SCIENTIFIC COMMITTEE

SIXTEENTH REGULAR SESSION

Online

11 – 20 August 2020

USA PURSE SEINE CATCH COMPOSITIONS

WCPFC-SC16-2020/ST-IP-05

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Executive Summary

Comparisons of species composition estimates with high quality independent datasets provides the means to assess the accuracy and precision of estimated species compositions obtained through varying methodologies, and from different data sources. Cannery data have the potential to provide an independent data source for validating WPCFC purse seine species and size compositions, which are currently estimated using observer samples, either directly or through the use of species composition models.

In this study, species and size compositions of USA purse seine catches were generated using vessel logsheets, unloadings logsheets, cannery receipts, observer grab samples, and species composition models. Trip-level species composition estimates were linked between data sets, to enable direct like-for-like comparisons, and a subset of trips were selected for comparative purposes, primarily based on selecting trips with consistent catch volumes across data sources. A range of trip-level attributes were assigned, to facilitate comparisons of species and size compositions at aggregated levels, for example for annual comparisons. Species and size compositions were then compared at a range of resolutions.

Comprehensive cannery receipts data were available for the majority of trips. Species compositions in cannery receipts were broadly consistent with equivalent grab-sample based estimates, though grab-sample based estimates of skipjack proportions were generally lower, and estimates of bigeye and yellowfin proportions higher. Additionally, grab-sample based estimates of size compositions had higher proportions of total catches (i.e. across all species) in the largest size categories (i.e. 7.5 – 20 lb and > 20 lb), and lower proportions in the smallest size categories (i.e. < 3 lb and 3 – 4 lb), compared to the cannery receipts data. It is important to note that it is not possible to determine from these analyses which data-source provides the most accurate estimate of catch compositions.

Comparisons of species and size compositions identified apparent variability in the accuracy of species and size discrimination between cannery locations. Comparisons also identified discrepancies between grab-sample and model-based estimates of species compositions. More detailed investigation of this for the WCPFC purse seine fishery in general may identify opportunities for improving species composition models that are currently used as part of the procedure to estimate species compositions for use in stock assessments and routine analyses.

Grab-sample based estimates of species compositions have previously been shown to be imprecise at a trip and set-level. Comparisons presented here suggest that grab-sample based estimates of species compositions are also relatively imprecise at the S_BEST resolution, using cannery receipts data as the point of comparison. Comprehensive cannery receipts data could be used where available, in combination with grab samples, to obtain trip-level and 'S_BEST' resolution species composition estimates for USA purse seine vessels that are likely to be more precise than those based on grab samples in isolation. However, it is not currently clear how the different data sources should best be combined in order to obtain the most accurate estimates of species compositions. The availability of comprehensive cannery receipts data more broadly would allow the benefits of cannery receipts data to be realised for other WCPO purse seine fleets, both for validating available estimates of species compositions, and potentially for more precise estimation of species compositions.

Introduction

Purse seine vessels operating in the Western and Central Pacific Ocean (WCPO) catch three main species, namely skipjack, yellowfin and bigeye tuna. It is difficult to obtain accurate species composition estimates given the volumes of catches. Furthermore, reported catches of species in purse seine logbooks have been demonstrated to be biased (e.g. Fonteneau, 1975). Species-specific catch estimates in the Western and Central Pacific Fisheries Commission (WCPFC) Convention Area are estimated by the Pacific Community based on data collected by observers through the Regional Observer Programme (e.g. Peatman et al., 2019). The proportions of each species in catches are estimated: directly using observer samples where observer coverage is sufficiently high; and otherwise using species composition models that are fitted to observer-sample based estimates of species compositions. These species composition estimates are used to generate catch histories for the stock assessments, and other routine analyses.

Comparisons of species composition estimates with high quality independent datasets provides the means to assess the accuracy and precision of different approaches to estimating species compositions (e.g. Lawson, 2014; Peatman et al, 2017b), and has been identified as a high priority activity in the WCPFC Project 60 work plan (Peatman et al., 2019). Cannery data have the potential to provide an independent data source for validating WPCFC purse seine species and size compositions, but this requires availability of comprehensive cannery receipts recorded to a species level (Lewis and Williams, 2016). Bigelow et al (2017) compared USA purse seine species composition estimates between vessel logsheets and cannery receipts. Skipjack proportions in vessel logsheets were higher than for the cannery receipts, with lower proportions of bigeye and yellowfin. High-level comparisons indicated lower proportions of skipjack, and higher proportions of bigeye and yellowfin in aggregate catch data held by SPC, which are based on observer-samples. Bigelow et al. (2017) recommended the continuation of catch composition analyses using different datasets, to contribute to robust estimates of purse seine catches by species. Williams (2018, 2019) compared observer-based estimates of USA purse seine species and size compositions against cannery receipts data provided to WCPFC through an initiative of the International Seafood Sustainability Foundation (ISSF). Proportions of large yellowfin and bigeye (> 20lbs) were lower in cannery receipt data than observer-based estimates.

This study aims to complement and extend earlier comparative analyses of USA purse seine catch compositions, by comparing estimated species and size compositions from a range of data-sources, and at varying resolutions. The data sources used for this study include data managed by the NOAA Pacific Islands Fisheries Science Center (PIFSC), as well as Pacific Community (SPC) data holdings. Regional purse seine logsheets (RPLs) were provided for USA purse seine trips that departed port in 2014 through to 2019, along with associated unloading logsheets (ULs) and cannery receipts (final out-turns – FOTs). Data from observer trips on USA flagged purse seiners were provided by SPC.

Methods

Logsheets, unloadings data and cannery receipts

The RPL, unloadings and cannery receipt datasets have identifiers which allow mapping of cannery data to unloading events, and unloading events to fishing trips. Trip-level species compositions were generated from logsheet data by summing catches from all reported fishing events, along with any instances where vessels received fish from other fishing vessels, noting that this is relatively rare, occurring once per 1,500 sets on average. Trip-level unloadings-based species compositions were generated by summing species volumes across unloading events.

Trip-level cannery receipt species compositions were obtained by summing species volumes across cannery transactions. Approximately 95% of cannery receipt data (by volume) are species specific. There is also a mixed-species code (MIXX) that is generally used for rejected and or damaged fish, and a skipjack/yellowfin combined code (S/Y). Catches recorded as 'MIXX' or 'S/Y' were attributed to skipjack, yellowfin and bigeye based on their proportion of species-specific catches, on a trip-by-trip basis. Cannery data for trips with high proportions of 'skipjack/yellowfin' catches were excluded as part of the selection process for trips to be used in comparisons (see below).

Cannery data were assigned to size categories based on the minimum and maximum weights of fish, using the size categories < 3lb, 3 - 4lb, 4 - 7.5 lb, 7.5 - 20 lb, and > 20 lb. Size categories of 7.5 - 22 lb and 22 lb + can also be used and were combined with 7.5 to 20 lb and 20 lb + to facilitate aggregation data across trips. For skipjack, the 7.5 - 20 lb and > 20 lb categories were combined to a > 7.5 lb category. Cannery data from other, or unspecified size categories, e.g. > 4 lb, were then allocated to the above size categories based on their proportion of size-specific catches, on a species and trip-specific basis.

Observer grab samples

Observer grab samples are routinely used to estimate species and size compositions in WCPO purse seine fisheries (e.g. Peatman et al., 2019; Abascal et al., 2014;). The approach to estimating set-level catch proportions of individuals by species and length, and proportions of catch weight by species, is described in Peatman et al. (2017a) and repeated here. Grab samples were used to estimate the proportion of fish in set k that were species i and length 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 j, and n_k is the total number of grab sampled fish from set k. Grab samples were then corrected for grab sample bias using correction factors pooled across species and association types (see Peatman et al., 2019 for the current estimates of correction factors). Set-specific corrected proportions by species and length, β_{ijk}, were calculated as

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

where r_j is the correction factor that applies to a fish of length 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

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

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 estimate of the set-specific catch w_k, to obtain catch weights of species i in set k, denoted w_{ik}

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

Trip-level estimates of species-specific catch were obtained by summing across set-specific catch weight estimates. Trip and free-school / associated set specific average species proportions were used for sets with no available grab samples. There were a limited number of sets with no grab samples, and no usable information on school association provided by the observer, e.g. where the association type was recorded as unknown. In these instances, average trip-level species proportions were applied. Trip-level species and size compositions were then obtained by converting from proportions of individuals by species and length (β_{ijk}) to catch weight proportions, applying these catch weight proportions to the set catch volume, and then summing across sets. Similar to the trip-level species specific catch estimates, average proportions by species and length were used for sets with no available grab samples, using trip and association-specific proportions where possible, otherwise using trip-specific proportions. The trip level estimates of species and size specific catches were used in comparisons of catch compositions with other data sources.

The grab-sample based set-level estimates of species and size specific catches were also used to generate USA fleet-level estimates of species and size compositions. USA fleet-level estimates of species compositions were obtained using a similar approach to that used to estimate species compositions for WCPFC purse seine fisheries (Peatman et al., 2019). RPL and observer data were assigned to strata of year, quarter, school association type (free school or associated) and 5° cell. Data were filtered for trips with at least one set in the WCPFC Convention Area, not including the area of overlap with the IATTC Convention Area. The strata-specific total proportion of catch by species was estimated by taking the sum of set and species specific catch estimates (w_{ik}) across observed sets, and dividing by the total observed catch in the strata. These proportions were then applied to the total reported catch in the strata to estimate the total species-specific catch. Estimates of catch compositions in WCPFC purse seine fisheries are currently based directly on observer samples for strata with > 20 % observer coverage (e.g. see Lawson, 2013). Strata with < 20 % observer coverage of catch accounted for < 3% of the USA fleet's total reported catch in the RPL dataset, including 1 % from strata with no observer coverage. Species-specific proportions for these strata were set at the average proportions for the appropriate year, quarter and association type (free school or associated).

USA fleet-level size compositions were estimated using a similar approach to Peatman et al (2020a). The set-specific proportions of individuals by species and length (β_{ijk}) were raised to set-specific estimated number of individuals by species and length using length-weight parameters i.e. so that the total estimated weight across species and lengths was equal to the observer's visual estimate of total catch for the set. Set-level length frequencies were then aggregated to strata of year, quarter, school association type and 5° cell, by summing across appropriate sets. The strata-level length frequencies were then converted to proportions of individuals by species and length. US fleet-level size compositions were then estimated separately for free school and associated sets:

1. Strata-level proportions of individuals by species and length were converted to catch weight proportions by species and length, using length-weight parameters to estimate the weight of individuals for each species and length combination.
2. For each year-quarter and school association type, the proportion of catch accounted for by each strata was multiplied by the strata-level catch weight proportions by species and length,

and these weighted proportions were then summed across strata to obtain an overall estimated catch weight proportion by species and length for the USA fleet.

3. The year-quarter and school association specific estimated catch weight proportions by species and length were then converted to proportions of individuals by species and length, again using the estimated weight of individual fish, to give estimated proportional length frequencies for the USA fleet.

Uncertainty in species compositions and size compositions was generated by bootstrapping from individual grab samples at the set-level. This appeared to be a sensible approach, given the high observer coverage in the fishery during the time period of the study, both in terms of coverage of trips, and coverage of sets for trips with observer placements. However, the resulting precision in species composition estimates was too high to be considered plausible and are not reported.

Species composition models

Beta-response species proportion models are currently used as part of the agreed methodology to estimate species compositions in WCPFC purse seine fisheries. In this study, the species composition models from Peatman et al. (2020b) were applied to set-level RPL data, and used to estimate trip-level estimates of species compositions. The depth of the 20°C isotherm was interpolated from NCEP GODAS monthly mean potential temperature at depth and re-gridded to a 1° spatial resolution (Behringer & Xue, 2004)[1]. The remaining explanatory variables were taken directly from the RPL data. Uncertainty in model predictions was generated by drawing sets of parameters at random from the multivariate normal distribution specified by the parameter means and their variance-covariance matrix. Similarly to the estimated uncertainty in grab-sample derived species compositions, the resulting precision in species composition estimates were too narrow to be considered plausible and are not reported. It should be noted that the species composition models were fitted to observer data from the range of flags operating in the WCPO purse seine fishery.

Linking trips between data sources

First, vessel identifiers from the RPL dataset were matched to vessel identifiers in the observer trips, using available information including vessel name and international radio call sign. This then allowed vessel-by-vessel comparisons and matching of RPL and observer trips. There were a total of 1,454 RPL trips and 1,257 observer trips with departure dates between 2014 and 2019, having excluded RPL trips where the vessel operated exclusively outside of the WCPFC Convention Area. Observer trips were then matched to a given RPL trip by taking all observer trips for the vessel in question and selecting the observer trip where the date of departure and/or date of return was within three days of the corresponding RPL trip dates. A tolerance of three days was used to allow for slight differences in dates between the RPL and observer datasets, for example due to the time zone used. This approach resulted in the successful linking of 1,254 RPL trips with observer trips. There were three instances where a single RPL trip was accounted for by two observer trips. In these cases the data from the observer trips were combined. There were also four instances where two RPL trips were accounted for by a single observer trip. In these cases the RPL trips were combined.

[1] Data accessed from NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, web site: https://www.esrl.noaa.gov/psd/

Bigelow et al. (2017) excluded trips with a greater than 20% difference in catch volumes between RPL data and cannery receipts when comparing species compositions between the two datasets. In comparisons of USA purse seine data from 2014 and 2015, 23 trips had differences greater than 20%, explained by partial unloadings data and/or incomplete cannery receipts (Bigelow et al., 2017). In this study, there were 19 trips in 2014 and 2015 with greater than a 20% difference in catch volumes between RPL data and cannery receipts (~ 4% of the total trips in these years), and 76 trips over the period 2014 to 2019 (~6% of the total trips). There were also 81 trips with no available cannery receipts, of which 41 trips were from 2016 (20% of the total trips in this year) and 31 from 2018 and 2019. It is likely that cannery receipts for some 2019 trips are currently unavailable due to the time delay in data provision (Bigelow et al., 2017). The cause of the relatively high number of trips in 2016 without cannery receipts is not clear. There were additionally 51 observer trips with a greater than 20% difference in catch volumes between the RPL data and the observer's visual estimates of catch. Investigation of these trips suggested that the differences were a result of incomplete observer logbook data, e.g. no visual estimates of catch for some sets, and/or data recording or data entry errors for the observer's visual estimate of catches. In this study data was excluded from trips with a greater than 20% difference in catch volumes between RPL data, and unloadings data, cannery receipts or observer data. This excluded data from 124 trips. Trips were also excluded if they were missing unloadings data and/or cannery receipts, which removed an additional 83 trips (including the 81 trips missing cannery receipts). Finally, exploratory analyses identified low rates of species-specific cannery receipts for some trips, which resulted in variable and in some cases unlikely catch compositions when raising to species-specific estimates. As such, a further 44 trips with < 80% species-specific cannery receipt data were also excluded. This left a final dataset of 999 RPL trips for comparisons.

An additional subset of trips was also generated, to assess sensitivity of results to the cut off for differences in catch volumes between datasets. Following Lewis & Williams (2016), the maximum difference in catch volumes between RPL data and each of the other data-sources was set at 5 %, leaving 480 RPL trips. This is referred to throughout as the 'high confidence' dataset.

Comparisons of species and size compositions between data-sources

Unloadings and cannery receipts data are provided on a trip-by-trip basis. As such, the finest resolution of catch composition comparisons considered in this study was individual trips. However, comparisons at more aggregated resolutions are also of interest. RPL data were used to calculate trip-level variables to be used to aggregate catch compositions for comparisons, including: the year and quarter with the highest proportion of catch for the trip in question; 'region' - the area accounting for the highest proportion of catch, with regions selected to have some consistency with the current regional structures used in MFCL stock assessments - 'west of 170E', '170E to 150W', and 'east of 150W'; and, 'cannery location' - the location that received the highest volume of catches in cannery receipts. This enabled comparison of catch compositions at a variety of resolutions, e.g. by year, quarter and region, though noting that these trip-level variables are necessarily a simplification.

Results

The total effort of USA purse seiners in the filtered RPL dataset demonstrates strong variation between year-quarters (Figure 1). One driver for this variability is the FAD closure implemented in the WCPFC Convention Area in the third quarter of the year, noting that the filtered dataset also includes effort in the IATTC Convention Area and the region covered by both IATTC and WCPFC Convention Areas. Overall, skipjack was estimated to account for 81.9% of the catch of USA purse seiners, with 14.3% and 3.8% accounted for by yellowfin and bigeye respectively (Figure 2). Associated sets had slightly lower proportions of skipjack (81.0%) and yellowfin (12.7%) and higher proportions of bigeye (6.3%). Conversely, free school sets had higher proportions of skipjack (83.0%) and yellowfin (16.4%), with lower proportions of bigeye (0.4%). Species proportions by length are provided in Appendix A. The median total length of skipjack was generally between 50 and 60 cm for free school sets (Figure 16). The size compositions of yellowfin in free school sets were multi-modal, with individuals generally ranging from 50cm to 150cm. The estimated size compositions of bigeye in free school sets were highly variable, due to the limited number of grab samples of bigeye given the low contribution of the species to free school catches. The size compositions of skipjack, yellowfin and bigeye in associated sets demonstrated less between-species variability, and smaller median sizes compared to the free-school size compositions (Figure 17).

Total catches were consistent across all data sources, both across the time period 2014 to 2019 and at finer scales (Table 2). Total catches in the unloadings and cannery receipts datasets were within 0.2% of the total reported catch in RPL data across the time period 2014 to 2019, with similar levels of consistency for annual catches. The total catch estimates from observer visual estimates were 1.5% lower than the reported catch for the time period 2014 to 2019, which again was relatively consistent between years.

