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Analysis of Longline Length Frequency Compositions for South Pacific Albacore

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Executive Summary

The size compositions of catches are a key source of information for the assessment of many stocks in the WCPO and assessments of tuna stocks in this region typically employ large quantities of length and/or weight frequency data. These data are characterised by inconsistent temporal and spatial resolution, may be subject to very small sample sizes and consequently exhibit high variability in some periods. To address some of these issues a data re-weighting procedure is undertaken to reduce some of the variability in length frequency data for the albacore caught by longline fisheries and to ensure that the stock assessment models the size composition of the catch correctly.

Two data re-weighting approaches are considered. The first, based on the distribution of total catch between spatial units within a region relative to the distribution of length sampling, the second, based on the scale of catches for each flag (vessel nationality) relative to their level of length sampling.

Re-scaled length frequency data were considered to be the most appropriate for use in the stock assessment when they were calculated based on spatial cell weighting with an 11 year-quarter moving average for catch scaling, and a minimum weighting threshold of 0.1. As an alternative, length frequencies determined using a minimum weighting threshold of 0.7 may also be considered although the effect of these alternative data in the assessment is expected to be small.

1 Introduction

The size compositions of catches are a key source of information for the assessment of many stocks in the WCPO and assessments of tuna stocks in this region typically employ large quantities of length and/or weight frequency data. For Albacore (*Thunnus alalunga*) in the WCPO, catch size composition data have been routinely collected from the fishery since the early 1960's. These data are characterised by inconsistent temporal and spatial resolution, may be subject to very small sample sizes and consequently exhibit high variability in some periods.

To address some of these issues with the size composition data the 2012 assessment of albacore tuna in the south Pacific Ocean (Hoyle et al., 2012) employed a data re-weighting approach similar to that used for the 2011 bigeye (*Thunnus obesus*) and yellowfin (*Thunnus albacares*) assessments (Hoyle and Langley, 2011) in which the length frequency data were re-scaled in accordance with the spatial variation in CPUE for a grid of 10 degree by 20 degree cells within each region of the assessment area. The external review of the bigeye assessment (Ianelli et al., 2012) considered that spatial re-scaling of size frequency data by long-term catch rather than CPUE would be a more appropriate approach to ensure that the stock assessment models the size composition of the catch correctly. The review recommended that further investigations be conducted in this respect and a revised re-weighting method (McKechmie, 2014) was developed and applied for the bigeye and yellowfin assessments conducted in 2014. This paper describes the application of the revised approach for albacore tuna in the WCPO.

As for the original analysis, two data re-weighting approaches were considered. The first was based on the distribution of total catch between spatial units within a region relative to the distribution of length sampling, the second was based on the scale of catches for each flag (vessel nationality) relative to their level of length sampling.

2 Methods

Catch length frequency data for albacore were extracted from SPC data holdings and separated into assessment regions (Figure 1). There are known to be unexplained shifts in the length frequency distributions for data collected at Pago Pago prior to 1972. These data were removed prior to conducting the analysis.

The length frequency data are collected and made available at a range of different spatial scales. For albacore the majority of the length frequency data are collected at either 5° x 5° cells (65%) or 10° x 20° cells (31%), the remainder being at either 5° x 10° or approximate 10° x 20° cells.

Some of the 10° x 20° cells overlap two or more region boundaries (see Figure 1). Data for cells that overlapped two region boundaries were divided by 2 and data for cells that overlapped four region boundaries were divided by 4. The size data could then be included in each region without giving greater weight to the overlapping cells.

2.1 Re-weighting by Spatial Cell

The calculation of spatial cell weightings and subsequent re-weighting of size composition data followed the approach described in [McKechnie \(2014\)](#). The procedure is described briefly below.

1. Cell weightings were calculated as per Equation 1 by summing the catch ($C_{i,t}$) of albacore (in numbers) for each $10^\circ \times 20^\circ$ cell ($i=1:M$) in a given year-quarter ($t=1:T$) and dividing it by the total catch for all cells in that year-quarter within an assessment region.
2. An additional temporal smooth was applied to the weighting function such that the weighting ($W_{i,t}$) was calculated over a moving time window spanning $t-k$ year-quarters to $t+k$ year-quarters. This was imposed in an attempt to prevent the assessment model from interpreting short term variation in lengths compositions (that may have resulted from variation in distribution of the catch) as variation in the size composition of the population.

$$W_{i,t} = \frac{\sum_{t-k}^{t+k} C_{i,t}}{\sum_{i=1}^M \sum_{t-k}^{t+k} C_{i,t}} \quad (1)$$

3. Re-weighted length frequencies were calculated by multiplying the numbers in length bin l (1cm bin width), in each cell-year-quarter by the ratio of the cell weighting to the total number of fish sampled in that cell-year-quarter (Equations 2,3).
4. An upper limit of 1,000 fish was set for a year-quarter to prevent very high sample sizes in some year-quarters from being overly influential. This was achieved by multiplying the area weighting by 1000 and then rescaling the ratios of cell weighting to total sample number to a maximum value of 1.0 within a region and year-quarter for those instances where ratios greater than 1.0 were achieved.

$$p_{i,t} = \min \left[\frac{W_{i,t} \cdot 1000}{\sum_l n_{i,t,l}}, 1.0 \right] \quad (2)$$

$$N_{t,l} = \sum_i n_{i,t,l} \cdot p_{i,t} \quad (3)$$

In addition to the procedure described above a limit on the lowest allowable weighting was imposed to reduce the influence of size data from cells with very little catch. For example if a limit of 0.3 were set, only those cells with normalised weightings of 0.3 or greater would be included in the re-weighting procedure. The choice of limit was somewhat arbitrary and based on the trade-off between preventing the loss of data from too many year-quarters (in the event of a high limit) and conversely, preventing undesirable temporal variation in the size compositions when two or more cells with very different size compositions contribute to the region-scale size distribution.

2.2 Re-weighting by Flag

The second re-weighting approach was based on the scale of catches for each flag (vessel nationality) relative to their level of length sampling. Calculation of the re-scaled length frequencies followed the same procedure

as described above except that weightings were calculated for individual flags ($f=1:F$) within each region rather than for spatial cells (i) within a region.

$$W_{f,t} = \frac{\sum_{t-k}^{t+k} C_{f,t}}{\sum_{f=1}^F \sum_{t-k}^{t+k} C_{f,t}} \quad (4)$$

$$p_{f,t} = \min \left[\frac{W_{f,t} \cdot 1000}{\sum_l n_{f,t,l}}, 1.0 \right] \quad (5)$$

$$N_{t,l} = \sum_f n_{f,t,l} \cdot p_{f,t} \quad (6)$$

Comparative analyses were conducted for both the spatial re-weighting and flag re-weighting approaches using two alternative assumptions for the extent of the temporal smooth in catch weights (either an 11 year-quarter moving average or an average catch calculated over the full time series) and a selection of minimum cell weighting threshold values (Table 1). Analyses were focussed on the preferred approach for bigeye and yellowfin based on spatial cell re-weighting and an 11 year-quarter moving average for the catch weightings. A limited set of comparative runs were conducted for alternative settings.

