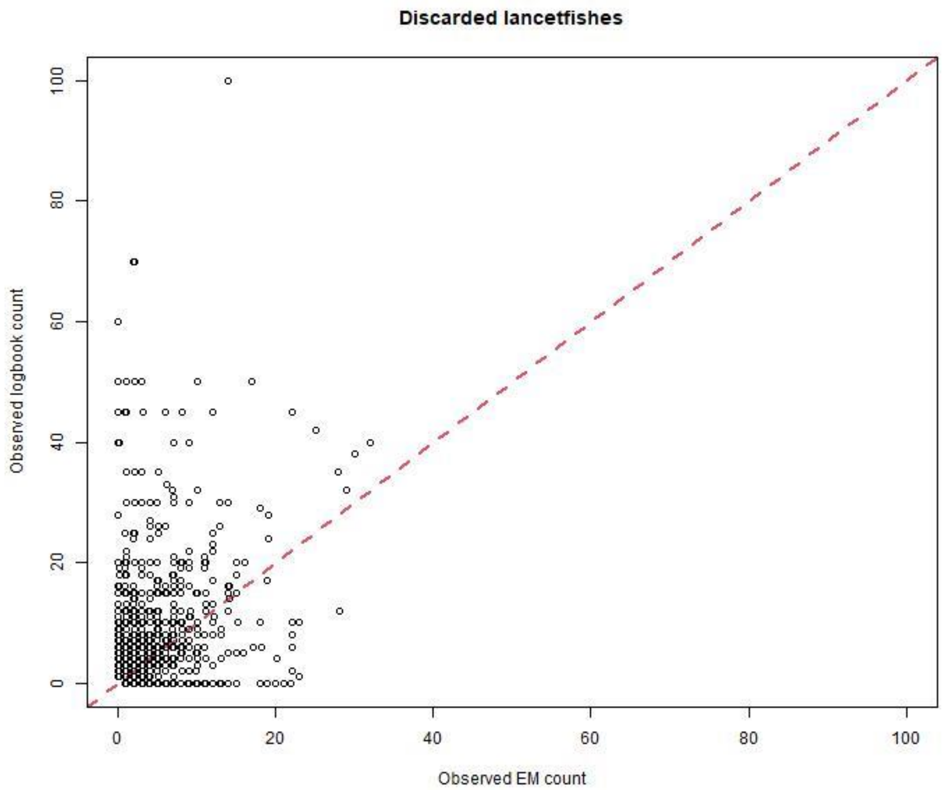


Figure 84: Proportion of shots with specific differences between EM and logbook counts for discarded lancetfishes across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

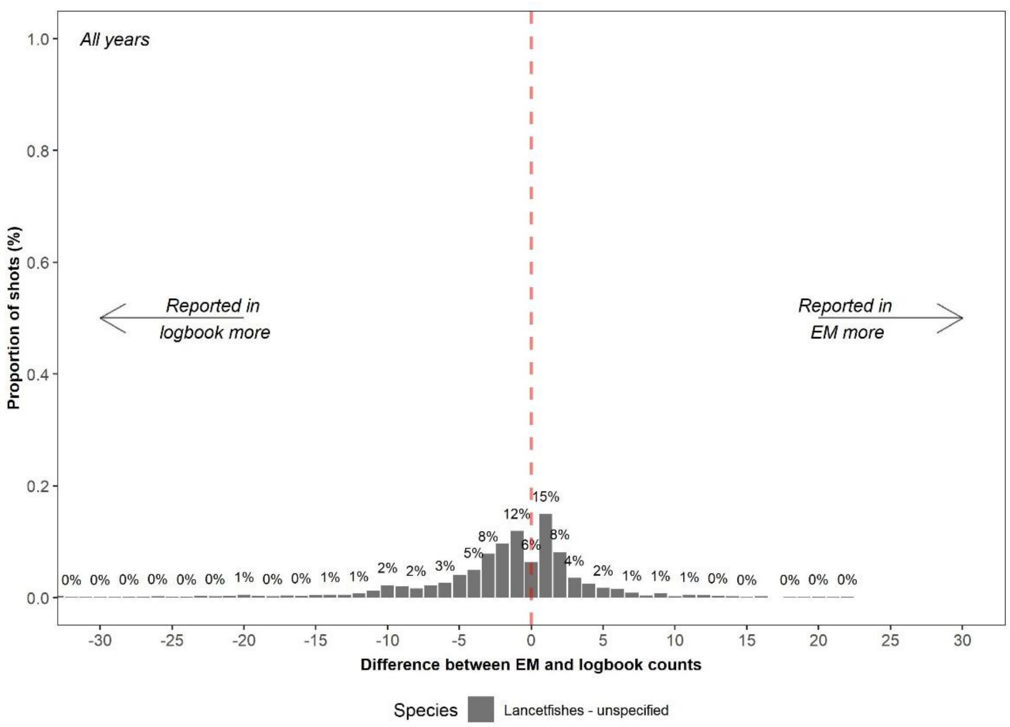


Figure 85: Proportion of shots with specific differences between EM and logbook counts for discarded lancetfishes for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

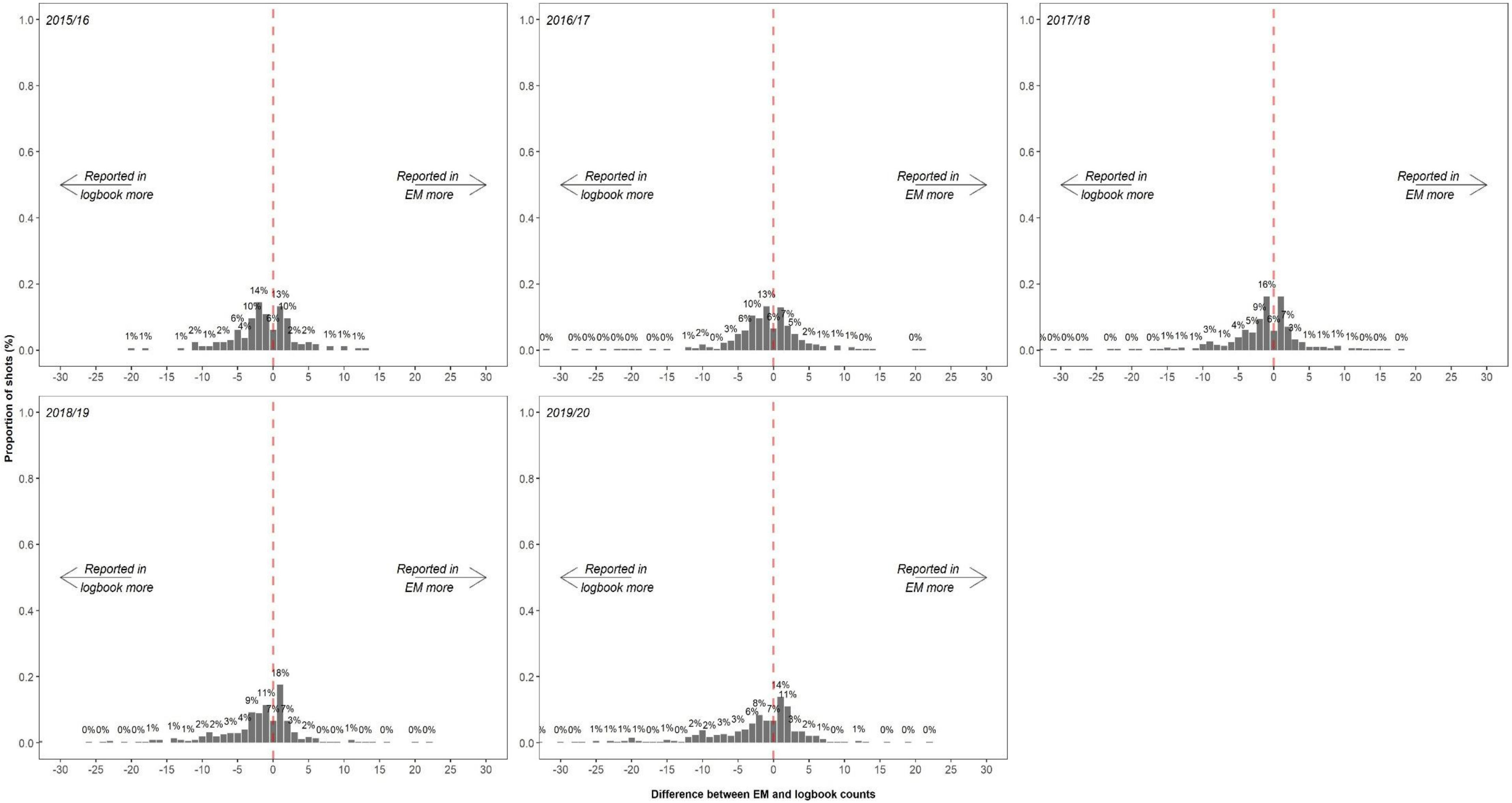


Figure 86: Number of shots with specific differences between EM and logbook counts for discarded lancetfishes across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