Overall proportions of catch by species and size category are summarised in Figure 3, based on observer grab samples and cannery receipts. For both datasets, the majority of skipjack were in the > 7.5 lb category, whereas the majority of yellowfin were in the > 20 lb category. Bigeye were more broadly spread amongst the 4 – 7.5 lb, 7.5 – 20 lb and > 20lb categories, with the highest proportion in the 7.5 – 20 lb category. Catch proportions of skipjack in the < 3 lb and 3 – 4 lb categories were higher in the cannery receipts data than the grab sample based estimated, with the opposite true for yellowfin and bigeye.

Annual comparisons of size compositions by cannery location indicated that almost all fish in the < 3 lb and 3 – 4 lb categories were recorded as skipjack for trips with a cannery location of Pago Pago (Appendix A, Figure 18). Furthermore, for this cannery location, large discrepancies were observed between cannery receipts and grab-sample estimates for the proportions of bigeye and yellowfin in the 7.5 – 20 lb and > 20 lb categories. In contrast, grab sample and cannery receipt size compositions were more consistent for trips with a cannery location of Bangkok, along with canneries located elsewhere i.e. outside of Pago Pago and Bangkok (Figure 4). Size compositions displayed regional variation, with a tendency for larger skipjack and yellowfin in catches east of 170°E (Figure 5). For all cannery locations, the proportion of catches in the < 3 lb and 3 – 4 lb categories across all three species were higher in cannery receipts than in grab-sample based estimates, with the opposite true for the proportion of catches in the 7.5 – 20 lb and > 20 lb categories (Table 3).

Comparisons of species compositions by year, and overall compositions for 2014 to 2019, are provided in Table 2. RPL based species compositions had relatively high proportions of skipjack, and relatively low proportions of bigeye and yellowfin, e.g. 88.4% skipjack, 9.6% yellowfin and 1.9% bigeye across the period 2014 to 2019. Unloadings based species compositions were similar to the RPL based estimates, though generally with slightly higher proportions of skipjack, and lower proportions of yellowfin and bigeye. Observer grab sample based estimates and the species composition model based estimates had relatively low proportions of skipjack, and relatively high proportions of bigeye and yellowfin, and were generally consistent with each other, e.g. 82.8% skipjack, 13.5 % yellowfin and 3.7% bigeye for grab sample estimates. The cannery receipts compositions generally had higher proportions of skipjack than the observer-based estimates and lower proportions of skipjack than the RPL and unloadings data, and vice versa for yellowfin and bigeye. Excluding data from trips with a cannery location of Pago Pago reduced the difference in species compositions between cannery receipts, and grab sample and model based estimates (Table 4). Relative differences in annual and overall species compositions were similar when using the more heavily filtered 'high-confidence' dataset (i.e. comparison of Table 4 and Table 7).

Relative differences in species composition estimates were detected both within and between data sources when filtering for trip subsets. Cannery receipts had higher proportions of skipjack for trips with a cannery location of Pago Pago, compared to canneries located elsewhere, whereas RPL species compositions were broadly similar regardless of cannery location (Table 5). Grab sample estimates of species compositions were more similar to cannery receipts compositions for trips with a cannery location of Bangkok, and canneries located outside of Bangkok and Pago Pago. However, grab sample and model-based estimates of species compositions had the highest proportions of yellowfin and bigeye, and the lowest proportions of skipjack, regardless of cannery location. There was also apparent regional variation in species compositions for all datasets, though noting that there were relatively few trips assigned to the east of 150°W region (Table 6).

Finer scale comparisons of species compositions were also undertaken, including at a trip-level, and a stratification of year, quarter and region, i.e. a stratification as close as possible to that used in the MFCL assessment models. Observer-based estimates demonstrated the most apparent variability relative to cannery-based compositions at a trip level (Figure 8), and unloadings-based compositions the least (Figure 7). Aggregating species compositions to combinations of year, quarter and region did reduce variability in species composition comparisons, though differences in species compositions between data sources remained (Figure 10 to Figure 13). Variability also remained high for strata with relatively low levels of catch. Fine-scale comparisons were also undertaken having excluded trips with a cannery location of Pago Pago, with comparable results (Appendix A, Figure 19 to Figure 26). Trip-level comparisons demonstrated less variability when using the 'high confidence' dataset though there was little apparent reduction in variability at a year-quarter and region resolution (Figure 29 and Figure 30).

Direct comparisons of observer and species composition model based estimates suggests that the models may have a tendency to 'fit down the middle', though noting that the random intercepts for vessel ID were set to zero when predicting (Figure 14, Figure 15).

Discussion

There have been a number of studies that have undertaken comparisons of catch compositions for WCPO purse seine fleets between different data sources. This study provides the most comprehensive comparative analysis for the USA purse seine fleet operating in the WCPO, and in doing so provides a complement to a similar exercise undertaken for the Japanese purse seine fleet (Peatman et al., 2017b).

The total volumes of catches, both overall and at finer resolutions, were consistent across the range of data sources used in the study, i.e. RPL data, unloadings data and cannery receipts, and observer visual estimates. Comprehensive cannery receipt data were available for the majority of the RPL trips, e.g. trip-level catches in cannery receipt data were within 5 % of the corresponding RPL data for 776 of the total 1,254 RPL trips which were matched to observer data.

Grab-samples estimates of catch compositions are known to be imprecise at a trip level (e.g. Lawson, 2014; Peatman et al., 2017b). The comparisons of species compositions presented here suggest that grab-sample based estimates are still relatively imprecise at a resolution of year-quarter, region and flag. This has implications on the accuracy of grab-sample based species compositions at the 'S_BEST' stratification, i.e. year, month, flag and fleet, 5° grid and association type, which are presumably less precise than estimates at a year-quarter, region and flag level, given the finer resolution of 'S_BEST' data.

The comparisons of species and size compositions suggest that cannery receipts data for the USA purse seine fleet are broadly comparable with grab-sample-based equivalents, though with some variability between cannery locations. Grab-sample based species compositions tended to have lower skipjack proportions and higher bigeye and yellowfin relative to cannery receipts data, as found by Bigelow et al. (2017). This tendency for lower skipjack proportions in grab-sample based estimates was consistently demonstrated in comparisons undertaken in this study, regardless of the subset of trips considered, or the resolution of comparisons. Relatedly, yellowfin and bigeye appear to have been recorded as skipjack in the 3 - 4 lb and < 3 lb categories in cannery receipts for trips with a cannery location of Pago Pago. This will act to increase the proportion of skipjack in cannery receipt-based species compositions, with a corresponding decrease in yellowfin and bigeye proportions. This could be partially addressed by correcting the species breakdowns for the < 3 lb and 3 – 4 lb categories in cannery receipts, e.g. by using grab-sample based compositions for these size classes. However, the proportion of catches in these smaller size categories across all three species is low, both in cannery receipts and grab sample-based estimates, and as such the resulting impact on species compositions is likely to be limited.

More generally, for all cannery locations, the proportions of catches in cannery receipts in the < 3 lb and 3 – 4 lb size categories across all species was higher in cannery receipts and lower grab-sample based estimates. Additionally, proportions of catches in the 7.5 – 20 lb and > 20 lb categories were higher in grab sample estimates, and lower in cannery receipts. These patterns could be explained by under-correction of grab sample bias, which would then lead to over-estimation of the proportions of large individuals in grab sample-based estimates, and under-estimation of small individuals. It could also reflect inaccuracies in assumed length-weight relationships as suggested by Williams (2019).

Comparisons of size compositions do not suggest a mechanism that would fully account for the higher proportions of yellowfin and bigeye in grab-sample estimates relative to cannery receipts data. Errors in species discrimination of bigeye and yellowfin would be required throughout the full size range of catches, either in grab samples or cannery receipts, in order to account for the consistency in species-specific proportions by size category along with the observed discrepancies in species compositions.

However, species discrimination in cannery data is generally thought to be less accurate for smaller individuals in part due to the lack of price differential between species (e.g. Itano et al., 2019; Lewis & Williams, 2016). As noted above, higher proportions of yellowfin in grab-sample estimates could result from under-correction of grab sample bias for large individuals, or inaccuracies in assumed length-weight relationships. Updated estimates of length-weight parameters through WCPFC Project 90 may help address the latter point (Macdonald et al., 2020). Whilst the cause of the differences in species compositions between grab-sample estimates and cannery receipts data is not clear, it is important to note that comparative analyses of this type are not necessarily intended to allow identification of the data source that provides the most accurate estimate of species compositions.

Discrepancies in catch proportions of 7.5 – 20lb and 20lb+ bigeye and yellowfin have previously been identified for USA purse seine catches (Williams, 2018; 2019), as well as WCPO purse seine fleets more broadly (Lewis & Williams, 2016). The findings of this study suggest that, at least for the USA purse seine fleet, these discrepancies are likely to have resulted from variation in the accuracy of size discrimination for bigeye and yellowfin between cannery locations.

Grab sample-based species composition estimates were similar to those from the species composition models at aggregated levels, e.g. for the period 2014-2019 as well as annually. However, comparisons suggest that the species composition models do not capture some of the finer-scale variation in catch compositions. Discrepancies at a trip level should be expected, given the low sampling rates achieved by the grab sampling protocol and the resulting noise in trip-level species composition estimates. However, inconsistencies were also apparent at a resolution of year-quarter and region. This supports the current methodology used to generate WCPO purse seine catch compositions, which uses direct grab sample-based estimates when observer coverage is sufficiently high. The differences between grab sample and model-based estimates observed in this study may be due to the inclusion of random vessel intercepts in the species composition models, and their treatment when generating predictions from aggregate effort data. Regardless, the apparent inconsistencies between model and direct grab-sample based estimates warrants additional investigation at a regional level.

Cannery data have the potential to provide relatively precise estimates of purse seine species compositions at a trip-level, given that the cannery data requires full, or near full, enumeration of catches by species and size category (Lewis & Williams, 2016). This requires comprehensive coverage of cannery data at a trip-level, along with accurate species discrimination of catches. The comparisons in this study suggest that the first condition is met for the majority of USA purse seine trips during the time period covered by this study. Comparative analyses of this type do not provide the means to assess the accuracy of species composition estimates, or species discrimination, for a particular data source in absolute terms. Targeted sampling of the range of species and size categories would allow for determination of the accuracy of species identification in cannery data, similar to that undertaken during port sampling of catches for the Japanese purse seine fleet (e.g. see a summary in Peatman et al., 2017).

As suggested by Lewis & Williams (2016), cannery data could also be used to adjust grab sample estimates of species compositions. This approach could be used to obtain more precise estimates of species compositions at finer resolutions. For example, grab sample estimates of species compositions could be used to disaggregate trip-level species compositions from cannery receipts to a resolution that would allow incorporation in to aggregate purse seine catch data, as well as time series of catches that are used in MFCL stock assessments. The methodology used to achieve this would need to account for the inherent uncertainty in grab-sample based estimates at the set and trip level. It would also be necessary to assess the cannery receipts to identify data that are appropriate for use in this context. For example, the cannery location-specific comparisons here suggest that the accuracy of species and size determination varies between canneries. Additionally, in this study it was necessary to exclude cannery receipts for trips with low proportions of species-specific data, as well as trips with partial unloadings and incomplete coverage of cannery receipts. Equally, grab-sample based estimates of species breakdowns could also be used to adjust cannery receipts data, e.g. for correcting species breakdowns of the < 3 lb and 3 – 4 lb size categories where necessary.

The findings of this study reiterate the utility of cannery receipts data in providing an independent dataset that can be used to validate grab-sample based species composition estimates that are currently used to generate species specific catches for the WCPO purse seine fishery. Cannery receipts data could also be used in combination with grab samples, and potentially other data sources including electronic monitoring (Itano et al., 2019) and video-based sampling, to generate fine-scale species composition estimates with greater precision than those that are possible using grab-samples in isolation, e.g. at an 'S_BEST' resolution. However, uncertainties remain as to how best to combine the various data sources to obtain the most accurate estimates of species compositions. Targeted sampling at canneries would be required to definitively assess the accuracy of species discrimination in cannery data, and could also inform how best to combine cannery data with other datasets for the purposes of species composition estimation. Comprehensive cannery receipts data for other WCPO purse seine fleets would allow the benefits of cannery data to be realised for a wider range of purse seine effort.

SC is invited to note the following:

- Comprehensive cannery receipts data were available for the majority of USA purse seine trips. Species compositions in cannery receipts were broadly consistent with equivalent grab-sample based estimates.
- Grab-sample based estimates of skipjack proportions were generally lower, and estimates of bigeye and yellowfin proportions generally higher, than those from cannery receipts data. It is not possible to determine from these analyses which data-source provides the most accurate estimate of catch compositions.
- Comparisons suggest that grab-sample based estimates of species compositions are likely to be relatively imprecise at the S_BEST resolution, using cannery receipts data as the point of comparison.
- Comprehensive cannery receipts data could be used where available, in combination with grab samples, to obtain trip-level and 'S_BEST' resolution species composition estimates for USA purse seine vessels that are more precise than those based on grab samples in isolation. However, additional targeted data collection may be necessary to inform the most appropriate way to combine the information across datasets, noting the observed differences between cannery receipts and grab-sample estimates of species compositions.
- Comparisons of species and size compositions identified apparent variability in the accuracy of species and size discrimination between cannery locations. This has potential relevance to analyses of cannery data for catches of other WCPO purse seine fleets.
- Comparisons identified discrepancies between grab-sample and model-based estimates of species compositions, both at a trip level and at a year-quarter and region resolution. More detailed investigation of this for the wider WCPO purse seine fishery would be helpful in determining whether this is caused by the use of random intercepts for vessel, and whether simplification of the species composition models is warranted.

Acknowledgements

This study was supported by the Western Pacific Regional Fishery Management Council. The author would like to thank Donnel Dy and Pauli Salmu (NOAA), and Aurélien Panizza, Emmanuel Schneiter and Peter Williams (SPC) for their assistance with database extracts. Finally, the author would like to express their gratitude to all those who contributed to the collection and management of the various data sources used in the study.

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Tables

Table 1 Length weight parameters by species, taken from Peatman et al. (2019).

Species	a	b
SKJ	1.144E-05	3.1483
YFT	2.512E-05	2.9396
BET	1.973E-05	3.0247

Table 2 Comparisons of species % by year and data source for the filtered dataset of 999 trips. The number of trips and data source specific total volume (metric tonnes) are also provided.

Year	Data Source	Trips	MT	SKJ	YFT	BET
2014	RPL	208	189,035	90.2%	9.0%	0.8%
2014	UL	208	188,853	90.9%	8.5%	0.6%
2014	Cannery	208	189,639	88.3%	10.5%	1.1%
2014	Observer	208	184,915	85.1%	12.6%	2.3%
2014	Model	208	188,705	84.6%	12.7%	2.6%
2015	RPL	211	177,944	92.1%	7.2%	0.7%
2015	UL	211	178,086	92.3%	7.0%	0.7%
2015	Cannery	211	179,136	90.2%	8.3%	1.5%
2015	Observer	211	174,519	87.2%	10.1%	2.7%
2015	Model	211	177,754	85.9%	11.9%	2.2%
2016	RPL	146	135,442	88.9%	8.2%	2.9%
2016	UL	146	134,995	90.4%	7.3%	2.3%
2016	Cannery	146	134,346	86.2%	10.4%	3.4%
2016	Observer	146	133,120	82.6%	12.7%	4.7%
2016	Model	146	135,152	82.1%	14.2%	3.8%
2017	RPL	131	108,632	84.4%	13.3%	2.3%
2017	UL	131	108,703	86.2%	12.0%	1.8%
2017	Cannery	131	108,872	80.9%	15.9%	3.2%
2017	Observer	131	107,062	76.5%	18.6%	4.9%
2017	Model	131	108,627	77.6%	17.8%	4.6%
2018	RPL	178	163,688	85.5%	10.7%	3.8%
2018	UL	178	163,721	88.1%	9.0%	2.9%
2018	Cannery	178	164,624	84.0%	11.6%	4.3%
2018	Observer	178	162,105	79.4%	15.3%	5.3%
2018	Model	178	163,585	79.8%	16.0%	4.2%
2019	RPL	125	123,239	87.3%	11.1%	1.6%
2019	UL	125	123,377	87.3%	10.8%	1.8%
2019	Cannery	125	123,441	85.9%	12.5%	1.6%
2019	Observer	125	123,167	83.5%	13.9%	2.5%
2019	Model	125	123,199	82.9%	14.5%	2.6%
Total	RPL	999	897,980	88.4%	9.6%	1.9%
Total	UL	999	897,733	89.5%	8.9%	1.6%
Total	Cannery	999	900,057	86.4%	11.2%	2.4%
Total	Observer	999	884,888	82.8%	13.5%	3.6%
Total	Model	999	897,022	82.5%	14.3%	3.2%

Table 3 Catch proportions by size category and species, for trips with a cannery location of a) Bangkok, b) Pago Pago and c) other locations.

a) Bangkok

	Cannery receipts				Grab-samples			
Category	**SKJ**	**YFT**	**BET**	**Overall**	**SKJ**	**YFT**	**BET**	**Overall**
<3lb	9.5%	2.3%	0.4%	8.4%	6.7%	1.7%	2.4%	5.8%
3lb+	8.2%	2.4%	1.8%	7.3%	5.7%	1.6%	3.1%	5.0%
4lb+	28.0%	10.2%	23.8%	25.7%	31.2%	12.6%	22.0%	28.2%
7.5lb+	54.3%	16.2%	45.7%	49.3%	56.5%	17.1%	38.4%	50.3%
20lb+	-	68.9%	28.3%	9.3%	-	67.1%	34.0%	10.6%

b) Pago Pago

	Cannery receipts				Grab-samples			
Category	**SKJ**	**YFT**	**BET**	**Overall**	**SKJ**	**YFT**	**BET**	**Overall**
<3lb	9.4%	0.0%	0.0%	8.4%	5.9%	1.5%	3.9%	5.3%
3lb+	9.3%	0.1%	0.2%	8.3%	5.1%	1.7%	3.4%	4.7%
4lb+	29.8%	5.3%	29.6%	27.6%	33.6%	12.9%	27.9%	30.9%
7.5lb+	51.5%	54.9%	67.3%	52.1%	55.4%	17.0%	36.7%	50.2%
20lb+	-	39.7%	2.9%	3.5%	-	66.9%	28.2%	8.9%

b) Other locations

	Cannery receipts				Grab-samples			
Category	**SKJ**	**YFT**	**BET**	**Overall**	**SKJ**	**YFT**	**BET**	**Overall**
<3lb	10.2%	2.9%	5.2%	9.1%	6.4%	1.6%	2.2%	5.6%
3lb+	9.2%	3.0%	6.7%	8.4%	5.5%	1.5%	2.1%	4.7%
4lb+	28.7%	10.0%	24.4%	26.3%	32.3%	11.1%	19.0%	28.7%
7.5lb+	51.9%	17.5%	36.5%	47.2%	55.8%	17.7%	41.6%	49.6%
20lb+	-	66.6%	27.2%	9.1%	-	68.1%	35.1%	11.5%

Table 4 Comparisons of species % by year and data source, having excluded trips with a cannery location of Pago Pago. The number of trips and data source specific total volume (metric tonnes) are also provided.

