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

Gillnet, Hook and Trap Sector

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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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<u>Note to readers:</u>

Due to the low number of vessels in the auto longline and set longline sectors of the GHAT, vessel-level analyses have been removed from the results section of this report to ensure confidentiality. However, the overall results in terms of fleet-wide inter-vessel variation are discussed in the executive summary and discussion sections of this report as they are relevant to the recommendations.

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 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 GHAT logbook and EM data (Emery et al., 2019a) analysed both retained and discarded species and interactions with TEP species, for the years 2015/16 and 2016/17. It identified an absence of shot level similarity between logbook and EM data for most species, except for some retained key commercial species (i.e., gummy and school shark). The study also identified for a range of species (e.g., elephantfish), the need for logbook reporting of retained and discarded catches to improve (e.g., to minimise under-reporting or improve species identification related issues), and some instances where EM reporting could also be improved (e.g., to improve species identification and allocation of species codes in EM databases).

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 GHAT. Specifically, the analysis aims to:

- Compare both fishery level and individual vessel level similarity between logbook and EM data for commercial, bycatch and TEP species;
- Determine if similarity 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 GHAT 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 gillnet (GNS), auto longline (LLA) and set longline (LLS) sectors of the GHAT.

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 expressed as differences 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 four years of EM data (five years in the case of TEP species) compared to two years in the previous study.

Results

The analyses presented in this report indicate that the overall level of congruence for the GHAT was:

- superior for key commercial species compared to byproduct/bycatch species;
- higher for retained than discarded catch;
- variable for interactions with TEP groups; and
- improving over time for some key commercial species, particularly in the gillnet sector.

Importantly, fleet-wide estimates conceal significant inter-annual and inter-vessel variation for some species. Consequently, whether GHAT logbook data can be used for scientific analysis and management decisions for any given species (or group of species) will depend on both the findings of the comparative analysis at both fleet and individual vessel level 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 scientific 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

In general, key commercial retained species (gummy shark, school shark, elephantfish and grouped sawsharks) in the gillnet sector had high congruence, while the results for other retained byproduct species had low congruence (Table 1). This high level of congruence was also detected in the previous analysis (Emery et al. 2019a) for retained gummy and school shark but not for elephantfish. Evidence from this study suggests that the reporting of retained elephantfish has improved through time.

Retained common and southern sawsharks were reported more in the logbook than by the EM analyst, with evidence suggesting the EM analyst was grouping them into sawsharks (mixed), as found in the previous study (Emery et al. 2019a). When sawsharks (mixed) along with southern and common sawsharks were combined into sawsharks (grouped) and assessed at a higher taxonomic level, it was evident that the total numbers (for retained catch at least) were more congruent with logbook records, indicative of an identification issue. 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). Furthermore, southern and common sawshark species can be difficult to differentiate from solely EM footage.

Discarded key commercial species

Reporting of key commercial discarded species in the gillnet sector was mixed. School shark was the most congruent across the time period, which is somewhat expected given its current status as a rebuilding stock and the importance placed by AFMA on accounting for all catches. Conversely, discarded gummy shark was consistently reported on average more by fishers in their logbook across the time period. When examining gummy shark combined with school shark and hound sharks (mixed) at a higher taxonomic level, congruence improved (like retained sawsharks (grouped)) suggesting EM analysts were having difficulties identifying discarded gummy shark.

Both discarded elephantfish and sawsharks (grouped) displayed low congruence across time, with more individuals being reported by the EM analyst than logbook. Importantly, there was evidence among both these species of persistent non-reporting of any discarded catch by a small number of individual vessels in their logbooks, despite the EM analyst reporting discards. This lack of reporting may have been due to one or a combination of: (i) misidentification of species and taxonomic issues; (ii) missed observations or incorrect reporting of fate; or (iii) incomplete logbook reporting.

In the auto-longline sector and to a lesser extent the set-longline sector, the findings again 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 key commercial species appeared to be relatively similar when comparing mean differences across the entire time period, in many instances, this 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 given other studies have highlighted the heterogeneity among fishers in respect to identification skill and diligence in logbook reporting (Macbeth et al., 2018).

Note that vessel level results (statistics and plots) are presented for GNS sector only, due to confidentiality requirements related to the small number of vessels in the LLA and LLS sectors.

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

Sector	Target species	Fate	Mean difference in reporting	Mean difference in reporting as a proportion of average catch	Year-level differences	Inter-vessel variability
Gillnet	Gummy shark	Retained	EM~Logbook	Low (<15%)	Improving	Negligible
		Discarded	Logbook>EM	High (>50%)	Improving	High
	School shark	Retained	EM~Logbook	Low (<15%)	Improving	Negligible
		Discarded	EM~Logbook	Low (<15%)	Improving	Low
	Elephantfish	Retained	EM>Logbook	Low (<15%)	Improving	Medium
		Discarded	EM>Logbook	Moderate (15-50%)	Improving	High
	Sawsharks (grouped)	Retained	EM>Logbook	Low (<15%)	Improving	Low
		Discarded	EM>Logbook	Moderate (15-50%)	Stable	High
Auto longline	Blue-eye trevalla	Retained	EM>Logbook	Low (<15%)	Variable	High
		Discarded	EM~Logbook	Low (<15%)	Variable	High
	Pink ling	Retained	EM>Logbook	Low (<15%)	Variable	High
		Discarded	Logbook>Em	High (>50%)	Variable	Negligible
	Ribaldo	Retained	EM>Logbook	Moderate (15-50%)	Variable	High
		Discarded	EM~Logbook	Low (<15%)	Improving	High
Set longline	Gummy shark	Retained	EM~Logbook	Low (<15%)	Variable	Medium
		Discarded	EM>Logbook	Moderate (15-50%)	Variable	Medium
	School shark	Retained	EM~Logbook	Low (<15%)	Improving	Low
		Discarded	EM~Logbook	Low (<15%)	Variable	Negligible

Threatened endangered and protected species

While further data is needed for the auto-longline and set-longline sectors to provide a more robust assessment of congruence among TEP species, reporting in the gillnet sector was mixed and variable through time. Cetaceans and to some extent pinnipeds displayed high congruence, while sharks and seabirds were reported more, on average, by the EM analyst. The reason that congruence was higher for marine mammals is probably the result of past compliance actions associated with misreporting and the initial focus of the EM program on accounting for all interactions with TEP species, but particularly dolphins and sea lions (AFMA, 2013).

While differences in observed counts were low in terms of absolute number (1-2 individuals) across all TEP groups, it is unclear why these interactions were not being reported by fishers. While it is possible these differences may be caused by missed observations, they could also be a result of incomplete 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.

Recommendations

The following recommendations aim to assist AFMA to identify and prioritise actions to increase the benefits of the EM and logbook data collection programs to inform management decisions. More detail on these recommendations is provided in the discussion and recommendations section of this report.

General recommendations

- **Confirm key drivers for a lack of congruence through outreach** – AFMA should investigate the key drivers of low congruence. This report has attempted to identify the most likely drivers, but in some cases, these cannot be confirmed without further information or investigation. This will help inform the management actions needed to improve logbook reporting (and EM data collection) for each sector or species. Depending on the key drivers in each case, the specific recommendations below then apply.
- **Implement a vessel specific approach to management** – There is significant variability in congruence between vessels. Therefore, improving overall congruence will in many cases need to be focussed on individual vessels. 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.
- **Review feedback processes and resourcing** – Several potential issues driving a lack of congruence between logbook and EM data in the GHAT fishery have persisted for over five years (i.e., between studies). AFMA should review the recommendations herein with a view to prioritise and implement timely changes to their education, feedback, and compliance processes.

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

- **Periodically review and seek to improve individual vessel EM systems where required** – AFMA should seek to improve EM systems on vessels whose systems are identified as hindering or not sufficiently enabling EM analysts to have a clear view of catch, discard, or interaction events. Solutions may include 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** – AFMA and the EM service provider should ensure EM analysts continue to be provided sufficient training. This includes from qualified experts (e.g., at sea observers, scientists) so that they are able to accurately identify species, particularly those that are more difficult to identify. Periodic audits on EM analyst reports to ensure consistency and maintenance of high-quality EM data through time should also be considered.
- **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 (i.e., CAAB codes) in the database (Appendix A).
- **Investigate whitefin swellshark CAAB code allocation in the logbook -** It has been previously noted by the EM service provider that the rollout of e-logbooks in the SESSF was accompanied with a software issue where the CAAB code for whitefin swellshark (*Cephaloscyllium albipinnum*) was assigned to species look-up common name draughtboard shark (*Cephaloscyllium laticeps*). So, fishers who record numbers of draughtboard shark in their e-logbooks were being recorded as whitefin swellshark by the software. This should be investigated by AFMA to determine if this is still occurring and corrected if it still is.

Improving logbook reporting

- **Improve the capability of fishers to identify and report species** – AFMA should conduct further outreach activities to inform fishers about their reporting responsibilities and/or educate them in species identification/taxonomy.
- **Strengthen feedback and education mechanisms** – It is recommended that AFMA resource and implement direct feedback/education (and where necessary compliance) processes between AFMA and vessel skippers (and/or crew) whose logbook reporting needs improvement. 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** – AFMA, in partnership with scientists and industry stakeholders should 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).

Using logbook and EM data for scientific analyses

- **Use of sector level congruent logbook data -** Where congruence between EM and logbook data for a given species is high at both the fleet and individual vessel level, the logbook data can generally be considered representative of the actual catch/discards in that sector and used 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. 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/sectors where logbook data is considered unreliable, EM data could be used directly to derive estimates of overall catches, catch rates or other parameters of interest to scientists and managers. However, any assumptions should be clear and appropriately recognised.

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 also be 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 GHAT and identify on board mechanisms to optimise EM data collection.

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 for the GHAT was to:

(i) compare the level congruence (i.e., similarity) between EM and logbook data for commercial, bycatch and protected species.

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

(iii) compare the level of congruence among individual vessels.

(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 GHAT were collated and aggregated by shot and the total number of species (either retained or discarded) for the period 1 July 2016 to 30 June 2020. This encompassed a total of 3,039 linked audited shots (including 2,677 in GNS, 195 in LLA and 167 in LLS) (Table 2). Data from 1 July 2015 to 30 June 2016 was not included in the analysis following discussions with AFMA (AFMA pers. comm. 2021) because during this period (up until April 2016), fishers in the GHAT were only required to record in their logbook the estimated weight of individual species and not the counts.

Table 2: Number of audited linked shots by sector and financial year in the GHAT

Sector	Financial year	Number of linked audited shots
Gillnet (GNS)	2016/2017	750
	2017/2018	759
	2018/2019	584
	2019/2020	584
Auto longline (LLA)	2016/2017	36
	2017/2018	40
	2018/2019	45
	2019/2020	74
Set longline (LLS)	2016/2017	9
	2017/2018	51
	2018/2019	20
	2019/2020	87

Additional processing of the data was required before it could be used in the analyses, including:

- The removal of a total of 51 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 (Emery et al. 2019a) 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).

2.2 Data analysis

Several approaches were applied to explore congruence between GHAT 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

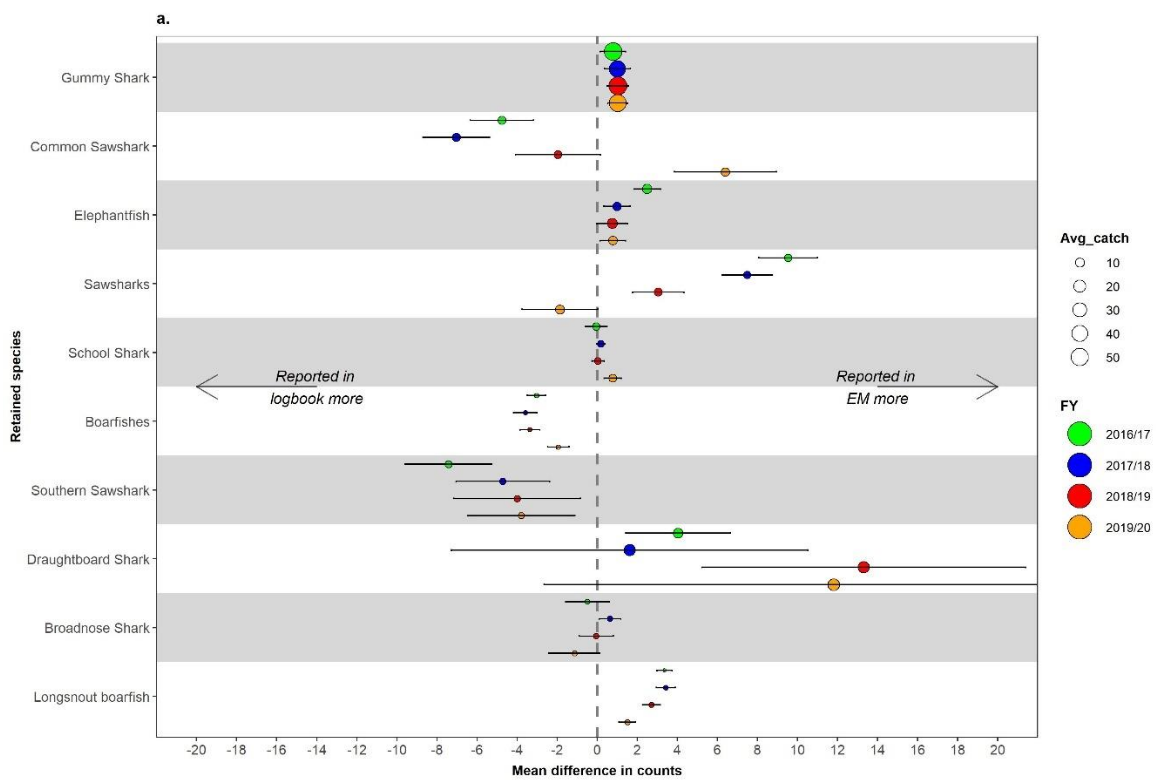
This calculates the proportional differences in counts between EM and logbook at an individual shot level by financial year (see example (d) in Box 1). This analysis identifies whether individual shots were clustered around zero (i.e., EM and logbooks counts were identical) or skewed either left or right (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

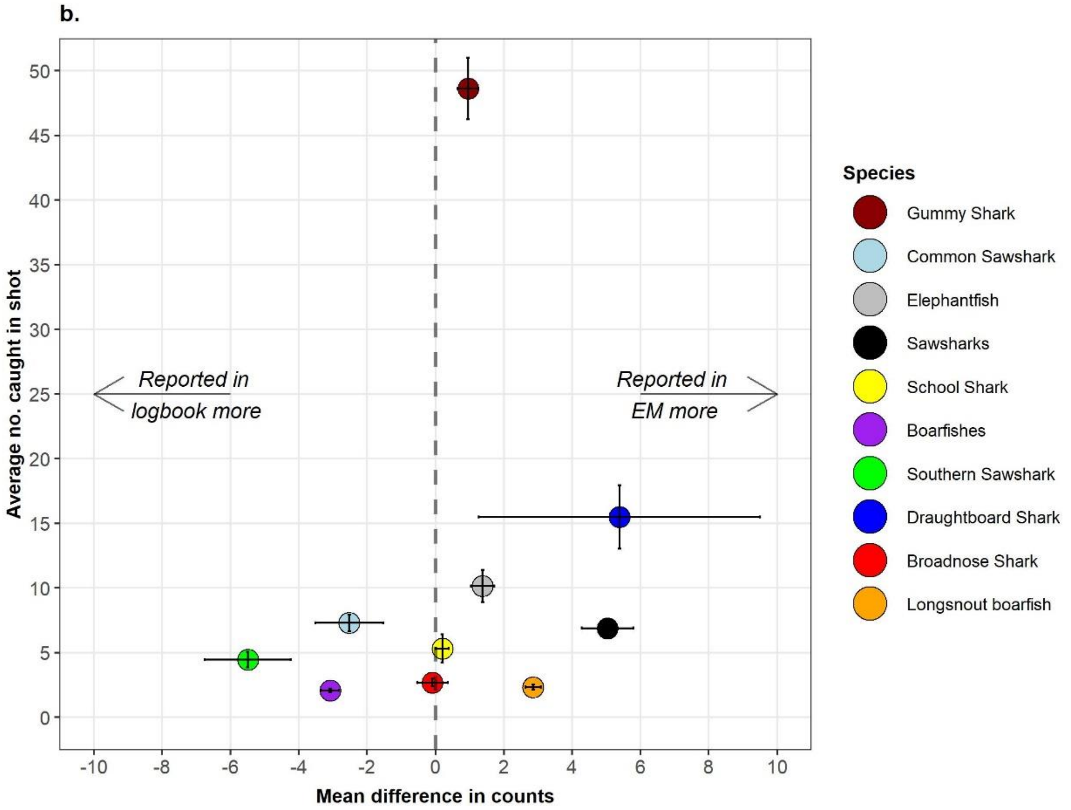
Given the heterogeneity in logbook reporting across vessels, analysis of shot-level differences in counts was undertaken and presented as kernel probability density functions (see example (f) in Box 1). This shows the shot-level differences in counts for a specific species, mean difference in counts 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 GHAT.

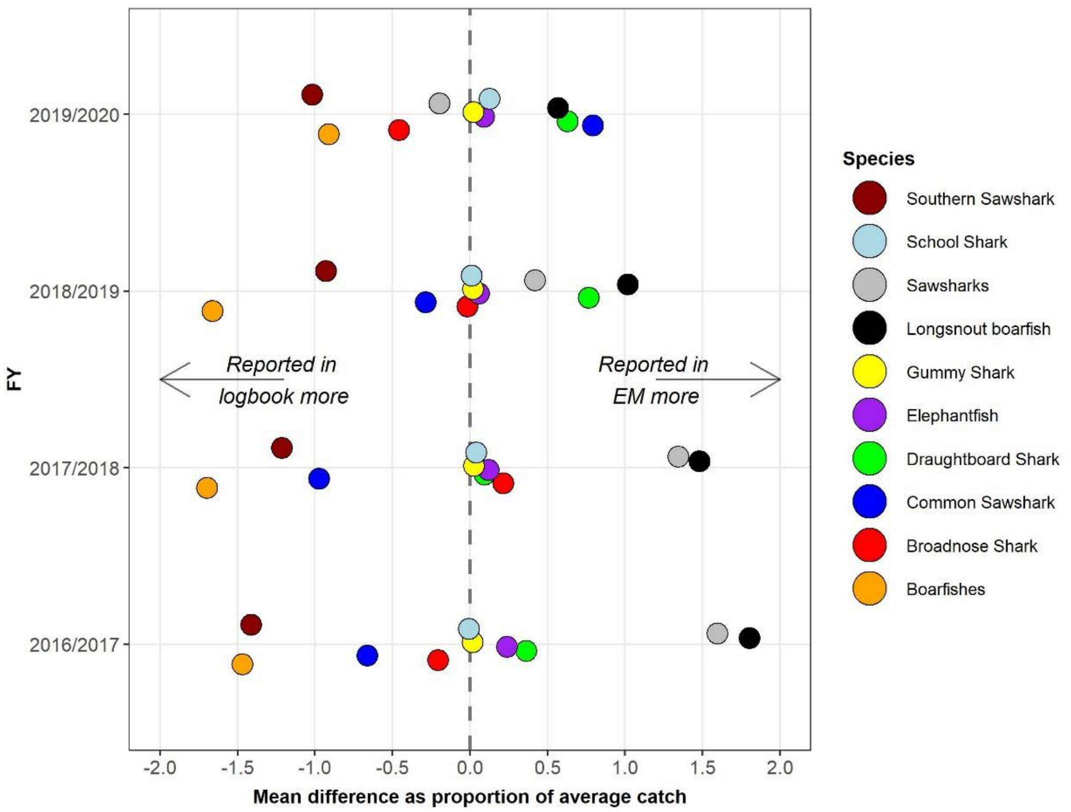
a. mean difference in counts



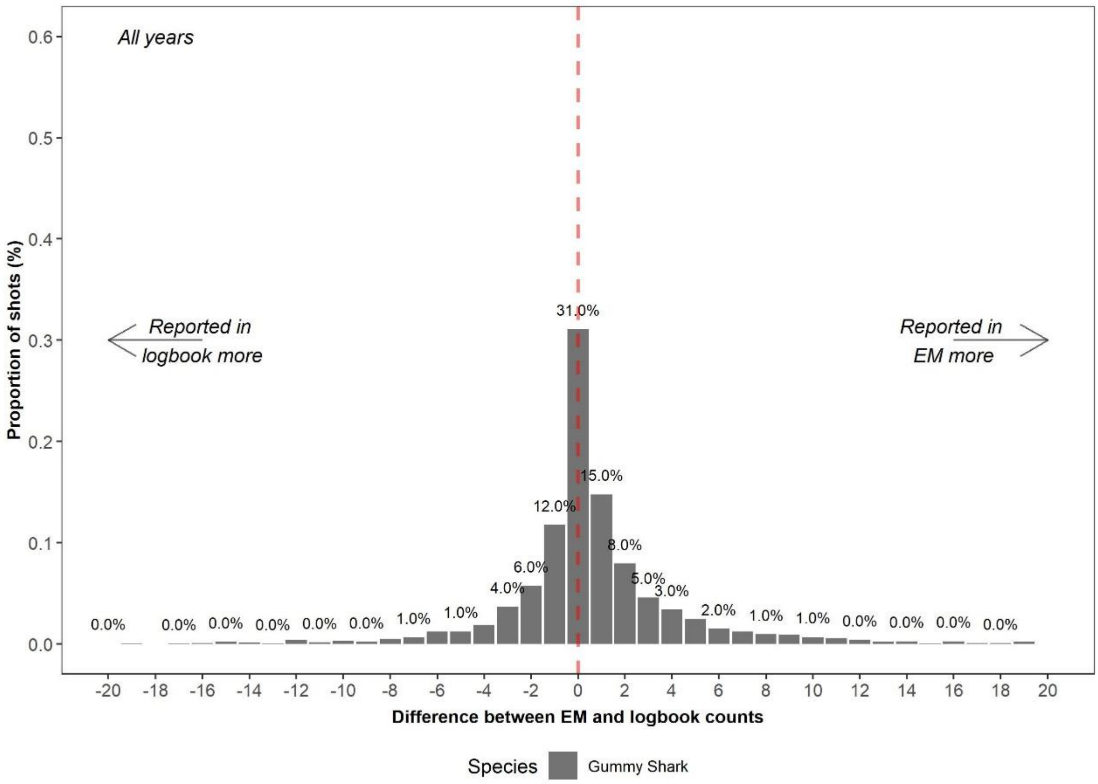
b. mean difference in counts relative to average catch no. of the shot



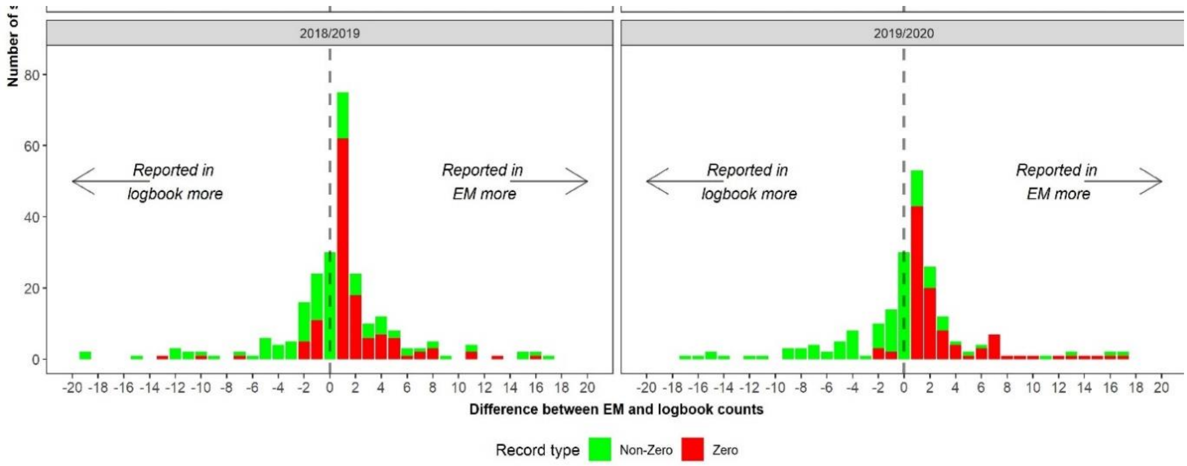
c. mean difference in counts as proportion of average catch no. of the shot



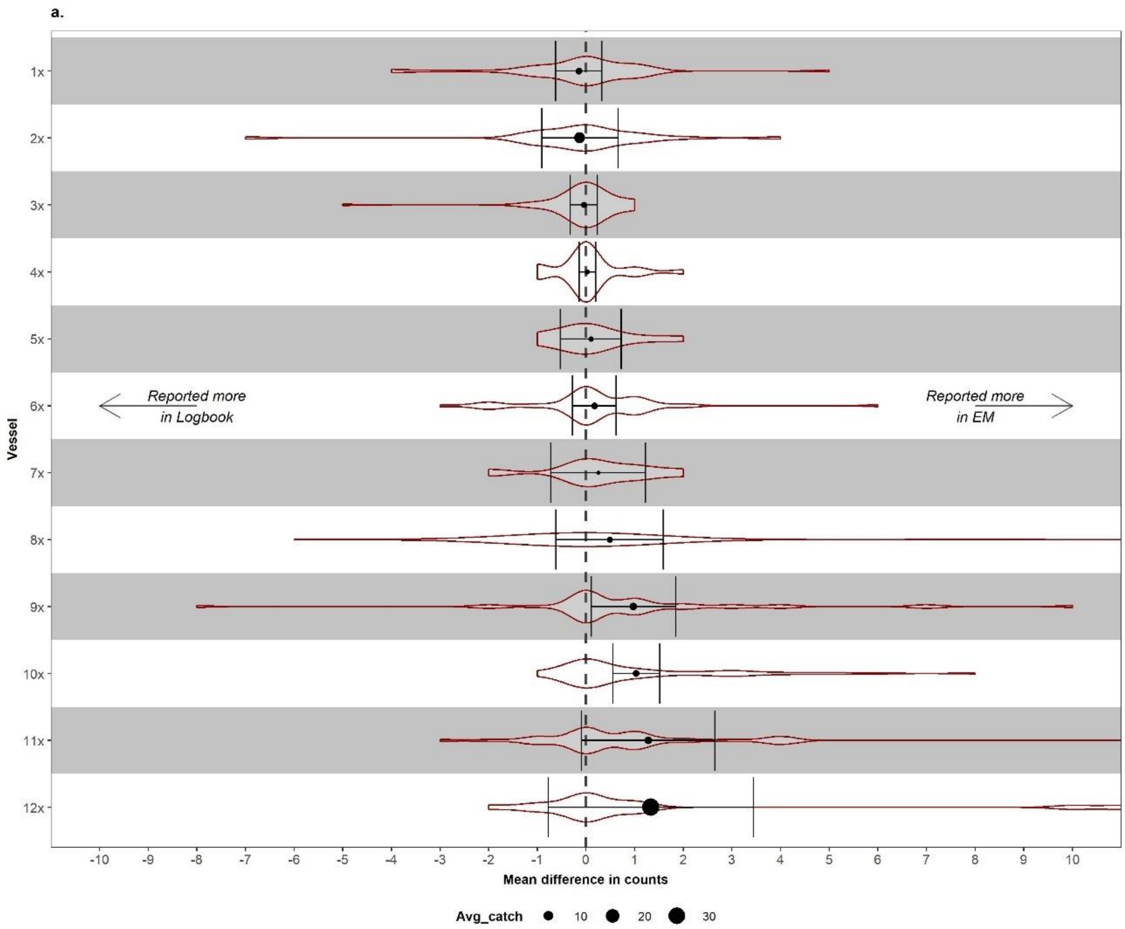
d. frequency histogram of shot level differences in counts as a proportion of total shots



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 GHAT

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

3 Results

3.1 Gillnet sector

3.1.1 Retained catch

In the GNS, there were a total of 10 species that made up 95% of the reported retained catch from the logbook audited shots between 2016/17 and 2019/20. These species are displayed in Table 3 in descending order of the proportion of catch.

The main retained target species, (specifically gummy, school shark and elephantfish) were reported in similar numbers by logbook and EM (Figure 1a, b and Table 3). For example, gummy shark had a mean difference in counts of 1.0 ± 0.3 individuals across the time period examined and the average number recorded as retained by both EM and logbook in a shot was 48.6 ± 2.4 individuals (Table 3). As a proportion of the average catch, the mean difference for gummy shark was 2%, which is minimal (Figure 2). Furthermore, individuals were not commonly unreported with <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). Common sawshark, southern sawshark and boarfishes (mixed) were reported in higher numbers by logbook than EM, while draughtboard shark and longsnout boarfish were reported more by EM than logbook (Figure 1). Broadnose shark was reported in similar numbers (-0.1± 0.4 individuals) between logbook and EM across the time period examined, while also being reported caught in low numbers (2.7 ± 0.3 individuals) by both EM and logbook in a shot (Table 3).

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 GNS.

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
Gummy shark	*Mustelus antarcticus*	1.0 (±0.3)	48.6 (±2.4)	2%	<1%
Common sawshark	*Pristiophorus cirratus*	-2.5 (±1.0)	7.3 (±0.6)	-34%	71%
Elephantfish	*Callorhinchus milii*	1.4 (±0.3)	10.2 (±1.2)	14%	24%
Sawsharks (mixed)	*Pristiophoridae spp.*	5.0 (±0.8)	6.9(±0.5)	73%	69%
School shark	*Galeorhinus galeus*	0.2 (±0.2)	5.3 (±1.1)	4%	16%
Boarfishes (mixed)	*Caproidae spp.*	-3.1 (±0.3)	2.1 (±0.1)	-148%	86%

Southern sawshark	*Pristiophorus nudipinnis*	-5.5 (±1.2)	4.5 (±0.6)	-123%	87%
Draughtboard shark	*Cephaloscyllium laticeps*	5.4 (±4.1)	15.5 (±2.5)	35%	62%
Broadnose shark	*Notorynchus cepedianus*	-0.1 (±0.4)	2.7 (±0.3)	-3%	56%
Longsnout boarfish	*Pentaceropsis recurvirostris*	2.9 (±0.2)	2.3 (±0.2)	122%	82%

Figure 1: Reporting of retained species in the GNS (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

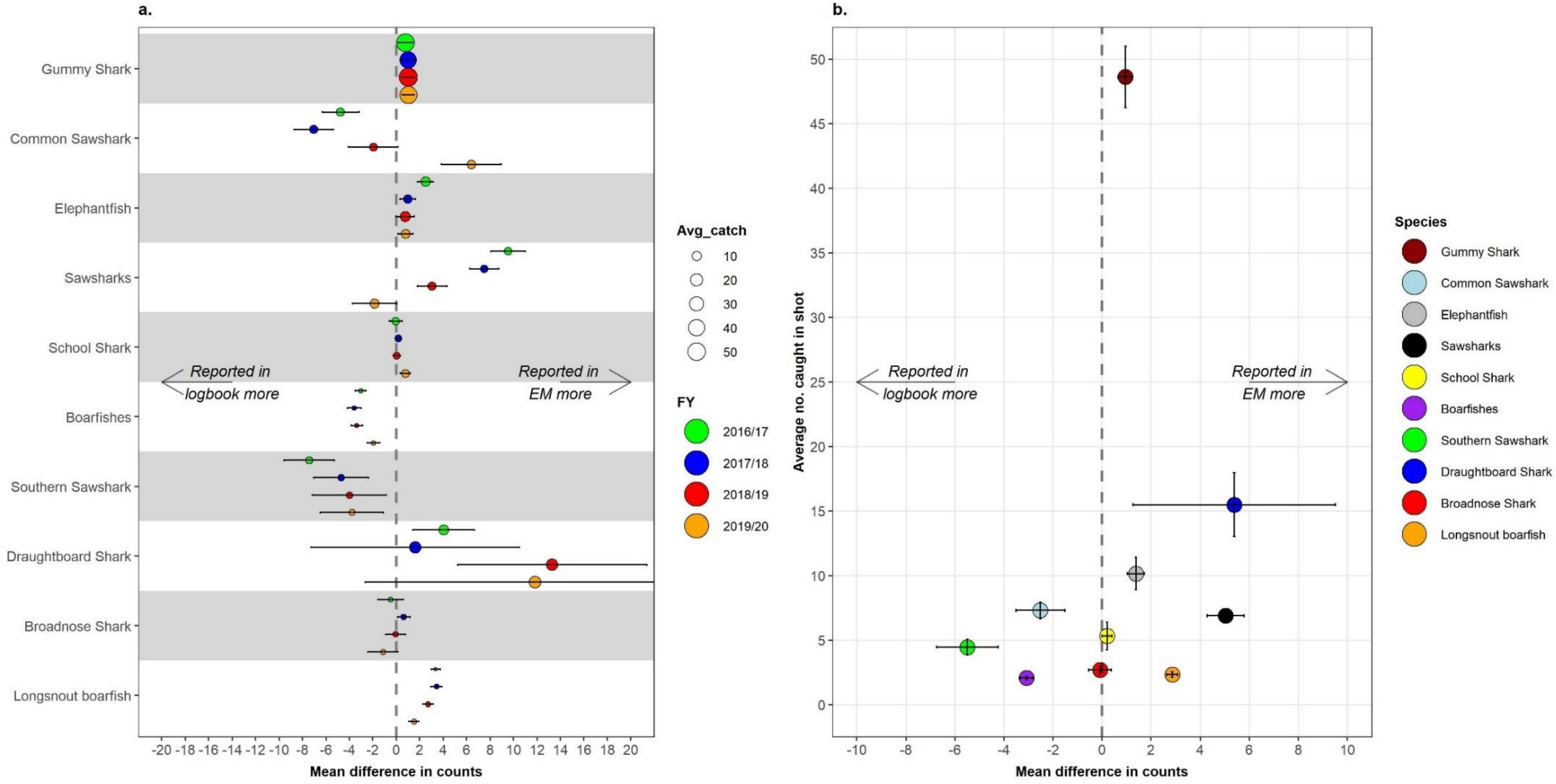
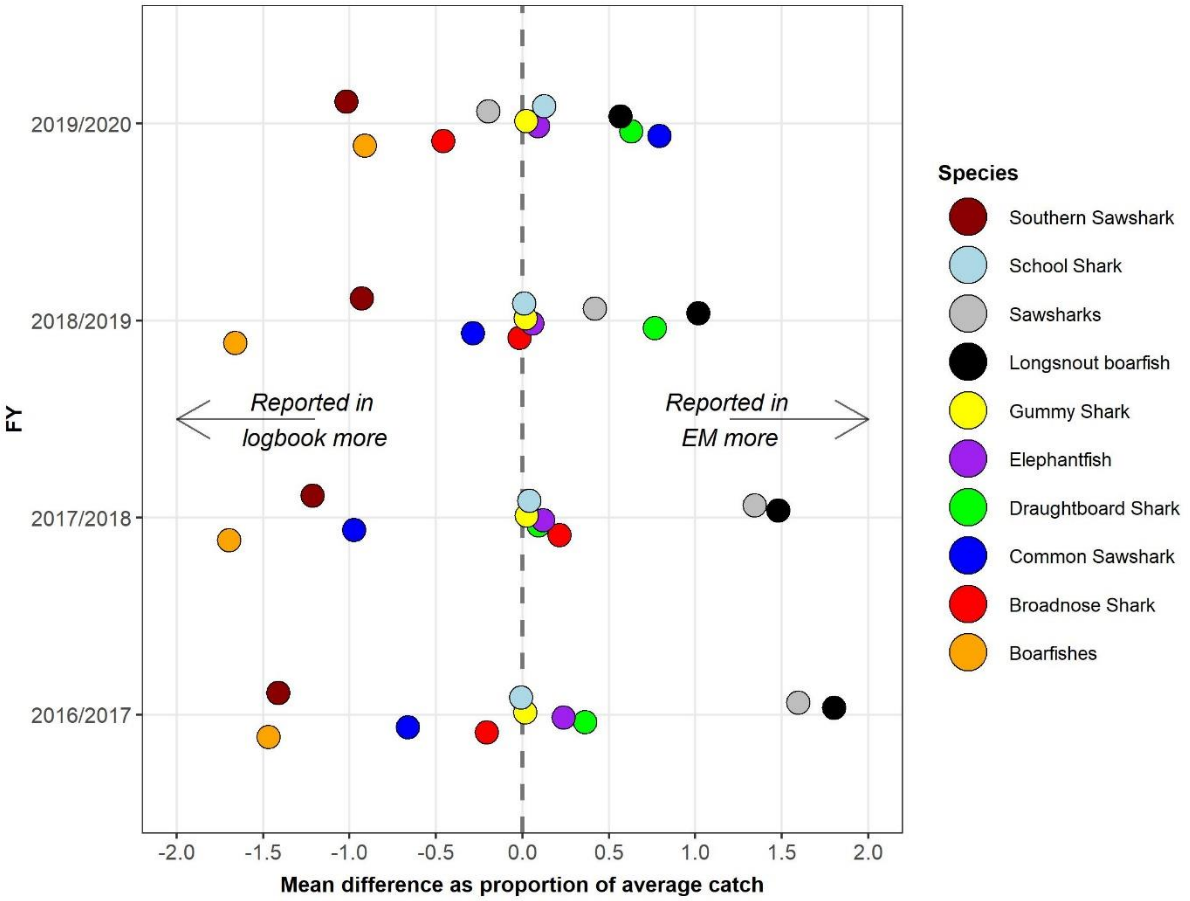


Figure 2: The mean difference in counts as a proportion of the average catch (average of EM and logbook reported) per shot for retained species in the GNS



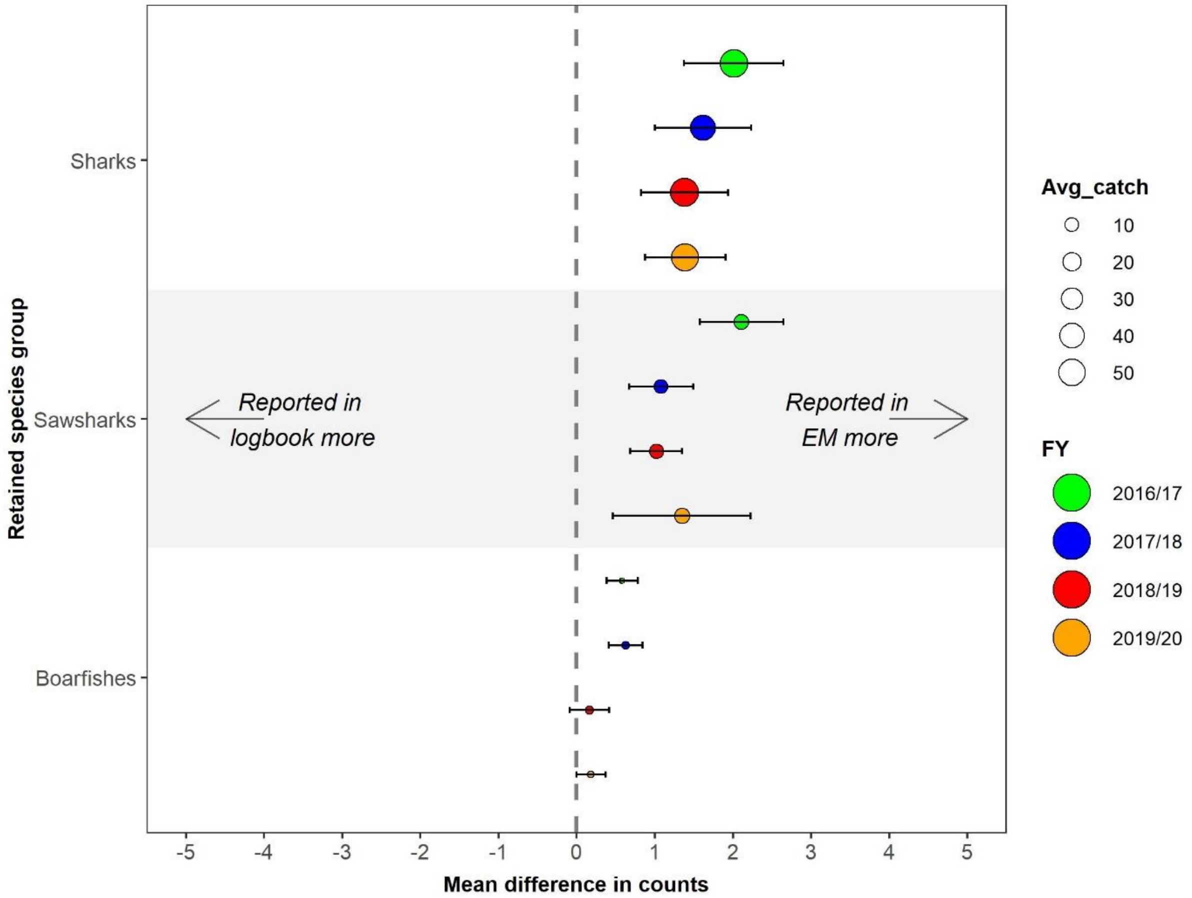
The results for some retained species reflected the EM analyst or fisher possibly not being able to identify some individuals to a species taxonomic level (e.g., southern sawshark for EM and longsnout boarfishes for logbook). Given there were some possible issues with identifying individuals to a species taxonomic level, some groups containing key target and byproduct species in the GNS were-re-analysed to examine overall congruence (Table 4).

Table 4: Individual species that were assessed at a higher taxonomic group level

Sawsharks Group	Sharks Group	Boarfishes Group
Sawsharks	Gummy shark	Boarfishes
Common sawshark	School shark	Longsnout boarfishes
Southern sawshark	Hound sharks	Short boarfish
		Blackspot boarfish
		Giant boarfish
		Bigspine boarfish

For retained catch, it became evident that overall total numbers being reported in these groups by the logbook and EM analyst were similar, however there was a slightly greater number on average being reported by EM (~+1-2 individuals) except for boarfishes (Figure 3). This indicates that while there seem to be issues with identifying to a species level for retained sawshark and boarfish catch, the overall total numbers seem to be more accurately reported at a higher taxonomic level. For sawsharks, EM is not always able to report these to a species taxonomic level and reporting them as sawsharks (mixed group), while for boarfishes it seems the opposite, with the logbook reporting them more as boarfishes (mixed group).

Figure 3: Mean difference in counts (mean ± 95% CI) across individual financial years for selected grouped species retained in the GNS



Gummy shark

Across the time period examined, 31% of shots audited that contained retained gummy shark had no difference in logbook and EM counts, 41% had higher counts reported by EM and 28% 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 4 and Figure 5). There was evidence of improvement in congruence through time, with 26% of shots in 2016/17 having no difference in logbook and EM counts, increasing to 34% by 2019/20 (Figure 6). While gummy shark was reported slightly more by EM (1.0 ± 0.3 individuals) across the time period examined, the average number recorded by both EM and logbook in a single shot was high (48.6 ± 2.4 individuals), so as a proportion of the average catch this difference was only 2% (Table 3). This suggest that for every 48.1 individuals reported by logbook, EM is reporting 49.1 individuals. Furthermore, individuals were not commonly unreported with <1% of shots containing a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool (Figure 7).

An examination of the data at an individual vessel level revealed that for most of the 36 vessels the confidence intervals for the mean difference in counts encompassed zero, with not a large amount of variation between shots (Figure 8a, b, and c). This suggested a high level of congruence overall for the fleet. A few vessels had higher numbers reported by EM across the time period examined but the average number recorded by both EM and logbook in a single shot was also high. One vessel had higher counts reported by logbook (-7.4 ± 3.6 individuals) with a large average catch (62.3 ± 15.2 individuals) across the time period examined, suggesting EM may be having some issues either correctly identifying gummy shark or observing gummy shark being retained (note a similar issue was also observed on this vessel for school shark).

Figure 4: Logbook and EM reported counts from individual shots containing retained gummy shark across time period examined. Red dashed line is the 1:1 line.

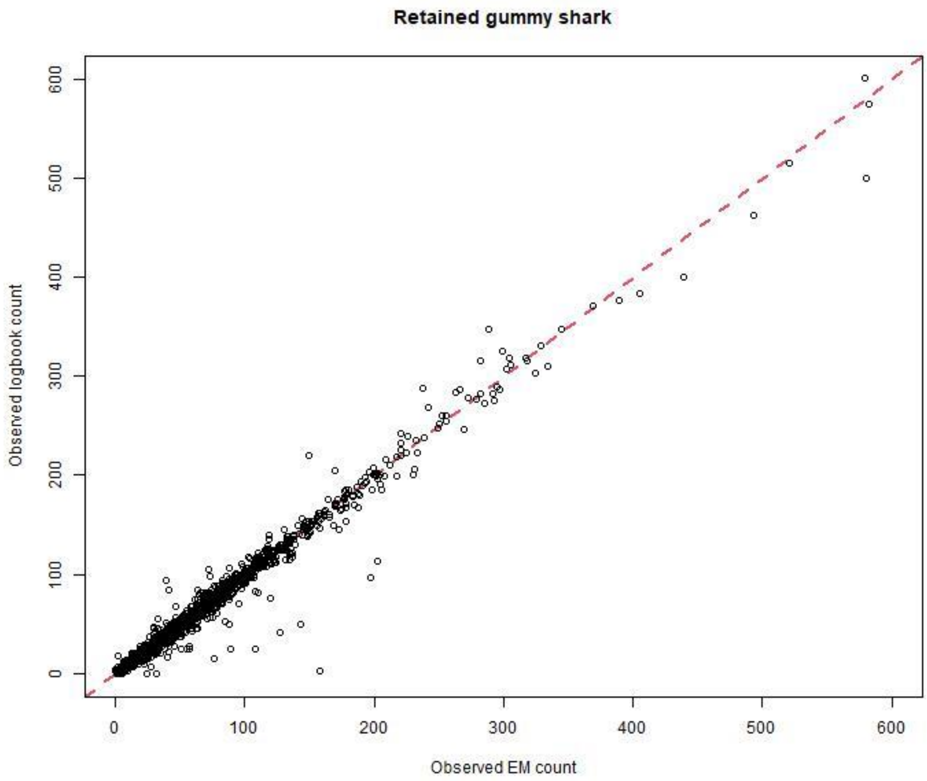


Figure 5: Proportion of shots with specific differences between EM and logbook counts for retained gummy shark across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

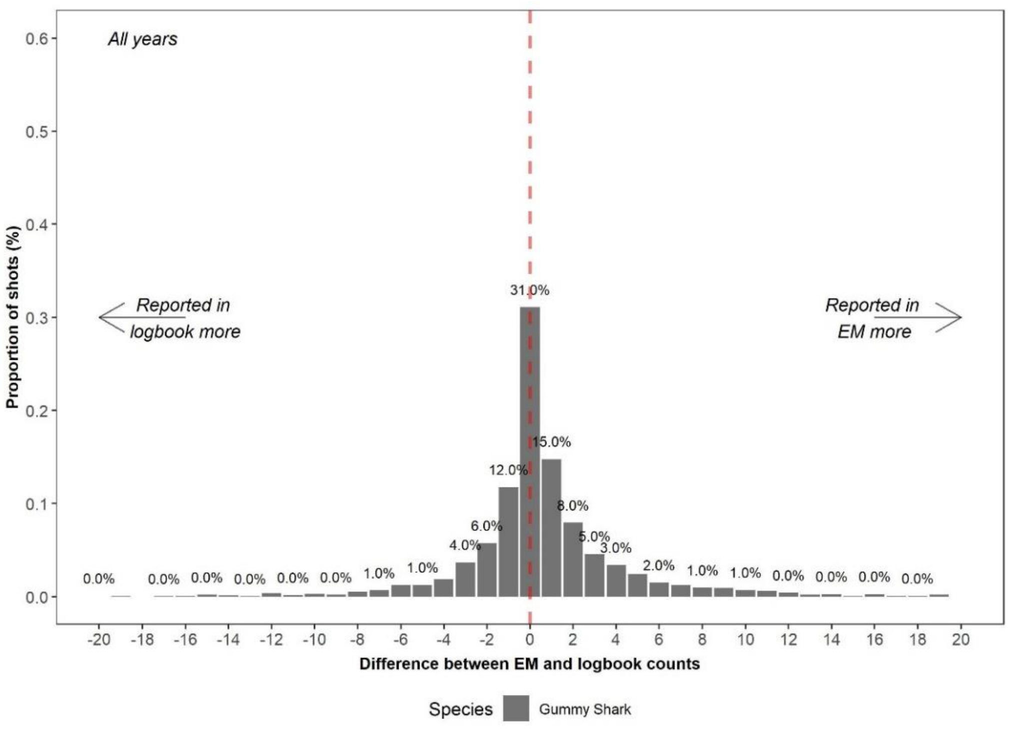


Figure 6: Proportion of shots with specific differences between EM and logbook counts for retained gummy shark for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

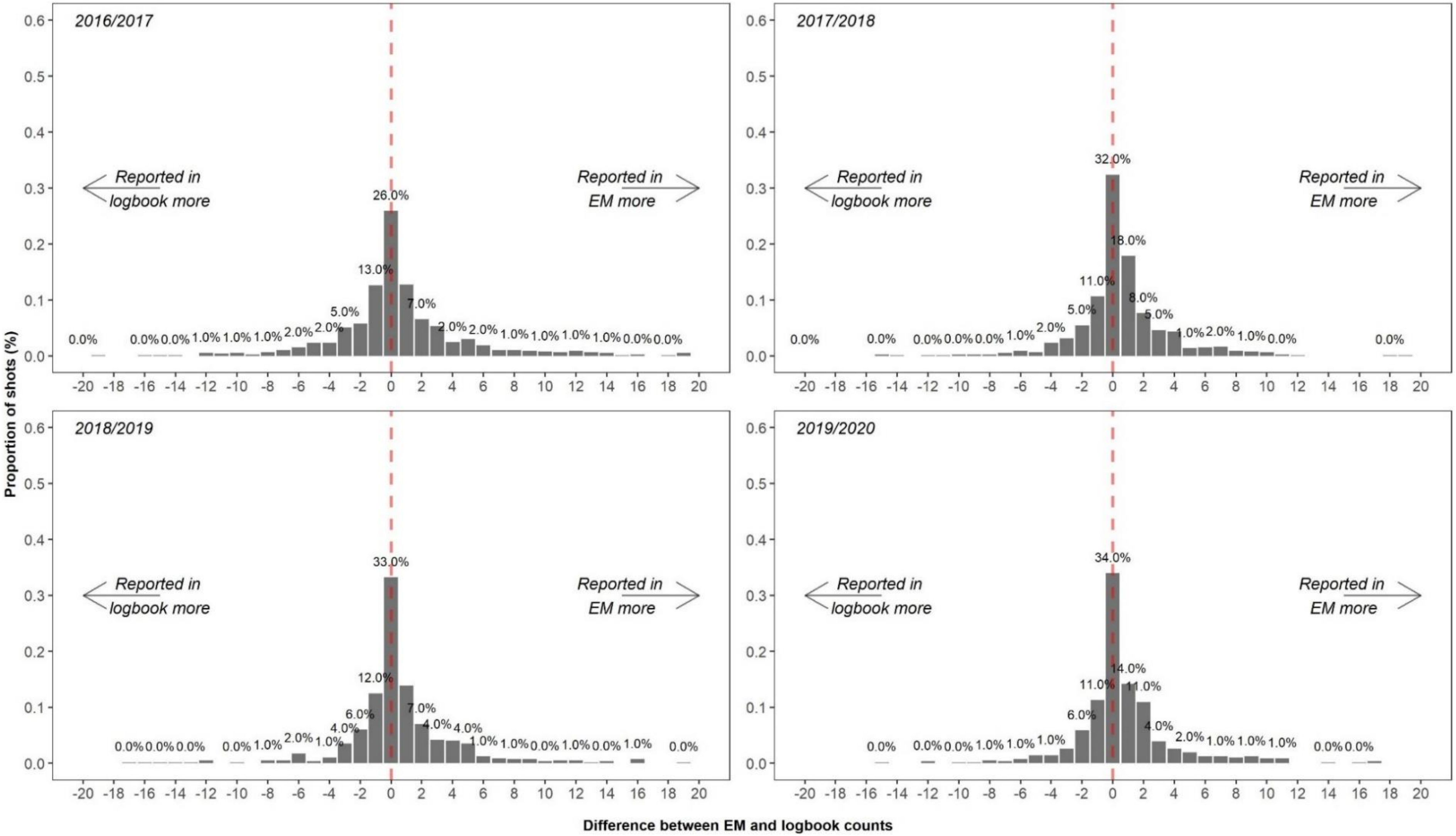


Figure 7: Number of shots with specific differences between EM and logbook counts for retained gummy shark across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

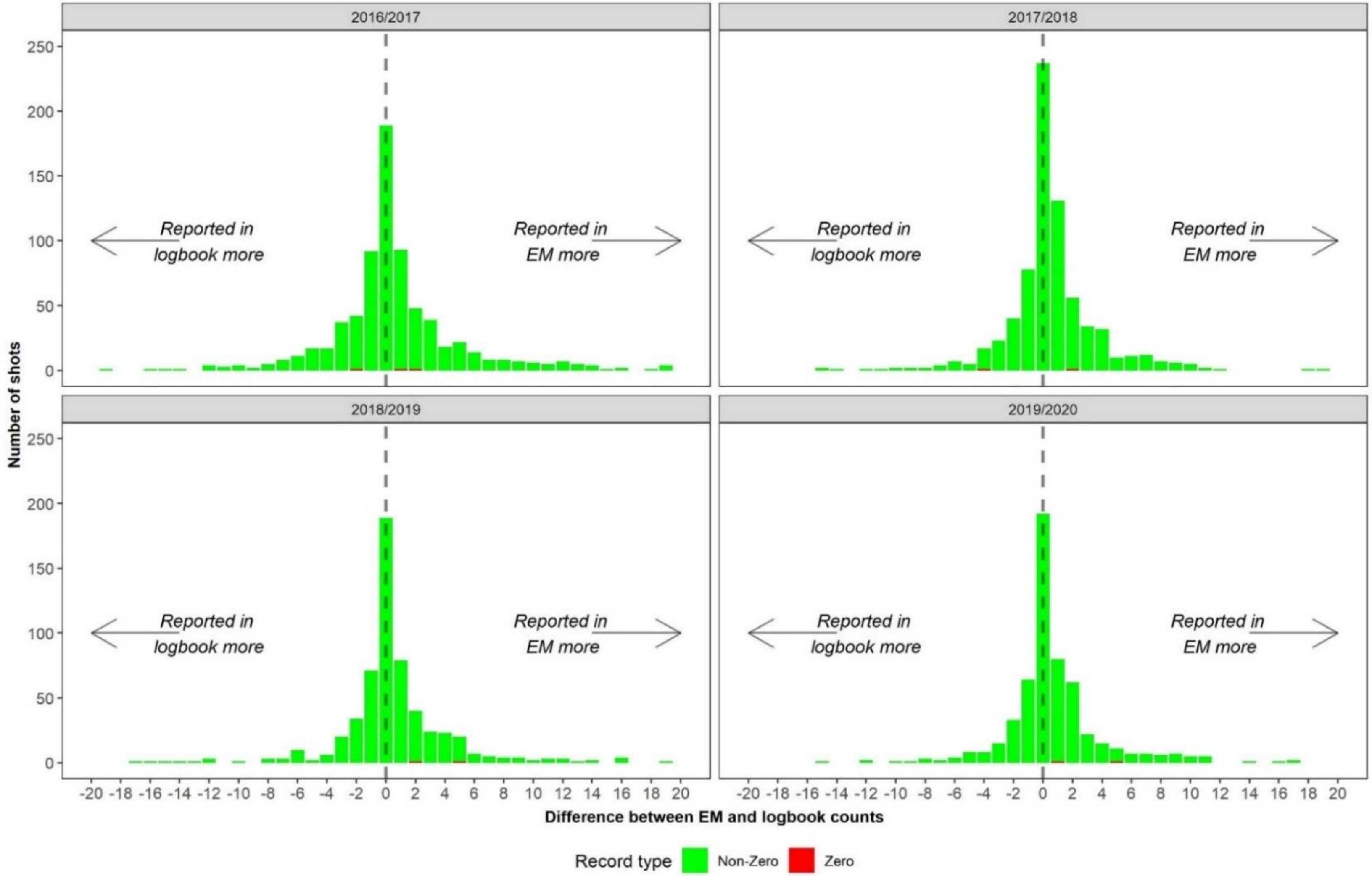


Figure 8a: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing retained gummy shark across the time period examined by vessel. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

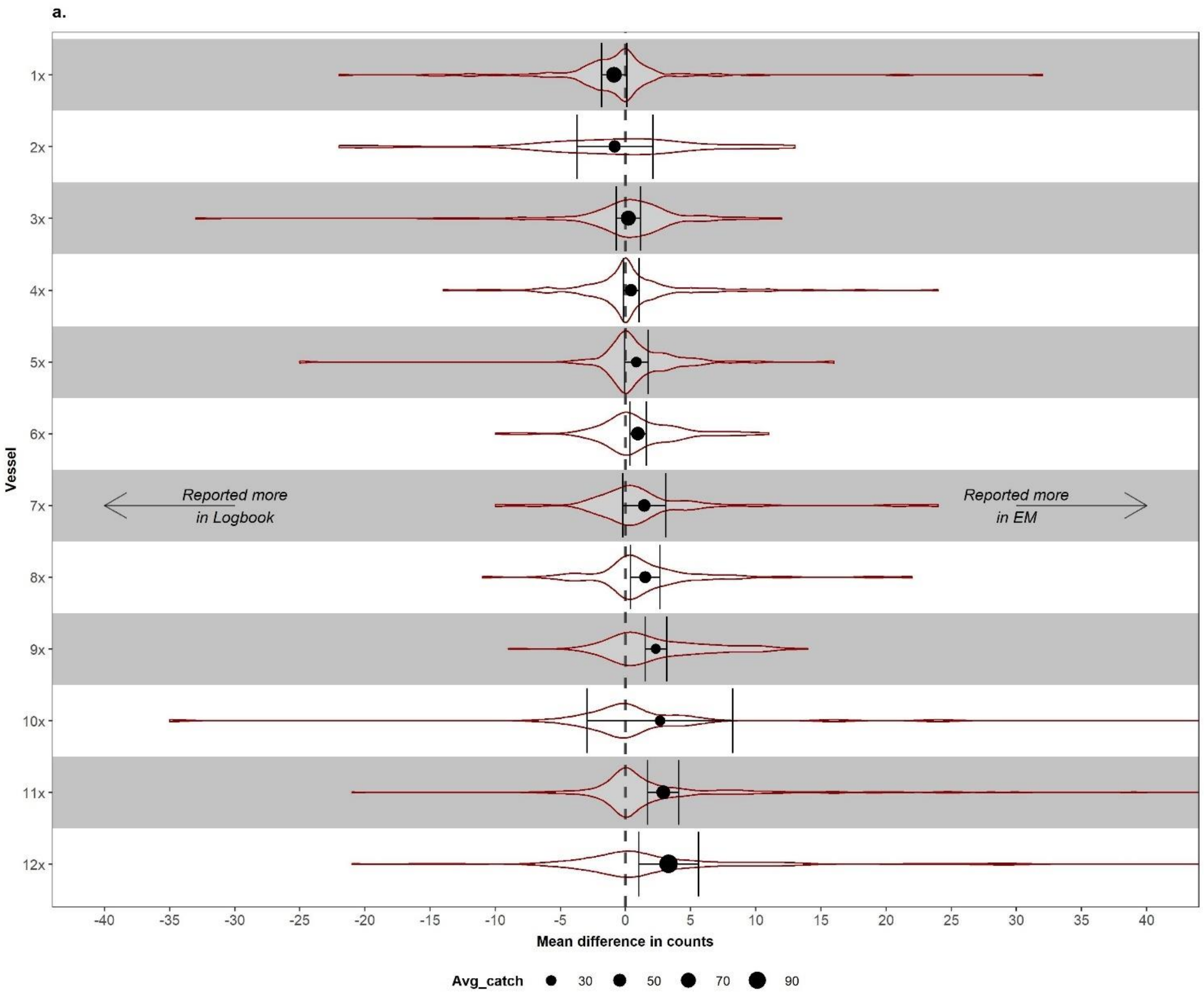


Figure 8b: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing retained gummy shark across the time period examined by vessel. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

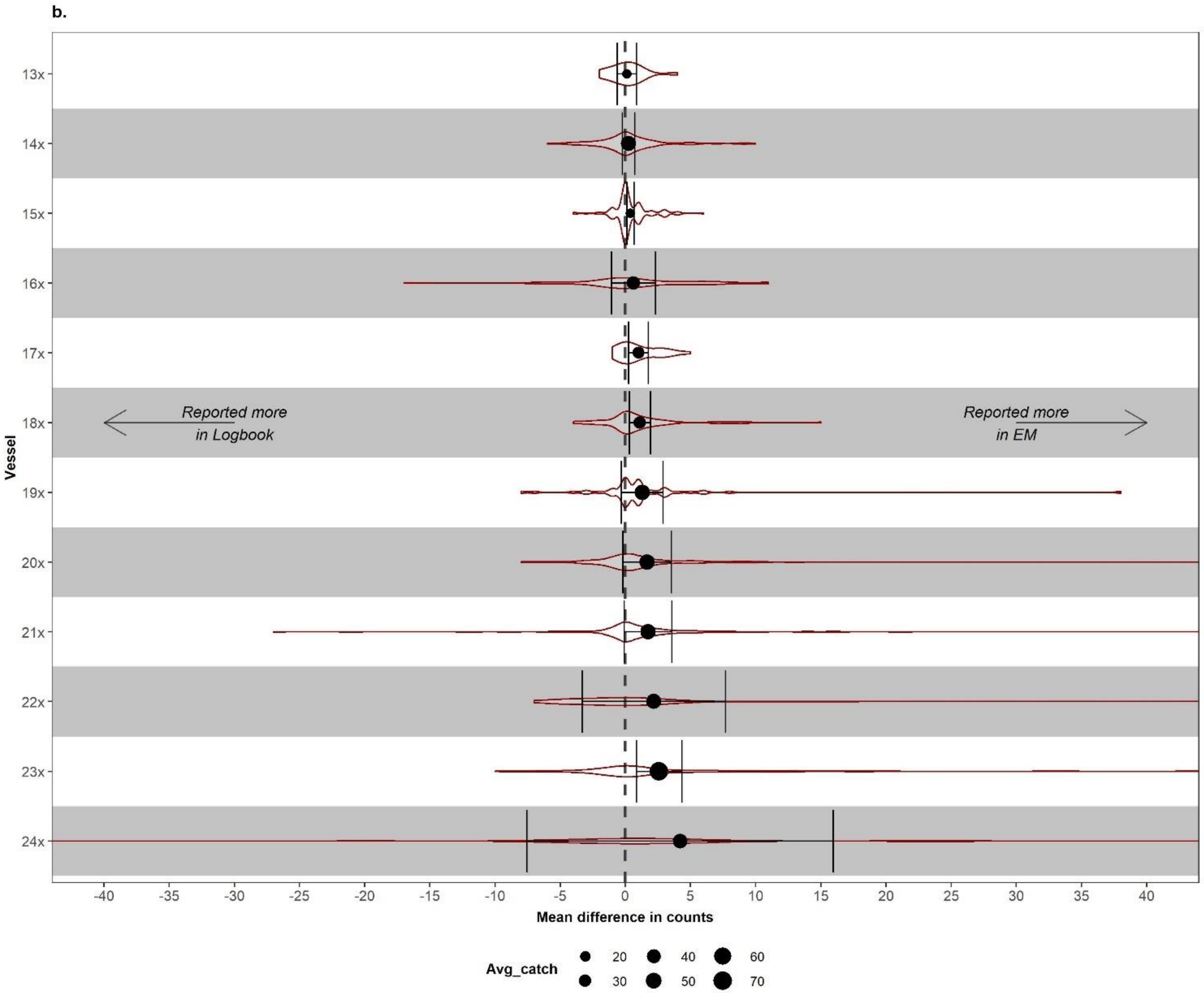
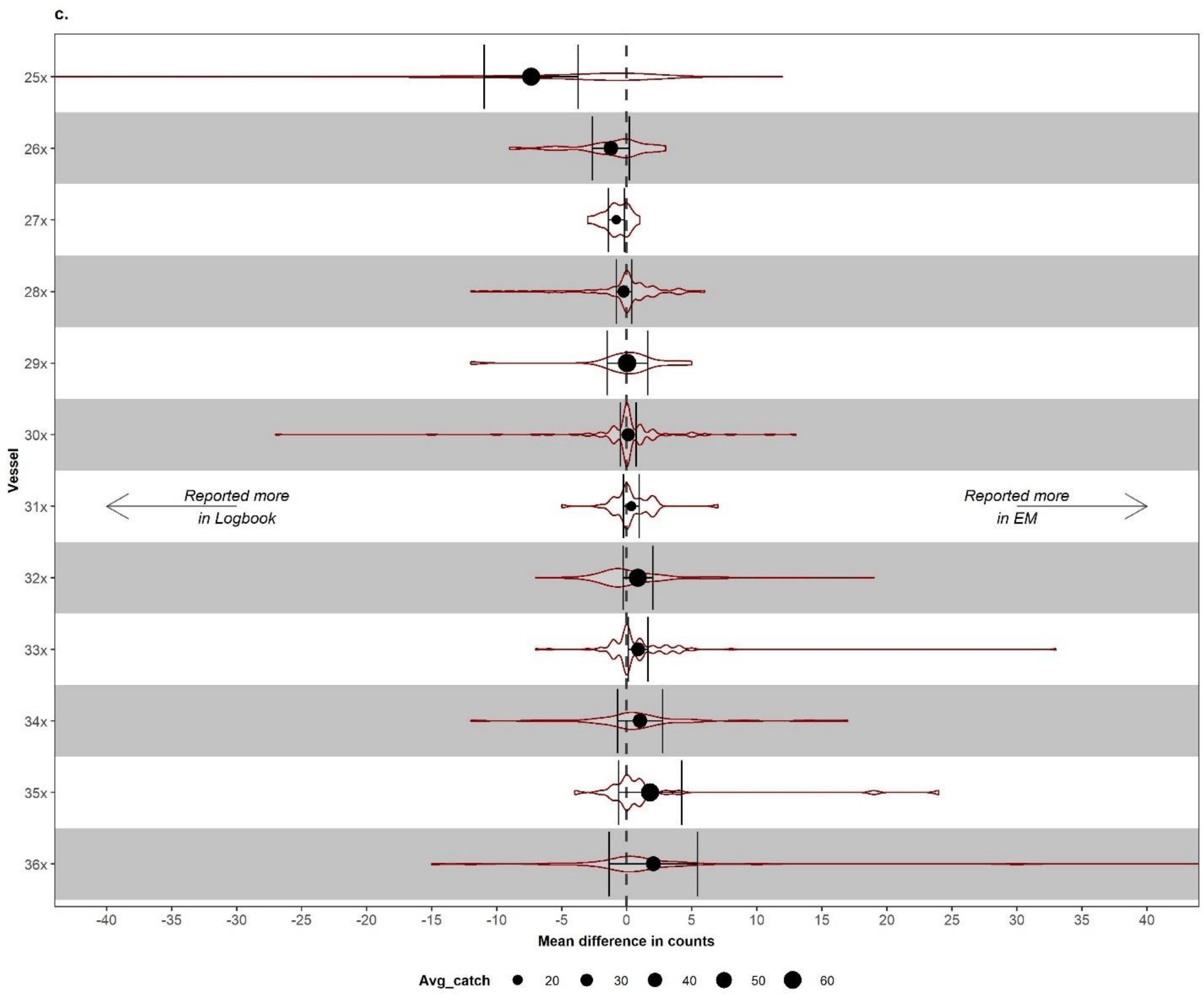


Figure 8c: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing retained gummy shark across the time period examined by vessel. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



School shark

Across the time period examined, 54% of shots audited that contained retained school shark had no difference in logbook and EM counts, 28% had higher counts reported by EM and 17% had higher counts reported by logbook. When differences in counts between logbook and EM were observed in a single shot these were mainly only ~1-2 individuals (Figure 9 and Figure 10). There was evidence of improvement in congruence through time, with 49% of shots in 2016/17 having no difference in logbook and EM counts, increasing to 60% by 2019/20 (Figure 11). The mean difference in counts was negligible across the time period examined (0.2 ± 0.2 individuals) with the average number recorded by both EM and logbook in a single shot relatively low (5.3 ± 1.1 individuals) so as a proportion of the average catch this difference was only 4% (Table 3). This suggest that for every 5.2 individuals reported by logbook, EM is reporting 5.4 individuals. Around 16% of total shots contained a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool, suggesting there is still a small number of shots where ~1-2 individuals are being overlooked (Figure 12). However, evidence suggests this has reduced through time.

