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Analysis of tropical purse seine length data for skipjack, bigeye and yellowfin tunas

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Executive Summary

Size data for purse seine fisheries in the WCPO are important inputs to the regional stock assessments, to both ensure that catches are removed from the appropriate parts of the population (i.e., through the estimation of selectivity), and to provide information on important biological processes such as growth and recruitment variability.

This paper describes the available data and the approaches to construct the purse seine size data used in the 2014 tropical tuna stock assessments. The improvements outlined in this paper include those provided through the “Independent Review of the 2011 bigeye assessment” (Ianelli et al., 2011).

In addition to updates to the estimation of selectivity bias of grab samples collected by observers (Lawson, 2013), the major changes to the purse seine size data over those used in the 2011 assessments for bigeye, skipjack and yellowfin tunas are: the inclusion of more recent observer grab samples, corrected for selectivity bias; the inclusion of NMFS port sampling data from Pago Pago; and the weighting of the samples by the spatial distribution of the catch at the level of model strata (i.e., school association, quarter and model region).

Introduction

Size data are used in the WCPFC stock assessments to inform on the removals by each fishery, and, indirectly, on the status of the stocks. Ideally, sampling effort should reflect the distribution of the catch among the different variables within a stratum (*e.g.*, sampling effort should be proportional to the catch of each flag included in the fleet definition, to the spatial distribution of the catch, etc.). This way, removals are accurately accounted for, and variations in sizes reflect changes in the population, or in other factors (selectivity, recruitment, etc.) that might be accounted for in the model. However, there are sources of variation due to the effects of the sampling (Hoyle, 2011).

Two of the main biases related to the sampling, which can be corrected *post hoc*, are (i) the systematic bias in the grab samples traditionally collected by observers aboard purse seiners (Lawson, 2008) and (ii) the different spatial distribution of the sampling effort and the catch.

The lower availability of the smaller size classes in the observer samples, which affects both the species and the size compositions, is corrected using the procedure described by Lawson (2013).

Temporal variations in fish sizes have been partially attributed to changes in the long-term distribution of the sampling effort (Hoyle and Langley, 2011) and has reduced the reliability of the length samples, thus leading to a significant down-weighting of the effective sample sizes in the models (*e.g.*, Hoyle et al., 2011). The catch length-frequency varies within each region, and one of the recommendations of the independent review of the 2011 WCPO bigeye tuna assessment (Ianelli et al., 2011) was re-scaling these length-frequency data by the catch. Such a procedure requires good spatial coverage of the sampling effort.

This document summarizes the size data currently available for the skipjack, bigeye and yellowfin tuna assessments in the Western and Central Pacific Fisheries Commission Convention Area (WCPFC-CA), and describes the procedure than has been used to re-scale the size sampling data.

Methods

Analysis of data available

Size data provided to the Secretariat for the Pacific Community (SPC) Oceanic Fisheries Programme (OFP) by the member countries or regional programs are merged into a master database. This database groups size data according to the gear, year, month, spatial strata (most frequently 5x5 degree square cells) and, in the case of the purse seine fisheries, type of association.

In total, there are 16 programs that have collected length data for the three tropical tunas caught by the purse seine fleets (Table 1). However, until very recently, the vast majority of information has come from just 4 programs: US Multilateral Treaty Port Sampling and Observer Programs, and the observer programs of Papua New Guinea (national) and the FSM Arrangement (sub-regional) (Figure 1).

Sample sizes were merged by year and model region to illustrate the number of samples available for the main programs (Figures 2-4). Given the importance of the size data being representative of the size composition of the catch, the coverage of each program was estimated as the percentage of the catch in cells with size data versus total catch in the region for each year and quarter (Figures 5-7).

Given the different temporal and spatial distribution of the main sources of size data (the US Multilateral Treaty Port Sampling data- which is the only source of information on size composition of the purse seine catch prior to the mid 1990's- and the different observer programs), Figures 8-9 show the distribution of the catches of all flags combined vs. the distribution of the sampling effort of the main two sources of size data.

Data correction

Data from the different observer programs were corrected (both species composition and length frequency distribution) for selectivity bias by grab samplers, grouped by 5x5 square, year/quarter and type of association, and weighted by set weight.

These data were then merged with the port sampling data from the US Multilateral Treaty program (grouped as above). Those strata (year, quarter, 5x5 cell, species and type of association) with less than 30 fish sampled were excluded, and the sample size within a stratum was limited to a maximum of 1000. The re-scaling of the size data at the region level according to the catch distribution was done as follows:

(i) The percentage in weight of each length class in the sample was estimated by multiplying the number of fish by the average weight using the length-weight relationship $W = a \cdot L^b$, with the coefficients given in Table 2, and then dividing by the total weight of the samples.
(ii) For each stratum and length class, estimates for cells with no size information located within the convex hull were obtained by linear interpolation.
(iii) The weight of each length class in the catch was obtained by multiplying the values obtained above by the weight of the catch in each 5x5 cell.
(iv) Data were merged at the region level, thus obtaining the weight of the catch by length class, region, year, quarter, species and type of association.
(v) The estimates from (iv) were divided by the average weight of each length class to get the number of fish by length class in each stratum (region, year, quarter, species and type of association), divided by the total number of fish in that stratum and multiplied by the original sample size.
(vi) Finally, a correction factor accounting for the catch coverage was applied, by multiplying by the ratio of the catch in 5x5 cells for which the length samples are available to the total catch.

Results and Discussion

Analysis of data available

The SPC holds length data for the three tropical tunas from a total of 16 sampling programs (Table 1). Ten of these databases originate from different regional or national observer programs, while the remaining six are based on port sampling data. Before 2000, the majority of length samples come from the U.S. National Marine Fisheries Service port sampling program for U.S. purse seiners in Pago Pago and, to a lesser extent, from an observer program on that fleet. From the early 2000s, observer data become the main source of information on the size composition of the purse seine fishery (Figure 1), in particular since the increase to 100% observer coverage in 2010 under CMM2008-01 and the requirement of observer coverage during FAD closures under CMM2011-1.

The coverage of each data source also varies depending on the region. Figures 2, 3 and 4 show the number of samples collected by year, assessment model region and program type for skipjack, yellowfin and bigeye tuna, respectively. Data from observer programs are the main source of samples, especially for skipjack and since the late 1990's.

Regarding the spatial coverage of the samples, Figures 5, 6 and 7 illustrate the percentage of the catch for which there are size estimates (with a resolution of 5x5 degrees in latitude and longitude and quarter) by year, program and region for skipjack, yellowfin and bigeye tuna, respectively. In general, the coverage of the yellowfin and skipjack tuna catch is good, particularly in the westernmost equatorial region (regions 4 and 7 in the skipjack and yellowfin/bigeye assessment models, respectively) since the early 2000s with the development of observer programs. The coverage of the US Multilateral Treaty Port Sampling since the late 1980s was relatively high, particularly in the eastern equatorial areas (regions 3 and 4 of the skipjack and yellowfin/bigeye assessment models, respectively). Nevertheless, the coverage of the bigeye tuna catch is low to moderate, with the exception of the model regions 3 and 8 in the last decade, mainly due to the increased coverage of observer programs.

The distribution of the US Treaty Port Sampling program logically mimics the distribution of the US fleet. Therefore, the sample sizes in the eastern WCPO are proportionally higher than the catch of the purse seine fleet (all flags combined) in this area. There are no data available from this program after 2009 (Figure 8). The sampling effort from observer programs seems to better reflect the distribution of the catch (Figure 9), but data are missing from the early years. Sampling effort in the westernmost regions (regions 4 and 7 of the skipjack and yellowfin/bigeye assessments, respectively) is minimal throughout the time series.

Data correction

The grab sampling traditionally carried out by observers aboard purse-seiners has been shown to be subject to several biases (Lawson, 2008). These biases affect the estimation of both the species composition of the catch and the size frequency distribution, by systematically overestimating the amount of fish in the larger size classes. Therefore, length data from observers are corrected following the method described in Lawson (2013).

The port sampling data are also biased: small fish were frequently discarded at sea, before the development of full-retention regulations, and are not present in the port sampling datasets; set weight affect species compositions and is not necessarily taken into account in the port sampling designs; well mixing or fish sorting occurs; etc. (see Lawson 2008 for further details).

However, due to the paucity of data from observer programs, especially before the 2000's, the port sampling data are used to complement the information available from observer programs. The US Treaty Port Sampling Program has the broadest temporal and spatial coverage among all the programs. However, it is only representative of the US purse seine fleet.

Under the assumption that the selectivity of the purse seine fleets is the same for all the flags, and noting the spatial and temporal variability in the size distribution of the catch, port sampling (US) and observer data (mainly US Treaty, PNG and FSM Arrangement) have been re-scaled taking into account the distribution of the catch of all the purse seine fleets combined.

The filtering described in the previous section resulted in a loss of about 20% of the strata available, but which accounted for less than 0.5% of the fish sampled. This largely avoided artifact size distributions caused by a low sample size, and was offset by the interpolation from adjacent cells with more robust estimates.

The re-scaling of the data did not generally produce dramatic differences in relation to the un-scaled values, but avoided isolated unusual distributions, caused by mismatches between the distribution of the catch and the sampling effort which might be very influential during the assessment process.

Overall, corrections during the early period, when port-sampling data were dominant, tend to better reflect the distribution of the catch and may imply significant changes. Observer data tend to be more representative of the spatial distribution of the catch and have a higher sample size. As a result, in the latest years of the analysis, the corrections applied to the size data mainly reflect the correction of the grab sampling bias (*e.g.*, Figure 10).