Year	Data Source	Trips	MT	SKJ	YFT	BET
2014	RPL	154	134,666	90.4%	8.8%	0.8%
2014	UL	154	134,549	90.9%	8.5%	0.7%
2014	Cannery	154	135,670	87.5%	11.1%	1.4%
2014	Observer	154	131,164	84.5%	13.0%	2.4%
2014	Model	154	134,336	85.0%	12.5%	2.6%
2015	RPL	164	131,100	90.8%	8.4%	0.9%
2015	UL	164	131,133	90.7%	8.4%	0.9%
2015	Cannery	164	132,509	88.2%	9.9%	2.0%
2015	Observer	164	128,444	84.7%	12.1%	3.2%
2015	Model	164	130,910	85.1%	12.7%	2.2%
2016	RPL	110	97,627	87.4%	9.3%	3.4%
2016	UL	110	97,320	88.4%	8.6%	2.9%
2016	Cannery	110	96,843	83.6%	12.0%	4.4%
2016	Observer	110	95,080	80.1%	14.5%	5.4%
2016	Model	110	97,337	80.5%	15.7%	3.8%
2017	RPL	98	72,462	84.0%	13.9%	2.2%
2017	UL	98	72,359	83.9%	13.9%	2.2%
2017	Cannery	98	72,701	78.1%	18.0%	3.9%
2017	Observer	98	70,942	75.1%	20.0%	4.9%
2017	Model	98	72,457	77.4%	18.8%	3.8%
2018	RPL	118	93,046	90.0%	8.3%	1.7%
2018	UL	118	93,041	89.7%	8.4%	1.9%
2018	Cannery	118	93,810	84.5%	12.5%	3.0%
2018	Observer	118	91,538	82.0%	14.5%	3.5%
2018	Model	118	92,976	81.7%	15.0%	3.4%
2019	RPL	83	70,694	87.4%	11.5%	1.1%
2019	UL	83	70,777	86.4%	12.5%	1.0%
2019	Cannery	83	71,008	83.0%	15.1%	1.9%
2019	Observer	83	70,377	81.4%	15.8%	2.8%
2019	Model	83	70,654	82.0%	15.6%	2.4%
Total	RPL	727	599,595	88.8%	9.6%	1.6%
Total	UL	727	599,180	88.9%	9.6%	1.5%
Total	Cannery	727	602,541	84.9%	12.5%	2.6%
Total	Observer	727	587,545	82.0%	14.5%	3.6%
Total	Model	727	598,670	82.5%	14.6%	2.9%

Table 5 Comparisons of species % by (trip-level) cannery location and data source. The number of trips and data source specific total volume (metric tonnes) are also provided. Cannery locations were defined for each trip as the location which received the highest volume of fish in the cannery receipts data.

Destination	Data source	Trips	MT	SKJ	YFT	BET
Bangkok	RPL	429	338,817	89.7%	9.2%	1.1%
Bangkok	UL	429	339,328	89.8%	9.2%	1.1%
Bangkok	Cannery	429	343,067	85.1%	12.6%	2.4%
Bangkok	Observer	429	331,635	82.5%	14.1%	3.4%
Bangkok	Model	429	338,142	83.1%	14.2%	2.7%
Pago Pago	RPL	272	298,385	87.7%	9.7%	2.7%
Pago Pago	UL	272	298,553	90.9%	7.4%	1.7%
Pago Pago	Cannery	272	297,516	89.3%	8.6%	2.1%
Pago Pago	Observer	272	297,342	84.6%	11.7%	3.7%
Pago Pago	Model	272	298,352	82.6%	13.6%	3.8%
Others	RPL	298	260,778	87.6%	10.2%	2.2%
Others	UL	298	259,852	87.7%	10.2%	2.1%
Others	Cannery	298	259,474	84.7%	12.4%	2.9%
Others	Observer	298	255,910	81.3%	14.9%	3.8%
Others	Model	298	260,528	81.7%	15.1%	3.2%

Table 6 Comparisons of species % by (trip-level) region and data source, having excluded trips with a cannery location of Pago Pago. The number of trips and data source specific total volume (metric tonnes) are also provided. Regions were defined for each trip as the area with the highest reported (RPL) catch.

Region	Datasource	Trips	MT	SKJ	YFT	BET
West of 170E	RPL	311	237,007	89.2%	9.3%	1.5%
West of 170E	UL	311	237,205	89.3%	9.3%	1.4%
West of 170E	Cannery	311	239,442	82.6%	14.4%	3.0%
West of 170E	Observer	311	231,893	80.0%	16.3%	3.7%
West of 170E	Model	311	236,432	79.9%	16.8%	3.3%
170E to 150W	RPL	403	346,450	88.9%	9.7%	1.4%
170E to 150W	UL	403	346,015	89.0%	9.8%	1.2%
170E to 150W	Cannery	403	347,066	86.7%	11.2%	2.1%
170E to 150W	Observer	403	339,507	83.4%	13.3%	3.3%
170E to 150W	Model	403	346,100	84.2%	13.2%	2.6%
East of 150W	RPL	13	16,138	81.0%	13.1%	5.9%
East of 150W	UL	13	15,960	81.1%	10.4%	8.5%
East of 150W	Cannery	13	16,033	80.1%	11.1%	8.8%
East of 150W	Observer	13	16,145	79.5%	12.1%	8.4%
East of 150W	Model	13	16,138	82.3%	12.3%	5.5%

Figures

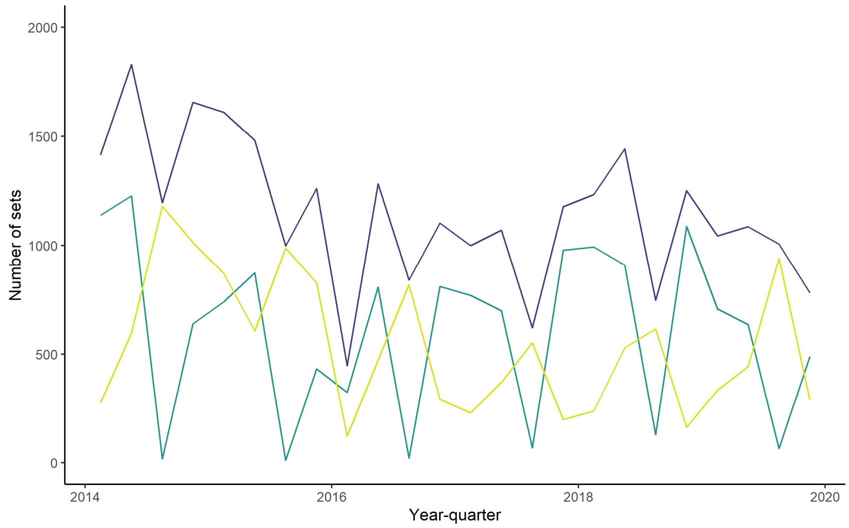


Figure 1 Total sets (purple), associated sets (turquoise) and free school sets (yellow) for USA purse seiners by year-quarter, having filtered for trips with at least one from set in the WCPFC Convention Area (excluding the area overlapping with the IATTC Convention Area).

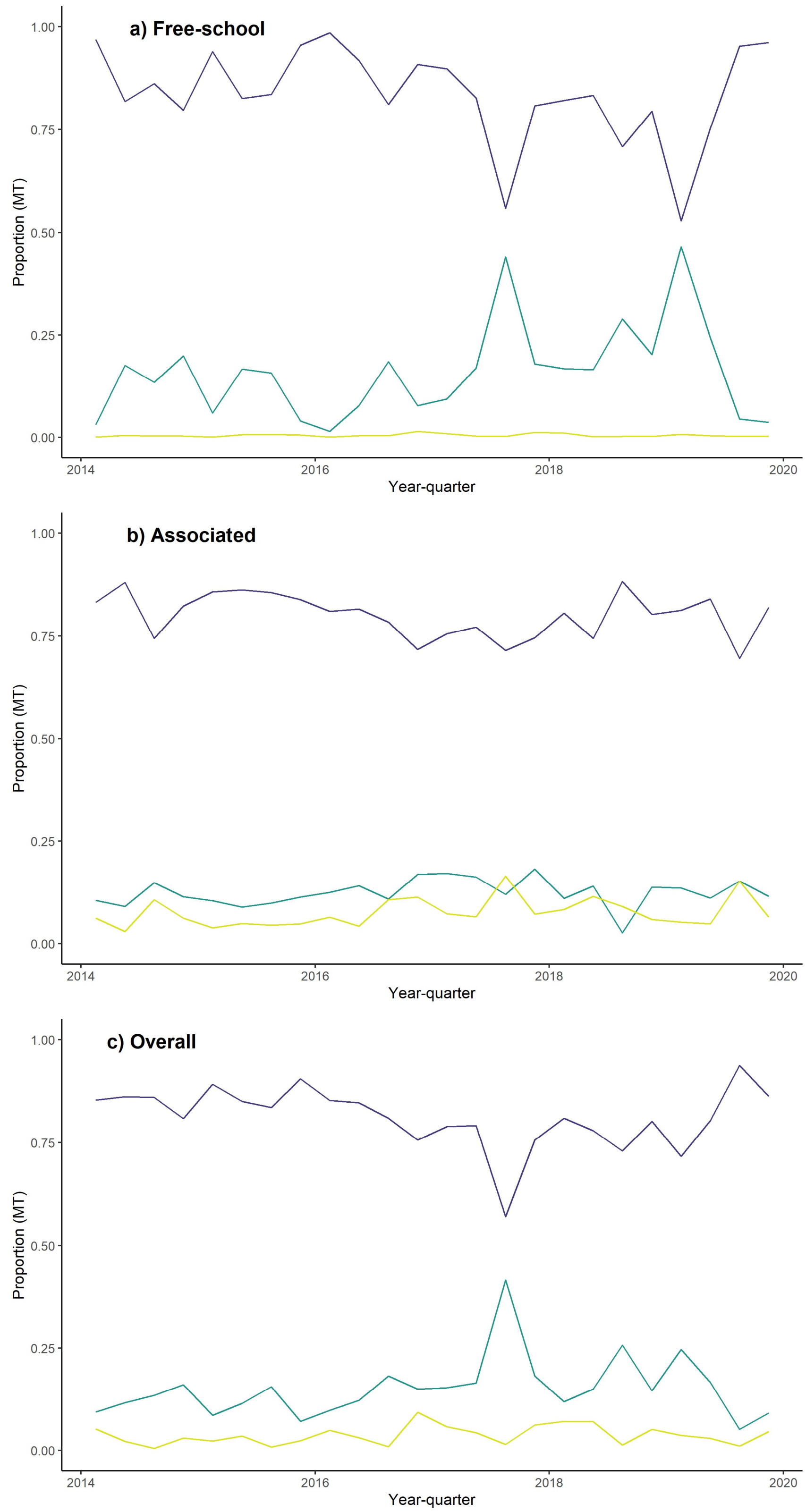


Figure 2 Grab-sample based estimates of USA purse seine catch proportions (MT) for skipjack (purple), yellowfin (turquoise) and bigeye (yellow) for a) free school sets, b) associated sets, and c) all sets.

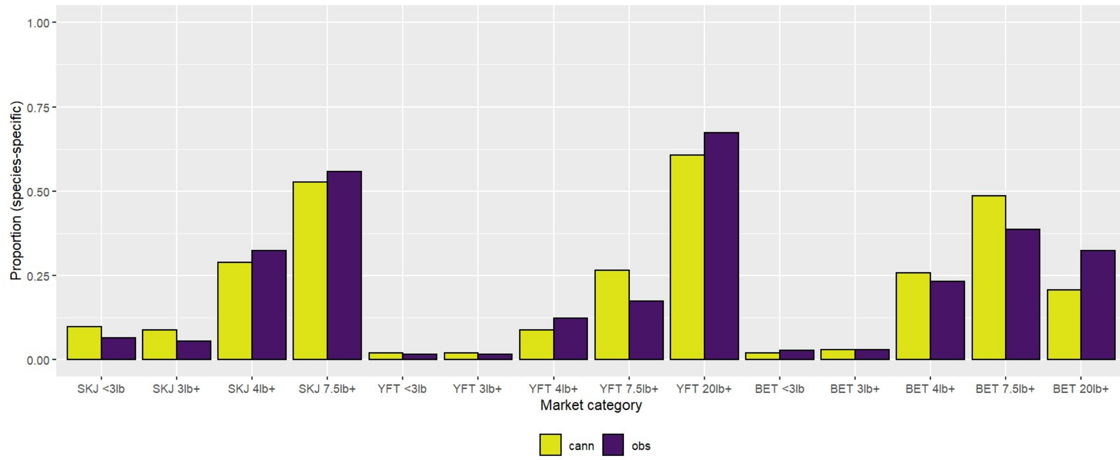


Figure 3 Overall species-specific proportions by size category based on cannery receipts (yellow) and observer grab samples (purple).

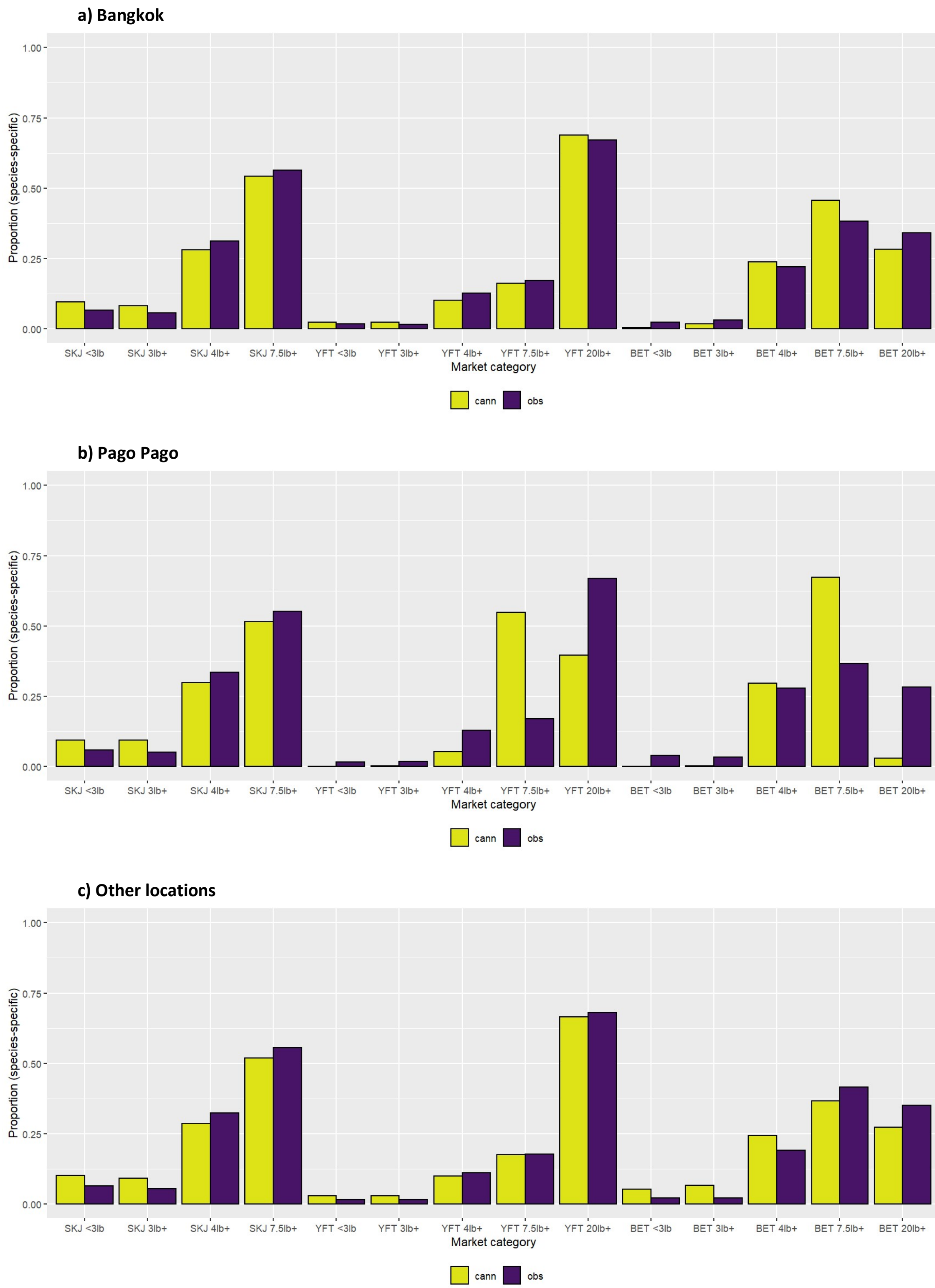


Figure 4 Species-specific proportions by size category based on cannery receipts (yellow) and observer grab samples (purple) for trips where the highest proportion of catches had a cannery location of a) Bangkok, b) Pago Pago, and c) all other locations.