An examination of the data at an individual vessel level revealed that for most of the 36 vessels the confidence intervals for the mean difference in counts encompassed zero, with not a large amount of variation between shots (Figure 13a, b, and c). One vessel had higher counts reported by logbook (-3.5 ± 5.6 individuals) with a large average catch (32.6 ± 7.0 individuals) relative to the rest of the fleet across the time period examined, suggesting EM may be having some issues either correctly identifying school shark or observing school shark being retained (note a similar issue was also observed on this vessel for gummy shark).

Figure 9: Logbook and EM reported counts from individual shots containing retained school shark across time period examined. Red dashed line is the 1:1 line.

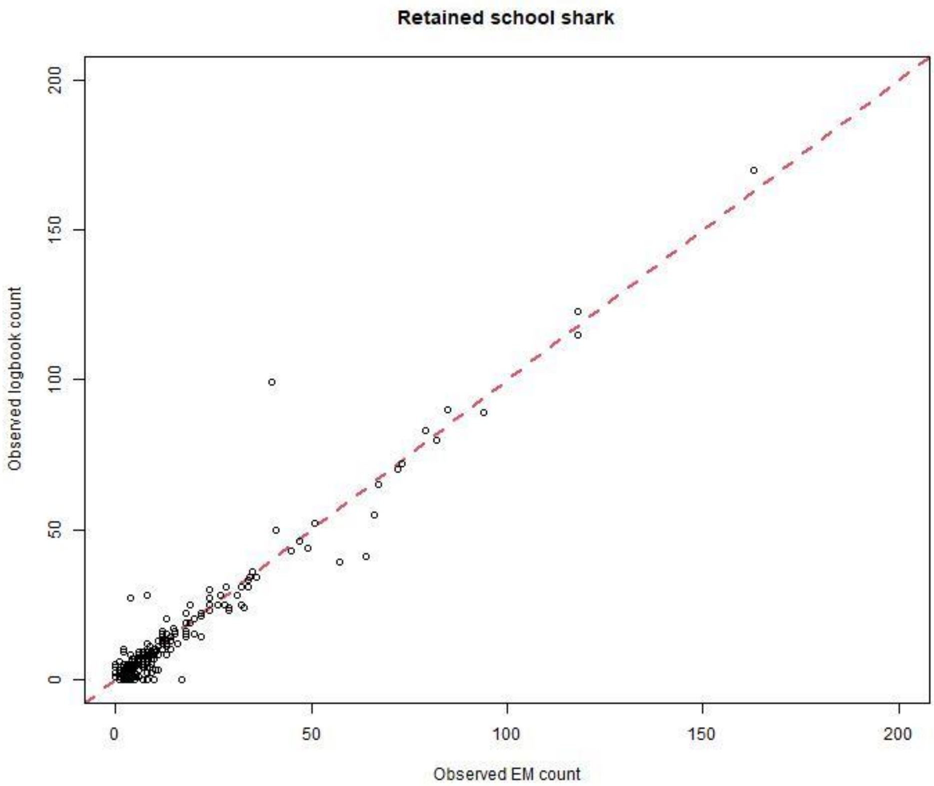


Figure 10: Proportion of shots with specific differences between EM and logbook counts for retained school shark across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

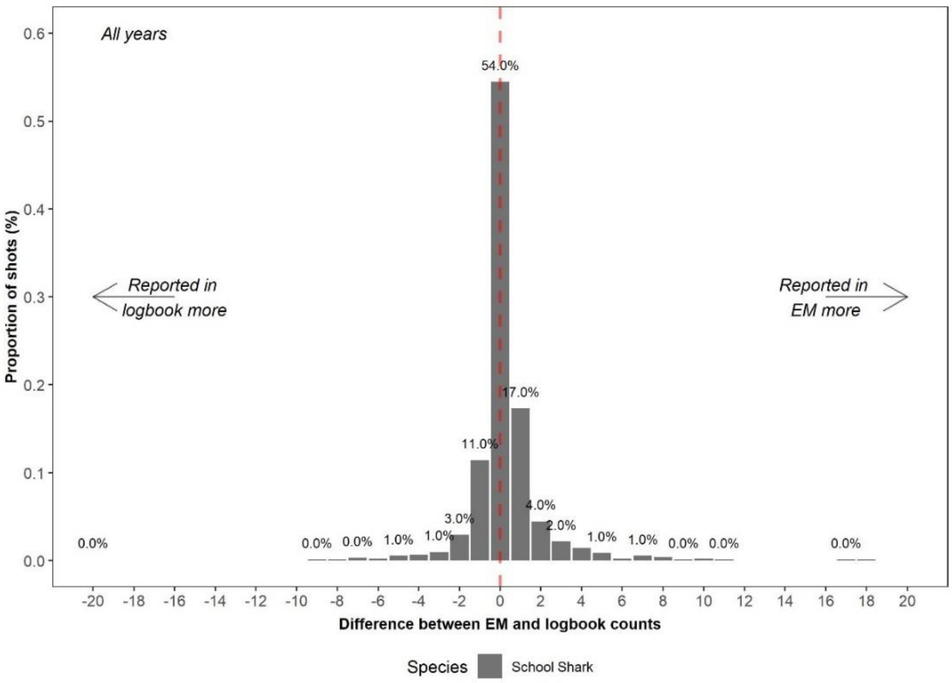


Figure 11: Proportion of shots with specific differences between EM and logbook counts for retained school shark for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

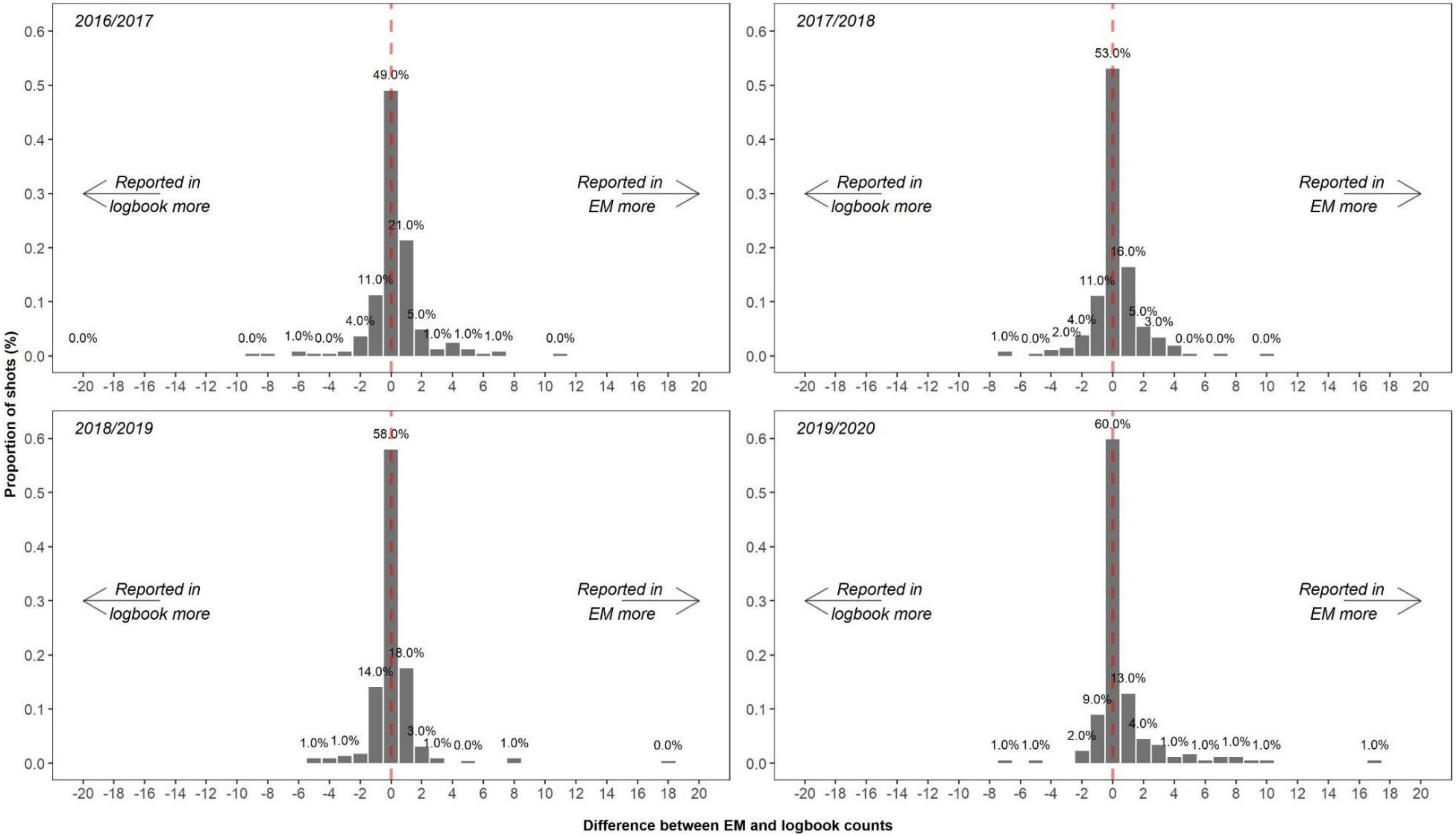


Figure 12: Number of shots with specific differences between EM and logbook counts for retained school shark across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

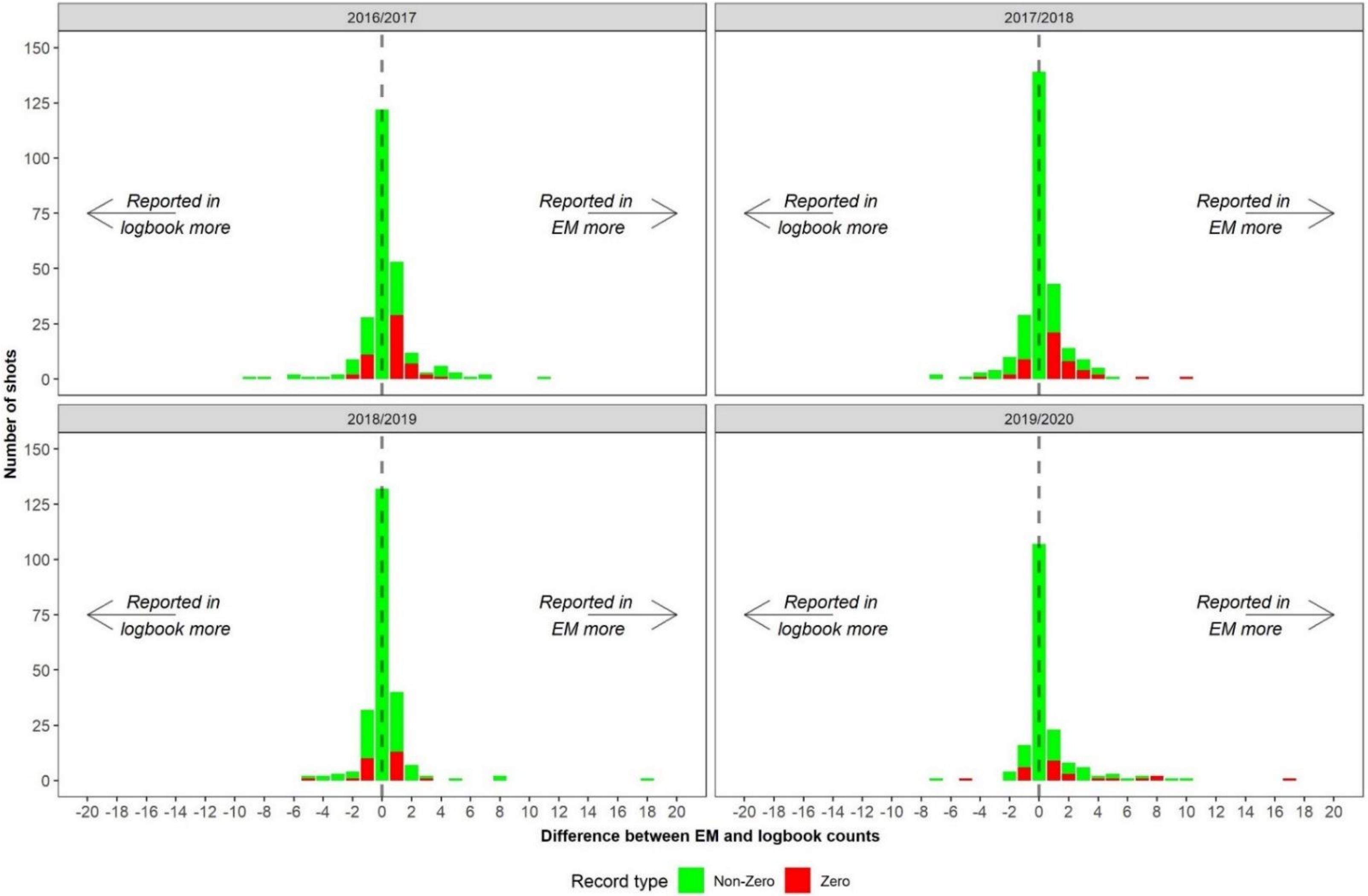


Figure 13a: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing retained school shark across the time period examined by vessel. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

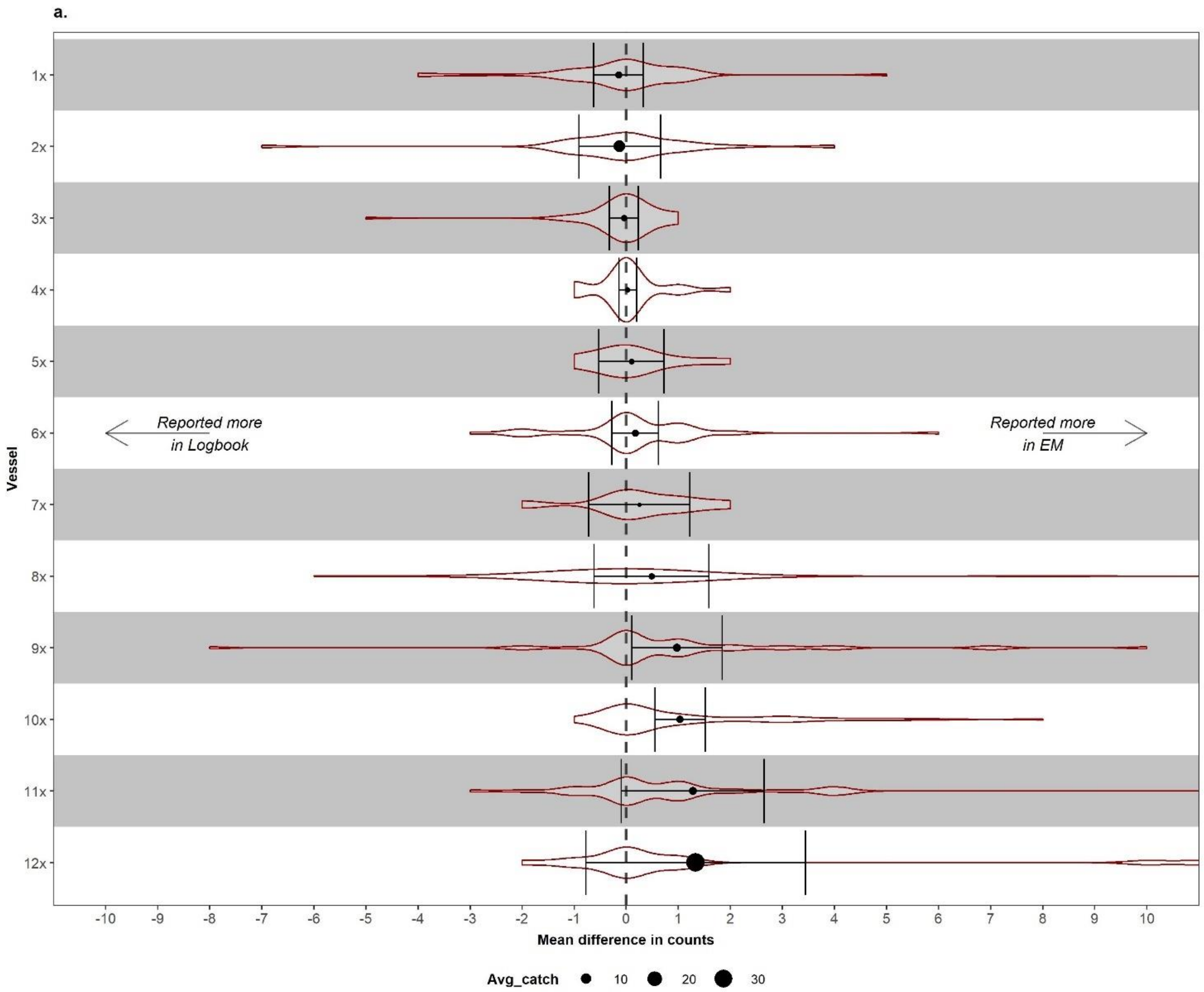


Figure 13b: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing retained school shark across the time period examined by vessel. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

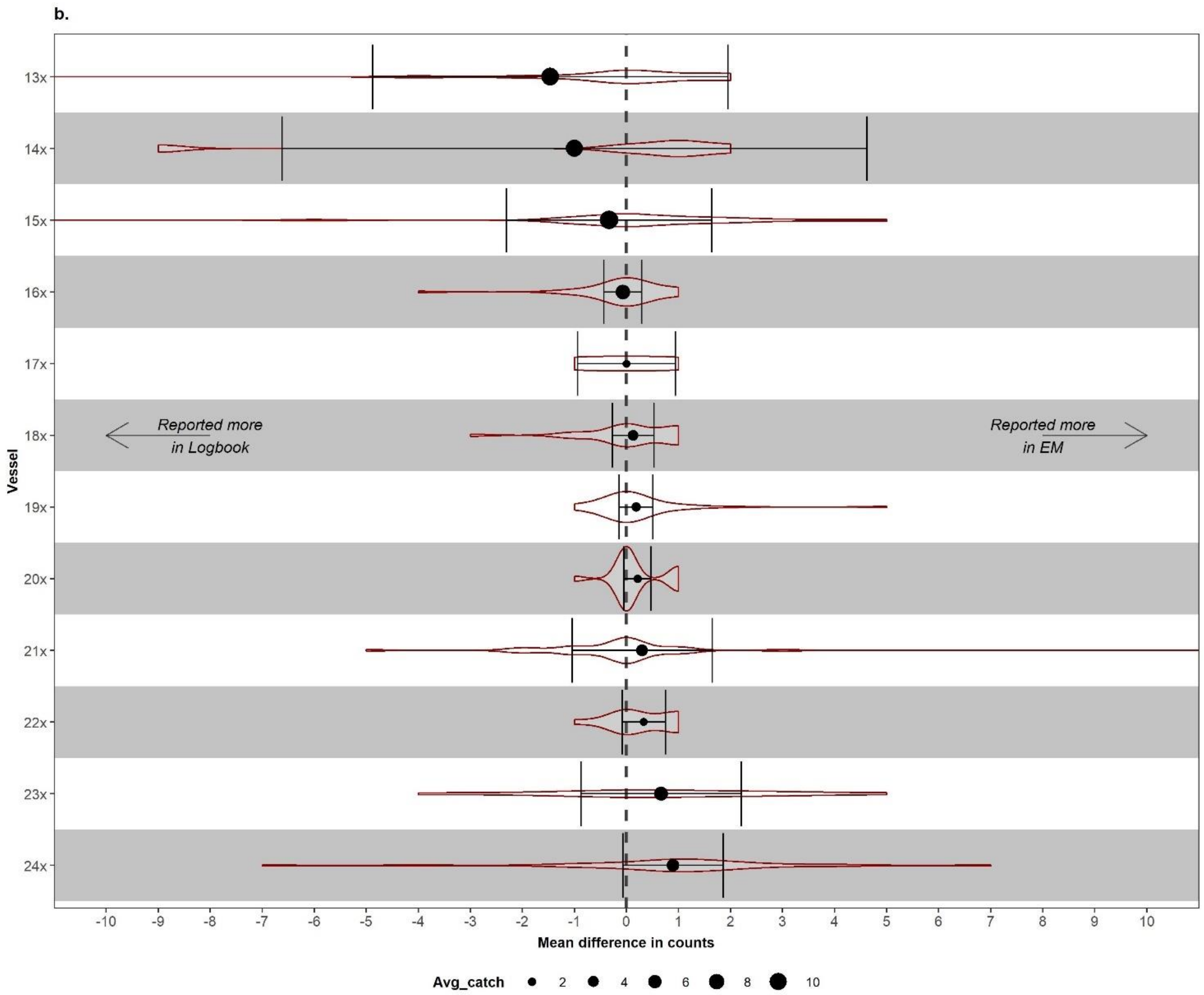
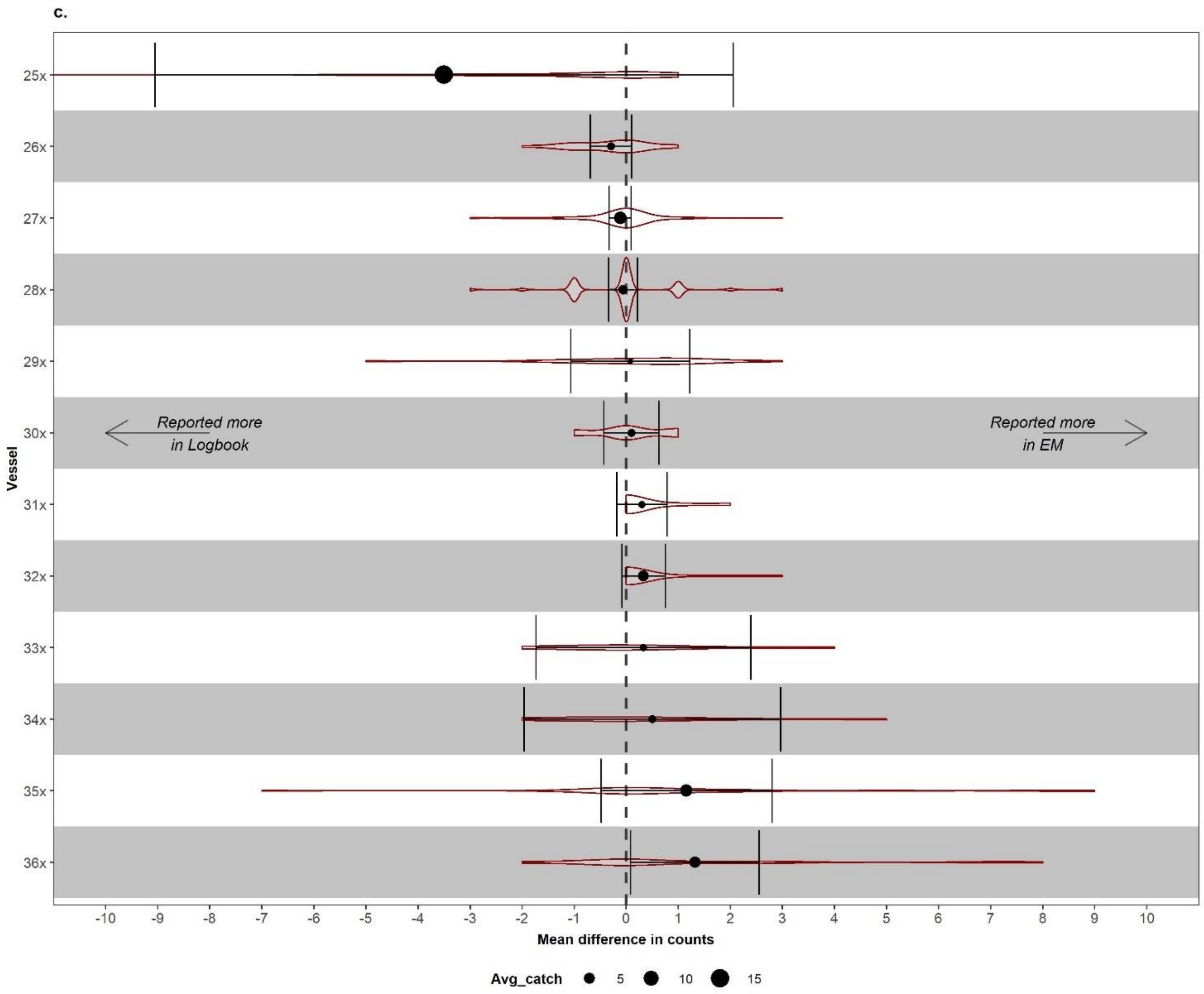


Figure 13c: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing retained school shark across the time period examined by vessel. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



Elephantfish

Across the time period examined, 34% of shots audited that contained retained elephantfish had no difference in logbook and EM counts, 46% had higher counts reported by EM and 20% had higher counts reported by logbook. When differences in counts between logbook and EM were observed in a single shot these were only ~1-3 individuals (Figure 14 and Figure 15). There was evidence of improvement in congruence through time, with 26% of shots in 2016/17 having no difference in logbook and EM counts, increasing to 43% by 2019/20 (Figure 16). The mean difference in counts was low at 1.4 ± 0.3 individuals, but still suggesting that EM is reporting a greater number on average than in logbooks. The average number record by both EM and logbook in a single shot was 10.2 ± 1.2 individuals so as a proportion of the average catch this difference was 14% (Table 3). This suggest that for every 9.5 individuals reported by logbook, EM is reporting 11.6 individuals. Around 24% of total shots contained a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool, suggesting there is still several shots where ~1-3 individuals are being overlooked (Figure 17). This is likely primarily driven by several vessels not reporting any retained elephantfish catch in their logbook (see below). However, evidence suggests this has reduced substantially in the last two years (2018/19 and 2019/20).

An examination of the data at an individual vessel level revealed that for most of the 32 vessels the confidence intervals for the mean difference in counts encompassed zero, but there was much greater variability than observed for gummy and school shark (Figure 18a, b, and c). Importantly, there were four vessels where no retained elephantfish was being reported at all in logbooks but being reported by EM, which may warrant further investigation. If these four vessels were removed from the analysis, then the mean difference in counts (outlined above) would be lower, as well as the proportion of total shots containing a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool.

Figure 14: Logbook and EM reported counts from individual shots containing retained elephantfish across time period examined. Red dashed line is the 1:1 line.

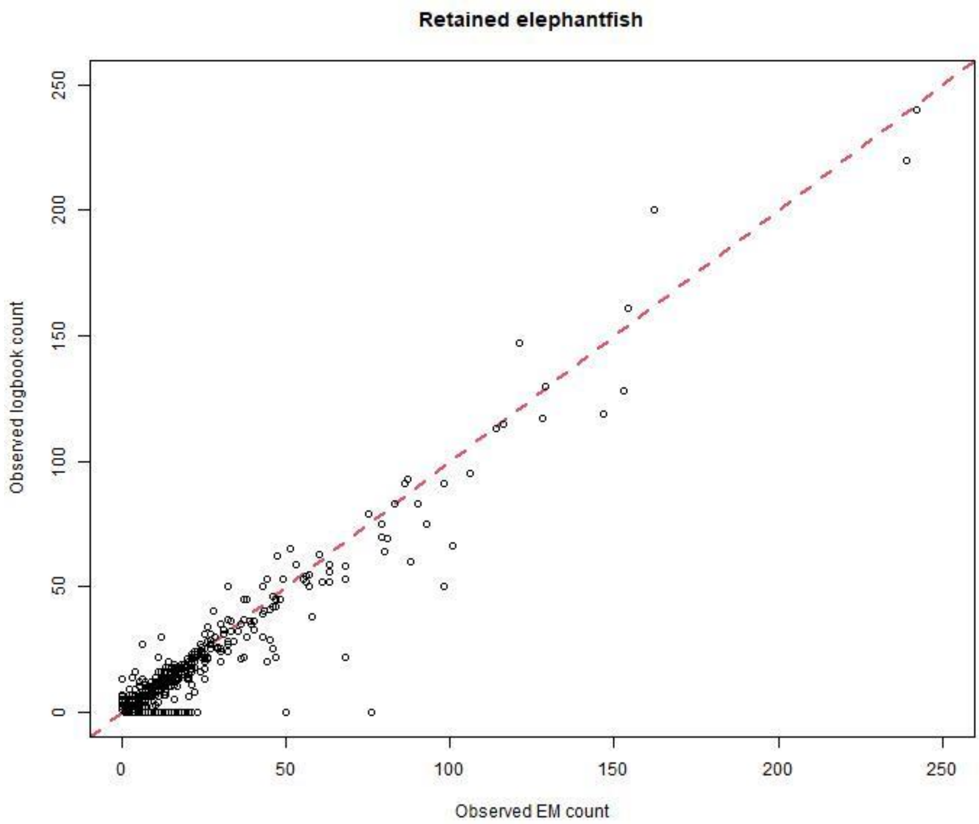


Figure 15: Proportion of shots with specific differences between EM and logbook counts for retained elephantfish across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

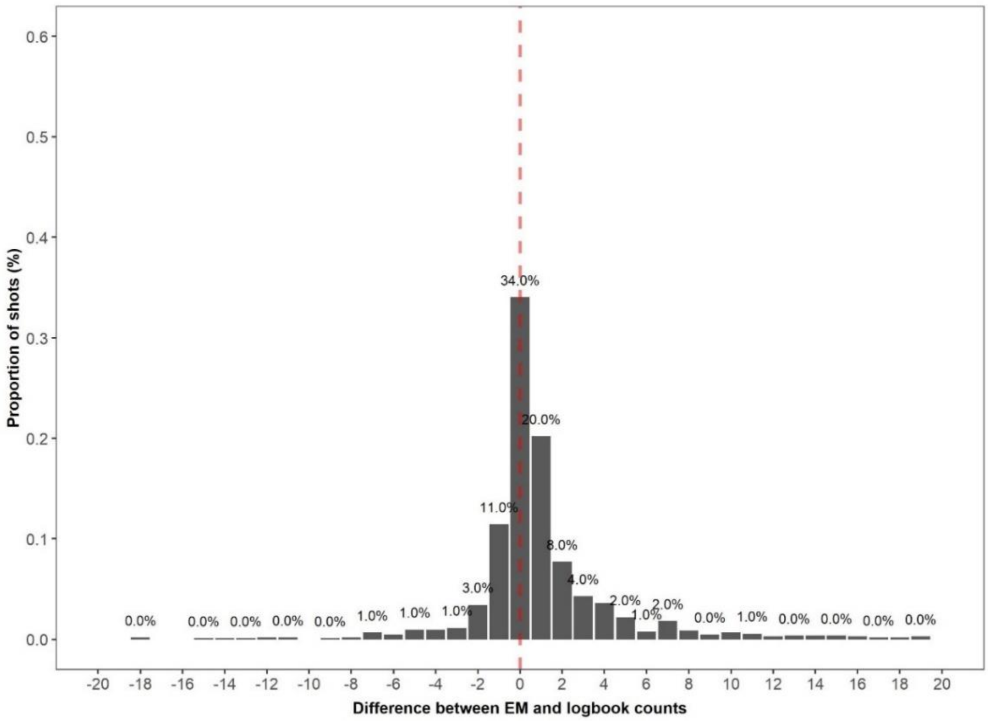


Figure 16: Proportion of shots with specific differences between EM and logbook counts for retained elephantfish for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

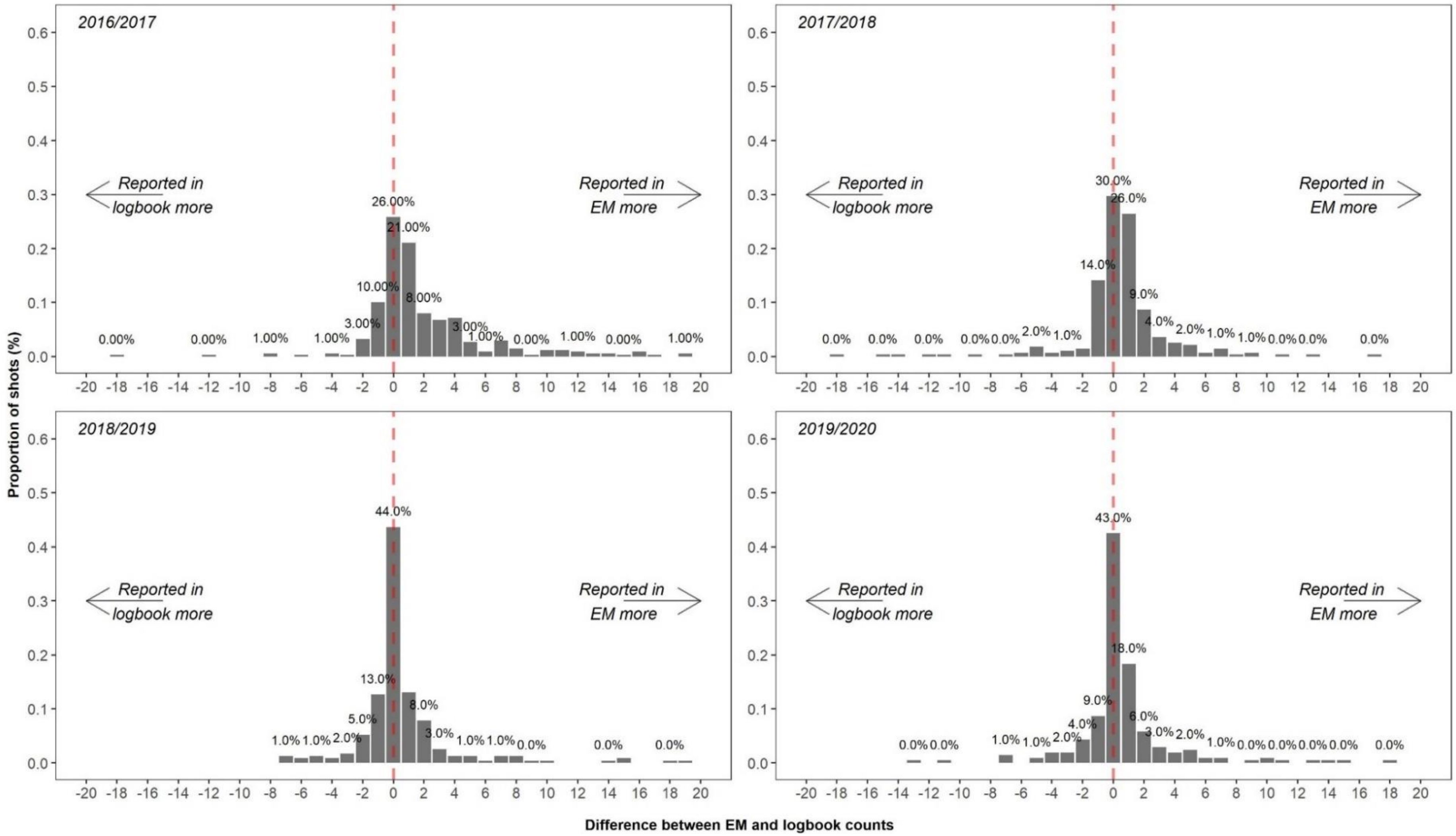


Figure 17: Number of shots with specific differences between EM and logbook counts for retained elephantfish across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

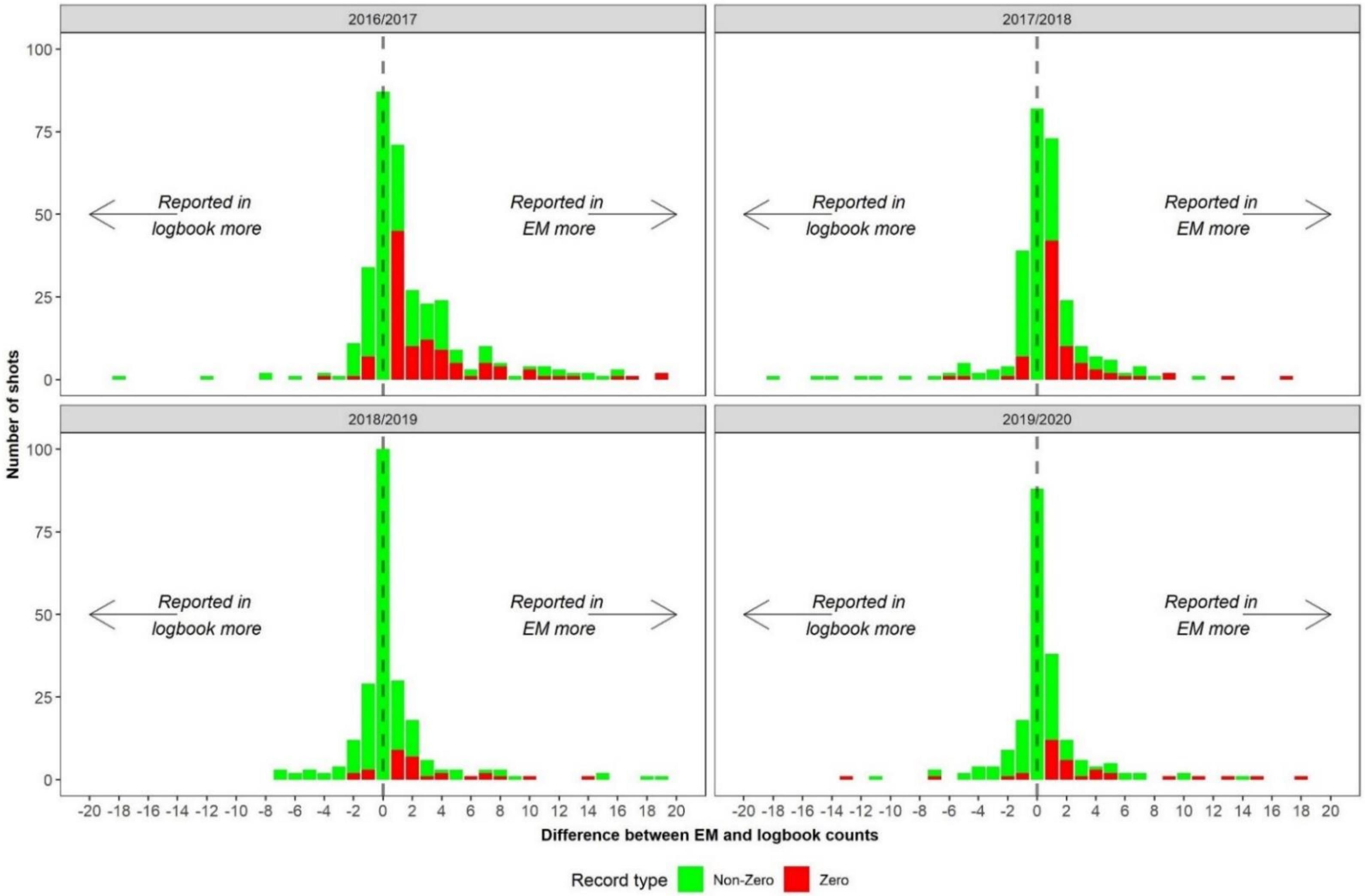


Figure 18a: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing retained elephantfish across the time period examined by vessel. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

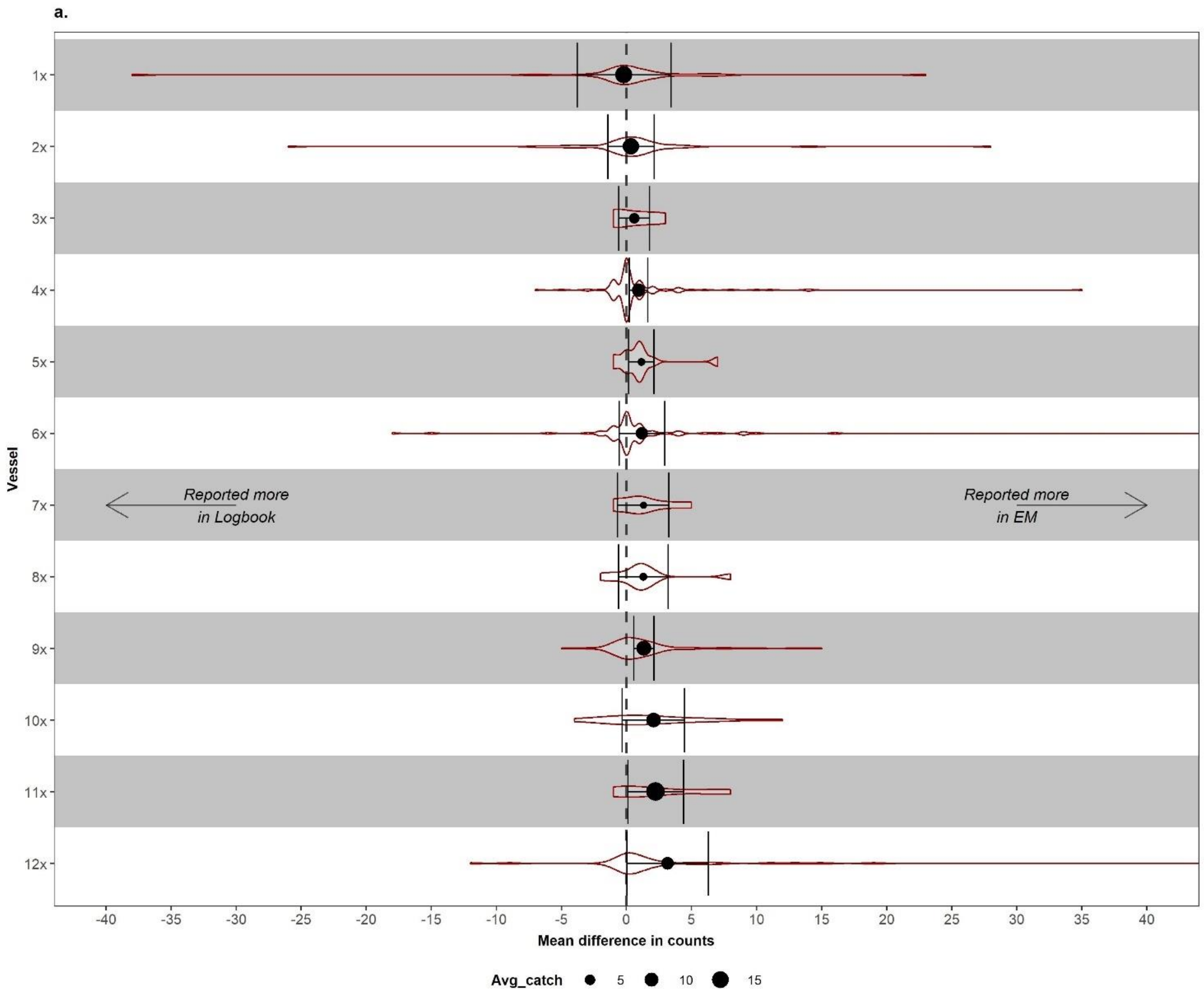


Figure 18b: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing retained elephantfish across the time period examined by vessel. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

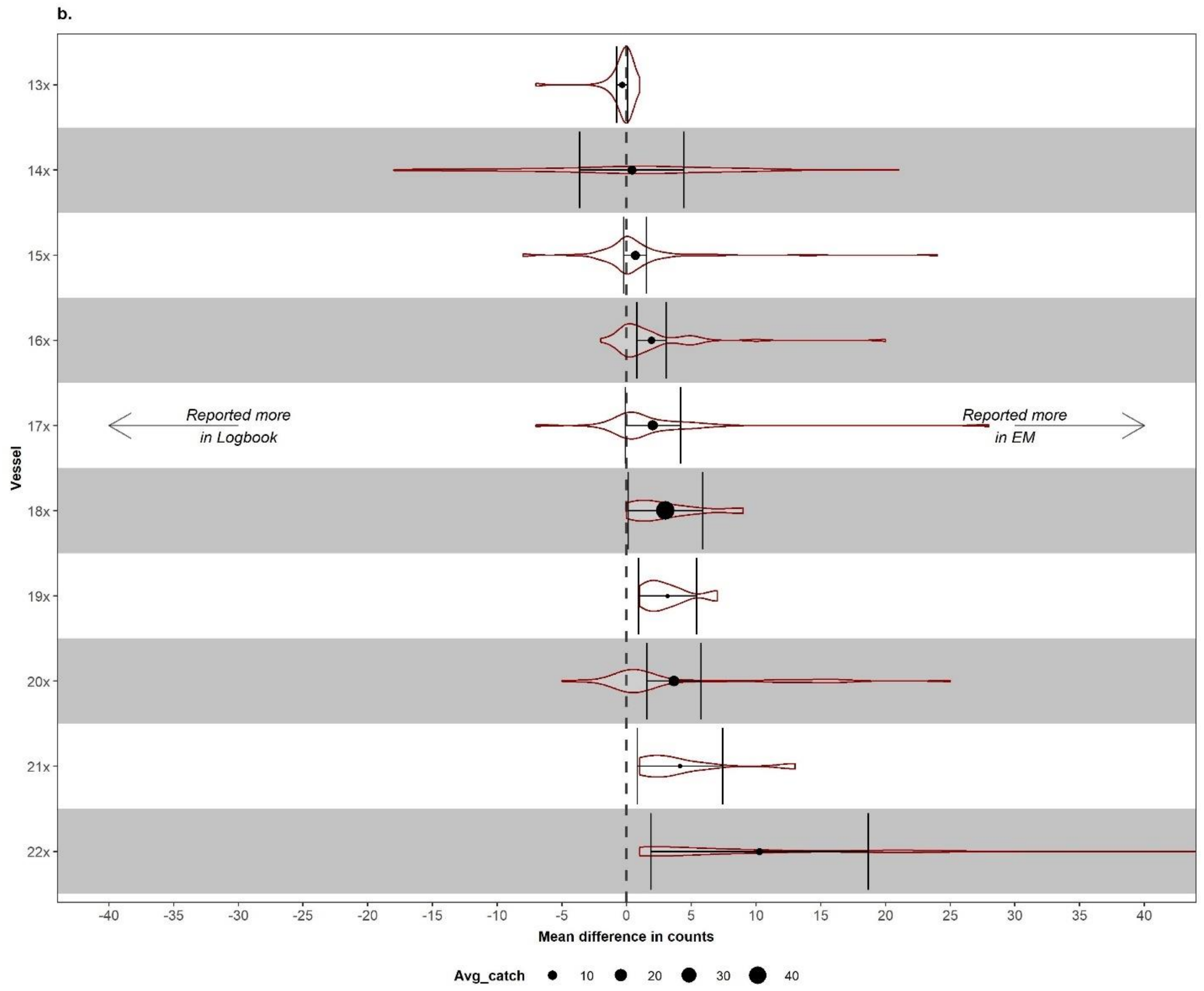
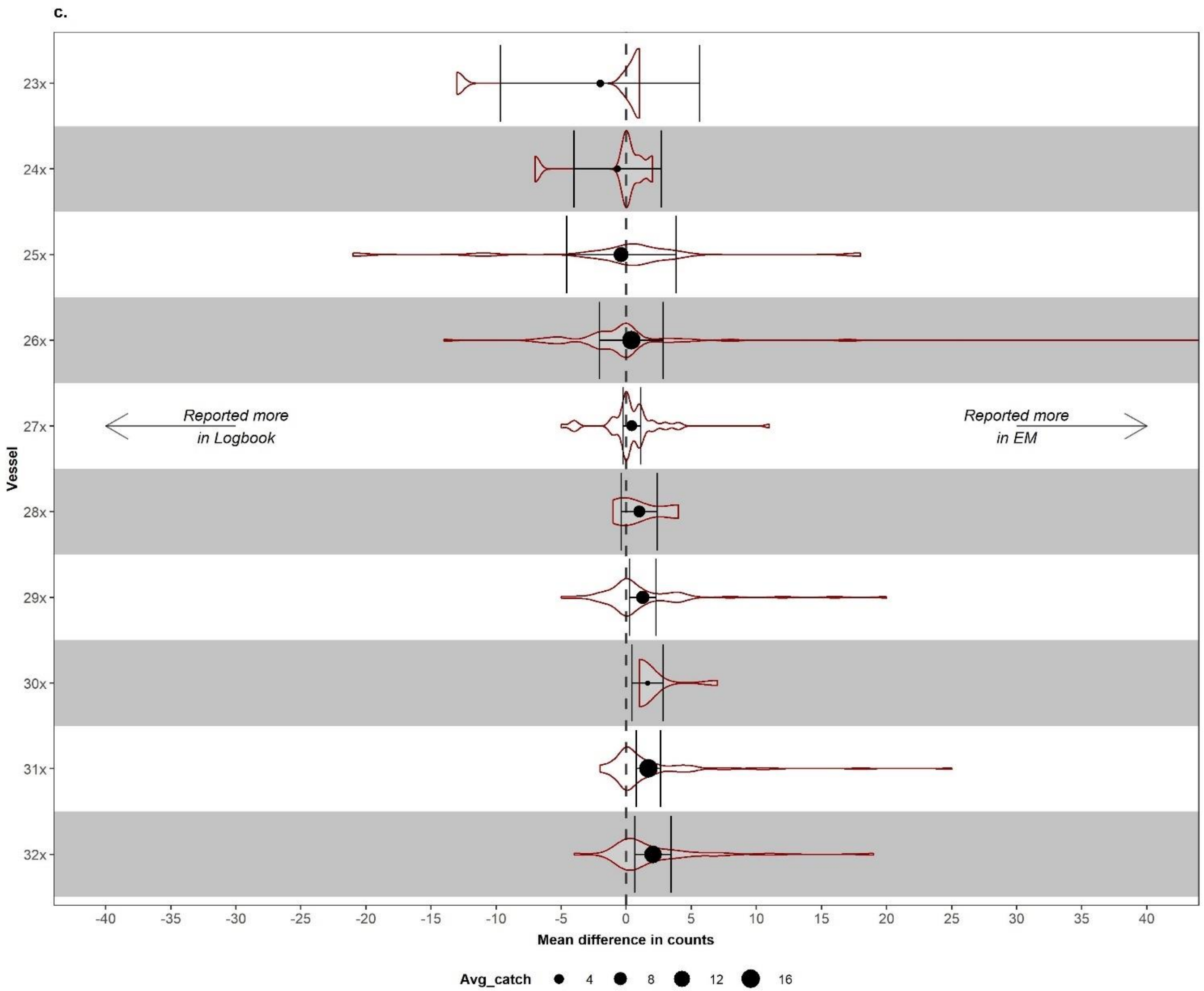


Figure 18c: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing retained elephantfish across the time period examined by vessel. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



Sawsharks (grouped)

Across the time period examined, 40% of shots audited that contained retained sawsharks (grouped) had no difference in logbook and EM counts, 45% had higher counts reported by EM and 15% had higher counts reported by logbook. When differences in counts between logbook and EM were observed in a single shot these were typically around ~1-4 individuals (Figure 19 and Figure 20). There was evidence of improvement in congruence through time, with 35% of shots in 2016/17 having no difference in logbook and EM counts, increasing to 44% by 2019/20 (Figure 21). The mean difference in counts was low at 1.4 ± 0.3 individuals, but still suggesting that EM is reporting a greater number on average than in logbooks. The average number recorded by both EM and logbook in a single shot was 11.5 ± 0.8 individuals, so as a proportion of the average catch this difference was around 13% (Table 3). This suggest that for every 10.8 individuals reported by logbook, EM is reporting 12.2 individuals. Only 11% of total shots contained a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool, suggesting that while there are some shots where ~1-4 individuals are being overlooked, it is not as prevalent in comparison to other commercial species, such as elephantfish (Figure 22).

An examination of the data at an individual vessel level revealed that for most of the 36 vessels the confidence intervals for the mean difference in counts encompassed zero, but there was a large amount of variation between shots (Figure 23a, b and c). Furthermore, many shots had higher differences in counts than observed for gummy and school shark. This included shots with greater numbers being reported by EM than logbook and vice-versa, but again skewed more towards EM reporting higher numbers than logbook.

Figure 19: Logbook and EM reported counts from individual shots containing retained sawsharks (grouped) across time period examined. Red dashed line is the 1:1 line.

