ALTERNATIVE APPROACHES TO THE REVISION OF OFFICIAL SPECIES COMPOSITION FOR THE SPANISH LOG-ASSOCIATED CATCH-AND-EFFORT DATA FOR TROPICAL TUNA SPECIES IN 2018

Prepared by: IOTC Secretariat[1], 9 November 2019

Purpose

To provide the Working Party on Data Collection and Statistics (WPDCS) with a range of alternative scenarios for the re-estimation of tropical tuna species composition of time-area, log-associated catches reported by the Spanish component of the European Union purse seine fleet in 2019, and the rationale for this re-estimation.

Background

During the 21st session of the Working Party on Tropical Tuna (WPTT21) held from October 21st to October 26th in Donostia – San Sebastian (Spain) it was noted that the official catch figures for Bigeye tuna reported for 2018 by all purse seine fleets combined (**Fig. 1a**) were over 50% higher than previous year (45,740 t in 2018 vs. 29,697 t in 2017) and that – in particular – this increase was almost exclusively accounted for by the log-associated component of the fishery, as free-school catches decreased sensibly in comparison with previous year (3,033 t in 2018 vs. 10,143 t in 2017).

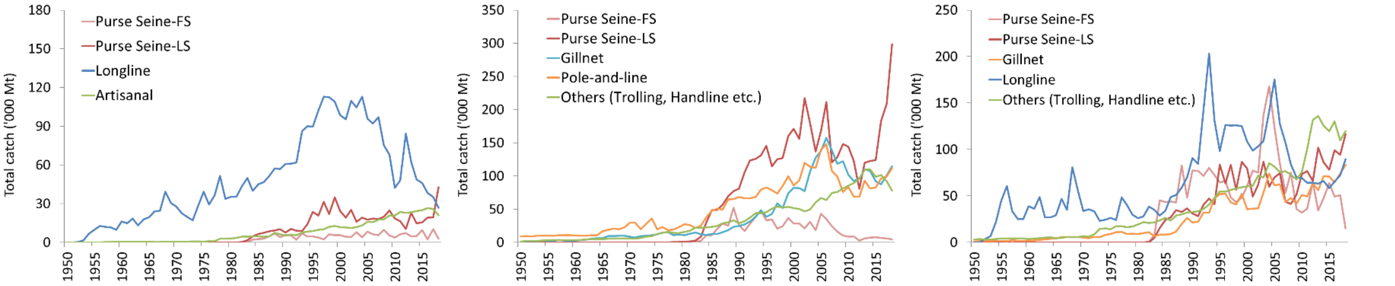

Fig. 1 (a-c) – Reported Bigeye tuna (left), Skipjack tuna (center) and Yellowfin tuna (right) catches by fishery (1950-2018)

The relative increase in catches from the log-associated component of the purse seine fishery was not only specific to Bigeye tuna but also evident for all other tropical tuna species, although to different extents (**Fig. 1b-c**), with Skipjack tuna recording the highest increase in the proportion of log-associated vs. free-school catches in 2018.

While focusing on Bigeye tuna catches from the log-associated component of the global purse seine fishery, the WPTT acknowledged that the major contribution to the increase in reported catches for the species from 2017 to 2018 was coming from the European Union fleet, in particular from vessels flagged by EU,Spain, that increased their log-associated catches for the species from 7,926 t in 2017 to 24,507 t in 2018, thus exceeding in 2018 the total of log-associated catches reported by all other purse seine fleet in 2017 (**Table 1a-b**).

On the contrary, EU,Spain free-school catches for the species went down from 4,419 t to 1,666 t during the same period.

As the reported effort for the EU,Spain purse seine fleet (hours spent fishing) showed just a minor increase between 2017 and 2018 (going from 42,147 to 44,632 hours respectively, corresponding to a 5% increase overall) a further analysis was attempted in order to identify possible hot-spots within the EU,Spain purse seine fleet fishing grounds explored in 2018, where Bigeye tuna could have turned to be particularly abundant.

[1] IOTC-Secretariat@fao.org

Fleet / Year		2017	2018
EU	*Spain*	12,345	26,174
	France	4,590	4,875
	Italy	332	
	Total	17,267	31,049
Indonesia			5,116
I.R. Iran		29	
Japan		424	283
Korea (Rep. of)		844	1,058
Mauritius		1,353	1,784
Philippines		26	
Seychelles		9,754	6,450
Total		29,697	45,740

Table 1a – Bigeye tuna purse-seine catches (t) by fleet and year (all fishing modes combined)[2]

Fishing mode		**Free-school**		**Log-associated**	
Fleet / Year		**2017**	**2018**	**2017**	**2018**
EU	*Spain*	4,419	1,666	7,926	24,507
	France	1,680	570	2,910	4,305
	Italy	233		99	
	Total	6,332	2,237	10,935	28,812
Indonesia					5,116
I.R. Iran		10		19	
Japan		55		369	283
Korea (Rep. of)		132		712	1,058
Mauritius		631	346	722	1,438
Philippines				26	
Seychelles		2,983	450	6,771	6,000
Total		10,143	3,033	19,554	42,707

Table 1b – Bigeye tuna purse-seine catches (t) by fishing mode, fleet and year[3]. Catches breakdown by type of fishing operation (free-school / log-associated) for EU,Italy, Indonesia, I.R. Iran and Philippines based on expert knowledge.

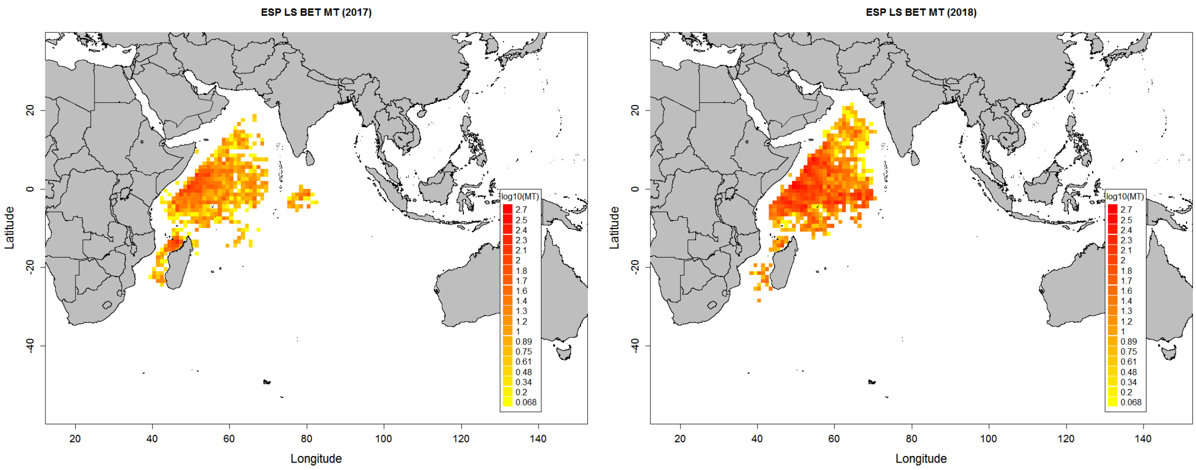

Fig. 2 (a-b) – Geospatial location of yearly, log-associated catches of Bigeye tuna as reported[3] by the EU,Spain purse seine fleet a) in 2017 (left) and b) in 2018 (right), recorded over 1°x1° grids (values in $\log_{10}$ metric tons)

Geospatial plots of reported Bigeye tuna catch in weight for the EU,Spain purse seine fleet in 2018 (limited to log-associated catches, **Fig. 2b**) did not show any evident hot-spot when compared with data reported for 2017 (**Fig. 2a**): rather, a generalized tendency to catch more Bigeye tuna (in absolute terms) was apparent in 2018, together with a clear expansion of the fishing grounds towards the Arabian sea. Also, the complete disappearance of any fishing activity on the border with the Eastern Indian Ocean was noted in comparison with 2017 (fishing grounds located at around 0° latitude North and 80° longitude East).

EU,Spain confirmed that, beside the evident change in fishing operations for its purse seine fleet in 2018 – now almost exclusively fishing on log-associated schools – several changes in the type of statistical methodologies adopted for the production of final catch statistics were introduced during the same year, with species composition now estimated on a per-vessel basis rather than through the usual *T3* process.

[2] Source: *Nominal catches by fleet, year, gear, IOTC area and species (WPTT21)* at https://tinyurl.com/WPTT21-NC
[3] Source: *Catch and effort data - surface fisheries (WPTT21)* at https://tinyurl.com/WPTT21-CEPSBB.

As other comparable purse seine fleets (EU,France, Seychelles and Mauritius) had changed their operations during 2018, to the point that the free-school component of the catches reported by these fleets is almost negligible when compared to 2017, the extremely marked increase in Bigeye tuna catches reported by EU,Spain in 2018 could potentially be explained by the introduction of said changes to the national statistical systems and processes rather than the described changes in fishing operations (or by a combination of the two).

To corroborate this hypothesis and identify any marked difference in species composition introduced by the new estimation methodologies, an alternative analysis of the geo-spatial catches reported by the industrial purse seine fleets was attempted by plotting the proportion of Bigeye tuna vs. Yellowfin tuna recorded by each fleet in the 1°x1° grids where these were operating during 2017 and 2018.

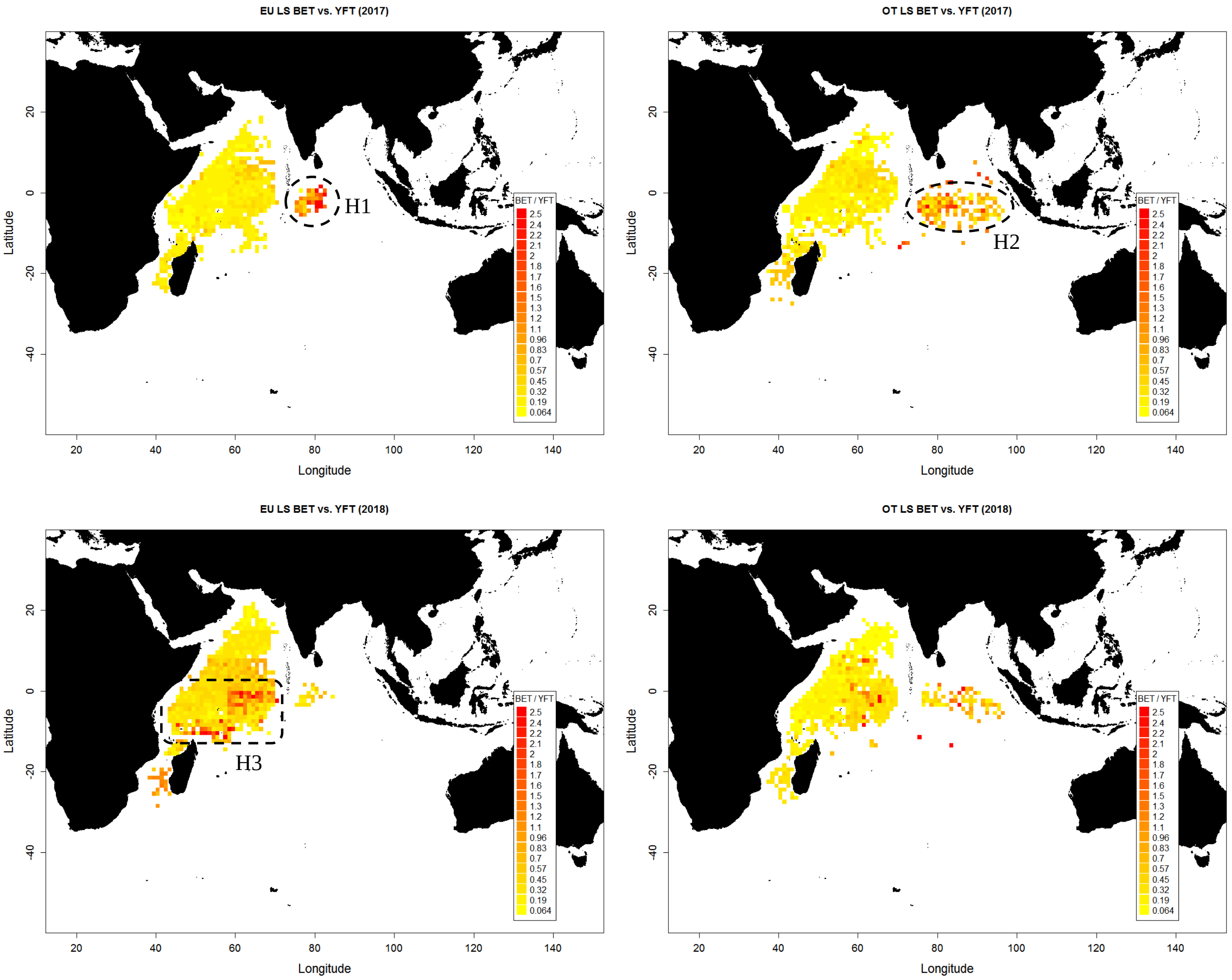

Fig. 3 (a-d) – Relative proportion of log-associated Bigeye tuna catches vs. Yellowfin tuna log-associated catches reported[3] by year and grid by the European Union (EU) and all other (OT) purse seine fleets. a) EU PS fleet in 2017 (top-left), b) all other PS fleets in 2017 (top-right), c) EU PS fleet in 2018 (bottom-left), d) all other PS fleets in 2018 (bottom-right). EU PS fleet includes catches reported by EU,Spain and EU,France only, as geo-spatial catches from EU,Italy are not available. Data for the OT fleet includes information provided by Japan, Mauritius, Republic of Korea and Seychelles.

The geospatial plots in **Fig. 3a-d** show the relative proportion of Bigeye tuna vs. Yellowfin tuna caught on log-associated schools by the European and non-European purse seine fleets in 2017 and 2018 (as officially reported).

Beside the different extent of the fishing grounds covered by such fleets over the years (with the OT fleet extending further in the Eastern Indian Ocean than the EU fleet, but not as North as the latter in 2018) these plots show that:

- hotspots exist where reported Bigeye tuna catches are higher than reported yellowfin tuna catches (in the same grid) for both the EU and OT purse seine fleet in 2017 (H1 and H2), and that these are approximately located in the grids around 0° latitude North and 80° longitude East (**Fig. 3a-b**);
- the proportion of reported Bigeye tuna vs. Yellowfin tuna catches per grid is generally lower than 1 (i.e. *less* Bigeye tuna than Yellowfin tuna is reported as caught in each grid) in the Western and South-Western Indian Ocean (beside the hotspots above) for both the EU and OT purse seine fleet in 2017 (**Fig. 3a-b**), and for the OT purse seine fleet in 2018 (**Fig. 3d**);
- the proportion of reported Bigeye tuna vs. Yellowfin tuna catches per grid is higher than 1 (i.e. *more* Bigeye tuna than Yellowfin tuna is reported as caught in each grid) in the Western and South-Western Indian Ocean for the EU purse seine fleet in 2018 (**Fig. 3c**);
- a regular, geometric pattern emerges (H3) for such fleet in grids around 60° longitude East and between 10° latitude North and 10° longitude South, as well as below 10° latitude South and between 40° and 60° longitude East (**Fig. 3c**), and that such pattern might indicate an issue with the estimation of species composition for the EU fleet (or for one of its components).