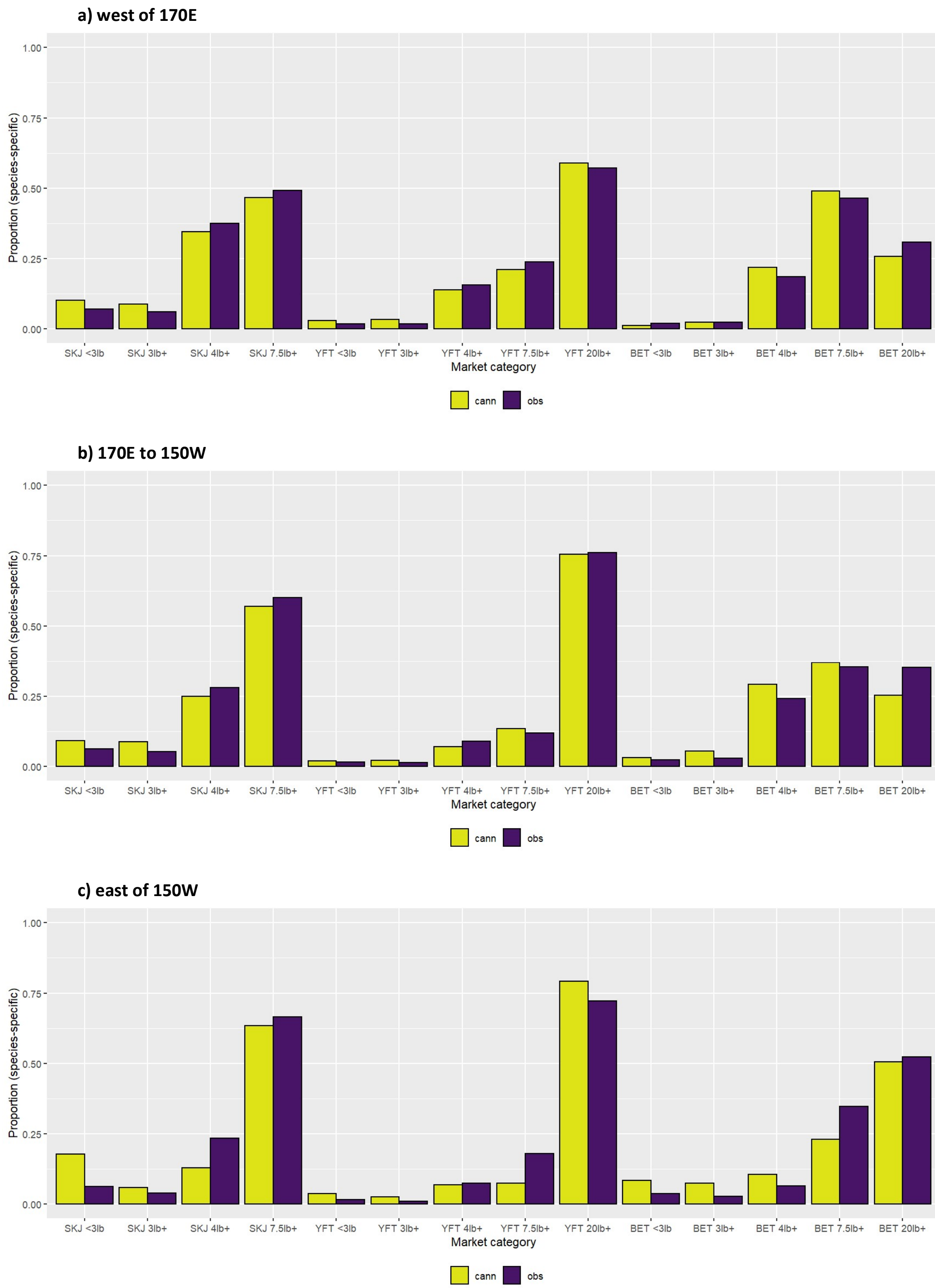


Figure 5 Species-specific proportions by size category based on cannery receipts (yellow) and observer grab samples (purple) for trips where the highest proportion of total catches were made a) west of 170°E, b) 170E to 150W and c) east of 150W. Trips with a cannery location of Pago Pago were excluded.

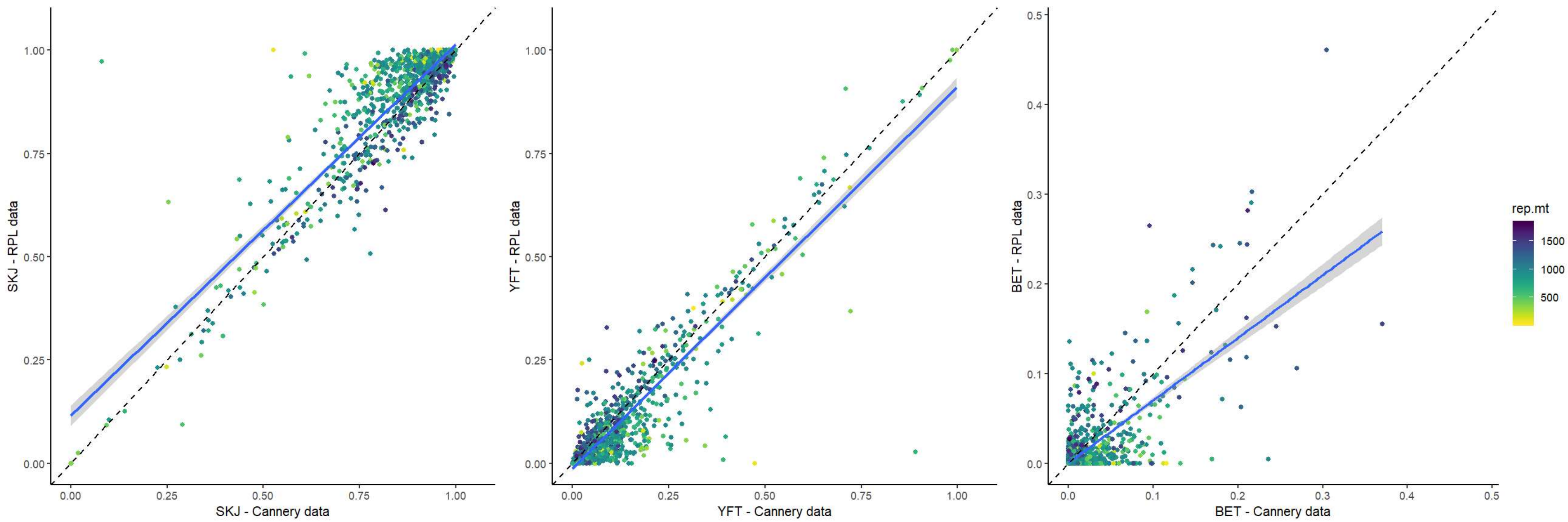


Figure 6 Trip-level comparisons of cannery receipt based species proportions (x-axis) with RPL based species proportions (y-axis) for skipjack (left panel), yellowfin (centre) and bigeye (right). The solid blue line in each panel represents a linear model fitted to the data points. The datapoints are coloured by their total reported catch.

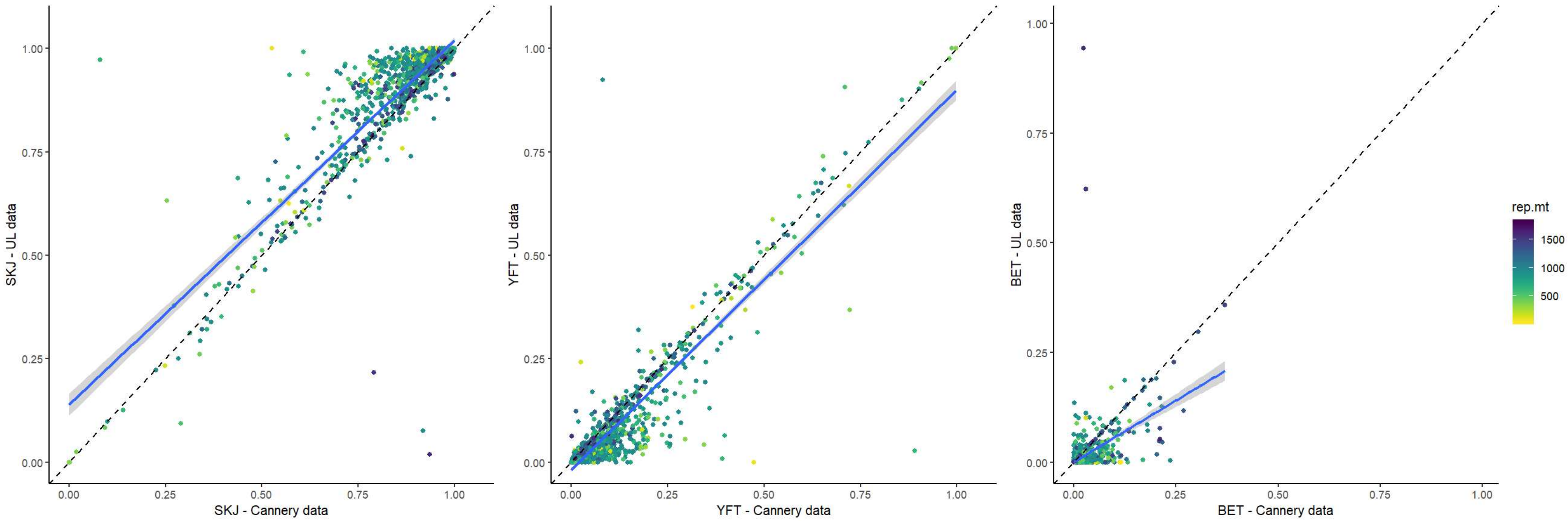


Figure 7 Trip-level comparisons of cannery receipt based species proportions (x-axis) with unloadings based species proportions (y-axis) for skipjack (left panel), yellowfin (centre) and bigeye (right). The solid blue line in each panel represents a linear model fitted to the data points. The datapoints are coloured by their total reported catch.

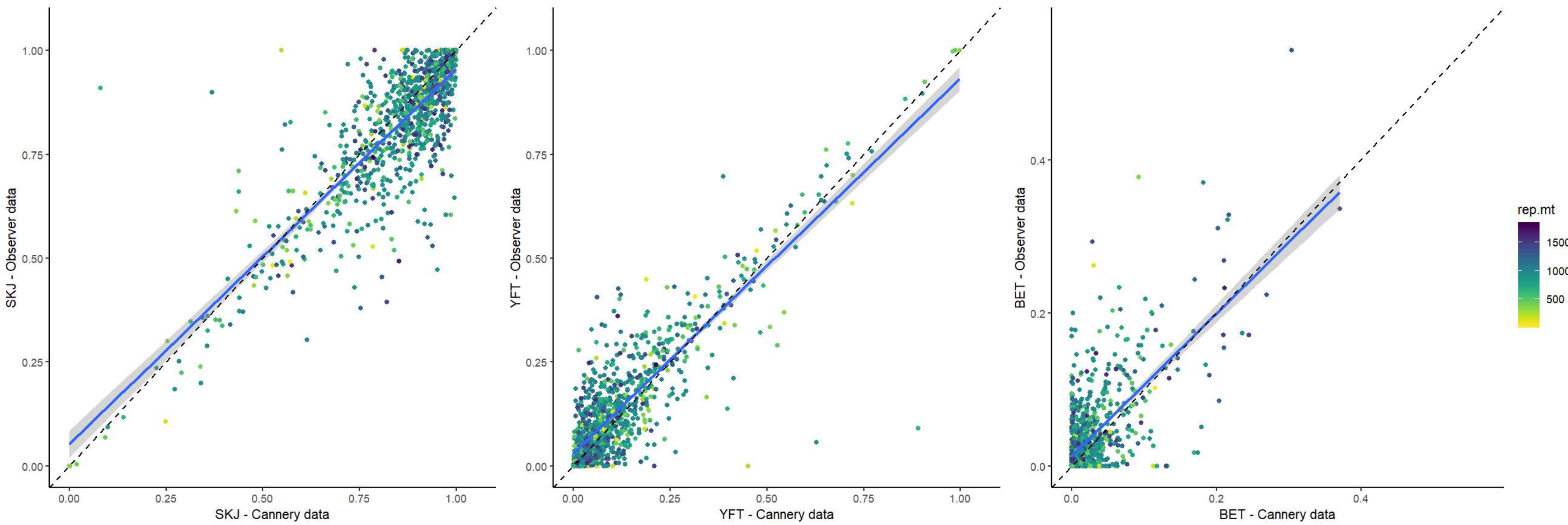


Figure 8 Trip-level comparisons of cannery receipt based species proportions (x-axis) with observer grab sample based species proportions (y-axis) for skipjack (left panel), yellowfin (centre) and bigeye (right). The solid blue line in each panel represents a linear model fitted to the data points. The datapoints are coloured by their total reported catch.

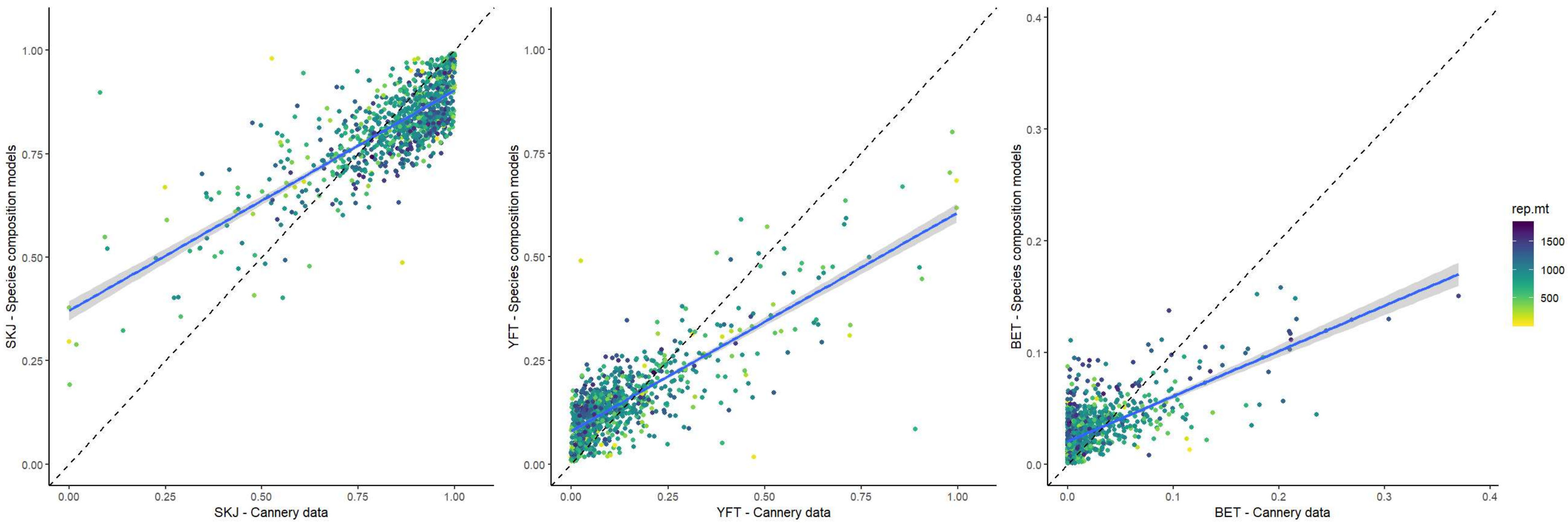


Figure 9 Trip-level comparisons of cannery receipt based species proportions (x-axis) with species composition model based species proportions (y-axis) for skipjack (left panel), yellowfin (centre) and bigeye (right). The solid blue line in each panel represents a linear model fitted to the data points. The datapoints are coloured by their total reported catch.

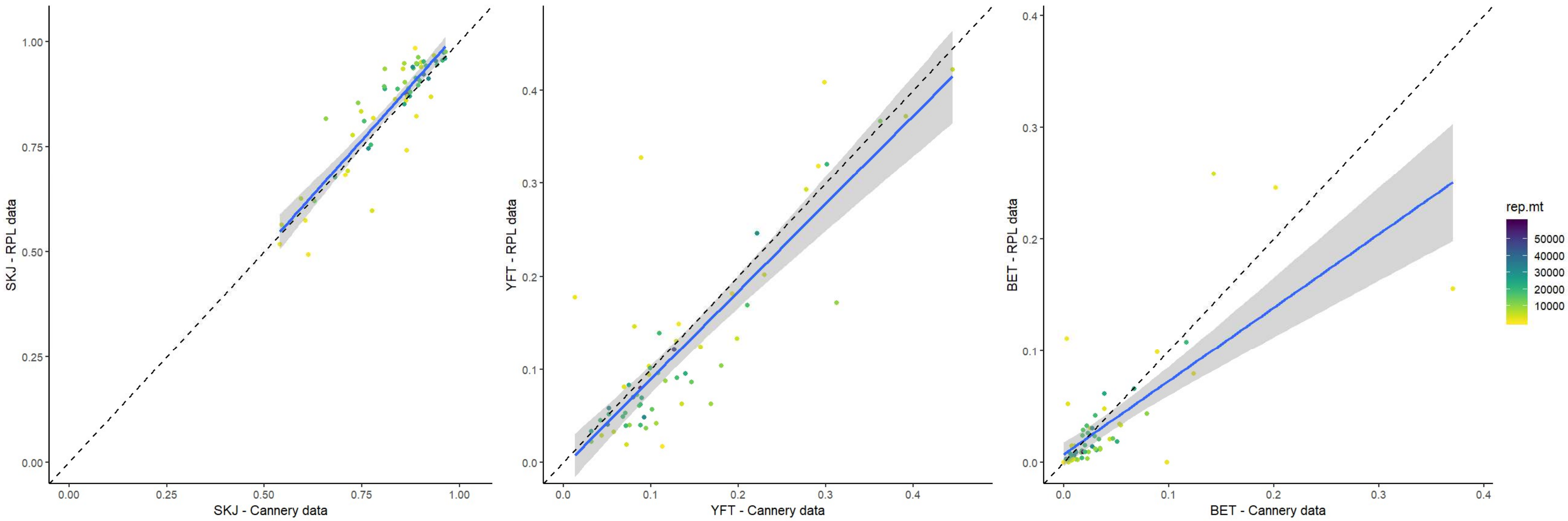


Figure 10 Year, quarter and region-level comparisons of cannery receipt based species proportions (x-axis) with RPL based species proportions (y-axis) for skipjack (left panel), yellowfin (centre) and bigeye (right). The solid blue line in each panel represents a linear model fitted to the data points. The datapoints are coloured by their total reported catch.

