SCIENTIFIC COMMITTEE
SIXTEENTH REGULAR SESSION

ELECTRONIC MEETING
11 – 20 August 2020

ANALYSIS OF PURSE SEINE AND LONGLINE SIZE FREQUENCY DATA FOR BIGEYE AND YELLOWFIN TUNA IN THE WCPO

WCPFC-SC16-2020/SA-IP-18

T. Peatman[1], N. Ducharme Barth[2], M. Vincent[2]

[1] Independent fisheries consultant for the Pacific Community, Ocean Fisheries Programme
[2] Pacific Community, Ocean Fisheries Programme, Noumea, New Caledonia

Executive Summary

This Information Paper describes the pre-processing of size composition data prior to integration into the 2020 stock assessment models for yellowfin and bigeye.

The reweighting procedures were developed based on the approaches of Abascal et al. (2014) for purse seine compositions, McKechnie (2014) for regular longline fisheries, and Tremblay-Boyer et al. (2018) for index longline fisheries.

Descriptions of the reweighted time series for inclusion in the yellowfin and bigeye stock assessment are provided for:

Purse Seine

- Region 3 associated and free-school fisheries 13 and 14 respectively;
- Region 4 associated and free-school fisheries 15 and 16 respectively;
- Region 7 associated and free-school fisheries 25 and 26 respectively;
- Region 8 associated and free-school fisheries 30 and 31 respectively.

Longline

- Fishery 1, Region 1 (Regular) weight compositions;
- Fishery 2, Region 2 (Regular) weight and length compositions;
- Fishery 4, Region 3 (Regular) weight compositions;
- Fishery 5, Region 3 (Regular) weight compositions;
- Fishery 9, Region 4 (Regular) weight and length compositions;
- Fishery 11, Region 5 (Regular) weight and length compositions;
- Fishery 12, Region 6 (Regular) weight and length compositions;
- Fishery 6, Region 7 (Regular) weight compositions;
- Fishery 7, Region 7 (Regular) weight compositions;
- Fishery 8, Region 8 (Regular) weight compositions;
- Region 1 (index fishery), weight compositions;
- Region 2 (index fishery), weight and length compositions;
- Region 3 (index fishery), weight compositions;
- Region 4 (index fishery), weight and length compositions;
- Region 5 (index fishery), weight and length compositions;
- Region 6 (index fishery), weight and length compositions;
- Region 7 (index fishery), weight compositions;
- Region 8 (index fishery), weight compositions;
- Region 9 (index fishery), weight compositions.

Purse seine length compositions for skipjack tuna were also estimated due to the methodology used and are also presented.

Introduction

This Information Paper describes the pre-processing of size composition data prior to integration into the 2020 stock assessment models for yellowfin and bigeye. Pre-processing is undertaken to ensure all fish removals from the population are modelled at the correct size and that fish sizes in the model are representative of the size of fish in the population. Statistical correction of size composition data is required as length and weight samples are often collected unevenly in space and time such that the samples require reweighting spatially using either catch (to be representative of the size of fish being removed from the population) and/or CPUE (to be representative of the size of fish in the population) as well as correction for any known measurement bias.

Methods

The reweighting procedures were developed based on the approaches of Abascal et al. (2014) for purse seine compositions, McKechnie (2014) for regular longline fisheries, and Tremblay-Boyer et al. (2018) for index longline fisheries. Where possible, attempts were made to harmonise the approaches used to reweight purse seine and longline catch compositions.

Purse seine data preparation

US Multilateral Treaty Port Sampling data were extracted from SPC's LF_MASTER database. Data from 2010 onwards were excluded due to the high observer coverage during this period. Samples that could not be attributed to assessment fisheries were excluded, e.g. samples with unknown school association. Samples provided at a 10 (latitude) x 20° (longitude) resolution were split to 5° cells, using the proportion of reported US catch in each 5° cell, for the year-quarter and association type in question (i.e. associated vs unassociated).

Observer grab and spill samples were extracted from SPC's master observer database, along with the total set catches recorded by observers, for 'all-flag' purse seine fisheries 13 and 14 (region 3), 15 and 16 (region 4), 24 and 25 (region 8) and 30 and 31 (region 7). Data from an observer's first purse seine trip were excluded. Spill samples were used where available from paired grab / spill trips, otherwise grab samples were used. Grab samples were corrected for grab sample bias using correction factors (Peatman et al. 2019).

Longline data preparation

Available length and weight samples from SPC's LF_MASTER and WT_MASTER databases were extracted. Size samples, and aggregate longline catch data, were aggregated to consistent flag-fleet groupings, using lookup tables held by SPC's Data Management team. Approximately 20 % of weight samples and 25 % of length samples have been provided to SPC at a 10 x 20° resolution. As such we used 10 x 20° as the spatial resolution of the size samples as per McKechnie (2014). However, 10 x 20° cells can span multiple assessment regions as well as the boundary of the spatial domain of the assessment models. Size samples were aggregated to a 10 x 20° and region resolution as follows:

- There are a relatively low number of bigeye weight samples provided to SPC at a 4 (lat) x 10° (lon) resolution. These 4 x 10° data were converted to a 10 x 10° resolution by splitting samples 50:50 from any 4 x 10° cell that spanned multiple 10 x 10° cells. These samples were then treated consistently with other samples provided at 10 x 10° resolution.
- All size samples were then split to a 5° resolution using the proportion of reported catches by 5° degree cell for a given year, quarter and flag-fleet. For example, size samples for the USHW flag-fleet provided at a 10 x 20° resolution were split between the eight 5° cells contained in the 10 x 20° cell, using the proportion of reported catches of the USHW flag-fleet in each 5°

cell. Size samples were then filtered for 5° cells inside the spatial domain of the assessment models. The finer-resolution size samples were then assigned to an MFCL region, and size samples in each region were then aggregated back up to a 10 x 20° resolution.

A number of size samples were excluded from the analysed dataset. Size samples from the TWOS fleet in region 3 from 2004 onwards were excluded due to an unexplained shift in sizes (following McKechnie, 2014). A limited number of apparently erroneously large yellowfin weight samples in region 7 during the 1970s were also identified and excluded, i.e. samples with weights exceeding 115 kg.

PS reweighting methodology

The resolution of strata used in the reweighting process was year, quarter, 5° cell, and association type (free-school vs associated)[3]. Purse seine fishery size compositions used length as the unit of size. First, we implemented a set-level lower limit for observer sampling intensity, i.e. total samples per tonne of catch. A lower limit for sampling intensity is one way to exclude sets with data entry errors, and also ensures that high volume sets with low levels of sampling do not have excessive influence on reweighted length compositions in years with relatively limited sampling coverage[4]. The lower limit was set at approximately 20 % of the target grab sampling rate, i.e. 0.33 grab samples per tonne[5].

Observer samples were then raised from set-level to strata-level by first converting set-level numbers by species and length to proportions by species and length. These proportions were then raised to estimated numbers caught by species and length, so that the estimated set catch across all species summed to the observer's estimate of catch weight for the set. Length weight parameters used in this process are provided in Table 1. We then aggregated from set-level to strata-level by summing estimated numbers caught by species and length across sets, and rescaled the strata-level numbers so that the total numbers of fish in each strata was equal to the original sample size. US Multilateral Treaty Port Sampling data were raised to a strata-level by summing numbers of samples by length and species across records, and the samples were then were combined with the strata-level observer samples. At this stage, size samples were filtered for a minimum number of samples by species.

Strata-level numbers by length and species were then raised to an MFCL fishery resolution, i.e. year, quarter and fishery:

1. Strata-level numbers by species and length were converted to catch-weight proportions by species and length, using the length weight parameters in Table 1.
2. Strata-level catch weight proportions by species and length were then converted to total catch by species and length by multiplying by strata-level catches.
3. These were then aggregated across strata to obtain MFCL fishery resolution catch weights by species and length (i.e. by year, quarter and fishery).
4. Catch weights by species and length were then converted to numbers caught by species and length using the average weight of each fish (using the length-weight relationships).
5. Numbers caught by species and length were converted to proportions by species and length, then multiplied by the original number of samples, and then reduced by the proportion of catch at the MFCL fishery resolution accounted for by strata with length samples.

[3] Similar to the longline reweighting process, the definition of strata can be user-defined to provide flexibility.
[4] Four sets with apparent data issues were also excluded, where non-random samples were recorded as grab samples. This was confirmed by investigation of raw data in SPC's observer database.
[5] The target grab sampling rate is 5 fish per brail, which equates to 5 fish per 3 tonnes of catch assuming a 5 metric tonne capacity brail which is approximately 60 % fill on average.

6. The MFCL fishery resolution length compositions were then filtered for year-quarters where sampled strata accounted for a minimum proportion of the total catch of the fishery. This limit is referred to as the 'minimum total weighting'.

Effective samples were then rescaled appropriately, with different approaches used for different MFCL size composition likelihood components. This is described in the section 'Rescaling MFCL resolution size compositions'. We note that this process of raising strata-level size compositions to an MFCL purse seine fishery resolution is equivalent to the catch reweighting approach implemented for regular longline fisheries (see below), with a time window of 1 quarter.

Longline reweighting methodology

Longline size compositions were reweighted separately for each combination of species, size unit, and index vs regular fishery. For a given combination, the size data were filtered for the appropriate species and size unit, then separated by MFCL fishery. For index fisheries, data were filtered for the flags used in the CPUE standardisations Ducharme Barth et al. (2020), and optionally filtered for flag-fleets corresponding to a selected MFCL fishery for each region. Size samples and reported catches were aggregated to strata-level, where the definition of strata is user-defined to provide flexibility.

Strata weights for regular fisheries were then calculated using the proportion of fishery catch over a time-window of $2k-1$ quarters accounted for by each strata

$$W_{s,t} = \frac{\sum_{t-k}^{t+k} C_{s,t}}{\sum_{s} \sum_{t-k}^{t+k} C_{s,t}}$$

where $W_{s,t}$ is the strata weight for strata *s* in year-quarter *t*, and *C* is the reported catch. Strata weights for index fisheries were equivalent, but weighting by estimated relative abundance from the CPUE standardisation models instead of catch (Ducharme Barth et al., 2020).

Strata-level size compositions were raised to MFCL fishery resolution, i.e. year, quarter and fishery, by first converting from strata-level numbers by size-class to proportions by size class. The strata-level proportions by size class were then multiplied by the strata weight, and summed across strata to obtain MFCL fishery resolution proportions by size class. These MFCL fishery resolution proportions by size class were then multiplied by the total samples for the fishery and year-quarter to obtain numbers by size class. This approach implicitly scaled the effective sample size at the MFCL fishery resolution for the proportion of catch (regular fisheries) or abundance (index fisheries) accounted for by strata with samples. The MFCL fishery resolution length compositions were then filtered for year-quarters where sampled strata account for a minimum proportion of the total catch of the fishery (regular fishery) or the total abundance in the MFCL region (index fisheries), i.e. where the sum of strata weights $W_{s,t}$ from sampled strata exceeded a specified proportion. These minimum proportions are referred to throughout as the 'minimum total weighting'.

Effective samples were then rescaled appropriately, with different approaches used for different MFCL size composition likelihood components. This is described in the section 'Rescaling MFCL resolution size compositions'.

Weight compositions have generally been preferred for longline size compositions in previous bigeye and yellowfin assessments. Weight samples are considered to be more representative of the commercial Japanese longline fleet, as historically the majority of Japanese length samples were collected on training vessels whereas weight samples are collected on commercial vessels (e.g.

McKechnie, 2014; Hoyle and Langley, 2011). This is an important consideration given that the majority of size samples up to the 1990s were from Japanese vessels. We note that length-based sampling of commercial Japanese vessels in the WCPO did increase from 2004 onwards (Satoh, 2019). In the last 20 years there has tended to be more widespread collection of length samples, and in many cases the coverage of length samples is greater both temporally and with respect to flag-fleets (see Appendix B). As such, we explored the use of both weight and length compositions for regular and index longline fisheries, with weight samples used in the early part of the time series, and length samples used in the latter part where necessary. The decision of whether, and when, to switch from weight samples was made on a case-by-case basis, taking account of the sampling coverage by flag-fleets, and the plausibility of the resulting reweighted size compositions. We also looked at the proportions of available length samples from JP flagged vessels, given the concerns around potential bias resulting from the use of length samples collected on training vessels. We did not consider the simultaneous use of both weight and length compositions for a given fishery given the recommendations by Ianelli et al. (2011).

Rescaling MFCL resolution size compositions

By default, the purse seine and longline reweighting procedures set the effective sample size for an MFCL fishery to be equal to the original sample size, reduced by the proportion of total catch (purse seine and regular longline fisheries) or abundance (index longline fisheries) from strata with size samples. We used two approaches to rescaling these effective sample sizes: one for use with MFCL's default size composition likelihood; and one for use with the self-scaling multinomial likelihood. When using the self-scaling multinomial likelihood, we set the effective sample size to be equal to the original sample size for purse seine fisheries, and half of the original sample size for longline fisheries. The 50 % reduction for longline fisheries was implemented to account for use of the same size samples in size compositions for both regular and index fisheries (see discussion in Hamer and Pilling (2020)). Effective sample sizes for the default size composition likelihood were set using an approach based on McKechnie (2014). This adjustment process is implemented within MFCL. Observed sample sizes are scaled downwards by a user-specified factor, typically in the range of 10 to 200, reduced by 50 % for longline fisheries if there are both regular and index fisheries, and then capped at a user-specified maximum number.

Results

Visual investigation of initial longline and purse seine reweighting runs indicated a number of instances where strata with low levels of samples and high strata weights resulted in implausible MFCL resolution size compositions. A minimum species and strata-specific sample size of 30 improved the reweighted size compositions whilst excluding relatively few samples, e.g. less than 0.5 % of total samples for purse seine length compositions. A minimum species and strata specific sample size of 30 was implemented for all reweighted size compositions.

Reweighted purse seine length compositions are provided in Figure 1 to Figure 8. The reweighted length compositions had less noise than unweighted size comps, mainly due to the various data filters applied. The reweighted length compositions demonstrate apparent cohort progression in a range of fisheries.

McKechnie (2014) used a time-window of 11 quarters for calculation of regular longline fisheries strata weights. Visual examination of initial reweighting runs for longline fisheries did not provide support

for changing the time-window for strata weights, and so we used a time-window of 11 quarters for both regular and index fisheries size compositions.

We tested a range of strata definitions for regular longline fishery compositions, including spatial stratification (at a 10 x 20 resolution), stratification by flag-fleet, and stratification both spatially and by flag-fleet. We used spatial stratification to generate reweighted size compositions for the regular fisheries, as used in the 2018 South Pacific albacore assessment (Tremblay-Boyer et al, 2018). Spatial stratification is logically coherent with the sharing of a selectivity function for flag-fleets within a MFCL fishery; as a result, variation in size compositions in catches should result from spatial variation in the underlying population, rather than differences in selectivity between flag-fleets. Whilst this is unlikely to be true, there were insufficient size data to use stratification both spatially and by flag-fleet. We note that stratification by flag-fleet also gave similar reweighted size compositions to spatial stratification.

The choice of minimum total weighting represented a compromise between attempting to remove temporal variation in sizes as a result of limited and unbalanced sampling, whilst attempting to minimise excessive filtering of size compositions and so preserve sample sizes (e.g. McKechnie, 2014). Comparison of different minimum total weightings suggested that a lower limit of 0.3 was appropriate for regular longline fisheries and for purse seine fisheries. However, for some index fisheries a lower limit of 0.3 resulted in excessive removal of size compositions, e.g. regions 5 and 6 for bigeye, and a lower limit of 0.1 was selected.

McKechnie (2014) restricted weight samples for 'all-flag' fisheries to those from JP vessels, and then used JP length samples from 1990 onwards for region 4, and used weight samples from all flags for regions 5 and 6 from 1995 onwards when weight samples from JP vessels were more limited. Here we used all available weight samples for each fishery in the early period. In practise, this does not impact the reweighted size compositions due to the paucity of size samples from other fleets before 2000 (Appendix B).

The size units for the recommended reweighted regular longline fishery compositions were:

- **Region 1** (fishery 1), **region 2** (fishery 2), **region 3** fishery 4 'all flags' and fishery 5 'offshore', **region 7** fishery 6 'offshore' and fishery 7 'all-flags', and **region 8** (fishery 8) - weight compositions throughout;
- **Region 4** (fishery 9) - weight compositions through to 2003, followed by length compositions;
- **Region 5** (fishery 11) - weight compositions through to 1999 and 1994 for bigeye and yellowfin respectively, followed by length compositions;
- **Region 6** (fishery 12) – weight compositions through to 1999, followed by length compositions.

There were insufficient size samples to generate regular fishery size compositions for region 9 fishery 29 ('all-flags'), though the fishery accounted for relatively low catches. For index fisheries, we used the size units as described above for the regular fisheries. We also generated index fishery compositions for region 9, using weight composition data from Australian fleets. Reweighted size compositions for regular fisheries are included in Figure 9 to Figure 18. The temporal coverage in reweighted size compositions varies between fisheries and regions as a result of the availability and coverage of size samples. The availability of weight samples in regions 5 and 6 is particularly patchy (Figure 14 and Figure 15). We note that the reweighted size compositions for index and regular longline fisheries are broadly comparable to each other, and to the unweighted size compositions. Switching from weight to length compositions may introduce a step-wise temporal change in apparent

size compositions if there is conflict between the two datasets. As such, we also generated weight only compositions for both regular and index longline fisheries.

Index fisheries are intended to allow size compositions to inform temporal and spatial variation in population abundance and size, with regular fisheries allowing catch to be removed from the population at the appropriate size (Tremblay-Boyer et al, 2019). As such, for index fisheries it would be advisable to filter data for a single MFCL fishery in each region, to prevent changes in sampling between MFCL fisheries resulting in apparent shifts in size compositions in the underlying population. For regions 1 to 8, we filtered index fishery data for flag-fleets in the 'all flag' fisheries. For region 9 we filtered size samples for Australia, which account for the majority of size samples. There was also interest in generating index fishery size compositions using all available samples from flags used in the CPUE standardisations (e.g. including off-shore samples in regions 3 and 7). The resulting reweighted size compositions are included in Appendix C. The index fishery size compositions for regions 3 and 5 were relatively consistent regardless of whether size samples were filtered for fleets included in the 'all-flags' fisheries. Including samples from US fleets in region 2 resulted in more stable size compositions from 2000 onwards for both bigeye and yellowfin (i.e. comparing Figure 20 and Figure 49). Including samples from off-shore fleets in region 7 resulted in an increase in average sizes of both yellowfin and bigeye in the mid-2000s (i.e. comparing Figure 25 and Figure 52), driven by an increase in the size of fish in the off-shore fishery (Figure 17).

Recommendations

- Preference should be given to using length samples for longline size compositions for the 'all-flags' fisheries in region 4 (fishery 9), region 5 (fishery 11) and region 6 (fishery 12) based on availability of samples and a visual examination of the plausibility of the resulting size comps.
- Weight samples should be preferred for fishery 2 ('all-flags, region 2) despite the relatively low coverage of weight samples since the mid-2000s, given the high proportion of length samples from JP vessels. The use of these length samples may result in biased size composition estimates given the collection of length samples on JP training vessels.
- For 'all-flags 'longline fisheries in regions 4, 5 and 6 (fisheries 9, 11 and 12) there may be large discrepancies between the end of the time-series of weight compositions and the start of the length compositions. If this becomes apparent in the assessments, then the use of weight compositions throughout should be considered for these fisheries.
- Preference should be given to filtering longline index fisheries for size samples from a single MFCL fishery. However we note that in the case of region 2, the reweighted size compositions have better temporal coverage and more plausible temporal trends from 2000 onwards with inclusion of samples from the US fishery 3.
- The recommended minimum total weightings are 0.3 for regular longline fisheries and purse seine fisheries, and 0.1 for index longline fisheries. As proposed by others (e.g. McKechnie, 2014), the sensitivity of the assessment model to the level of the minimum total weighting limit should be assessed.

Acknowledgments

The analyses reported in this Information Paper contribute to meeting the current objectives of WCPFC-SC Project 60. T. Peatman's contribution was supported by the European Union's "Pacific-European Union Marine Partnership Programme". The authors would like to thank S. Nicol, G. Pilling and J. Hampton for their constructive comments on an earlier version of the report, and S. McKechnie for his advice on size compositions.

References

Abascal, F., T. Lawson, P. Williams (2014). Analysis of tropical purse seine length data for skipjack, bigeye and yellowfin tunas. WCPFC-SC10-2014/SA-IP-05.

Ducharme Barth, N., M. Vincent, T. Vidal. (2020). Analysis of Pacific-wide operational longline dataset for bigeye and yellowfin tuna catch-per-unit-effort (CPUE). WCPFC-SC16-2020/SA-IP-07.

Hamer, P., G. Pilling. (2020). Report on 2020 pre-assessment workshop. WCPFC-SC16-2020/SA-IP-02.

Hoyle, S.D., A.D. Langley (2011). Spatial size data stratification for length-based stock assessments. WCPFC-SC7-2011/SA-IP-09.

Ianelli J., M. Maunder, A. Punt (2011). Independent review of 2011 WCPO Bigeye Tuna assessment. WCPFC-SC8-2012/SA-WP-01.

McKechnie, S. (2014). Analysis of longline size frequency data for bigeye and yellowfin tunas in the WCPO. WCPFC-SC10-2014/SA-IP-04.

Peatman T., S. Fukofuka, T. Park, P. Williams, J. Hampton and N. Smith (2019) Better purse seine catch composition estimates: progress on the Project 60 work plan. WCPFC-SC15-2019/ST-WP-02.

Satoh K. (2019). Longline data – Japanese size-composition data. Presentation at the 2nd Review of the stock assessment of yellowfin tuna in the Eastern Pacific Ocean. La Jolla, California, 2 – 6 December 2019. Accessed at: https://www.iattc.org/Meetings/Meetings2019/YFT-02/_English/YFT-02-PRES_Longline%20data%20Japanese%20size-composition%20data.pdf.

Scott, R.D., S. McKechnie (2015) Analysis of Longline Length Frequency Compositions for South Pacific Albacore. WCPFC-SC11-2015/SA-IP-06.

Tremblay-Boyer, L., S. McKechnie, G. Pilling (2018). Background Analysis for the 2018 stock assessment of South Pacific albacore tuna. WCPFC-SC14-2018/ SA-IP-07.

Tables

Table 1 Length weight parameters by species.

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

Figures

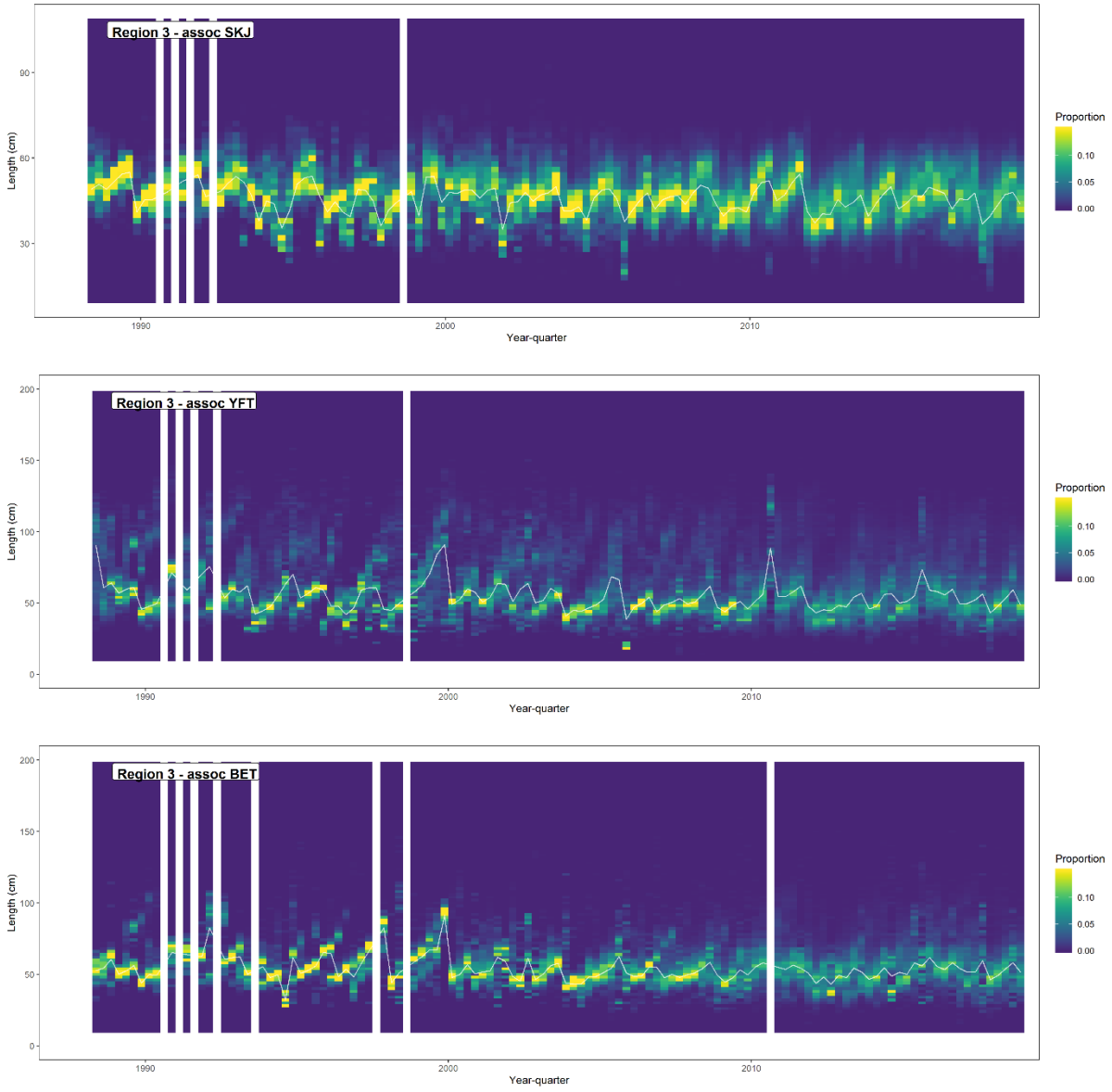


Figure 1 Reweighted length compositions for skipjack (top), yellowfin (middle) and bigeye (bottom) purse seine fishery 13 (associated, region 3), with a minimum total weighting of 0.3. The median length class is provided as a solid white line.

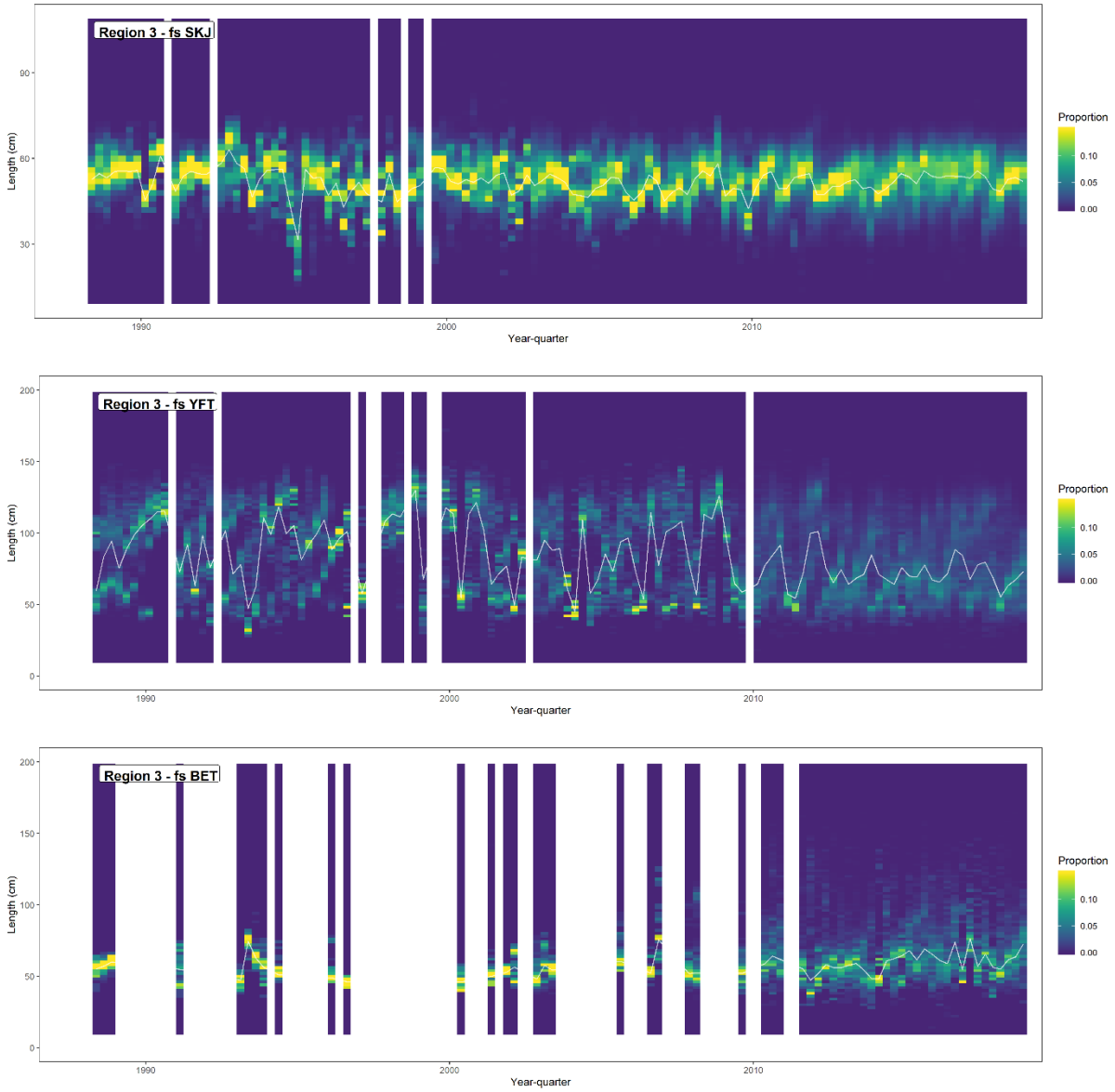


Figure 2 Reweighted length compositions for skipjack (top), yellowfin (middle) and bigeye (bottom) purse seine fishery 14 (unassociated, region 3), with a minimum total weighting of 0.3. The median length class is provided as a solid white line.

