Scientific catch estimation for the global FAD tropical tuna purse seine fishery in the Indian Ocean

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Abstract

This analysis compares IOTC catch data in the public domain with an alternative estimation for associated (log school) purse seine catches based on port sampling data from the European Union sampling program aggregated by 5º square or statistical area, year and quarter.

The underlying assumption is that any fleet fishing in the same spatio-temporal strata and on log schools will have, on average, the same catch composition.

Species composition distribution in the sampled strata (year, quarter and 5x5º cell or statistical area) was estimated by bootstrapping across the catch by species derived from each sample and was applied to the total catch (aggregated across flags) reported in these strata. For unsampled strata, a correction factor was estimated by comparing the species composition reported and estimated in sampled strata on a yearly basis. This correction factor was then applied to the total catch on log school in each unsampled strata.

The estimated catch levels when port sampling data weighted by the size category are used are close to the ones in the public domain, with some exception as in 2018. Moreover, it also indicates some deviations in the early time series and in the most recent years. Two approaches for the catch estimation, one based on the raw samples and another one in which species composition is estimated separately for different catch categories (<10 kg, 10-30 kg and >30 kg) and adjusted according to the amount of each fraction as reported in the logbooks, were tested.

While this analysis does not provide any insight on the best procedure to estimate catch composition in the purse seine fishery, it provides a time-consistent, scientific-based, estimate of catches for the purse seine fishery that can be of use for future stock assessments.

Introduction

The estimation of catch composition in purse seine fisheries have proved problematic since the beginning of the fisheries. Due to the resemblance of the juveniles of yellowfin *Thunnus albacares* and bigeye tuna *Thunnus obesus, the* frequent overreporting of skipjack tuna *Kastuwonus pelamis* catches and the way the purse seine catches are directly brailed into the wells, catches reported in logbooks, particularly for small individuals- normally linked to catches on floating objects- are typically inaccurate and need to be corrected (e.g., Fonteneau et al., 1976; Báez et al., 2019).

CPCs have provided catch estimates as required by the mandatory statistical requirements on a regular basis. These provisions are assumed accurate and are used for the assessment of the different stocks. In the case of the three main fleets involved in the fishery, namely Spain, France and Seychelles, the species and size composition of the catch have been corrected since the early 1990’s (the so-called T3 methodology) based on a combination of port sampling data (species and size composition by fishing mode- i.e., free school or floating object (FOB) sets, weight category, quarter and statistical area), logbook declaration (catch by weight category, fishing mode, quarter and statistical area) and landing slips (ratio from total landed catch vs total catch recorded in logbooks) following a methodology developed by the Working Group on Juvenile Tropical Tunas (Anon. 1984) and further refined in the framework of a joint project (European ET Research Programme No. 95/37: "Analysis of the Tropical Tuna Multi-species Sampling Scheme") by France and Spain (Pallarés and Petit, 1998; Pianet et al., 2000).

In addition to the refinement in the methodology after 1998 mentioned above, the introduction of catch limits for yellowfin tuna by Resolution 16/01 implied the need of CPCs for developing monitoring, control and surveillance processes that may have changed the methodology followed in the past and produced inconsistencies in the catch time series. Moreover, the procedure for the estimation of catches in some instances is not, or poorly, documented.

The current study does not focus on the accuracy or appropriateness of different methodologies, nor examines estimates at the CPC level. It is aimed at using a consistent methodology across CPCs and through time, based on port sampling data, to provide scientific estimates for the global purse seine fishery operating in the Indian Ocean. These estimates can be of use in future stock assessments of bigeye, skipjack and yellowfin tuna and solve some of the issues linked to the methodological changes the implementation of catch limits may have had in CPCs catch estimation and reporting.

Methodology

Port sampling data

Port sampling data were obtained from the sampling at landing in the ports of Victoria, Mombassa and Diego Suarez in the framework of the Spanish Institute of Oceanography (IEO) and the French Research Institute for Development (IRD) sampling programs and, later, from the EU data collection regulation sampling programs.