The same geospatial plots as in **Fig. 3a-d** were produced for the different components of the EU purse seine fleet for which geospatial data was available[3] in 2017 and 2018 (EU,Spain and EU,France) and are presented in **Fig. 4a-d**.

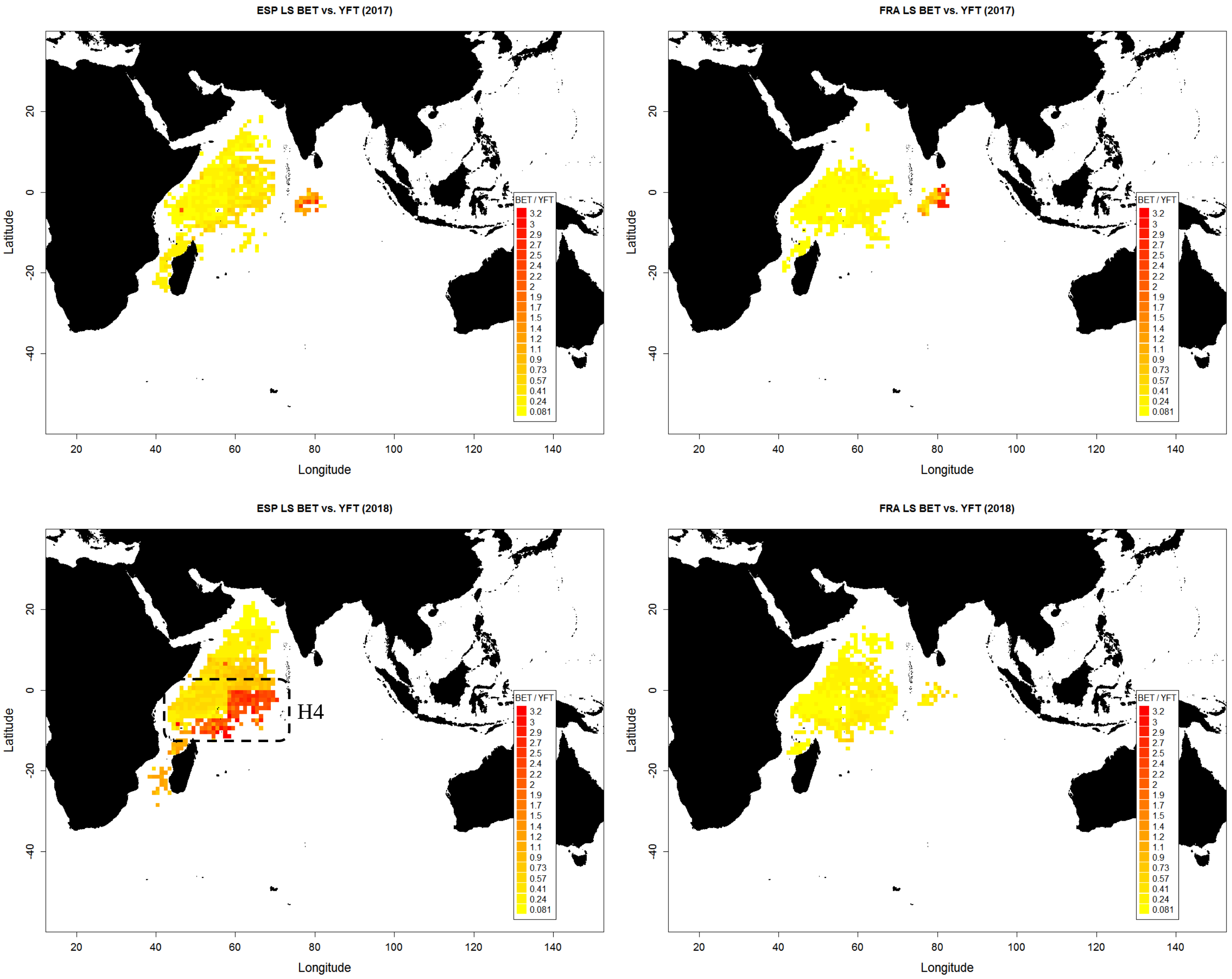

Fig. 4 (a-d) – Relative proportion of log-associated Bigeye tuna catches vs. log-associated Yellowfin tuna catches reported[3] by year and grid by the EU,Spain (ES) and EU,France (FRA) component of the EU purse seine fleet. a) Top-left, EU,Spain in 2017, b) Top-right, EU,France in 2017, c) Bottom-left, EU,Spain in 2018, d) Bottom-right, EU,France in 2018.

The geospatial plot of the relative proportion of Bigeye tuna vs. Yellowfin tuna log-associated catches reported by EU,Spain in 2018 (**Fig. 4c**) further highlights the geometrical, regular pattern (H4) that was already evident (albeit less marked) for the EU fleet in its entirety during 2018 (H3, **Fig. 3c**).

Although it is expected that some kind of regular pattern might appear as the result of the estimation processes that might include information from adjacent grids, statistical areas and comparable fleets (as is the case of the T3 process adopted by the EU and – possibly – of the new methodology implemented by Spain since 2018) what the area H4 in **Fig. 4c** shows is a potential bias in species composition for the involved grids, where recorded catches of Bigeye tuna are up to three times higher than catches of Yellowfin tuna in the same grid, and that this peculiarity is not shared by the French component of the European Union purse seine fleet that also operates in the same waters, but specific of the Spanish component of the same fleet in 2018 only.

A different type of analysis that considers the number of grids where recorded log-associated catches of Bigeye tuna exceed those of Yellowfin tuna reported by the same fleet shows that in recent years it was common for the OT purse seine fleet to record log-associated catches of Bigeye tuna higher than catches of Yellowfin tuna (in the same grid) while this behaviour appears to be evident for the EU purse seine fleet only from 2017 onwards (and in particular for 2018, see **Fig. 5a**).

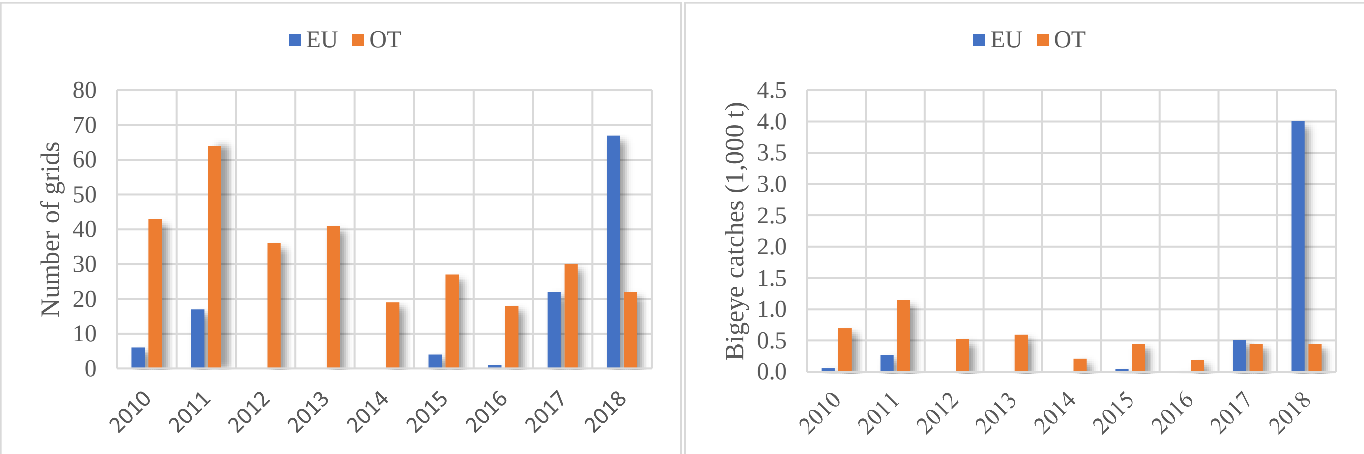

Fig. 5 (a-b) – a) Number of grids for which reported[3] log-associated catches of Bigeye tuna are higher than log-associated catches of Yellowfin tuna by year and fleet (left), b) Sum of log-associated catches of Bigeye tuna reported[3] in grids where these are higher than the log-associated catches of Yellowfin tuna by year and fleet (right). Data is presented for the aggregated European Union purse seine fleet ("EU", that includes information from EU,France, EU,Italy and EU,Spain) and for all other PS fleets ("OT", that includes information from Japan, Mauritius, Republic of Korea and Seychelles).

Yet, when considering the amount of Bigeye tuna log-associated catches recorded in such grids, it appears that these are particularly high (around 4,000 t) only for the EU fleet in 2018, while those recorded by the OT fleet are relatively minor (see Figure 6b).

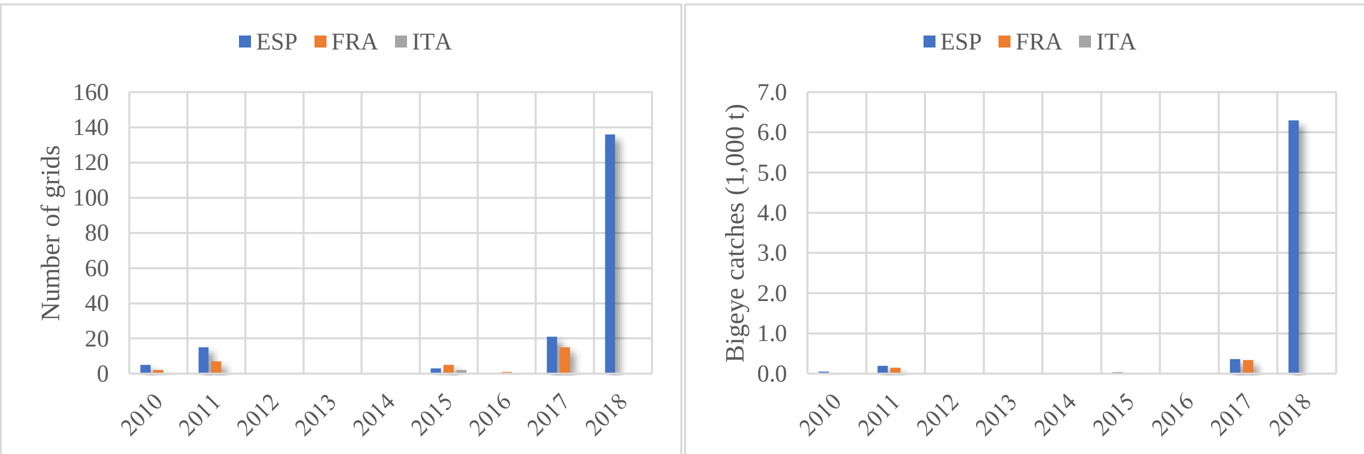

Fig. 6 (a-b) – a) Number of grids for which reported[3] log-associated catches of Bigeye tuna are higher than log-associated catches of Yellowfin tuna by year and European Union flag (left), b) Sum of log-associated catches of Bigeye tuna reported[3] in grids where these are higher than the log-associated catches of Yellowfin tuna by year and EU flag (right).

Fig. 6a-b present the results of this same analysis applied to the distinct flags originally included in the EU purse seine fleet: in this case it is evident how the majority of grids in which log-associated catches of Bigeye tuna are higher than log-associated catches of Yellowfin tuna is recorded by EU,Spain in 2017 and 2018 (**Fig. 6a**), and that – when considering the amount of Bigeye tuna log-associated catches recorded in such grids – these are particularly high for the EU,Spain fleet in 2018 (around 6,300 t, see **Fig. 6b**).

The differences in both the number of grids as well as in the Bigeye tuna catch amounts recorded in those grids where Bigeye tuna log-associated catches are higher than Yellowfin tuna log-associated catches between EU 2018 (**Fig. 5a-b**) and EU,ESP 2018 (**Fig. 6a-b**) (67 grids, 4,012 t and 136 grids, 6,295 t respectively) are explained by the compensatory effect introduced – for the generalized EU analysis in **Fig. 5a-b** – by the time-area catches reported by EU,France in those grids where both EU fleets operate.

Noting the results of this simple qualitative analysis, the WPTT suggested to attempt a re-estimation of the species composition of log-associated captures reported by EU,Spain in 2018 by using the species composition recorded by the same fleet in 2017, while keeping total log-associated captures for all tropical tuna from the fleet to the same level of 2018.

Considering that $BET_{2017} = 7,926$ t, $SKJ_{2017} = 83,426$ t and $YFT_{2017} = 36,583$ t are the reported[3] log-associated catches by species for EU,Spain in 2017 and that $TROP_{2017} = BET_{2017} + SKJ_{2017} + YFT_{2017} = 127,935$ t, then the relative species compositions of EU,Spain log-associated captures for 2017 are:

1) $pBET_{2017} = \frac{BET_{2017}}{TROP_{2017}} = \frac{7,926\ t}{127,935\ t} \approx 0,061953$

2) $pSKJ_{2017} = \frac{SKJ_{2017}}{TROP_{2017}} = \frac{83,426\ t}{127,935\ t} \approx 0,652097$

3) $pYFT_{2017} = \frac{YFT_{2017}}{TROP_{2017}} = \frac{36,583\ t}{127,935\ t} \approx 0,285950$

with:

4) $pBET_{2017} + pSKJ_{2017} + pYFT_{2017} = 1$.

Similarly, considering that $BET_{2018} = 24,499$ t, $SKJ_{2018} = 132,071$ t and $YFT_{2018} = 43,644$ t are the reported[3] log-associated catches by species for EU,Spain in 2018 and that $TROP_{2018} = BET_{2018} + SKJ_{2018} + YFT_{2018} = 200,214$ t, then the relative species compositions of EU,Spain log-associated captures for 2018 are:

5) $pBET_{2018} = \frac{BET_{2018}}{TROP_{2018}} = \frac{24,499\ t}{200,214\ t} \approx 0,122364$

6) $pSKJ_{2018} = \frac{SKJ_{2018}}{TROP_{2018}} = \frac{132,071\ t}{200,214\ t} \approx 0,659649$

7) $pYFT_{2018} = \frac{YFT_{2018}}{TROP_{2018}} = \frac{43,644\ t}{200,214\ t} \approx 0,217986$

with:

8) $pBET_{2018} + pSKJ_{2018} + pYFT_{2018} = 1$.

