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Improving the quality of Japanese purse seine catch composition estimates: a Project 60 collaboration

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Executive Summary

In 2017 the Pacific Community and the Japanese National Research Institute of Far Seas Fisheries collaborated on analyses of Japanese purse seine vessels catch data. The analyses focused on the estimation and comparison of species and size compositions of purse seine catches based on a variety of data sources.

This collaborative effort is an input to Project 60, the overall objective of which 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.

Trip-level species compositions of Japanese purse seiners from 2010 to 2015 were estimated using: logbook data; landings slips data; landing slips data corrected for misclassification of yellowfin and bigeye using market sampling data; observer grab samples; and, observer grab samples corrected for grab selectivity bias. For Japanese purse seiners, the (fully enumerated) landings slips dataset is likely to give the most accurate estimate of purse seine catch species compositions, particularly after correction for misclassification of small yellowfin and bigeye. Based on comparison of estimated species compositions:

- Grab sample derived species compositions under-estimated skipjack and over-estimated bigeye and yellowfin relative to corrected landings data.
- Correction of grab samples reduced the bias in species compositions.
- The biases in grab sample based catch compositions and size compositions, and the reduction in bias with correction for selectivity bias, are consistent with grab selectivity bias identified in earlier work (e.g. Lawson, 2013).
- The low magnitude of bias in corrected grab-sample based species compositions suggests that corrected grab-sample based estimates can be used to obtain (almost) unbiased species compositions when aggregated across trips.
- There is considerable variability in the accuracy of grab-sample based catch compositions at the trip-level.
- Corrected landings slips data should be used to obtain trip level species compositions estimates of Japanese purse seiners.
- Corrected grab sample based species compositions could be used to disaggregate trip-level species compositions to the S_BEST stratification.
- Further work should explore the accuracy and precision of grab-sample based catch compositions at finer resolutions routinely used in analyses and assessments.

For 6 paired grab and spill trips undertaken on Japanese purse seiners, the comparison of species compositions were extended to include estimates of species compositions based on spill samples. Based on comparison of species compositions for the paired trips:

- Corrected grab-sample derived species compositions were similar to spill-sample derived catch composition, when considering only sets where both grab and spill samples were taken. This suggests that species composition estimates based on corrected grab-samples are consistent with compositions derived from spill samples, at least when aggregated across trips.
- When considering all sets within paired grab-spill sample trips, spill-sample derived species compositions were the most accurate observer-sampling based estimates of species compositions.

Trip and species-specific size compositions were estimated from landings slips data, grab samples and, corrected grab samples, using size ranges from market categories of Japanese ports. Based on comparisons of size compositions:

- Grab sample based size compositions generally underestimated the proportion of smaller fish, and overestimated the proportion of larger fish.
- Correction of grab samples reduced, but did not always remove, the bias in size compositions.
- These observations are consistent with grab selection bias identified in earlier work through Project 60.

The report concludes with recommendations for consideration by the Scientific Committee, including approaches to estimate historic purse seine species compositions for Japanese purse seiners.

Postscript - catch by species based on the mandatory logbooks of the Japanese purse seine fishery operated in the WCPO area were submitted by Japan to SPC. The catch by species were corrected using the logbook data, market slip data and port sampling data.

1 Introduction

In 2017 the Pacific Community (SPC) and the Japanese National Research Institute of Far Seas Fisheries (NRIFSF) have collaborated on analyses of Japanese purse seine vessels catch data. Specifically, the analyses have focused on the estimation of species and size compositions of purse seine catches based on a variety of data sources. This collaborative effort is an input to Project 60, the overall objective of which 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. Interested readers are directed to Smith & Peatman (2016) and Peatman et al. (2017) for more information on Project 60.

Species compositions of purse seine catches in the WCPFC are currently estimated using information collected by observers through the WCPFC regional observer programme (ROP), given that catch compositions reported in vessel logbooks have a tendency to be biased (e.g. Fonteneau, 1975). A summary of the current WCPFC approach is provided in Hampton & Williams (2015). In order to assess the accuracy of observer-based species compositions, it is necessary to have information on the actual species composition of catches. Lawson (2014) used cannery receipts, port sampling data and/or landings slips to assess the accuracy of observer based species compositions for 14 purse seine trips, including four on vessels flagged to Japan (JP). Japanese purse seine vessels normally unload in Japanese ports, at which point the landings are fully enumerated. In this study, SPC and NRIFSF used all available data from Japanese fishing trips undertaken from 2010 onwards to compare observer based species and size compositions with the landings dataset, allowing comparison of species and size compositions from over 770 fishing trips.

2 Methods

2.1 Overview of datasets used

In Japan (NRIFSF), purse seine data for logbook, landings slips, market and fish well samplings are available from 1995 onward. The data for 2016 were very preliminary when this analysis was conducted and accordingly only the data up to 2015 were used. In addition, the treatment of all the data provided by Japan necessarily followed the "Agreed conditions for collaboration on tuna research between SPC-OFP staff(s) and NRIFSF staff(s)" because these data are confidential and so normally not available for such analysis, or provided to SPC.

2.1.1 Logbook data

Logbooks mandatory for distant water purse seine vessels are compiled at NRIFSF. Logbook coverage is almost 100%. Logbook data include information on date, location, status of activity (operation, searching, cruising etc.), school type, and catch in weight by species for each date. If more than one operation was completed in one day, the data are available for each operation including any null sets. Catch amounts for each set include species composition as estimated on board. Japan submitted catch statistics based on logbook data for this collaborative work.

2.1.2 Observer data

WCPFC ROP observers routinely sample purse seine catches for length using the grab sampling protocol. Observers are instructed to take 5 fish at random from each brail, and record the species and length of each fish sampled. Spill sampling has also been undertaken on purse seine vessels in the

WCPO, as part of paired grab and spill sampling trips, hereafter referred to as paired trips. More information on grab and spill sampling can be found in Lawson (2008). Paired trips require an additional observer to undertake spill sampling, with the other observer collecting grab samples. In spill sampling, a metal bin is filled with catch directly from the brail, and the species and length of every fish within the bin is recorded. Spill sampling requires the measurement of more fish per brail than grab sampling, and so brails are sampled less regularly. Observers are instructed to sample every tenth brail, with the initial brail to be sampled increasing sequentially from one set to the next. For example, for the 3rd set of a trip, the observer should sample the 3rd brail, followed by the 13th brail and so on. Samples are collected on a set-by-set basis for both grab and spill sampling, with observers instructed to undertake the relevant sampling protocol for every set. As such, grab and spill samples can be used to generate species and size compositions specific to variables that change between sets, for example school association types. Paired trips allow direct comparison of grab sample and spill sample based species and size compositions whilst controlling for the effects of other variables, as both sampling protocols are implemented on the same sets. Paired trips are particularly valuable when accurate estimates of species and size compositions are available from additional datasets, normally from port-sampling or landings sales slips.

2.1.3 Landings slips

Since 1995, NRIFSF has collected market slips mainly from the three major landing ports of distant water purse seine landings in Japan, Yaizu, Makurazaki and Yamagawa. The data coverage is almost 100% for the ports which provide market slips, and for the cruises operated in the equatorial area. Market slips include information on vessel name, landing date and the amount (in kg) of landing for each market category (Figure 8, Appendix B, 3). There is no information on school type.