This sampling procedure selects wells that contain catches from the same spatial strata (termed ET areas), the same fishing mode (FOB or free school sets) and the same quarter to characterize species and size composition in each stratum. The detailed process for sampling is described in Sarralde et al 2009.

Catch data

Catch data from 1990 to 2022 were obtained from the IOTC public domain (https://iotc.org/WPTT/25/Data/05-CESurface, accessed on the 8th September 2023). In this dataset, all catch data are classified by fishing mode, month and 1º cell (with the exception of 347 t in the early 1990's provided at 5º resolution).

Correction

Species composition was estimated at two different stratification levels: (Step 1) 5x5º cell, set type, year and quarter; and (Step 2) ET area, set type, year and quarter. The definition of the ET areas is shown in table 1.

Samples from wells with catch from different 5x5 cell (or ET area in step 2), year-quarter or fishing modes were not included. Furthermore, samples with less than 100 fish or strata will less than 5 samples were also removed. Table 2 illustrates the number of samples retained after each filtering step.

Fish numbers at size were converted to weight using IOTC length-weight conversion factors (https://iotc.org/WPTT/24/Data/13-Equations). Confidence intervals (10th and 90th percentiles) were estimated by boostrapping across samples and total catch by 1x1º cell and quarter (aggregated across flags) in the IOTC public domain was split into the three species based on the estimated composition from the samples. First, catches were corrected by the species composition estimated in the same 5ºx5º/quarter (step 1). Catch composition in the strata that could not be corrected in the previous step, because there were no estimates for that 5x5 grid/quarter, was corrected by the species composition estimated in the same ET area/quarter (step 2). Finally, for those strata that were not sampled at the 5x5 or ET area/quarter level, a yearly correction factor, estimated at the species level based on the difference between the reported and estimated catch in sampled strata that year, was applied (step 3).

In the traditional T3 process, species composition is estimated by weight category (<10 kg, 10-30kg and >30 kg categories) and then weighted according to the total catch by category (as declared in the logbooks) in the sets contributing to the sampled wells. This may partially remove biases linked to the selectivity at sampling of certain sizes over the others (e.g., Peatman et al., 2018), size sorting at unloading, etc. We assayed two correction procedures: (1) based in this approach (the catch composition in the samples is weighted according to the <10, 10-30 and >30 catch in the sampled wells) and (2) assuming a perfect random sampling, hence using the raw sampling data.

Preliminary analyses indicated significant deviations between the estimates and the reported catches in the earlier time-series when free school catches were corrected. This seemed to be linked to a different targeting, when fishing on free schools, between sampled and unsampled flags (EU vessels mainly targeting large yellowfin tuna schools and other flags mainly targeting skipjack). This led to estimates that seemed artefact. Therefore, it was decided to only correct FAD catches and assume free-school catches are accurately reported.

Results and discussion

Figure 1 shows the percentage of catch that has been corrected using each of the procedures. For most of the time series, over 90% of the catch could be corrected using the estimations at 5x5/quarter or ET area/quarter level. However, sampling coverage for some years was very low (1998, 1999, 2017 and 2020), and most of the estimates were derived from the yearly correction factor.

The estimation of catch composition in the samples shows that the use of raw samples underestimates the amount of skipjack and overestimate the amount of yellowfin as compared to the samples weighted by category (Figure 2). These results tend to demonstrate a possible bias in the selection of the fish during the sampling. Similarly, previous studies comparing “grab” samples (i.e., samples selected by the observers) and “spill” (samples taken from a bin were part of the catch is spilt) have shown that observers tend to underselect smaller fish, generally resulting in an underestimation of skipjack catches and an overestimation of yellowfin catches (Lawson, 2009). The correction by commercial category might solve this issue, since it would remove the impact of the overrepresentation of large yellowfin in the sample. The sampling condition and methodology at landing differs from the sampling by observers during the brailing, but the hypothesis of non-random selection of the fish remains valid and should be further investigated.