Figures 11 to 16 show the temporal series of the uncorrected vs corrected median sizes. In general, trends are quite similar, with lower values in the corrected dataset due to the grab sampling correction, and eventual differences caused by a mismatch between sampling effort and catch locations. In some cases, *e.g.*, unassociated yellowfin tuna fisheries in region 3 around 2005 (Figure 14), the size frequency distributions are multimodal and the grab sampling correction and scaling can result in significant differences in the median values.

References

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Hoyle S., Kleiber P., Davies N., Langley A. and Hampton, J. (2011). Stock assessment of skipjack tuna in the western and central Pacific Ocean. WCPFC-SC7-2011/SA-WP-04.

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

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

Lawson T. (2008). Factors affecting the use of species composition data collected by observers and port samplers from purse seiners in the Western and Central Pacific Ocean. WCPFC–SC4–2008/ST–WP–03

Lawson, T. (2013). Update on the estimation of the species composition of the catch by purse seiners in the Western and Central Pacific Ocean, with responses to tecent Independent Reviews. WCPFC–SC9–2013/ST–WP–03.

Table 1. Number of length frequency samples by program and year for the three tropical tunas from the purse seine fleets in the WCPO from 20°N to 20°S. TTPS: US Multi-lateral treaty Port sampling data; TTOB: US Multi-lateral treaty Observer data; PGO: PNG Observer Data; FMOB: FSM Observer Data; FAOB: FSM Arrangement Observer program; SBOB: Solomon Islands Observer Data; SPPS: Regional Port sampling data; JPSJ: Japan length data (Skipjack); JPPS: Japanese PS sampling program; KIOB: Kiribati Observer program; KRPS: Korea sampling program; MHOB: Marshall Islands Observer Data; SPOB: SPC Observer Data; TVOB: Tuvalu Observer Data; NROB: Nauru Observer data; IAWP: US Purse seine data by WPYRG areas for WCPO.

	1984-1992	1993-1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
TTPS	338756	284210	44280	58843	102962	130212	46824	39127	32793	34515	33925	36788	50970	562			
TTOB		3732	69314	84338	67907	79049	46720	28879	49127	30465	15972	29383	60761	107095	257468	225314	90649
PGOB		31774	1796	3712	3005	19912	67344	68684	88585	124674	148796	103460	125247	178627	304866	358184	458442
FMOB		43623	10737	19885	26994	17123	7513	6894	10390	10371	5179	13883	4597	14241	111676	132630	49845
FAOB				1623	2520	3940	16973	36722	71376	55889	66754	66405	44455	55475	142289	119025	16513
SBOB			46475	5387	5173	3514	7359	11248	36673	15576	1023	4806	22294	7642	130778	120999	122684
SPPS		45589	13325	1250	882	1089	1015	1050	1575	1270	4258	2245					
JPSJ		51644	15652	10624	10506	10732	14205	24339	14829	11215	15626	17757	13147	14394			
JPPS		9678	1043	1837	1144	108											
KIOB							3445	1425	2888	1414	16256	18127	15061	38386	104557	64377	73457
KRPS											833	399	5297				
MHOB									3265	17490	19387	37573	8898	27779	40649	37004	45548
SPOB		28701	15860	7589	3986	1304			1083			826		19676			
TVOB																	17850
NROB															5404	8387	
IAWP	4542																
Grand Total	**343298**	**498951**	**218482**	**195088**	**225079**	**266983**	**211398**	**218368**	**312584**	**302879**	**328009**	**331652**	**350727**	**463877**	**1097687**	**1065920**	**874988**

Table 2. Coefficients of the length-weight relationships.

Species	a	b
Skipjack	$0.8639 \cdot 10^{-05}$	3.2174
Yellowfin	$2.5120 \cdot 10^{-05}$	2.9396
Bigeye	$1.9729 \cdot 10^{-05}$	3.0247

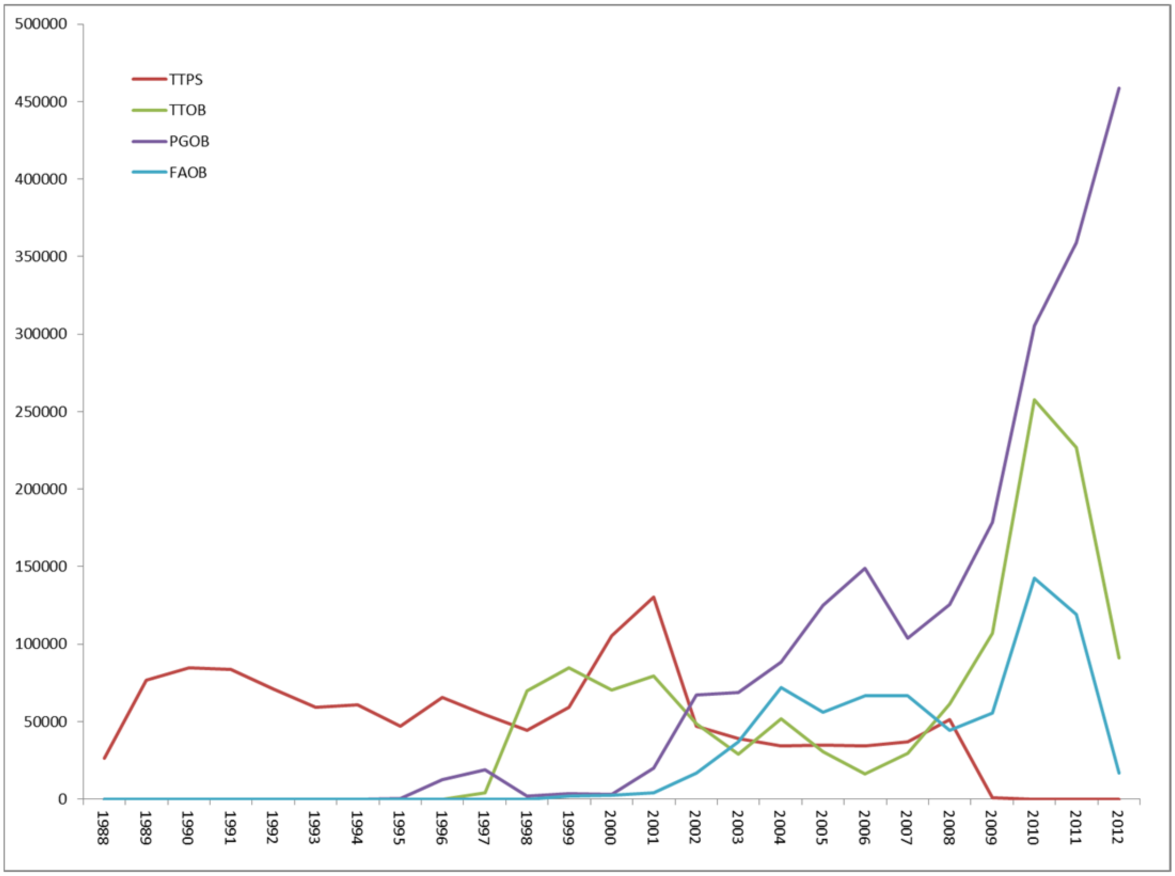

Figure 1. Number of length samples of the three tropical tuna species by year for the main sampling programs. TTPS: US Multi-lateral treaty Port sampling; TTOB: US Multi-lateral treaty Observer data; PGOB: PNG Observer data; FAOB: FSM Arrangement Observer Program. The number of samples for recent years shown in this figure, and those shown below, may increase as data continue to be provided to SPC.