For bigeye tuna, a market category for the smallest size fish (e.g. less than 1.5kg) does not exist because there is no demand from the fish buyers to separate yellowfin and bigeye for this smallest size category for all three landing ports, and also for the second smallest size category for Yaizu port. Thus the smaller bigeye are typically classified into the corresponding weight category of yellowfin tuna. Also, bigeye tuna are sometimes misidentified as yellowfin and vice versa, and so some mixture of species data does occur for yellowfin and bigeye tuna categories in the sorted market category.

Figure 3 shows the proportion of landing for each market category of skipjack tuna, and Figure 4 shows the same for yellowfin and bigeye tuna. Basically the proportion of PS products is smaller than corresponding size class for B products. The proportion of smallest or second smallest size of yellowfin tuna, for which the market category for the corresponding size of bigeye tuna does not exist, was less than 10% of the landings. The proportion of yellowfin tuna 10kg up (the largest market size category for yellowfin tuna) was highest in all the ports. However, taking into account that the amount of landing of bigeye tuna is much smaller than that of yellowfin tuna, even a small proportion of the smallest fish category of yellowfin tuna may affect the assessment of the catch/landings of bigeye tuna.

2.1.4 Market sampling

NRIFSF has conducted port sampling of purse seine catch from fishing operations in the equatorial area in cooperation with several organizations since 1995. Port sampling is conducted at three major landing sites, Yaizu (Shizuoka Pref.), Makurazaki and Yamagawa (Kagoshima Pref.). Generally, this sampling occurs two or three times in total per month (a part of this sampling is for the vessels fishing in the Indian Ocean). Port sampling at Yamagawa has only been conducted since 2010. In a port sampling event, the fish from one vessel and one cruise are selected and sampled. Market category and/or fish well sampling are conducted at each port sampling event.

As for market category sampling, 100 fish are randomly sampled from each market category (although occasionally more than or less than 100 fish are sampled). After species identification, length, weight (for the first 20 fish for each species), and total weight of sampled fish for each species are measured. Both "B" (brine) (normal product) and "PS" (high quality product) exist, but sampling is done only for B product fish. Fish size and species composition for PS are regarded to be the same as those in the B product.

Figure 1 (left) shows the annual change in the number of market category sampling with sampling coverage. Market category sampling has been conducted more or less 30 times per year. The annual sampling coverage (based on the number of cruises) is 9-16%.

Figure 2 shows the annual trend in the number of the fish measured, including the number by species. More or less 30,000 fish were measured annually. As for the species composition, approximately 50% in number of the landings was skipjack.

2.1.5 Fish well sampling

For fish well sampling, up to three fish wells per cruise are selected for sampling on the condition that the well was filled by only one fishing operation and so detailed information on the operation is available. From each fish well selected, a total of approximately one tonne of fish are sampled, with the sample taken in at three sub-samples at separate times. Length and weight are measured for sampled fish (noting weight is generally up to 20 fish for each species). Information on the operation for the corresponding fish well, such as, date, location, school type, catch amount, are provided by the vessel.

Figure 1 (right) shows the annual change in the number of fish well sampling events with sampling coverage. Fish well sampling has been conducted approximately 20-30 times per year. In 2010-2011, a special project was conducted and much more fish well sampling was done. Except for that period, sampling coverage of landings was approximately 10% (based on the number of cruises).

Figure 5 shows the annual trend in the number of the fish measured including the number by species or school type. More or less 20,000 fish were measured annually. As for species, approximately 80% in number of the landings was skipjack. As for school type, log schools (including FADs) were dominant until 2009, after that the proportion of both log and free school were similar, or free school was dominant. Figure 6 shows the geographical distribution for operations for which fish well sampling was conducted. It covers almost the entire equatorial area of the WCPO.

2.1.6 Landings slips, corrected using market sampling

The catch by species based on the mandatory logbooks of the Japanese purse seine fishery operated in the tropical area (20N-20S) of WCPO area have been submitted to SPC. Under the collaborative work related to Project 60 between SPC and Japan, the catch by species were revised using the methodology described below, using the market slip data and the port sampling data. Japan selected the bigeye catch limitation option as its management measure under CMM2008-01, and submitted the catch by species of this fishery from 2001 to 2004 corrected by the market slip data and the port sampling data. The statistics were revised using a correction factor (corrected catch / logbook catch) calculated for each market category averaged from 2001 to 2004. In this study, the duration for the revised period was from 1995 to 2015. Therefore, the averaged correction factor calculated for 2001 to 2004 is not used in this study.

We have three kinds of data for the catch by species for each cruise mentioned above, the logbook (log), the market slip (market) and the corrected statistics by port sampling data (corrected). The number of cruises conducted by Japanese purse seine vessels operating in the tropical area (20N-20S) of the WCPO from 1995 to 2015 was 5,051. The cruises were grouped according to the presence/absence of the three kinds of data. The first group has the log data, the market data and the corrected data, and composed of 628 cruises (12.4 %). The second group has the log data and the market data but the corrected data are not available (4,252 cruises, 84.2％). The third group possess only the log data, and the market and the corrected data were not available or incomplete for various reasons (171 cruises, 3.4 %).

The mixing of species for skipjack market categories is extremely rare, thus the skipjack catch in the market categories were considered true skipjack catches in a cruise in this study. For the first step, for the first group, the catch by species reported by the market data is corrected using the species mixture rate in weight (yellowfin / (bigeye + yellowfin)) for each market category in each market (Yaizu, Makurazaki and Yamagwa). The correction is implemented for all market categories of a landing of a cruise, and then sum up to the corrected catch by species. For the second group, the annual average values of the mixture rate for each market category were calculated using the corrected data. The annual average values for each market category were labelled as “universal factor A”, which were then used to correct the catch by species in the market data for the second group. The catch by species of the third group was corrected by annual correction factors in weight (yellowfin / (yellowfin + bigeye)) using the corrected catch by species of the first and second groups. The annual average values were labelled “universal factor B”.

In addition to these treatments mentioned above, the following treatments were also implemented. Regarding the first group, in cases where the number of yellowfin plus bigeye measured for each market category in a port sampling event was less than 50, the universal factors (A, B or WP) are used instead of the correction factor of the port sampling event.

For the second group, if an appropriate annual correction factor was not obtained, the correction factor WP (Whole Period; 1995-2015) was used. The correction factors of each market category before 2009 in Yamagawa port, are shared with those of Makurazaki port. This is considered appropriate because the port sampling program was not conducted before 2009 in Yamagawa port, and the composition of market categories of the two ports were similar. The “wounded” market category usually has no correction factor, thus the proportion of species of the “wounded” market category was based on the corrected catch by species except for the wounded category of the cruise.

2.2 Linking between datasets

In order to link observer data stored at SPC and data provided by JP, several iterations were necessary. First of all a data audit of the Japanese datasets was conducted in order to identify similar data fields with the SPC datasets, set up the mapping protocols and identify existing issues in the JP data (e.g. duplicated trips, missing information, spelling mistakes).