3 Results

Overall, the results of the various re-scaling approaches and alternative parameter settings produced broadly similar results in terms of the temporal trends and the spread of the distributions of the re-weighted length frequencies. The results are graphically displayed as comparative boxplots by year-quarter of the length composition, bubble plots by year-quarter of median length and density plots of length composition aggregated over all year-quarters for each region. Since the results of the various re-scaling approaches were quite similar, only a subset of the results are presented graphically below.

For all scenarios, the re-weighted length frequencies comprised fewer observations than the raw data but typically had tighter distributions with much fewer points at extreme values. For some regions and model settings the re-scaled length frequencies may comprise as little as 10% of the raw data (Table 2). In spite of this, comparative density plots of the raw and re-weighted length frequencies were very similar for most regions. However, in the case of the southernmost regions (regions 3, 6 and 8) for which the quantity of data removed by the re-scaling process was generally greatest, some notable differences are apparent between the raw and the re-scaled length frequencies (see for example Figure 5).

Differences in results when applying either a minimum weighting threshold of zero or 0.1 were negligible, and further increases in the minimum weighting threshold had relatively little effect. Differences in the resulting length frequency data are difficult to discern from the various plots and in many instances the quantity of additional data removed by applying a higher threshold was small (Table 2).

A comparative scenario using weightings based on the full time series with a minimum weighting threshold of 0.3 produced re-scaled length frequencies that were very similar to those achieved with 11 year-quarter moving average weightings.

For the flag re-weighted length frequencies (Figures 9 to 10) there were some clear departures of the re-scaled length frequencies from the raw data, particularly towards the end of the time series. For some regions the method appeared to be introducing noise to the length frequencies rather than removing it (see for example Figure 9, regions 4 and 5). This is likely due to length composition data being available for a greater number of flags such that the relative proportion of samples for those flags was smaller and consequently more likely to be excluded from the analysis, even at very low weighting thresholds. The flag based re-weighting approach suffers from the fact that the number of flags contributing data can change markedly over time and potentially means that the more comprehensive the sampling coverage, in terms of the number of different nations submitting data, the more data that are removed from the analysis because the relative proportion of data available for each flag is lower. The flag based re-weighting approach was not considered further in this analysis.

There were some anomalously small length frequencies in region 1 in 1995 that were apparent in both the raw and re-scaled data (see for example Figure 3). This appears to be due to a small number of samples that were probably taken from sets that caught particularly small fish. Whilst they clearly stand out as different from the rest of the time series there was no other reason to remove them and have therefore been retained in the analysis.

The southernmost regions exhibit a strong seasonal pattern in length distributions with the size of fish captured in the first season being smaller than at other times of the year (Figure 2). The re-scaling procedure failed to track this bi-modal distribution in length frequencies and, for all runs, the re-scaled length compositions for regions 3,6 and 8 are notably different from the raw data.

4 Discussion

Re-scaled length frequency data based on spatial cell weighting with an 11 year-quarter moving average for catch scaling, and a minimum weighting threshold of 0.1, are considered to be the most appropriate length frequency data for use in the stock assessment. This decision is based on the largely qualitative comparison of distributions of the raw and re-scaled length frequencies.

Re-scaling length frequency data can potentially impact the assessment in two ways. The first and most obvious is the potential modification of the distribution of the length frequency data. We have shown that the quantity of data in the tails of the distribution has been reduced by the re-scaling process but that, for most regions, the overall shape of the distribution has been retained. In this respect the re-scaling procedure can be considered to be working effectively.

The second potential impact of the re-scaling procedure is to change the weighting that the size composition data attain within the assessment. For composition data where a multinomial likelihood is often applied, weights may be determined by input sample sizes. The weights applied to individual data sets can be an important contributor to model results. Pre-processing of the length compositions can reduce the estimated effective sample size and consequently reduce the influence of those data in the assessment. For this reason we suggest that re-scaled length frequencies for the extremes of the minimum weighting threshold (0.1 and 0.7) be considered, although the difference in the quantity of data between these two options is generally small and any impact on the assessment is also therefore expected to be small. It should be noted that

the effective sample size can be determined from a number of alternative approaches and depending on the method employed the input sample size may not be an important consideration.

All of the re-scaling approaches provided re-weighted length frequencies for the southern regions that comprised a higher proportion of larger fish than the raw data. This was particularly apparent for regions 6 and 8 and is due to the length samples that contain smaller fish being taken in cells and time periods when catches were low.

5 Conclusion

Re-scaled length frequency data based on spatial cell weighting with an 11 year-quarter moving average for catch scaling and a minimum weighting threshold of 0.1 are considered to be the most appropriate length frequency data for use in the stock assessment (Figures 3 to 5). As an alternative, length frequencies determined using a minimum weighting threshold of 0.7 (Figures 6 to 8) may also be considered although the effect of these alternative data in the assessment is expected to be small.

There was generally little to choose from between different options for the spatial cell re-weighting approach. The flag based re-scaling method performed less well and this method will require further development if it is to be considered again in the future.

References

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Table 1: Run combinations of minimum weighting thresholds examined for spatial cell and flag based rescaling procedures employing either 11 yr-qtr moving average weights or weights based on the full time series.

	11 yr-qtr					full TS
spatial	0.0	0.1	0.3	0.5	0.7	0.3
flag		0.1	0.3			0.3

Table 2: Proportion of length frequency data removed from the raw data by the re-scaling procedure for the base case of spatial cell re-weighting with an 11 yr-qtr moving average and minimum cell weighting thresholds of 0.1 and 0.7 for each region of the assessment area.

