REVIEW OF YELLOWFIN TUNA STATISTICAL DATA

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Introduction

Total nominal catches reported for the 16 species under the mandate of the Indian Ocean Tuna Commission (IOTC) have steadily increased from the 1950s to reach a maximum of more than 1.91 million t in 2018 and 1.8 million t in 2020. Tropical tuna have always dominated the total IOTC catch between 1950 and 2020, although their contribution has varied over time in relation with different factors such as the expansion of fisheries targeting other species categories, the inception of the purse seine fishery in the 1980s, and the influence of piracy threat in the late 2010s. In 2020, the total catch of tropical tuna in the Indian Ocean has been estimated at 1.07 t, reaching 59.3% of catches of all IOTC species combined.

The overarching objective of the paper is to provide participants at the regular meeting of the 23rd Session of the IOTC Working Party on Tropical Tunas (WPTT23(AS)) with a review of the status of the information available on yellowfin tuna (*Thunnus albacares*). The document provides an overview of the data available in the IOTC Secretariat databases as of October 2021 and describes the progress achieved in relation to the collection and verification of data, identifies problem areas and proposes actions that could be undertaken to improve them.

Materials

Several fisheries data sets shall be reported to the IOTC Secretariat by the Contracting Parties and Cooperating Non-Contracting Parties (CPCs) as per the IOTC Conservation and Management Measures (CMMs) and following the standards and formats defined in the IOTC Reporting guidelines. Although not mandatory, the use of the IOTC forms is recommended to report the data to the Secretariat as they facilitate data curation and management.

Nominal catch data

Nominal catches correspond to the total retained catches (in live weight) estimated per year, Indian Ocean major area, fleet, and gear (IOTC Res. 15/02) and can be reported through IOTC form 1RC. In addition, in order to support the monitoring of the catch limits implemented by some industrial fisheries as part of the rebuilding plan for yellowfin tuna, IOTC Res. 19/01 requests CPCs to submit their catches of yellowfin tuna from 2019 explicitly disaggregated by vessel length and area of operation (i.e., for vessel of 24 m overall length and over, and for those under 24 m if they fish outside the Exclusive Economic Zone (EEZ) of the flag state) (IOTC Form 1RC-YFT).

Changes in the IOTC consolidated data sets of nominal catches (i.e., raw and best scientific estimates) may be required as a result of:

i. Updates, received by December 30th each year, of the preliminary data for longline fleets submitted by June 30th of the same year (IOTC Res. 15.02);

ii. Revisions of historical data by CPCs following corrections of errors, addition of missing data, changes in data processing, etc.

iii. Changes in the estimation process performed by the Secretariat based on evidence of improved methods and/or assumptions (e.g., selection of proxy fleets, updated morphometric relationships) and upon endorsement by the Scientific Committee.

Geo-referenced catch and effort data

Catch and effort data refer to fine-scale data, usually from logbooks, reported in aggregated format and stratified per year, month, grid, fleet, gear, type of school, and species (IOTC Res. 15/02). The IOTC forms designed for reporting geo-referenced catch and effort data vary according to the nature of the fishing gear (e.g., surface, longline, and coastal gears). In addition, information on the use of fish aggregating devices (FADs) and activity of the support vessels that assist industrial purse seiners also has to be collected and reported to the Secretariat through IOTC forms 3FA and 3SU.

Discard data

The IOTC follows the definition of discards adopted by FAO in previous reports (Alverson et al. 1994, Kelleher 2005) which considers all non-retained catch, including individuals released alive or discarded dead. Estimates of total annual discard levels in live weight (or number) by Indian Ocean major area, species and type of fishery shall be reported to the Secretariat as per IOTC Res. 15/02. The IOTC form 1DI has been designed for the reporting of discards and the data contained shall be extrapolated at the source to represent the total level of discards for the year, gear, fleet, Indian Ocean major area, and species concerned, including turtles, cetaceans, and seabirds.

Nevertheless, discard data reported to the Secretariat with IOTC Form 1DI are generally scarce, not raised, not complying with all IOTC reporting standards. For these reasons, the most accurate information available on discards comes from the IOTC Regional Observer Scheme (IOTC Res. 11/04) that aims to collect detailed information (e.g., higher spatio-temporal resolution, fate) on discards of IOTC and bycatch species for industrial fisheries (see below).

Size frequency data

The size composition of catches may be derived from the data set of individual body lengths or weights collected at sea and during the unloading of fishing vessels. The IOTC Form 4SF provides all fields requested for reporting size frequency data to the Secretariat following a stratification by fleet, year, gear, type of school, month, grid and species as required by IOTC Res. 15/02. While the great majority of size data reported with IOTC Form 4SF are for retained catches, some size data on fish discarded at sea may be collected through onboard observer programs and reported to the Secretariat as part of the Regional Observer Scheme (see below).

Socio-economic data

The IOTC Form 7PR has been designed to voluntarily report prices of fish per type of product and market for the target species of Indian Ocean tuna and tuna-like species. To date, very little information is available on the socio-economics of tuna and tuna-like fisheries (e.g., sale price, operating costs, jobs) at the IOTC Secretariat.

Regional Observer Scheme

The IOTC definition for bycatch may differ from those used in other areas and fisheries as bycatch species correspond to all species other than the 16 IOTC listed in Annex B of the IOTC Agreement, whether caught or interacted with by fisheries for tuna and tuna-like species in the IOTC area of competence. Hence, early juveniles of tropical tunas (<1-1.5 kg) that are generally not marketable are not considered as a bycatch of tuna fisheries although they are not targeted in most cases.

Resolution 11/04 on a *Regional Observer Scheme* (ROS) makes provision for the development and implementation of national observer schemes among the IOTC CPCs starting from July 2010 with the overarching objective of collecting *"verified catch data and other scientific data related to the fisheries for tuna and tuna-like species in the IOTC area of competence"*. The ROS aims to cover *"at least 5% of the number of operations/sets for each gear type by the fleet of each CPC while fishing in the IOTC Area of competence of 24 meters overall length and over, and under 24 meters if they fish outside their EEZs shall be covered by this observer scheme"*. Observer data collected as part of the ROS include: (i) fishing activities and vessel positions, (ii) catch estimates with a view to identifying catch composition and monitoring discards, bycatch, and size frequency, (iii) gear type, mesh size and attachments employed by the master, and (iv) information to enable the cross-checking of entries made to the logbooks (i.e., species composition and quantities, live and processed weight and location). A first technical description of the ROS data requirements is available in Athayde & IOTC (2018).

(IOTC 2020c) provides a comprehensive description of the status, coverage, and data collected as part of the ROS. Although incomplete and characterized by a large variability in coverage between fisheries and over space and time, observer data include information on the fate of the catches (i.e. retained or discarded at sea) as well as on the condition of the discards. Observer data are also the main source of spatial information on interactions between IOTC fisheries and seabirds, marine turtles, cetaceans, as well as any other species encountered.

To date, the ROS regional database contains information for a total of 1,492 commercial fishing trips (845 from purse seine vessels and 647 from longline vessels of various types) made during the period 2005-2019 from 7 fleets: Japan, EU,France and Sri Lanka for longline fisheries and EU,Spain, EU,France, Japan, Korea, Mauritius, and Seychelles for purse seine fisheries. In addition, some observer reports have been submitted to the Secretariat by some CPCs (e.g., Taiwan,China) but data sets were not provided in electronic format at the operational level following the ROS standards, *de facto* preventing the entry of the data in the ROS regional database.

Tagging data

Release and recovery data gathered in the framework of the Indian Ocean Tuna Tagging Programme (IOTTP), which encompass data gathered during the Regional Tuna Tagging Project – Indian Ocean (RTTP-IO) and data gathered during a series of small-scale tuna tagging projects in Maldives, India, Mayotte, Indonesia and by other institutions, e.g., the Southeast Asian Fisheries Development Center (SEAFDEC) and the National Research Institute of Far Seas Fisheries (NRIFSF), with the support of IOTC. In 2012, the data from past projects implemented in Maldives in the 1990s were added to the tagging database at the Secretariat.

Methods

The release of the curated public-domain data sets for yellowfin tuna is done following some processing data steps which are briefly summarized below.

Data processing

First, standard controls and checks are performed to ensure that the metadata and data submitted to the Secretariat are consistent and include all mandatory fields (e.g., dimensions of the strata, etc.). The controls depend on each type of data set and may require the submission of revised data from CPCs if the original one is found to be incomplete.

Second, a series of processing steps is applied to derive the best scientific estimates of nominal catches for the 16 IOTC species (see **Appendix V** of IOTC (2014)), by implementing the following rules:

a. When nominal catches are not reported by a CPC, catch data from the previous year may be repeated or catches may be derived from a range of sources, e.g., partial catch and effort data, the FAO FishStat database, data on imports of tropical tunas from processing factories collaborating with the International Seafood Sustainability Foundation, etc.;

b. For some specific fisheries characterized by well-known, outstanding issues in terms of data quality, a process of re-estimation of species and/or gear composition may be performed based on data available from other years or areas, or by using proxy fleets, i.e., fleets occurring in the same strata which are assumed to have a very similar catch composition, e.g., Moreno et al. (2012) and IOTC (2018);

c. Finally, a disaggregation process is performed to break down the catches by species and gear when they are reported as aggregates (**Table 1**).

Table 1: List of species groups including yellowfin tuna

Species code	Name	Scientific name
TUN	Tunas nei	*Thunnini*
TUS	True tunas nei	*Thunnus spp*
TUX	Tuna-like fishes nei	*Scombroidei*
AG45	Albacore, yellowfin tuna and bigeye tuna	*Thunnus alalunga; Thunnus albacares; Thunnus obesus*
AG35	Yellowfin tuna and skipjack tuna	*Thunnus albacares; Katsuwonus pelamis*
AG45	Albacore, yellowfin tuna and bigeye tuna	*Thunnus alalunga; Thunnus albacares; Thunnus obesus*
TUN	Tunas nei	*Thunnini*

Third, and applying only to the five major IOTC species (albacore, bigeye tuna, skipjack tuna, yellowfin tuna, and swordfish), geo-referenced catches are raised to the best scientific estimates of nominal catches using available information and by either leveraging data from proxy fleets or adopting substitution schemes when the spatio-temporal information is not available for a given stratum. For this reason, the raised data sets represent the best scientific estimates of the geo-referenced catches given the information available to the Secretariat and the issues with data availability and data quality affecting several fisheries. The raised data are comprised of catches in weight and number and stratified by year, month, fleet, gear, school type (when available) and 5x5 degrees grid, covering the entire time series for which nominal catches are available. The average weight of swordfish in the catch can be computed directly from the raised weights and numbers for each fishery, with the accuracy of the results being directly proportional to the availability and quality of geo-referenced catch and size-frequency data for the stratum.

Fourth, and applying to all 16 IOTC species plus the most common shark species defined in the appendices of IOTC Resolution 15/01, filtering and conversions are applied to the size-frequency data in order to harmonize their format and structure and remove data which are non-compliant with IOTC standards, e.g., because provided with size bins exceeding the maximum width considered meaningful for the species (IOTC 2020a). The standard length measurements considered at IOTC are the eye fork length (EFL; straight distance from the orbit of the eye to the fork of the tail) for black and blue marlins and the fork length (FL; straight distance from the tip of the lower jaw to the fork of the tail) for all other species subject to mandatory size measurements (IOTC 2020a). All size samples collected using other types of measurements are converted into FL and EFL by using the IOTC equations, considering size range and intervals that may vary with species. If no IOTC-endorsed equations exist to convert from a given length measurement for a species to the standard FL and EFL measurements, the original size data are not disseminated but kept within the IOTC databases for future reference.

Last, a specific process is applied to the tagging data collected for the three tropical tuna species, to specifically filter dubious records, correct for potential tag loss, and adjust for under-reporting of recaptures (IOTC 2020b).

Data quality

A scoring system has been designed to assess the quality of the nominal catch, catch-effort, and size-frequency data available at the Secretariat for all IOTC species. The determination of the score varies according to each type of data set and aims to account for reporting coverage and compliance with IOTC reporting standards (**Table 2**). Overall, the lower the score, the better the quality. It is to note that the quality scoring does not account for sources of uncertainty affecting the nominal catches such as under-reporting and misreporting.

Table 2: Key to IOTC quality scoring system

Data set	Criterion	By species	By gear
Nominal catch	Fully available	0	0
	Partially available	2	2
	Fully estimated	4	4
Catch and effort	Available according to standards	0	0
	Not available according to standards	2	2
	Low coverage (<30% logbooks)	2	
	Not available	8	
Size frequency	Available according to standards	0	0
	Not available according to standards	2	2
	Low coverage (<1 fish per ton caught)	2	
	Not available	8	

Results

Nominal catches

Historical trends (1950-2020)

Nominal catches of yellowfin tuna show an increasing trend over the last seven decades with some variability between years. The total catches showed a slow increase between the mid-1950s and mid-1980s, averaging between 18,000 t and 87,000 t, with longliners and gillnetters as the main fisheries (**Table 3** & **Figs. 1-2**).

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

Fishery	1950s	1960s	1970s	1980s	1990s	2000s	2010s
Purse seine | Other		4	143	1,170	2,185	3,590	7,224
Purse seine | FS			18	31,552	64,938	89,204	43,728
Purse seine | LS			17	17,597	56,278	61,890	90,214
Longline | Other				354	5,706	14,488	7,432
Longline | Fresh			615	4,286	47,612	34,157	20,601
Longline | Deep-freezing	21,990	41,352	29,589	33,824	66,077	56,671	17,704
Line | Coastal longline	168	1,262	1,771	3,488	6,158	11,106	27,874
Line | Trolling	1,004	1,820	4,194	6,681	11,204	13,292	17,679
Line | Handline	624	643	2,948	8,030	20,087	34,506	70,164
Baitboat	2,111	2,318	5,810	8,295	12,803	16,072	17,528
Gillnet	1,572	4,115	7,928	12,034	39,199	58,819	77,350
Other	80	189	310	674	1,133	1,746	2,566
Total	27,548	51,704	53,344	127,986	333,379	395,540	400,064

Catches increased rapidly in the early 1980s with the arrival of the purse seiners and increased activity of longliners and other fleets, reaching around 400,000 t by 1993 (**Figs. 1-2**). Exceptionally high catches were recorded between 2003 and 2006 – with the highest catches ever recorded in 2004 at over 540,000 t – while catches of bigeye tuna, which are generally associated with the same fishing grounds as yellowfin tuna, remained at average levels.

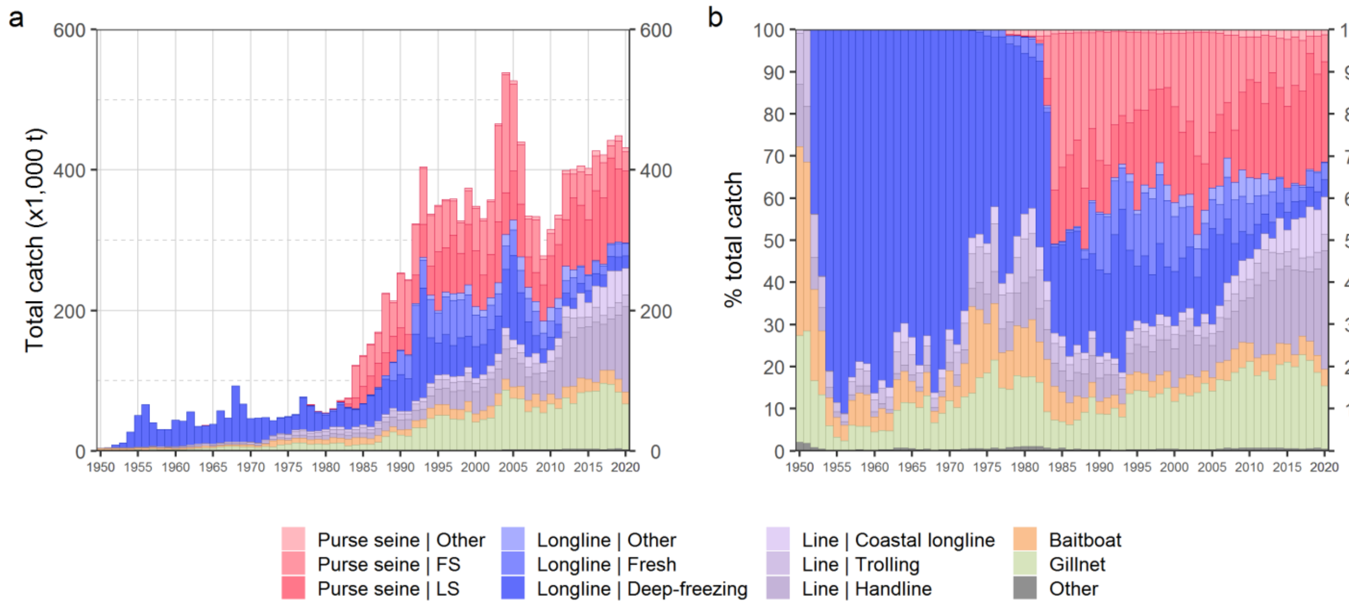

Figure 1: Annual time series of cumulative nominal absolute (a) and relative (b) catches of yellowfin tuna in metric tons (t) by fishery for the period 1950-2020. LS = schools associated with floating objects; FS = free-swimming schools. Data source: yellowfin tuna raised time-area catches

Between 2007 and 2010 catches dropped considerably (to around 52% of 2004 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 EEZ of Somalia. Catches by purse seiners also declined over the same period – albeit not to the same extent as longliners – due to the presence of security personnel onboard purse seine vessels of the EU and Seychelles, which has enabled fishing operations to continue. Since 2011, catches have steadily increased from 338,000 t to an average of around 430,000 t between 2016 and 2020, and a maximum close to 450,000 t in 2019 (**Table 4**). Furthermore, total catch levels of around 440,000 t reported for 2018 might be underestimated (to some extent) because of changes in data processing methodology confirmed by EU,Spain for its purse seine fleet for that year (IOTC 2019a).

Table 4: Best scientific estimates of annual nominal catches of yellowfin tuna by fishery in metric tons (t) for the period 2011-2020. The background intensity color of each cell is directly proportional to the catch level. Data source: yellowfin tuna raised time-area catches

Fishery	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Purse seine | Other	5,516	5,479	6,235	8,323	9,102	7,390	10,855	7,145	6,876	5,309
Purse seine | FS	36,453	64,593	34,459	47,426	63,963	49,460	50,700	17,944	40,147	27,557
Purse seine | LS	76,659	66,166	101,898	86,417	78,395	99,268	94,479	121,699	103,774	102,686
Longline | Other	13,899	20,626	11,699	1,081	1,204	1,544	1,593	1,464	1,990	543
Longline | Fresh	22,727	17,818	28,992	23,769	22,028	16,817	13,984	16,827	19,787	17,669
Longline | Deep-freezing	19,814	18,849	15,028	14,523	16,608	17,740	16,482	20,686	19,443	17,716
Line | Coastal longline	11,255	15,167	13,245	34,072	20,866	30,484	40,560	52,555	45,072	38,009
Line | Trolling	17,359	21,379	27,320	15,096	14,150	21,135	12,728	15,767	17,742	16,960
Line | Handline	58,071	78,565	70,016	71,484	73,901	86,023	65,557	72,959	91,668	121,443
Baitboat	14,009	15,512	24,055	20,542	17,642	12,391	18,370	20,030	18,625	16,992
Gillnet	57,848	72,749	65,191	80,416	82,572	82,881	94,515	92,437	80,359	64,843
Other	2,318	2,744	2,748	2,839	2,397	2,484	1,994	2,626	3,161	1,969
Total	335,928	399,646	400,885	405,987	402,828	427,619	421,818	442,139	448,642	431,696

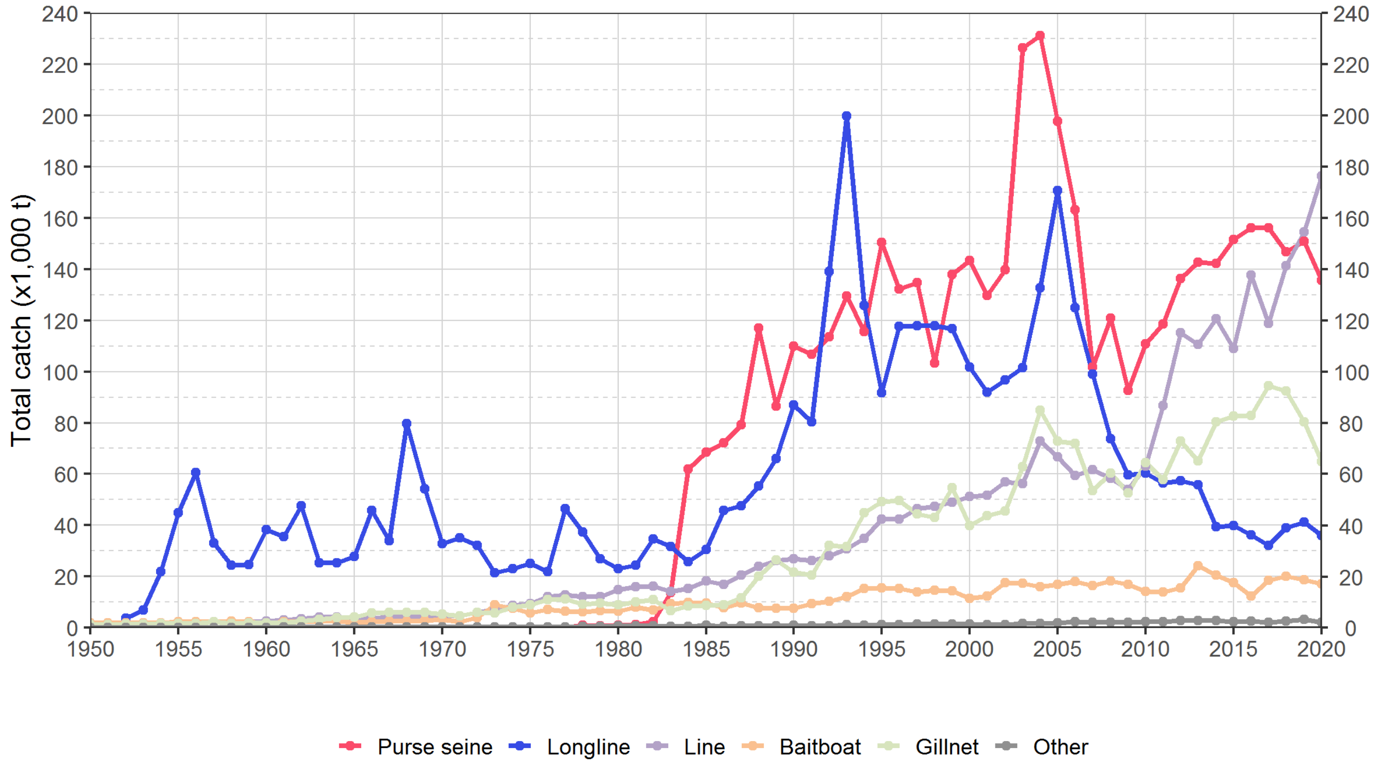

Figure 2: Annual time series of nominal catches of yellowfin tuna by fishery group in metric tons (t) for the period 1950-2020. Data source: [best scientific estimate of nominal catches]

Contrary to other oceans, the artisanal fishery component of yellowfin catches in the Indian Ocean has always been substantial, accounting annually for more than 40% of the total catches from the mid-1970s to the early 1980s and since 2007. Between 2016 and 2020, the mean annual catches of artisanal fisheries were close to 210,000 t (47% of total catches), while industrial fisheries caught on average 230,000 t every year (**Fig. 3**).