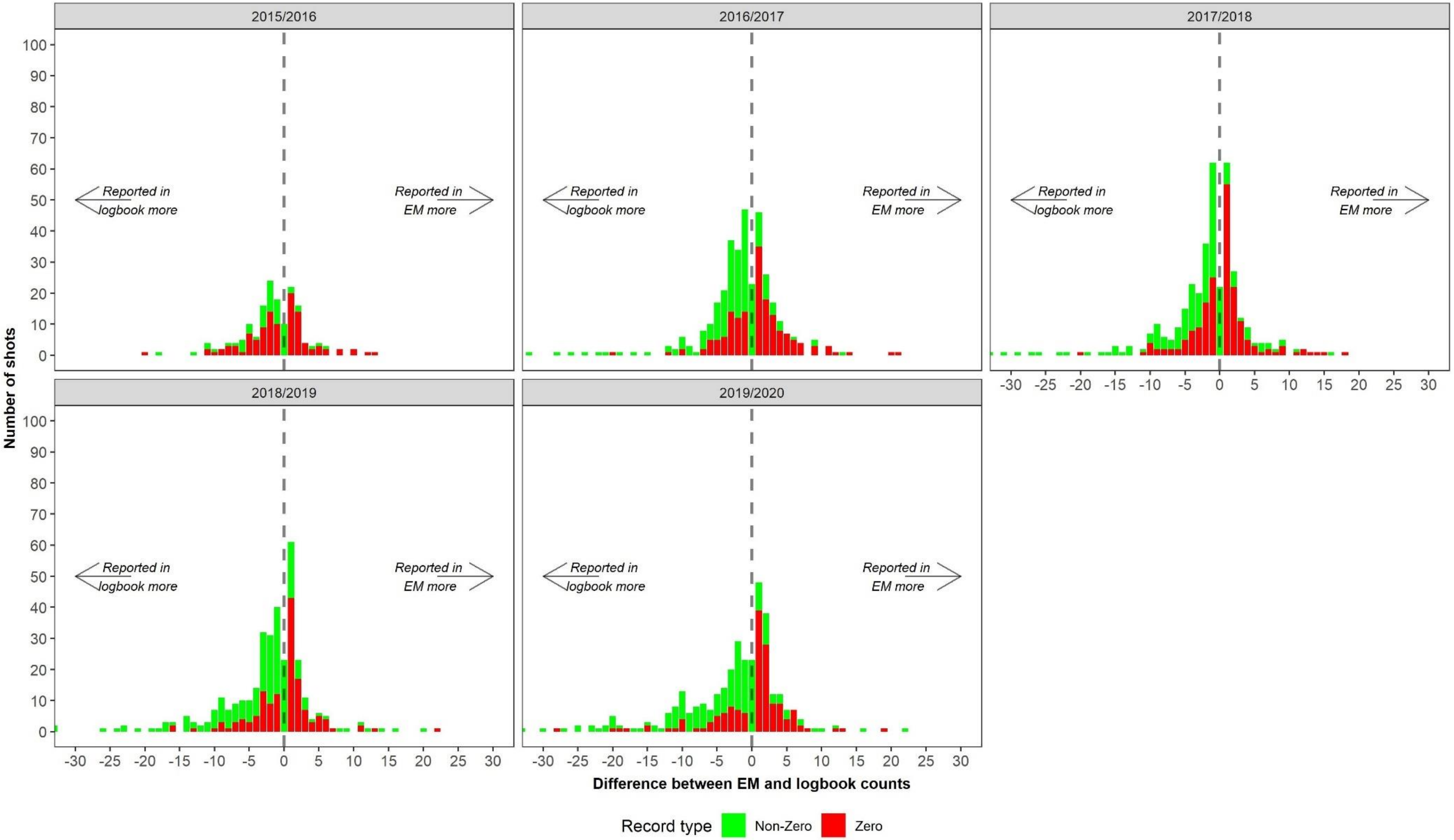
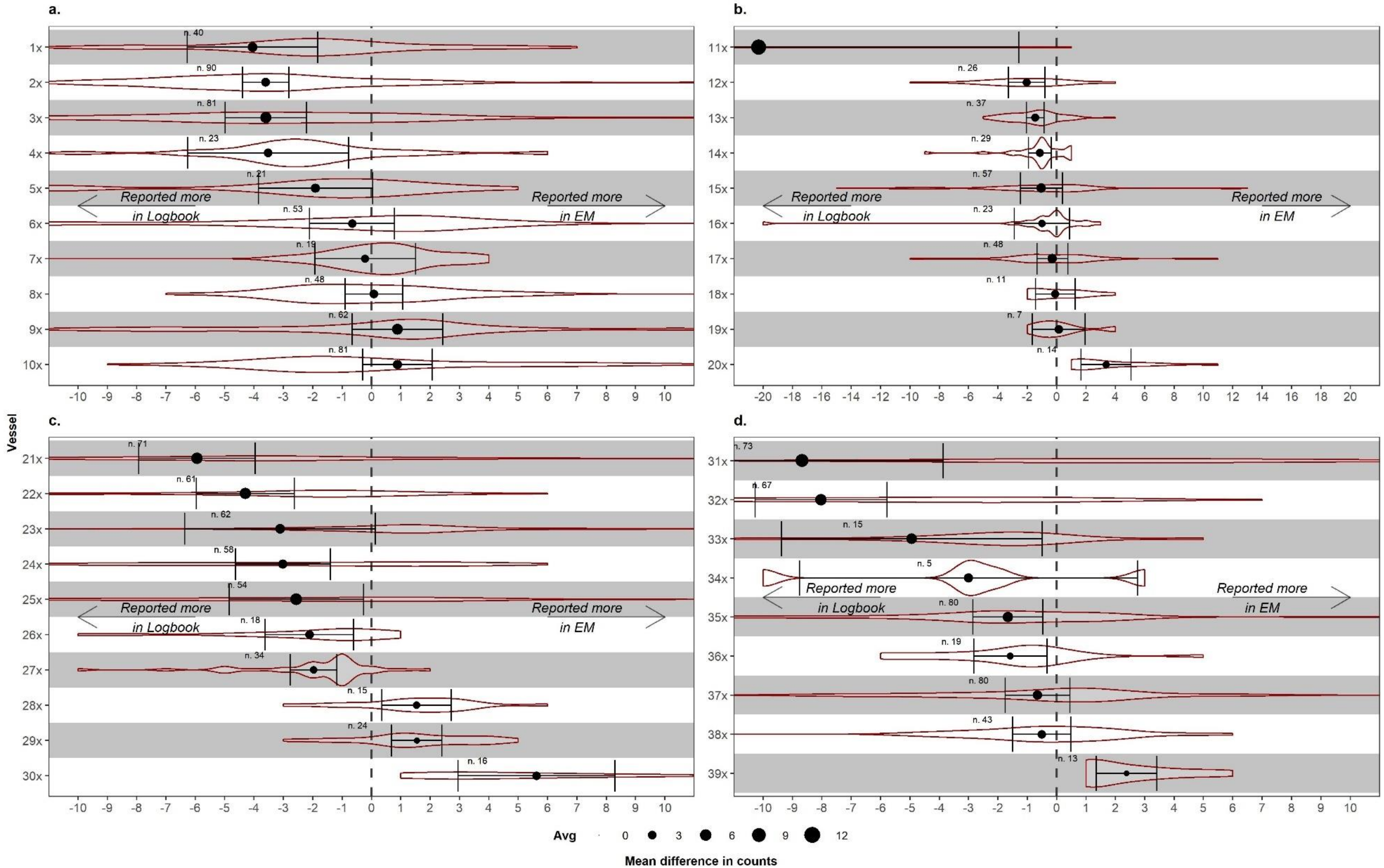


Figure 87: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing discarded lancetfishes across the time period. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



3.3 Threatened, Endangered and Protected (TEP) and no take species

3.3.1 Seabirds, marine mammals, and turtles

There was a total of 140 audited shots that contained a reported interaction with at least one TEP species (within the seabirds, marine mammals and turtles groups) in the time period analysed (2015/2016 to 2019/2020). These were analysed at both a species and TEP group (seabirds, marine mammals, and marine turtles) taxonomic level for analysis. Of the audited reported interactions, 57% were with marine turtles, 30% with seabirds and 13% with marine mammals.