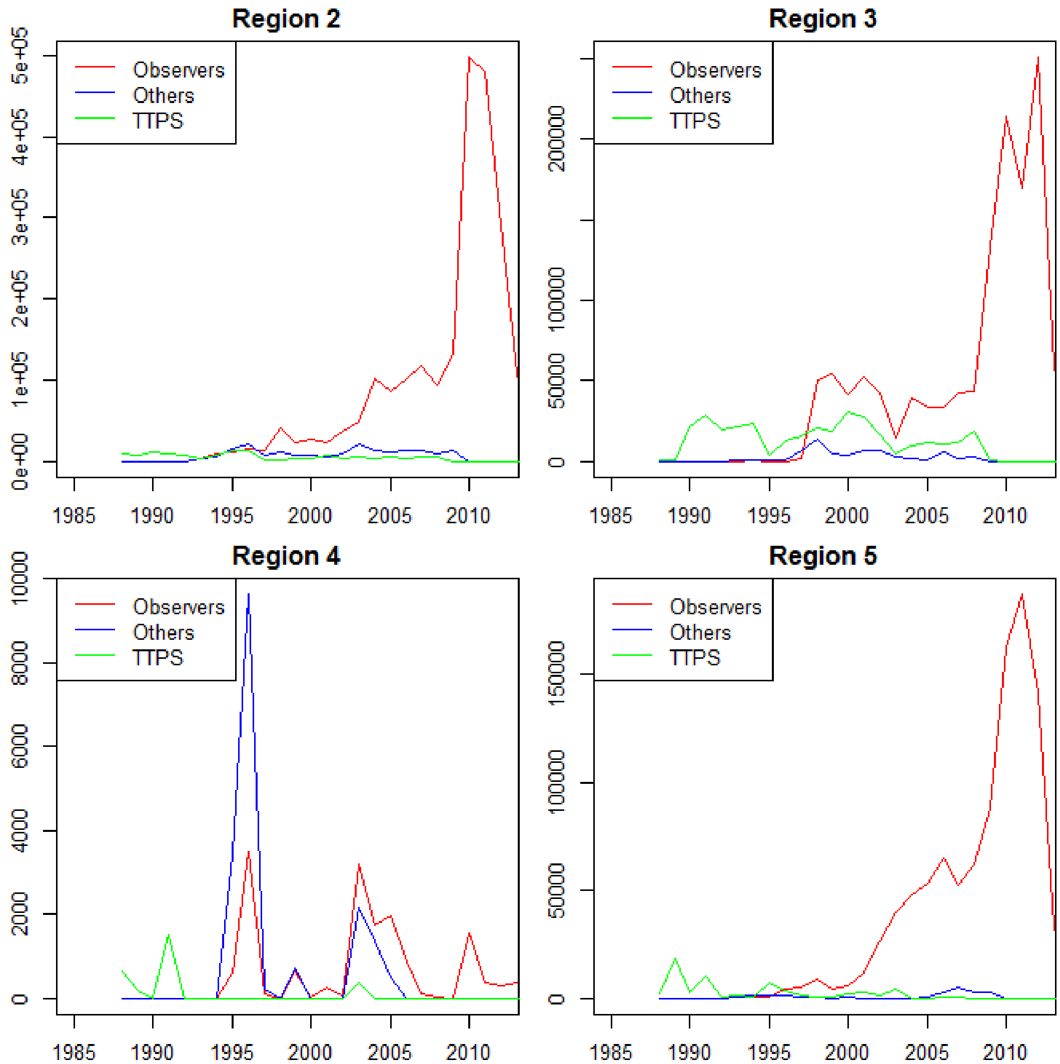

Figure 2. Number of skipjack length samples by year and program group. TTPS: US Treaty Port Sampling Program.

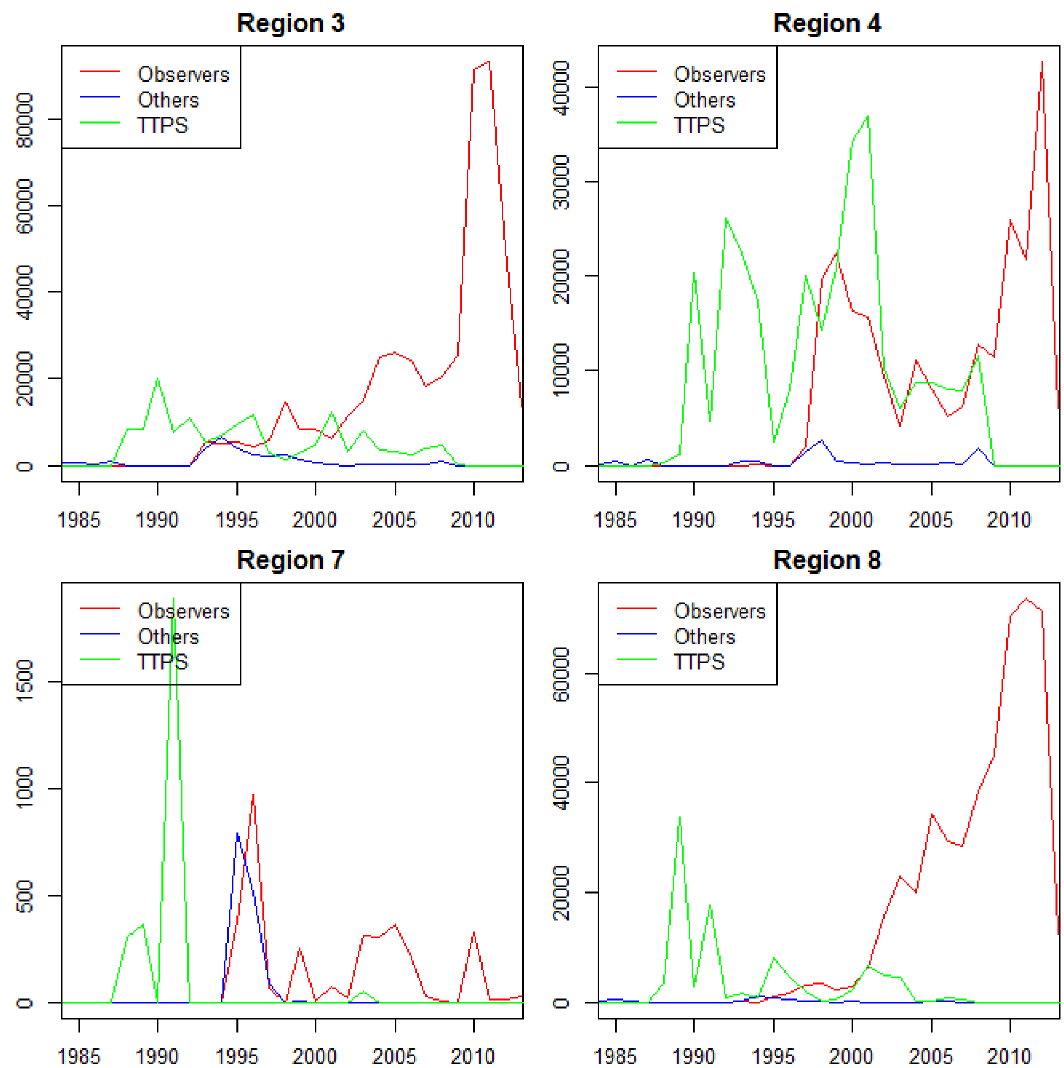

Figure 3. Number of yellowfin tuna length samples by year and program. TTPS: US Treaty Port Sampling Program.

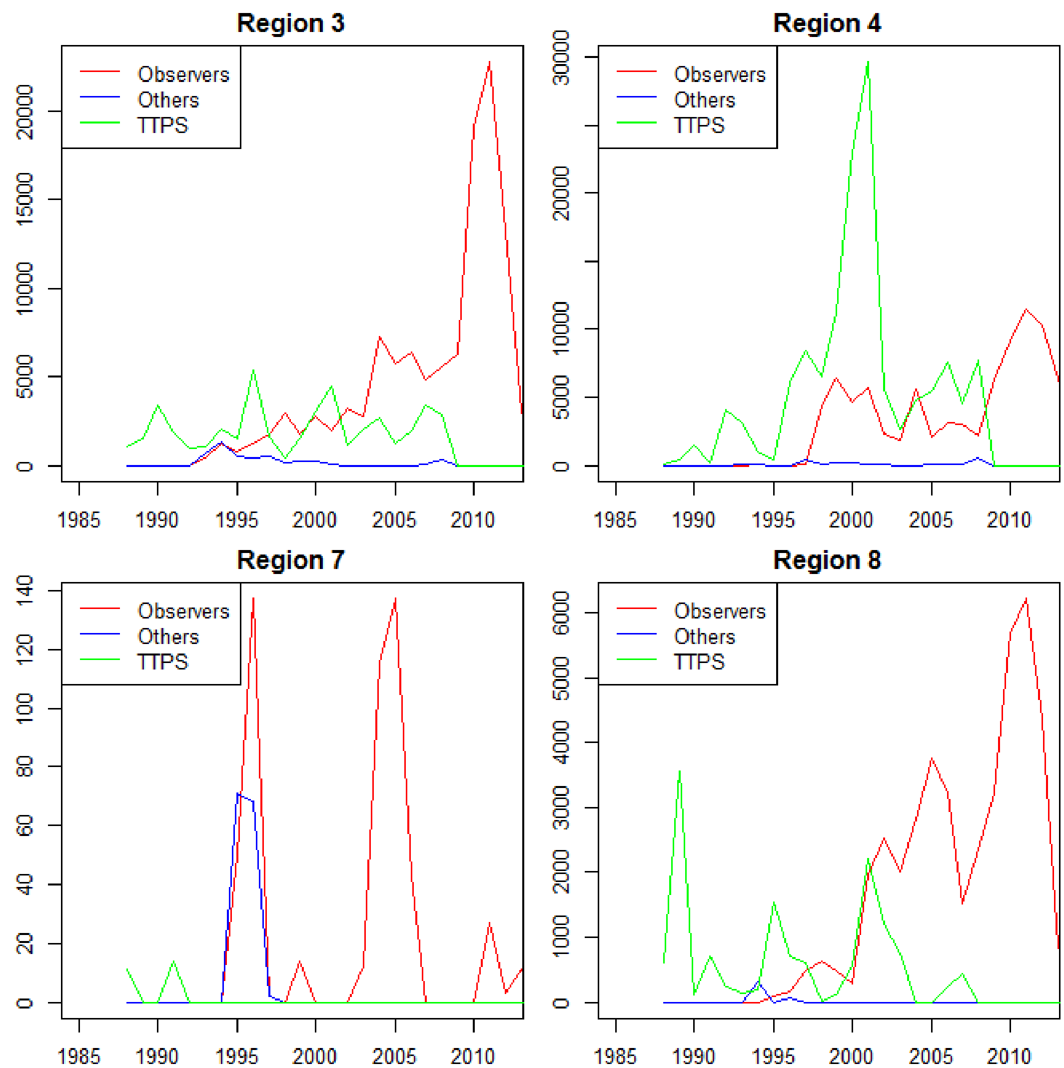

Figure 4. Number of bigeye length samples by year and program. TTPS: US Treaty Port Sampling Program.