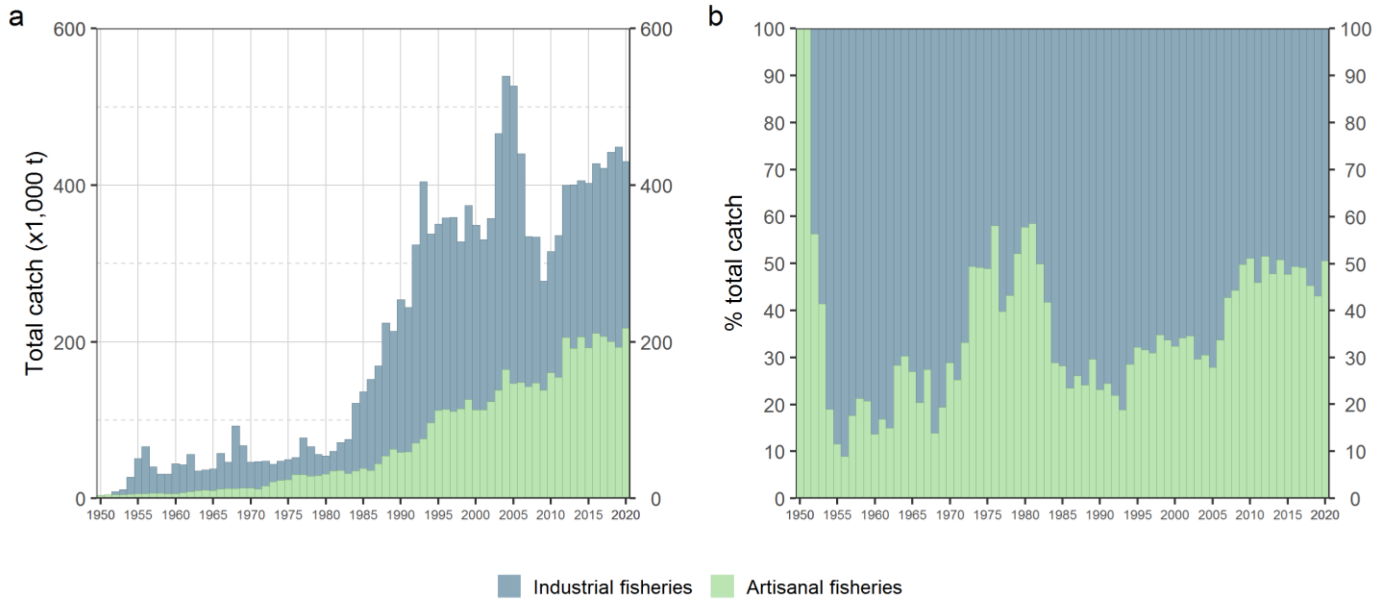

Figure 3: Annual time series of cumulative nominal absolute (a) and relative (b) catches of yellowfin tuna by type of fishery in metric tons (t) for the period 1950-2020. Data source: [best scientific estimate of nominal catches]

Regarding purse seine fisheries, historical captures of yellowfin tuna by fishing mode showed a general increasing trend in percentages of catches from FOB-associated schools from 2004 onward, accompanied by yearly fluctuations on the relative percentages of the two fishing modes, which can vary of up to 20% between two consecutive years. Regarding the main component flags of the EU purse seine fleet, EU,France appears to have generally relied less on catches from

FOB-associated schools, to the point that the percentage over total yellowfin tuna catches for the flag exceeded 60% only in 2011 and from 2017 onward. On the contrary, EU,Spain as well as Seychelles regularly reported over 60% of their yellowfin tuna catches from FOB-associated schools since 2009. Between 2011 and 2020, catches from all purse seine fleets combined showed a fluctuation between 51% and 87% in the fraction of catches from FOB-associated schools. Around 87% of yellowfin tuna catches caught with purse seines came from FOB-associated schools in 2018, and around 79% in 2020 (**Fig. 4**).

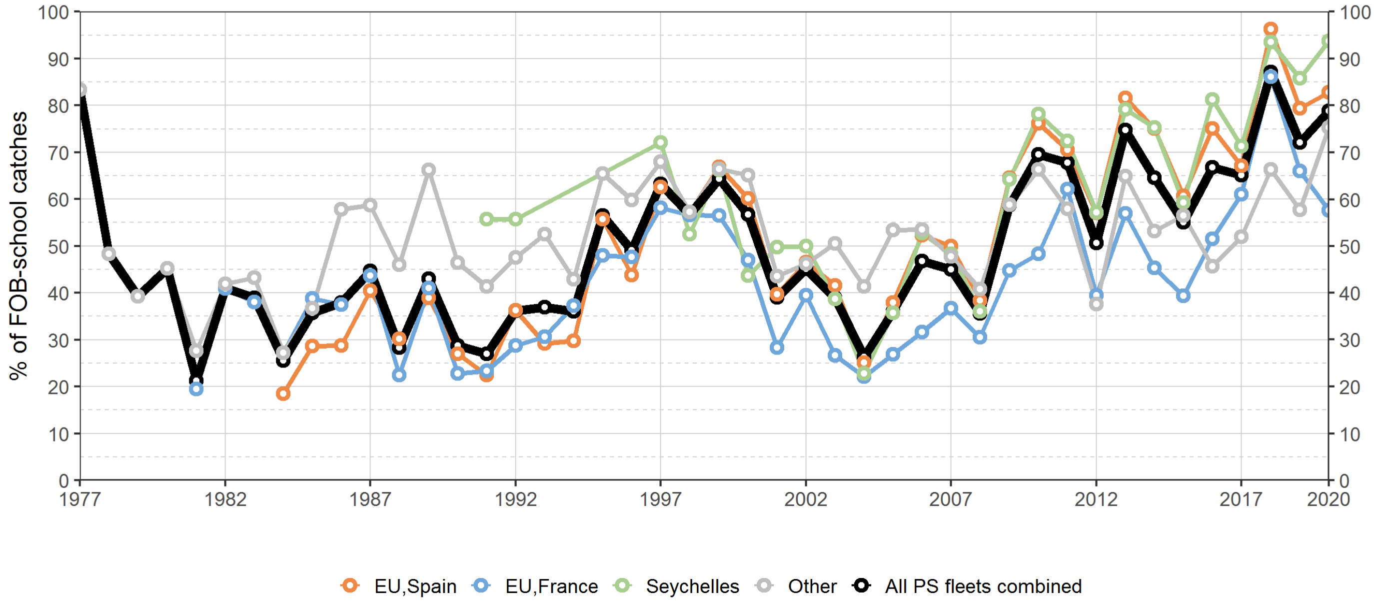

Figure 4: Annual percentages of purse seine FOB-associated catches of yellowfin tuna by fleet for the period 1977-2020. *Other* includes purse seine fleets such as ex-Soviet Union, I.R. Iran, France (Mayotte), Mauritius, Japan, Korea, Indonesia, Thailand, EU,Italy, Belize and others. Data source: time-area catch dataset for purse seine fisheries (Res. 15/02)

Main fishery features (2016-2020)

Yellowfin tuna is caught by a large diversity of fisheries from many fleets operating all over the Indian Ocean. Between 2016 and 2020, purse seine fisheries (all fishing modes combined, and including catches from small purse seiners and ringnetters) reported an average annual catch of around 150,000 t of yellowfin tuna, contributing to around 34% of the total nominal catches (**Table 5**). During the same period, line fisheries in coastal areas represented the other major contributor of yellowfin tuna catches, with an average annual catch of around 146,000 t of which 88,000 t caught with handlines, 41,000 t with coastal longlines, and 17,000 t with trolling lines.

Between 2016 and 2020, gillnet fisheries represented 4% of the recent catches with more than 80,000 t caught annually. Industrial longline and baitboat fisheries represented around 2% and 1% of the yellowfin tuna catches, respectively (**Table 5 & Fig. 2**).

Table 5: Mean annual catches of yellowfin tuna by fishery in metric tons (t) between 2016 and 2020. LS = schools associated with floating objects; FS = free-swimming schools. Data source: yellowfin tuna raised time-area catches

Fishery	Fishery code	Catch	Percentage
Purse seine | LS	PSLS	104,381	24.0
Line | Handline	LIH	87,530	20.2
Gillnet	GN	83,007	19.1
Line | Coastal longline	LIC	41,336	9.5
Purse seine | FS	PSFS	37,162	8.6
Longline | Deep-freezing	LLD	18,413	4.2
Baitboat	BB	17,282	4.0
Longline | Fresh	LLF	17,017	3.9
Line | Trolling	LIT	16,867	3.9
Purse seine | Other	PSOT	7,515	1.7
Other	OT	2,447	0.6
Longline | Other	LLO	1,427	0.3

In recent years (2016-2020), average annual catches of yellowfin tuna have been shared between several CPCs, to the point that around 80% of all annual catches is accounted for by nine distinct fleets, with I.R. Iran, EU,Spain, Maldives, and Seychelles reaching (or getting close to) 10% of average annual catches each (**Fig. 5**).

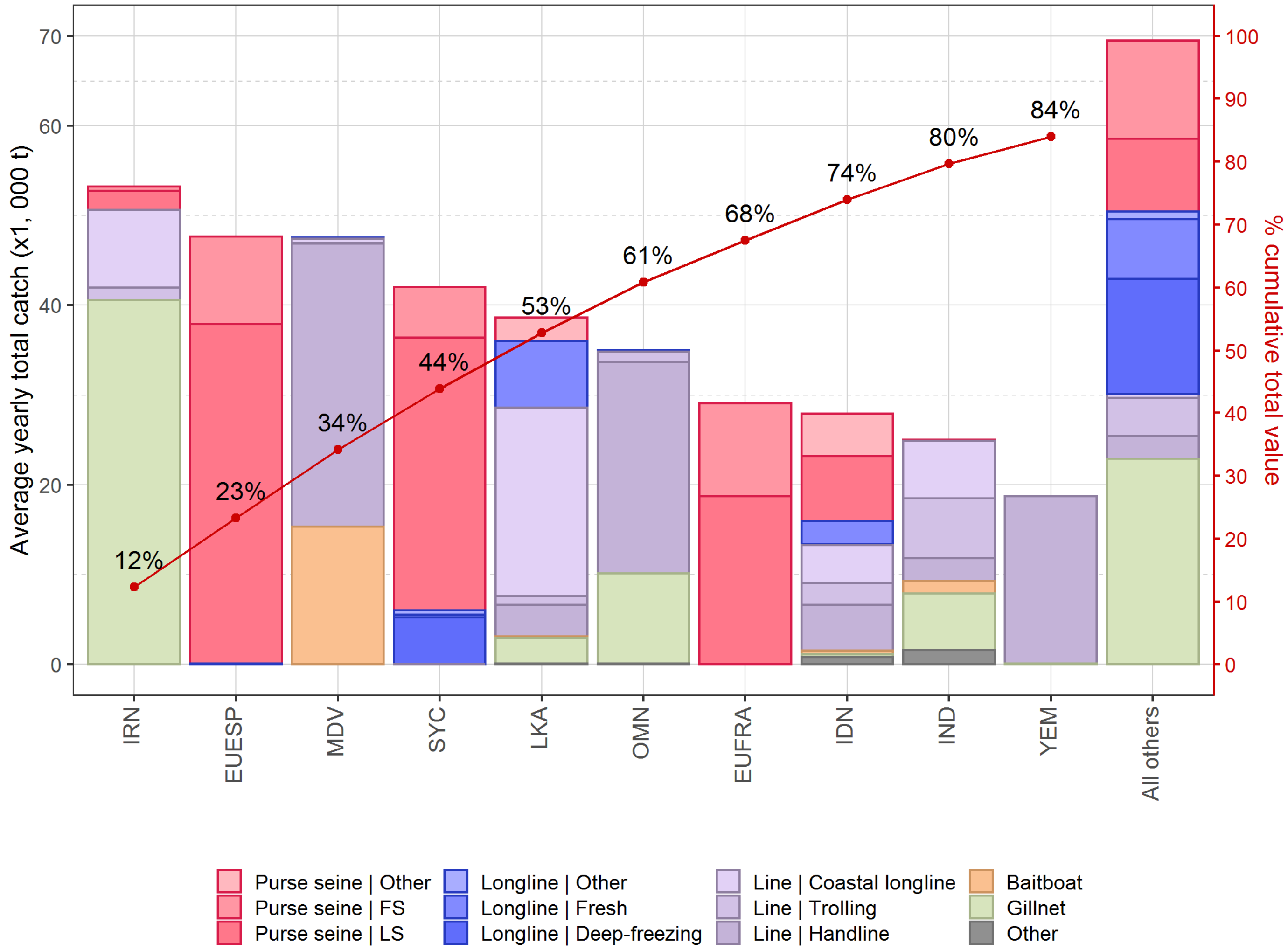

Figure 5: Mean annual catches of yellowfin tuna by fleet and fishery in metric tons (t) between 2016 and 2020, with indication of cumulative catches by fleet. FS = free-swimming schools; LS = schools associated with floating objects. Data source: yellowfin tuna raised time-area catches

Catch trends by fishery group in the same period (2016-2020) show a slight decrease in catches from purse seiners since 2016, a relatively stable trend in catches from longliners and baitboats (as well as from vessels using all other gears), a generalized decrease in catch levels for gillnetters and a marked increasing trend in catches reported from line fisheries, that in 2020 recorded a peak in catches of around 180,000 t since the beginning of the period considered (**Fig. 6**).

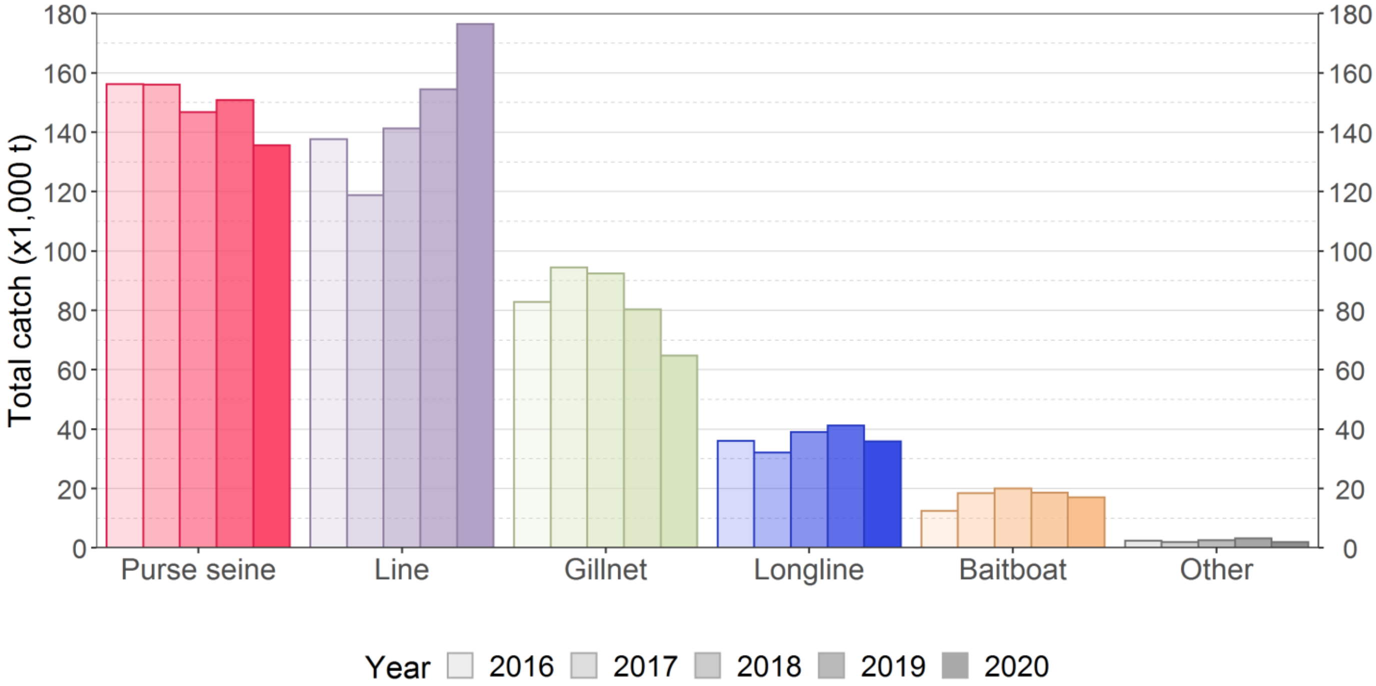

Figure 6: Annual catch trends of yellowfin tuna by fishery group in metric tons (t) between 2016 and 2020. Data source: [best scientific estimate of nominal catches]

Regarding purse seines, recent catch trends show that all the major fleets (EU,Spain, Seychelles, and EU,France) have reduced their catch levels since 2016, with the only notable exception being Indonesia (which ranks fourth in terms of catches of yellowfin tuna for the period and fishery considered) and whose catches increased sensibly compared to 2016 levels (**Fig. 8a**). Mauritius (aggregated under *All others*) ranks fifth in this category, with an increasing trend in purse seine yellowfin catches detected from 2016 to 2019, followed by a sharp decrease in 2020 associated to a comparable decrease in efforts. Overall, the decrease in catches strongly varied with the type of school association. Catches on free-swimming schools showed a sharp decline between 2016 and 2018 for the EU and Seychelles fleets and re-increased thereafter, although at lower catch levels than reported for 2016 (**Fig. 7a**). Meanwhile, the catches on FOB-associated schools showed a decreasing trend between 2016 and 2020 for all fleets (except for Indonesia), with the notable exception of 2018 when a maximum total catch of more than 120,000 t caught on FOB-associated schools (**Fig. 7b**).