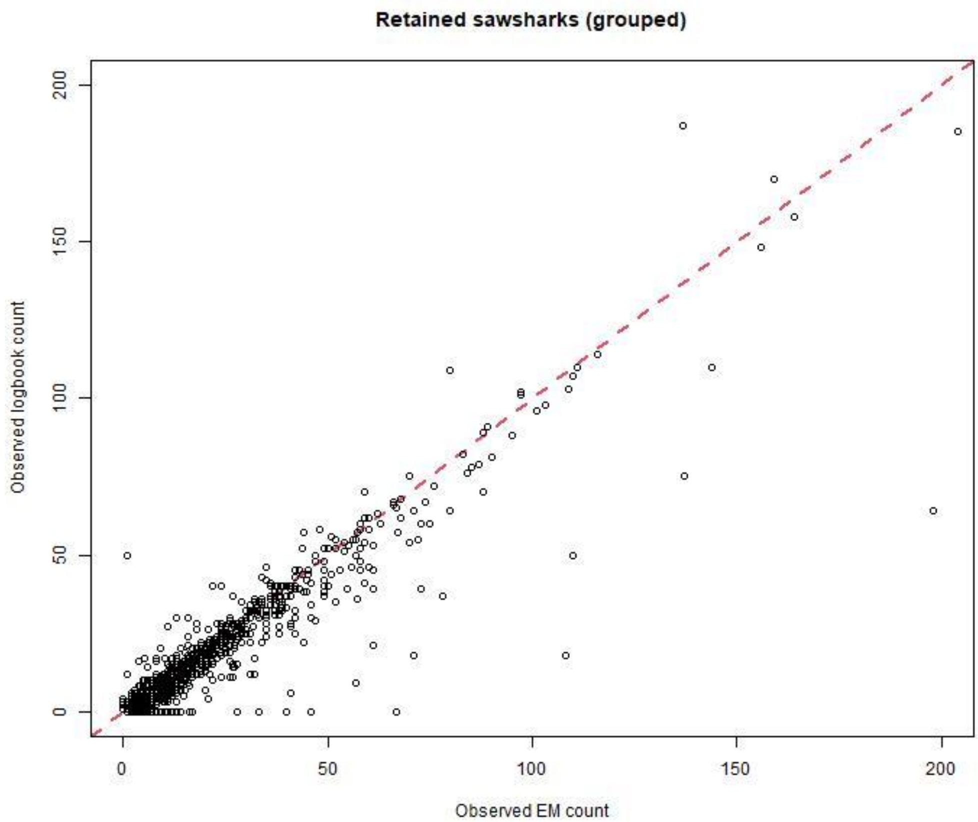


Figure 20: Proportion of shots with specific differences between EM and logbook counts for retained sawsharks (grouped) across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

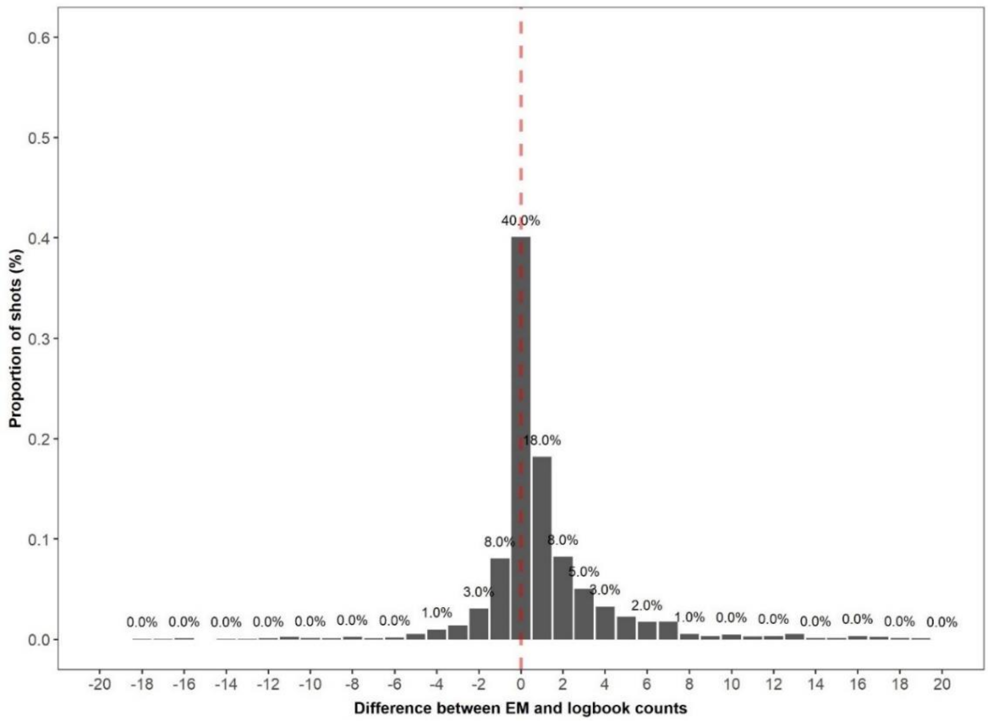


Figure 21: Proportion of shots with specific differences between EM and logbook counts for retained sawsharks (grouped) for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

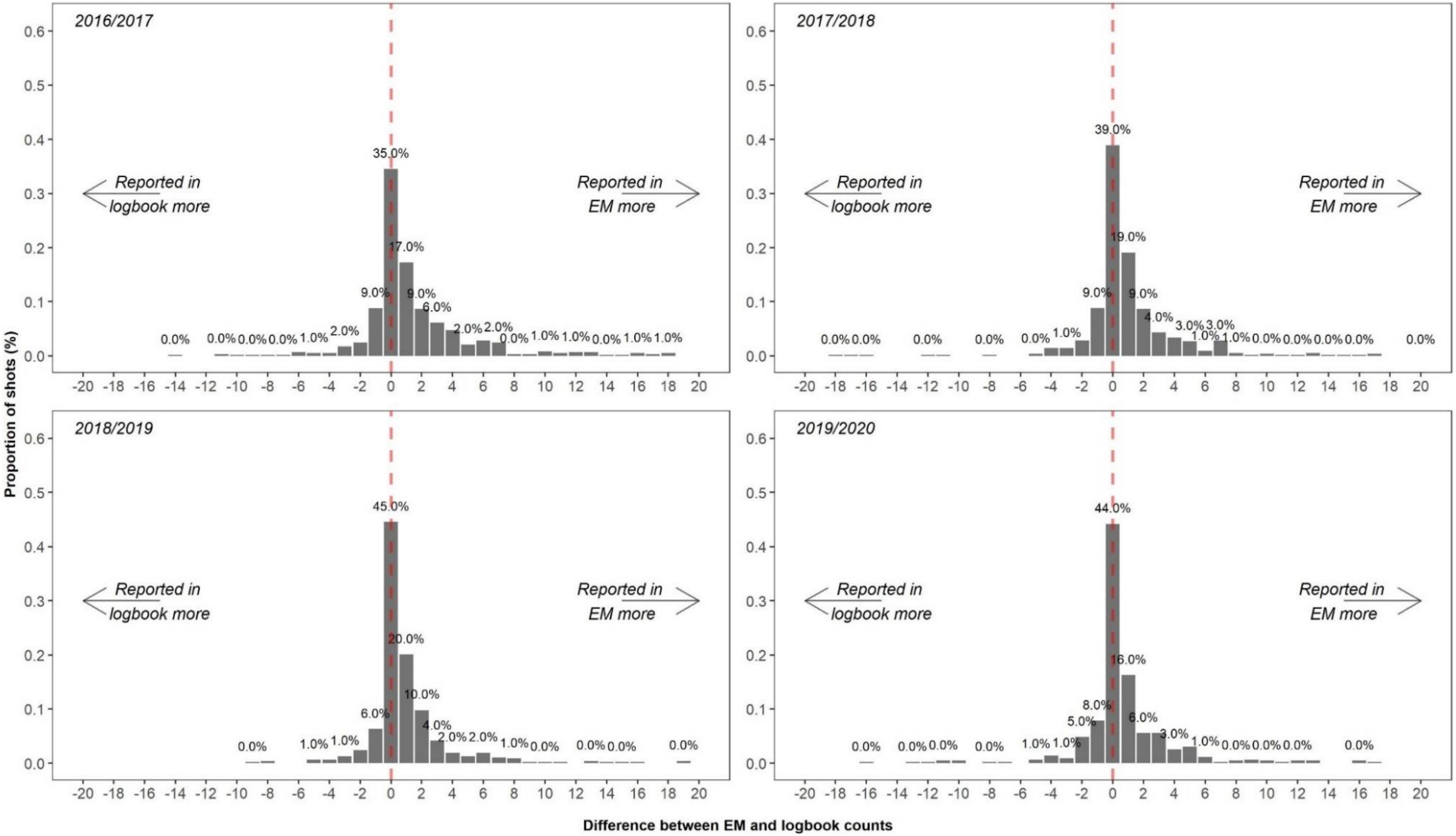


Figure 22: Number of shots with specific differences between EM and logbook counts for retained sawsharks (grouped) across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

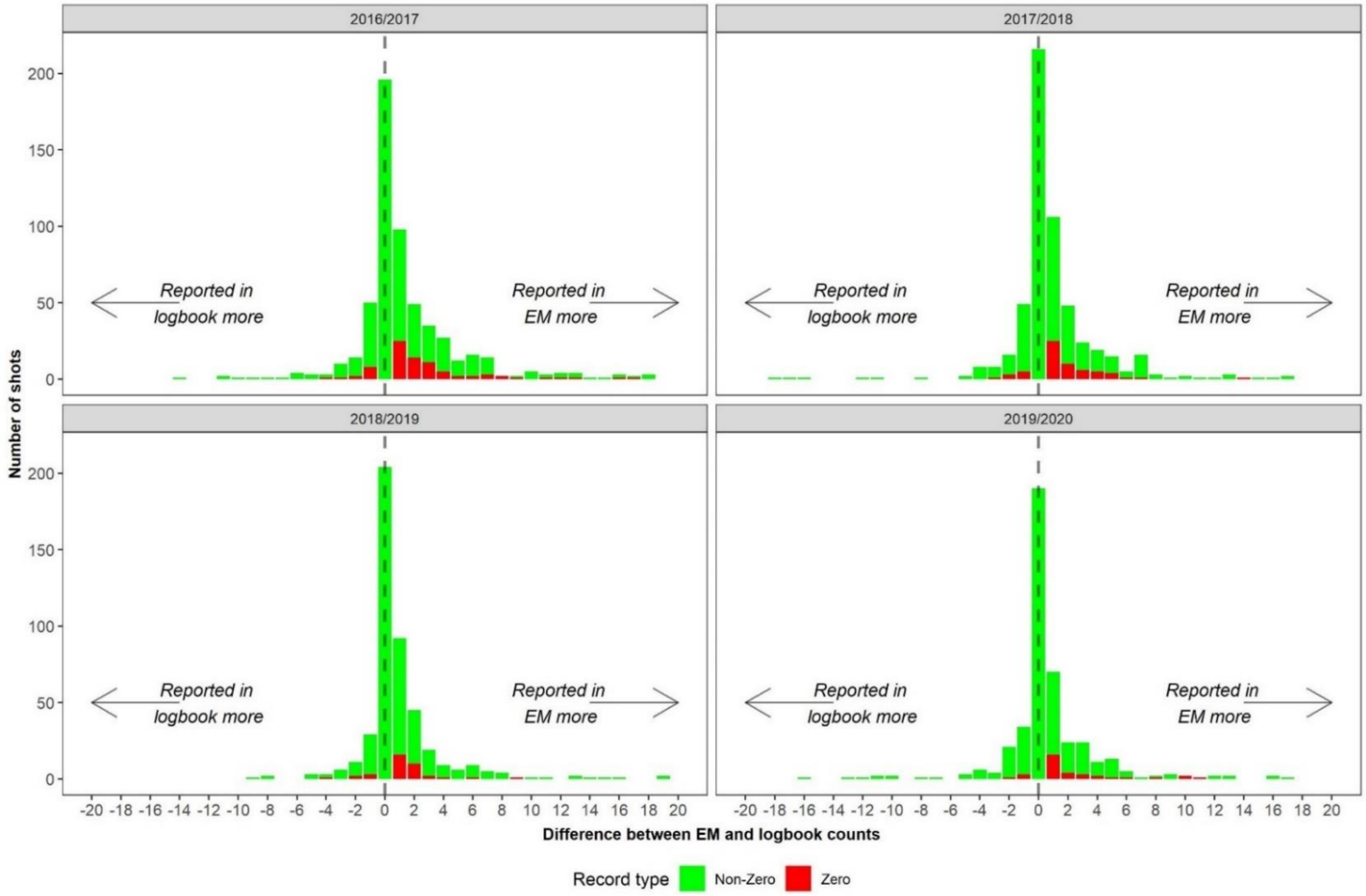


Figure 23a: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing retained sawsharks (grouped) across the time period examined by vessel. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

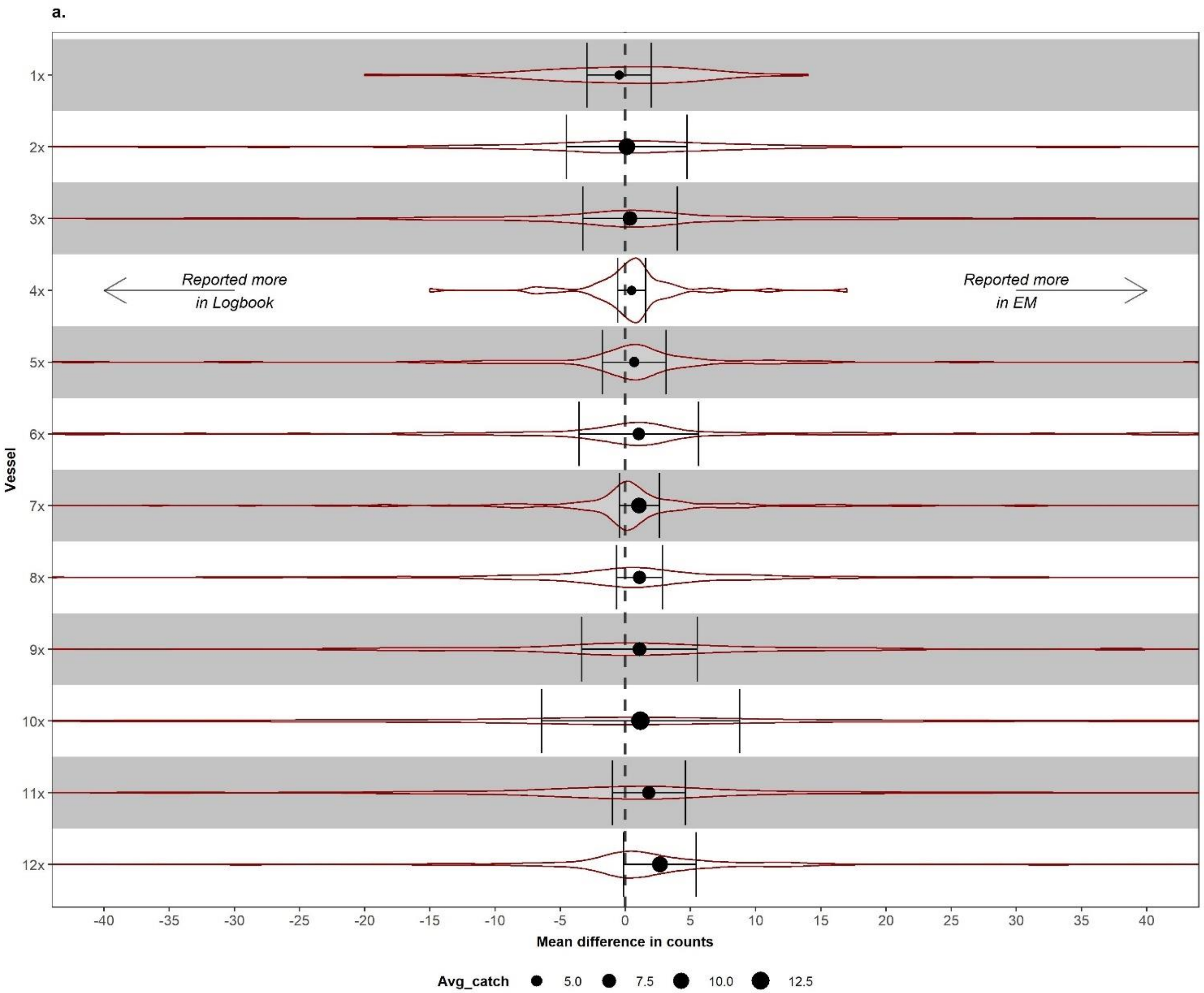


Figure 23b: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing retained sawsharks (grouped) across the time period examined by vessel. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

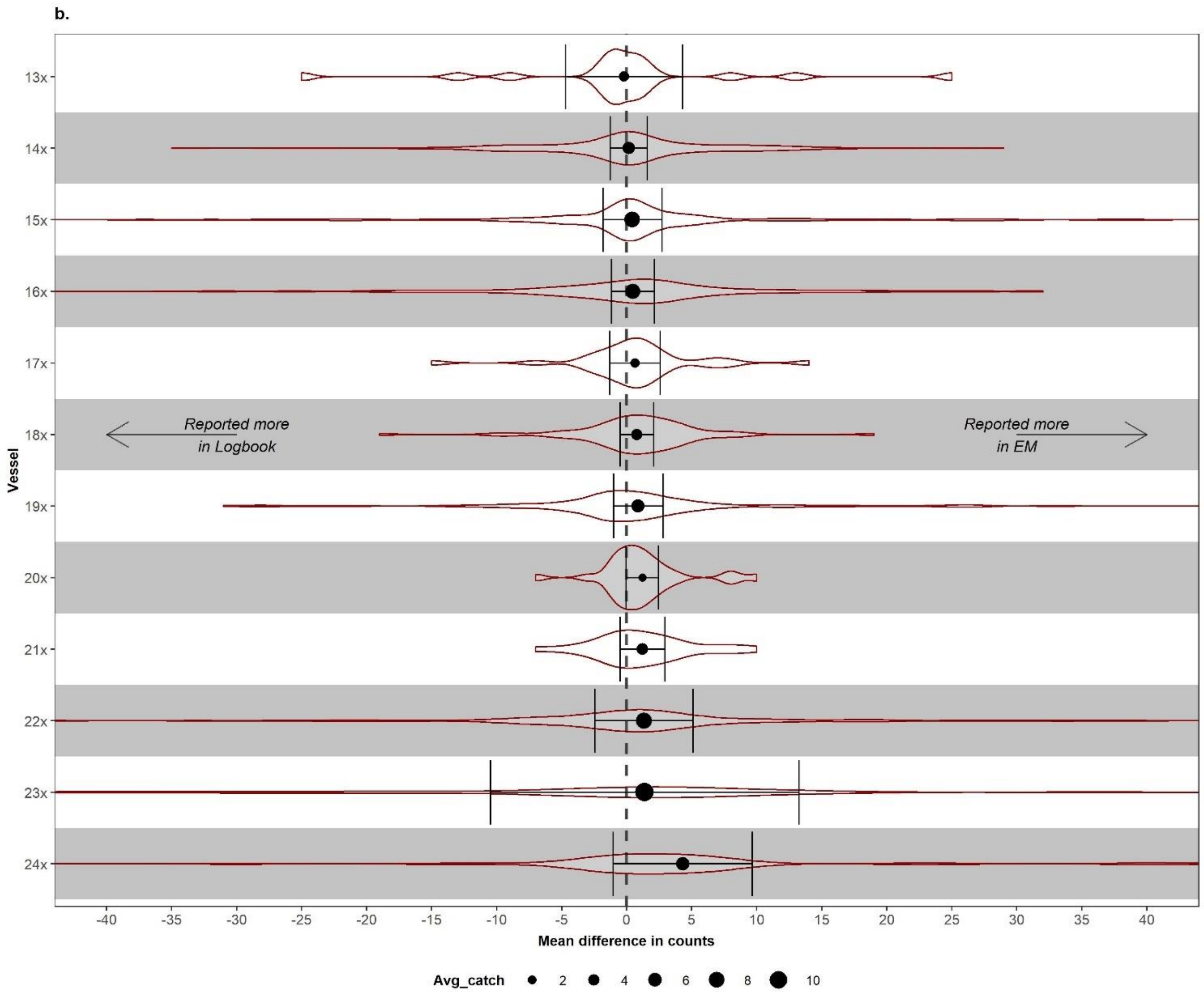
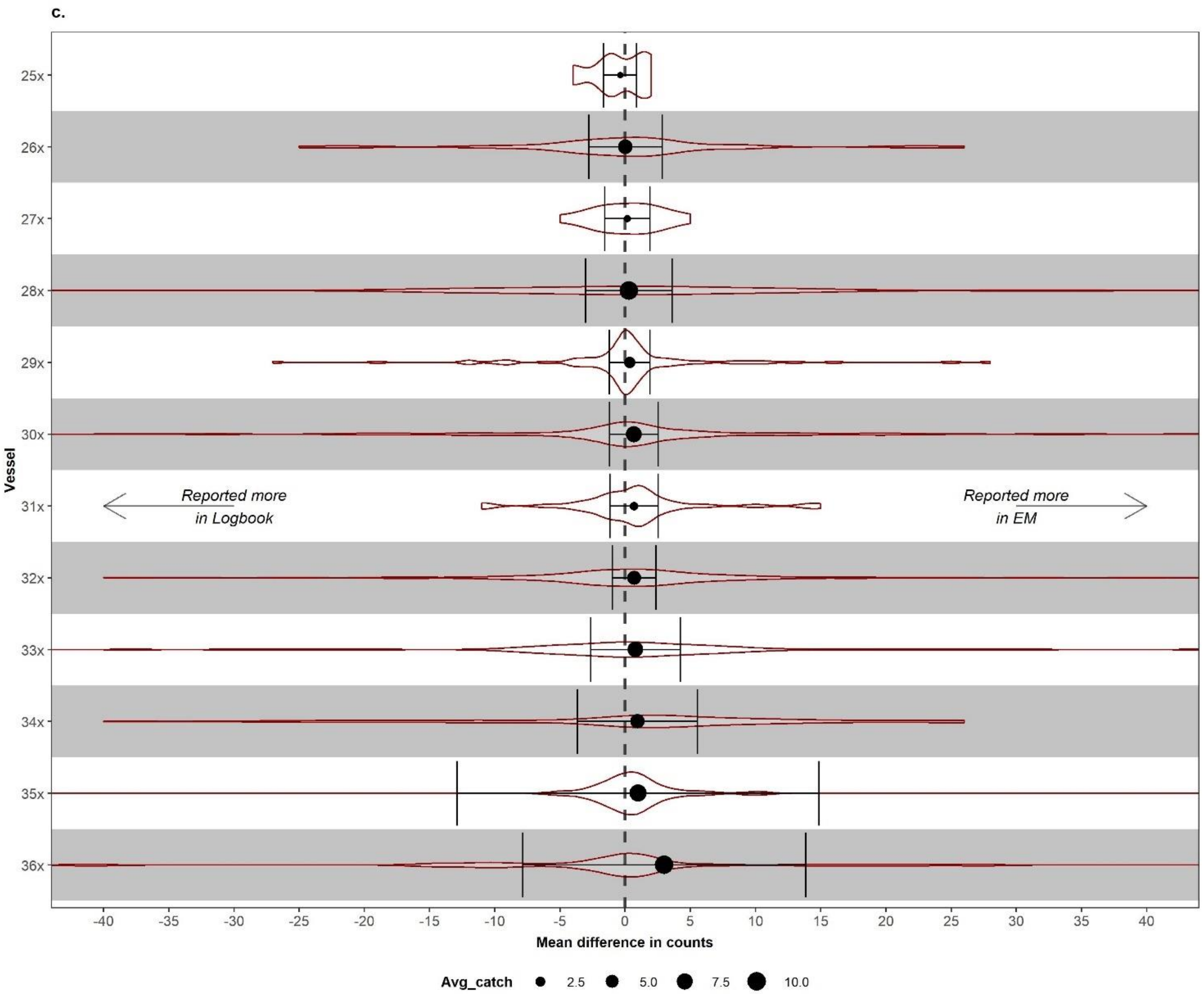


Figure 23c: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing retained sawsharks (grouped) across the time period examined by vessel. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



3.1.2 Discarded catch

In the GNS, there were a total of 12 species that made up 95% of the reported discarded catch from the logbook audited shots between 2016/17 and 2019/20. These species are displayed in (Table 5 and Figure 24a, b) in descending order of the proportion of catch.

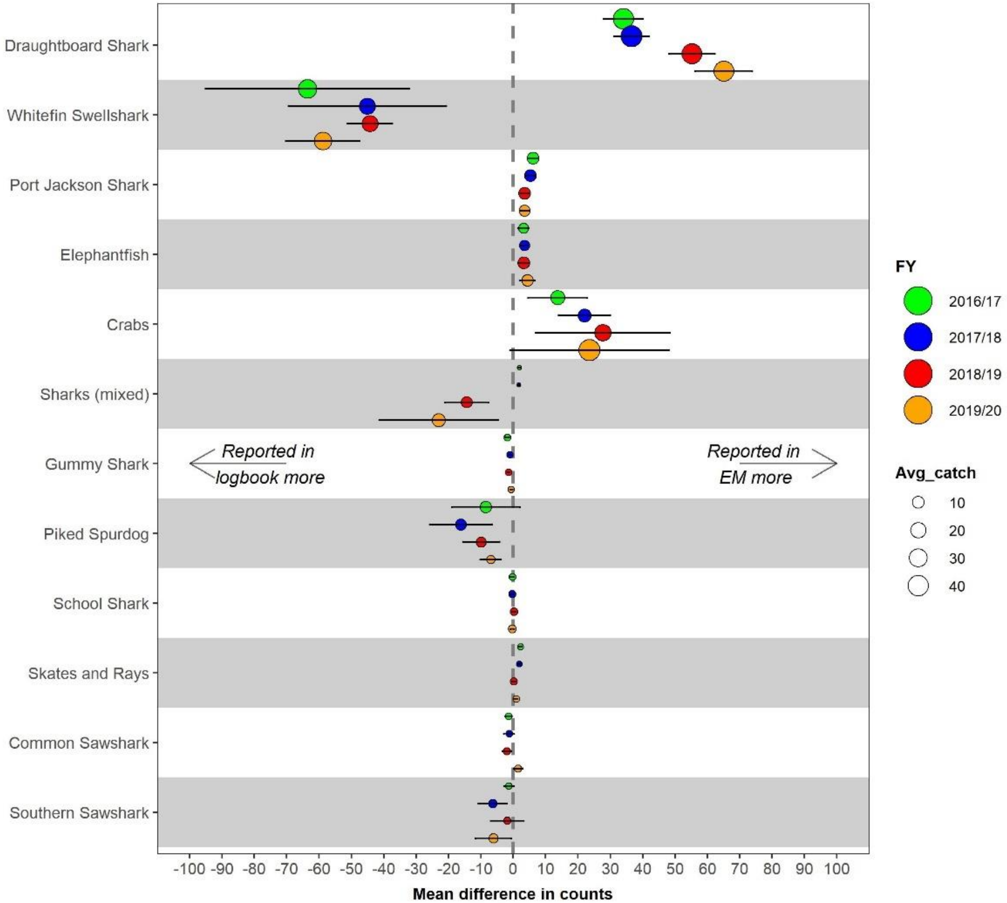
For most discarded species, both the mean difference in counts as a proportion of the average catch and the proportion of zeros reporting by either logbook or EM when ≥1 individual was reported by the other data collection tool was high and substantially greater than for retained catch (Table 5). Common sawshark, southern sawshark, piked spurdog, sharks (mixed group), whitefin swellshark and gummy shark were all reported in higher numbers by logbook than EM, while draughtboard shark, Port Jackson shark, elephantfish and skates and rays (mixed group) were reported more by EM than logbook (Figure 25). School shark was the exception, with a mean difference in counts of -0.2 ± 0.3 individuals across the time period examined and the average number recorded discarded by both EM and logbook in a shot was 2.7 ± 0.1 individuals. As a proportion of the average catch, the mean difference for school shark was therefore only -6% (Table 5). However, individuals were commonly unreported with 49% 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 5: 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 GNS.

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
Draughtboard shark	*Cephaloscyllium laticeps*	46.3 (±3.4)	40.9 (±2.3)	113%	59%
Whitefin swellshark	*Cephaloscyllium albipinnum*	-51.7 (±6.4)	25.9 (±3.2)	-199%	99%
Port Jackson shark	*Heterodontus portusjacksoni*	4.8 (±0.7)	9.7 (±0.7)	49%	43%
Elephantfish	*Callorhinchus milii*	3.5 (±0.8)	7.6 (±0.9)	46%	55%
Crabs (mixed group)	*Crustacea*	21.6 (±7.7)	23.0 (±5.5)	94%	84%
Sharks (mixed group)	*Elasmobranchii*	-8.5 (±4.7)	5.7 (±2.3)	-148%	97%
Gummy shark	*Mustelus antarcticus*	-1.2 (±0.2)	2.0 (±0.2)	-61%	67%
Piked spurdog	*Squalus megalop*	-10.2 (±4.6)	7.3 (±2.4)	-140%	96%

School shark	*Galeorhinus galeus*	-0.2 (±0.3)	2.7 (±0.1)	-6%	49%
Skates and rays (mixed group)	*Elasmobranchii*	1.3 (±0.2)	1.7 (±0.1)	77%	84%
Common sawshark	*Pristiophorus cirratus*	-0.9 (±0.7)	2.2 (±0.4)	-39%	94%
Southern sawshark	*Pristiophorus nudipinnis*	-4.0 (±2.0)	3.0 (±0.9)	-130%	97%

Figure 24: Reporting of discarded species in the GNS (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.



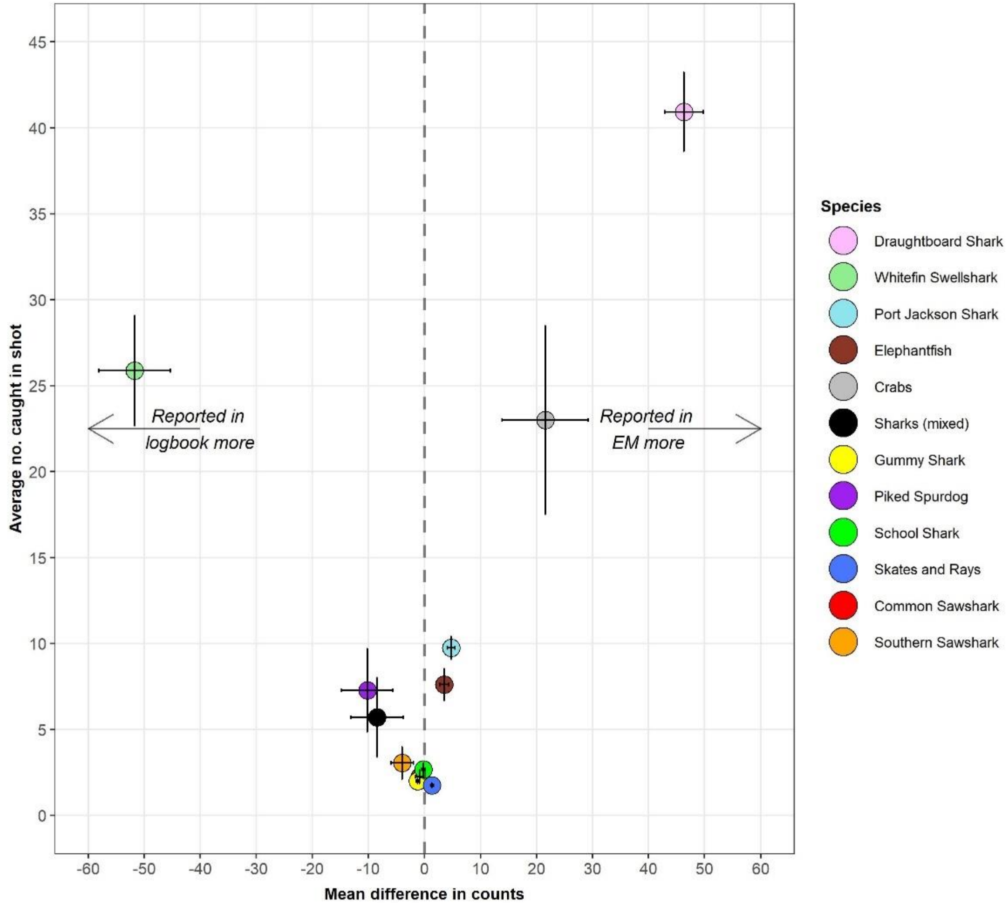
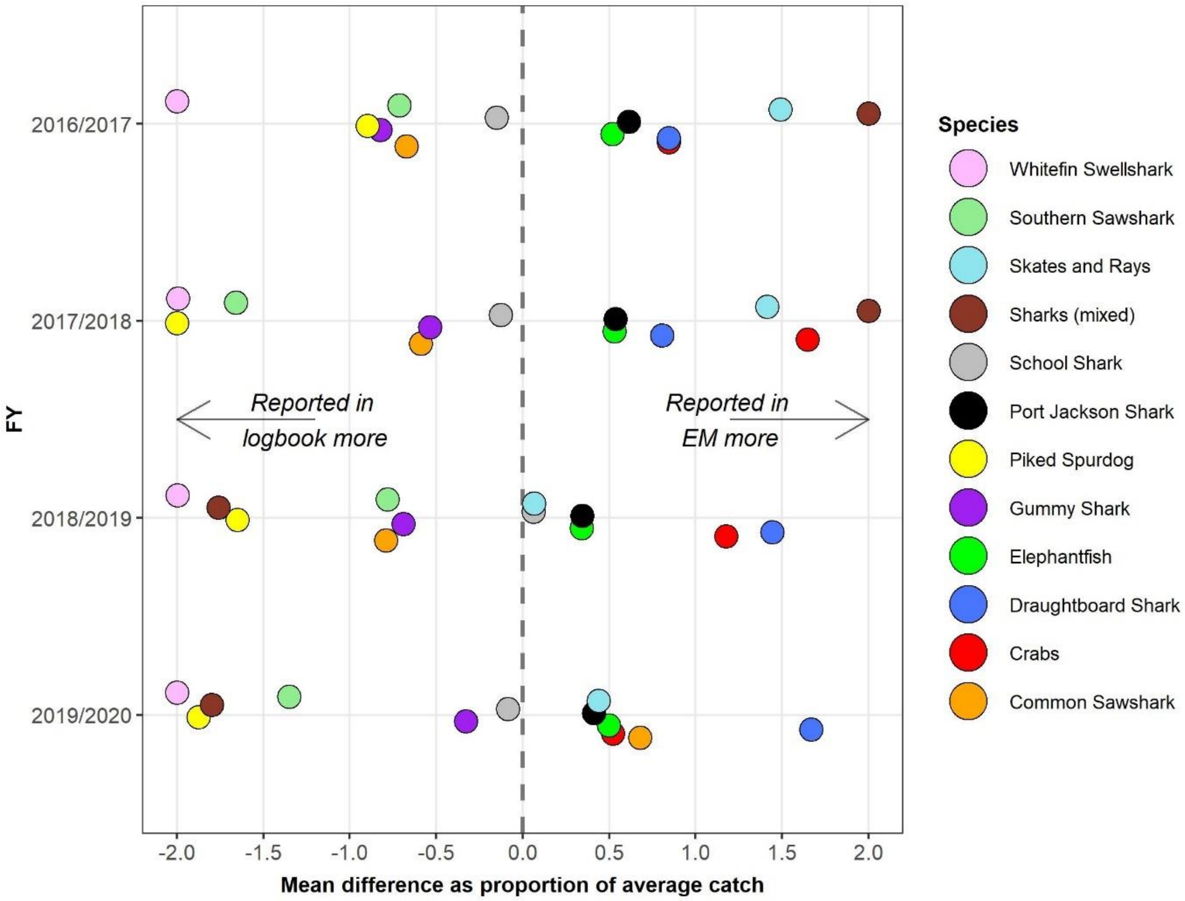


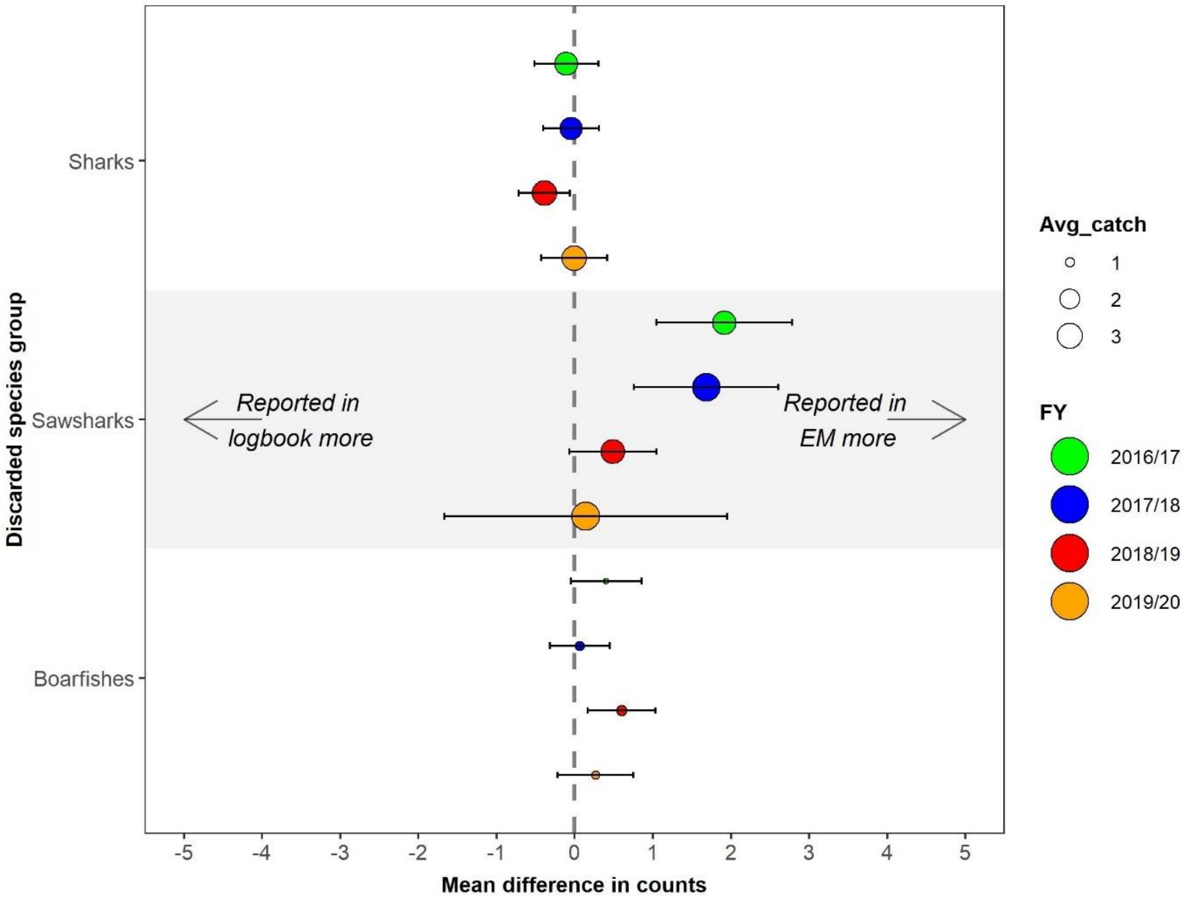
Figure 25: The mean difference in counts as a proportion of the average catch (average of EM and logbook reported) per shot for discarded species in the GNS



As previously noted for retained stocks, the results for some discarded species possibly reflected the EM analyst or fisher not being able to identify some individuals to a species taxonomic level (e.g., southern sawshark for EM). Given there were possible issues with identifying individuals to a species taxonomic level, the same groups containing key target and byproduct species in the GNS were-re-analysed to examine overall congruence (Figure 26).

For discarded catch, there were improvements observed in congruence for sharks (mixed group), which suggests that the EM analyst is having some issues identifying discarded gummy shark and therefore grouping it as hound sharks (mixed group) (Figure 26). Consequently, while there seems to be issues with identifying to a species level for discarded gummy shark, the overall total numbers seem to be more accurately reported at a higher taxonomic level. While the mean difference in counts was low across most years for sawsharks (mixed group), it was evident that as a proportion of the average catch discarded, there was clear logbook underreporting relative to EM, predominately in the earlier years (Figure 26). This indicates that for discarded sawsharks (mixed group), it is not necessarily issues with fishers identifying species to the lowest taxonomic level.

Figure 26: Mean difference in counts (mean ± 95% CI) across individual financial years for selected grouped species discarded in the GNS.



Gummy shark

Across the time period examined, 9% of shots audited that contained discarded gummy shark had no difference in logbook and EM counts, 33% had higher counts reported by EM and 58% had higher counts reported by logbook. When differences in counts between logbook and EM were observed in a single shot these were mainly between ~1-3 individuals (Figure 27 and Figure 28). There was evidence of some improvement in congruence through time, with 6% of shots in 2016/17 having no difference in logbook and EM counts, increasing to 12% by 2019/20 (Figure 29). Gummy shark was reported discarded slightly more by EM (-1.2 ± 0.2 individuals) across the time period examined, but the average number recorded discarded by both EM and logbook in a single shot was low (2.0 ± 0.2 individuals), so as a proportion of the average catch this difference was significant at -61% (Table 5) and led to a clear left-hand skew in the distribution of differences in counts. This suggest that for every 2.6 individuals reported by logbook, EM is reporting 1.4 individuals discarded. Furthermore, individuals were commonly unreported with 67% 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 ~1-3 individuals are being overlooked (Figure 30). This is somewhat driven by several vessels not reporting any discarded gummy shark catch in their logbook (see below).

An examination of the data at an individual vessel level revealed much higher variation across vessels than for retained gummy shark catch, but with a trend towards more individuals being reported in logbooks than EM (with some exceptions) (Figure 31a, b, and c). This pattern was similarly evident in the density of differences in counts at the shot level according to the violin plots. There were many vessels that had significantly higher numbers being reported by logbook than EM suggesting EM may be having some issues either correctly identifying gummy shark or observing gummy shark being discarded. There were some exceptions to this pattern however, with several vessels reporting no discarded gummy shark in the logbook, but EM reporting individuals discarded, which may warrant further investigation.

Figure 27: Logbook and EM reported counts from individual shots containing discarded gummy shark across time period examined. Red dashed line is the 1:1 line.

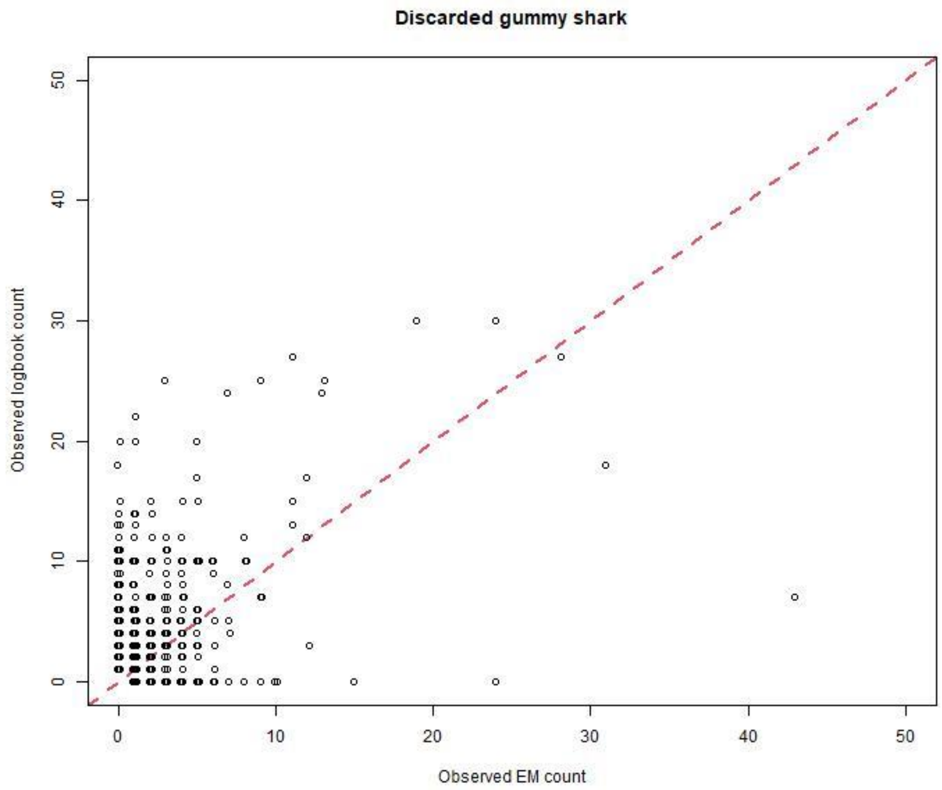


Figure 28: Proportion of shots with specific differences between EM and logbook counts for discarded gummy shark across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

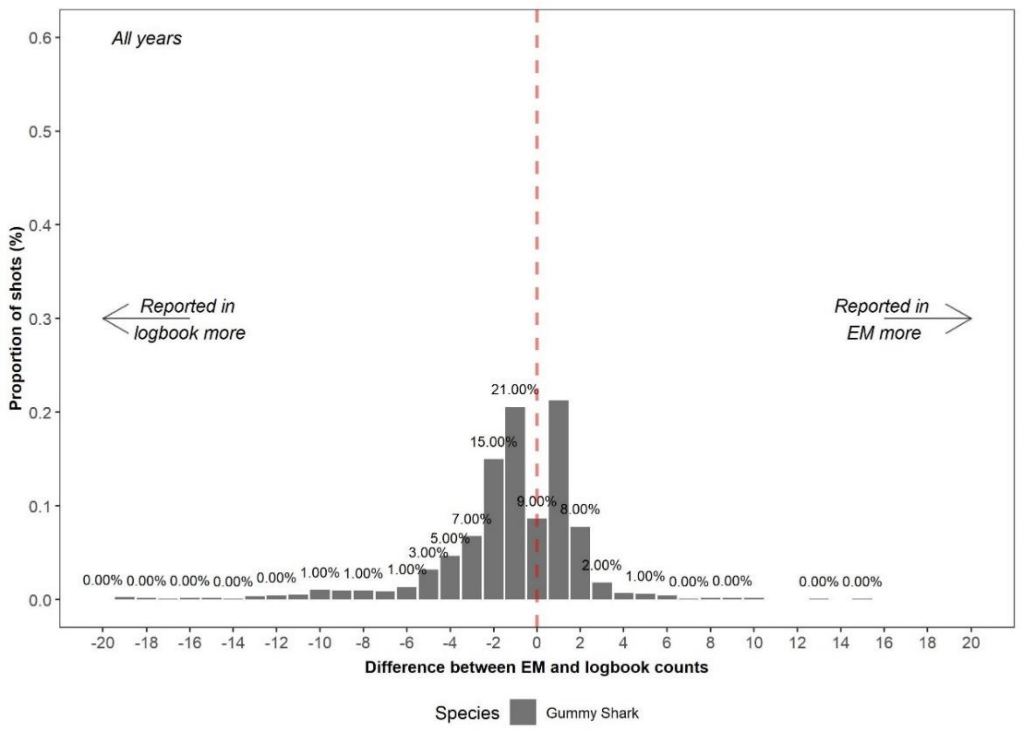


Figure 29: Proportion of shots with specific differences between EM and logbook counts for discarded gummy shark for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

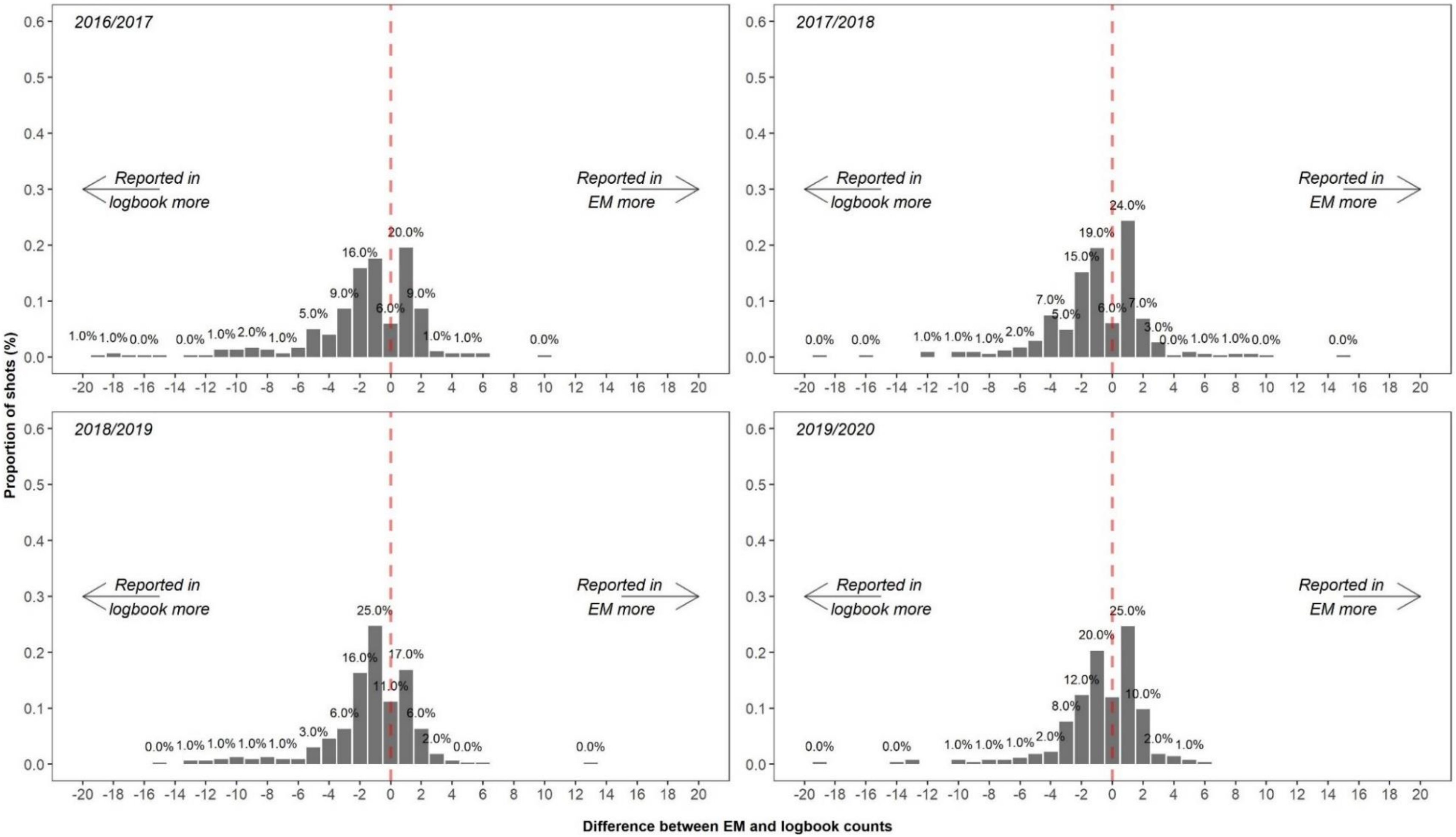


Figure 30: Number of shots with specific differences between EM and logbook counts for discarded gummy shark across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

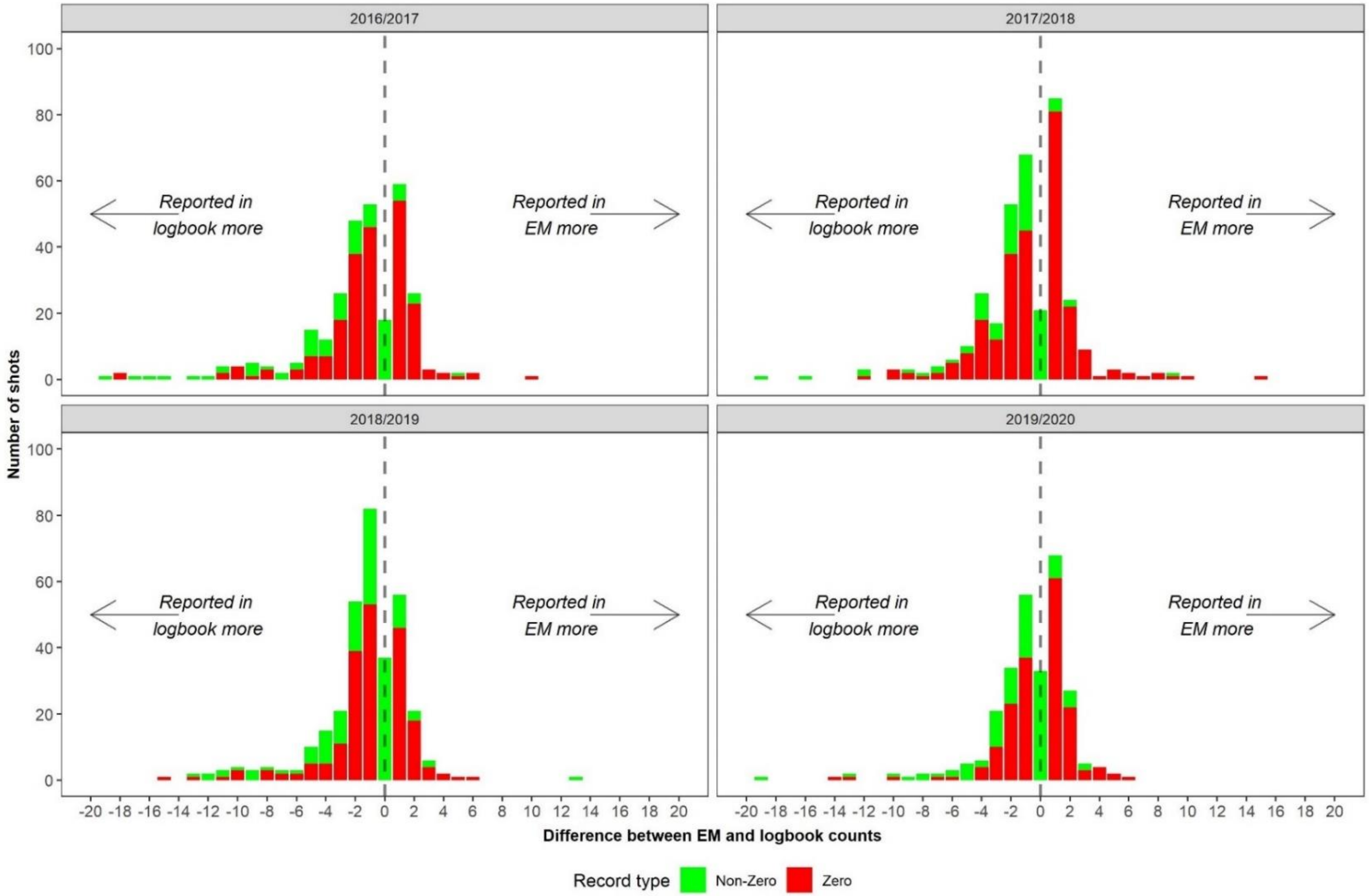


Figure 31a: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing discarded gummy shark across the time period examined by vessel. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

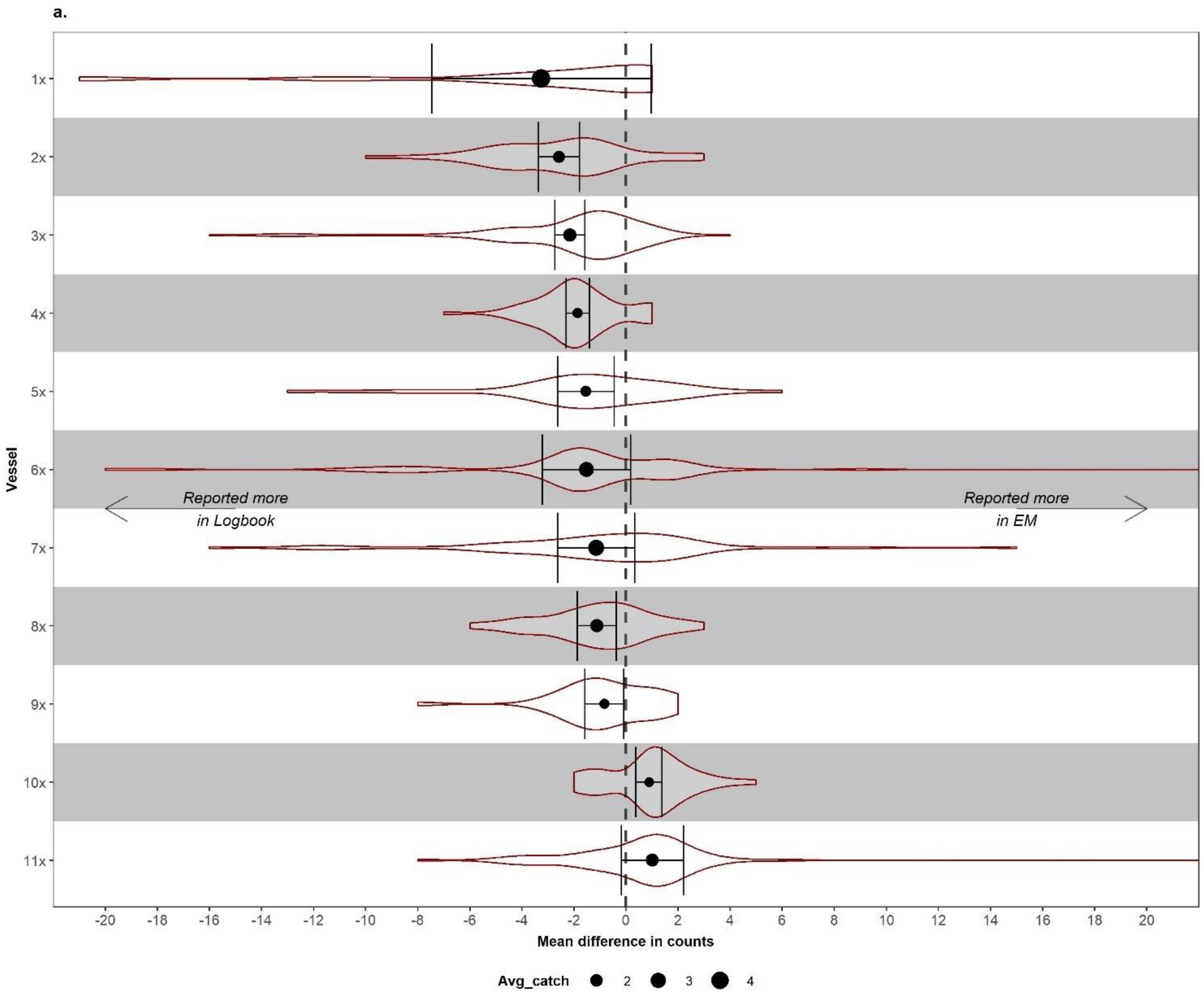


Figure 31b: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing discarded gummy shark across the time period examined by vessel. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

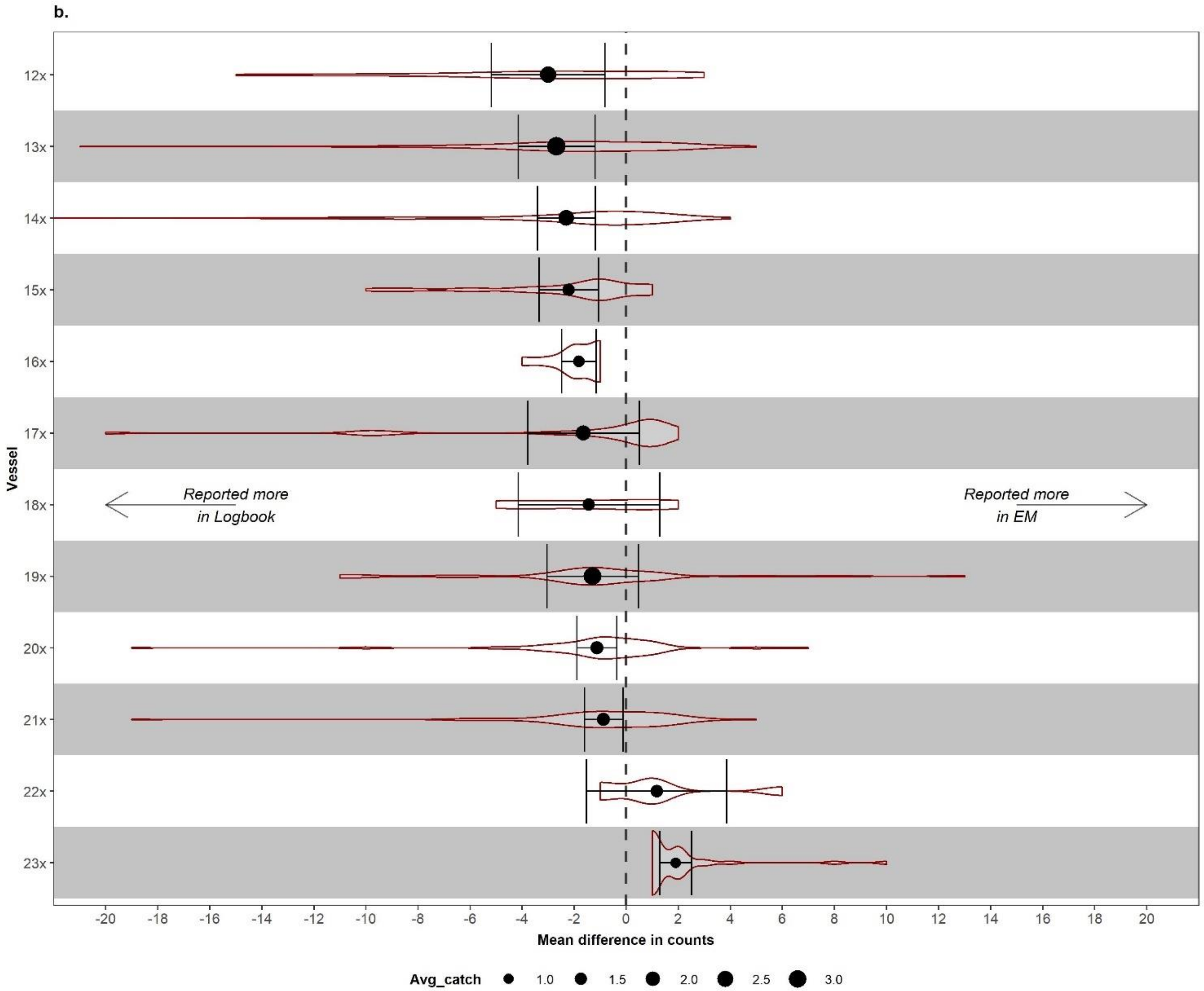
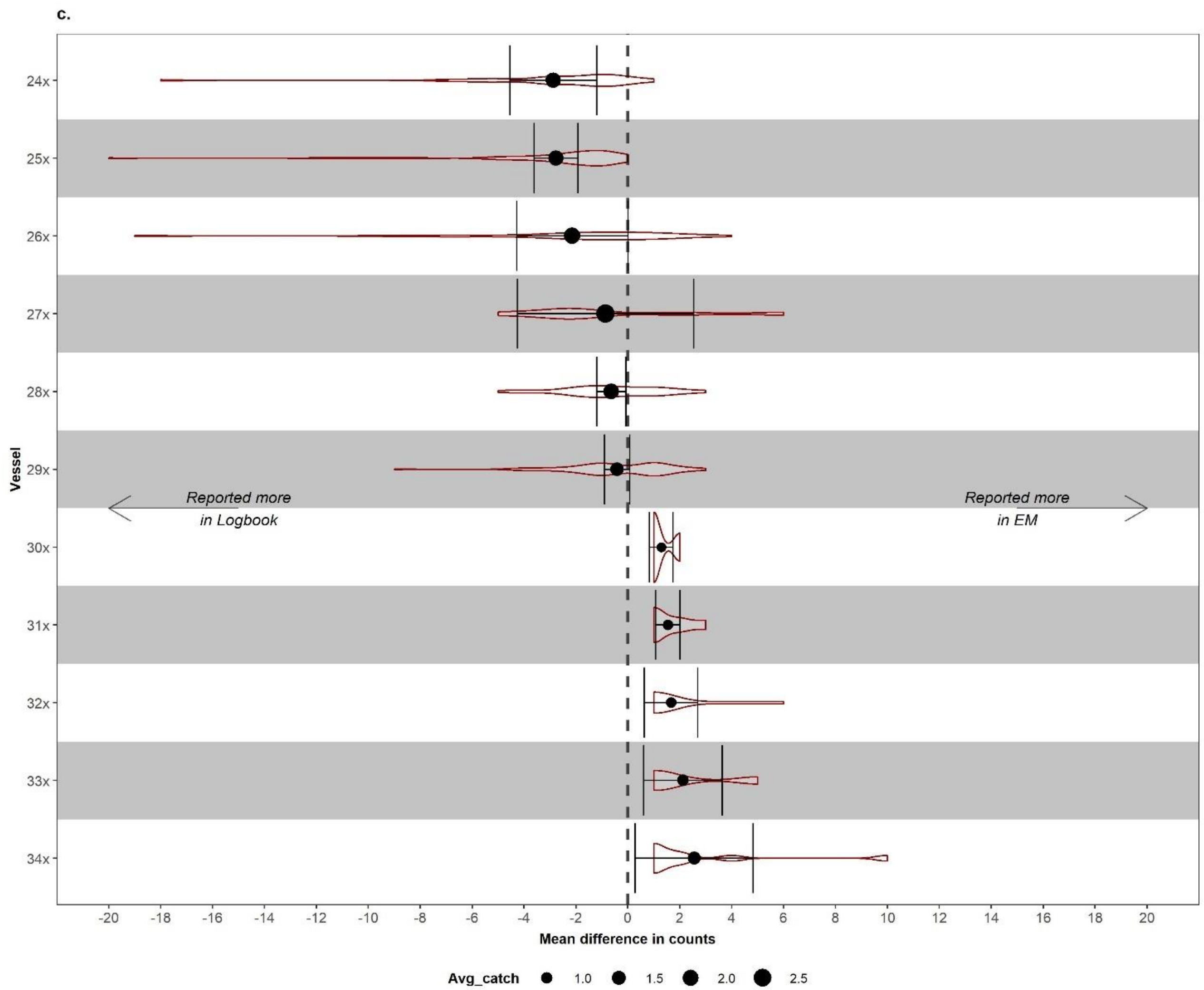


Figure 31c: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing discarded gummy shark across the time period examined by vessel. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



School shark

Across the time period examined, 20% of shots audited that contained discarded school shark had no difference in logbook and EM counts, 42% had higher counts reported by EM and 38% 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 32 and Figure 33). There was evidence of some improvement in congruence through time, with 16% of shots in 2016/17 having no difference in logbook and EM counts, increasing to 22% by 2019/20 (Figure 34). The mean difference in counts was negligible across the time period examined (-0.2 ± 0.3 individuals) with the average number recorded discarded by both EM and logbook in a single shot low (2.7 ± 0.1 individuals) so as a proportion of the average catch, this difference was only -6% (Table 5). This suggest that for every 2.8 individuals reported by logbook, EM is reporting 2.6 individuals. Around 49% of total shots contained a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool, suggesting there is numerous shots where ~1-2 individuals are being overlooked (Figure 35). This is somewhat driven by some vessels either not reporting any discarded school shark catch in their logbook or reporting substantially more than EM (see below).