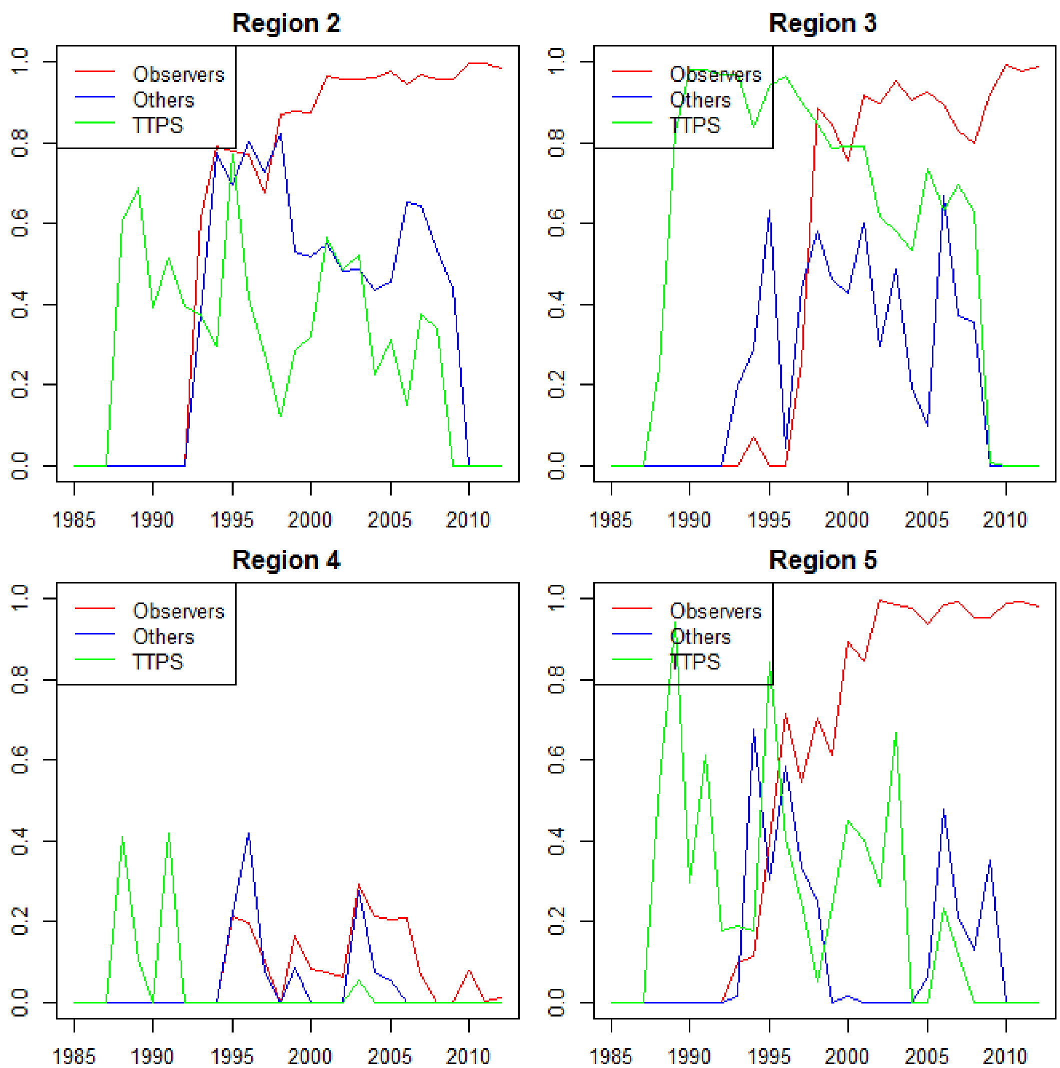

Figure 5. Coverage of SKJ length data as the proportion of purse seine catch in 5x5 cells with size data, divided by the total purse seine catch in the region (data pooled at the quarter level, but plotted yearly for display purposes).

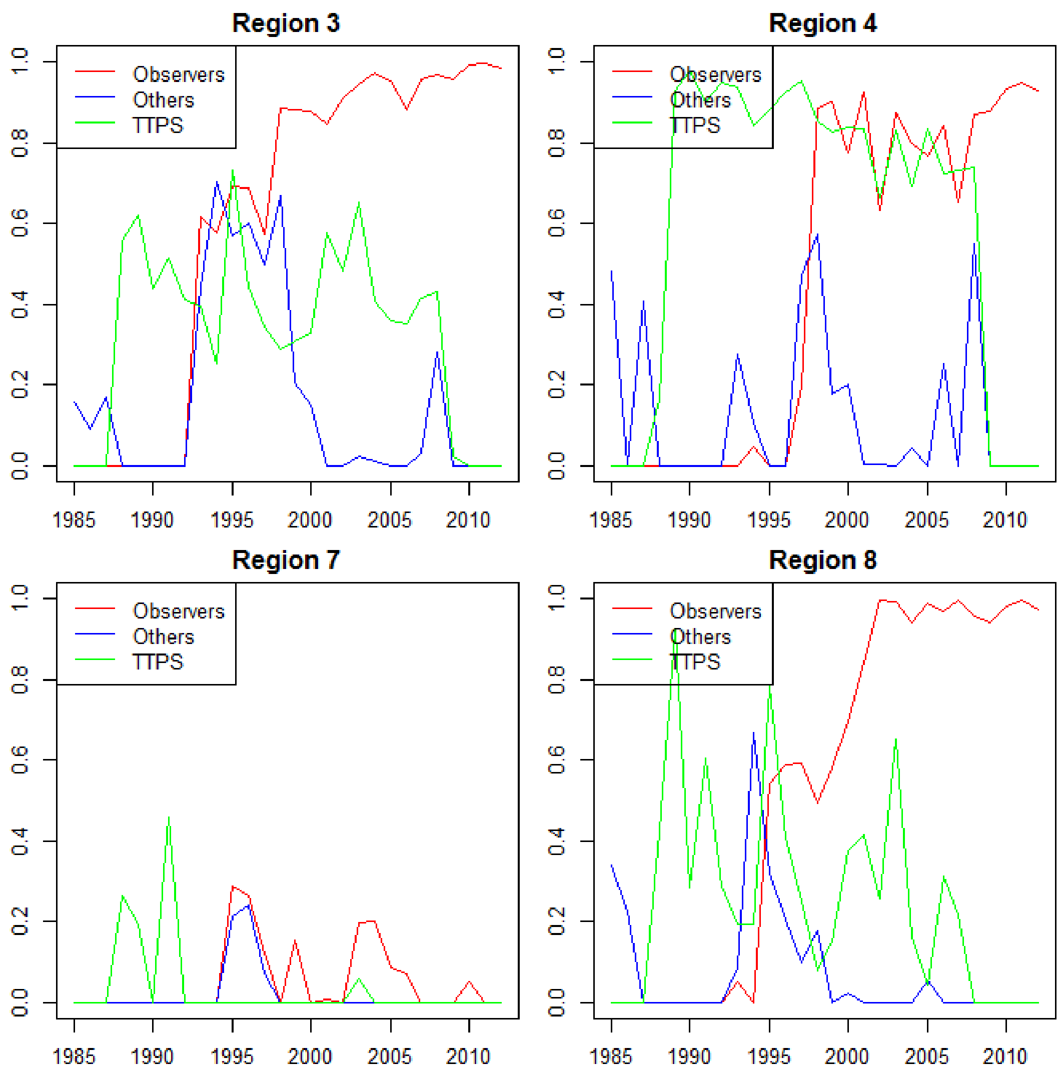

Figure 6. Coverage of YFT length data as the proportion of purse seine catch in 5x5 cells with size data, divided by the total purse seine catch in the region (data pooled at the quarter level, but plotted yearly for display purposes).

