REVIEW OF INDIAN OCEAN BIGEYE TUNA STATISTICAL DATA

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Introduction

The overarching objective of the paper is to provide participants at the preparatory meeting of the 24th Session of the IOTC Working Party on Tropical Tunas (WPTT24(DP)) with a review of the status of the information on bigeye tuna (*Thunnus obesus*) available in the IOTC Secretariat databases as of May 2022. The document provides an overview of the fisheries catching bigeye tuna in the Indian Ocean through temporal and spatial trends in catches and their main recent features, as well as an assessment of the reporting quality of the data sets. A full description of the data collated and curated by the Secretariat is available in IOTC (2022).

Nominal catch

Historical trends (1950-2020)

Nominal catches of bigeye tuna show an increasing trend over the last seven decades ranging between 7,000 and 136,000 t from the mid-1950s to the mid-2000s, with some variability between years. Catches dropped considerably from the late-2000s, reaching an annual average of 96,000 t during the 2010s, i.e., around 30% less than what caught on average during the previous decade. Longliners and purse seiners are the main fisheries comprising more than 90% of the catches between the 1950s and 2000s, and more than 80% in the last decade (**Table 1** & **Figs. 1-2**).

Table 1: Best scientific estimates of average annual nominal catches (t) of bigeye tuna by decade and fishery for the period 1950-2019. The background intensity color of each cell is directly proportional to the catch level. Data source: raised time-area catches

Fishery	1950s	1960s	1970s	1980s	1990s	2000s	2010s
Purse seine | Other			154	1,268	2,388	4,012	6,068
Purse seine | FS			0	2,340	4,824	6,196	6,033
Purse seine | LS			0	4,852	18,315	20,273	19,974
Longline | Other				106	359	1,101	1,293
Longline | Fresh			218	3,066	26,282	23,490	11,333
Longline | Deep-freezing	6,488	21,861	30,413	42,972	61,577	70,315	33,649
Line | Coastal longline	33	287	548	2,204	4,136	5,818	8,456
Line | Trolling	23	39	87	261	533	870	1,500
Line | Handline	9	8	110	181	163	227	1,158
Baitboat	21	50	110	249	544	997	513
Gillnet	15	25	77	598	785	1,492	3,970
Other			2	19	124	1,386	2,058
Total	6,589	22,269	31,720	58,117	120,031	136,178	96,005

Catches of bigeye tuna increased rapidly in the early 1980s with the development of the industrial purse seine fishery and the increased activity of vessels using longline and other gears (**Figs. 1-2**). Exceptionally high catches were recorded between 2000 and 2007, with the highest catches ever recorded in 1999 at over 160,000 t.

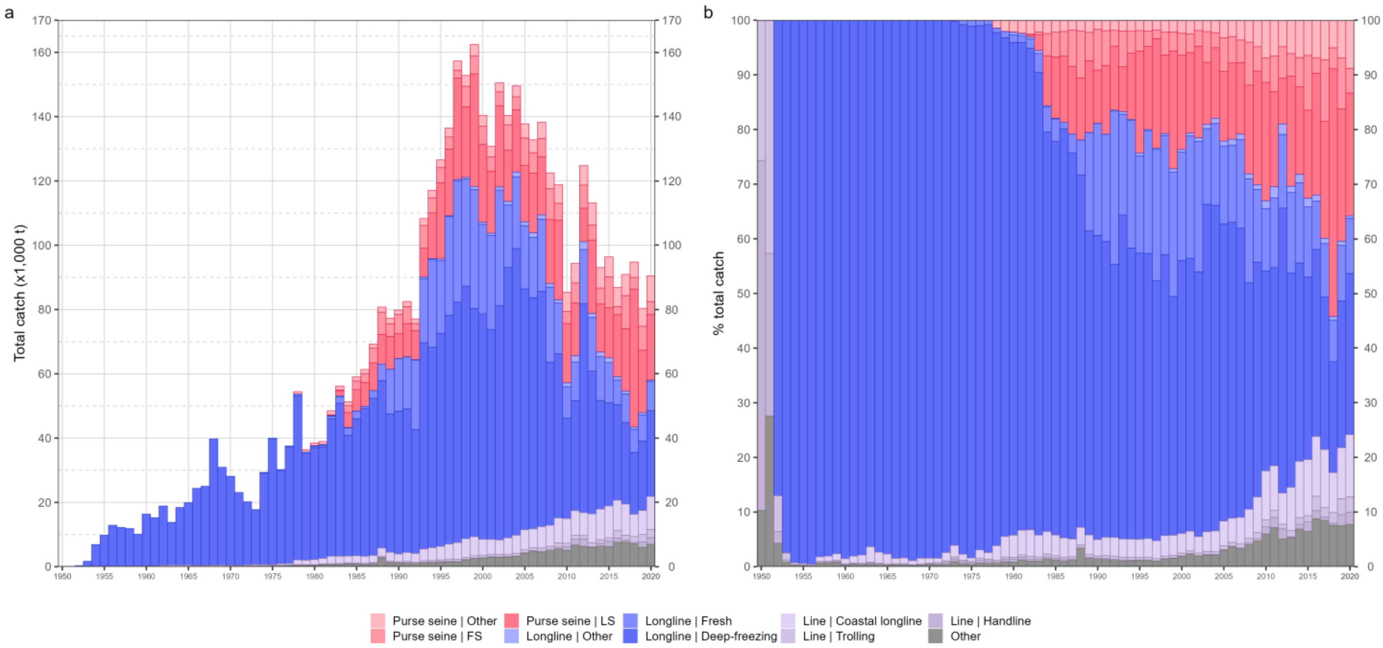

Figure 1: Annual time series of cumulative nominal absolute (a) and relative (b) catches (t) of bigeye tuna by fishery for the period 1950-2020. LS = schools associated with floating objects; FS = free-swimming schools. Data source: raised time-area catches

Between 2008 and 2009 catches dropped considerably to around 73% of 1999 levels, as longline fishing effort in the western Indian Ocean was displaced eastwards or reduced due to the threat of piracy in areas close to the Exclusive Economic Zone of Somalia. Catches by purse seiners also declined over the same period, albeit not to the same extent as longliners thanks to the presence of security personnel onboard purse seine vessels of the EU and Seychelles, which enabled fishing operations to continue. Catches of all purse seine fisheries combined were variable since 2011, with exceptionally high catches reported during 2018 (51,000 t) and potentially biased by changes in data processing methodologies confirmed by EU,Spain for its purse seine fleet for that year (IOTC 2019a b). Longline fisheries, on the contrary, showed marked increasing trends in reported catches of bigeye tuna in post-piracy years, reaching a peak of 84,000 t in 2012 before initiating a new decline that brought reported catch levels down to 27,000 t in 2018 (**Fig. 2**).

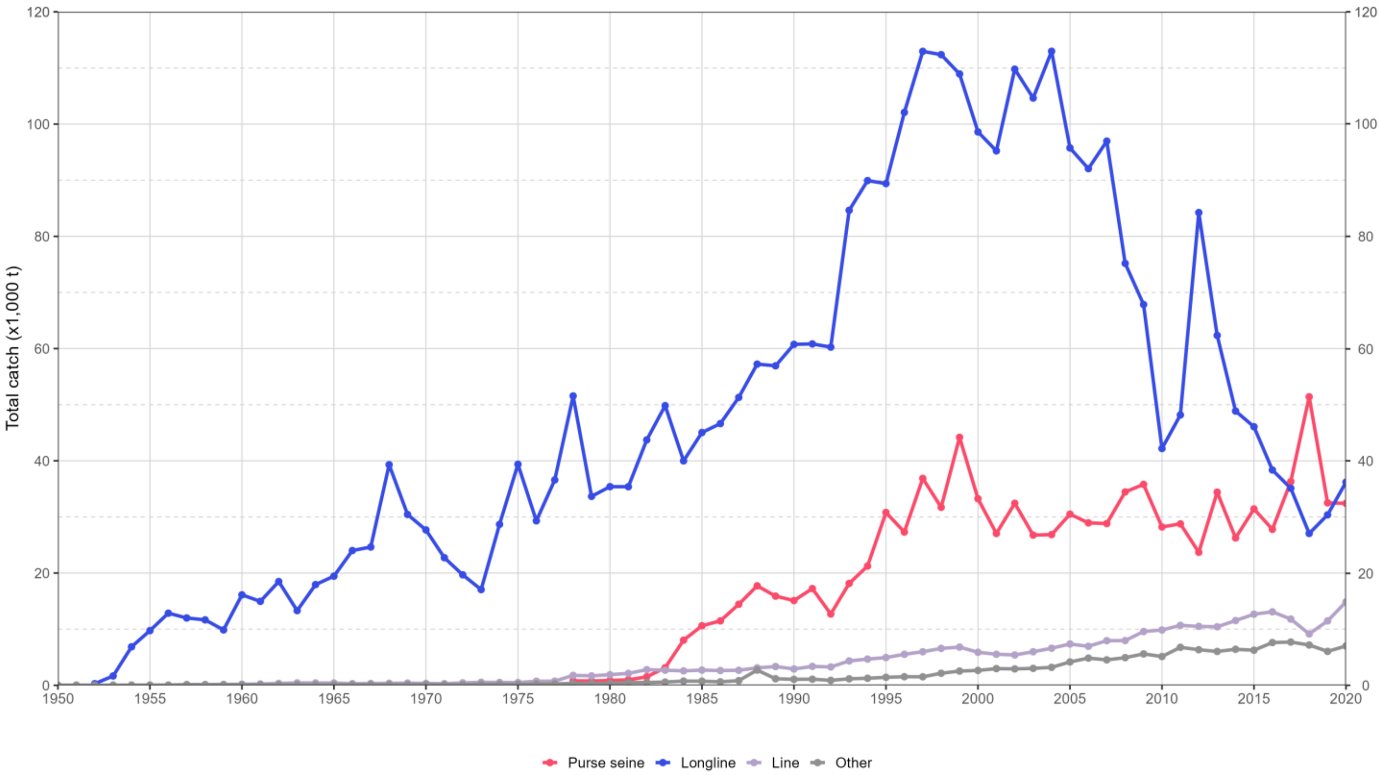

Figure 2: Annual time series of catches (t) of bigeye tuna by fishery group for the period 1950-2020. Data source: best scientific estimate of nominal catches

Table 2: Best scientific estimates of annual nominal catches (t) of bigeye tuna by fishery for the period 2011-2020. The background intensity color of each cell is directly proportional to the catch level. Data source: raised time-area catches

Fishery	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Purse seine | Other	6,154	6,078	6,938	6,375	6,240	5,966	6,604	4,805	5,586	7,995
Purse seine | FS	6,222	7,180	4,659	5,000	9,633	2,489	10,242	3,634	7,479	4,086
Purse seine | LS	16,386	10,434	22,809	14,882	15,547	19,330	19,456	42,965	19,440	20,334
Longline | Other	1,937	2,408	1,297	1,442	1,511	985	869	633	643	383
Longline | Fresh	12,031	16,816	16,725	13,650	12,401	7,672	8,895	7,196	8,166	9,151
Longline | Deep-freezing	34,206	65,015	44,320	33,768	32,153	29,706	25,343	19,220	21,562	26,664
Line | Coastal longline	7,690	7,114	8,965	9,581	9,916	9,508	9,695	6,912	7,504	10,276
Line | Trolling	1,245	1,075	1,303	1,113	1,100	2,299	1,549	1,888	2,345	2,580
Line | Handline	1,742	2,308	151	836	1,648	1,282	552	347	1,617	2,004
Baitboat	634	716	345	304	184	844	269	436	632	569
Gillnet	4,001	3,515	3,286	3,925	3,920	4,734	5,378	5,114	3,525	3,682
Other	2,126	2,100	2,397	2,183	2,142	2,033	2,053	1,621	1,881	2,748
Total	94,374	124,759	113,193	93,058	96,396	86,849	90,905	94,772	80,380	90,473

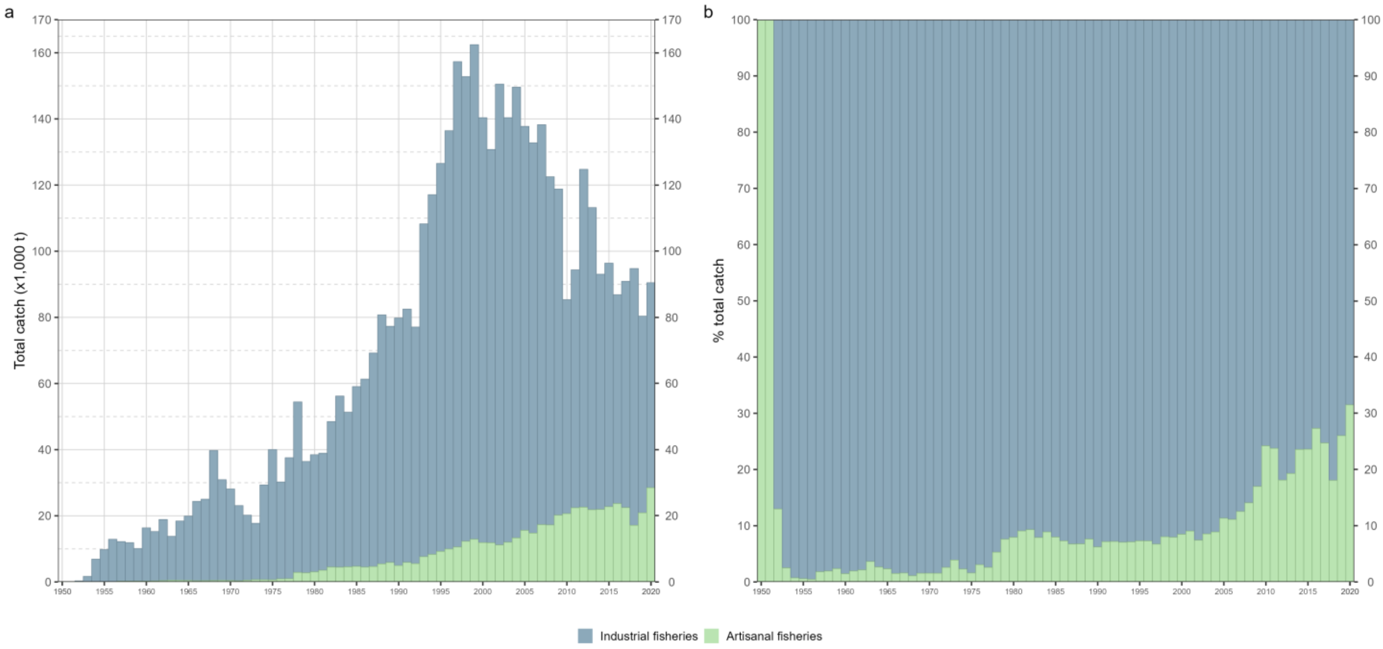

Figure 3: Annual time series of cumulative nominal absolute (a) and relative (b) catches (t) of bigeye tuna by type of fishery for the period 1950-2020. Data source: best scientific estimate of nominal catches

Trends in the artisanal fishery component of bigeye tuna catches in the Indian Ocean are characterized by relative stable levels between the early-1980s and the mid-2000s, followed by an increase to 31% of total catches reported for 2020. Between 2016 and 2020 mean annual catches of artisanal fisheries were close to 20,000 t (25% of total catches), with industrial fisheries catching on average 70,000 t every year (**Fig. 3**).

Estimated spatial distribution of catches

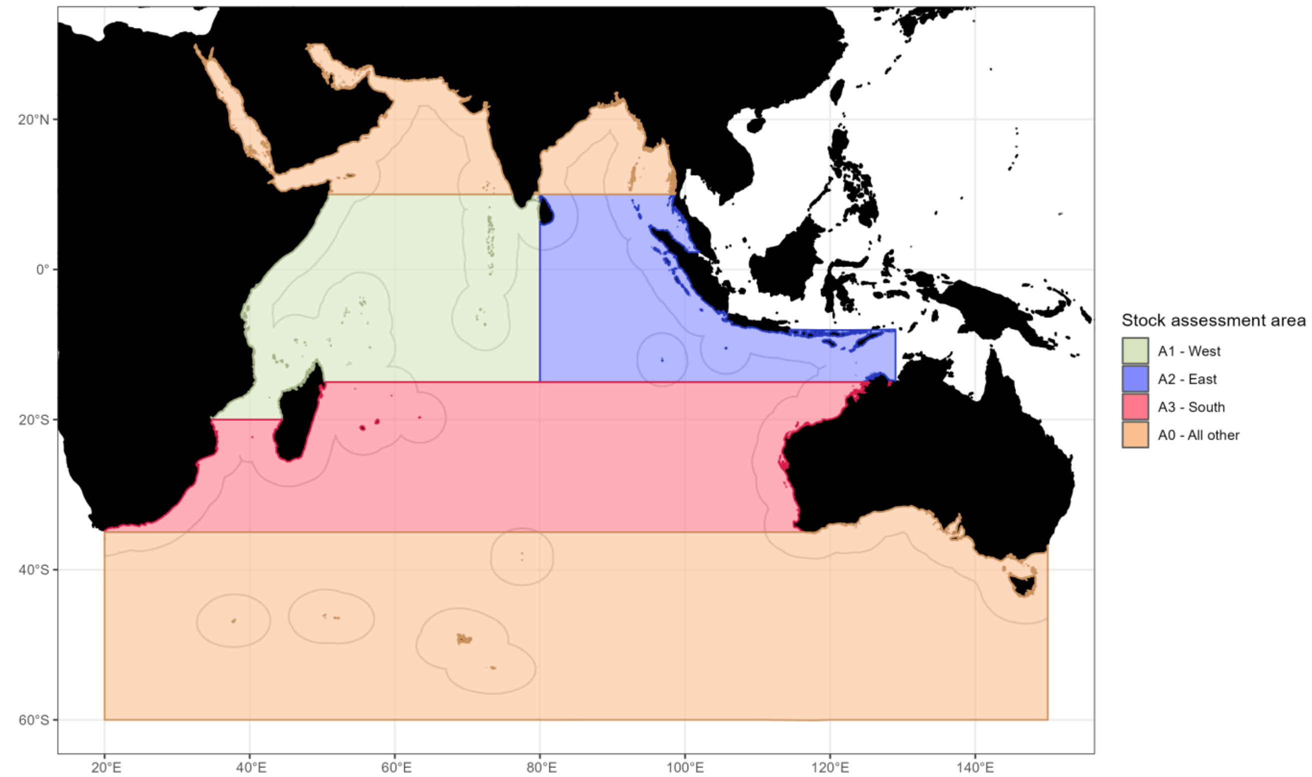

Figure 4: The four bigeye tuna stock assessment areas as defined in IOTC (2019a)

Table 3: Best scientific estimates of average annual nominal catches (t) of bigeye tuna by decade and stock assessment area for the period 1950-2019. The background intensity color of each cell is directly proportional to the catch level. Data source: raised time-area catches

SA area	1950s	1960s	1970s	1980s	1990s	2000s	2010s
A1 - West	2,432	11,692	17,392	34,821	56,689	76,647	52,910
A2 - East	3,593	6,908	9,964	18,156	43,739	41,644	32,230
A3 - South	198	2,587	2,847	2,664	14,738	14,385	7,642
A0 - All other	366	1,082	1,517	2,477	4,865	3,503	3,223
Total	6,589	22,269	31,720	58,117	120,031	136,178	96,005

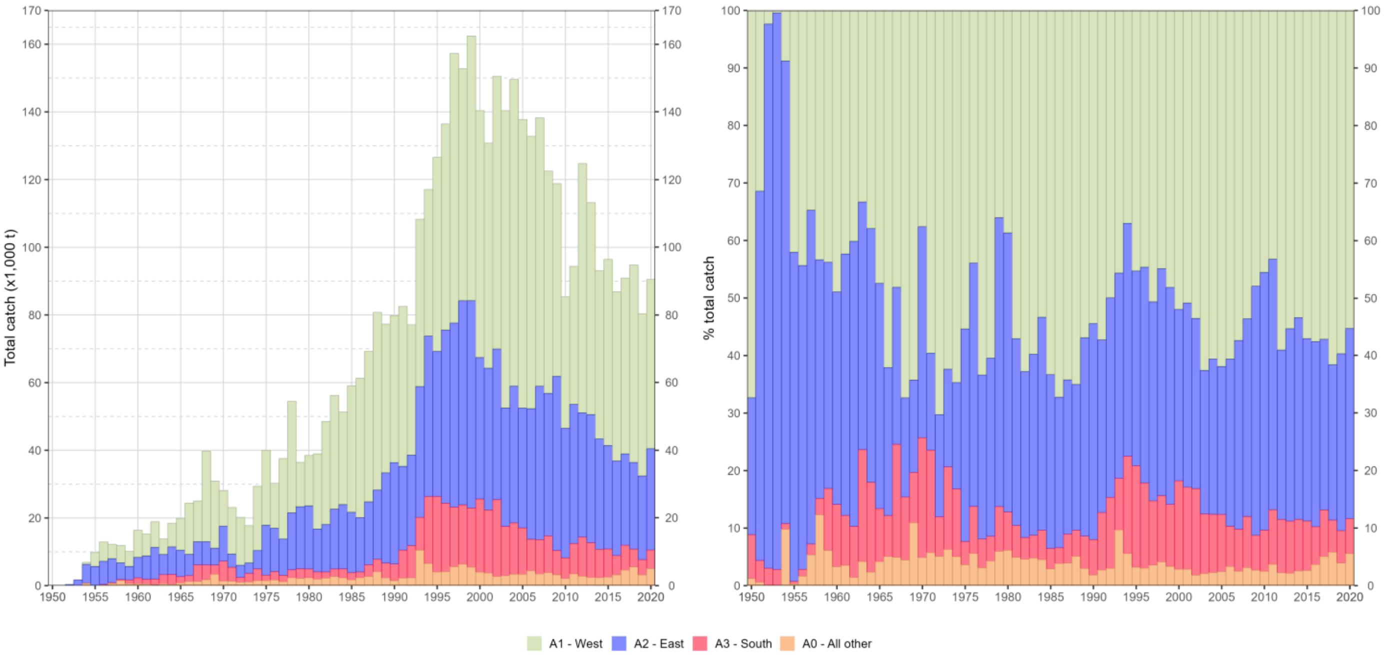

Figure 5: Annual time series of cumulative nominal absolute (a) and relative (b) catches (t) of bigeye tuna by stock assessment area for the period 1950-2020. Data source: raised time-area catches

Catches of bigeye tuna by stock assessment area are computed from the estimated raised catches for the species: as such, they include information provided ‘*as is*’ by the major industrial fleets (which generally report raised catch and effort data in agreement with IOTC requirements, raised to total catch and stratified by month, grid, and fishing mode) as well as estimated time-area catches computed for those fisheries - of mostly artisanal nature - for which no catch and effort information is available at all, or is missing for large periods of time.

The most recent bigeye stock assessment further breaks area A1 (*West*) into two sub-regions (*R1N* - *North* and *R1S* - *South*), while excluding area A0 (*All other*) from the analysis, and re-allocating catches from the latter to the corresponding adjacent areas (IOTC 2019a). In terms of catch trends by area, longline catches are mostly taken within the two equatorial regions (15°S to 10°N), while purse seine catches are predominantly taken within the western equatorial region. A seasonal longline fishery targeting albacore tuna operates in the southern region, where bigeye is taken mostly as a bycatch species.

Purse seine catch trends by fishing mode

Regarding purse seine fisheries, historical catches of bigeye tuna by fishing mode showed a general dominance in percentages of catches from schools associated with drifting floating objects (FOBs), accompanied by frequent yearly fluctuations on the relative percentages of the two fishing modes (i.e., free and associated schools). The Seychelles and EU purse seine fleets combined (limited to EU,Spain and EU,France, as little to no data is available for EU,Italy in recent years) reported over 60% of their bigeye tuna catches from FOB-associated schools since the early-2000s.

Between 2011 and 2020, catches from all purse seine fleets combined showed a fluctuation between 59% and 92% in the fraction of catches from FOB-associated schools, with around 92% of bigeye tuna catches reported from FOB-associated schools in 2018 and around 83% in 2020 (**Fig. 6**).

Among the flag-specific components of the EU purse seine fleet, EU,France seemed to be less dependent on catches of bigeye tuna from FOB-associated schools. This was particularly true until 2018, whereas in following years catches appeared to be split between the two fishing modes in similar proportion as reported by the rest of the EU (and assimilated) fleets.