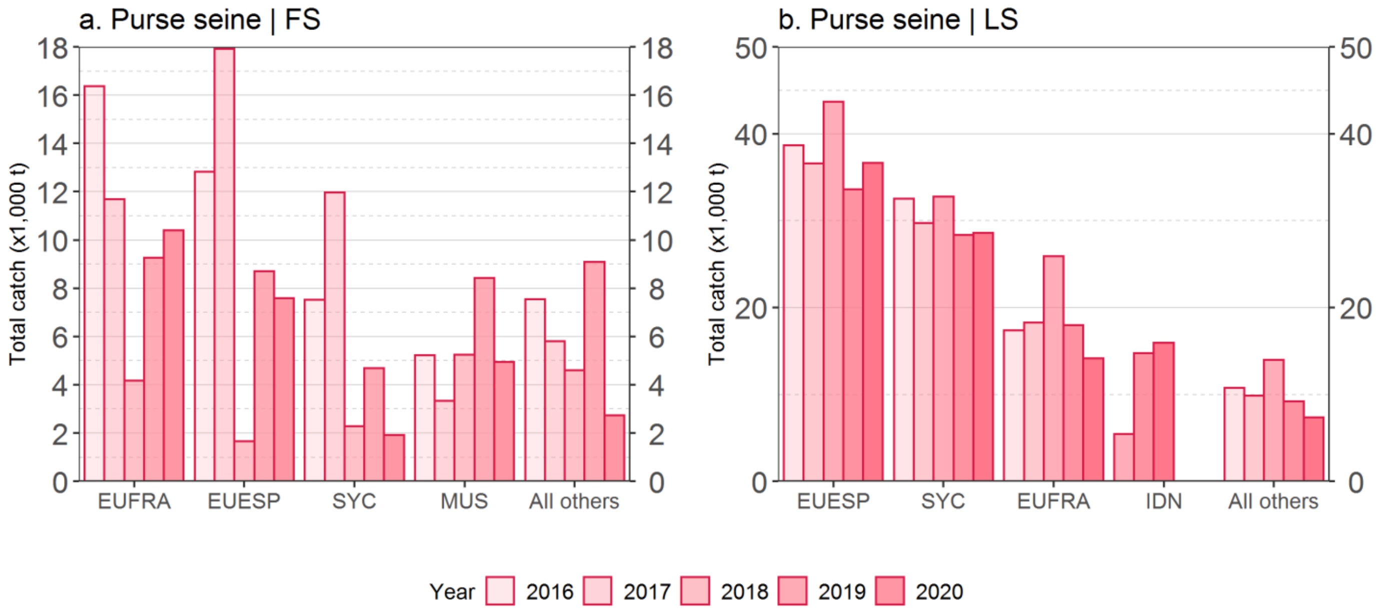

Figure 7: Annual purse seine catch trends of yellowfin tuna by fishing mode and fleet in metric tons (t) between 2016 and 2020. FS = free-swimming schools; LS = schools associated with floating objects

Recent longline catch trends by fleet also show a mixed situation when focusing on the key fleets. While longliners from Taiwan,China, China, and Japan (with the latter now aggregated under *All others*) have maintained or decreased their yellowfin tuna catch levels since 2016, catches reported by Sri Lanka and Seychelles have increased consistently in the last five years. All other longline fleets have reported relatively stable catch levels in the period concerned (**Fig. 8b**).

Fleets using line or assimilated gears (handline, troll-line, coastal longline) show generally stable trends in catch levels since 2016, with the only notable exception of handlines from Maldives, which appear to be facing a contraction phase compared to the peak year (2016), and Oman, which has instead registered an extremely marked increase in 2020 compared to previous years. Sri Lanka is also one of the main fleets whose catches of yellowfin tuna from their line fisheries increased during the last five years (as is also the case for all other line fleets combined) while catches from the handline fisheries of Yemen are estimated to be at constant levels due to the lack of information from the source (**Fig. 8c**).

The contribution to the increased catch levels for all the fleets aggregated as *All others* is mostly due to catches reported by coastal longliners of I.R. Iran, which has been supporting the development of this fishery in recent years (Hosseini et al. 2018).

Finally, catch trends for baitboat and gillnet fisheries (as well as fleets using all other gears) show a relatively stable situation over the last five years, with the only exception of Pakistani gillnetters that reported a marked decrease in catches since the peak year (2017) due to an extended period of fishing closure, high volatility in tuna market price, and poor environmental conditions in 2019 which also affected the Pakistani catches of neritic tunas (Moazzam 2021) (**Fig. 8d-f**).

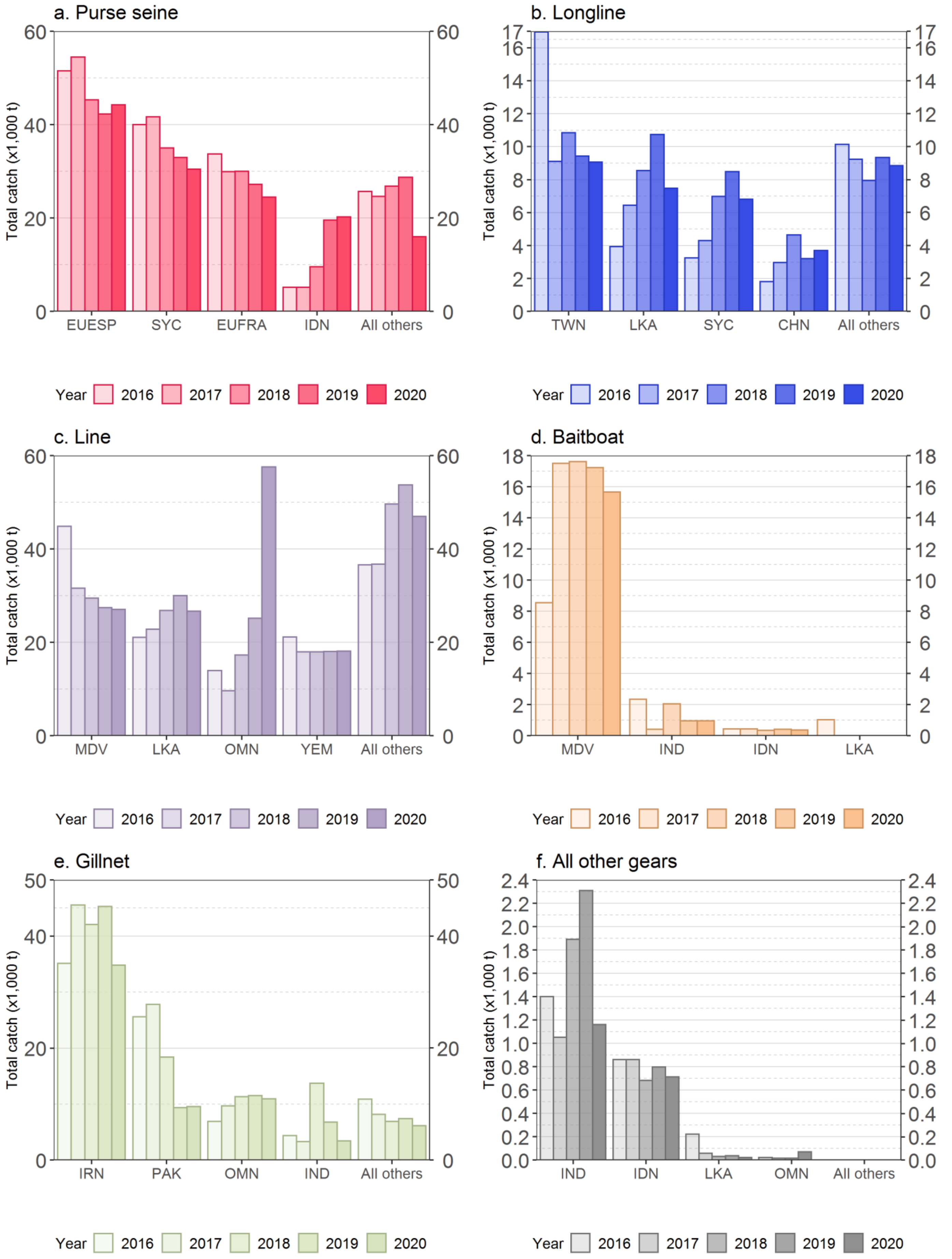

Figure 8: Annual catch trends of yellowfin tuna by fishery group and fleet in metric tons (t) between 2016 and 2020. Data source: best scientific estimate of nominal catches

Changes from previous WPTT

Very limited changes occurred in the time series of catches of yellowfin tuna since the last release of the data set of best scientific estimates of nominal catches, representing an overall change of around 200 t over the period 1950-2020 (**Fig. 9**). The main changes are a reduction of about 200 t of catches for the year 2019, while small fluctuations in catches (less than 1 t plus or minus) occurred in the entire time series due to new proxy records used to breakdown catches aggregates (by species and gears).

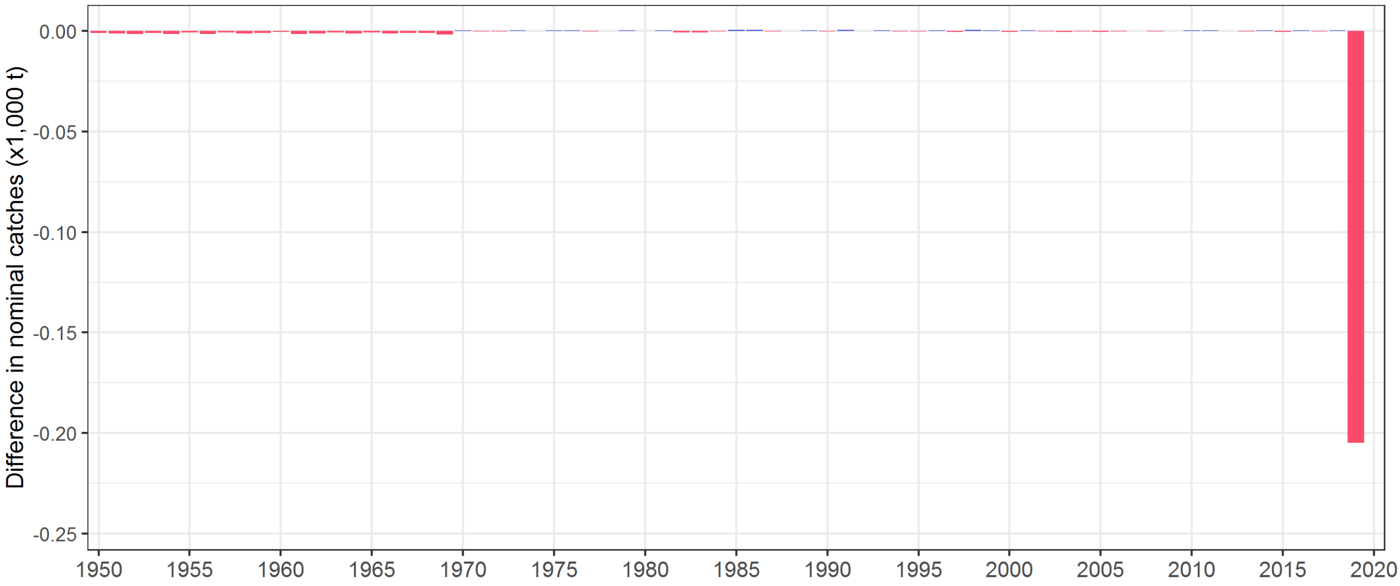

Figure 9: Differences in the available best scientific estimates of nominal catches of yellowfin tuna in metric tons (t) between this WPTT and its previous session (data preparatory meeting held in May 2021)

Uncertainties in nominal catch data

The overall quality of the nominal catches of yellowfin tuna shows some large variability between 1950 and 2020 (**Fig. 10**). In some years, a large portion of the nominal catches of yellowfin tuna had to be estimated through the breakdown of catches reported using species or gear aggregates. The data quality was particularly poor between 1994 and 2002 when less than 70% of the nominal catches were fully or partially reported, with most reporting issues coming from coastal fisheries. The quality has steadily improved over the last decade, to the point that around 86% of the catches was fully available from CPC submissions in 2020. Nevertheless, more than 32,000 t of nominal catches of yellowfin tuna (7% of the total catches) were scored between 6 and 8 and required to be mostly estimated by the Secretariat. In particular, the handline catches of Yemen were repeated from previous years at levels of about 18,000 t, based on information retrieved from the FAO global capture production database. Also, catches from the coastal longline fishery of India and gillnet fisheries of Tanzania and Pakistan contributed the most to the catch estimates.

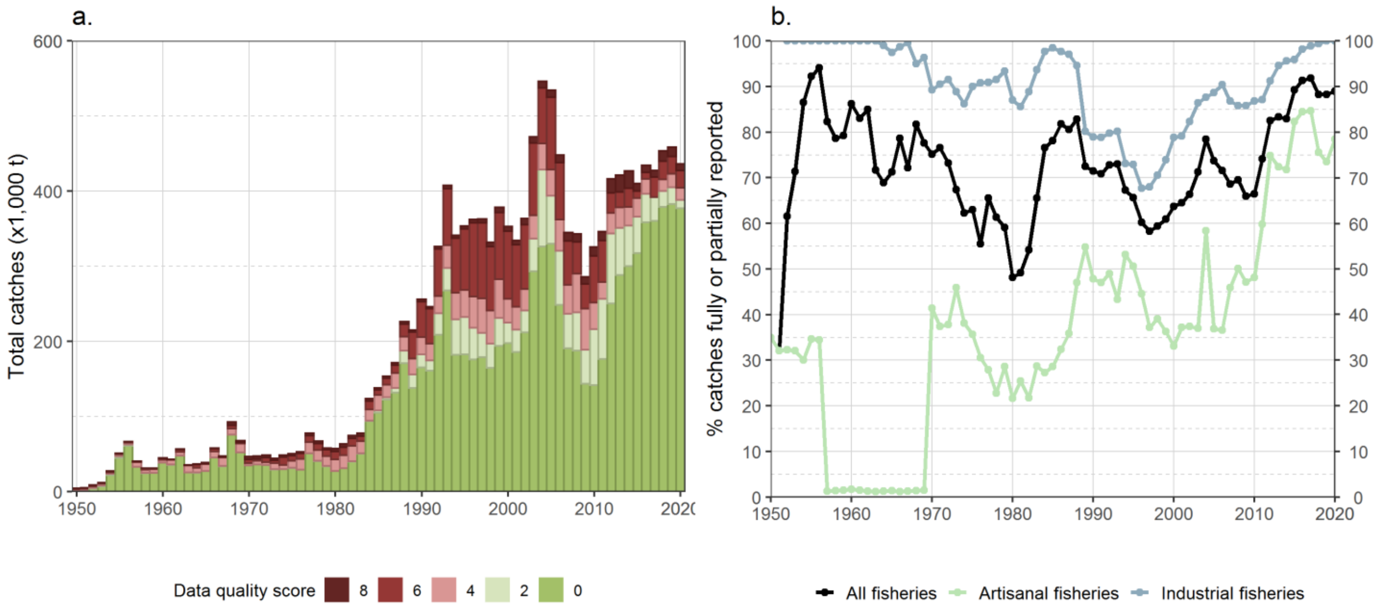

Figure 10: Annual nominal catches of yellowfin tuna in metric tons (t) estimated by quality score (barplot) and percentage of nominal catch fully/partially reported to the IOTC Secretariat (lines with dots) for all fisheries (a) and by type of fishery (b), in the period 1950-2020

Some important issues have been identified in the past to affect the time series of nominal catches of yellowfin tuna:

- Coastal fisheries of Indonesia, Madagascar, Yemen, and Sri Lanka (other than gillnet/longline): the nominal catches of yellowfin tuna for these fisheries have been estimated by the IOTC Secretariat in recent years (until 2014 for Sri Lanka). The quality of the estimates is thought to be very poor due to the lack of information available about the artisanal fisheries operating in these countries;
- Drifting gillnet fishery of Pakistan: revised catch series spanning the period 1987-2018 have been officially endorsed by the 22nd session of the Scientific Committee, and are now included in the IOTC database. These revised catch series resulted in increased catches of yellowfin tuna by more than 6,200 t each year between 1987 and 2018. There are large uncertainties around the estimates (IOTC 2019b);
- Gillnet fishery of Tanzania: catches have been repeated since 2014 in absence of information;
- Purse seine fishery of EU,Spain: changes introduced in the methodology used to estimate the species composition of the catch for 2018 resulted in figures largely contrasting with other segments of the same fleet (IOTC 2019a). To date, no official revision for the catches reported by the EU purse-seine fishery in 2018 has been received by the IOTC Secretariat while the species composition for 2019 onwards seems to have returned to levels comparable to 2017 and previous years;
- Longline fishery of Indonesia: no report of catches for national longliners that are not based in Indonesia (e.g., Port Louis, Mauritius).

Discard levels

The total amount of yellowfin 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 yellowfin tuna are mainly composed of fish smaller than 50 cm (~1.3 kg) although a few larger fish may be discarded when damaged (**Fig. 11**). 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).

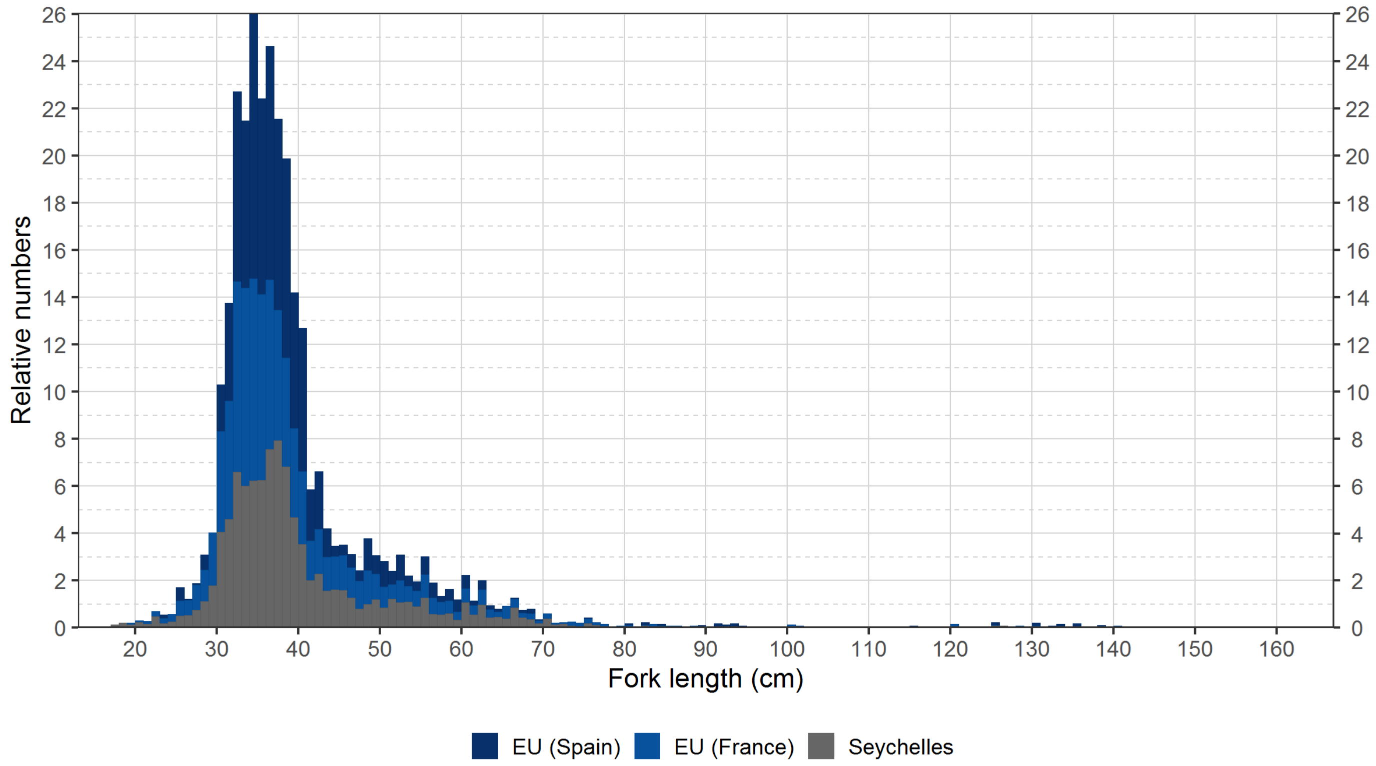

Figure 11: Fork length distribution of yellowfin tuna discarded at sea in purse seine fisheries during the period 2014-2019 (n = 82,172). Data source: IOTC ROS database

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 yellowfin tuna has been estimated at 0.42% in the fleet targeting yellowfin tuna and 3.43% 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 data show no clear pattern in the size of the yellowfin tunas discarded at sea (since the depredation process might not be size-selective) although the discards in the Reunion-based fresh longline fishery are smaller than in the Japanese deep-freezing longline fishery, i.e., a median of 63.5 cm vs. 94.5 cm (**Fig. 12**). 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 yellowfin 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).