We then started mapping of trips between the two datasets by data field such as trip dates, vessel identifiers and port of unloading. This step required several attempts as in some cases the dates were different for the same trip dependent on whether the WCPFC ROP observer had embarked later or disembarked earlier than the dates or departure/arrival of the JP trip. The same issue also occurs with the port of departure and arrival which could be different for the same trip between the two datasets. Lastly in this iteration, we identified that the naming of the same vessel could be different between the SPC vessel registry data and the JP vessel registry. This required building a specific look-up table for making the necessary data linkage.

The third step after having mapped the trips was to link the individual sets on each trip together between the two datasets. This link was made using the different dates and times provided for each set. This required some care as the time was not always reported identically (e.g. identical events differing by a few minutes between datasets), was not always provided, or was not always provided in the same time zone.

Following this iterative process, from the 1600 trips provided by JP, we were able to map 60% of them with trips in the SPC observer database for trips which had matching sets.

2.3 Estimation and comparison of species compositions

Grab and spill sample derived species compositions were estimated at a set-level, and then aggregated to trip-level, using the approach outlined in Peatman et al. (2017). Logbook species compositions were obtained by aggregating set level estimates to trip-level. Landing slips derived species compositions were obtained by aggregating across market categories.

The Japanese landing slips data are fully enumerated and are therefore likely to provide the most accurate species compositions data, particularly after correction for misclassification of small bigeye and yellowfin using market sampling data. As such, species compositions based on corrected landings slips data are used when available as the point of reference when comparing species compositions.

Lawson (2014) compared species compositions from logbooks, grab and spill sampling, and landings data for four Japanese purse seine trips. In this report we extend the analysis to include two additional paired trips undertaken in 2012, and include species compositions based on grab samples corrected for grab selectivity bias (referred to throughout as corrected grab samples) and landings data corrected for misclassification of small bigeye and yellowfin (referred to throughout as corrected landings data).

2.4 Estimation and comparison of size compositions

Landings slips data were used to generate species-specific size compositions, using size classifications from market categories. Set and species specific length-frequencies were generated from corrected grab samples as part of the process of estimating species compositions (Section 2.3). These length frequency distributions were converted to weight using length-weight parameters in Table 1 and aggregated across sets. These trip and species specific weight-frequency distributions were then aggregated to the appropriate market category size classification based on the species and landings port for the trip (see Appendix B, Table 13). Bigeye smaller than 1.5 kg (BET1_5under) were included in the equivalent yellowfin category (YFT1_5under) in corrected grab sample derived size compositions, to allow consistent comparisons with the landings size compositions.

The market category size ranges vary between port, and so port-specific comparisons were made. The size classifications for bigeye market categories at Yamakawa port differed for ‘PS’ and ‘B’ quality fish (see Figure 3 and Figure 4). We therefore used ‘B’ quality market categories to construct landings slips size compositions of bigeye landed at Yamakawa, given that ‘B’ quality market categories accounted for 90 % of BET landings at the port. Size ranges for damaged fish, i.e. ‘broken’, ‘heavily broken’ and ‘pressed’, were also excluded due to inconsistencies with market categories used for undamaged fish.

3 Results

3.1 Linking between datasets

In the SPC observer database there were 1,003 trips corresponding to our criteria (purse seine trips of JP vessels since 2010, for which we had length frequency samples).

In the JP dataset there were 1,600 trips. 60% of them (958 trips) were effectively mapped with SPC observer trips and sets.

However, in the SPC Observer database, there are several trips of JP vessels for which the set details or length information have not been yet provided. If we take into consideration these additional trips (hereafter “empty trips”, we mapped an additional 155 trips from the JP dataset which brings the total result to 70% with 1,113 trips from the JP dataset being mapped with an SPC Observer trip.

We can consider this exercise as successful, indicating a high level of coverage between the two datasets consistent with observer coverage estimates for WCPFC convention area-wide estimates (Williams et al., 2016; Williams et al., 2017). However, it is now necessary to seek the missing information in the SPC observer database to update these empty trips on one hand and to add the missing JP trips with WCPFC ROP observer on board on the other.

3.2 Paired grab-spill sampling trips

Six paired trips have been undertaken on Japanese flagged purse-seiners. Over the six trips, spill sample derived catch compositions were closest to the corrected landings data, with slight underestimation of skipjack and over-estimation of yellowfin and bigeye (Table 2). Grab sample derived catch compositions over-estimated skipjack and under-estimated yellowfin and bigeye, and correction of grab samples further increased these biases. Equivalent tables of species compositions are provided for each trip individually in Appendix A, along with a brief commentary. It is important to note that the relative accuracy of grab, corrected grab and spill sample derived species compositions do vary between trips.

However, the coverage of spill samples and grab samples for paired trips #5 and #6 were inconsistent and un-representative of the catch composition of the paired trips as a whole (see Appendix A). Restricting comparisons to 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). Note that landings and corrected landings data could not be included in Table 4, as these were available at trip-level only.

3.3 Corrected landings data

The annual catch by species of corrected and logbook data are shown in Appendix C. Note that these analysis are independent of the species composition comparisons (2010 onwards) reported below and were completed by Japan as a postscript to the rest of this research. There was no substantial differences between corrected and logbook for skipjack, whose average corrected / logbook ratio from 1995 to 2015 was 0.98. The catch amount of yellowfin tuna in the logbook data were always underestimated except for 1997. The average corrected / logbook ratio from 1995 to 2015 was 1.19. A strong El Nino year was observed in 1997, and the fishing grounds of the Japanese purse seine fishery moved to the eastern side of the WCPO, and it is well known that higher catches of bigeye occur in the eastern side when compared to the western side. This change of fishing conditions may have caused the exception in 1997. The catch of bigeye tuna in the logbook data were also always underestimated, and the average corrected / logbook ratio from 1995 to 2015 was 2.08. However, the ratios in 1995 (5.86) and 1996 (3.93) were extremely high compared to the other years. The Japanese purse seine fishery in the tropical area mainly catches bigeye tuna by FADs, and the fish length for FAD associated fish is relatively small. The Japanese purse seine fishery has been implemented around the FADs since around 1995. In some cases, the buyers in the Japanese ports do not require species identification, especially for smaller sized fish. For these reasons, species identification may not have been paid much attention just after the fleet expanding its usage of FADs. Thus, the average corrected value from 1997 to 2015, 1.78, is considered more appropriate to represent the average situation (Appendix C).

3.4 Species compositions

There were 1,383 trips with logbook and landings slips data (Table 5). Logbook data underestimated bigeye and yellowfin proportions by 42 % and 12 % respectively, with skipjack overestimated by 4 %. Misclassification of small bigeye and yellowfin in landings slips data resulted in underestimation of the proportional contribution of bigeye by 15 % and overestimation by 2 % for yellowfin, with an unbiased estimate of skipjack[1].

There were 776 trips with available logbook, landings slips and observer grab sampling data (Table 6). Logbook data underestimated bigeye and yellowfin proportions by 43 and 13 % respectively, with skipjack overestimated by 4 %. Misclassification of small bigeye and yellowfin in landings slips data resulted in underestimation of the proportional contribution of bigeye by 16 % and overestimation by 2 % for yellowfin, with an unbiased estimate of skipjack. Grab sample derived species

[1] The difference in skipjack catch tonnage (and total tonnage) between the corrected and uncorrected landings data results from rounding errors.

compositions overestimated bigeye and yellowfin proportions by 16 and 8 %, and underestimated skipjack by 2 %. Correction of grab samples reduced bias in species compositions, with bigeye overestimated by 3 % and yellowfin underestimated by 3 %.