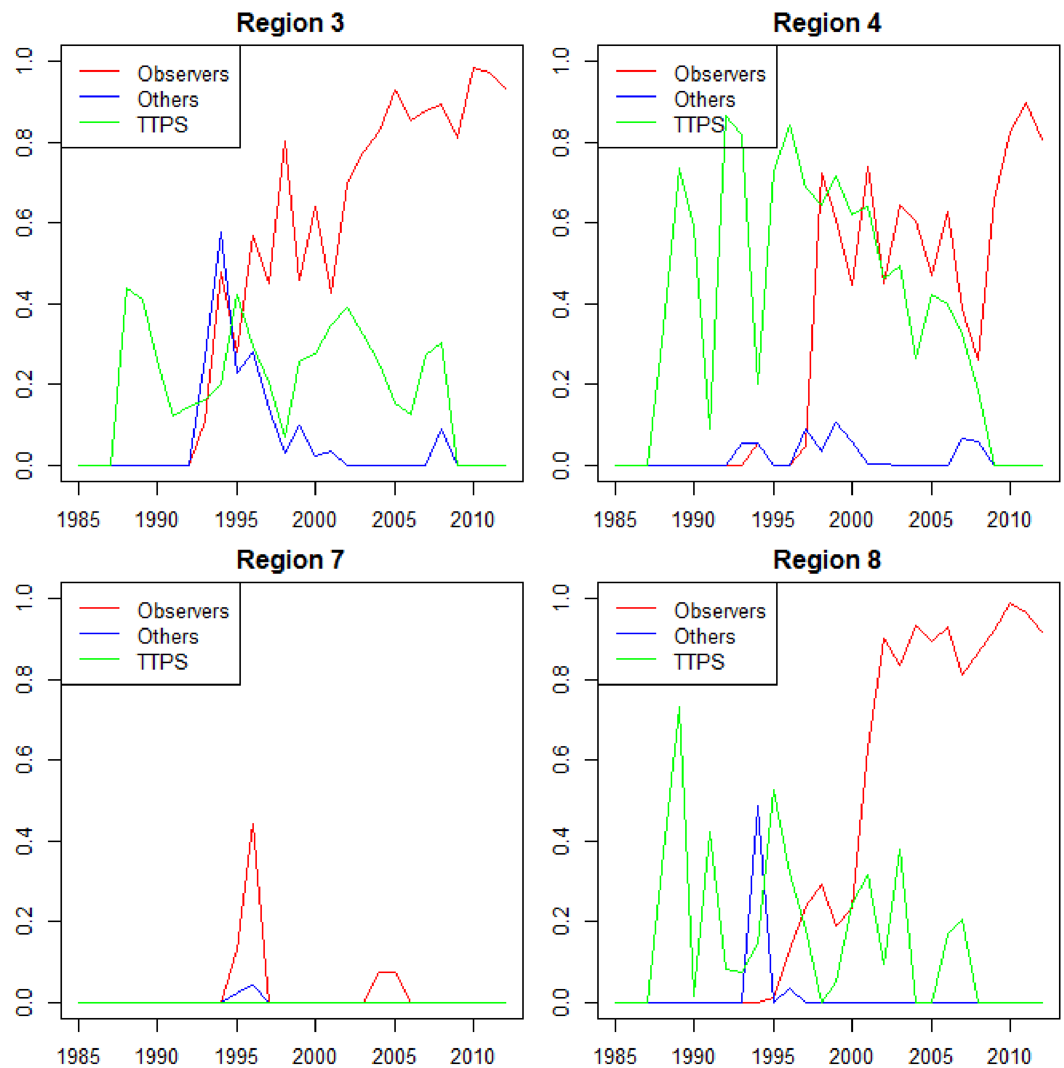

Figure 7. Coverage of BET length data as the proportion of purse seine catch in 5x5 cells with size data, divided by the total purse seine catch in the region (data pooled at the quarter level, but plotted yearly for display purposes).

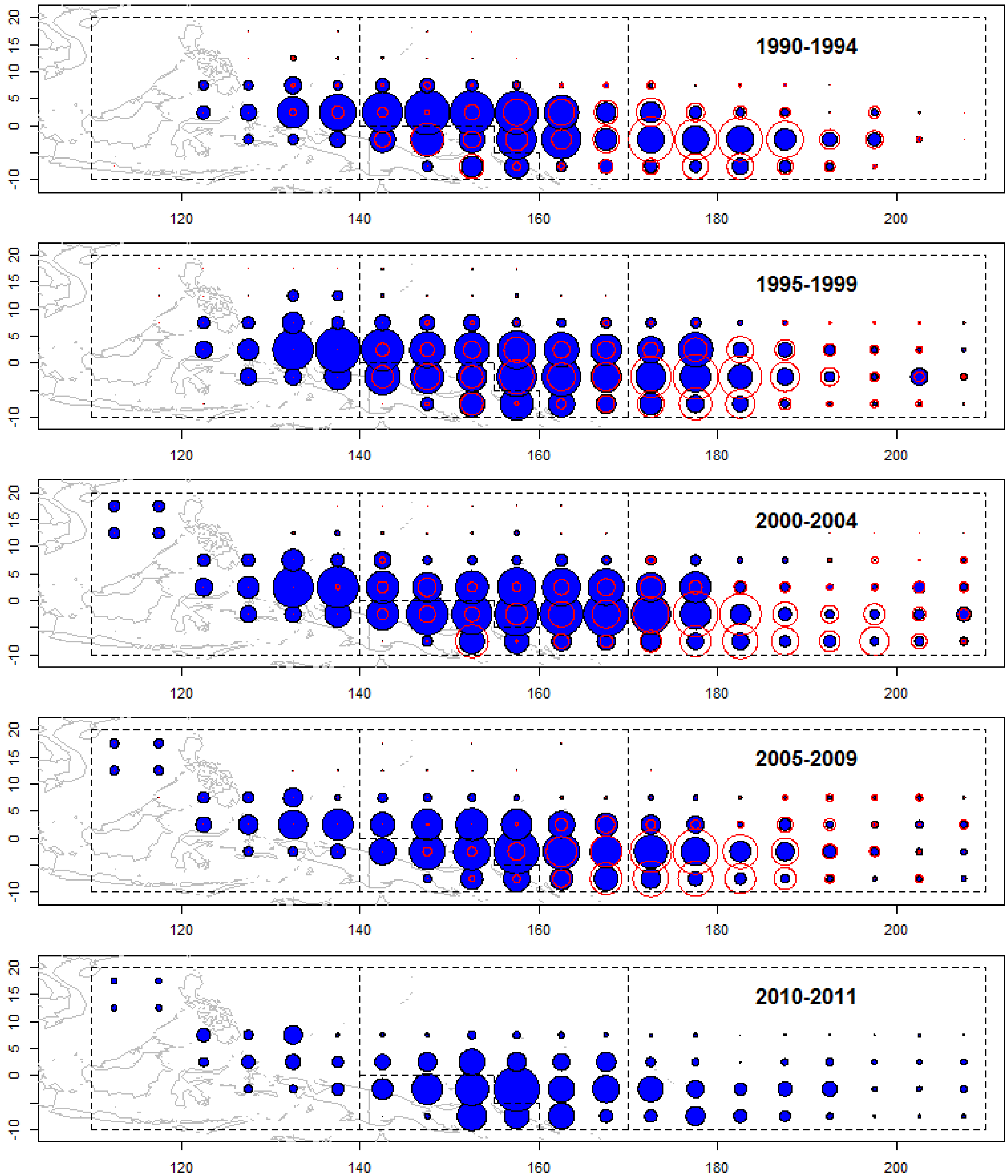

Figure 8. Number of samples from the US Treaty Port Sampling program (red hollow circle) vs purse seine catch of all flags combined (blue solid circle). Note: For display purposes, the size of the circles is corrected by the maximal catch (or number of samples) in each period, and is not comparable between periods.

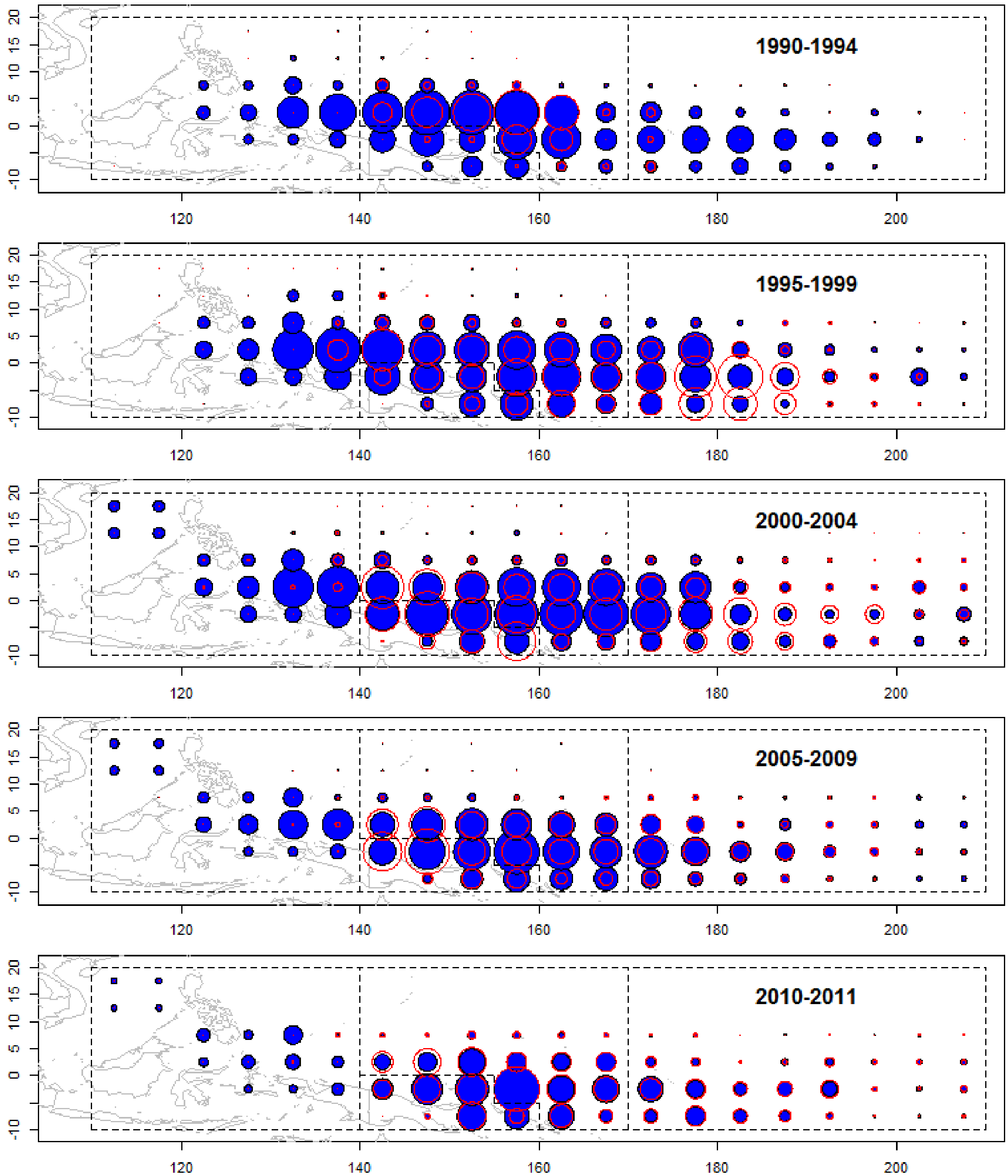

Figure 9. Number of samples from observer programs (red hollow circle) vs purse seine catch of all flags combined (blue solid circle). Note: For display purposes, the size of the circles is corrected by the maximal catch (or number of samples) in each period, and is not comparable between periods.

