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Better purse seine catch composition estimates: recent progress and future work plan for Project 60

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Review of Project 60 outputs and work plan

1 Introduction

1.1 Project Objective

The objective of the project is to improve the collection and representative nature of species composition data for tuna (skipjack, yellowfin and bigeye) caught by purse-seine fisheries in the WCPO in order to improve the stock assessments of these key target species in the WCPO.

1.2 Project History

Project 60 and work on the collection and evaluation of purse seine species composition data through paired sampling and unloading data comparisons began in April 2009. The initial duration of the project was from April 2009 to the end of January 2010. The project was extended in April 2010 through January 2011, and then from February 2011 to 31 January 2012.

Following discussion of the "Plan for the improvement of the availability and use of purse-seine composition data" (SPC-OFP 2012), the Scientific Committee made the following recommendation (Anon., 2012a) at para 89, section d: Project 60 be continued through 2013. The study has a target of 50 trips to be sampled, of which 35 trips will be completed by the end of 2012. The Commission (Anon., 2012b) supported the SC8 recommendation and approved the project with funding to cover the cost of the remaining 15 trips for further analysis. In 2014 further research for project 60 was supported under the SC9 unobligated budget, with additional funding from PNG.

SC11 noted that future work should include finalisation of analyses of existing data, the collection of further paired sampling data where these results can be compared to accurate estimates of landed weights by species and simulation modelling to assess alternative sampling protocols (Anon., 2015a). The Scientific Committee made the following recommendation (Anon., 2015a) at para 107:

a) *The WCPFC science/data service provider produce an update to Table 1 in ST-WP-02 annually (until an agreement on methodology can be reached) as it provides a very useful summary of the purse-seine catch estimates derived using the four different methods to ascertain catch composition.*
b) *In regards to the implementation of observer spill sampling in the tropical purse seine fishery,*
    i. *The WCPFC Secretariat and the WCPFC scientific services provider investigate operational aspects including alternatives for spill sampling on purse seine vessels where the current spill sampling protocol is difficult to implement and report back to SC12.*
    ii. *The WCPFC scientific services provider will undertake additional data collection and analyses to evaluate the benefits of spill sampling compared to corrected grab-sampling.*

To implement the 2015 Scientific Committee recommendations, and after approval from the Commission (Anon., 2015b), the WCPFC Secretariat contracted the Scientific Services Provider to continue Project 60. In 2016, the Scientific Service Provider proposed a work plan for the continuation of Project 60 (see Smith & Peatman, 2016) to the Scientific Committee. The 2016 Scientific Committee endorsed the proposed work plan for Project 60 for 2016-17, the scope of which is provided in Section 1.3, and recommended that the Scientific Service Provider proceed with the work plan as endorsed (Anon., 2016). The work plan relates to SC11 recommendation b) above, with recommendation a) addressed on an annual basis in a stand-alone report (e.g. Hampton & Williams, 2016; Hampton & Williams, 2017).

1.3 Project 60 Scope

The scope of work will include, but not be limited to, the following:

a) Continue to identify key sources of sampling bias in the manner in which species composition data are currently collected from WCPO purse seine fisheries and investigate how such biases can be reduced;
b) Review a broad range of sampling schemes at sea as well as onshore; develop appropriate sampling designs to obtain unbiased species composition data by evaluating the selected sampling procedures; extend sampling to include fleets, areas and set types where no representative sampling has taken place; verify, where possible, the results of the paired sampling against cannery, unloading and port sampling data;
c) Review current stock assessment input data in relation to purse-seine species composition and investigate any other areas to be improved in species composition data, including the improvements of the accuracy of collected data;
d) Update standard spill sampling methodology if required; and
e) Analyse additional data collected to evaluate the benefits of spill sampling compared to corrected grab-sampling.

1.4 Addressing SC12 recommendations

The SC recommendations from 2016 were that the Scientific Service Provider should proceed with the work plan for Project 60, as endorsed by SC12. This paper sets out work that was undertaken for Project 60 during the period July 2016 to August 2017, and proposes a work plan for August 2017 onwards. During 2017, collaborative work was undertaken by SPC and Japan's National Research Institute of Far Seas Fisheries. This work is reported in detail in Peatman et al. (2017), with appropriate material reproduced in this report where necessary.

2 Additional analyses to evaluate the benefits of spill samples compared to corrected grab samples

SC11 recommended that further analyses should be undertaken to evaluate the benefits of spill samples compared to grab samples (Anon., 2015a). Lawson (2014) compared species compositions from vessel logbooks, landings data (i.e. landing slips, cannery and container receipts), port sampling, grab sampling and spill sampling for 14 paired grab and spill sampling trips on Solomon Islands (10 trips) and Japanese (4 trips). In this 2017 work, the analysis has been extended to include corrected grab sample species compositions, along with five paired trips in PNG undertaken in 2014 and two additional Japanese paired trips. Grab samples were corrected for grab selectivity bias using the estimates of 'availability' presented in Lawson (2013).

We have reproduced the relevant material from Peatman et al. 2017 for the 6 Japanese paired trips, to prevent the need for continued reference to external information.

2.1 Methodology

2.1.1 Observer-based estimates of species compositions

The approach here was based on that used by Lawson (2014). Throughout we use i, j and k to refer to species, 1cm length bin and set respectively.

Grab sample based species compositions were estimated as follows. Grab samples were used to estimate the proportion of fish in set k that were species i and length bin j, denoted α_{ijk}

$$\alpha_{ijk} = \frac{n_{ijk}}{n_k}$$

where n_{ijk} is the number of sampled fish from set k that were species i and length bin j, and n_k is the total number of grab sampled fish from set k. The proportion of catch weight in set k from species i, denoted p_{ik}, was then calculated as

$$p_{ik} = \frac{\sum_j \alpha_{ijk}\, a_i j^{b_i}}{\sum_{ij} \alpha_{ijk}\, a_i j^{b_i}}$$

where a_i and b_i are species-specific length weight parameters (Table 1). Species and set specific catch weight proportions were then applied to the observer's visual estimates of the set-specific catch w_k, to obtain catch weights of species i in set k, denoted w_{ik}

$$w_{ik} = w_k\, p_{ik}$$

Species-specific catches (by set) were then aggregated across sets to obtain species-specific catches by trip.

Corrected grab sample based species compositions were estimated using the same approach as for grab samples, but the proportions of sampled fish by set, species and length bin, α_{ijk}, were corrected for 'availability' (Lawson, 2013). Corrected proportions, β_{ijk}, were calculated as

$$\beta_{ijk} = \frac{\alpha_{ijk}/A_j}{\sum_{ij} \alpha_{ijk}/A_j}$$

where A_j is the availability of length bin j and the denominator ensures that set-specific proportions sum to one. The proportion of catch weight in set k from species i, denoted p_{ik}, was then calculated as

$$p_{ik} = \frac{\sum_j \beta_{ijk}\, a_i j^{b_i}}{\sum_{ij} \beta_{ijk}\, a_i j^{b_i}}$$

Spill sample based species compositions were estimated using the same approach as for grab samples, but with α_{ijk} (the proportion of sampled fish in set k that were species i and length bin j) based on spill samples rather than grab samples. For sets with samples from more than one brail, we estimated proportions of catch weight by species (p_{ik}) separately for each sampled brail. We then took the mean species-specific catch proportion for the sampled brails, and used this to estimate the species-specific catch weights for the set in question.

2.1.2 PNG port-sampling based species compositions

Port-sampling data provided by PNG consisted of trip and well-specific length measurements by species, with sampling undertaken such that a similar proportion of catches in each well were sampled (e.g. see Kumasi et al., 2010). We therefore used all port samples for a trip to estimate the proportion of fish for the trip that were species i and length bin j, denoted α_{ij}

$$\alpha_{ij} = \frac{n_{ij}}{n}$$

where n_{ij} is the number of sampled fish that were species i and length bin j, and n is the total number of sampled fish for the trip. The proportion of catch weight for the trip from species i, denoted p_i, was then calculated as

$$p_i = \frac{\sum_j \alpha_{ij}\, a_i j^{b_i}}{\sum_{ij} \alpha_{ij}\, a_i j^{b_i}}$$

which was applied to the total reported catch from vessel logbook data to estimate species-specific catches for the trip.

2.2 Japanese paired trips

Species compositions were estimated and compared using: vessel logbooks; landings slips; landings slips, corrected for mis-classification of bigeye and yellowfin using market sampling (referred to as corrected landings data); grab samples; corrected grab samples; and, spill samples. Comparison of species compositions is provided in Appendix A (taken from Peatman et al., 2017).

Peatman et al. (2017) noted the difficulty in drawing robust conclusions on the relative accuracy of corrected grab and spill samples for the two additional paired sampling trips (JP trips #5 and #6, see Appendix A), as the coverage of grab samples and spill samples for both trips were inconsistent, and unrepresentative of the species compositions of the trip as a whole. Restricting comparisons to Japanese trips# 1 to 4 (Table 3), spill sample derived catch compositions were within 0.2 % of corrected landings data for all three target species (in absolute terms). Grab sample compositions underestimated skipjack and bigeye, and overestimated yellowfin. Correction of grab sample compositions reduced the magnitude of overestimation of yellowfin, increased the magnitude of underestimation of bigeye, and reduced the bias in skipjack estimates.

Restricting comparisons to sets with both grab and spill samples (Table 4), grab samples underestimated skipjack and overestimated yellowfin and bigeye relative to spill sample derived catch compositions. Correction of grab samples reduced both the underestimation of skipjack and the overestimation of yellowfin and bigeye, with catch compositions within 0.3 % for the three species (in absolute terms).

2.3 Solomon Islands paired trips

Lawson (2014) presented summaries of species compositions estimates for 10 paired grab and spill sample trips undertaken on Solomon Island purse seiners, based on observer sampling, vessel logsheets, landings data (i.e. cannery and container receipts) and cannery receipts adjusted with port sampling. The species composition tables have been updated to include species compositions based on corrected grab samples (Appendix B, Table 15 to Table 24).

Across the 10 trips, grab sample based species compositions had lower proportions of skipjack and higher proportions of yellowfin and bigeye compared to spill sampling based estimates (Table 5). After correction of grab samples, the relative differences in species proportions compared to spill sampling were reduced, but with higher proportions of skipjack and lower proportions of yellowfin compared to spill sampling based estimates.