3.5 Size compositions

Figure 8 shows a comparison of the proportion of the fish for each market category based on grab samples, corrected grab samples and landings data.

In general, (uncorrected) grab sample derived size compositions underestimated the proportion of smaller individuals (< 2.5 or 3 kg, depending on the port) and overestimated proportions of larger individuals (> 2.5 or 3 kg). This is consistent with the 'selectivity bias' of grab sampling (e.g. see Lawson, 2013). Correction of grab samples reduced, but did not completely remove, this bias. There are exceptions to the above, which are summarised here:

- For skipjack landings in Makurazaki, the proportion of landings greater than 4.5 kg was over-estimated using uncorrected grab samples, and slightly under-estimated with corrected grab samples.
- For bigeye landings in Yamakawa and Makurazaki, the proportion of landings in the BET 3up and 2.5up categories (respectively) were overestimated by grab samples, and the degree of overestimation increased with correction for grab sample selectivity bias.
- For yellowfin landings in Makurazaki, the proportion of landings in the largest market category (> 10 kg) was underestimated by grab samples, with the degree of underestimation (slightly) increasing with correction for grab sample bias.
- All bigeye landings in Yaizu were classified as BET 2.5 up. This classification appears to have been applied regardless of size, given the large proportion of bigeye greater than 10 kg in the observer data.
- For yellowfin landings in Yamakawa and Makurazaki, it is not clear if the size ranges of market categories were mutually exclusive (i.e. did not overlap). In the landing slips data for the two ports, sometimes landings of YFT 3 up occurs and YFT 5 up does not occur, and less frequently, vice versa. This may be the cause of large differences of the proportions of both categories.

4 Discussion

As noted in Section 2.3, the landings dataset is likely to give the most accurate estimate of purse seine catch species compositions, particularly after correction for misclassification of small yellowfin and bigeye. Grab sample derived species compositions under-estimated skipjack and over-estimated bigeye and yellowfin relative to corrected landings data. Correction of grab samples reduced the bias in species compositions, with the proportion of skipjack and bigeye over-estimated by 0.6 % and 3 % respectively, and yellowfin under-estimated by 3 %. The biases in grab sample based catch compositions and size compositions, and the reduction in bias with correction for selectivity bias, are consistent with grab selectivity bias identified in earlier work (e.g. Lawson, 2013). Furthermore the low magnitude of bias in corrected grab-sample based species compositions suggests that corrected grab-sample based estimates can be used to obtain (almost) unbiased species compositions when aggregated across trips. However, there is considerable variability in the accuracy of grab-sample based catch compositions at the trip-level. Comparison of corrected grab sample species compositions with corrected landings data at varying levels of aggregation would be a useful extension of the collaborative work, to explore the likely accuracy of corrected grab-sample based species compositions for the 'S_BEST' stratification, i.e. year, quarter, five degree square and association, and the temporal spatial resolution of MULTIFAN CL stock assessments, i.e. year, quarter, assessment region, and associated vs. unassociated set-type.

Corrected grab-sample derived species compositions were similar to spill-sample derived catch compositions for the 6 paired spill-grab trips, when considering only sets where both grab and spill samples were taken. This suggests that species composition estimates based on corrected grab-samples are consistent with compositions derived from spill samples, at least when aggregated across trips. Furthermore the over-estimation of yellowfin and bigeye and underestimation of skipjack in grab sample derived species compositions relative to spill sample estimates, and the reduction in bias with correction of grab samples for 'selectivity bias', are again consistent with grab selectivity bias. However it should be noted that there is again between-trip variability, *e.g.* grab samples under-estimated skipjack when looking across the 6 trips, but for some trips grab samples over-estimated skipjack.

When considering all sets within paired grab-spill sample trips, spill-sample derived species compositions were the most accurate observer-sampling based estimates of species compositions. However, as demonstrated by trips #5 and #6, observer-sampling based estimates of species compositions will only give accurate estimates of species compositions if sampled sets are representative of species compositions of the trip as a whole.

It is important to note that there was no market sampling or fish well sampling for the 6 paired trips. It would be preferable to target future paired trips on Japanese vessels for market and fish well sampling, to allow analyses to be undertaken at the finest resolutions, *e.g.* set-level comparisons of species compositions based on grab, spill and fish well sampling.

Historically, Japan submitted aggregate purse seine catch and effort data which was based directly on vessel logbooks, i.e. without correction for bias in species compositions. SPC had understood the aggregate data to be corrected, based on the various Japanese at-port monitoring programmes. Analyses presented here suggest that Japanese vessel logbook data underestimated bigeye and yellowfin by 42 and 12 % respectively for trips between 2010 and 2016 (Table 5). Corrected landings data should provide the most accurate and precise estimates of historic species compositions for Japanese purse seiners, given that the estimates are based on fully enumerated landings slips data and are corrected for misclassification of small bigeye and yellowfin. However, the corrected landings data is available at a trip-level only. The analyses presented here suggests that corrected grab-sample based species compositions could be used to disaggregate the trip level estimates to the S_BEST stratification. Corrected grab-sample based species compositions could be used for Japan until corrected landings data compositions are available, using the same approach used for other purse seine fleets operating in the WCPFC convention area.

We recommend that:

- The corrected landings dataset is used to generate historic species compositions for Japanese purse seiners;

- Corrected grab-sample based species compositions provide unbiased estimates at aggregated levels, and should be used to disaggregate corrected landings data to the S_BEST stratification;
- Future paired grab-spill sample trips on Japanese purse seiners should be prioritised for market and fish well sampling;
- Future collaborative work between SPC and Japan should include comparison of corrected landings data and corrected grab-sample based species compositions at varying levels of aggregation;
- High quality landings data as used in this analysis would significantly improve estimates of purse seine catch composition in other fleets; and
- Additional resources be allocated to recovering historical observer data records which have been identified as missing as a result of this research (see also Williams (2017) and Williams et al. (2017)).

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Tables and Figures

Table 1 Length-weight parameters used in the analyses.

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 paired trips. 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 paired trips #1, 2, 3 and 4. 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 paired trips, restricted to sets from which both grab and spill samples were collected. 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 percentages) based on logbook data, landings data, and landings data corrected for species misclassification using market sampling data (trips = 1,383).

Source	BET	SKJ	YFT	Total	BET %	SKJ %	YFT %
Logbook	15,339	825,680	163,960	1,004,979	1.5	82.2	16.3
Landings	23,125	808,683	195,291	1,027,098	2.3	78.7	19.0
Corrected landings	27,280	808,483	191,169	1,026,932	2.7	78.7	18.6

Table 6 Species compositions (metric tonnes and percentages) based on logbook data, landings data, landings data corrected for species misclassification using market sampling data, grab samples and grab samples corrected for selectivity bias (trips = 776).