The estimated catch levels when port sampling data weighted by the size category are used (Figure 3) are close to the ones in the public domain for most of the time series. However, there are significant departures at the beginning and end of the time series, particularly for BET and, to a lesser extent YFT. Skipjack catches fall within the estimated confidence intervals, but for the period 1990-1998 (before the new sampling protocol, as described in Pianet et al., 2000, was applied), were skipjack catches would be overreported according to these estimates.

As expected, the most significant deviation is the bigeye catch in 2018, with estimated FAD catch levels c. 50% lower than the ones in the public domain. However, significant differences between the public domain data and the current estimates are also observed at the beginning of the time series. Moreover, while estimates for yellowfin tuna and skipjack are within the confidence interval of the current estimates in the most recent period, estimates for bigeye in 2020, 2021 and 2022 are well below the reported levels. It must be noted the coverage in 2020 was very low, with only c. 12% and 25% of the catches being corrected at the 5x5/quarter and ET area/quarter level, respectively. Hence, estimates for this year must be taken with caution. On the other hand, c. 90% of the catch in 2021 and 2022 could be corrected using the 5x5 or the ET area/quarter estimates. The change in catch estimation in each of the correction steps is shown in figure 4.

Estimates using raw sampling data indicate a systematic bias for yellowfin and skipjack across the time series (Figure 5) when comparted to the public domain dataset. YFT estimates are consistently above the reported ones, while skipjack catches would be overreported in the public domain dataset according to these estimates. The analyses of selectivity biases (ie., biases due to the effect of non-random selection of fish) in onboard samplings carried out in the western Pacific Ocean have been subject to thorough scrutiny, since it is the basis for correcting global catches in the area. Results have generally concluded skipjack is systematically underestimated when using grab sampling procedures. Noting the above, and the fact that the T3 process relies on the catch by categories reported by skippers, it is considered that the approach using samples weighted by size category is more appropriate at this stage, but further studies would help identify approaches that ensure a random selection of fish and are not subject to skippers' reports, to a large extent eyeball estimates.

WPTT26 is invited to:

- Note the approach followed and the usefulness of using time-consistent, scientific-based estimates alternative to the ones reported by CPCs for future stock assessments.
- Provide advice on any further work that might improve the current estimates

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Table 1.- Large fishing zones (ET areas) in the Indian Ocean (source: Sarralde et al., 2000)

ZONE 1	Somalia	12ºN-50ºE 0ºN-70ºE	12ºN-70ºE 0ºN-35ºE
ZONE 2	Northwest Seychelles	0ºS-35ºE 7ºS-58ºE 10ºS-49ºE	0ºS-58ºE 7ºS-49ºE 10ºS-35ºE
ZONE 3	Eastern and Southern Seychelles	0ºS-58ºE 12ºS-70ºE 7ºS-49ºE	0ºS-70ºE 12ºS-49ºE 7ºS-58ºE
ZONE 4	Mozambique	10ºS-35ºE 45ºS-20ºE	10ºS-49ºE 45ºS-45ºE
ZONE 5	Chagos	5ºN-70ºE 12ºS-70ºE	5ºN-80ºE 12ºS-80ºE
ZONE 6	South of the Indian Ocean	12ºS-49ºE 25ºS-45ºE	12ºS-141ºE 25ºS-141ºE
ZONE 7	Gulf of Arabia	N of 12ºN and W of 70ºE + Gulf of Aden and Red Sea	
ZONE 8	India-Laccadivas	23ºN-70ºE 5ºN-70ºE	Coast of India 5ºN-80ºE
ZONE 9	Gulf of Bengal	N de 5ºN	E de 80ºE
ZONE 10	West Indonesia	5ºN-80ºE 12ºS-80ºE	Coast of Indonesia 12ºS-129ºE