However, a number of potential issues with the various datasets were identified by Lawson (2014), including: that vessel-logbook and landings-data species compositions did not appear to be independent; and, the species composition estimates suggested misidentification of yellowfin and bigeye by some port samplers and observers. Furthermore, a detailed examination of comments in the observer database indicated that the grab sampling observer on trips # 9 and 10 had at various times taken grab samples directly from the spill sampling bin citing concerns regarding the safety of obtaining samples from the brail (Appendix B, Table 23 and Table 24).

With these issues in mind, across the 10 trips, grab sample based species compositions had lower proportions of skipjack and higher proportions of yellowfin and bigeye compared to spill sampling based estimates (Table 5). After correction of grab samples, species compositions had higher proportions of skipjack and lower proportions of yellowfin compared to spill sampling based estimates.

Restricting comparisons to the 6 trips with available landings data and no suggestion of grab sampling from the spill sampling bin (Table 6), spill sample and corrected grab sample based species compositions were closer to landings data estimates than uncorrected grab samples. Restricting the comparison to sets on these 6 trips with both grab and spill samples (Table 7) indicates that corrected grab samples over the 62 associated sets gave very similar species compositions to spill samples, whereas uncorrected grab samples species compositions gave lower estimates for skipjack, and higher estimates of bigeye and yellowfin.

2.4 PNG paired trips

Port sampling data from Papua New Guinea were available for 5 paired trips, with species compositions estimated from vessel logbooks, port sampling, grab samples, corrected grab samples and spill samples (Appendix C, Table 25 to Table 29). Spill sampling based species compositions were closest to port sampling estimates across the five trips, with skipjack proportions 2.6% lower than, and yellow and bigeye proportions 5.6 and 10.4 % higher than, estimates from port sampling. Grab samples underestimated skipjack, and overestimated yellowfin and bigeye, relative to both spill sampling and port sampling based species compositions. Correction of grab samples reduced, but did not completely remove, this apparent bias in species compositions. Trip-level comparisons of species compositions, and a brief commentary, are provided in Appendix (Table 25 to Table 29).

2.5 Summary of paired trip species composition comparisons

In Sections 2.1.1, 2.3, 2.4, we compared species compositions for 21 paired trips on purse seiners. The 10 Solomon Islands trips consisted of predominantly associated sets. The 6 Japanese trips and 5 PNG trips consisted of a mixture of associated and unassociated sets, dominated by the former for the PNG trips and the latter for Japan trips. It is important to note that the relative accuracy in, and differences between, observer-based species compositions do demonstrate inter-trip variability. This is not surprising given the variability in grab sample derived estimates (see Hampton & Williams, 2015, Peatman et al. 2017). However, when looking at aggregate species composition estimates across paired trips, spill sampling gave more accurate estimates of species compositions than grab samples, with grab samples over-estimating yellowfin and bigeye, and under-estimating skipjack. Correction of grab samples reduced the bias in species compositions, giving similar species compositions to spill samples, particularly when comparing across sets where both grab and spill samples were taken.

3 Updated investigation of layering between brails

Lawson (2012) used grab samples from almost 14,000 sets to investigate inter-brail layering of fish by size, i.e. systematic changes in size-structure of the fish as the brailing process takes place. Purse seine observer coverage increased in 2010, resulting in a dramatic increase in the number of sampled sets that are now available. In this 2017 work, we update the layering analysis using grab samples, and extend the analysis to include spill samples.

3.1 Method

The approach outlined in Lawson (2012) was used for grab samples, with the following exceptions.

We excluded samples from sets if the recorded length frequency samples appeared to have been ordered by species, rather than ordered chronologically in the sequence that the fish were brailed, using Wald-Wolfowitz runs tests (Stevens, 1939) implemented using the R package randtests. We excluded sets if there was evidence of non-randomness in the ordering of species ($p < 0.05$). Lawson (2012) used a similar approach using bootstrap resampling. Our approach was computationally less demanding, which was important given the large increase in grab samples available for analysis. The process of identifying and excluding sets with apparent non-random ordering of grab sampled fish is required because observers do not record grab samples at a brail-level, and as such there is no explicit data-field that informs whether a grab sampled fish was taken from the beginning or end of the brailing process. However, observers are instructed to record grab sample information in the order that the fish are sampled, which allows us to infer where in the brailing process a sample was taken based on a samples position in the sequence of samples taken from a set.

Lawson (2012) made comparisons across all associated and unassociated sets, regardless of how large the set was. It is possible that inter-brail layering of fish is related in some way to the amount of catch in the purse seine. For this reason we also made comparisons for specific ranges of grab sampled fish, as a proxy for the number of sampled brails and therefore the amount of catch.

For spill samples, we calculated species-specific average weights per set using all spill sampled fish, and equivalent average weights for each sampled brail for each set. These species-specific average weight estimates were then used to track the change in average weights for each sampled brail relative to the average weight of the set. We looked at data from sets with two, three and four sampled brails separately, and compared average relative weights for the 1st sampled brail against the 2nd sampled brail and so on (rather than average relative weights from brail 1 against the average relative weights from brail 2 etc). Note that the first brail sampled varies from the first to the tenth brail, with every tenth brail sampled thereafter. Furthermore, only one brail was sampled for the majority of sets with spill samples, i.e.77 % of associated sets, and 82 % of unassociated sets.

The grab sampling dataset provides data for many more sets (100,000s v 100s), but with more uncertainty in average weight estimates as the number of sampled fish is generally lower than for spill sampling. Conversely, the spill sampling data has less uncertainty in average weight estimates, but we lose some resolution of where in the brailing process samples were taken, due both to the sampling protocol and need to have sufficient observations for meaningful comparison.

3.2 Results

Grab samples did not display systematic trends in average weight from the beginning to the end of the brailing process, with the exception of bigeye in associated sets (Figure 2). Bigeye in associated sets tended to increase in weight as the brailing process took place, with a mean weight of 98 % of the average weight across the set at the beginning of the brailing process, increasing to 104 % of the average weight at the end of brailing. This general trend was driven by sets with between 50 and 99 sampled fish, i.e. samples from 10 to 15 brails (Appendix D, Figure 5). No systematic trend was observed for sets with greater than 100 sampled fish.

For unassociated sets there were no apparent systematic trends in average weight from the beginning to the end of the brailing process (Figure 3). For associated sets, there were no apparent systematic trends in average weight for skipjack and yellowfin (Figure 4). The mean weight for spill-sampled bigeye tended to be highest for the last brail sampled. However, this appeared to be result from a limited number of sets with exceptionally large bigeye sampled near to the end of the brailing process, with no apparent increase in size for the majority of sampled sets.

4 Discussion of 2017 work, and implications on future work

Analysis of 21 paired trips indicates that corrected grab samples and spill samples give both consistent estimates of species compositions at aggregated levels, particularly when considering sets from which both grab and spill samples were taken, and, give estimates of species compositions that are close to those from in-port sampling. Furthermore, the recent collaborative work with Japan (Peatman et al. 2017) has demonstrated that corrected grab samples, at aggregated levels, provide species composition estimates with minimal bias for the 750 + trips analysed. These results suggest that corrected grab samples can deliver purse seine species composition estimates that, at least at aggregated levels, are: consistent with those from spill sampling; and, that have little bias. Further work to explore the precision and accuracy of corrected grab sample based species compositions at more refined levels of aggregation would be useful to explore the precision and bias in species composition estimates at the resolution at which purse seine species composition estimates are commonly used, i.e. the S_BEST stratification (year, month, 1 degree square, set type and flag) and, the spatial/temporal and fishery resolution of the MULTIFAN CL stock assessment models (year, quarter, region and associated/unassociated).

Layering of fish by size can potentially introduce bias in to observer based estimates of size and species compositions (e.g. see Lawson, 2013). Layering of fish by size within brails (intra-brail layering) would require consideration of the process by which fish are sampled from individual brails to obtain representative samples. Layering of fish between brails (inter-brail layering) would require consideration of how to apportion sampling effort between brails. It should be noted that is not clear how inter and intra-brail layering relate to layering of fish by size within the purse seine, but we are not directly interested in layering within the purse seine from the perspective of observer based sampling of catches for size and species compositions. We found no clear evidence of inter-brail layering was detected, save for a weak increasing trend in bigeye size from the beginning to the end of brailing in associated sets. The cause of this trend is not clear, and may not necessarily reflect inter-brail layering. For example, observers may have difficulties in sampling large bigeye at the beginning of brailing if the fish are still alive, though the lack of a similar trend for yellowfin suggests that this is unlikely. Regardless, it appears likely that the increasing trend in bigeye size observed for associated sets has minimal impact on the bias in grab sample based size and species compositions, given the observed bias in grab sample based species compositions for skipjack and yellowfin, and bigeye for unassociated sets, despite the lack of evidence for inter-brail layering. Furthermore, intra-brail layering does not appear to be an important issue given the similarity in spill sample and corrected grab sample based species compositions from the paired trips, despite the fact that grab samples are normally taken from the top of the brail, whereas spill samples are taken from the bottom of the brail. It is important to note that the grab samples collected to date do appear to contradict the hypothesis that bigeye 'float' to the surface of purse seine and so are more likely to be found in early brails (e.g. see Lawson, 2013) – we found no clear evidence of a decrease in the number of bigeye sampled in later brails compared to early brails.

As we should expect, experience from the paired trips indicates that grab and spill sample based species compositions are most reliable if all sets are sampled, otherwise there is the risk that the sampled sets may not be representative of the trip as a whole. This reiterates the importance of ensuring that spill samples are collected from all sets. However, there are a number of occasions in paired trips where spill samples were not taken from sets because the number of brails was lower than the allocated first-brail for spill sampling (which increases sequentially from 1 to 10). With the current spill sampling protocol, a pragmatic way to address this could be to re-allocate a first-brail of spill sampling for these sets, which increases sequentially from 1 to 5. The apparent lack of inter-brail layering suggests that it is not critical which brail is sampled in these cases, but a prescribed randomised approach to brail selection is still advisable. The re-allocation of the first brail for spill sampling would need to be done before brailing starts, to be most effective.