Then, by applying the same species compositions reported by EU,Spain in 2017 ($pBET_{2017}$, $pSKJ_{2017}$ and $pYFT_{2017}$) to the log-associated tropical tuna catches reported by EU,Spain in 2018 ($TROP_{2018}$) the revised log-associated catches by species for 2018 become:

9) $rBET_{2018} = pBET_{2017}\ x\ TROP_{2018} = BET_{2017}\ x\ \frac{TROP_{2018}}{TROP_{2017}} \approx$ **12,403.925** t

10) $rSKJ_{2018} = pSKJ_{2017}\ x\ TROP_{2018} = SKJ_{2017}\ x\ \frac{TROP_{2018}}{TROP_{2017}} \approx$ **130,558.902** t

11) $rYFT_{2018} = pYFT_{2017}\ x\ TROP_{2018} = YFT_{2017}\ x\ \frac{TROP_{2018}}{TROP_{2017}} \approx$ **57,251.172** t

with $rBET_{2018}$, $rSKJ_{2018}$ and $rYFT_{2018}$ resulting in the revised log-associated catches for EU,Spain in 2018 and $rBET_{2018} + rSKJ_{2018} + rYFT_{2018} = BET_{2018} + SKJ_{2018} + YFT_{2018} = TROP_{2018} = 200,214$ t.

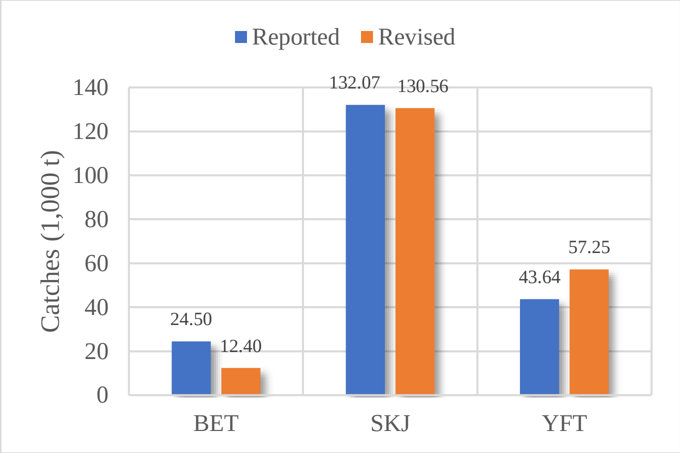

Fig. 7– Reported vs. revised log-associated catches of tropical tuna for the EU,Spain purse seine fleet in 2018

Bigeye tuna and Yellowfin tuna are the species most affected by this re-estimation approach, with Skipjack tuna remaining almost at the same levels as originally reported for the log-associated catches of EU,Spain in 2018 (**Fig. 7**).

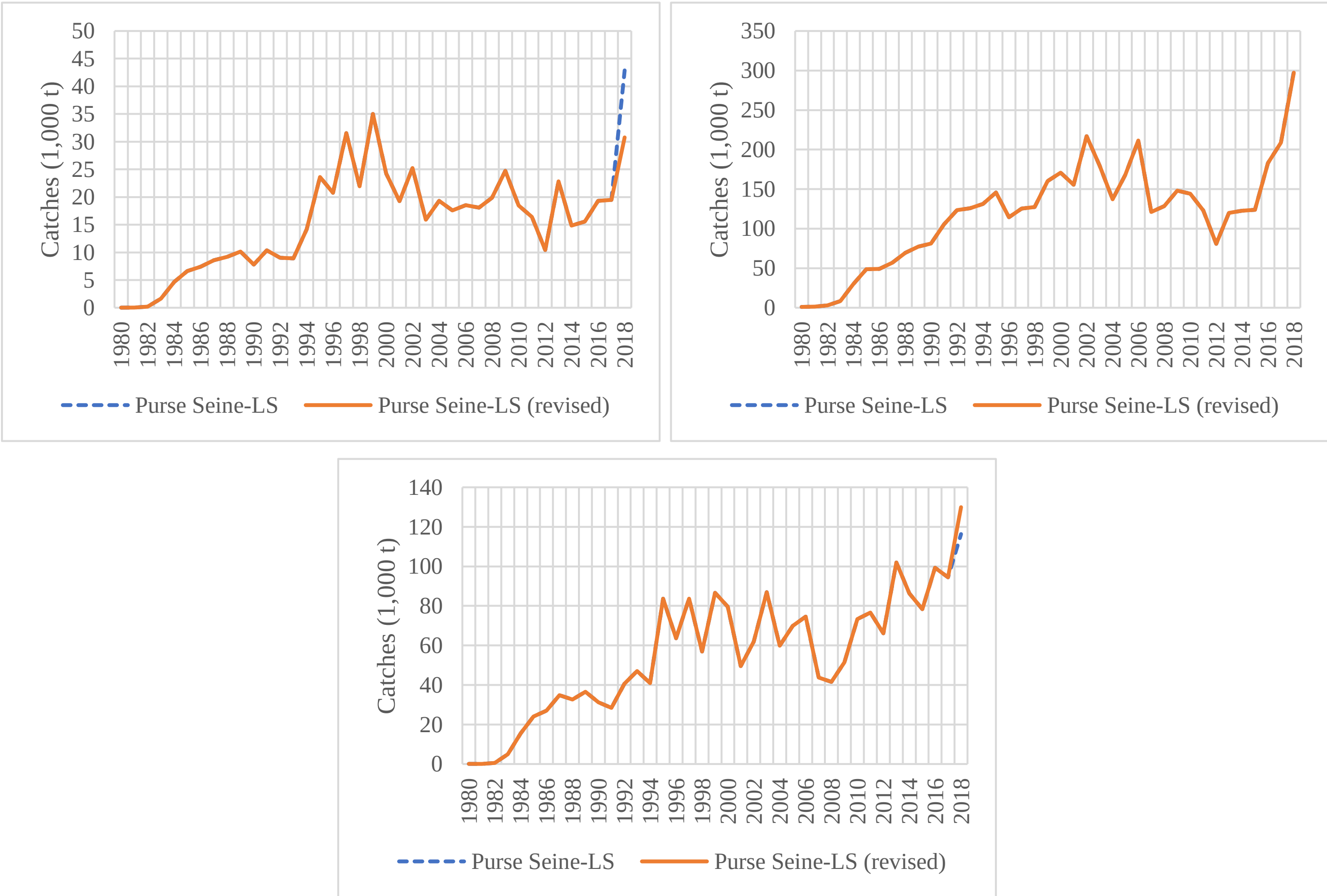

Fig. 8 (a-c) – Reported vs. revised log-associated catch series of tropical tunas for all purse seine fleets (1980-2018) a) Bigeye tuna (top-left), b) Skipjack tuna (top-right), c) Yellowfin tuna (bottom-center)

The WPTT acknowledged the results of this re-estimation process and requested that catch series for all tropical tunas that include the revised EU,Spain log-associated data be used for assessment, MSE and management advice purposes (**Fig. 8 a-c**).

While this approach served well the purpose of determining the revised total levels of log-associated catches of tropical tuna species for EU,Spain for the year concerned (2018), at the same time it could be considered as too simplistic as it applies the same constant scaling factor (i.e., total log-associated catches of tropical tunas for 2018 times the total log-associated catches of tropical tunas for 2017, or $\frac{TROP_{2018}}{TROP_{2017}}$) to the original log-associated catches of each tropical tuna species reported in 2017.

Furthermore, it does not considers how to update the time-area catches for the EU,Spain log-associated catches of 2018 and, for this reason, alternative approaches that exploit the availability of time-area catches for the concerned fleet, as well as for fleets with similar behaviour and characteristics, are considered here as potential replacement for the re-estimation procedure presented at the WPTT21.

Alternative approaches to the re-estimation of geospatial catch composition

The completeness and accuracy of the statistical data available for the major industrial purse seine fleets at the IOTC Secretariat are generally high: time-area catches are readily available by fleet, month, fishing operation mode (free-school vs. log-associated) and 1°x1° grid, and usually directly raised to the total catch by species by the data providers.

For this reason, and considering that the WPTT requested the revised catch series to be used also for stock assessment purposes, the re-estimation of the species composition for the EU,Spain log-associated catches of 2018 needs to be extended to the level of the time-area catches as well.

One fundamental pre-requisite applies to the approach presented below: we assume that the total catches reported by month and grid (in 2018) by EU,Spain for the log-associated component of its purse seine fishery are correctly estimated, and that only the actual species composition should be re-evaluated.

Raised time-area catches are available (in 2017 and 2018) for a number of industrial purse seine fleets that include EU,Spain, EU,France, Japan, Mauritius, Republic of Korea and Seychelles. For this exercise, we will focus only on those fleets (EU,Spain, EU,France and Seychelles) that are known to operate in similar areas and share similar characteristics and mode of operation.

As the actual species composition (i.e. capture by distinct tropical tuna species) is available for a number of years and on a monthly basis for all the 1°x1° grids in which such fisheries operate, we will utilize this information to infer the revised species composition for time-area log-associated catches of EU,Spain in 2018 on a monthly and grid-wise basis.

What needs to be established at this stage is which proxy fleet (or fleets) should be used to infer the needed monthly information for each and every grid in which the EU,Spain purse seine fleet had reported log-associated captures of tropical tunas in 2018.

Methodology

If we consider:

12) $C_{f,s}(y,m,g)$ as the *log-associated catches (in metric tons) of species **s** reported by fleet **f** in year **y** and month **m** for the 1°x1° grid **g***
13) $B_f(y,m,g) = C_{f,BET}(y,m,g)$ as the *log-associated catches (in metric tons) of Bigeye tuna reported by fleet **f** in year **y** and month **m** for the grid **g***
14) $S_f(y,m,g) = C_{f,SKJ}(y,m,g)$ as the *log-associated catches (in metric tons) of Skipjack tuna reported by fleet **f** in year **y** and month **m** for the grid **g***
15) $Y_f(y,m,g) = C_{f,YFT}(y,m,g)$ as the *log-associated catches (in metric tons) of Yellowfin tuna reported by fleet **f** in year **y** and month **m** for the grid **g***
16) $T_f(y,m,g) = B_f(y,m,g) + S_f(y,m,g) + Y_f(y,m,g)$ as the *log-associated catches (in metric tons) of all tropical tuna species reported by fleet **f** in year **y** and month **m** for the grid **g***
17) $pB_f(y,m,g) = \frac{B_f(y,m,g)}{T_f(y,m,g)}$ as the proportion of *Bigeye tuna log-associated catches over the total tropical tunas log-associated catches reported by fleet **f** in year **y** and month **m** for the grid **g***

18) $pS_f(y,m,g) = \frac{S_f(y,m,g)}{T_f(y,m,g)}$ as the proportion of *Skipjack tuna log-associated catches over the total tropical tunas log-associated catches reported by fleet **f** in year **y** and month **m** for the grid **g***

19) $pY_f(y,m,g) = \frac{Y_f(y,m,g)}{T_f(y,m,g)}$ as the proportion of *Yellowfin tuna log-associated catches over the total tropical tunas log-associated catches reported by fleet **f** in year **y** and month **m** for the grid*

20) $G_{f,s}(y,m)$ as *the set of grids for which non-zero log-associated catches of species **s** are reported by fleet **f** in year **y** and month **m***

21) $Proxies = \{ X_{f1,y1}, X_{f2,y2}, \ldots, X_{fn,yn} \}$ as *an ordered list of pre-determined fleet / year combinations $X_{f,y}$ that could be used as proxy data sources*

22) $\Pi(m,g,x)$ as *the first X_{f_i,y_i} in the set **x** of fleet / year combinations for which* $\exists\, S\colon C_{f_i,s}(y_i,m,g) \geq 0$

23) $Fleet(X_{f,y})$ as *the reference fleet for the placeholder $X_{f,y}$, with $Fleet(X_{f,y}) = f$*

24) $Year(X_{f,y})$ as *the reference year for the placeholder $X_{f,y}$, with $Year(X_{f,y}) = y$*

then the re-estimated log-associated catches of tropical tunas for EU,Spain in 2018 for month *m* and grid g $K_{ESP,s}(m,g)$ can be calculated as follows:

25) $\forall\,(m,g) : \exists\, C_{ESP,s}\,(2018,m,g) \;\Rightarrow\; K_{ESP,BET}\,(m,g) = \begin{cases} T_{ESP}(2018,m,g)\ x\ pB_{Fleet(X_{f,y})}\big(Year(X_{f,y}),m,g\big)\ when\ X_{f,y} \neq \phi \\ T_{ESP}(2018,m,g)\ x\ pBET_{2017}\ when\ X_{f,y} = \phi \end{cases}$

with $pBET_{2017}$ as determined in 1)

26) $\forall\,(m,g) : \exists\, C_{ESP,s}\,(2018,m,g) \;\Rightarrow\; K_{ESP,SKJ}\,(m,g) = \begin{cases} T_{ESP}(2018,m,g)\ x\ pS_{Fleet(X_{f,y})}\big(Year(X_{f,y}),m,g\big)\ when\ X_{f,y} \neq \phi \\ T_{ESP}(2018,m,g)\ x\ pSKJ_{2017}\ when\ X_{f,y} = \phi \end{cases}$

with $pSKJ_{2017}$ as determined in 2)

27) $\forall\,(m,g) : \exists\, C_{ESP,s}\,(2018,m,g) \;\Rightarrow\; K_{ESP,YFT}\,(m,g) = \begin{cases} T_{ESP}(2018,m,g)\ x\ pY_{Fleet(X_{f,y})}\big(Year(X_{f,y}),m,g\big)\ when\ X_{f,y} \neq \phi \\ T_{ESP}(2018,m,g)\ x\ pYFT_{2017}\ when\ X_{f,y} = \phi \end{cases}$

with $pYFT_{2017}$ as determined in 3)

and $X_{f,y} = \Pi(m,g,Proxies)$

What 25), 26) and 27) express is that for each pair of month and grid for which there is a record of tropical tuna log-associated catches reported by EU,Spain in 2018, then the re-estimated value of such catches will be set to:

a) The total log-associated catches of tropical tunas recorded by EU,Spain for that month and grid in 2018 ($T_{ESP}(2018,m,g)$) multiplied by the proportion of species-specific log-associated catches over total tropical tunas log-associated catches recorded by the identified proxy fleet / year combination for the same month and grid ($pB_{Fleet(X_{f,y})}\big(Year(X_{f,y}),m,g\big)$ in the case of Bigeye tuna) when the former ($X_{f,y}$) exists, or

b) The total log-associated catches of tropical tunas recorded by EU,Spain for that month and grid in 2018 ($T_{ESP}(2018,m,g)$) multiplied by the overall proportion of species-specific log-associated catches over tropical tunas log-associated catches recorded by EU,Spain in 2017 ($pBET_{2017}$, in the case of Bigeye tuna) when no proxy fleet / year combination exists with alternative proportions of species-specific tuna log-associated catches in the grid and month considered.

Option b) is the fall-back solution that applies anytime there is no proxy fleet and year combination that can provide alternative proportions of catches for the species concerned in the grid and month under consideration, and corresponds to using the overall species composition values as defined in 1), 2) and 3) to re-estimate the log-associated catches of each tropical tuna species.

Option a) on the contrary, applies when a proxy fleet and year combination exists for the grid and month considered, and provides alternative proportions of catches for the species concerned.