Overall, the reporting at a TEP group level was somewhat congruent, but there were still differences in counts observed (i.e., ±1-2 individuals) between EM and logbook. A total of 45%, 59% and 55% of all shots had no difference in counts for seabirds, marine mammals, and marine turtles respectively and there was no clear skew towards EM or logbook reporting more individuals than the other. A total of 29%, 12% and 19% of all shots had higher numbers (i.e., ±1-2 individuals) being reported by the EM analyst (Table 6, Figure 88, Figure 90). There were a minority of shots where more than one interaction with either a seabird (5%) or marine mammal (6%) was not reported by one data collection tool.

Reporting at the species level in the ETBF was mixed and it was clear that the EM analyst was having difficulty in identifying all interactions to a species level (Figure 89). For marine turtles, while it seemed the EM analyst could identify leatherback turtles, there were more issues identifying hard-shelled marine turtles to a species level, resulting in them being classified as marine turtles (mixed). A similar result was also observed for whales, where the EM analyst was more likely to label these interactions as whales (mixed) (Figure 89).

Reporting at the vessel level across TEP group, identified inter-vessel variation in reporting (Figure 91). Seven vessels had fully congruent TEP reporting (*x3, x5, x10, x12, x13, x21 and x31*). Conversely, there were some vessels where EM was reporting more individuals than the logbook (*x1, x8, x9, x15, x19, x24, x26, x29*). For seabirds, marine mammals, and marine turtles there was a total of 11, 2 and 11 vessels respectively (out of total 31 with audited shots) that had higher numbers of interactions being reported by EM compared to logbook.

Table 6: Total number of interactions with TEP groups recorded by EM and logbook in the ETBF by financial year.

TEP group	FY	EM total no.	Logbook total no.	No. audited shots with interaction
Seabirds	2015/16	2	2	3
	2016/17	1	3	3
	2017/18	8	15	11
	2018/19	16	11	12
	2019/20	13	9	7
	Total	**40**	**40**	**36**
Marine mammals	2015/16	0	2	2
	2016/17	2	4	3
	2017/18	4	5	5
	2018/19	5	5	5
	2019/20	2	1	2
	Total	**13**	**17**	**17**
Marine turtles	2015/16	3	5	6
	2016/17	12	19	21
	2017/18	21	24	25
	2018/19	21	16	26
	2019/20	12	12	13
	Total	**69**	**76**	**91**

Figure 88: Frequency histograms of the difference in counts between EM and logbook for individual shots across TEP groups in the ETBF across the time period analysed (where positive numbers = higher EM counts and negative numbers = higher logbook counts).

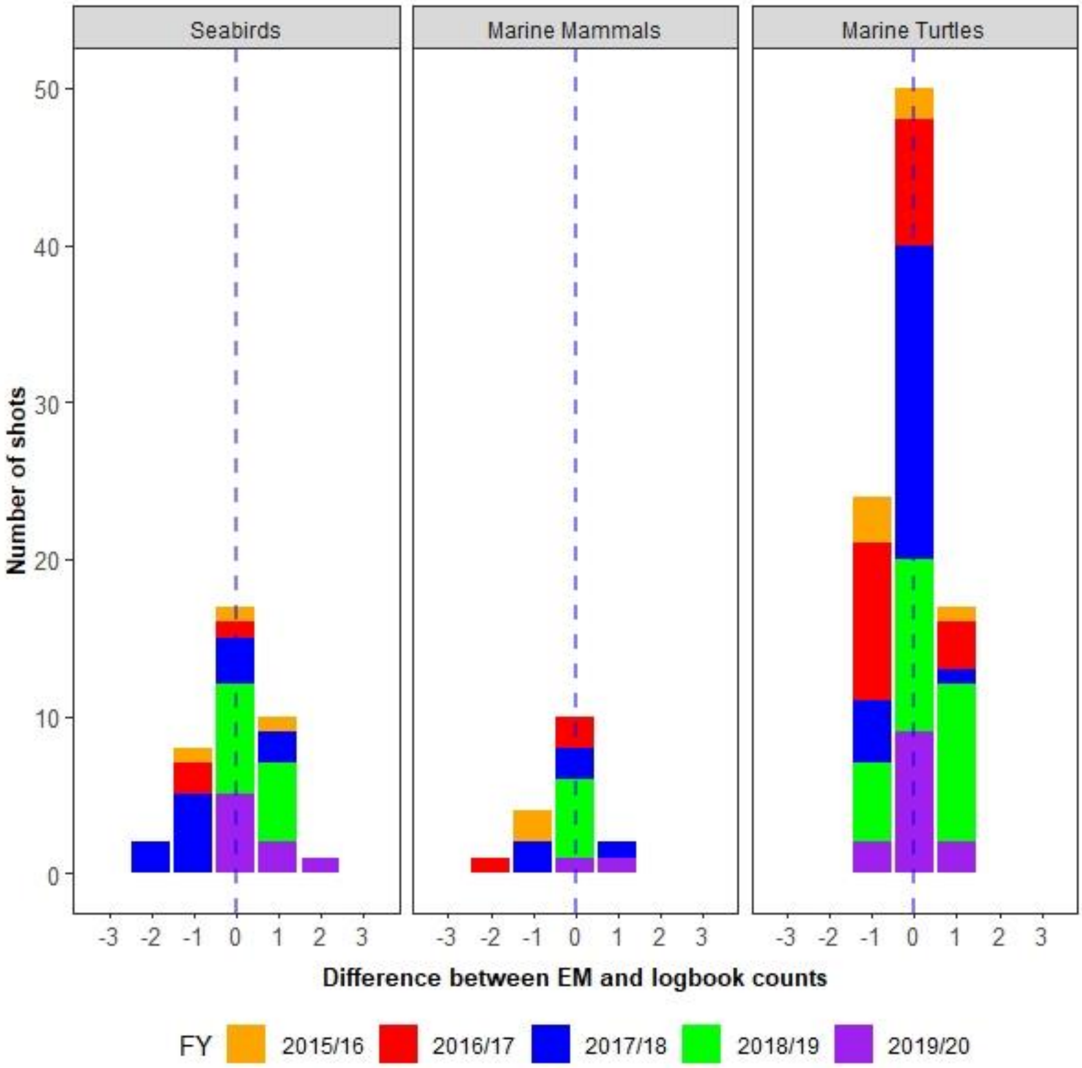


Figure 89: Frequency histograms of the difference in counts between EM and logbook for individual shots across TEP groups in the ETBF across the time period analysed (where positive numbers = higher EM counts and negative numbers = higher logbook counts).