5 Work plan for August 2017 onwards

We propose the following activities for August 2017 onwards under Project 60, with reporting to SC14:

i. Undertake additional paired grab-spill sample trips, targeting trips that are likely to be covered by in-port sampling to maximise the value of the paired grab-spill dataset.
ii. Undertake trials of electronic monitoring approaches to obtaining at-sea estimates of purse seine catch composition, targeting trips that are likely to be covered by in-port sampling to maximise the value of the paired grab-spill dataset. Such trials should include:
    a. determining the best placement of cameras and their technical specifications for various types of purse seine vessel and the methods they use to load fish into wells;
    b. determining an optimum image sampling design, to provide the most accurate and precise set- and/or trip-level estimates of species and size composition possible, determined by comparison with accurate unloadings/port sampling data.
iii. Extend the analysis of Peatman et al. (2017) to include comparison of corrected landings data and corrected grab-sample based species compositions of Japanese purse seiners at varying levels of aggregation (i.e. the S_BEST stratification, and the temporal/spatial/fishery structure of the MULTIFAN CL assessments).
iv. Explore opportunities to undertake a similar analysis for other fleets with accurate species composition estimates from in-port sampling to use as the basis of comparison, preferably a fleet with a higher proportion of associated sets compared to the Japanese fleet.
v. Undertake exploratory analyses of the full paired grab/spill dataset to identify variables affecting the bias in grab sample derived species compositions.
vi. Explore other observer data fields to determine a better approach to identifying and excluding sets with apparent non-random ordering of grab sampled fish;
vii. Expand the investigation of layering between brails to quantitatively assess layering with respect to species composition rather than fish size.
viii. Construct a revised simulation model, potentially with the functionality to include inter-brail layering of bigeye.
ix. Use the simulation model to explore the performance of different approaches to estimating species compositions. This should include comparison of the precision and bias of species composition estimates at various levels of aggregation. Approaches to estimating species compositions should include:
    a. Grab sample derived estimates:
        i. Using the 'availability' based correction from Lawson (2013).
        ii. Using the multinomial based approach advocated during external review of Project 60 (e.g. see McArdle, 2013).

iii. The details of these approaches will be informed by iii.) – e.g. stratification in the multinomial based approach.
b. Spill sampling.
c. Electronic monitoring derived estimates.

x. Review the models used to generate species compositions in instances of low observer coverage (e.g. see Hampton & Williams, 2015).

xi. On the basis of the above, determine:
a. The optimal approach to generate historic purse seine species composition indices;
b. The optimal at-sea sampling protocol to obtain species composition estimates in the short and medium term.

A cost-benefit analysis should also be considered in future, to ensure that at-sea sampling is preferable to in-port based sampling for the estimation of purse seine species compositions in the longer-term.

6 Recommendations

We recommend that the Scientific Committee:

- Consider the work plan prosed for the remainder of 2017
- Consider the medium-term work required to obtain better estimates of purse seine catch composition as outlined in the paper, including
  - Additional analyses of existing data
  - The ongoing need for paired spill/grab sampling trips in the medium term
  - Additional analyses of new data
  - Trials of electronic monitoring approaches
- Approve the minor changes to the observer sampling protocol for brail sampling as identified in the paper, and
- Make the TCC aware of the potential utility of these analyses, and the intended ongoing work, in their ongoing work on purse seine catch composition.

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Tables

Table 1 Length-weight parameters used in the analyses, taken from the 2016 skipjack assessment (McKechnie et al, 2016) and the 2014 yellowfin (Davies et al., 2014) and bigeye (Harley et al., 2014) assessments.

Species	a	b
SKJ	8.64E-06	3.2174
YFT	2.51E-05	2.9396
BET	1.97E-05	3.0247

Table 2 Species compositions (metric tonnes and %) by data source for all 6 Japanese paired trips (see Appendix A, Table 9 to Table 14). Total sets (logsheets) and sets and fish sampled (grab samples and spilled samples) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Type of Data	Unassociated	Associated	Total	sampled	MT	%	MT	%	MT	%	MT
Logsheets	128	37	167		4,012	77.6	1,001	19.4	160	3.1	5,173
Grab samples	58	29	87	4,894	3,629	77.5	832	17.8	222	4.7	4,683
Corrected grab samples	58	29	87	4,894	3,738	79.8	754	16.1	192	4.1	4,683
Spill samples	52	27	79	21,926	3,493	75.4	964	20.8	178	3.8	4,635
Landings					4,120	76.6	1,070	19.9	188	3.5	5,378
Corrected landings					4,120	76.6	1,048	19.5	210	3.9	5,378

Table 3 Species compositions (metric tonnes and %) by data source for Japanese paired trips #1, 2, 3 and 4 (see Appendix A, Table 9 to Table 12). Total sets (logsheets) and sets and fish sampled (grab samples and spilled samples) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Type of Data	Unassociated	Associated	Total	sampled	MT	%	MT	%	MT	%	MT
Logsheets	101	25	128		2,557	80.2	517	16.2	114	3.6	3,188
Grab samples	49	19	68	3,198	2,543	77.2	652	19.8	97	2.9	3,293
Corrected grab samples	49	19	68	3,198	2,614	79.4	595	18.1	84	2.5	3,293
Spill samples	41	18	59	15,370	2,432	78.9	536	17.4	113	3.7	3,082
Landings					2,649	79.0	583	17.4	120	3.6	3,353
Corrected landings					2,649	79.0	577	17.2	126	3.8	3,353

Table 4 Species compositions (metric tonnes and %) by data source for all 6 Japanese paired trips, restricted to sets from which both grab and spill samples were collected (see Appendix A, Table 9 to Table 14). Total sets (logsheets) and sets and fish sampled (grab samples and spilled samples) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Type of Data	Unassociated	Associated	Total	sampled	MT	%	MT	%	MT	%	MT
Logsheets	47	29	76		3,548	82.2	622	14.4	146	3.4	4,316
Grab samples	49	27	76	4,407	3,384	78.0	743	17.1	212	4.9	4,339
Corrected grab samples	49	27	76	4,407	3,481	80.2	673	15.5	185	4.3	4,339
Spill samples	49	27	76	21,848	3,493	80.5	668	15.4	178	4.1	4,339

Table 5 Species compositions (metric tonnes and %) by data source for 10 Solomon Islands paired trips undertaken from 2011 to 2013 (see Appendix B, Table 15 to Table 24). Total sets and fish sampled are also provided for grab, spill and port sampling.

	Number of sets			Fish	SKJ		YFT		BET		Total
Data source	Unassociated	Associated	Total	sampled	MT	%	MT	%	MT	%	MT
Logsheets	5	113	118		1,896	57.3	1,393	42.1	22	0.7	3,310
Grab samples	5	109	114	6,727	1,691	51.5	1,546	47.1	49	1.5	3,286
Corrected grab	5	109	114	6,727	1,881	57.2	1,364	41.5	41	1.2	3,286
Spill samples	3	110	113	43,454	1,814	53.2	1,559	45.7	36	1.1	3,410

Table 6 Species compositions (metric tonnes and %) by data source for Solomon Islands paired trips with landings data (i.e. Trip #s 1 to 6) (see Appendix B, Table 15 to Table 20). Total sets (logsheets) and sets and fish sampled (grab, spill and port sampling) are also provided. Note trip # 9 was excluded from the table, as comments fields indicated that the grab observer had taken grab samples directly from the spill bucket, rather than brails, during some sets due to safety concerns.

	Number of sets			Fish	SKJ		YFT		BET		Total
Data source	Unassociated	Associated	Total	sampled	MT	%	MT	%	MT	%	MT
Logsheets	1	64	65		1,146	57.7	822	41.4	17	0.9	1,985
Grab samples	1	64	65	3,704	892	44.9	1,062	53.5	33	1.7	1,987
Corrected grab	1	64	65	3,704	1,008	50.7	952	47.9	28	1.4	1,987
Spill samples	0	62	62	25,807	992	51.3	928	48.0	14	0.7	1,934
Landings	-	-	-	-	1,098	55.6	876	44.4	0	0.0	1,974

Table 7 Species compositions (metric tonnes and %) by data source for Solomon Islands paired trips with landings data (i.e. Trip #s 1 to 6), restricted to sets from which both grab and spill samples were collected (see Appendix B, Table 15 to Table 20). Total sets (logsheets) and sets and fish sampled (grab, spill and port sampling) are also provided. Note trip # 9 was excluded from the table, as comments fields indicated that the grab observer had taken grab samples directly from the spill bucket, rather than brails, during some sets due to safety concerns.

	Number of sets			Fish	SKJ		YFT		BET		Total
Data source	Unassociated	Associated	Total	sampled	MT	%	MT	%	MT	%	MT
Grab samples	0	62	62	3,539	865	44.7	1,036	53.6	33	1.7	1,934
Corrected grab	0	62	62	3,539	979	50.6	927	48.0	28	1.4	1,934
Spill samples	0	62	62	25,807	992	51.3	928	48.0	14	0.7	1,934

Table 8 Species compositions (metric tonnes and %) by data source for 5 PNG paired trips undertaken in 2014 (see Appendix C, Table 25 to Table 29). Total sets (logsheets) and sets and fish sampled (grab samples and spilled samples) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Data source	Unassociated	Associated	Total	sampled	MT	%	MT	%	MT	%	MT
Logsheets	11	27	38		1,000	78.8	269	21.2	0	0.0	1,269
Grab samples	11	22	33	2,004	721	60.3	437	36.5	38	3.2	1,197
Corrected grab samples	11	22	33	2,004	769	64.2	398	33.2	31	2.6	1,197
Spill samples	11	19	30	5,903	764	67.7	332	29.4	32	2.8	1,127
Port sampling	-	-	-	56,859	883	69.6	354	27.9	33	2.6	1,269

Figures

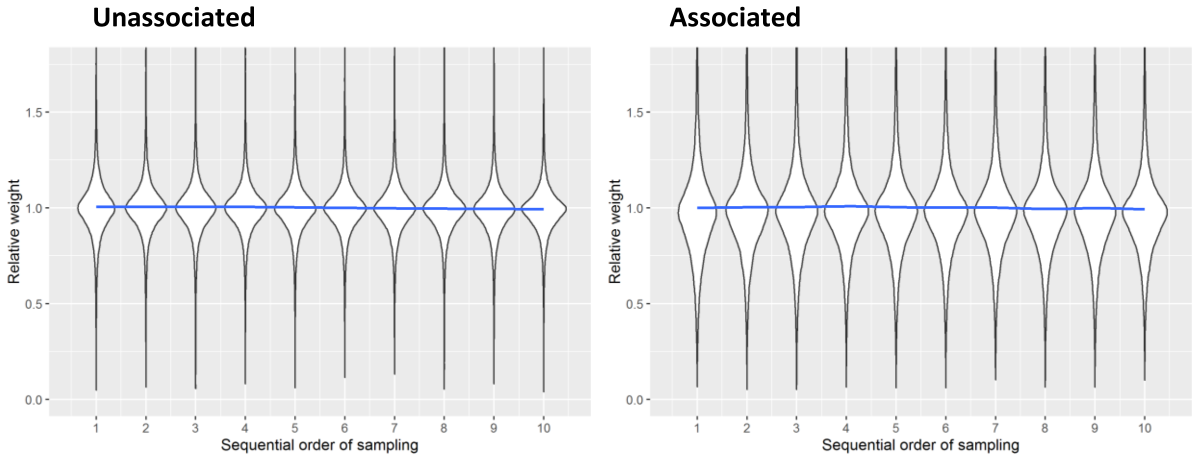


Figure 1 The relative average weight of grab sampled fish (i.e. as a proportion of the estimated average fish weight at the set level) against the sequential order of grab sampling for unassociated (left, n = 40, 162) and associated sets (right, n = 33,896). A cubic regression spline was fitted to the observations to provide an indication of the overall trend in relative average weight (blue line).