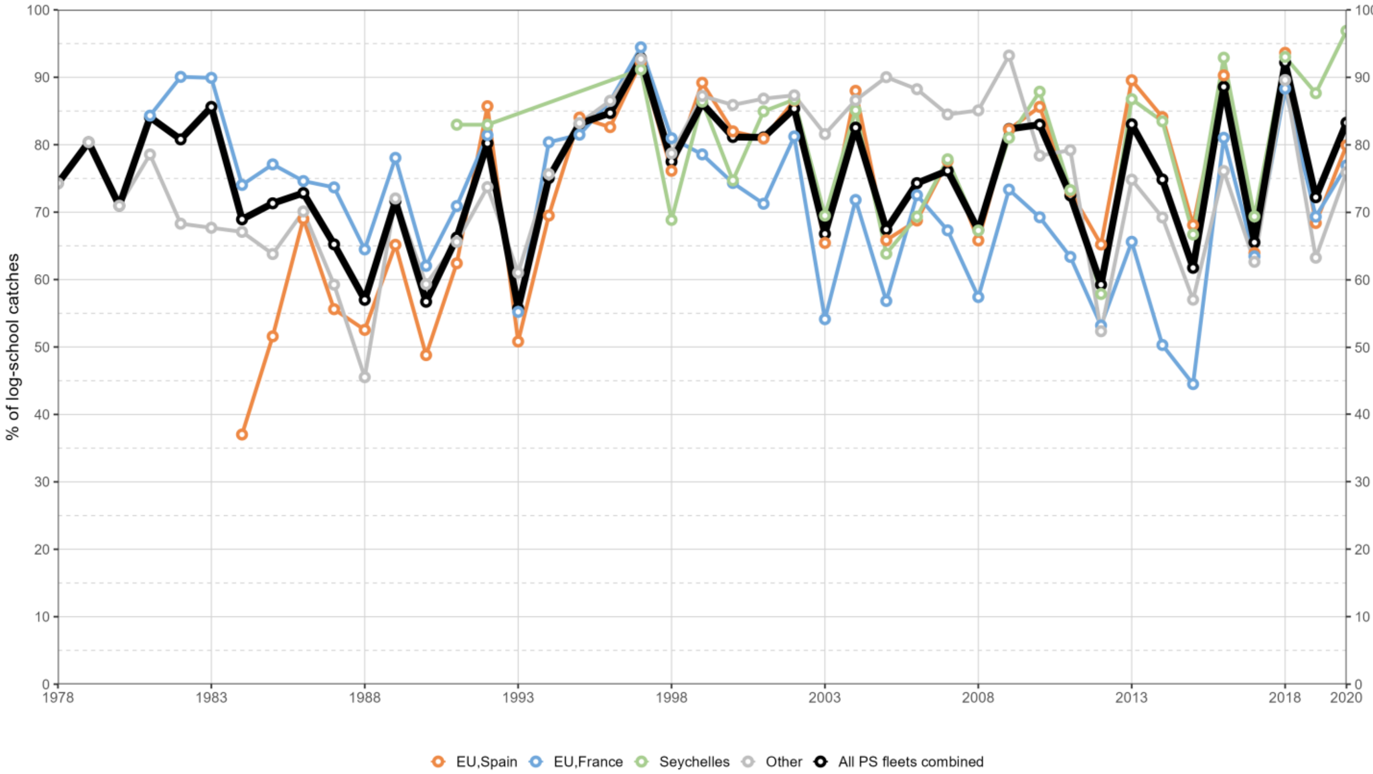

Figure 6: Annual percentages of purse seine FOB-associated catches of bigeye tuna by fleet for the period 1977-2020. *Other* includes purse seine fleets such as ex-Soviet Union, I.R. Iran, France (Mayotte), Mauritius, Japan, Korea, Indonesia, Thailand, EU,Italy, Belize and others. Data source: time-area catch dataset for purse seine fisheries (Res. 15/02)

Main fishery features (2016-2020)

Bigeye tuna is caught mainly by longline and purse seiner fisheries from different fleets operating all over the Indian Ocean. Between 2016 and 2020, purse seine fisheries (all fishing modes combined) caught annually more than 36,000 t of bigeye tuna, contributing to around 41% of the total nominal catches (**Table 4**). During the same period, industrial longline fisheries represented the second main contributor of bigeye tuna catches, with about 33,000 t caught annually. Between 2016 and 2020, line fisheries represented around 14% of the recent catches with more than 10,000 t caught annually (**Table 4 & Fig. 2**).

Table 4: Mean annual catches (t) of bigeye tuna by fishery between 2016 and 2020. LS = schools associated with floating objects; FS = free-swimming schools. Data source: raised time-area catches

Fishery	Fishery code	Catch	Percentage
Longline | Deep-freezing	LLD	24,499	27.6
Purse seine | LS	PSLS	24,305	27.4
Line | Coastal longline	LIC	8,779	9.9
Longline | Fresh	LLF	8,216	9.3
Other	OT	7,104	8.0
Purse seine | Other	PSOT	6,191	7.0
Purse seine | FS	PSFS	5,586	6.3
Line | Trolling	LIT	2,132	2.4
Line | Handline	LIH	1,161	1.3
Longline | Other	LLO	703	0.8

Average annual catches of bigeye tuna between 2016 and 2020 have been shared between several CPCs, with around 94% of all annual catches accounted for by ten distinct fleets, with Indonesia, EU,ESP, Seychelles and Taiwan, China contributing to 15% or more of average annual catches each (**Fig. 7**).

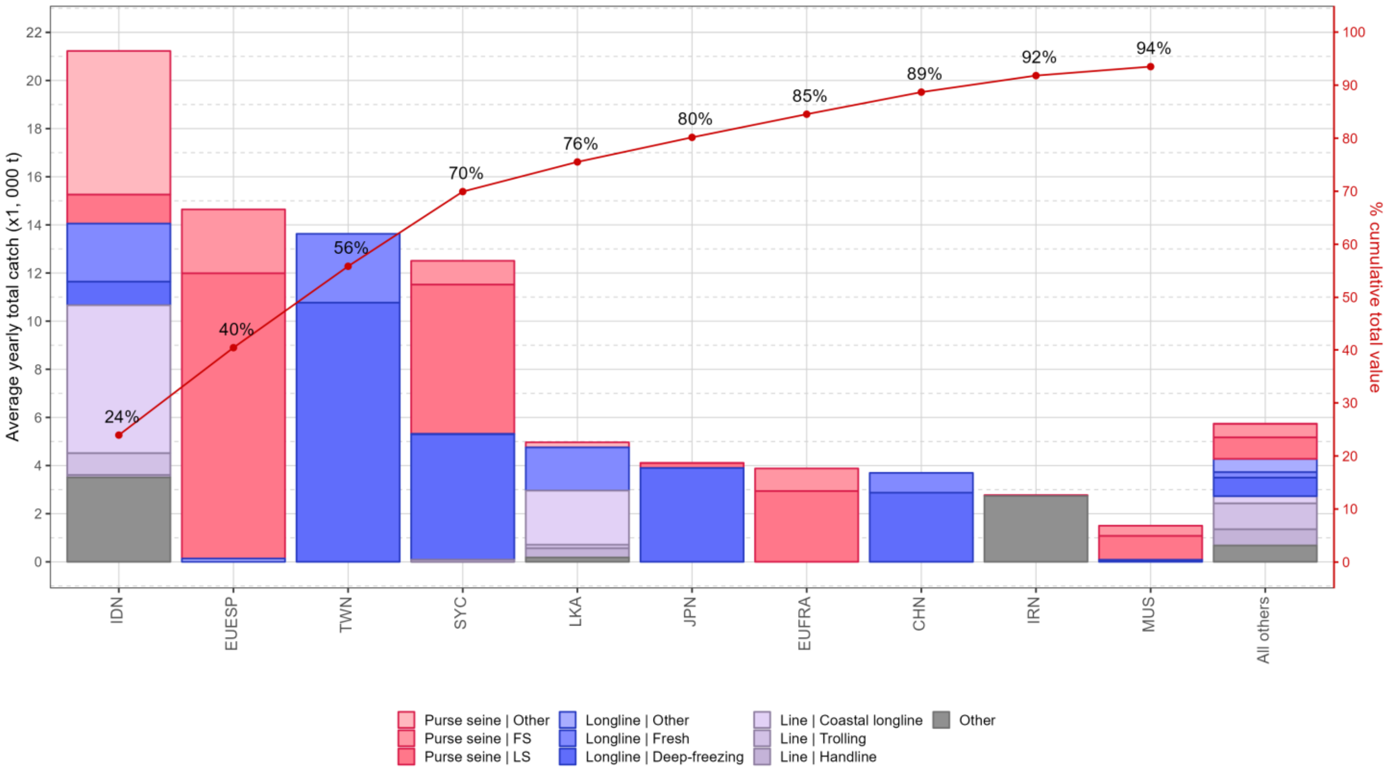

Figure 7: Mean annual catches (t) of bigeye tuna by fleet and fishery between 2016 and 2020, with indication of cumulative catches by fleet. FS = free-swimming schools; LS = schools associated with floating objects. Data source: raised time-area catches

Catch trends by fishery group in the same period (2016-2020) show opposite behaviors between longline and purse seiner fisheries, with relatively stable trends in catches from lines as well as from vessels using all other gears (**Fig. 8**).

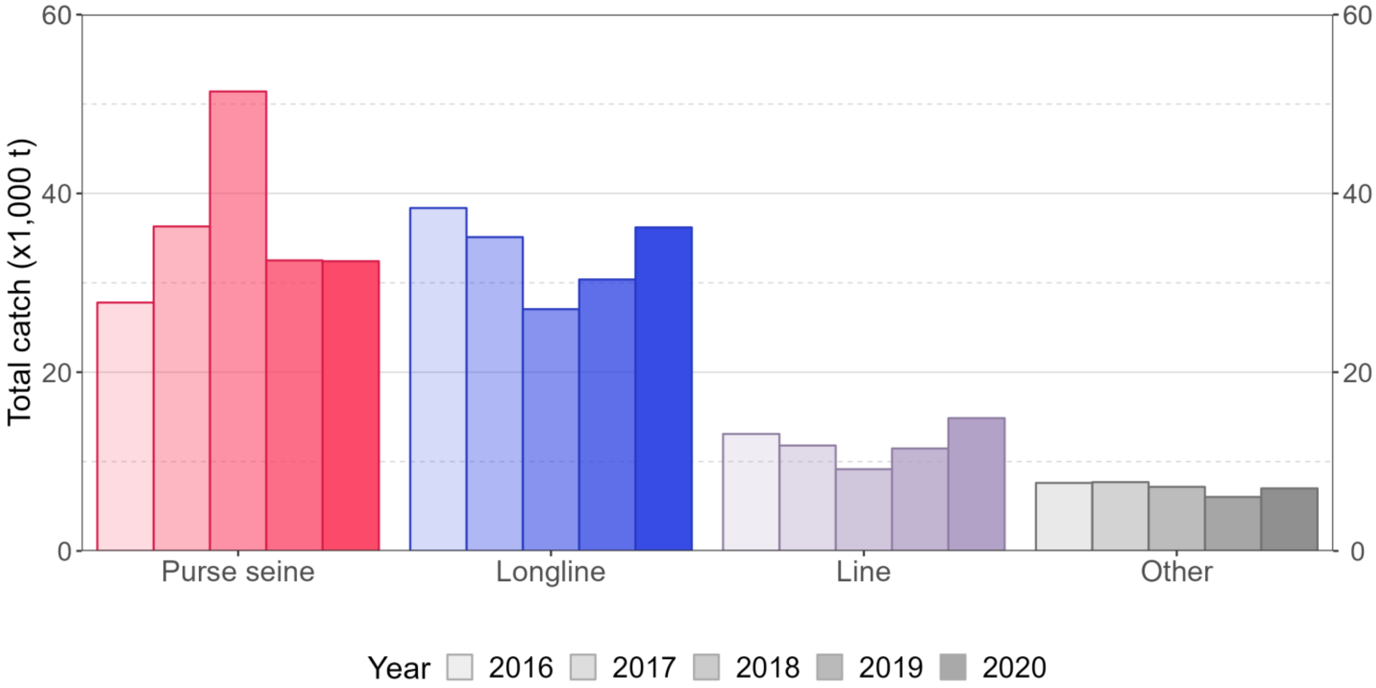

Figure 8: Annual catch (t) trends of bigeye tuna by fishery group between 2016 and 2020. Data source: best scientific estimate of nominal catches

Regarding industrial purse seine fisheries, while catches from all fleets combined remained stable in the last few years after reaching a recent peak in 2018 (**Fig. 8**) recent catch trends by fleet for all fishing modes combined show marked fluctuations in the contribution from EU,Spain and Indonesia, while catches reported by Seychelles are effectively more stable. Catches from EU,France (as well as from all other purse seine fleets combined) show a generally increasing trend in catches since 2016, which is followed by a declining trend starting from 2018 (**Fig. 10a**).

Overall, changes in catches from purse seine fleets strongly vary with the type of school association. Catches on free-swimming schools (which are generally lower in magnitude) show a mixed situation with changes between years for all fleets involved (**Fig. 9a**). On the contrary, catches on FOB-associated schools show a generally decreasing recent trend, with the exception of EU,Spain in 2018 when an unprecedented total catch of around 25,000 t was reported on FOB-associated schools (**Fig. 9b**). These exceptional levels of reported catches were limited to one year only, with the EU confirming that these might have been caused by changes in the species compositions estimation procedure implemented by EU,Spain for the year concerned (IOTC 2019a b).

As a result, the overall tropical species composition reported by the EU purse seine fleet in 2018 is considered to be unreliable (IOTC 2019c) and both the WPTT and WPDCS have requested the EU to ensure that updated catches for the fleets and years concerned are provided to the IOTC Secretariat as a matter of priority (IOTC 2021b a).

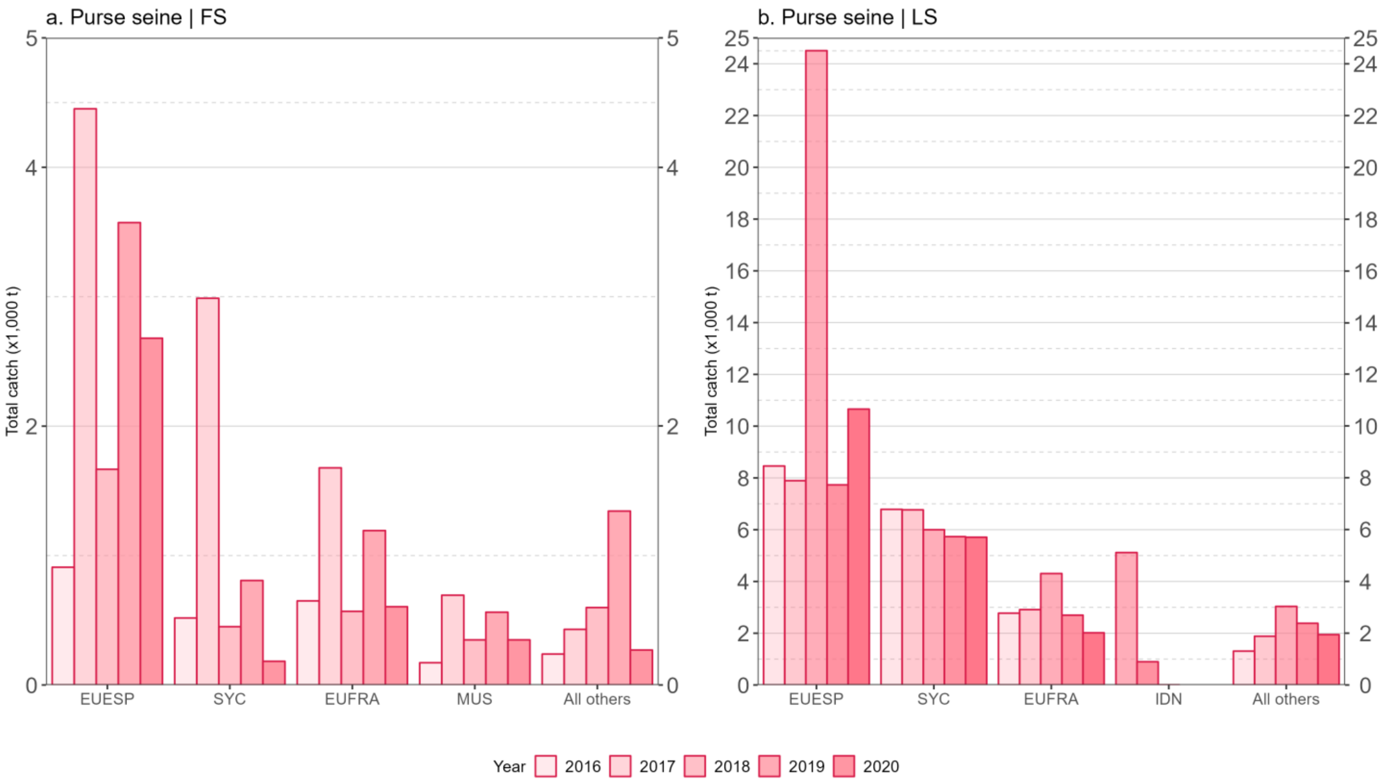

Figure 9: Annual purse seine catch (t) trends of bigeye tuna by fishing mode and fleet between 2016 and 2020. FS = free-swimming schools; LS = schools associated with floating objects. Data source: raised time-area catches

Recent data from longline fleets show a decreasing trend in bigeye catches from 2016 to 2018, followed by a new increase in catches that brought the totals almost back to 2016 levels (**Fig. 8**), thanks in particular to contributions from the deep-freezing and fresh longline fisheries of Taiwan,China, Seychelles, Japan and China. All other longline fleets (including also those targeting swordfish or bycatch species) are aggregated under *All others* and have decreased their bigeye tuna catch levels since 2016 (**Fig. 10b**).

Fleets using line or assimilated gears (handline, troll-line, coastal longline) show similar trends in catch levels as the industrial longline fisheries since 2016 (**Fig. 8**). At fleet level, notable exceptions are represented by the troll-line and handline fisheries of Comoros, whose trend is constantly increasing since the beginning of the period considered, and by the handline and coastal longline fisheries of Maldives, which appear to be facing a very strong contraction phase. Indonesia represents another exception to the overall trend identified for the artisanal line fisheries, having increased quite sensibly their catches of bigeye since 2016, which are now mostly attributed to vessels using coastal longlines and troll-lines (**Fig. 10c**).

Finally, contributions to catch levels from all the fisheries aggregated as *All others* (which are basically stable since 2016 and include gears such as gillnets, liftnets, and pole-and-lines) show a mixed situation when focusing on the key fleets. In fact, catches for this fishery group reported by Indonesia have markedly increased in 2020 while contributions from I.R. Iran and Maldives steadily decreased over the last five years (**Fig. 10c-d**).

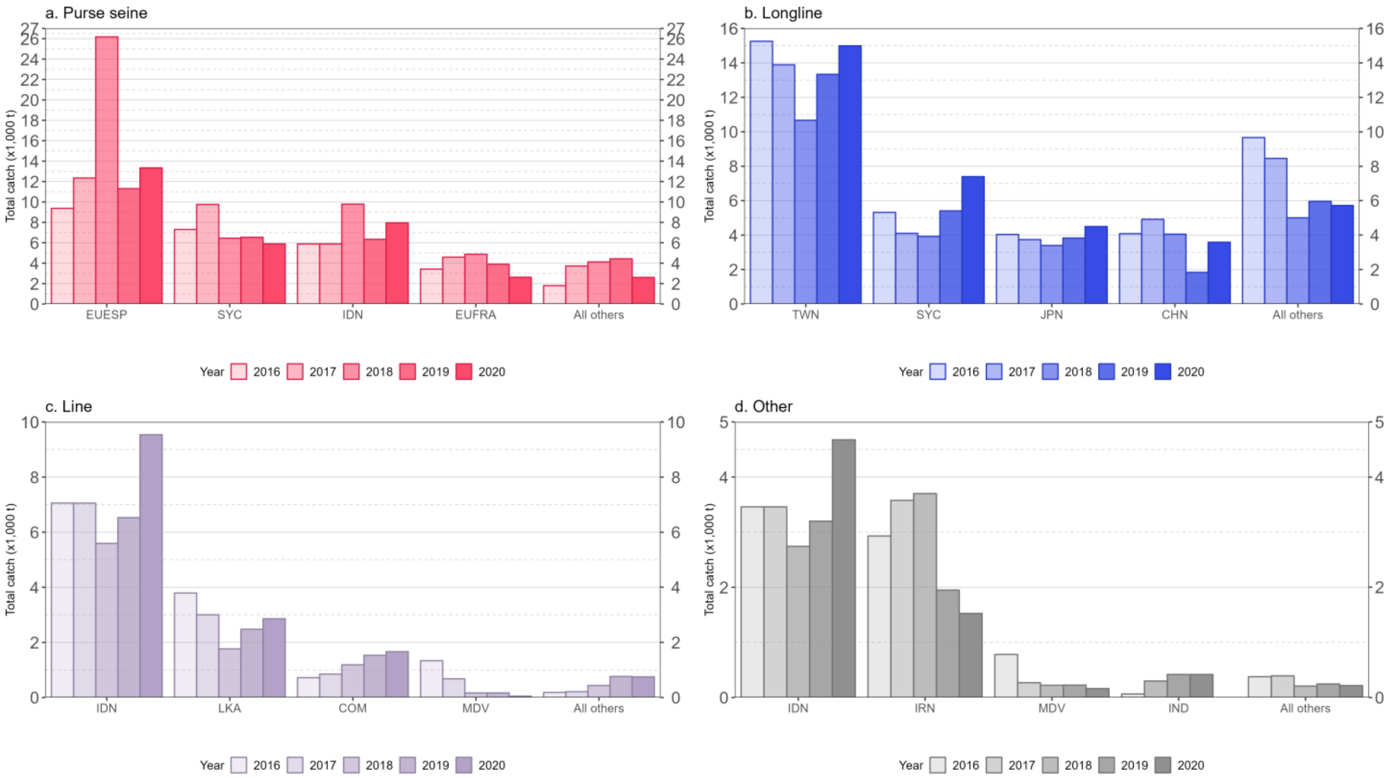

Figure 10: Annual catch trends of bigeye tuna by fishery group and fleet in metric tons (t) between 2016 and 2020. Data source: best scientific estimate of nominal catches

Changes from previous WPTT

Relatively limited changes occurred in the time series of catches of bigeye tuna since the release of the data set of best scientific estimates of nominal catches for the 23rd session of the Working Party on Tropical Tunas (assessment meeting) in October 2021, representing an overall annual change of 2,900 t in 2019 and of 6,975 t in 2020 (**Fig. 11**).

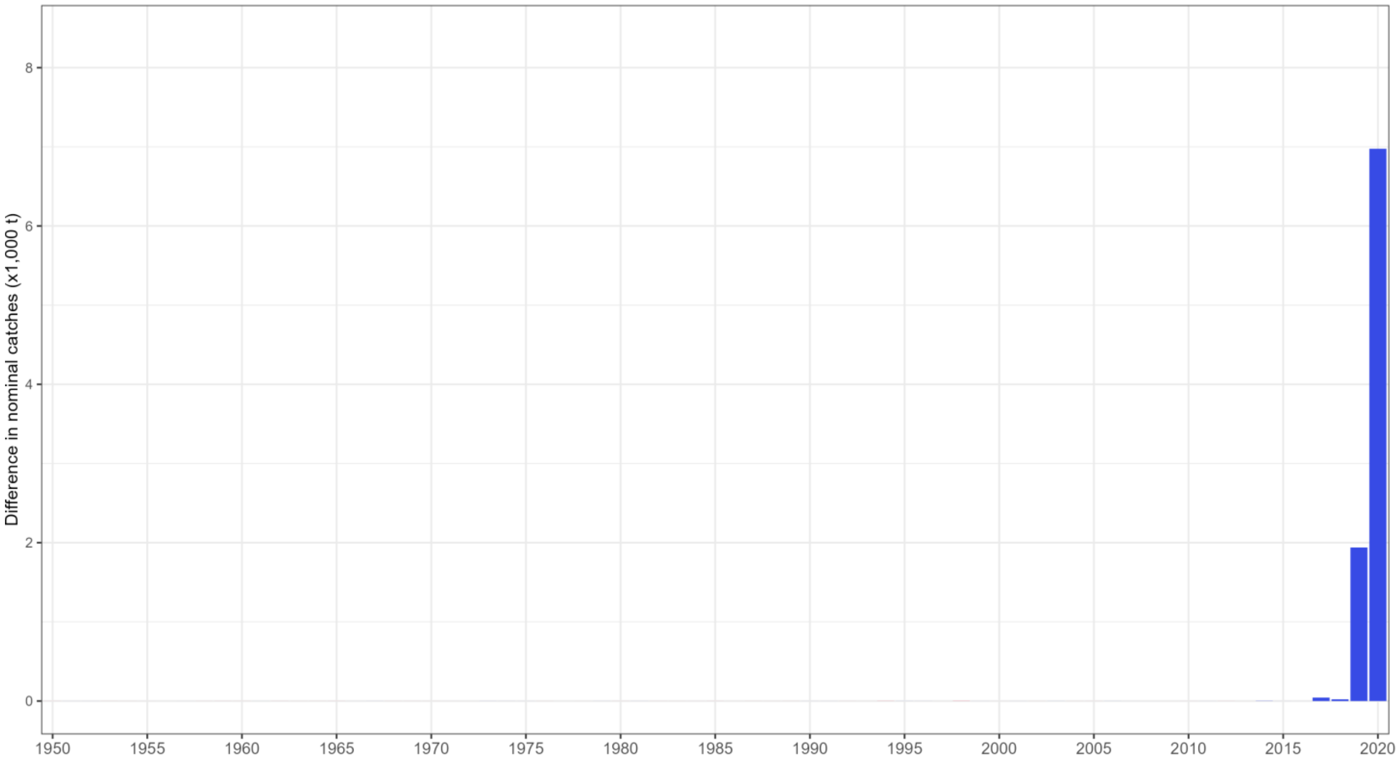

Figure 11: Differences in the available best scientific estimates of nominal catches (t) of bigeye tuna in between this WPTT and its previous session (assessment meeting held in October 2021)

These changes are mainly due to an increase of 2,809 t in catches reported by the longline fleet of Seychelles and by the line fishery of Sri Lanka in 2019, and of about 6,954 t in catches reported by the longline fleet of Seychelles and by the gillnet, longline, purse seine, line and other fishery of Indonesia for the year 2020. In the case of Indonesia, the detected changes are due to updates to the official estimates of total catches reported to the Scientific Committee in December 2021, i.e., well beyond the conclusion of the works of the WPTT for the same year.

Small fluctuations in catches (less than 1 t plus or minus per year) occurred in the entire time series due to new proxy records used to breakdown catches aggregates by species and gears, complemented by displacement of catches from the Western area to the Eastern area of the Indian Ocean due to improved reporting of geo-referenced catch data, such as in the case of Sri Lankan gillnet, line and longline fisheries in 2019, and Sri Lankan and Korean longline fisheries in 2020 (**Table 5**).