Range of potential estimation scenarios

Considering the extent and quality of geospatial data currently available to the IOTC Secretariat, as well as the nature and characteristics of the industrial purse-seine fleets operating in the Indian Ocean, several different approximation scenarios could be envisaged: these consist of different sequences for the *Proxies* set described in 21) and are summarized in the table below.

Scenario	First proxy	Second proxy	Third proxy	Fourth proxy
0 (default case)	AVG ESP,2017	-	-	-
1	ESP,2017	AVG ESP,2017	-	-
2	FRA,2018	SYC,2018	ESP,2017	AVG ESP,2017
3	FRA,2018	ESP,2017	SYC,2018	AVG ESP,2017
4	SYC,2018	FRA,2018	ESP,2017	AVG ESP,2017
5	SYC,2018	ESP,2017	FRA,2018	AVG ESP,2017
6	ESP,2017	FRA,2018	SYC,2018	AVG ESP,2017
7	ESP,2017	SYC,2018	FRA,2018	AVG ESP,2017

Table 2 – Proxy-ing scenarios for the re-estimation of EU,Spain log-associated catches of tropical tunas in 2018

The calculations in 25), 26) and 27) can be applied to the eight different scenarios in Table 2 and will yield different revised time-area log-associated catches for EU,Spain 2018 depending on the availability of month-wise and grid-wise data for the proxy fleets defined by each scenario, as well as on the species composition by month and grid provided by the proxy fleet.

AVG ESP,2017 is equivalent to applying the same fixed proportion (by tropical tuna species) inferred from the global EU,Spain log-associated catches recorded in 2017: therefore, *Scenario 0* extends the same approach suggested by the WPTT21 to time-area catches as well.

Examples

M	G	Reported log-associated catches (t)											
		ESP						FRA			SYC		
		2018			2017			2018			2018		
		BET	SKJ	YFT	BET	SKJ	YFT	BET	SKJ	YFT	BET	SKJ	YFT
1	5100050	*20.25*	*96.25*	*27.02*	5.04	26.26	16.64	-	-	-	-	-	-
1	5102059	*6.86*	*34.56*	*7.79*	-	-	-	1.61	10.54	7.49	-	-	-
1	5100051	*52.47*	*257.80*	*64.23*	-	-	-	-	-	-	33.94	281.59	87.86
1	5101056	*6.27*	*30.78*	*7.70*	13.08	74.51	25.39	7.22	51.81	13.78	-	-	-
1	5100052	*13.15*	*65.41*	*15.51*	5.50	32.07	8.58	-	-	-	25.99	206.95	84.76
1	5100053	*19.61*	*98.85*	*22.29*	-	-	-	12.51	90.47	21.22	7.01	54.11	26.25
1	5102064	*14.43*	*48.82*	*22.14*	3.13	15.13	13.41	1.47	8.89	9.93	4.29	35.87	10.53
1	5107057	*1.43*	*7.09*	*1.54*	-	-	-	-	-	-	-	-	-

Table 3 – Sample time-area catches as originally reported for the fleets and years concerned by the proxies in Table 2.

Scenario 0 revises the log-associated catches by month and area reported by EU,Spain in 2018 by applying the *overall* species composition of log-associated catches reported by the same fleet in 2017 to total log-associated catches of tropical tuna by month and grid (for the same fleet). The overall species composition for

EU,Spain in 2017 are provided in 1), 2) and 3), while a sample result of this re-estimation procedure is shown in **Table 4a**.

Month	Grid	Log-associated catches (t)							
		ESP							
		2018			2018 (revised)			2018	2018 (rev)
		BET	SKJ	YFT	BET	SKJ	YFT	Tot	Tot
1	5100050	*20.25*	*96.25*	*27.02*	8.89	93.59	41.04	143.52	143.52
1	5102059	*6.86*	*34.56*	*7.79*	3.05	32.09	14.07	49.21	49.21
1	5100051	*52.47*	*257.80*	*64.23*	23.20	244.21	107.09	374.50	374.50
1	5101056	*6.27*	*30.78*	*7.70*	2.77	29.18	12.80	44.75	44.75
1	5100052	*13.15*	*65.41*	*15.51*	5.83	61.34	26.90	94.07	94.07
1	5100053	*19.61*	*98.85*	*22.29*	8.72	91.78	40.25	140.75	140.75
1	5102064	*14.43*	*48.82*	*22.14*	5.29	55.68	24.42	85.39	85.39
1	5107057	*1.43*	*7.09*	*1.54*	0.62	6.56	2.88	10.06	10.06

Table 4a – (sample) revised time-area log-associated catches for EU,Spain 2018 calculated by applying **Scenario 0**

Month	Grid	Log-associated catches (t)											
		ESP						FRA			SYC		
		2018 (revised)			2017			2018			2018		
		BET	SKJ	YFT	BET	SKJ	YFT	BET	SKJ	YFT	BET	SKJ	YFT
1	5100050	15.09	78.62	49.82	5.04	26.26	16.64	-	-	-	-	-	-
1	5102059	3.05	32.09	14.07	-	-	-	1.61	10.54	7.49	-	-	-
1	5100051	23.20	244.21	107.09	-	-	-	-	-	-	33.94	281.59	87.86
1	5101056	5.18	29.51	10.06	13.08	74.51	25.39	7.22	51.81	13.78	-	-	-
1	5100052	11.21	65.37	17.49	5.50	32.07	8.58	-	-	-	25.99	206.95	84.76
1	5100053	8.72	91.78	40.25	-	-	-	12.51	90.47	21.22	7.01	54.11	26.25
1	5102064	8.44	40.79	36.16	3.13	15.13	13.41	1.47	8.89	9.93	4.29	35.87	10.53
1	5107057	0.62	6.56	2.88	-	-	-	-	-	-	-	-	-

Table 4b – (sample) revised time-area log-associated catches for EU,Spain 2018 calculated by applying **Scenario 1** (proxy records used for re-estimation of species composition). When no proxy value is highlighted in light blue, then the overall species composition from EU,Spain 2017 as in Scenario 0 is applied (cells with dark yellow background).

Month	Grid	Log-associated catches (t)											
		ESP						FRA			SYC		
		2018 (revised)			2017			2018			2018		
		BET	SKJ	YFT	BET	SKJ	YFT	BET	SKJ	YFT	BET	SKJ	YFT
1	5100050	15.09	78.62	49.82	5.04	26.26	16.64	-	-	-	-	-	-
1	5102059	4.03	26.41	18.77	-	-	-	1.61	10.54	7.49	-	-	-
1	5100051	31.51	261.42	81.57	-	-	-	-	-	-	33.94	281.59	87.86
1	5101056	4.44	31.84	8.47	13.08	74.51	25.39	7.22	51.81	13.78	-	-	-
1	5100052	7.70	61.28	25.10	5.50	32.07	8.58	-	-	-	25.99	206.95	84.76
1	5100053	14.18	102.53	24.05	-	-	-	12.51	90.47	21.22	7.01	54.11	26.25
1	5102064	6.19	37.41	41.79	3.13	15.13	13.41	1.47	8.89	9.93	4.29	35.87	10.53
1	5107057	0.62	6.56	2.88	-	-	-	-	-	-	-	-	-

Table 4c – (sample) revised time-area log-associated catches for EU,Spain 2018 calculated by applying **Scenario 2** (proxy records used for re-estimation of species composition). When no proxy value is highlighted in light blue, then the overall species composition from EU,Spain 2017 as in Scenario 0 is applied (cells with dark yellow background).

Month	Grid	Log-associated catches (t)											
		ESP						FRA			SYC		
		2018 (revised)			2017			2018			2018		
		BET	SKJ	YFT	BET	SKJ	YFT	BET	SKJ	YFT	BET	SKJ	YFT
1	5100050	15.09	78.62	49.82	5.04	26.26	16.64	-	-	-	-	-	-
1	5102059	4.03	26.41	18.77	-	-	-	1.61	10.54	7.49	-	-	-
1	5100051	31.51	261.42	81.57	-	-	-	-	-	-	33.94	281.59	87.86
1	5101056	4.44	31.84	8.47	13.08	74.51	25.39	7.22	51.81	13.78	-	-	-
1	5100052	11.21	65.37	17.49	5.50	32.07	8.58	-	-	-	25.99	206.95	84.76
1	5100053	14.18	102.53	24.05	-	-	-	12.51	90.47	21.22	7.01	54.11	26.25
1	5102064	6.19	37.41	41.79	3.13	15.13	13.41	1.47	8.89	9.93	4.29	35.87	10.53
1	5107057	0.62	6.56	2.88	-	-	-	-	-	-	-	-	-

Table 4d – (sample) revised time-area log-associated catches for EU,Spain 2018 calculated by applying **Scenario 3** (proxy records used for re-estimation of species composition). When no proxy value is highlighted in light blue, then the overall species composition from EU,Spain 2017 as in Scenario 0 is applied (cells with dark yellow background).

Month	Grid	Log-associated catches (t)											
		ESP						FRA			SYC		
		2018 (revised)			2017			2018			2018		
		BET	SKJ	YFT	BET	SKJ	YFT	BET	SKJ	YFT	BET	SKJ	YFT
1	5100050	15.09	78.62	49.82	5.04	26.26	16.64	-	-	-	-	-	-
1	5102059	4.03	26.41	18.77	-	-	-	1.61	10.54	7.49	-	-	-
1	5100051	31.51	261.42	81.57	-	-	-	-	-	-	33.94	281.59	87.86
1	5101056	4.44	31.84	8.47	13.08	74.51	25.39	7.22	51.81	13.78	-	-	-
1	5100052	7.70	61.28	25.10	5.50	32.07	8.58	-	-	-	25.99	206.95	84.76
1	5100053	11.29	87.17	42.29	-	-	-	12.51	90.47	21.22	7.01	54.11	26.25
1	5102064	7.23	60.42	17.74	3.13	15.13	13.41	1.47	8.89	9.93	4.29	35.87	10.53
1	5107057	0.62	6.56	2.88	-	-	-	-	-	-	-	-	-

Table 4e – (sample) revised time-area log-associated catches for EU,Spain 2018 calculated by applying **Scenario 4** (proxy records used for re-estimation of species composition). When no value is highlighted, then the overall species composition from EU,Spain 2017 (as in Scenario 0) is applied.

Month	Grid	Log-associated catches (t)											
		ESP						FRA			SYC		
		2018 (revised)			2017			2018			2018		
		BET	SKJ	YFT	BET	SKJ	YFT	BET	SKJ	YFT	BET	SKJ	YFT
1	5100050	15.09	78.62	49.82	5.04	26.26	16.64	-	-	-	-	-	-
1	5102059	4.03	26.41	18.77	-	-	-	1.61	10.54	7.49	-	-	-
1	5100051	31.51	261.42	81.57	-	-	-	-	-	-	33.94	281.59	87.86
1	5101056	5.18	29.51	10.06	13.08	74.51	25.39	7.22	51.81	13.78	-	-	-
1	5100052	7.70	61.28	25.10	5.50	32.07	8.58	-	-	-	25.99	206.95	84.76
1	5100053	11.29	87.17	42.29	-	-	-	12.51	90.47	21.22	7.01	54.11	26.25
1	5102064	7.23	60.42	17.74	3.13	15.13	13.41	1.47	8.89	9.93	4.29	35.87	10.53
1	5107057	0.62	6.56	2.88	-	-	-	-	-	-	-	-	-

Table 4f – (sample) revised time-area log-associated catches for EU,Spain 2018 calculated by applying **Scenario 5** (proxy records used for re-estimation of species composition). When no proxy value is highlighted in light blue, then the overall species composition from EU,Spain 2017 as in Scenario 0 is applied (cells with dark yellow background).

Month	Grid	Log-associated catches (t)											
		ESP						FRA			SYC		
		2018 (revised)			2017			2018			2018		
		BET	SKJ	YFT	BET	SKJ	YFT	BET	SKJ	YFT	BET	SKJ	YFT
1	5100050	15.09	78.62	49.82	5.04	26.26	16.64	-	-	-	-	-	-
1	5102059	4.03	26.41	18.77	-	-	-	1.61	10.54	7.49	-	-	-
1	5100051	31.51	261.42	81.57	-	-	-	-	-	-	33.94	281.59	87.86
1	5101056	5.18	29.51	10.06	13.08	74.51	25.39	7.22	51.81	13.78	-	-	-
1	5100052	11.21	65.37	17.49	5.50	32.07	8.58	-	-	-	25.99	206.95	84.76
1	5100053	14.18	102.53	24.05	-	-	-	12.51	90.47	21.22	7.01	54.11	26.25
1	5102064	8.44	40.79	36.16	3.13	15.13	13.41	1.47	8.89	9.93	4.29	35.87	10.53
1	5107057	0.62	6.56	2.88	-	-	-	-	-	-	-	-	-

Table 4g – (sample) revised time-area log-associated catches for EU,Spain 2018 calculated by applying **Scenario 6** (proxy records used for re-estimation of species composition). When no proxy value is highlighted in light blue, then the overall species composition from EU,Spain 2017 as in Scenario 0 is applied (cells with dark yellow background).

Month	Grid	Log-associated catches (t)											
		ESP						FRA			SYC		
		2018 (revised)			2017			2018			2018		
		BET	SKJ	YFT	BET	SKJ	YFT	BET	SKJ	YFT	BET	SKJ	YFT
1	5100050	15.09	78.62	49.82	5.04	26.26	16.64	-	-	-	-	-	-
1	5102059	4.03	26.41	18.77	-	-	-	1.61	10.54	7.49	-	-	-
1	5100051	31.51	261.42	81.57	-	-	-	-	-	-	33.94	281.59	87.86
1	5101056	5.18	29.51	10.06	13.08	74.51	25.39	7.22	51.81	13.78	-	-	-
1	5100052	11.21	65.37	17.49	5.50	32.07	8.58	-	-	-	25.99	206.95	84.76
1	5100053	8.72	91.78	40.25	-	-	-	12.51	90.47	21.22	7.01	54.11	26.25
1	5102064	8.44	40.79	36.16	3.13	15.13	13.41	1.47	8.89	9.93	4.29	35.87	10.53
1	5107057	0.62	6.56	2.88	-	-	-	-	-	-	-	-	-

Table 4h – (sample) revised time-area log-associated catches for EU,Spain 2018 calculated by applying **Scenario 7** (proxy records used for re-estimation of species composition). When no proxy value is highlighted in light blue, then the overall species composition from EU,Spain 2017 as in Scenario 0 is applied (cells with dark yellow background).

Tables 4b-h provide a sample of the results (and of the proxy information used) when applying the eight different proxying scenarios.

Re-estimation results according to the proposed scenarios

To re-estimate the total log-associated catch by species for EU,Spain 2018 it is necessary to apply the process above to all months and grids for which log-associated catches of any tropical tuna species are reported by the fleet for 2018. The results for all potential scenarios are shown in **Table 5**, **Fig. 9** (absolute catch values) and **Table 6**, **Fig. 10** (differences with original catch values).