Weighting Threshold	Region							
	1	2	3	4	5	6	7	8
0.1	0.43	0.66	0.76	0.46	0.51	0.59	0.50	0.44
0.7	0.44	0.81	0.89	0.54	0.74	0.81	0.58	0.60

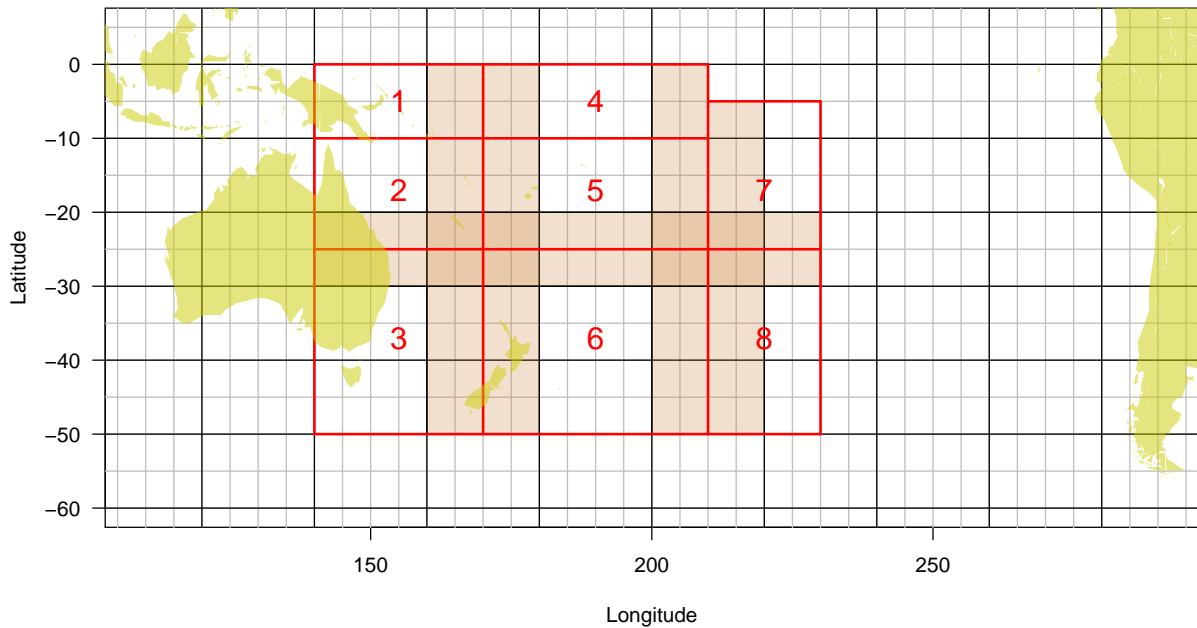


Figure 1: Albacore assessment regions (red boxes). Gridlines indicate the the 5x5 and 10x20 cells that were used for spatial cell weighting. Shaded areas indicate the 10x20 cells that overlap region boundaries.

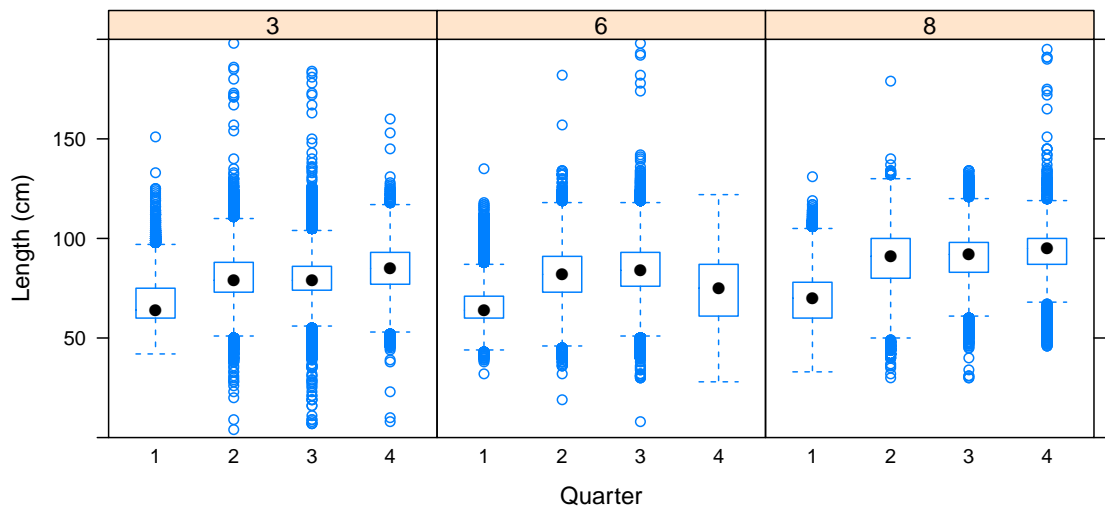


Figure 2: Boxplots of raw albacore length frequency data aggregated for all years by quarter for the most southerly regions (3 6 and 8) of the assessment area.