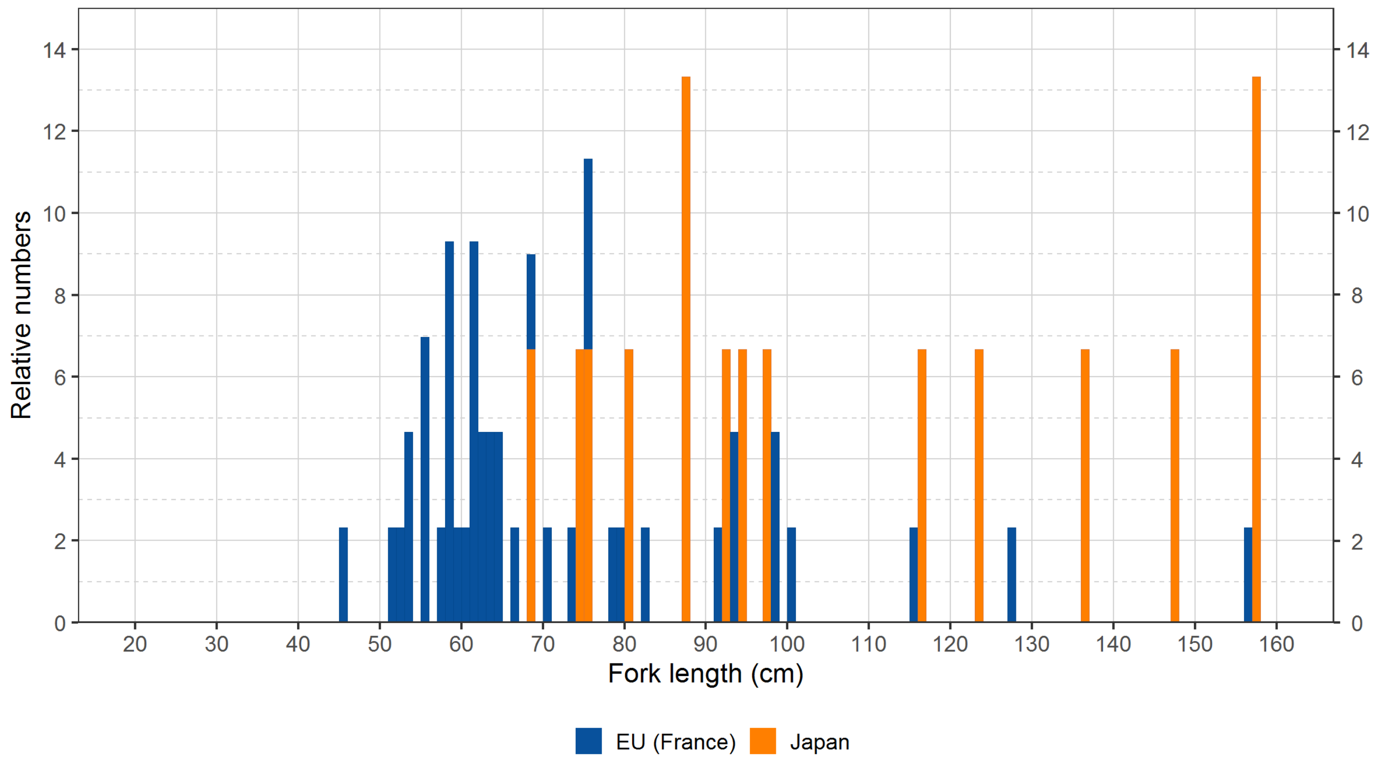

Figure 12: Fork length distribution of yellowfin tuna discarded at sea in longline fisheries during the period 2009-2018 (n = 232). Data source: IOTC ROS database

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 catches

Spatial distribution of catches

Estimated geo-referenced catches show the spatial expansion and major changes that took place in the fisheries targeting yellowfin tuna over the last decades (**Fig. 13**). As early as the 1950s, yellowfin 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.

Throughout the 1960s and 1970s, the longline fisheries expanded in the south-western part of the Indian Ocean, including in the Mozambique Channel (**Fig. 13b-c**). From the 1980s, the purse seine fishery developed in the western Indian Ocean, with most of the yellowfin tuna caught in free-swimming schools (**Fig. 13d**).

During the 1990s and 2000s, the purse seine fishery increased its catches and expanded its fishing grounds in the western Indian Ocean while the coastal fisheries of the northern countries of the Indian Ocean grew substantially in importance and a large fresh longline fishery developed in the north-eastern Indian Ocean (**Fig. 13e-f**).

The overall annual distribution of yellowfin tuna catches by fishery has changed little over the period 2016-2020 (**Fig. 14**). Most yellowfin tuna catches are located in the central and western Indian Ocean, with important catches also reported around Sri Lanka and along the coasts of Indonesia. Purse seine largely dominates in the western Indian Ocean around the Seychelles archipelago (between 20°S and 10°N), and the fishery showed an expansion towards the north between 2016 and 2020.

Georeferenced catches by fishery and decade (1950-2009)

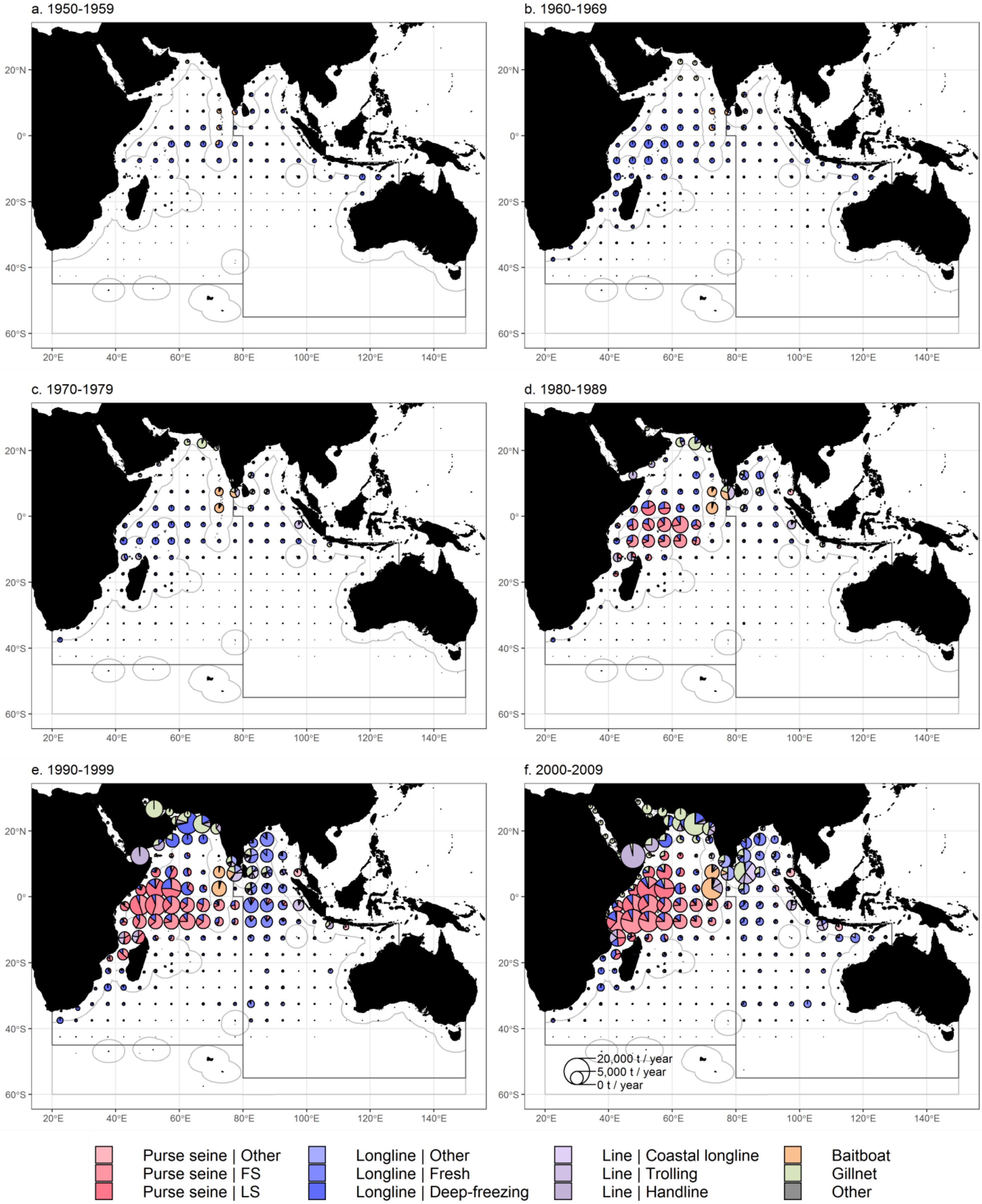

Figure 13: Estimated average annual time-area catches of yellowfin tuna in metric tons (t) / year, by decade, 5x5 grid and fishery. Data source: yellowfin tuna raised time-area catches

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

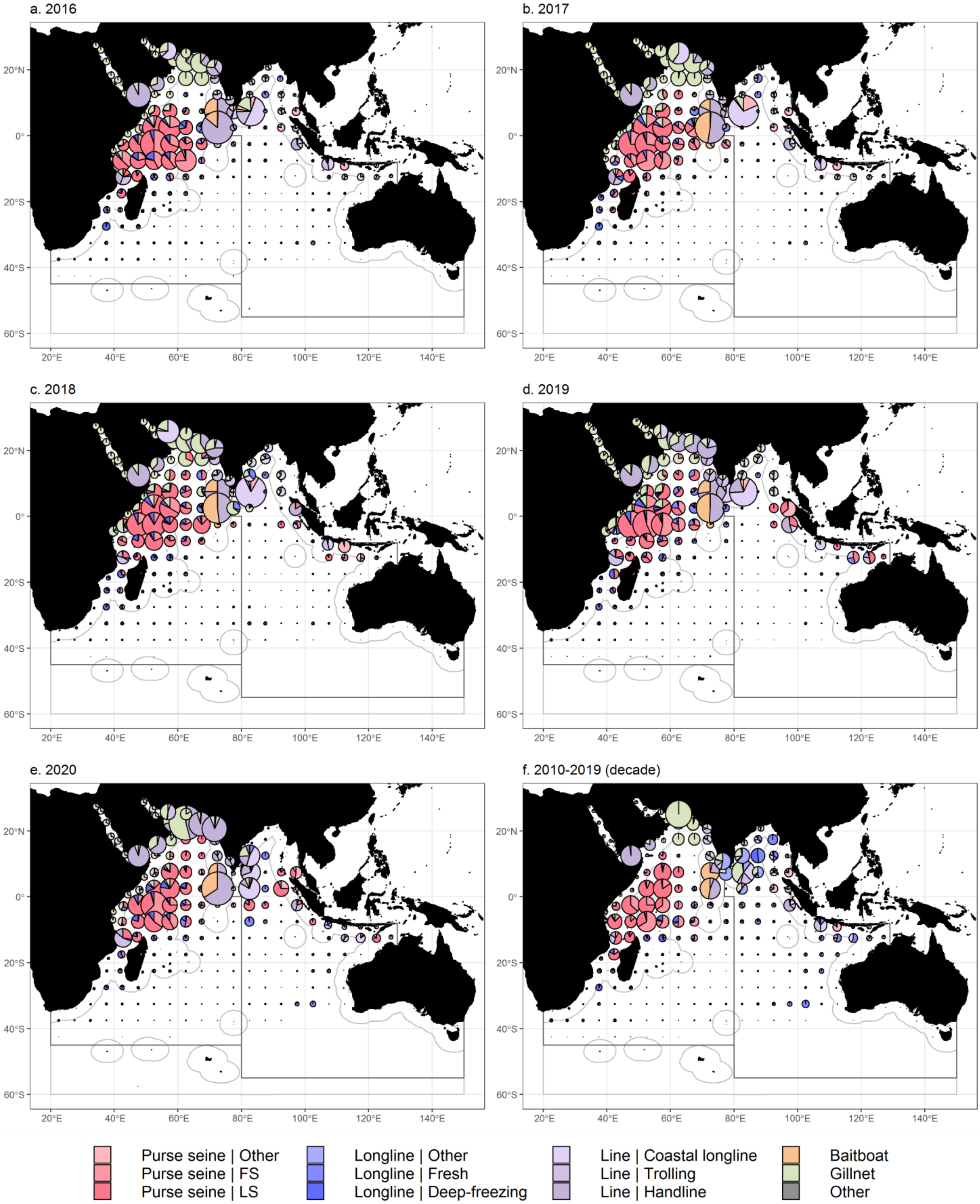

Figure 14: Estimated average annual time-area catches of yellowfin tuna in metric tons (t) / year, by year / decade, 5x5 grid and fishery. Data source: yellowfin tuna raised time-area catches

Indonesia appears to have developed an industrial purse seine fishery since 2018 (**Fig. 14d-e**), which mainly operates in coastal areas of the eastern Indian Ocean with vessels of LOA between 30 and 40 m. Baitboat fishing is essentially concentrated in the Maldives archipelago while gillnet and line fisheries (handline, trolling and coastal longline) are widely used along the coasts of Yemen, Oman, Pakistan, 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-effort data is driven to some extent by the relative contribution of artisanal fisheries to the total catches of yellowfin tuna (**Fig. 15b**). The main issues identified in the past concern:

- the fresh-tuna longline fishery of Taiwan,China, for which data have only been available since 2006, and the fresh-tuna longline fishery of Indonesia, with data only available from 2018 onward (although logbook coverage is thought to be low);
- the gillnet fisheries of I.R. Iran (before 2007) and Pakistan, for which data are either incomplete or lacking;
- the gillnet-longline fishery of Sri Lanka (until 2014), described by poor quality effort data;
- important coastal fisheries using hand and/or troll lines, in particular: Oman, Yemen, Madagascar, India, and Indonesia (until 2018), for which no data (or incomplete data) have been reported to the Secretariat.

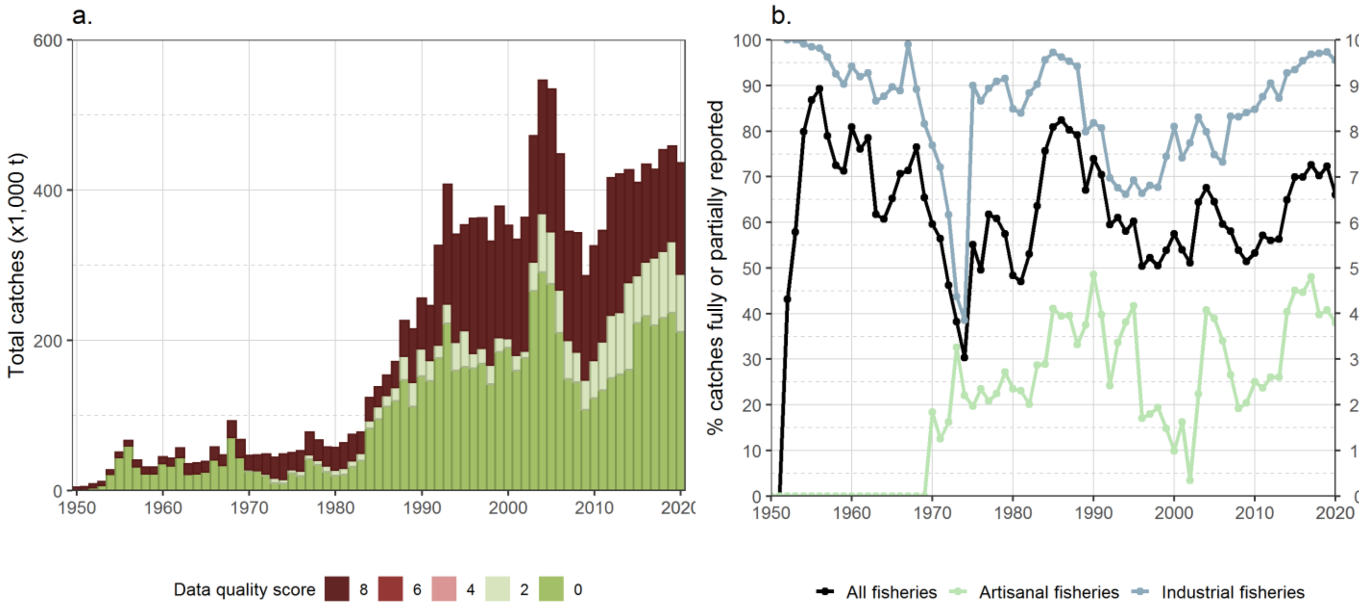

Figure 15: Annual nominal catches (t) of yellowfin tuna estimated by quality score (barplot) and percentage of geo-referenced catches reported to the IOTC Secretariat in agreement with the requirements of Res. 15/02 (lines with dots) for all fisheries (a) and by type of fishery (b), in the period 1950-2020

The percentage of data considered of good quality (scores of 0-2) varied between 50%-74% during the 1990s and 2000s, and has stabilized over the last decade showing an overall increasing trend from 56% in 2012 to 73% in 2012, with 66% of good quality data available in 2020 (**Fig. 15a-b**). Catch and effort data have progressively become available for some important fisheries such as coastal and fresh longline as well as hand line from Sri Lanka since 2014, coastal longline from I.R. Iran since 2016, small-scale purse seine and fresh longline from Indonesia since 2018, and some smaller fisheries such as trolling from Indonesia and hand line from Kenya since 2018.

Nevertheless, geo-referenced catch-effort data were not available for about 34% (i.e., around 150,000 t) of the total nominal catches of yellowfin tuna in 2020.

No information was available for several coastal fisheries, including:

- the handline fisheries of Oman (~58,000 t), Yemen (~18,000 t), and India (~5,000 t);

- the gillnet fisheries of Oman (~11,000 t), Pakistan (~8,000 t), Tanzania (~4,000t), and India (~3,000 t);
- the coastal longline and trolling fisheries of: India (~10,000 t), Comoros (~5,000 t), and I.R. Iran (~4,000 t).

In addition, no spatial information has been provided by a few industrial purse seine fisheries such as EU,Italy (since 2016) and I.R. Iran (since the beginning of the time series), with the two fleets accounting in 2020 for relatively low total catch levels of yellowfin tuna of ~2,300 t and ~600 t, respectively.

Size distribution and estimated weights

Temporal patterns and trends in size distributions

Industrial purse seine fisheries

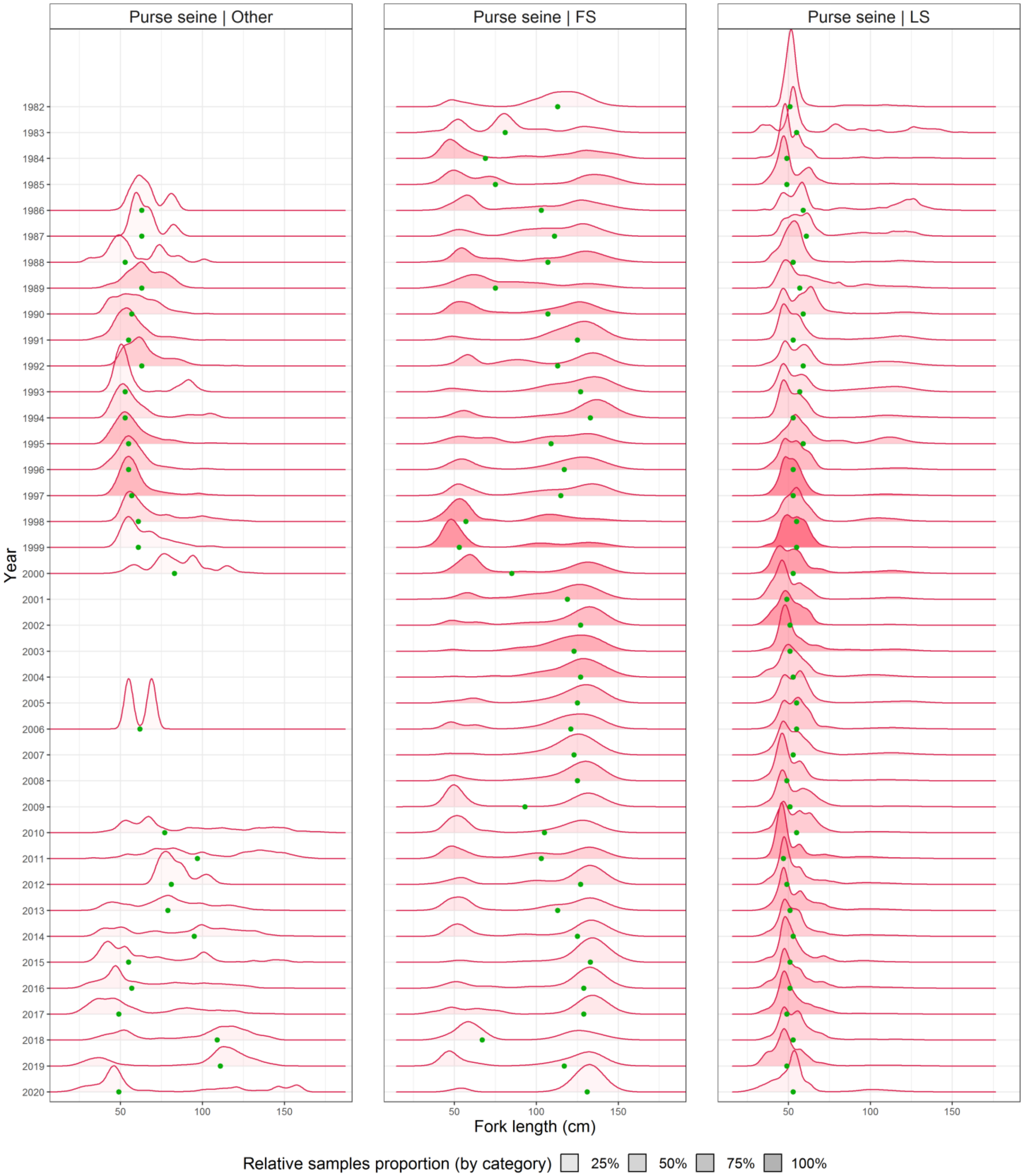

Figure 16: Relative size distribution (fork length in 2 cm size bins) of yellowfin tuna caught by all purse seine fleets for the period 1982-2020. Other = no information provided on the school association; FS = free-swimming schools; LS = schools associated with floating objects. Fill intensity is proportional to the number of samples recorded for the year, while the green dot corresponds to the median value. Data source: yellowfin tuna standardized size-frequency dataset (Res. 15/02)