An examination of the data at an individual vessel level revealed that for most of the 28 vessels reporting discarded school shark, the confidence intervals for the mean difference in counts encompassed zero (Figure 36a, b, and c). Some vessels had higher counts reported in logbooks compared to EM, with a large average number discarded relative to the rest of the fleet across the time period examined. This suggests EM may be having some issues either correctly identifying school shark or observing school shark being discarded. There was one vessel, which didn't report any discarded school shark in the logbook, but EM reported individuals discarded, which may warrant further investigation.

Figure 32: Logbook and EM reported counts from individual shots containing discarded school shark across time period examined. Red dashed line is the 1:1 line.

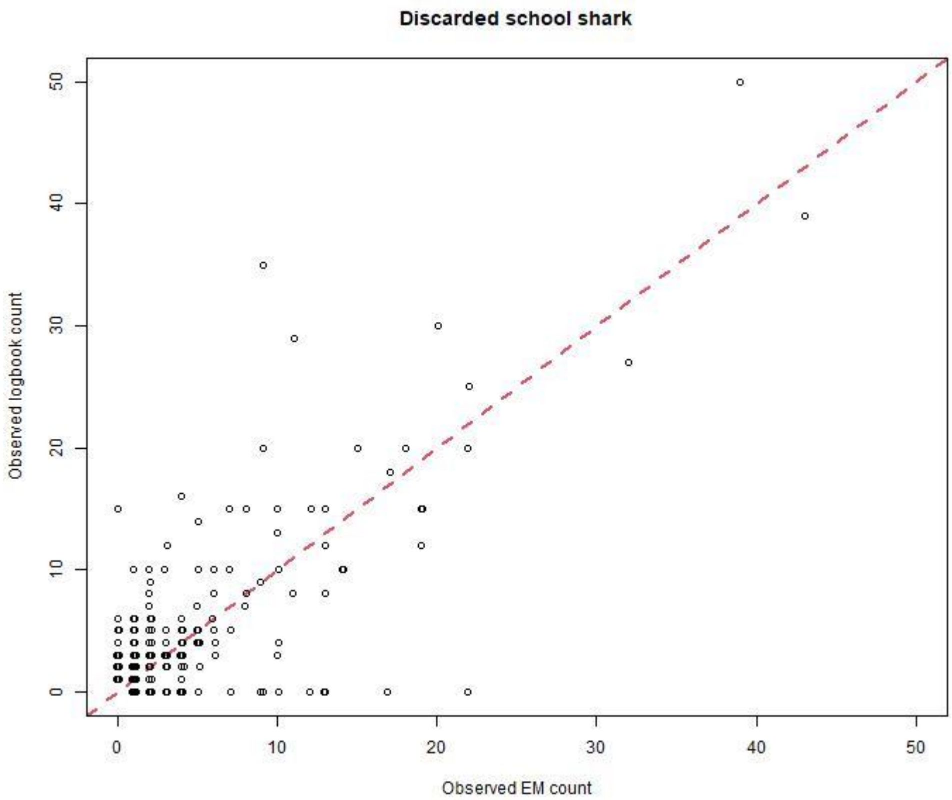


Figure 33: Proportion of shots with specific differences between EM and logbook counts for school shark across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

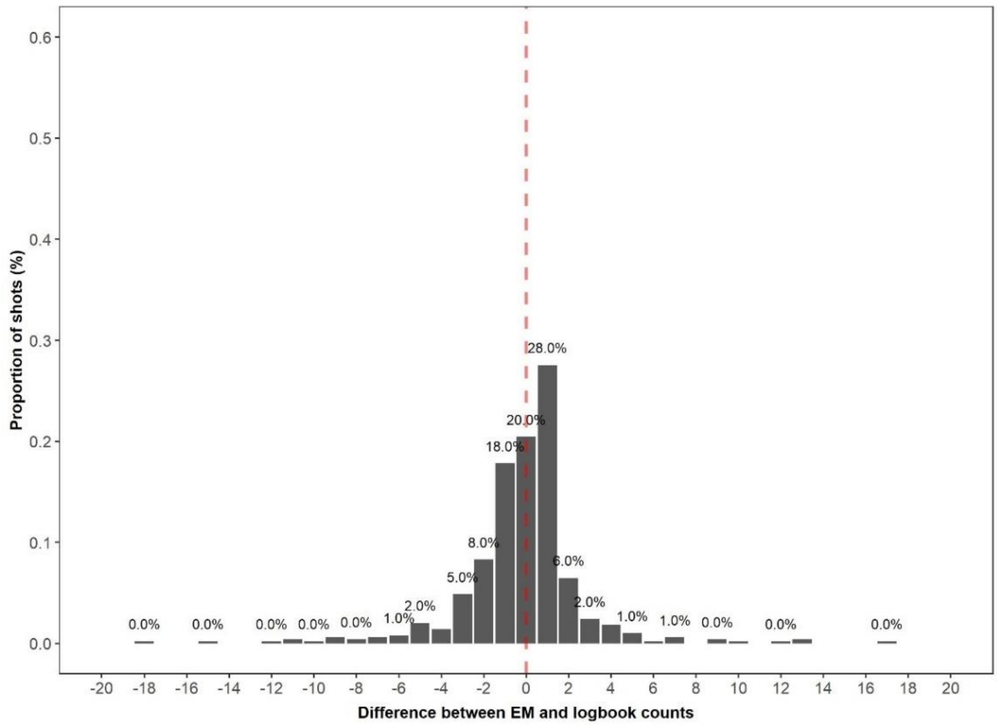


Figure 34: Proportion of shots with specific differences between EM and logbook counts for discarded school shark for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

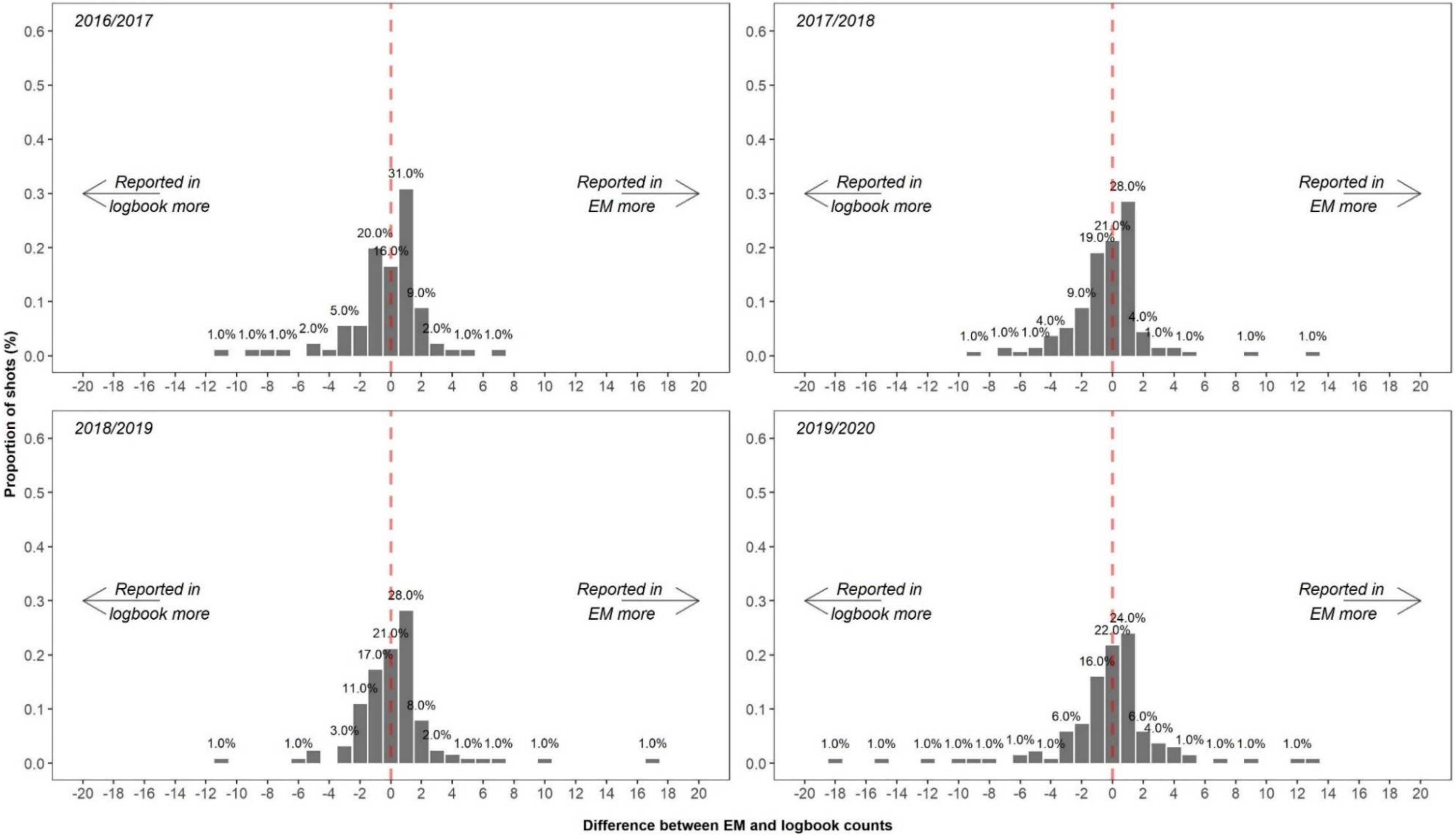


Figure 35: Number of shots with specific differences between EM and logbook counts for school shark across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

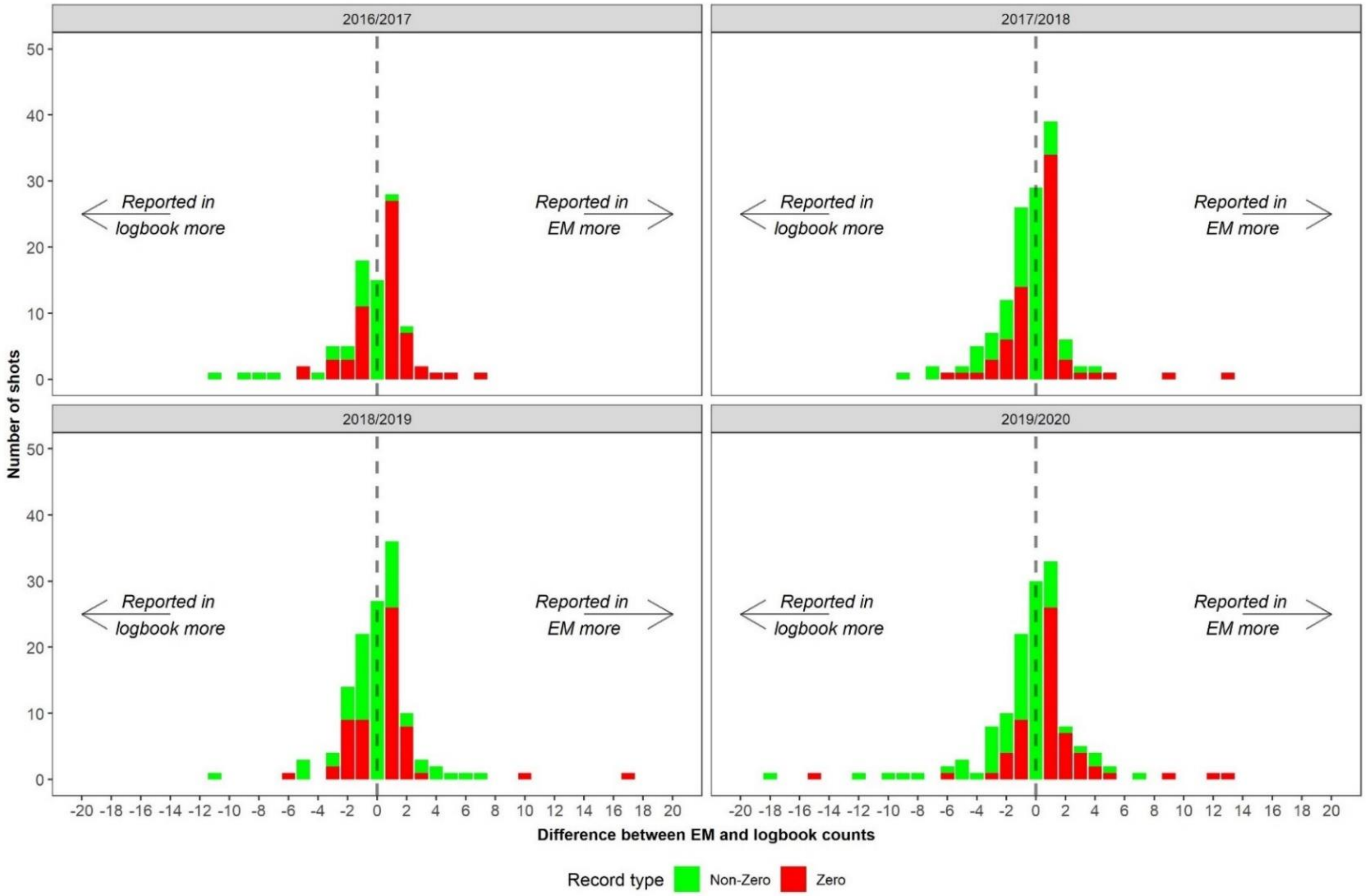


Figure 36a: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing discarded school shark across the time period examined by vessel. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

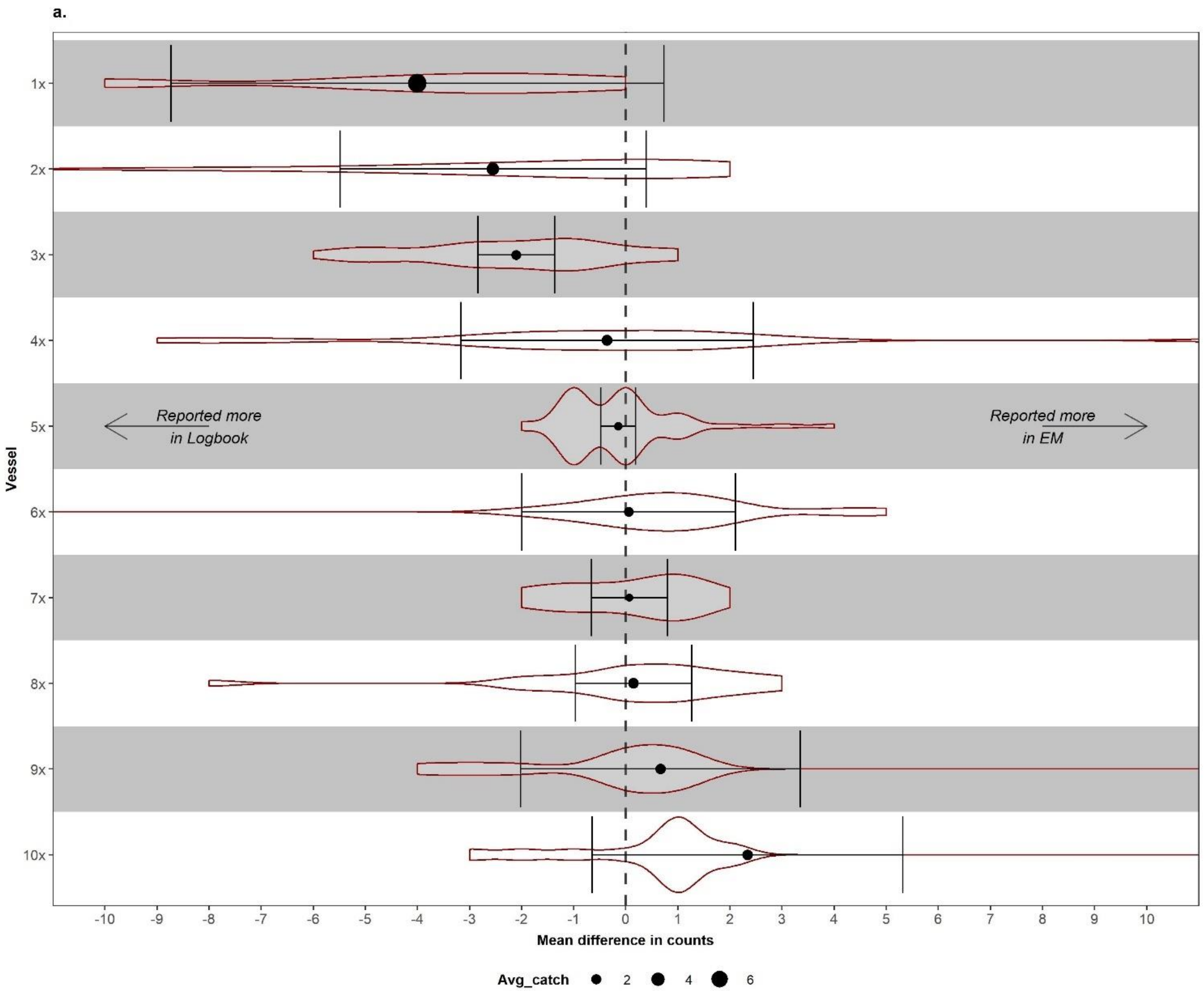


Figure 36b: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing discarded school shark across the time period examined by vessel. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

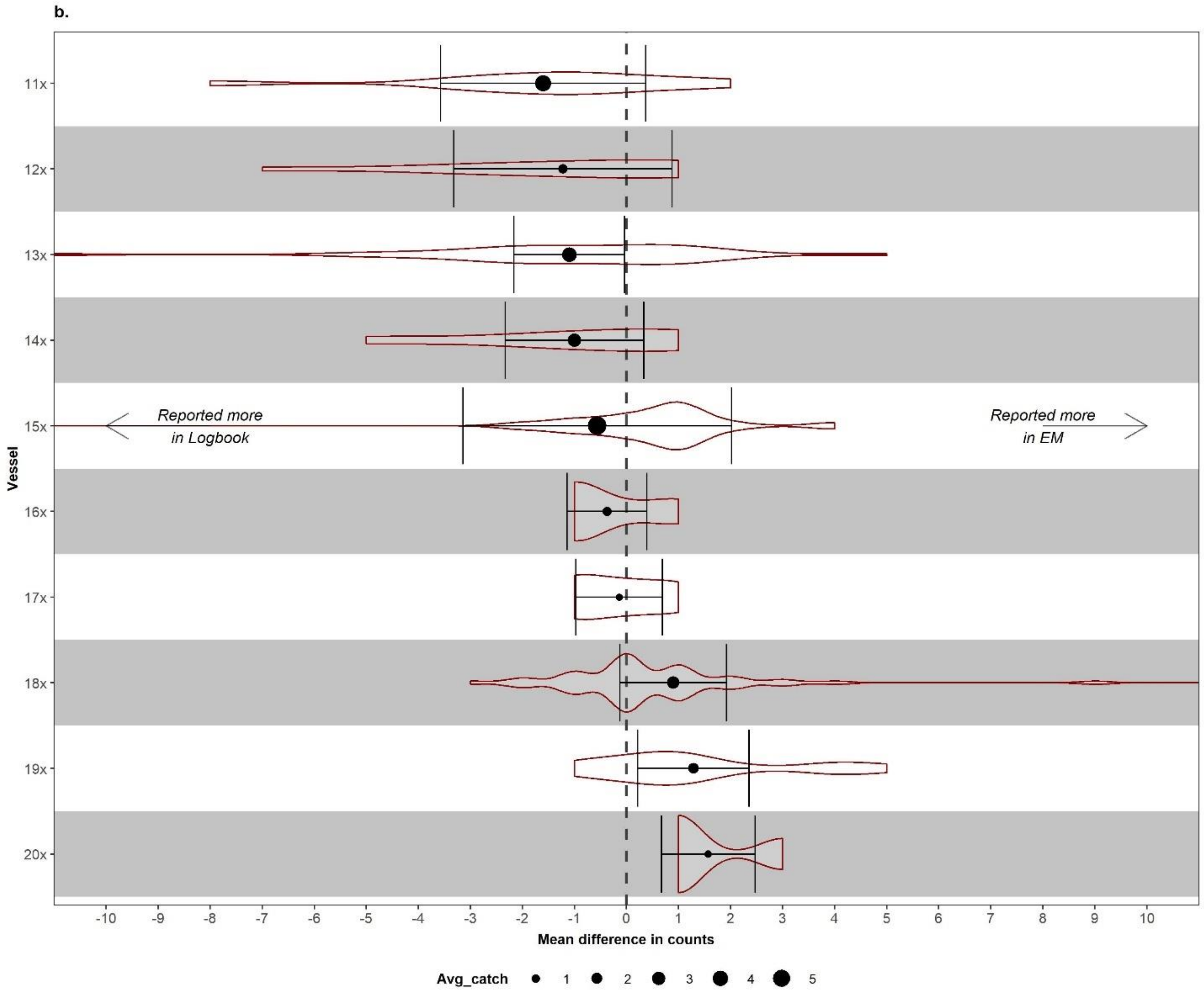
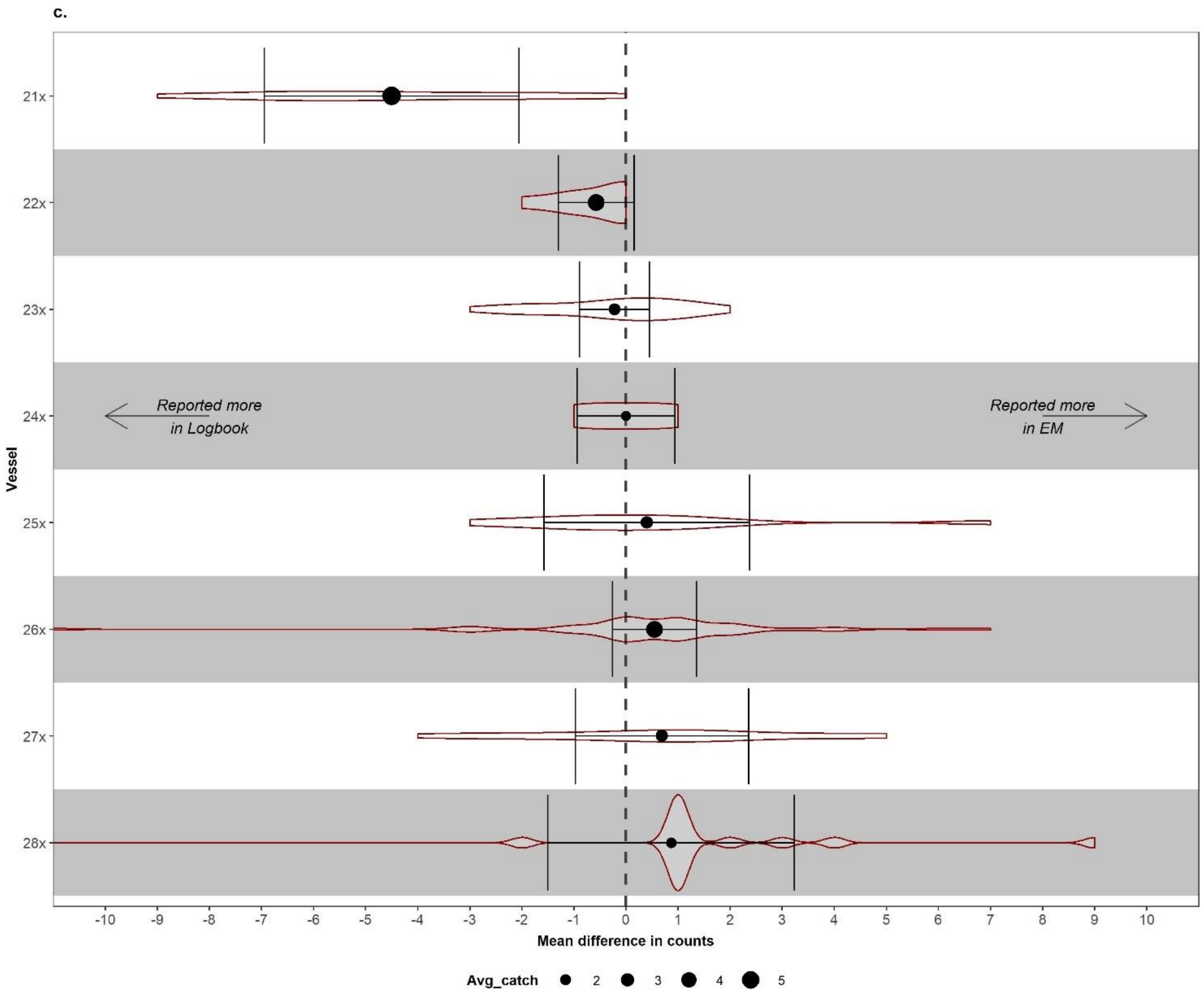


Figure 36c: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing discarded school shark across the time period examined by vessel. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



Elephantfish

Across the time period examined, 10% of shots audited that contained discarded elephantfish had no difference in logbook and EM counts, 65% had higher counts reported by EM and 25% had higher counts reported by logbook. When differences in counts between logbook and EM were observed in a single shot these were mainly between ~1-3 individuals (Figure 37 and Figure 38). There was evidence of improvement in congruence through time, with 6% of shots in 2016/17 having no difference in logbook and EM counts, increasing to 14% by 2019/20 (Figure 38). Elephantfish was reported discarded more by EM (3.5 ± 0.8 individuals) across the time period examined, with the average number recorded discarded by both EM and logbook in a single shot around 7.6 ± 0.9 individuals, so as a proportion of the average catch this difference was significant at 46% (Table 5) and led to a clear right hand skew in the distribution of differences in counts (Figure 39). This suggest that for every 5.85 individuals reported by logbook, EM is reporting 9.35 individuals. Furthermore, individuals were commonly unreported with 55% 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 ~1-3 individuals are being overlooked (Figure 40). This is somewhat driven by several vessels not reporting any discarded elephantfish catch in their logbook (see below).

An examination of the data at an individual vessel level revealed much higher variation across the 34 vessels reporting discarded elephantfish than for retained elephantfish, and a clear trend towards more individuals being reported in EM than logbooks (Figure 41a, b and c). This pattern was similarly evident in the density of differences in counts at the shot level according to the violin plots. Importantly, there were three vessels, where no discarded elephantfish was being reported at all in logbooks but being reported by EM, which may warrant further investigation. There were also several other vessels with substantial differences in counts, in terms of EM reporting substantially higher numbers than logbook.

Figure 37: Logbook and EM reported counts from individual shots containing discarded elephantfish across time period examined. Red dashed line is the 1:1 line.

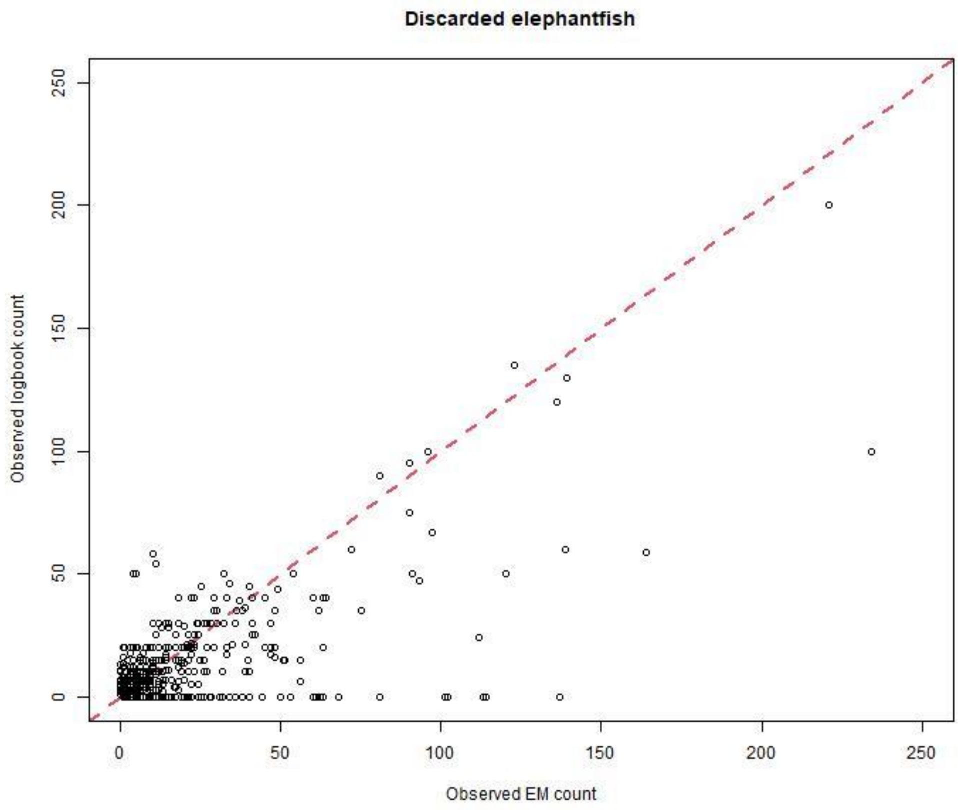


Figure 38: Proportion of shots with specific differences between EM and logbook counts for discarded elephantfish across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

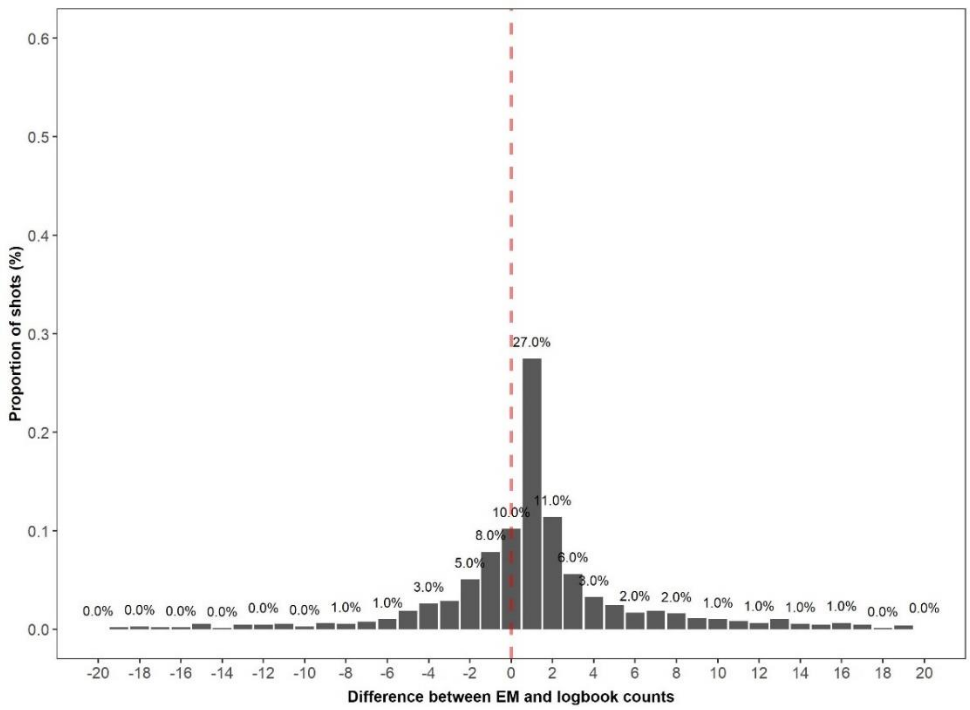


Figure 39: Proportion of shots with specific differences between EM and logbook counts for discarded elephantfish for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

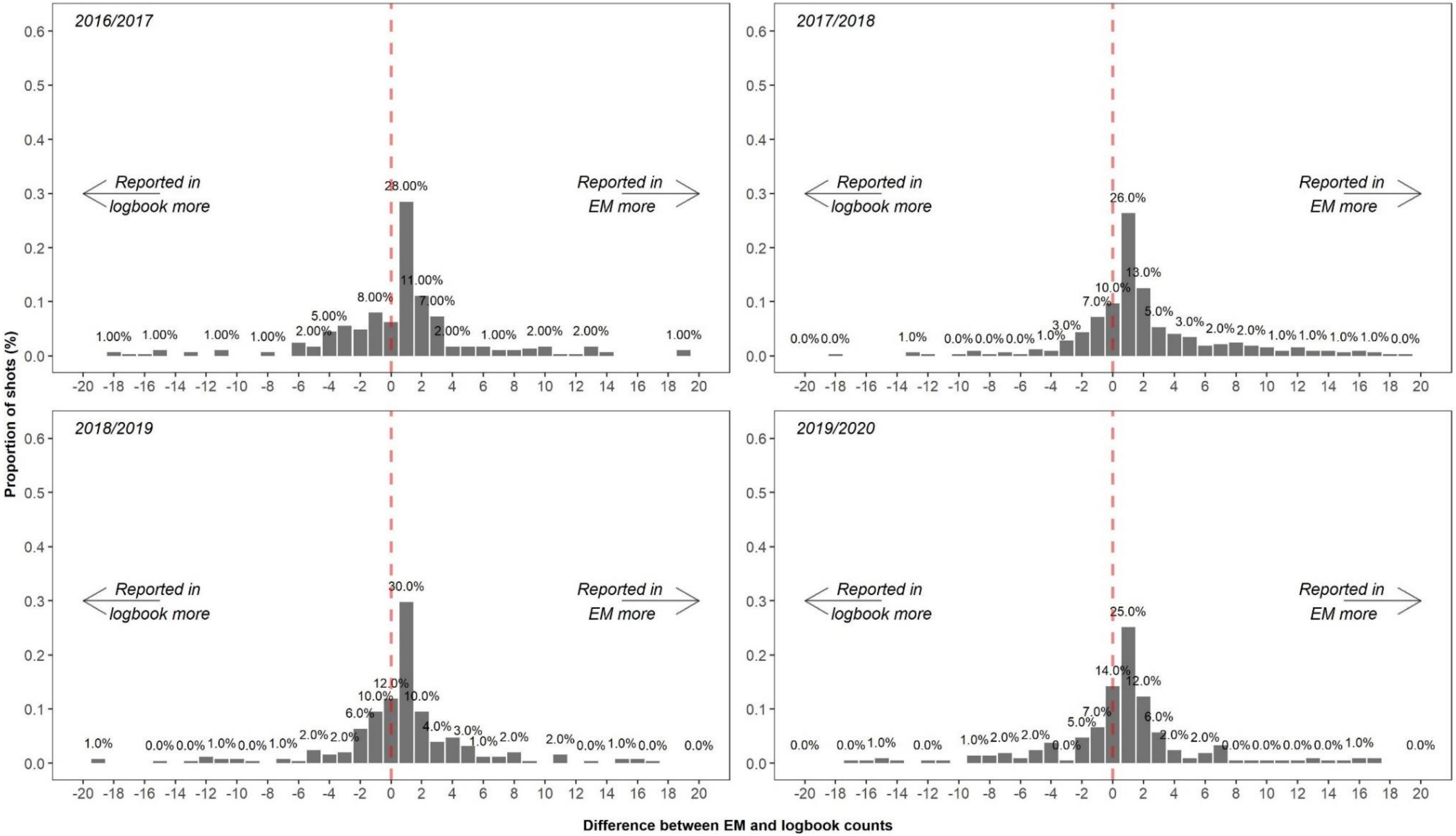


Figure 40: Number of shots with specific differences between EM and logbook counts for discarded elephantfish across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

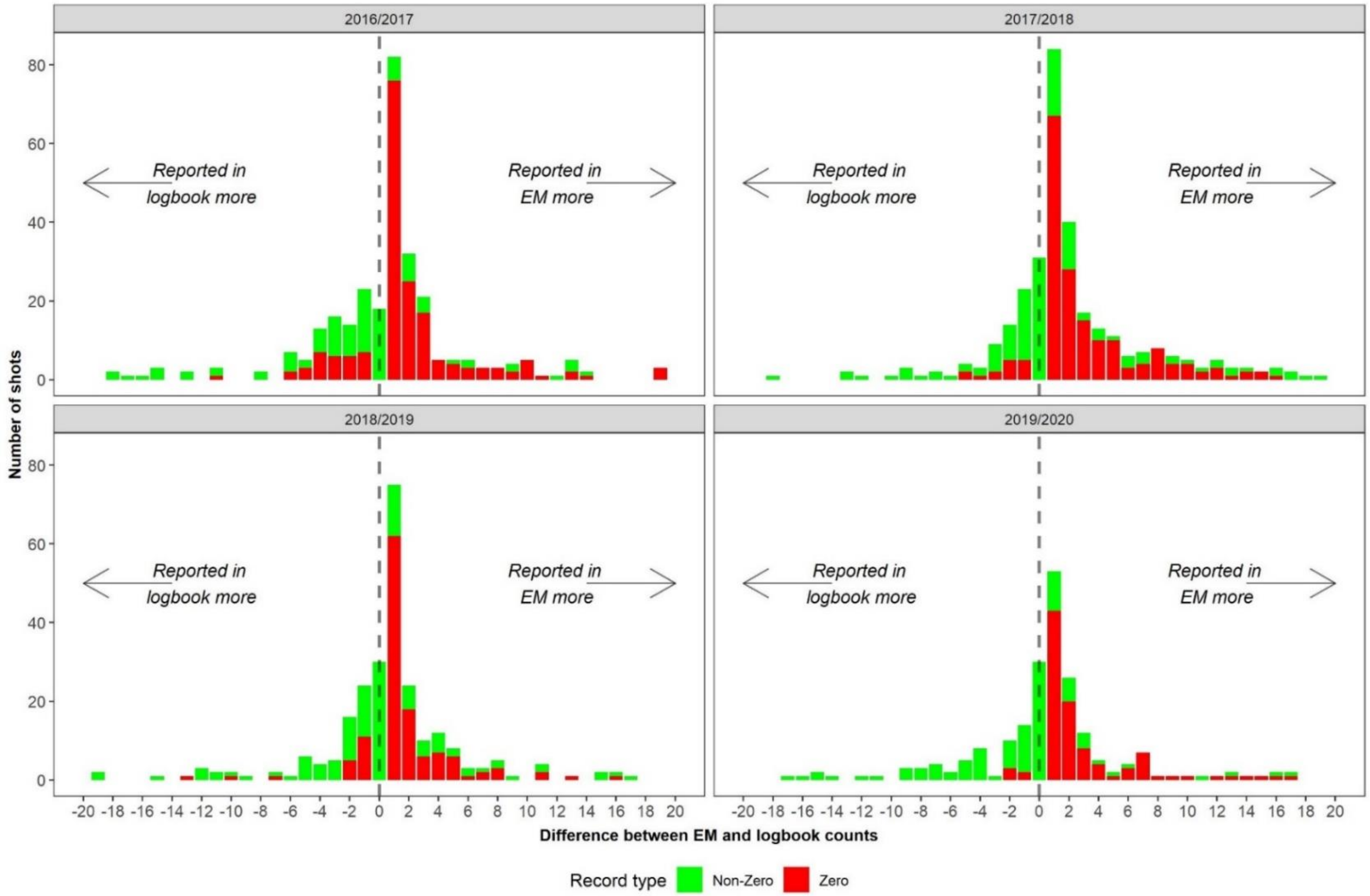


Figure 41a: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing discarded elephantfish across the time period examined by vessel. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

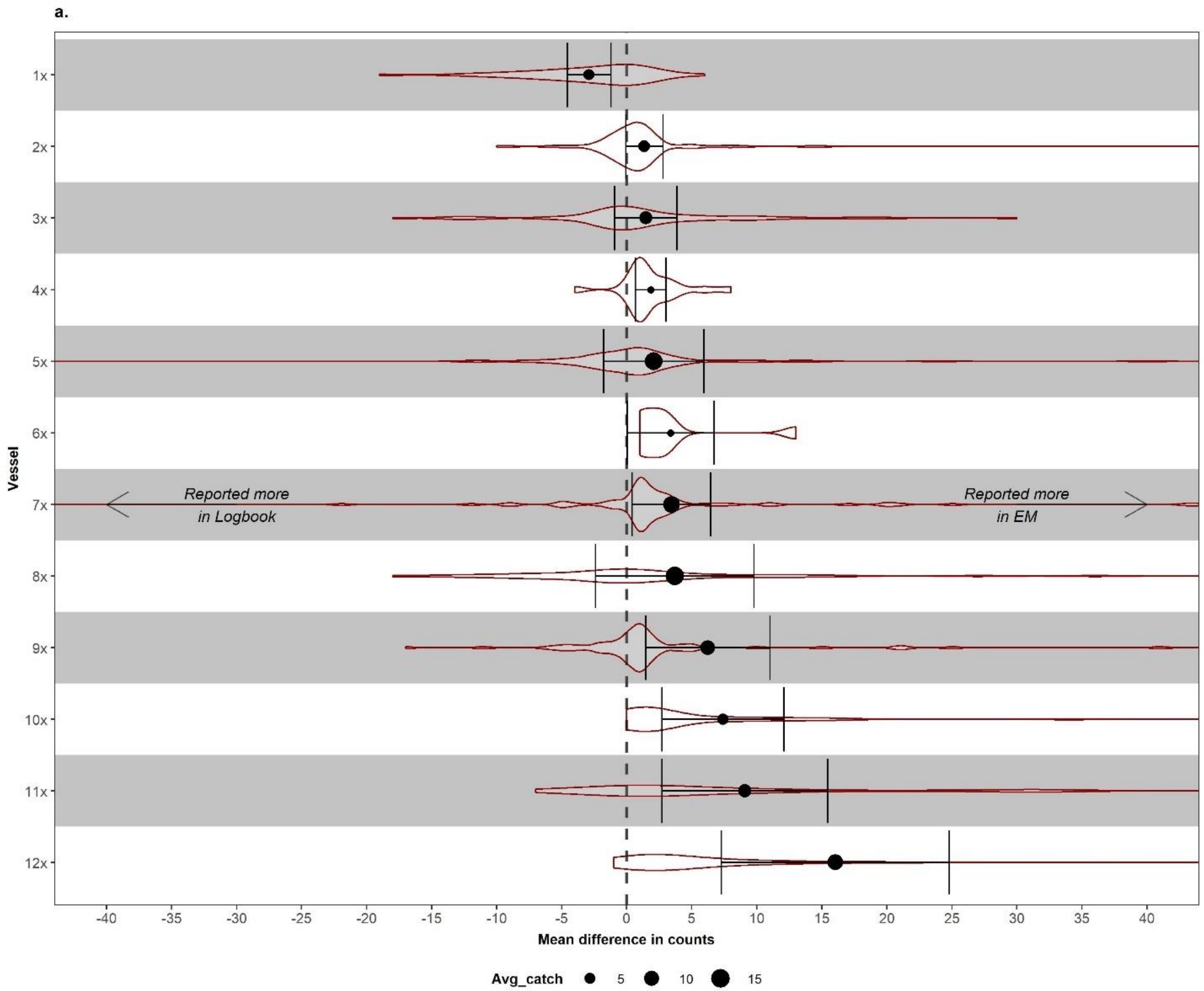


Figure 41b: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing discarded elephantfish across the time period examined by vessel. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

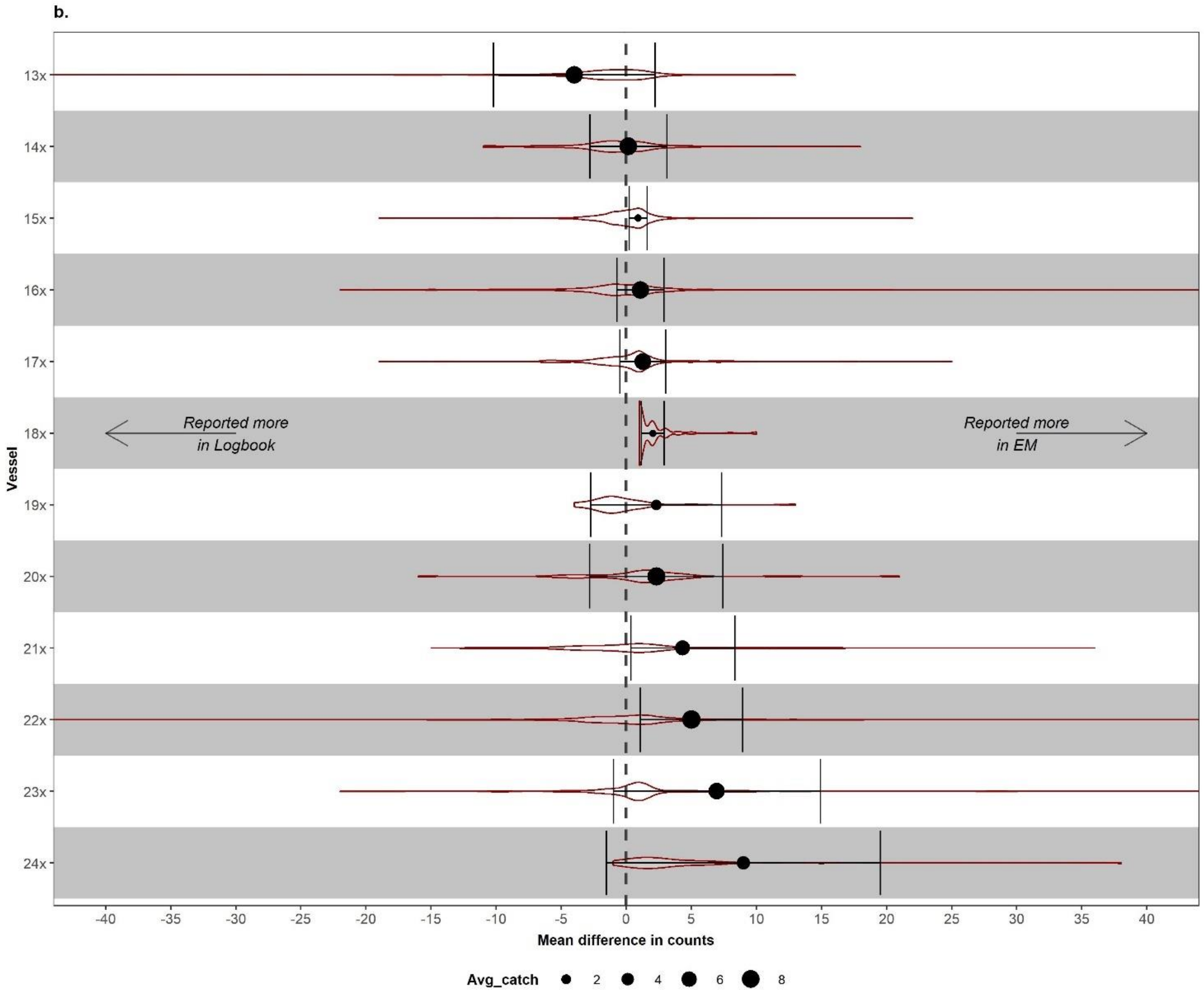
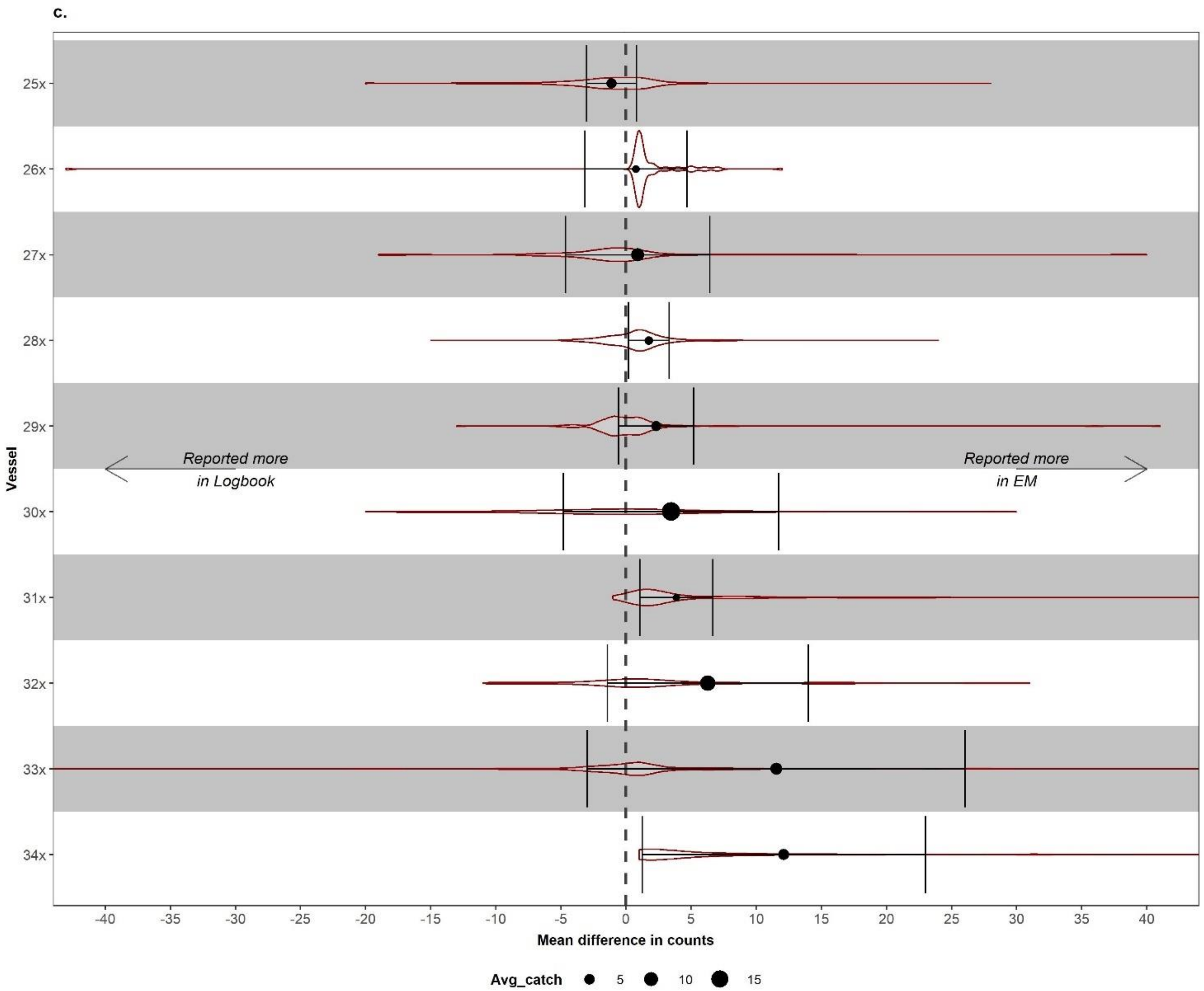


Figure 41c: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing discarded elephantfish across the time period examined by vessel. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



Sawsharks (grouped)

Across the time period examined, 8% of shots audited that contained discarded sawsharks (grouped) had no difference in logbook and EM counts, 64% had higher counts reported by EM and 28% had higher counts reported by logbook. When differences in counts between logbook and EM were observed in a single shot these were around ~1-3 individuals (Figure 42 andFigure 43). There was inter-annual variation in congruence through time with 6% of shots in 2016/17 having no difference in logbook and EM counts, increasing to 12% in 2017/18 before declining to 5% in 2019/20 (Figure 44). Sawsharks (grouped) was reported discarded more by EM (1.1 ± 0.5 individuals) across the time period examined, with the average number recorded discarded by both EM and logbook in a single shot around 3.1 ± 0.4 individuals, so as a proportion of the average catch this difference was significant at 35% (Table 5) and led to a slight right hand skew in the distribution of differences in counts (Figure 44). This suggest that for every 2.55 individuals reported by logbook, EM is reporting 3.65 individuals. Furthermore, individuals were commonly unreported with 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 some shots where ~1-3 individuals are being overlooked (Figure 40). This is likely driven primarily by several vessels not reporting any discarded sawsharks (grouped) catch in their logbook (see below).

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 encompassed zero, but there was a large amount of variation between shots (Figure 41a, b and c). Importantly, there were three vessels, where no discarded sawsharks (grouped) was being reported at all in logbooks but being reported by EM, which may warrant further investigation. There were also several other vessels with substantial differences in counts, in terms of EM reporting substantially higher numbers than logbook.

Figure 42: Logbook and EM reported counts from individual shots containing discarded sawsharks (grouped) across time period examined. Red dashed line is the 1:1 line.