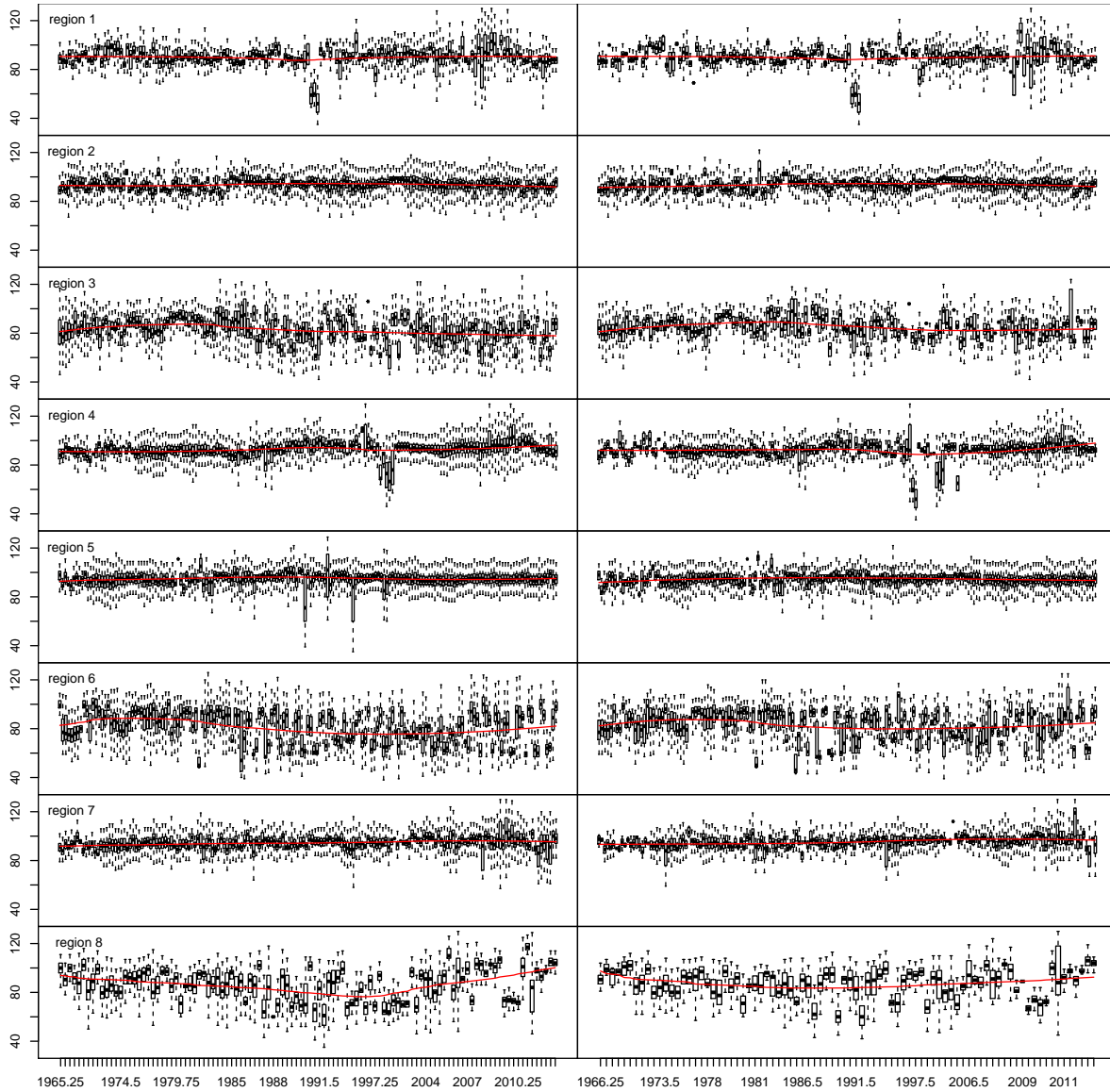


Figure 3: Boxplots of raw (left panels) and re-weighted (right panels) albacore length frequency data by year-quarter and for each region: Re-weighted LFs are based on spatial cell weighting for an 11 quarter time period and a 10% threshold for the lowest total weighting

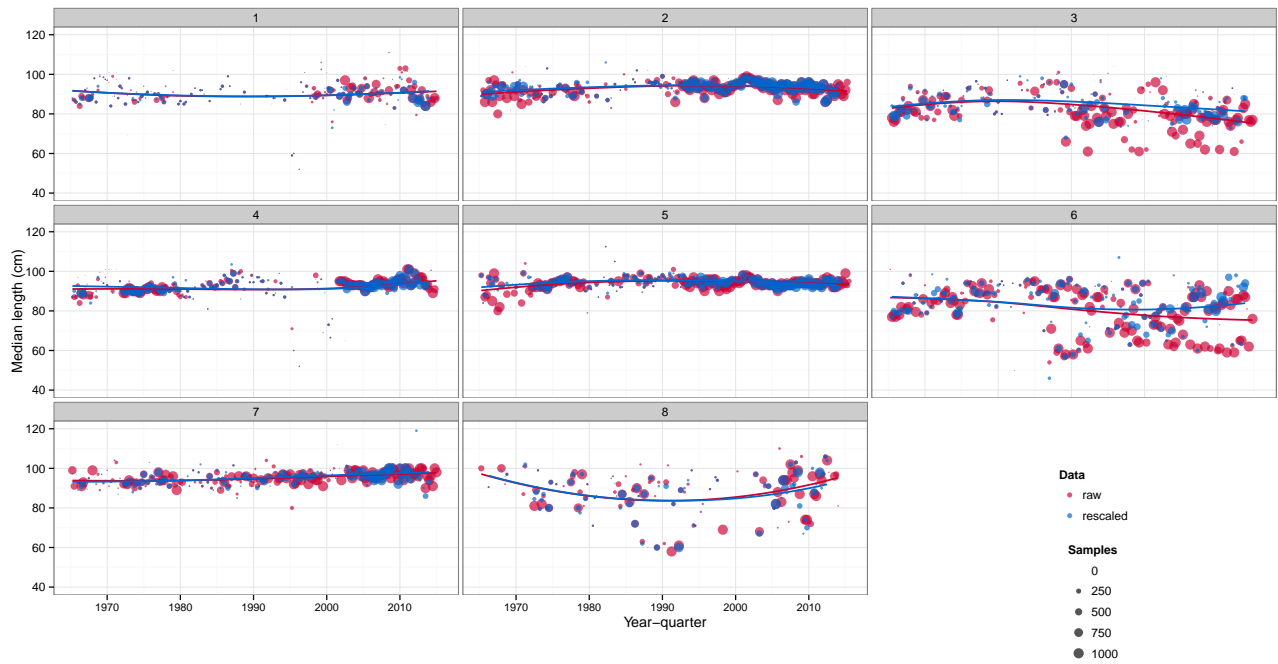


Figure 4: Density plots of raw and re-weighted albacore length frequency data by region: Re-weighted LFs are based on spatial cell weighting for an 11 quarter time period and a 10% threshold for the lowest total weighting

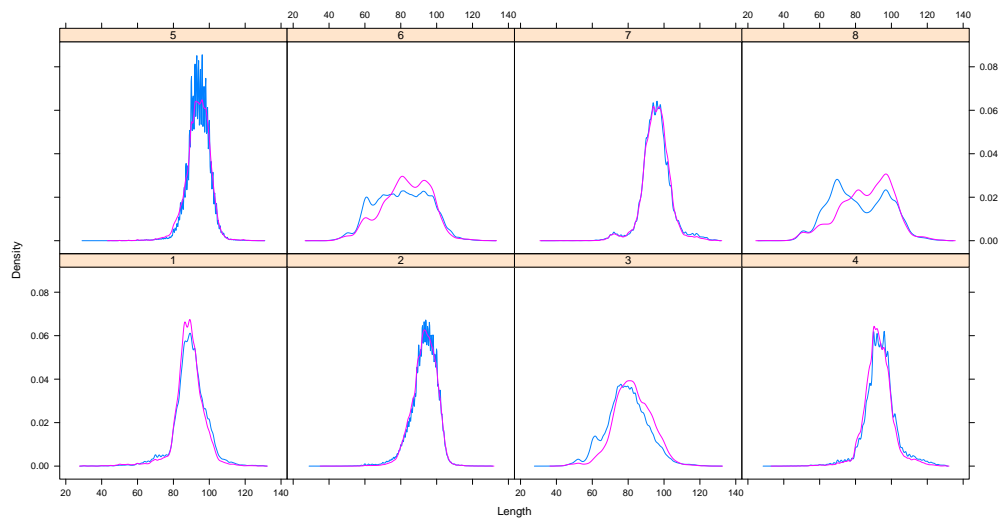


Figure 5: Density plots of raw (blue) and re-weighted (red) albacore length frequency data by region: Re-weighted LFs are based on spatial cell weighting for an 11 quarter time period and a 10% threshold for the lowest total weighting