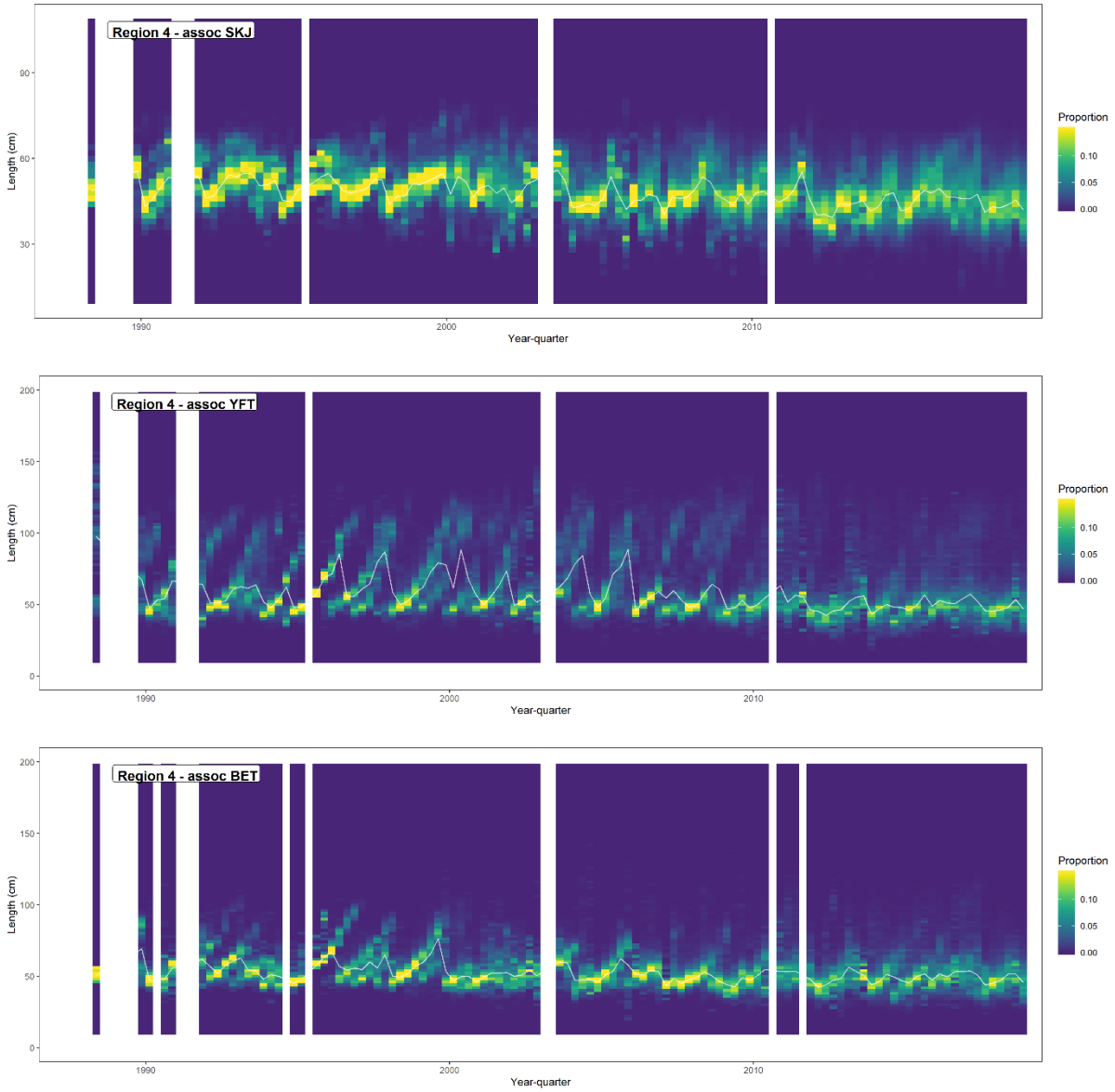


Figure 3 Reweighted length compositions for skipjack (top), yellowfin (middle) and bigeye (bottom) purse seine fishery 15 (associated, region 4), with a minimum total weighting of 0.3. The median length class is provided as a solid white line.

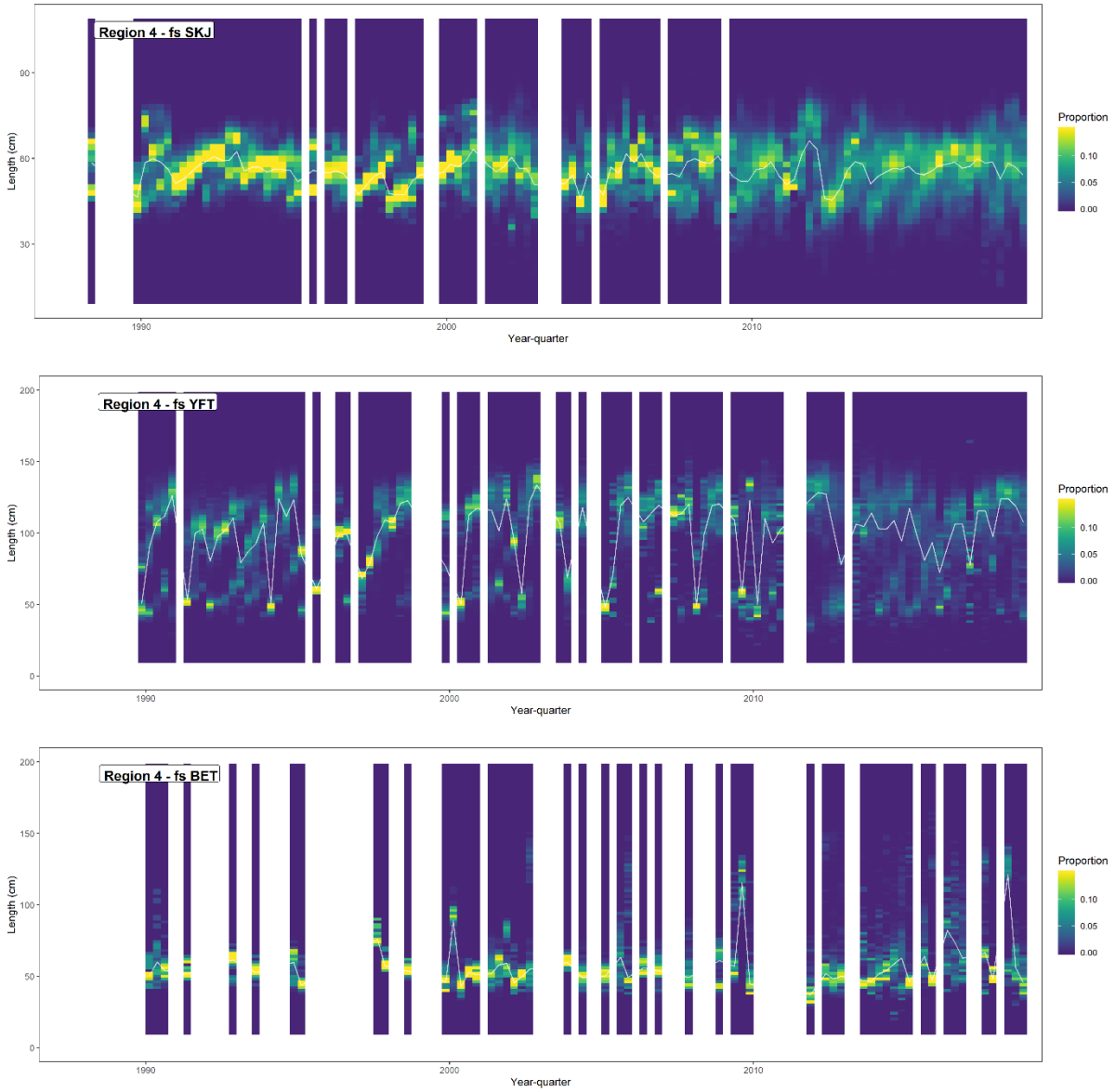


Figure 4 Reweighted length compositions for skipjack (top), yellowfin (middle) and bigeye (bottom) purse seine fishery 16 (unassociated, region 4), with a minimum total weighting of 0.3. The median length class is provided as a solid white line.

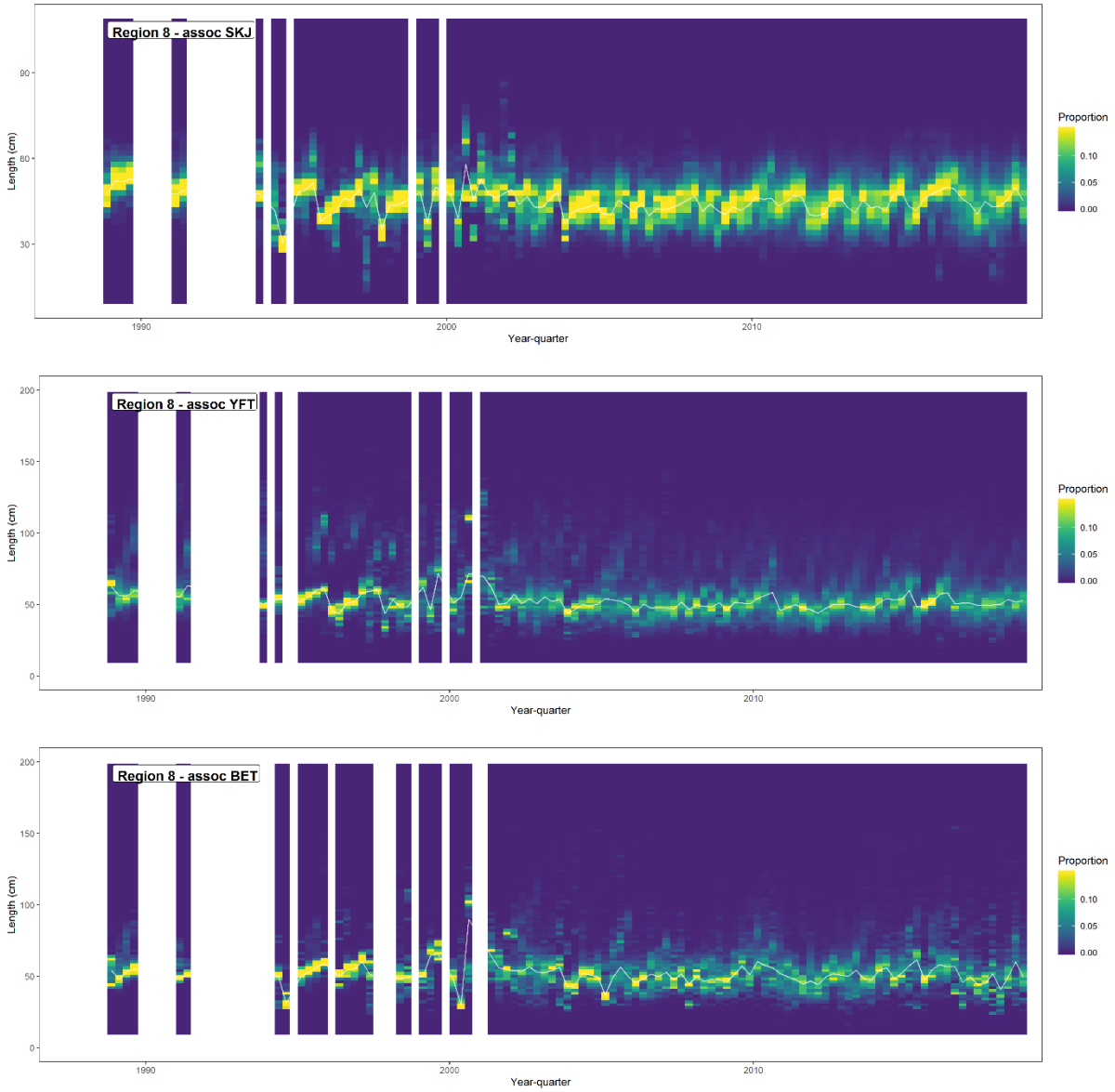


Figure 5 Reweighted length compositions for skipjack (top), yellowfin (middle) and bigeye (bottom) purse seine fishery 25 (associated, region 8), with a minimum total weighting of 0.3. The median length class is provided as a solid white line.

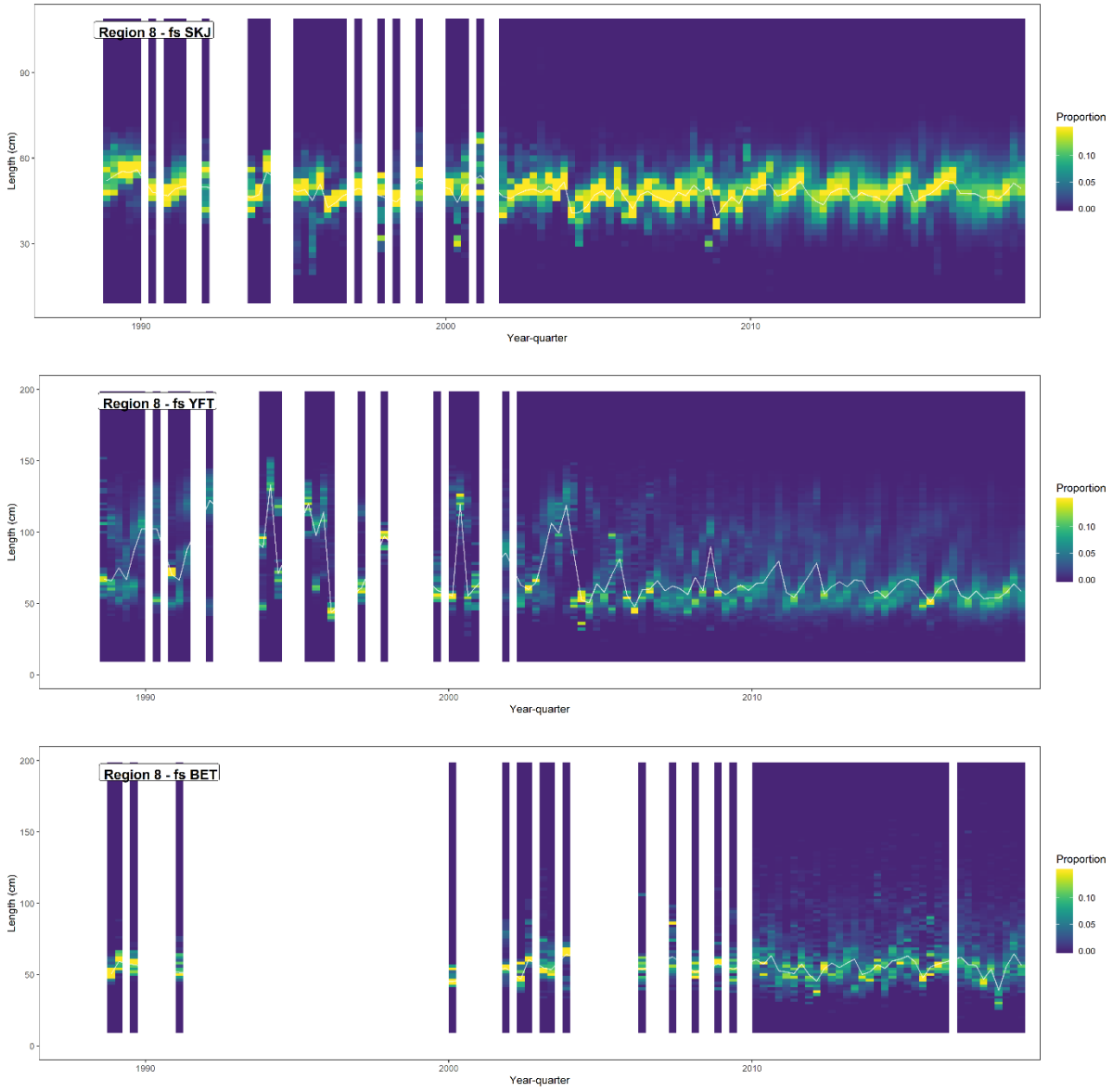


Figure 6 Reweighted length compositions for skipjack (top), yellowfin (middle) and bigeye (bottom) purse seine fishery 26 (unassociated, region 8), with a minimum total weighting of 0.3. The median length class is provided as a solid white line.

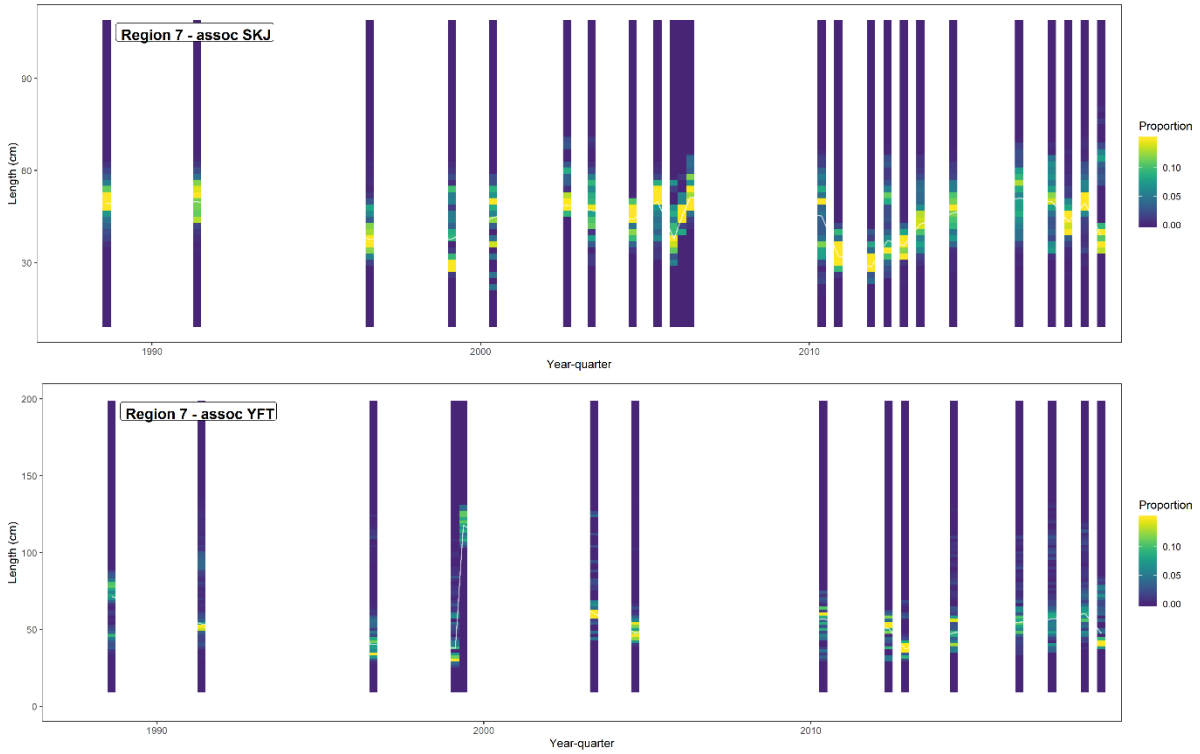


Figure 7 Reweighted length compositions for skipjack (top) and yellowfin (bottom) purse seine fishery 30 (associated, region 7), with a minimum total weighting of 0.3. Reweighted length compositions for bigeye were available for one year-quarter and are not included. The median length class is provided as a solid white line.

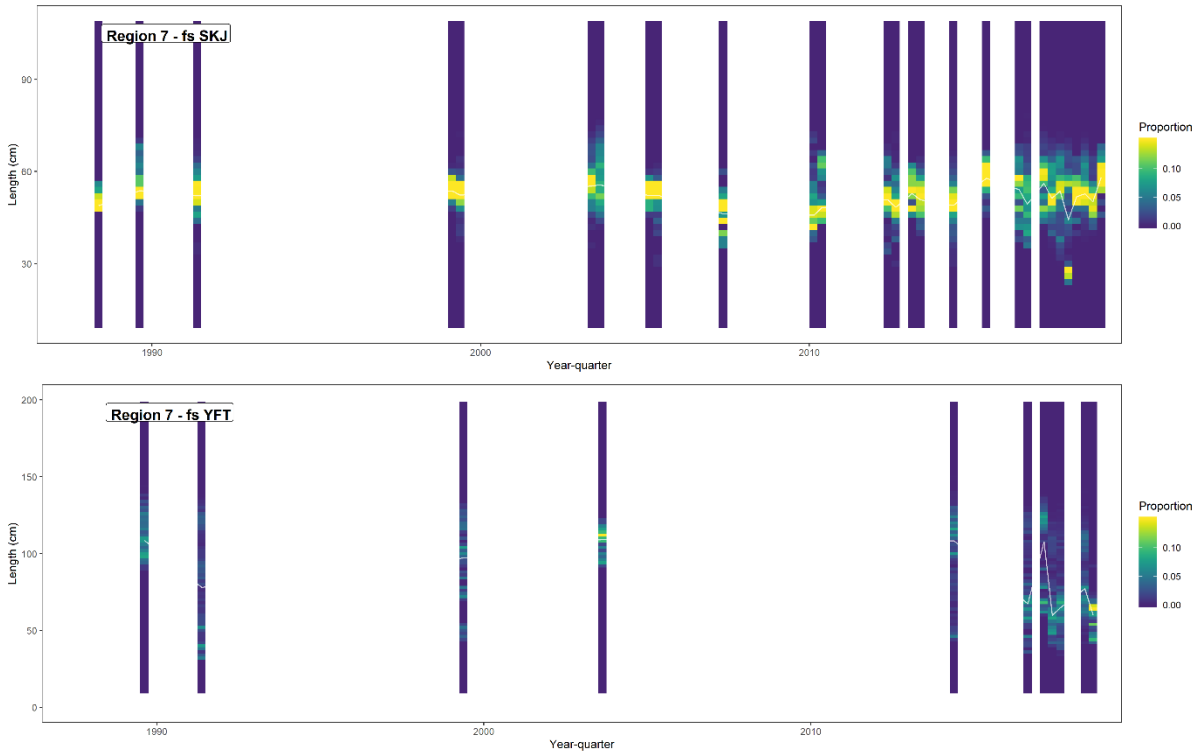
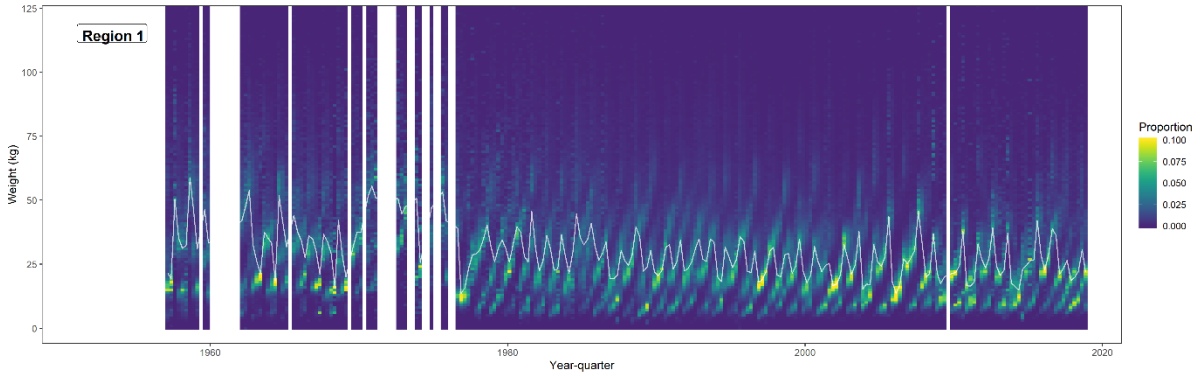


Figure 8 Reweighted length compositions for skipjack (top), yellowfin (bottom) purse seine fishery 31 (unassociated, region 7), with a minimum total weighting of 0.3. Reweighted length compositions for bigeye were available for two year-quarters and are not included. The median length class is provided as a solid white line.

a) Reweighted compositions for bigeye regular fishery 1, region 1



b) Reweighted compositions for yellowfin regular fishery 1, region 1

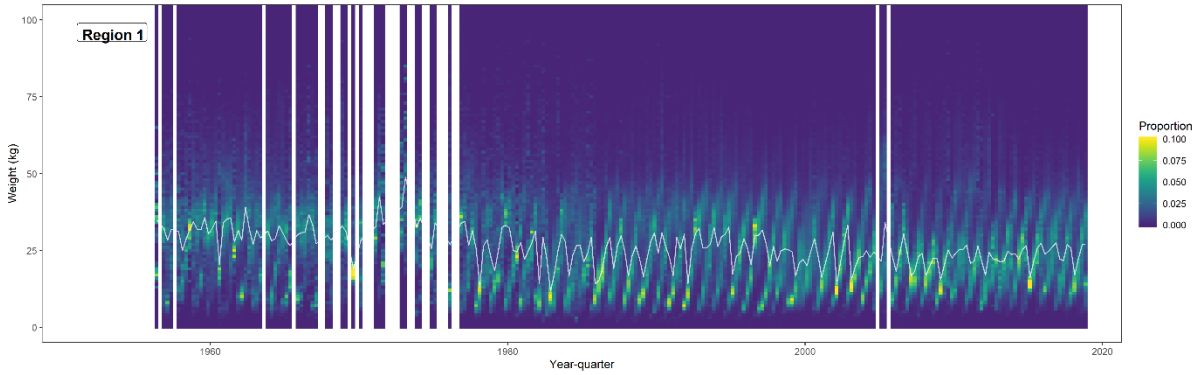
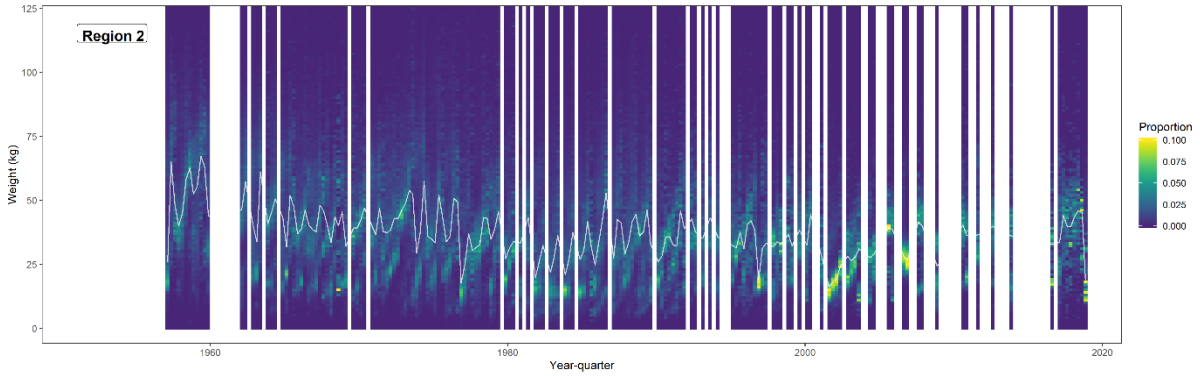


Figure 9 Reweighted weight compositions for bigeye (a) and yellowfin (b) for regular longline fishery 1 (region 1), with a minimum total weighting of 0.3. The median size class is provided as a solid white line.