	Original	Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
BET	24,507.31	12,405.38	12,189.67	11,184.86	11,721.77	10,619.20	10,600.05	11,423.88	11,274.47
SKJ	132,078.80	130,574.50	131,127.20	127,721.10	127,657.30	131,385.70	132,063.50	130,425.90	131,966.80
YFT	43,652.48	57,258.63	56,921.65	61,332.61	60,859.50	58,233.65	57,575.04	58,388.73	56,997.32
Total	200,238.59	200,238.51	200,238.52	200,238.57	200,238.57	200,238.55	200,238.59	200,238.51	200,238.59

Table 5 –Total log-associated catches for EU,Spain (2018, by species) re-estimated according to the different proxy configurations described in the eight scenarios in Table 2. Values are in metric tons (t)

As expected, the log-associated total catches for BET, SKJ and YFT re-estimated by applying the proxy mechanism defined by Scenario 0 (12,405 t, 130,574 t and 57,258 t respectively) are perfectly matching – if not for some minor differences possibly due to rounding issues – with the re-estimated catches calculated with the approach proposed by the WPTT 21 (12,403 t, 130,558 t and 57,251 t respectively).

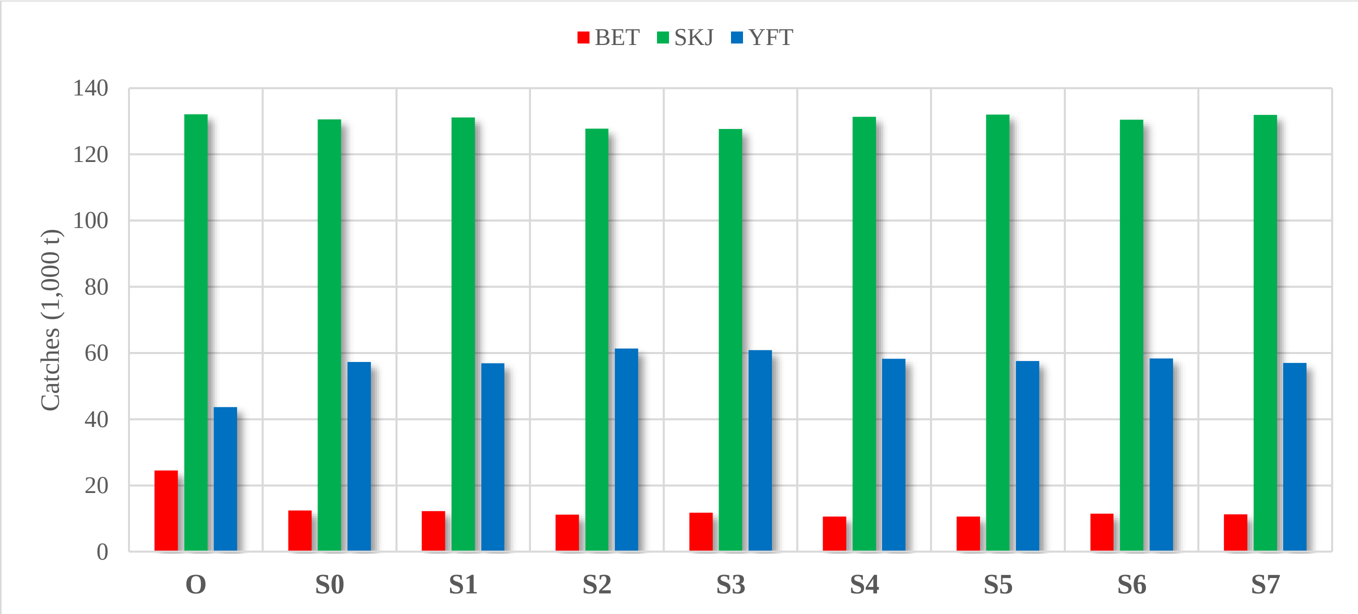

Fig. 9 – Re-estimated log-associated EU,Spain catches for 2018 according to the eight different proxy scenarios in Table 2. "O": original data; "S0", …, "S7": Scenarios #0 to 7.

	Original	Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
BET	0	-12,101.93	-12,317.64	-13,322.45	-12,785.54	-13,888.11	-13,907.26	-13,083.43	-13,232.84
SKJ	0	-1,504.30	-951.60	-4,357.70	-4,421.50	-693.10	-15.30	-1,652.90	-112.00
YFT	0	13,606.15	13,269.17	17,680.13	17,207.02	14,581.17	13,922.56	14,736.25	13,344.84
Total	0	-0.08	-0.07	-0.02	-0.02	-0.04	0.00	-0.08	0.00

Table 6 – Differences between re-estimated total log-associated catches for EU,Spain (2018, by species) and original log-associated catches by species according to the different proxy configurations described in the eight scenarios in Table 2. Values are in metric tons (t)

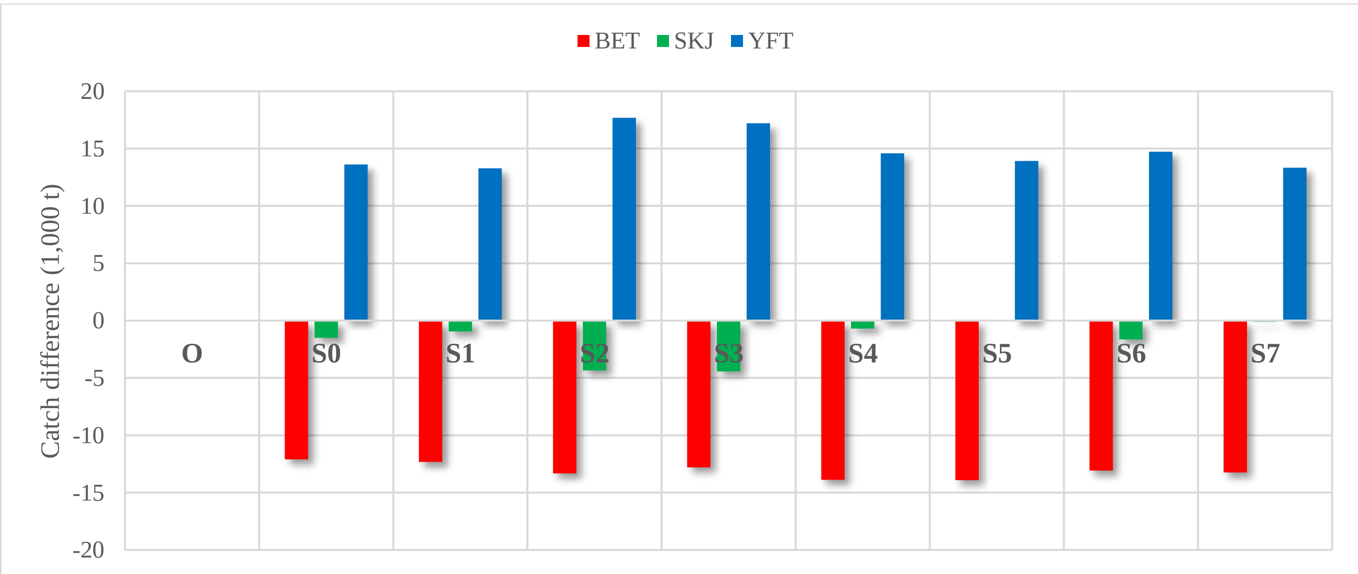

Fig. 10 – Difference between Original and re-estimated log-associated EU,Spain catches for 2018 according to the eight different proxy scenarios in Table 2. "O": original data, "S0", …, "S7": Scenarios #0 to 7.

Conclusions and recommended actions

The resulting re-estimated time-area, log-associated catches for the EU,Spain component of the European Union purse seine fisheries tend to be comparable across all eight different scenarios, as well as with the results of the much simpler, region-wide re-estimation performed at the WPTT21 (see **Table 5**).

In terms of choosing a preferred scenario for the preparation of a revised set of time-area catches to be submitted for endorsement to the IOTC Working Party on Data Collection and Statistics and eventually to the IOTC Scientific Committee, a number of preliminary considerations should be made.

First and foremost, the Bigeye tuna catch revision that was originally triggered by the unusually high log-associated catch values recorded for the species in 2018 has an impact (regardless of the chosen scenario) on the other two tropical tuna species as well, in particular on the log-associated catches of Yellowfin tuna (see **Table 6** and **Fig. 10**) for which the increases in catches for 2018 after the re-estimation will range from 13,269 (Scenario 1) to 17,680 (Scenario 2) metric tons *more* than what currently reported by EU,Spain.

Considering the importance of having reliable Yellowfin tuna catch statistics to properly evaluate the effectiveness of Resolution 19/01, whatever decision is taken in regards to the choice of a preferred re-estimation scenario, its results in terms of adjustments to the official (i.e. current) Yellowfin tuna catch series have to be properly dealt with when assessing the effect of said Resolution.

Furthermore, the eight proposed scenarios are all defined on the basis of information available on a relatively short timeframe (data for 2017 and / or 2018), with potential sensible changes in fishing operations implemented by the fleets used as proxies during any of these years that might introduce bias in the final estimations as well.

As there is no accurate methodology to determine the impact of these changes in the final results, the choice of the most likely re-estimation scenario would benefit from expert knowledge to be provided by representatives of the involved CPCs, that might confirm (or reject) the validity of using time-area species composition information from their fleet to re-estimate the EU,Spain data for 2018.

Also, it might be worth considering a longer timeframe (i.e. the last ten years of data, or comparable intervals) over which an average species composition for the concerned fleets would be calculated and used as primary (or secondary) proxy for one of the existing scenarios or – as well – as a basis for a completely new scenario that will combine long-term average data with other existing proxies covering more recent years.

Regardless of the chosen proxies, one of the basic assumptions in the proposed procedure for the re-estimation of time-area log-associated catches for EU,Spain is that all fleets (be it the EU one, broken down by its component flags, or the Seychelles fleet) operating in the same year, month and grid should ultimately report comparable species composition for captures of tropical tuna species in the stratum. While this is in line with the way in which T3 estimates are produced, at the same time it smooths away the individual vessels effect.

As EU,Spain has confirmed the introduction of a new statistical methodology to estimate the species composition of captures from its purse seine fleet during 2018, it might also be particularly important to understand whether the new methodology could retroactively be applied back in time: this, with the goal of uniformly re-estimating the catch composition for the fleet also for years prior to 2018, see how this compares with the data officially submitted for 2018 and most of all determine whether the same types of marked regular patterns shown in **Fig. 4c** also became apparent during previous years.

Additionally, it should be clarified whether the new methodology adopted by EU,Spain has been used only for the estimation of total catches by species for 2018 or – on the contrary – also applied to the production of the time-area catches officially[3] submitted to the IOTC Secretariat, noting that the total captures by species resulting from the latter are perfectly in line with the nominal catches reported as a separate data set by EU,Spain.

Finally, it is particularly important to recall that a study[4] presented by Herrera M. and Baez J. C. at the 20th Session of the IOTC Working Party on Tropical Tuna (WPTT20, 2018) compared species composition values resulting from the T3 process (for the EU and Seychelles purse seine fleets) with the same information inferred from actual sale slips available to the authors: the study concluded that in the Indian Ocean there might be a potential under-estimation of catches for both Bigeye and Yellowfin tuna and a corresponding over-estimation of catches of Skipjack.

These results, if confirmed, will call for further actions to ensure that all data available to the IOTC for scientific and management purposes is properly updated to reflect the actual status of tropical tuna captures by the European Union purse seine fleet.

[4] https://iotc.org/sites/default/files/documents/2018/10/IOTC-2018-WPTT20-17.pdf

Geo-spatial plots of time-area catches (species and fleet composition)

Original data

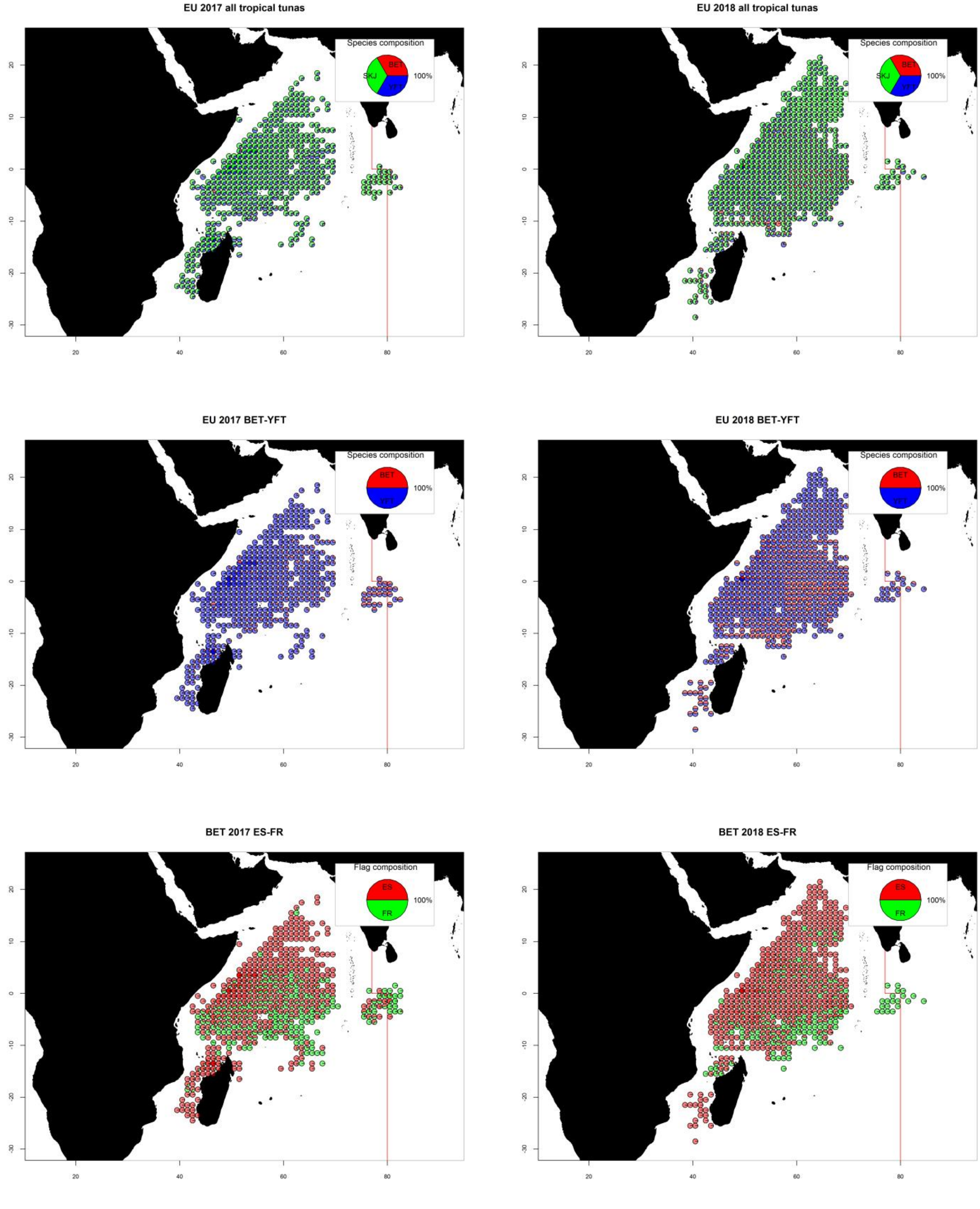

Figure A.1 (a-f) – Tropical tuna relative species composition (log-associated school) for the EU purse seine fleet a) in 2017 (top - left) and b) in 2018 (top-right); Relative proportion of BET vs. YFT tuna for the EU purse seine fleet c) in 2017 (center-left) and d) in 2018 (center-right); Relative contribution to BET catches by EU,Spain and EU,France to the EU purse seine fleet e) in 2017 (bottom-left) and f) in 2018 (bottom-right). Plot colour intensity is linearly proportional to the total catches recorded in the grid.