Table 5: Changes in best scientific estimates of average annual nominal catches (t) of bigeye tuna by year, fleet, fishery group and main Indian Ocean area, limited to absolute values higher than 10 t. Data source: best scientific estimate of nominal catches 2019 and 2020

Year	Fleet	Fishery group	Area	Current (t)	Previous (t)	Difference (t)
2020	EUMYT	Line	Western Indian Ocean	34	68	-34
	IDN	Gillnet	Eastern Indian Ocean	1,928	1,181	747
		Line	Eastern Indian Ocean	9,538	5,841	3,696
		Longline	Eastern Indian Ocean	1,933	2,064	-131
		Other	Eastern Indian Ocean	2,748	1,683	1,065
		Purse seine	Eastern Indian Ocean	7,959	7,663	296
	KEN	Longline	Western Indian Ocean	64	0	64
	KOR	Longline	Eastern Indian Ocean	114	0	114
		Longline	Western Indian Ocean	169	283	-114
	LKA	Gillnet	Eastern Indian Ocean	155	170	-15
		Gillnet	Western Indian Ocean	15	0	15
		Longline	Eastern Indian Ocean	103	2,753	-2,650
		Longline	Western Indian Ocean	2,650	0	2,650
	SYC	Longline	Western Indian Ocean	7,397	6,116	1,281
2019	CHN	Longline	Eastern Indian Ocean	44	16	28
		Longline	Western Indian Ocean	1,793	1,822	-28
	LKA	Gillnet	Eastern Indian Ocean	207	47	160
		Gillnet	Western Indian Ocean	4	164	-160
		Line	Eastern Indian Ocean	2,477	1,582	895
		Longline	Eastern Indian Ocean	426	130	296
		Longline	Western Indian Ocean	1,817	2,113	-296
	SYC	Line	Western Indian Ocean	89	0	89
		Longline	Western Indian Ocean	5,408	3,494	1,914

Uncertainties in nominal catch data

Reporting quality

The quality of the nominal catches of bigeye tuna reported to the IOTC Secretariat shows major variability over the years (**Fig. 12**). The quality is mostly driven by the contribution of industrial fisheries to the total catches and showed a major declining trend from the 1970s to the 1990s when a substantial part of the catch had to be estimated for non-reporting (NEI) and Indonesian longline fleets (Herrera 2002). The situation improved throughout the 2000s although some estimation was still performed for NEI, Indonesian, and Indian longline fleets. The reporting quality has shown an increasing trend since the early 2010s due to increased reporting of nominal catch data for some artisanal fleets and implementation of Port State Measures which progressively reduced the extent of illegal, unreported, and unregulated (IUU) fisheries in the Indian Ocean (**Fig. 12**).

Some issues in reporting have been identified over the last decade for some artisanal fleets, including troll lines from Madagascar, small-scale purse seine and handline fisheries from Mozambique, as well as for the fresh longline fishery of Tanzania which operated between 2011 and 2014. Furthermore, catches of Indonesian artisanal fisheries have been annually re-estimated since the early 2010s based on fixed species compositions that depend on each fishing gear and were derived from samples mostly collected in the 2000s (Moreno et al. 2012). In 2020, the percentage of bigeye tuna catch fully or partially reported to the Secretariat was 75%.

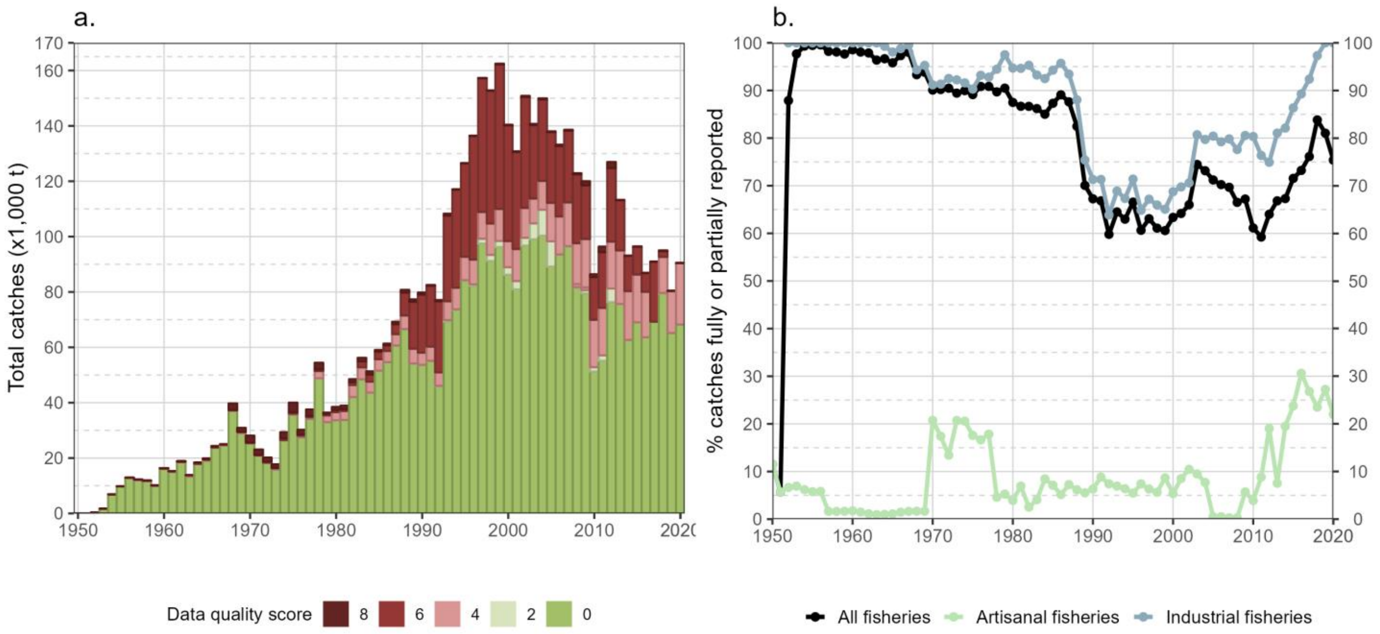

Figure 12: Annual nominal catches (t) of bigeye tuna estimated by quality score (barplot) and percentage of nominal catch fully/partially reported to the IOTC Secretariat (lines with dots) for all fisheries (a) and by type of fishery (b), in the period 1950-2020

Details on potential bias in species composition for the EU purse seine fleet

The Working Party on Tropical Tuna at its 21st session in October 2019 highlighted how the relative composition of tropical species reported by the EU purse seine fleet for the statistical year 2018 was in potential disagreement with previous years, as well as with other fleets (such as Seychelles) operating under similar conditions and in comparable fishing grounds.

In particular, it was noted how the percentage of bigeye catches reported for FOB-associated school by the EU during 2018 (10.39%) was higher than before (average: 6.44%), at the expense of yellowfin tuna, which accounts for 25.08% of total catches in the same year (average: 30.76%), while skipjack contribution remained quite stable at 64.53% (average: 62.8%) (**Table 6**).

Table 6: Annual species composition (in % of catches by species) of the three tropical tunas as reported by the FOB-associated component of the European Union purse seine fleet (all flags combined) for the years 2015-2020. The background intensity color of each cell is directly proportional to the catch level (by species). Data source: time-area catch dataset for purse seine fisheries (Res. 15/02)

Year	BET (%)	YFT (%)	SKJ (%)
2015	7.0	35.1	57.9
2016	6.6	33.1	60.2
2017	6.0	30.4	63.6
2018	10.4	25.1	64.5
2019	5.2	25.8	69.0
2020	7.3	29.4	63.3

Table 7: Annual species composition (in % of catches by species) of the three tropical tunas as reported by the FOB-associated component of the Seychelles and Mauritius purse seine fleets combined for the years 2015-2020. The background intensity color of each cell is directly proportional to the catch level (by species). Data source: time-area catch dataset for purse seine fisheries (Res. 15/02)

Year	BET (%)	YFT (%)	SKJ (%)
2015	7.4	35.6	56.9
2016	6.3	31.7	62.0
2017	6.4	27.9	65.7
2018	5.7	27.2	67.1
2019	6.4	27.5	66.2
2020	5.5	25.4	69.0

When considering the various flags comprised under the EU purse seine fleet, then the disproportion in bigeye tuna catches compared to previous years becomes more evident in the Spanish component of the fleet, reaching a peak of 12.24% in 2018 compared to an average of 6.8% for all other years (**Table 8**)

Table 8: Annual species composition (in % of catches by species) of the three tropical tunas as reported by the FOB-associated component of the European Union (Spain) purse seine fleet for the years 2015-2020. The background intensity color of each cell is directly proportional to the catch level (by species). Data source: time-area catch dataset for purse seine fisheries (Res. 15/02)

Year	BET (%)	YFT (%)	SKJ (%)
2015	7.1	34.0	58.9
2016	7.0	32.2	60.8
2017	6.2	28.6	65.2
2018	12.2	21.8	66.0
2019	5.3	22.9	71.8
2020	8.3	28.6	63.1

Conversely, neither the French component of the EU purse seine fleet (**Table 9**) nor any other of the EU-assimilated purse seine fleets (i.e., Seychelles and Mauritius) present the same anomaly encountered for EU,Spain in 2018 in terms of species composition (**Tables 10 and 11**).

Table 9: Annual species composition (in % of catches by species) of the three tropical tunas as reported by the FOB-associated component of the European Union (France) purse seine fleet for the years 2015-2020. The background intensity color of each cell is directly proportional to the catch level (by species). Data source: time-area catch dataset for purse seine fisheries (Res. 15/02)

Year	BET (%)	YFT (%)	SKJ (%)
2015	6.6	38.4	55.0
2016	5.7	35.5	58.8
2017	5.5	34.8	59.7
2018	5.6	33.6	60.8
2019	5.0	33.5	61.5
2020	4.5	31.5	64.0

Table 10: Annual species composition (in % of catches by species) of the three tropical tunas as reported by the FOB-associated component of the Seychelles purse seine fleet for the years 2015-2020. The background intensity color of each cell is directly proportional to the catch level (by species). Data source: time-area catch dataset for purse seine fisheries (Res. 15/02)

Year	BET (%)	YFT (%)	SKJ (%)
2015	7.0	34.5	58.5
2016	6.9	32.9	60.2
2017	6.6	28.9	64.5
2018	5.0	27.5	67.5
2019	5.9	29.1	65.1
2020	5.2	26.2	68.5

Table 11: Annual species composition (in % of catches by species) of the three tropical tunas as reported by the FOB-associated component of the Mauritius purse seine fleet for the years 2015-2020. The background intensity color of each cell is directly proportional to the catch level (by species). Data source: time-area catch dataset for purse seine fisheries (Res. 15/02)

Year	BET (%)	YFT (%)	SKJ (%)
2015	9.3	40.3	50.4
2016	5.9	36.2	57.9
2017	5.4	33.2	61.4
2018	8.8	37.2	54.0
2019	8.7	25.4	65.9
2020	8.1	33.1	58.7

In 2019, the IOTC Working Party on Tropical Tuna requested the IOTC Secretariat to re-estimate a time-series of tropical tuna catches for the EU purse seine fleet to override the officially produced catch statistics for the year 2018, by applying the same species composition as for previous years to the total catches of the FOB-associated component of EU catches for 2018 (IOTC 2019c). This updated time series has been used to support a sensitivity run of the assessment carried on in 2019 but has not yet been included in the IOTC databases, nor is used anywhere in this report.

Discard levels

The total amount of bigeye tuna discarded at sea remains unknown for most fisheries and time periods despite the obligation to report these data as per IOTC Res. 15/02. Furthermore, and except for very specific situations (i.e., the fish caught is considered unfit for human consumption or there is insufficient storage capacity following the final set of a trip), all tropical tunas caught with purse seine have to be retained onboard since 2013 (IOTC Res. 19/05).

Discarding of tropical tunas is thought to be small in coastal fisheries and negligible in baitboat fisheries (Miller et al. 2017). Besides, data collected by observers at sea have shown that the level of discarding of tropical tunas is low in the Indian Ocean purse seine fishery, and discarding mostly occurs in schools associated with floating objects (Amandè et al. 2012). Purse seine discards of bigeye tuna are mainly composed of fish smaller than 60 cm (~5.7 kg) although a few larger fish may be discarded when damaged (**Fig. 13**). Estimates for the main component of the Indian Ocean purse seine fleet showed they amount to a few hundred tons annually (Ruiz et al. 2018).

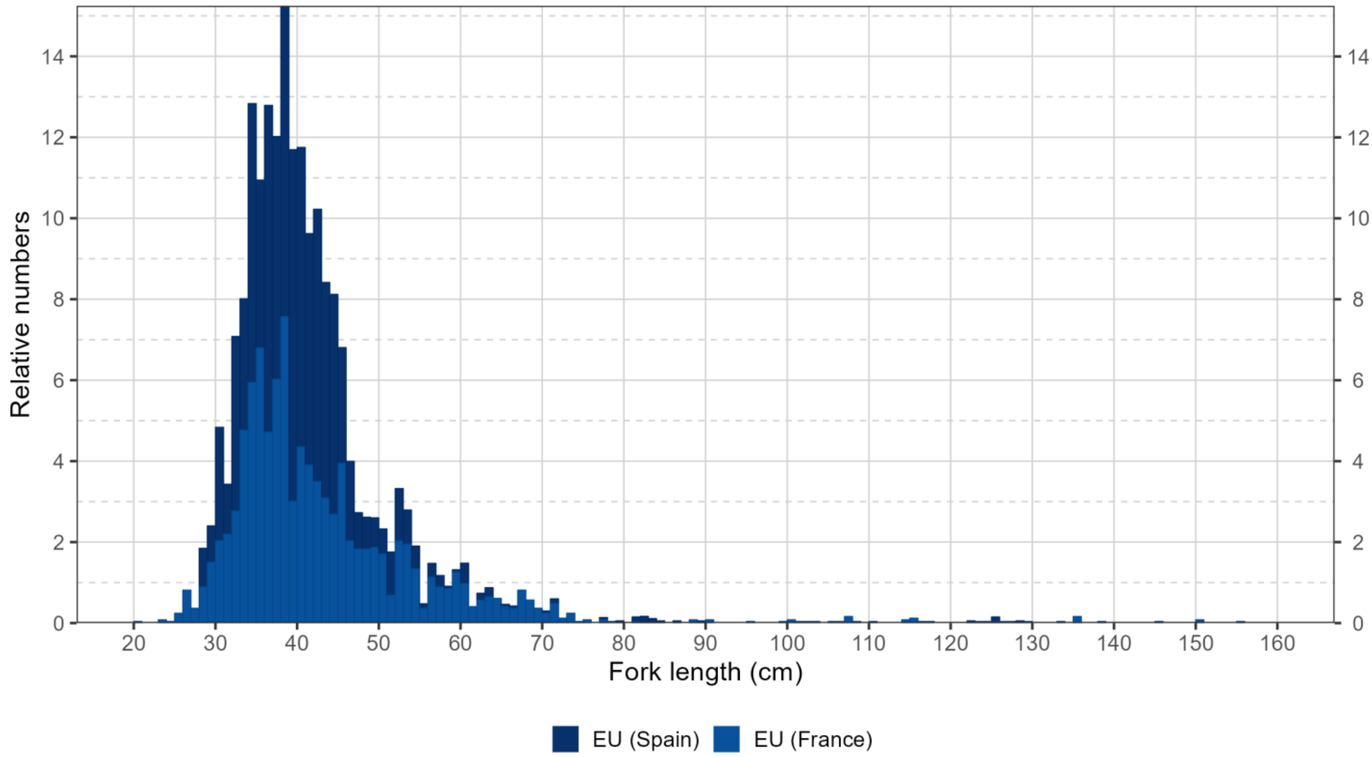

Figure 13: Fork length distribution of bigeye tuna discarded at sea in purse seine fisheries during the period 2016-2020 (n = 8,482). Data source: IOTC ROS database

Discarding may also occur in tropical longline fisheries, mainly due to depredation by sharks and cetaceans (Rabearisoa et al. 2018). In the Taiwanese longline fishery of the Indian Ocean for instance, the discarding rate of bigeye tuna has been estimated at 4.97% in the fleet targeting bigeye tuna during 2004-2008 (Huang & Liu 2010).

There is currently little information in the ROS database on discarding practices in longline fisheries except for a small sample of fish observed in French and Japanese longliners during 2009-2018. The size of the bigeye tunas discarded at sea by the Reunion-based fresh longline fishery are smaller than in the Japanese deep-freezing longline fishery, i.e., a median of 77.5 cm vs. 87.5 cm (**Fig. 14**). Recently, the practice of high grading in longline fisheries has been suggested to occur in some pelagic longline fisheries operating in the South of the Indian Ocean. Preliminary analysis conducted on size data of retained bigeye tuna caught in Indian Ocean longline fisheries does not seem to support the hypothesis of major changes in discarding practice, e.g., linked to high grading in relation with the implementation of Res. 17/01 (Medley et al. 2021).

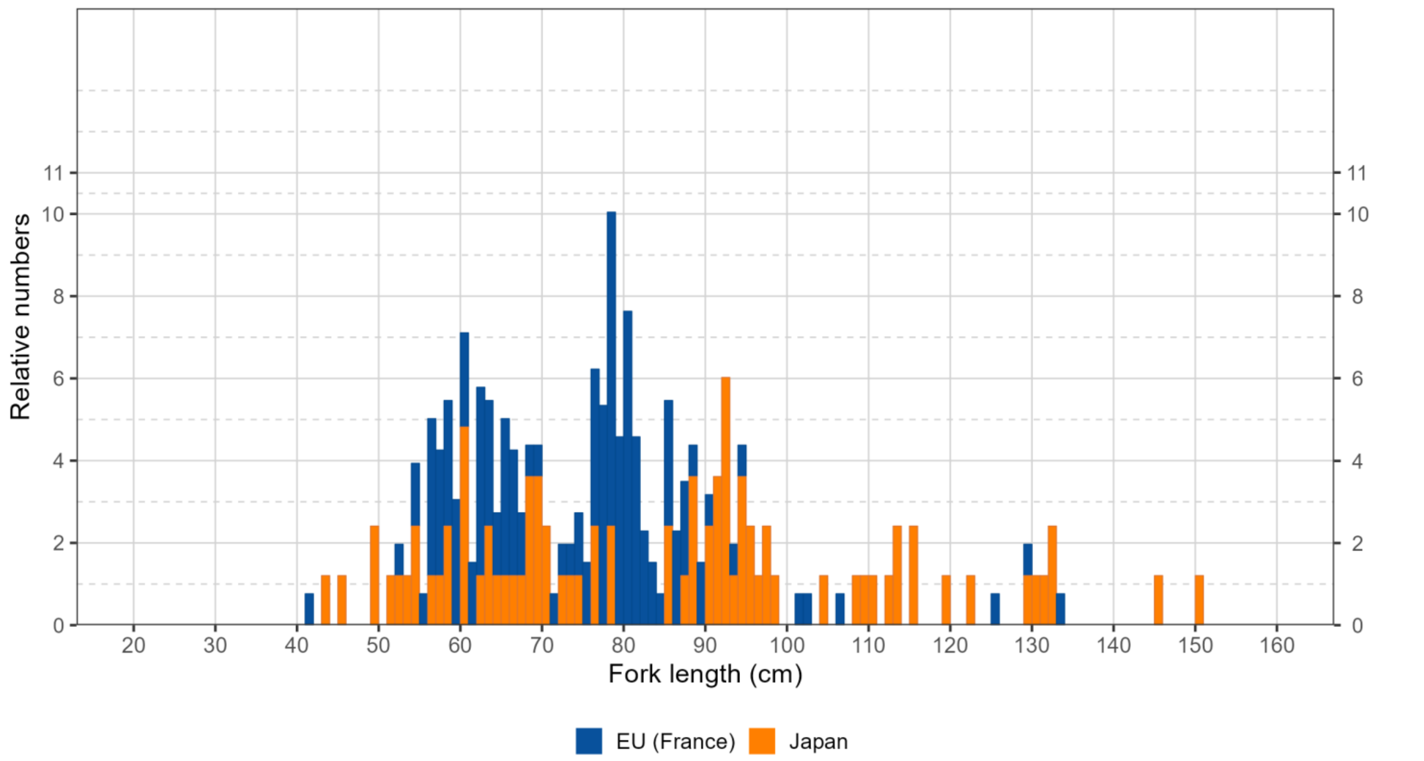

Figure 14: Fork length (cm) distribution of bigeye tuna discarded at sea in longline fisheries during the period 2009-2020 (n = 345). Data source: IOTC ROS database

Overall, more data on discards collected from observers at sea are required to better assess the extent and variability of discarding practices in Indian Ocean longline fisheries. The IOTC Secretariat acknowledges that several of the CPCs currently submitting ROS trip reports have all the information and the technical knowledge to provide the original scientific data in a format more suitable for incorporation in the ROS database, and therefore the Secretariat is seeking active collaboration from all concerned CPCs to ensure that new and historical ROS data could be properly submitted and used for further analysis.

Geo-referenced catch

Spatial distribution of catches

Estimated geo-referenced catches show the spatial expansion and major changes that took place in the fisheries targeting bigeye tuna over the last decades (**Fig. 15**). As early as the 1950s, bigeye tuna was caught by large-scale longline fisheries across most of the Indian Ocean while coastal gillnet and line fisheries were active in the Arabian Sea and baitboats in the Maldives and off the south-western coast of India representing a small contribution to the bigeye tuna total catches.

Throughout the 1960s and 1970s, the longline fisheries expanded in the south-western part of the Indian Ocean, including in the Mozambique Channel (**Fig. 15b-c**). From the 1980s, the purse seine fishery developed in the western Indian Ocean, with most of the bigeye tuna caught by log-associated schools (**Fig. 15d**).

During the 1990s and 2000s, the purse seine fishery increased its catches and expanded its fishing grounds in the western Indian Ocean while a large fresh longline and line fishery developed in the north-eastern Indian Ocean (**Fig. 15e-f**).

The overall annual distribution of bigeye tuna catches by fishery has changed little over the period 2016-2020 (**Fig. 16**).

Geo-referenced catches by fishery and decade (1950-2009)

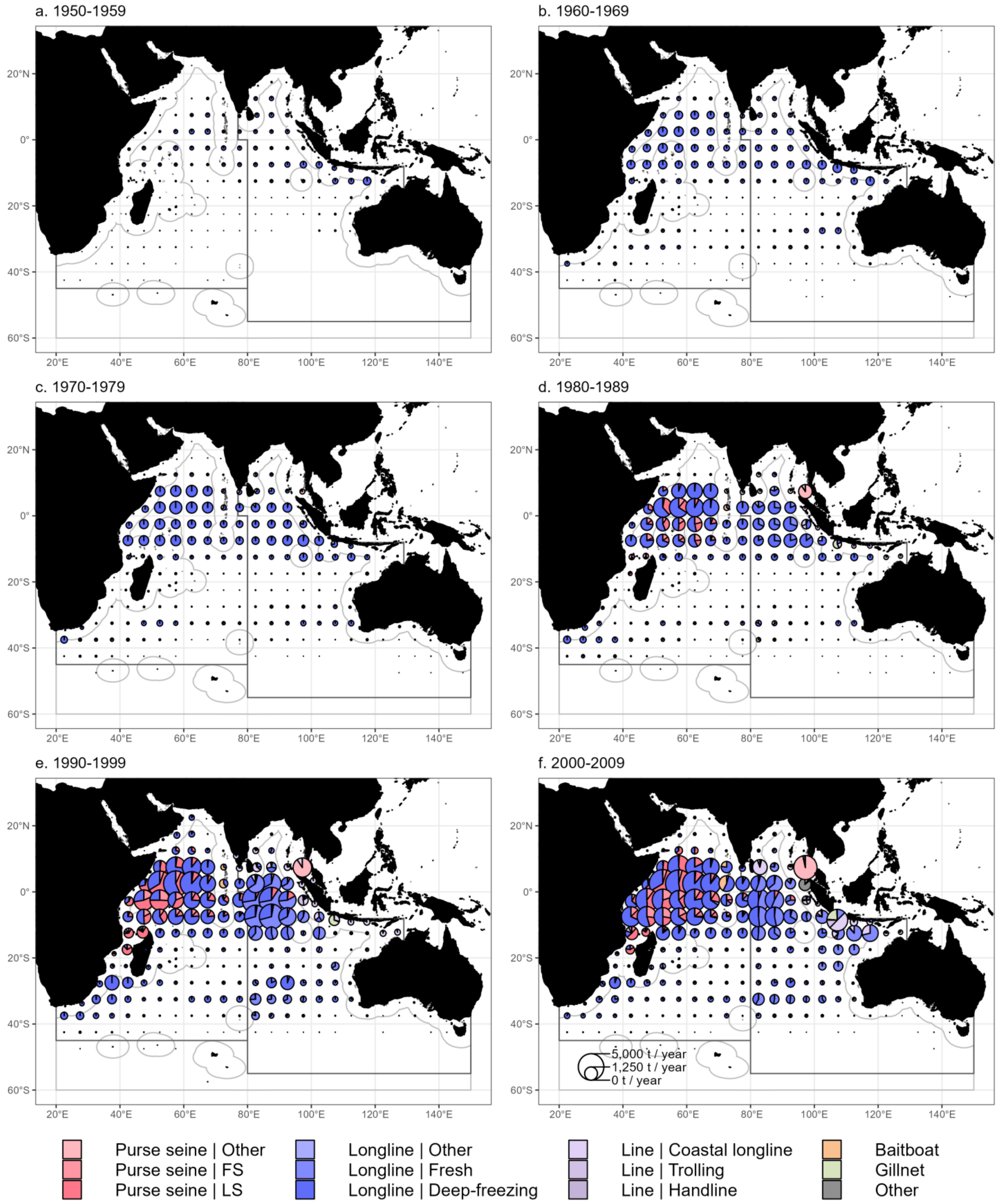

Figure 15: Estimated mean annual time-area catches (t) of bigeye tuna by decade, 5x5 grid, and fishery. Data source: raised time-area catches

Geo-referenced catches by fishery, last years (2016-2020) and decade (2010-2019)