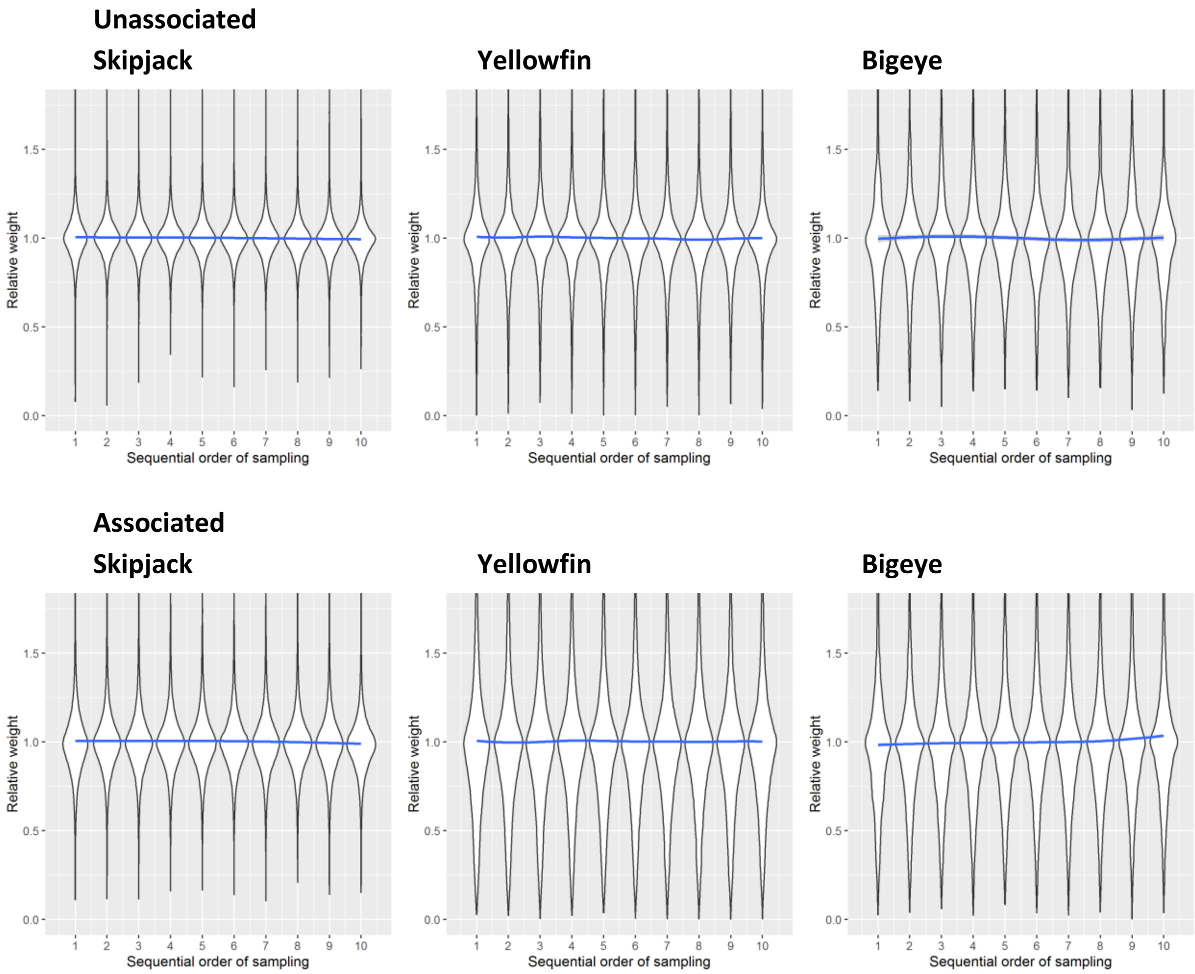
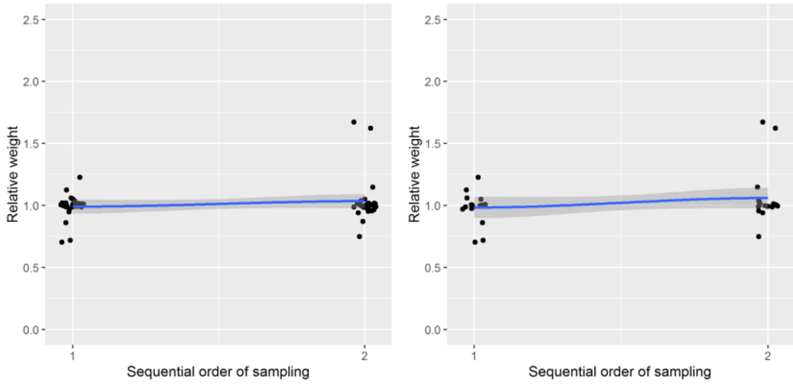


Figure 2 The relative average weight of grab sampled fish (i.e. as a proportion of the estimated species-specific average fish weight at the set level) against the order of grab sampling for skipjack (left), yellowfin (middle) and bigeye (right) and unassociated (top, n = 40,162) and associated sets (bottom, n = 33,896). A cubic regression spline was fitted to the observations to provide an indication of the overall trend in relative average weight (blue line).

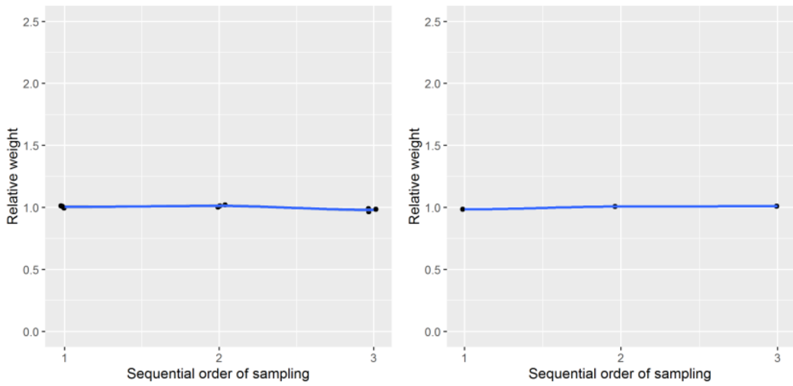
Two sampled brails

Skipjack **Yellowfin**



Three sampled brails

Skipjack **Yellowfin**



Four sampled brails

Skipjack **Yellowfin**

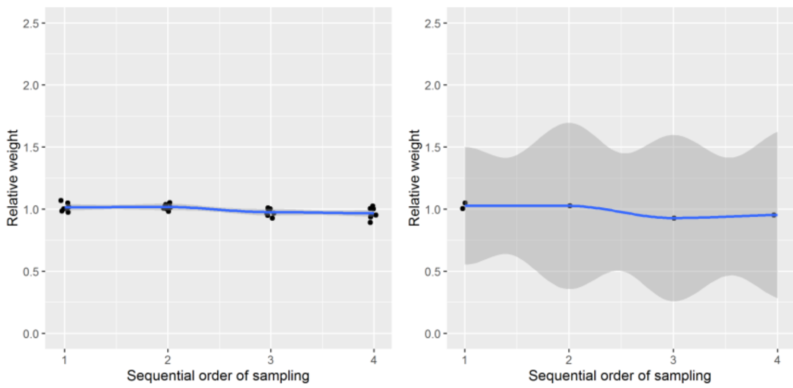


Figure 3 The relative average weight of spill sampled fish (i.e. as a proportion of the estimated species-specific average fish weight at the set level) for unassociated sets for skipjack (left) and yellowfin (right) with two (top, n = 35), three (middle, n = 4) and four (bottom, n = 7) sampled brails. Bigeye excluded due to limited samples. A cubic regression spline was fitted to the observations to provide an indication of the overall trend in relative average weight (blue line).