Table 2.- Number of samples retained after each filtering step by year

		Step 1 (5x5º)				Step 2 (ET area)			
Year	Original	Spatiotemporal strata	Set type	100 fish th.	5 sample th.	Spatiotemporal strata	Set type	100 fish th.	5 sample th.
1990	306	260	260	246	179	301	301	287	273
1991	468	392	389	377	285	443	443	431	405
1992	388	330	319	311	212	366	366	356	345
1993	396	335	333	330	214	380	380	377	358
1994	546	452	446	445	317	518	518	517	499
1995	696	561	556	556	429	662	662	662	649
1996	607	471	462	459	316	554	554	550	534
1997	569	444	438	434	312	535	535	531	510
1998	92	81	79	79	39	87	87	87	78
1999	53	42	41	40	0	50	50	49	25
2000	207	156	155	153	96	198	198	196	172
2001	866	667	665	650	516	837	837	819	796
2002	1033	823	823	813	641	1021	1021	1010	980
2003	1213	1020	1020	1006	868	1187	1187	1172	1145
2004	1247	984	983	959	873	1229	1229	1201	1181
2005	1700	1302	1286	1254	1110	1595	1595	1559	1545
2006	1720	1293	1291	1254	1102	1554	1554	1511	1484
2007	1391	908	908	887	738	1261	1261	1235	1216
2008	1543	1033	1029	1001	877	1387	1387	1354	1334
2009	1258	801	791	776	617	1135	1135	1120	1097
2010	1407	844	820	809	679	1244	1244	1233	1202
2011	1367	895	870	857	714	1183	1183	1171	1144
2012	1522	1027	998	946	820	1347	1347	1291	1278
2013	907	595	575	566	448	778	778	769	757
2014	911	620	602	529	426	831	831	754	739
2015	706	517	510	483	384	679	679	651	634
2016	517	336	336	333	190	489	489	486	466
2017	334	259	256	249	149	311	311	305	281
2018	733	467	461	459	309	612	612	610	582
2019	1029	770	757	755	631	958	958	956	945

2020	83	47	46	46	22	67	67	67	60
2021	787	576	572	569	471	716	716	713	679
2022	778	545	531	529	400	642	642	640	622

Table 3.- Percentage of the total catch corrected by each method.

Year	5x5/quarter	ET/quarter	Correction/year
1990	33.32	45.76	20.92
1991	58.62	32.67	8.71
1992	41.9	45.32	12.78
1993	38.28	48.02	13.7
1994	50.08	37.09	12.84
1995	68.5	21.65	9.84
1996	62.63	30.65	6.72
1997	63.2	23.5	13.3
1998	13.12	22.96	63.92
1999	0	3.17	96.83
2000	39.6	23.93	36.47
2001	64.79	27.04	8.17
2002	70.7	25.94	3.37
2003	71.77	23.63	4.6
2004	77.28	20.16	2.56
2005	75.94	20.89	3.17
2006	82.78	13.4	3.82
2007	67.37	26.13	6.5
2008	75.11	18.84	6.05
2009	68.27	27.66	4.07
2010	73.4	24.32	2.28
2011	76.9	19.61	3.49
2012	62.15	36	1.85
2013	65.04	32.35	2.61
2014	66.44	27.8	5.77
2015	56.93	37.28	5.79
2016	29.63	62.46	7.9
2017	19.16	43.79	37.05
2018	54.63	39.86	5.51
2019	69.53	20.34	10.13
2020	11.83	24.52	63.65
2021	66.81	21.6	11.59
2022	63.87	28.61	7.51