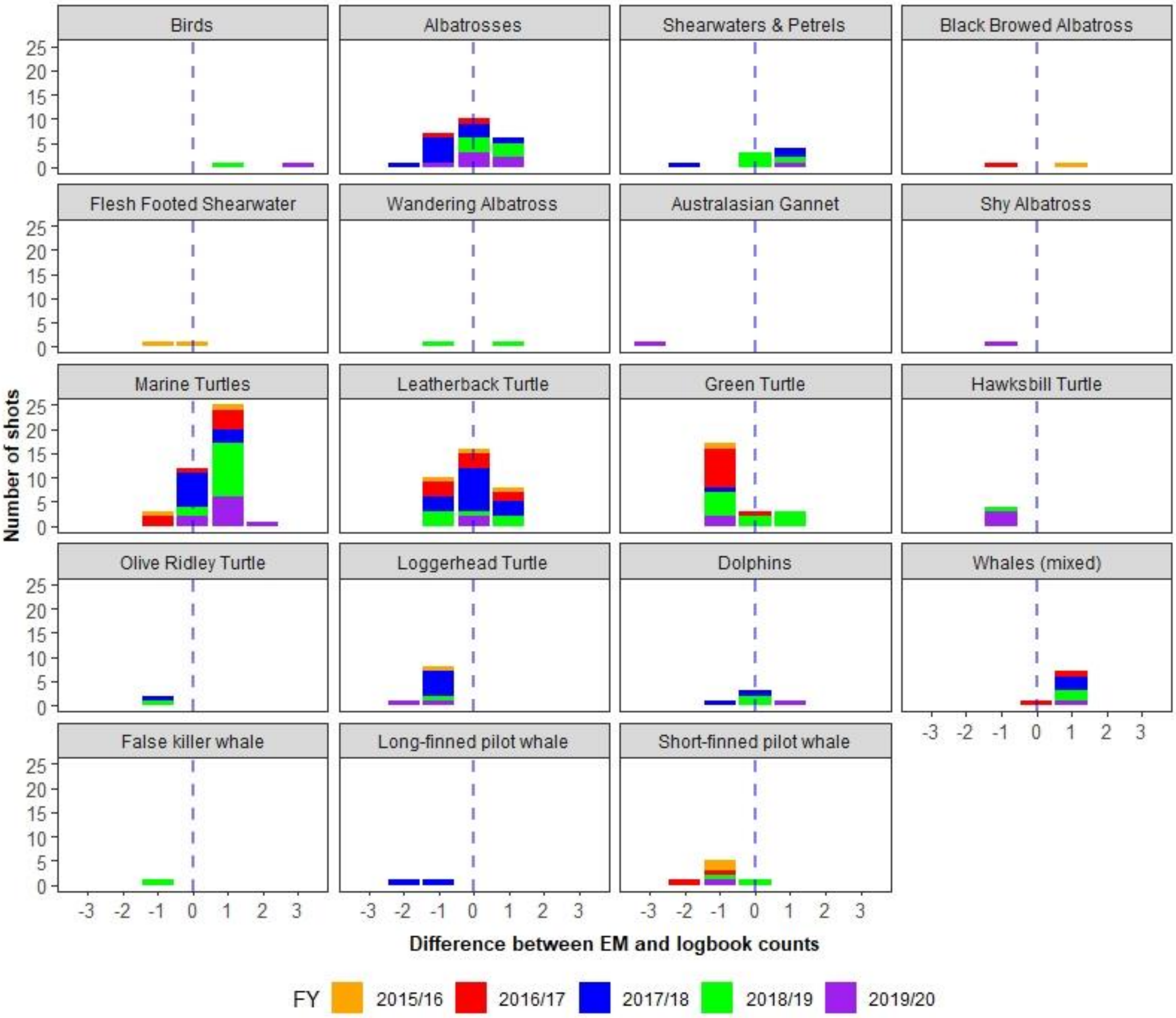


Figure 90: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts by financial year of all shots containing TEP interactions. Grey dashed line equates to zero difference.

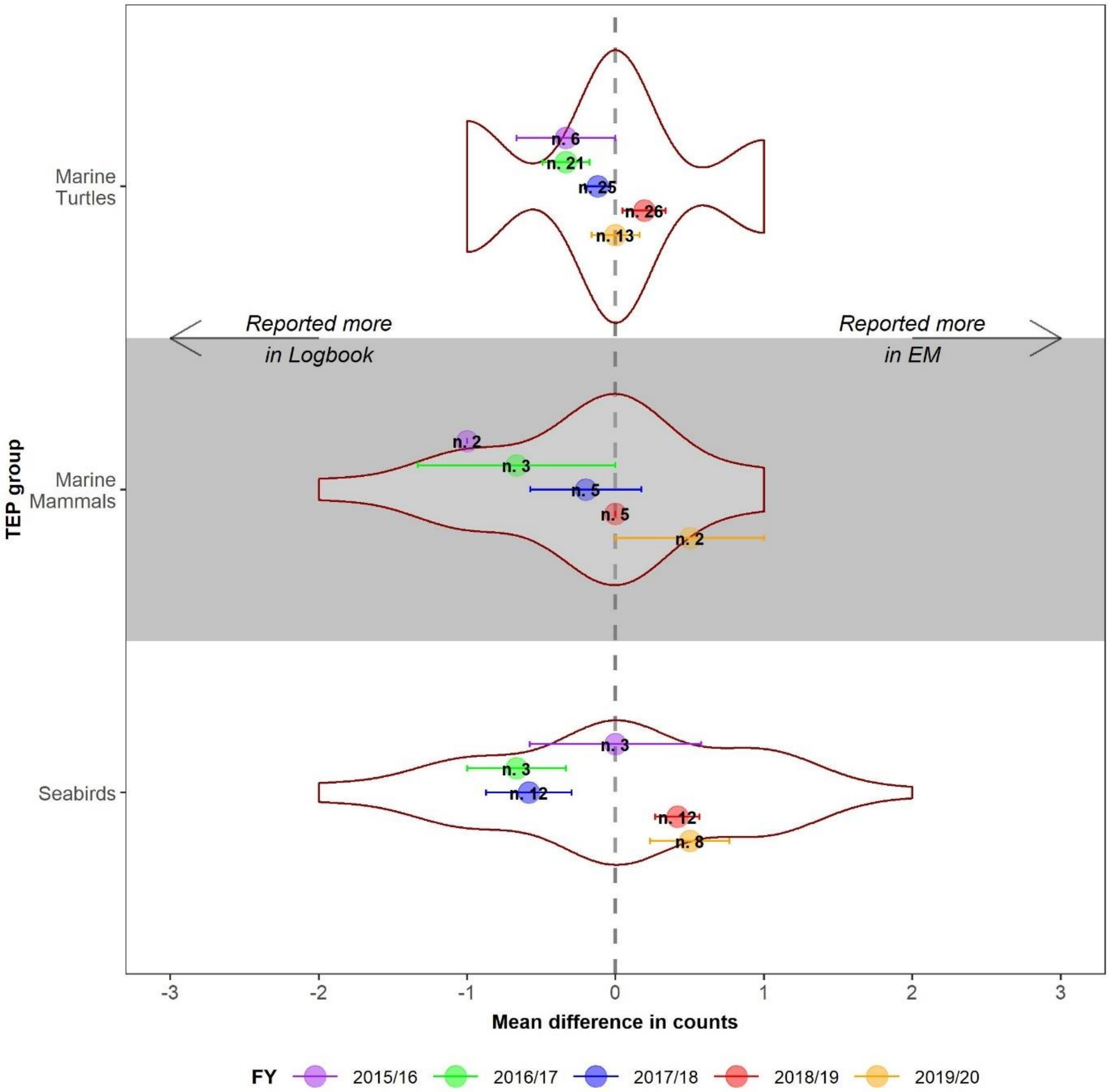
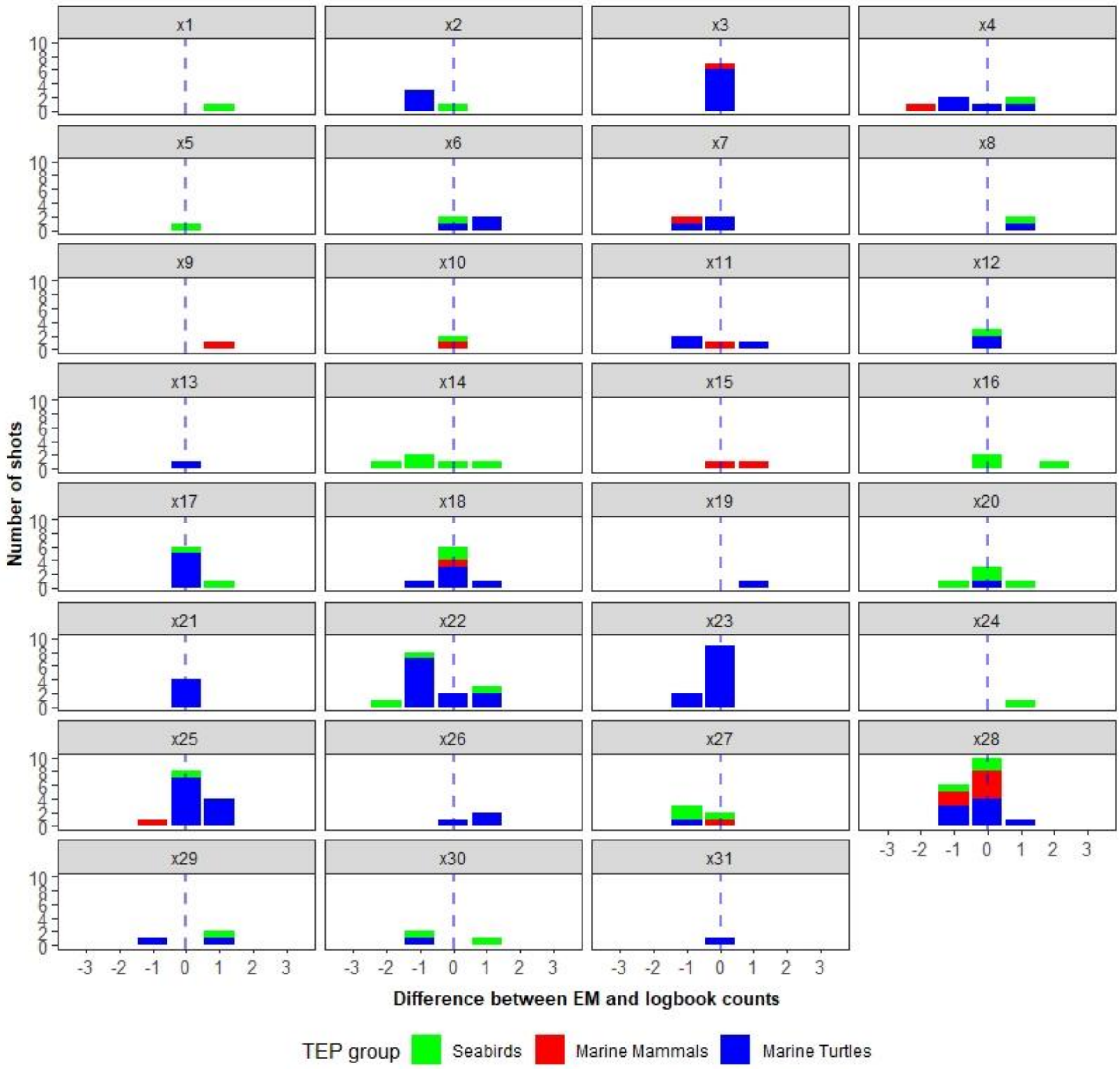


Figure 91: Frequency histograms of the difference in counts between EM and logbook for individual shots across TEP groups in the ETBF across the time period analysed by individual vessel (where positive numbers = higher EM counts and negative numbers = higher logbook counts).