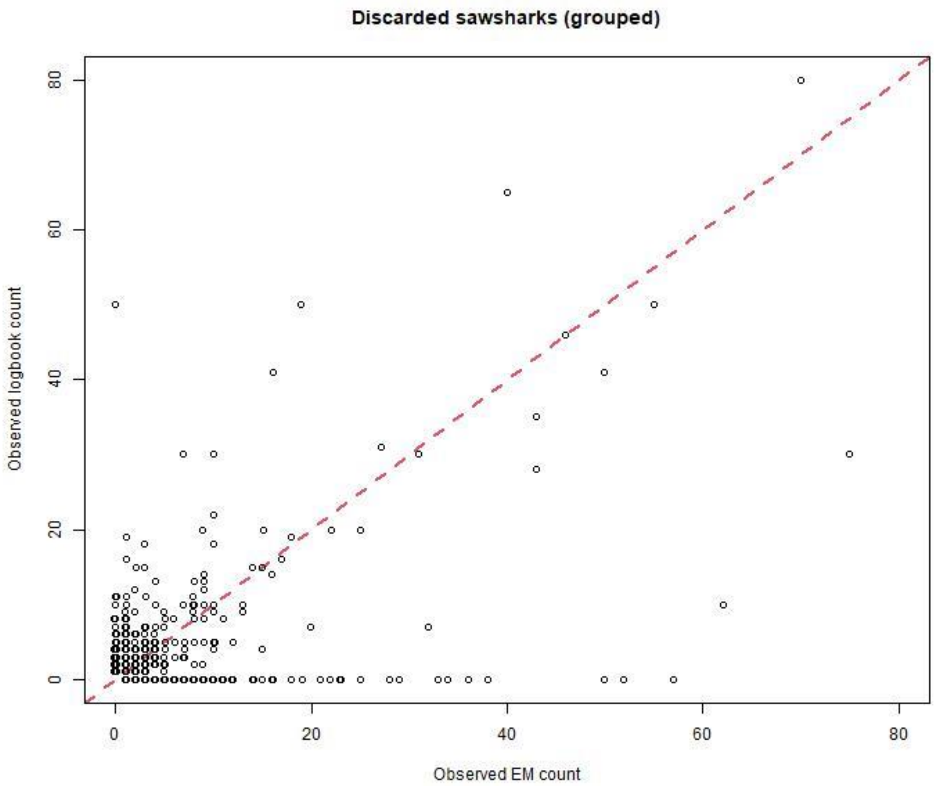


Figure 43: Proportion of shots with specific differences between EM and logbook counts for discarded sawsharks (grouped) across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

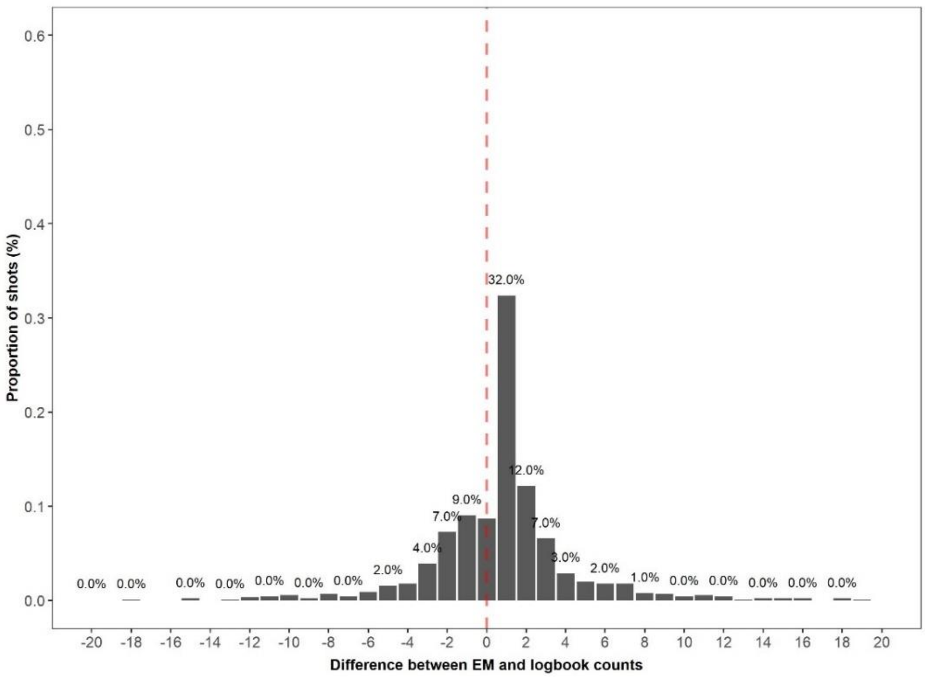


Figure 44: Proportion of shots with specific differences between EM and logbook counts for discarded sawsharks (grouped) for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

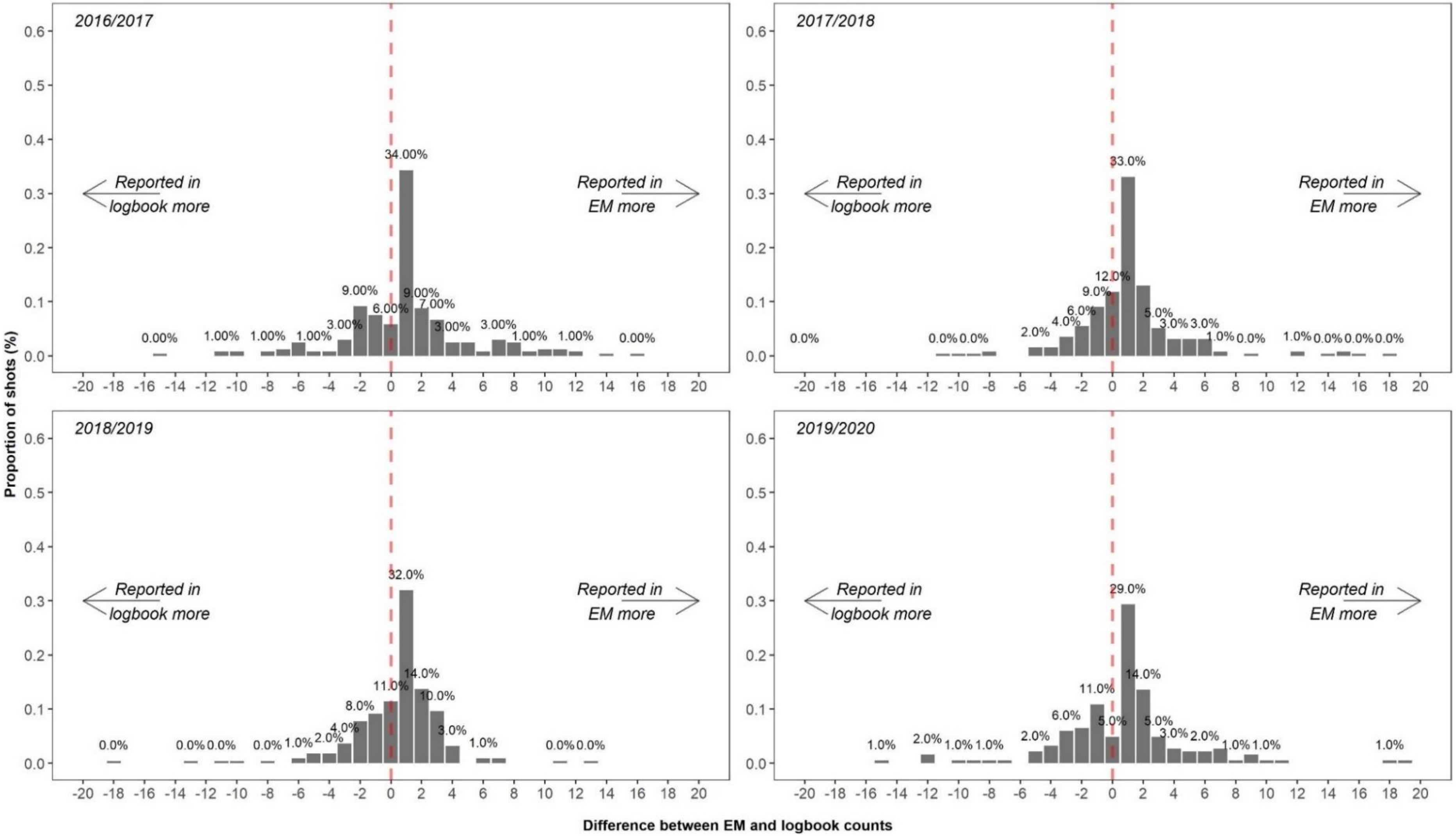


Figure 45: Number of shots with specific differences between EM and logbook counts for discarded sawsharks (grouped) across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been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

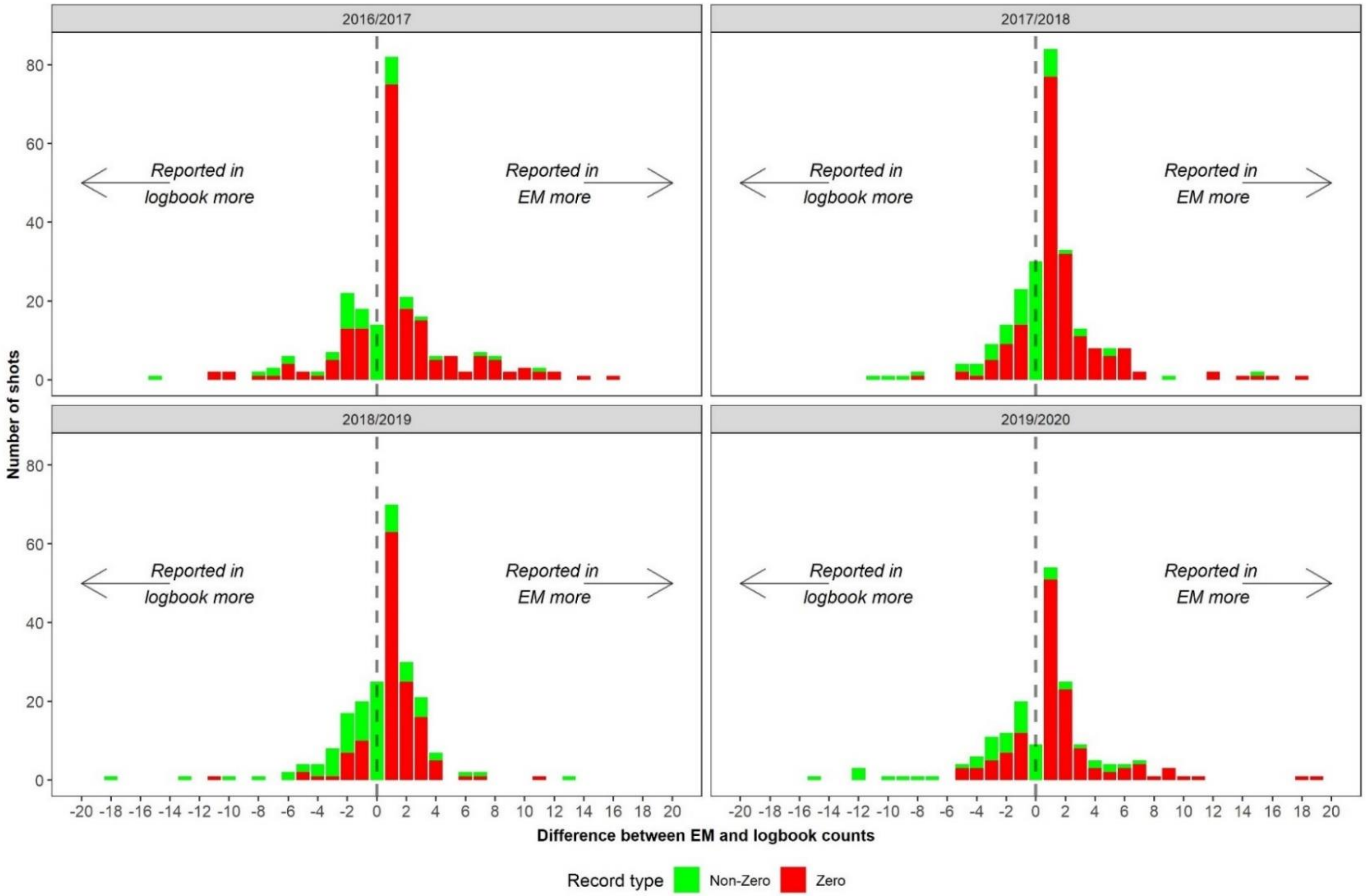


Figure 46a: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing discarded sawsharks (grouped) across the time period examined by vessel. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

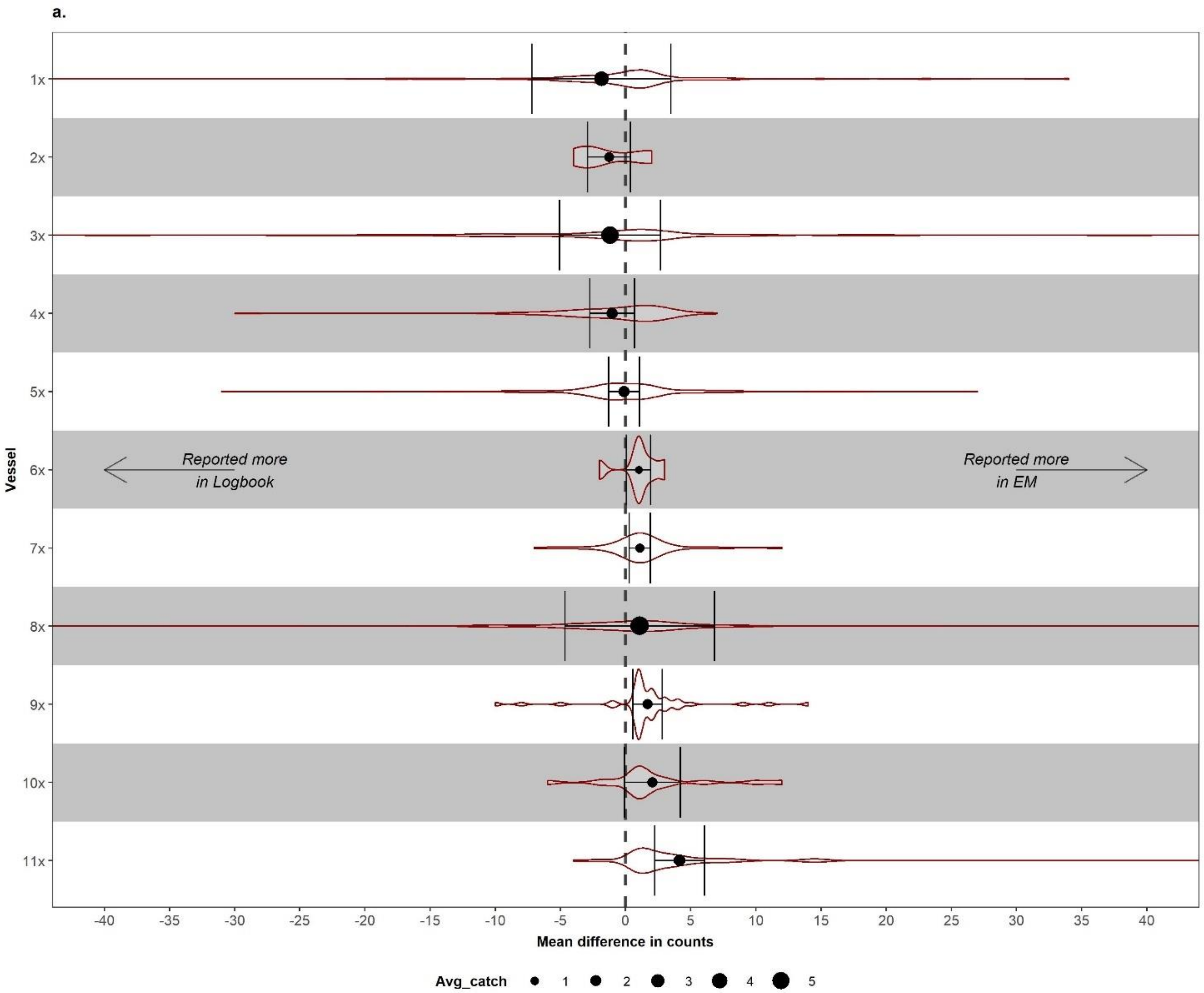


Figure 46b: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing discarded sawsharks (grouped) across the time period examined by vessel. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

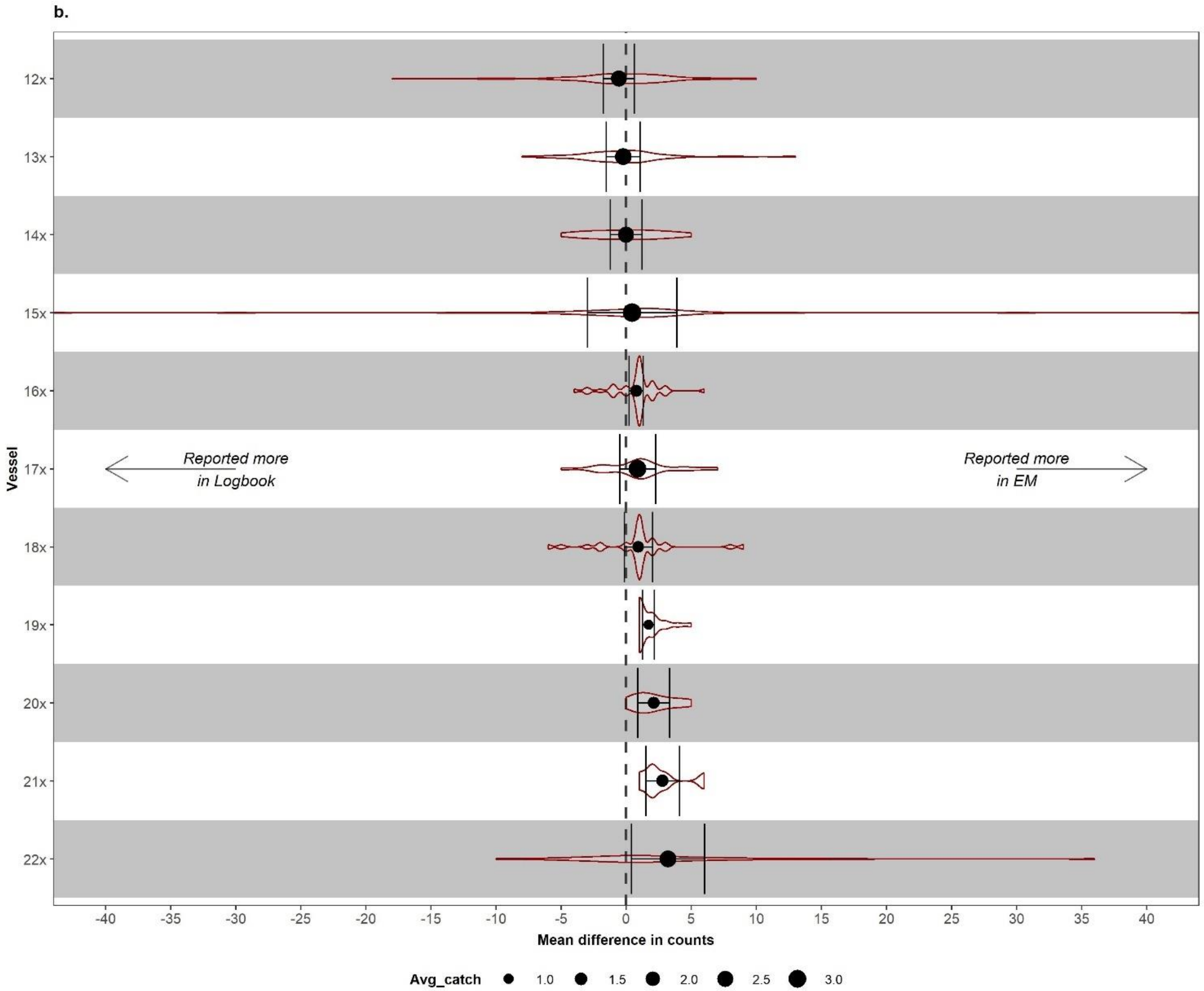
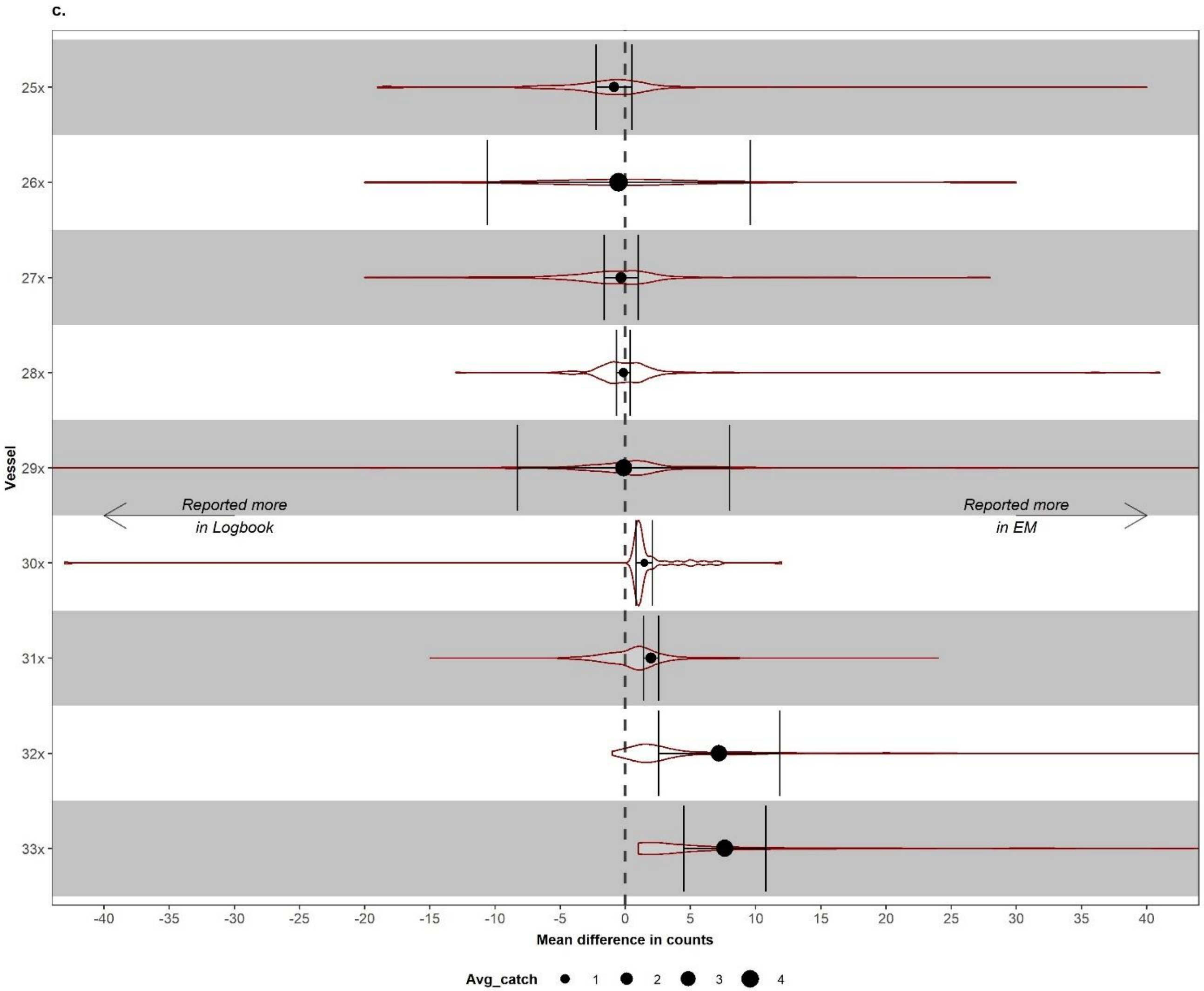


Figure 46c: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts of all shots containing discarded sawsharks (grouped) across the time period examined by vessel. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



3.1.3 Threatened, Endangered and Protected (TEP) species

There was a total of 165 audited shots that contained a reported interaction with a TEP species in the time period analysed (2015/2016 to 2019/2020). Of these, 124 were from the GNS, Due to taxonomic identification issues in the entire dataset, species were placed into TEP groups (seabirds, pinnipeds, cetaceans, and sharks) for analysis. Appendix B contains a table with the TEP groups disaggregated at a species level.

Overall, reporting of TEP groups in the GNS was mixed. When comparing individual TEP groups, it was evident that EM tended to report a slightly higher number of sharks and seabirds than the logbook, which was not evident for pinnipeds and cetaceans (Figure 47 and Figure 48). When differences in reporting were observed, these were low in terms of absolute number (i.e., ±1-2 individuals) (Table 6 and Figure 47).

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

TEP group	FY	EM total no.	Logbook total no.	Notes
Sharks	2015/16	6	6	
	2016/17	11	9	
	2017/18	13	11	
	2018/19	8	8	
	2019/20	1	0	*Only 1 audited shot containing TEP species
Cetaceans	2015/16	2	2	*Only 2 audited shots containing TEP species
	2016/17	7	4	
	2017/18	6	8	
	2018/19	10	11	
	2019/20	3	3	*Only 3 audited shots containing TEP species
Pinnipeds	2015/16	3	2	*Only 3 audited shots containing TEP species
	2016/17	7	9	
	2017/18	5	3	
	2018/19	5	5	
	2019/20	8	9	
Seabirds	2015/16	3	3	*Only 3 audited shots containing TEP species
	2016/17	10	7	
	2017/18	8	5	
	2018/19	3	1	*Only 3 audited shots containing TEP species
	2019/20	7	3	
Total	**All years**	**126**	**109**	

Figure 47: Frequency histograms of the difference in counts between EM and logbook for individual shots across TEP groups in the GNS across the time period analysed (where positive numbers = higher EM counts and negative numbers = higher logbook counts).

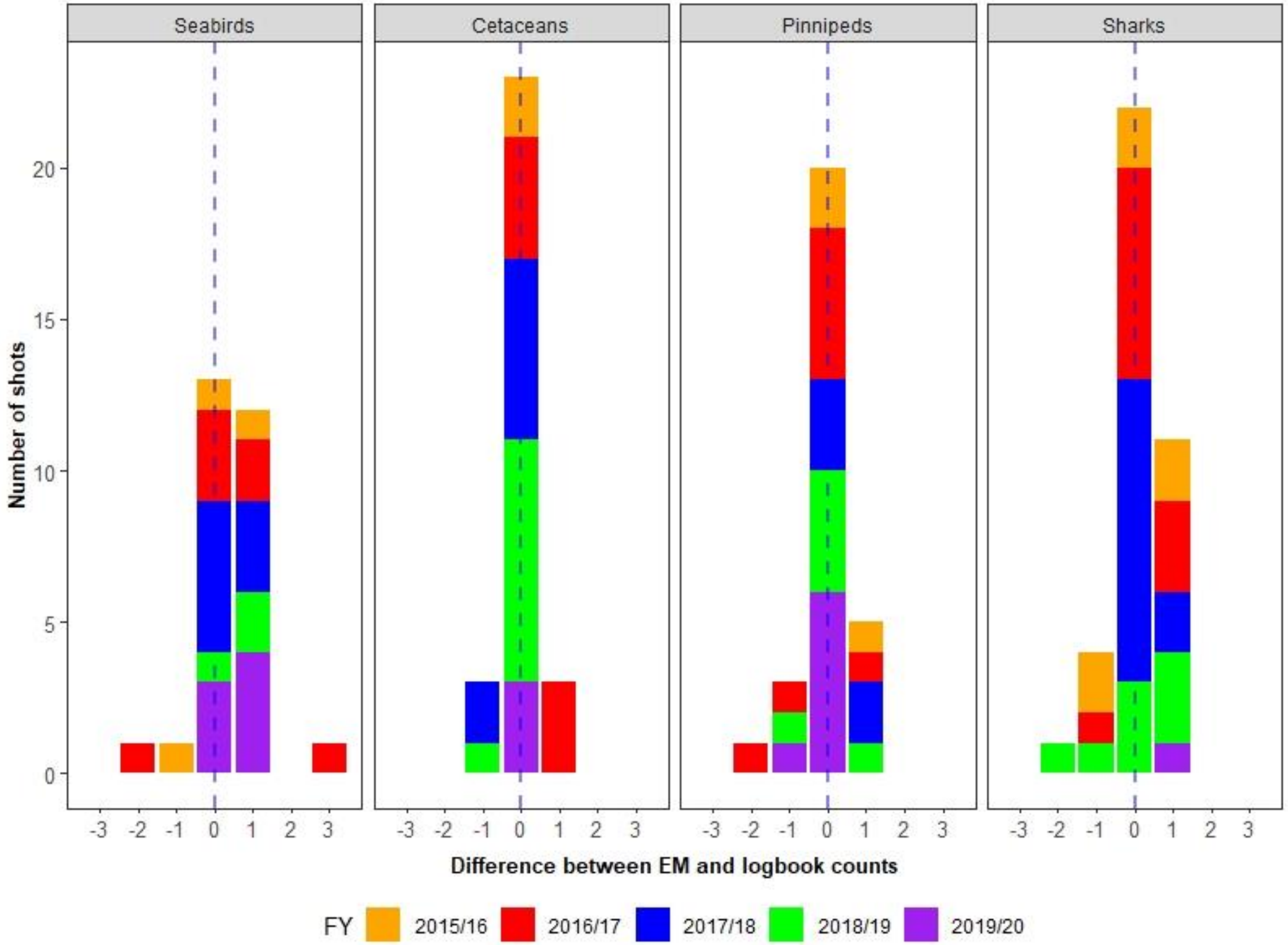
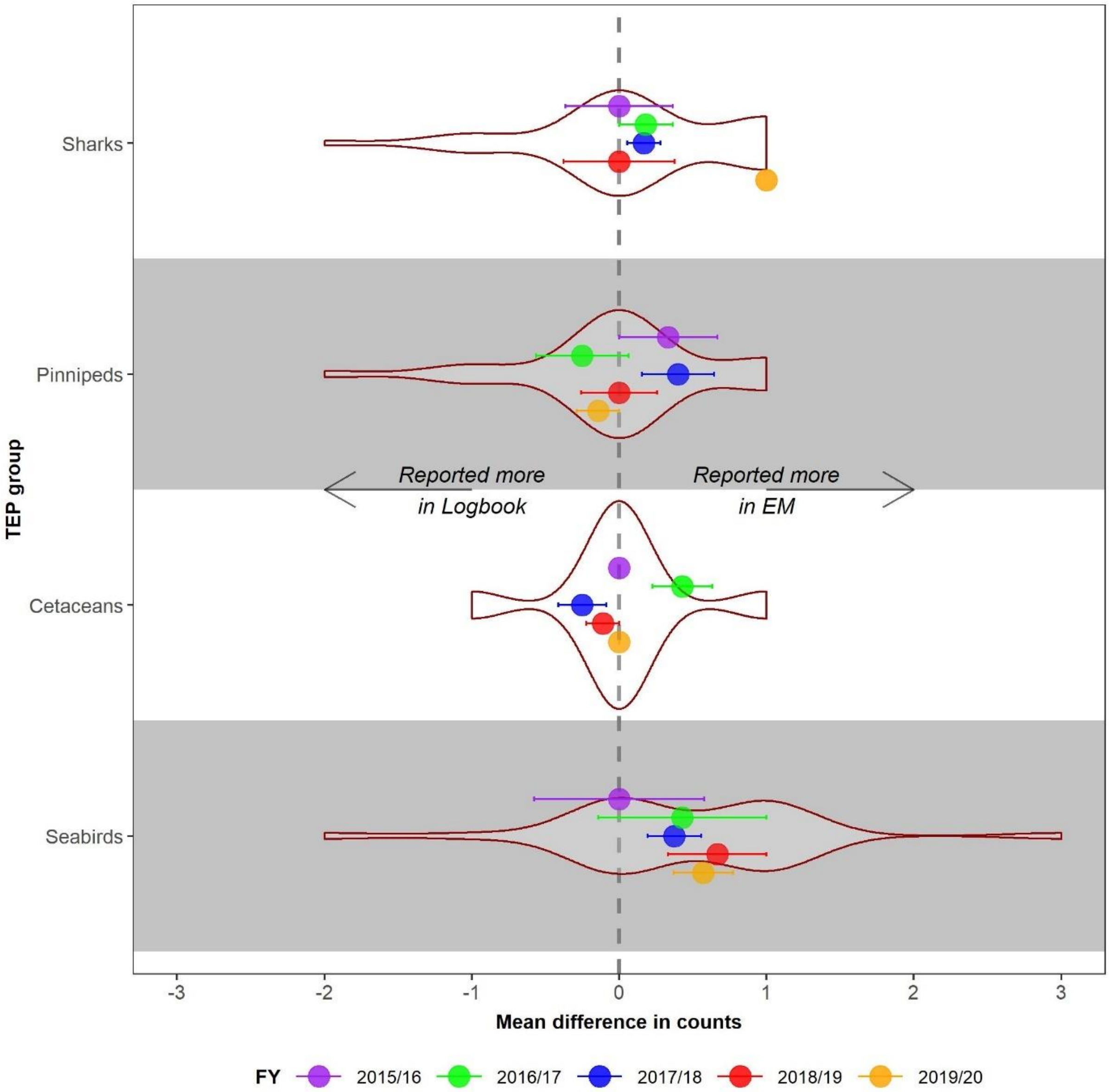


Figure 48: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts by financial year of all shots containing TEP interactions. Grey dashed line equates to zero difference.



3.2 Auto-longline sector

3.2.1 Retained catch

In the LLA, there were a total of 8 species that made up 95% of the reported retained catch from the logbook audited shots between 2016/17 and 2019/20. These species are displayed in Table 7 in descending order of the proportion of catch.

The main retained target species, specifically pink ling and blue-eye trevalla were reported in higher numbers by EM across the time period but with substantial inter-annual variation, particularly for pink ling (Table 7). For example, pink ling was reported more by EM in 2016/17 and 2018/19 but more by logbook in 2017/18 (Figure 49). Ribaldo and gummy shark were reported in greater numbers by EM, while blue grenadier was reported in greater numbers by logbook. The results for both ocean perch species reflect the EM analyst not being able to identify individuals to a species taxonomic level (Figure 50).

Table 7: 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 GNS.

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
Pink ling	*Genypterus blacodes*	28 (±28.9)	231 (±46.3)	12%	14%
Blue-eye trevalla	*Hyperoglyphe antarctica*	11.4 (±17.2)	207.1 (±60.3)	5%	14%
Ribaldo	*Mora moro*	25.0 (±9.1)	67.9 (±18.7)	37%	18%
Reef ocean perch	*Helicolenus percoides*	-71.8 (±36.6)	37.5 (±18.3)	-191%	97%
Gummy shark	*Mustelus antarcticus*	7.6 (±13.6)	54.2 (±15)	14%	14%
Bigeye ocean perch	*Helicolenus barathri*	-78.2 (±29.6)	39.1 (±14.8)	-200%	100%
Blue grenadier	*Macruronus novaezelandiae*	-4.6 (±5.8)	12.5 (±5.6)	-36%	29%
Gemfish	*Rexea solandri*	0.3 (±4.9)	15.0 (±6.6)	1%	28%

Figure 49: Reporting of retained species in the LLA (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) retained in a shot (mean ± 95% CI) across all financial years.

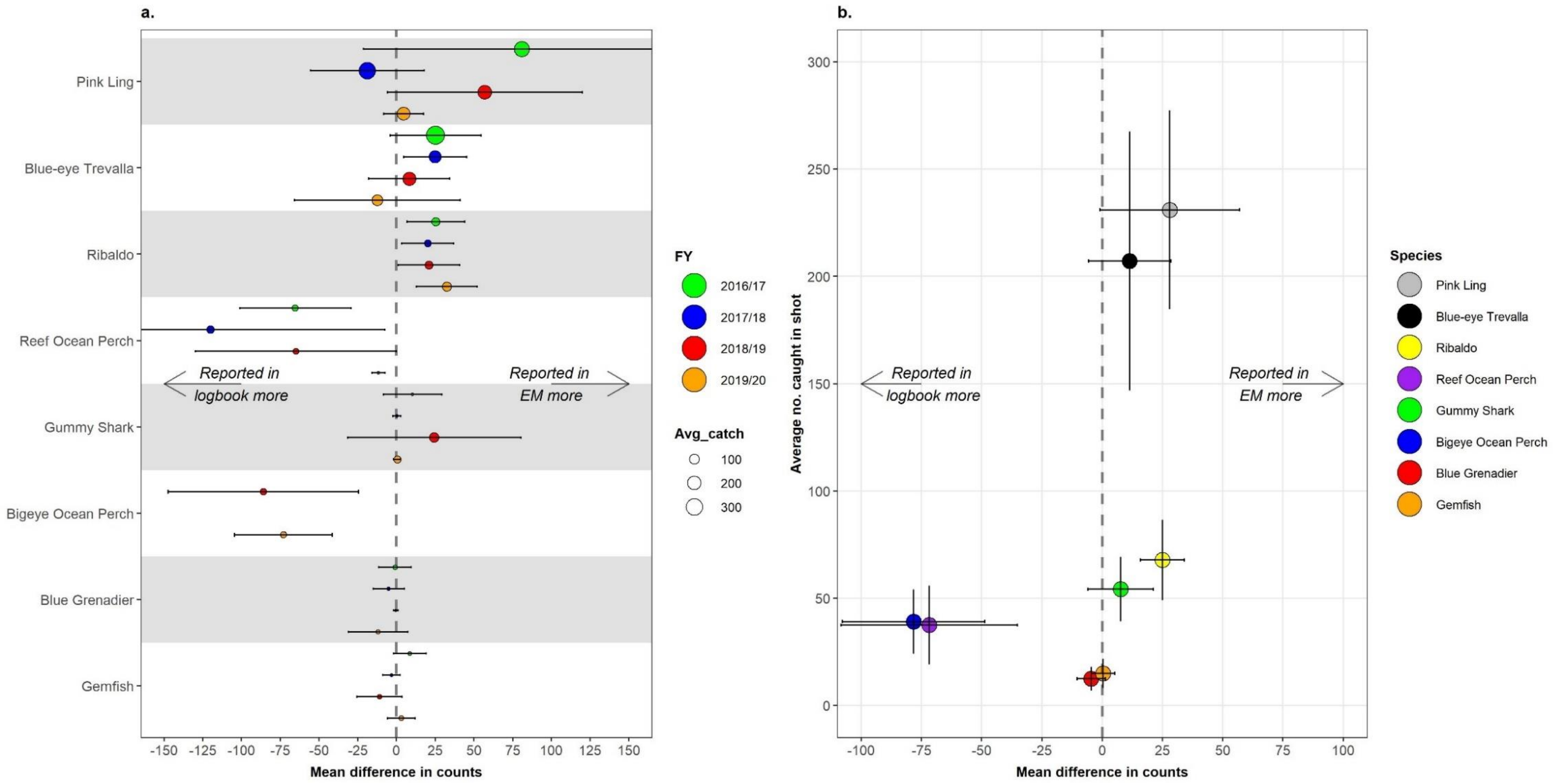
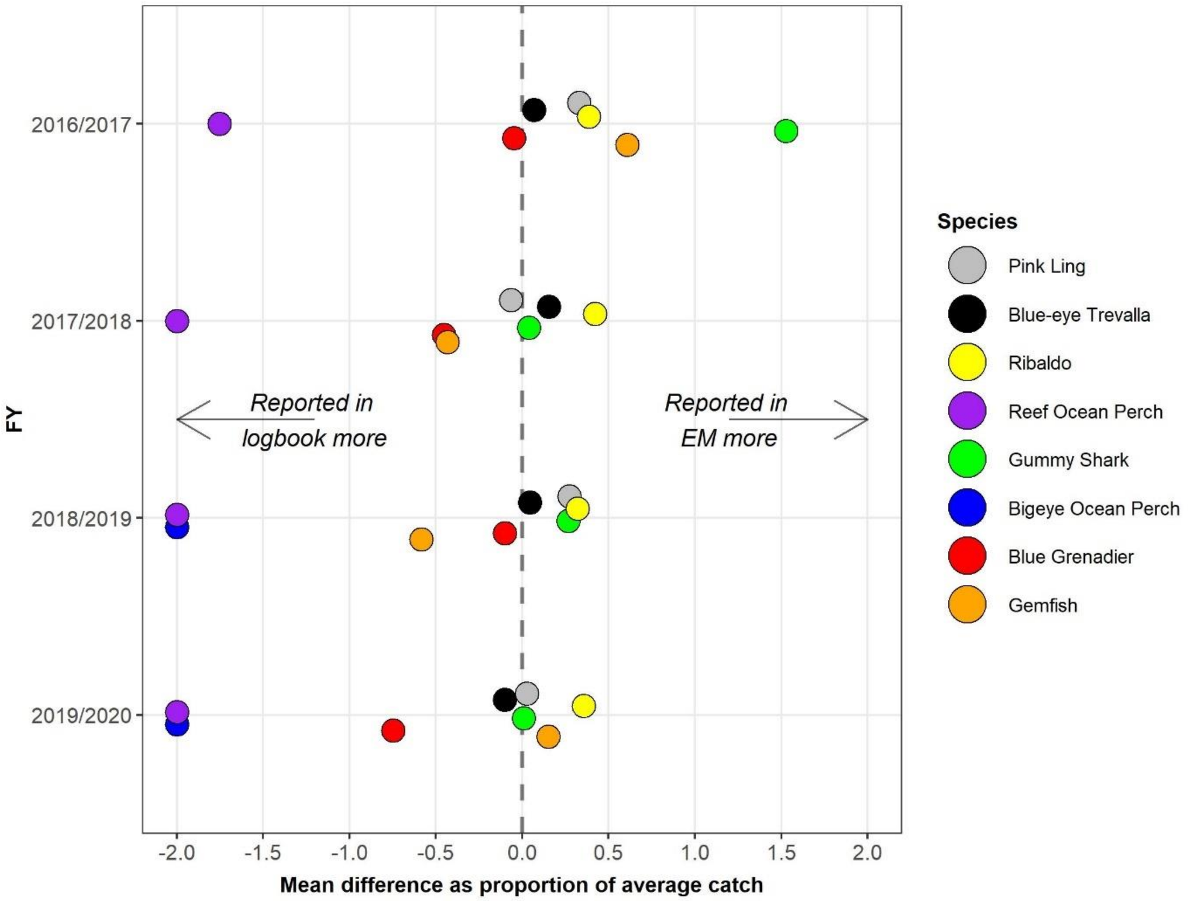


Figure 50: The mean difference in counts as a proportion of the average catch (average of EM and logbook reported) per shot for retained species in the LLA



Blue-eye Trevalla

Across the time period examined, 12% of shots audited that contained retained blue-eye trevalla had no difference in logbook and EM counts, 55% had higher counts reported by EM and 33% had higher counts reported by logbook. When differences in counts between logbook and EM were observed these were variable at the shot level, but mainly were up to ~10 individuals (Figure 51 and Figure 52). The level of congruence displayed high inter-annual variability, with 9% of shots in 2016/17 having no difference in logbook and EM counts, decreasing to 3% in 2018/19, before increasing to 24% by 2019/20 (Figure 53). While blue-eye trevalla was reported more by EM (11.4 ± 17.2 individuals) across the time period examined, the average number recorded by both EM and logbook in a single shot was high (207.1 ± 60.3 individuals), so as a proportion of the average catch, this difference was only 5% (Table 7). This suggest that for every 201.4 individuals reported by logbook, EM is reporting 212.8 individuals. Individuals were sometimes unreported, with 14% of shots containing a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool (Table 7), however there was clear inter-annually variability present (Figure 54).

Figure 51: Logbook and EM reported counts from individual shots containing retained blue-eye trevalla across time period examined. Red dashed line is the 1:1 line.

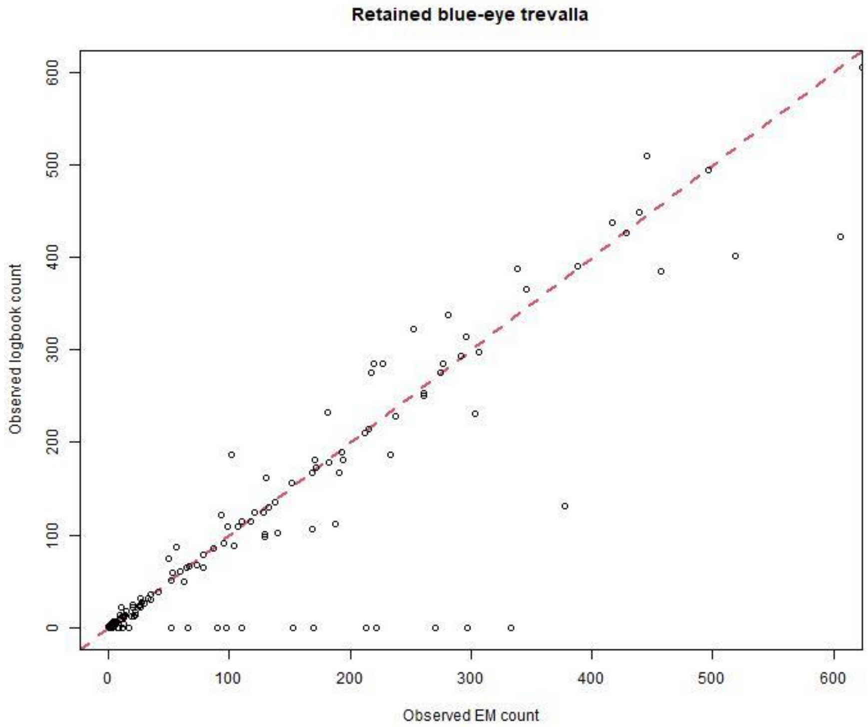


Figure 52: Proportion of shots with specific differences between EM and logbook counts for retained blue-eye trevalla across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

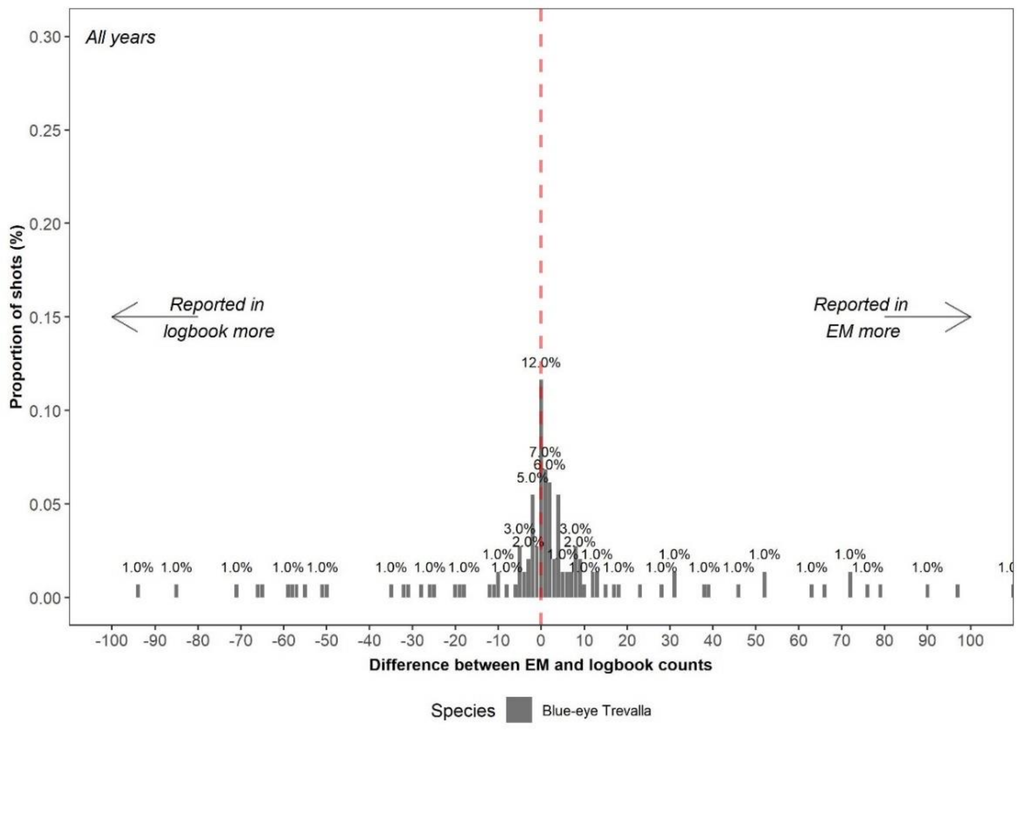


Figure 53: Proportion of shots with specific differences between EM and logbook counts for retained blue-eye trevalla for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

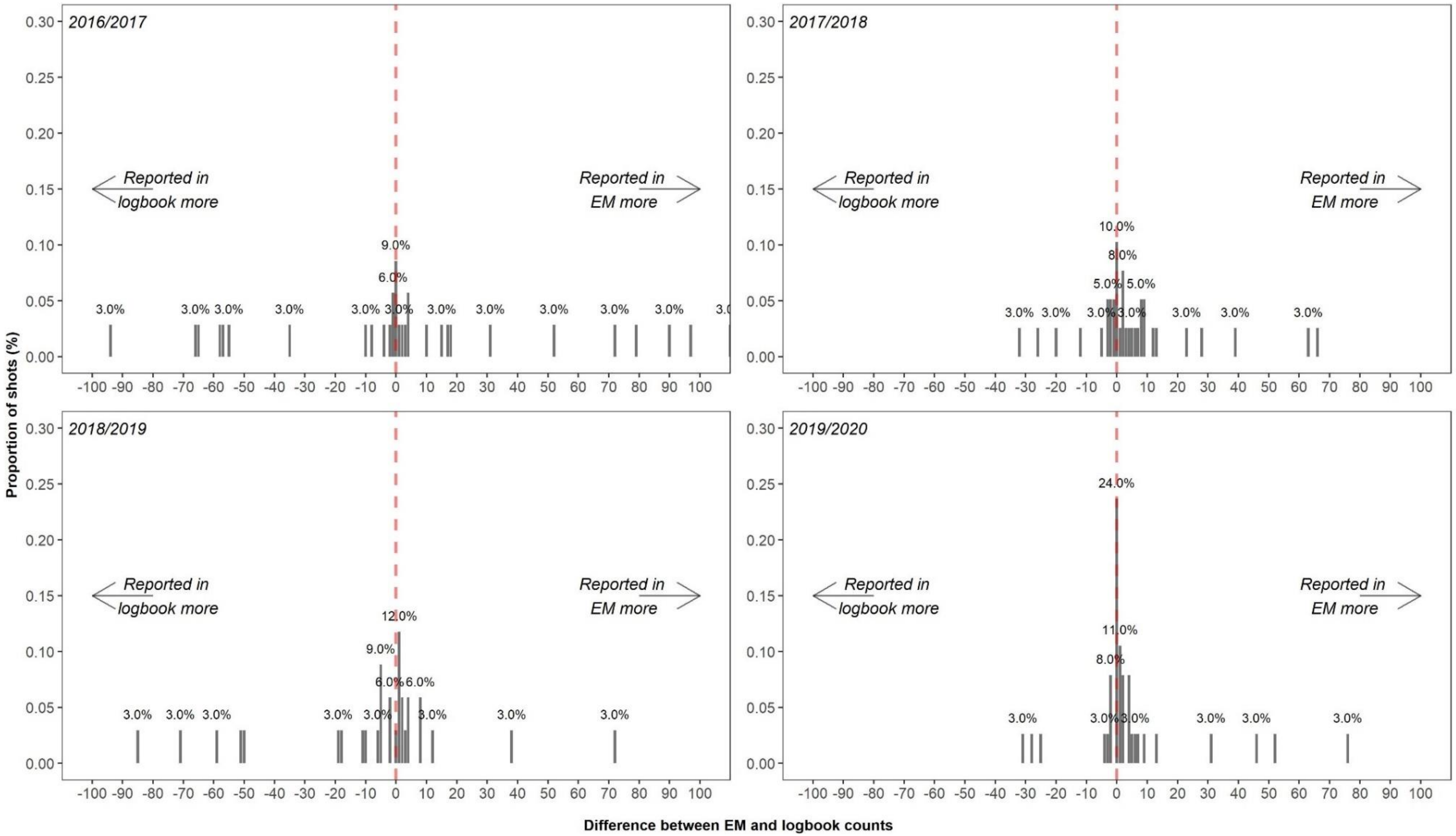
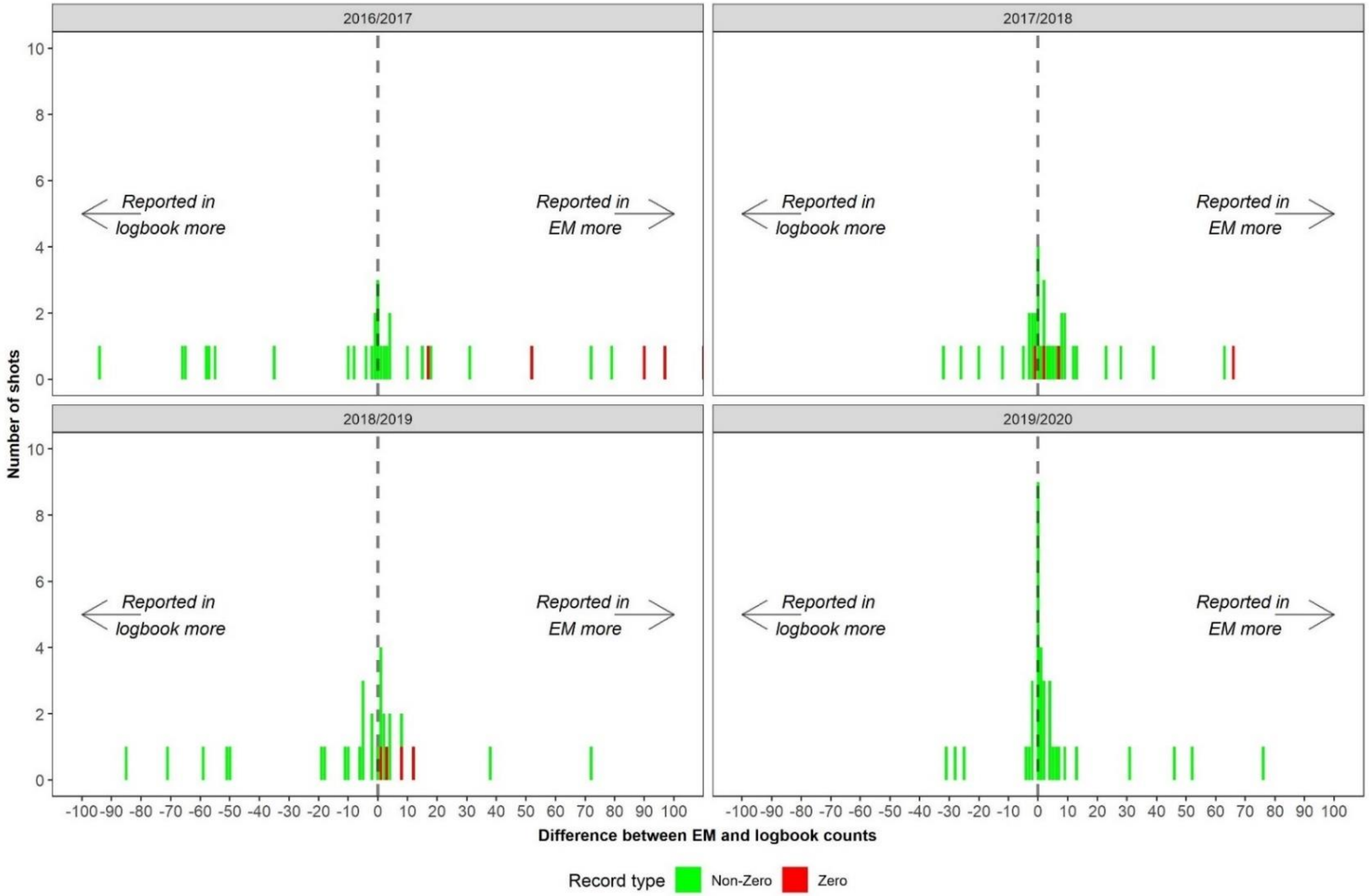


Figure 54: Number of shots with specific differences between EM and logbook counts for retained blue-eye trevalla across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



Pink Ling

Across the time period examined, 5% of shots audited that contained retained pink ling had no difference in logbook and EM counts, 60% had higher counts reported by EM and 35% had higher counts reported by logbook. When differences in counts between logbook and EM were observed these were variable at the shot level, but mainly were up to ~20 individuals (Figure 55 and Figure 56). The level of congruence displayed high inter-annual variability, with 0% of shots in 2016/17 having no difference in logbook and EM counts, increasing to 9% in 2018/19, before decreasing to 7% by 2019/20 (Figure 57). Pink ling was reported more by EM (28 ± 28.9 individuals) across the time period examined but the average number recorded by both EM and logbook in a single shot was high (231 ± 46.2 individuals), so as a proportion of the average catch, this difference was 12% (Table 7). This suggest that for every 217 individuals reported by logbook, EM is reporting 245 individuals. Individuals were sometimes unreported, with 14% of shots containing a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool (Table 7), however there was clear inter-annually variability present (Figure 58).

Figure 55: Logbook and EM reported counts from individual shots containing retained pink ling across time period examined. Red dashed line is the 1:1 line.

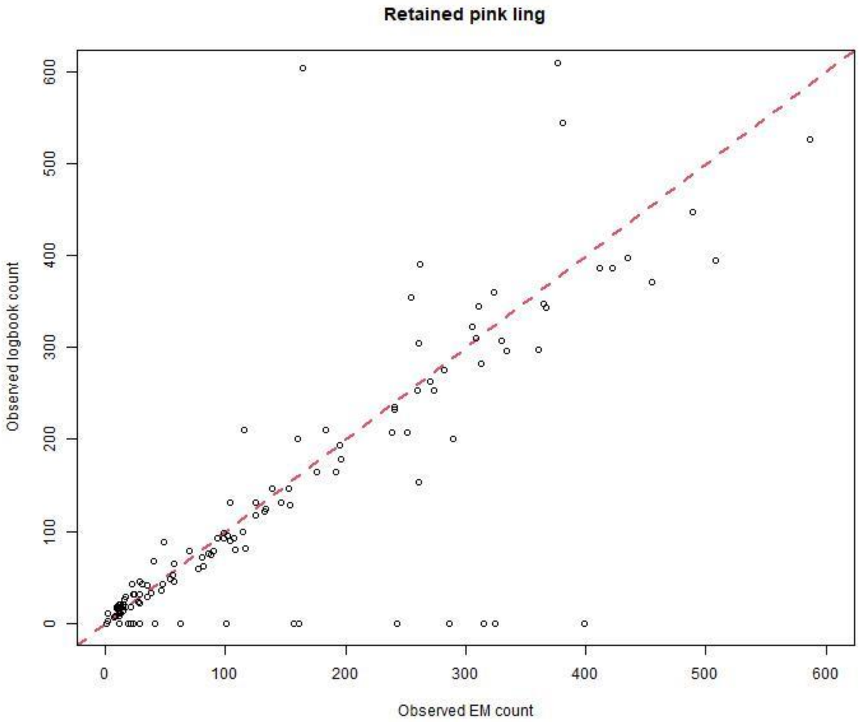


Figure 56: Proportion of shots with specific differences between EM and logbook counts for retained pink ling across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

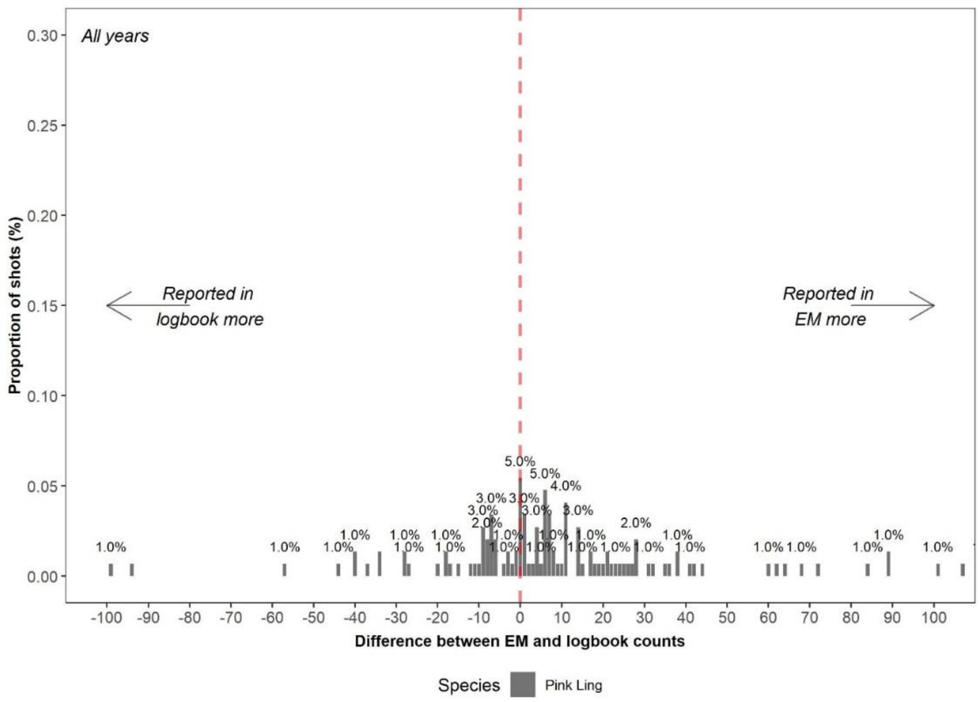


Figure 57: Proportion of shots with specific differences between EM and logbook counts for retained pink ling for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

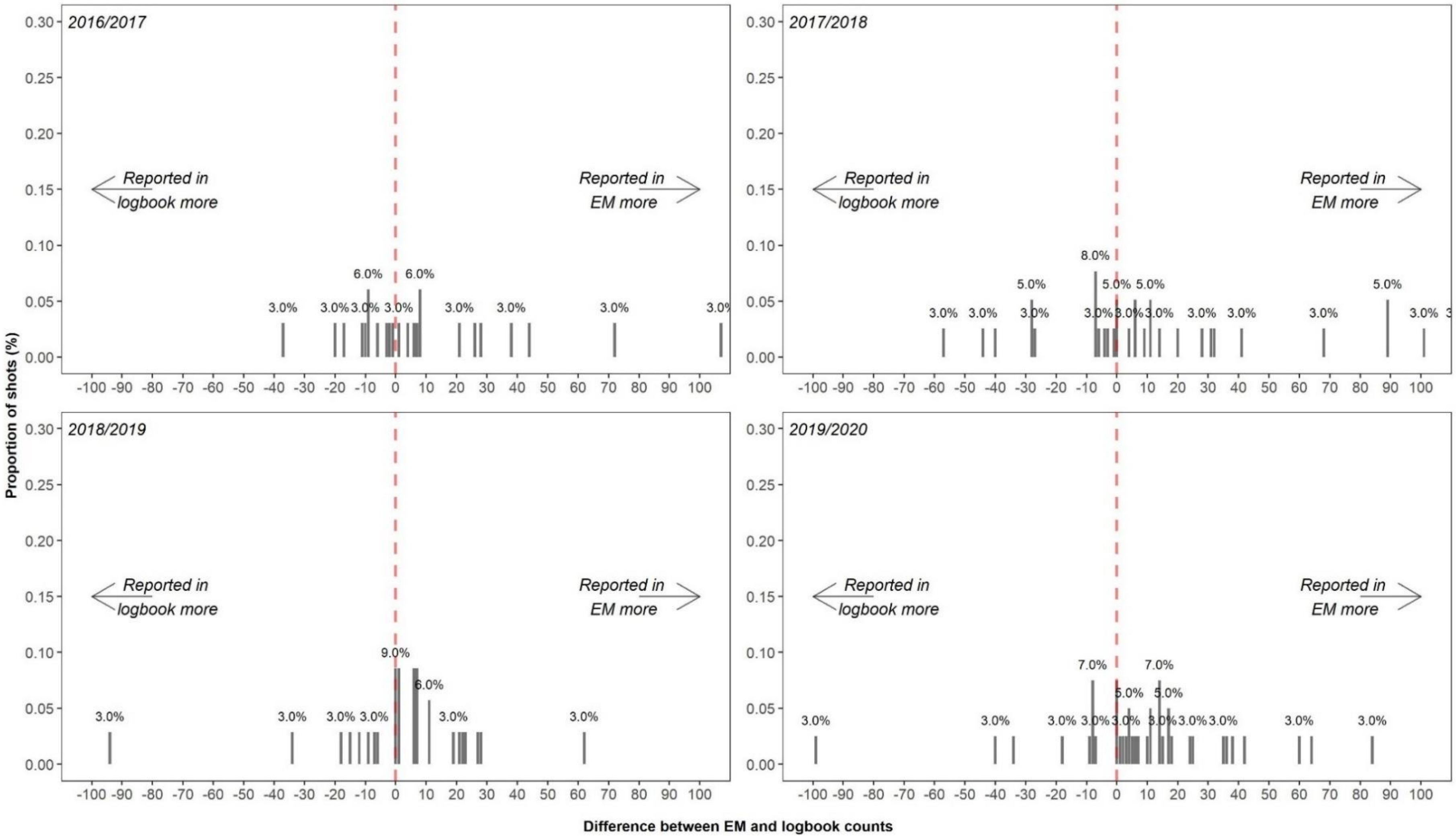
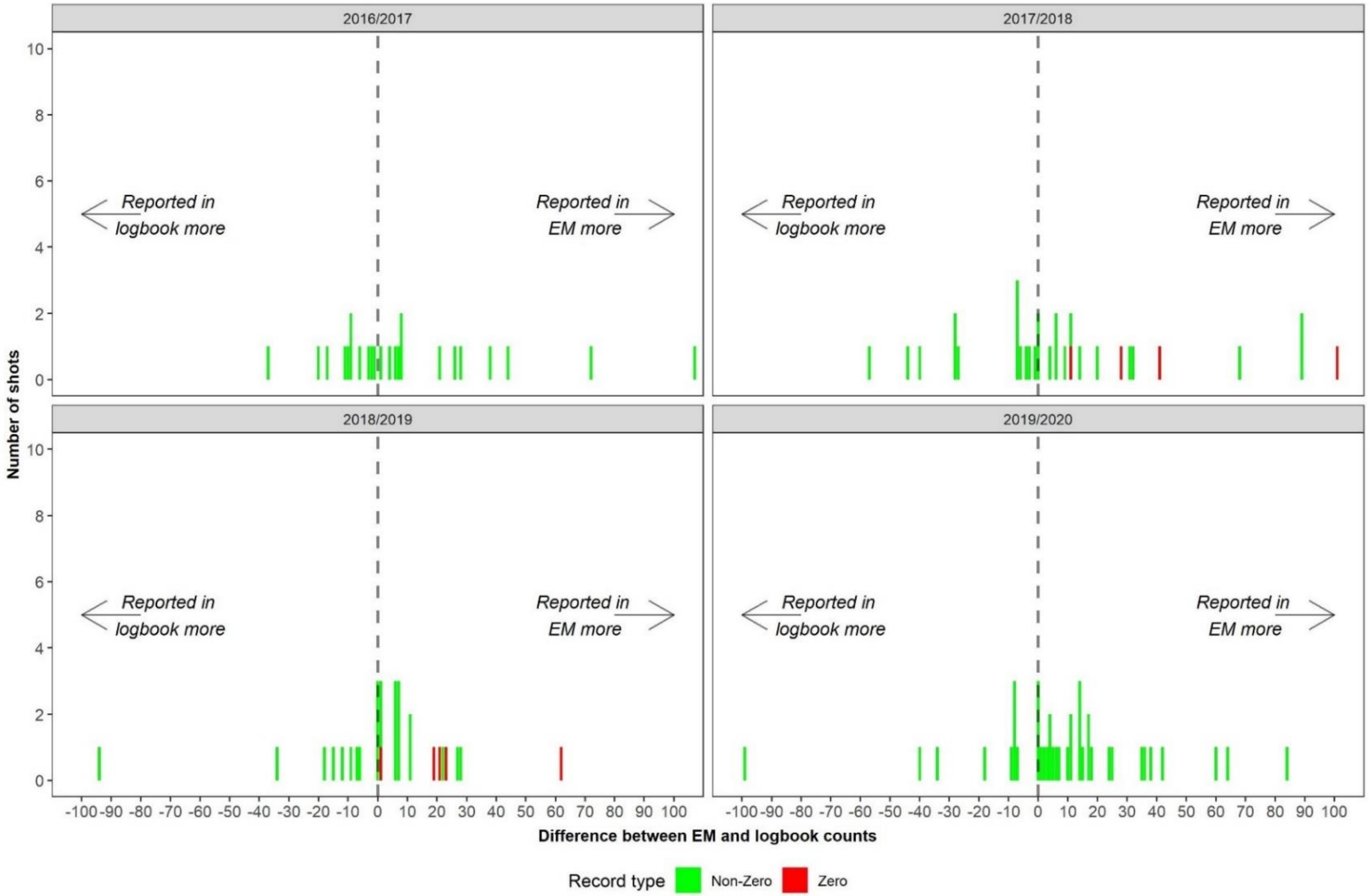


Figure 58: Number of shots with specific differences between EM and logbook counts for retained pink ling across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



Ribaldo

Across the time period examined, 8% of shots audited that contained retained ribaldo had no difference in logbook and EM counts, 64% had higher counts reported by EM and 38% had higher counts reported by logbook. When differences in counts between logbook and EM were observed these were variable at the shot level, but mainly were up to ~10 individuals (Figure 59 and Figure 60). The level of congruence displayed high inter-annual variability, with 6% of shots in 2016/17 having no difference in logbook and EM counts, decreasing to 3% in 2018/19, before increasing to 11% by 2019/20 (Figure 61). Ribaldo was reported retained more by EM (25 ± 9.1 individuals) across the time period examined, with the average number recorded retained by both EM and logbook in a single shot around 67.9± 18.7 individuals (Table 7), so as a proportion of the average catch this difference was significant at 37% and led to a clear right hand skew in the distribution of differences in counts (Figure 61). This suggest that for every 55.4 individuals reported by logbook, EM is reporting 80.4 individuals. Furthermore, individuals were sometimes unreported with 18% of shots containing a zero record for either EM or logbook when ≥1 individual was reported discarded by the other data collection tool (Figure 62). On this evidence there is some issues with the reporting of this species, primarily by logbook.