a) Reweighted compositions for bigeye regular fishery 2, region 2



b) Reweighted weight compositions for yellowfin regular fishery 2, region 2

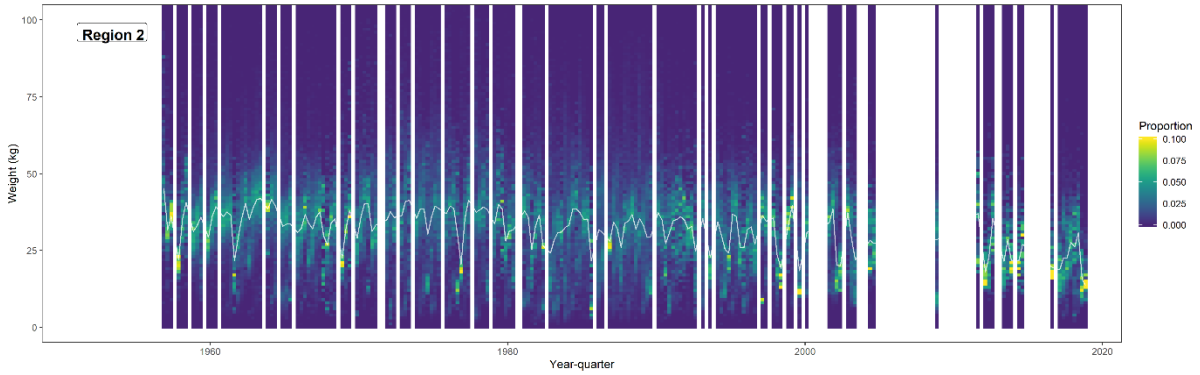
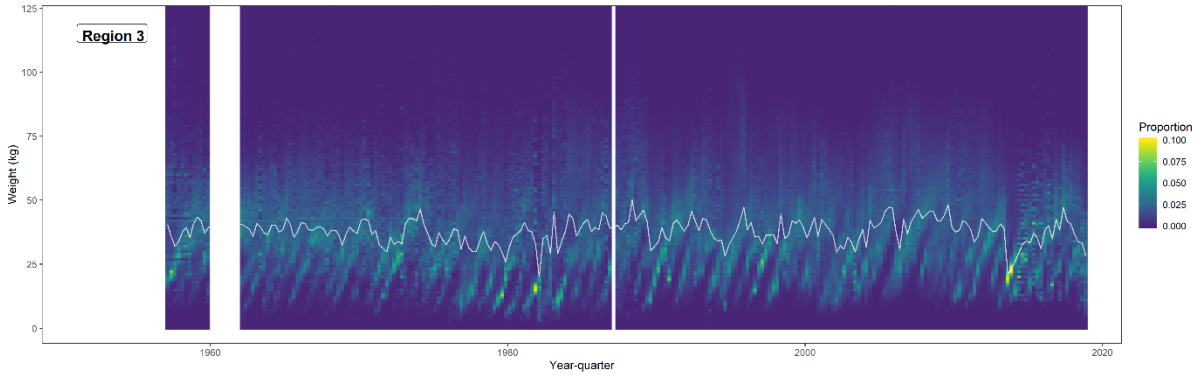


Figure 10 Reweighted weight compositions for (a) bigeye and (b) yellowfin for regular longline fishery 2 (region 2), with a minimum total weighting of 0.3. The median size class is provided as a solid white line.

a) Reweighted compositions for bigeye regular fishery 4, region 3



b) Reweighted compositions for yellowfin regular fishery 4, region 3

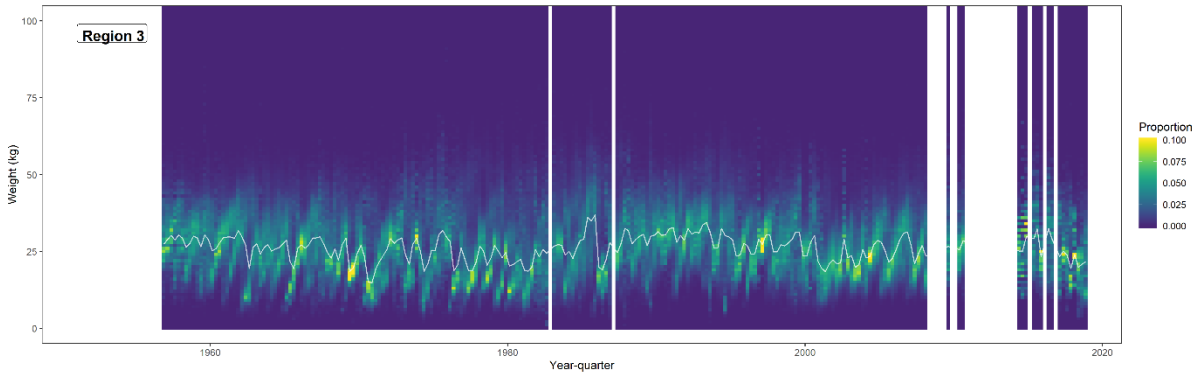
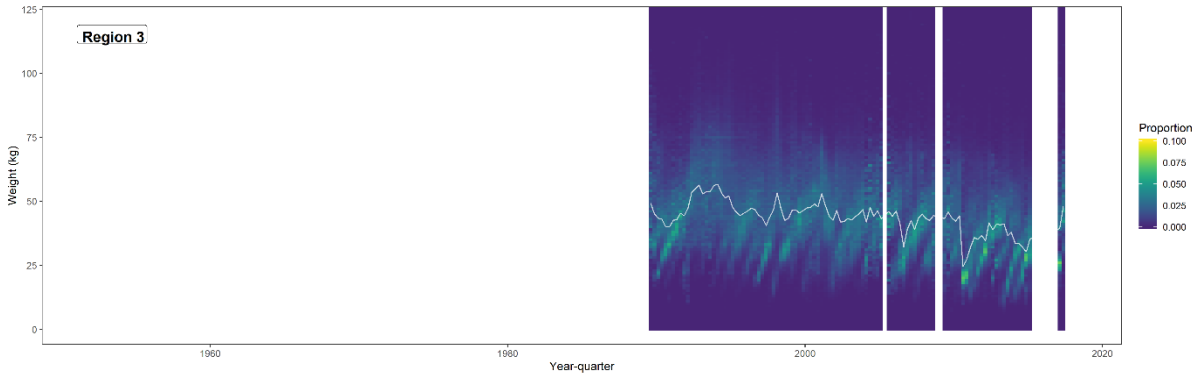


Figure 11 Reweighted weight compositions for bigeye (a) and yellowfin (b) for regular longline fishery 4 (region 3, 'all-flags'), with a minimum total weighting of 0.3. The median size class is provided as a solid white line.

a) Reweighted compositions for bigeye regular fishery 5, region 3



b) Reweighted compositions for yellowfin regular fishery 5, region 3

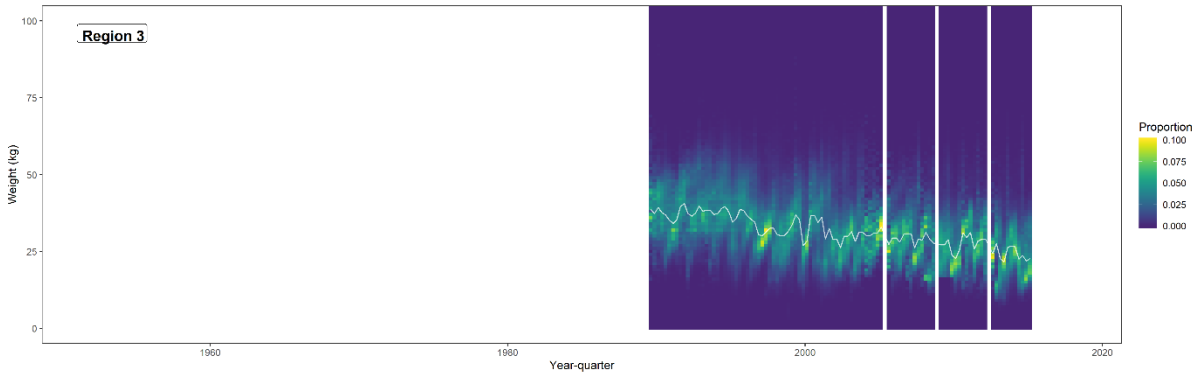
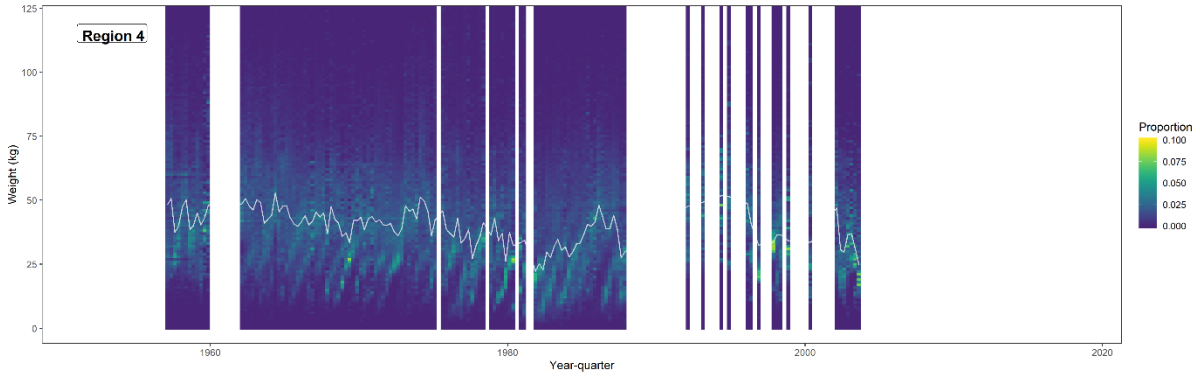
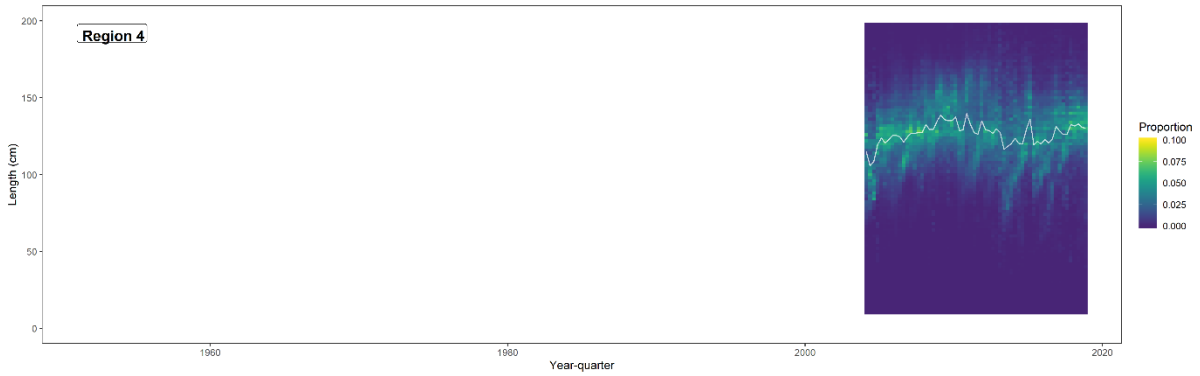


Figure 12 Reweighted weight compositions for bigeye (a) and yellowfin (b) for regular longline fishery 5 (region 3, 'offshore'), with a minimum total weighting of 0.3. The median size class is provided as a solid white line.

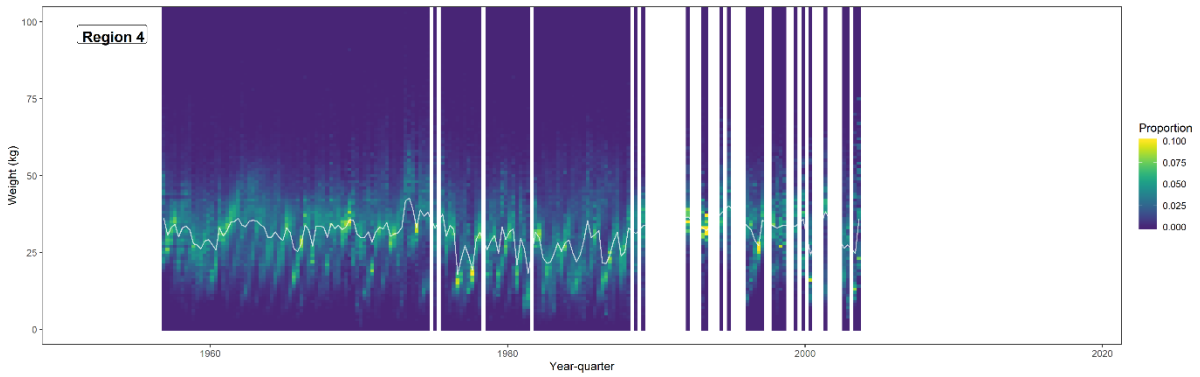
a) Reweighted weight compositions for bigeye regular fishery 9, region 4



b) Reweighted length compositions for bigeye regular fishery 9, region 4



c) Reweighted weight compositions for yellowfin regular fishery 9, region 4



d) Reweighted length compositions for yellowfin regular fishery 9, region 4

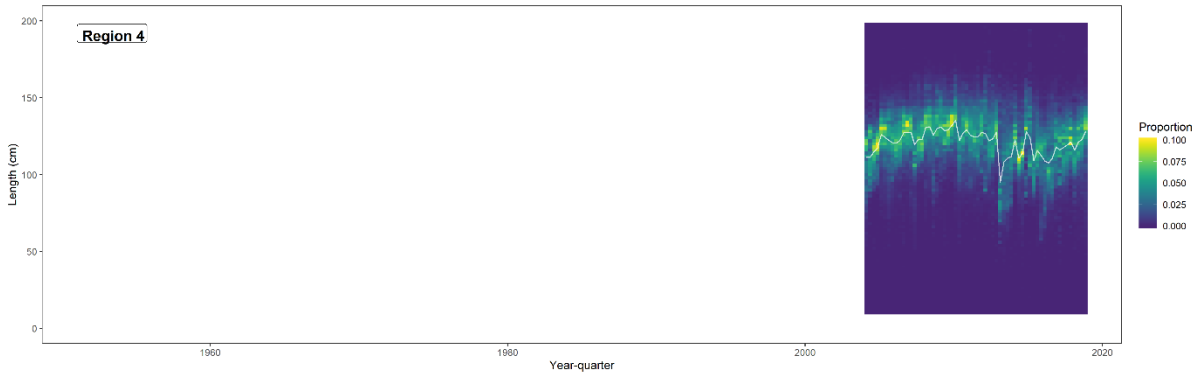
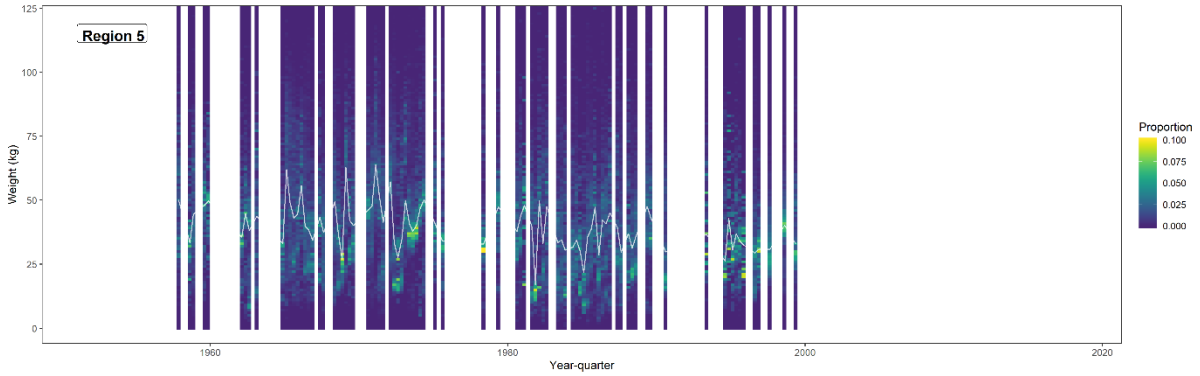
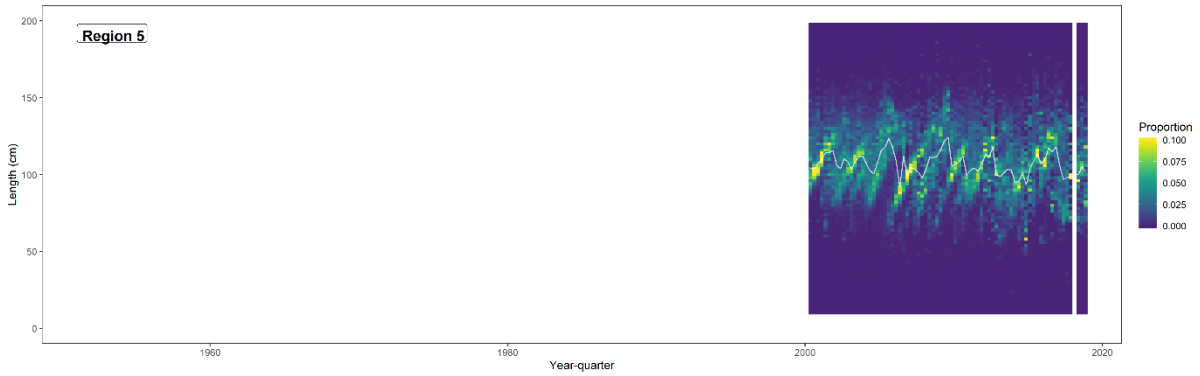


Figure 13 Reweighted weight (a) and length (b) compositions for bigeye and reweighted weight (c) compositions and length (d) compositions for yellowfin for regular longline fishery 9 (region 4), with a minimum total weighting of 0.3. The median size class is provided as a solid white line.

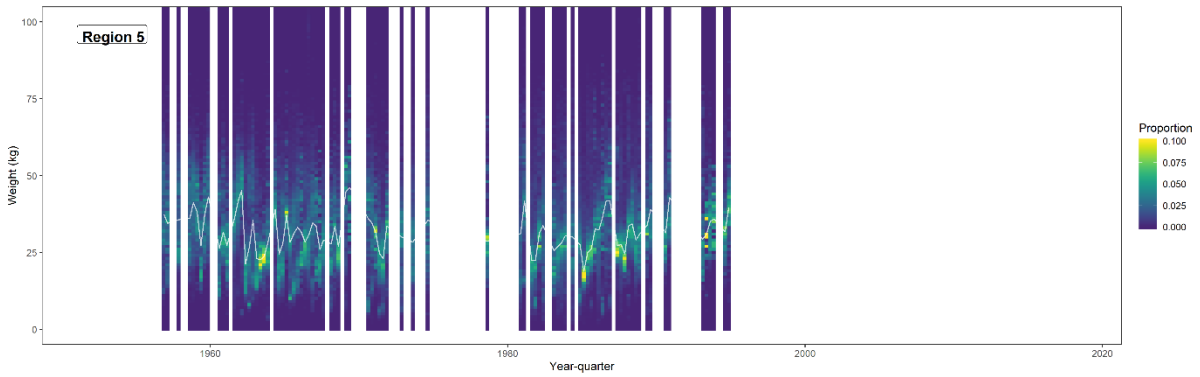
a) Reweighted weight compositions for bigeye regular fishery 11, region 5



b) Reweighted length compositions for bigeye regular fishery 11, region 5



c) Reweighted weight compositions for yellowfin regular fishery 11, region 5



d) Reweighted length compositions for yellowfin regular fishery 11, region 5

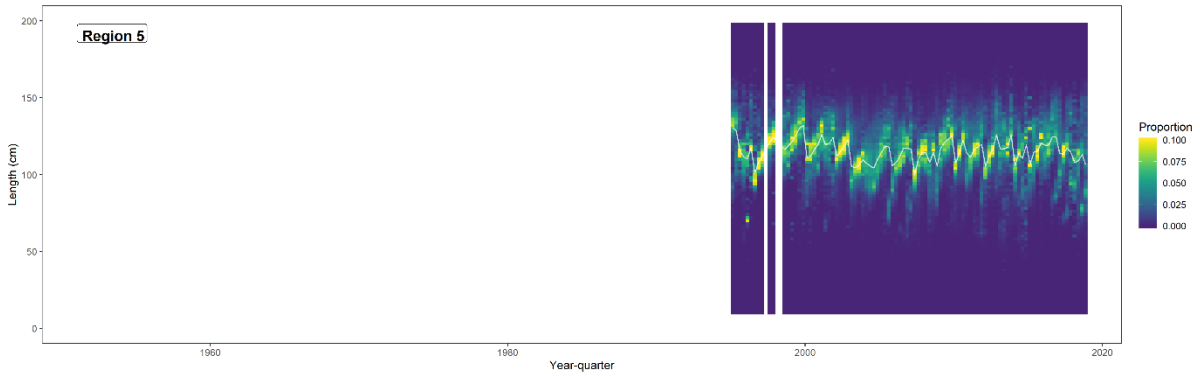
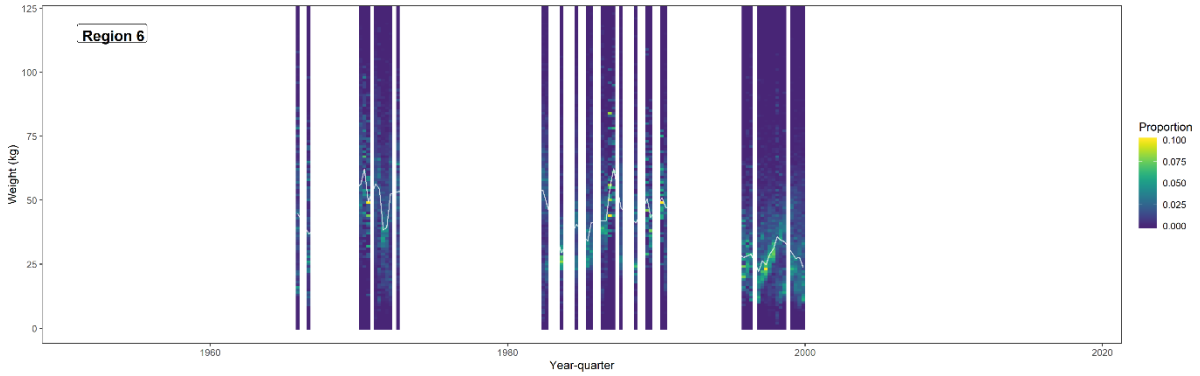
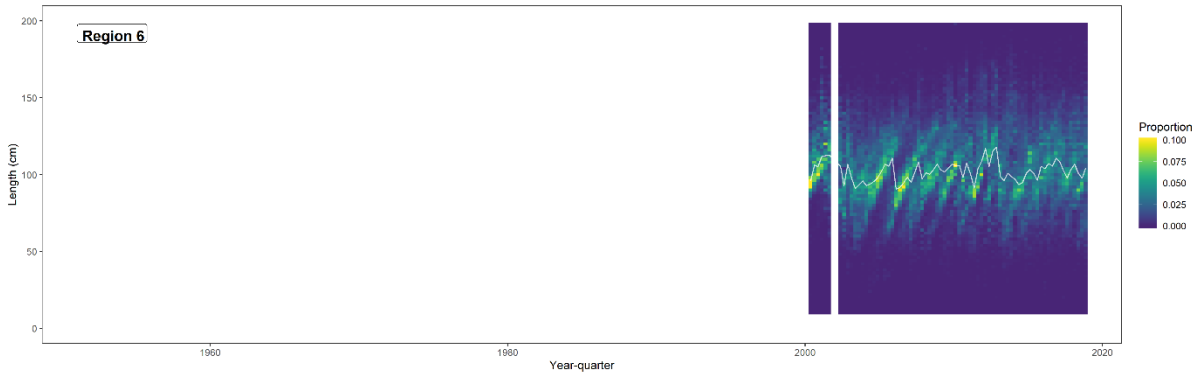


Figure 14 Reweighted weight (a) and length (b) compositions for bigeye and reweighted weight (c) compositions and length (d) compositions for yellowfin for regular longline fishery 11 (region 5), with a minimum total weighting of 0.3. The median size class is provided as a solid white line.

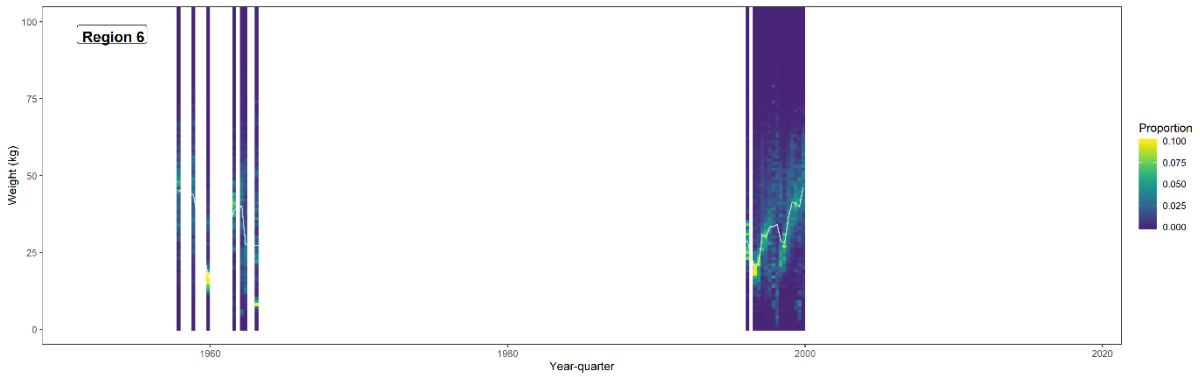
a) Reweighted weight compositions for bigeye regular fishery 12, region 6



b) Reweighted length compositions for bigeye regular fishery 12, region 6



c) Reweighted weight compositions for yellowfin regular fishery 12, region 6



d) Reweighted length compositions for yellowfin regular fishery 12, region 6

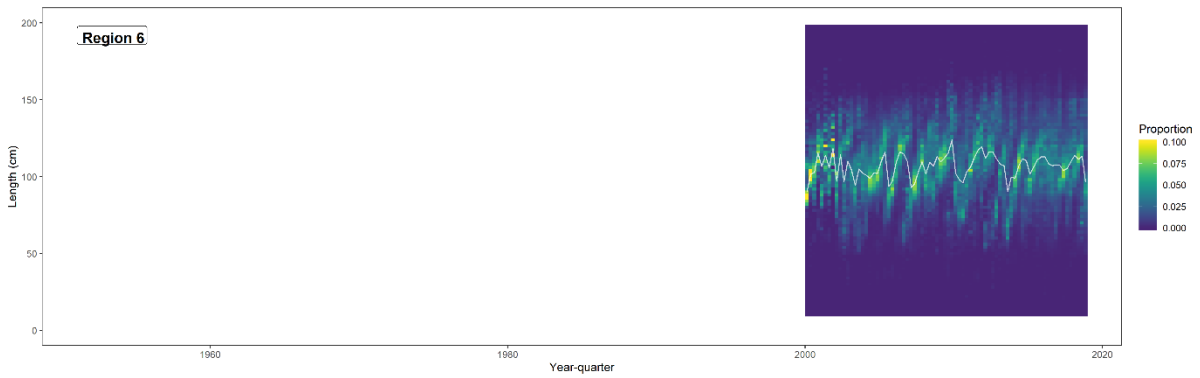
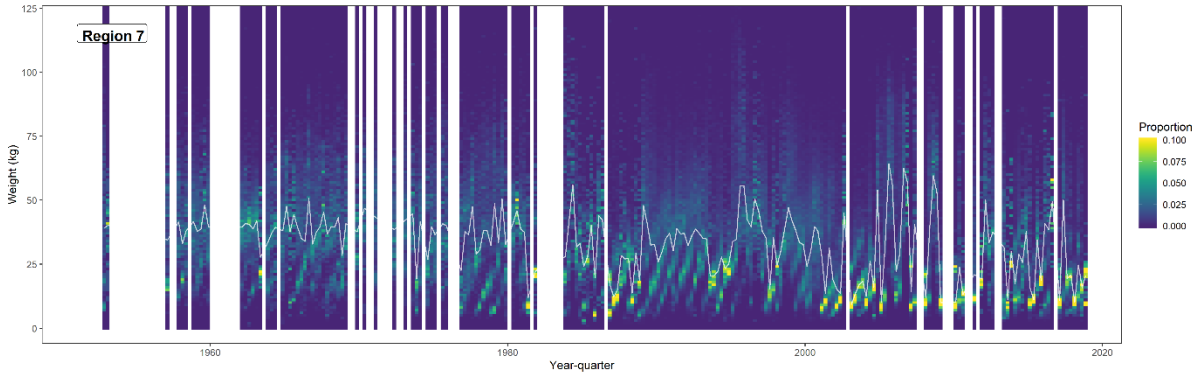


Figure 15 Reweighted weight (a) and length (b) compositions for bigeye and reweighted weight (c) compositions and length (d) compositions for yellowfin for regular longline fishery 12 (region 6), with a minimum total weighting of 0.3. The median size class is provided as a solid white line.