Source	BET	SKJ	YFT	Total	BET %	SKJ %	YFT %
Logbook	8,620	470,832	87,946	567,398	1.5	83.0	15.5
Landings	13,008	459,351	105,941	578,301	2.2	79.4	18.3
Corrected landings	15,514	460,000	103,722	579,236	2.7	79.4	17.9
Grab samples	16,624	415,058	103,123	534,805	3.1	77.6	19.3
Corrected grab	14,749	427,277	92,779	534,805	2.8	79.9	17.3

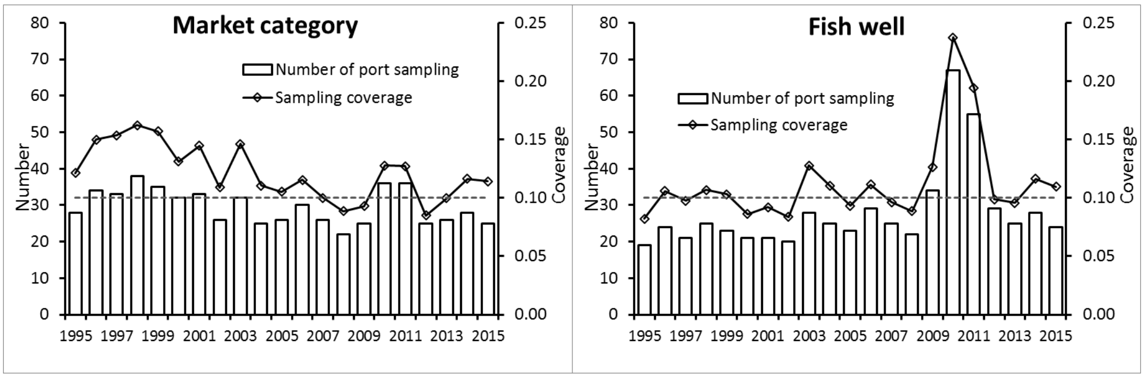


Figure 1 The number of port sampling and sampling coverage (based on the number of cruises) in each year. Dashed horizontal line indicates 10% coverage.

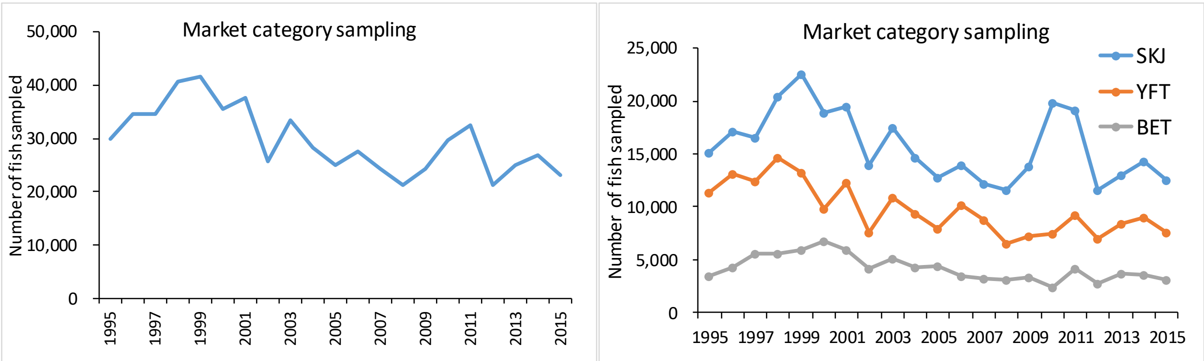


Figure 2 The number of fish sampled by market category sampling for each year. Left: total number, right: number by species.

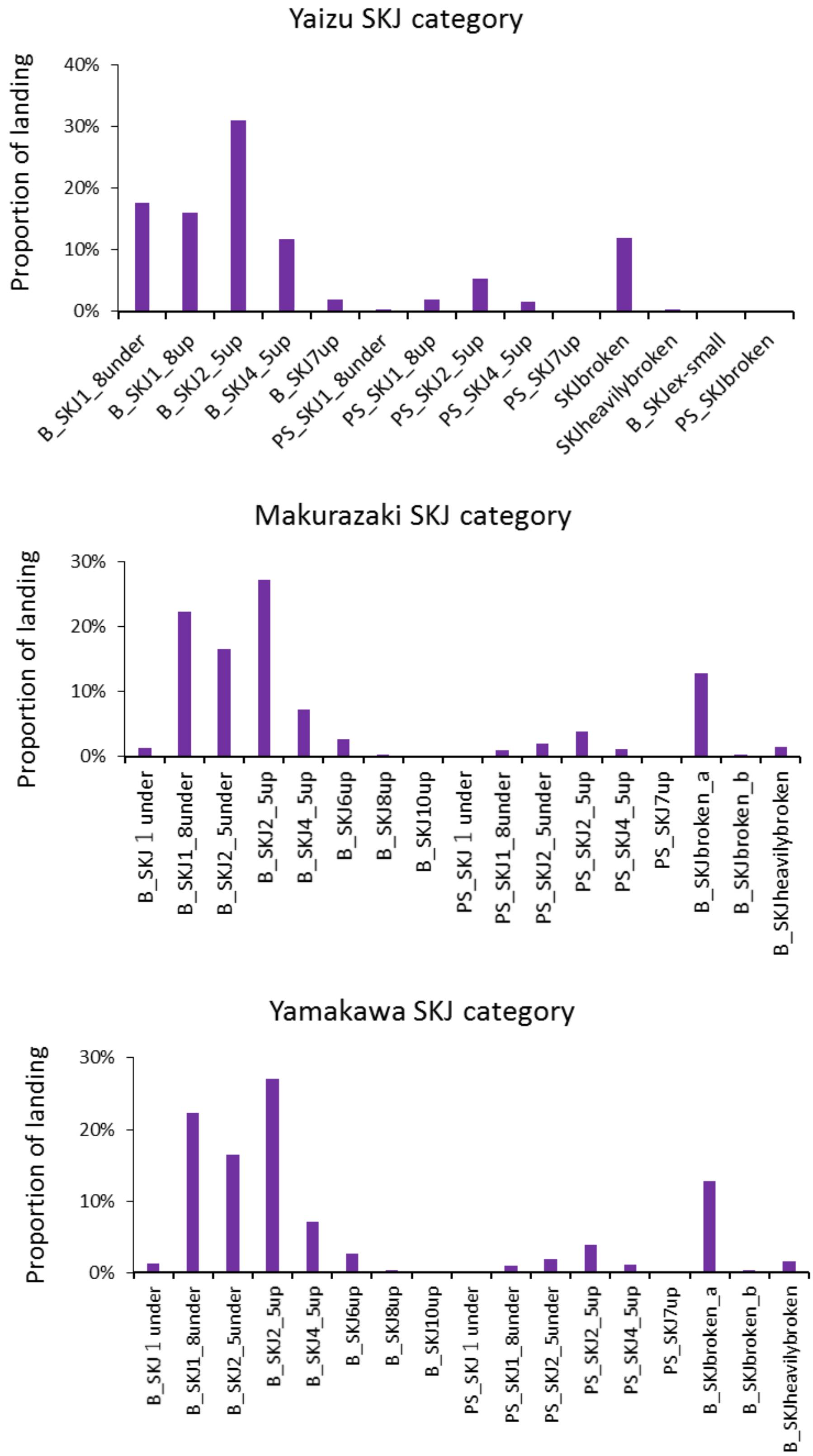


Figure 3 Amount of landings (average for 1995-2015) for each market category for skipjack tuna in each port. "B" and "PS" indicate brine (normal) and higher quality product, respectively.