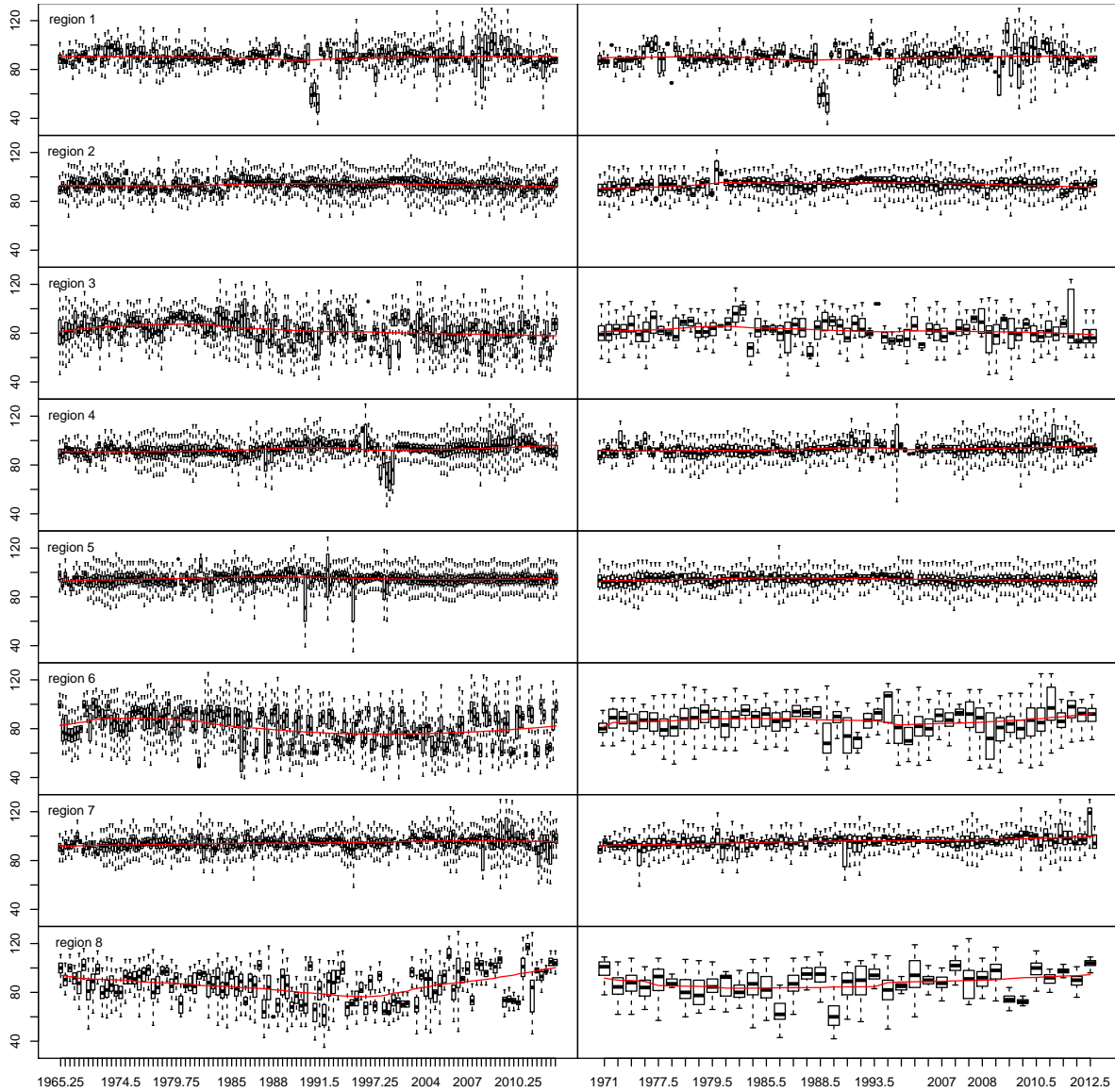


Figure 6: Boxplots of raw (left panels) and re-weighted (right panels) albacore length frequency data by year-quarter and for each region: Re-weighted LFs are based on spatial cell weighting for an 11 quarter time period and a 70% threshold for the lowest total weighting

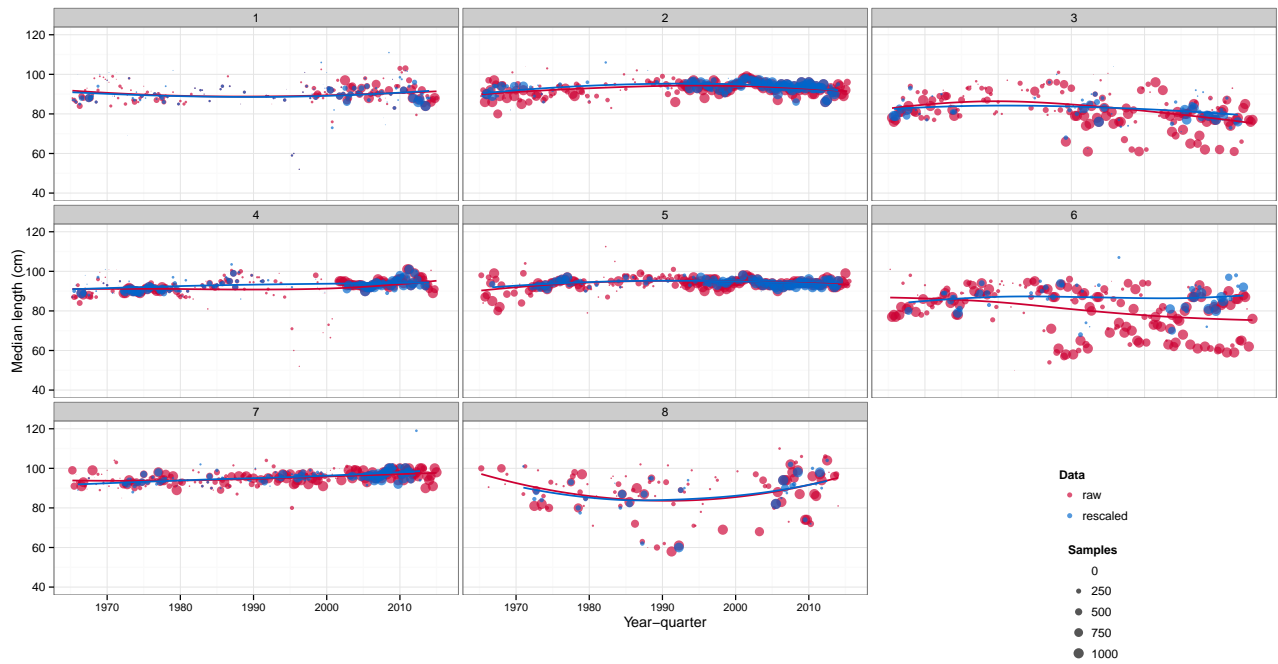


Figure 7: Density plots of raw and re-weighted albacore length frequency data by region: Re-weighted LFs are based on spatial cell weighting for an 11 quarter time period and a 70% threshold for the lowest total weighting