Industrial longline fisheries

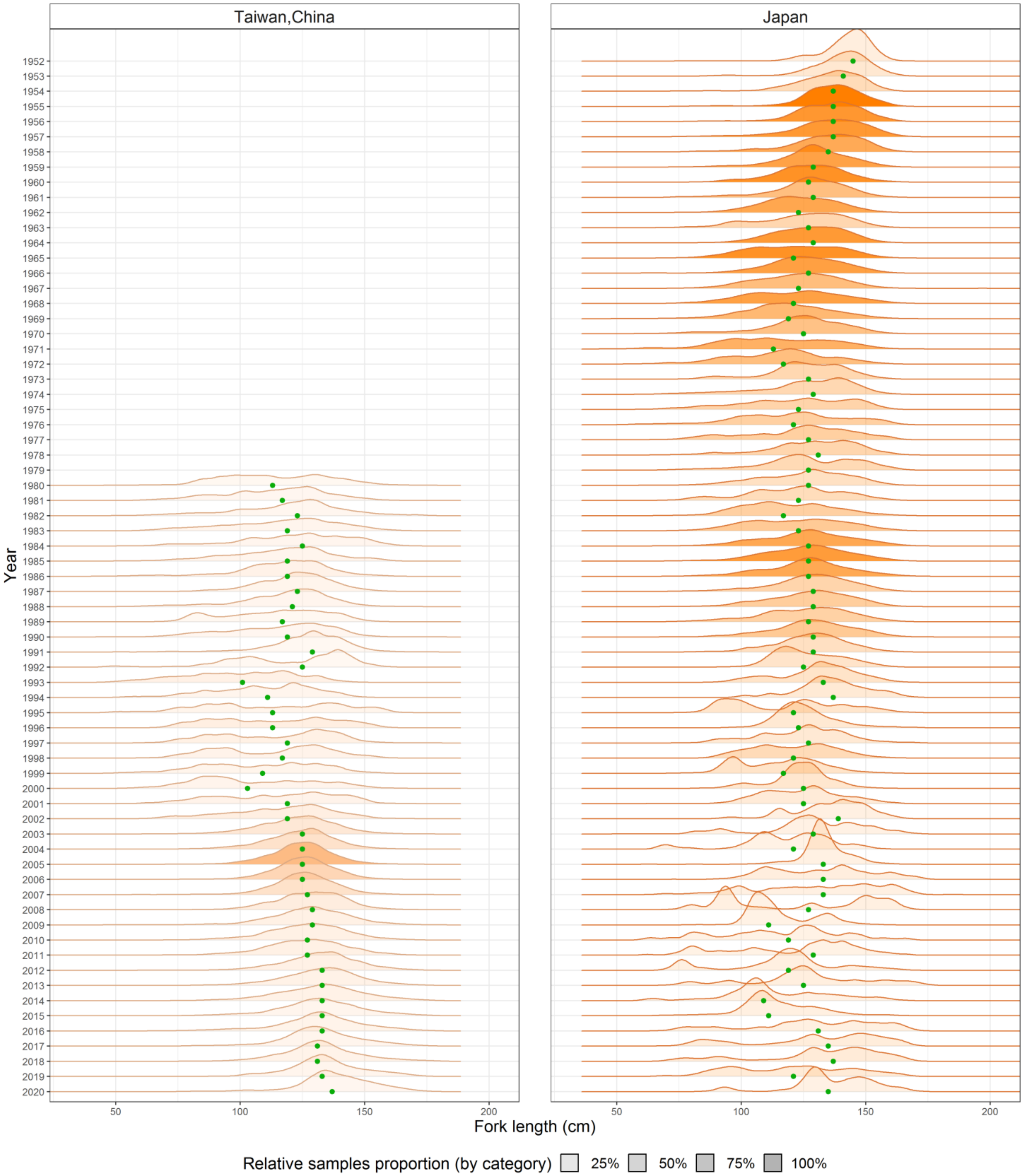

Figure 17: Relative size distribution (fork length in 2 cm size bins) of yellowfin tuna caught by the main deep-freezing longline fleets for the period 1952-2020. Fill intensity is proportional to the number of samples recorded for the year, while the green dot corresponds to the median value. Data source: yellowfin tuna standardized size-frequency dataset (Res. 15/02)

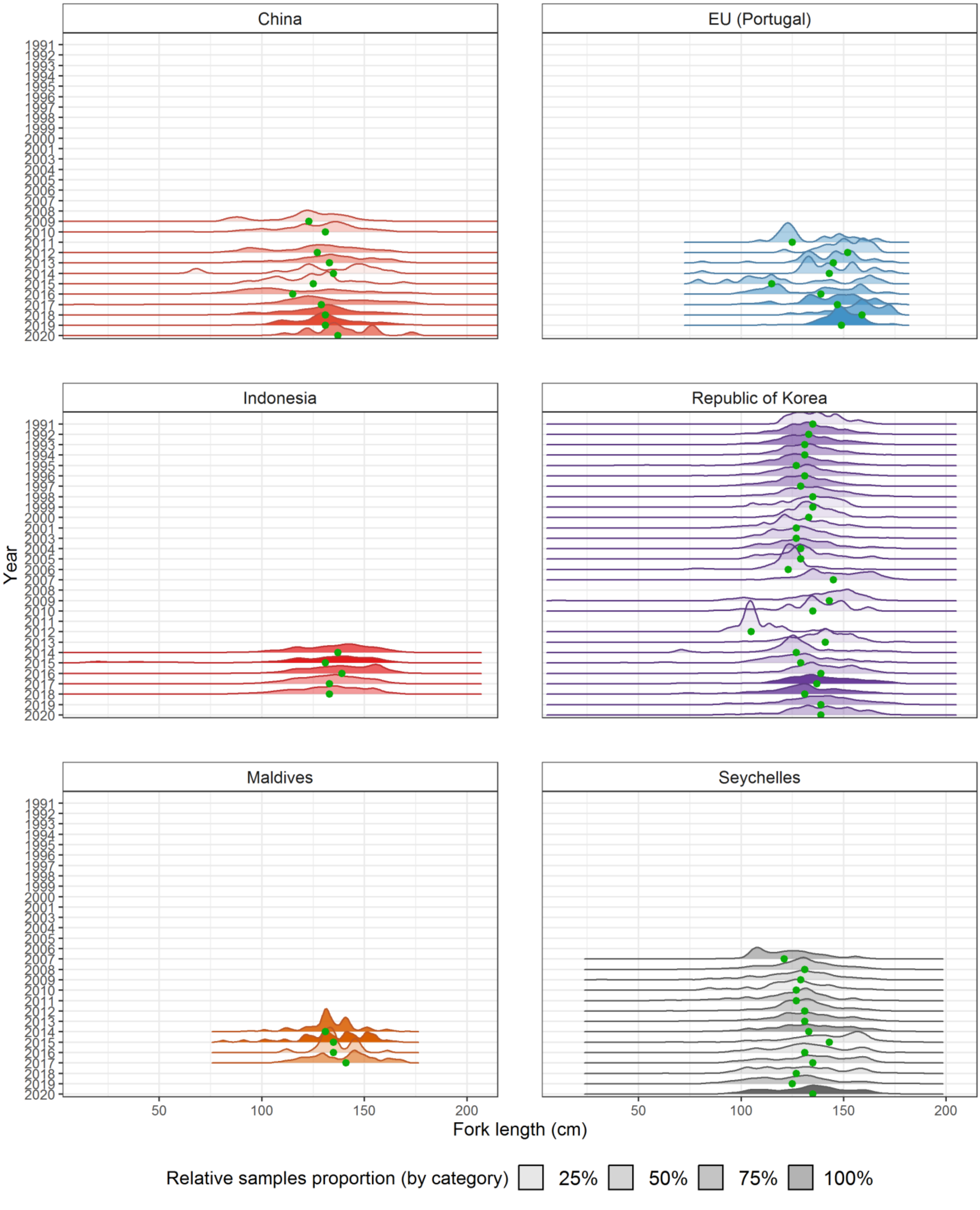

Figure 18: Relative size distribution (fork length in 2 cm size bins) of yellowfin tuna caught by all other longline fleets (excluding Japan and Taiwan,China), by fleet for the period 1991-2020. Data source: yellowfin tuna standardized size-frequency dataset (Res. 15/02)

Temporal trends in estimated average weights

Trends in average weights of yellowfin 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 estimated for the longline fisheries of Japan and Taiwan,China are stable at around 40-50 kg / fish (**Fig. 20**). On the contrary, average weights estimated for the log-associated school component of the purse seine fisheries show a declining trend from the mid-1990s onward, and the resulting estimated average weight of yellowfin tuna caught by this fishery is now as low as 6.8 kg / fish.

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).

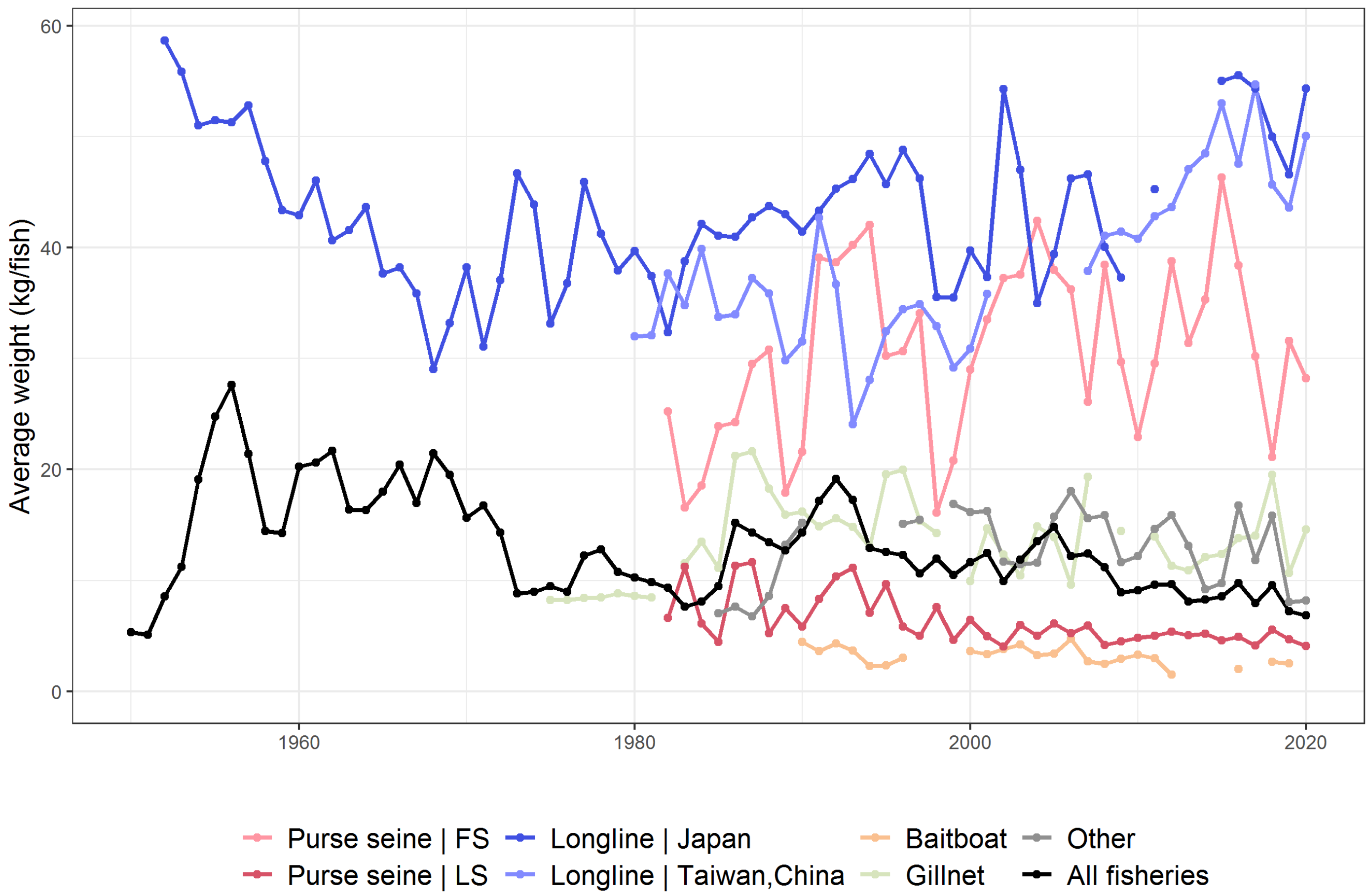

Figure 19: Combined estimated yellowfin tuna average weight (kg/fish) by fishery and year. Data are only shown for those years for which the original size samples cover strata with reported catches (by year and fishery) higher than 50 t. LS = schools associated with floating objects; FS = free-swimming 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: yellowfin tuna raised time-area catches

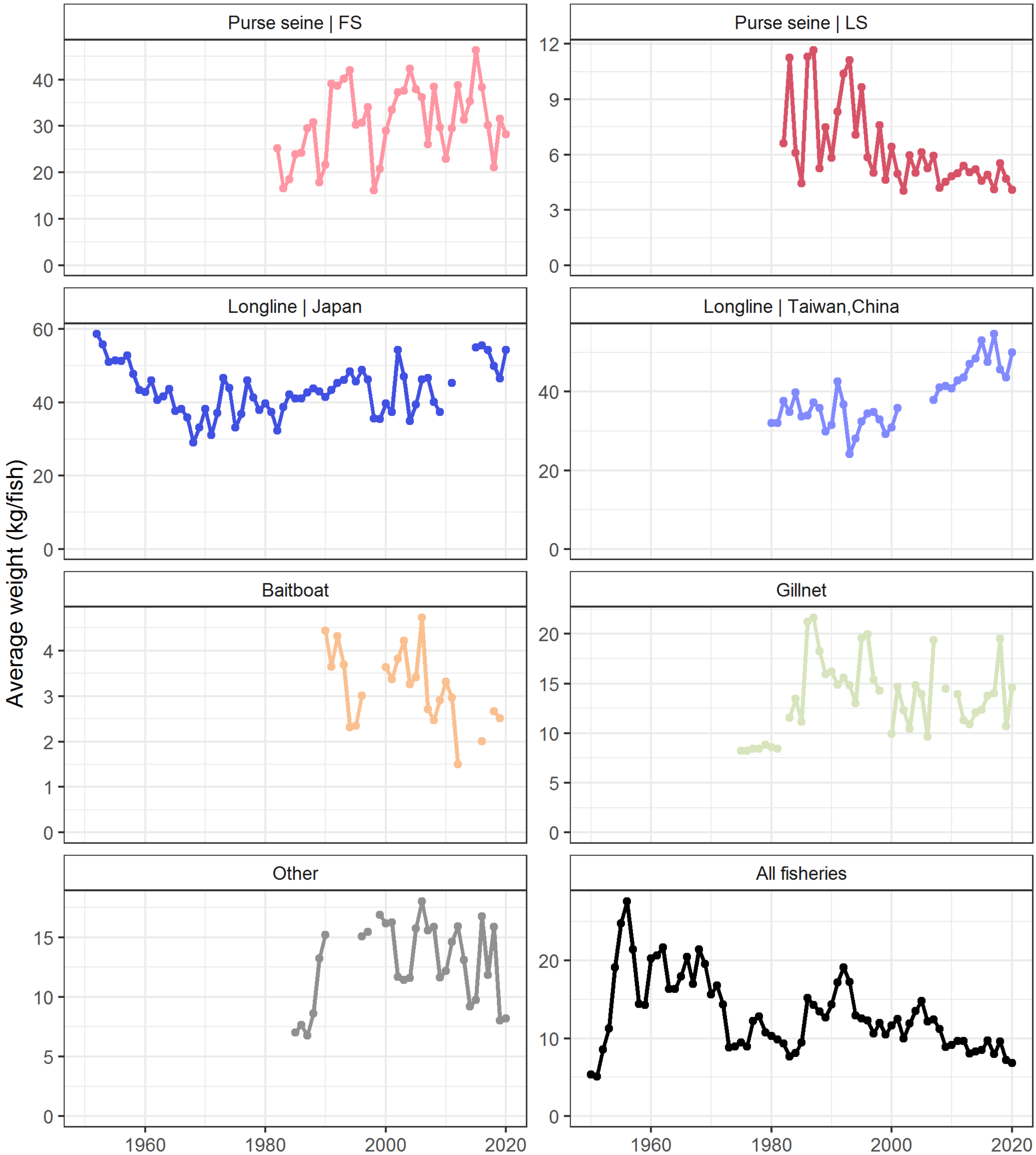

Figure 20: Estimated yellowfin tuna average weight (kg/fish) by fishery and year. Data are only shown for those years for which the original size samples cover strata with reported catches (by year and fishery) higher than 50 t. LS = schools associated with floating objects; FS = free-swimming schools. 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: yellowfin tuna 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. 19**).

Spatial distribution of average weights

Estimated average weights by decade (1950-2019)

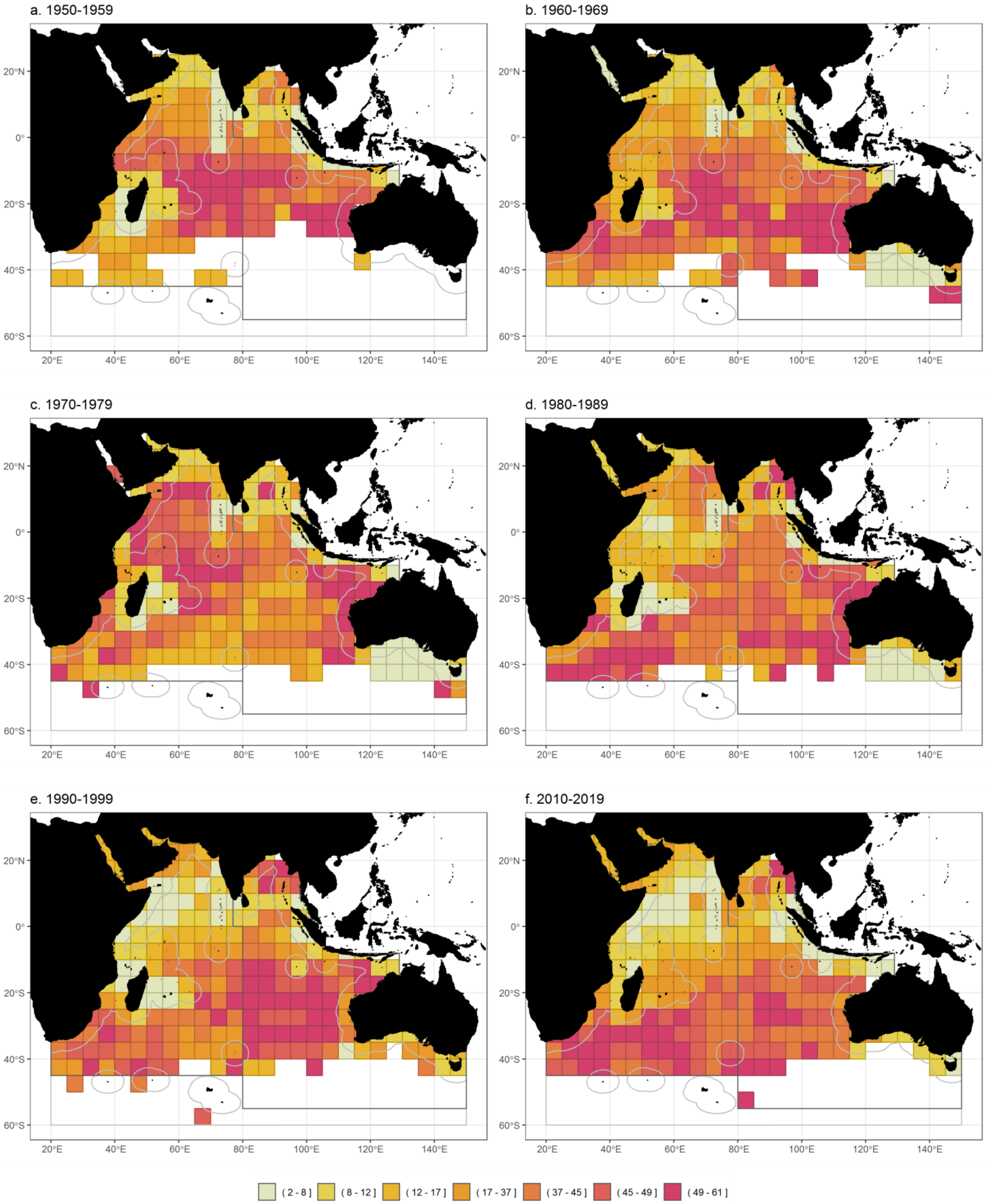

Figure 21: Estimated average weight (kg/fish) by decade and 5x5 grid, for all fisheries combined for the period 1950-2019. Data source: yellowfin tuna raised time-area catches