3.3.2 Sharks and blue and black marlin

Protected and no-take species of sharks (shortfin and longfin mako, porbeagle and silky shark) and marlins (blue and black marlin) were analysed separately to marine mammal, seabird and turtle species due to the recording of these species sometimes in either the catch composition or wildlife and protected species databases, requiring them to be collated for analysis.

Most interactions were with shortfin mako, blue marlin and black marlin (Table 7). It was evident that the EM analyst was not able to identify these sharks and marlins to a species level, with significantly higher numbers reported by fishers in their logbook across all years (Figure 92 and Figure 93). This is likely due to shark and blue and black marlin species being cut off (released) while still in the water where EM has a less clear view of catch items.

Table 7: Total number of interactions with TEP groups recorded by EM and logbook in the ETBF by financial year.

Species	FY	EM total no.	Logbook total no.
Shortfin mako	2015/16	58	1,961
	2016/17	128	2,137
	2017/18	180	2,364
	2018/19	162	1,914
	2019/20	98	1,568
	Total	**626**	**9,944**
Longfin mako	2015/16	3	7
	2016/17	0	15
	2017/18	1	14
	2018/19	1	6
	2019/20	1	4
	Total	**6**	**46**
Silky shark	2015/16	0	472
	2016/17	0	177
	2017/18	0	277
	2018/19	0	104
	2019/20	0	221
	Total	**0**	**1,251**
Porbeagle shark	2015/16	0	8
	2016/17	30	34
	2017/18	4	131
	2018/19	0	1
	2019/20	0	1
	Total	**34**	**175**
Black marlin	2015/16	10	1,525
	2016/17	8	780
	2017/18	29	1,709
	2018/19	11	1,031
	2019/20	34	1,367

	Total	**92**	**6,412**
Blue marlin	2015/16	18	1,984
	2016/17	16	1,043
	2017/18	14	1,388
	2018/19	8	900
	2019/20	4	798
	Total	**60**	**6,113**

-

Figure 92: Frequency histograms of the difference in counts between EM and logbook for individual shots across black and blue marlin and shortfin mako in the ETBF across the time period analysed (where positive numbers = higher EM counts and negative numbers = higher logbook counts).

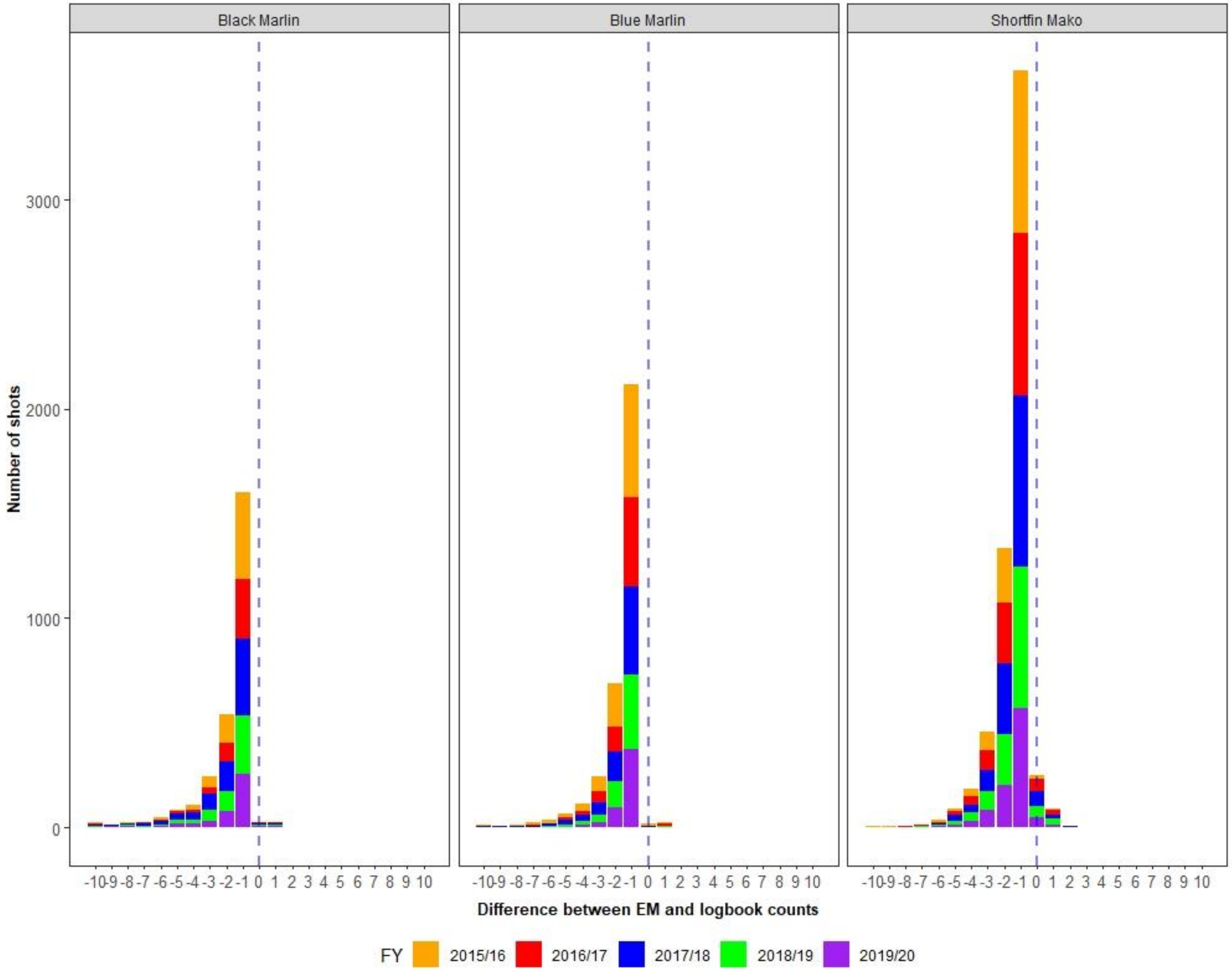
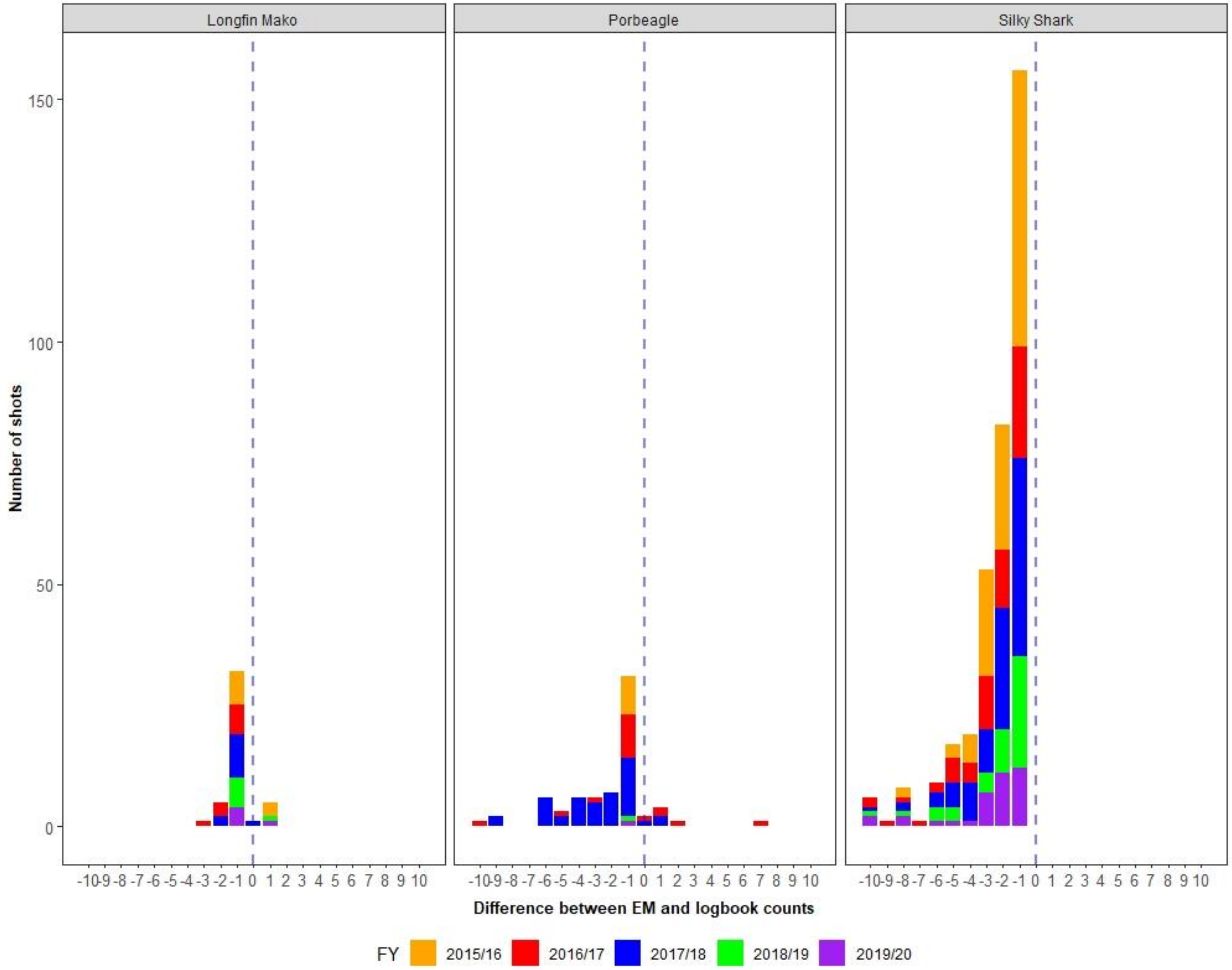