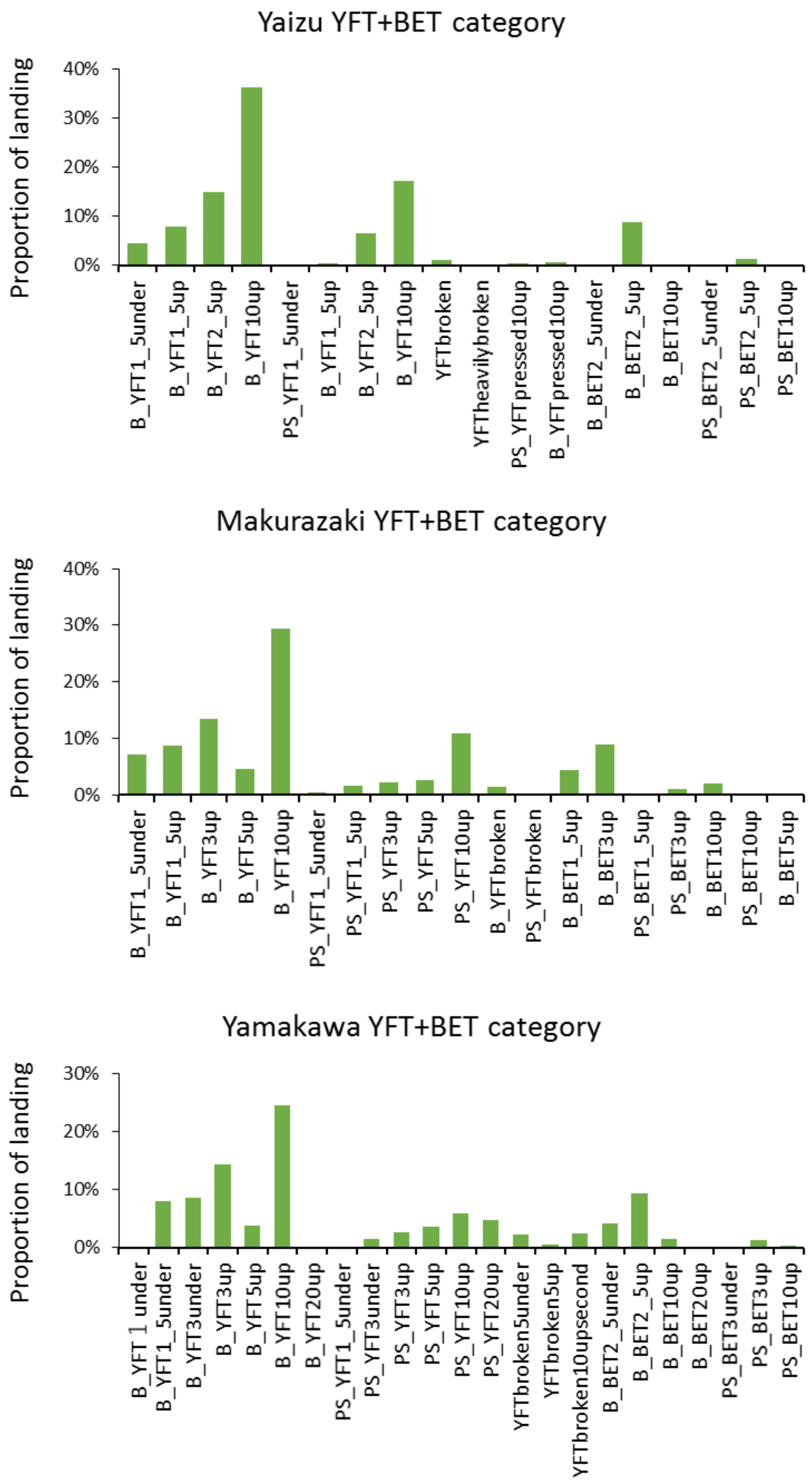
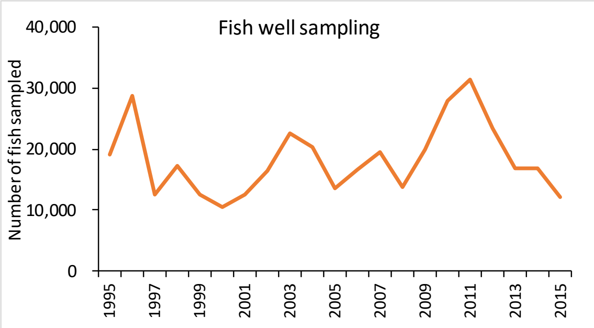
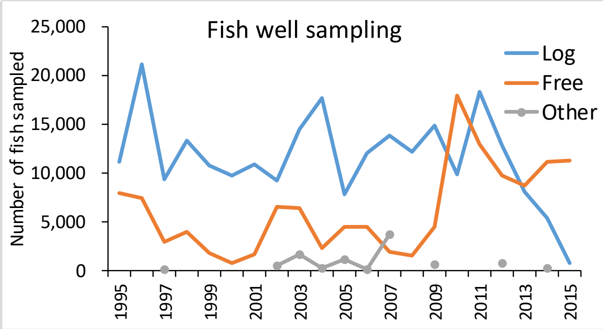


Figure 4 Amount of landings (average for 1995-2015) for each market category for yellowfin and bigeye tuna in each port. "B" and "PS" indicate brine (normal) and higher quality product, respectively.





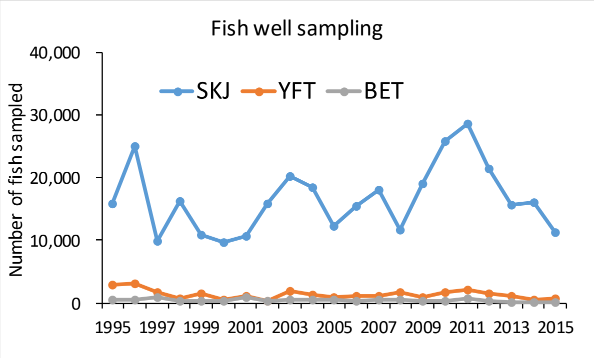


Figure 5 The number of fish sampled by market category sampling for each year. Top left: total number, top right: number by school type, bottom left: number by species.