Figure 59: Logbook and EM reported counts from individual shots containing retained ribaldo across time period examined. Red dashed line is the 1:1 line.

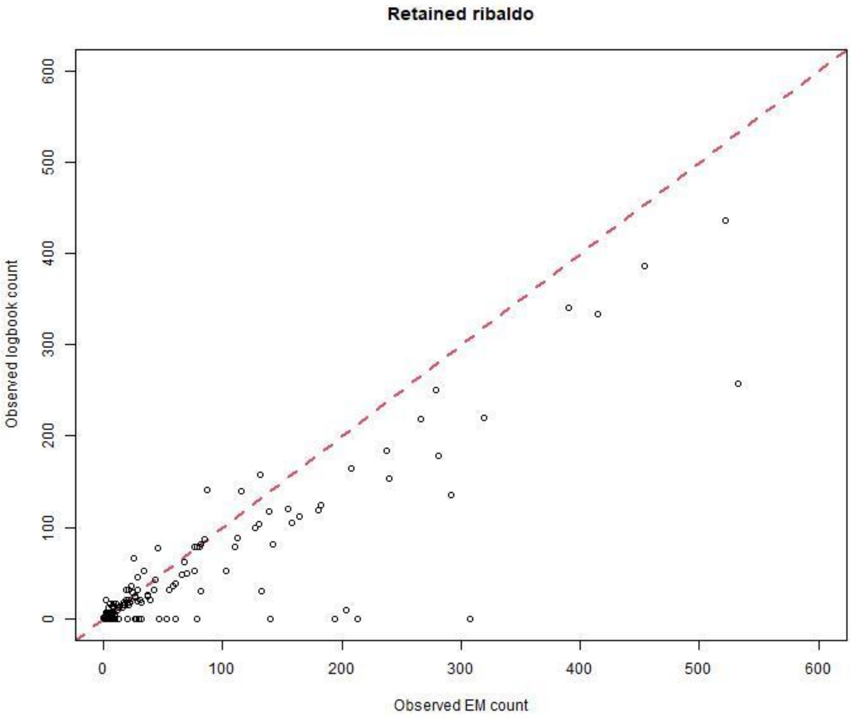


Figure 60: Proportion of shots with specific differences between EM and logbook counts for retained ribaldo across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

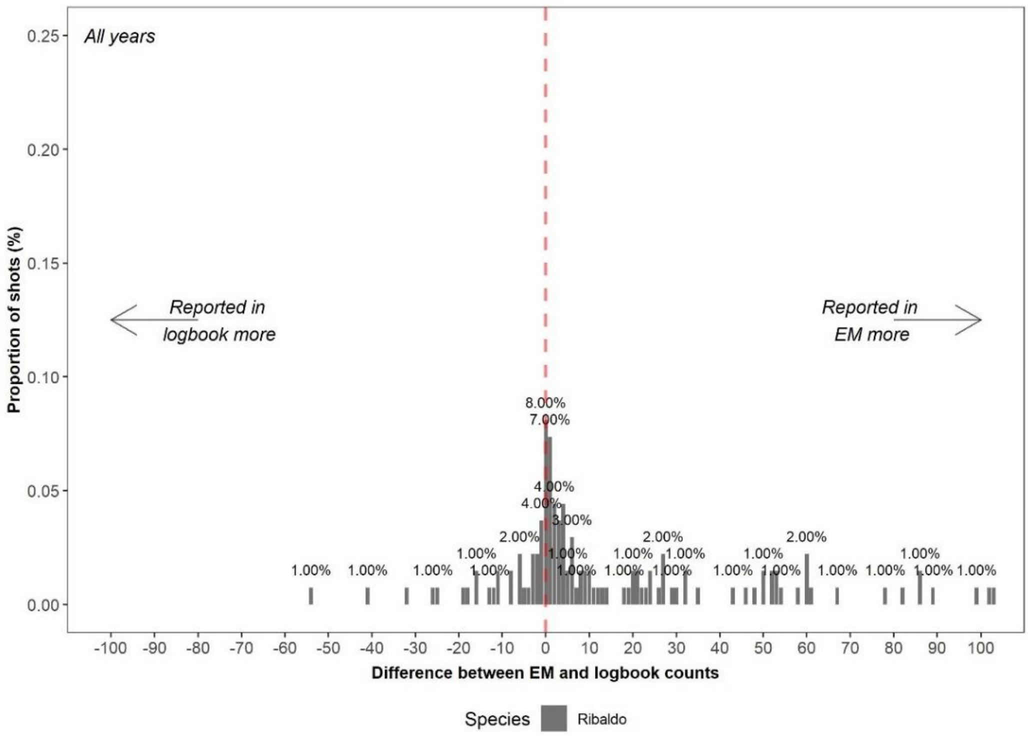


Figure 61: Proportion of shots with specific differences between EM and logbook counts for retained ribaldo for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

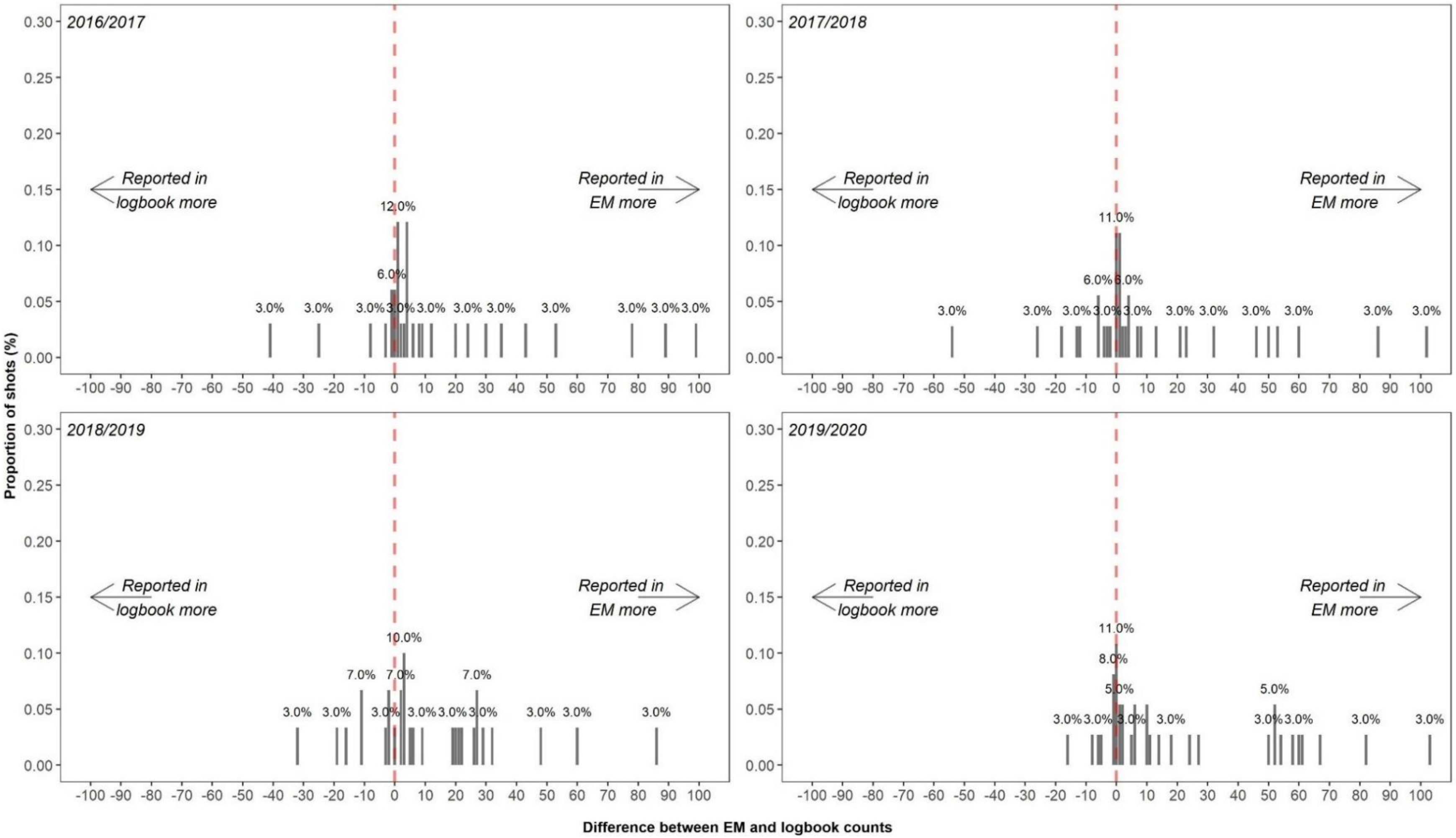
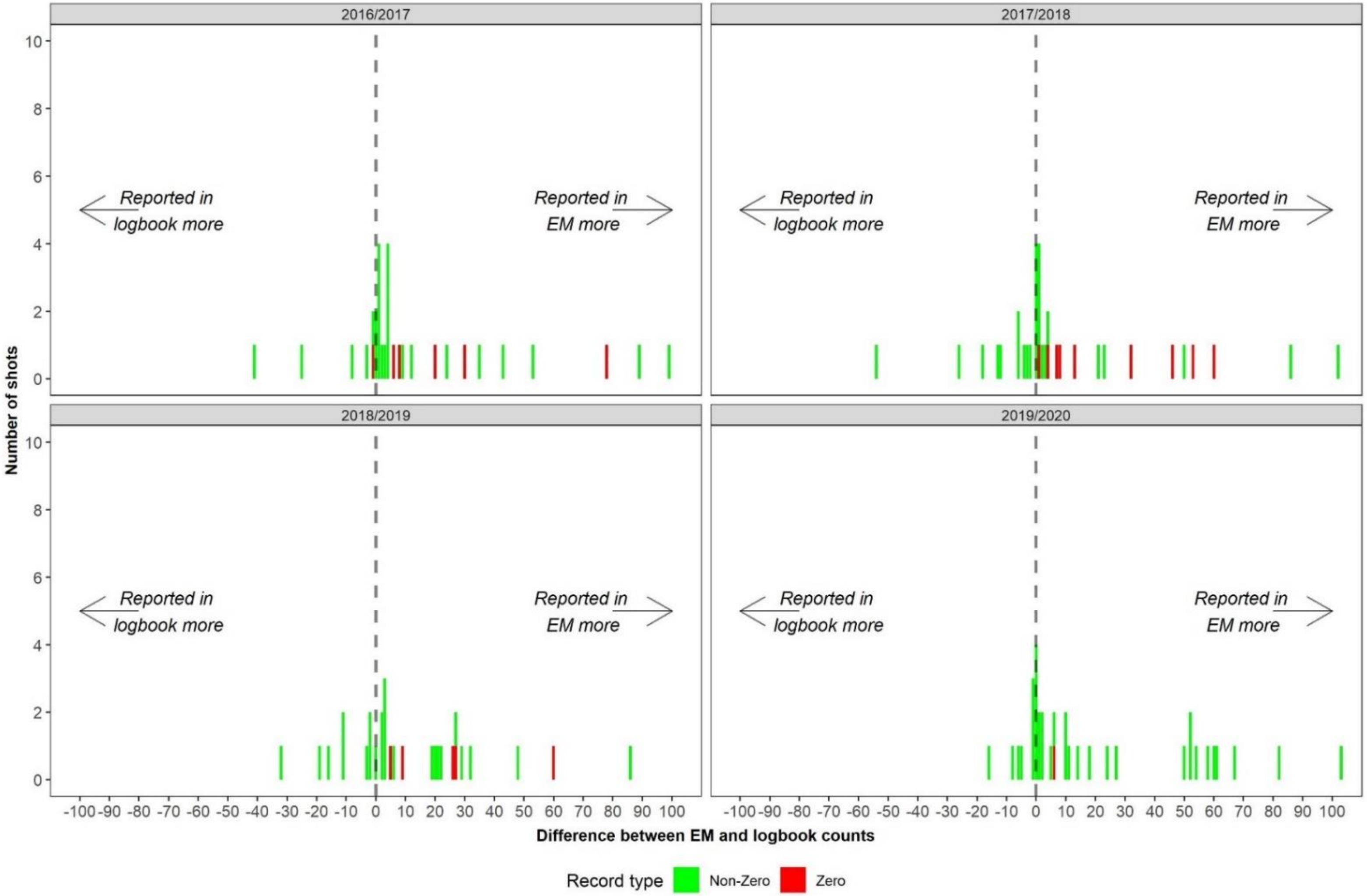


Figure 62: Number of shots with specific differences between EM and logbook counts for retained ribaldo across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



3.2.2 Discarded catch

In the LLA, there were a total of 18 species that made up 95% of the reported discarded catch from the logbook audited shots between 2016/17 and 2019/20. These species are displayed in Table 8 in descending order of the proportion of catch.

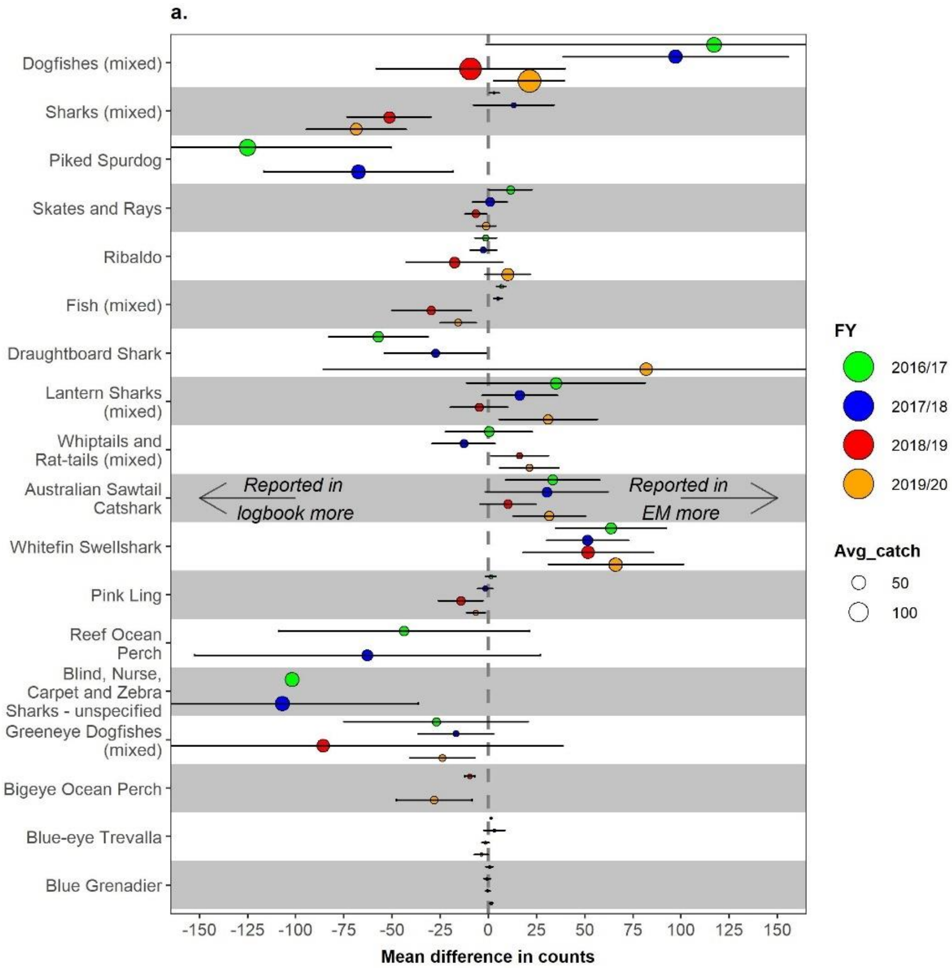
There was substantial inter-annual variation in the reporting of main target discarded species such as pink ling, ribaldo and blue-eye trevalla. For example, pink ling was reported more by EM in 2016/17 but in later years more by logbook (Figure 63 and Figure 64). A similar pattern was also observed for blue-eye trevalla. For other discarded species, congruence was low, with some species, such as piked spurdog and draughtboard shark reported in greater numbers by logbook, while others, such as dogfishes (mixed group) and whitefin swellshark reported in higher numbers by EM (Figure 63 and Figure 64). There were also many shots where individuals were not reported as discarded by either EM or logbook but ≥1 individual was reported by the other data collection tool for the same shot. Clearly, there are either some species identification issues (e.g., possibly due to camera resolution, positioning or misidentification), or the species being considered low priority for reporting or deliberate under-reporting or over-reporting.

Table 8: 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 GNS.

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
Dogfishes (mixed group)	*Squaliformes*	45.2 (±26.5)	102.9 (±29.6)	44%	62%
Sharks (mixed group)	*Elasmobranchii*	-47.5 (±15.2)	28.5 (±7.7)	-167%	77%
Piked spurdog	*Squalus megalop*	-93.6 (±42.2)	59.6 (±21.9)	-157%	80%
Skates and rays	*Elasmobranchii*	0.3 (±3.6)	15.7 (±3.0)	2%	34%
Ribaldo	*Mora moro*	-1.8 (±6.9)	22.5 (±9.0)	-8%	51%
Fish (mixed group)	*Teleost*	-11.8 (±7.0)	10.1 (±3.4)	-116%	78%
Draughtboard shark	*Cephaloscyllium laticeps*	-28.1 (±26.6)	26.0 (±11.5)	-108%	93%
Lantern sharks (mixed group)	*Etmopterus*	19.0 (±13.3)	23.9 (±6.2)	80%	77%

Whip-tails and rat-tails (mixed group)	*Macrouridae*	0.7 (±10.0)	16.9 (±4.7)	4%	85%
Australian sawtail catshark	*Figaro boardmani*	27.0 (±11.1)	21.8 (±5)	124%	78%
Whitefin swellshark	*Cephaloscyllium albipinnum*	58.4 (±14.8)	37.5 (±7.3)	156%	85%
Pink ling	*Genypterus blacodes*	-5.8 (±3.6)	8.6 (±2.9)	-68%	48%
Reef ocean perch	*Helicolenus percoides*	-53.4 (±50.1)	26.7 (±25.1)	-200%	100%
Blind, nurse, carpet and zebra sharks (mixed group)	*Elasmobranchii*	-106.3 (±60.6)	53.2 (±30.3)	-200%	100%
Greeneye dogfishes (mixed group)	*Squaliformes*	-37.2 (±27.2)	19.1 (±13.5)	-195%	100%
Bigeye ocean perch	*Helicolenus barathri*	-20.9 (±12.1)	10.5 (±6.0)	-200%	100%
Blue-eye trevalla	*Hyperoglyphe antarctica*	-0.0 (±1.5)	1.9 (±0.7)	-2%	83%
Blue grenadier	*Macruronus novaezelandiae*	0.3 (±0.7)	1.6 (±0.4)	20%	71%

Figure 63: Reporting of discarded species in the LLA (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.



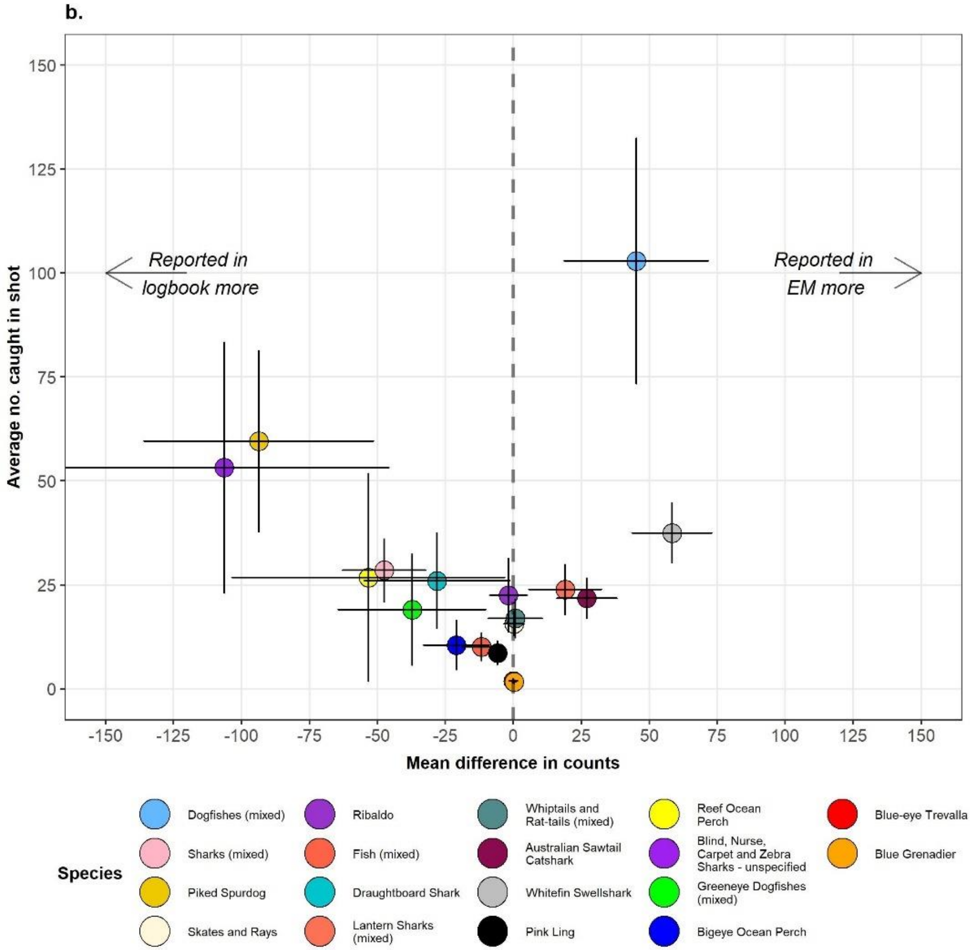
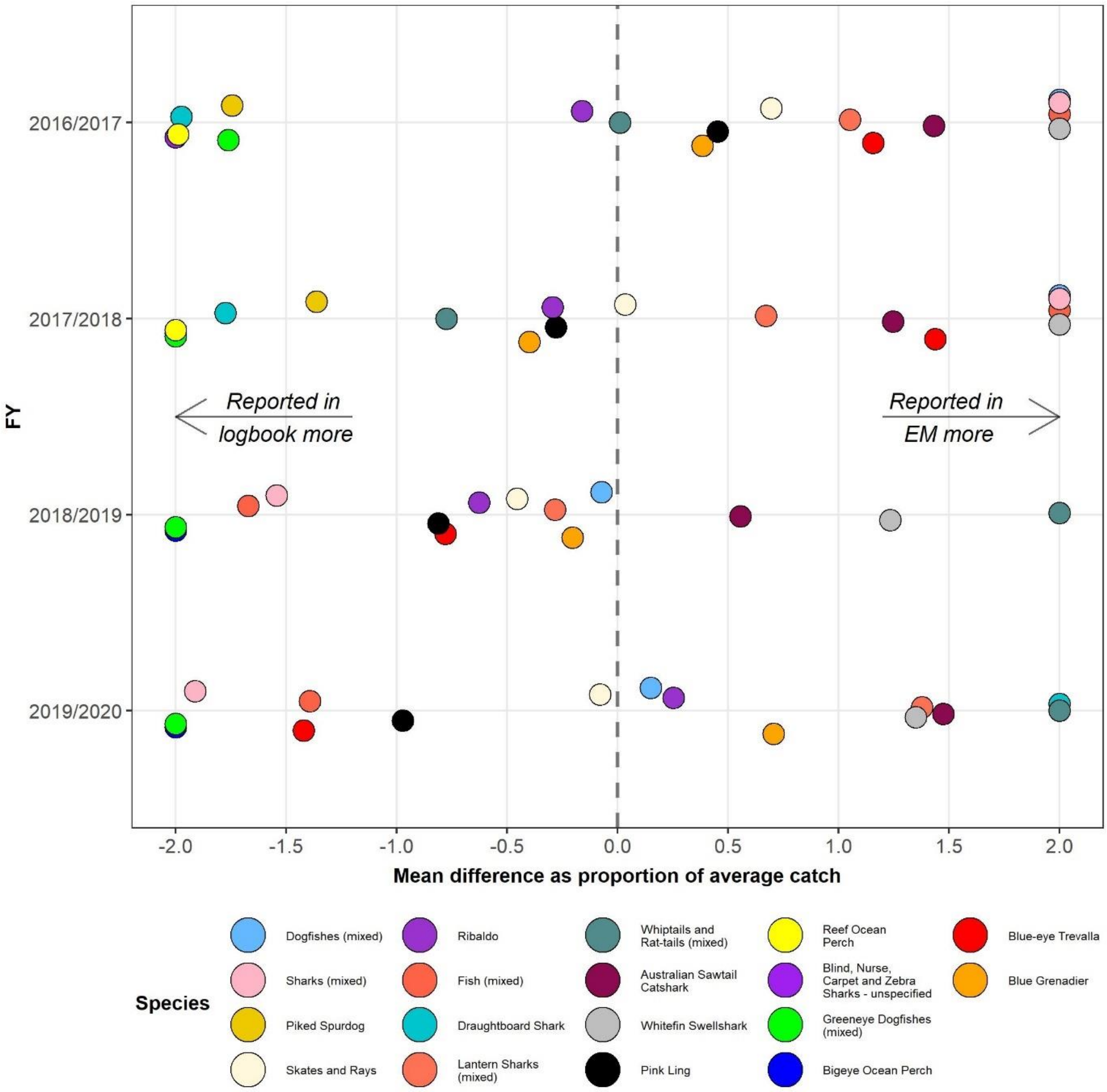


Figure 64: The mean difference in counts as a proportion of the average catch (average of EM and logbook reported) per shot for discarded species in the LLA



Blue-eye Trevalla

Across the time period examined, 6% of shots audited that contained discarded blue-eye trevalla had no difference in logbook and EM counts, 54% had higher counts reported by EM and 40% had higher counts reported by logbook. When differences in counts between logbook and EM were observed these were variable at the shot level, but mainly were up to ~5 individuals (Figure 65 and Figure 66) The level of congruence displayed high inter-annual variability, with 9% of shots in 2016/17 having no difference in logbook and EM counts, decreasing to 0% in 2017/18, before increasing to 7% by 2019/20 (Figure 67). There was no clear mean difference in counts of discarded blue-eye trevalla (-0.0 ± 1.5 individuals) across the time period examined and the average number recorded by both EM and logbook in a single shot was very low (1.9 ± 0.7 individuals), so as a proportion of the average catch, this difference was only -2% (Table 8). This suggest that for every 1.9 individuals reported by logbook, EM is also reporting 1.9 individuals, however there were distinct differences in vessels that need to be noted (see below). Individuals were often unreported, with 83% of shots containing a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool (Table 8), however there was clear inter-annually variability present (Figure 68).

Figure 65: Logbook and EM reported counts from individual shots containing discarded blue-eye trevalla across time period examined. Red dashed line is the 1:1 line.

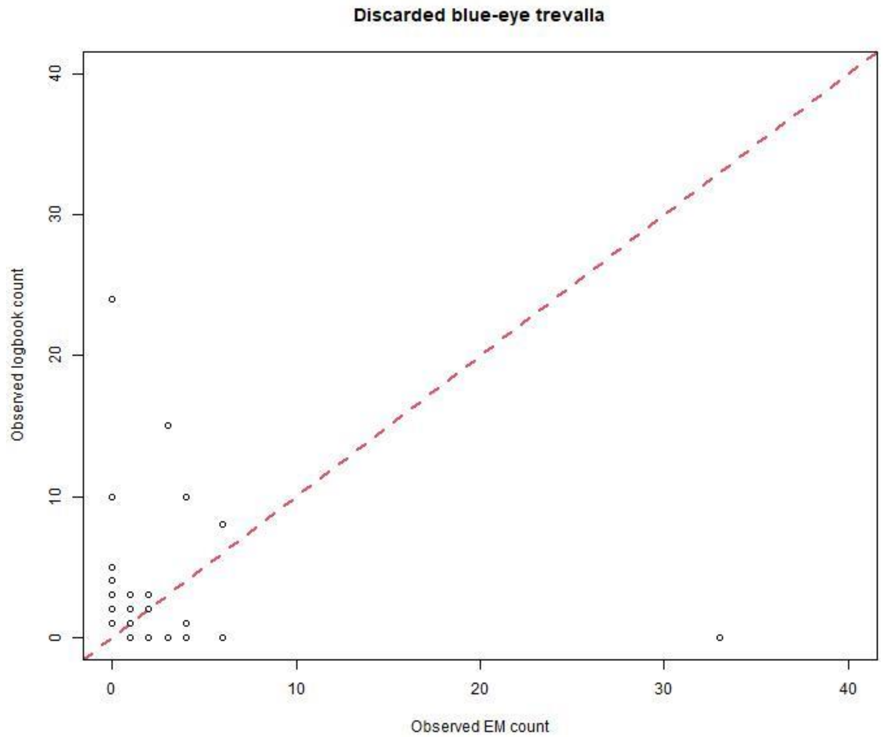


Figure 66: Proportion of shots with specific differences between EM and logbook counts for discarded blue-eye trevalla across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

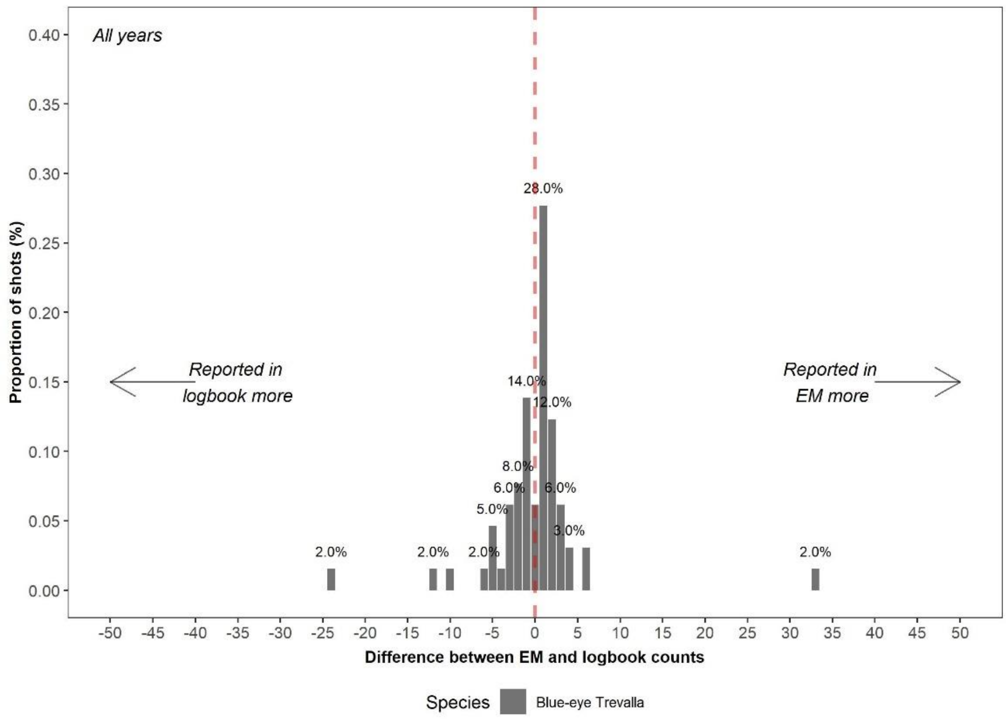


Figure 67: Proportion of shots with specific differences between EM and logbook counts for discarded blue-eye trevalla for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

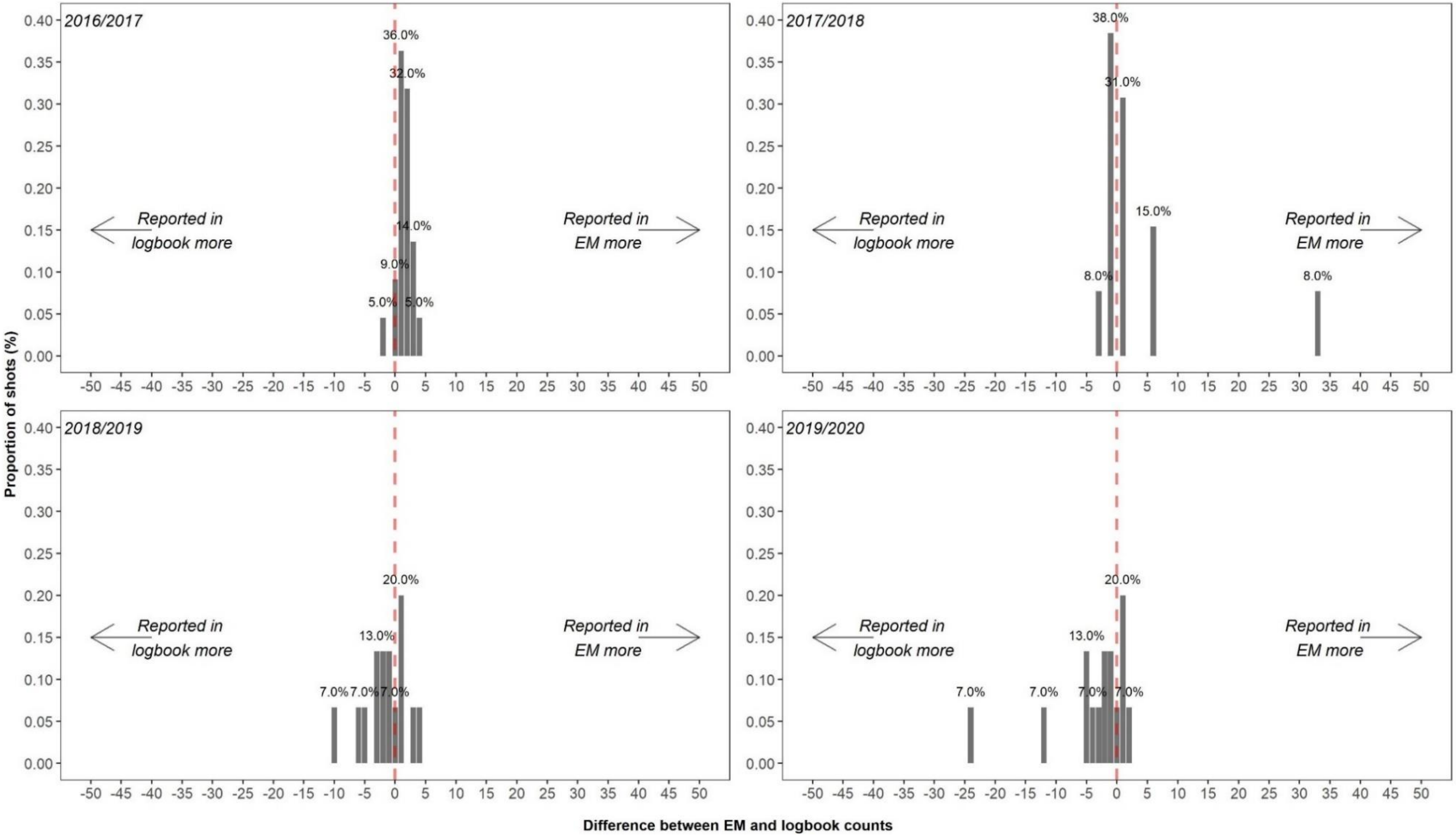
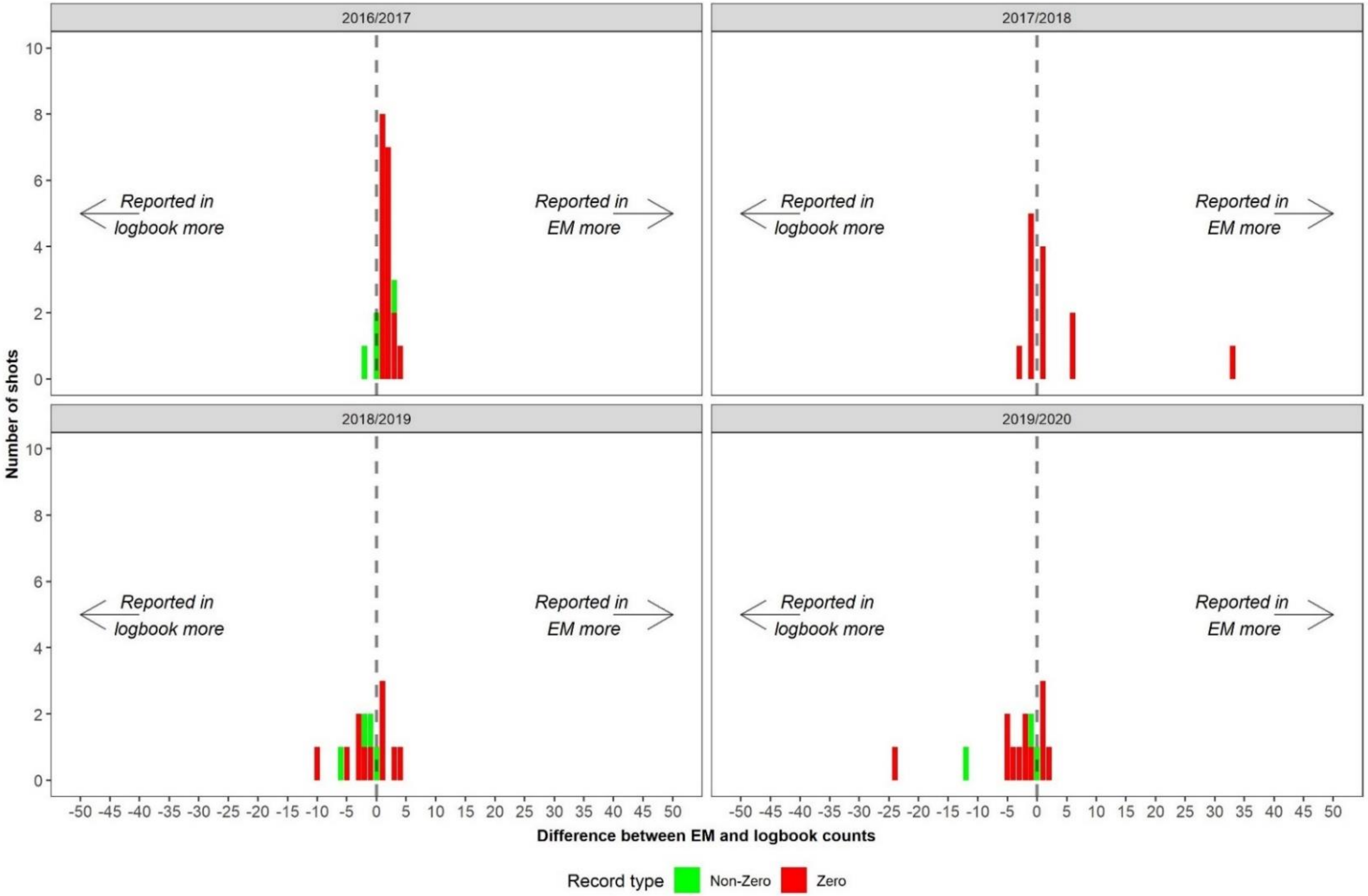


Figure 68: Number of shots with specific differences between EM and logbook counts for discarded blue-eye trevalla across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



Pink Ling

Across the time period examined, 4% of shots audited that contained discarded pink ling had no difference in logbook and EM counts, 44% had higher counts reported by EM and 52% had higher counts reported by logbook. When differences in counts between logbook and EM were observed these were variable at the shot level, but mainly were up to ~10 individuals (Figure 69 and Figure 70). The level of congruence displayed high inter-annual variability, with 0% of shots in 2016/17 having no difference in logbook and EM counts, increasing to 7% in 2018/19, before decreasing to 6% by 2019/20 (Figure 71). Discarded pink ling were reported more by logbook (-5.8 ± 3.6 individuals) across the time period examined but the average number recorded by both EM and logbook in a single shot was low (8.6 ± 2.9 individuals), so as a proportion of the average catch, this difference was high at -68% (Table 8) and led to a clear left hand skew in the distribution of differences in counts . This suggest that for every 11.5 individuals reported discarded by logbook, EM is reporting 5.7 individuals. Individuals were often unreported, with 48% of shots containing a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool (Table 8), however there was clear inter-annually variability present (Figure 72).

Figure 69: Logbook and EM reported counts from individual shots containing discarded pink ling across time period examined. Red dashed line is the 1:1 line.

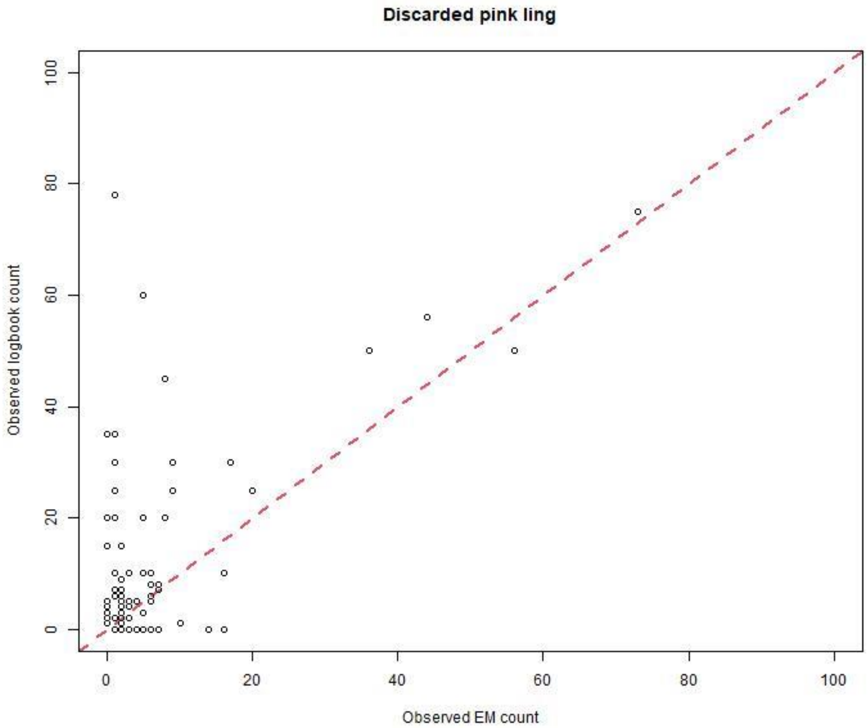


Figure 70: Proportion of shots with specific differences between EM and logbook counts for discarded pink ling across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

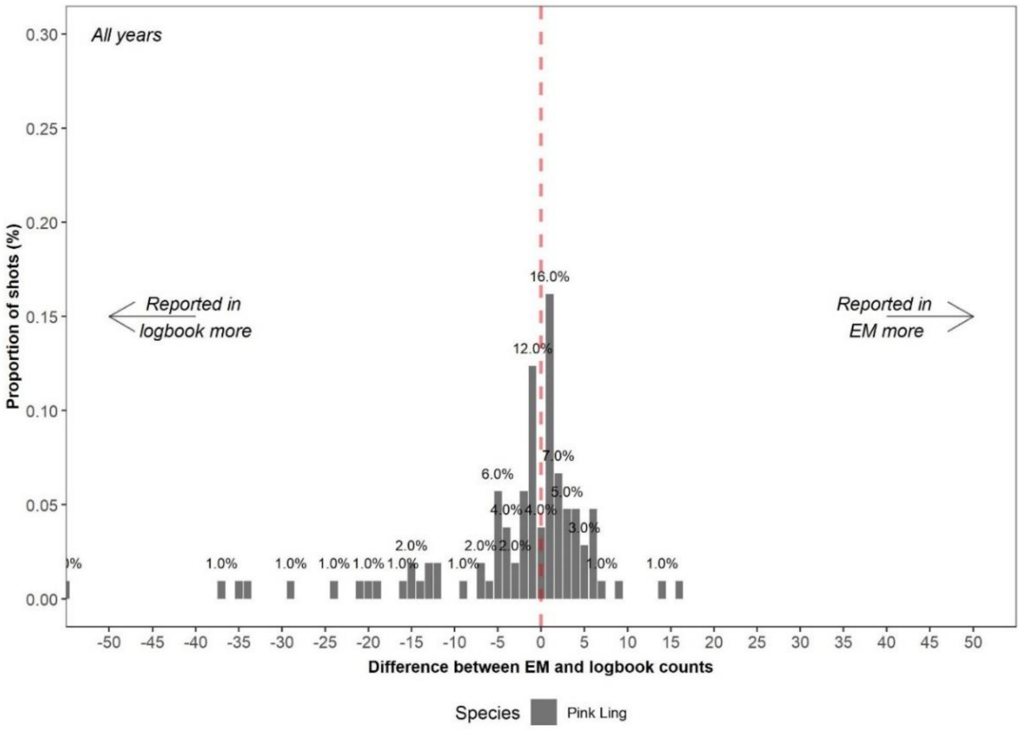


Figure 71: Proportion of shots with specific differences between EM and logbook counts for discarded pink ling for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

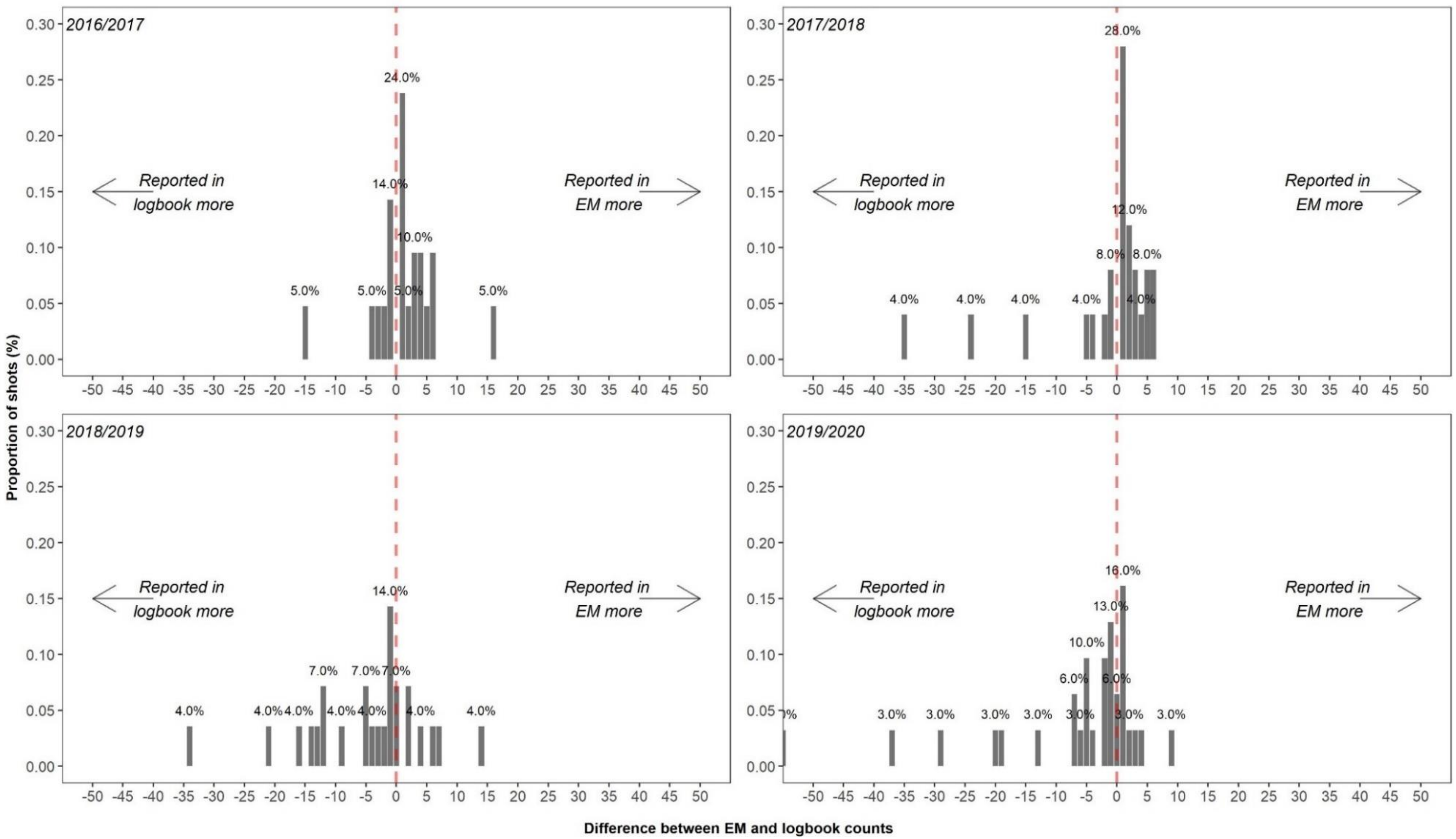
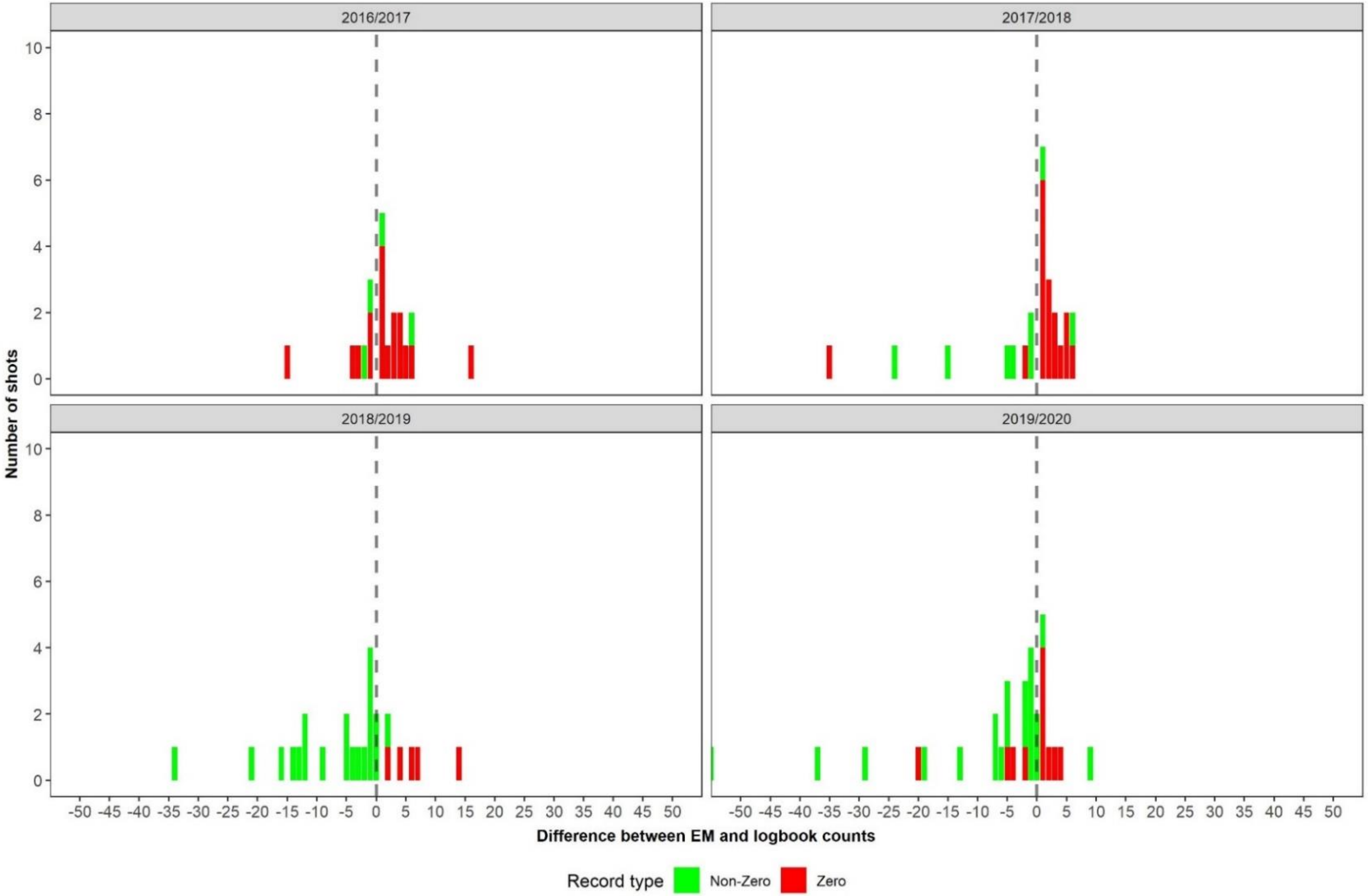


Figure 72: Number of shots with specific differences between EM and logbook counts for discarded pink ling across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.



Ribaldo

Across the time period examined, 3% of shots audited that contained ribaldo had no difference in logbook and EM counts, 60% had higher counts reported by EM and 37% had higher counts reported by logbook. When differences in counts between logbook and EM were observed these were variable at the shot level, but mainly were up to ~20 individuals (Figure 73 and Figure 74). The level of congruence displayed high inter-annual variability, with 0% of shots in 2016/17 and 2017/18 having no difference in logbook and EM counts, before increasing to 7% by 2019/20 (Figure 75). Ribaldo was reported discarded slightly more by logbook (-1.8 ± 6.9 individuals) across the time period examined, with the average number recorded retained by both EM and logbook in a single shot around 22.5 ± 9.0 individuals, so as a proportion of the average catch this difference was only -8% (Table 8). This suggest that for every 23.4 individuals reported by logbook, EM is reporting 21.6 individuals, however there were distinct differences in vessels that need to be noted (see below). Furthermore, individuals were often unreported with 51% of shots containing a zero record for either EM or logbook when ≥1 individual was reported discarded by the other data collection tool (Figure 76).