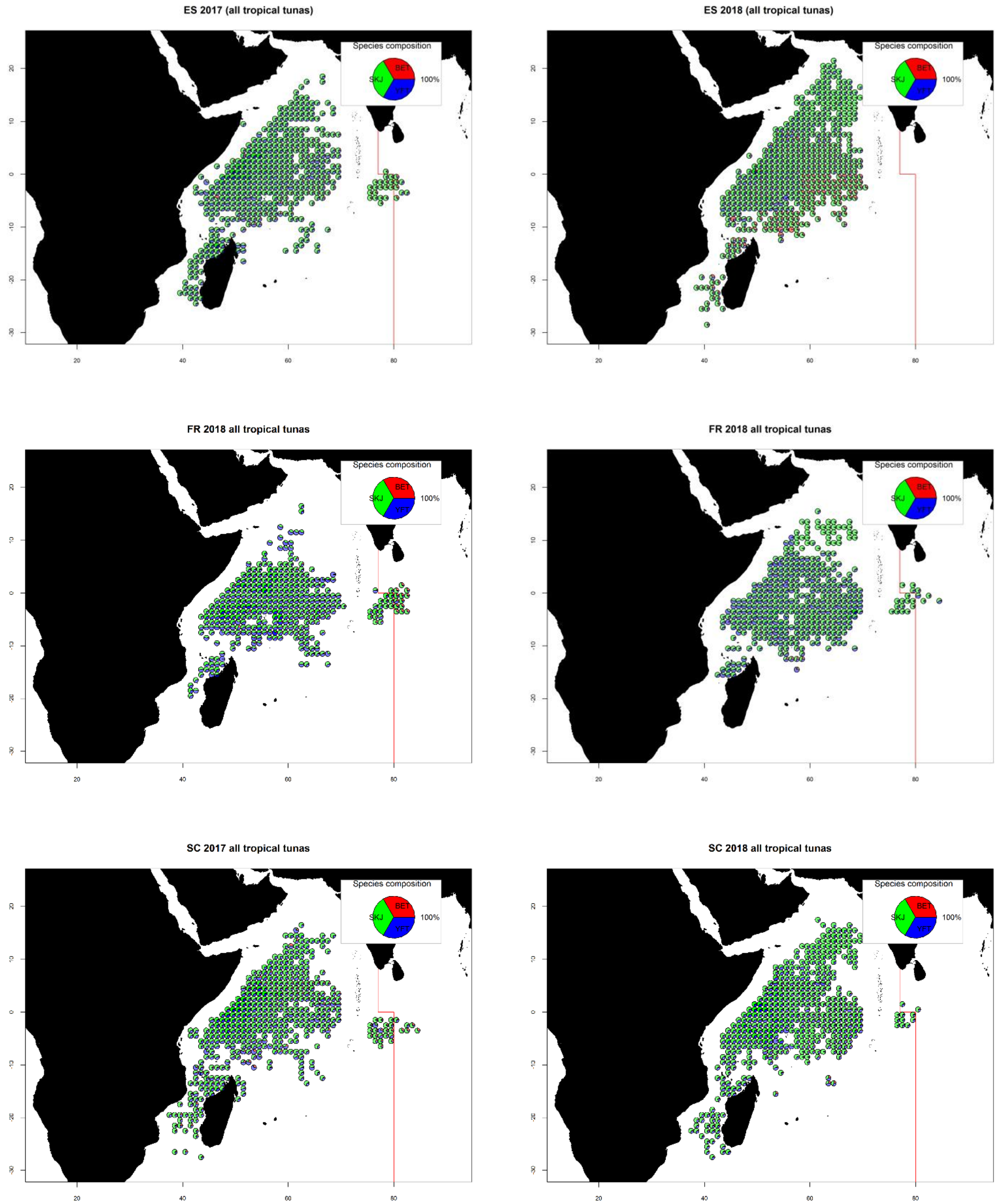

Figure A.2 (a-f) – Tropical tuna relative species composition (log-associated school) for EU,Spain a) in 2017 (top -left) and b) in 2018 (top-right); for EU,France c) in 2017 (center-left) and d) in 2018 (center-right); for Seychelles e) in 2017 (bottom-left) and f) in 2018 (bottom-right). Plot colour intensity is linearly proportional to the total catches recorded in the grid.

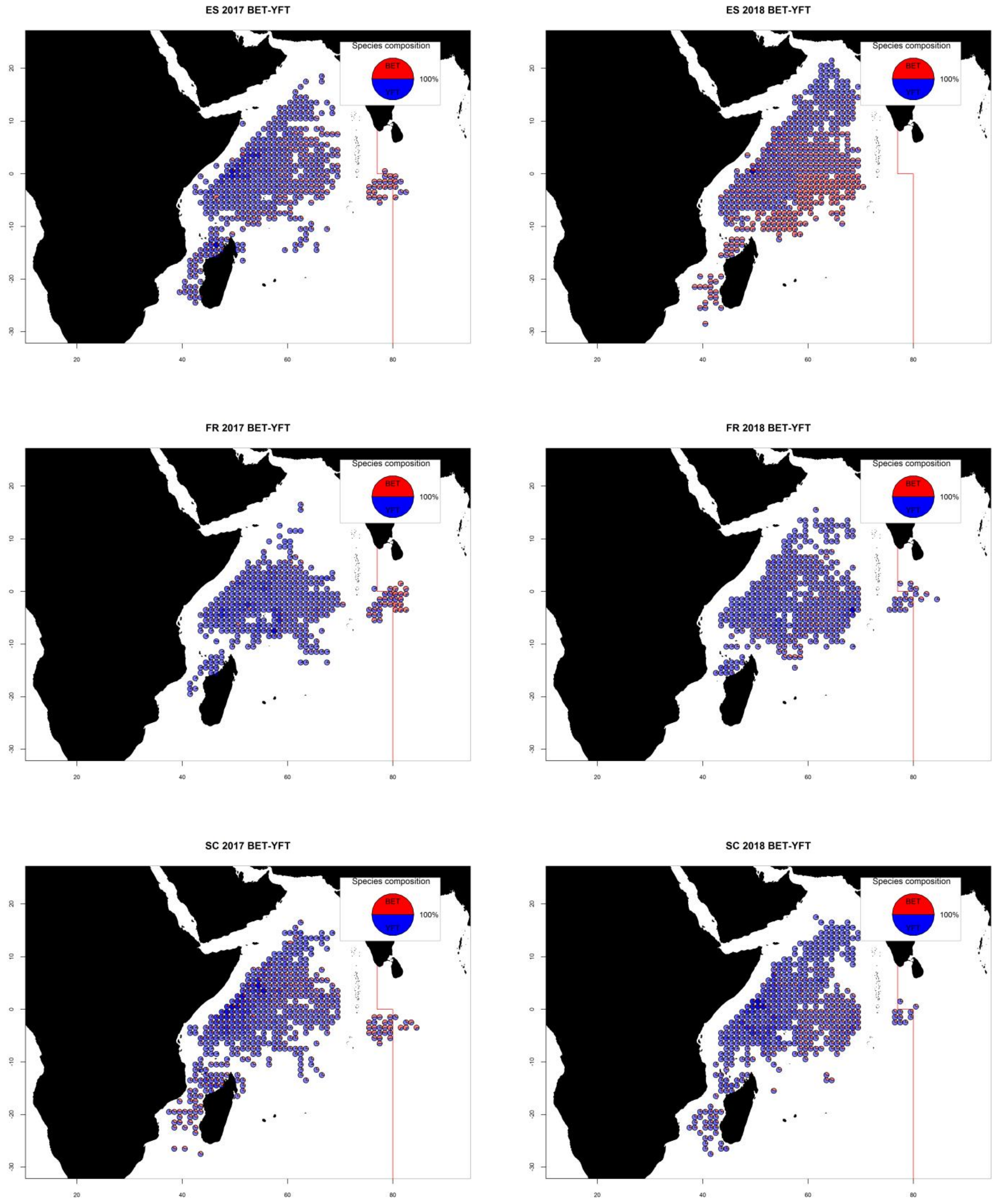

Figure A.3 (a-f) – Relative abundance of Bigeye vs. Yellowfin tuna (log-associated school) for EU,Spain a) in 2017 (top -left) and b) in 2018 (top-right); for EU,France c) in 2017 (center-left) and d) in 2018 (center-right); for Seychelles e) in 2017 (bottom-left) and f) in 2018 (bottom-right). Plot colour intensity is linearly proportional to the total catches recorded in the grid.

Scenario 0: re-estimation results

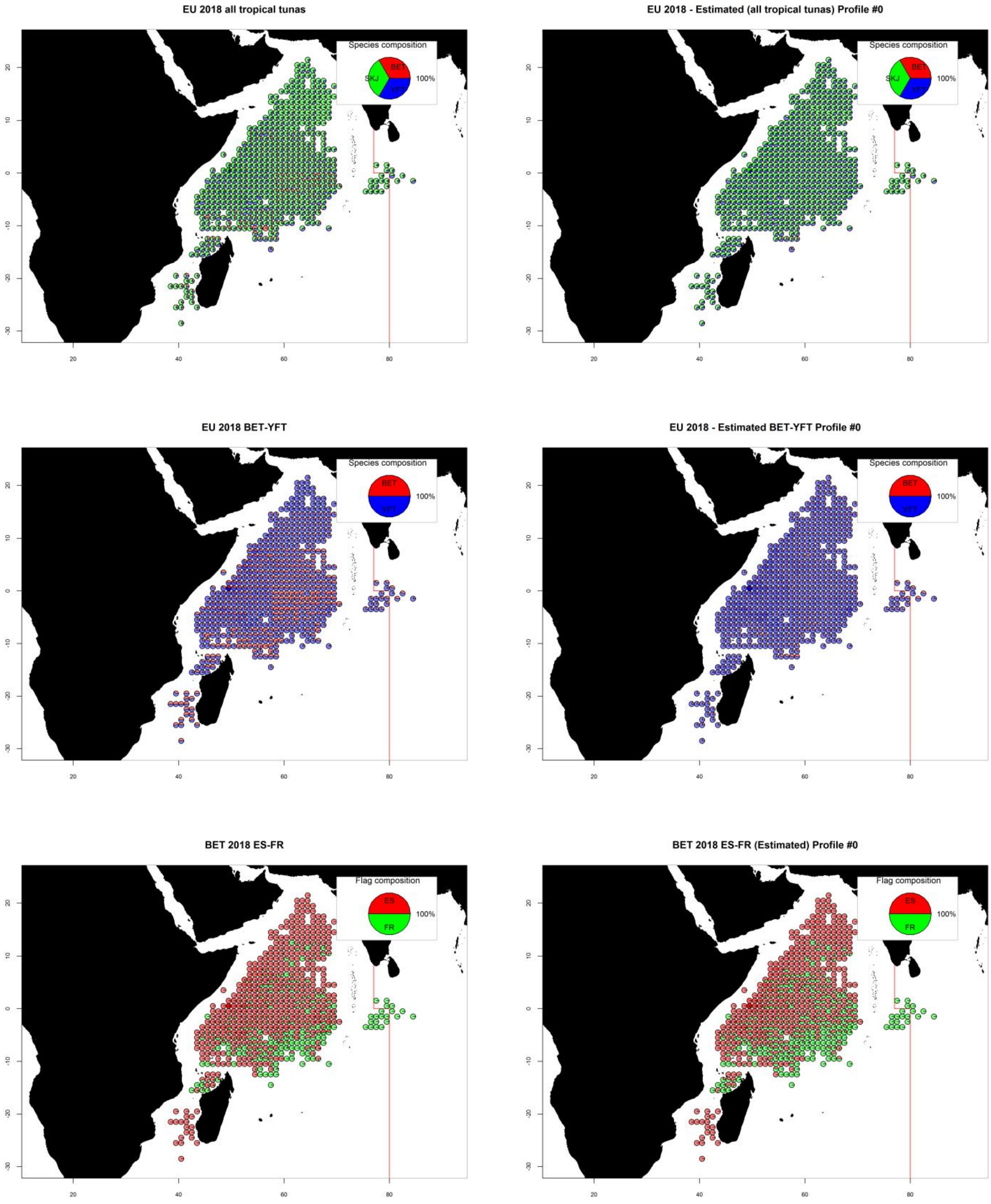

Figure A.4 (a-f) – Comparison between original and re-estimated (according to **Scenario 0**) European Union tropical tuna log-associated catches: a) original proportion of tropical tuna by species in 2018 (top-left), b) including the EU,Spain component re-estimated for 2018 (top-right), c) original relative proportion of BET vs. YFT in 2018 (center-left), d) including the EU,Spain component re-estimated for 2018 (center-right), e) original relative proportion of BET catches by EU flag in 2018 (bottom-left), f) including the EU,Spain component re-estimated for 2018 (bottom-right). Plot colour intensity is linearly proportional to the total catches recorded in the grid.