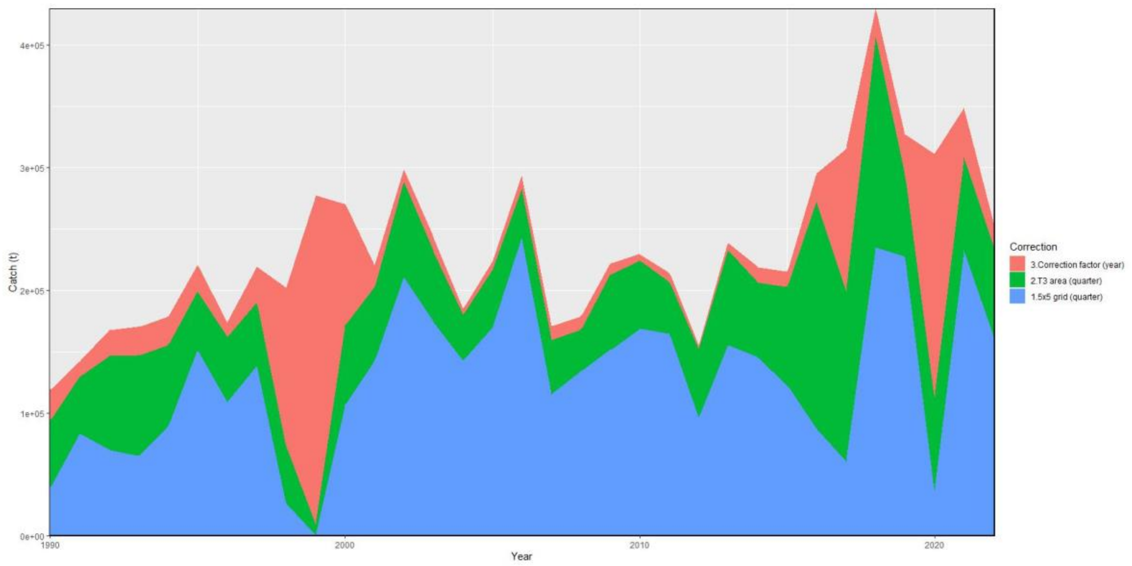

Fig 1.- Catch corrected at the 5x5/quarter, T3 area/quarter and yearly correction factor.

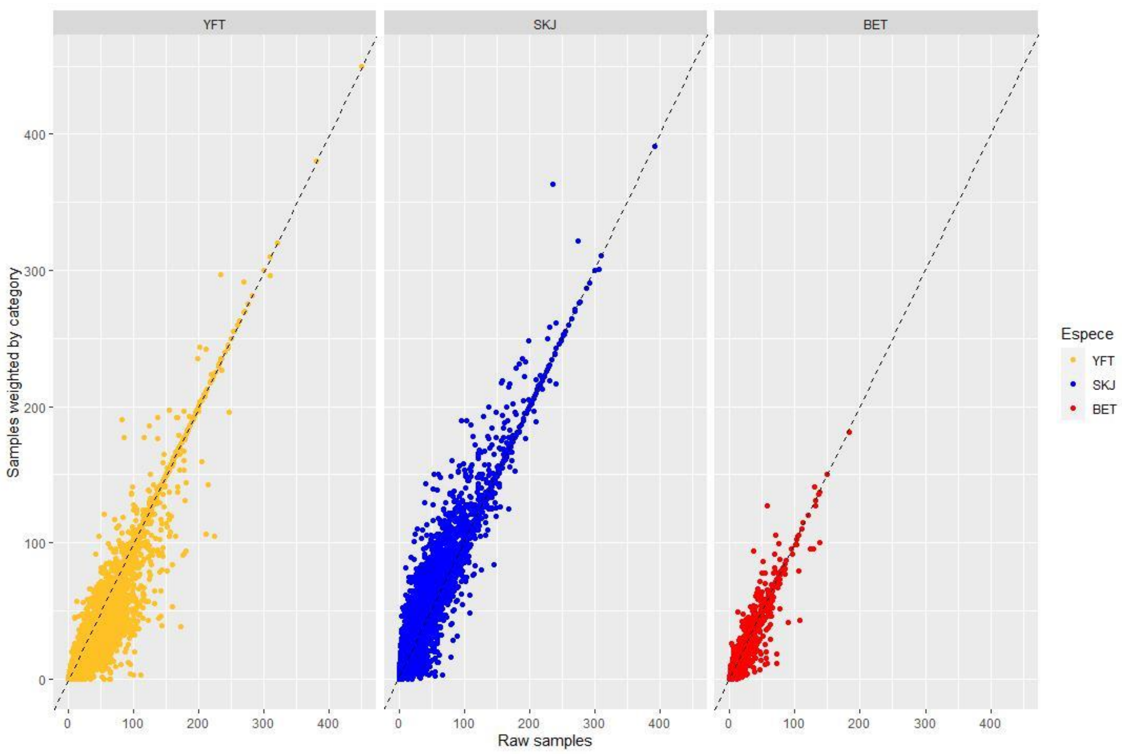

Figure 2.- Set catch by species estimated from raw samples and samples weighted by size category.