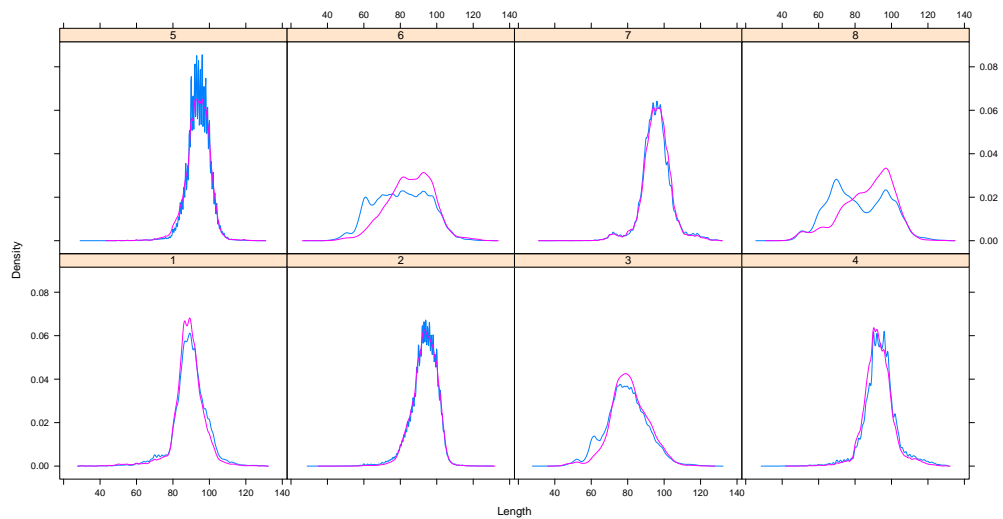


Figure 8: Density plots of raw (blue) and re-weighted (red) albacore length frequency data by region: Re-weighted LFs are based on spatial cell weighting for an 11 quarter time period and a 70% threshold for the lowest total weighting

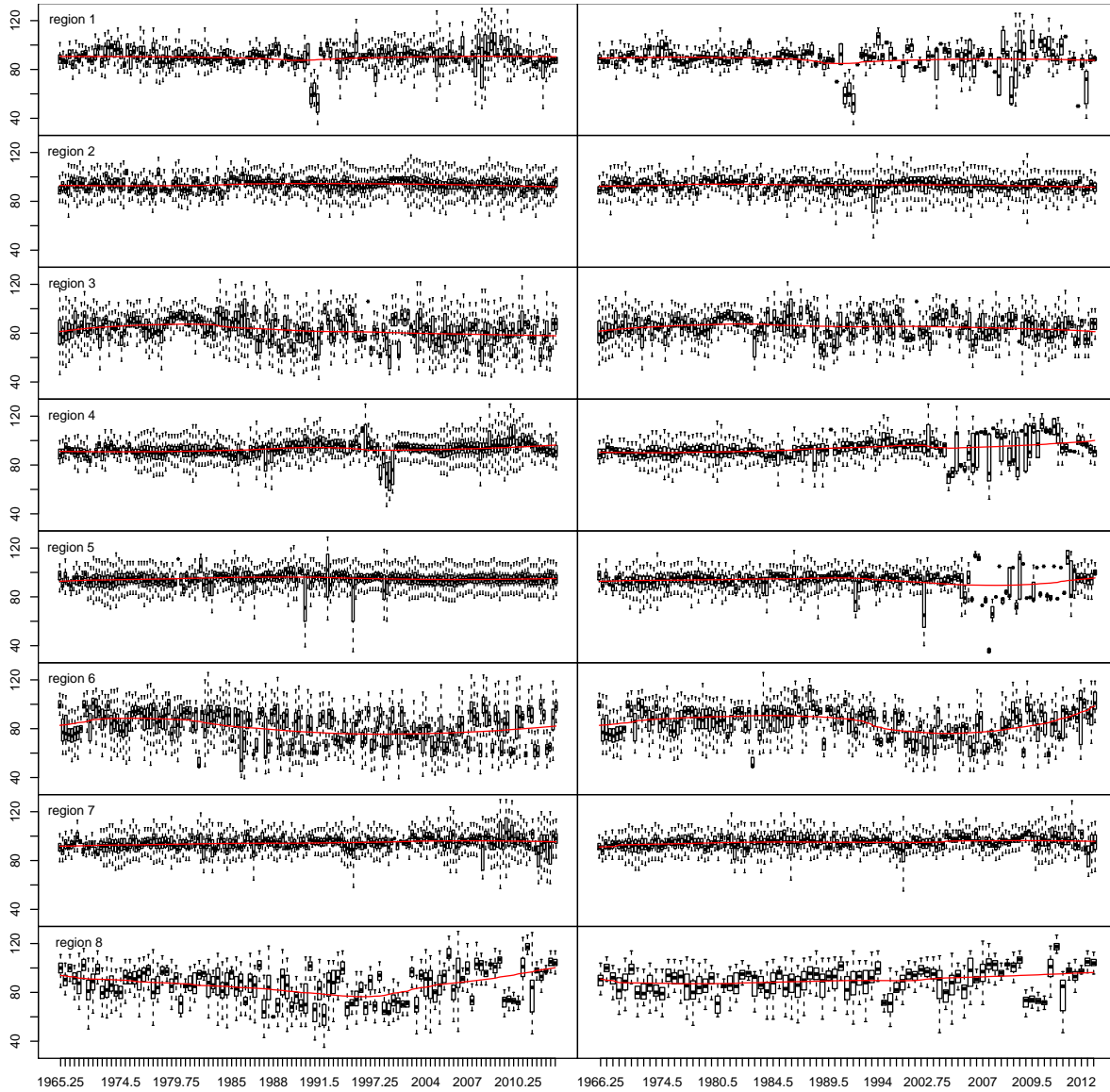


Figure 9: Boxplots of raw (left panels) and re-weighted (right panels) albacore length frequency data by year-quarter and for each region: Re-weighted LFs are based on flag weighting for an 11 quarter time period and a 10% threshold for the lowest total weighting