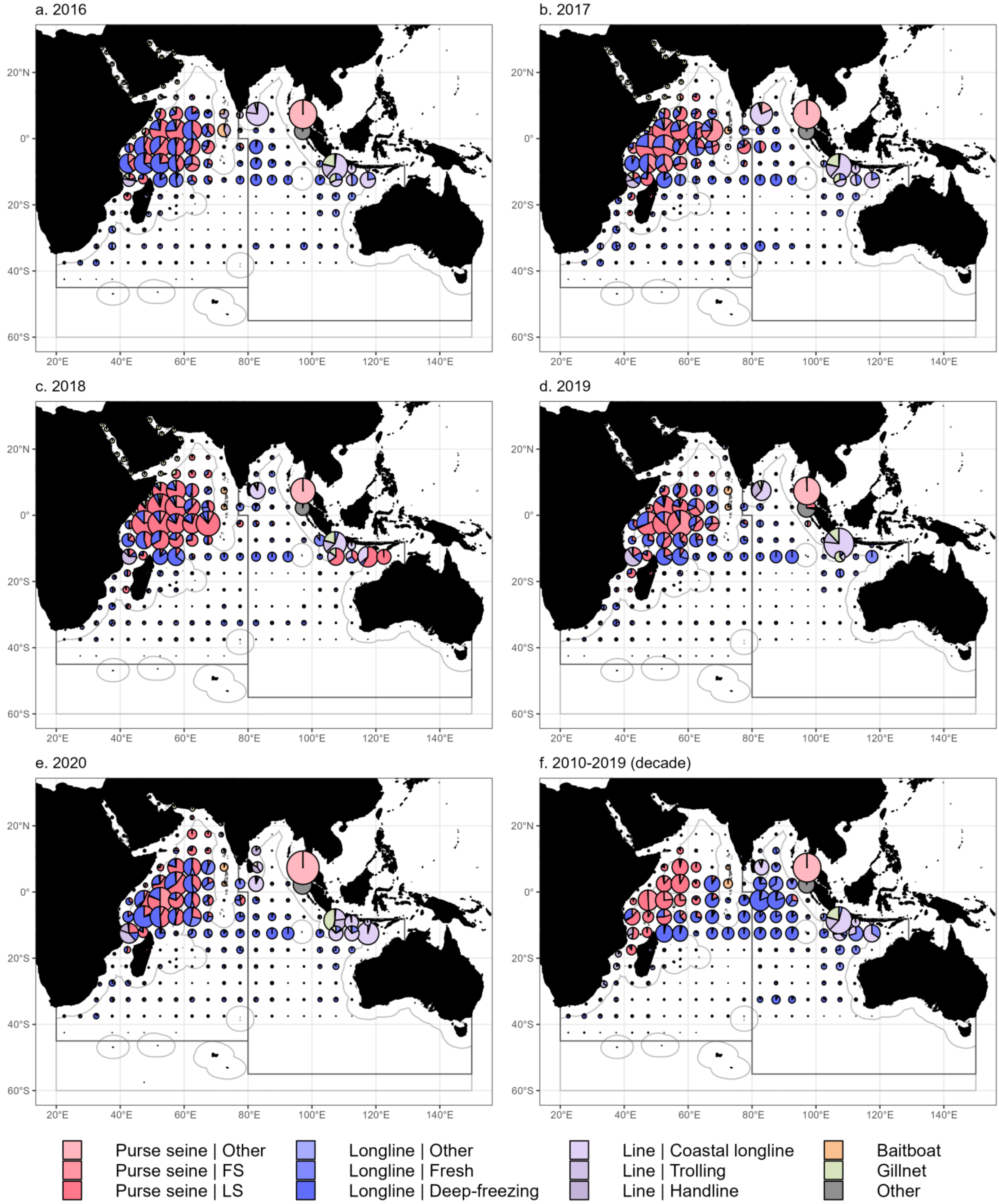

Figure 16: Estimated mean annual time-area catches (t) of bigeye tuna by year / decade, 5x5 grid, and fishery. Data source: raised time-area catches

Indonesia appears to have developed an industrial purse seine fishery since 2018 (**Fig. 16d-e**), which mainly operates in coastal areas of the eastern Indian Ocean with vessels of length overall (LOA) between 30 and 40 m. Baitboat fishing is essentially concentrated in the Maldives archipelago while line fisheries (handline, trolling and coastal longline) are widely used along the coasts of India, Sri Lanka, and Indonesia.

Uncertainties in catch and effort data

Catch and effort series are available for most industrial fisheries and some important artisanal fisheries. However, for many artisanal fisheries, these data are either not available or are considered to be of poor quality. Consequently, the trend in quality of the catch and effort data is driven to some extent by the relative contribution of artisanal fisheries to the total catches of bigeye tuna (**Fig. 17b**). The main issues identified in the past concern:

- the fresh-tuna longline fishery of Taiwan,China, for which data have only been available since 2007;
- purse seine and fresh-tuna longline fisheries of Indonesia, with data only available from 2018 onward (although logbook coverage is thought to be low);
- the purse seine fisheries of I.R. Iran (until 2004) for which data are either incomplete or lacking;
- the longline fisheries of Sri Lanka (since 2014), described by poor quality effort data;
- some coastal fisheries using hand and/or troll lines for which no data (or incomplete data) have been reported to the Secretariat, in particular: Comoros (until 2018), Indonesia (2018 and 2020), Mauritius (since 2011 but without data from 2013 to 2015), and France,Reunion (until 2012).

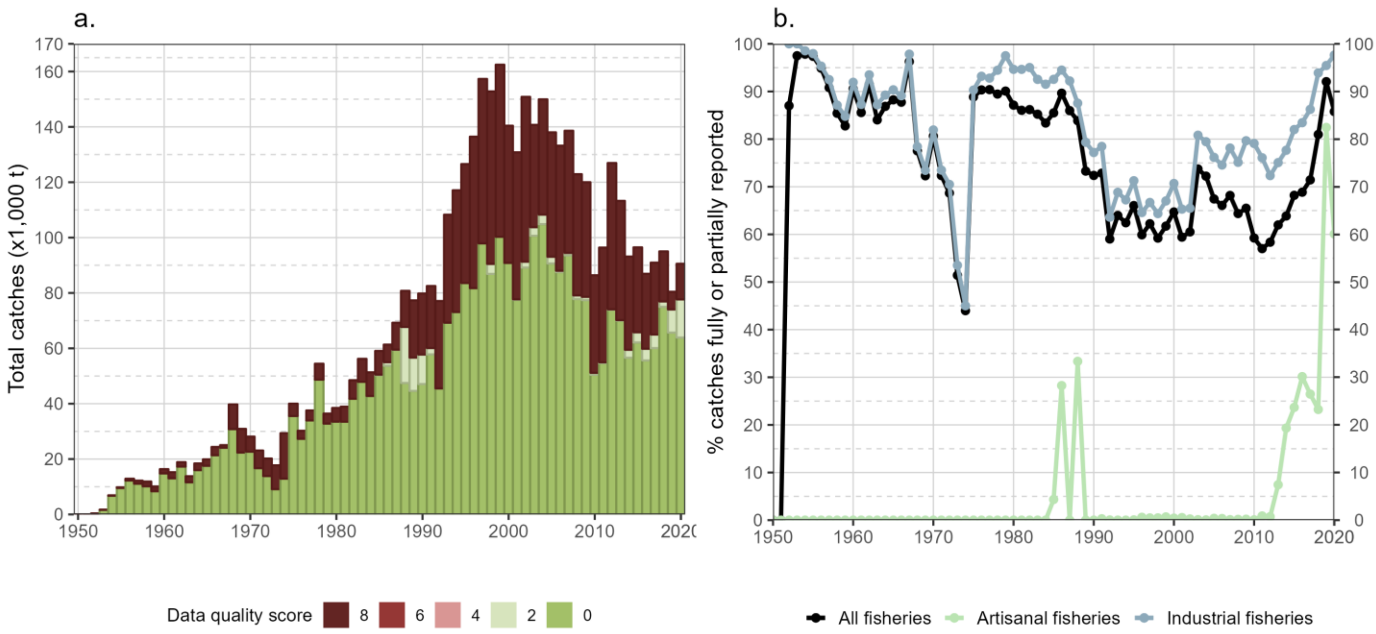

Figure 17: Annual nominal catches (t) of bigeye tuna estimated by quality score (barplot) and percentage of geo-referenced catches reported to the IOTC Secretariat in agreement with the requirements of Res. 15/02 (lines with dots) for all fisheries (a) and by type of fishery (b), in the period 1950-2020

The percentage of data considered of good quality (scores of 0-2) varied between 59%-74% during the 1990s and 2000s, and has stabilized over the last decade showing an overall increasing trend from 57% in 2011 to 92% in 2019, with 86% of good quality data available in 2020 (**Fig. 17a-b**). Catch and effort data have progressively become available for some important fisheries such as coastal and fresh longlines as well as hand lines from Sri Lanka since 2014, coastal longlines from I.R. Iran since 2016, small-scale purse seines and fresh longlines from Indonesia since 2018, and some smaller fisheries such as trolling from Indonesia and hand line from Kenya since 2018.

Nevertheless, geo-referenced catch and effort data were not available for about 14% (i.e., around 10,000 t) of the total nominal catches of bigeye tuna in 2020. In addition, no spatial information has been provided by the EU,Italy industrial purse seine fishery (since 2016), accounting in 2020 for relatively low total catch levels of bigeye tuna of ~300.

Further details on potential bias in species composition for the EU purse seine fleet

In the section dedicated to uncertainties in nominal catch data for bigeye tuna it was already highlighted how a potential bias in species composition was detected in 2018 for one of the flag of the EU purse seine fleet (i.e., EU,Spain). In fact, relative total catch composition for the year and fleet concerned showed an higher than average presence of bigeye tuna in sets from FOB-associated schools.

As this data is sourced directly from the geo-referenced time-area catches provided to the Secretariat by the EU purse seine fleet, it might be worth exploring the relative proportion of the two species to the level of resolution available for this data set, i.e., on regular grids of 1° in size.

Figure 18 shows the relative proportion of bigeye vs. yellowfin tuna by 1°x1° grid (all months combined) for the Spanish component of the European Union purse seine fleet fishing on FOB-associated schools during the years between 2015 and 2020. Grids with a color shifting towards red indicate areas where bigeye tuna is preponderant (in weight of catches reported) compared to yellowfin tuna.

Data for the year 2018 (**Fig. 18.d**) confirms the trend described earlier at nominal catch level, and further highlights the areas of the Indian Ocean where the proportion of reported bigeye tuna catches exceeds that of yellowfin tuna.

As species composition for European Union and assimilated fleets is derived from actual samples fed into the T3 process and also by data collected in other spatial-temporal strata through a substitution scheme (Pallarés & Hallier 1997, Duparc et al. 2020), the emergence of clearly defined geographical areas with straight borders perfectly aligned with meridians and parallels is considered to be a side-effect of the T3 process (**Fig. 18.d**). In this specific case, the area where the preponderance of bigeye tuna is clearly evident (for 2018) corresponds to the *EU PS statistical area 3 - Southeast Seychelles*.

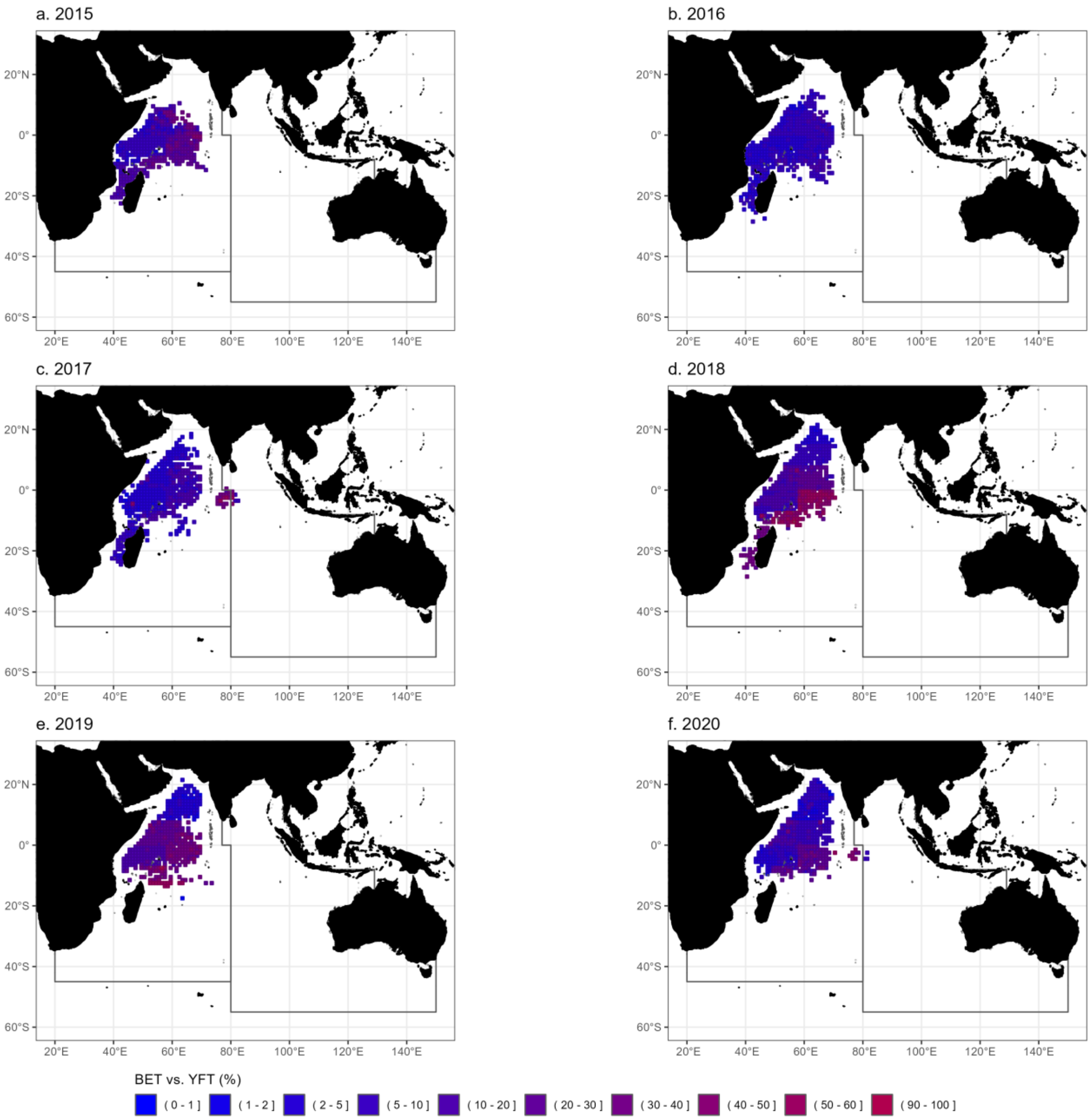

Figure 18: Relative percentages of catches of bigeye tuna vs. yellowfin tuna reported for the Spanish FOB-associated component of the European Union purse seine fleet for the period 2015-2020. Data source: time-area catch dataset for purse seine fisheries (Res. 15/02)

The issue can also be addressed from a different perspective, i.e., by correlating a specific, rounded value of the recorded proportions of bigeye vs. yellowfin tuna (as percentages) with the fraction of grids that report that given proportion value.

Figure 19 provides a summary, for the years between 2015 and 2020, of this metric calculated for the Spanish component of the European Union purse seine fleet fishing on FOB-associated schools. The X-axis in each faceted plot corresponds to a given percentage of bigeye vs. yellowfin tuna, while the Y-axis corresponds to the fraction of 1°x1° grids for which that percentage was reported.

With this assumption, the year 2018 clearly shows an higher than average number of grids reporting a fraction of bigeye tuna ranging from 65% to 80% of the total weight (between 2% and 4% of grids per each percentage point of proportion), whereas for all other years the maximum proportion detected does not exceed 50%, with generally less than 4% of grids reporting each possible value up to that maximum.

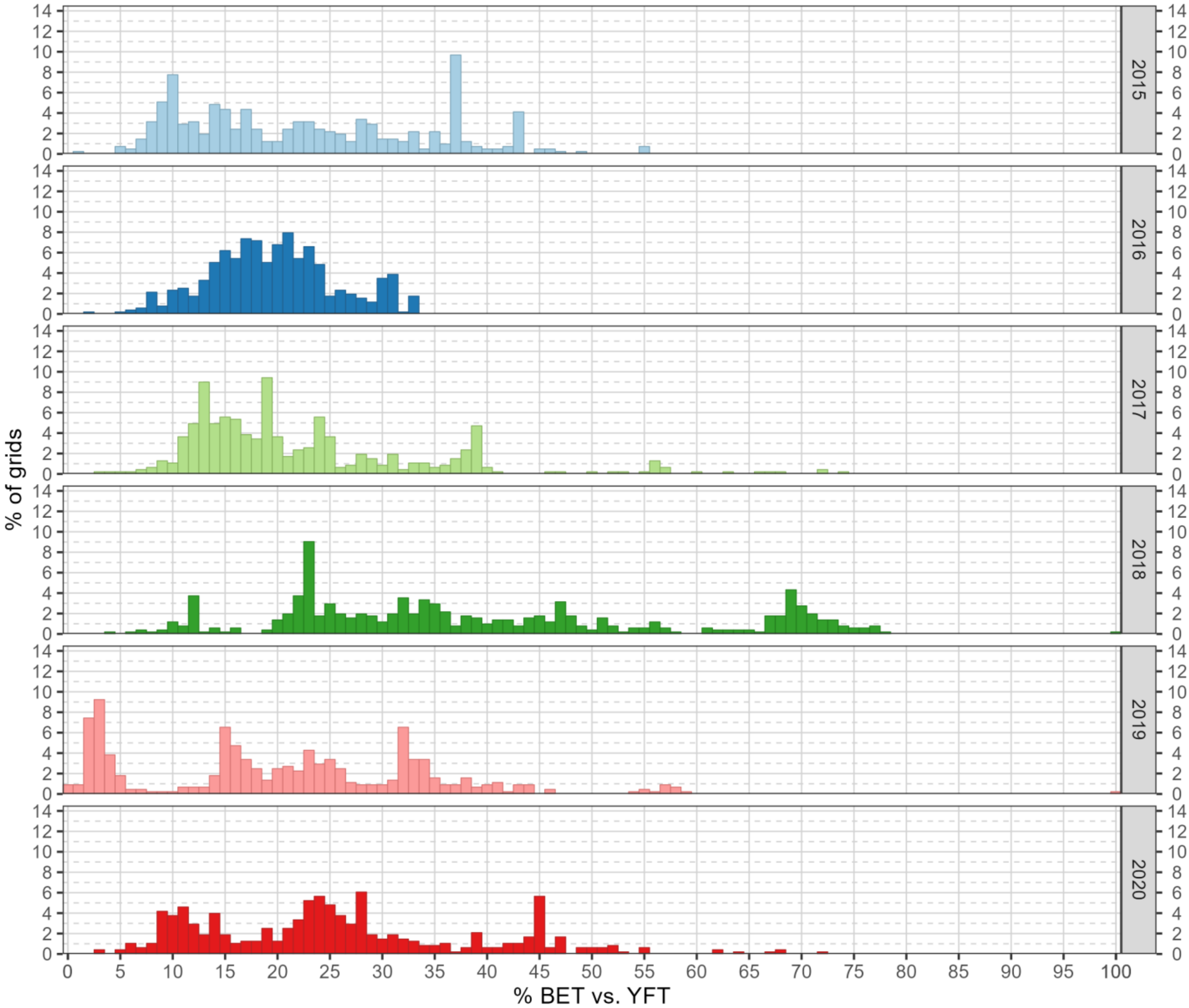

Figure 19: Percentages of 1°x1° grids by relative fraction of catches of bigeye tuna vs. yellowfin tuna reported for the Spanish FOB-associated component of the European Union purse seine fleet for the period 2015-2020. Data source: time-area catch dataset for purse seine fisheries (Res. 15/02)

A similar plot produced for the French component of the European Union purse seine fleet fishing on FOB-associated schools shows a more homogeneous behavior, with no year (in the range considered) presenting a proportion of bigeye tuna larger than 50% for any significant fraction of grids, if not for a few limited points in 2017 (**Figure 20**)

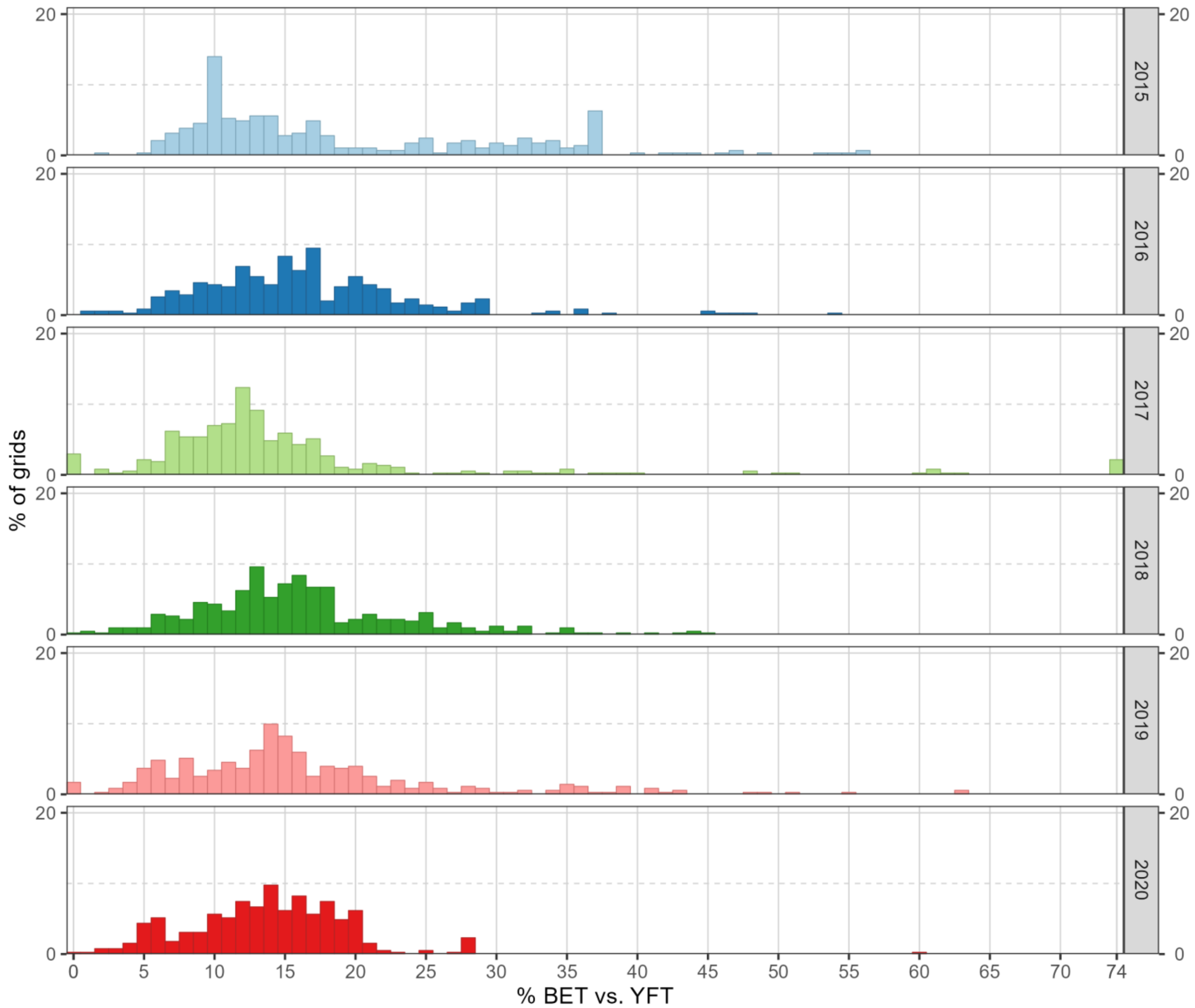

Figure 20: Percentages of 1°x1° grids by relative fraction of catches of bigeye tuna vs. yellowfin tuna reported for the French FOB-associated component of the European Union purse seine fleet for the period 2015-2020. Data source: time-area catch dataset for purse seine fisheries (Res. 15/02)

As recalled, in 2019 the IOTC Secretariat was requested by the Working Party on Tropical Tuna to provide (for assessment purposes) a revised time series of catches for the European Union purse seine fleet that uses an average of the species composition from previous years to adjust the disproportion in bigeye tuna catches reported by the Spanish component for 2018 (IOTC 2019c).

Similarly, the Scientific bodies of IOTC might require the Secretariat to also adjust the time-area catches reported by EU,Spain in 2018: in that case, rather than applying a simplistic approach that averages species composition over entire years and fleets, it could be preferable to provide a more fine grained, proxy-based geospatial approach to update species composition at grid and month level for the year and fleet concerned (IOTC 2019c).