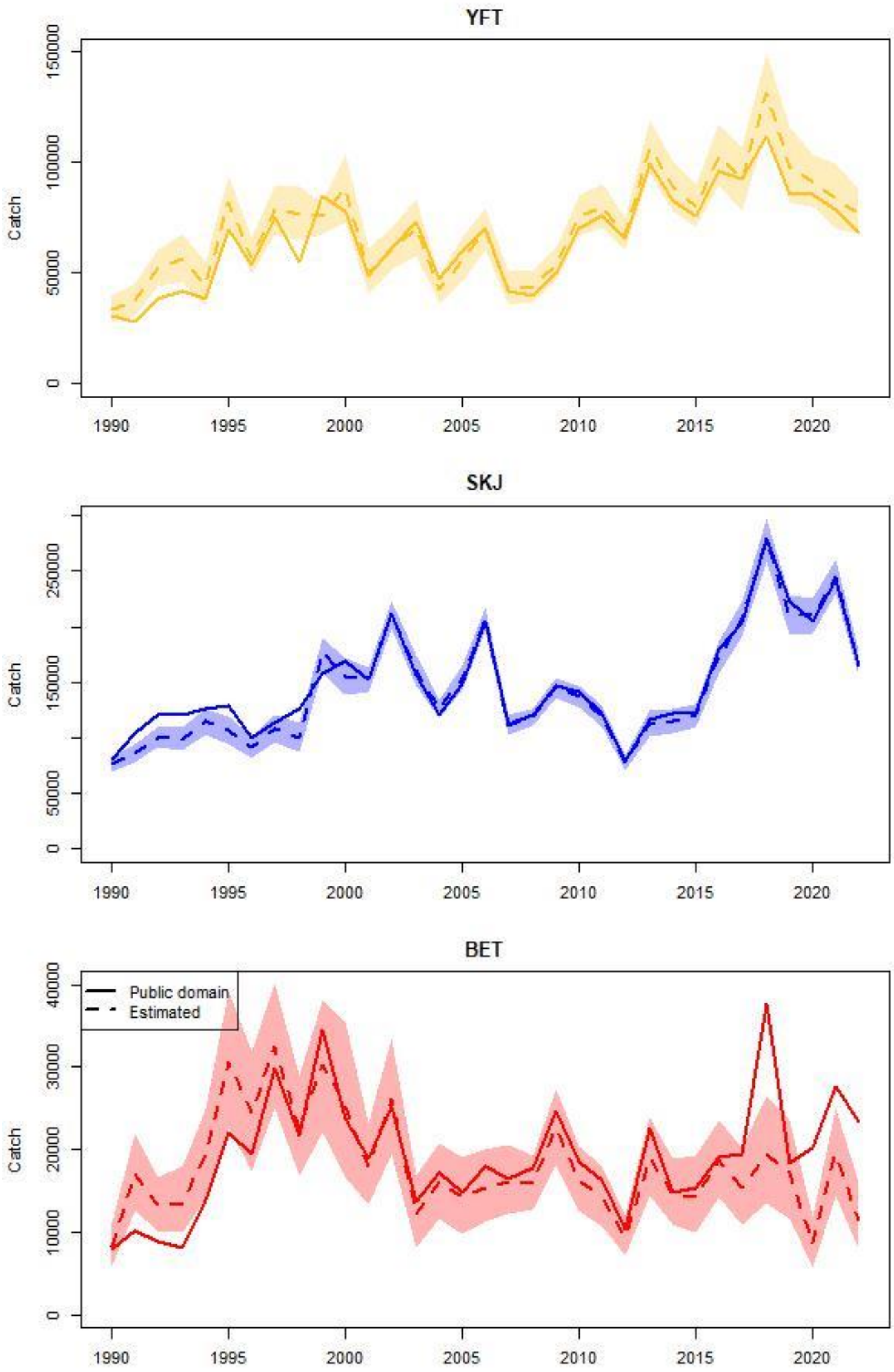

Fig 3.- Estimated global FAD purse seine catch by species and year using the catch composition from port sampling data weighted by catch category.