Scenario 1: re-estimation results

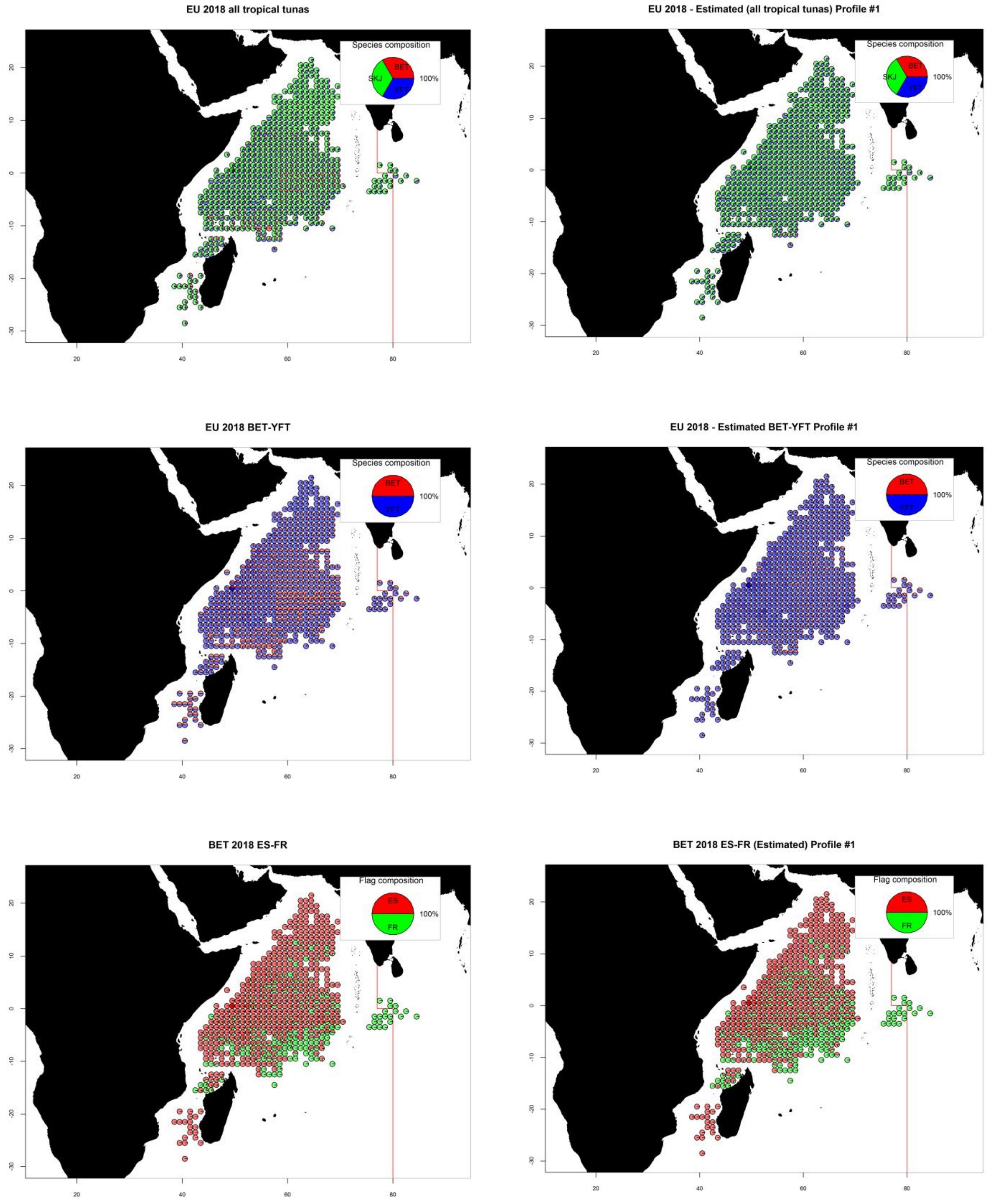

Figure A.5 (a-f) – Comparison between original and re-estimated (according to **Scenario 1**) European Union tropical tuna log-associated catches: a) original proportion of tropical tuna by species in 2018 (top-left), b) including the EU,Spain component re-estimated for 2018 (top-right), c) original relative proportion of BET vs. YFT in 2018 (center-left), d) including the EU,Spain component re-estimated for 2018 (center-right), e) original relative proportion of BET catches by EU flag in 2018 (bottom-left), f) including the EU,Spain component re-estimated for 2018 (bottom-right). Plot colour intensity is linearly proportional to the total catches recorded in the grid.

Scenario 2: re-estimation results

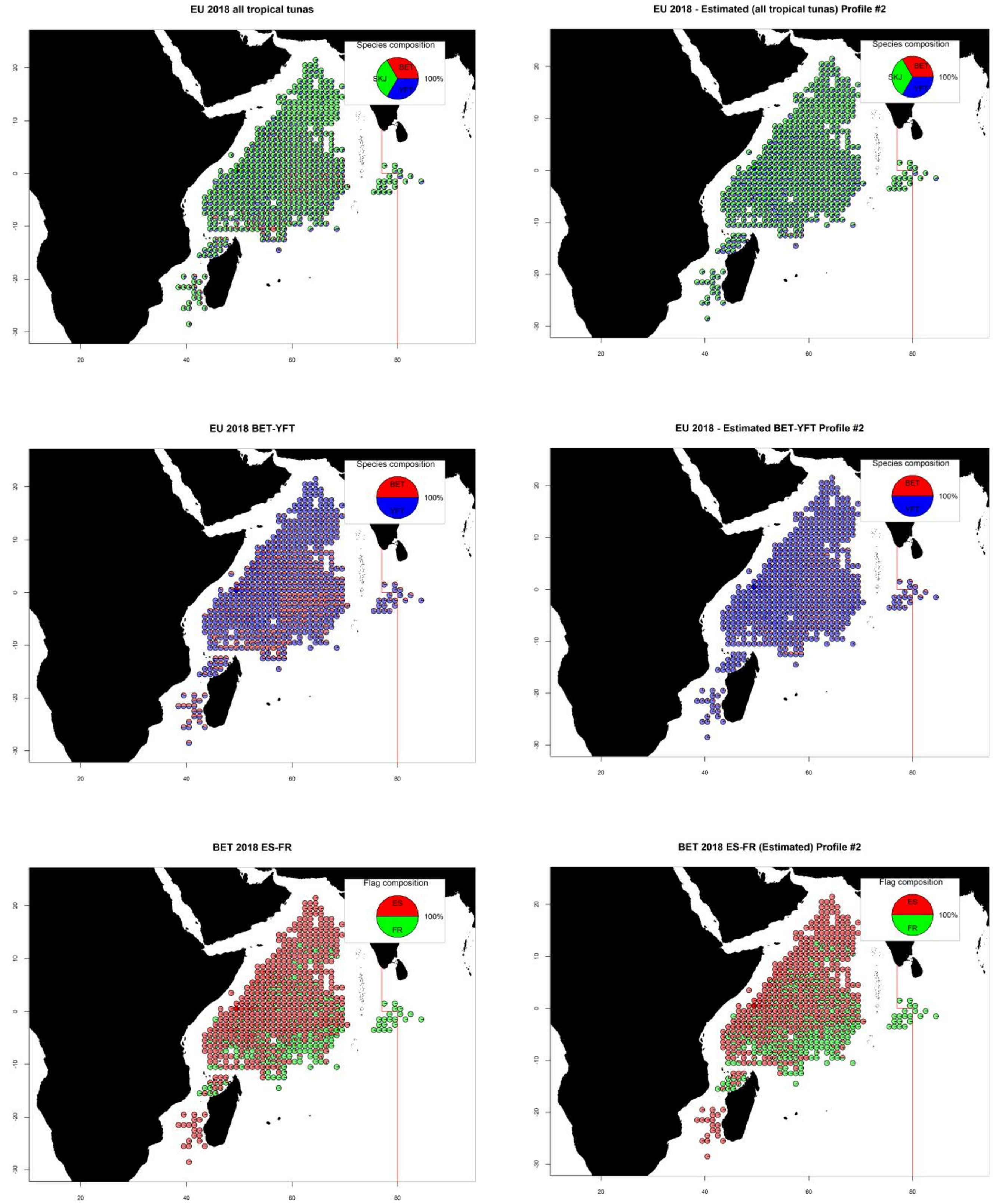

Figure A.5 (a-f) – Comparison between original and re-estimated (according to **Scenario 2**) European Union tropical tuna log-associated catches: a) original proportion of tropical tuna by species in 2018 (top-left), b) including the EU,Spain component re-estimated for 2018 (top-right), c) original relative proportion of BET vs. YFT in 2018 (center-left), d) including the EU,Spain component re-estimated for 2018 (center-right), e) original relative proportion of BET catches by EU flag in 2018 (bottom-left), f) including the EU,Spain component re-estimated for 2018 (bottom-right). Plot colour intensity is linearly proportional to the total catches recorded in the grid.

Scenario 3: re-estimation results

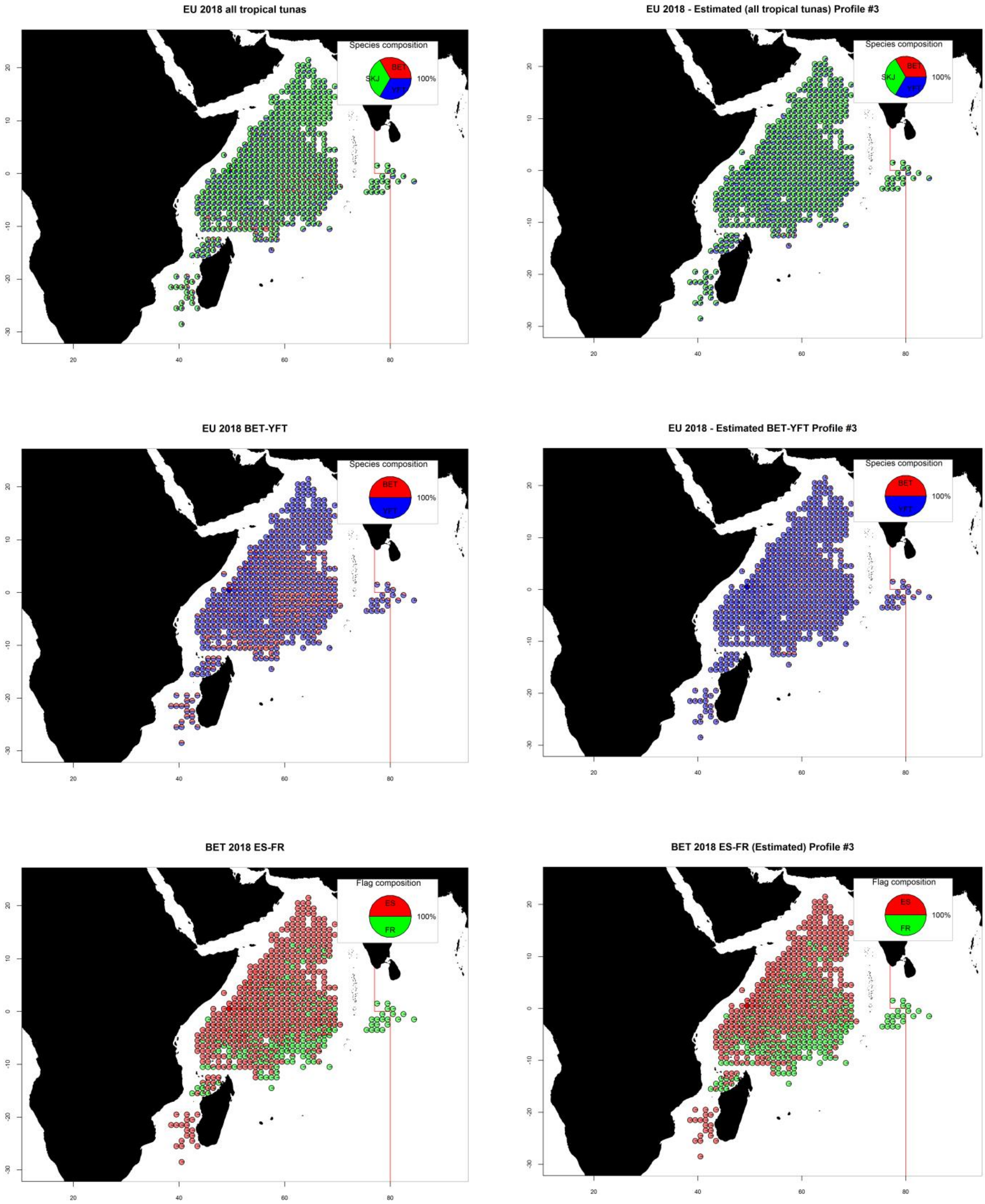

Figure A.6 (a-f) – Comparison between original and re-estimated (according to **Scenario 3**) European Union tropical tuna log-associated catches: a) original proportion of tropical tuna by species in 2018 (top-left), b) including the EU,Spain component re-estimated for 2018 (top-right), c) original relative proportion of BET vs. YFT in 2018 (center-left), d) including the EU,Spain component re-estimated for 2018 (center-right), e) original relative proportion of BET catches by EU flag in 2018 (bottom-left), f) including the EU,Spain component re-estimated for 2018 (bottom-right). Plot colour intensity is linearly proportional to the total catches recorded in the grid.

Scenario 4: re-estimation results

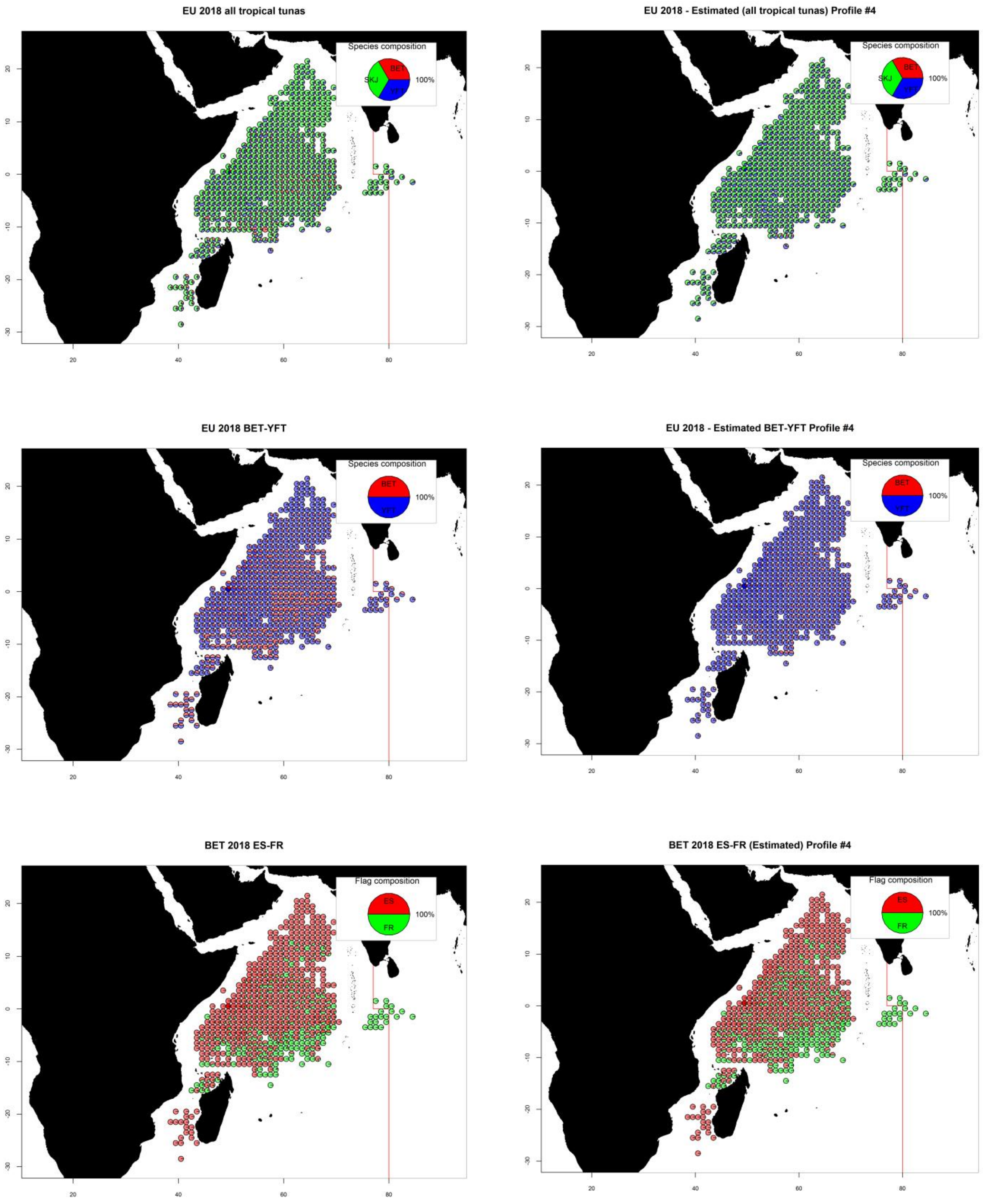

Figure A.7 (a-f) – Comparison between original and re-estimated (according to **Scenario 4**) European Union tropical tuna log-associated catches: a) original proportion of tropical tuna by species in 2018 (top-left), b) including the EU,Spain component re-estimated for 2018 (top-right), c) original relative proportion of BET vs. YFT in 2018 (center-left), d) including the EU,Spain component re-estimated for 2018 (center-right), e) original relative proportion of BET catches by EU flag in 2018 (bottom-left), f) including the EU,Spain component re-estimated for 2018 (bottom-right). Plot colour intensity is linearly proportional to the total catches recorded in the grid.