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

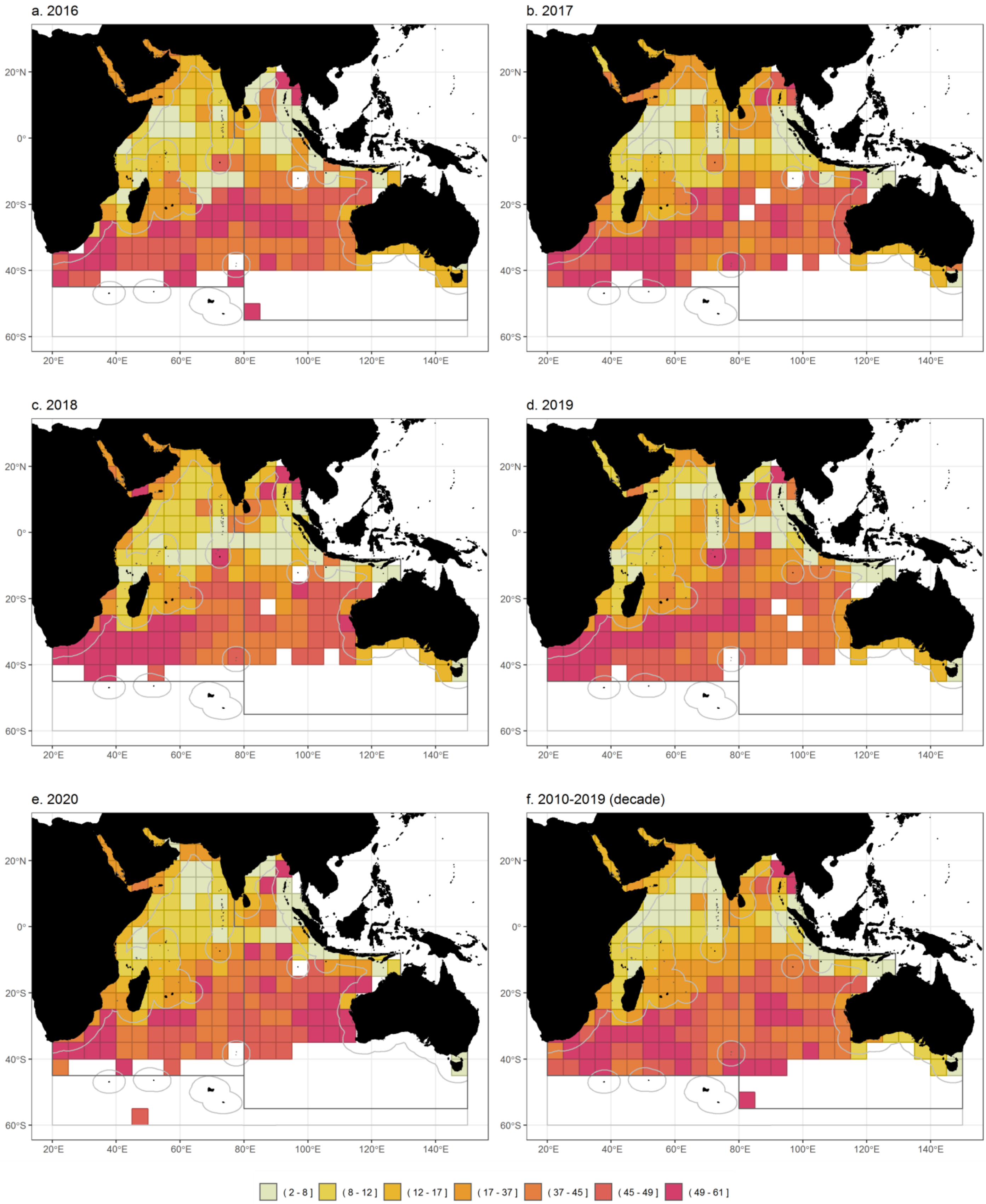

Figure 22: Estimated average weight (kg/fish) by year and 5x5 grid, for all fisheries combined for the period 2016-2020 and for the decade 2010-2019. Data source: yellowfin tuna raised time-area catches

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

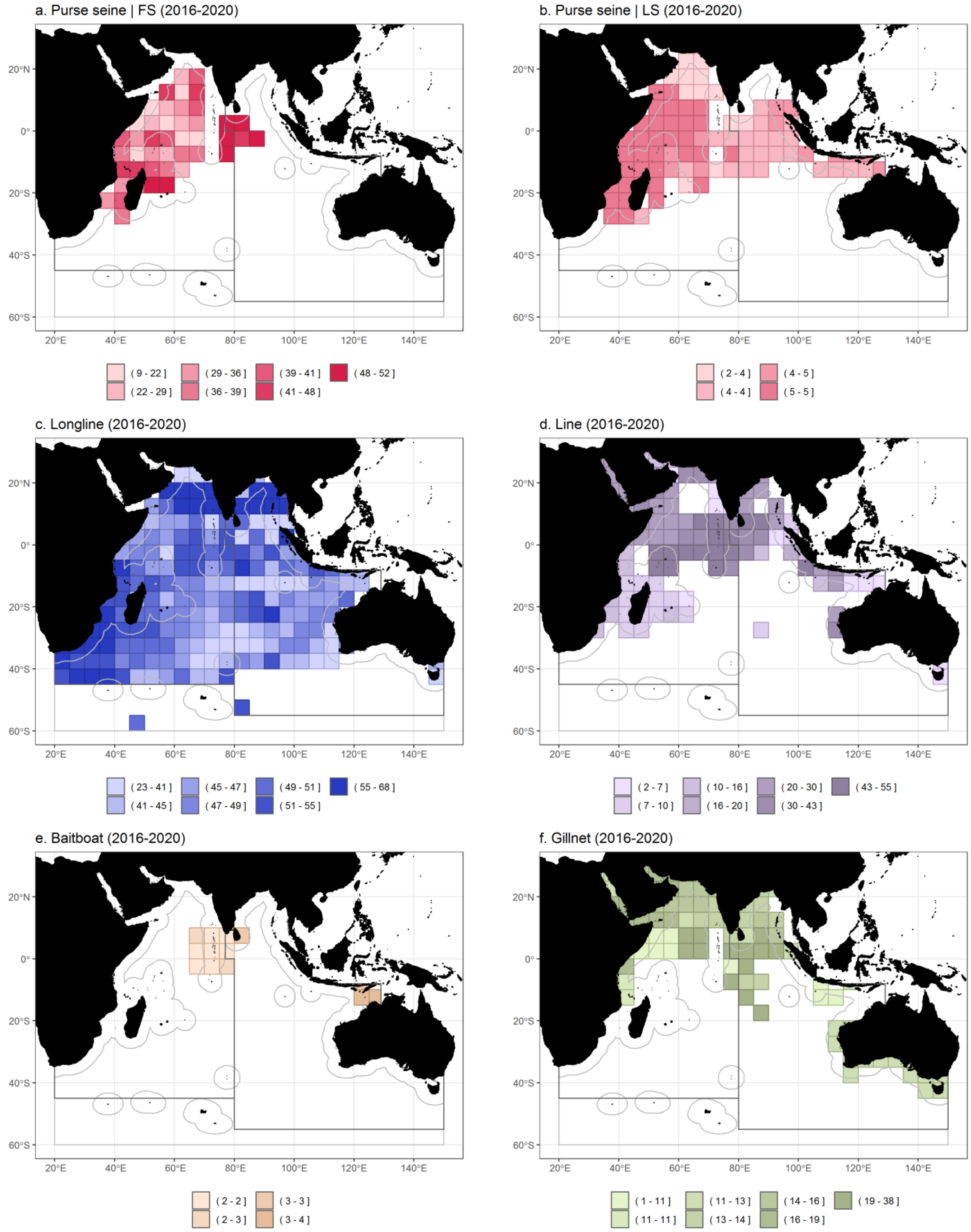

Figure 23: Estimated average weight (kg/fish) by 5x5 grid and fishery group for the period 2016-2020. LS = schools associated with floating objects; FS = free-swimming schools. Data source: yellowfin tuna raised time-area catches

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 yellowfin 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 remained at around 47% since 1984 (ranging between 36% and 63%) (**Fig. 24a**). Following an increase in quality from about 37% in 2020 to around 61% in 2017, the quality substantially decreased to 37% in 2020.

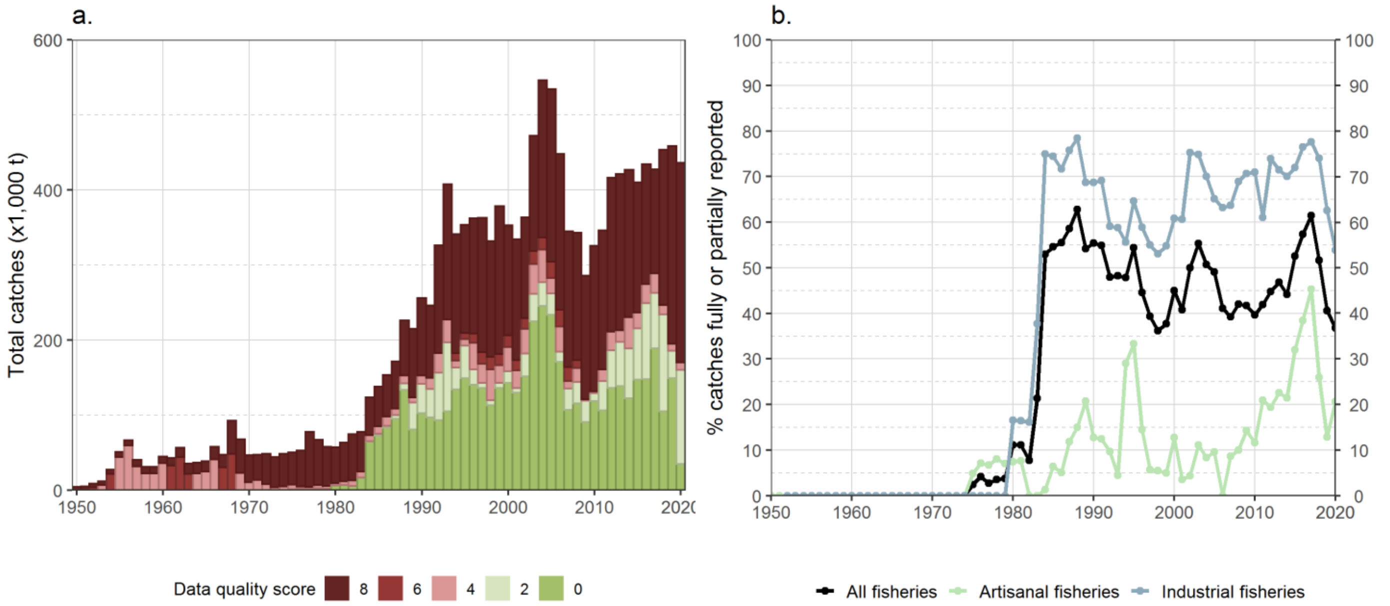

Figure 24: Annual nominal catches (t) of yellowfin tuna estimated by quality score (barplot) and percentage of geo-referenced size-frequency data reported to the IOTC Secretariat in agreement with the requirements of Res. 15/02 (lines with dots) for all fisheries (a) and by type of fishery (b), in the period 1950–2020

Industrial purse seine fisheries

Size-frequency data for yellowfin 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. 25**) and FOB-associated schools (**Fig. 27**) 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 (2018), EU,Spain (2019), Mauritius (2017), and Seychelles (2017, 2018 and 2019) (**Table 6**), which all show a much higher first mode in the lower part of the size distribution (at around 60 cm FL) (**Fig. 25**).

Similar discrepancies can also be found in the case of size-frequencies from FOB-associated schools, with data showing sub-modes at around 100 and 130 cm FL for EU,Spain (2018) and EU,France (2019, 2020) (**Table 7**). 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. 27**).

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 fraction of what usually provided in the past (**Fig. 25**).

Size-frequency data for 2020 is completely absent for EU,Spain and only available in limited numbers for EU,France, Mauritius, and Seychelles (**Fig. 27**), 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. 29**). 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. 29**).

The size-distribution of Indonesian samples is quite peculiar and indicates that the fishery is catching smaller than average individuals as the very strong mode at around 30 cm FL seems to suggest. Considering that the data are originally reported as sourced from the *small purse seine* component of the Indonesian fleet (IOTC gear code *PSS*, that includes vessels with a LOA well above 24 m, that appear to operate in coastal waters on the basis of the geo-referenced catches available to the IOTC Secretariat from 2018 onward) further clarification might be required to estimate the accuracy and representativeness of these samples and whether or not they could be properly used for scientific purposes.

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).

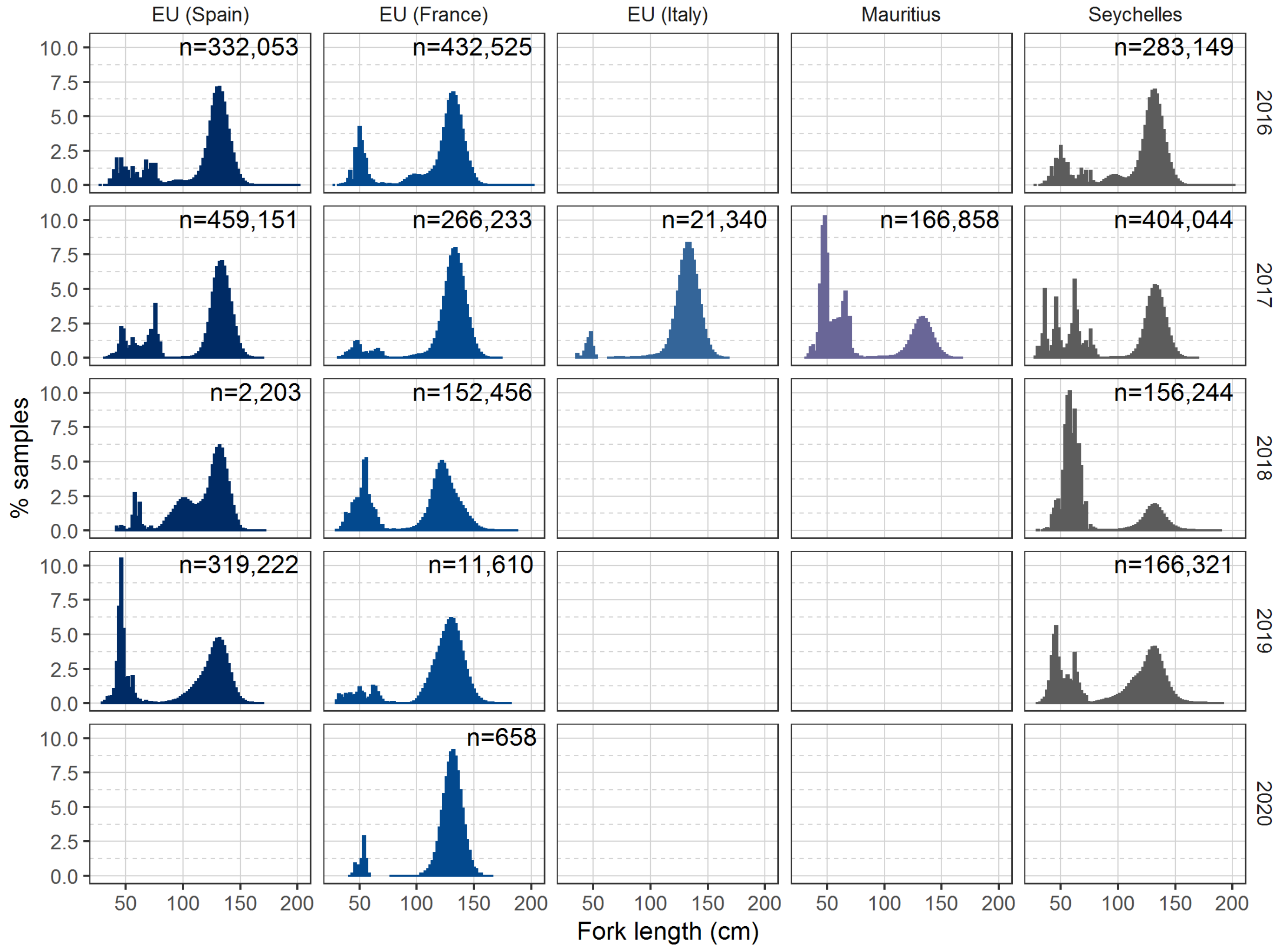

Figure 25: Relative size distribution of yellowfin tuna (fork length in cm) recorded for free-swimming schools, by year (2016–2020) and main purse seine fleet. Data source: yellowfin tuna standardized size-frequency dataset (Res. 15/02)

Table 6: Percentage of sampled yellowfin 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: yellowfin tuna standardized size-frequency dataset (Res. 15/02)

Fleet	2016	2017	2018	2019	2020
EUESP	20	21	9	37	
EUFRA	21	10	36	14	8
MUS		66			
SYC	20	42	77	41	

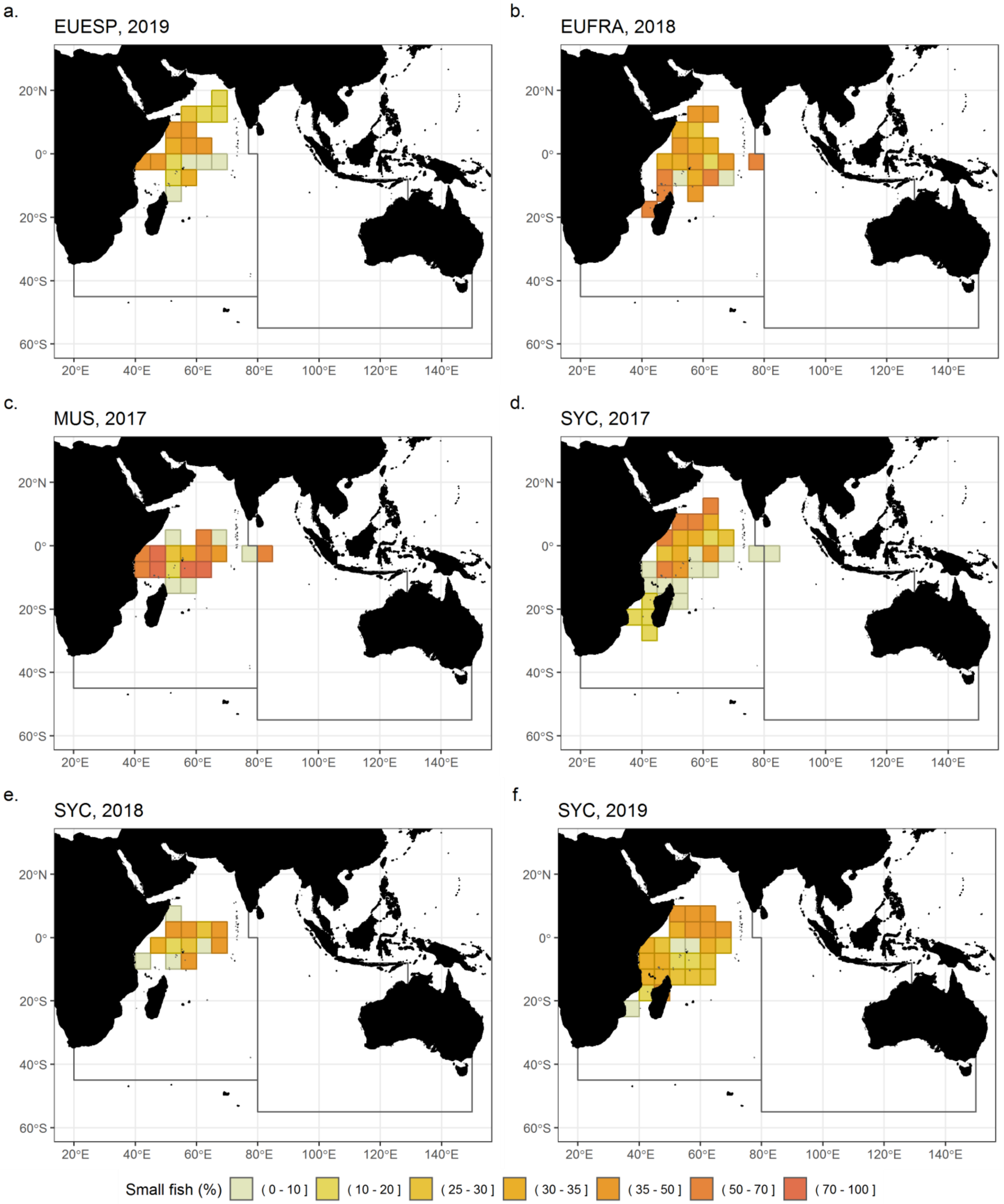

Figure 26: Spatial distribution of sampled yellowfin tuna with fork length below 75 cm recorded by the major purse seine fleets fishing on free-swimming schools, as reported for the period 2016-2020. Data source: yellowfin tuna standardized size-frequency dataset (Res. 15/02)