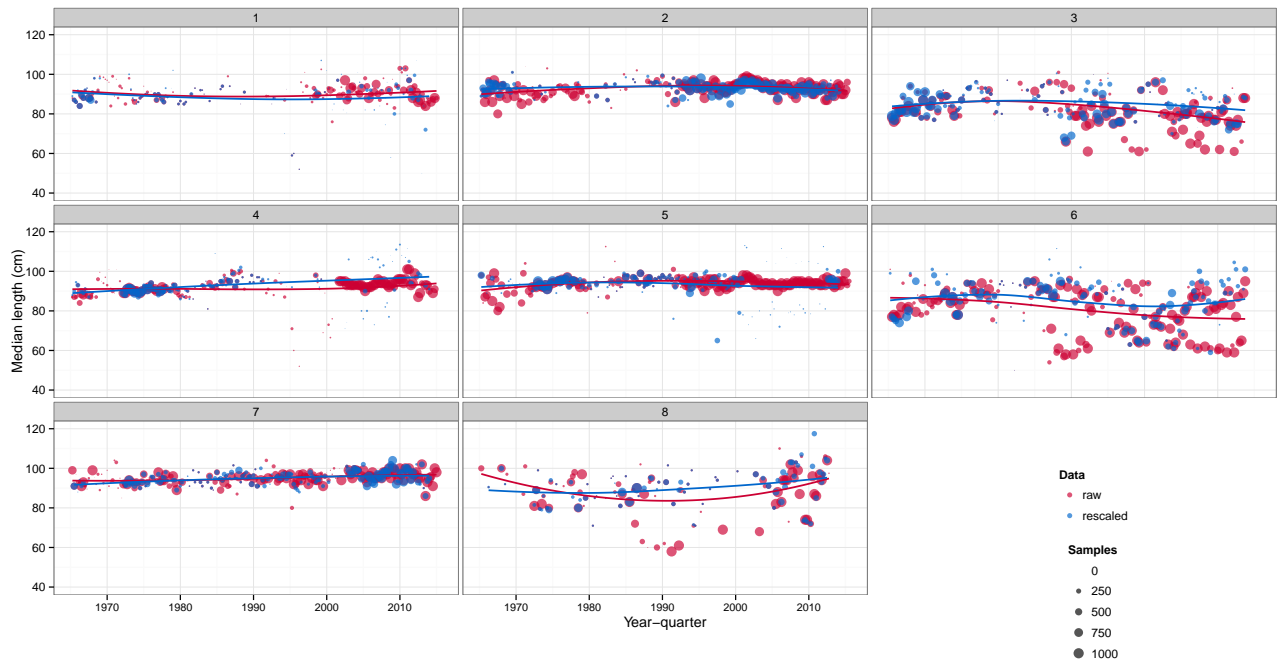


Figure 10: Density plots of raw and re-weighted albacore length frequency data by region: Re-weighted LFs are based on flag weighting for an 11 quarter time period and a 10% threshold for the lowest total weighting

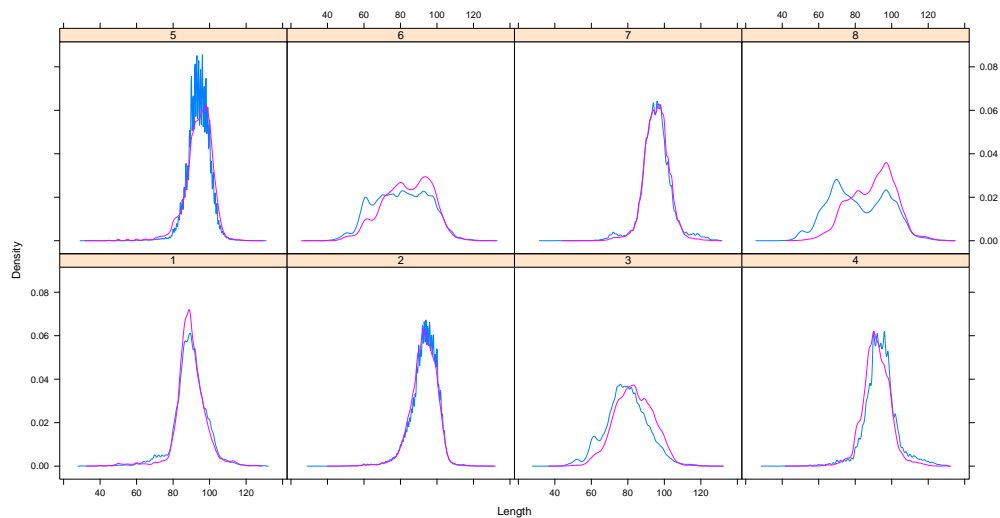


Figure 11: Density plots of raw (blue) and re-weighted (red) albacore length frequency data by region: Re-weighted LFs are based on flag weighting for an 11 quarter time period and a 10% threshold for the lowest total weighting