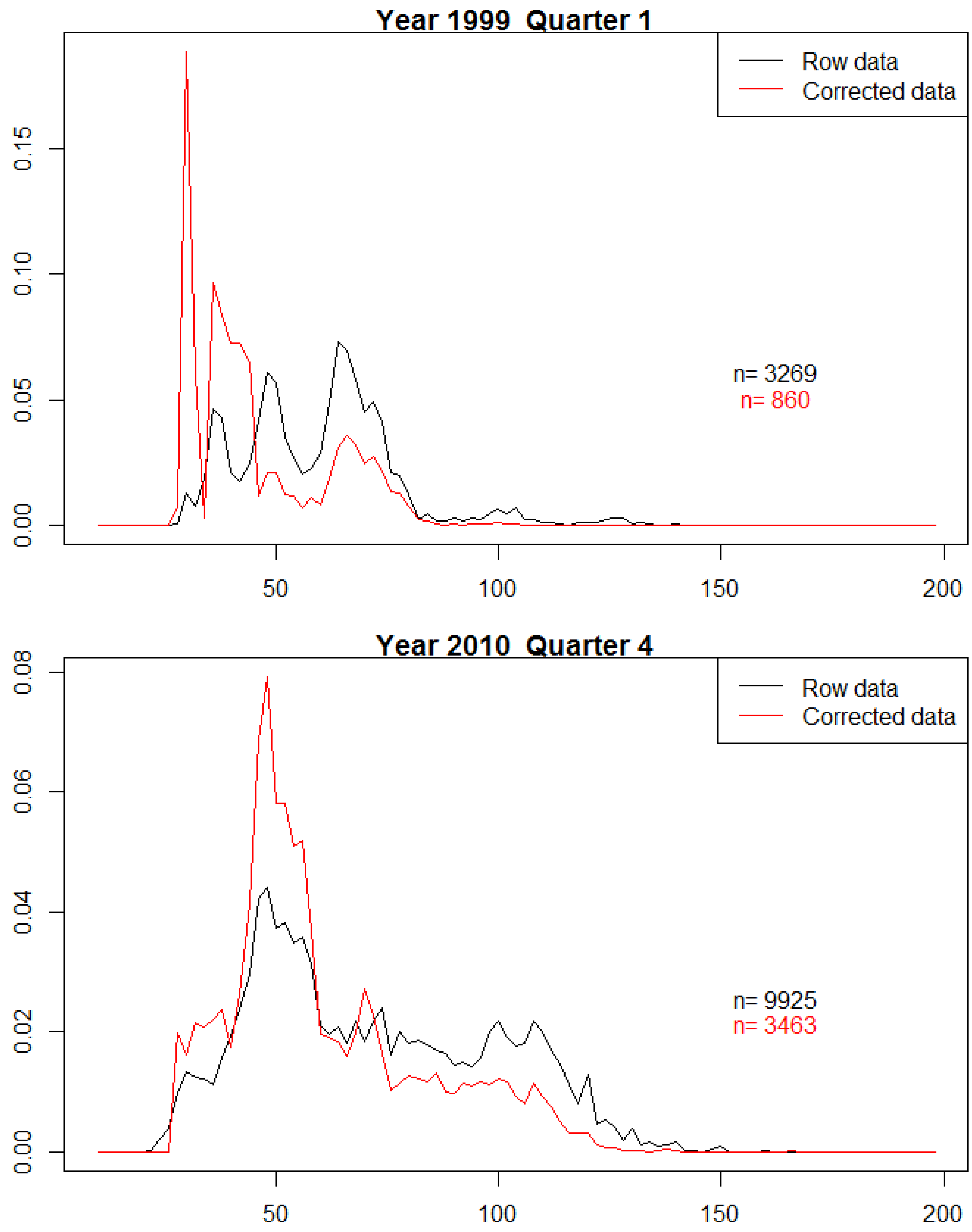

Figure 10.- Comparison of the uncorrected and corrected length distributions of the catch for the yellowfin purse seine associated fishery in region 3 at the beginning (mainly port sampling data) and end (dominated by observer data) of the time series.

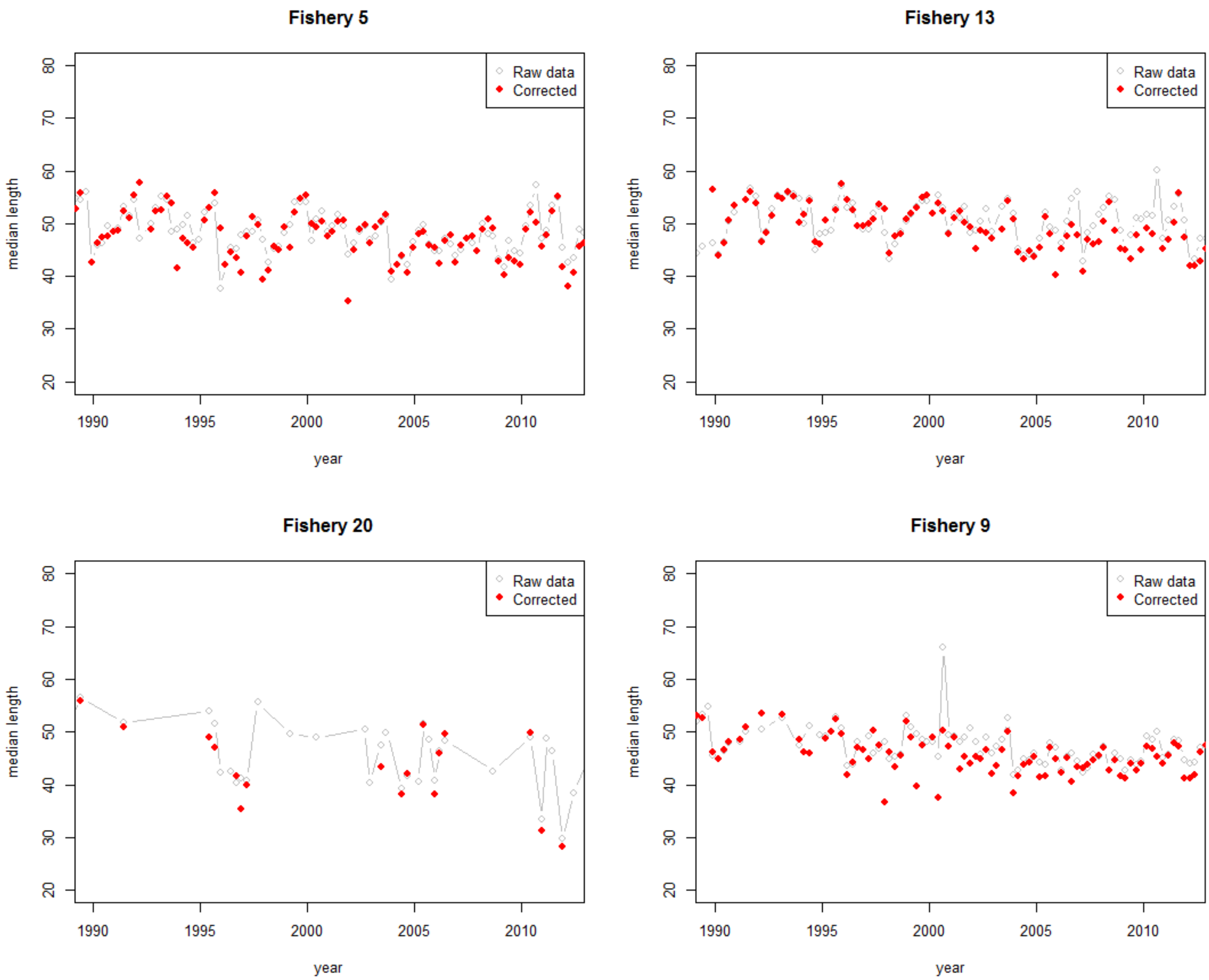

Figure 11. Comparison of the uncorrected and corrected median lengths in the skipjack associated purse seine fishery in the model regions 2, 3, 4 and 5 (fisheries 5, 13, 20 and 9, respectively).