Size composition of the catch

Samples availability

By fishery group

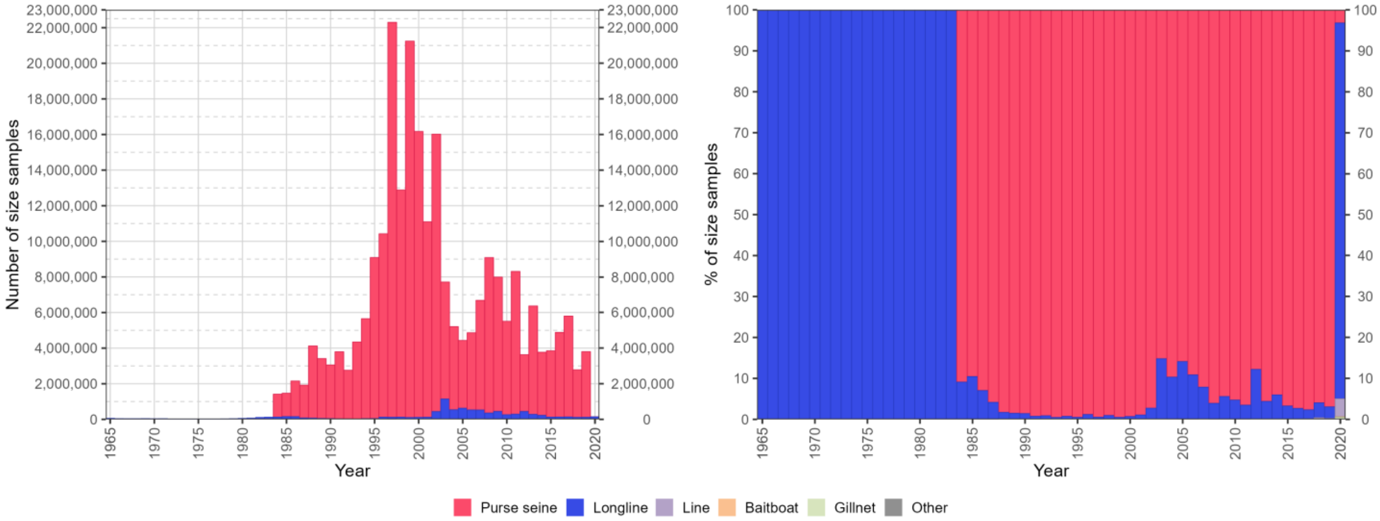

Figure 21: Availability of bigeye tuna size-frequency data as absolute number of samples (left) and relative number of samples (right) per year and fishery group. Data source: standardized size-frequency dataset (Res. 15/02)

Comprehensive size-frequency data for bigeye tuna are only available from the beginning of the 1980s (see also Uncertainties in size-frequency data).

Most of the samples available to the IOTC Secretariat have been collected since the development of the purse seine fishery in the Indian Ocean, and reported as '*raised*' samples (i.e., processed at the source to represent *catch-at-size* for the fleets and years concerned). This explains the magnitude of the samples available from these fisheries which at its peak reached over 20 million individual lengths reported for a single year (**Fig. 21**).

The contribution of longline fisheries to the total available samples for the species became more evident during the 2000s, and reflects the actual level of catches from these fisheries. In general, samples from all other fisheries (using baitboats, gillnets and miscellaneous gears mostly of artisanal nature) are limited and highly depending on the fleet (**Fig. 29**).

Due to the CoViD-19 pandemic, size-frequency data of bigeye tuna collected by purse seine fisheries are basically unavailable for 2020, if not for a very limited number of individuals sampled by EU,France, Mauritius and Seychelles.

The spatial distribution of the available samples by fishery type in the last five years (**Fig. 22**) is generally representative of the fishing grounds where the fisheries operate, and proportional to the level of recorded captures.

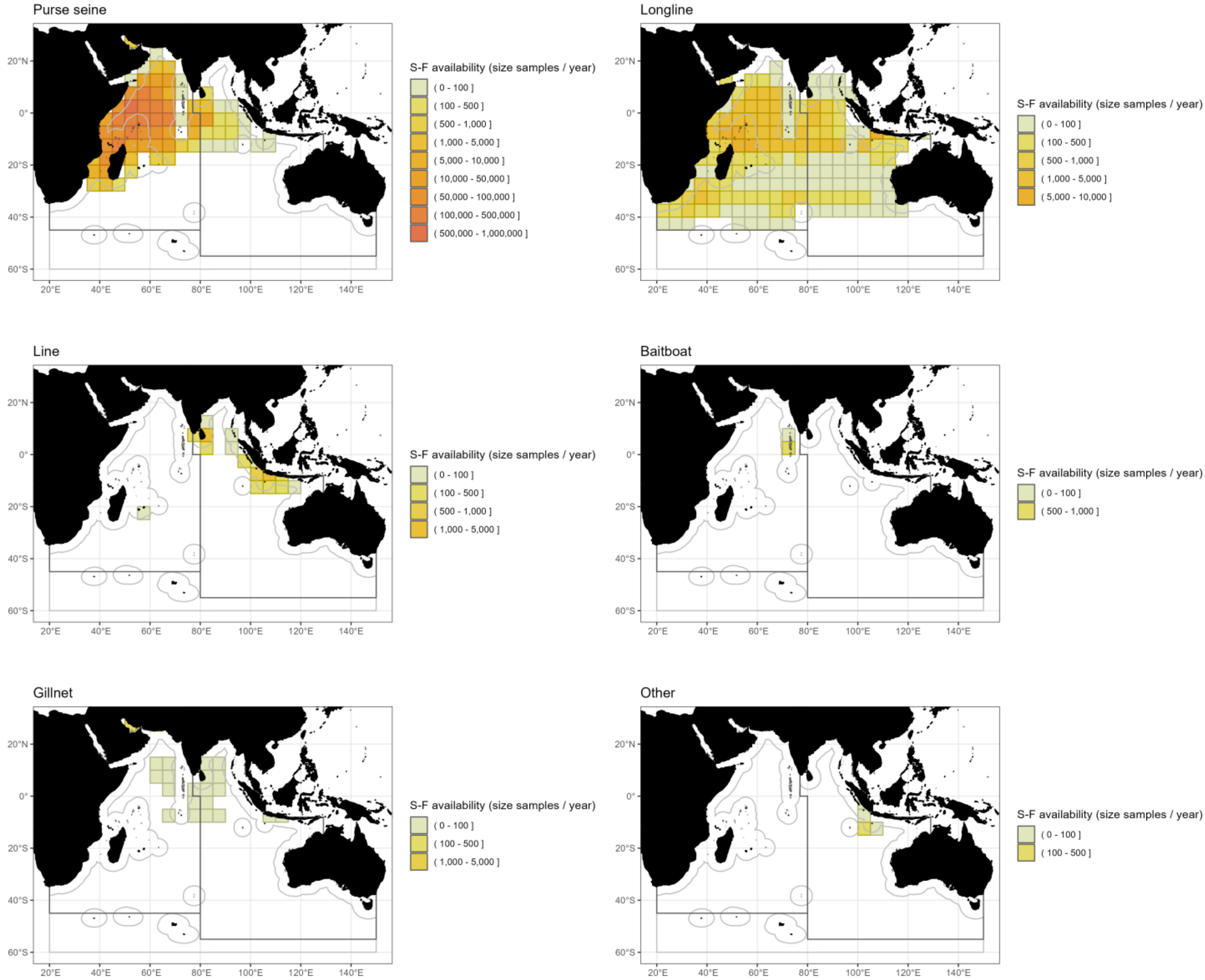

Figure 22: Spatial distribution (average number of samples per grid per year) of available bigeye tuna size-frequency data for each fishery group in the period 2016-2020. Data source: standardized size-frequency dataset (Res. 15/02)

By fishery

Purse seine fisheries

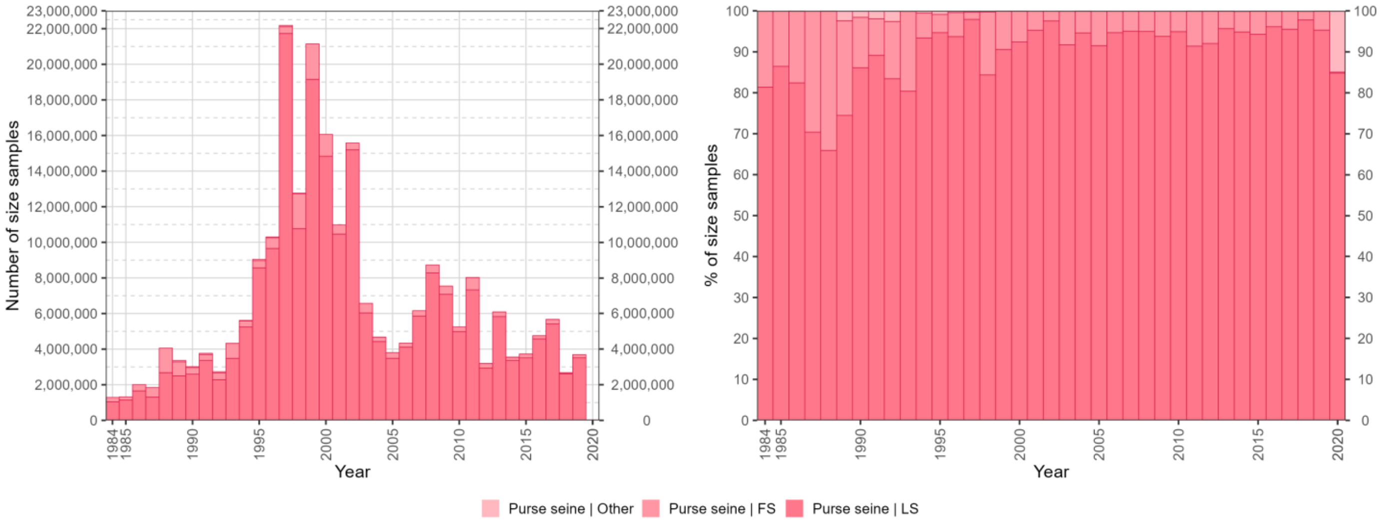

Figure 23: Availability of bigeye tuna size-frequency data as absolute number of samples (left) and relative number of samples (right) per year and purse seine fishery type. Data source: [standardized size-frequency dataset](#) (Res. 15/02)

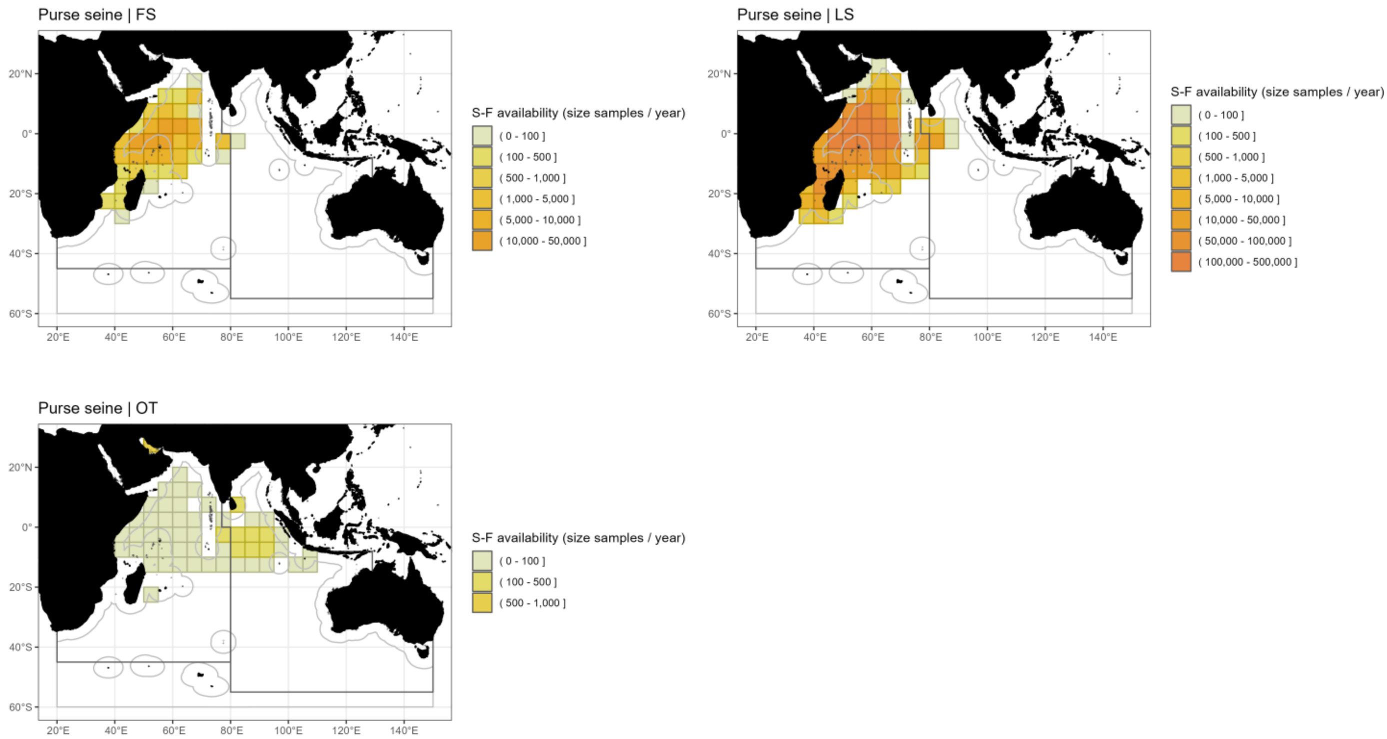

Figure 24: Spatial distribution (average number of samples per grid per year) of available bigeye tuna size-frequency data by purse seine fishery types in the period 2016-2020. Data source: [standardized size-frequency dataset](#) (Res. 15/02)

Longline fisheries

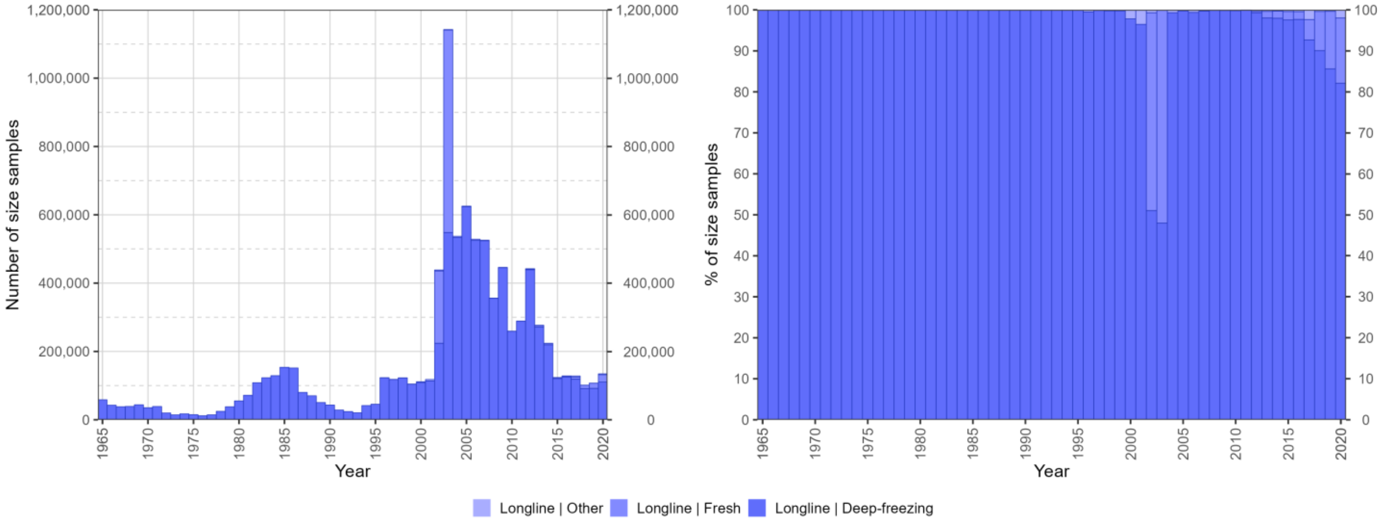

Figure 25: Availability of bigeye tuna size-frequency data as absolute number of samples (left) and relative number of samples (right) per year and longline fishery type. Data source: [standardized size-frequency dataset] (Res. 15/02)

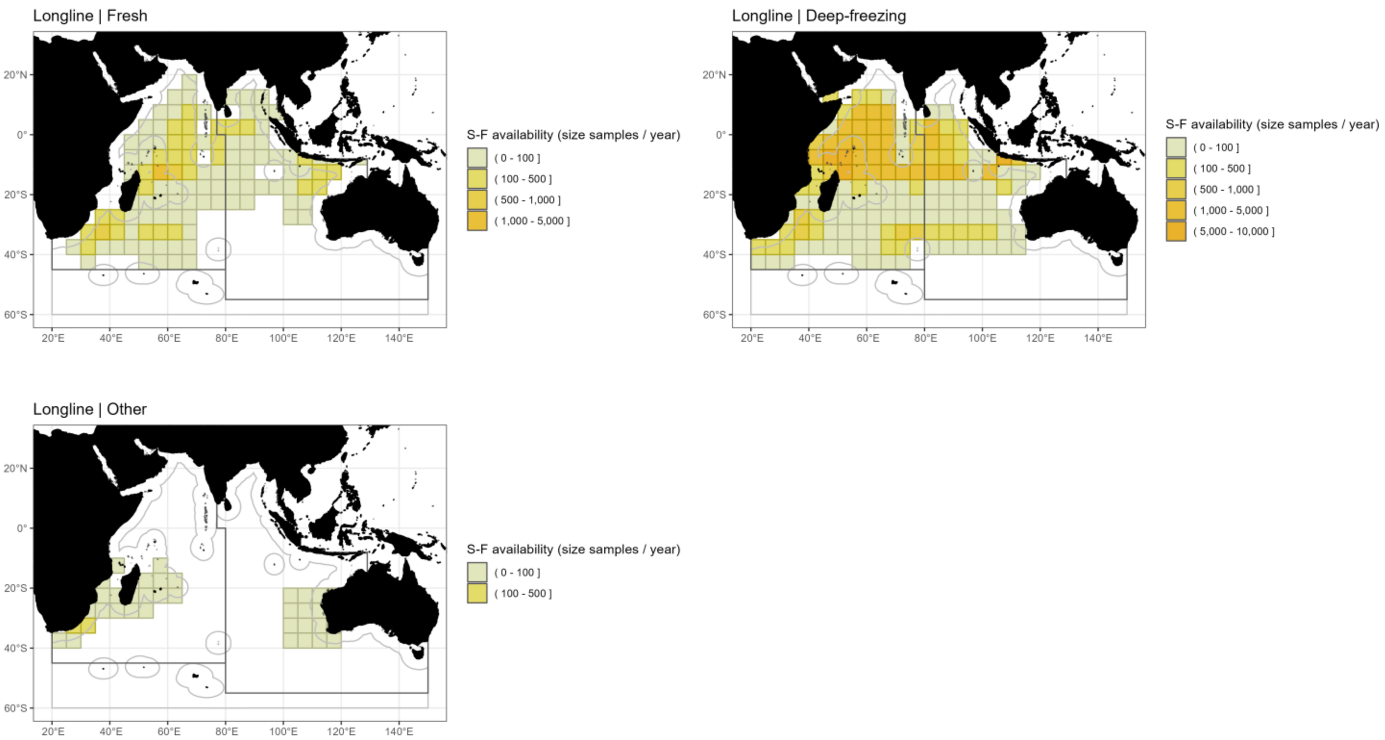

Figure 26: Spatial distribution (average number of samples per grid per year) of available bigeye tuna size-frequency data by longline fishery types in the period 2016-2020. Data source: [standardized size-frequency dataset] (Res. 15/02)

Line fisheries

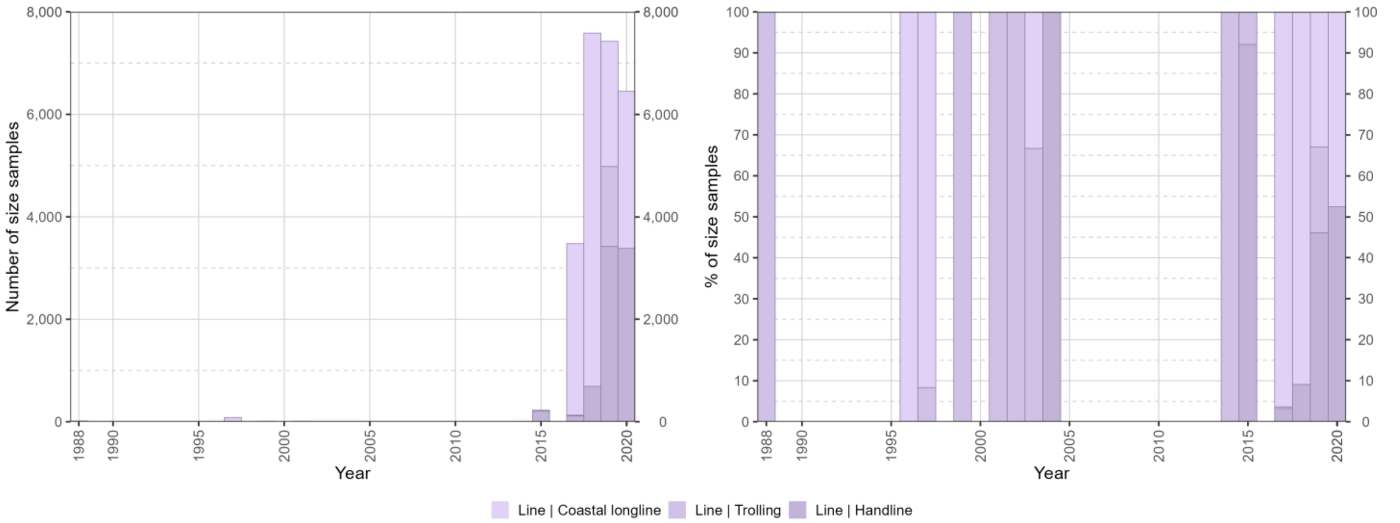

Figure 27: Availability of bigeye tuna size-frequency data as absolute number of samples (left) and relative number of samples (right) per year and line fishery type. Data source: standardized size-frequency dataset (Res. 15/02)

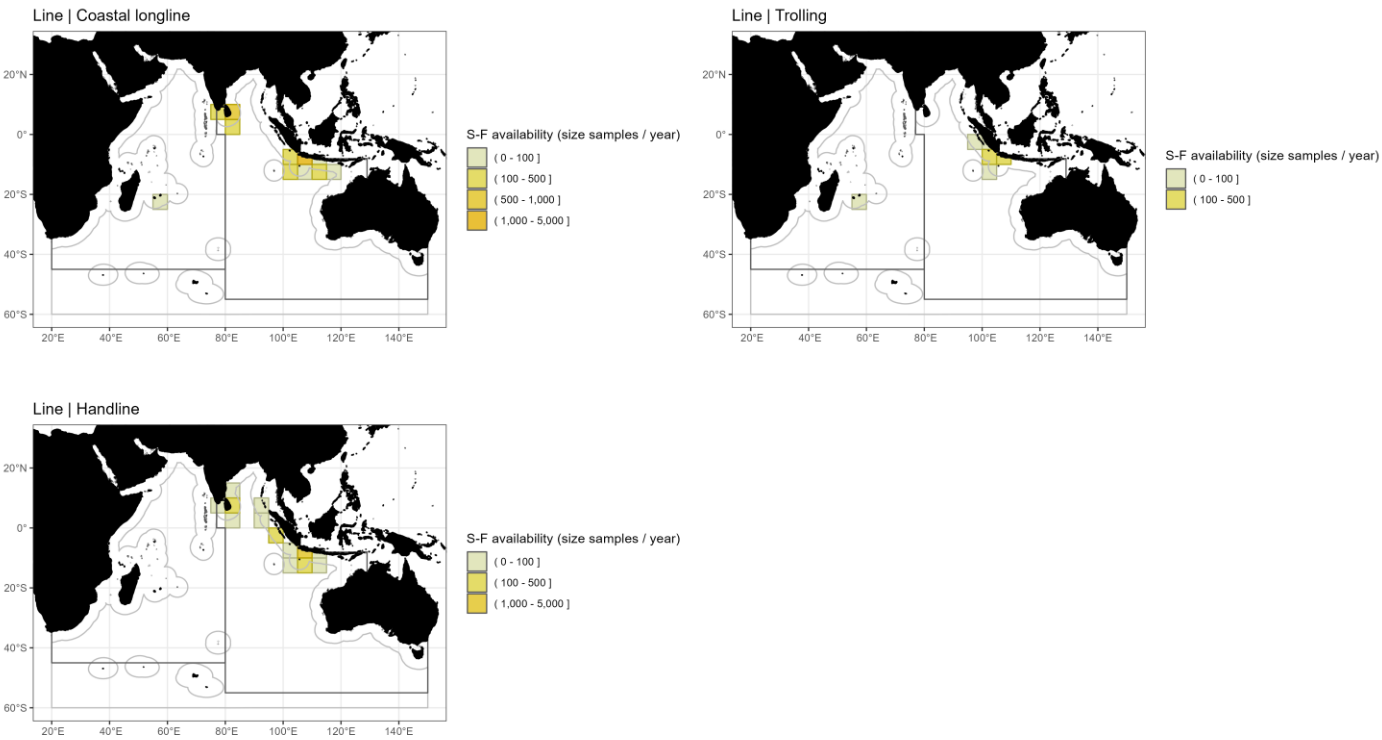

Figure 28: Spatial distribution (average number of samples per grid per year) of available bigeye tuna size-frequency data by line fishery types in the period 2016-2020. Data source: standardized size-frequency dataset (Res. 15/02)

Other fisheries

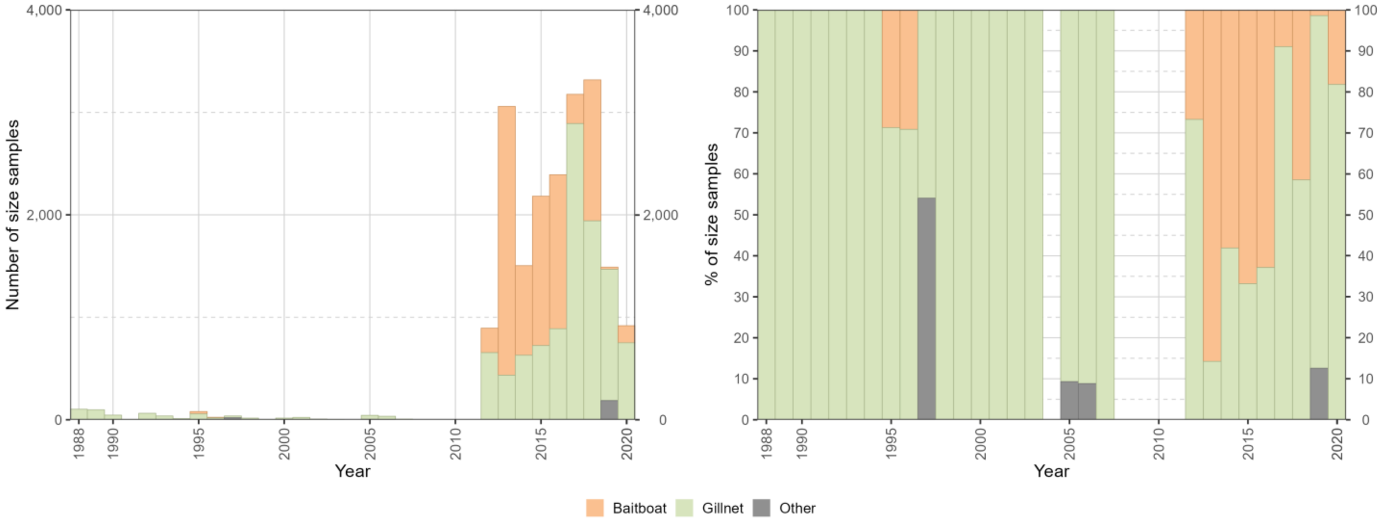

Figure 29: Availability of bigeye tuna size-frequency data as absolute number of samples (left) and relative number of samples (right) per year and all other fishery types. Data source: standardized size-frequency dataset (Res. 15/02)