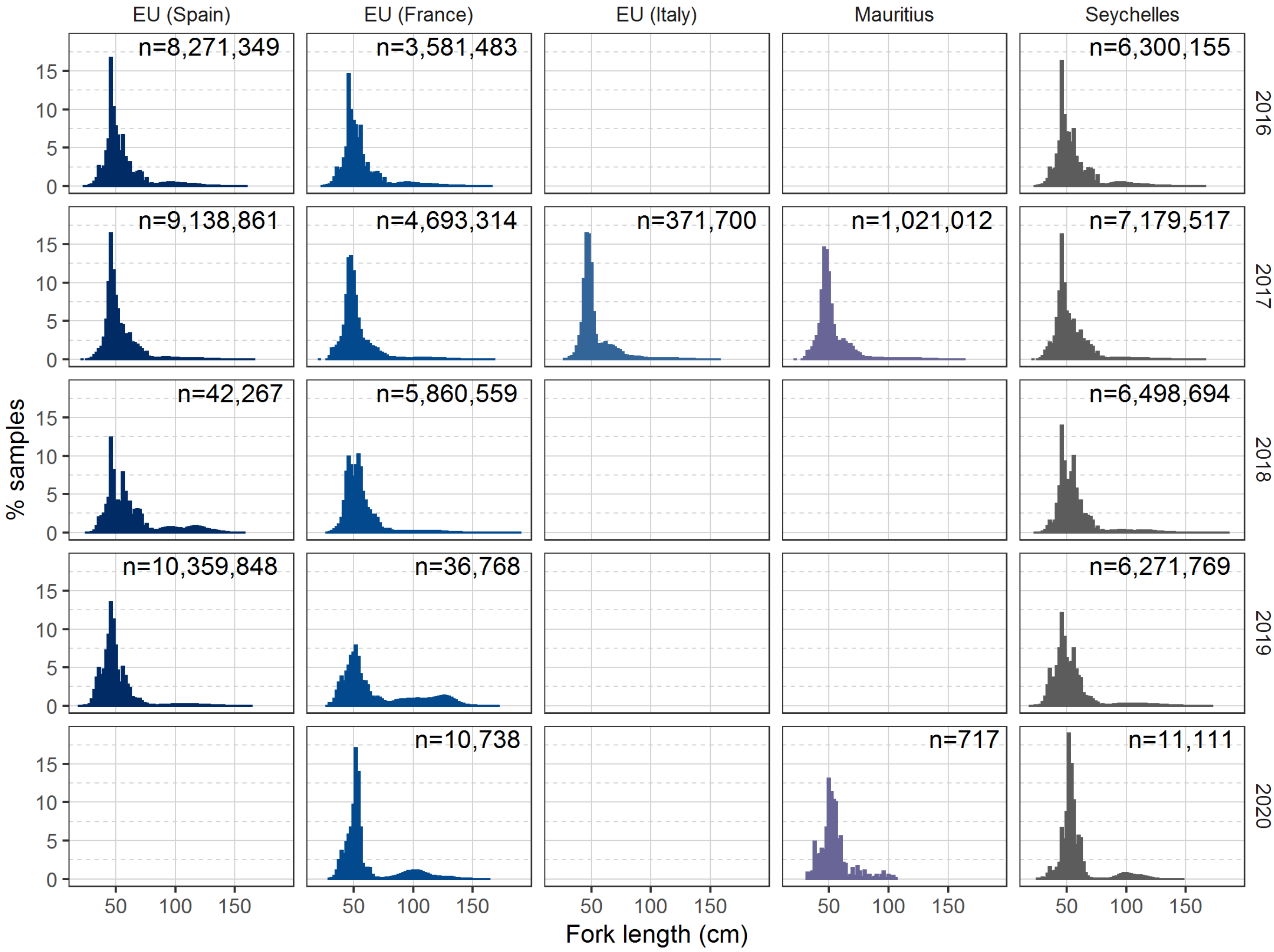

Figure 27: Relative size distribution of yellowfin tuna (fork length in cm) recorded for FOB-associated schools, by year (2016–2020) and major purse seine fleet. Data source: yellowfin tuna standardized size-frequency dataset (Res. 15/02)

Table 7: Percentage of sampled yellowfin 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: yellowfin tuna standardized size-frequency dataset (Res. 15/02)

Fleet	2016	2017	2018	2019	2020
EUESP	9	6	18	4	
EUFRA	9	6	7	29	17
MUS		6			8
SYC	9	5	7	6	8

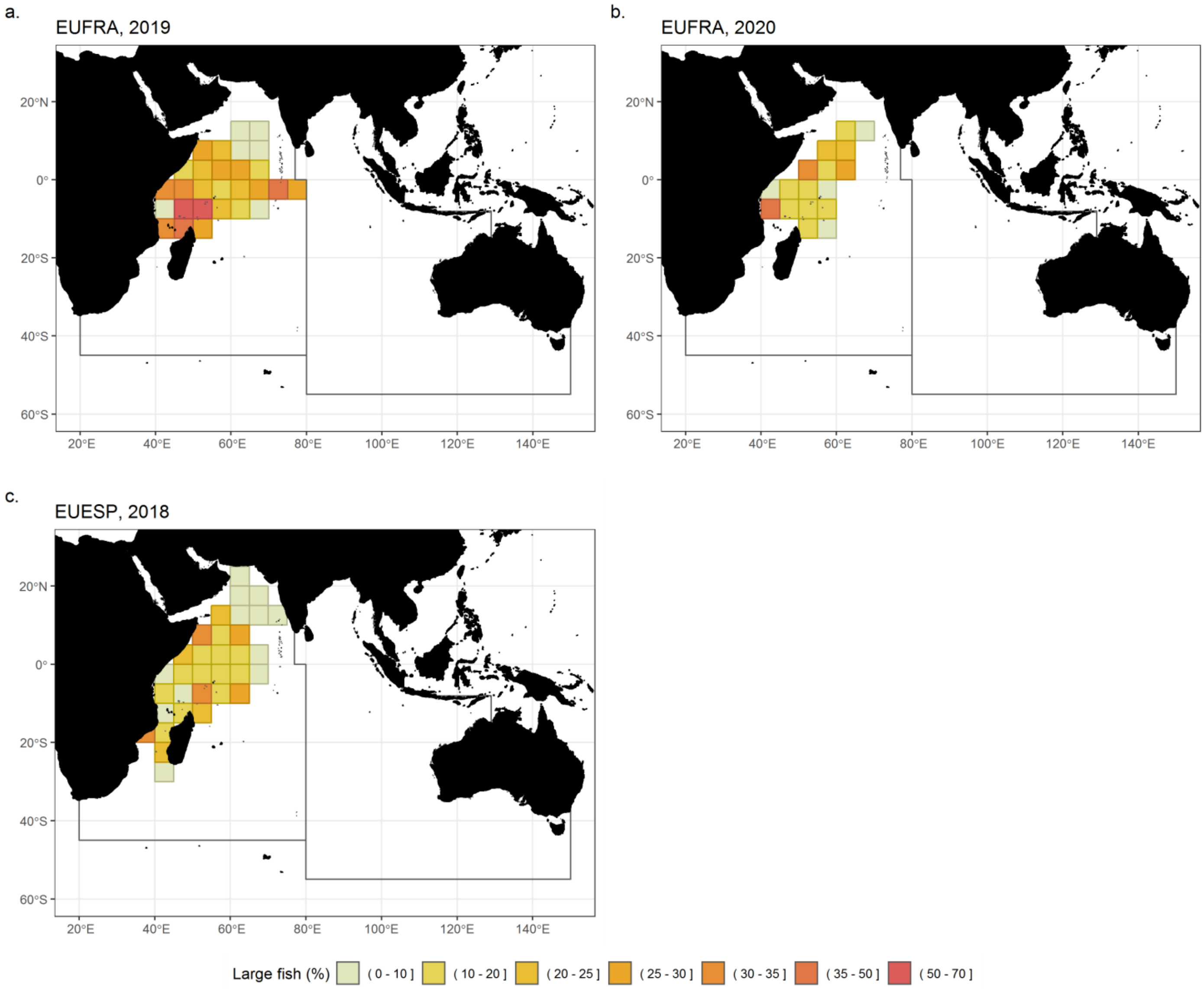

Figure 28: Spatial distribution of sampled yellowfin tuna with fork length above 75 cm recorded by the major purse seine fleets fishing on FOB-associated schools, as reported for the period 2016-2020. Data source: yellowfin tuna standardized size-frequency dataset (Res. 15/02)

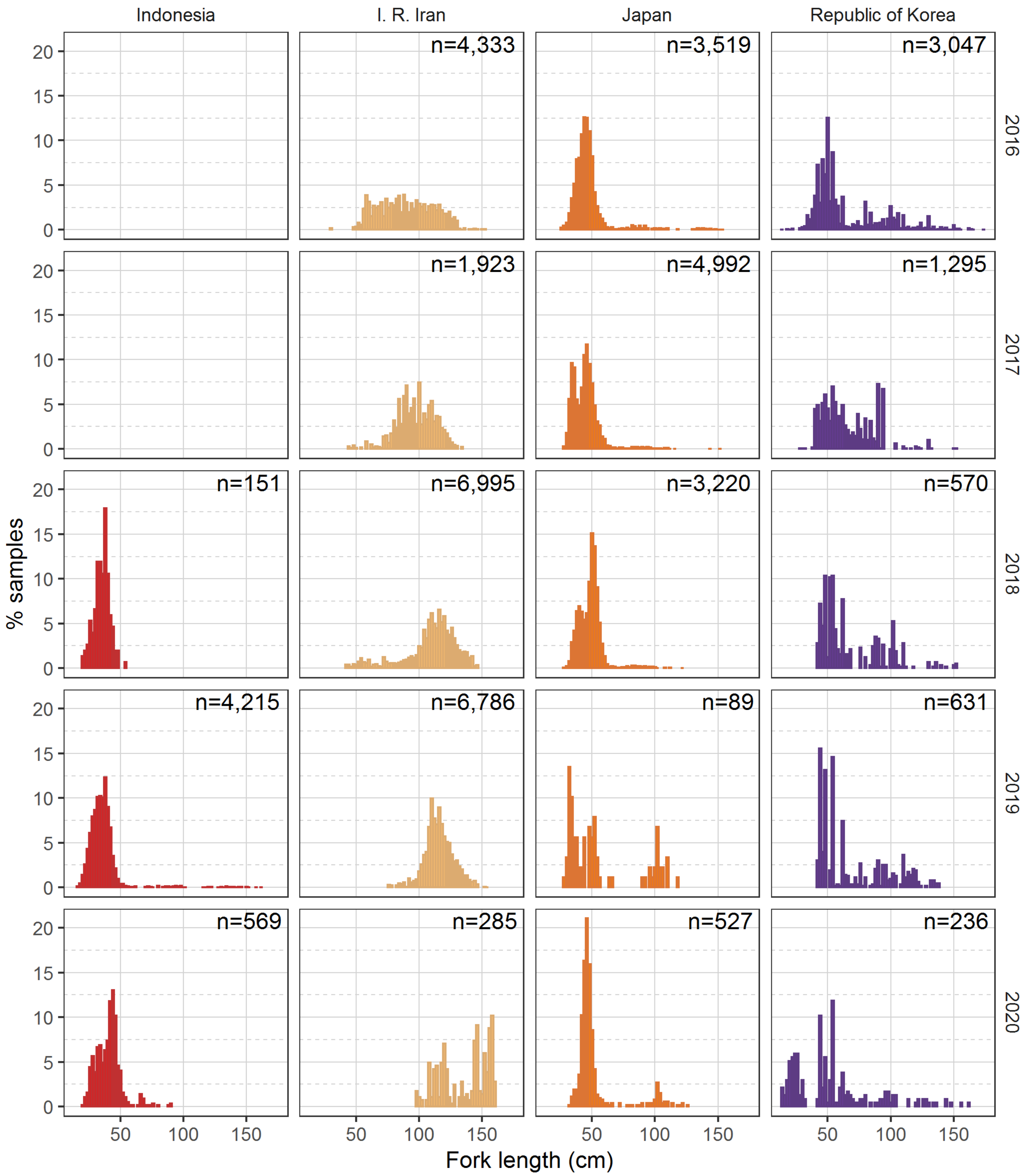

Figure 29: Relative size distribution of yellowfin tuna (fork length in cm) recorded for unclassified schools, by year (2016–2020) and other purse seine fleet. Data source: [yellowfin tuna standardized size-frequency dataset] (Res. 15/02)

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 & Hoyle 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-2021-WPTT23(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 (**Fig. 30**). 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 15 kg / fish in favour of the former, as detected in 2020 (when the coverage level of the size-frequency data was of around 3.9 samples per metric ton) (**Fig. 30**).

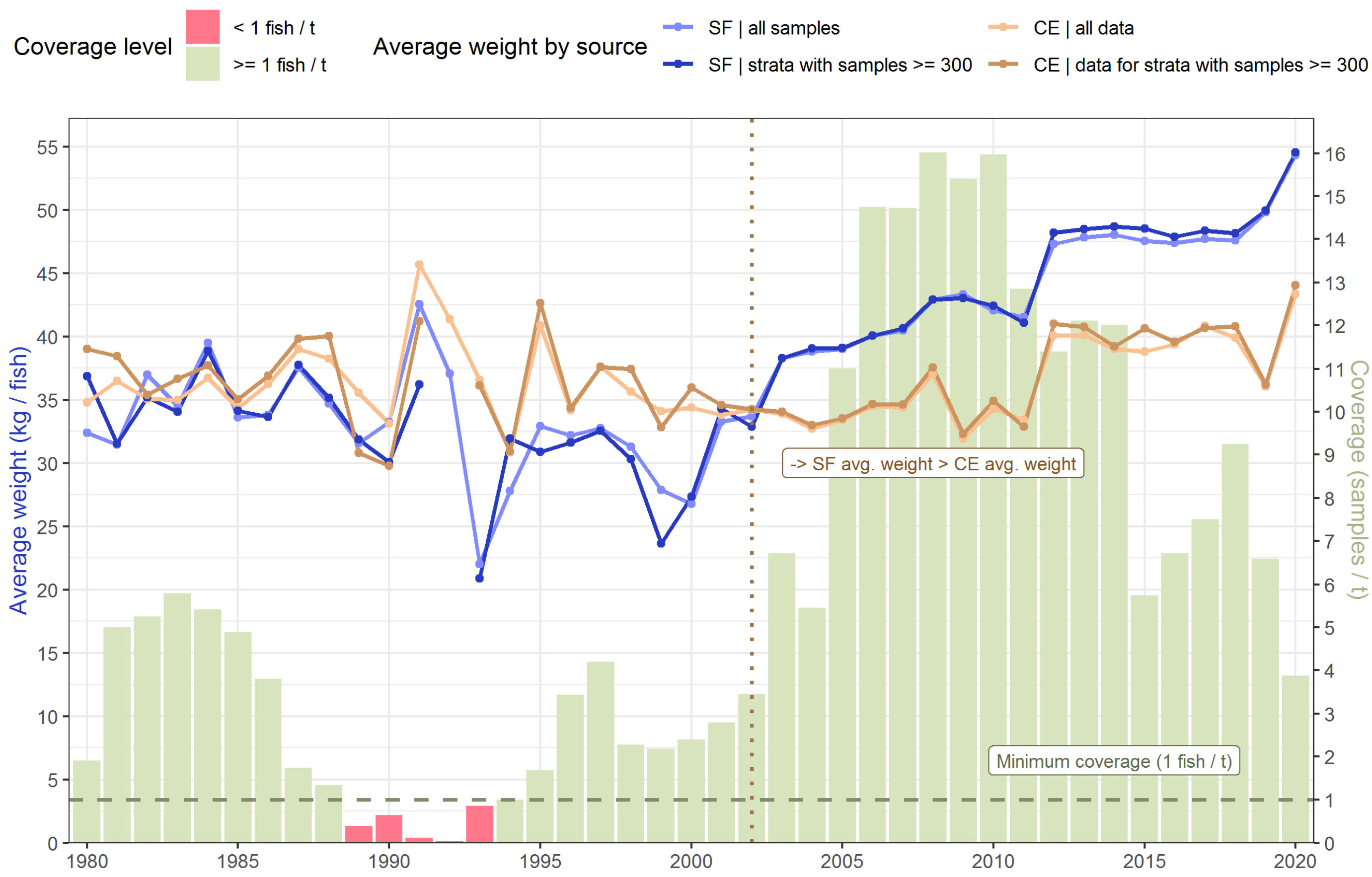

Figure 30: Difference in average weights of yellowfin tuna caught by the deep-freezing fleet of Taiwan,China as calculated from the available size-frequency and catch-and-effort data (1980-2020). Data source: yellowfin tuna standardized size-frequency dataset and time-area catch dataset for longline 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 Japanese logbooks and onboard observers is not in full agreement, with the latter (observer data) showing a higher number of smaller fish measured in the category between 60 and 100 cm FL (**Fig. 31a**);
- Size data from Taiwanese logbooks and observers are in almost perfect agreement (**Fig. 31b**);

- Size data from logbooks are in reasonable agreement between the two fleets, with a mode at around 130 cm FL and comparable tails (**Fig. 31c**);
- Size data from observers confirm a tendency in measuring smaller fish in the case of the Japanese fleet (**Fig. 31d**).

In the period considered (2000-2020), yellowfin tuna size-frequency records submitted by the Japanese fleet were comprised of 24,653 individuals recorded in logbooks and 24,891 individuals measured by onboard observers. In this case, the number of individuals measured by observers was slightly higher than the one 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, yellowfin tuna size-frequency records submitted by the Taiwanese fleet were comprised of 2,539,422 individuals recorded in logbooks, and 33,784 individuals measured by onboard observers. In this case, the magnitude of the size data collected by observers corresponds to ~ 1.3% 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. 31-32** 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.

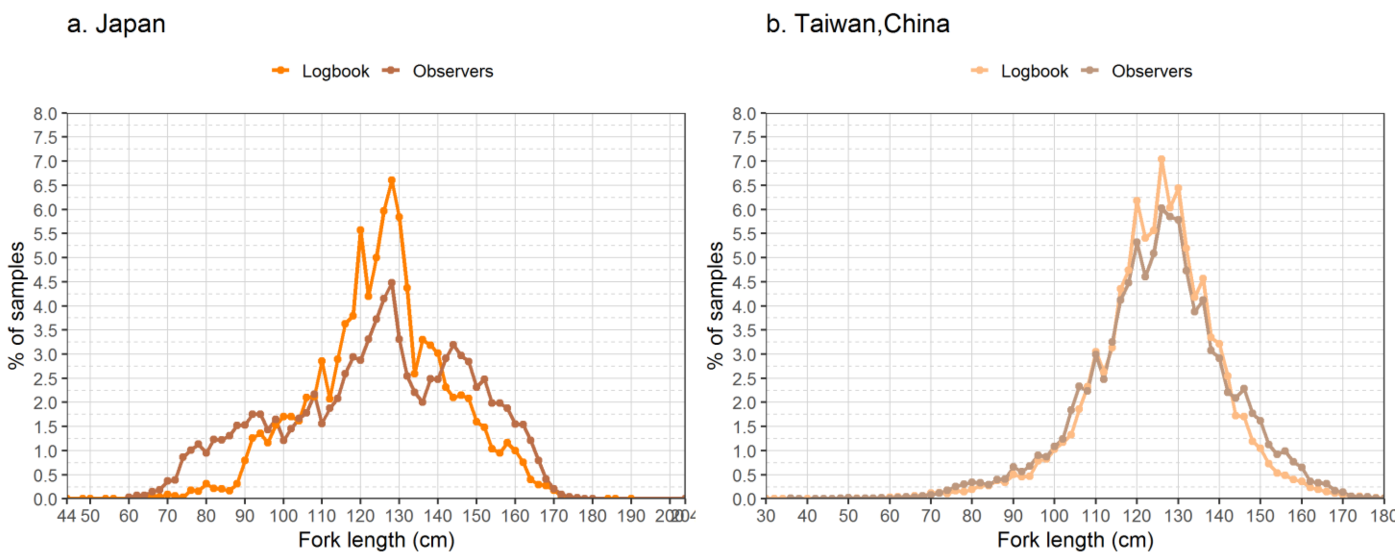

Figure 31: Relative size distribution (fork length in 2 cm size bins) of yellowfin tuna caught by the deep-freezing longline fleets of Japan and Taiwan,China, by fleet and origin. Data source: [yellowfin tuna standardized size-frequency dataset](#) (Res. 15/02)

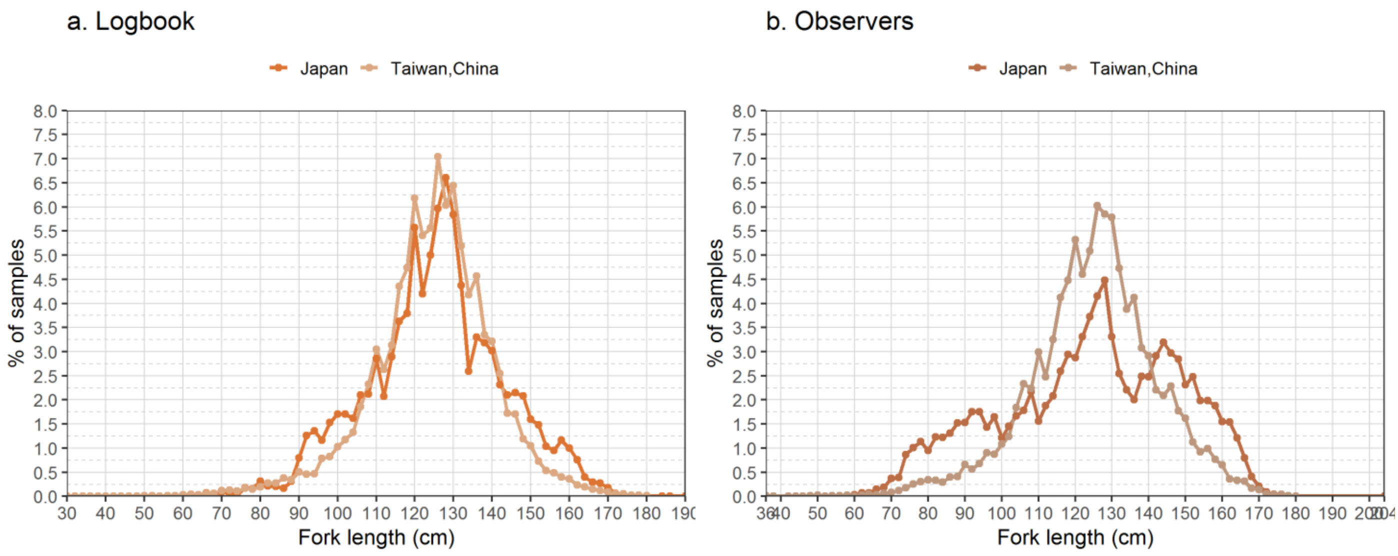

Figure 32: Relative size distribution (fork length in 2 cm size bins) of yellowfin tuna caught by the deep-freezing longline fleets of Japan and Taiwan,China, by origin and fleet (2000-2019). Data source: yellowfin tuna standardized size-frequency dataset (Res. 15/02)

Coverage levels of yellowfin 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. Japanese longliners, instead, reached or surpassed that level only in years from 2017 onward - which is an indication that the representativeness of yellowfin tuna samples from the Japanese deep-freezing longliners in previous years might not be optimal (**Fig. 33a-b**). Same considerations can be made for size-frequency data from the other longline fleets with the possible exception of those from Seychelles which are relatively well sampled (**Fig. 33c-e**).