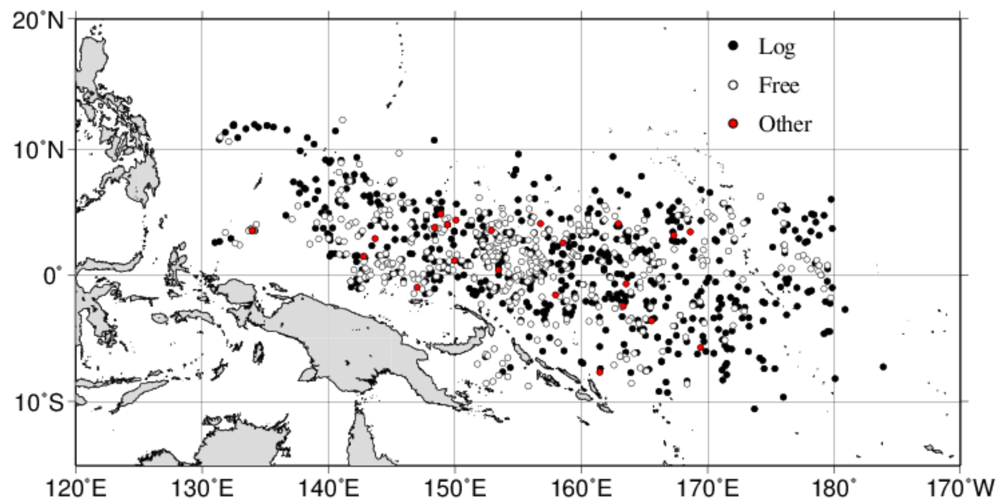


Figure 6 Geographical distribution for purse seine fisheries operations for which fish well sampling was conducted.

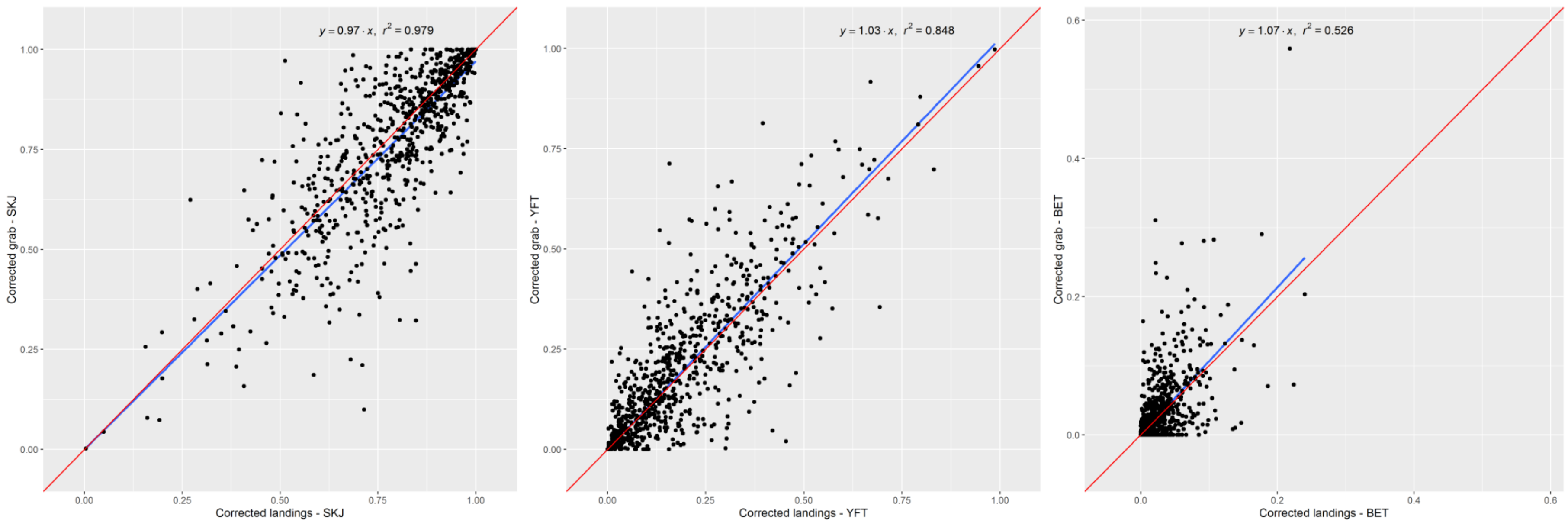


Figure 7 Trip-level species compositions from corrected landings data (x-axis) against those derived from corrected grab sample data for skipjack (left), yellowfin (middle) and bigeye (right). A simple linear model (with no intercept) was fitted (blue line), along with y = x for comparison (red line).

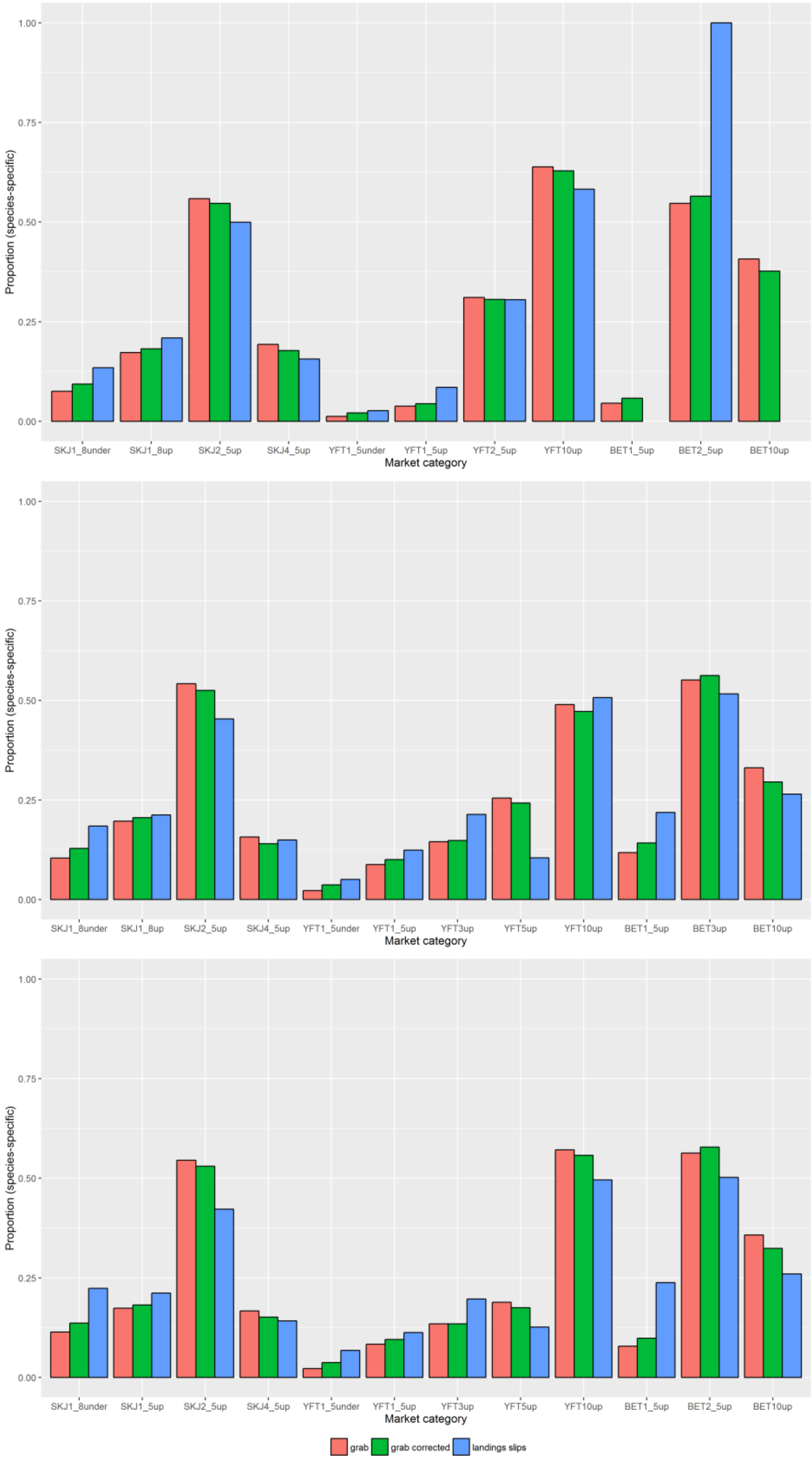


Figure 8 Species-specific proportions by market category for landings in Yaizu (top), Makurazaki (middle) and Yamakawa (bottom panel) based on grab samples (red), corrected grab samples (green) and landings data (blue).