a) Reweighted compositions for bigeye regular fishery 7, region 7



b) Reweighted compositions for yellowfin regular fishery 7, region 7

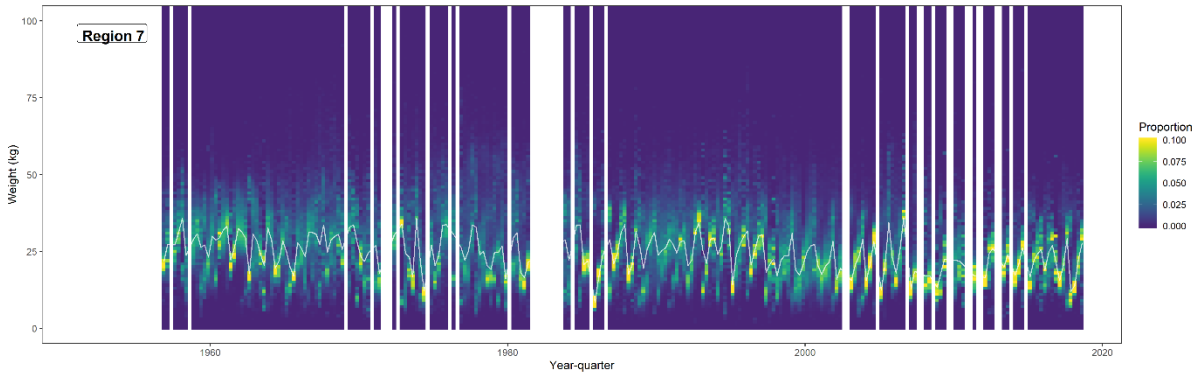
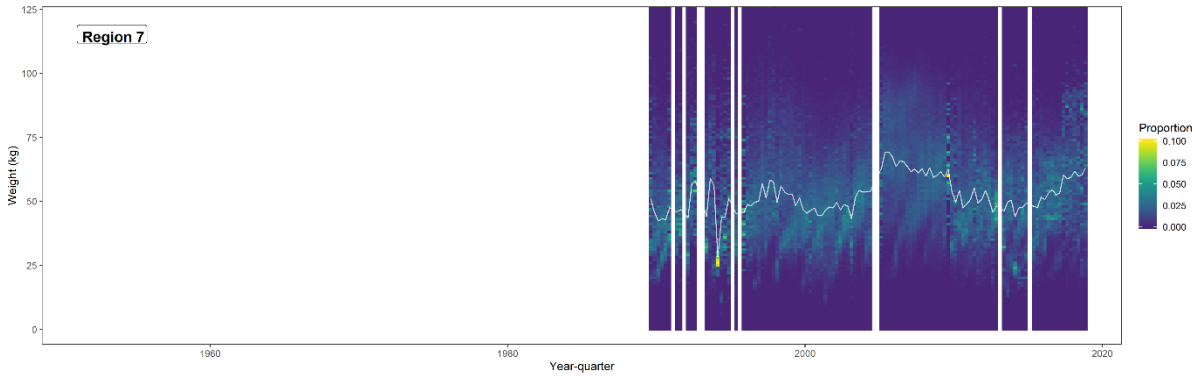


Figure 16 Reweighted weight compositions for bigeye (a) and yellowfin (b) for regular longline fishery 7 (region 7, 'all-flags'), with a minimum total weighting of 0.3. The median size class is provided as a solid white line.

a) Reweighted compositions for bigeye regular fishery 6, region 7



b) Reweighted compositions for yellowfin regular fishery 6, region 7

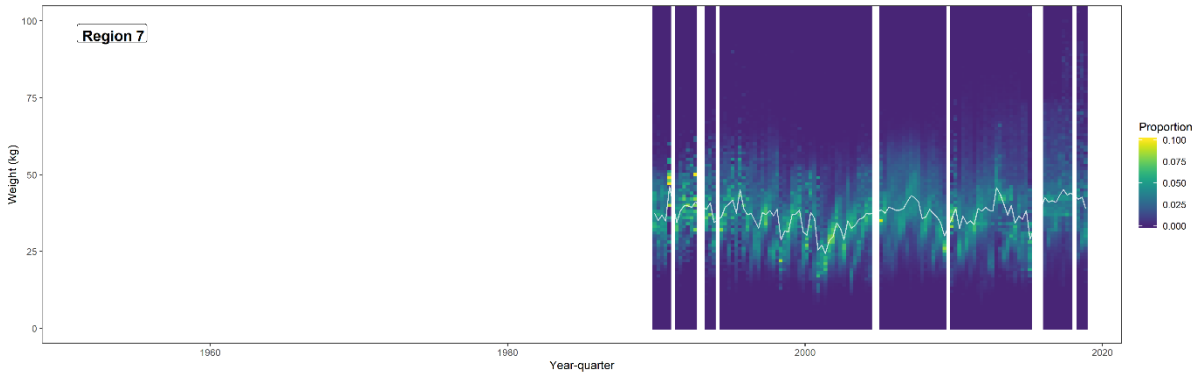
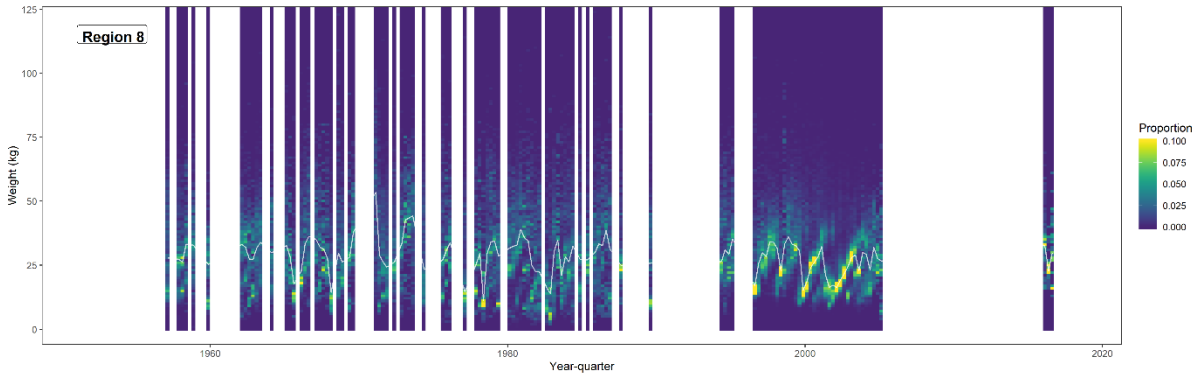


Figure 17 Reweighted weight compositions for bigeye (a) and yellowfin (b) for regular longline fishery 6 (region 7, 'offshore'), with a minimum total weighting of 0.3. The median size class is provided as a solid white line.

a) Reweighted compositions for bigeye regular fishery 8, region 8



b) Reweighted compositions for yellowfin regular fishery 8, region 8

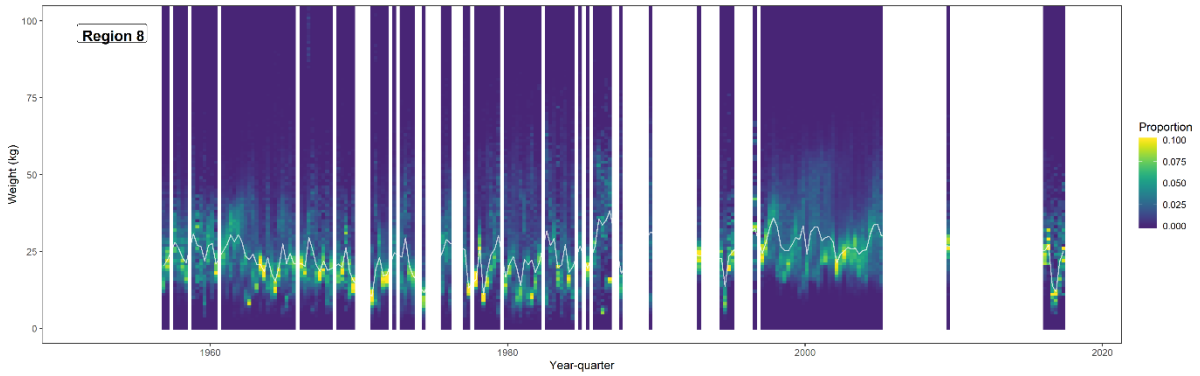
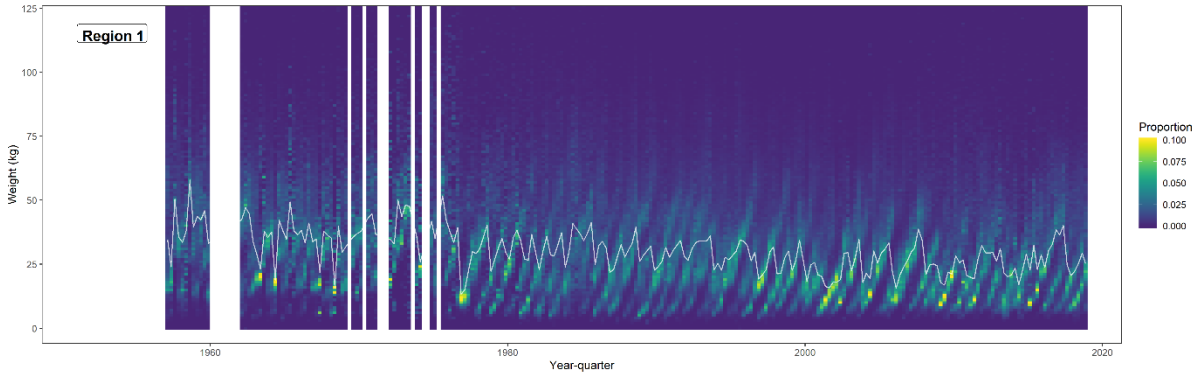


Figure 18 Reweighted weight compositions for bigeye (a) and yellowfin (b) for regular longline fishery 8 (region 8), with a minimum total weighting of 0.3. The median size class is provided as a solid white line.

a) Reweighted compositions for the bigeye index in region 1



b) Reweighted compositions for the yellowfin index fishery in region 1

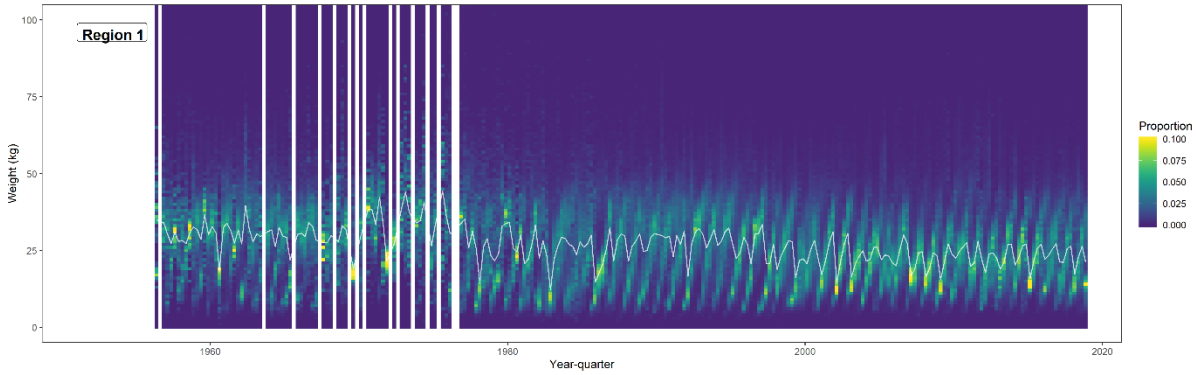
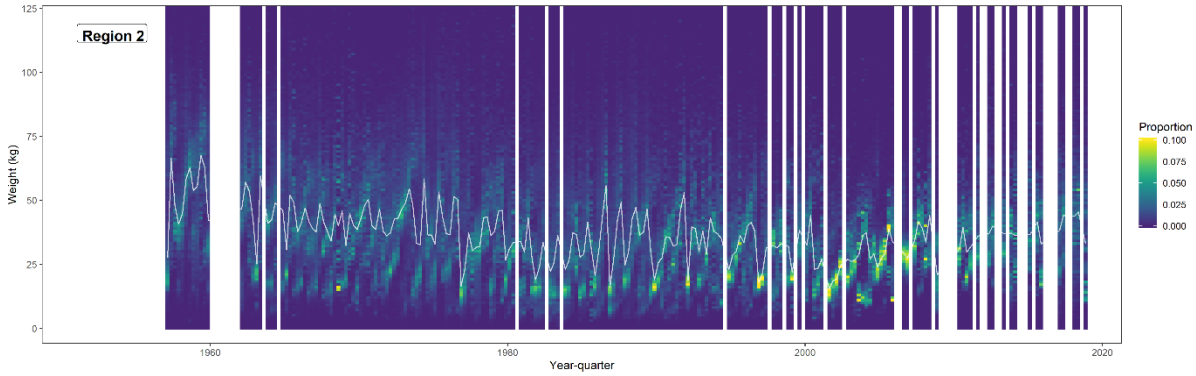


Figure 19 Reweighted weight compositions for bigeye (a) and yellowfin (b) for the index longline fishery in region 1, with a minimum total weighting of 0.1. The median size class is provided as a solid white line.

a) Reweighted compositions for the bigeye index fishery in region 2



c) Reweighted weight compositions for the yellowfin index fishery in region 2

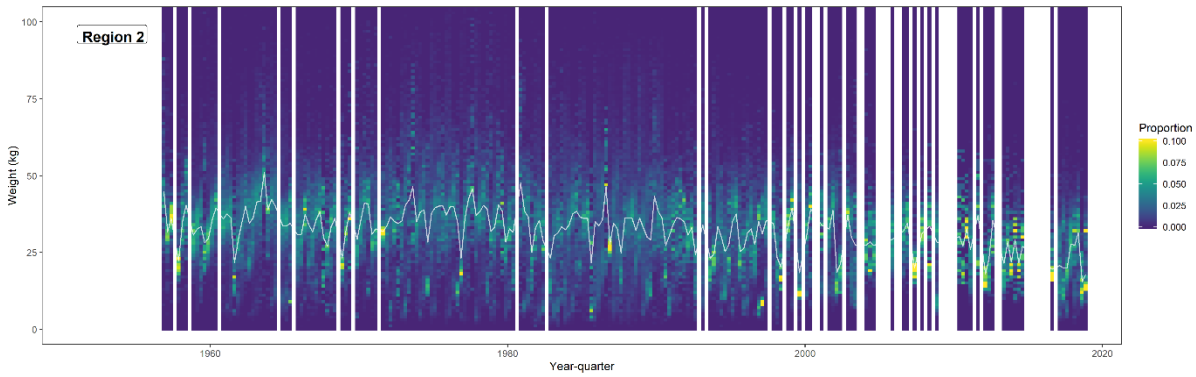
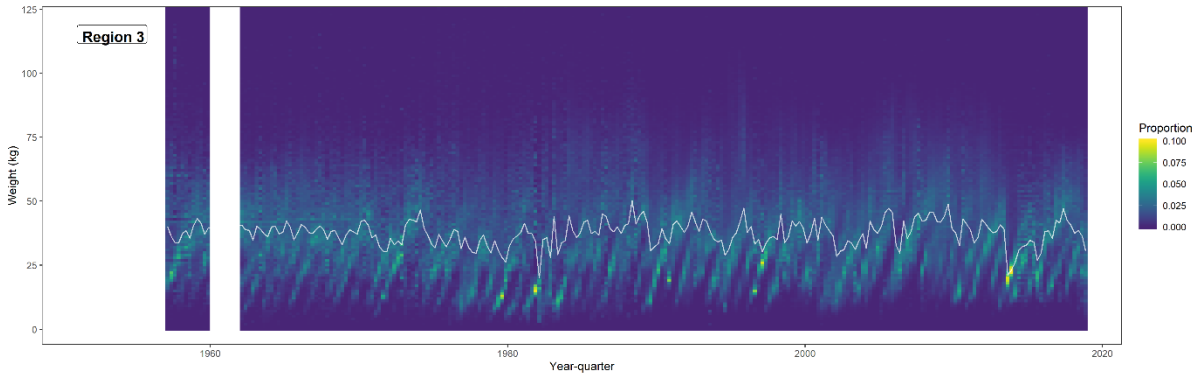


Figure 20 Reweighted weight (a) and length (b) compositions for bigeye and reweighted weight (c) compositions and length (d) compositions for yellowfin for the index fishery in region 2, with a minimum total weighting of 0.1. The median size class is provided as a solid white line.

a) Reweighted compositions for the bigeye index fishery in region 3



b) Reweighted compositions for the yellowfin index fishery in region 3

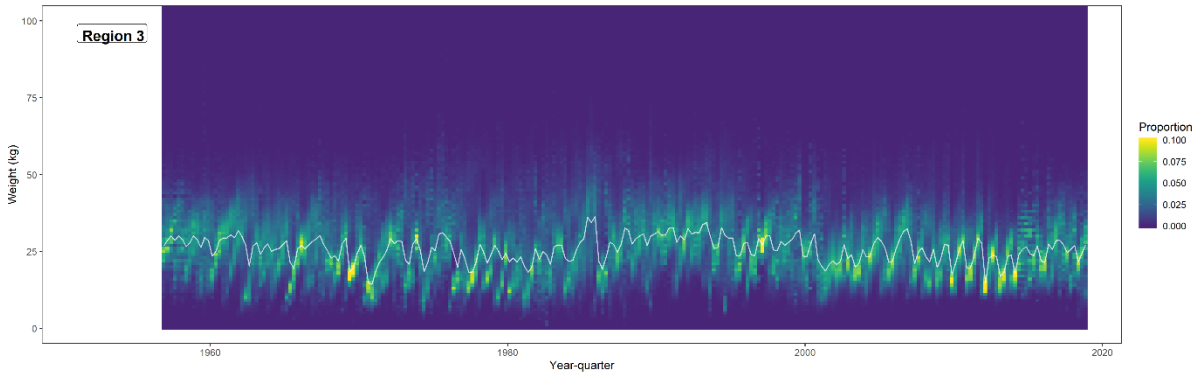
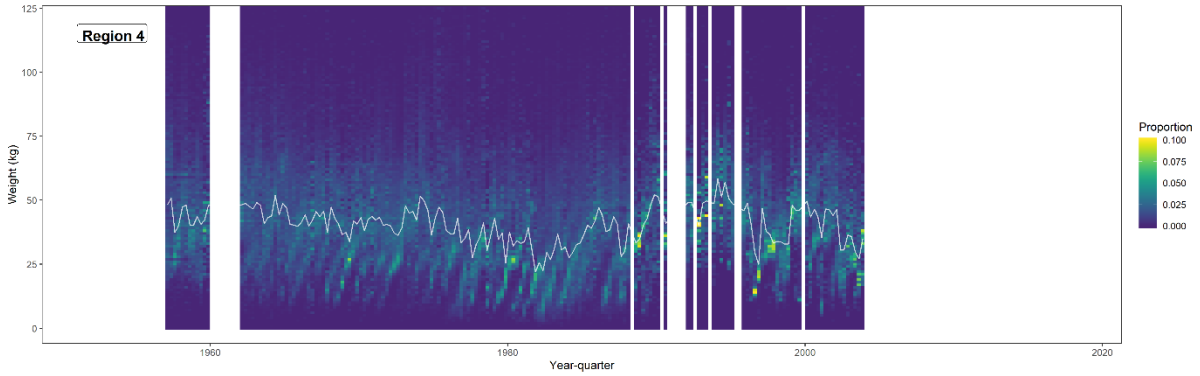
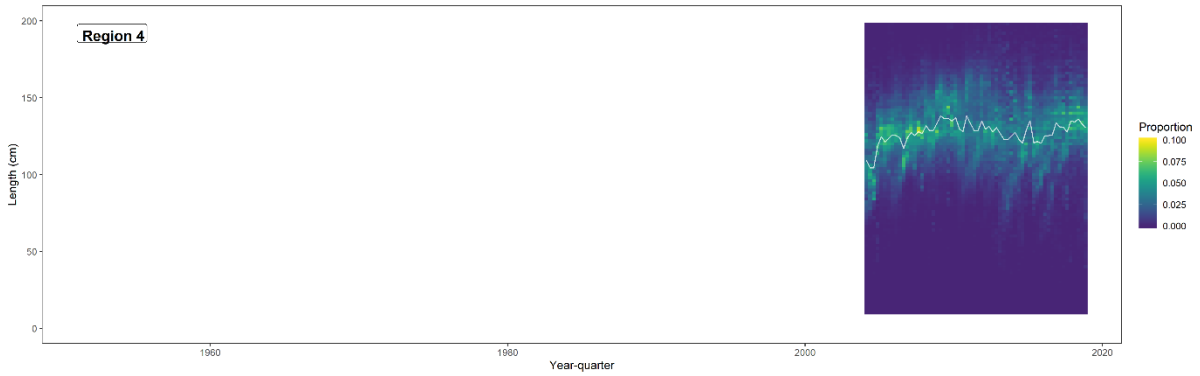


Figure 21 Reweighted weight compositions for bigeye (a) and yellowfin (b) for the index longline fishery in region 3, with a minimum total weighting of 0.1. The median size class is provided as a solid white line.

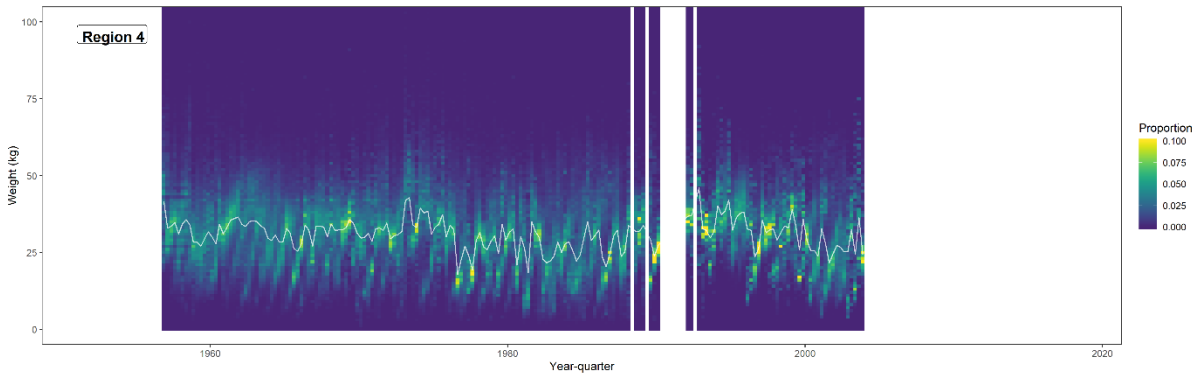
a) Reweighted weight compositions for the bigeye index fishery in region 4



b) Reweighted length compositions for the bigeye index fishery in region 4



c) Reweighted weight compositions for the yellowfin index fishery in region 4



d) Reweighted length compositions for the yellowfin index fishery in region 4

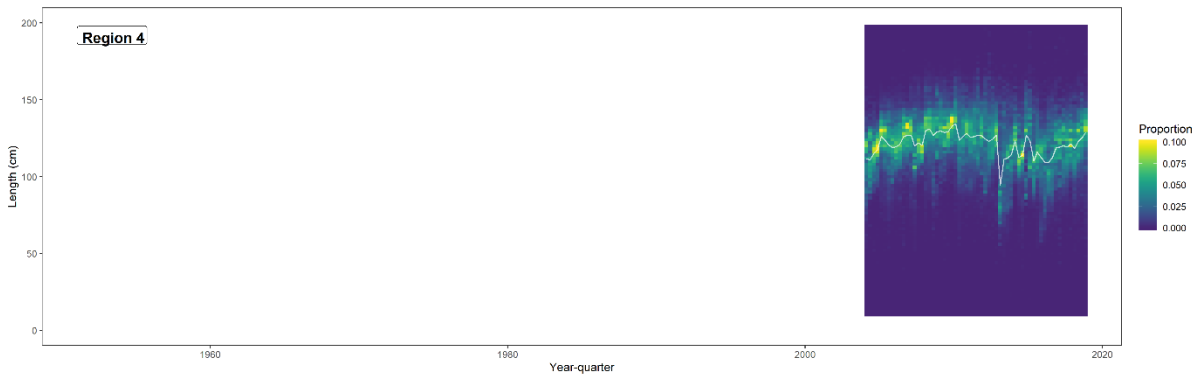
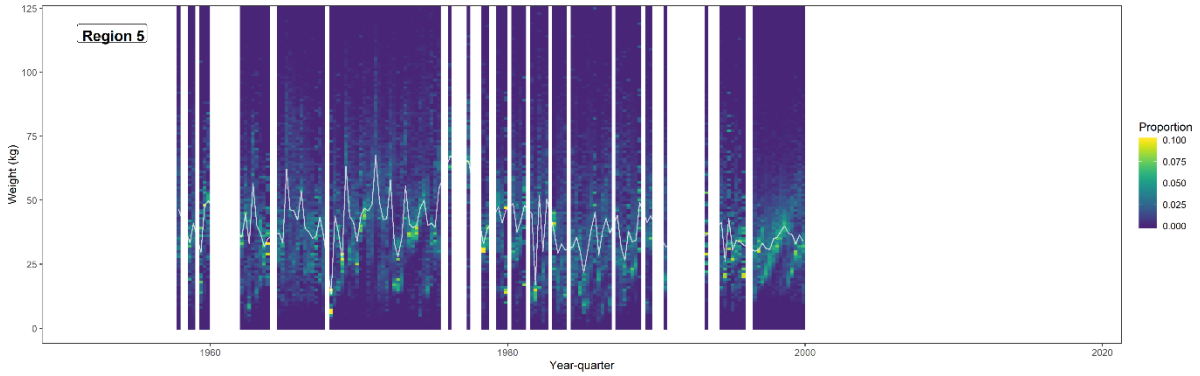
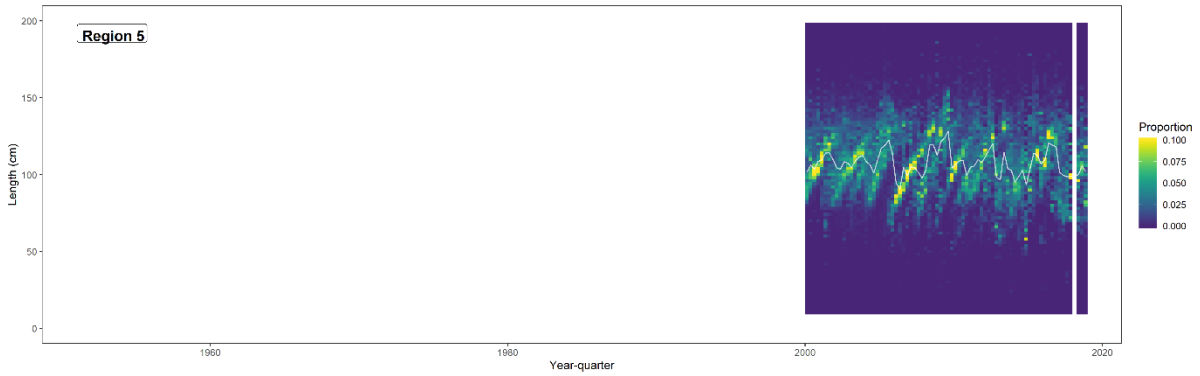


Figure 22 Reweighted weight (a) and length (b) compositions for bigeye and reweighted weight (c) compositions and length (d) compositions for yellowfin for the index longline fishery in region 4, with a minimum total weighting of 0.1. The median size class is provided as a solid white line.