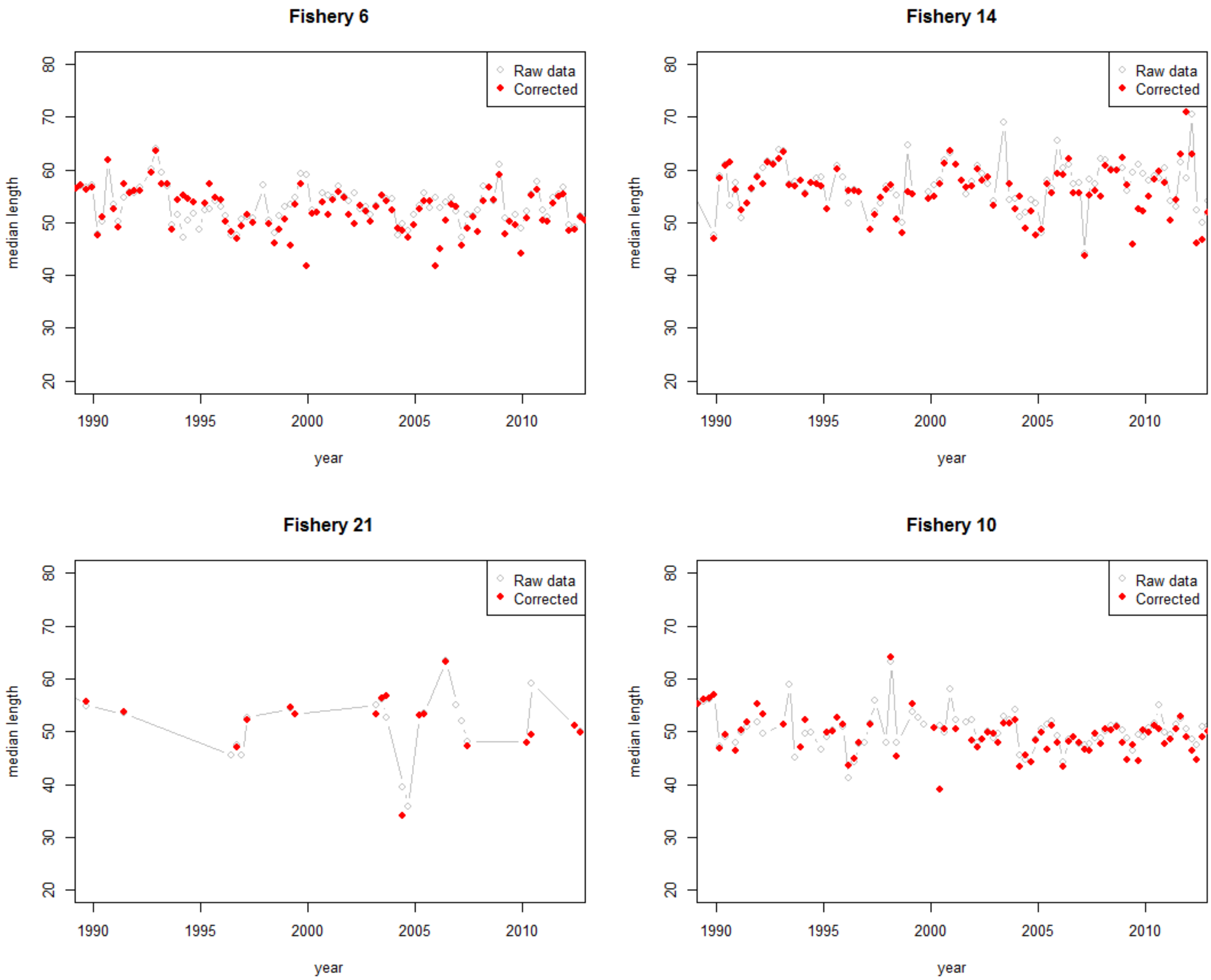

Figure 12. Comparison of the uncorrected and corrected median lengths in the skipjack unassociated purse seine fishery in the model regions 2, 3, 4 and 5 (fisheries 6, 14, 21 and 10, respectively).

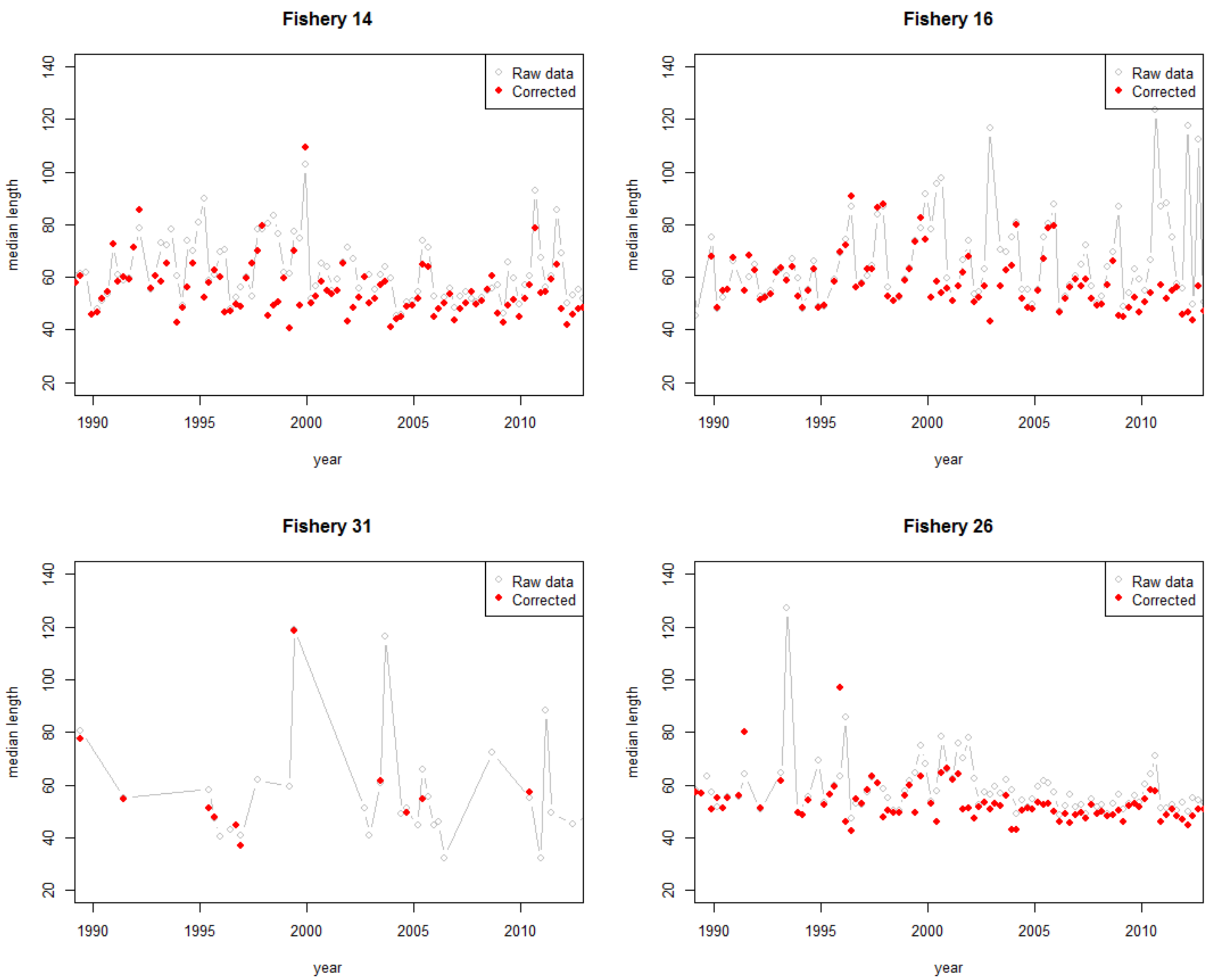

Figure 13. Comparison of the uncorrected and corrected median lengths in the yellowfin associated purse seine fishery in the model regions 3, 4, 7 and 8 (fisheries 14, 16, 31 and 26, respectively).