Figure 93: Frequency histograms of the difference in counts between EM and logbook for individual shots across porbeagle, silky shark and longfin mako in the ETBF across the time period analysed (where positive numbers = higher EM counts and negative numbers = higher logbook counts).



4 Discussion and recommendations

Introduction

One of the key objectives of the AFMA EM program in the ETBF is to validate fishery logbook information (i.e., catch composition, discards, and interactions with threatened, endangered, and protected (TEP) species) through EM analysts auditing a minimum 10% of shots from each vessel. When coupled with a continual feedback loop with fishers, AFMA aims to increase the accuracy of self-reported logbook data, thereby improving fisheries management decision-making.

To assess whether this objective is being met, there is a need to periodically review the level of congruence between EM analyst and logbook reporting to determine if: (i) the EM analyst can accurately record all retained and discarded catch, as well as interactions with TEP species; (ii) the level of reporting by fishers in their logbook is congruent with the EM analyst and (iii) whether the level of congruence between EM and logbook has improved through time. Consequently, with several years of logbook data collection since the implementation of EM in the ETBF, the purpose of this analysis was to:

- Compare both fishery level and individual vessel level congruence between logbook and EM data through time for key commercial, bycatch and TEP species.
- Identify, where possible, factors contributing to any differences between EM and logbook data.
- Develop recommendations for i) improving both logbook and EM future data collection in the ETBF and ii) the use of current logbook and EM data in scientific analyses and management processes.

At a high level, the analyses presented in this report indicate that the overall level of congruence for the ETBF was:

- superior for key commercial species compared to byproduct/bycatch species,
- higher for retained than discarded catch; and
- higher for TEP groups (i.e., seabirds, marine turtles, and marine mammals) than at a species taxonomic level.

Importantly, fleet-wide estimates across the period analysed, concealed significant inter-annual and inter-vessel variation for some species. This finding highlights the importance of proper feedback and management follow-up with industry, at both a sector and more importantly individual vessel level, to ensure continual improvements in both EM and logbook data collection moving forward.

Consequently, whether ETBF logbook data can be utilised for scientific analysis and management decision making processes, for any given species (or group of species) will depend on the findings from the comparative analysis at both fleet and individual vessel levels and the type of analysis being undertaken and/or management process to be informed. It may also be possible for the EM data to be used:

- directly in the analyses as a replacement for logbook data;
- as a source of information to help correct for logbook biases; or
- to identify and screen out biased or non-representative logbook data.

The following sections discuss the outcomes listed above in greater detail and then provide recommendations for (i) improving both logbook and EM future data collection in the ETBF and (ii) the use of current logbook and EM data in scientific analyses and management processes.

Key findings

In general, retained target tuna and billfish species (albacore, bigeye, yellowfin, southern bluefin tuna, swordfish and striped marlin) had high congruence, while the results for other retained byproduct species, such as skipjack tuna had lower congruence. This is likely a factor of quota management in the ETBF which requires weights of key commercial species to be independently verified upon landing (Larcombe et al. 2016). Similarly, given key commercial species would be regularly processed in the hauling station area, they were more likely to be observed by and familiar to the EM analyst reviewing the footage. This high level of congruence was also detected in the previous analysis (Emery et al. 2019a) for retained tuna and billfish species. Like the previous study (Emery et al. 2019a), there continues to be taxonomic issues in the reporting of retained escolar and rudderfish, with the EM analyst predominately recording them as the escolar and fishers rudderfish.

Congruence between reporting methods within a species was lower for discarded than retained species, with higher mean difference in counts as a proportion of the average catch. Furthermore, the proportion of zeros reported by either logbook or EM when ≥1 individual was reported by the other data collection tool was also higher. In general, discarded individuals were reported in greater numbers at the species level by logbook than EM across the time period, suggesting that EM having some issues either identifying to the species level, or observing individuals being discarded. To investigate this further, the discarded tuna, shark and oilfish species were grouped at a higher taxonomic level for analysis. When examining both tuna (grouped) and oilfishes (grouped) at a higher taxonomic level, overall congruence improved and in general, were reported in greater numbers by EM than logbook. This suggests that while the EM analyst was having difficulties in identifying discarded tuna to a species taxonomic level, they were still observing individuals being discarded. Furthermore, escolar and rudderfish are potentially identified to species level differently on logbooks and EM. When examining sharks (grouped) it was evident that the EM analyst was still having issues in observing all discarding events, with greater numbers still reported by logbook than EM.

In practice, many of the discarded species are released without being brought on board the boat, often to maximise the survivability of the animal being released. This means that it is often impossible for the EM analyst to observe the distinguishing features of the animal being release to the species level. These identification issues can often arise due to poor image quality caused by external factors such as weather, waves and lighting, or the quality of the camera systems (Evans and Molony, 2011; Mangi et al., 2015; van Helmond et al. 2015; Wallace et al., 2013). A similar issue was observed by Briand et al. (2017) in French tropical tuna purse-seine fisheries where recording individuals to a species level was difficult when cameras were not near discard operations, or discard operations occurred outside the full view of the camera. Furthermore, when tuna or other species are damaged (through depredation), and key distinguishing features are not observed from the available imagery, EM analysts will group these damaged catch items up to the next taxonomic group and in most cases likely damaged tuna, for instance, would be recorded as tuna (mixed) during EM review (Piasente, M., pers comm. 2022). There was also significant inter-vessel and inter-annual variability for all discarded tuna and billfish species, with some vessels not reporting any individuals in their logbook, despite individuals being reported by EM.

Importantly, there was evidence of persistent non-reporting of discarded catch by a small number of individual vessels in their logbooks, despite the EM analyst reporting discarded individuals. This is likely a result of incomplete logbook reporting and may warrant further investigation.

All commercial fishers operating in AFMA fisheries accredited under the *Environment Protection and Biodiversity Conservation (EPBC) Act* are required to report in their commercial logbooks all interactions with TEP species during fishing operations. Accurate reporting is imperative to understand the magnitude of interactions with TEP species to ensure fishing is not likely to adversely affect the conservation status of a TEP species or a population of that species. Overall, the reporting at a TEP group level (i.e., seabirds, marine turtles, marine mammals) was somewhat congruent, but there were still differences in counts observed (i.e., ±1-2 individuals) between EM and logbook.