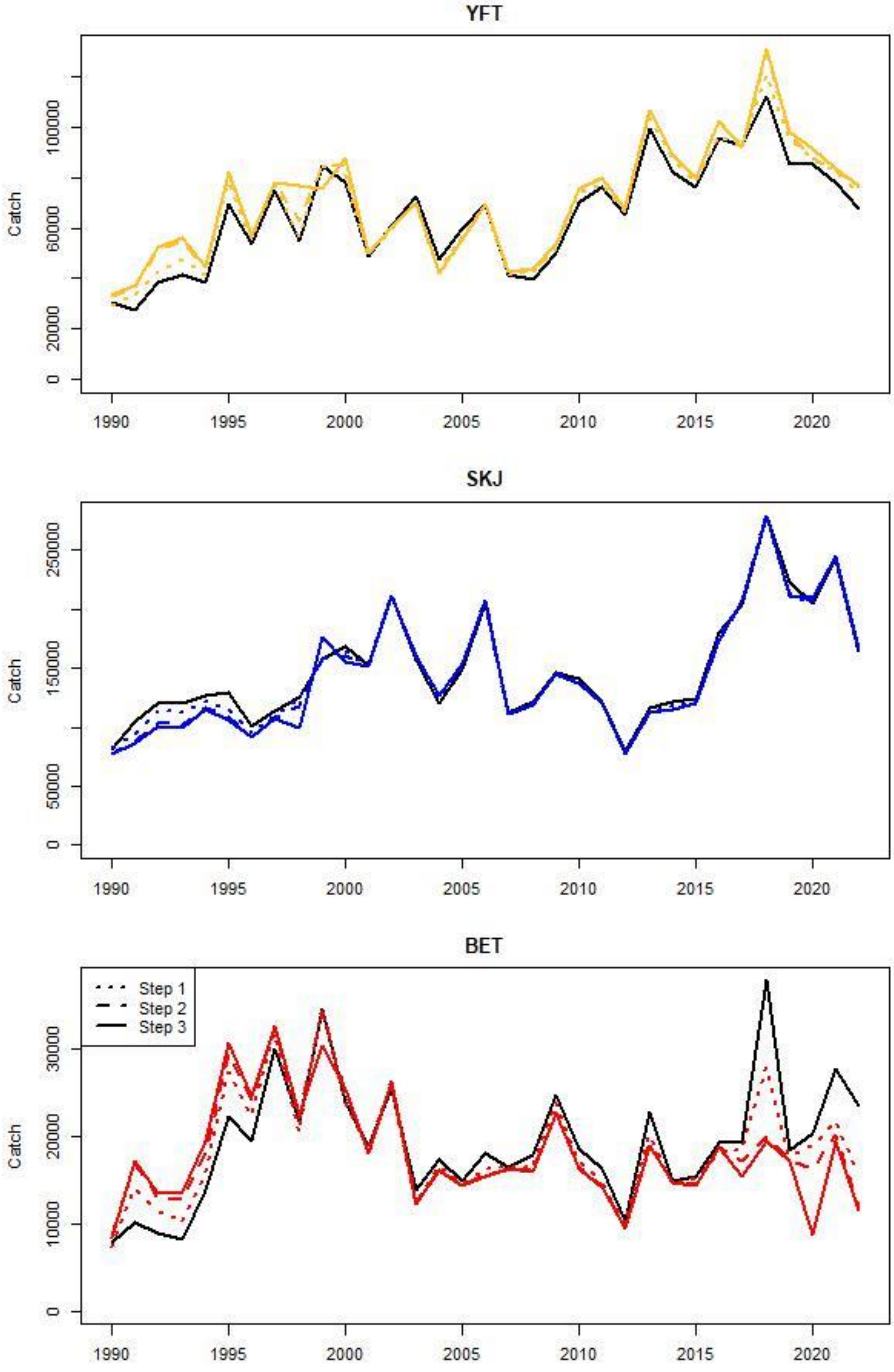

Fig 4.- Change in estimated catch by species and year in each of the correction steps.