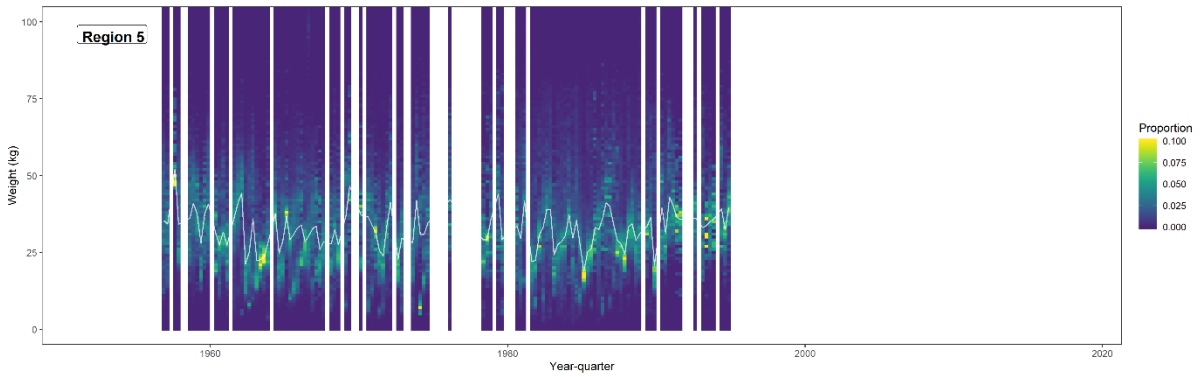
a) Reweighted weight compositions for the bigeye index fishery in region 5



b) Reweighted length compositions for the bigeye index fishery in region 5



c) Reweighted weight compositions for the yellowfin index fishery in region 5



d) Reweighted length compositions for the yellowfin index fishery in region 5

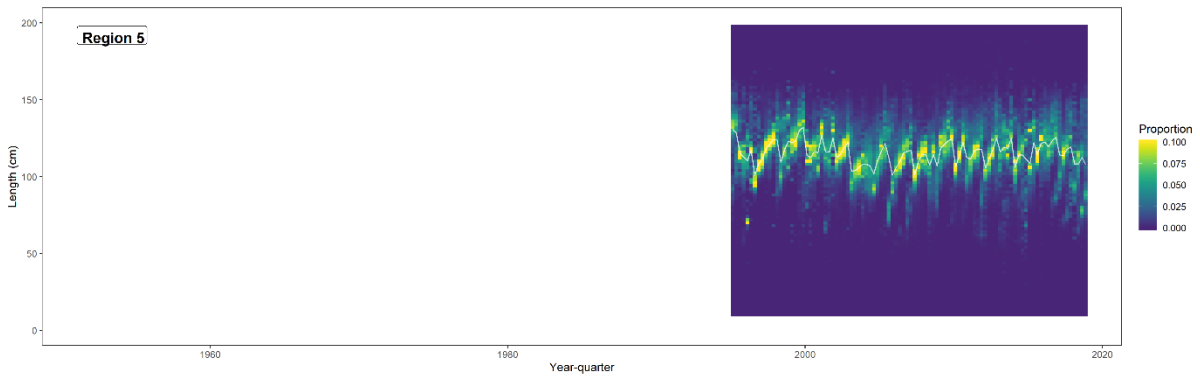
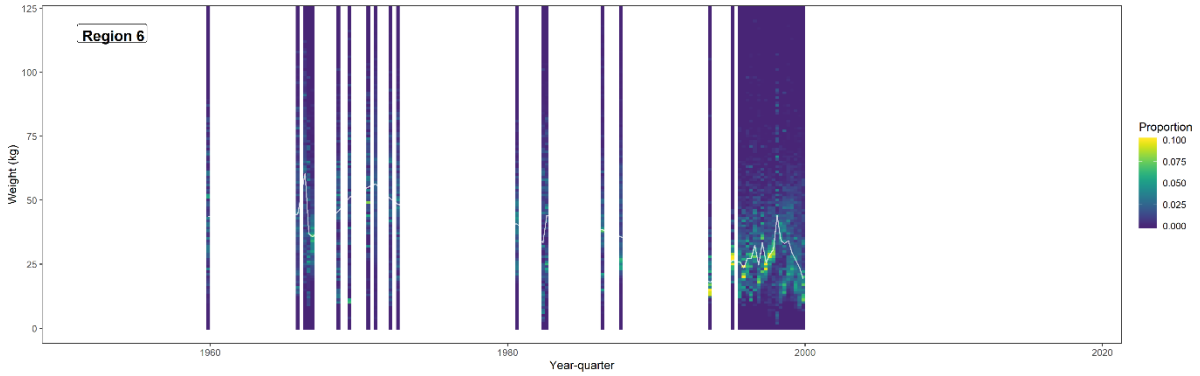
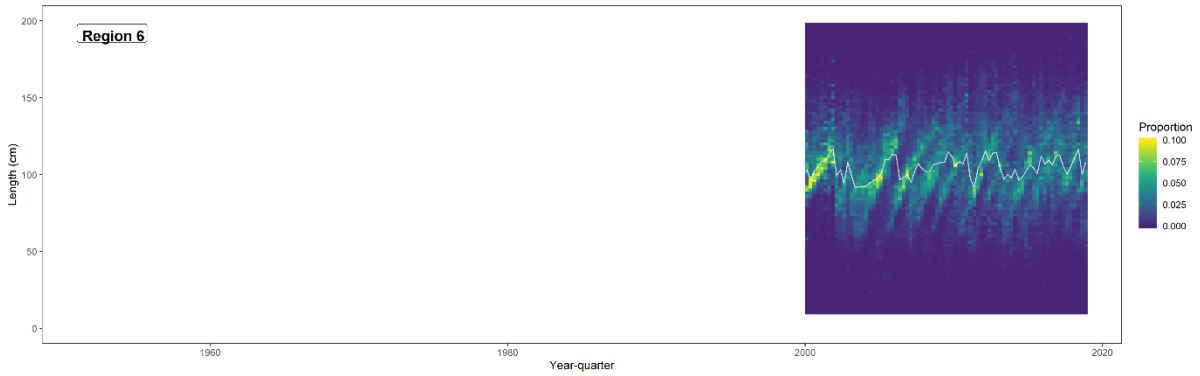


Figure 23 Reweighted weight (a) and length (b) compositions for bigeye and reweighted weight (c) compositions and length (d) compositions for yellowfin for the index longline fishery in region 5, with a minimum total weighting of 0.1. The median size class is provided as a solid white line.

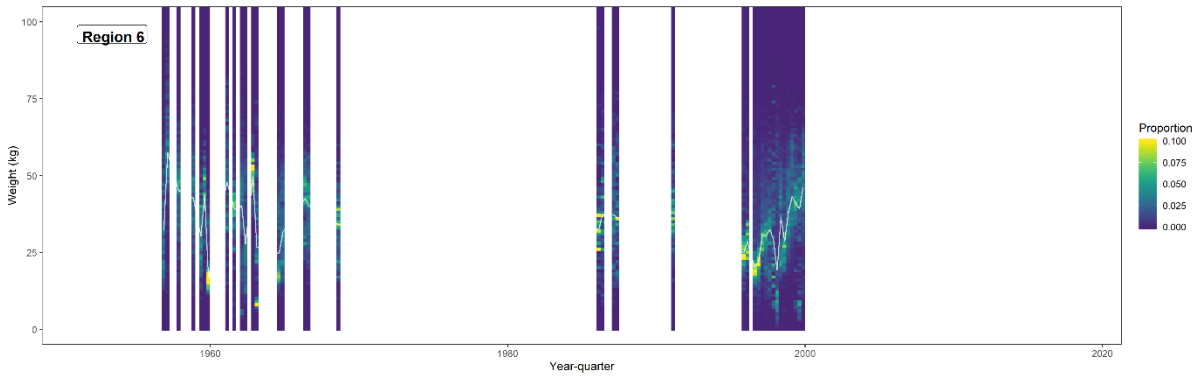
a) Reweighted weight compositions for the bigeye index fishery in region 6



b) Reweighted length compositions for the bigeye index fishery in region 6



c) Reweighted weight compositions for the yellowfin index fishery in region 6



d) Reweighted length compositions for the yellowfin index fishery in region 6

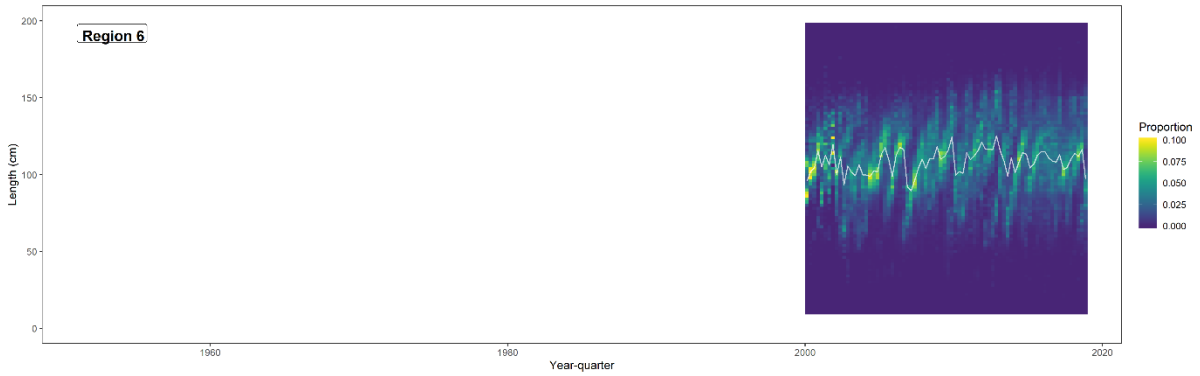
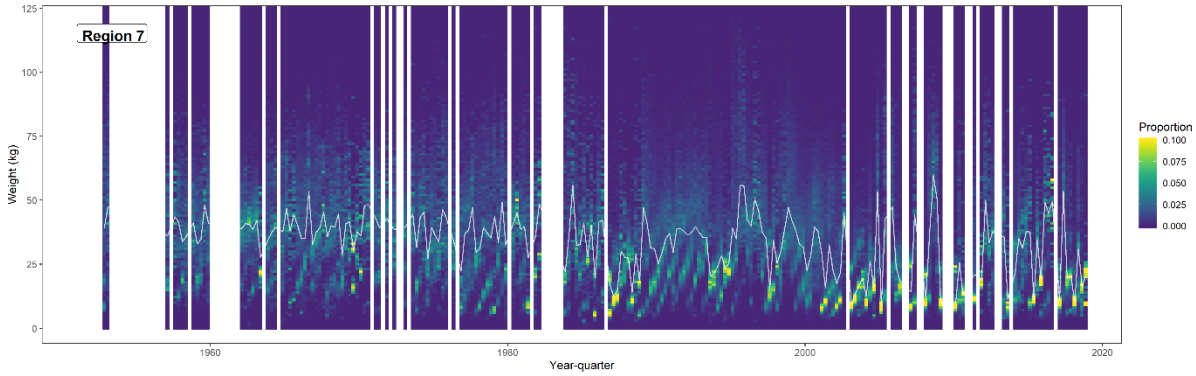


Figure 24 Reweighted weight (a) and length (b) compositions for bigeye and reweighted weight (c) compositions and length (d) compositions for yellowfin for the index longline fishery in region 6, with a minimum total weighting of 0.1. The median size class is provided as a solid white line.

a) Reweighted compositions for the bigeye index fishery in region 7



b) Reweighted compositions for the yellowfin index fishery in region 7

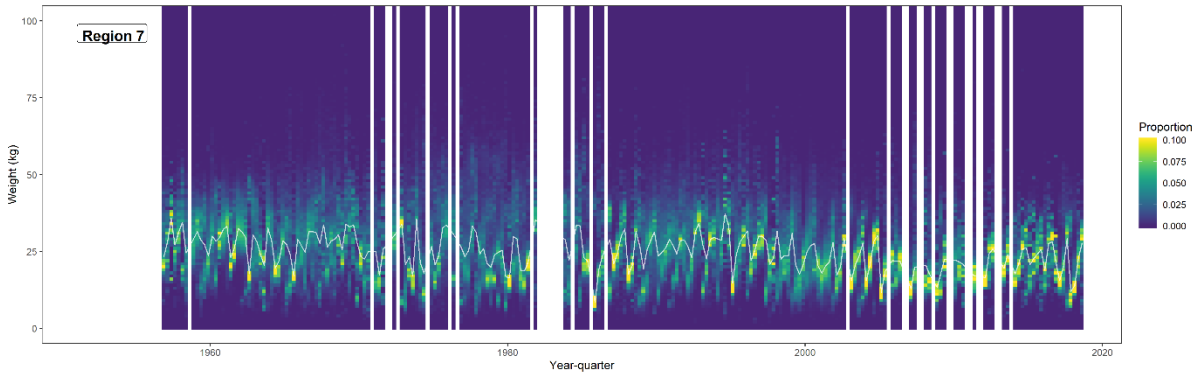
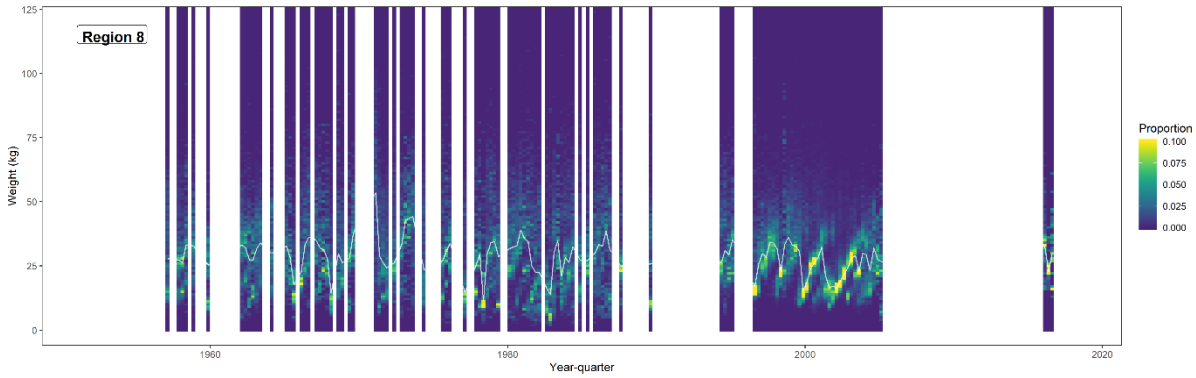


Figure 25 Reweighted weight compositions for bigeye (a) and yellowfin (b) for the index longline fishery in region 7, with a minimum total weighting of 0.1. The median size class is provided as a solid white line.

a) Reweighted compositions for the bigeye index fishery in region 8



b) Reweighted compositions for the yellowfin index fishery in region 8

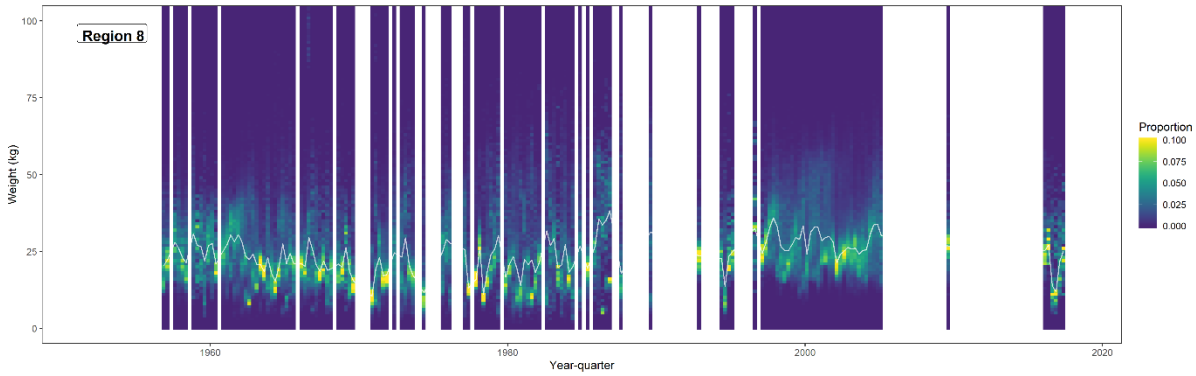
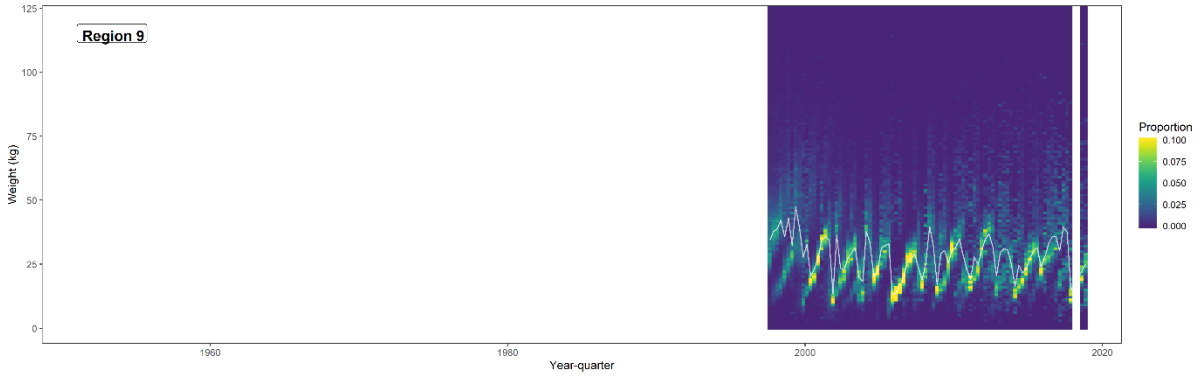


Figure 26 Reweighted weight compositions for bigeye (a) and yellowfin (b) for the index longline fishery in region 8, with a minimum total weighting of 0.1. The median size class is provided as a solid white line.

a) Reweighted compositions for the bigeye index fishery in region 9



b) Reweighted compositions for the yellowfin index fishery in region 9

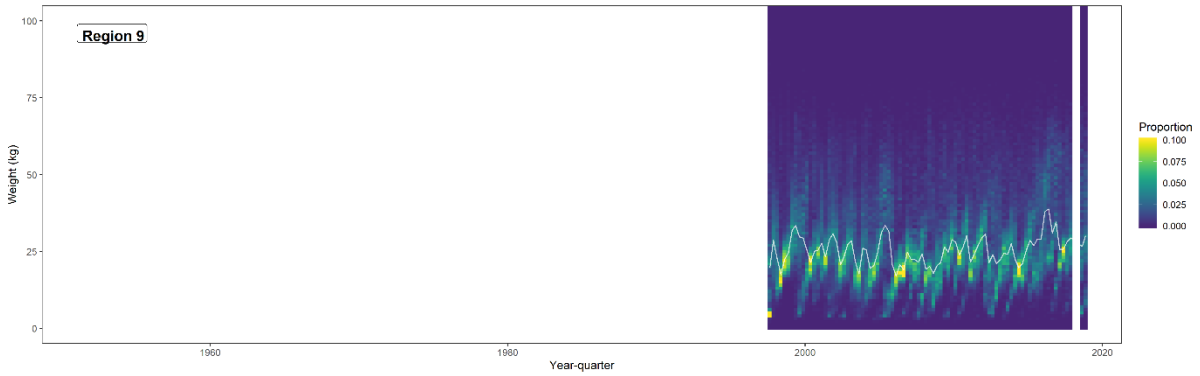


Figure 27 Reweighted weight compositions for bigeye (a) and yellowfin (b) for the index longline fishery in region 9, with a minimum total weighting of 0.1. The median size class is provided as a solid white line.

Appendix A

Purse seine data summaries

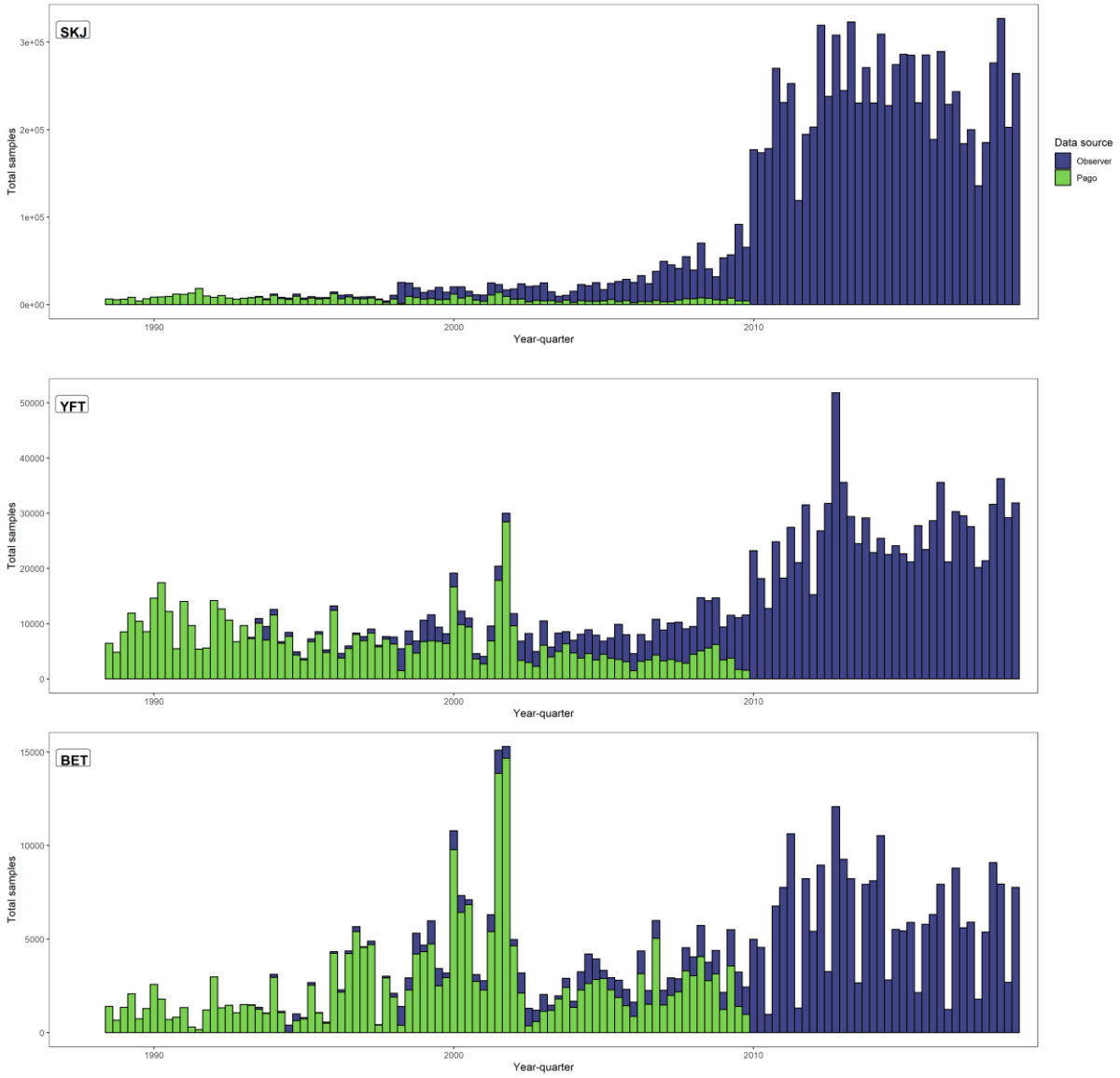


Figure 28 Total samples by data source and year-quarter for skipjack (top panel), yellowfin (middle) and bigeye (bottom).

Appendix B

Longline data summaries – bigeye

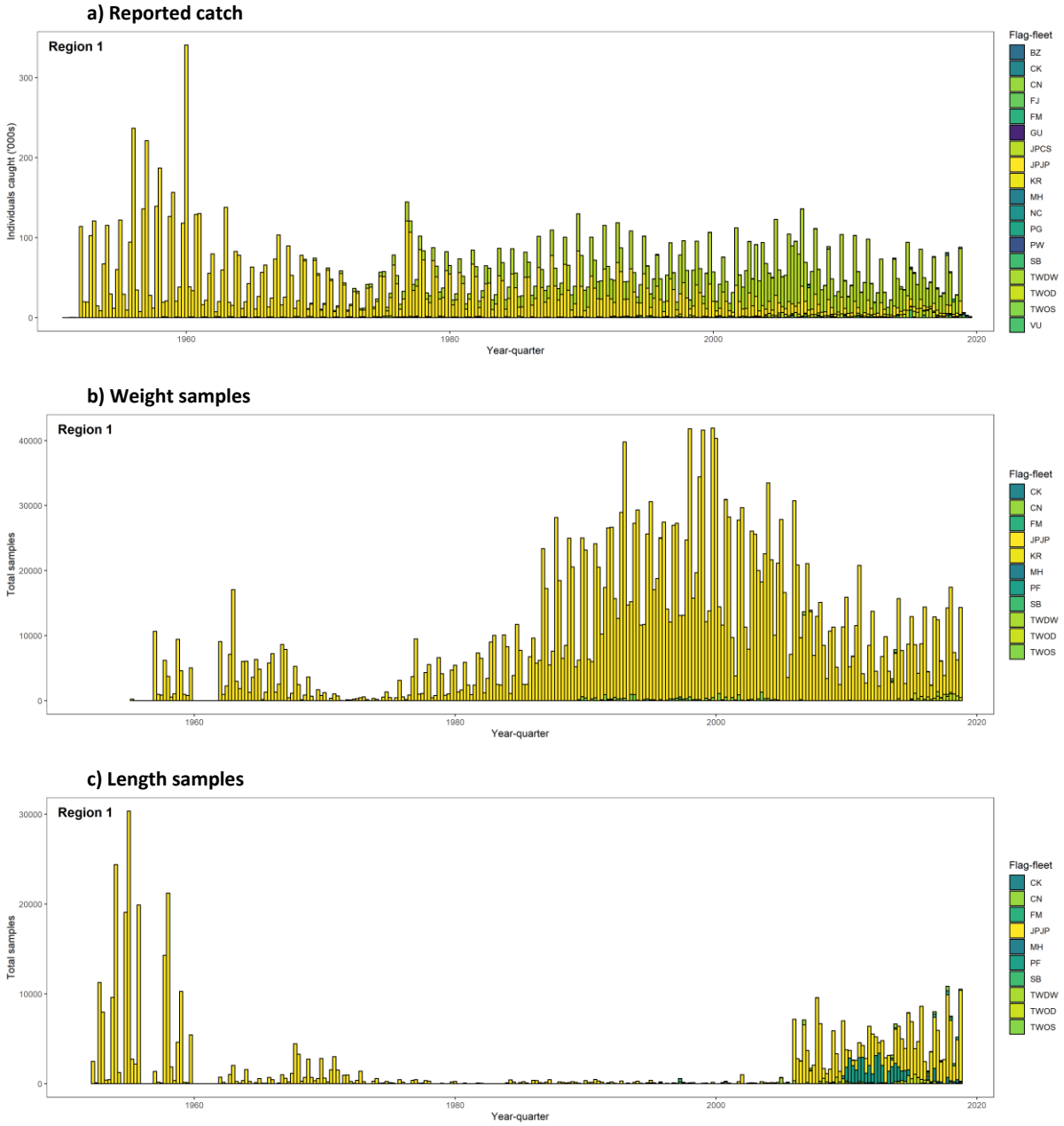


Figure 29 Total reported bigeye catch (top panel), weight samples (middle panel) and length samples (bottom panel) by flag-fleet for region 1, fishery 1 (i.e. 'all-flags').

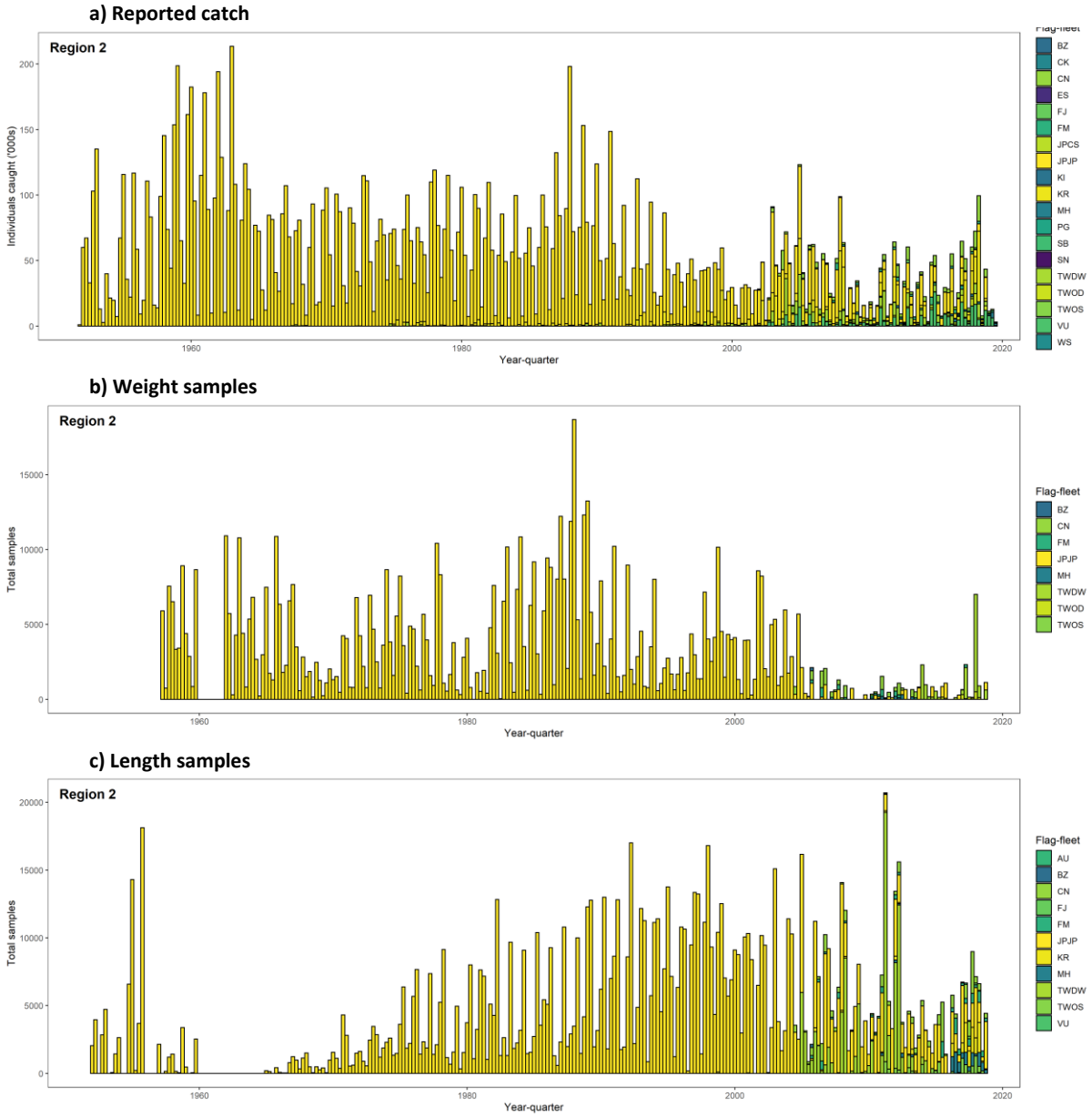


Figure 30 Total reported bigeye catch (top panel), weight samples (middle panel) and length samples (bottom panel) by flag-fleet for region 2, fishery 2 (i.e. 'all-flags').