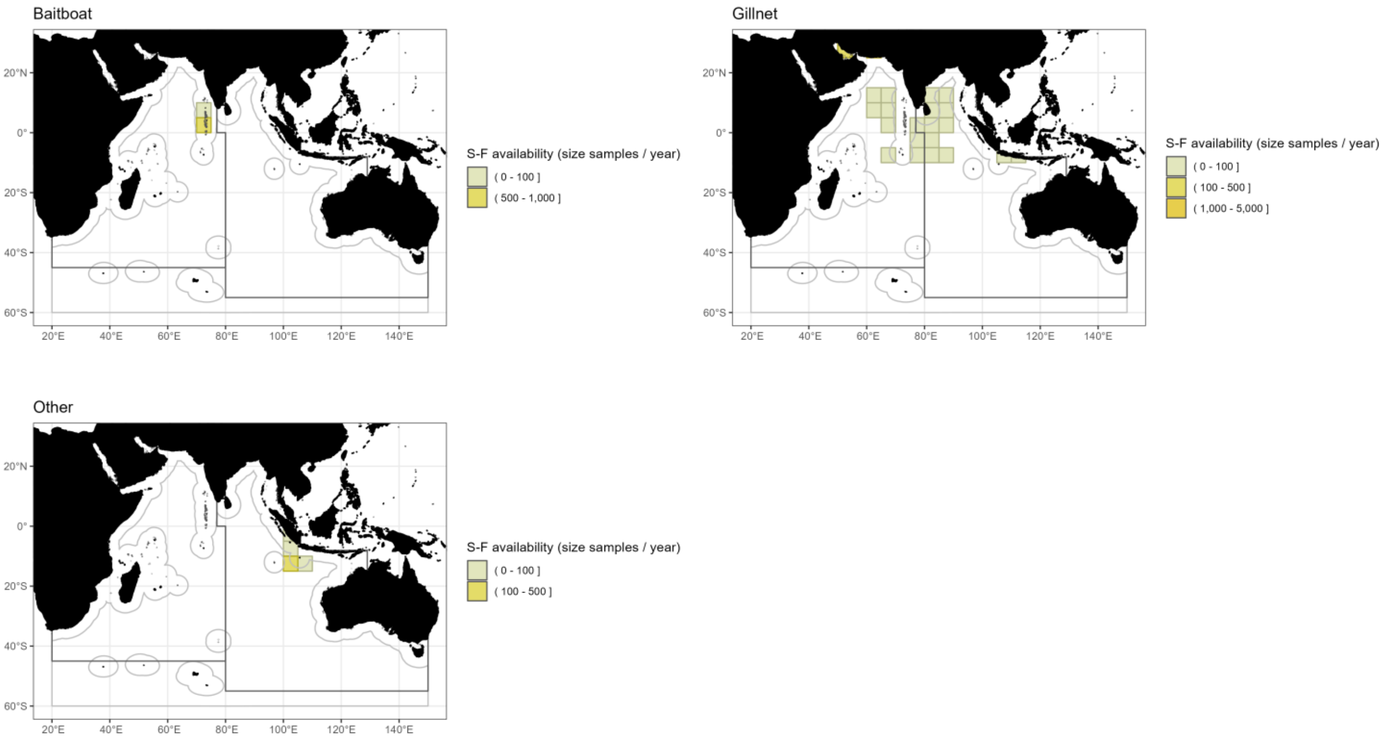

Figure 30: Spatial distribution (average number of samples per grid per year) of available bigeye tuna size-frequency data by all other fishery types in the period 2016-2020. Data source: standardized size-frequency dataset (Res. 15/02)

Temporal patterns and trends in size distributions

Industrial purse seine fisheries

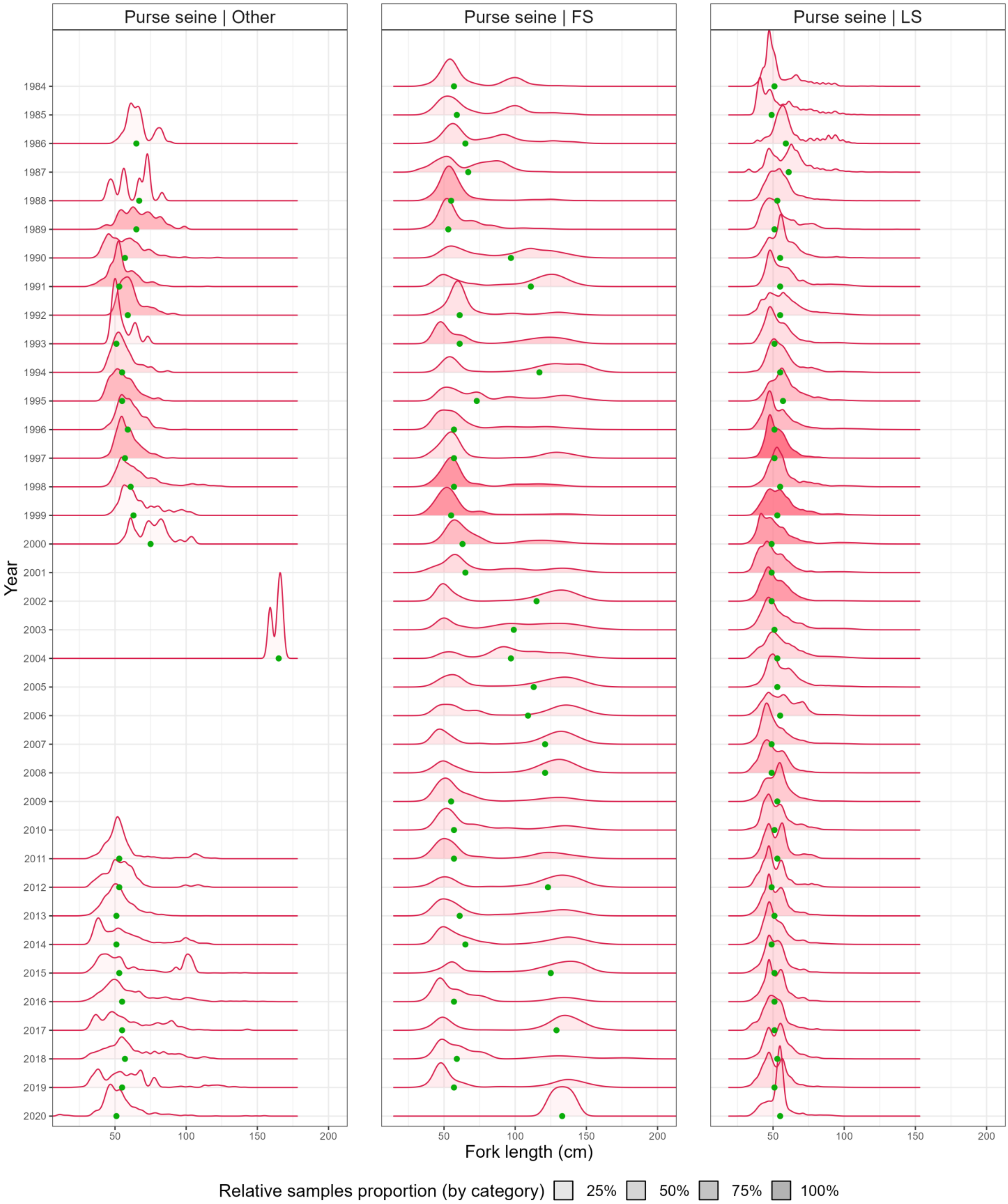

Figure 31: Relative size distribution (fork length in 2 cm size bins) of bigeye tuna caught by all purse seine fleets for the period 1984-2020. Other = no information provided on the school association; FS = free-swimming schools; LS = schools associated with floating objects. Fill intensity is proportional to the number of samples recorded for the year, while the green dot corresponds to the median value. Data source: standardized size-frequency dataset (Res. 15/02)

Industrial longline fisheries

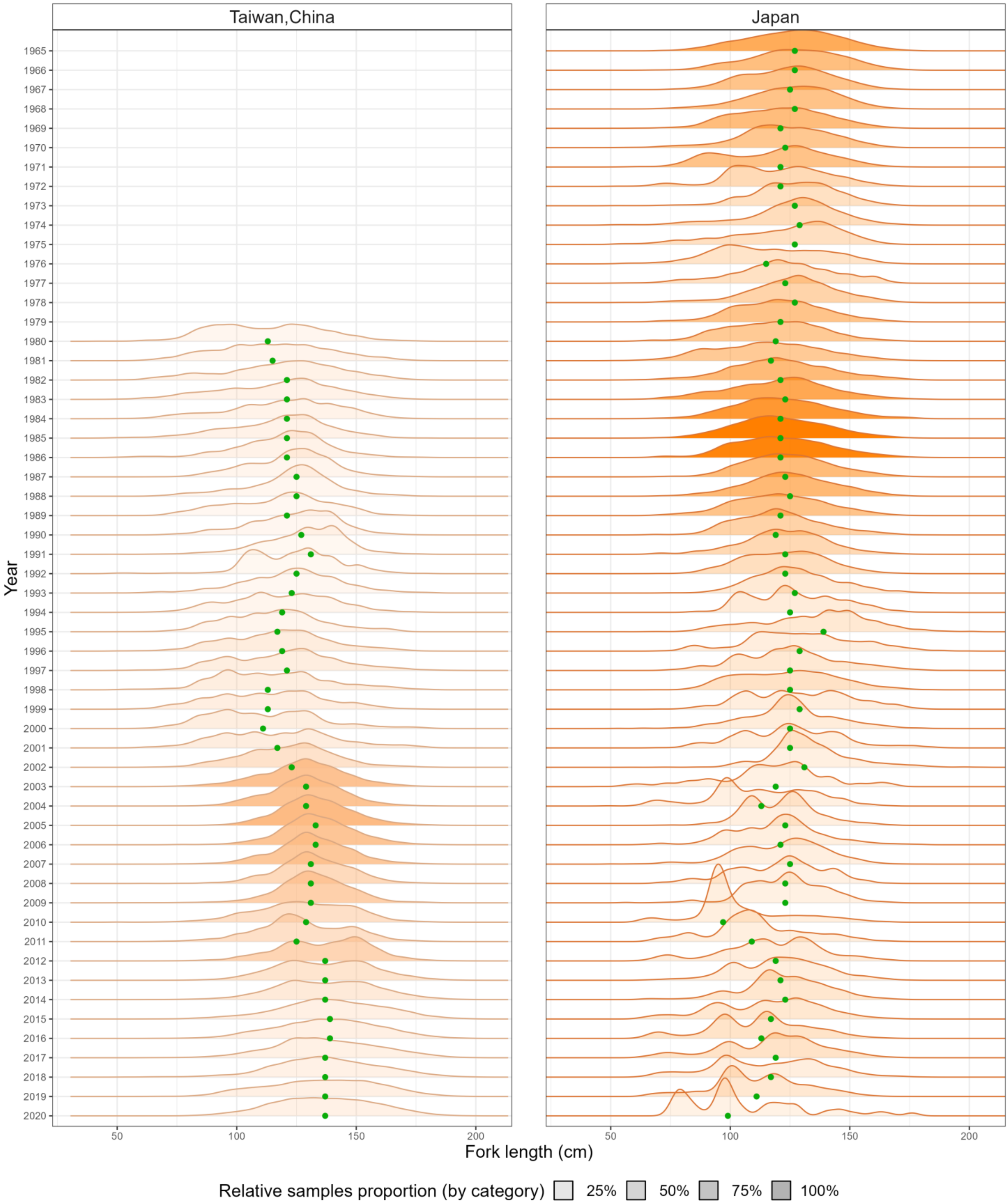

Figure 32: Relative size distribution (fork length in 2 cm size bins) of bigeye tuna caught by the main deep-freezing longline fleets for the period 1965-2020. Fill intensity is proportional to the number of samples recorded for the year, while the green dot corresponds to the median value. Data source: [standardized size-frequency dataset] (Res. 15/02)

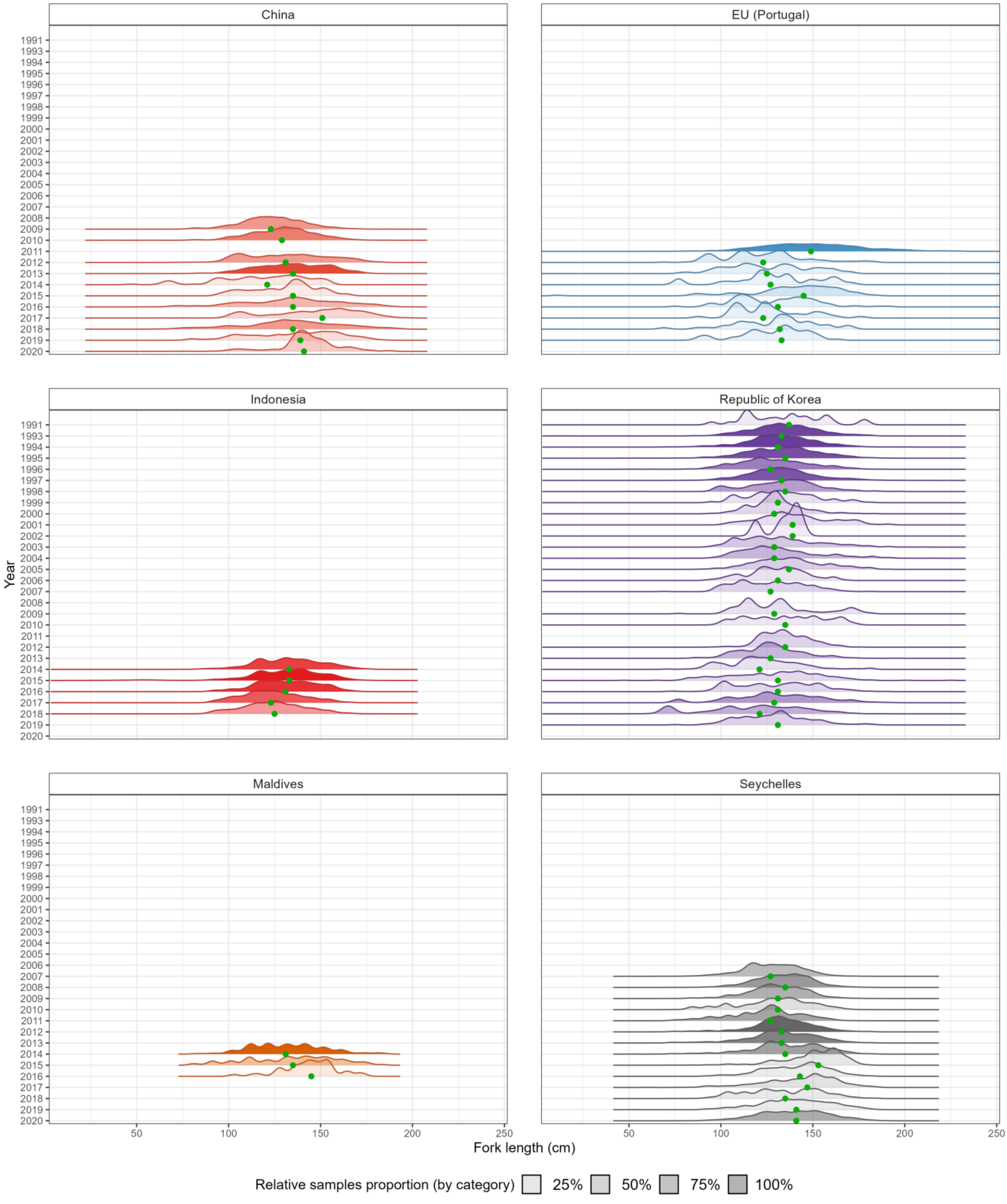

Figure 33: Relative size distribution (fork length in 2 cm size bins) of bigeye tuna caught by all other longline fleets (excluding Japan and Taiwan,China), by fleet for the period 1991-2020. Data source: standardized size-frequency dataset (Res. 15/02)

Temporal trends in estimated average weights

Trends in average weights of bigeye tuna can be derived from the raised time-area catches in weight and numbers. While they can be estimated for the entire time series and for each fishery, due to the lack of original samples for several strata (especially in the early periods of the fisheries) they are considered accurate only for those periods for which actual samples are available and cover strata that correspond to at least 50 t of retained catches per year.

Considering the limitations in the original data and in the process that produces this estimation, it shall be noted that the average weights calculated for the longline fisheries of Japan and Taiwan,China are relatively stable and fluctuate at around 40-60 kg (**Fig. 35**). The FOB-associated component of all Indian Ocean purse seine fisheries shows a relative stable trend since the mid-1980s, with an estimated average weight of 3.7 kg in 2020 which is very close to the estimated average for all fisheries combined, which in 2020 was estimated at 4.1 kg.

In fact, the overall estimated trend in average weights (**Fig. 35 - 'Áll fisheries'**) shows a clear decreasing pattern, driven in recent years by the analogous behavior of average weights estimated for the FOB-associated component of the purse seine fisheries (**Fig. 35 - 'Purse seine | LS'**), which is the fishery accounting for the majority of catches for the species in the same period.

Trends in average weight for all other fisheries (baitboat, gillnet and all other gears) are more difficult to assess due to the inherently artisanal nature of several of them, which in turn implies a lower number of available samples which are often of lower quality compared to those provided by industrial fleets (recorded through logbooks or collected by scientific observers, in several cases).

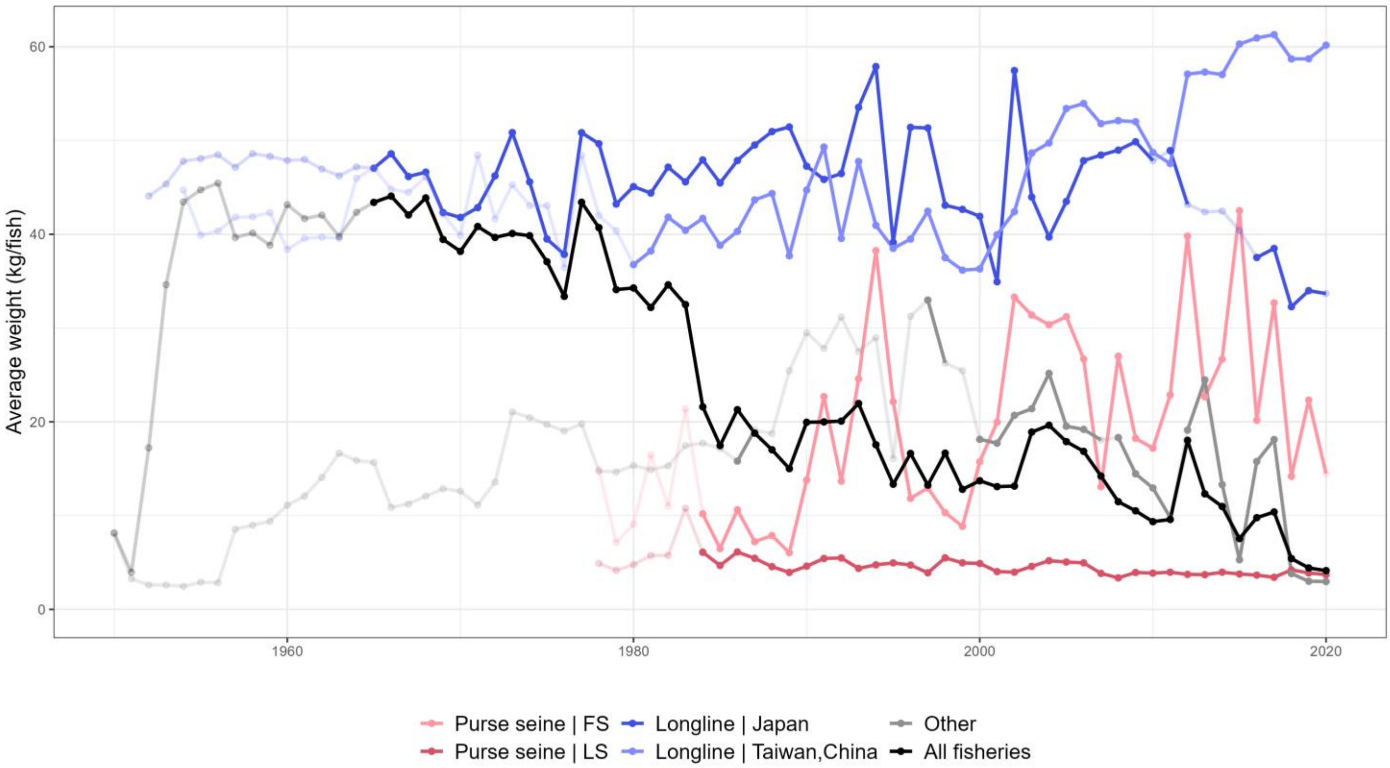

Figure 34: Combined estimated bigeye tuna average weight (kg/fish) in the catch by fishery and year. Semi-transparent points correspond to years for which the original size samples cover strata with reported catches (by year and fishery) **lower** than 50 t. LS = schools associated with floating objects; FS = free-swimming schools. Longline | Japan = includes data from longliners flagged by Japan, Rep. of Korea and Thailand; Longline | Taiwan = includes data from longliners flagged by Taiwan,China and all other flags not otherwise mentioned. Data source: raised time-area catches

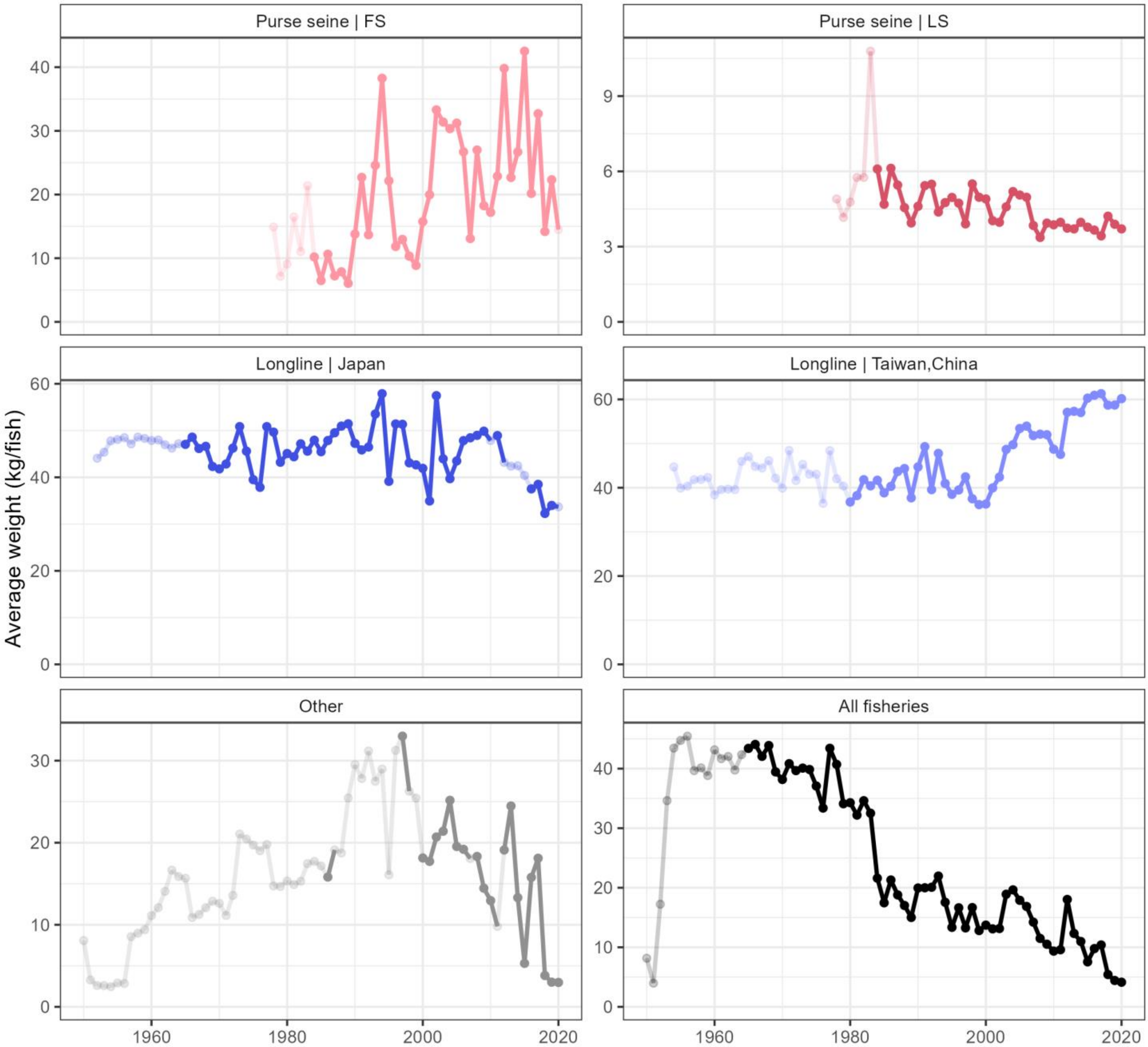

Figure 35: Estimated bigeye tuna average weight (kg/fish) in the catch by fishery and year. Semi-transparent points correspond to years for which the original size samples cover strata with reported catches (by year and fishery) **lower** than 50 t. LS = schools associated with floating objects; FS = free-swimming schools. Longline | Japan = includes data from longlines flagged by Japan, Rep. of Korea and Thailand; Longline | Taiwan = includes data from longlines flagged by Taiwan,China and all other flags not otherwise mentioned. Data source: raised time-area catches

Overall, the trend in average weights that results from combining data for all fisheries together shows a clear and steady decrease in the size of fish caught since the beginning of the 1990s, which can be explained by the generalized decline in deployed efforts by several industrial longline fleets combined with the rapid increase in catches from log-associated schools in the purse seine fishery (**Fig. 34**).