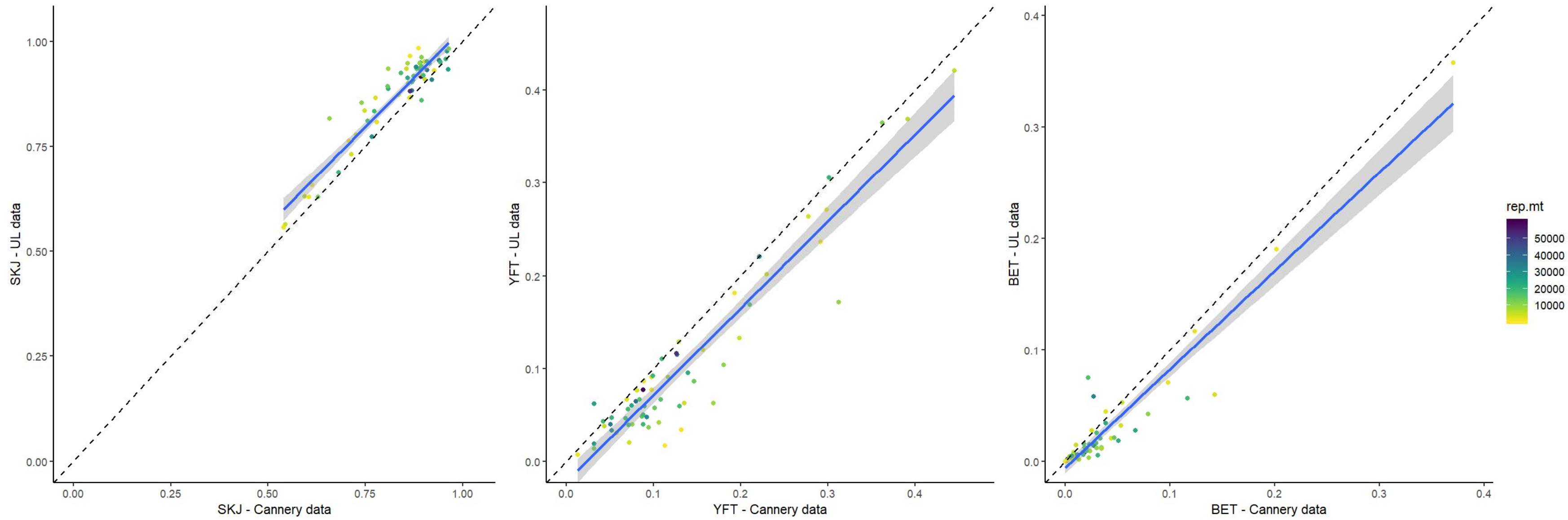


Figure 11 Year, quarter and region-level comparisons of cannery receipt based species proportions (x-axis) with unloadings based species proportions (y-axis) for skipjack (left panel), yellowfin (centre) and bigeye (right). The solid blue line in each panel represents a linear model fitted to the data points. The datapoints are coloured by their total reported catch.

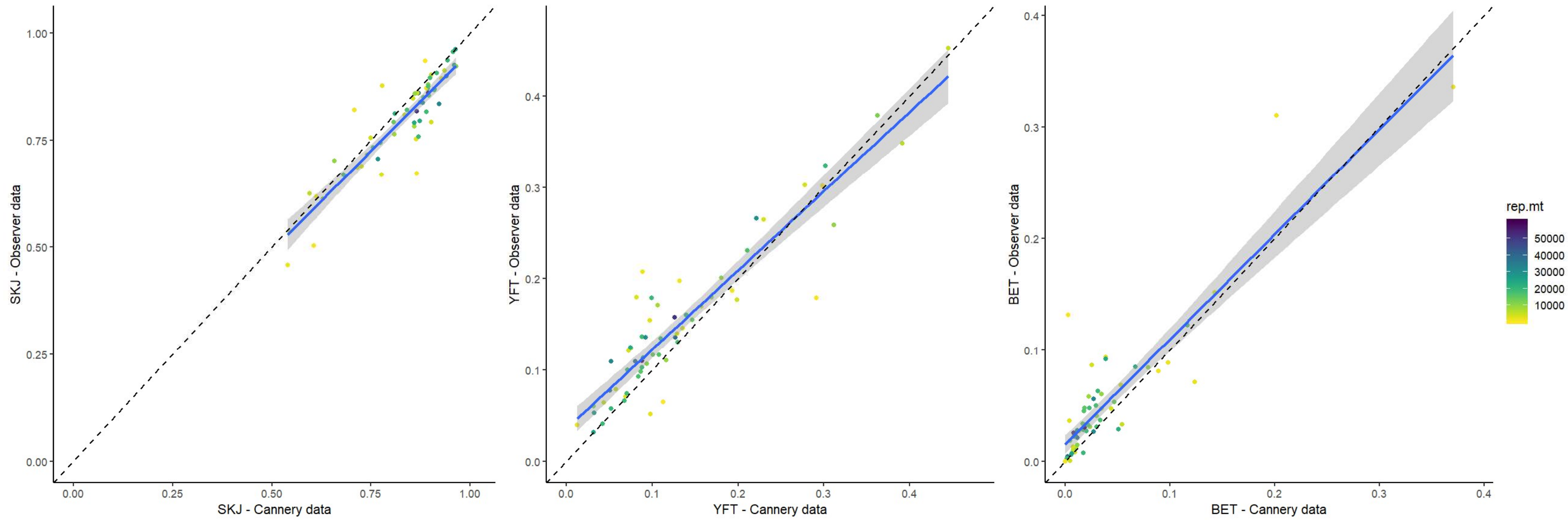


Figure 12 Year, quarter and region-level comparisons of cannery receipt based species proportions (x-axis) with observer grab sample based species proportions (y-axis) for skipjack (left panel), yellowfin (centre) and bigeye (right). The solid blue line in each panel represents a linear model fitted to the data points. The datapoints are coloured by their total reported catch.

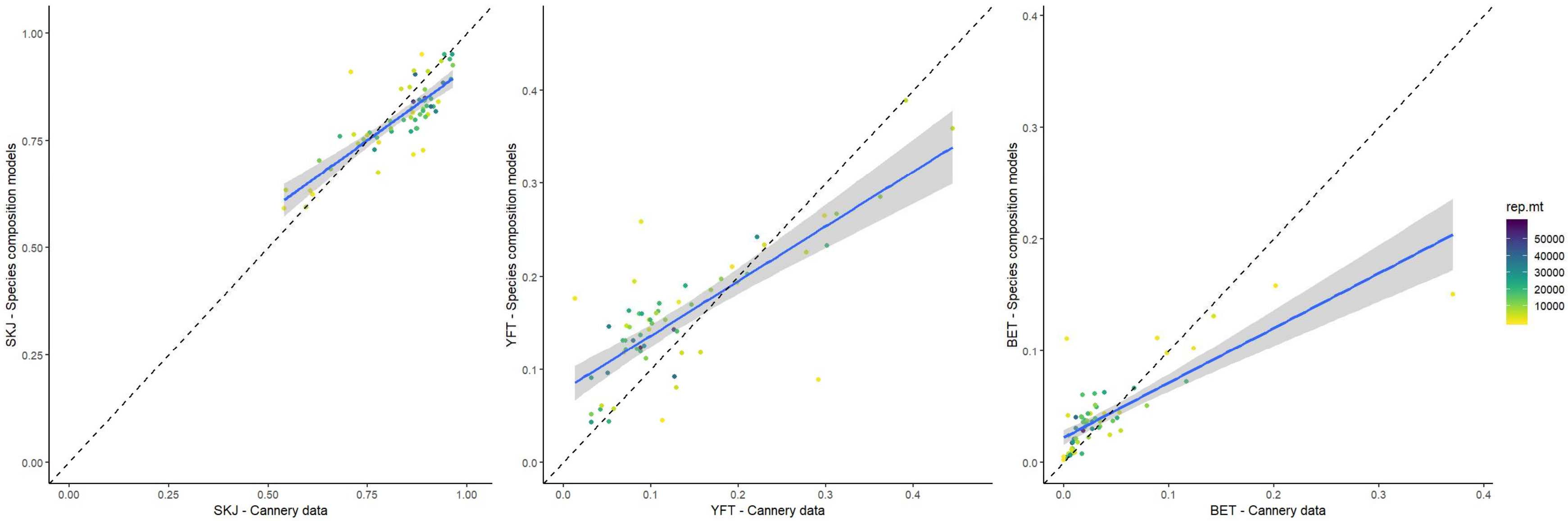


Figure 13 Year, quarter and region-level comparisons of cannery receipt based species proportions (x-axis) with species-composition model based species proportions (y-axis) for skipjack (left panel), yellowfin (centre) and bigeye (right). The solid blue line in each panel represents a linear model fitted to the data points. The datapoints are coloured by their total reported catch.

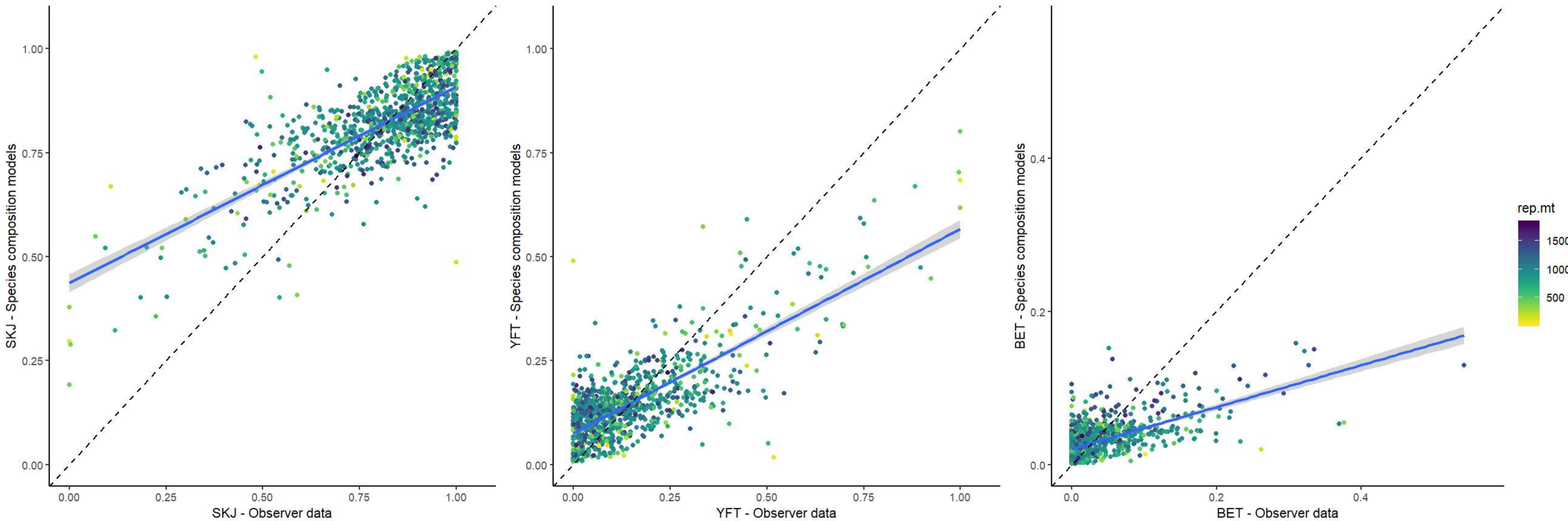


Figure 14 Trip-level comparisons of observer-based species proportions (x-axis) with species composition model based species proportions (y-axis) for skipjack (left panel), yellowfin (centre) and bigeye (right). The solid blue line in each panel represents a linear model fitted to the data points. The datapoints are coloured by their total reported catch.

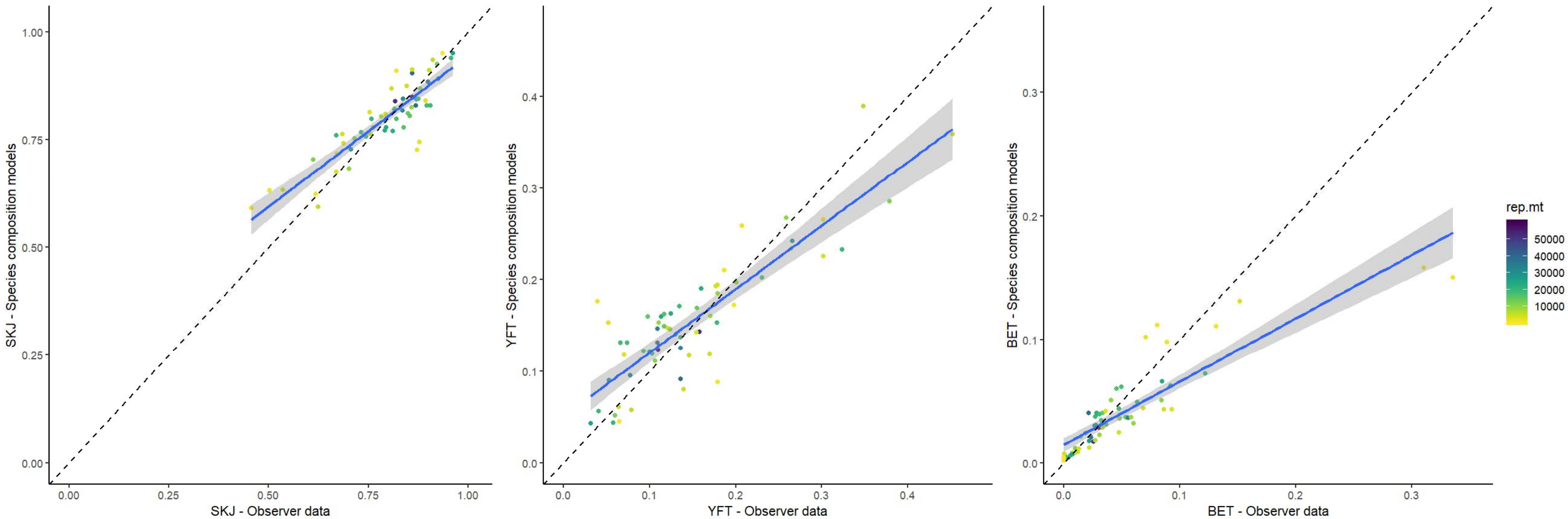


Figure 15 Year, quarter and region-level comparisons of observer-based species proportions (x-axis) with species composition model based species proportions (y-axis) for skipjack (left panel), yellowfin (centre) and bigeye (right). The solid blue line in each panel represents a linear model fitted to the data points. The datapoints are coloured by their total reported catch.

Appendix A

Additional tables

Table 7 Comparisons of species % by year and data source for the 'high confidence' dataset, having excluded trips with a cannery location of Pago Pago. The number of trips and data source specific total volume (metric tonnes) are also provided.