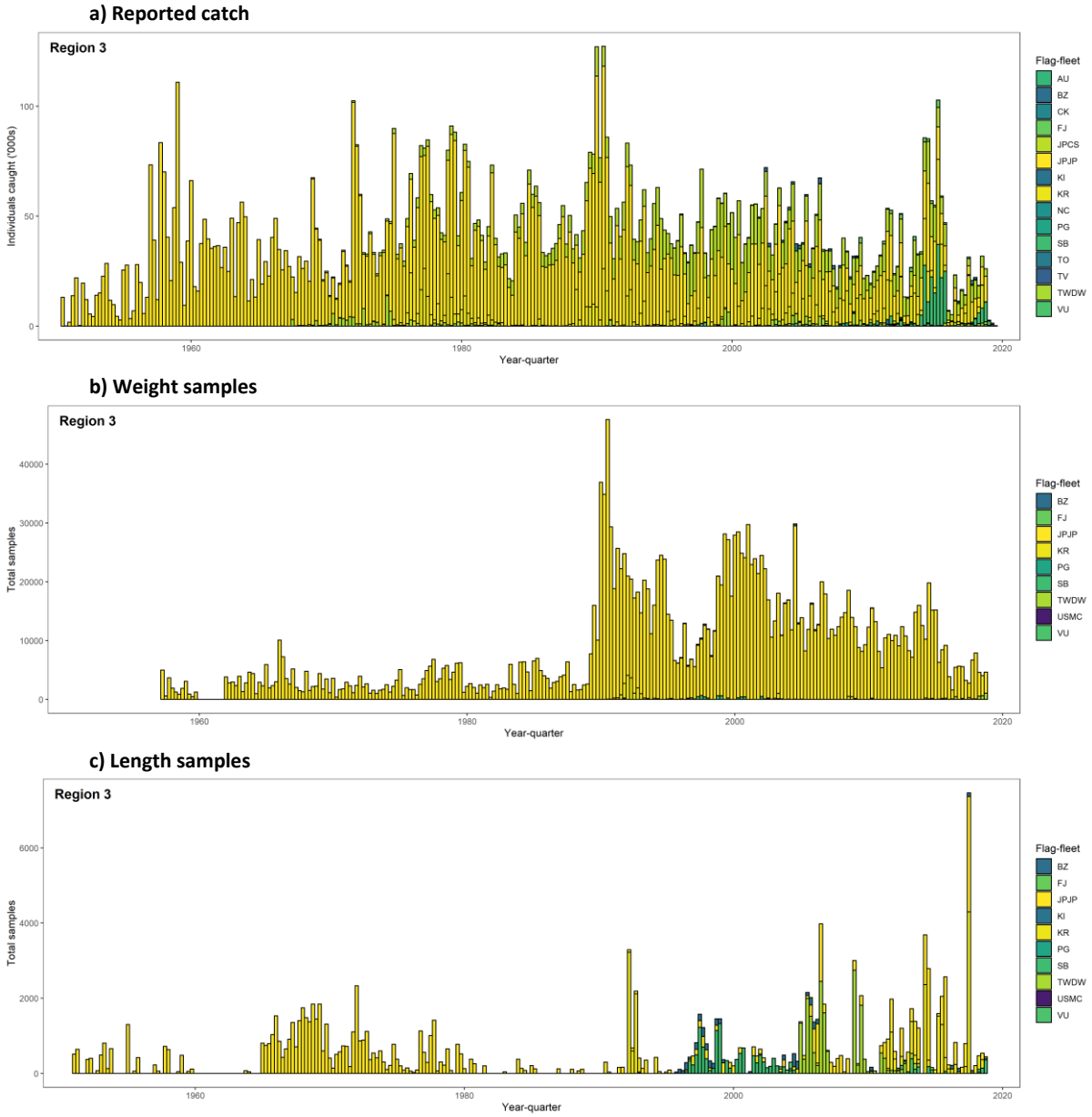


Figure 31 Total reported bigeye catch (top panel), weight samples (middle panel) and length samples (bottom panel) by flag-fleet for region 3, fishery 4 (i.e. 'all-flags').

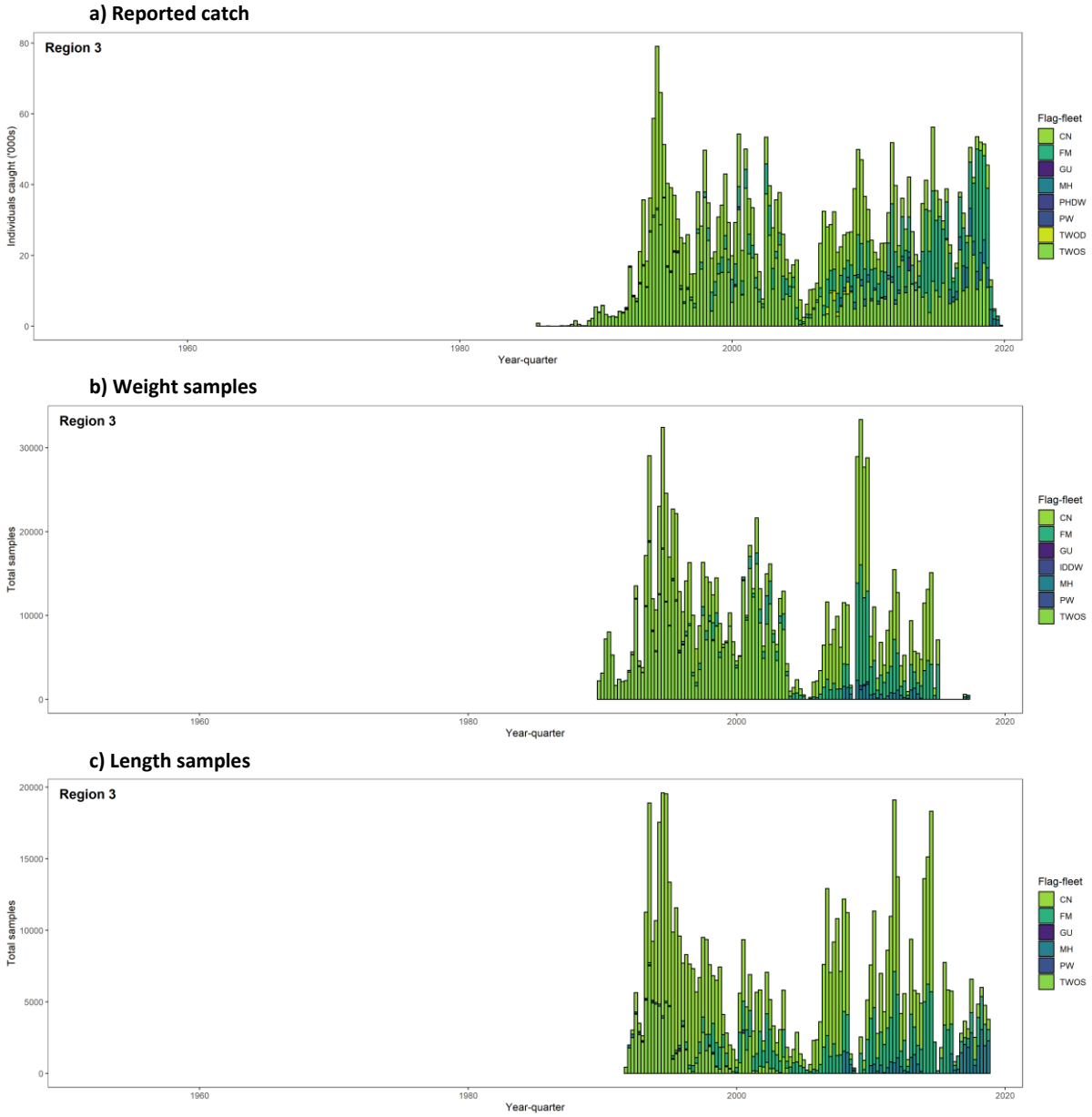


Figure 32 Total reported bigeye catch (top panel), weight samples (middle panel) and length samples (bottom panel) by flag-fleet for region 3, fishery 5 (i.e. 'offshore').

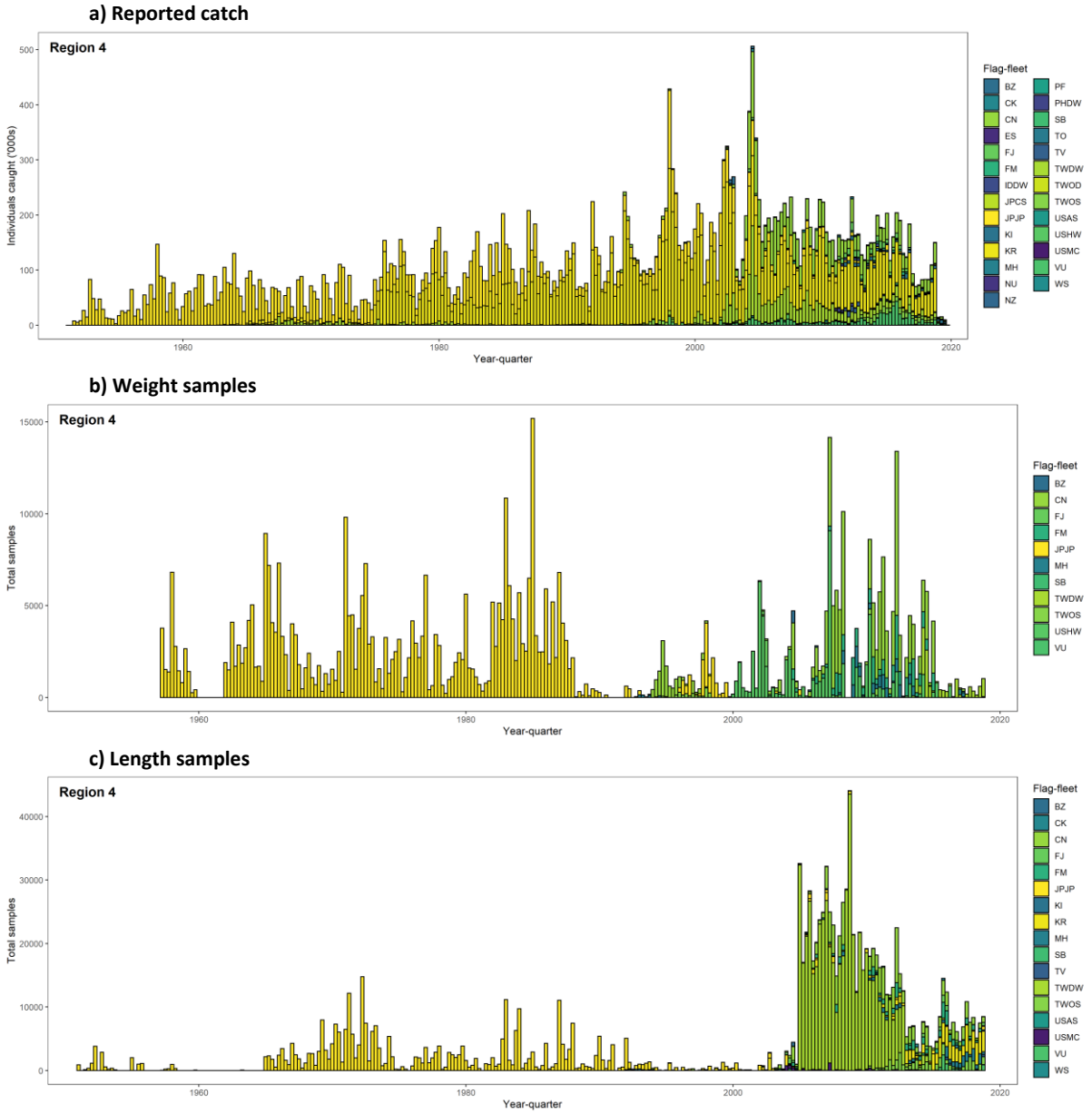


Figure 33 Total reported bigeye catch (top panel), weight samples (middle panel) and length samples (bottom panel) by flag-fleet for region 4, fishery 9 (i.e. 'all-flags').

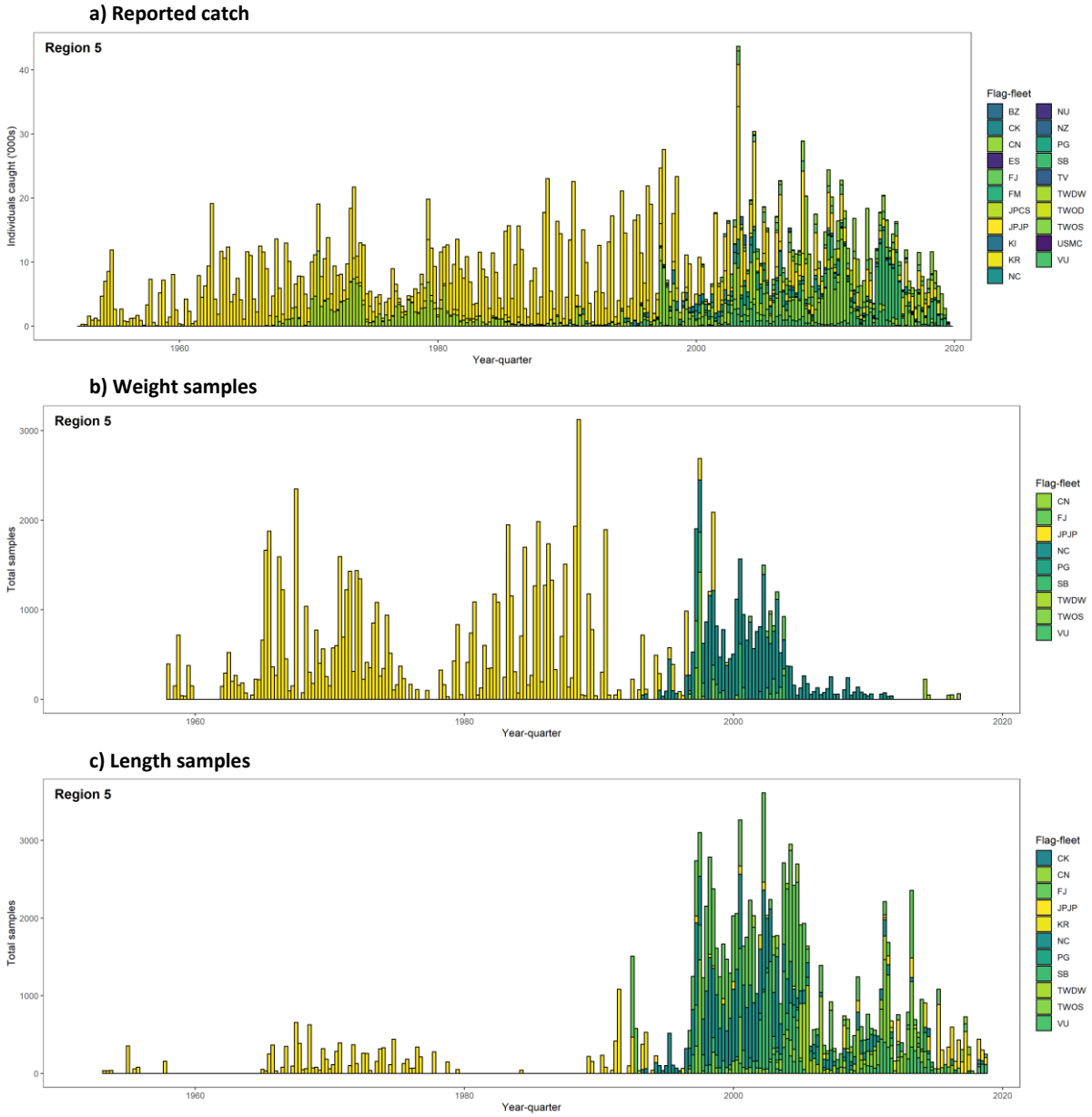


Figure 34 Total reported bigeye catch (top panel), weight samples (middle panel) and length samples (bottom panel) by flag-fleet for region 5, fishery 11 (i.e. 'all-flags').

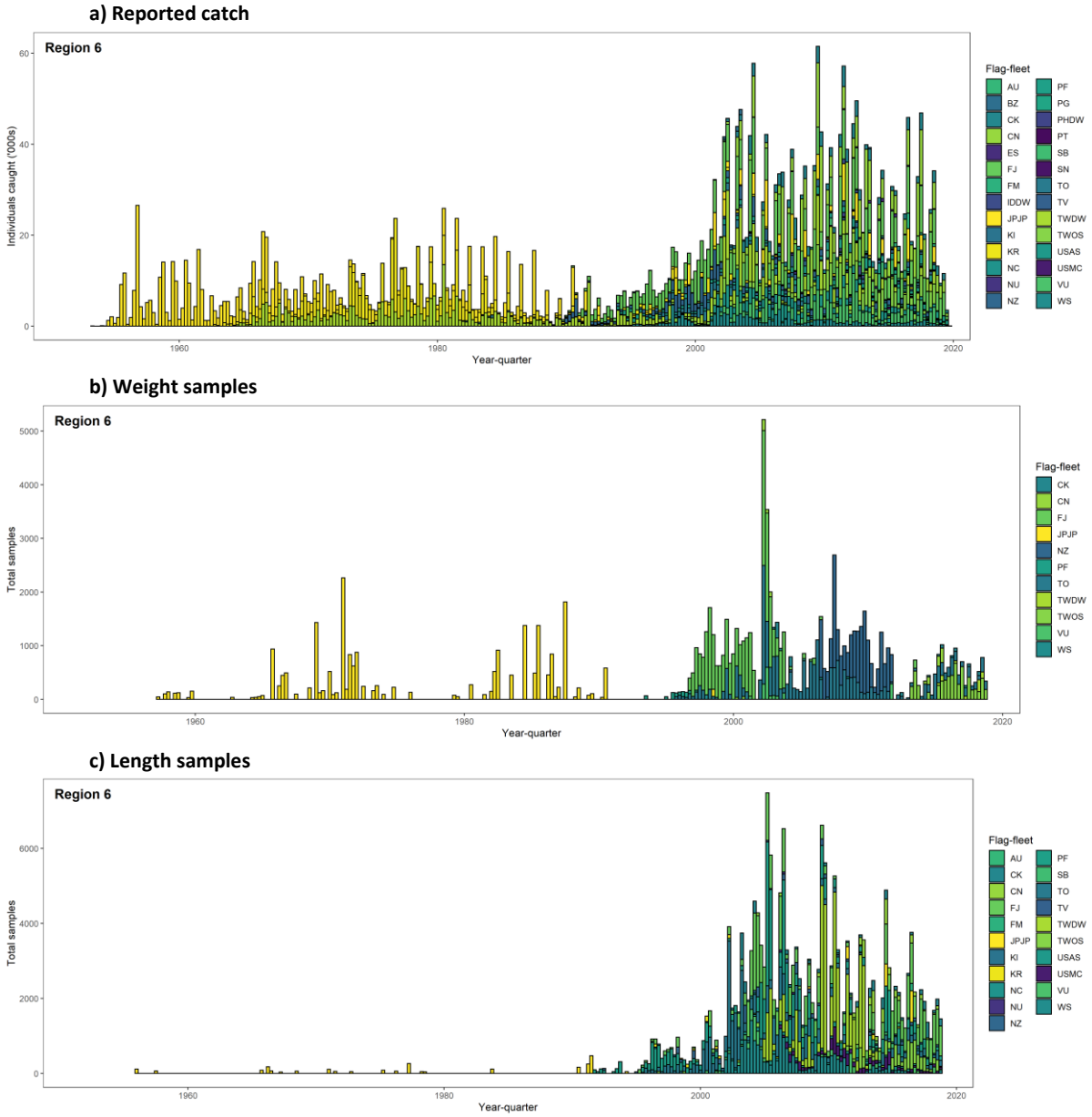


Figure 35 Total reported bigeye catch (top panel), weight samples (middle panel) and length samples (bottom panel) by flag-fleet for region 6, fishery 12 (i.e. 'all-flags').

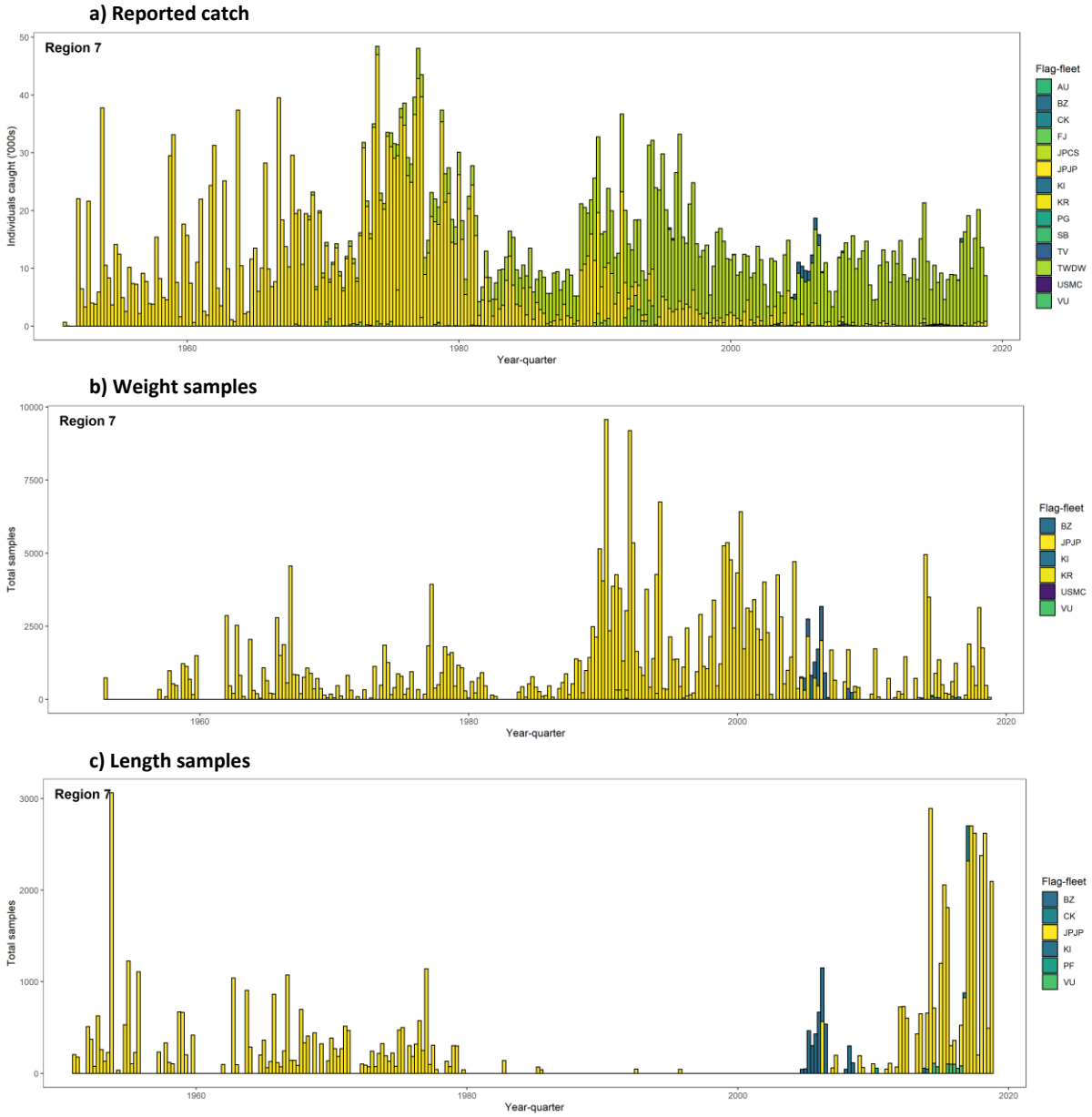


Figure 36 Total reported bigeye catch (top panel), weight samples (middle panel) and length samples (bottom panel) by flag-fleet for region 7, fishery 7 (i.e. 'all-flags').

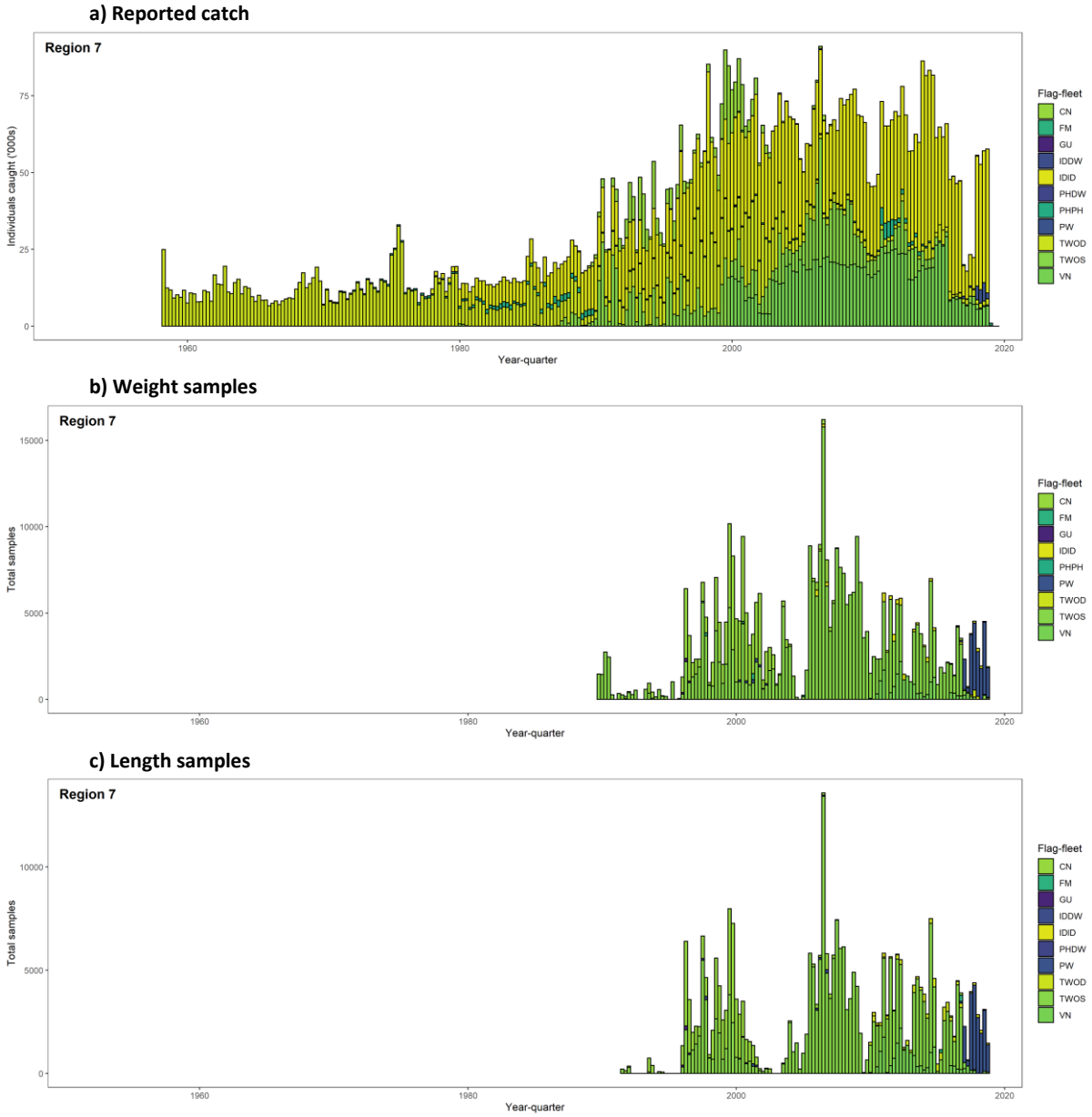


Figure 37 Total reported bigeye catch (top panel), weight samples (middle panel) and length samples (bottom panel) by flag-fleet for region 7, fishery 6 (i.e. 'offshore').