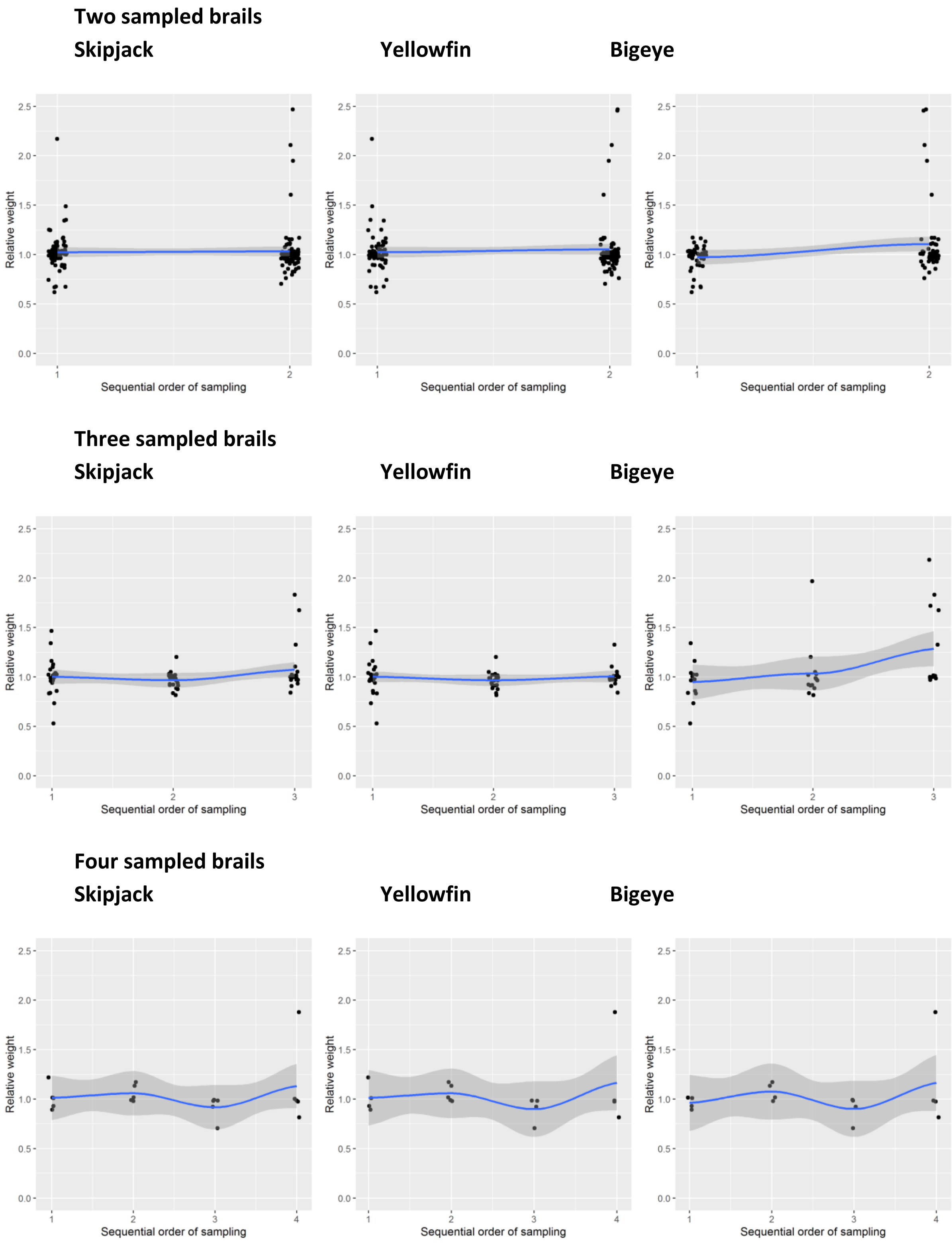


Figure 4 The relative average weight of spill sampled fish (i.e. as a proportion of the estimated species-specific average fish weight at the set level) for associated sets for skipjack (left), yellowfin (middle) and bigeye (right) with two (top, n = 83), three (middle, n = 24) and four (bottom, n = 5) sampled brails. A cubic regression spline was fitted to the observations to provide an indication of the overall trend in relative average weight (blue line).

Appendix A

Species compositions for six Japanese paired trips, taken from Peatman et al. (2017). Trips #1 to #4 correspond to Japanese trips #1 to #4 in Lawson (2014).

Table 9 Species compositions (metric tonnes and %) by data source for Japan paired trip # 1 (Vessel A, 29th January to 24th February 2012). Total sets (logsheets) and sets and fish sampled (grab samples and spilled samples) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Type of Data	Unassociated	Associated	Total	sampled	MT	%	MT	%	MT	%	MT
Logsheets	27	0	27		1,094	99.5	6	0.5	0	0.0	1,100
Grab samples	16	0	16	1,465	1,070	97.6	26	2.4	0	0.0	1,096
Corrected grab samples	16	0	16	1,465	1,076	98.1	20	1.9	0	0.0	1,096
Spill samples	12	0	12	3,206	985	98.9	11	1.1	0	0.0	996
Landings					1,152	98.3	20	1.7	0	0.0	1,171
Corrected landings					1,152	98.3	20	1.7	0	0.0	1,171

- This trip consisted of 27 sets, all unassociated, with 8 zero-catch sets.
- Grab samples were collected from 16 sets, with no grab sampling from three skunk sets totalling approximately 15 mt.
- Spill samples were collected from 12 sets, with no spill sampling from the three sets lacking grab samples, and no spill sampling from a further four sets totalling 115 tonnes.
- Species compositions from each datatype are reasonably consistent, largely due to the skipjack dominated nature of the catch. Corrected grab sample derived catch compositions were slightly closer to the corrected landings data, compared to grab sample and spill sample catch compositions.

Table 10 Species compositions (metric tonnes and %) by data source for Japan paired trip # 2 (Vessel A, 2nd March to 19th April 2012). Total sets (logsheets) and sets and fish sampled (grab samples and spilled samples) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Type of Data	Unassociated	Associated	Total	sampled	MT	%	MT	%	MT	%	MT
Logsheets	48	9	57		534	56.2	406	42.8	10	1.0	950
Grab samples	22	3	25	881	540	49.2	521	47.4	37	3.4	1,098
Corrected grab samples	22	3	25	881	585	53.3	479	43.6	34	3.1	1,098
Spill samples	19	3	22	4,080	567	54.5	440	42.3	34	3.2	1,041
Landings					544	54.1	433	43.2	27	2.7	1,004
Corrected landings					544	54.1	431	42.9	30	2.9	1,004

- This trip consisted of 57 sets, 48 of which were unassociated, including 26 zero-catch sets (all unassociated).
- Grab samples were collected from 25 sets, with no grab sampling from five unassociated sets totalling 21 tonnes.
- Spill samples were collected from 22 sets, with no spill sampling from the five sets lacking grab samples, and a further three sets totalling 64 tonnes, along with the five sets mentioned above.
- Spill sample and corrected grab sample derived catch compositions were closest to those from corrected landings slips.

Table 11 Species compositions (metric tonnes and %) by data source for Japan paired trip # 3 (Vessel B, 29th April to 31st May 2012). Total sets (logsheets) and sets and fish sampled (grab samples and spilled samples) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Type of Data	**Unassociated**	**Associated**	**Total**	**sampled**	**MT**	**%**	**MT**	**%**	**MT**	**%**	**MT**
Logsheets	3	12	16		425	75.2	40	7.1	100	17.7	565
Grab samples	1	11	12	349	462	82.2	47	8.4	53	9.4	562
Corrected grab samples	1	11	12	349	480	85.4	38	6.7	44	7.9	562
Spill samples	1	10	11	3,971	430	79.0	45	8.2	70	12.8	544
Landings					445	75.7	63	10.7	80	13.6	587
Corrected landings					445	75.7	62	10.6	81	13.7	587

- This trip consisted of 16 sets, 12 of which were associated, including two zero-catch unassociated sets and one zero-catch set with association type 'others'.
- Grab samples were collected from 12 sets, with no grab samples collected on an associated set totalling 5 mt.
- Spill samples were collected from 11 sets, with no spill samples collected from the associated set lacking grab samples, and an additional associated set totalling 15 mt.
- Spill sample catch compositions were closest to those from corrected landings slips. Correction of grab samples increased the bias in species compositions.

Table 12 Species compositions (metric tonnes and %) by data source for Japan paired trip # 4 (Vessel B, 7th June to 4th July 2012). Total sets (logsheets) and sets and fish sampled (grab samples and spilled samples) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Type of Data	**Unassociated**	**Associated**	**Total**	**sampled**	**MT**	**%**	**MT**	**%**	**MT**	**%**	**MT**
Logsheets	23	4	28		504	88.0	65	11.3	4	0.7	573
Grab samples	10	5	15	503	471	87.8	58	10.9	7	1.3	536
Corrected grab samples	10	5	15	503	473	88.2	58	10.8	5	1.0	536
Spill samples	9	5	14	4,113	450	90.0	40	8.0	10	2.0	500
Landings					510	86.3	67	11.3	14	2.3	590
Corrected landings					510	86.3	65	10.9	16	2.7	590

- This trip consisted of 28 sets, 23 of which were unassociated, including 10 zero-catch unassociated sets and one zero-catch set with association type 'others'.
- Grab samples were collected from 15 sets, with no grab samples taken from two unassociated sets totalling 8 mt.
- Spill samples were collected from 14 sets, with no spill samples from the two sets lacking grab samples, and an additional unassociated set of 20 tonnes.
- Grab and corrected grab sample derived catch compositions were both similar to those from corrected landings data, though both underestimated bigeye proportions. Spill sample derived catch compositions underestimated yellowfin and bigeye, and overestimated skipjack proportions.
- The 20 tonne set missing grab samples was pure yellowfin, based both on logbook data and grab samples. If this set had been spill sampled, the spill sample catch compositions would have slightly overestimated yellowfin (14.2 %), and underestimated skipjack (83.9 %) and bigeye (1.9 %).

Table 13 Species compositions (metric tonnes and %) by data source for Japan paired trip # 5 (Vessel C, 15th September to 10th October 2012). Total sets (logsheets) and sets and fish sampled (grab samples and spilled samples) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Type of Data	Unassociated	Associated	Total	sampled	MT	%	MT	%	MT	%	MT
Logsheets	18	2	20		877	85.2	139	13.5	14	1.3	1,030
Grab samples	7	2	9	901	648	91.7	29	4.1	30	4.2	707
Corrected grab samples	7	2	9	901	657	92.9	27	3.8	23	3.3	707
Spill samples	8	2	10	3,422	607	74.1	186	22.7	27	3.2	820
Landings					896	85.8	125	12.0	23	2.2	1,045
Corrected landings					896	85.8	113	10.8	36	3.4	1,045

- This trip had 20 sets, 18 of which were unassociated, with 7 zero-catch sets (all unassociated).
- Grab samples were taken from 9 sets, with no grab samples collected on 4 unassociated sets totalling 240 tonnes. These unsampled sets include 2 sets of pure yellowfin totalling 115 tonnes, based on both spill sample and logbook catch compositions.
- Spill samples were taken from 10 sets, with no spill samples taken from 3 unassociated sets totalling 175 tonnes.
- It is difficult to form robust conclusions based on comparisons of grab sample and spill sample derived catch compositions, given that the coverage of both sampling types was inconsistent and unrepresentative of the trip as a whole.
- It is clear that grab and corrected grab samples underestimated yellowfin and overestimated skipjack, based on the sets sampled. However if grab samples had been taken from the 2 pure yellowfin sets, as was the case for spill sampling, then yellowfin would have been overestimated, as seen with the spill sampling compositions.