Year	Data Source	Trips	MT	SKJ	YFT	BET
2014	RPL	65	60,422	89.8%	9.2%	1.1%
2014	UL	65	60,481	90.2%	8.9%	0.9%
2014	Cannery	65	60,631	86.7%	11.6%	1.7%
2014	Observer	65	60,353	83.8%	13.5%	2.7%
2014	Model	65	60,387	85.3%	12.0%	2.7%
2015	RPL	61	48,793	91.8%	7.3%	1.0%
2015	UL	61	48,831	91.8%	7.2%	1.0%
2015	Cannery	61	49,040	89.9%	8.4%	1.7%
2015	Observer	61	48,672	86.6%	10.5%	2.9%
2015	Model	61	48,763	85.8%	12.2%	2.0%
2016	RPL	48	42,988	87.3%	9.3%	3.4%
2016	UL	48	42,972	88.5%	7.9%	3.6%
2016	Cannery	48	42,876	84.2%	11.0%	4.8%
2016	Observer	48	42,653	79.9%	14.9%	5.3%
2016	Model	48	42,988	80.7%	15.4%	4.0%
2017	RPL	49	41,051	86.2%	11.2%	2.6%
2017	UL	49	41,037	86.1%	11.2%	2.7%
2017	Cannery	49	41,197	81.5%	14.3%	4.2%
2017	Observer	49	40,817	78.7%	16.6%	4.6%
2017	Model	49	41,051	78.9%	16.9%	4.2%
2018	RPL	64	55,568	90.2%	7.8%	2.0%
2018	UL	64	55,530	89.7%	8.0%	2.3%
2018	Cannery	64	56,159	84.7%	12.0%	3.3%
2018	Observer	64	55,413	82.2%	14.1%	3.6%
2018	Model	64	55,568	81.2%	15.3%	3.5%
2019	RPL	48	42,525	89.1%	9.4%	1.5%
2019	UL	48	42,382	87.6%	11.0%	1.4%
2019	Cannery	48	42,764	83.6%	13.9%	2.5%
2019	Observer	48	42,213	82.4%	14.3%	3.3%
2019	Model	48	42,525	81.9%	15.3%	2.8%
Total	RPL	335	291,347	89.2%	8.9%	1.9%
Total	UL	335	291,232	89.2%	8.9%	1.9%
Total	Cannery	335	292,668	85.3%	11.8%	2.9%
Total	Observer	335	290,122	82.5%	13.9%	3.7%
Total	Model	335	291,282	82.5%	14.3%	3.1%

Additional figures

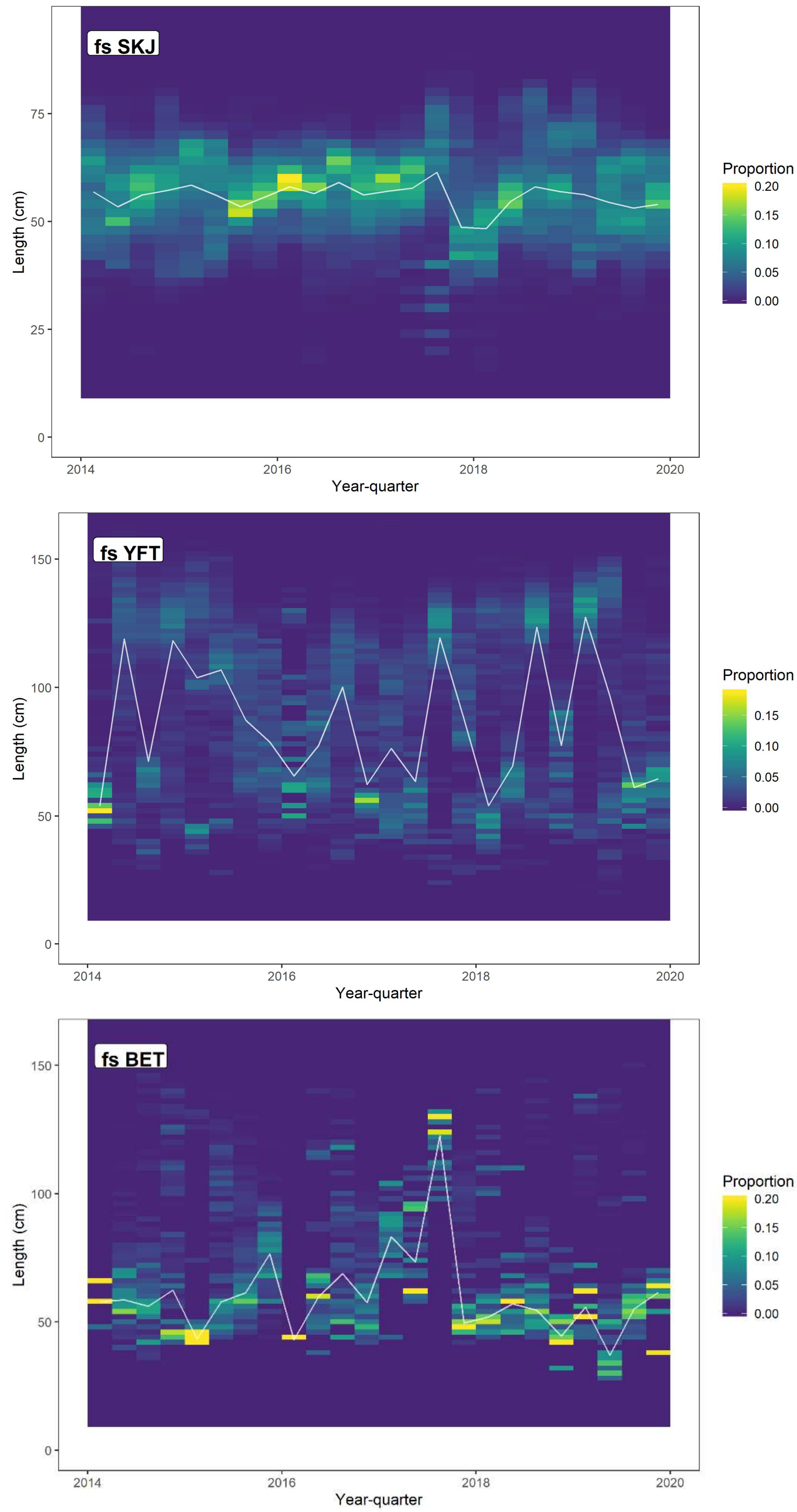


Figure 16 Estimated species-specific catch proportions (individuals) by length through time for free-school catches by USA purse seine vessels, based on observer grab samples. The median length is given by the solid white line.

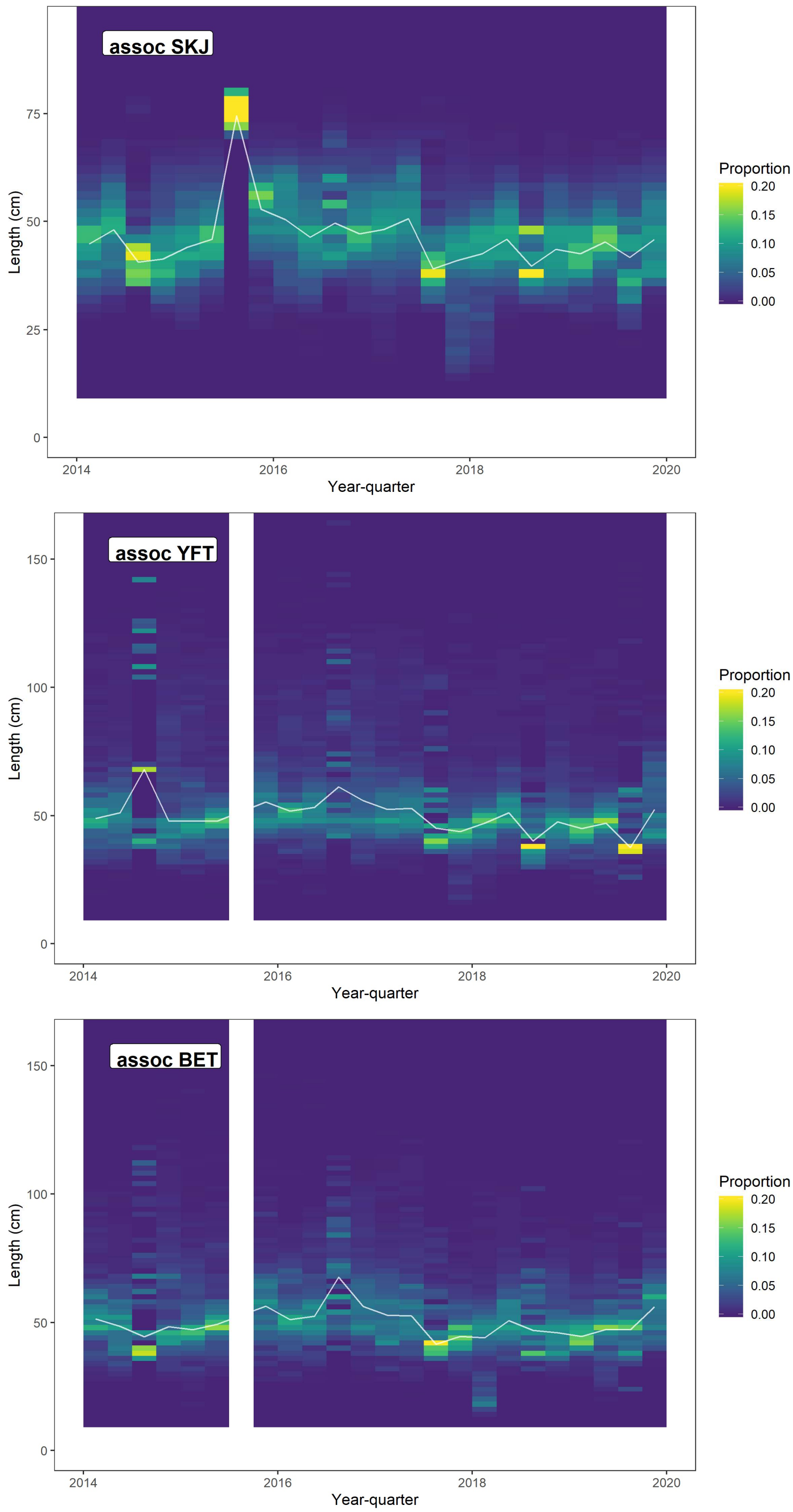
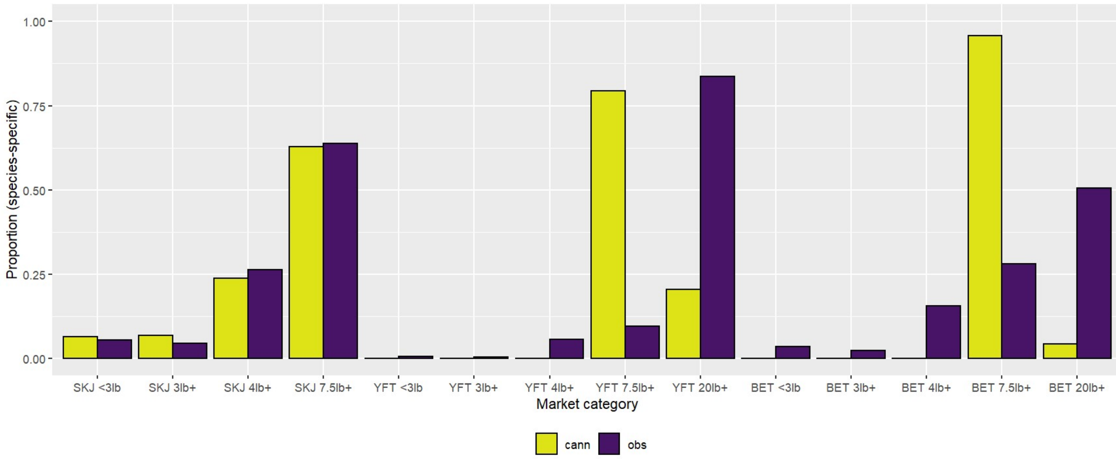
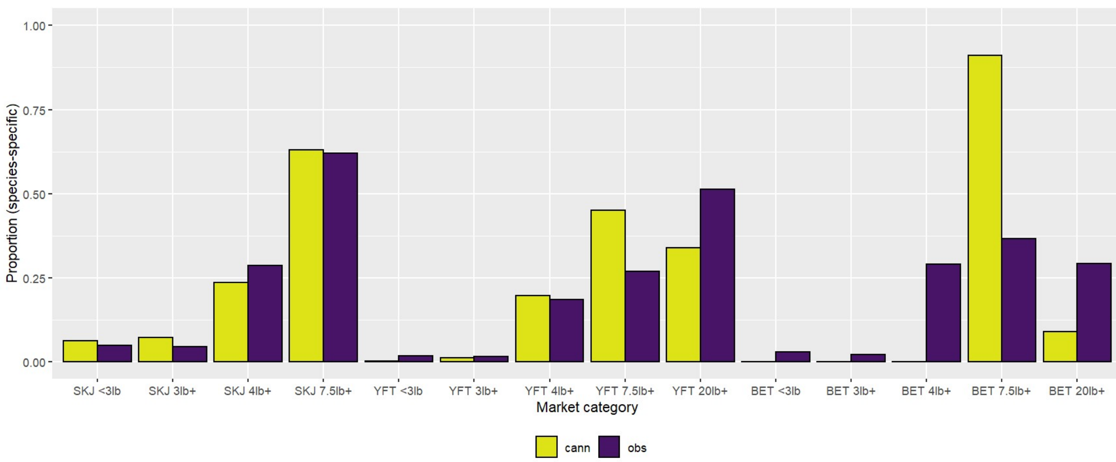


Figure 17 Estimated species-specific catch proportions (individuals) by length through time for free-school catches by USA purse seine vessels, based on observer grab samples. The median length is given by the solid white line.

a) 2014



b) 2015



c) 2016

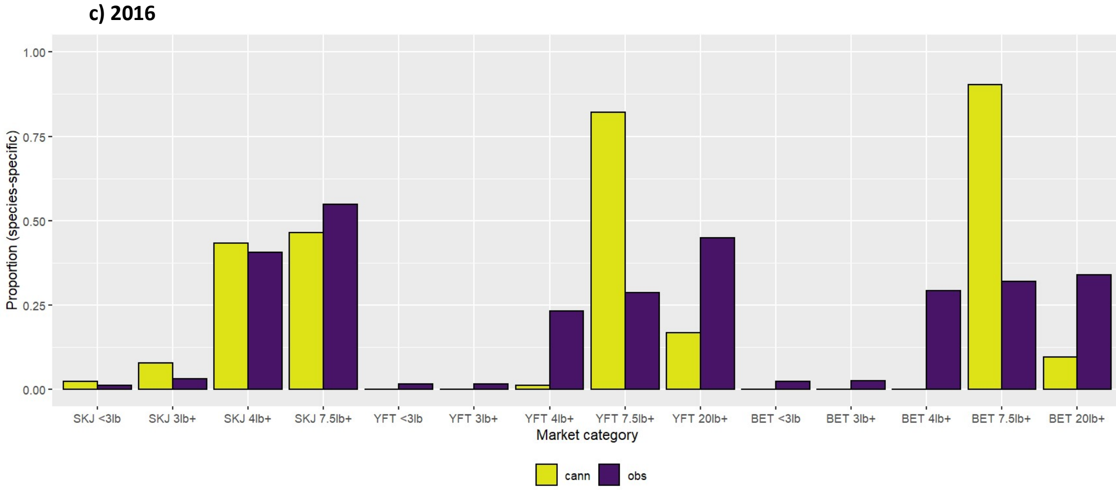
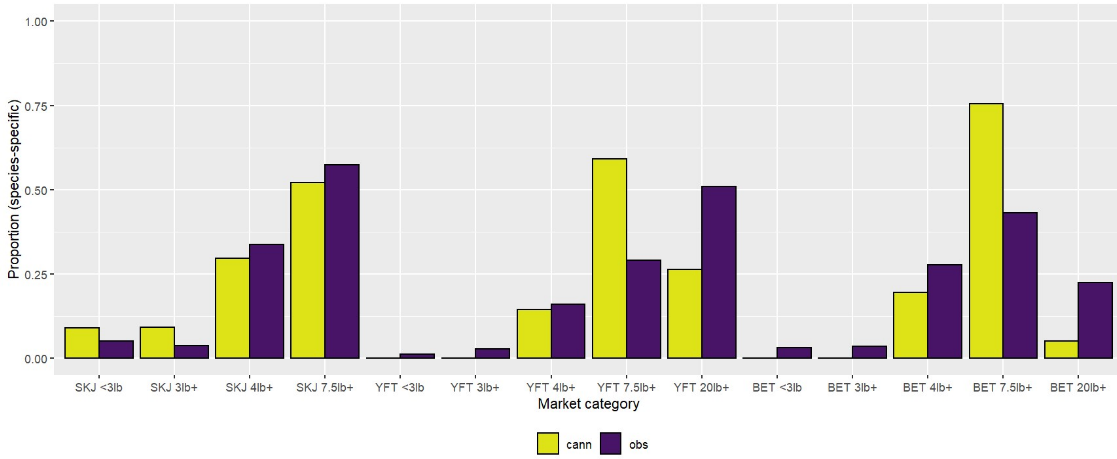
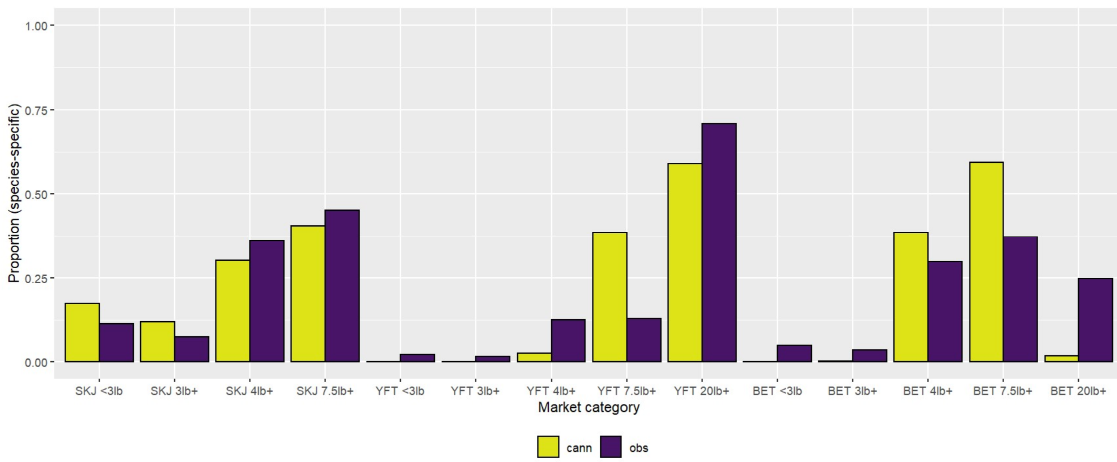


Figure 18 Annual species-specific proportions by size category based on cannery receipts (yellow) and observer grab samples (purple) for trips with a cannery location of Pago Pago with a departure year of a) 2014, b) 2015, c) 2016, d) 2017, e) 2018 and f) 2019. Note panels d) to f) are on the following page.

d) 2017



e) 2018



f) 2019

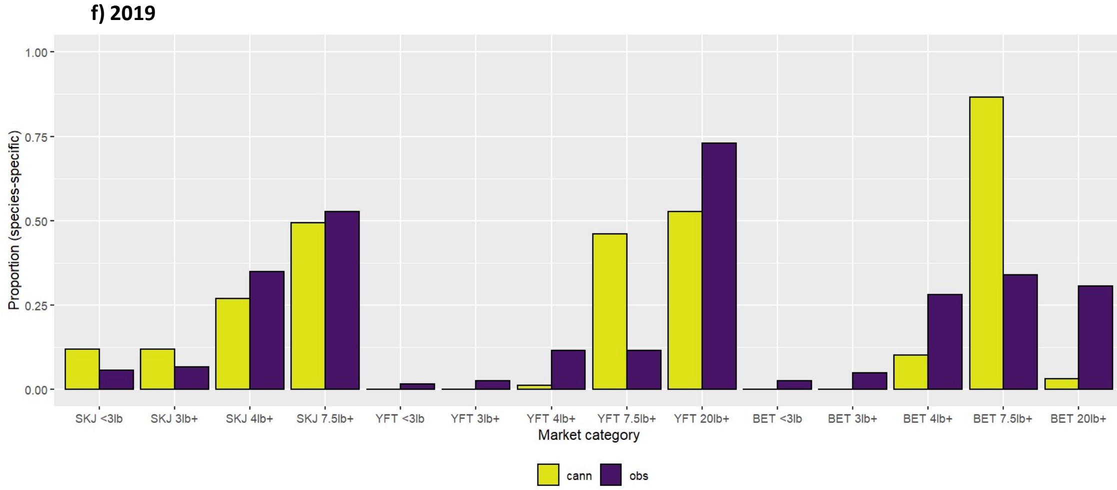


Figure 18 continued.