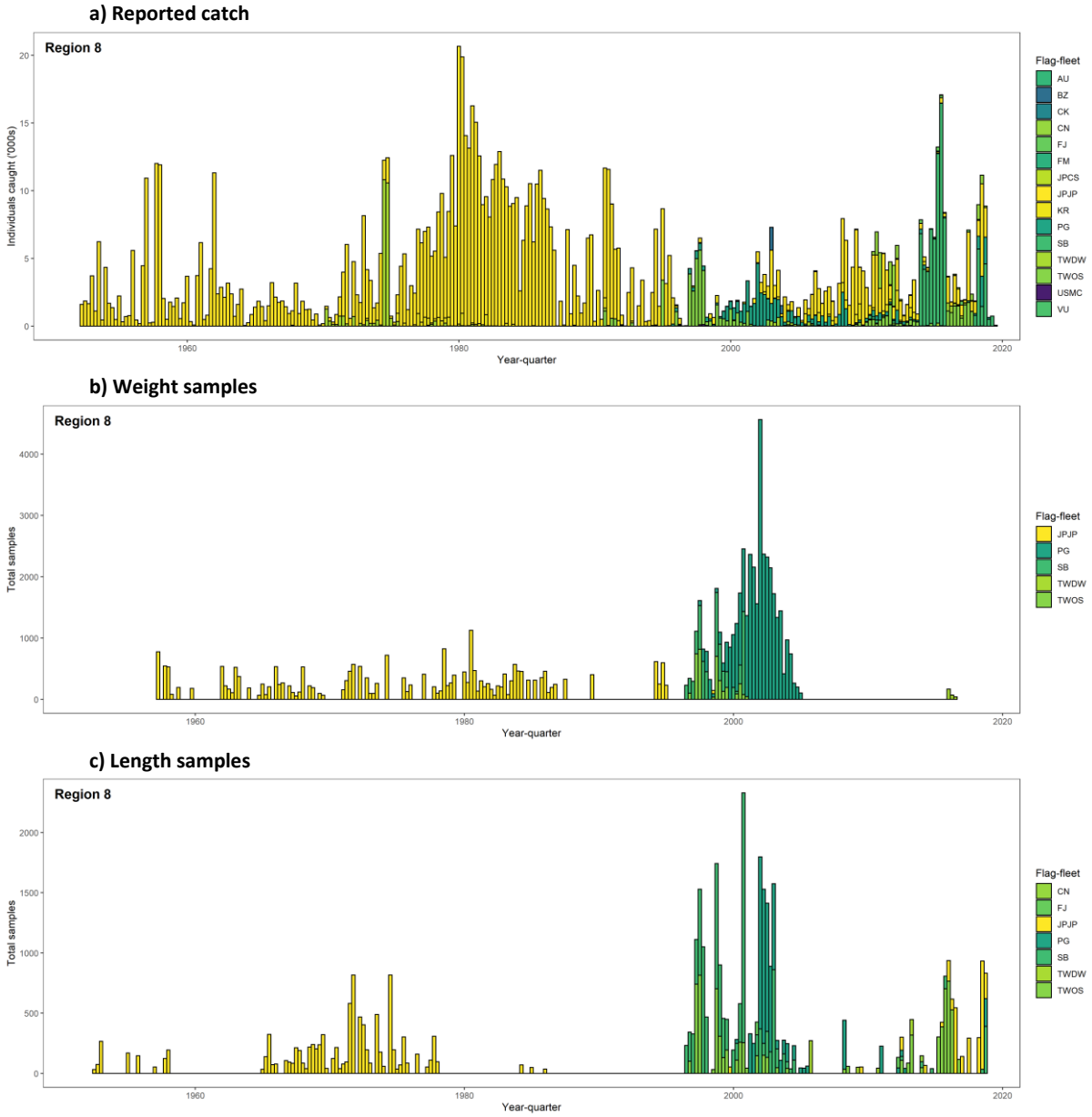


Figure 38 Total reported bigeye catch (top panel), weight samples (middle panel) and length samples (bottom panel) by flag-fleet for region 8, fishery 8 (i.e. 'all-flags').

Longline data summaries – yellowfin

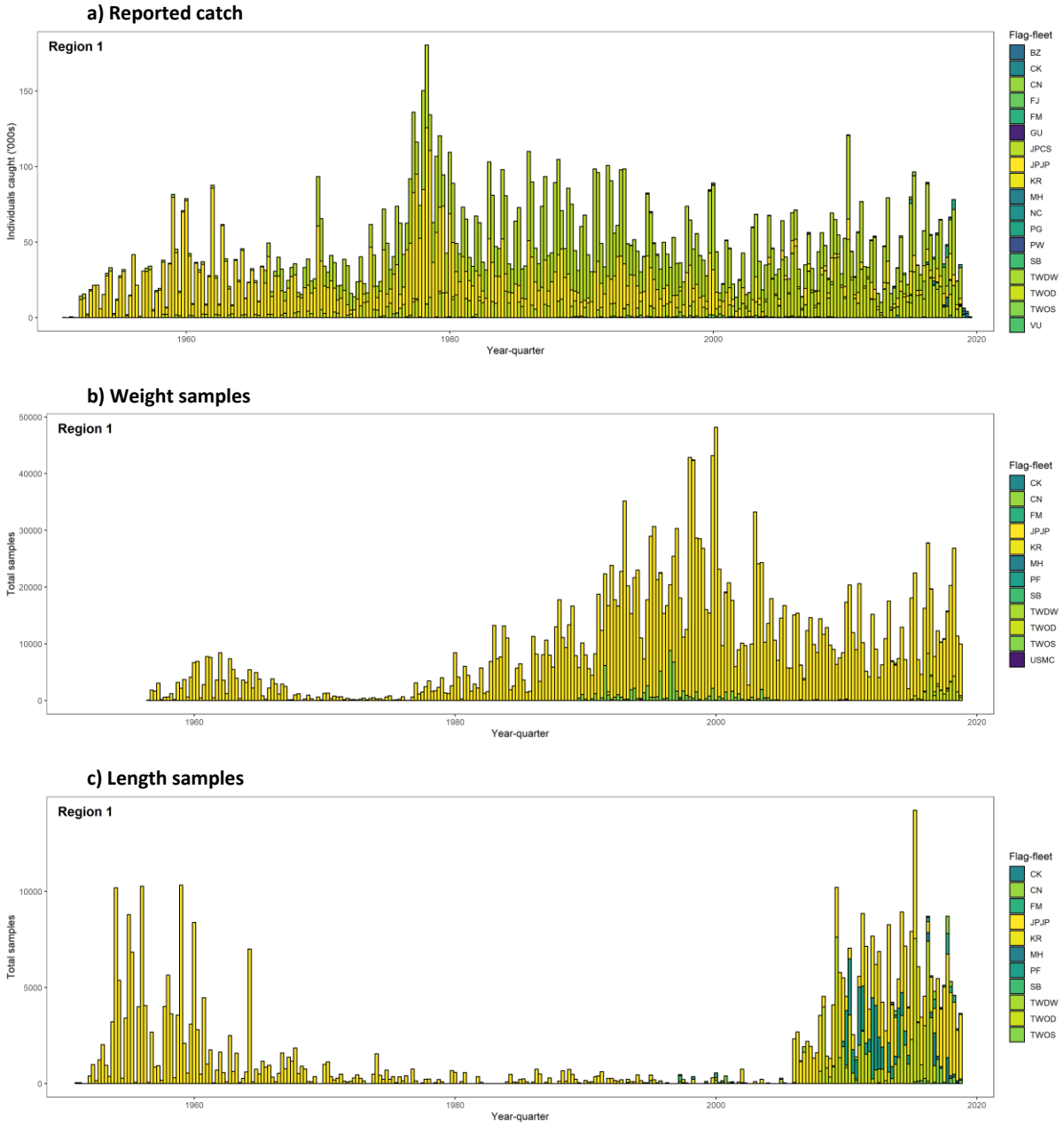


Figure 39 Total reported yellowfin catch (top panel), weight samples (middle panel) and length samples (bottom panel) by flag-fleet for region 1, fishery 1 (i.e. 'all-flags').

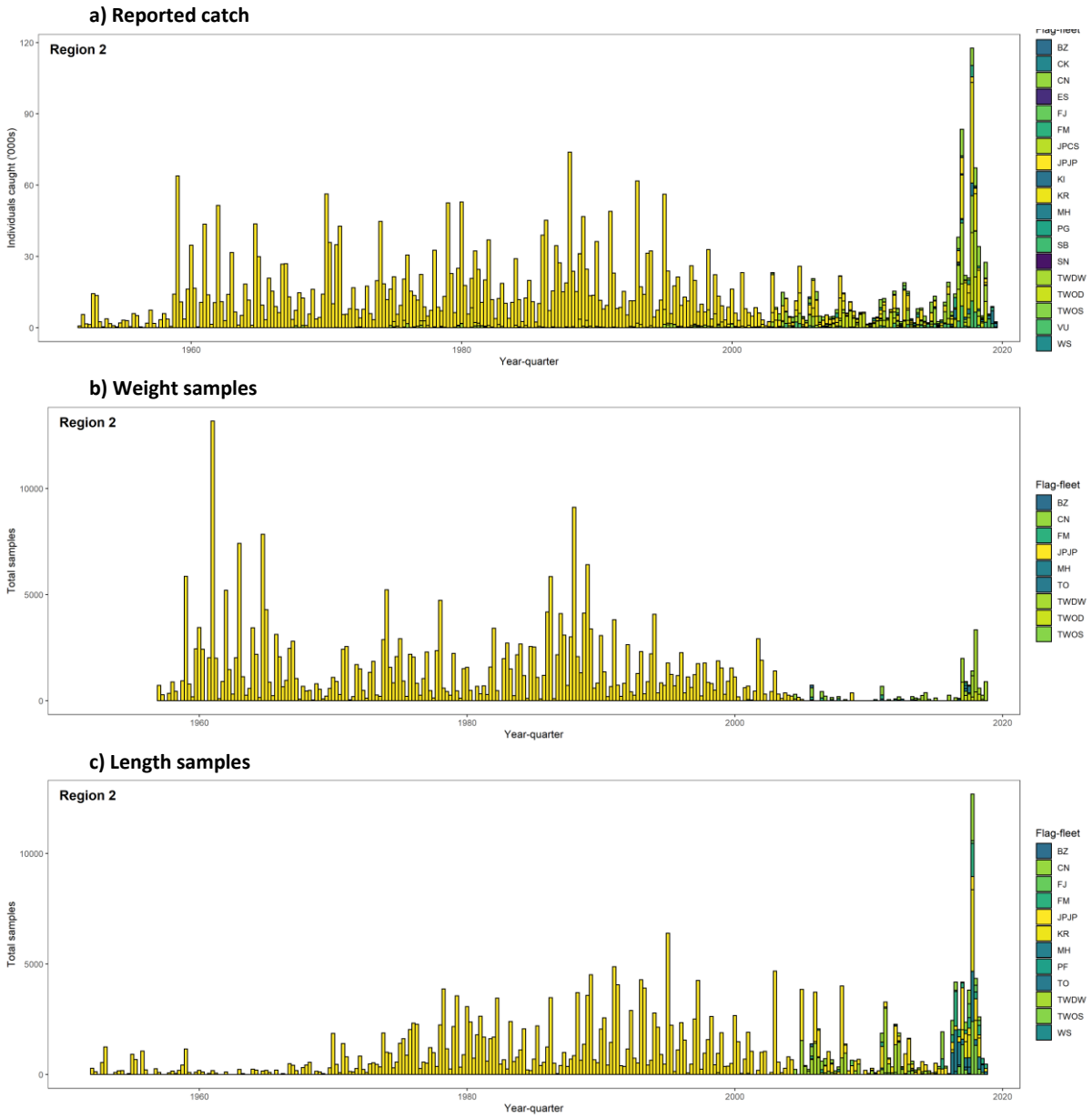


Figure 40 Total reported yellowfin catch (top panel), weight samples (middle panel) and length samples (bottom panel) by flag-fleet for region 2, fishery 2 (i.e. 'all-flags').

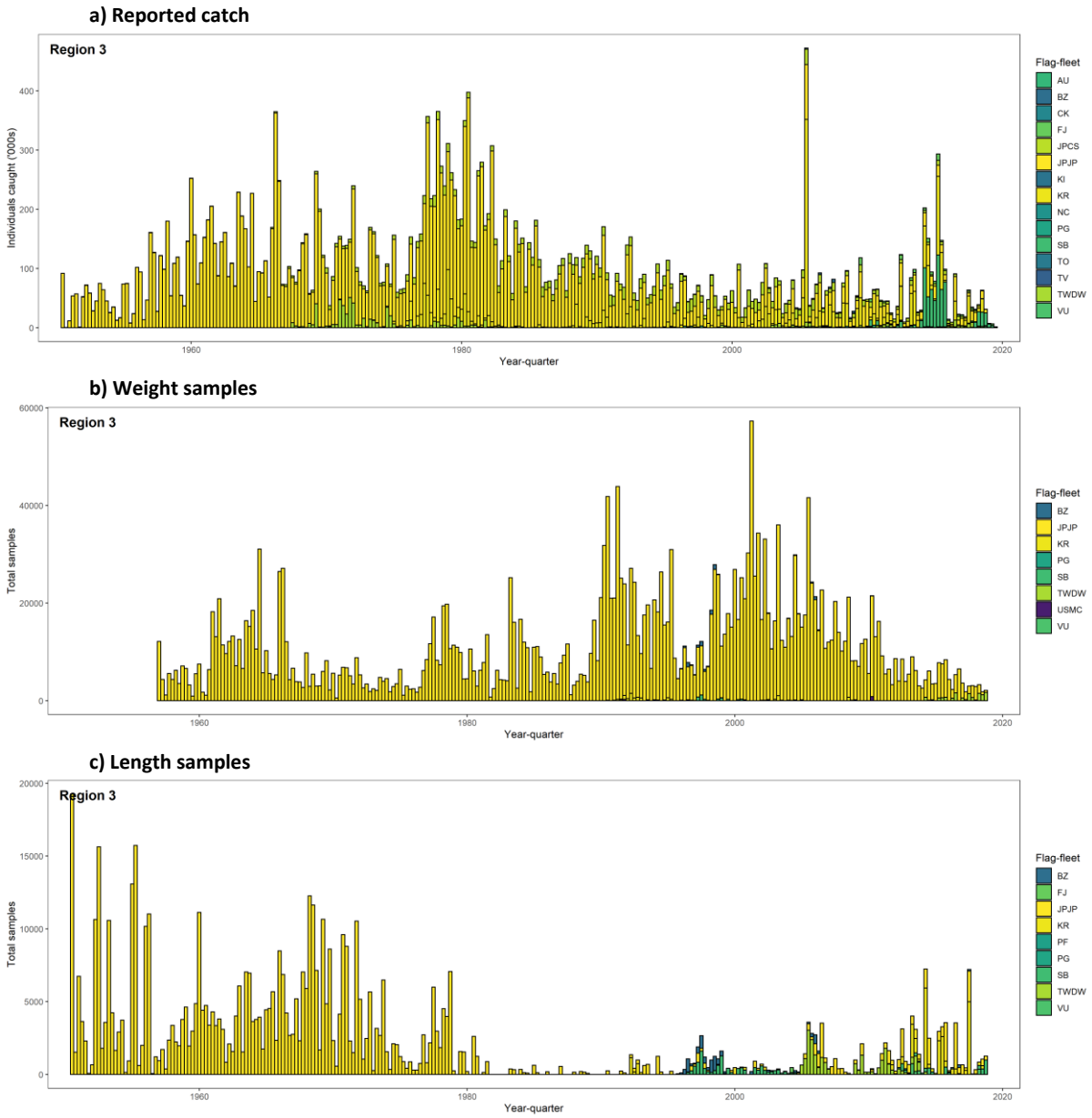


Figure 41 Total reported yellowfin catch (top panel), weight samples (middle panel) and length samples (bottom panel) by flag-fleet for region 3, fishery 4 (i.e. 'all-flags').

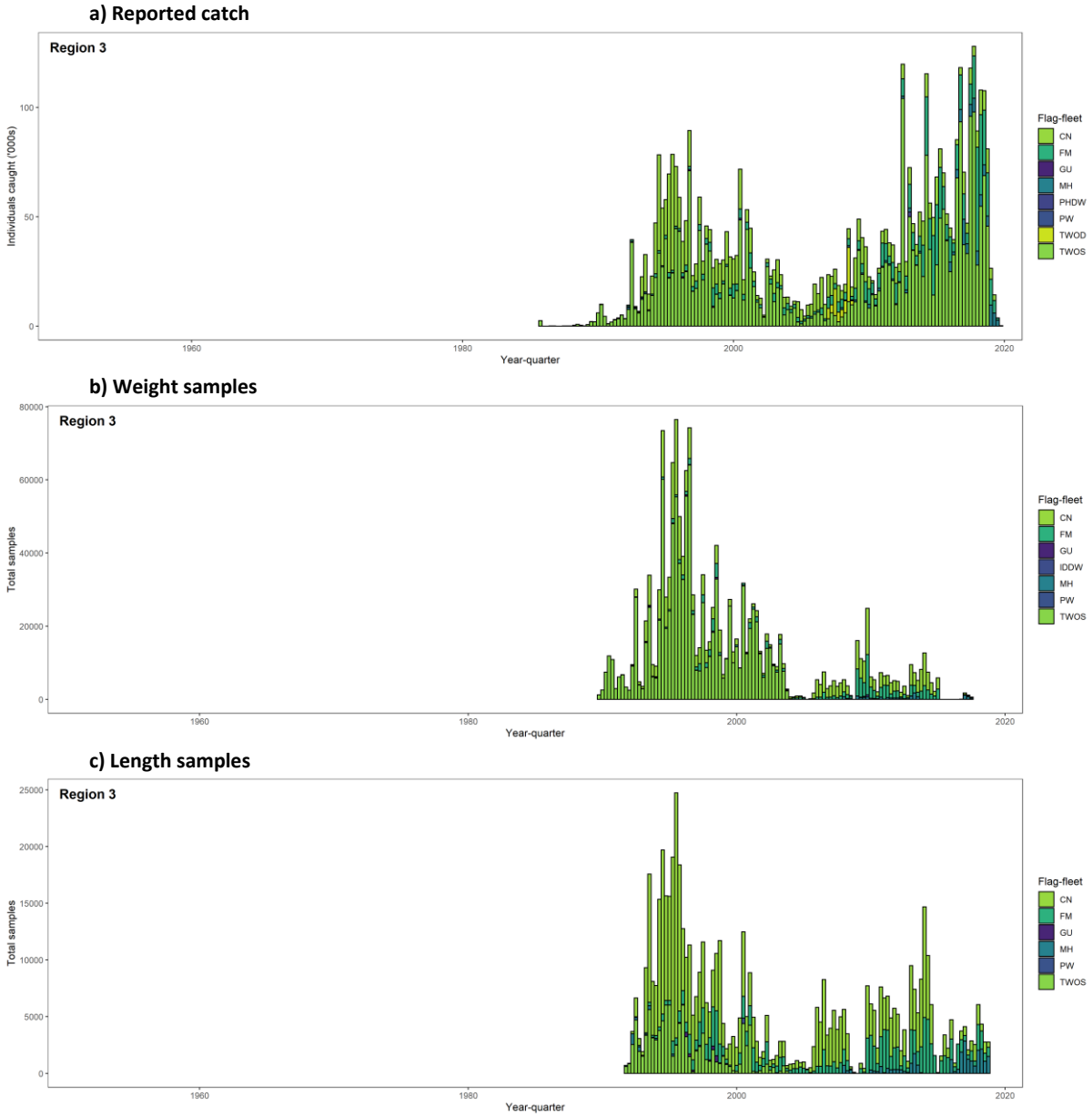


Figure 42 Total reported yellowfin catch (top panel), weight samples (middle panel) and length samples (bottom panel) by flag-fleet for region 3, fishery 5 (i.e. 'offshore').

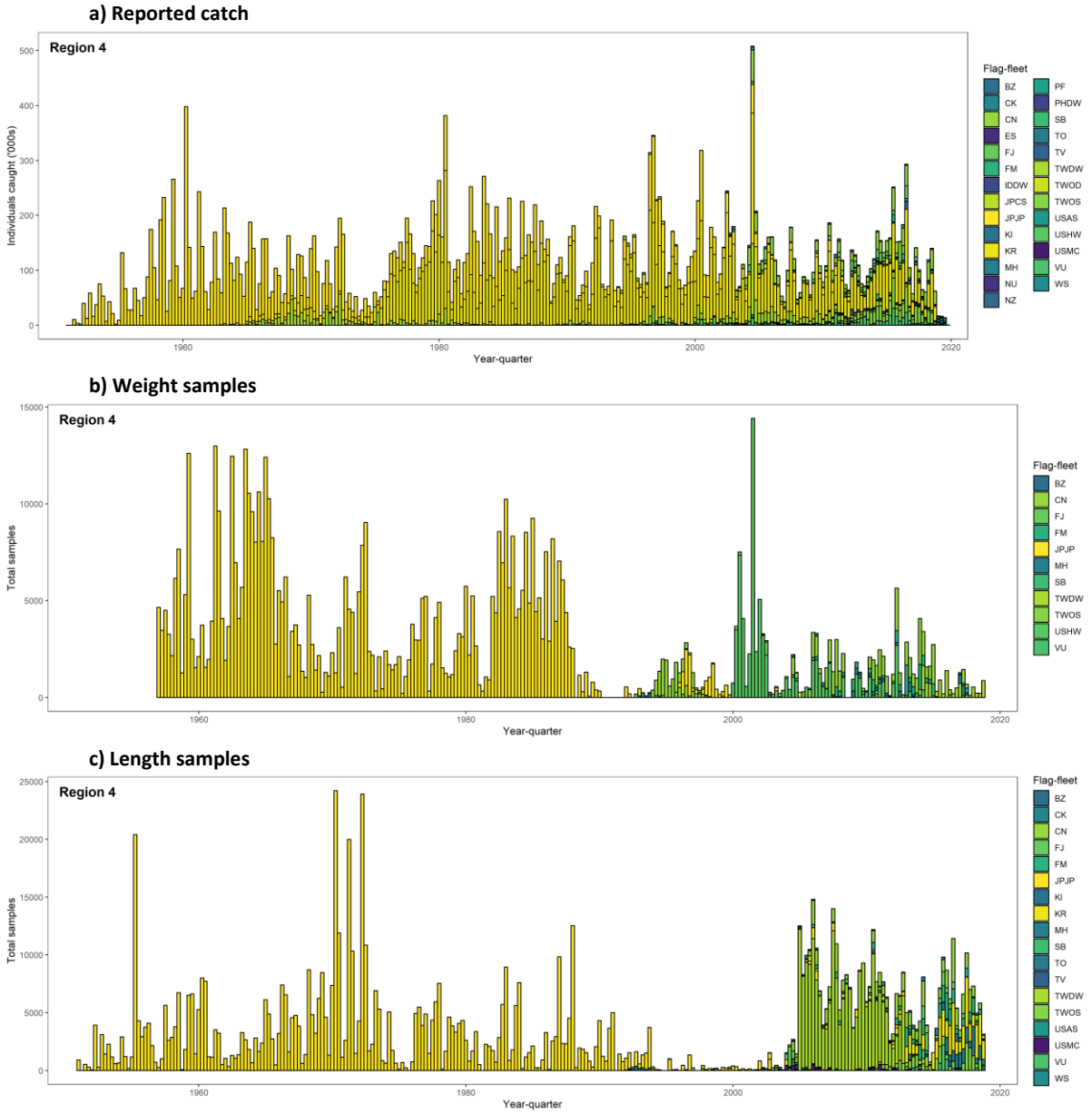


Figure 43 Total reported yellowfin catch (top panel), weight samples (middle panel) and length samples (bottom panel) by flag-fleet for region 4, fishery 9 (i.e. 'all-flags').

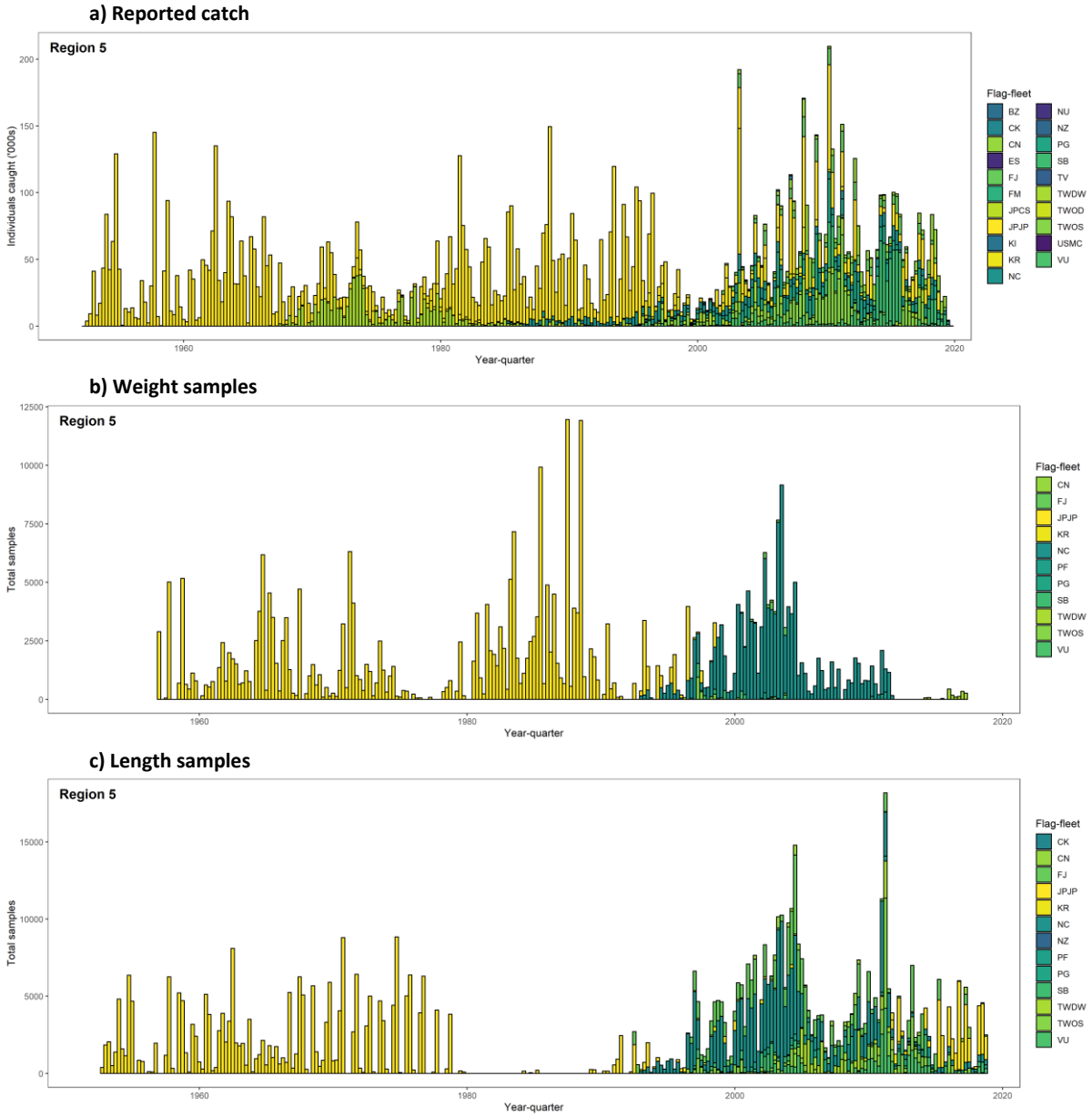


Figure 44 Total reported yellowfin catch (top panel), weight samples (middle panel) and length samples (bottom panel) by flag-fleet for region 5, fishery 11 (i.e. 'all-flags').

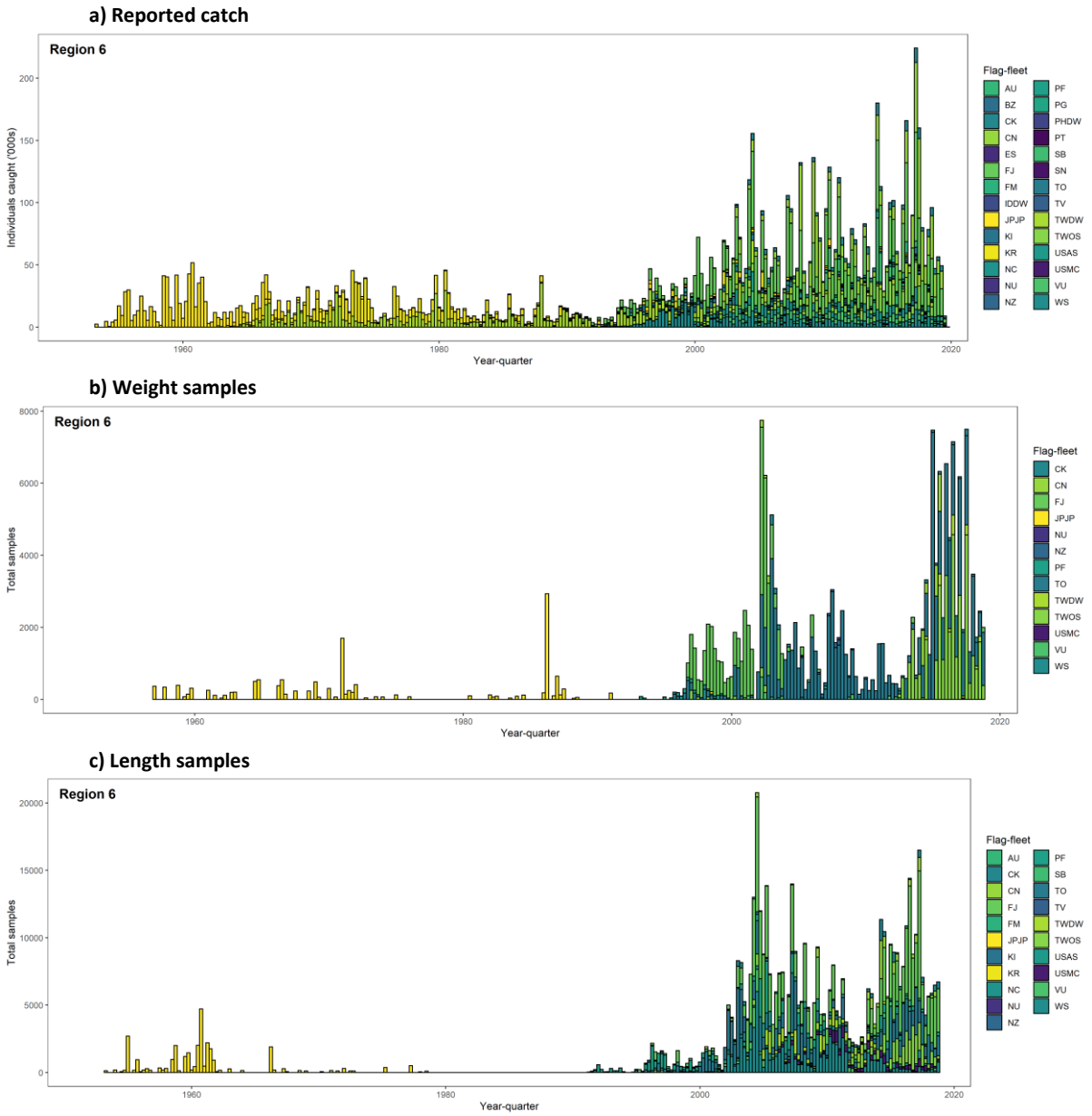


Figure 45 Total reported yellowfin catch (top panel), weight samples (middle panel) and length samples (bottom panel) by flag-fleet for region 6, fishery 12 (i.e. 'all-flags').