Table 14 Species compositions (metric tonnes and %) by data source for Japan paired trip # 6 (Vessel C, 13th October to 30th October 2012). Total sets (logsheets) and sets and fish sampled (grab samples and spilled samples) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Type of Data	Unassociated	Associated	Total	sampled	MT	%	MT	%	MT	%	MT
Logsheets	9	10	19		578	60.5	345	36.1	33	3.4	956
Grab samples	2	8	10	795	437	64.0	151	22.1	95	14.0	684
Corrected grab samples	2	8	10	795	467	68.3	132	19.3	85	12.4	684
Spill samples	3	7	10	3,134	454	61.9	241	32.9	38	5.2	733
Landings					574	58.6	362	36.9	44	4.5	981
Corrected landings					574	58.6	358	36.5	48	4.9	981

- This trip had 19 sets, 9 of which were unassociated, with 4 zero-catch sets (all unassociated).
- Grab samples were taken from 10 sets, with no samples taken from 5 sets totalling 220 tonnes.
- Spill samples were taken from 10 sets, with no samples taken from 5 sets totalling 160 tonnes.
- Again, it is difficult to form robust conclusions based on comparisons of grab sample and spill sample derived catch compositions, given that the coverage of both sampling types was inconsistent and unrepresentative of the trip as a whole.

Spill samples derived catch compositions were closer to corrected landings data than grab and corrected grab sample, but this is primarily due to the fact that one additional unassociated set was spill sampled, which happened to be pure yellowfin (based on logbook and spill sampling).

Appendix B
Species compositions for ten Solomon Islands paired trips. Trip numbers correspond to those used in Lawson (2014).

Table 15 Species compositions (metric tonnes and %) by data source for Solomon Islands paired trip # 1 (Vessel A, 27th November to 13th December 2011). Total sets (logsheets) and sets and fish sampled (grab, spill and port sampling) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Data source	Unassociated	Associated	Total	sampled	MT	%	MT	%	MT	%	MT
Logsheets	1	10	11		185	52.9	165	47.1	0	0.0	350
Grab samples	1	10	11	690	132	48.1	139	50.8	3	1.0	273
Corrected grab	1	10	11	690	145	52.9	126	46.0	3	1.1	273
Spill samples	0	10	10	2,902	107	44.5	132	55.1	1	0.4	240
Landings					146	44.7	181	55.3	0	0.0	327
Port sampling				2,301	146	44.7	180	55.1	1	0.2	327

- 11 sets were reported for this trip, of which 10 were on anchored FADs and one on an unassociated school.
- Grab samples were collected from all 11 sets, with spill samples missing from the one unassociated set of approximately 30 tonnes.
- Spill samples gave the closest species compositions to those from landings and port sampling data.
- Grab samples gave higher estimates of skipjack and bigeye, and lower estimates of yellowfin, compared to those from spill samples and landings data. Correction of grab samples increased the apparent bias in species compositions.

Table 16 Species compositions (metric tonnes and %) by data source for Solomon Islands paired trip # 2 (Vessel B, 19th June to 12th July 2012). Total sets (logsheets) and sets and fish sampled (grab and spill samples) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Data source	Unassociated	Associated	Total	sampled	MT	%	MT	%	MT	%	MT
Logsheets	0	15	15		194	55.5	155	44.2	1	0.3	350
Grab samples	0	15	15	671	159	55.5	127	44.5	0	0.0	286
Corrected grab	0	15	15	671	175	61.3	111	38.7	0	0.0	286
Spill samples	0	14	14	6,719	178	64.6	98	35.4	0	0.0	276
Landings					213	61.6	132	38.3	0	0.0	345

- 15 sets were reported for this trip, all on drifting FADs.
- Grab samples were collected from all 15 sets. Spill samples were collected from 14 sets, with no spill samples from one set of approximately 10 tonnes.
- Corrected grab samples gave species compositions closest to those from landing estimates.
- Grab sample species compositions had more yellowfin, and less skipjack, than estimates from corrected grab samples.
- Spill sample species compositions had more skipjack, and less yellowfin, than estimates from corrected grab samples.

Table 17 Species compositions (metric tonnes and %) by data source for Solomon Islands paired trip # 3 (Vessel C, 28th August to 8th September 2012). Total sets (logsheets) and sets and fish sampled (grab, spill and port sampling) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Data source	Unassociated	Associated	Total	sampled	MT	%	MT	%	MT	%	MT
Logsheets	0	10	10		194	53.9	166	46.1	0	0.0	360
Grab samples	0	10	10	514	188	47.3	210	52.7	0	0.0	398
Corrected grab	0	10	10	514	218	54.8	180	45.2	0	0.0	398
Spill samples	0	9	9	4,017	177	45.5	212	54.5	0	0.0	388
Landings					207	54.0	176	46.0	0	0.0	383
Port sampling				778	207	54.0	176	46.0	0	0.0	383

- 10 sets were reported for this trip, 9 on anchored FADs and one on a log.
- Grab samples were taken from all sets. Spill samples were taken from 9 sets, with none taken from a set of 10 tonnes which was almost all skipjack.
- Grab sample based skipjack proportions were lower than, and yellowfin proportions greater than, those from landings and port-sampling. Correction of grab samples gave species compositions that were almost identical to those from the landings and port sampling data.
- Spill sample based species compositions were similar to those from (uncorrected) grab samples.
- Lawson (2014) concluded that it was unclear which data source gave the most accurate estimate of species composition given the large difference between spill sample based estimates and those from the landings and port sampling data. The consistency of the corrected grab sample compositions with those from landings and port sampling data would suggest that the landings and port sampling data are most accurate. It should be noted that the port sampler was the same as for trips 4 and 6. Comparison of species compositions for both trips suggests inaccuracies in discrimination between yellowfin and bigeye (Table 18 and Table 20).

Table 18 Species compositions (metric tonnes and %) by data source for Solomon Island paired trip # 4 (Vessel C, 14th to 24th September 2012). Total sets (logsheets) and sets and fish sampled (grab, spill and port sampling) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Data source	Unassociated	Associated	Total	sampled	MT	%	MT	%	MT	%	MT
Logsheets	0	11	11		235	64.4	128	35.1	2	0.5	365
Grab samples	0	11	11	699	201	47.1	222	52.1	3	0.8	426
Corrected grab	0	11	11	699	223	52.4	200	46.9	3	0.7	426
Spill samples	0	11	11	4,101	227	53.3	196	46.0	3	0.7	426
Landings					208	54.8	171	45.2	0	0.0	379
Port sampling				2,073	208	54.8	171	45.2	0	0.0	379

- 11 sets were reported for this trip, 10 on anchored FADs and one on a drifting FAD.
- Spill samples based species compositions were closest to those from the landings and port sampling data.
- Grab samples based skipjack proportions were lower, and yellowfin and bigeye proportions higher, than those from spill sampling data.
- Correction of grab samples reduced the apparent bias in species compositions, giving similar estimates to those from spill sampling.
- Lawson (2014) noted that the species compositions from landings and port sampling data were likely to be inaccurate, given the absence of bigeye in landings and port sampling species compositions, and the presence of bigeye in species compositions from other data sources. It

should be noted that the port sampler was the same as for trips 3 and 6, and a similar issue was observed for trip 6 (Table 20).

Table 19 Species compositions (metric tonnes and %) by data source for Solomon Islands paired trip # 5 (Vessel C, 28th September to 12th October 2012). Total sets (logsheets) and sets and fish sampled (grab and spill samples) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Data source	Unassociated	Associated	Total	sampled	MT	%	MT	%	MT	%	MT
Logsheets	0	11	11		230	64.8	125	35.2	0	0.0	355
Grab samples	0	11	11	683	106	25.9	290	71.0	12	3.0	409
Corrected grab	0	11	11	683	118	29.0	279	68.4	11	2.6	409
Spill samples	0	11	11	4,838	196	48.0	212	52.0	0	0.0	409
Landings					231	63.9	131	36.1	0	0.0	361

- 11 sets were reported for this trip, all on anchored FADs.
- Grab samples and spill samples were taken from all sets.
- Spill sample based species compositions were closest to the landings data. However species compositions were markedly different to those from landings data, with lower proportions of skipjack and higher proportions of yellowfin.
- Grab sample based skipjack proportions were far lower than those from spill samples, with the opposite true of yellowfin.
- Correction of grab samples resulted in a slight increase in skipjack, and decrease in yellowfin, proportions.
- Lawson (2014) noted that it was unclear which estimates of species compositions were likely to be most accurate for this trip, and that the discrepancy in bigeye compositions between the grab and spill sampling observer could point to issues with species identification.

Table 20 Species compositions (metric tonnes and %) by data source for Solomon Islands paired trip # 6 (Vessel C, 16th to 27th October 2012). Total sets (logsheets) and sets and fish sampled (grab, spill and port sampling) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Data source	Unassociated	Associated	Total	sampled	MT	%	MT	%	MT	%	MT
Logsheets	0	7	7		108	52.7	83	40.5	14	6.8	205
Grab samples	0	7	7	447	107	54.8	74	37.8	14	7.4	195
Corrected grab	0	7	7	447	128	65.6	56	28.9	11	5.5	195
Spill samples	0	7	7	3,230	107	54.9	78	40.0	10	5.1	195
Landings					93	52.5	85	47.5	0	0.0	178
Port sampling				1,405	93	52.5	85	47.5	0	0.0	178

- 7 sets were reported for this trip, all on anchored FADs.
- Spill sample based species compositions were most similar to those from landings and port sampling data.
- Spill sample and grab sample catch compositions were similar. Correction of grab samples increased the proportion of skipjack and decreased the proportion of yellowfin and bigeye.
- Lawson (2014) noted that the species compositions from landings and port sampling data were likely to be inaccurate, given the absence of bigeye in landings and port sampling species compositions, and the presence of bigeye in species compositions from other data sources. It should be noted that the port sampler was the same as for trips 3 and 4, and a similar issue was observed for trip 4 (Table 18).

Table 21 Species compositions (metric tonnes and %) by data source for Solomon Islands paired trip # 7 (Vessel C, 2nd to 22nd November 2012). Total sets (logsheets) and sets and fish sampled (grab and spill samples) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Data source	**Unassociated**	**Associated**	**Total**	**sampled**	**MT**	**%**	**MT**	**%**	**MT**	**%**	**MT**
Logsheets	0	17	17		215	59.6	146	40.4	0	0.0	360
Grab samples	0	17	17	995	313	68.0	138	30.0	9	2.1	461
Corrected grab	0	17	17	995	337	73.1	116	25.2	8	1.7	461
Spill samples	0	16	16	5,929	306	66.6	146	31.8	7	1.5	460

- 17 sets were reported for this trip, all on anchored FADs.
- No landings or port sampling data were available for the trip.
- Grab samples were collected from all sets. Spill samples were collected from 16 sets, with no samples collected from a set of approximately 1 tonne.
- Grab sample and spill sample based species compositions were similar, though with less bigeye for spill samples. Corrected grab sample compositions had more skipjack, and less yellowfin.