Spatial distribution of average weights

Estimated average weights by decade (1950-2019)

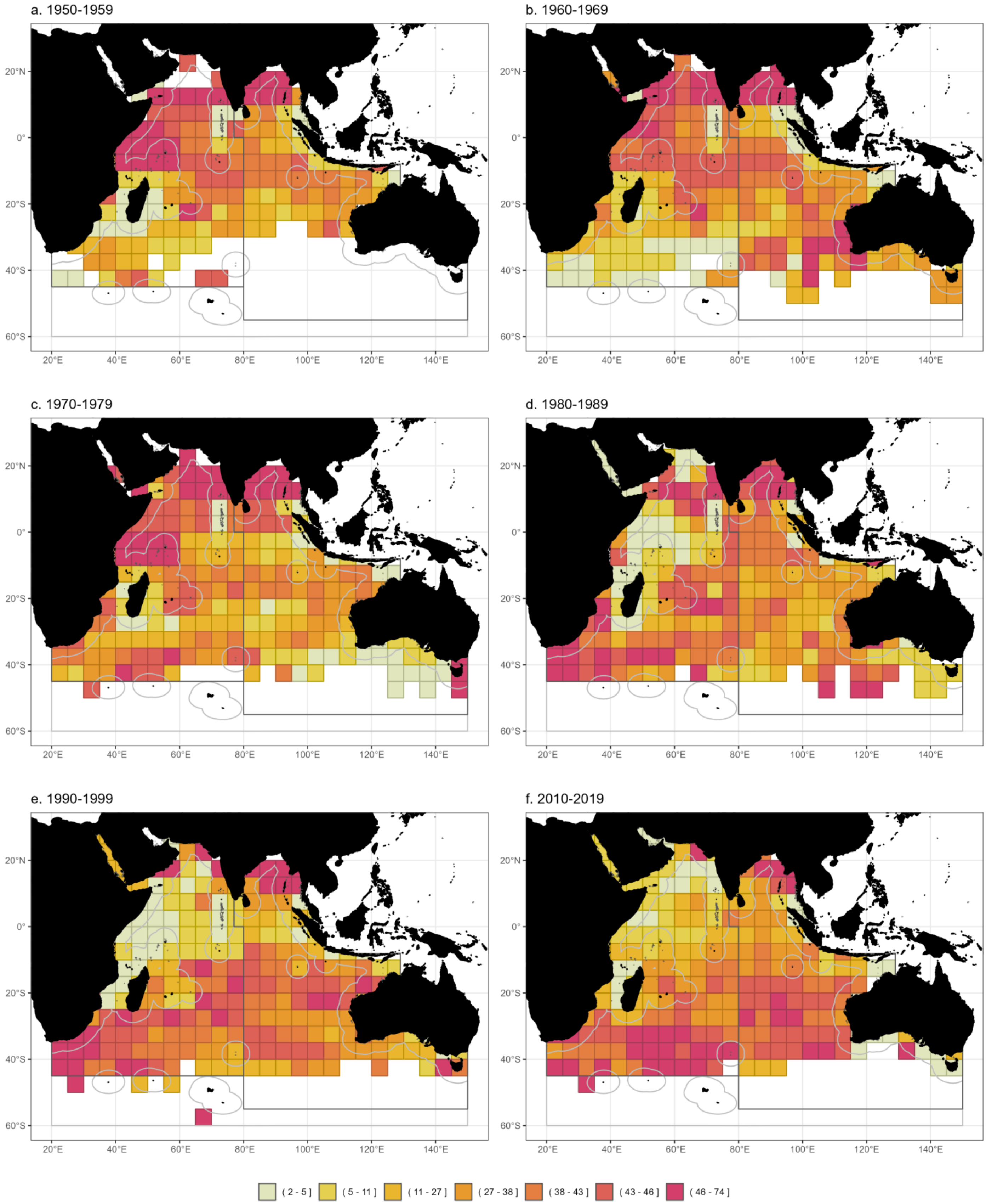

Figure 36: Estimated bigeye tuna average weight (kg/fish) in the catch by decade and 5x5 grid, for all fisheries combined for the period 1950-2019. Data source: raised time-area catches

Estimated average weights by year (2016-2020) and last decade (2010-2019)

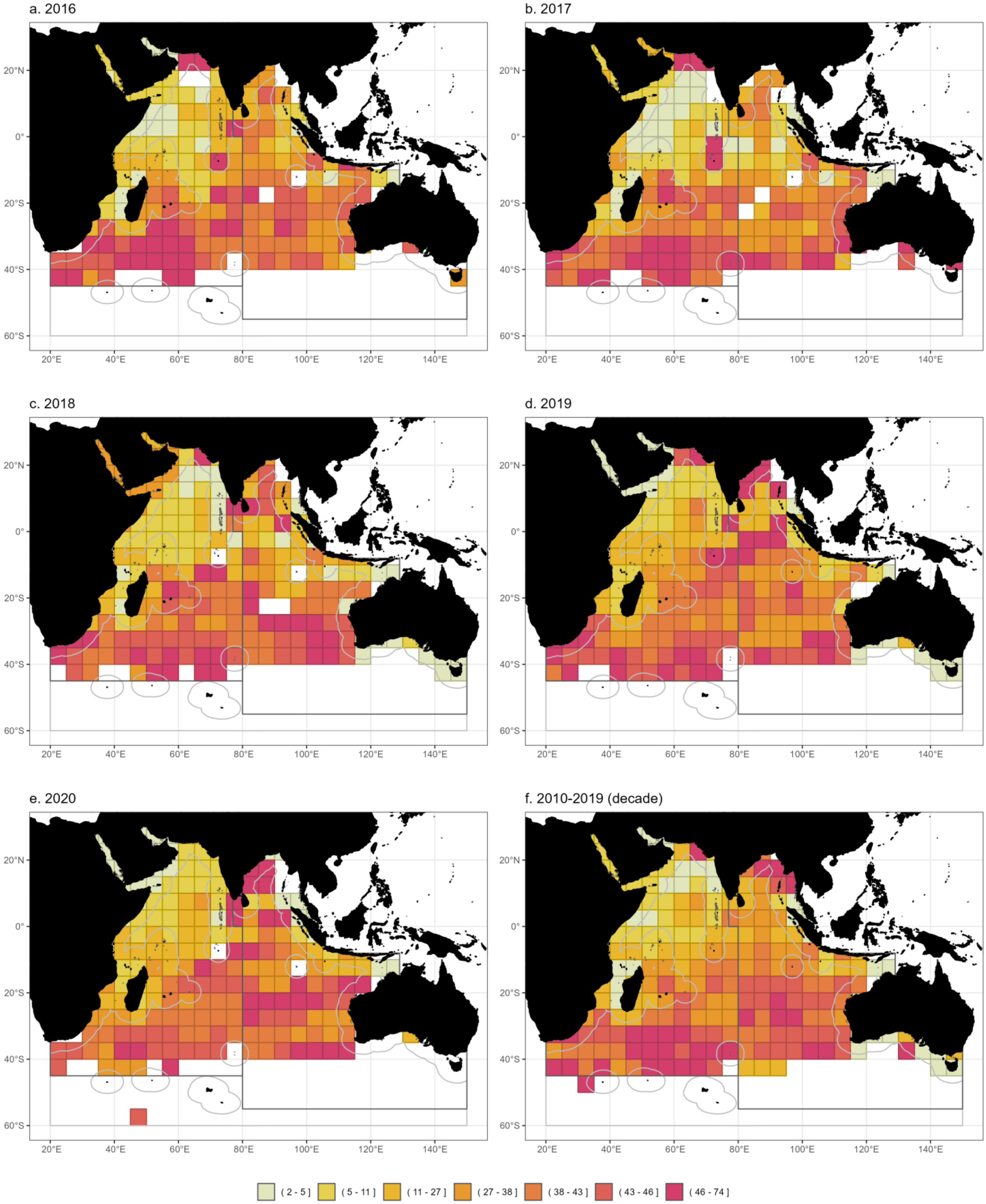

Figure 37: Estimated bigeye tuna average weight (kg/fish) in the catch by year and 5x5 grid, for all fisheries combined for the period 2016-2020 and for the decade 2010-2019. Data source: raised time-area catches

Estimated average weights by fishery group in recent years (2016-2020)

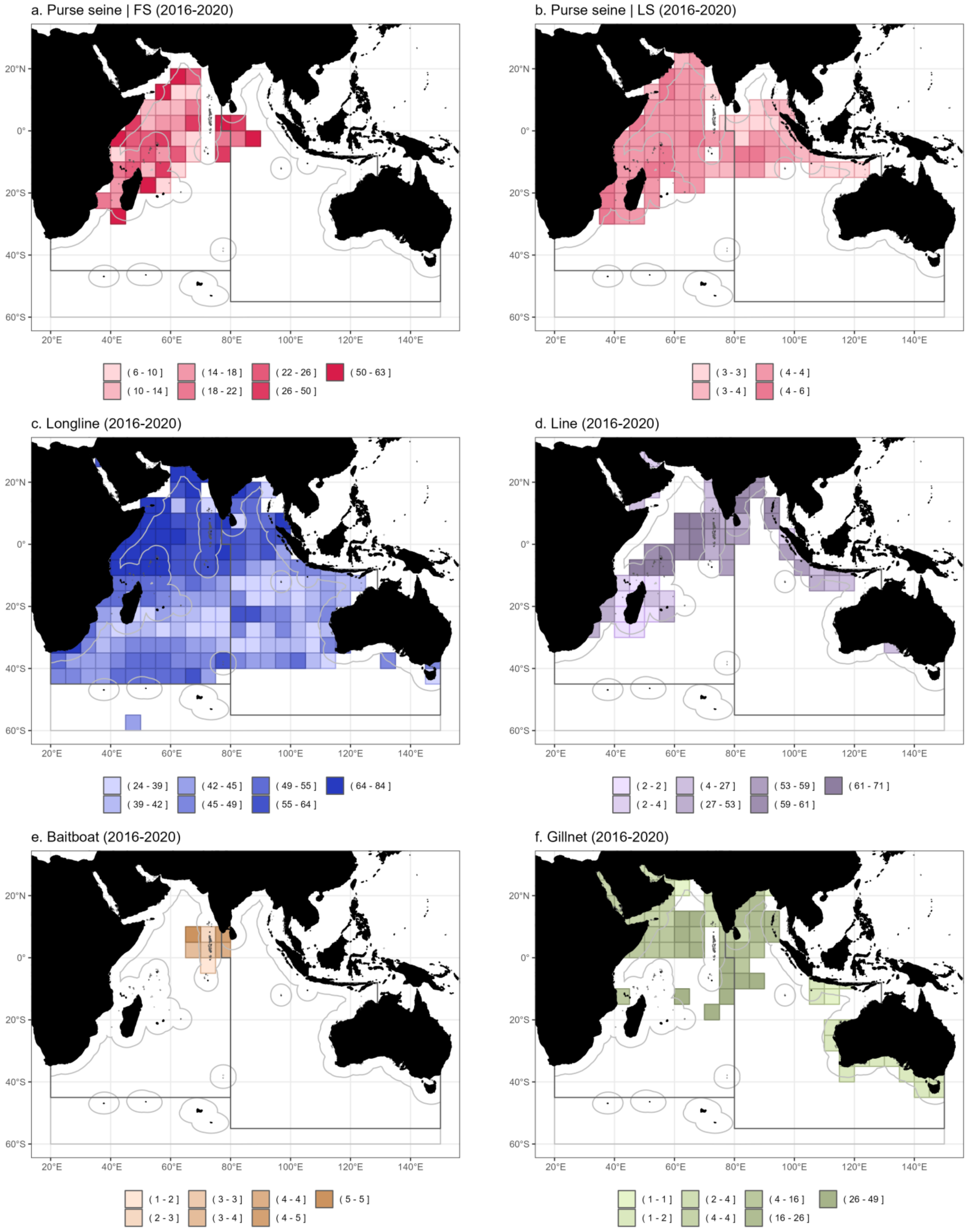

Figure 38: Estimated bigeye tuna average weight (kg/fish) in the catch by 5x5 grid and fishery group for the period 2016-2020. LS = schools associated with floating objects; FS = free-swimming schools. Data source: raised time-area catches

Uncertainties in size-frequency data

The overall quality – as measured by the percentage of nominal catches with size data of quality scores between 0-2 – of size data available for bigeye tuna in IOTC databases is poor, particularly for artisanal fisheries. Almost no size data are available prior to the 1980s and the fraction of data of acceptable quality averages around 51% since 1984 (ranging between 32% and 86%) with a marked increase in quality from about 45% in 2011 to around 86% in 2019 (**Fig. 39a**).

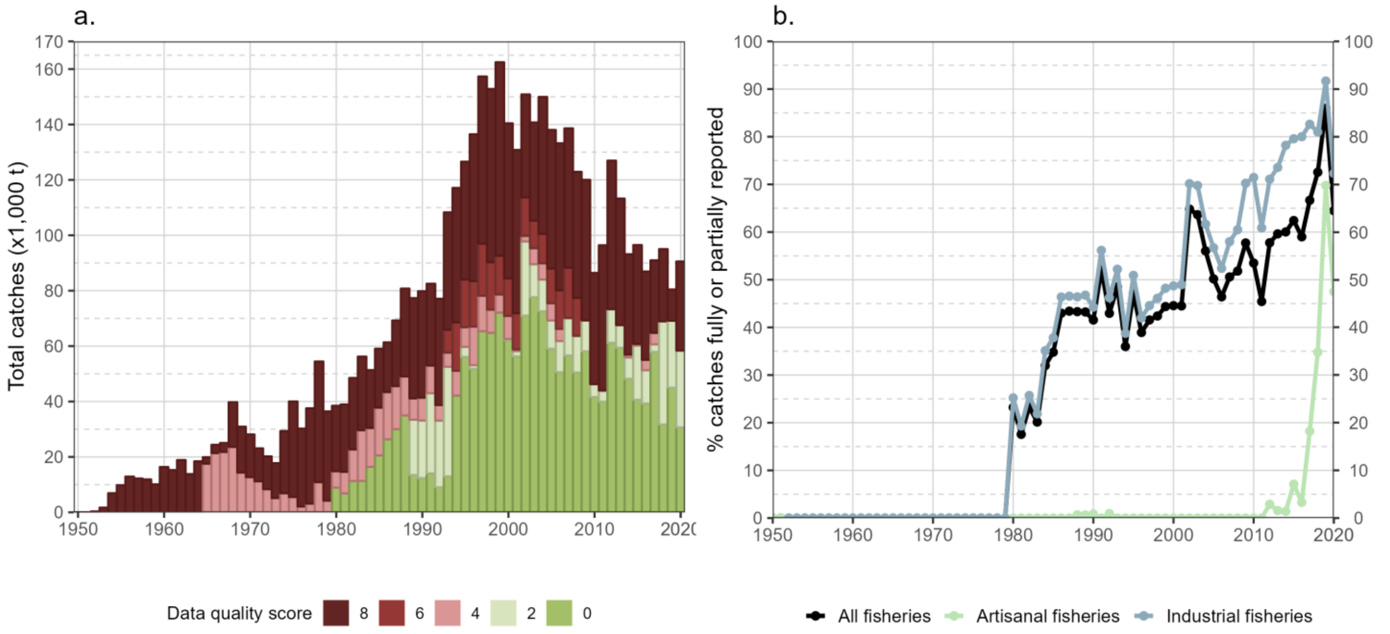

Figure 39: Annual nominal catches (t) of bigeye tuna estimated by quality score (barplot) and percentage of geo-referenced size-frequency data reported to the IOTC Secretariat in agreement with the requirements of Res. 15/02 (lines with dots) for all fisheries (a) and by type of fishery (b), in the period 1950–2020

Industrial purse seine fisheries

Size-frequency data for bigeye tuna are available for several years for the major industrial purse seine fleets. Depending on the fleet and year, though, the data can comprise a mix of raw (as recorded) and raised (to total catches) measurements, which in turn yield sensible differences in the magnitude of the fish sampled across fleets and years. Regarding the EU fleet (and assimilated flags, i.e., Seychelles and Mauritius in the last decade), it has been suggested by national scientists that raw and raised samples differ only in total numbers of fish measured, and that actual differences in the resulting size distribution between the two types of records can be treated as negligible.

Considering the main purse seine fleets, the difference in number of fish sampled between free-swimming schools (**Fig. 40**) and FOB-associated schools (**Fig. 42**) reflects the different percentages of sets taken on the two different fishing modes, with free-school sets being generally lower in numbers than FOB-associated ones.

Also, the length distributions for the two fishing modes tend to have very distinct characteristics, with fish measured from free-swimming schools showing two modes, of which the most marked is located at around 140 cm FL, while fish measured from FOB-associated schools tends to have one single mode at around 50 cm FL.

For free-swimming schools, though, data show some notable exceptions to this trend, specifically for EU,France (2016 and 2018), EU,Spain (2016 and 2019), Mauritius (2017), and Seychelles (2016, 2018 and 2019) (**Table 12**), which all show a much higher first mode in the lower part of the size distribution (at around 50 cm FL) (**Fig. 40**).

In the case of size-frequencies from FOB-associated schools, the main mode is defined around 50 cm FL. Altought some data showing values at around 100 and 130 cm FL for EU,Spain (2018) and EU,France (2019, 2020) not really represent a sub-mode as in free-swimming schools (**Table 13**). Data for these strata have been provided as raw measurements, while all others are reported as raised to total catches, i.e., they can be considered to represent catch-at-size (**Fig. 42**).

Considering the impracticalities of managing a mix of raw and raised size data, as it is currently the case, the IOTC Secretariat is liaising with concerned CPCs to ensure that either both data sets are provided at the same time, or preference is given to raw measurements for both historical and new data submissions.

It is also worth noting that data for the Italian-flagged component of the EU purse seine fleet are only available for the years 2015 and 2017. Also, data from Mauritian purse seiners with correct attribution of the fishing mode are only available for the year 2017, as data for 2018 and 2019 - collected by observers at sea - have been reported to the IOTC Secretariat without explicit information on the school type.

It has been challenging for several fleets to implement regular sampling programmes in 2020 due to the insurgence of the CoViD-19 pandemic, and therefore size data for 2020 is very limited in numbers, particularly when considering fish caught on free-swimming schools for which data is only available from EU,France albeit to levels corresponding to a negligible fraction of what usually provided in the past (**Fig. 40**).

Size-frequency data for 2020 is completely absent for EU,Spain and only available in limited numbers for EU,France, Mauritius, and Seychelles (**Fig. 42**), with EU,Spain confirming their ongoing effort to recover size data from private companies and share it by the end of 2021 (IOTC, pers. comm.).

Size-frequency data for all other industrial purse seine fleets include information from Indonesia, I.R. Iran, Japan, and Republic of Korea (**Fig. 44**). Unfortunately, except for I.R. Iran in 2015, the size data submitted to the IOTC Secretariat by these fleets are not categorized by fishing mode and therefore cannot be directly compared with the corresponding information from all other fleets. At the same time, the characteristics of the size distributions available for each of these fleets are such to suggest that Indonesian purse seiners as well as Japanese and Korean ones (to a lesser extent) are mostly fishing on FOB-associated schools, whereas Iranian purse seiners appear to have been fishing predominantly on free-swimming schools in recent years (**Fig. 44**).

Size data reported by non-EU fleets do not always comply with the requirement of sampling at least one fish per metric ton of retained catches by species. In particular, data from Indonesia and the Republic of Korea (collected by observers at sea) are consistently below the threshold set by Res. 15/02 for all years concerned, and this further questions the representativeness of the length samples reported by the two fleets.

Finally, these fleets seem to have been less affected by the CoViD-19 pandemic, as data were regularly provided by all of them (albeit in lower numbers for Indonesia and I.R. Iran).

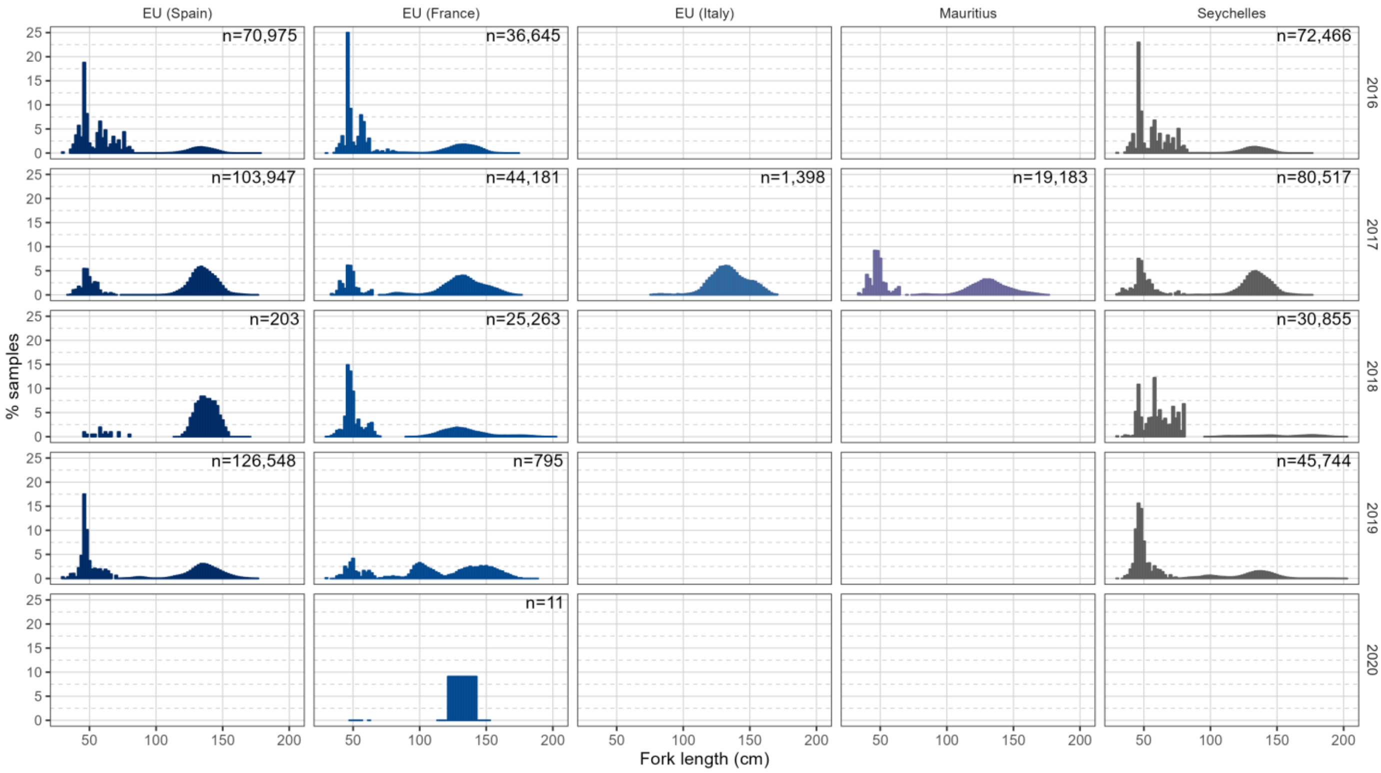

Figure 40: Relative size distribution of bigeye tuna (fork length in cm) recorded for free-swimming schools, by year (2016–2020) and main purse seine fleet. Data source: standardized size-frequency dataset (Res. 15/02)

Table 12: Percentage of sampled bigeye tuna with fork length below 75 cm recorded by the major purse seine fleets fishing on free-swimming schools, as reported for the period 2016-2020. Data source: standardized size-frequency dataset (Res. 15/02)