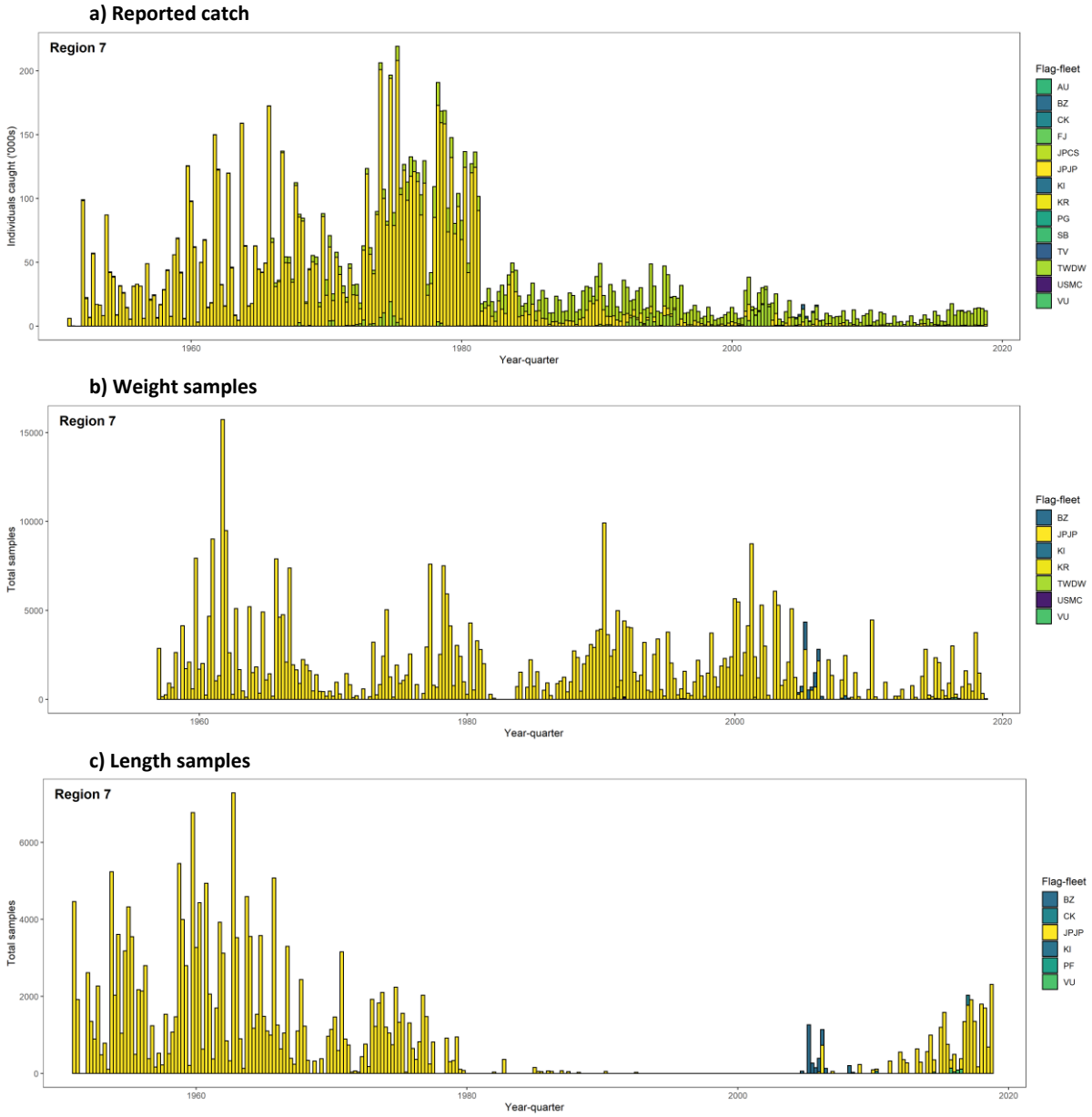


Figure 46 Total reported yellowfin catch (top panel), weight samples (middle panel) and length samples (bottom panel) by flag-fleet for region 7, fishery 7 (i.e. 'all-flags').

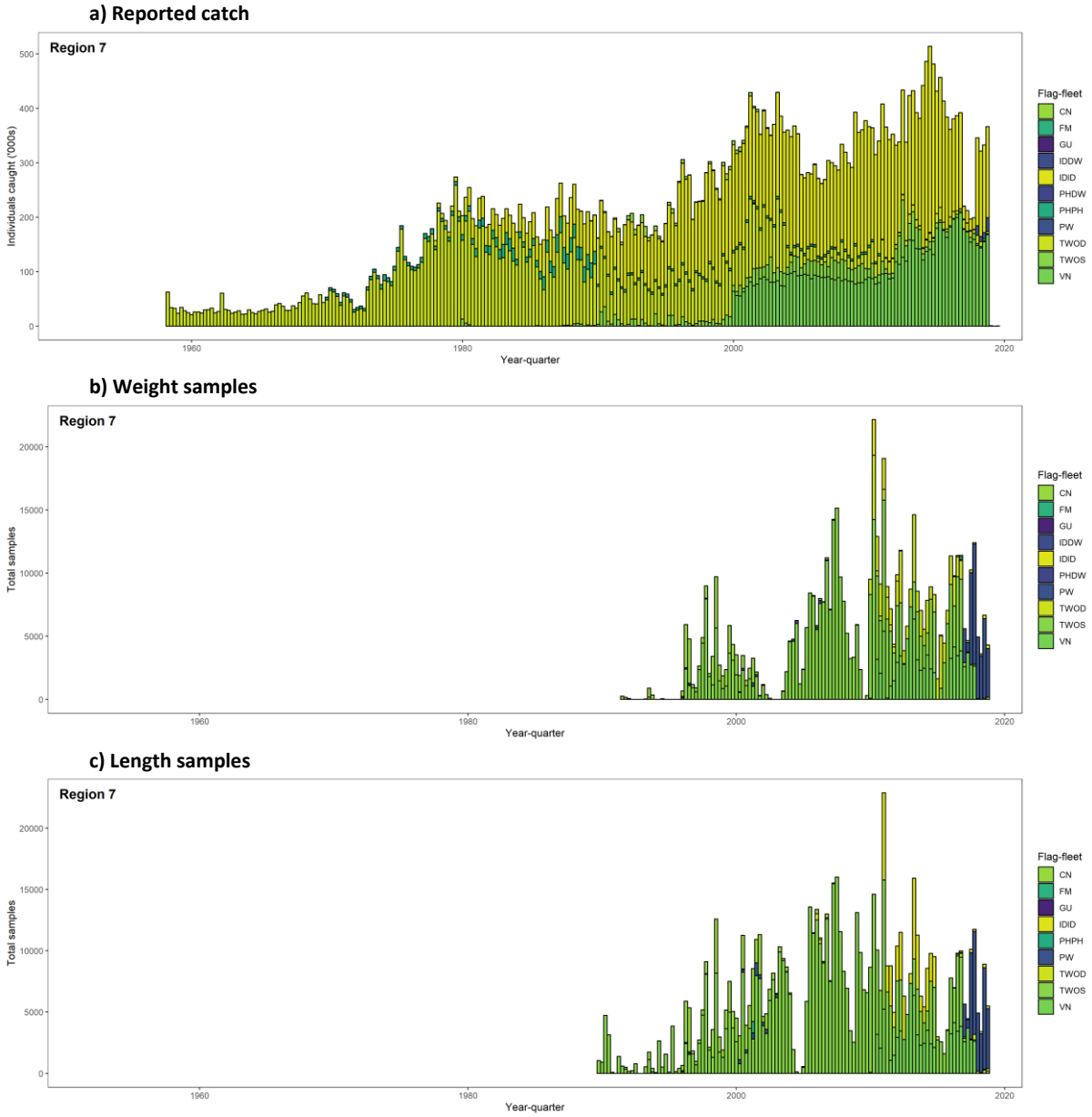


Figure 47 Total reported yellowfin catch (top panel), weight samples (middle panel) and length samples (bottom panel) by flag-fleet for region 7, fishery 6 (i.e. 'offshore').

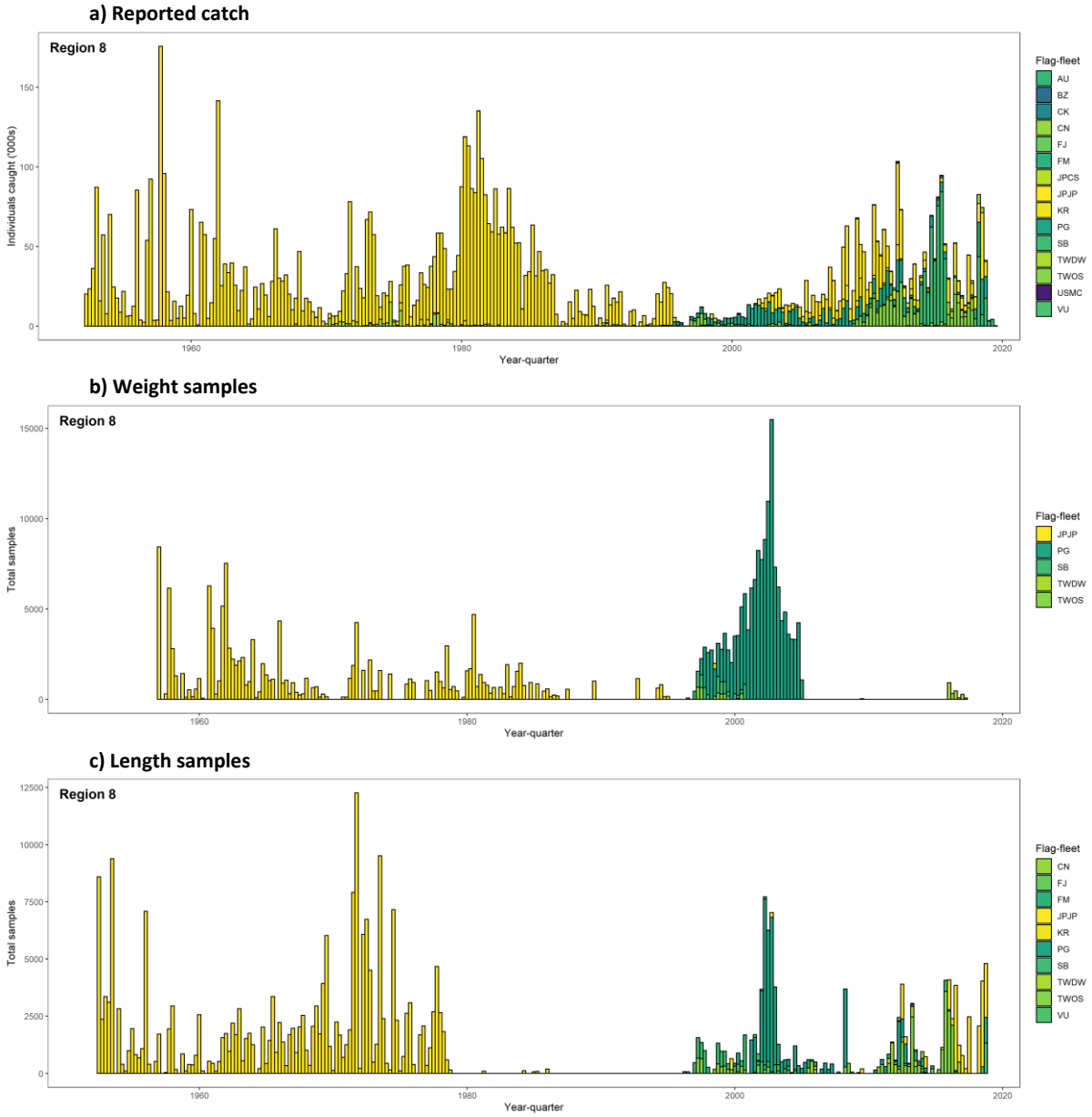
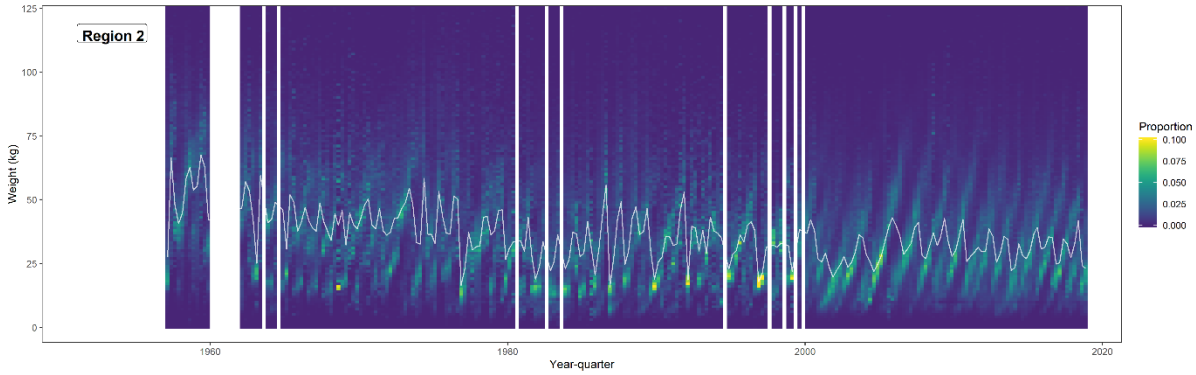


Figure 48 Total reported yellowfin catch (top panel), weight samples (middle panel) and length samples (bottom panel) by flag-fleet for region 8, fishery 8 (i.e. 'all-flags').

Appendix C

Alternative index fishery size compositions using size samples from all fisheries in a region

a) Reweighted weight compositions for the bigeye index fishery in region 2



c) Reweighted weight compositions for the yellowfin index fishery in region 2

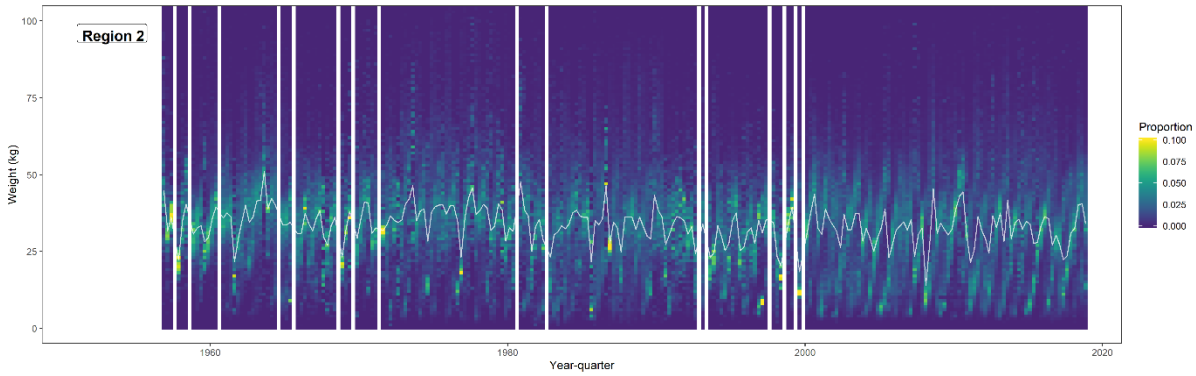
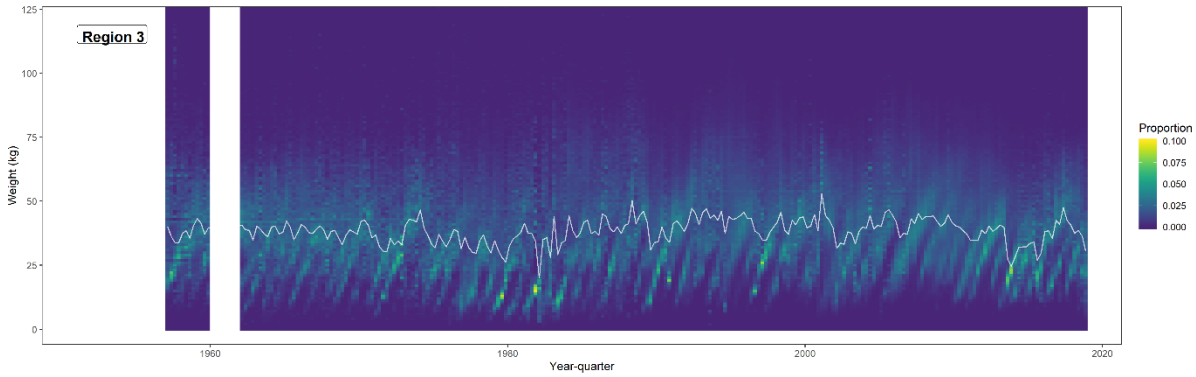


Figure 49 Reweighted weight compositions for (a) bigeye and (b) yellowfin for the index fishery in region 2, with a minimum total weighting of 0.1 and including size samples from all MFCL fisheries in region 2. The median size class is provided as a solid white line.

a) Reweighted compositions for the bigeye index fishery in region 3



b) Reweighted compositions for the yellowfin index fishery in region 3

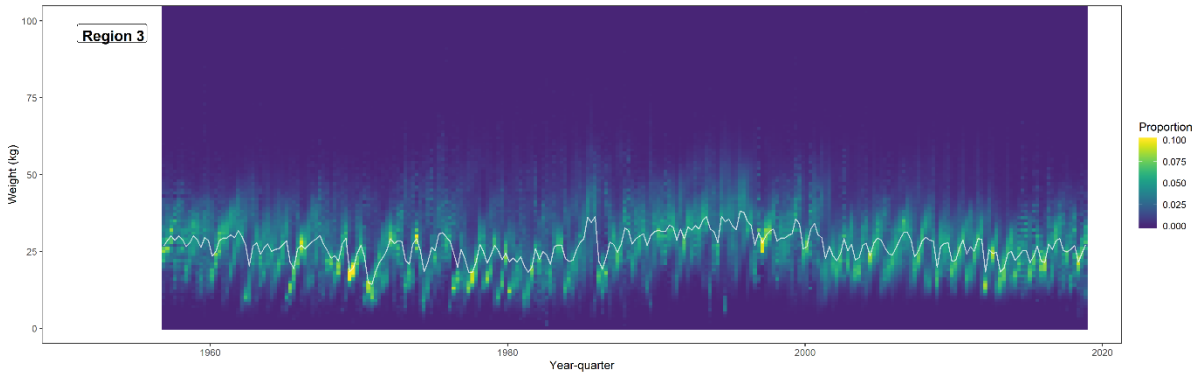
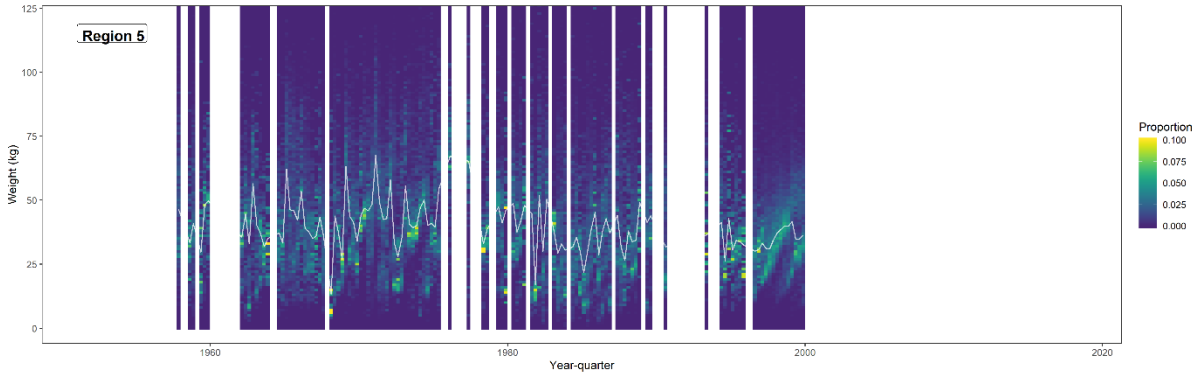
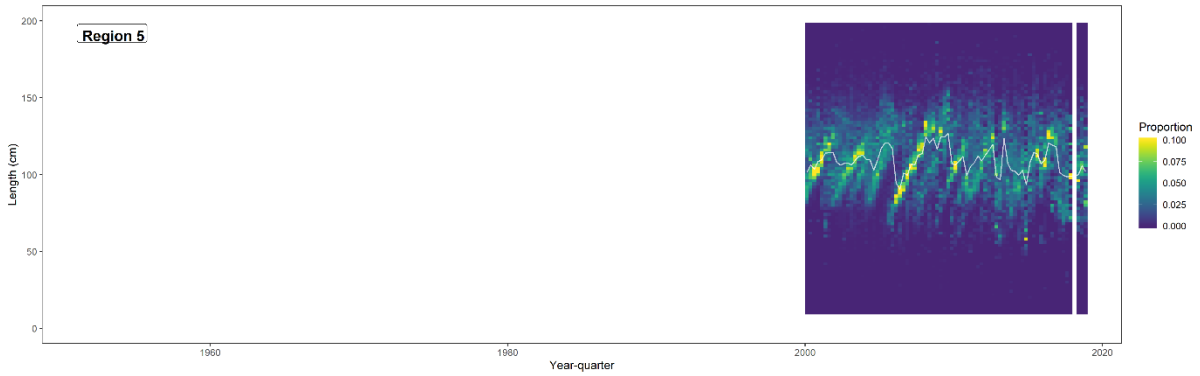


Figure 50 Reweighted weight compositions for bigeye (a) and yellowfin (b) for the index longline fishery in region 3, with a minimum total weighting of 0.1 and including size samples from all MFCL fisheries in region 3. The median size class is provided as a solid white line.

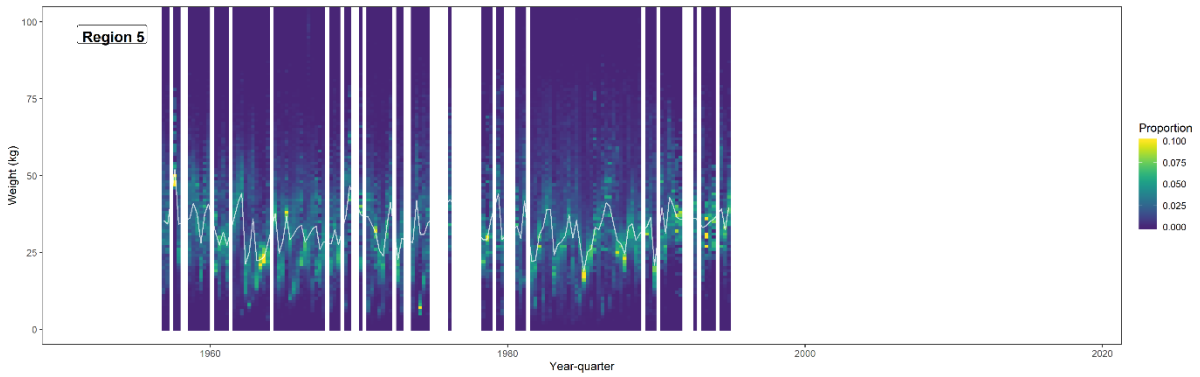
a) Reweighted weight compositions for the bigeye index fishery in region 5



b) Reweighted length compositions for the bigeye index fishery in region 5



c) Reweighted weight compositions for the yellowfin index fishery in region 5



d) Reweighted length compositions for the yellowfin index fishery in region 5

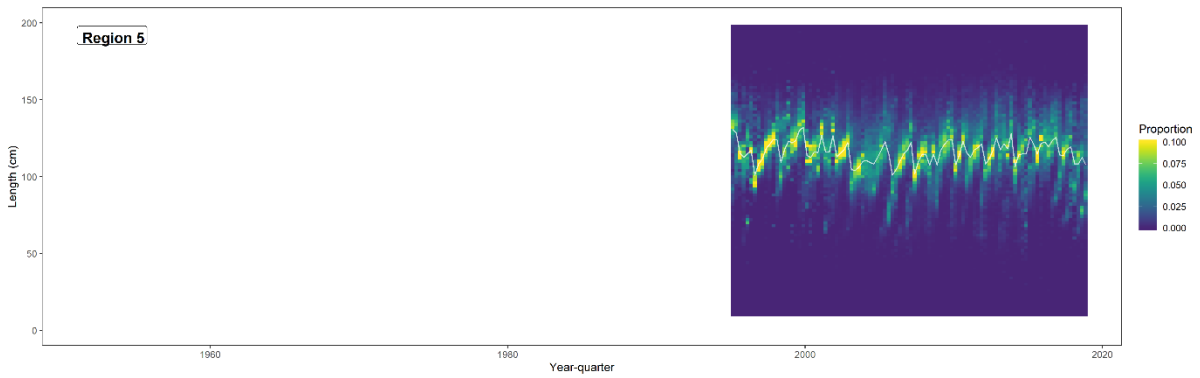
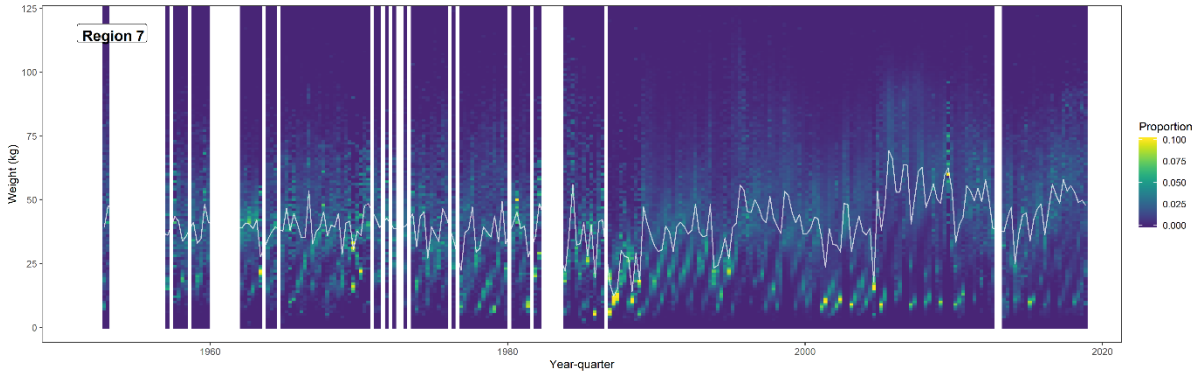


Figure 51 Reweighted weight (a) and length (b) compositions for bigeye and reweighted weight (c) compositions and length (d) compositions for yellowfin for the index longline fishery in region 5, with a minimum total weighting of 0.1 and including size samples from all MFCL fisheries in region 5. The median size class is provided as a solid white line.

a) Reweighted compositions for the bigeye index fishery in region 7



b) Reweighted compositions for the yellowfin index fishery in region 7

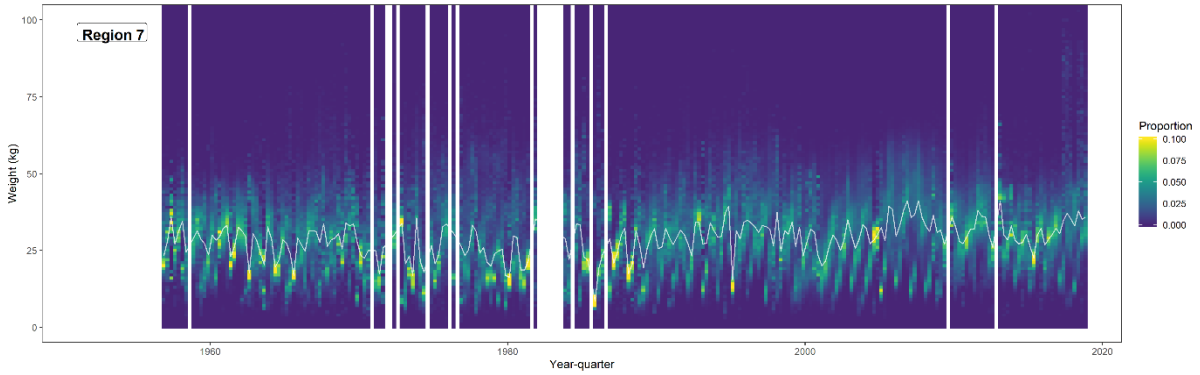


Figure 52 Reweighted weight compositions for bigeye (a) and yellowfin (b) for the index longline fishery in region 7, with a minimum total weighting of 0.1 and including size samples from all MFCL fisheries in region 7. The median size class is provided as a solid white line.