Table 22 Species compositions (metric tonnes and %) by data source for Solomon Islands paired trip # 8 (Vessel D, 23rd to 10th December 2012). Total sets (logsheets) and sets and fish sampled (grab and spill samples) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Data source	**Unassociated**	**Associated**	**Total**	**sampled**	**MT**	**%**	**MT**	**%**	**MT**	**%**	**MT**
Logsheets	1	14	15		224	62.2	132	36.5	5	1.3	360
Grab samples	1	14	15	670	218	63.3	120	34.9	6	1.8	345
Corrected grab	1	14	15	670	233	67.5	107	31.0	5	1.5	345
Spill samples	1	14	15	4,825	185	53.6	153	44.3	7	2.1	345

- 15 sets were reported for this trip, 12 on anchored FADs, 2 on drifting FADs and one associated school.
- No landings or port sampling data were available for the trip.
- Grab samples and spill samples were collected from all sets.
- Spill samples gave the lowest estimates of skipjack and the highest estimates of bigeye and yellowfin.
- Grab samples gave higher estimates of skipjack, and lower estimates of yellowfin and bigeye, compared to spill sample species compositions.
- Correction of grab samples further increased the proportion of skipjack, and decreased the proportion of yellowfin and bigeye.

Table 23 Species compositions (metric tonnes and %) by data source for Solomon Islands paired trip # 9 (Vessel C, 22nd to 28th May 2013). Total sets (logsheets) and sets and fish sampled (grab samples and spilled samples) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Data source	Unassociated	Associated	Total	sampled	MT	%	MT	%	MT	%	MT
Logsheets	0	7	7		180	70.4	76	29.6	0	0.0	255
Grab samples	0	5	5	308	106	63.0	62	37.0	0	0.0	168
Corrected grab	0	5	5	308	125	74.0	44	26.0	0	0.0	168
Spill samples	0	7	7	3,511	182	61.5	106	36.0	8	2.6	296
Landings					181	70.5	76	29.5	0	0.0	257

- 7 sets were reported for this trip, 4 on logs and 3 on anchored FADs.
- Grab samples and spill samples were collected from all sets. However grab samples from two sets were excluded from the analysis, as an unspecified proportion of the fish were taken from the spill sampling bin due to difficulties in safely accessing brails. These two sets totalled approximately 125 tonnes.
- Corrected grab samples gave the closest species compositions to those from landings data. If grab samples had been taken from the remaining two sets, species compositions would likely have been slightly more different to those from landings data (0.76/0.22/0.02 SKJ/YFT/BET).
- Grab sample based species compositions gave higher estimates of skipjack, and the lowest estimate of yellowfin and bigeye.
- Spill samples gave lower estimates of skipjack, and higher estimates of yellowfin and bigeye.

Table 24 Species compositions (metric tonnes and %) by data source for Solomon Islands paired trip # 10 (Vessel C, 16th to 26th June 2013). Total sets (logsheets) and sets and fish sampled (grab samples and spilled samples) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Data source	Unassociated	Associated	Total	sampled	MT	%	MT	%	MT	%	MT
Logsheets	3	11	14		132	37.6	219	62.4	0	0.0	350
Grab samples	3	9	12	1,050	162	49.8	163	50.2	0	0.0	325
Corrected grab	3	9	12	1,050	179	55.2	145	44.8	0	0.0	325
Spill samples	2	11	13	3,382	150	39.9	226	60.1	0	0.0	376

- 14 sets were reported for this trip, 11 on anchored FADs and 3 unassociated schools.
- No landings or port sampling data were available for the trip.
- Grab samples were collected from all sets. Grab samples from two sets were excluded from the analysis, as an unspecified proportion of the fish were taken from the spill sampling bin due to difficulties in safely accessing brails. These two sets totalled approximately 55 tonnes. Spill samples were collected from 13 sets, with no samples collected from a set of approximately 3 tonnes.
- Spill samples gave the lowest estimates of skipjack and the highest estimates of bigeye.
- Grab samples gave higher estimates of skipjack, and lower estimates of yellowfin and bigeye, compared to spill sample species compositions.
- Correction of grab samples further increased the proportion of skipjack, and decreased the proportion of yellowfin and bigeye.

Appendix C
Species compositions for five paired trips in PNG.

Table 25 Species compositions (metric tonnes and %) by data source for PNG paired trip # 1 (Vessel A, 26th March to 12th May 2014). Total sets (logsheets) and sets and fish sampled (grab samples and spilled samples) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Data source	Unassociated	Associated	Total	sampled	MT	%	MT	%	MT	%	MT
Logsheets	8	2	10		374	90.1	41	9.9	0	0.0	415
Grab samples	6	3	9	595	349	89.9	30	7.6	10	2.5	388
Corrected grab samples	6	3	9	595	354	91.3	26	6.8	8	2.0	388
Spill samples	6	4	10	2,597	342	81.5	64	15.3	13	3.2	420
Port sampling	-	-	-	13,805	328	79.1	82	19.8	4	1.0	415

- 10 sets were reported for this trip, with 8 and 6 recorded as unassociated in the vessel and observer logbooks respectively.
- Grab samples were collected from 9 sets, with no grab sampling from one log set of approximately 30 mt.
- Spill samples were collected from all 10 sets.
- Spill samples gave the closest species compositions to the port sampling estimates.
- Grab sample compositions gave higher skipjack and bigeye proportions, and lower yellowfin proportions, than the port-sampling estimates. Correction of grab samples further reduced the accuracy of species compositions.
- The bias in grab-sample based species compositions was partially a result of the species composition of the log set which was not grab sampled, which had a high proportion of yellowfin (based on logsheet and spill sampling).
- However, comparison of spill and grab-sample based compositions suggests that skipjack was over-represented, and yellowfin under-represented, in grab-samples for the remaining sets.

Table 26 Species compositions (metric tonnes and %) by data source for PNG paired trip # 2 (Vessel A, 21st May to 31st May 2014). Total sets (logsheets) and sets and fish sampled (grab samples and spilled samples) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Data source	Unassociated	Associated	Total	sampled	MT	%	MT	%	MT	%	MT
Logsheets	3	0	3		69	42.6	93	57.4	0	0.0	162
Grab samples	2	0	2	192	26	19.0	107	77.8	4	3.2	138
Corrected grab samples	2	0	2	192	36	26.3	97	70.3	5	3.4	138
Spill samples	2	0	2	238	54	39.4	77	56.2	6	4.4	138
Port sampling	-	-	-	1,726	52	32.1	96	59.4	14	8.5	162

- Three sets were reported for this trip, all of which were unassociated.
- Grab and spill samples were collected from 2 sets, with no samples of either type from one set of < 5 tonnes.
- Spill sample based species compositions were closest to port sampling estimates.
- Spill sample based skipjack proportions were greater than, and yellowfin and bigeye proportions less than, the port sampling estimates.
- Grab sample based skipjack and bigeye proportions were less, and yellowfin greater, than port sampling estimates. Correction of grab samples reduced, but did not completely remove, the apparent bias in species compositions.

Table 27 Species compositions (metric tonnes and %) by data source for PNG paired trip # 3 (Vessel A, 7th to 25st June 2014). Total sets (logsheets) and sets and fish sampled (grab samples and spilled samples) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Data source	Unassociated	Associated	Total	sampled	MT	%	MT	%	MT	%	MT
Logsheets	0	1	1		84	70.0	36	30.0	0	0.0	120
Grab samples	0	1	1	145	40	38.6	64	61.4	0	0.0	104
Corrected grab samples	0	1	1	145	45	43.0	59	57.0	0	0.0	104
Spill samples	0	1	1	116	51	48.6	47	45.2	6	6.2	104
Port sampling	-	-	-	4,649	62	51.3	54	44.8	5	3.8	120

- One (associated) set was reported for this trip.
- Both grab samples and spill samples were taken from the set, with more samples for grab than spill samples.
- Spill sample based species compositions were closest to port sampling estimates.
- Spill sample based skipjack proportions were lower than, and yellowfin and bigeye proportions greater than, port sampling estimates.
- Grab sample based skipjack proportions were lower than, and yellowfin proportions greater than, port sampling estimates. No bigeye were found in grab samples. Correction of grab samples reduced, but did not completely remove, the apparent bias in species compositions.

Table 28 Species compositions (metric tonnes and %) by data source for PNG paired trip # 4 (Vessel B, 12th March to 6th April 2014). Total sets (logsheets) and sets and fish sampled (grab samples and spilled samples) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Data source	Unassociated	Associated	Total	sampled	MT	%	MT	%	MT	%	MT
Logsheets	0	13	13		406	87.1	60	12.9	0	0.0	466
Grab samples	3	8	11	806	260	56.2	178	38.5	24	5.3	462
Corrected grab samples	3	8	11	806	282	61.1	161	34.9	19	4.0	462
Spill samples	3	5	8	1,336	263	72.5	93	25.8	6	1.6	362
Port sampling	-	-	-	15,419	382	82.0	74	15.9	10	2.1	466

- 13 sets were reported for this trip, with 13 and 8 sets recorded as associated in the vessel and observer logbooks respectively.
- Grab samples were collected from 11 sets, with no grab samples taken from two associated sets totalling 10 mt.
- Spill samples were collected from 8 sets, with no spill samples from five associated sets. Four of these five sets totalled approximately 25 tonnes, with the remaining set accounting for approximately 90 tonnes.
- Spill sample based species compositions were closest to port sampling estimates. Spill sample based skipjack and bigeye proportions were lower than, and yellowfin greater than, port sampling estimates.
- Spill sample species compositions would likely have been closer to port sample estimates (~ 0.76/0.22/0.02 SKJ/YFT/BET) if the all sets had been sampled, particularly the 90 tonne set which grab samples and logsheet data suggest was almost all skipjack.
- Grab sample based skipjack proportions were lower than, and yellowfin and bigeye proportions greater than, estimates from port sampling. Correction of grab samples reduced, but did not completely remove, the apparent bias in species compositions.

Table 29 Species compositions (metric tonnes and %) by data source for PNG paired trip # 5 (Vessel B, 24th May to 25th June 2014). Total sets (logsheets) and sets and fish sampled (grab samples and spilled samples) are also provided.