Fleet	2016	2017	2018	2019	2020
EUESP	77	30	8	56	
EUFRA	71	30	65	24	0
MUS		47			
SYC	75	40	77	72	

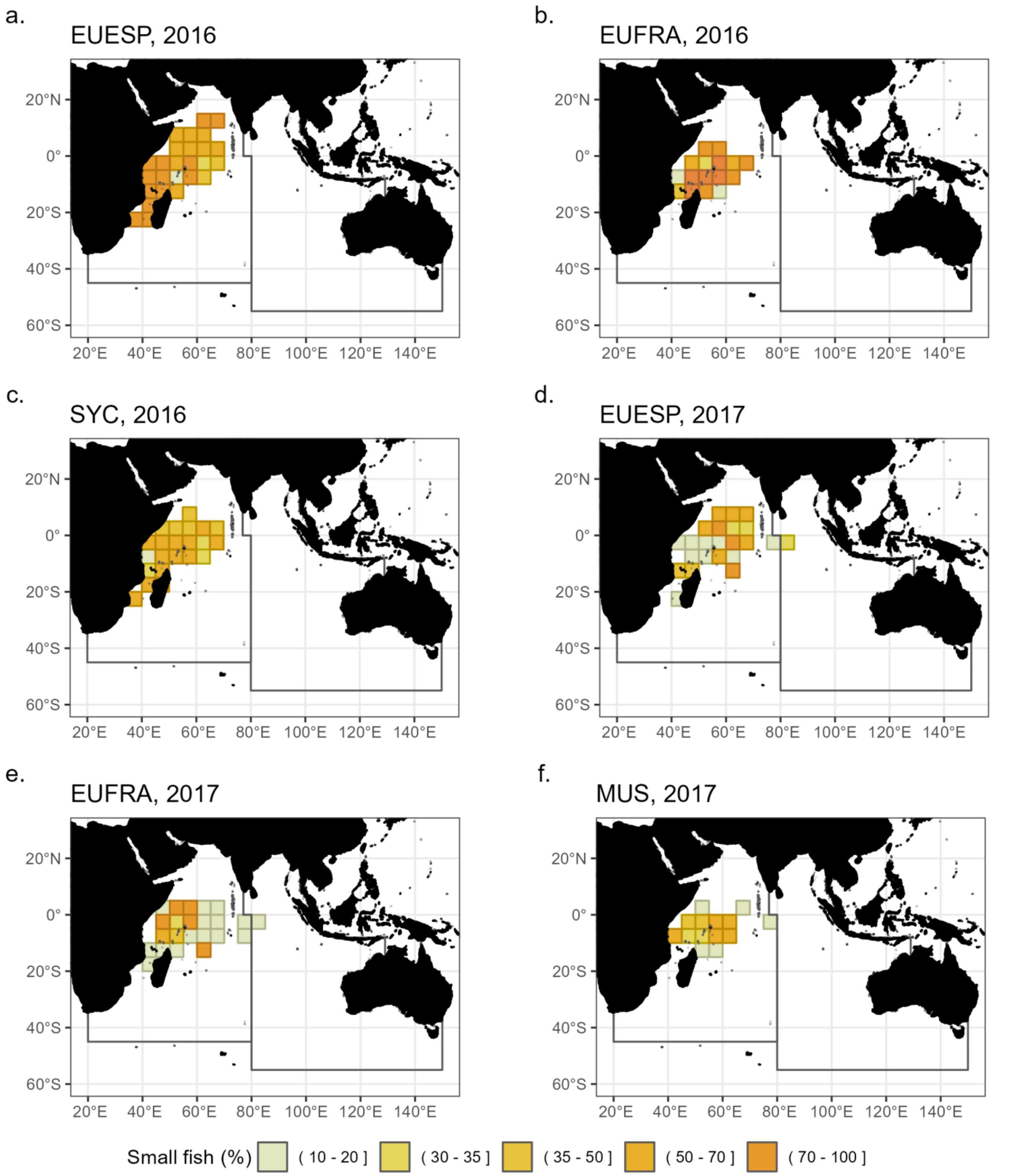

Figure 41: Spatial distribution of sampled bigeye tuna with fork length below 75 cm recorded by the major purse seine fleets fishing on free-swimming schools, as reported for the period 2016-2020. Data source: standardized size-frequency dataset (Res. 15/02)

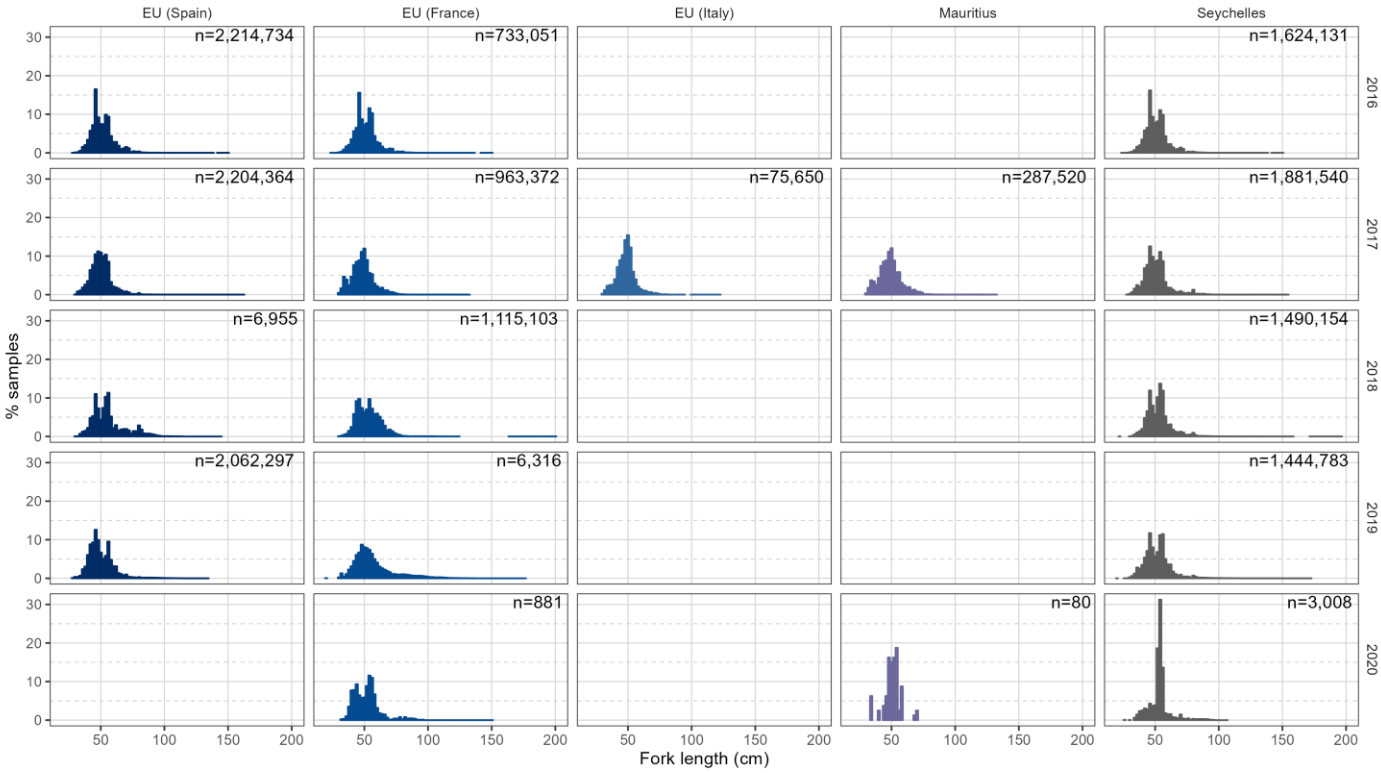

Figure 42: Relative size distribution of bigeye tuna (fork length in cm) recorded for FOB-associated schools, by year (2016–2020) and major purse seine fleet. Data source: standardized size-frequency dataset (Res. 15/02)

Table 13: Percentage of sampled bigeye tuna with fork length above 75 cm recorded by the major purse seine fleets fishing on FOB-associated schools, as reported for the period 2016-2020. Data source: standardized size-frequency dataset (Res. 15/02)

Fleet	2016	2017	2018	2019	2020
EUESP	2	1	12	3	
EUFRA	2	1	2	13	4
MUS		1			0
SYC	2	4	3	4	3

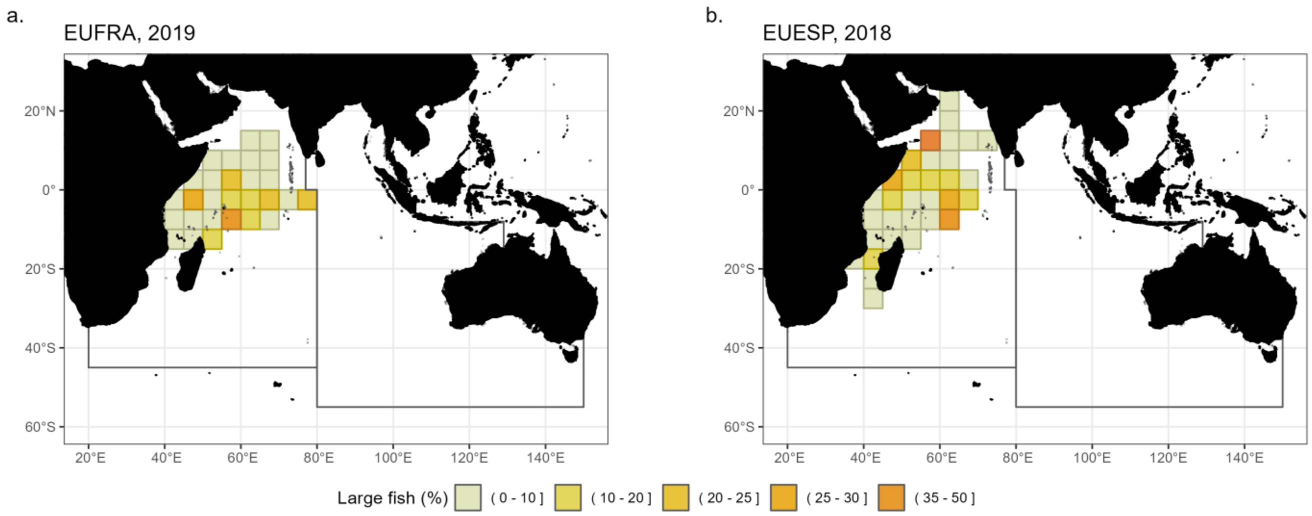

Figure 43: Spatial distribution of sampled bigeye tuna with fork length above 75 cm recorded by the major purse seine fleets fishing on FOB-associated schools, as reported for the period 2016-2020. Data source: standardized size-frequency dataset (Res. 15/02)

Figure 44: Relative size distribution of bigeye tuna (fork length in cm) recorded for unclassified schools, by year (2016–2020) and other purse seine fleet. Data source: standardized size-frequency dataset (Res. 15/02)

Industrial longline fisheries

The major industrial longline fisheries appear to be well-sampled for several years and fleets, with some of them (Japan, Rep. of Korea, China, Taiwan,China and EU,Portugal) having consistently reporting data from observers at sea in recent periods. Nevertheless, ongoing discussions on potential bias in sampling involving the longline fleets of Japan and Taiwan,China (mostly) have not yet been resolved (Geehan & Pierre 2013, Hoyle et al. 2021).

In the case of the Taiwanese deep-freezing longline fleet, the availability of well-sampled size-frequency data and of geo-referenced catches both in numbers and weights allows performing a comparison between the average weights calculated from the two data sets. Average weights from the size-frequency data set are calculated by applying the length-weight conversion equation to the number of samples reported for each size bin (IOTC-2022-WPTT24(DP)-DATA13). Average weights from the catch-and-effort data set are calculated by dividing the catch in weight by the catch in numbers available for the same strata.

The available size-frequency data for the Taiwanese fishery are sampled well-above the minimum level of 1 fish per ton of retained catches (as required by Res. 15/02), if not for the years between 1989 and 1993. The average weights calculated from the two data sets are in (variable) agreement only until 2002: from this point in time onward, the average weight calculated from the size-frequency data set is consistently higher than the average weight calculated from the catch-and-effort data set up to a maximum difference of around 10 kg / fish in favour of the former, as detected in 2020 (when the coverage level of the size-frequency data was of around 5.6 samples per metric ton) (**Fig. 45**).

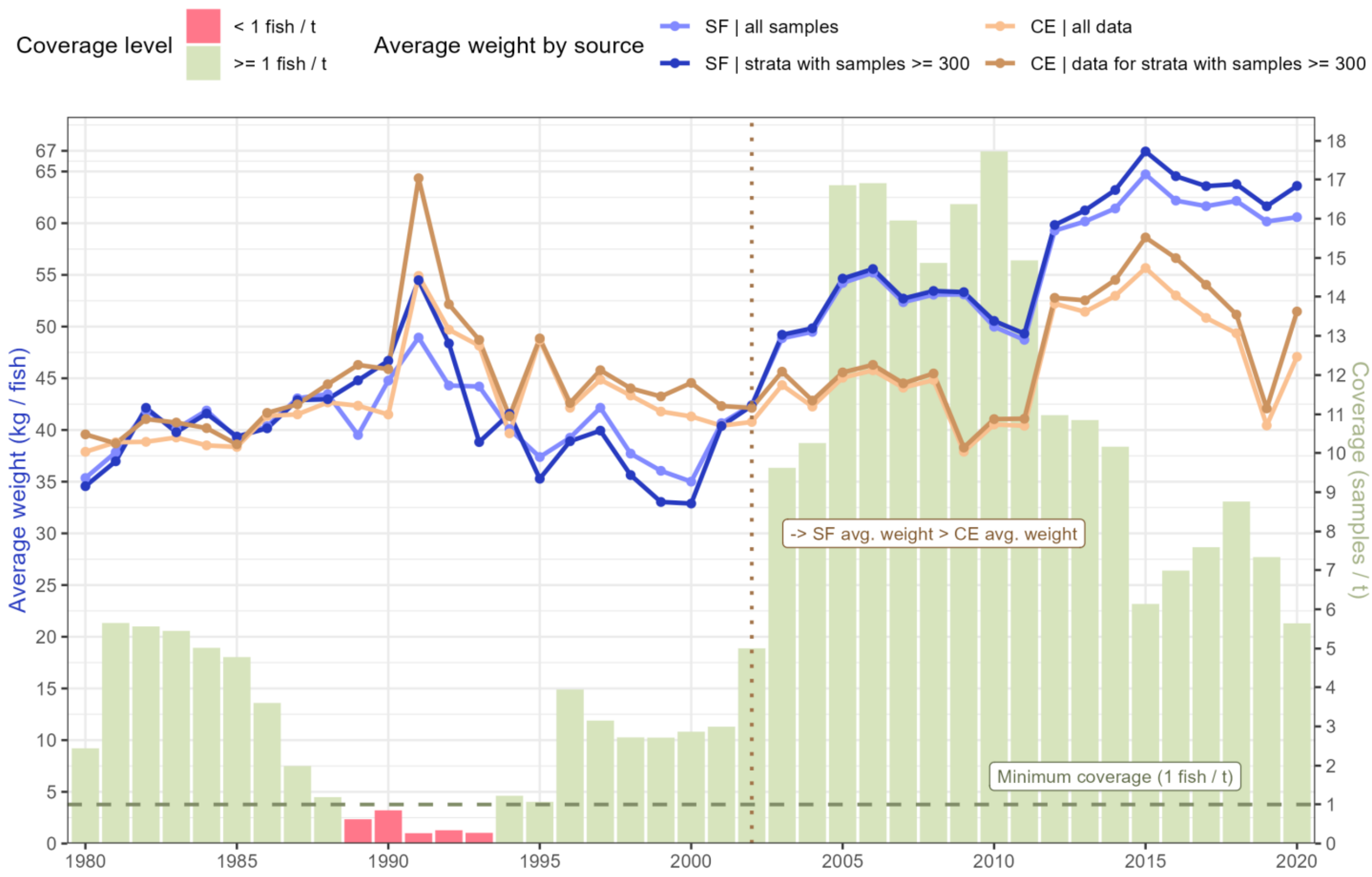

Figure 45: Difference in average weights of bigeye tuna caught by the deep-freezing fleet of Taiwan,China as calculated from the available size-frequency and catch-and-effort data (1980-2020). Data source: standardized size-frequency dataset and time-area catch dataset for longline fisheries (Res. 15/02)

These results seem to imply that, from 2003 onward, either the size sampling is biased towards larger fish, or that the logbook data used to produce the catch-and-effort records submitted to the IOTC Secretariat are inaccurate. This, notwithstanding the fact that length measurements for the Taiwanese longline fleet include samples taken by scientific observers at sea (generally less than 5-10% of total annual samples since 2003).

Further analysis on the size distribution for both Japanese and Taiwanese longliners in the years for which measurements from logbook and observers were both available at the same time (2000-2020) shows that:

- Size data from logbooks and onboard observers is not in full agreement for both Japan and Taiwan,China, with observer data generally showing a higher number of smaller fish measured in the category between 60 and 120 cm FL (**Fig. 46a-b**);
- Size data from logbooks are in partial agreement between the two fleets, with a mode at around 130-140 cm FL, although tails are not fully comparable across the two fleets (**Fig. 47a-b**);
- Size data from observers confirm a tendency in measuring smaller fish in the case of the Japanese fleet (**Fig. 47b**).

In the period considered (2000-2020), bigeye tuna size-frequency records submitted by the Japanese fleet were comprised of 20,949 individuals recorded in logbooks and 66,901 individuals measured by onboard observers. In this case, the number of individuals measured by observers was three times higher than the recorded in logbooks, also because starting from 2012 Japan has been providing - in agreement with the requirements of Res. 15/02 - size-frequency data exclusively sourced from their observer program.

On the contrary, and in the same period considered, bigeye tuna size-frequency records submitted by the Taiwanese fleet were comprised of 5,372,038 individuals recorded in logbooks, and 128,980 individuals measured by onboard observers. In this case, the magnitude of the size data collected by observers corresponds to ~ 2.4% of that reported in logbooks, even though Taiwan,China has been consistently providing both sources of information since 2002.

The heterogeneity between sources of information over the years (particularly for what concerns Japanese longliners) and the fact that the results presented in **Figs. 46-47** were derived from a combination of data that spans across several years and over the entire Indian Ocean (i.e., the spatial location of sampled individuals and variability in fishing grounds across decades were not taken into account) call for further investigations to confirm these preliminary findings.

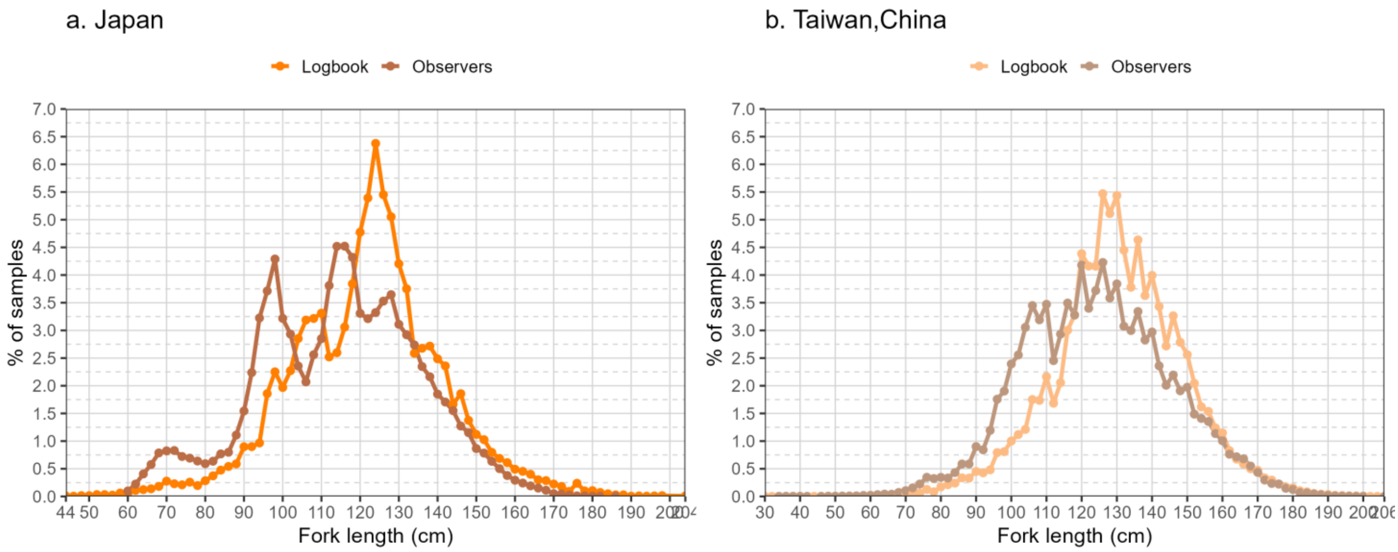

Figure 46: Relative size distribution (fork length in 2 cm size bins) of bigeye tuna caught by the deep-freezing longline fleets of Japan and Taiwan,China, by fleet and origin. Data source: standardized size-frequency dataset (Res. 15/02)

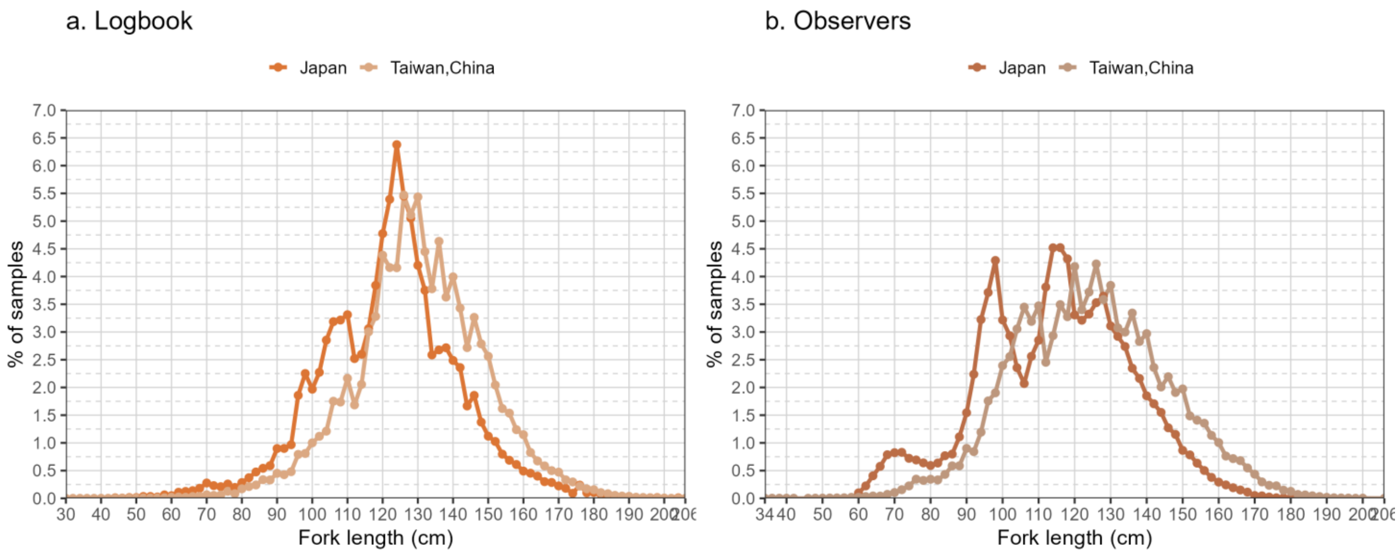

Figure 47: Relative size distribution (fork length in 2 cm size bins) of bigeye tuna caught by the deep-freezing longline fleets of Japan and Taiwan,China, by origin and fleet (2000-2019). Data source: standardized size-frequency dataset (Res. 15/02)

Coverage levels of bigeye tuna samples over the period considered indicate that Taiwanese longliners were regularly exceeding the minimum threshold of 1 measured fish per metric ton of retained catches. Size-frequency data from the other longline fleets reached or surpassed that level only in afew years over the same period with the exception of those from Seychelles which are relatively well sampled (**Fig. 48c-e**).

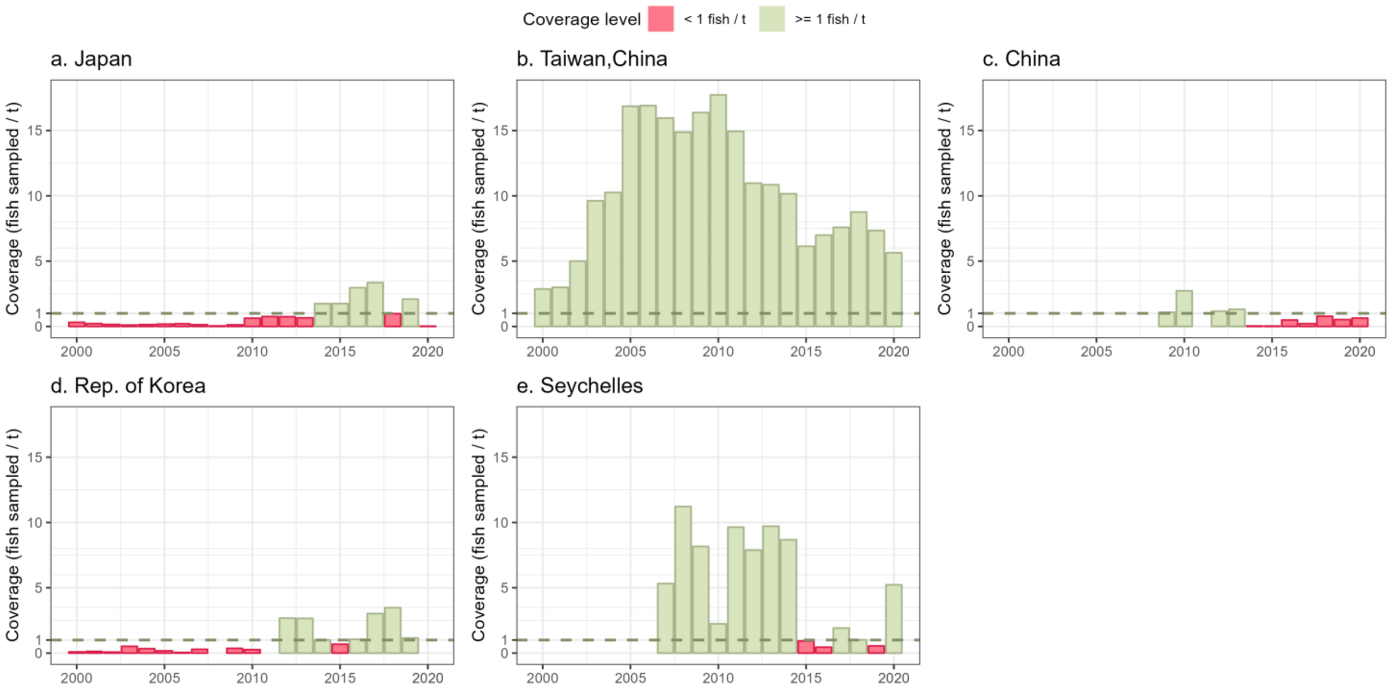

Figure 48: Size-frequency samples coverage (number of fish measured by t of retained catches) of bigeye tuna caught by the deep-freezing longline fleets of Japan (a), Taiwan,China (b), China (c), Rep. of Korea (d) and Seychelles (e), by fleet and year (2000-2020). Data source: standardized size-frequency dataset (Res. 15/02)

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