Appendix A
Paired trip comparisons

Table 7 Species compositions (metric tonnes and %) by data source for 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 8 Species compositions (metric tonnes and %) by data source for 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 9 Species compositions (metric tonnes and %) by data source for 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 10 Species compositions (metric tonnes and %) by data source for 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 11 Species compositions (metric tonnes and %) by data source for 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 12 Species compositions (metric tonnes and %) by data source for 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
Market categories used in size comparisons

Table 13 Market categories used for size composition comparisons for landings at Yaizu (top), Makurazaki (middle) and Yamakawa (bottom).

Port	Species	Category	Min kg	Max kg
Yaizu	SKJ	SKJ1_8under	0	1.8
Yaizu	SKJ	SKJ1_8up	1.8	2.5
Yaizu	SKJ	SKJ2_5up	2.5	4.5
Yaizu	SKJ	SKJ4_5up	4.5	NA
Yaizu	YFT	YFT1_5under	0	1.5
Yaizu	YFT	YFT1_5up	1.5	2.5
Yaizu	YFT	YFT2_5up	2.5	10
Yaizu	YFT	YFT10up	10	NA
Yaizu	BET	BET1_5under	0	1.5
Yaizu	BET	BET2_5under	1.5	2.5
Yaizu	BET	BET2_5up	2.5	10
Yaizu	BET	BET10up	10	NA

Port	Species	Category	Min kg	Max kg
Makurazaki	SKJ	SKJ1_8under	0	1.8
Makurazaki	SKJ	SKJ1_8up	1.8	2.5
Makurazaki	SKJ	SKJ2_5up	2.5	4.5
Makurazaki	SKJ	SKJ4_5up	4.5	NA
Makurazaki	YFT	YFT1_5under	0	1.5
Makurazaki	YFT	YFT1_5up	1.5	3
Makurazaki	YFT	YFT3up	3	5
Makurazaki	YFT	YFT5up	5	10
Makurazaki	YFT	YFT10up	10	NA
Makurazaki	BET	BET1_5under	0	1.5
Makurazaki	BET	BET1_5up	1.5	3
Makurazaki	BET	BET3up	3	10
Makurazaki	BET	BET10up	10	NA

Port	Species	Category	Min kg	Max kg
Yamakawa	SKJ	SKJ1_8under	0	1.8
Yamakawa	SKJ	SKJ2_5under	1.8	2.5
Yamakawa	SKJ	SKJ2_5up	2.5	4.5
Yamakawa	SKJ	SKJ4_5up	4.5	NA
Yamakawa	YFT	YFT1_5under	0	1.5
Yamakawa	YFT	YFT3under	1.5	3
Yamakawa	YFT	YFT3up	3	5
Yamakawa	YFT	YFT5up	5	10
Yamakawa	YFT	YFT10up	10	NA
Yamakawa	BET	BET1_5under	0	1.5
Yamakawa	BET	BET2_5under	1.5	2.5
Yamakawa	BET	BET2_5up	2.5	10
Yamakawa	BET	BET10up	10	NA

Appendix C
Attempt to correct logbook catch by species using port sampling data for Japanese purse seine fisheries (postscript analyses by Japan)

To prepare corrected logbook catch by species using port sampling data for Japanese purse seine fisheries, postscript Satoh and Matsumoto used the following approach:

- After the cruise based correction was calculated (Section 2.1.6), the catches by species of a cruise were then broken down into set-by-set level, and then compiled into the SPC format (by monthly, 1 x 1 degree with school type).
- First, the correction factor by species for each cruise (corrected catch / catch in logbook) and the catch amount per set (corrected landing / number of set per cruise) was calculated. Next, if the catch in logbook was not zero the corrected catch by species for a set was calculated as the product of the correction factor by the catch by species in the logbook data. If the catch of a species is zero in the logbook even though the amount of catch in the market slip for the species is not zero, all sets for the cruise were assigned the corrected catch amount per set (the amount of catch of the species in the market slip – strictly speaking, the market slip corrected by the universal factors – were divided by the number of sets of the cruise, and assigned the divided value as the corrected catch of the species for each set).

Table 14 Annual amount of catch reported by logbook and corrected using port sampling data of Japanese purse seine operated in topical area (20N-20S) of WCPO from 1995 to 2015.

Year	Log (SKJ)	Corrected (SKJ)	corrected / log (SKJ)	Log (YFT)	Corrected (YFT)	corrected / log (YFT)	Log (BET)	Corrected (BET)	corrected / log (BET)
1995	113,770	113,645	1.00	39,780	41,029	1.03	469	2,748	5.86
1996	138,473	138,758	1.00	20,303	24,161	1.19	752	2,951	3.93
1997	86,144	84,912	0.99	52,456	51,903	0.99	7,518	13,207	1.76
1998	133,669	134,819	1.01	34,765	38,062	1.09	2,289	4,869	2.13
1999	119,467	118,269	0.99	37,222	41,619	1.12	2,764	6,249	2.26
2000	136,633	134,461	0.98	31,968	36,711	1.15	3,718	9,212	2.48
2001	123,890	119,970	0.97	31,269	37,734	1.21	5,328	9,883	1.85
2002	148,500	148,813	1.00	16,910	21,857	1.29	3,629	6,096	1.68
2003	130,064	127,844	0.98	23,786	30,511	1.28	3,767	5,178	1.37
2004	134,970	131,954	0.98	19,937	27,111	1.36	3,471	6,023	1.74
2005	153,064	151,714	0.99	23,125	28,277	1.22	3,974	6,725	1.69
2006	157,722	155,393	0.99	24,847	33,139	1.33	3,464	4,660	1.35
2007	160,092	159,131	0.99	23,267	29,516	1.27	3,391	5,169	1.52
2008	153,277	149,750	0.98	30,520	37,779	1.24	5,218	7,845	1.50
2009	163,593	159,543	0.98	30,455	37,444	1.23	3,113	5,607	1.80
2010	164,717	162,509	0.99	37,114	41,190	1.11	2,350	3,743	1.59
2011	137,437	134,880	0.98	29,854	32,265	1.08	2,056	3,827	1.86
2012	167,519	163,052	0.97	22,849	28,397	1.24	2,853	5,343	1.87
2013	154,513	145,506	0.94	19,268	24,417	1.27	2,306	4,694	2.04
2014	134,663	125,226	0.93	30,396	35,933	1.18	3,114	5,586	1.79
2015	114,190	108,119	0.95	32,946	37,537	1.14	3,614	5,466	1.51