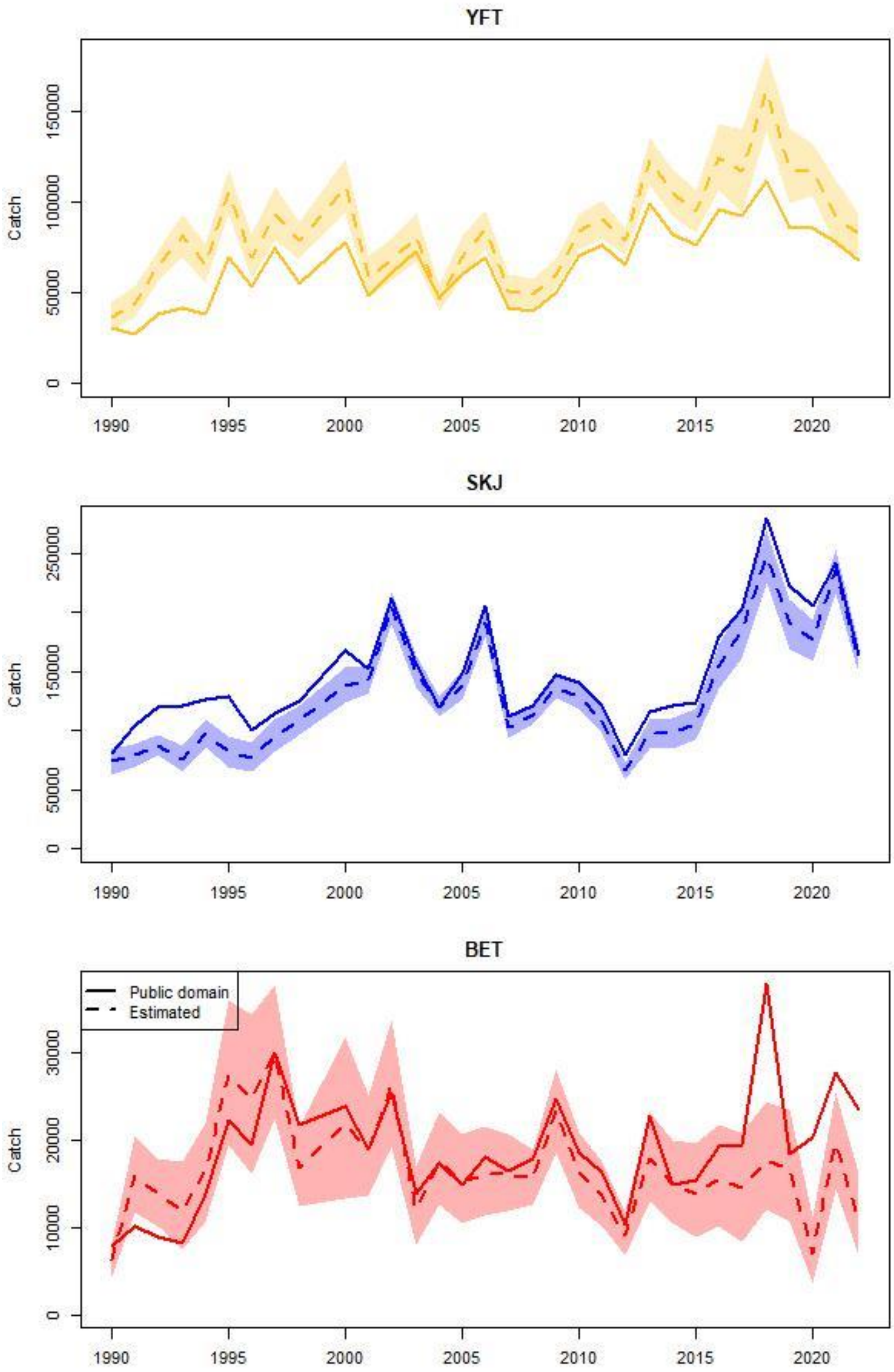

Fig 5.- Estimated global FAD purse seine catch by species and year using the catch composition from raw port sampling data.