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

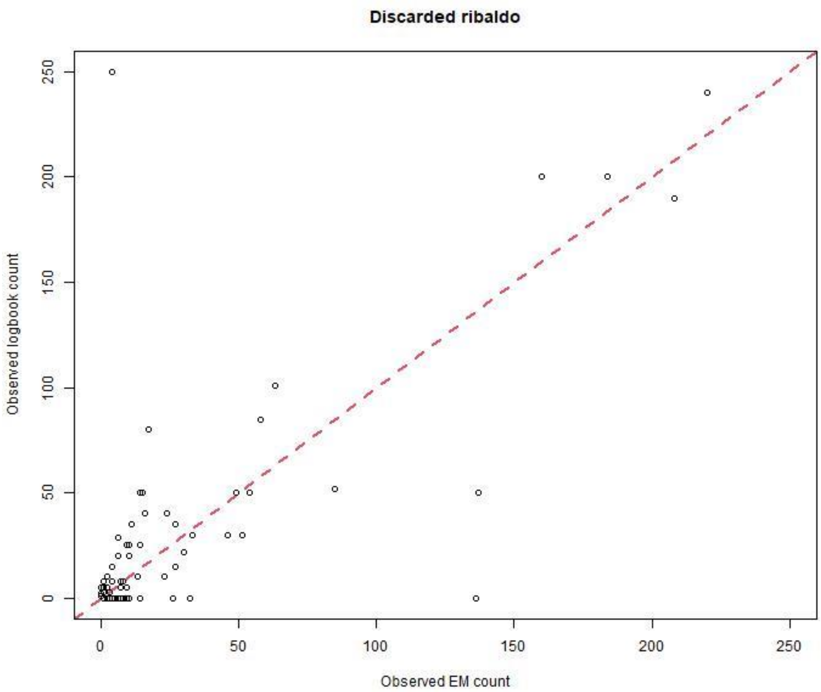


Figure 74: Proportion of shots with specific differences between EM and logbook counts for discarded ribaldo across the time period examined. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

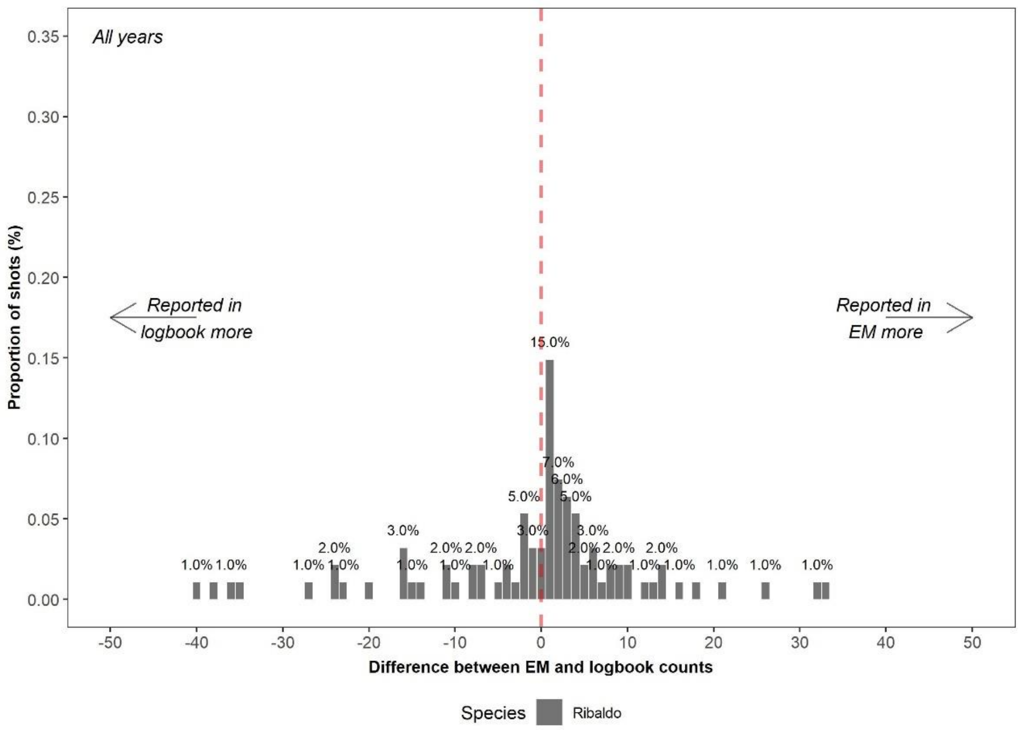


Figure 75: Proportion of shots with specific differences between EM and logbook counts for discarded ribaldo for each financial year. Red dashed line equates to zero difference. Note the figure has been trimmed on the x-axis.

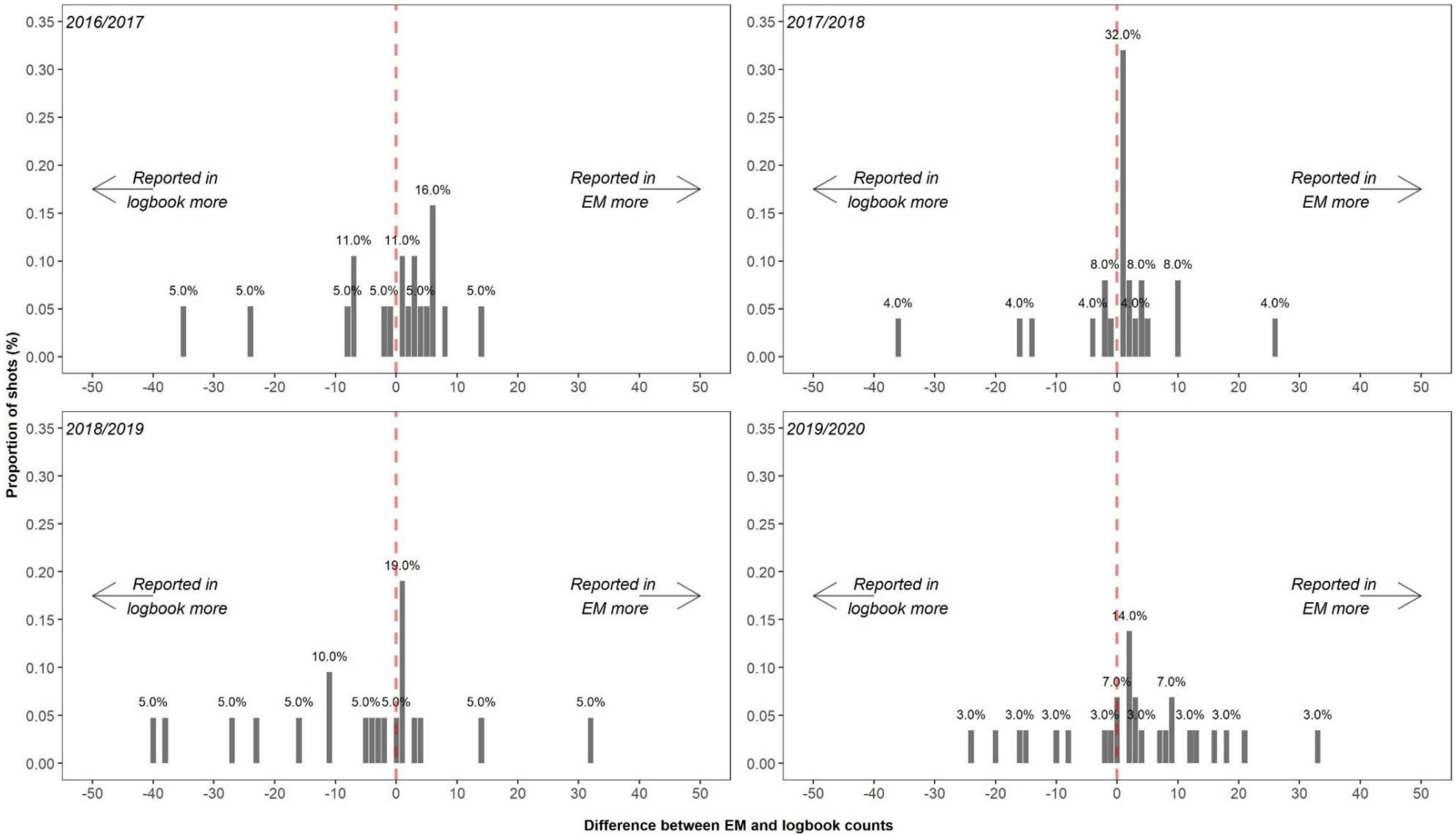
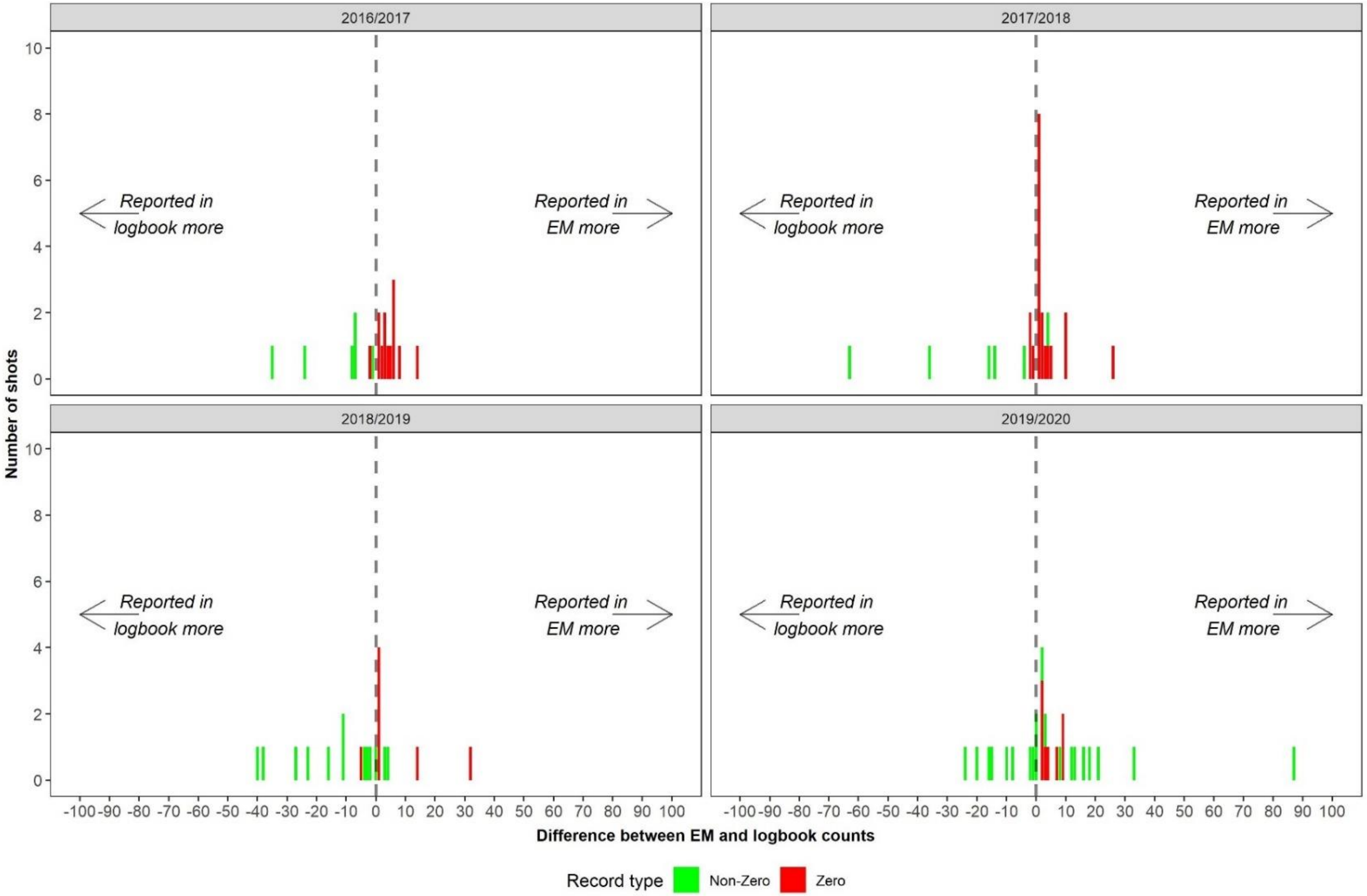


Figure 76: Number of shots with specific differences between EM and logbook counts for discarded ribaldo across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference. Note the figure has been trimmed on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



3.2.3 Threatened, Endangered and Protected (TEP) species

There was a total of 165 audited shots that contained a reported interaction with a protected species in the time period analysed (2015/16 to 2019/20). Of these, 39 were from the LLA and only two from the LLS. Consequently, when it came to analysis, the shots from the LLA and LLS were combined for a total of 41 audited shots. Due to taxonomic identification issues in the entire dataset, species were placed into TEP groups (seabirds, pinnipeds, cetaceans, and sharks) for analysis. Appendix B contains a table with the TEP groups disaggregated at a species level.

There was an overall low number of audited shots with TEP interactions in the LLA and LLS. Sharks and seabird interactions had the greatest number of audited shots of all the TEP groups, and the results indicated there were some differences in reporting (Figure 77 and Table 9) For seabirds, when differences in reporting were observed these were low in terms of absolute number (i.e., ±1 individual) but for sharks it was evident there were several shots in some years with large absolute differences where EM was reporting more than logbook (Figure 77 and Figure 78). The other two TEP groups (pinnipeds and cetaceans) only had one or two audited shots with interactions and therefore were not very useful to interpret results.

Table 9: Total number of interactions with TEP groups recorded by EM and logbook in the GNS by financial year.

TEP group	FY	EM total no.	Logbook total no.	Notes
Sharks	2015/16	15	3	
	2016/17	5	5	
	2017/18	2	0	*Only 2 audited shots containing TEP species
	2018/19	13	6	
	2019/20	4	5	*Only 2 audited shots containing TEP species
Cetaceans	2019/20	1	1	*Only 1 audited shot containing TEP species
Pinnipeds	2016/17	1	0	*Only 1 audited shot containing TEP species
	2017/18	1	1	*Only 1 audited shot containing TEP species
Seabirds	2015/16	4	3	
	2016/17	7	7	
	2017/18	6	9	
	2018/19	8	9	*Only 3 audited shots containing TEP species
	2019/20	1	1	*Only 1 audited shot containing TEP species
Total	**All years**	**68**	**50**	

Figure 77: Frequency histograms of the difference in counts between EM and logbook for individual shots across TEP groups in the LLA and LLS across the time period analysed (where positive numbers = higher EM counts and negative numbers = higher logbook counts).

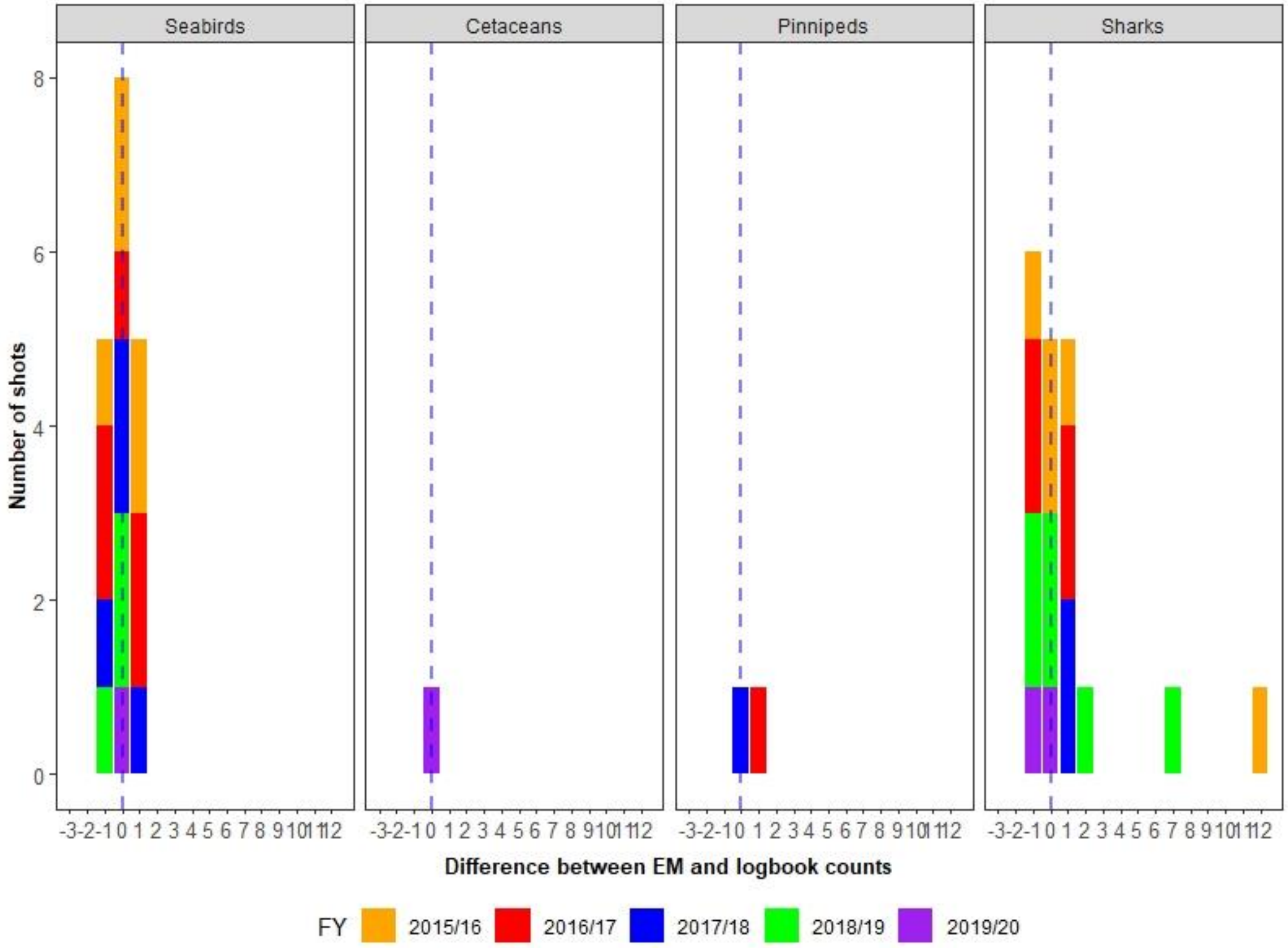
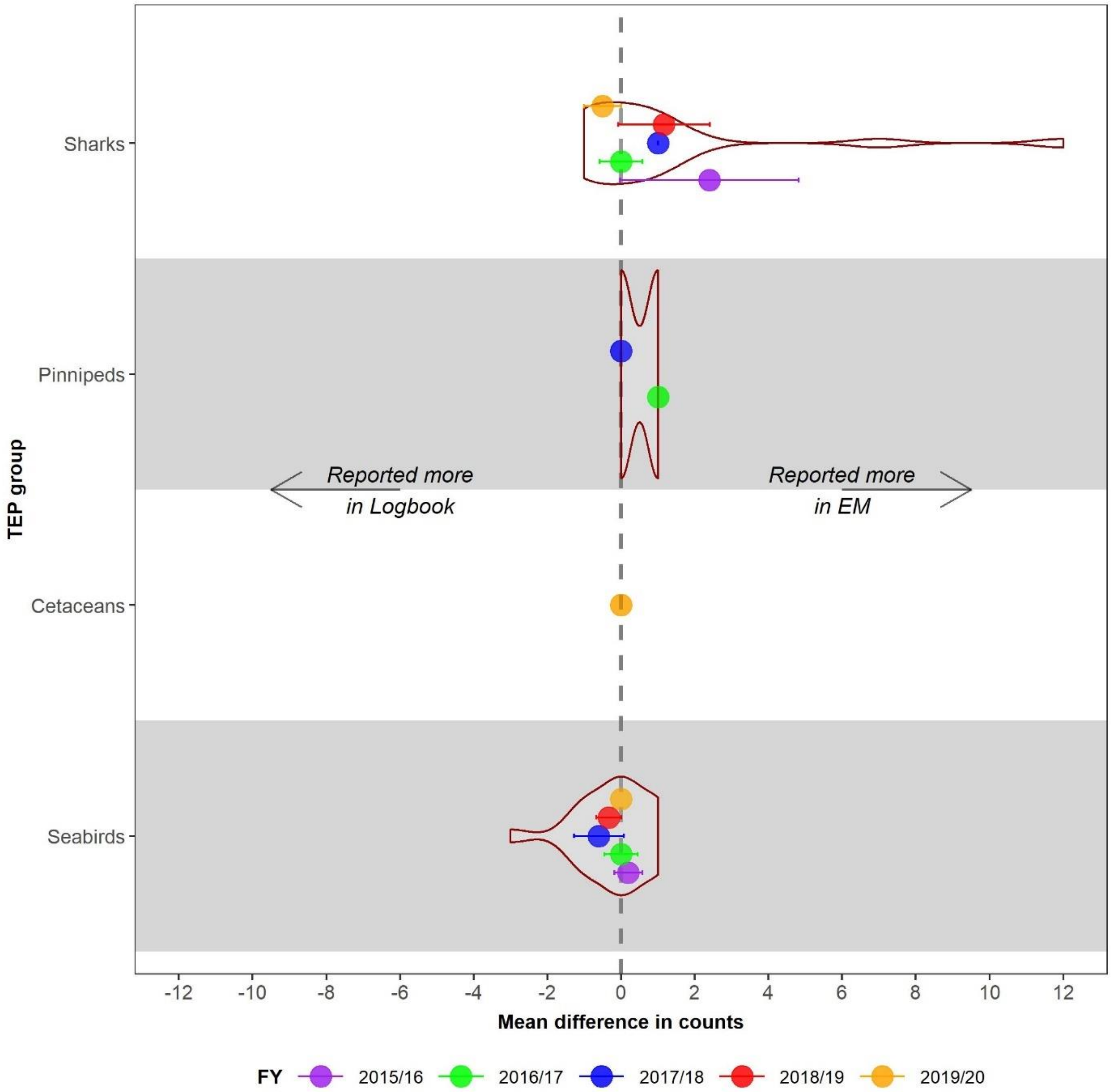


Figure 78: Kernel probability density of difference in counts for individual shots (red violin plot) and mean ± 95% CI difference in counts by financial year of all shots containing TEP interactions. Grey dashed line equates to zero difference.



3.3 Set-longline sector

3.3.1 Retained catch

In the LLS, there were a total of 7 species that made up 95% of the reported retained catch from the logbook audited shots between 2016/17 and 2019/20. These species are displayed in Table 10 in descending order of the proportion of catch.

The main retained commercial species, specifically gummy and school shark were reported in similar numbers by logbook and EM (Figure 79 and Table 10). For example, gummy shark had a mean difference in counts of 1.3 ± 0.9 individuals across the time period examined and the average number recorded as retained by both EM and logbook in a shot was 55.4 ± 7.9 individuals (Table 10). As a proportion of the average catch the mean difference for gummy shark was therefore only 2%, which is minimal (Figure 80). Furthermore, individuals were not unreported with 0% of shots containing a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool (Table 10). Apart from school shark and perhaps broadnose shark however, the results for other retained species are not that useful to interpret due to the overall low number of audited shots where these species were retained.

Table 10: 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 LLS.

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
Gummy shark	*Mustelus antarcticus*	1.3 (±0.9)	55.4 (±7.9)	2%	0%
School shark	*Galeorhinus galeus*	0.7 (±0.6)	18.3 (±8.3)	4%	11%
Pink ling	*Genypterus blacodes*	3.2 (±5.8)	80.4 (±128.4)	4%	20%
Broadnose shark	*Notorynchus cepedianus*	-0.7 (±1.0)	2.6 (±0.8)	-27%	73%
Draughtboard shark	*Cephaloscyllium laticeps*	-15.6 (±6.0)	7.8 (±3.0)	-200%	100%
Striped trumpeter	*Latris lineata*	3.4 (±5.1)	7.6 (±4.9)	44%	10%
Skates and rays (mixed group)	*Elasmobranchii*	-7.6 (±6.8)	3.9 (±3.3)	-195%	100%

Figure 79: Reporting of retained species in the LLS (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) retained in a shot (mean ± 95% CI) across all financial years.

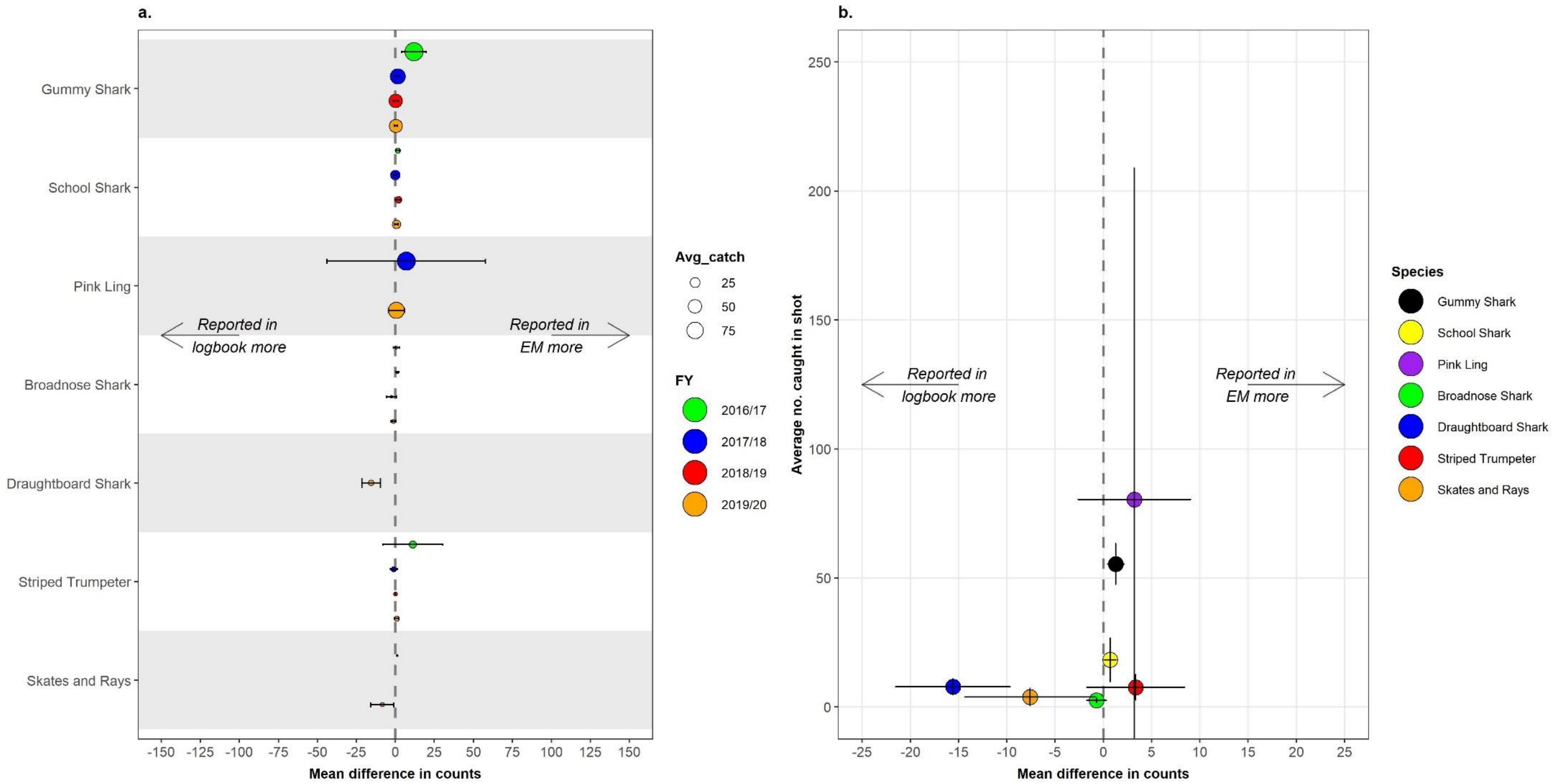
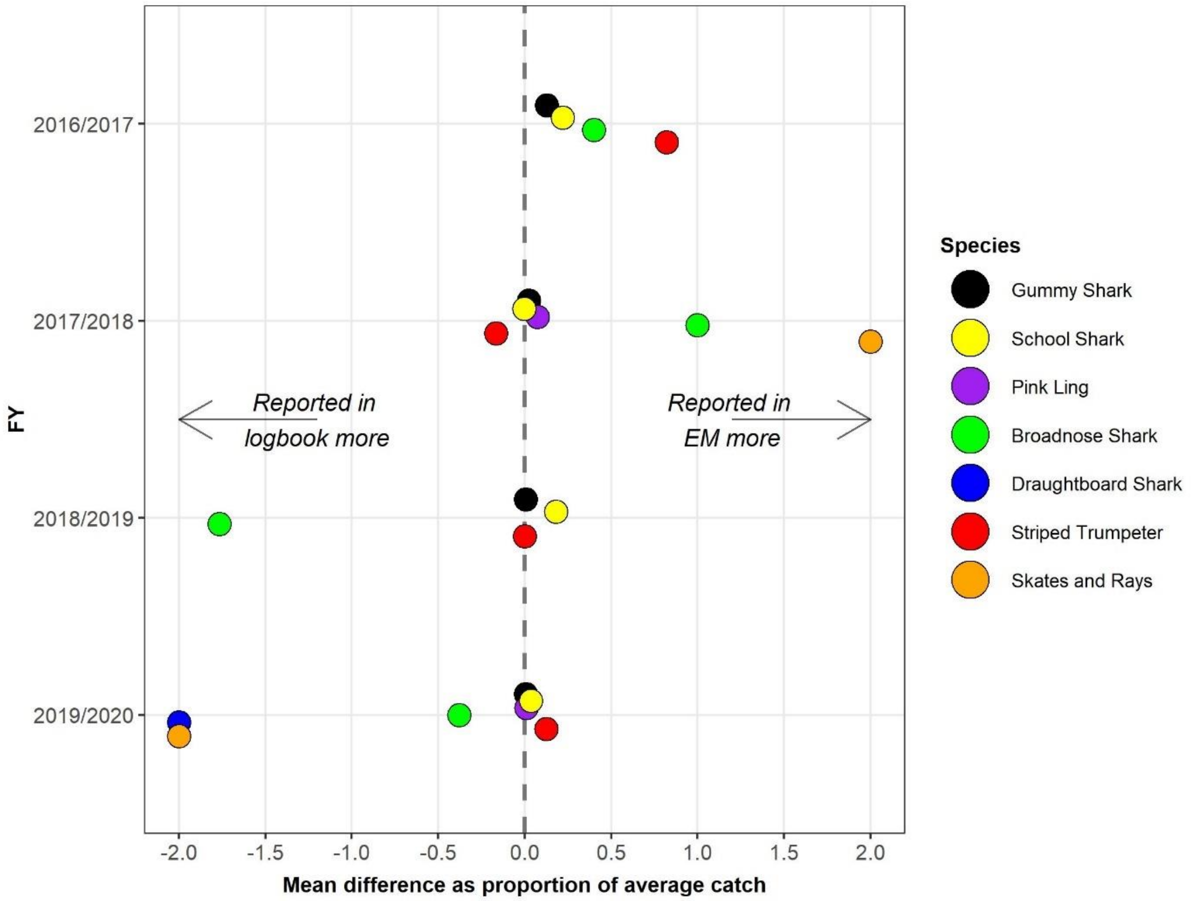


Figure 80: The mean difference in counts as a proportion of the average catch (average of EM and logbook reported) per shot for retained species in the LLS



Gummy shark

Across the time period examined, 25% of shots audited that contained retained gummy shark had no difference in logbook and EM counts, 44% had higher counts reported by EM and 31% had higher counts reported by logbook. When differences in counts between logbook and EM were observed these were variable at the shot level, but mainly were up to ~10 individuals (Figure 81 and Figure 82). Apart from in 2016/17 (where there was a low number of shots audited with gummy shark recorded as retained), the level of congruence fluctuated between 24-30% of shots having no difference in logbook and EM counts (Figure 83). The mean difference in counts was negligible across the time period examined (1.3 ± 0.9 individuals) with the average number recorded by both EM and logbook in a single shot high (55.4 ± 7.9 individuals) so as a proportion of the average catch, this difference was only 2% (Table 10). This suggest that for every 55 individuals reported by logbook, EM is reporting 56 individuals. No shots contained a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool, suggesting that individuals are being observed retained by both data collection tools (Figure 84).

Figure 81: Logbook and EM reported counts from individual shots containing retained gummy shark across time period examined. Red dashed line is the 1:1 line.

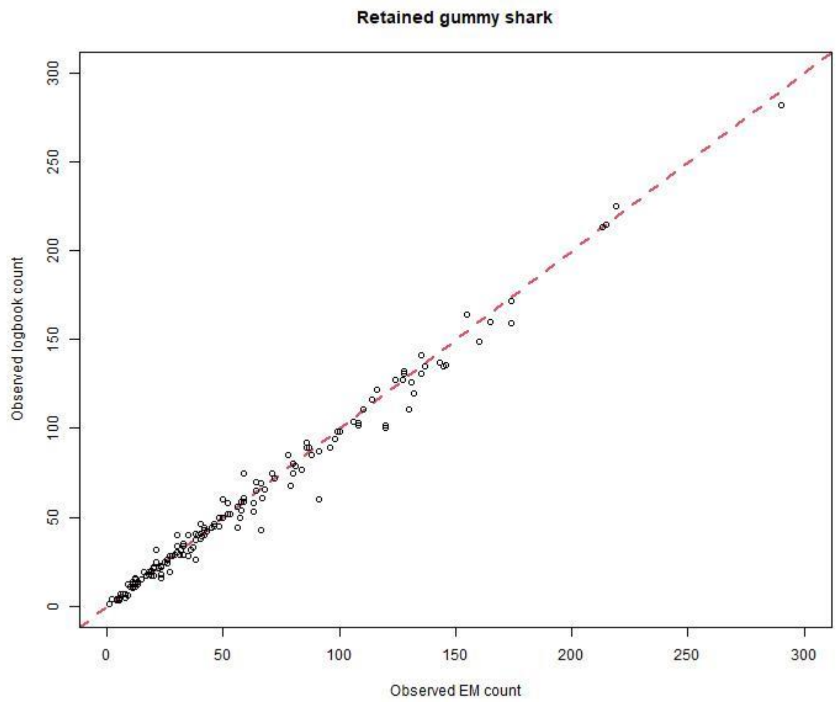


Figure 82: Proportion of shots with specific differences between EM and logbook counts for retained gummy shark across the time period examined. Red dashed line equates to zero difference.

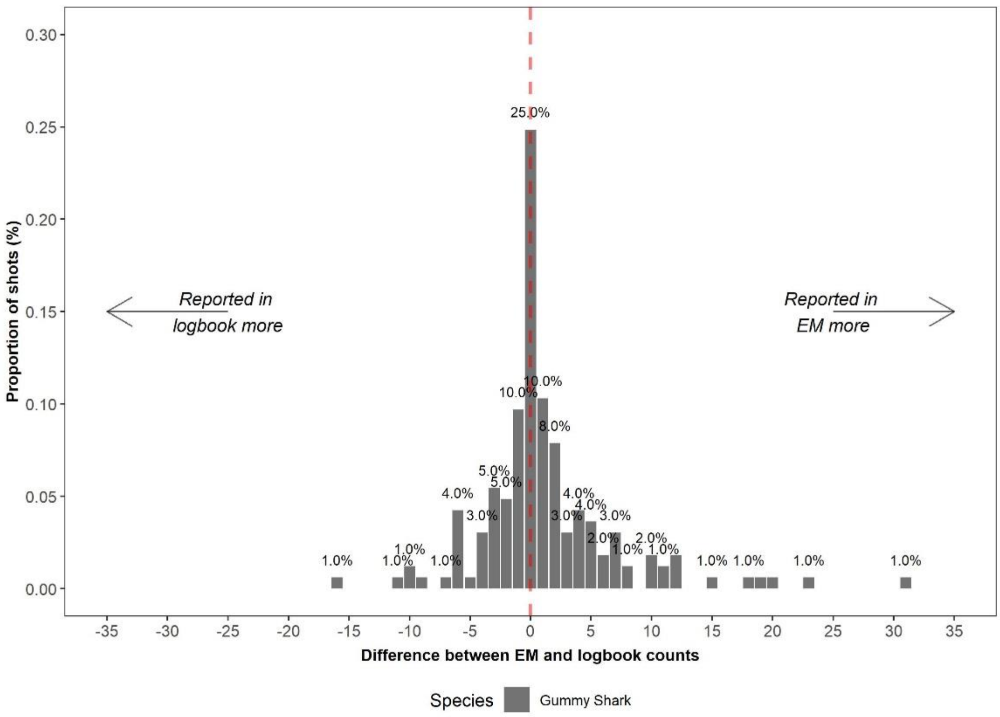


Figure 83: Proportion of shots with specific differences between EM and logbook counts for retained gummy shark for each financial year. Red dashed line equates to zero difference.

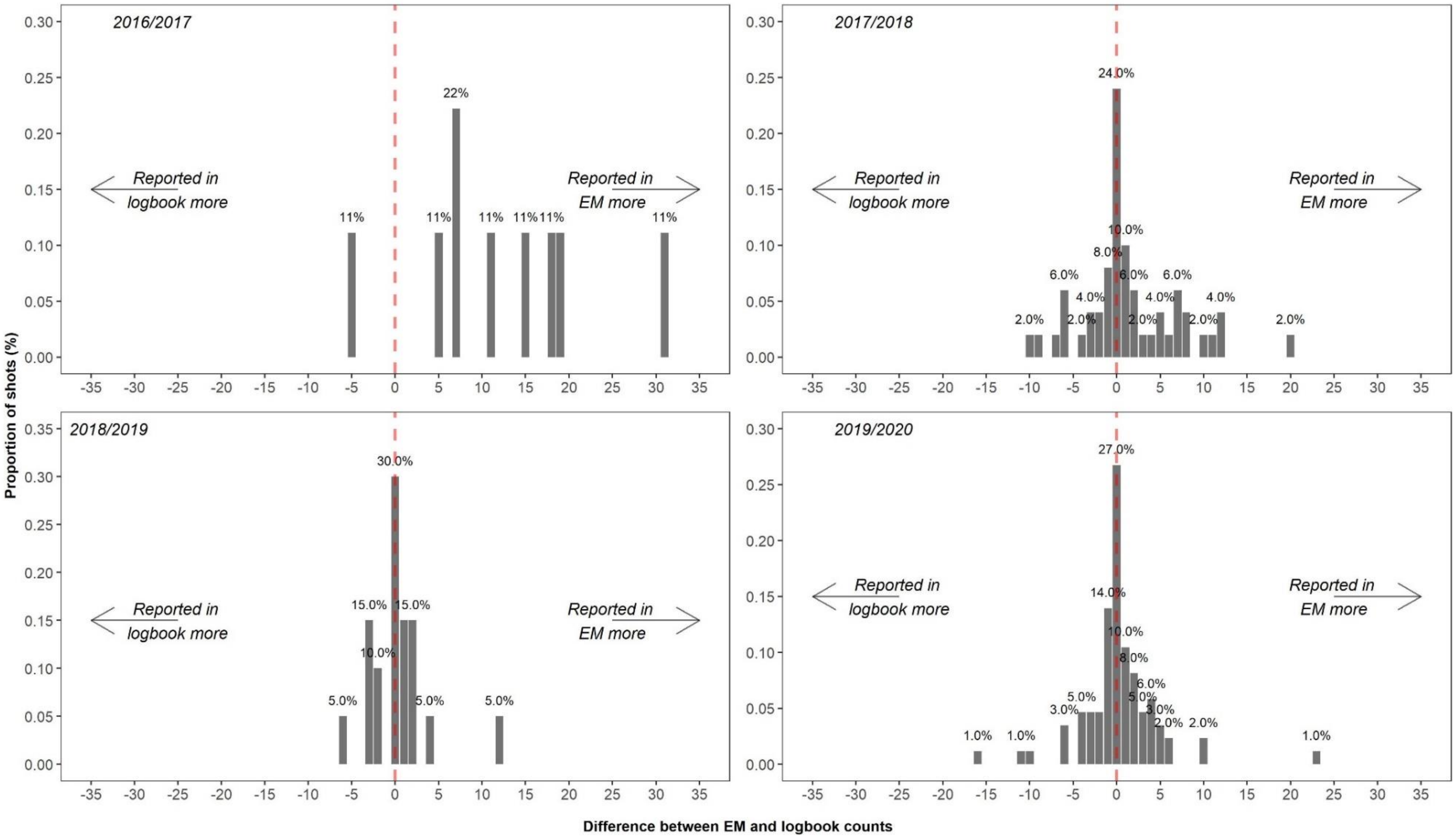
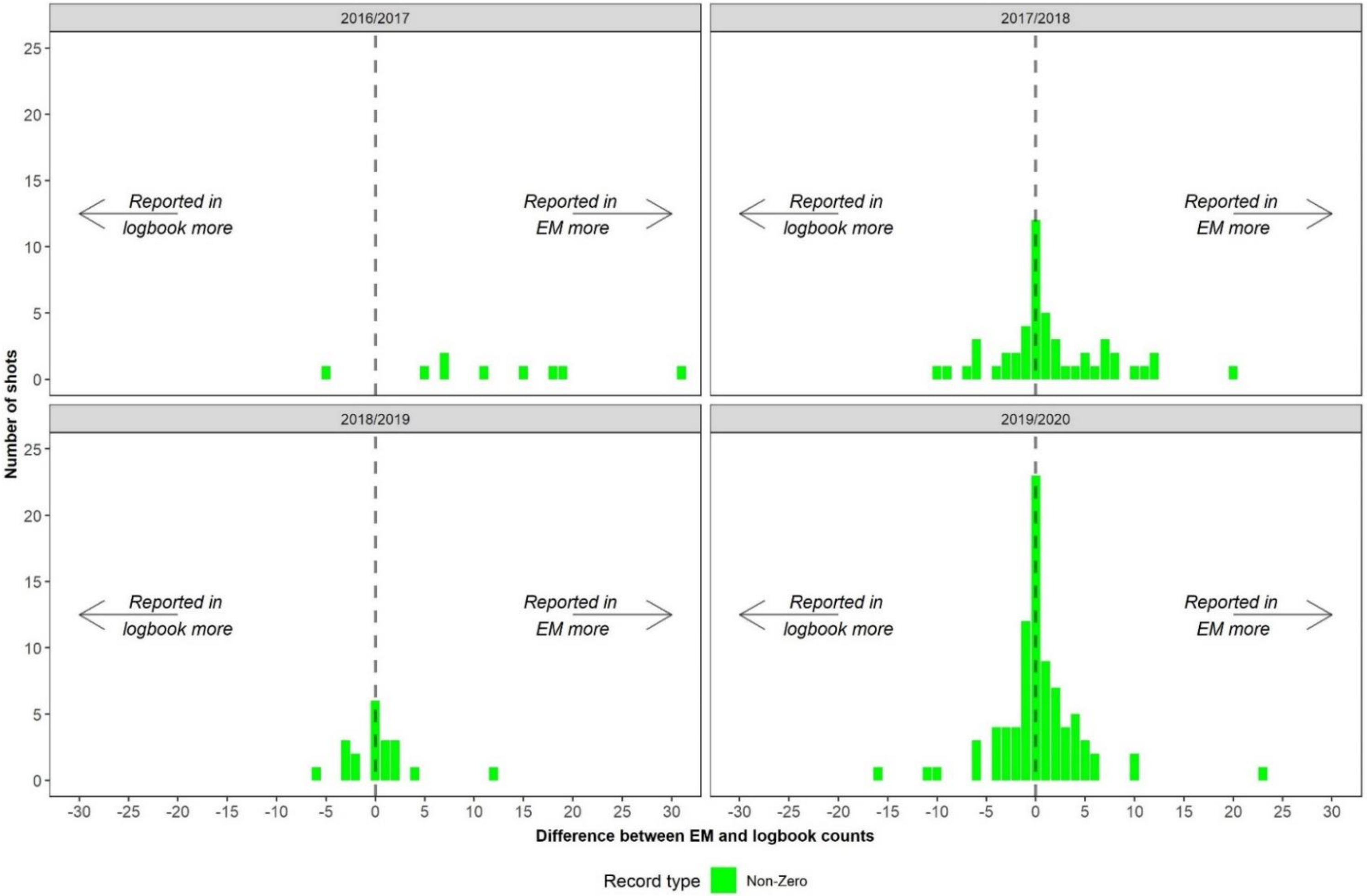


Figure 84: Number of shots with specific differences between EM and logbook counts for retained gummy shark across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference.



School shark

Across the time period examined, 36% of shots audited that contained retained school shark had no difference in logbook and EM counts, 40% had higher counts reported by EM and 24% had higher counts reported by logbook. When differences in counts between logbook and EM were observed these were variable at the shot level, but mainly between 1-5 individuals (Figure 85 and Figure 86). There were not many audited shots with retained school shark in 2016/17 and 2018/19. In 2017/18, there was 25% of shots with no difference in logbook and EM counts, which increased to 42% in 2019/20. (Figure 87). The mean difference in counts was negligible across the time period examined (0.7 ± 0.6 individuals) with the average number recorded by both EM and logbook in a single shot high (18.3 ± 8.3 individuals) so as a proportion of the average catch, this difference was only 4% (Table 10). This suggest that for every 17.95 individuals reported by logbook, EM is reporting 18.65 individuals. Individuals were sometimes unreported, with 11% of shots containing a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool (Table 10) with the majority of these in 2017/18 and 2019/20 (Figure 88).

Figure 85: Logbook and EM reported counts from individual shots containing retained school shark across time period examined. Red dashed line is the 1:1 line.

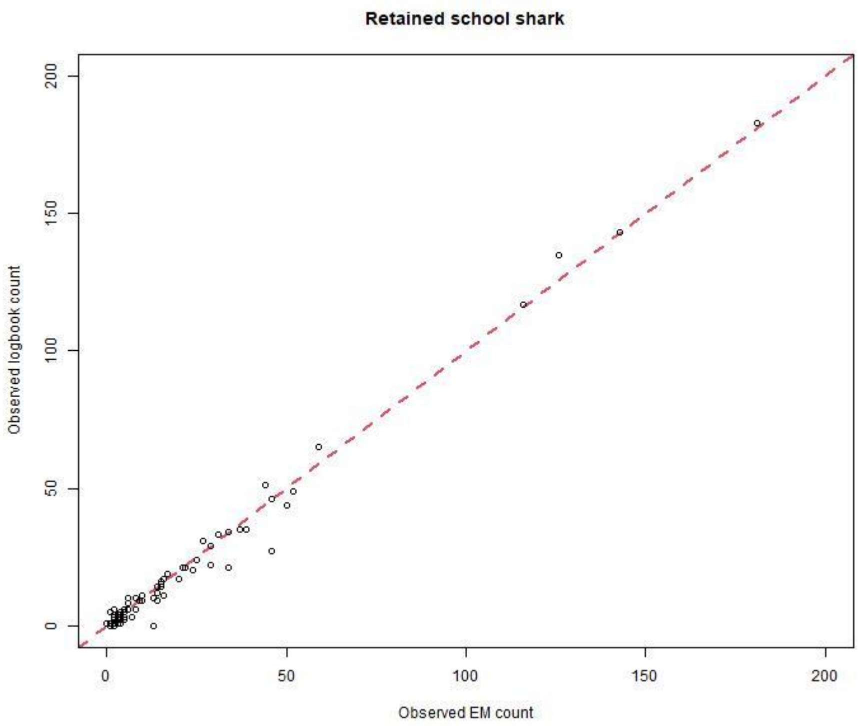


Figure 86: Proportion of shots with specific differences between EM and logbook counts for retained school shark across the time period examined. Red dashed line equates to zero difference.

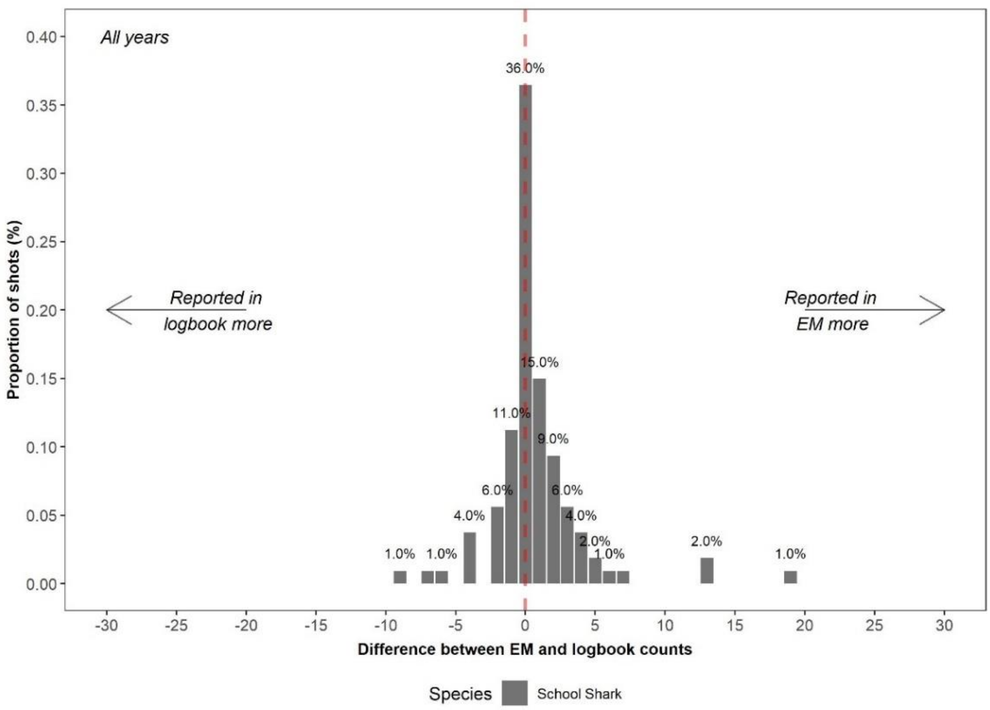


Figure 87: Proportion of shots with specific differences between EM and logbook counts for retained school shark for each financial year. Red dashed line equates to zero difference.

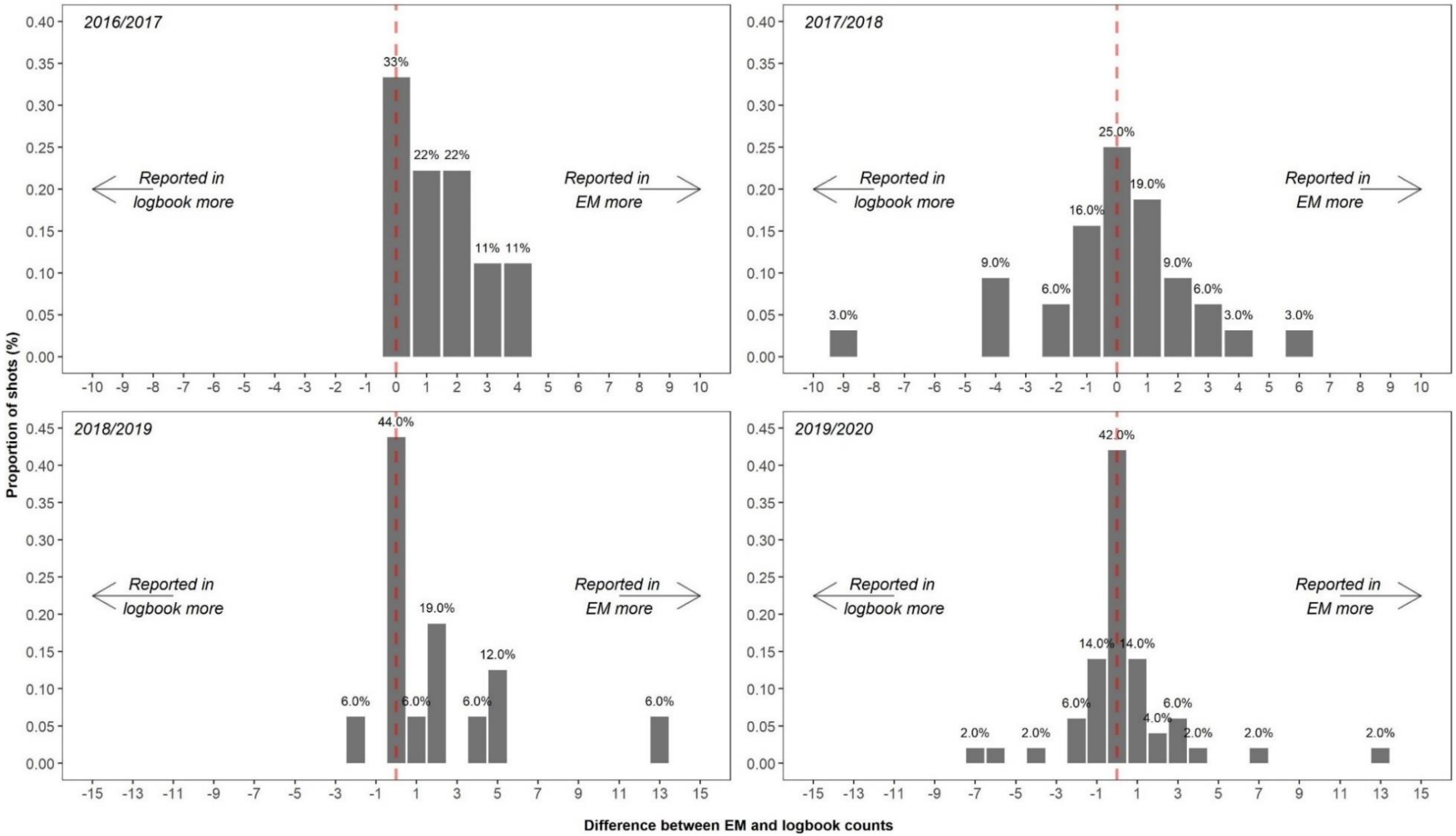
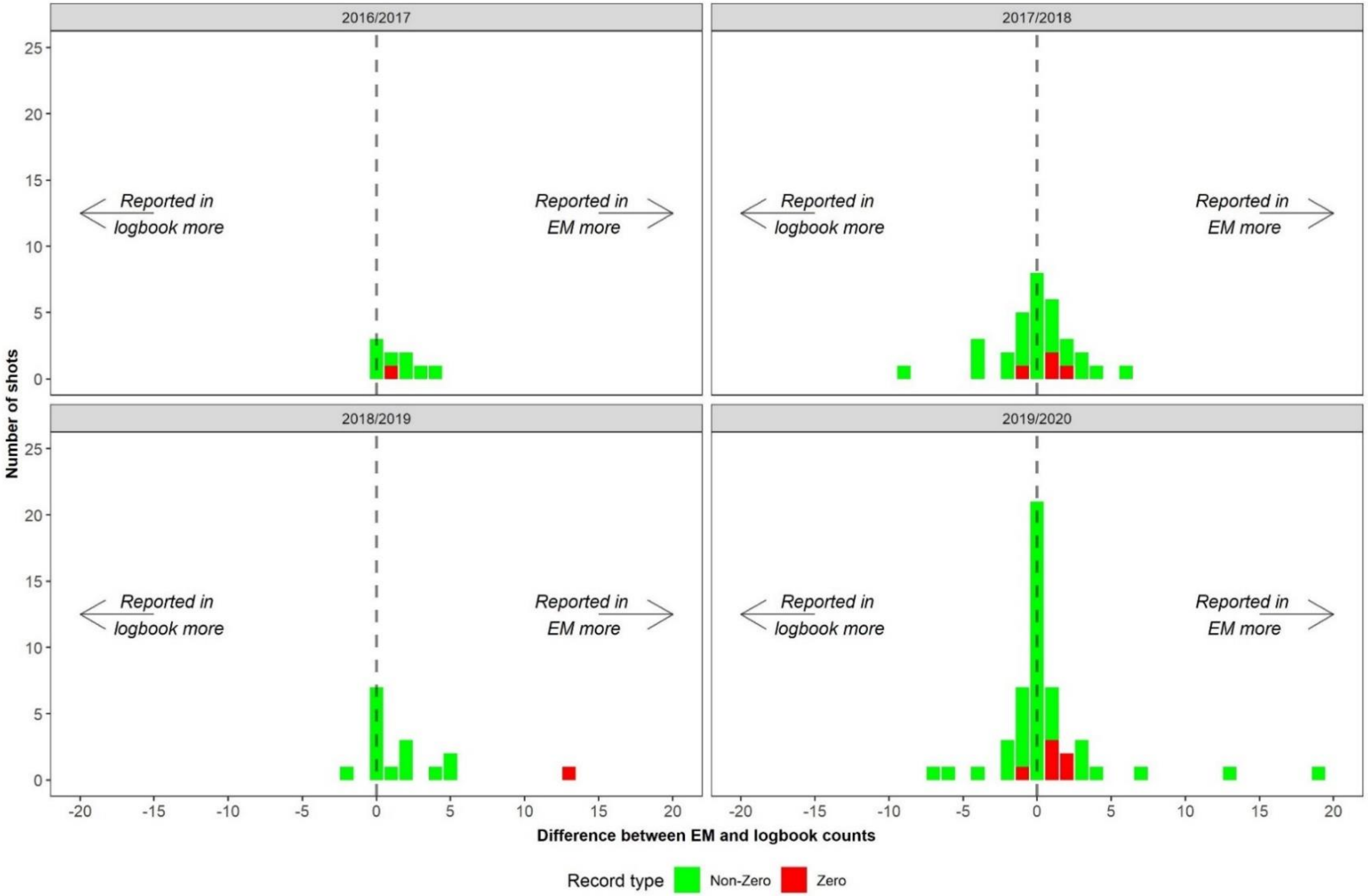


Figure 88: Number of shots with specific differences between EM and logbook counts for retained school shark across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference.



3.3.2 Discarded catch

In the LLS, there were a total of 10 species that made up 95% of the reported discarded catch from the logbook audited shots between 2016/17 and 2019/20. These species are displayed in Table 11 in descending order of the proportion of catch.

Apart from school shark, most discarded species were not reported in similar numbers by logbook and EM (Figure 89 and Table 11). Many species such as draughtboard shark and dogfishes (mixed group) were reported in higher numbers by the EM analyst, while others, such as sharks (mixed group) and Gulper sharks, sleeper sharks, dogfishes (mixed group) were reported in higher numbers in logbook. This led to mean differences in counts as a proportion of average catch that were high (Table 11). Gummy shark wasn't discarded often but overall, its mean difference in counts as a proportion of average catch was high compared to discarded school shark (Figure 89 and Figure 90). School shark had a mean difference in counts of -0.2 ± 2.1 individuals across the time period examined and the average number recorded as discarded by both EM and logbook in a shot was 8.5 ± 3.9 individuals (Table 11). As a proportion of the average catch, the mean difference in counts for school shark was therefore only -2%, which is negligible (Figure 90).

Table 11: 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 LLS.

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
Sharks (mixed group)	*Elasmobranchii*	-13.9 (±6.7)	8.4 (±3.1)	-164%	88%
Skates and rays (mixed group)	*Elasmobranchii*	-1.1 (±3.1)	7.9 (±1.8)	-14%	56%
School shark	*Galeorhinus galeus*	-0.2 (±2.1)	8.5 (±3.9)	-2%	44%
Gummy shark	*Mustelus antarcticus*	1.4 (±0.9)	3.4 (±0.8)	43%	57%
Gulper sharks, sleeper sharks, dogfishes (mixed group)	*Elasmobranchii*	-10.1 (±8.1)	7.6 (±3.3)	-132%	90%
Draughtboard shark	*Cephaloscyllium laticeps*	12.1 (±4.0)	8.8 (±3.1)	137%	76%
Dogfishes (mixed group)	*Squaliformes*	16.0 (±6.3)	9.6 (±3.7)	166%	92%
Whitefin swellshark	*Cephaloscyllium albipinnum*	1.0 (±3.9)	5.2 (±3.0)	19%	60%

Piked spurdog	*Squalus megalop*	2.1 (±5.3)	4.7 (±2.6)	45%	88%
Broadnose shark	*Notorynchus cepedianus*	5.0 (±3.9)	4.1 (±2.1)	121%	76%

Figure 89: Reporting of discarded species in the LLS (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.