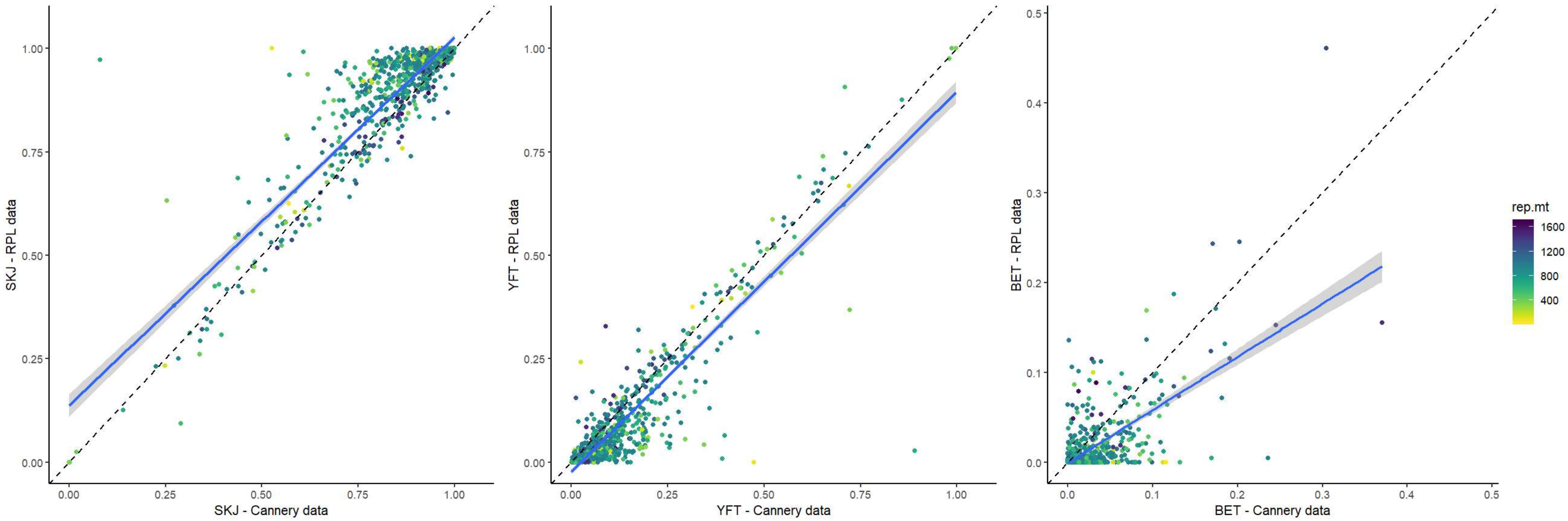


Figure 19 Trip-level comparisons of cannery receipt based species proportions (x-axis) with RPL based species proportions (y-axis) for skipjack (left panel), yellowfin (centre) and bigeye (right). The solid blue line in each panel represents a linear model fitted to the data points. The datapoints are coloured by their total reported catch. Trips with a cannery location of Pago Pago were excluded.

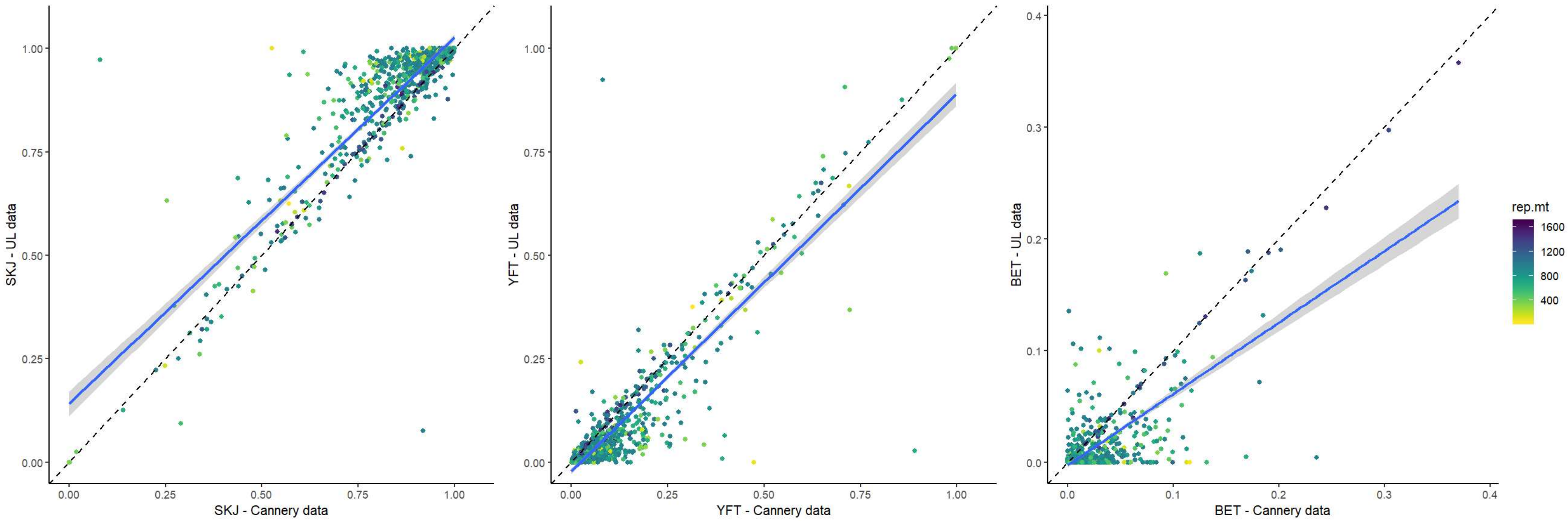


Figure 20 Trip-level comparisons of cannery receipt based species proportions (x-axis) with unloadings based species proportions (y-axis) for skipjack (left panel), yellowfin (centre) and bigeye (right). The solid blue line in each panel represents a linear model fitted to the data points. The datapoints are coloured by their total reported catch. Trips with a cannery location of Pago Pago were excluded.

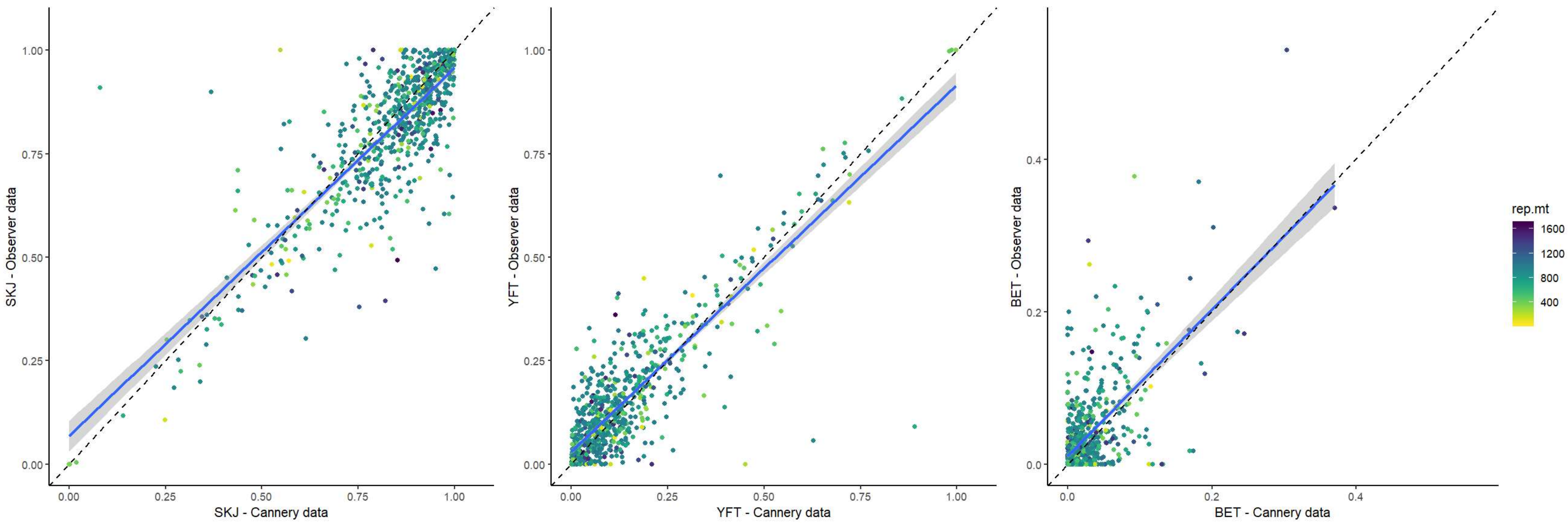


Figure 21 Trip-level comparisons of cannery receipt based species proportions (x-axis) with observer grab sample based species proportions (y-axis) for skipjack (left panel), yellowfin (centre) and bigeye (right), having excluded trips with a cannery location of Pago Pago. The solid blue line in each panel represents a linear model fitted to the data points. The datapoints are coloured by their total reported catch.

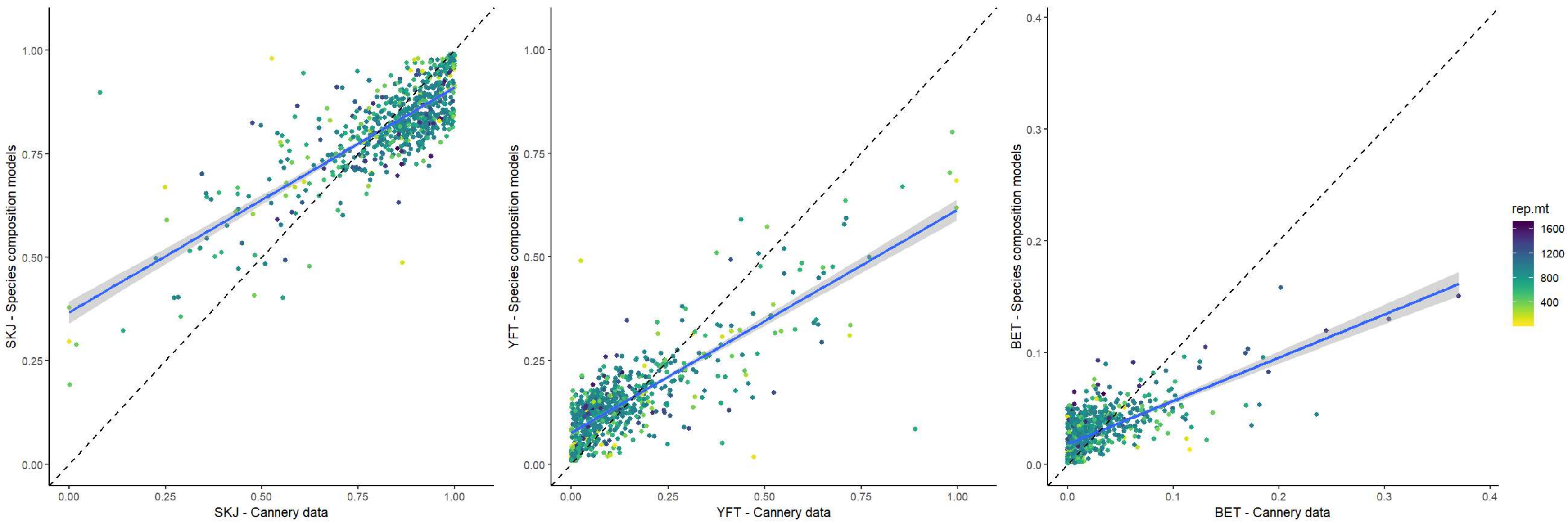


Figure 22 Trip-level comparisons of cannery receipt based species proportions (x-axis) with species composition model based species proportions (y-axis) for skipjack (left panel), yellowfin (centre) and bigeye (right), having excluded trips with a cannery location of Pago Pago. The solid blue line in each panel represents a linear model fitted to the data points. The datapoints are coloured by their total reported catch.

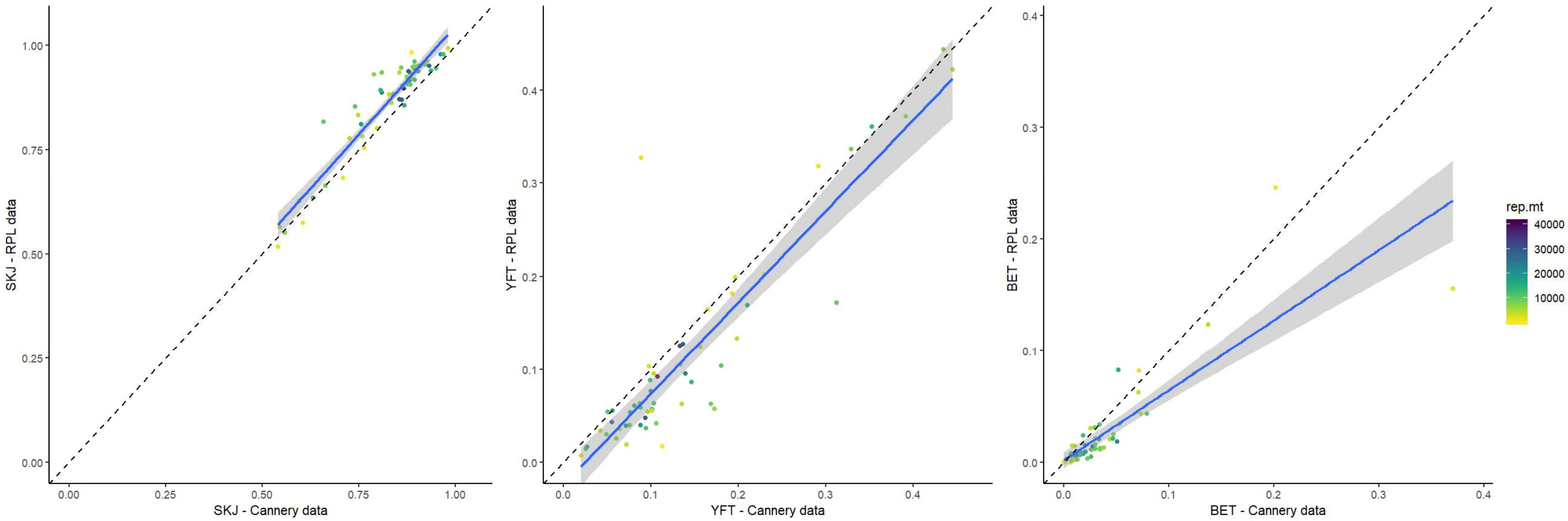


Figure 23 Year, quarter and region-level comparisons of cannery receipt based species proportions (x-axis) with RPL based species proportions (y-axis) for skipjack (left panel), yellowfin (centre) and bigeye (right), having excluded trips with a cannery location of Pago Pago. The solid blue line in each panel represents a linear model fitted to the data points. The datapoints are coloured by their total reported catch.

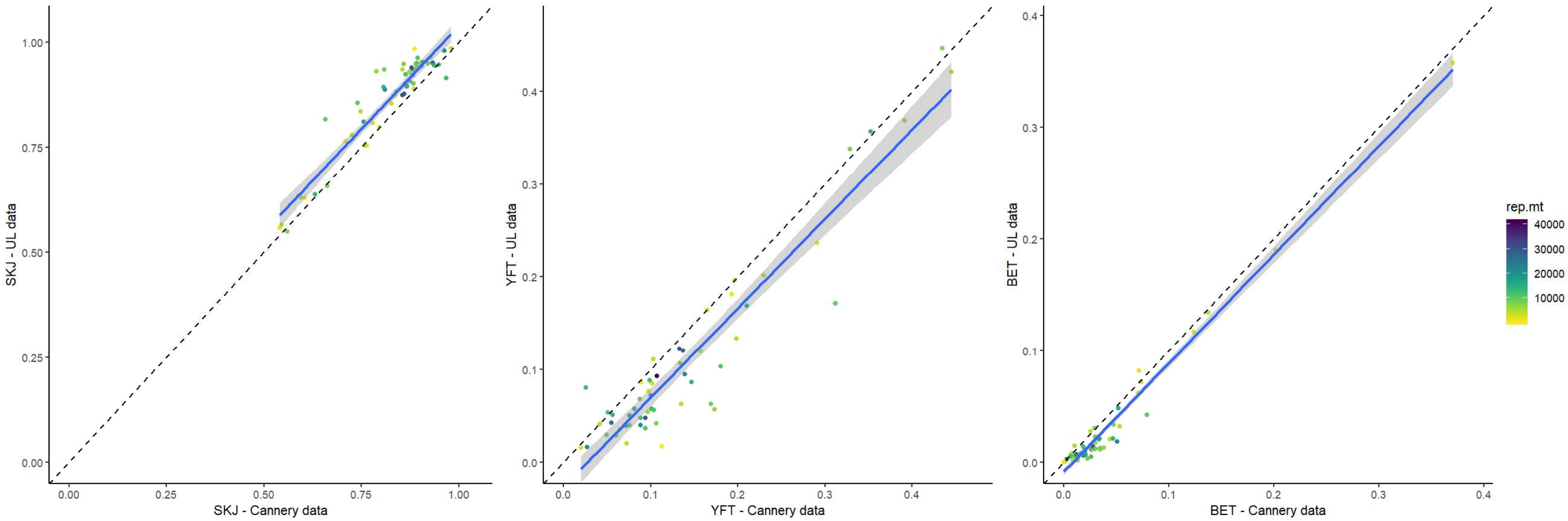


Figure 24 Year, quarter and region-level comparisons of cannery receipt based species proportions (x-axis) with unloadings based species proportions (y-axis) for skipjack (left panel), yellowfin (centre) and bigeye (right), having excluded trips with a cannery location of Pago Pago. The solid blue line in each panel represents a linear model fitted to the data points. The datapoints are coloured by their total reported catch.