	Number of sets			Fish	SKJ		YFT		BET		Total
Data source	Unassociated	Associated	Total	sampled	MT	%	MT	%	MT	%	MT
Logsheets	0	11	11		67	63.2	39	36.8	0	0.0	106
Grab samples	0	10	10	266	46	43.8	59	56.2	0	0.0	105
Corrected grab samples	0	10	10	266	51	48.5	54	51.5	0	0.0	105
Spill samples	0	9	9	1,616	54	51.8	50	47.9	0	0.3	104
Port sampling	-	-	-	21,260	59	55.4	47	44.6	0	0.0	106

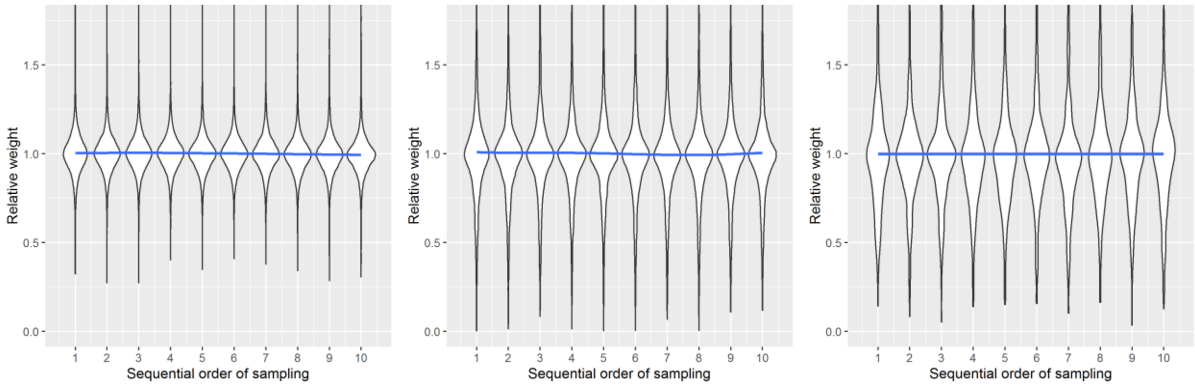
- 11 sets were reported for this trip, all associated.
- Grab samples were taken from 10 sets, with no grab samples collected from one set of approximately 1 tonne.
- Spill samples were taken from 9 sets, with no spill samples taken from two sets totalling < 2 tonnes.
- Spill sample based species compositions were closest to port sampling estimates. Spill sample based skipjack proportions were lower than, and yellowfin proportions greater than, port sampling estimates.
- Grab sample based skipjack proportions were lower than, and yellowfin proportions greater than, estimates from port sampling. Correction of grab samples reduced, but did not completely remove, the apparent bias in species compositions.

Appendix D
Additional figures relevant to inter-brail layering

Unassociated sets

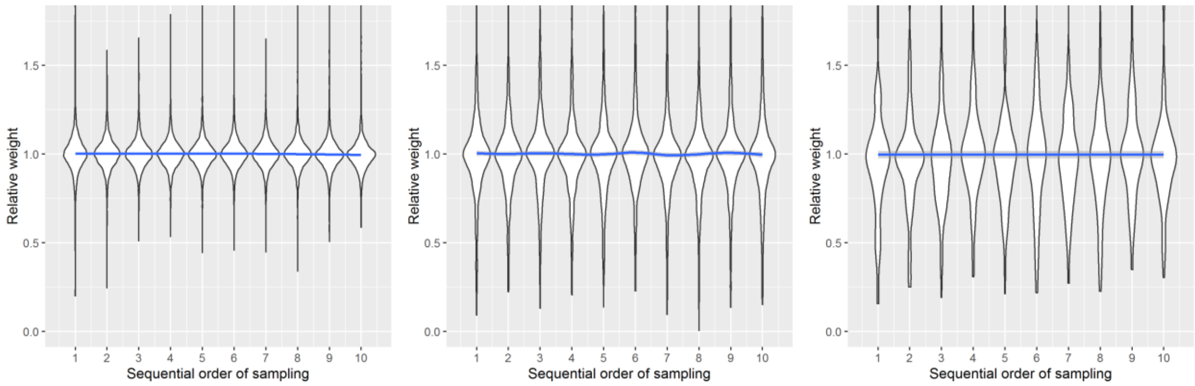
50 to 99 grab samples

Skipjack **Yellowfin** **Bigeye**



100 to 149 grab samples

Skipjack **Yellowfin** **Bigeye**



150 + grab samples

Skipjack **Yellowfin** **Bigeye**

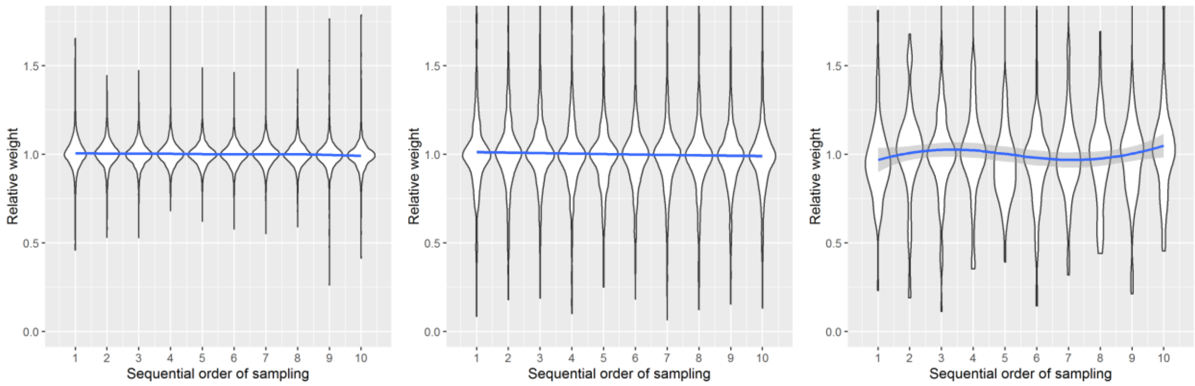


Figure 5 The relative average weight of grab sampled fish (i.e. as a proportion of the estimated species-specific average fish weight at the set level) against the order of grab sampling for skipjack (left), yellowfin (middle) and bigeye (right), for unassociated sets with 50 to 99 samples (n = 14,822), 100 to 149 samples (n = 4,252) and 150 + samples (n =-2897). A cubic regression spline was fitted to the observations to provide an indication of the overall trend in relative average weight (blue line).

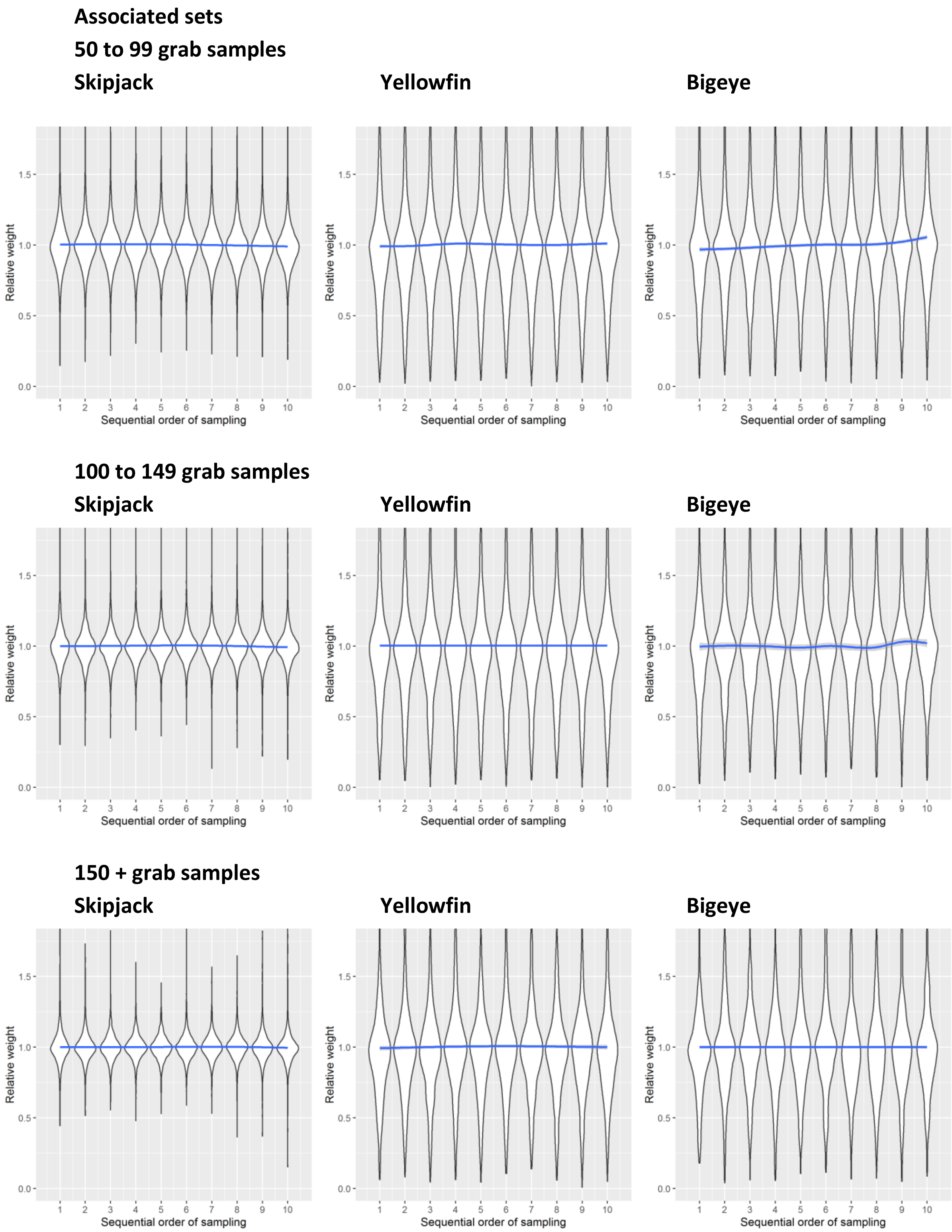


Figure 6 The relative average weight of grab sampled fish (i.e. as a proportion of the estimated species-specific average fish weight at the set level) against the order of grab sampling for skipjack (left), yellowfin (middle) and bigeye (right), for associated sets with 50 to 99 samples (n = 12,455), 100 to 149 samples (n =-3,758) and 150 + samples (n= 2,076). A cubic regression spline was fitted to the observations to provide an indication of the overall trend in relative average weight (blue line).