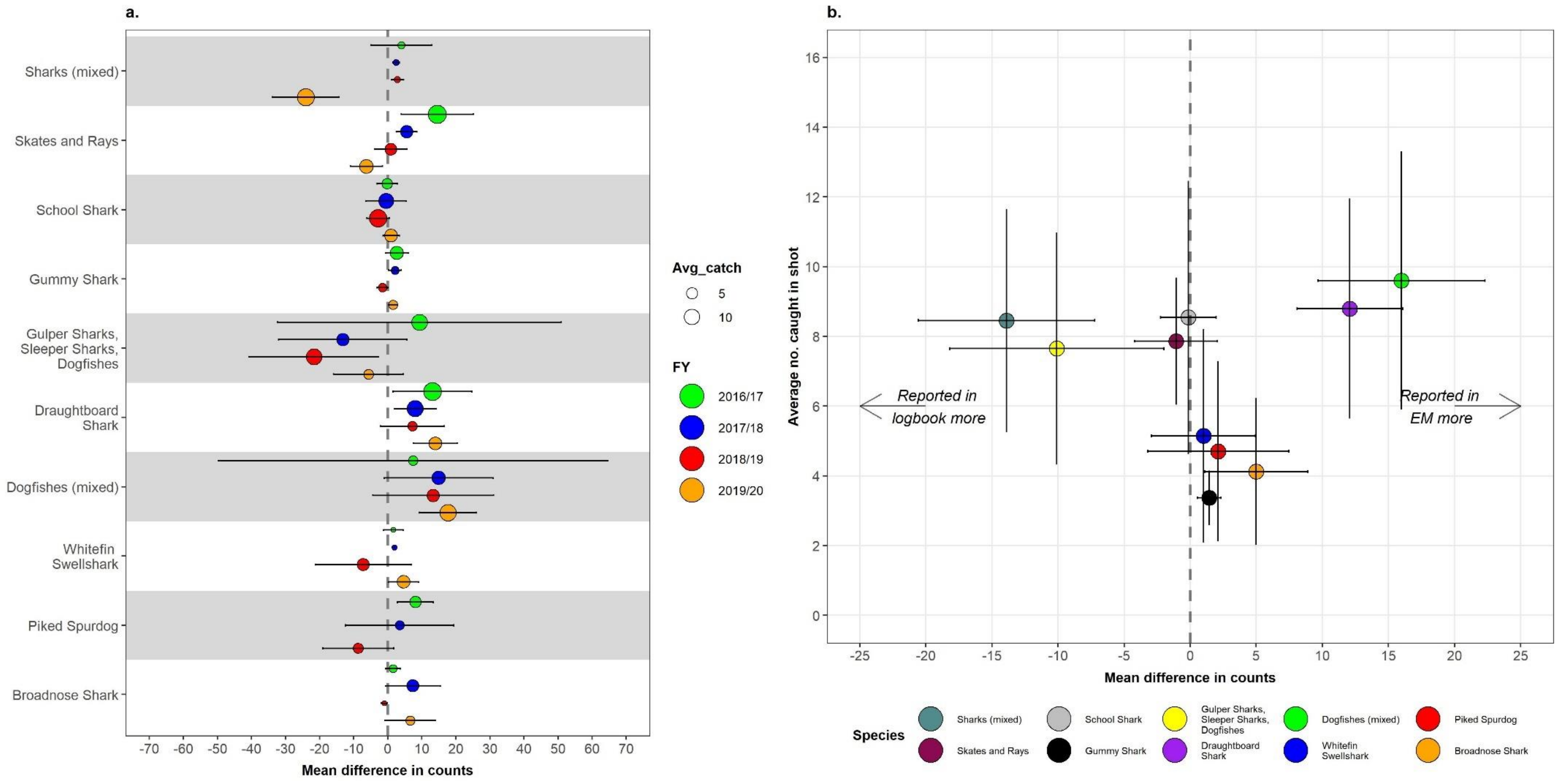
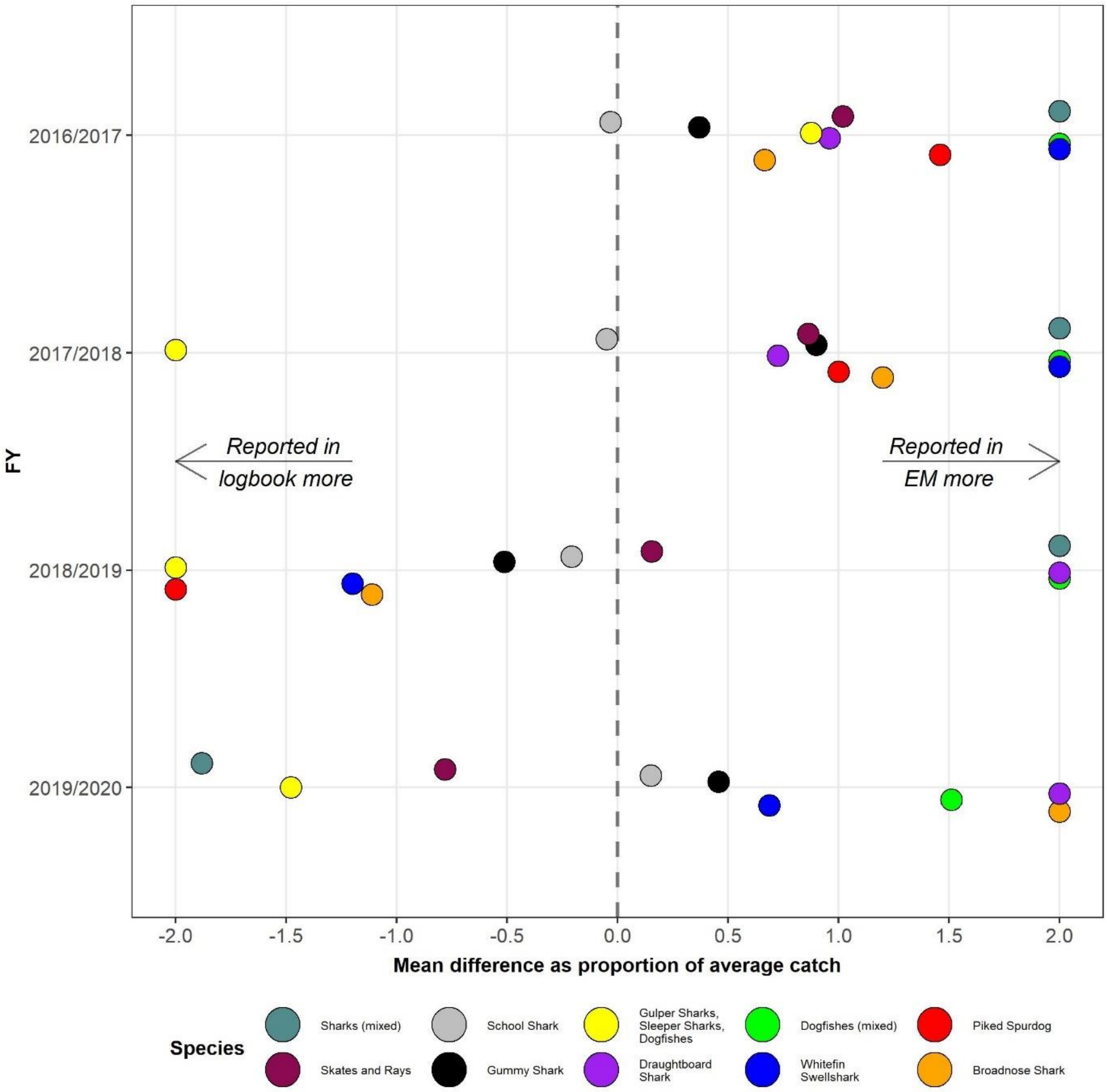


Figure 90: The mean difference in counts as a proportion of the average catch (average of EM and logbook reported) per shot for discarded species in the LLS



Gummy shark

Across the time period examined, 10% of shots audited that contained discarded gummy shark had no difference in logbook and EM counts, 63% had higher counts reported by EM and 27% had higher counts reported by logbook. When differences in counts between logbook and EM were observed these were variable at the shot level, but mainly were up to ~6 individuals (Figure 91 and Figure 92). The level of congruence displayed high inter-annual variability, with 11% of shots in 2016/17 having no difference in logbook and EM counts, decreasing to 3% in 2018/19, before increasing to 24% by 2019/20 (Figure 93). As previously noted for the retained catch of gummy shark, there were not many audited shots of discarded gummy shark in 2016/17 and 2018/19. Gummy shark was reported slightly more by EM (1.4 ± 0.9 individuals) across the time period examined but the average number recorded by both EM and logbook in a single shot was very low (3.4 ± 0.8 individuals), so as a proportion of the average catch, this difference was 43% (Table 11). This suggest that for every 2.7 individuals reported by logbook, EM is reporting 4.1 individuals. Individuals were also often unreported, with 57% of shots containing a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool (Table 11). However, there was clear inter-annual variability present (due to lack of audited shots) and a bias towards logbooks not reporting any individuals when ≥1 individual was reported by EM (Figure 94).

Figure 91: Logbook and EM reported counts from individual shots containing discarded gummy shark across time period examined. Red dashed line is the 1:1 line.

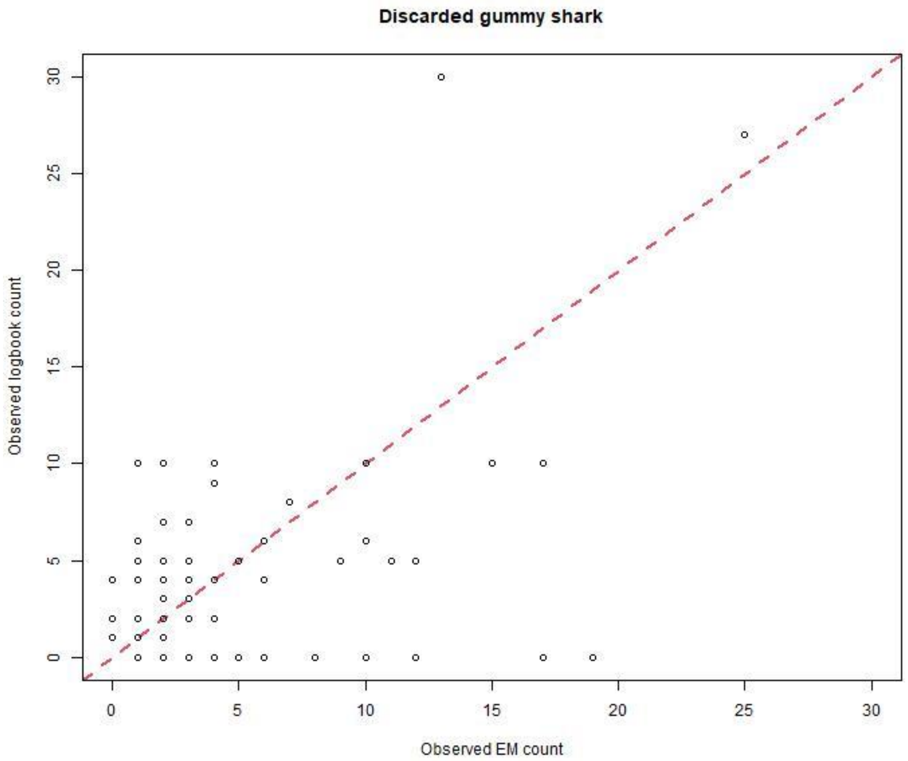


Figure 92: Proportion of shots with specific differences between EM and logbook counts for discarded gummy shark across the time period examined. Red dashed line equates to zero difference.

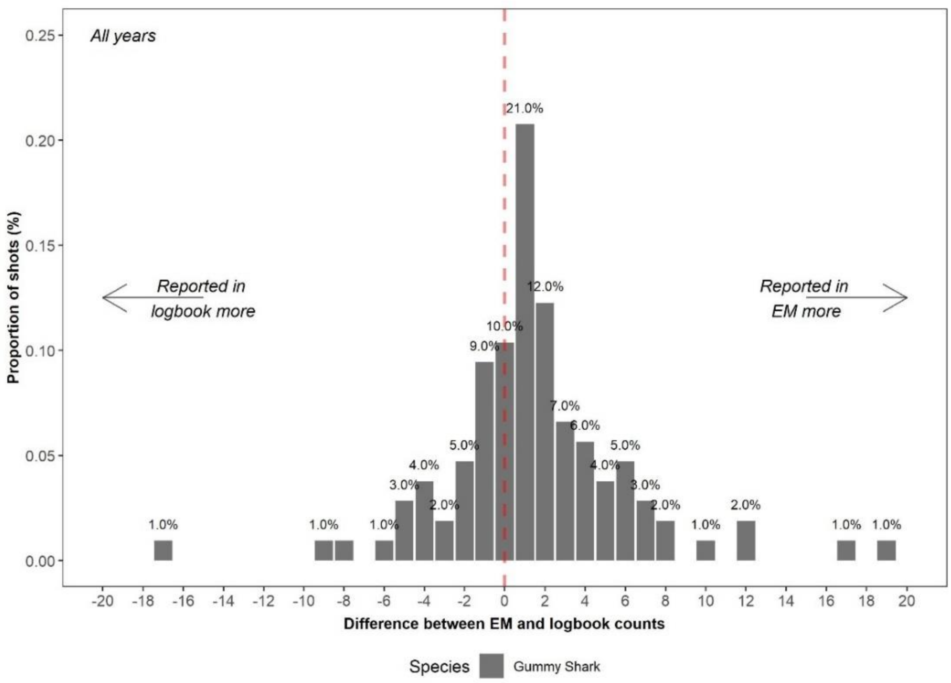


Figure 93: Proportion of shots with specific differences between EM and logbook counts for discarded gummy shark for each financial year. Red dashed line equates to zero difference.

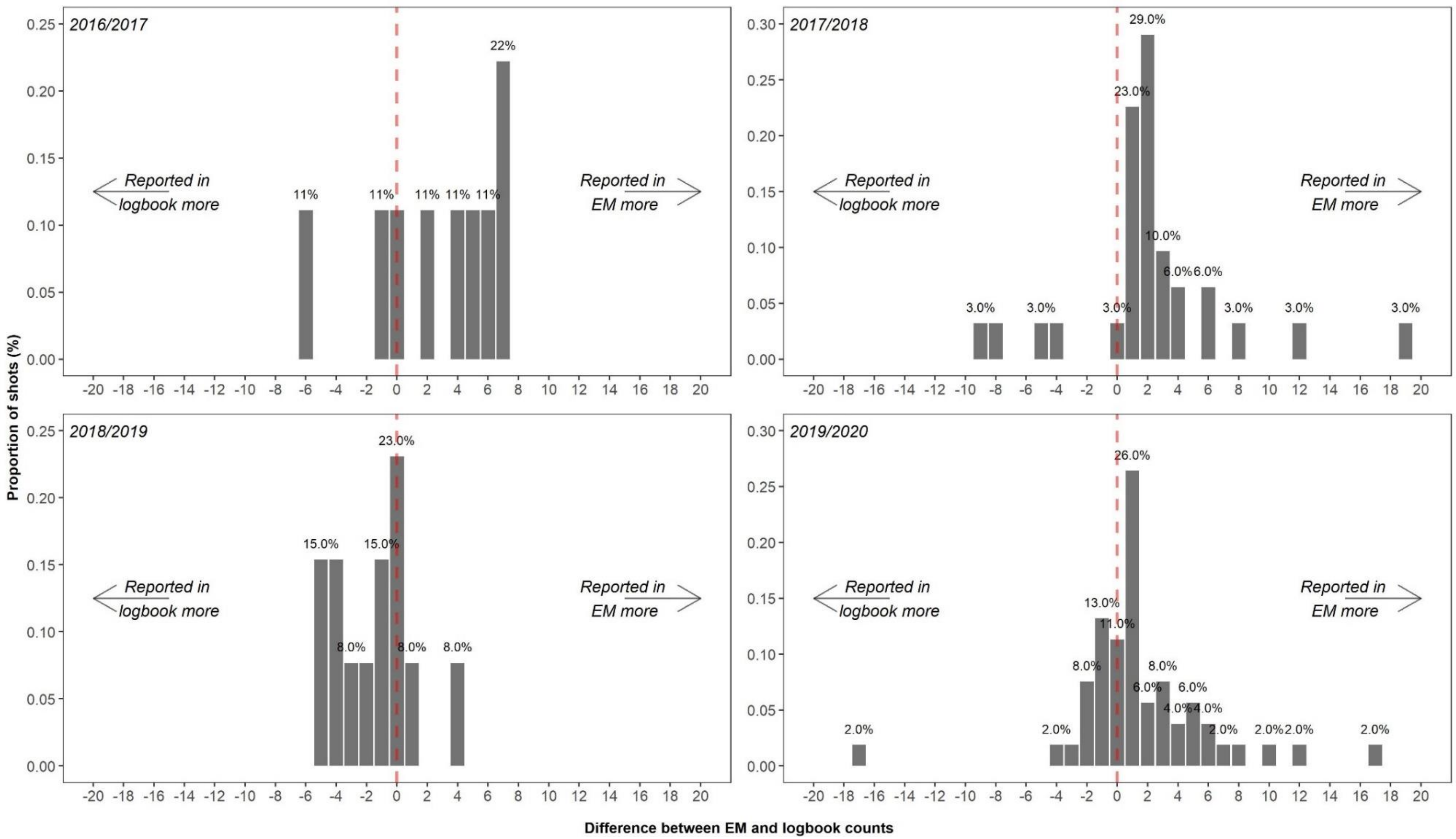
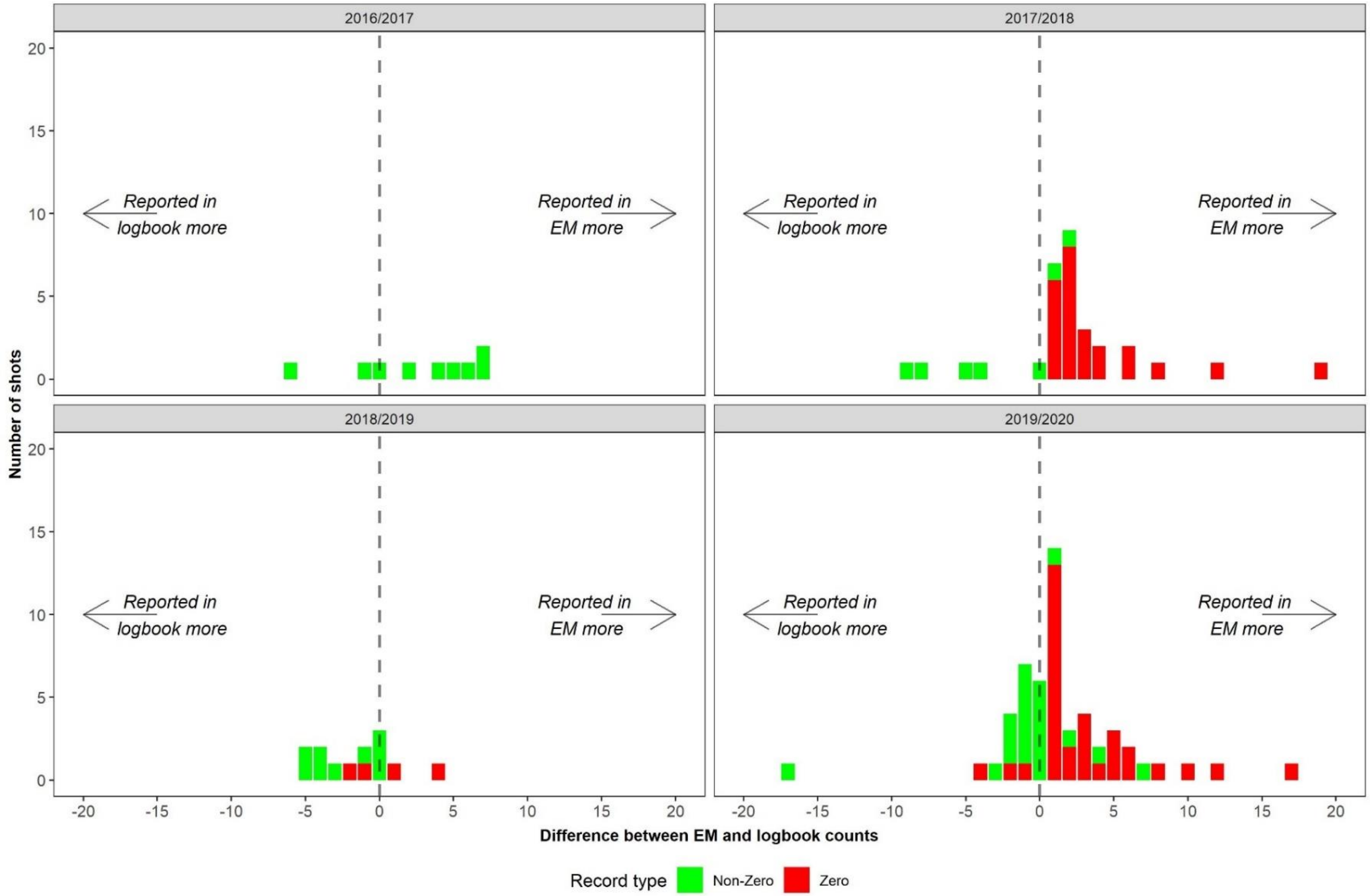


Figure 94: Number of shots with specific differences between EM and logbook counts for discarded gummy shark across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference.



School shark

Across the time period examined, 16% of shots audited that contained discarded school shark had no difference in logbook and EM counts, 52% had higher counts reported by EM and 32% had higher counts reported by logbook. When differences in counts between logbook and EM were observed these were variable at the shot level, but mainly were between 1-5 individuals (Figure 95 and Figure 96) The level of congruence displayed high inter-annual variability, with 14% of shots in 2016/17 having no difference in logbook and EM counts, decreasing to 12% in 2017/18, before increasing to 23% in 2018/19 and declining again to 17% in 2019/20 (Figure 97). As previously noted for the retained catch of school shark, there were not many audited shots of discarded school shark in 2016/17 and 2018/19. School shark was reported in similar numbers by EM and logbook (-0.2 ± 2.1 individuals) across the time period examined, with the average number recorded by both EM and logbook in a single shot low (8.5 ± 3.9 individuals), so as a proportion of the average catch, this difference was negligible at -2% (Table 11).This suggest that for every 8.6 individuals reported by logbook, EM is reporting 8.4 individuals. Individuals were also often unreported, with 44% of shots containing a zero record for either EM or logbook when ≥1 individual was reported by the other data collection tool (Table 11). However, there was clear inter-annually variability present (due to lack of audited shots) and a bias towards logbooks not reporting any individuals when ≥1 individual was reported by EM (Figure 98).

Figure 95: Logbook and EM reported counts from individual shots containing discarded school shark across time period examined. Red dashed line is the 1:1 line.

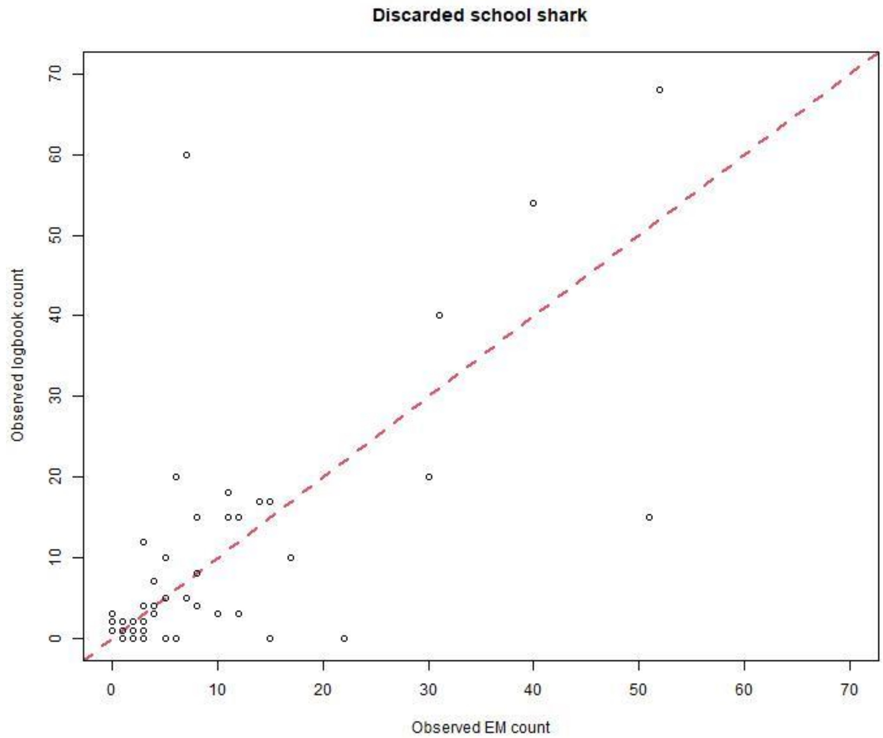


Figure 96: Proportion of shots with specific differences between EM and logbook counts for discarded school shark across the time period examined. Red dashed line equates to zero difference.

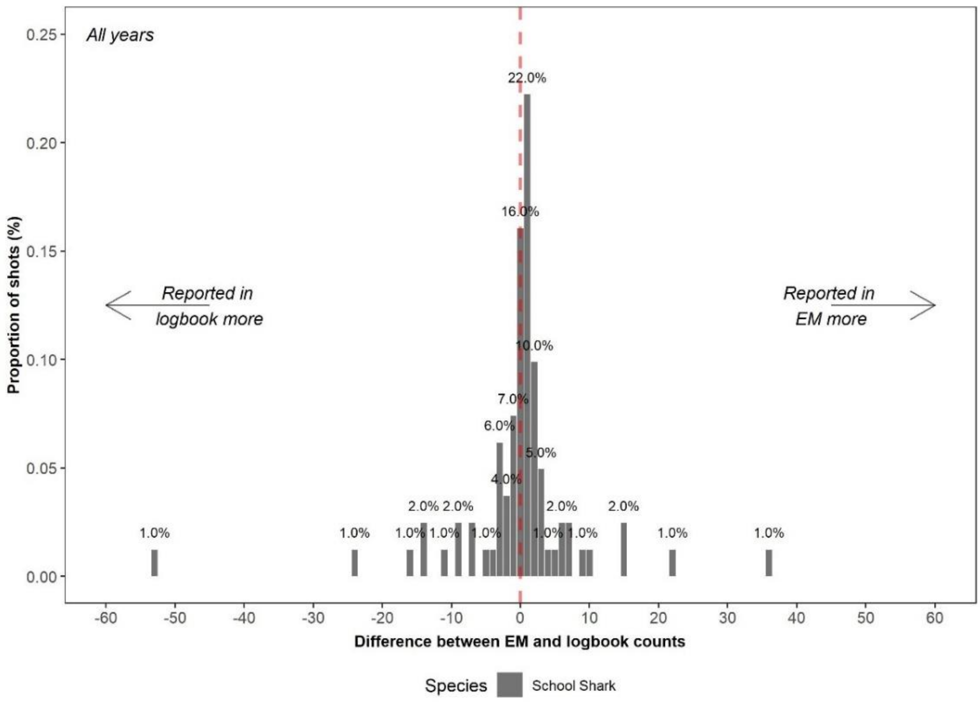


Figure 97: Proportion of shots with specific differences between EM and logbook counts for discarded school shark for each financial year. Red dashed line equates to zero difference.

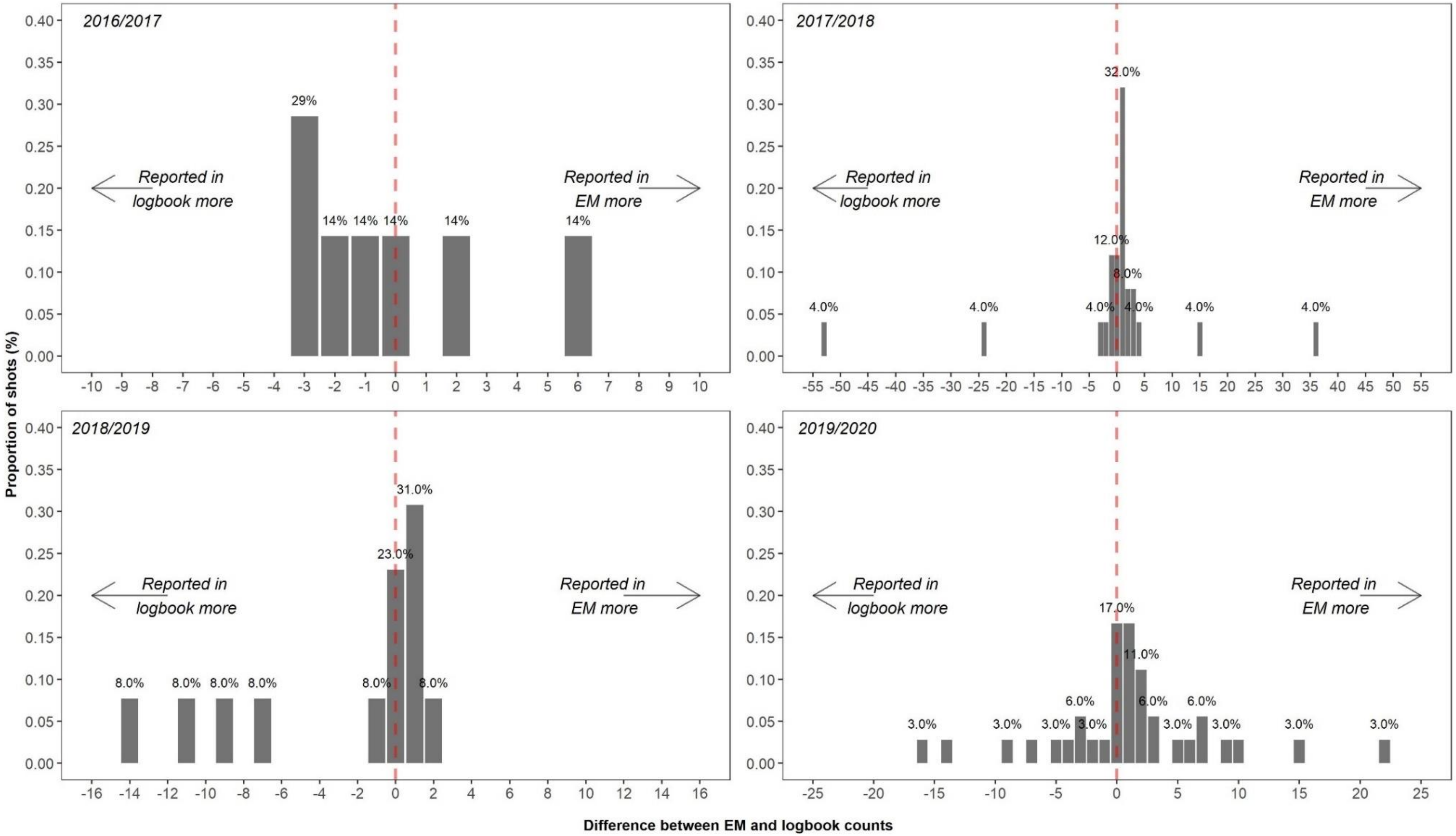
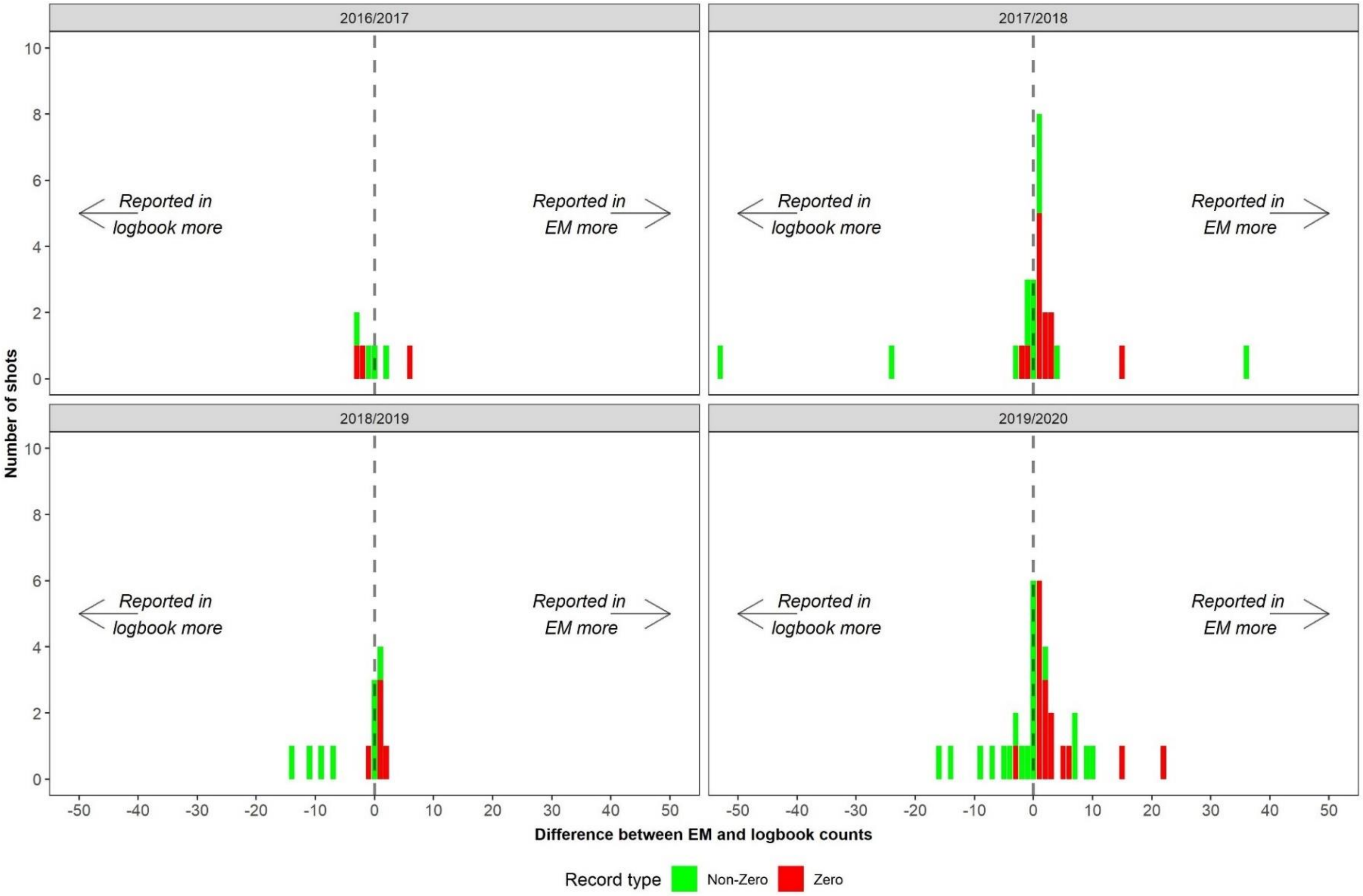


Figure 98: Number of shots with specific differences between EM and logbook counts for discarded school shark across all shots for each financial year, including whether the record from either EM or logbook contained a zero. Black dashed line equates to zero difference.



4 Discussion and recommendations

Introduction

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.

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 GHAT, the purpose of this analysis was to:

- Compare both fishery level and individual vessel level similarity between logbook and EM data for commercial, bycatch and TEP species;
- Determine if similarity 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 GHAT logbook and EM data in scientific analyses/assessments and ii) management actions to further improve, where necessary, future logbook and EM data collection/reporting.

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

- superior for key commercial species compared to byproduct/bycatch species;
- higher for retained than discarded catch;
- variable for interactions with TEP groups; and
- improving over time for some key commercial species, particularly in the gillnet sector.

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 GHAT logbook data can be used for scientific analysis and management decisions for any given species (or group of species) will depend on both the findings of the comparative analysis at both fleet and individual vessel level 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 scientific 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 GHAT and (ii) the use of current logbook and EM data in scientific analyses and management processes.

Key findings

Gillnet sector

In general, key commercial retained species (gummy shark, school shark, elephantfish and sawsharks (grouped)) in the gillnet sector had high congruence, while the results for other retained byproduct species had low congruence. This is likely a factor of quota management in the GHAT, 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 gummy and school shark but not for elephantfish. Evidence from this study suggests that the reporting of retained elephantfish has improved through time, as fishers have improved their logbook reporting. For example, Emery et al. (2019a) found significant underreporting of retained elephantfish in the early years of EM implementation, which aligned with the observations of Braccini et al (2011) of elephantfish catch underreporting in Bass Strait. However, in the more recent years (2018/19 and 2019/20), there was evidence that congruence had substantially improved to almost half of all audited shots having no difference in counts.

Retained common and southern sawsharks were reported more in the logbook than by the EM analyst, with evidence suggesting the EM analyst was grouping them into sawsharks (mixed), like the previous study (Emery et al. 2019a). The grouping of species into general categories by the EM analyst was similarly observed by Ames (2005) in a comparison of at-sea observer and EM data in the Alaska Pacific Halibut longline fishery. When sawsharks (mixed) along with southern and common sawsharks were combined into sawsharks (grouped) and assessed at a higher taxonomic level, it was evident that the total numbers (for retained catch at least) were more congruent with the logbook, indicative of an identification issue with EM. 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). Furthermore, southern and common sawsharks are difficult to differentiate from solely EM footage.

Reporting of discards of key commercial species in the gillnet sector was mixed. School shark was the most congruent across the time period, which is somewhat expected given its current status as a rebuilding stock and the importance placed on accounting for all catches by AFMA. Under the rebuilding plan, school shark caught alive must be released, so in complying with this measure fishers would often handle the animal differently to other species, and in most cases providing the EM analyst with a clear view to determine life status of the school shark on release (Piasente, M., pers comm. 2022). Conversely, discarded gummy shark was consistently reported on average more by fishers in their logbook across the time period. When examining gummy shark combined with school shark and hound sharks (mixed) at a higher taxonomic level, congruence improved (like retained sawsharks (grouped)) suggesting the EM analyst was having difficulties in identifying discarded gummy shark to the species level. For example, when gummy shark is 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 gummy shark would be recorded as hound sharks (mixed) during EM review (Piasente, M., pers comm. 2022). Furthermore, the EM analyst will only record the fate of an individual (damaged or not) as discarded if they observe them being discarded in view of the camera immediately after capture. Consequently, if they are discarded later once the haul is complete and after the cameras have stopped recording, this would be recorded as a retained individual by the EM analyst (Piasente, M., pers comm. 2022). 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.

Both discarded elephantfish and sawsharks (grouped) displayed low congruence across the time period, with more individuals being reported by the EM analyst than logbook. Importantly, there was evidence among both these species of persistent non-reporting of any discarded catch by a small number of individual vessels in their logbooks, despite the EM analyst reporting discards. This is likely a result of incomplete logbook reporting.

In general, the results for other discarded byproduct species in the gillnet sector displayed low congruence, like the previous study (Emery et al. 2019a). A contributing factor for the gillnet sector at least could be the large number of individuals being brought onto the vessel simultaneously and subsequently discarded. For example, Bartholomew et al. (2018) reported that EM analysts had difficulty in distinguishing between individuals when the catch exceeded 15 individuals being brought on deck in Peruvian small-scale gillnet fisheries. Similarly, the ability of fishers to identify and count all discarded species in their logbooks is likely to be restricted by the need to ensure operational efficiency (Lara-Lopez 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.

Auto-longline and set-longline sector

In the auto-longline sector and to a lesser extent the set-longline sector, the findings again 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 key commercial 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. 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).

Threatened, endangered and protected species

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.

In the gillnet sector, reporting was mixed and variable through time, with cetaceans and to some extent pinnipeds displaying high congruence, while sharks and seabirds were reported more, on average, by the EM analyst. The reason that congruence was higher for marine mammals, is probably the result of the past compliance actions associated with misreporting and the initial focus of the EM program on accounting for all interactions with TEP species, but particularly dolphins and sea lions (AFMA, 2013).

While differences in observed counts were low in terms of absolute number (1-2 individuals) across all TEP groups, it is unclear why these interactions were not being reported by fishers. 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 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, these results for TEP groups in the gillnet sector may reflect the importance placed initially by AFMA on reporting all interactions with marine mammals as outlined above (AFMA, 2013). But further data (i.e., audited shots with interactions observed) is needed, particularly for the other auto-longline and set-longline sectors to provide a more robust assessment of congruence for TEP species.

Recommendations

The aim of this study was to provide AFMA with an understanding of the level of logbook reporting accuracy in the GHAT 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 increase the benefits of the EM and logbook data collection programs to inform management decisions. These are also summarised at an individual species level for each sector in Table 12 and Table 13 below.

General recommendations

- **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.
- **Implement 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.
- **Review feedback processes and EM capacity and resourcing** – Several potential issues driving a lack of congruence between logbooks and EM data in the GHAT fishery 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.

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 gummy shark). 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 to have a clear view of catch, discard or interaction events. Solutions may include 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) in the longline sectors of the GHAT 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 should ensure EM analysts continue to be provided sufficient training. This includes from qualified experts (e.g., at sea observers, scientists) so that they are able to accurately identify species, particularly those that are more difficult to identify (e.g., common and southern sawshark). Periodic audits on EM analyst reports to ensure consistency and maintenance of high-quality EM data through time should also be considered. 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 (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.
- **Investigate whitefin swellshark CAAB code allocation in the logbook -** Whitefin swellshark (*Cephaloscyllium albipinnum*) was reported in higher numbers by the logbook across the time period examined, while draughtboard shark (or Australian Swell shark) (*Cephaloscyllium laticeps*) was being reported in higher numbers by EM. While whitefin swellshark is often confused with other species of draughtboard shark (Bray, 2016), it has been previously noted by the EM service provider that the rollout of e-logbooks in the SESSF was accompanied with a software issue where the CAAB code for whitefin swellshark was assigned to species look-up common name draughtboard shark. So fishers who record numbers of draughtboard shark in their e-logbooks were being recorded as whitefin swellshark by the software. This should be investigated by AFMA to determine if this is still occurring today because whitefin swellshark (*Cephaloscyllium albipinnum*) is listed as *critically endangered* on the IUCN Red List and is also nominated for priority assessment as *critically endangered* under the *EPBC Act 1999*. This species

was also considered *depleted* in the recent Shark Report Card (Shark Report (fish.gov.au)). If the e-logbook software is misreporting draughtboard shark as whitefin swellshark, it may have ramifications for any analyses using logbook catch data as a basis for determining fishing mortality for whitefin swellshark.

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., discarded elephantfish), due to either missed observations, misidentification, or misreporting. In some cases, there has been improvements through time (e.g., retained elephantfish), but in other cases there has not (e.g., discarded sawsharks grouped).

- **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 should 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 boarfish species (possible identification issue) and draughtboard sharks (possible misreporting issue) in the gillnet sector.
- **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 and previous (Emery et al., (2019a), results indicate that this alone is unlikely to promote improved reporting practices. 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, should 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 and discarded school shark), 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/sectors 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.

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 GHAT was on the key commercial 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* sector, 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 GHAT to help identify any areas where EM systems and data collection require improvement.

Table 12: Summary of recommendations by species for the gillnet sector

Fate	Species	Mean difference as proportion of average catch	Inter-annual differences	Inter-vessel variability	Species-level recommendations	General recommendations
Retained	Gummy shark	2%	Improving	Negligible	• None	• Continual feedback (communication loop) between EM analysts and fishers on reporting levels. • Prescribe clear tolerance levels for logbook reporting
	School shark	4%	Improving	Negligible	• None	
	Elephantfish	14%	Improving	Medium	• At an individual vessel level - outreach activities to inform fishers about their reporting responsibilities and/or educate them in species identification/taxonomy.	
	Sawsharks (grouped)	13%	Improving	Low	• Improve/maintain the capability of EM analysts to identify species • At an individual vessel level - outreach activities to inform fishers about their reporting responsibilities and/or educate them in species identification/taxonomy.	
Discarded	Gummy shark	-61%	Improving	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.	
	School shark	-6%	Improving	Low		

	Elephantfish	46%	Improving	High	• Outreach activities to inform fishers about their reporting responsibilities and/or educate them in species identification/taxonomy. • Review and seek to improve vessel EM systems where required	
	Sawsharks (grouped)	35%	Stable	High	• Improve/maintain the capability of EM analysts to identify species • Review and seek to improve vessel EM systems where required • Outreach activities to inform fishers about their reporting responsibilities and/or educate them in species identification/taxonomy.	

Table 13: Summary of recommendations by species for the auto and set longline sectors

Fate	Species	Mean difference as proportion of average catch	Inter-annual differences	Inter-vessel variability	Species-level recommendations	General recommendations
Retained	Gummy shark (LLS)	2%	Variable	Medium	• None	• Continual feedback (communication loop) between EM analysts and fishers on reporting levels. • Prescribe clear tolerance levels for logbook reporting
	School shark (LLS)	4%	Improving	Low	• None	
	Blue-eye trevalla (LLA)	5%	Variable	High	• At an individual vessel level - outreach activities to inform fishers about their reporting responsibilities and/or educate them in species identification/taxonomy.	
	Pink ling (LLA)	12%	Variable	High		
	Ribaldo (LLA)	37%	Variable	High		
Discarded	Gummy shark (LLS)	43%	Variable	Medium	• At an individual vessel level - outreach activities to inform fishers about their reporting responsibilities and/or educate them in species identification/taxonomy.	
	School shark (LLS)	-2%	Variable	Negligible	• None	
	Blue-eye trevalla (LLA)	-2%	Variable	High	• Outreach activities to inform fishers about their reporting responsibilities and/or educate them in species identification/taxonomy. • Review and seek to improve vessel EM systems where required	
	Pink ling (LLA)	-68%	Variable	Negligible		
	Ribaldo (LLA)	-8%	Improving	High		

References

AFMA (2013), South East Management Advisory Committee (SEMAC) Meeting No. 13: 15-16 October 2013 - Minutes, Australian Fisheries Management Authority, Canberra, 43 pp.

AFMA (2020) Australian Fisheries Management Authority Electronic Monitoring Program – Program Overview June 2020, 24pp.

Ames, R. T., Williams, G. H., and Fitzgerald, S. M. (2005). Using digital video monitoring systems in fisheries: application for monitoring compliance of seabird avoidance devices and seabird mortality in Pacific halibut longline fisheries. 93 pp.

Ames, R.T., Leaman, B.M., Ames, K.L., (2007). Evaluation of video technology for monitoring of multispecies longline catches. North American Journal of Fisheries Management 27, 955-964.

Bartholomew, D.C., Mangel, J.C., Alfaro-Shigueto, J., Pingo, S., Jimenez, A., Godley, B.J., (2018) Remote electronic monitoring as a potential alternative to on-board observers in small-scale fisheries. Biological Conservation 219, pp. 35-45.

Basran, CJ. Sigurðsson G.M. (2021) Using Case Studies to Investigate Cetacean Bycatch/Interaction Under-Reporting in Countries with Reporting Legislation, 8,

Braccini, J. M., Etienne, M. P., and Martell, S. J. D. (2011). Subjective judgement in data subsetting: implications for CPUE standardisation and stock assessment of non-target chondrichthyans. Marine and Freshwater Research, 62: pp. 734-743.

Briand, K., Bonnieux, A., Le Dantec, W., Le Couls, S., Bach, P., Maufroy, A., Relot-Stirnemann, A., Sabarros, P., Vernet, A.L., Jehenne, F., Goujon, M., (2017) Comparing electronic monitoring system with observer data for estimating non-target species and discards on French tropical tuna purse seine vessels, pp. 25.

Brown, CJ, Desbiens, A, Campbell, MD, Game, ET, Gilman, E, Hamilton, RJ, Heberer, C, Itano, D and Pollock, K (2021). Electronic monitoring for improved accountability in western Pacific tuna longline fisheries. Marine Policy 132: 104664.

Emery, T.J., Noriega, R., Williams, A.J. & Larcombe, J. (2019a) Measuring congruence between electronic monitoring and logbook data in Australian Commonwealth longline and gillnet fisheries, Ocean & Coastal Management 168, pp. 307-321.

Emery, T.J., Noriega, R., Williams, A.J. & Larcombe, J. (2019b) Changes in logbook reporting by commercial fishers following the implementation of electronic monitoring in Australian Commonwealth fisheries, Marine Policy 104, pp. 135-145.

Evans, R., Molony, B., (2011). Pilot evaluation of the efficacy of electronic monitoring on a demersal gillnet vessel as an alternative to human observers, Fisheries Research Report No. 221. Department of Fisheries, Western Australia, North Beach, Western Australia, pp. 20

Forget, F., Muir, J., Hutchinson, M., Itano, D., Sancristobal, I., Leroy, B., Filmalter, J., Martinez, U., Holland, K., Restrepo, V., Dagorn, L. (2021) Quantifying the accuracy of shark bycatch estimations in tuna purse seine fisheries, Ocean and Coastal Management, 210, 105637.

Goldsworthy, S. D., Page, B., Shaughnessy, P. D., and Linnane, A. (2010). Mitigating Seal Interactions in the SRLF and the Gillnet Sector SESSF in South Australia. Report to the Fisheries Research and Development Institute. SARDI Publication No. F2009/000613-1. SARDI Research Report Series No. 405.

Lara-Lopez, A., Davis, J., Stanley, B., (2012). Evaluating the use of onboard cameras in the shark gillnet fishery in South Australia. Australian Fisheries Management Authority, Canberra, Australia, pp. 65.

Larcombe J, Noriega R, Timmiss T. (2016) Catch reporting under e-monitoring in the Australian Pacific longline fishery. Report for the 2nd Meeting of the Electronic Reporting and Electronic Monitoring Intersessional Working Group, Bali, Indonesia, August 2016. Canberra, Australia: Australian Bureau of Agricultural and Resource Economics and Sciences. pp. 20

Kindt-Larsen, L., Dalskov, J., Stage, B., Larsen, F., (2012). Observing incidental harbour porpoise *Phocoena phocoena* bycatch by remote electronic monitoring. Endangered Species Research 19, 75-83.

Macbeth WG, Butcher PA, Collins D, McGrath SP, Provost SC, Bowling AC, et al. (2018) Improving reliability of species identification and logbook catch reporting by commercial fishers in an Australian demersal shark longline fishery. Fisheries Management and Ecology.25 pp. 186-202.

Mangi SC, Smith S, Catchpole TL. (2016) Assessing the capability and willingness of skippers towards fishing industry-led data collection. Ocean & Coastal Management.134, pp.11-19

Mortensen, Lars & Ulrich, Clara & Olesen, Hans & Bergsson, Heiðrikur & Berg, C.W. & Tzamouranis, Nikolaos & Dalskov, Joergen. (2017). Effectiveness of fully documented fisheries to estimate discards in a participatory research scheme. Fisheries Research. 187, pp. 150-157

Piasente M, Stanley B, Timmiss T, McElderry H, Pria M, Dyas M. (2012) Electronic onboard monitoring pilot project for the Eastern Tuna and Billfish Fishery. FRDC Project 2009/048. Canberra: Australian Fisheries Management Authority. pp. 104.

Rudd, M.B. and Branch, T.A. (2017), Does unreported catch lead to overfishing? Fish and Fisheries, 18: pp. 313-323.

Ruiz, J., Batty, A., Chavance, P., McElderry, H., Restrepo, V., Sharples, P., Santos, J., Urtizberea, A., (2015). Electronic monitoring trials on in the tropical tuna purse-seine fishery. ICES Journal of Marine Science. 72, pp. 1201-1213

Stanley, R.D., McElderry, H., Mawani, T., Koolman, J., (2011). The advantages of an audit over a census approach to the review of video imagery in fishery monitoring. ICES Journal of Marine Science. 68, pp. 1621-1627.

van Helmond ATM, Chen C, Poos JJ. (2015) How effective is electronic monitoring in mixed bottom-trawl fisheries? ICES Journal of Marine Science, 72. pp. 1192-1200.

van Helmond, ATM, Mortensen, LO, Plet-Hansen, KS, et al. (2020) Electronic monitoring in fisheries: Lessons from global experiences and future opportunities. Fish and Fisheries, 2020, 21 pp. 162-189.

Vecchione, M., Mickevich, M.F., Fauchald, K., Collette, B.B., Williams, A.B., Munroe, T.A., Young, R.E., (2000). Importance of assessing taxonomic adequacy in determining fishing effects on marine biodiversity. ICES Journal of Marine Science. 57 pp. 677-681.

Wallace, F., Faunce, C., Loefflad, M., (2013). Pressing rewind: a cause for pause on electronic monitoring in the North Pacific? ICES Document CM/2013J:11, ICES Annual Science Conference, Rejkjavik, Iceland.

Walsh WA, Kleiber P, McCracken M. (2002) Comparison of logbook reports of incidental blue shark catch rates by Hawaii-based longline vessels to fishery observer data by application of a generalized additive model Fisheries Research. 58 pp. 79-94.

Walsh WA, Ito RY, Kawamoto KE, McCracken M (2005). Analysis of logbook accuracy for blue marlin (*Makaira nigricans*) in the Hawaii-based longline fishery with a generalized additive model and commercial sales data. Fisheries Research. 75 pp. 175-192

Appendix A: Errors in species codes

Blue = Primary code used in database for analysis

Byproduct Species

CAAB Code	Species Name	Used by	Notes
37012001	Thresher shark	Both	
37012901	Thresher Sharks (mixed)	EM	
37012000	Thresher Sharks	EM	Very limited EM use
37015001	Draughtboard Shark	Both	
37015906	Draughtboard Sharks (mixed)	Both	Very limited EM use
37018001	Bronze Whaler	Both	
37018902	Bronze Whaler Shark	EM	
37353001	Snapper	Both	
37353903	Snappers - Pagrid	EM	

Bycatch Species

CAAB Code	Species Name	Used by	Notes
24207073	Bailer Shell	EM	
24207000	Bailer Shells	EM	
24207900	Bailer Shell (mixed)	EM	
37258002	Alfonsino	Both	
37258000	Alfonsinos	EM	
37024000	Angel Sharks	Both	
37024900	Angel Shark (mixed)	EM	
37367000	Boarfishes	Both	
37367905	Boarfishes (mixed)	EM	Very limited EM use
37288003	Butterfly gurnard	EM	Very limited EM use
37288901	Butterfly gurnard (mixed)	Both	
37015000	Catsharks - unspecified	Both	
37015901	Catsharks (mixed)	EM	Very limited EM use
28850000	Crabs	Both	
28850901	Crabs (mixed)	EM	
37020923	Dogfishes (mixed)	Both	Very limited logbook use
37990071	Dogfish Sharks (mixed)	Logbook	Very limited logbook use
37043001	Elephantfish	Both	
37043000	Elephantfishes	EM	Very limited EM use
37020902	Endeavour Dogfishes (mixed)	EM	Very limited EM use
37020001	Endeavour Dogfish	Logbook	Very limited logbook use
37990020	Fish Oceanic (mixed)	Both	Very limited logbook use
37999999	Fish (mixed)	Both	Very limited logbook use
37990009	Flounders (mixed all types)	Both	
37990014	Flounders (mixed)	EM	Very limited EM use

37020901 37020007	Greeneye Dogfishes (mixed) Greeneye Dogfish (obsolete)	EM Logbook	Very limited EM use
37019000 37019902	Hammerhead Sharks - unspecified Hammerhead Sharks (mixed)	Both EM	 Very limited EM use
37465000 37465903	Leatherjackets - unspecified Leatherjackets (mixed)	Both EM	
37441911 37441000 37337907	Mackerels (mixed) Mackerels Mackerel scads (mixed)	Both EM EM	 Very limited EM use
23659901 23659000	Octopus (mixed) Octopuses	EM Both	
37311901 37311907	Rockcod (Aethaloperca & Anyperodon) Rockcod Anthiinae sub species	Logbook EM	Very limited logbook use Very limited EM use
37023000 37023900	Sawsharks Sawshark (mixed)	Both EM	
37990018 37990030 37031900 37031000	Skates and Rays Skates and Rays (mixed) Skates (mixed) Skates	Both Both EM Both	
37378900 37378000	Trumpeters (mixed) trumpeters	Logbook EM	Very limited logbook use Very limited EM use
37441912 37441925	Tuna (mixed) Tuna (Thunnus)	Both EM	
37384901 37384000	Wrasses (mixed) Wrasses	Both EM	
37445902 37445014 37445001	Blue-eye Trevalla spp. Ocean Blue-eye Trevalla Blue-eye Trevalla	EM Logbook Both	Very limited EM use Very limited Logbook use
37067901 37067900 37067000	Conger eel (Gnathophis) Conger eel (mixed) Conger eels	EM EM Both	Very limited EM use Very limited EM use
37287901 37287949	Ocean & Coral Perch Ocean Perch Family	EM EM	
37266902 37266000	Oreodories (mixed) Oreodories	EM EM	
37224002 37224901	Ribaldo Ribaldos	Both EM	 Very limited EM use
37232901 37232000 37232900 37232902	Whiptails – Macrourid Whiptails and Rat-tails (mixed) Whiptails – Coelorinchid Whiptails - Coryphaenoid	EM Both EM EM	 Very limited EM use Very limited EM use
37337000 37337908	Trevallies and Scads – unspecified Trevallies (mixed)	EM EM	Very limited EM use Very limited EM use

37445000	Trevallas	EM	Very limited EM use
37311901 37311907	Rockcod (Aethaloperca & Anyperodon) Rockcod Anthiinae sub species	Logbook EM	
37020907 37020925	Lantern Sharks (mixed) Lantern Sharks Family	Both EM	
37020000 37020921 37020908 37020023	Gulper Sharks, Sleeper Sharks, Dogfishes Gulper Sharks Family Gulper Sharks (mixed) Gulper Shark	Both EM EM Logbook	 Limited EM use Limited Logbook use

Appendix B: TEP interactions at species level by sector

GNS sector interactions

TEP species	FY	EM total no.	Logbook total no.
Albatrosses	2015/16	1	0
	2016/17	1	1
	2017/18	0	0
	2018/19	1	0
	2019/20	2	0
Australian fur seal	2015/16	1	0
	2016/17	0	1
	2017/18	0	1
	2018/19	0	3
	2019/20	0	4
Birds	2015/16	1	0
	2016/17	2	0
	2017/18	0	0
	2018/19	0	0
	2019/20	0	1
Bottlenose dolphin	2015/16	0	0
	2016/17	1	0
	2017/18	0	1
	2018/19	0	0
	2019/20	0	0
Common dolphin	2015/16	2	2
	2016/17	3	3
	2017/18	4	4
	2018/19	2	6
	2019/20	1	1
Cormorants	2015/16	0	0
	2016/17	0	2
	2017/18	3	3
	2018/19	1	0
	2019/20	1	0
Dolphins	2015/16	0	0
	2016/17	3	1
	2017/18	2	3
	2018/19	8	5
	2019/20	2	2
Eared seals	2015/16	0	0
	2016/17	7	0
	2017/18	3	0

	2018/19	4	0
	2019/20	8	0
Haired seals	2015/16	2	0
	2016/17	0	0
	2017/18	2	0
	2018/19	1	0
	2019/20	0	0
Little penguin	2015/16	0	1
	2016/17	0	0
	2017/18	0	1
	2018/19	0	0
	2019/20	0	0
New Zealand fur seal	2015/16	0	0
	2016/17	0	1
	2017/18	0	0
	2018/19	0	0
	2019/20	0	3
Penguins	2015/16	1	0
	2016/17	0	0
	2017/18	2	0
	2018/19	0	0
	2019/20	0	0
Petrels and Shearwaters	2015/16	0	1
	2016/17	7	1
	2017/18	2	1
	2018/19	0	0
	2019/20	3	0
Red Cormorant	2015/16	0	0
	2016/17	0	0
	2017/18	0	0
	2018/19	0	0
	2019/20	0	1
Seals	2015/16	0	2
	2016/17	0	7
	2017/18	0	2
	2018/19	0	2
	2019/20	0	2
Shearwaters	2015/16	0	1
	2016/17	0	1
	2017/18	1	0
	2018/19	1	1
	2019/20	1	1
Shortfin mako	2015/16	6	6
	2016/17	9	7
	2017/18	13	11

	2018/19	8	8
	2019/20	1	0
Terns	2015/16	0	0
	2016/17	0	2
	2017/18	0	0
	2018/19	0	0
	2019/20	0	0
White shark	2015/16	0	0
	2016/17	2	2
	2017/18	0	0
	2018/19	0	0
	2019/20	0	0
Total	**All Years**	**126**	**109**

LLA and LLS sector interactions

TEP species	FY	EM total no.	Logbook total no.
Albatrosses	2015/16	0	0
	2016/17	1	0
	2017/18	1	0
	2018/19	0	0
	2019/20	1	1
Eared seals	2015/16	0	0
	2016/17	1	0
	2017/18	0	0
	2018/19	0	0
	2019/20	0	0
Haired seals	2015/16	0	0
	2016/17	0	0
	2017/18	1	0
	2018/19	0	0
	2019/20	0	0
Harrison's Dogfish	2015/16	0	0
	2016/17	2	0
	2017/18	1	0
	2018/19	0	0
	2019/20	0	0
Killer whale	2015/16	0	0
	2016/17	0	0
	2017/18	0	0
	2018/19	0	0
	2019/20	1	1
Longfin mako	2015/16	0	0
	2016/17	0	0
	2017/18	0	0

	2018/19	0	2
	2019/20	0	0
Mackerel sharks	2015/16	0	0
	2016/17	2	0
	2017/18	0	0
	2018/19	2	0
	2019/20	0	0
Petrels and Shearwaters	2015/16	3	2
	2016/17	6	7
	2017/18	4	7
	2018/19	2	0
	2019/20	0	0
Porbeagle shark	2015/16	1	1
	2016/17	0	1
	2017/18	0	2
	2018/19	0	2
	2019/20	0	2
Shearwaters	2015/16	0	1
	2016/17	0	1
	2017/18	0	0
	2018/19	3	3
	2019/20	3	4
Seals	2015/16	0	0
	2016/17	0	0
	2017/18	0	1
	2018/19	0	0
	2019/20	0	0
Shearwaters	2015/16	0	0
	2016/17	0	0
	2017/18	1	0
	2018/19	6	9
	2019/20	0	0
Shortfin mako	2015/16	2	2
	2016/17	1	4
	2017/18	0	0
	2018/19	1	1
	2019/20	1	1
Southern dogfish	2015/16	12	0
	2016/17	0	0
	2017/18	1	0
	2018/19	7	0
	2019/20	0	0
White chinned petrel	2015/16	1	1
	2016/17	0	0
	2017/18	0	2

	2018/19 2019/20	0 0	0 0
Total	**All Years**	**68**	**50**