A total of 45%, 59% and 55% of all shots had no difference in counts for seabirds, marine mammals, and marine turtles respectively and there was no clear skew towards EM or logbook reporting more individuals than the other. Conversely, reporting at the species level for TEPs was mixed and it was evident that the EM analyst was having difficulty in identifying all interactions. For example, while it seemed that the EM analyst could identify leatherback turtles, there were more issues identifying other marine turtles to a species level, resulting in them being classified as marine turtles (mixed). This could be a result of most turtles being released without being bought on board the boat as per turtle release guidelines. This was also apparent for specific shark species (shortfin, longfin mako, silky and porbeagle shark), as well as blue marlin and black marlin, where the EM analyst was not able to identify these to a species level, with significantly higher numbers being reported at the species level by fishers in their logbook across the time period. This was likely due to the 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 either detection or identification by the EM analyst. Unobserved discards of shark species were also observed during the integrated EM system pilot study in the ETBF and the Alaskan Pacific halibut longline fishery (Ames et al., 2005, 2007; Larcombe et al., 2016). Ruiz et al. (2015) also noted that EM analyst estimates for shark species in a tropical purse seine fishery were significantly lower than at sea observer estimates, while Bartholomew et al. (2018) found that EM analysts only captured turtle interactions 50% of the time in Peruvian small-scale gillnet fisheries.

Importantly, there was inter-vessel variation in reporting for TEP species, with some vessels having perfect congruence (i.e., no difference in counts) and others where EM was reporting more individuals than the logbook. For seabirds, marine mammals and marine turtles there was a total of 11, 2 and 11 vessels respectively (out of total 31 with audited shots) that had higher numbers of interactions being reported by EM compared to logbook. It is unclear why these interactions were not being reported by these vessels. In a Danish integrated EM system trial, porpoise bycatch was reported in higher numbers by the EM analyst than in logbooks, as they dropped out of the net before being observed by the fishers, but cameras were placed appropriately to capture these interactions (Kindt-Larsen et al. 2012). While it is possible these differences may be caused by missed observations, they could also be a result of incomplete or inaccurate logbook reporting, which has previously been shown to be an issue for TEP species (e.g., Goldsworthy et al., 2010; Brown et al., 2021; Basran et al., 2021). There was also evidence for occasional instances where fishers reported TEP interactions that were missed by EM. This can occur for a range of reasons, including vessels not maintaining and cleaning cameras, gaps in data for key camera views due to system functionality issues as well as short term weather conditions that prevented clear EM views. As operational issues are identified for the program, AFMA has the capacity to investigate how image quality and camera placements, or configurations may have contributed to logbook reported TEP interactions not being identified during EM review. Given the importance of effective and reliable monitoring of interactions with TEP species to ensure sustainable fisheries, continual education of fishers by AFMA regarding species identification and accurate logbook reporting remains critical, as does ensuring vessel camera placements/views continue to be optimised/improved.

Overall, the findings of this work highlight the importance of considering results at both the individual year and vessel level, rather than simply across the entire fleet and time period. While EM and logbook reporting of some retained species appeared to be relatively similar when comparing mean differences across the entire time period, in many instances, examination of frequency distributions and “violin-plots” of differences highlighted that congruence differed significantly between years and between individual vessels, with some vessels having higher logbook counts and others having higher EM counts. This result is not surprising when studies have highlighted the heterogeneity among fishers in respect to identification skill and diligence in logbook reporting (Macbeth et al., 2018). There is also likely disparity in the experience, skill and local knowledge of EM analysts reviewing footage (Piasente et al., 2012). Given that various studies have confirmed that some fishers are poor at identifying species and underreport both retained and discarded catch in their logbook relative to observers and EM (Brown et al. 2021; Macbeth et al., 2018; Mangi et al., 2016) there is a clear need for AFMA to continually educate fishers on the importance of accurate reporting of catch composition and fishing activities in their logbook, with particular emphasis on those boats identified as not reporting any of a particular taxa they are known to discard.

Recommendations

The aim of this study was to provide AFMA with an understanding of the level of logbook reporting accuracy in the ETBF fishery in recent years, by assessing the level of congruence (i.e., similarity) between EM analyst data and fisher logbook data, at the species, sector, and vessel level. The outcomes of this study can be divided into three key areas:

- Species for which there appears to be high congruence between logbook and EM data;
- Species for which there appears to be lower congruence (between logbook and EM data) that may be due primarily to missed observations, misidentification, or misreporting by fishers in their logbook; and
- Species for which there appears to be lower congruence (between logbook and EM data) that may be due primarily to limitations with current EM systems (generally or among specific vessels) in facilitating accurate species identification or recording all relevant catch and discard events.

The following recommendations aim to assist AFMA to identify and prioritise actions to further improve the AFMA EM Program, which will help improve the benefits of the EM and logbook data collection programs for science and management decisions. These are also summarised at an individual species level for each sector in Table 8 below.

General recommendations

- **Review feedback processes and EM capacity and resourcing** – Several potential issues driving a lack of congruence between logbooks and EM data in the ETBF fishery (such as species identification issues for escolar/rudderfish and sharks) were also identified in the previous report by Emery et al., (2019a). The persistence of some of these issues in the fishery suggests that AFMA might need to review its management and/or compliance processes to ensure there are sufficient resources and capacity to implement the required education, reporting feedback and compliance processes that will improve congruence in the future. Continued cases of low congruence will undermine the value and use of logbook (and EM) data for fishery science and management processes.
- **Confirm key drivers for a lack of congruence through outreach** – a lack of congruence between EM and logbook data for a specific species may occur due to a range of factors. This report has attempted to identify the most likely drivers, but in some cases, these cannot be confirmed without further information or investigation. For those cases, it is recommended that AFMA investigate (through discussion with EM providers, industry, and scientists where necessary) and seek further information to confirm these factors, which will then inform the subsequent management actions needed to improve congruency in the future. Depending on the key drivers confirmed in each case, the specific recommendations below then apply.
- **Utilise a vessel-specific approach to management -** In some cases, the investigations (and subsequent management actions) mentioned above will need to occur at the individual vessel level. This is because there are many instances where only specific vessels have higher, or lower, logbook reported catch/discards levels (relative to EM reported levels), while the rest of the fleet display high congruence. Furthermore, examination of the reporting practices and specific configuration of EM systems found on vessels with high congruence, might in some cases inform advice and solutions for vessels with low congruence.

Noting the above general recommendations, the following recommendations focus on improving congruence where specific drivers/causes of non-congruence have been identified and confirmed.

Improving EM data

This study identified several instances where EM reporting of species catches, or discards was on average, lower than the logbook reported levels (e.g., discarded tuna and billfish species). Potential causes may include issues with vessel EM systems and the ability of EM analysts to accurately identify species or even observe these events occurring. As such, it is recommended that AFMA:

- **Periodically review and seek to improve individual vessel EM systems where required** – It is recommended that AFMA investigate, with the potential need to improve EM systems on individual vessels for which those systems are identified as hindering or not sufficiently enabling EM analysts a clear view of catch, discard or interaction events. Solutions may include adding/moving/modifying camera positions and angles on those vessels, requiring vessels to remove objects obstructing camera views, or requiring fishers to only discard fish within view of the camera, or while cameras are recording during the haul. Solutions to enable better recording of "cut-off" discards (where fish are cut off the line, while in the water and prior to bringing on board) should continue to be sought, noting this is a key outstanding challenge for improving EM data collection in longline fisheries globally.

- **Improve/maintain the capability of EM analysts to identify species** – It is recommended that AFMA and the EM service provider ensure EM analysts continue to be provided sufficient training, including from qualified experts (e.g. at sea observers, scientists) to accurately identify species, particularly for species for which identification is more difficult and that periodic audits are conducted on EM analyst reports to ensure consistency and maintenance of high quality EM data through time (this is particularly needed for various discarded shark species and blue and black marlin species). Precise taxonomic identification is crucial to assessing fish stocks (Ruiz et al., 2015; Vecchione et al., 2000), whether that be by stock assessment for key commercial species or ecological risk assessment (ERA) methods for byproduct and bycatch species. The capability of EM analysts to accurately identify and determine the fate of species (retained/discarded) could also be improved if the crew adopted practices that increased their visibility to the camera (e.g., placing an individual in close view of the camera prior to discarding).
- **Remove duplicate CAAB codes -** Future analyses such as this would also benefit through the removal by AFMA and the EM service provider of duplicate species fields for the same species (or taxa) (i.e., CAAB codes) in the database. In the previous analysis (Emery et al., 2019a) and in this study, significant processing (cleaning) of the linked data needed to occur to remove and combine duplicate CAAB codes (see Appendix A). Most of these duplicate CAAB codes were being used by EM analysts through time.

Improving logbook data

This study identified several instances where logbook reporting of species catches or discards was on average lower than the EM analyst reported levels (e.g., retained skipjack tuna and discarded tuna (grouped)), due to either missed observations, misidentification, or misreporting. This was particularly evident at the individual vessel rather than fleet-wide level.