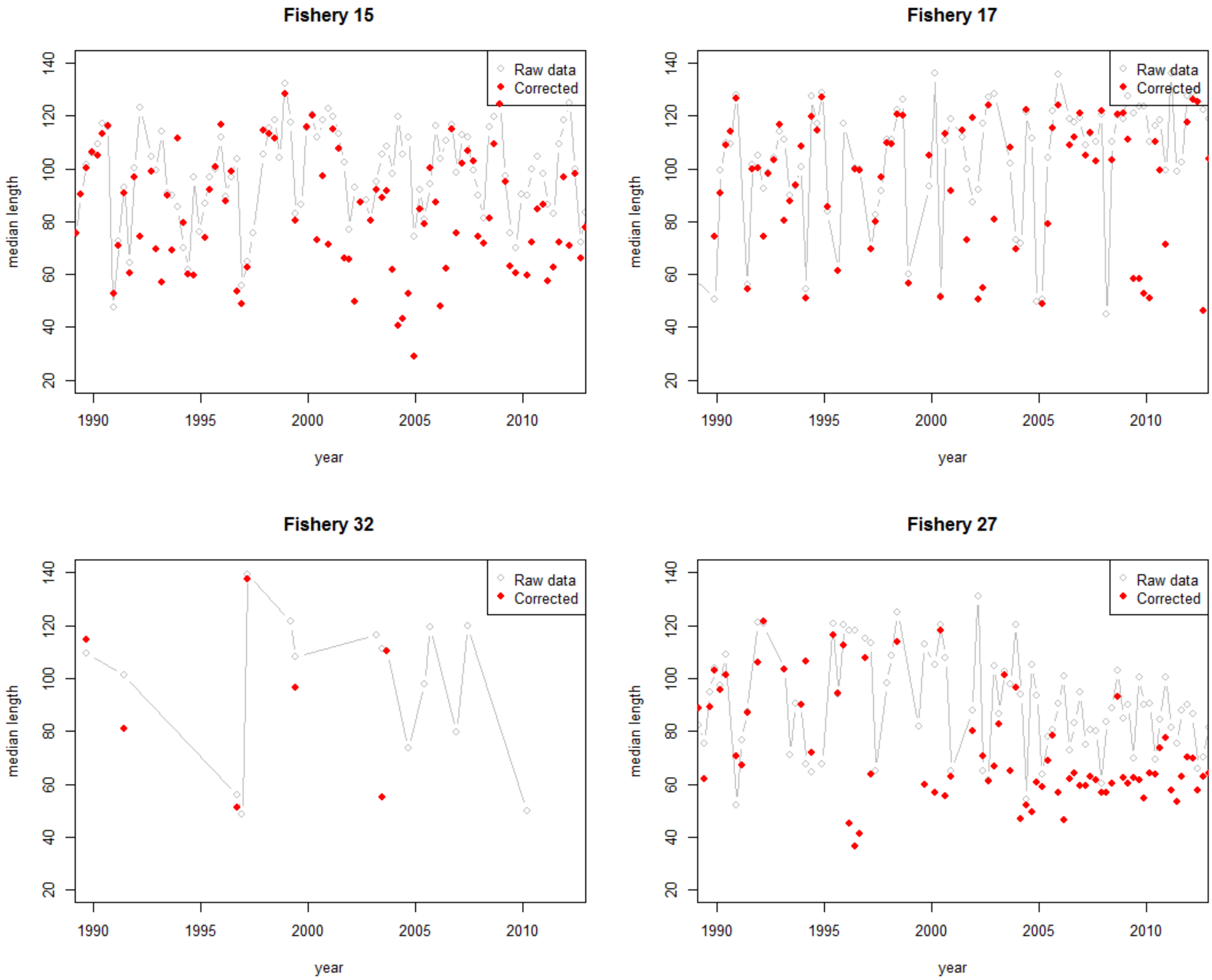

Figure 14. Comparison of the uncorrected and corrected median lengths in the yellowfin unassociated purse seine fishery in the model regions 3, 4, 7 and 8 (fisheries 15, 17, 32 and 27, respectively).

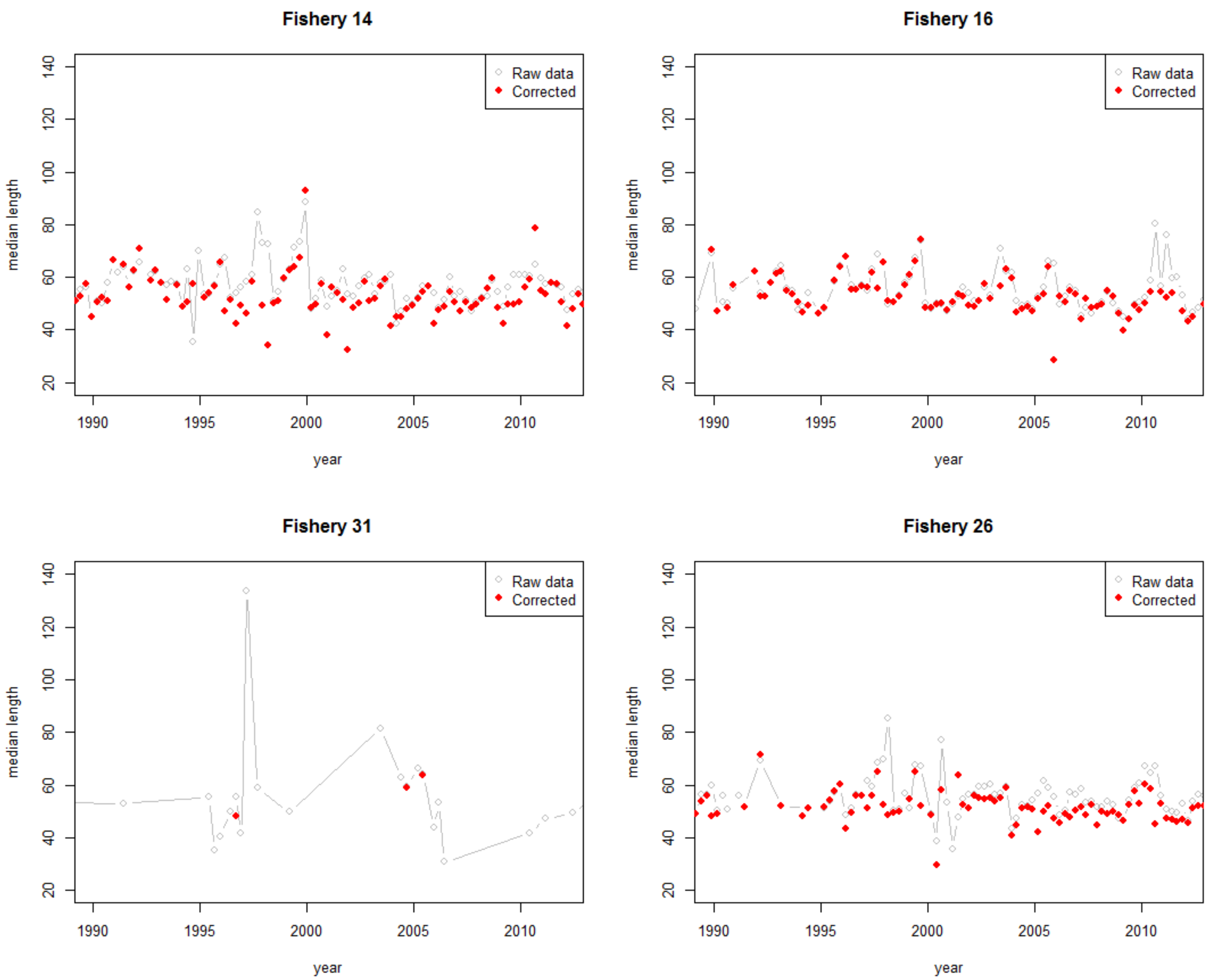

Figure 15. Comparison of the uncorrected and corrected median lengths in the bigeye associated purse seine fishery in the model regions 3, 4, 7 and 8 (fisheries 14, 16, 31 and 26, respectively).

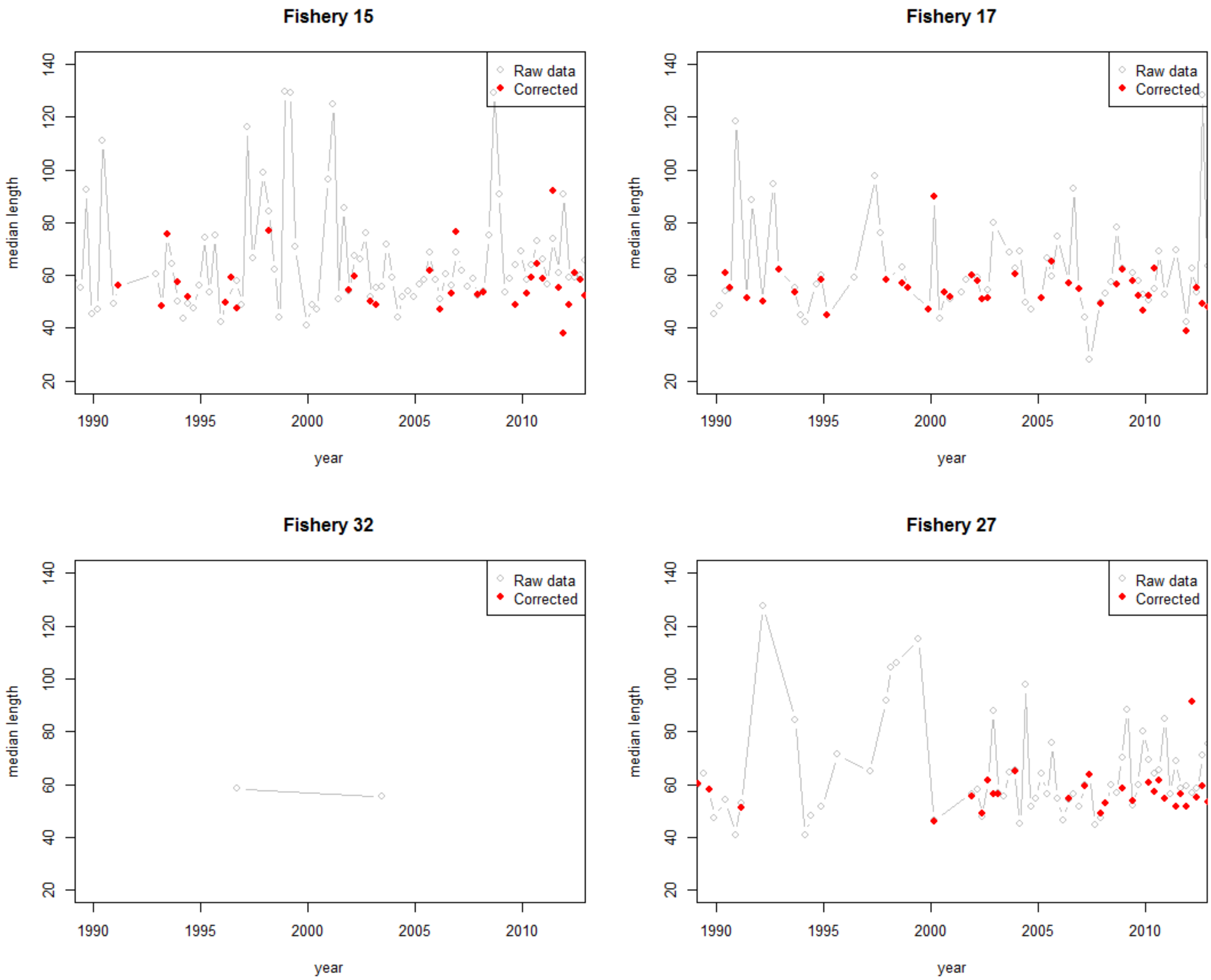

Figure 16. Comparison of the uncorrected and corrected median lengths in the bigeye unassociated purse seine fishery in the model regions 3, 4, 7 and 8 (fisheries 15, 17, 32 and 27, respectively).