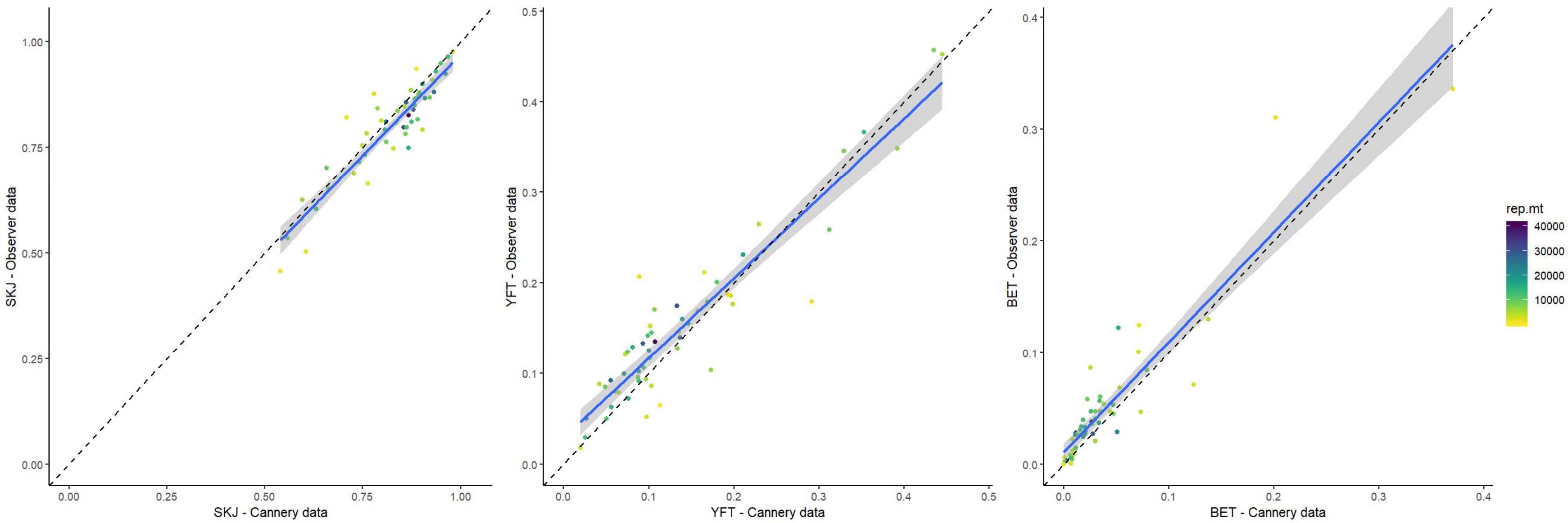


Figure 25 Year, quarter and region-level comparisons of cannery receipt based species proportions (x-axis) with observer grab sample based species proportions (y-axis) for skipjack (left panel), yellowfin (centre) and bigeye (right), having excluded trips with a cannery location of Pago Pago. The solid blue line in each panel represents a linear model fitted to the data points. The datapoints are coloured by their total reported catch.

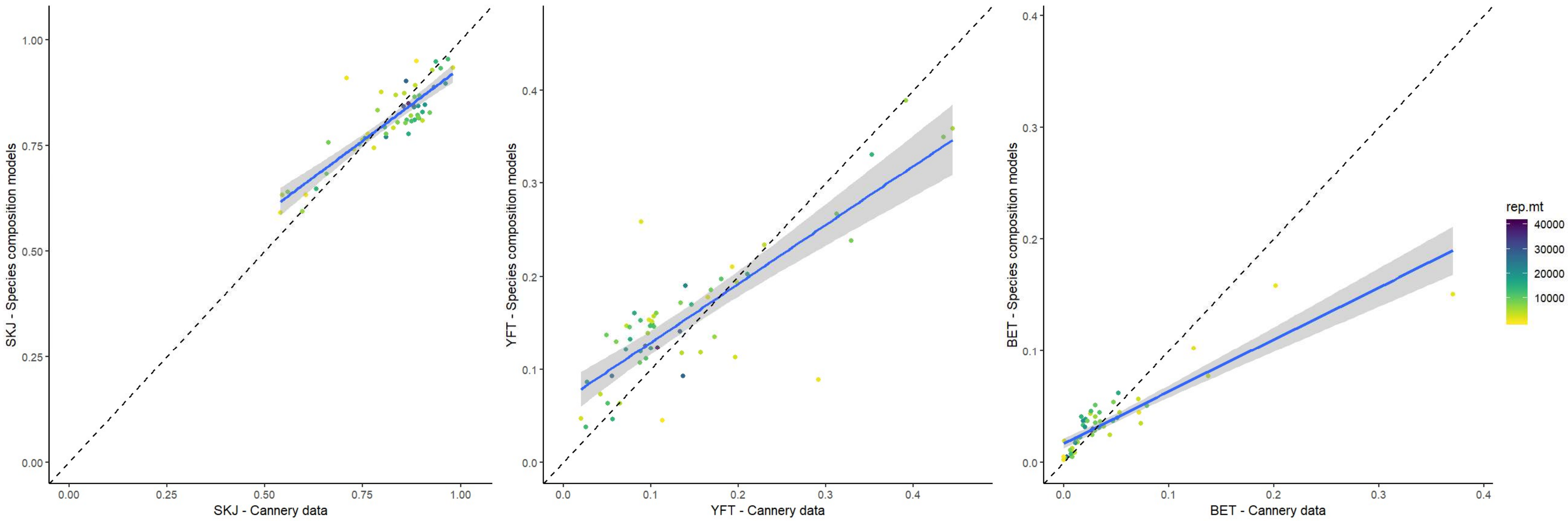


Figure 26 Year, quarter and region-level comparisons of cannery receipt based species proportions (x-axis) with species-composition model based species proportions (y-axis) for skipjack (left panel), yellowfin (centre) and bigeye (right), having excluded trips with a cannery location of Pago Pago. The solid blue line in each panel represents a linear model fitted to the data points. The datapoints are coloured by their total reported catch.

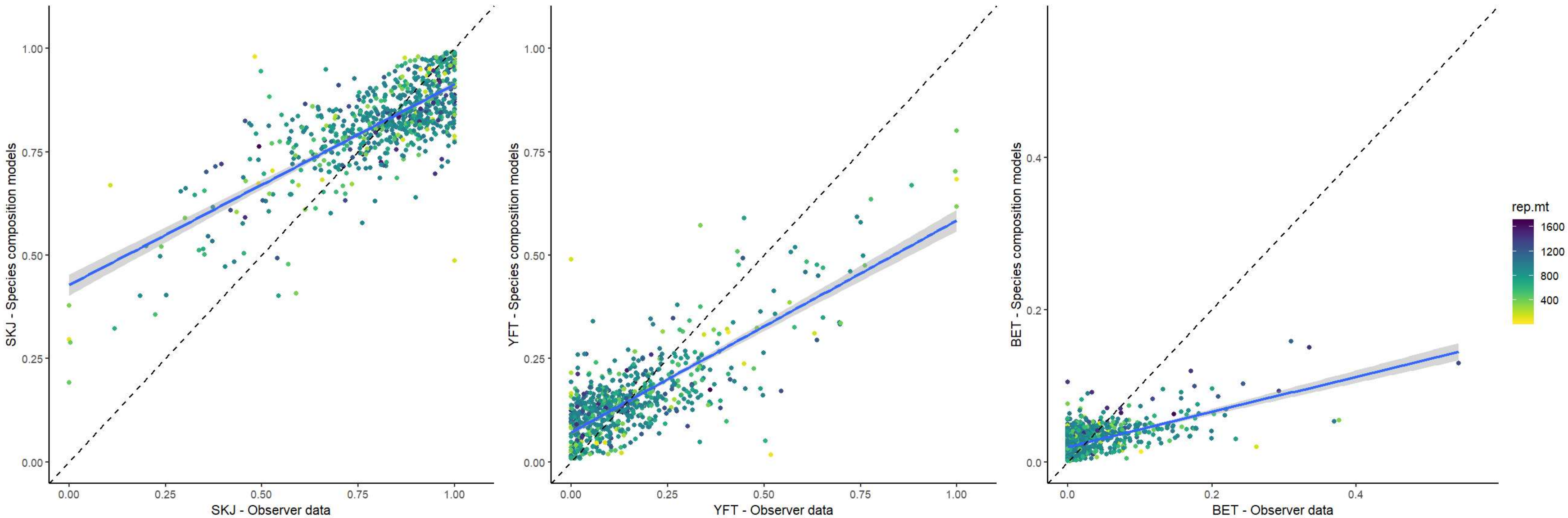


Figure 27 Trip-level comparisons of observer-based species proportions (x-axis) with species composition model based species proportions (y-axis) for skipjack (left panel), yellowfin (centre) and bigeye (right), having excluded trips with a cannery location of Pago Pago. The solid blue line in each panel represents a linear model fitted to the data points. The datapoints are coloured by their total reported catch.

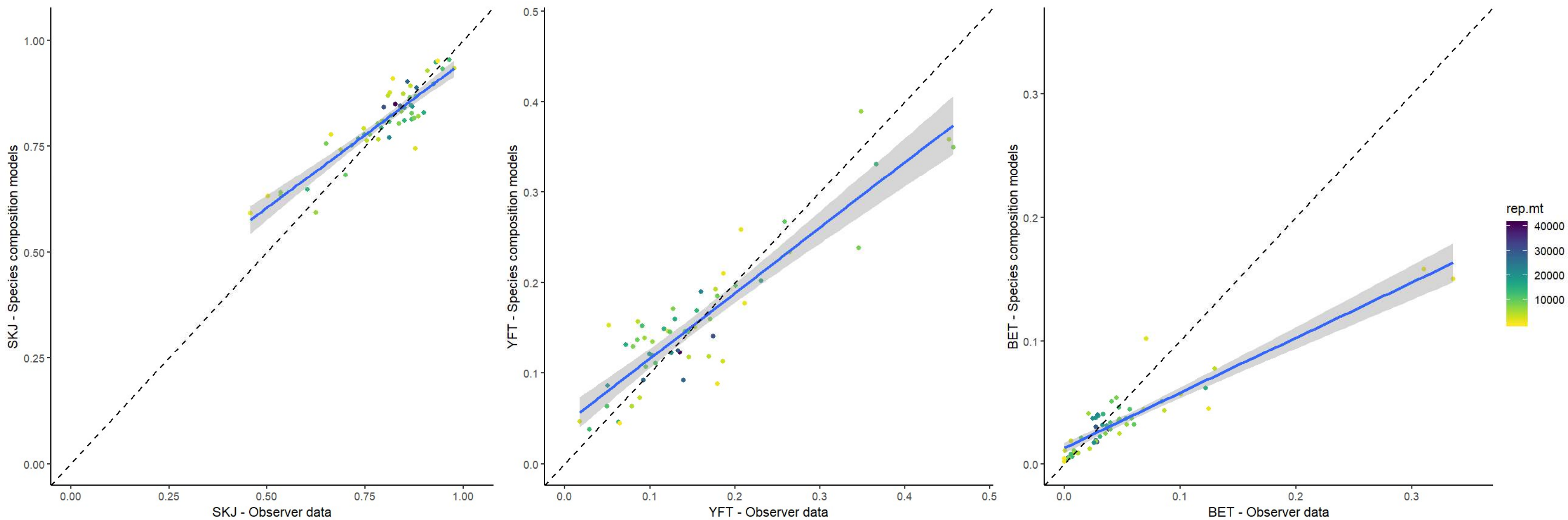


Figure 28 Year, quarter and region-level comparisons of observer-based species proportions (x-axis) with species composition model based species proportions (y-axis) for skipjack (left panel), yellowfin (centre) and bigeye (right), having excluded trips with a cannery location of Pago Pago. The solid blue line in each panel represents a linear model fitted to the data points. The datapoints are coloured by their total reported catch.

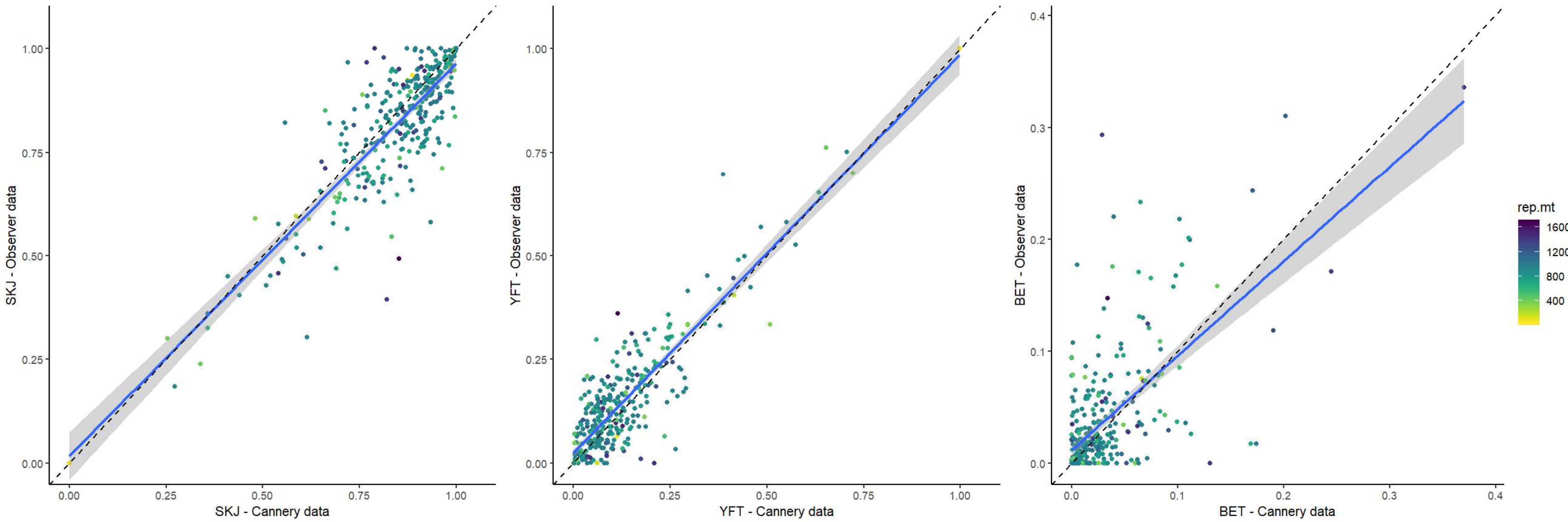


Figure 29 Trip-level comparisons of cannery receipt based species proportions (x-axis) with observer grab sample based species proportions (y-axis) for skipjack (left panel), yellowfin (centre) and bigeye (right), using the 'high-confidence dataset' and having excluded trips with a cannery location of Pago Pago. The solid blue line in each panel represents a linear model fitted to the data points. The datapoints are coloured by their total reported catch.

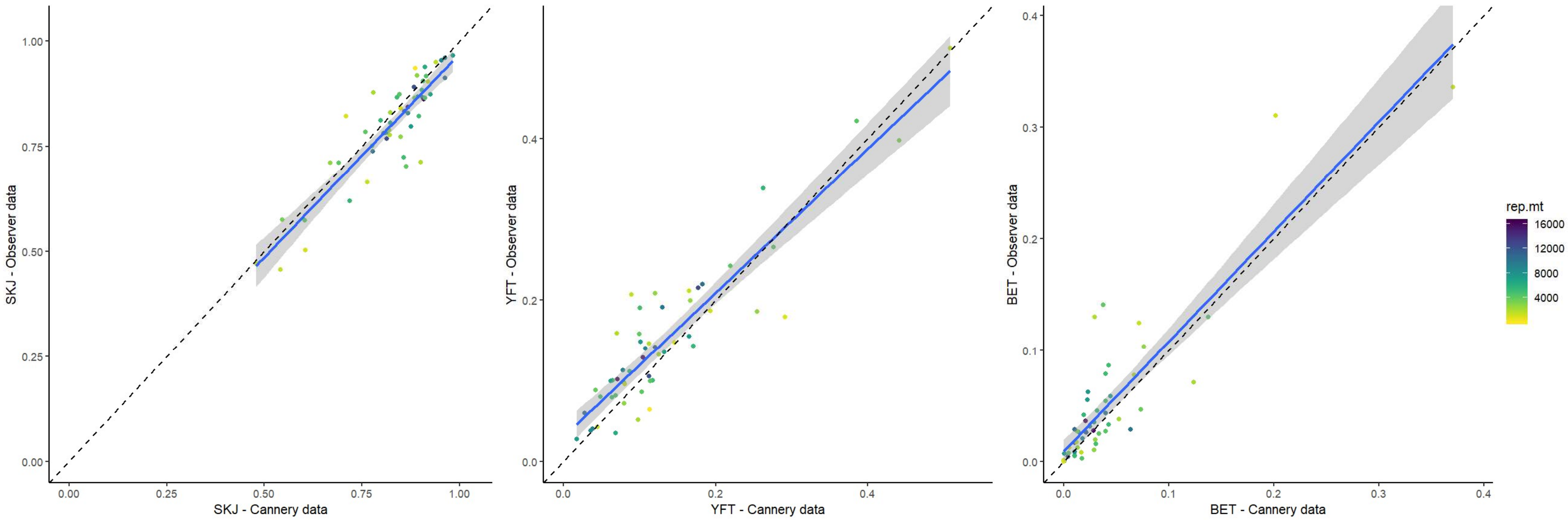


Figure 30 Year, quarter and region-level comparisons of cannery receipt based species proportions (x-axis) with observer grab sample based species proportions (y-axis) for skipjack (left panel), yellowfin (centre) and bigeye (right), having excluded trips with a cannery location of Pago Pago. The solid blue line in each panel represents a linear model fitted to the data points. The datapoints are coloured by their total reported catch.