- **Improve the capability of fishers to identify and report species** – Where instances of species misidentification and misreporting by fishers reoccur (which can result in either over or under-reporting of a species on logbooks relative to EM) it is recommended that AFMA conduct further outreach activities to inform fishers about their reporting responsibilities and/or educate them in species identification/taxonomy. For example, this study identified this may be occurring for retained skipjack tuna and escolar/rudderfish as well as TEP species (seabirds, marine mammals and marine turtles).
- **Strengthen feedback and education mechanisms** – AFMA currently requires the EM service provider to distribute monthly logbook-EM comparison reports to vessel owners, to inform them of their skipper (and/or crew) logbook reporting relative to the EM analyst. Ideally, vessel owners provide feedback to skippers/crew in situations where improvements to reporting performance are needed. However, the current results indicate that this alone is unlikely to promote improved reporting practices on all vessels in the fleet. It is therefore recommended that AFMA resource and implement direct feedback/education (and where necessary compliance) processes between AFMA managers and vessel skippers (and/or crew) whose logbook reporting needs improvement. The importance of a continual feedback (communication) loop between EM analysts, AFMA and fishers on reporting standards with the aim to improve performance,

cannot be overstated and it is recommended that this comprises a critical component of the AFMA EM program resourcing and prioritisation going forward. As a starting point, AFMA can use the summary information on individual vessel congruence for specific species (in this report) to undertake targeted management actions.

- **Prescribe clear tolerance levels for logbook reporting** – Associated with the previous recommendation, it is recommended that AFMA, in partnership with scientists and industry stakeholders, determine prescribed tolerance levels for logbook reporting of retained, discarded catch and TEP interactions through the development of quantitative evaluation standards, such as those developed for Canadian fisheries (Stanley et al. 2011). This will facilitate greater certainty and acceptance among industry as to AFMA's expectations and improve overall logbook reporting performance.

Considering scientific analyses using logbook data

The report has identified cases at a sector, vessel, and species level for which congruence between logbooks and EM is consistently high and other cases where, to different degrees, it requires improvement. The implications for the use of logbook data by scientists differs between these cases.

- **Use of sector level congruent data -** Where congruence between EM and logbook data (for a given species reported catch and discards) is high at both the fleet and individual vessel level (e.g., retained tuna and billfish species), scientists and managers can have increased confidence that the data is representative of the actual catch/discards in that sector and in using the logbook data directly for analysis/assessment and management purposes.
- **Accounting for under-reporting in logbooks** – For some species, where logbook data at a vessel level identifies either missed observations, misidentification, or misreporting (against EM data), scientists should carefully consider whether to include and how to adjust/account for logbook data from these vessels for scientific assessments/analyses. Often, retained and discarded catch numbers and weights from logbooks are used as the principal source of information in catch standardisations and stock assessments, the results of which underpin management decisions (Walsh et al., 2002; Walsh et al., 2005). Similarly, these data are used as part of residual risk assessments within ERAs conducted in Commonwealth fisheries. For analyses such as CPUE standardisation, logbook data from vessels that consistently under-report a species (discards for example), might need to be excluded on the basis that that logbook data will not be representative of the actual catch and effort trends and relationships of the vessel and fleet through time. For analyses such as total discard estimates, the ratio of EM to logbook discards, at either vessel or fleet levels, might be used to correct the data.
- **Use of EM data directly in scientific analyses –** while EM data may only represent ~10% of the fishing events in the fishery, it may be the case that for some species/vessels where logbook data is considered unreliable, EM data might be used directly to derive estimates of overall catches, catch rates or other parameters of interest to scientists and managers, providing the assumptions being applied in using the data in that way, are appropriately recognised. For some taxa, especially for discarded catch, species level identification may be an issue in such analyses.

Further research

- **Analyses of factors driving differences in EM and logbook reports -** It is evident that congruence sometimes differs between vessels. While further investigation to confirm key causes of this is recommended, it may also be worth further exploring model-based analyses that attempt to assess the influence of multiple potential drivers simultaneously. For example, models that examine the potential influence of factors such as time of day (lighting), sea/weather conditions, skipper, number of crew onboard and other factors could be useful to further explore.
- **Congruence of byproduct and bycatch species of interest -** The focus of this work for the ETBF was on the target tuna and billfish species, however there is scope to further investigate the congruence between EM and logbook reporting of other significant byproduct or bycatch species if required. Furthermore, analysis of the life status at haul of byproduct and bycatch species could also be investigated.
- **At-sea observer and EM analyst comparative analyses -** Using EM data to validate logbook data requires that the EM data itself is accurate, and for fisheries where fish come on board sequentially (i.e., not en masse) and for species where fish are not discarded or cut off prior to hauling on board, confidence in the accuracy of EM data is generally high. However, demonstrating the accuracy of EM data conclusively for *each* species and vessel is difficult with the available information. Globally, a range of other published studies have compared at-sea observer data to EM analyst data to validate the EM data collection method. Those studies have highlighted situations in which EM has limitations that need careful attention and further development. A small trial to compare at-sea observer, EM analyst, and fisher-reported logbook data might be beneficial in the ETBF to help identify any areas where EM systems and data collection require improvement.

Table 8: Summary of recommendations by species for the ETBF

Fate	Species	Mean difference as proportion of average catch	Inter-annual differences	Inter-vessel variability	Species-level recommendations	General recommendations
Retained	Albacore	6%	Variable	Medium	• None	• Continual feedback (communication loop) between EM analysts and fishers on reporting levels. • Prescribe clear tolerance levels for logbook reporting
	Yellowfin tuna	2%	Variable	Negligible	• None	
	Southern bluefin tuna	<1%	Improving	Negligible	• None	
	Swordfish	6%	Stable	Low	• None	
	Bigeye tuna	1%	Improving	Negligible	• None	
	Mahi mahi	2%	Stable	Medium	• None	
Discarded	Albacore	-44%	Variable	High	• Improve/maintain the capability of EM analysts to identify species • Review and seek to improve vessel EM systems where required • At an individual vessel level - outreach activities to inform fishers about their reporting responsibilities and/or educate them in species identification/taxonomy.	
	Yellowfin tuna	-90%	Variable	High		
	Southern bluefin tuna	-37%	Variable	High		
	Swordfish	<1%	Declining	Medium		
	Bigeye tuna	-66%	Variable	Medium		
	Mahi mahi	-10%	Variable	Medium		

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Appendix A: Errors in species codes

Blue = Primary code used in database for analysis

Byproduct Species

CAAB Code	Species Name	Used by	Notes	Preference CAAB Code
37018001 37018902	Bronze Whaler Bronze Whaler Shark	Both EM		37018001
37439008 37439901	Escolar Escolar & Oilfish	Both EM		37439008

Bycatch Species

CAAB Code	Species Name	Used by	Notes	
37382901 37439001	Barracudas Barracouta	EM Both	 Very limited EM use	 37439001
37999999 37990020	Fish (mixed) Fish Oceanic (mixed)	Both EM		37999999
37019000 37019902	Hammerhead Sharks - unspecified Hammerhead Sharks (mixed)	Both EM	 Very limited EM use	37019000
37439015 37439000	Longfin Escolar Longfin Escolars & Gemfishes	EM EM	Very limited EM use	37439000
37272000 37272002	Oarfishes Oarfish	EM Logbook	 Very limited logbook use	37272000
37470002 37470000	Ocean Sunfish Ocean sunfishes	Both EM		37470002
37268001 37268000	Opah opahs	EM EM	 Very limited EM use	37268001
37035999 37035010	Pelagic stingrays Pelagic stingray	EM EM	 Very limited EM use	37035999
37342900 37342000	Pomfrets Pomfrets - unspecified	EM Logbook	 Very limited logbook use	37342900

37445000	Trevallas	EM	Very limited EM use	37445000
37337902	Trevally (mixed)	EM	Very limited EM use	
37337908	Trevallies (mixed)	EM	Very limited EM use	
37012001	Thresher Shark	Both		37012001
37012901	Thresher Sharks (mixed)	Both	Very limited logbook use	
37012000	Thresher Sharks	EM		
37467000	Toadfishes unspecified	Both	Very limited EM use	37467000
37467900	Toadfishes - Lagocephalid	EM		
37990018	Skates and Rays	Both		37990018
37990030	Skates and Rays (mixed)	EM		
37031000	Skates	EM	Very limited EM use	
37439504	Snake Mackerel (obsolete)	EM		37439010
37439010	Snake Mackerel	Both		
37441912	Tuna (mixed)	Both		37441912
37441925	Tuna (Thunnus)	EM		