Scenario 5: re-estimation results

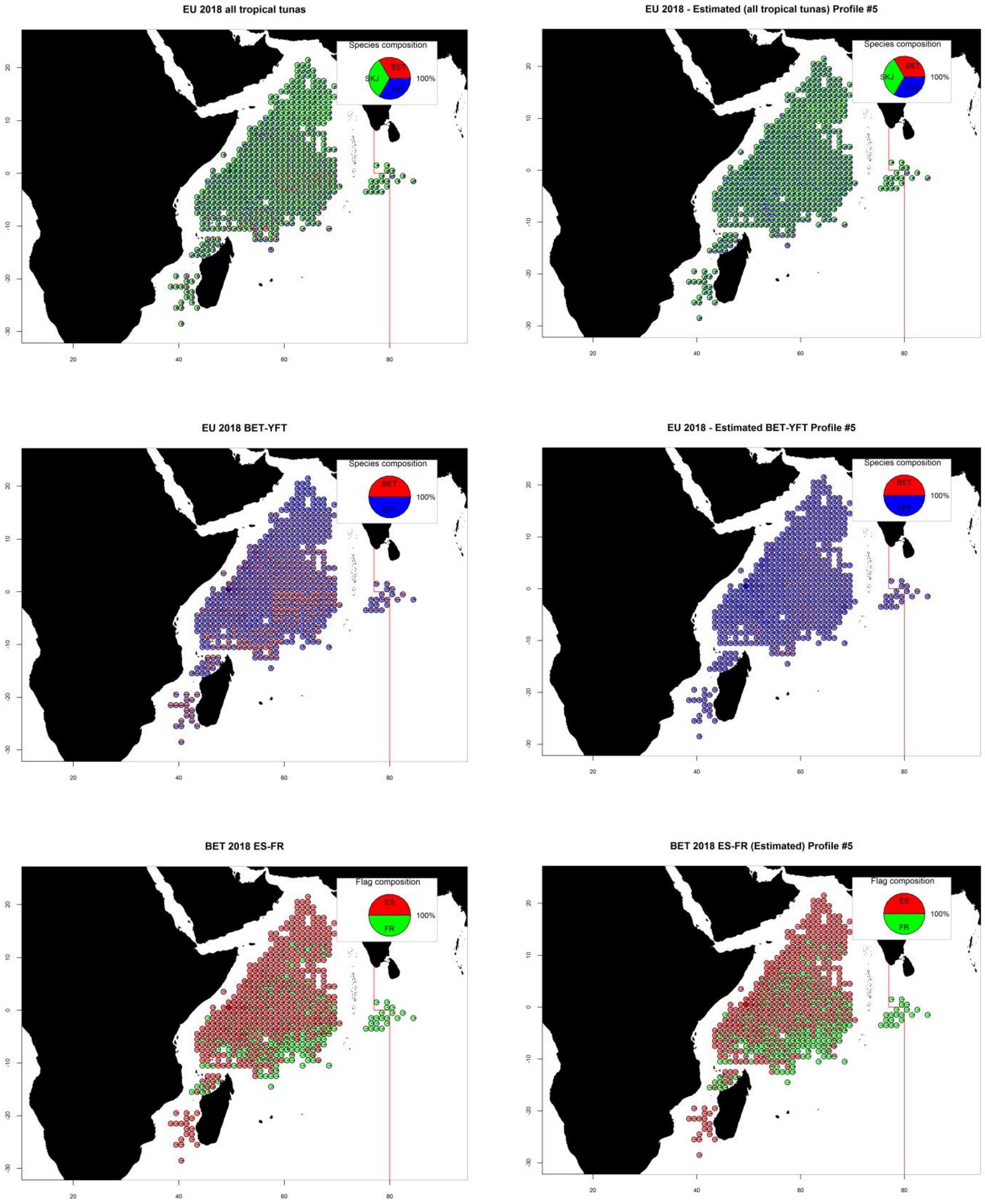

Figure A.8 (a-f) – Comparison between original and re-estimated (according to **Scenario 5**) European Union tropical tuna log-associated catches: a) original proportion of tropical tuna by species in 2018 (top-left), b) including the EU,Spain component re-estimated for 2018 (top-right), c) original relative proportion of BET vs. YFT in 2018 (center-left), d) including the EU,Spain component re-estimated for 2018 (center-right), e) original relative proportion of BET catches by EU flag in 2018 (bottom-left), f) including the EU,Spain component re-estimated for 2018 (bottom-right). Plot colour intensity is linearly proportional to the total catches recorded in the grid.

Scenario 6: re-estimation results

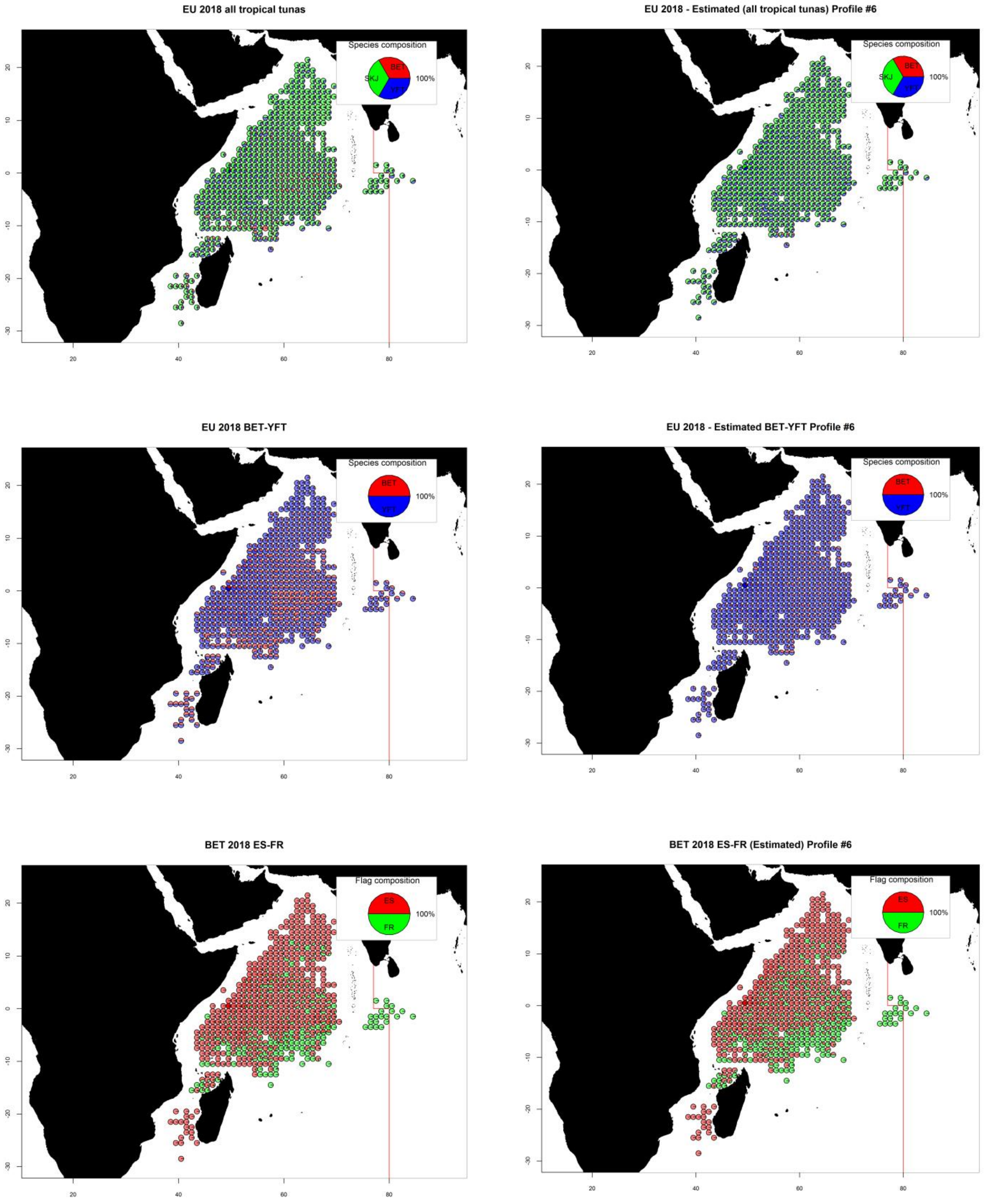

Figure A.9 (a-f) – Comparison between original and re-estimated (according to **Scenario 6**) European Union tropical tuna log-associated catches: a) original proportion of tropical tuna by species in 2018 (top-left), b) including the EU,Spain component re-estimated for 2018 (top-right), c) original relative proportion of BET vs. YFT in 2018 (center-left), d) including the EU,Spain component re-estimated for 2018 (center-right), e) original relative proportion of BET catches by EU flag in 2018 (bottom-left), f) including the EU,Spain component re-estimated for 2018 (bottom-right). Plot colour intensity is linearly proportional to the total catches recorded in the grid.

Scenario 7: re-estimation results

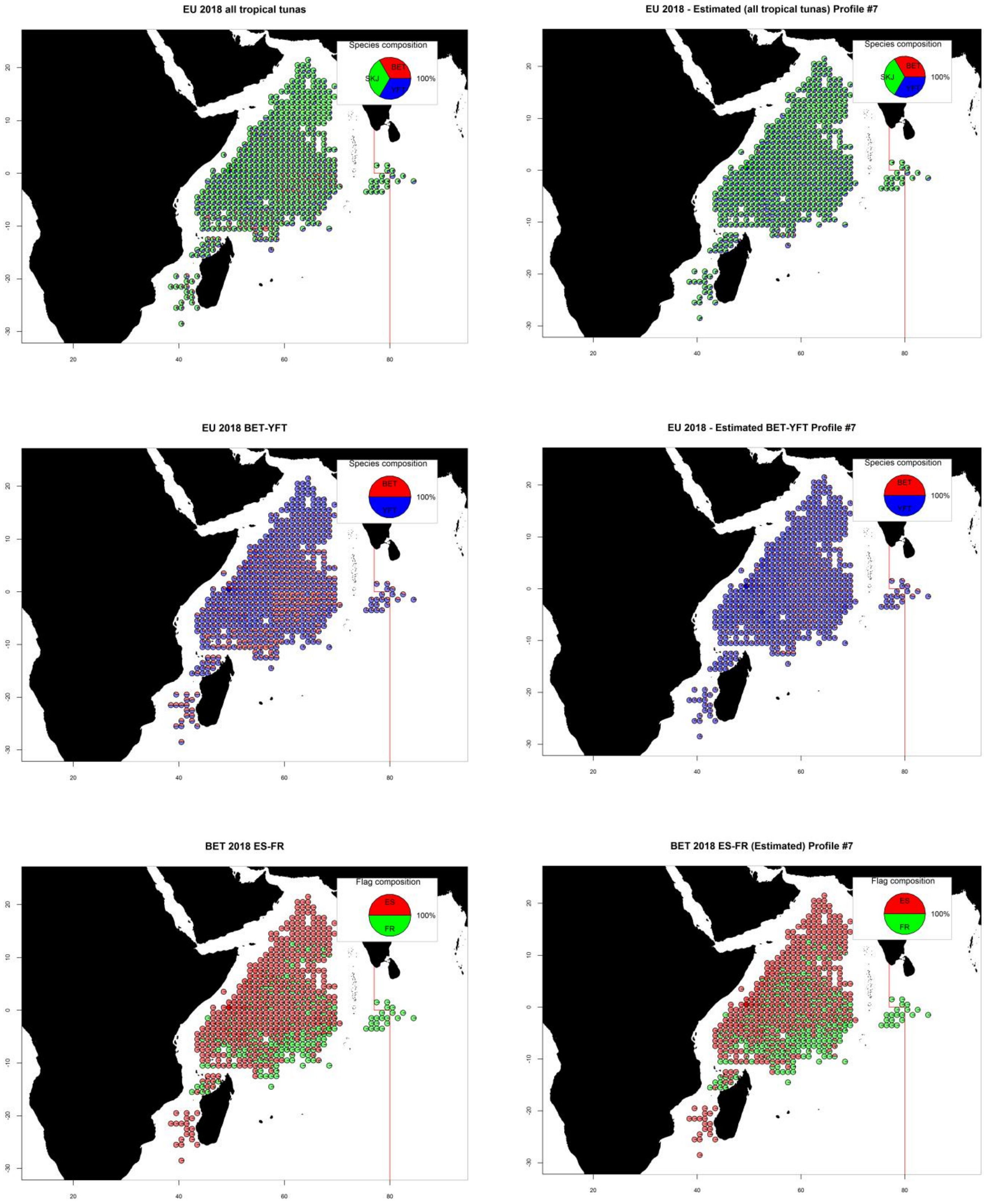

Figure A.10 (a-f) – Comparison between original and re-estimated (according to **Scenario 7**) European Union tropical tuna log-associated catches: a) original proportion of tropical tuna by species in 2018 (top-left), b) including the EU,Spain component re-estimated for 2018 (top-right), c) original relative proportion of BET vs. YFT in 2018 (center-left), d) including the EU,Spain component re-estimated for 2018 (center-right), e) original relative proportion of BET catches by EU flag in 2018 (bottom-left), f) including the EU,Spain component re-estimated for 2018 (bottom-right). Plot colour intensity is linearly proportional to the total catches recorded in the grid.