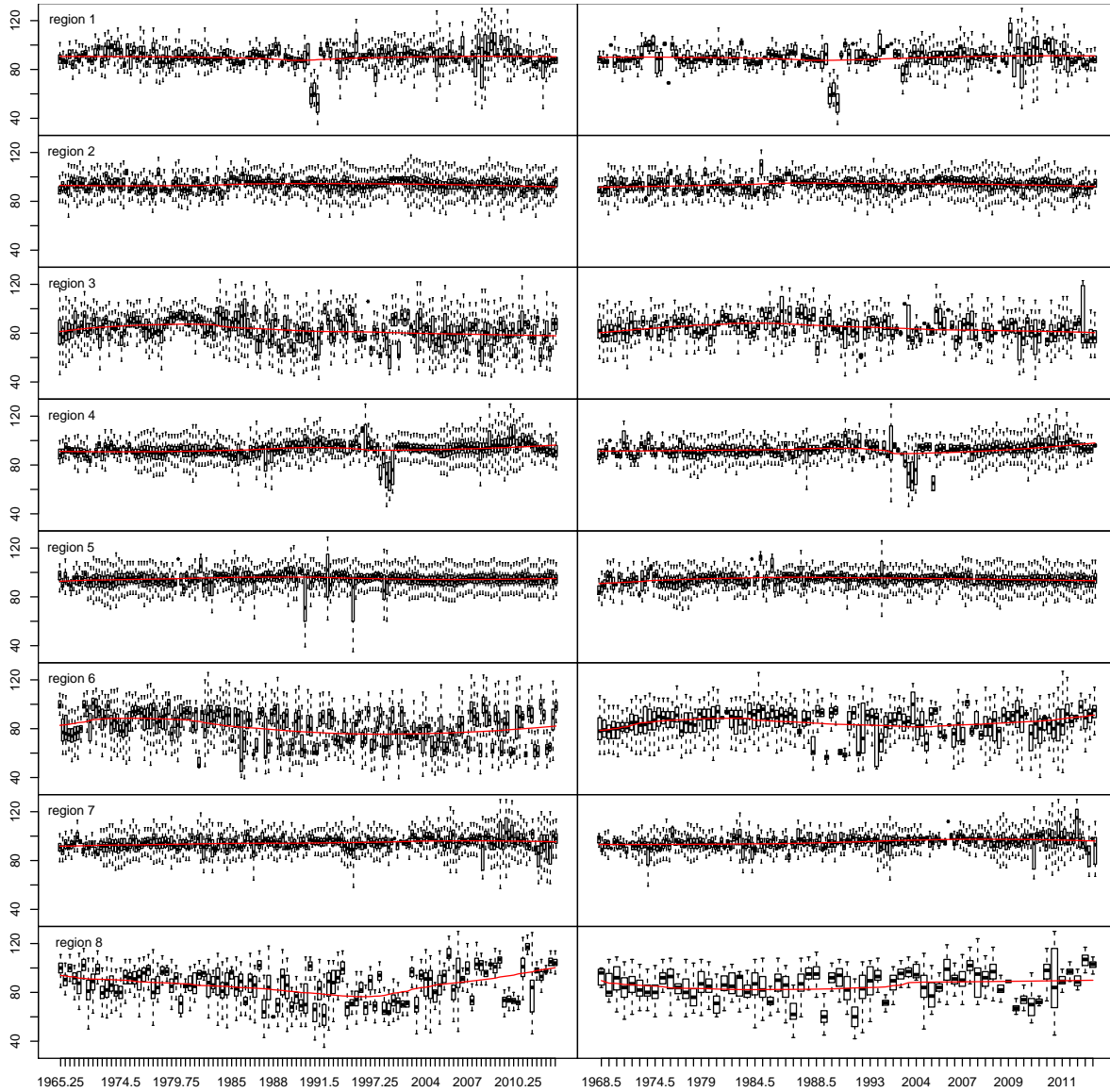


Figure 12: Boxplots of raw (left panels) and re-weighted (right panels) albacore length frequency data by year-quarter and for each region: Re-weighted LFs are based on spatial cell weighting for an 11 quarter time period and a 30% threshold for the lowest total weighting

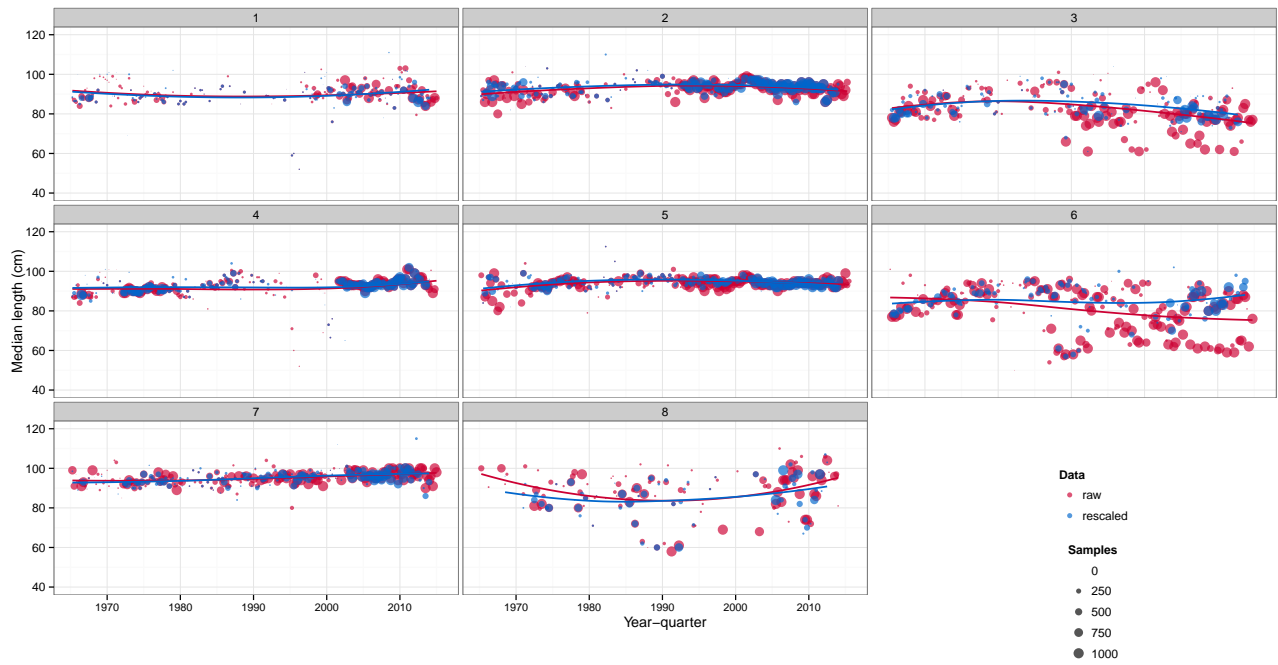


Figure 13: Density plots of raw and re-weighted albacore length frequency data by region: Re-weighted LFs are based on spatial cell weighting for the full time period and a 30% threshold for the lowest total weighting

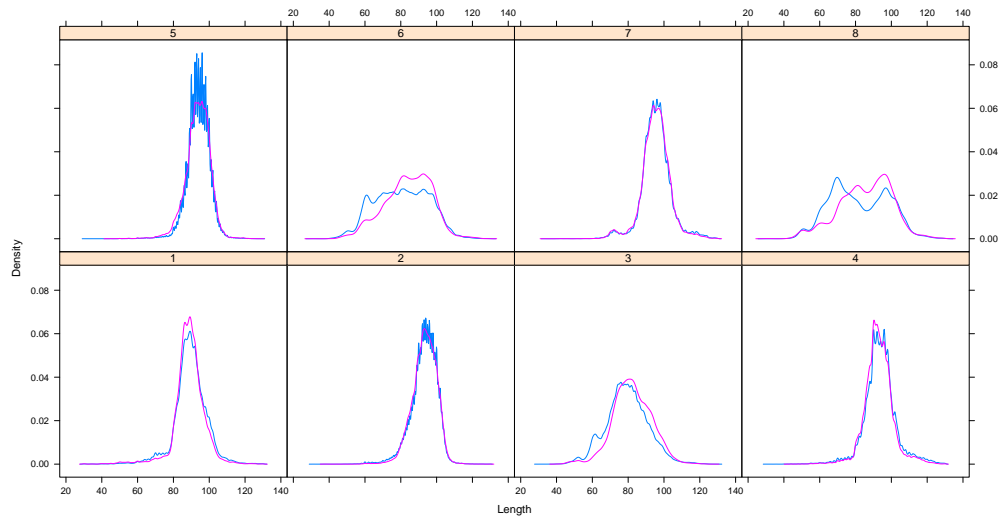


Figure 14: Density plots of raw (blue) and re-weighted (red) albacore length frequency data by region: Re-weighted LFs are based on spatial cell weighting for the full time period and a 30% threshold for the lowest total weighting