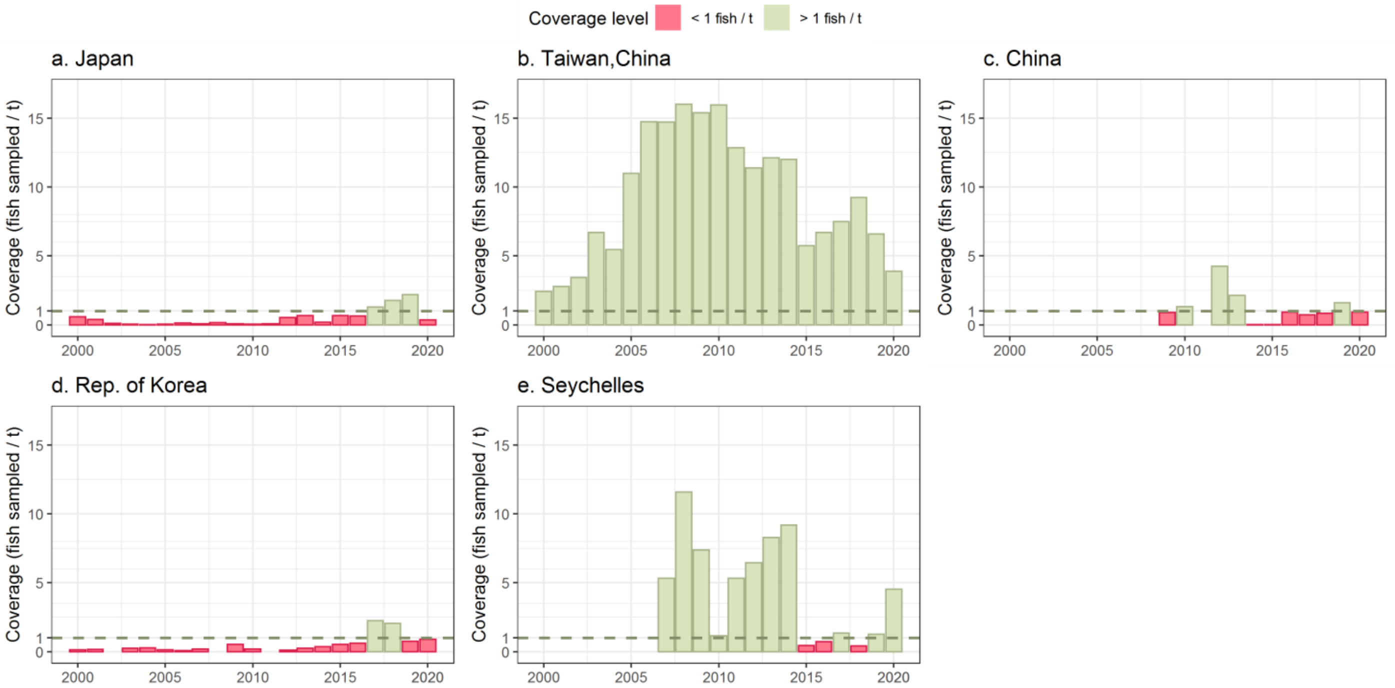

Figure 33: Size-frequency samples coverage (number of fish measured by t of retained catches) of yellowfin tuna caught by the deep-freezing longline fleets of Japan (a), Taiwan,China (b), China (c), Rep. of Korea (d) and Seychelles (e), by fleet and year (2000-2020). Data source: yellowfin tuna standardized size-frequency dataset (Res. 15/02)

Appendix - effort trends for tropical tuna fisheries

Longline fisheries, by decade (1950-2009)

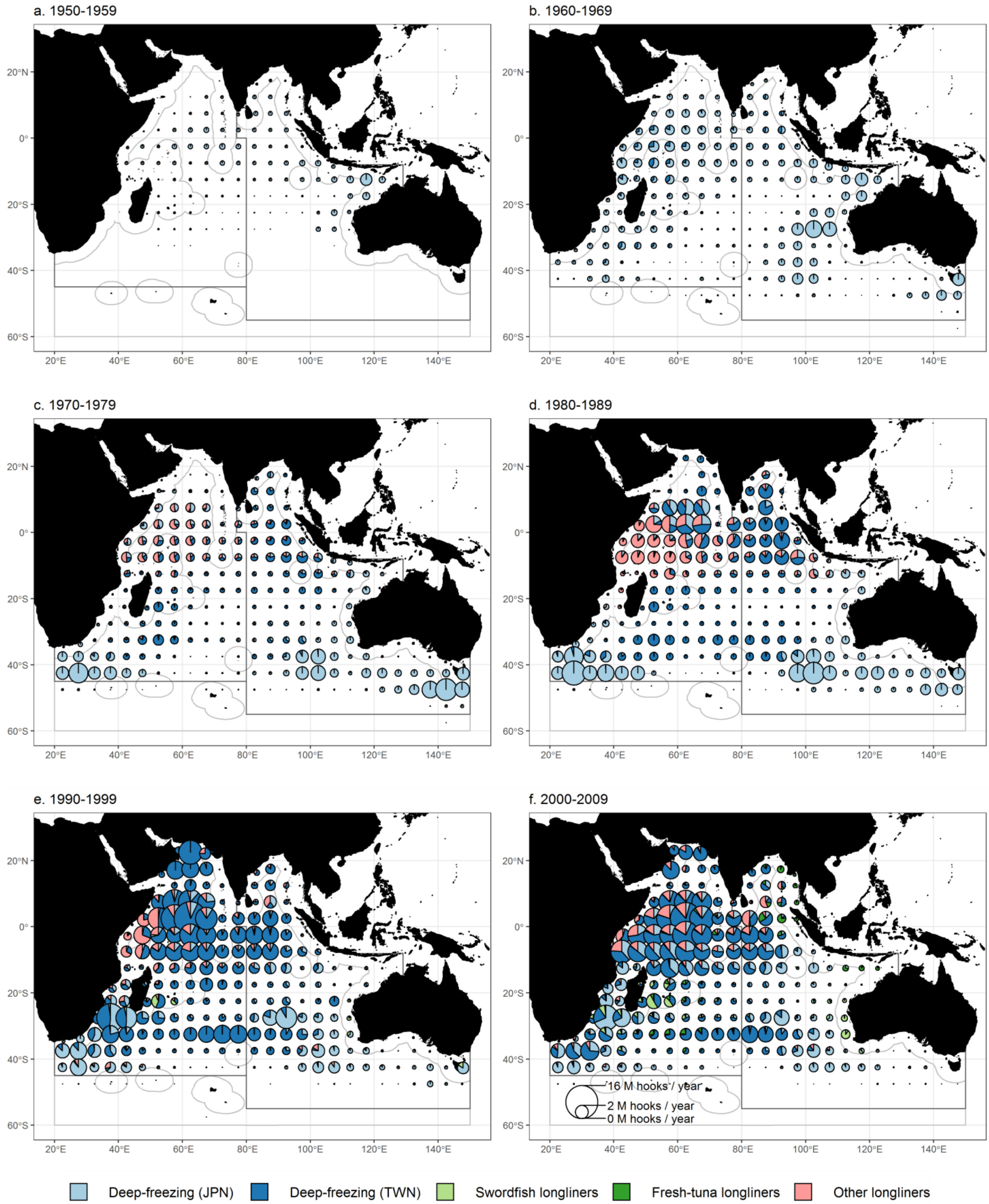

Figure 34: Average annual effort exerted by industrial longline fleets in millions of hooks set / year, by decade, 5x5 grid and fleet. Data source: time-area effort dataset for longline fisheries (Res. 15/02)

Longline fisheries, by last years (2016-2020) and decade (2010-2019)

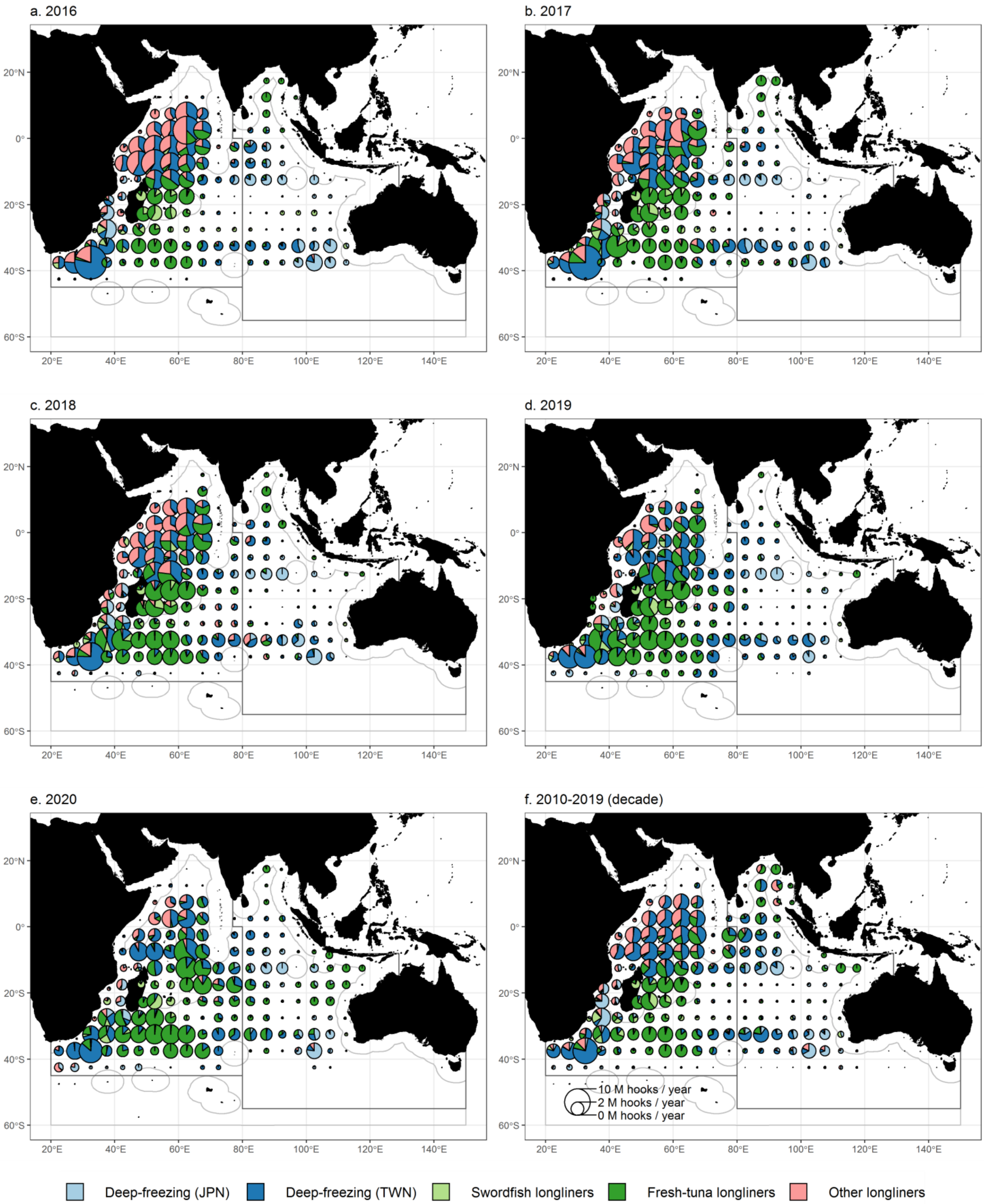

Figure 35: Average annual effort exerted by industrial longline fleets in millions of hooks set / year, by year / last decade, 5x5 grid and fleet. Data source: time-area effort dataset for longline fisheries (Res. 15/02)

Purse seine fisheries, by decade (1980-2009)

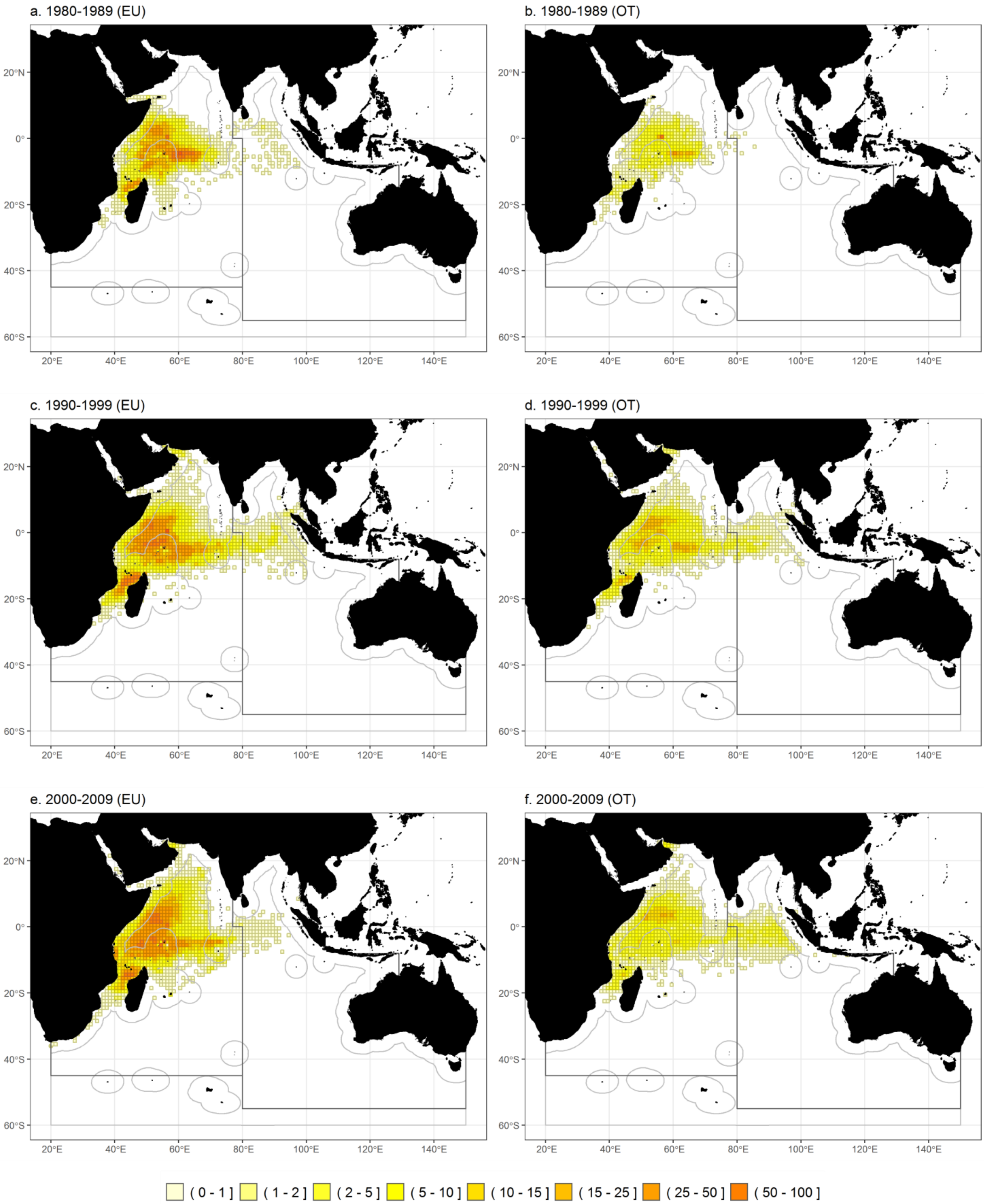

Figure 36: Average annual effort exerted by the industrial purse seine fleets of the European Union and assimilated flags (EU) vs. all other flags (OT) in fishing days / year, by decade, 1x1 grid and fleet. Data source: time-area effort dataset for purse-seine fisheries (Res. 15/02)

Purse seine fisheries (EU) by last years (2016-2020) and decade (2010-2019)

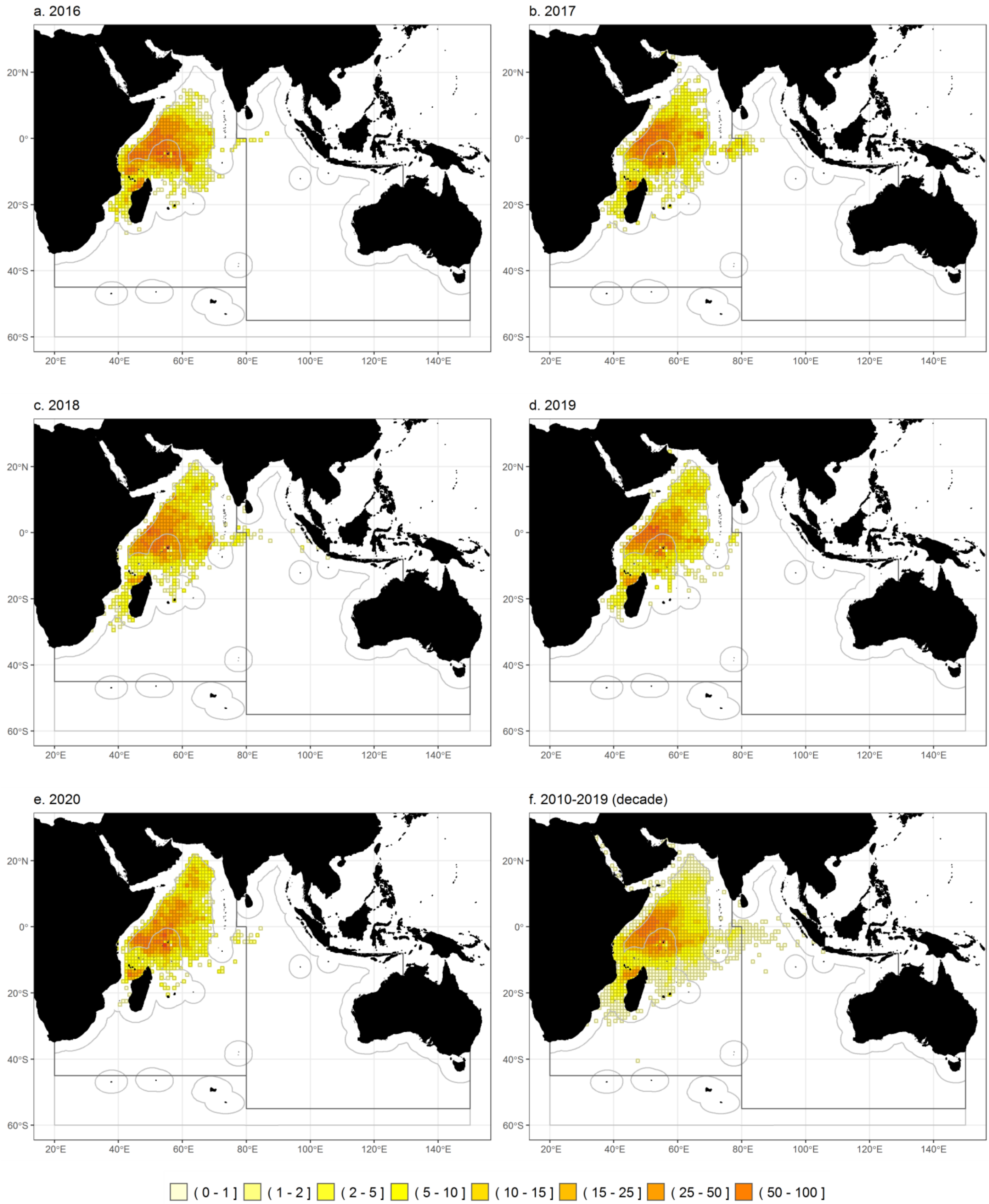

Figure 37: Average annual effort exerted by the industrial purse seine fleets of the European Union and assimilated flags (EU) in fishing days / year, by year / decade and 1x1 grid. Data source: time-area effort dataset for purse-seine fisheries (Res. 15/02)

Purse seine fisheries (OT) by last years (2016-2020) and decade (2010-2019)

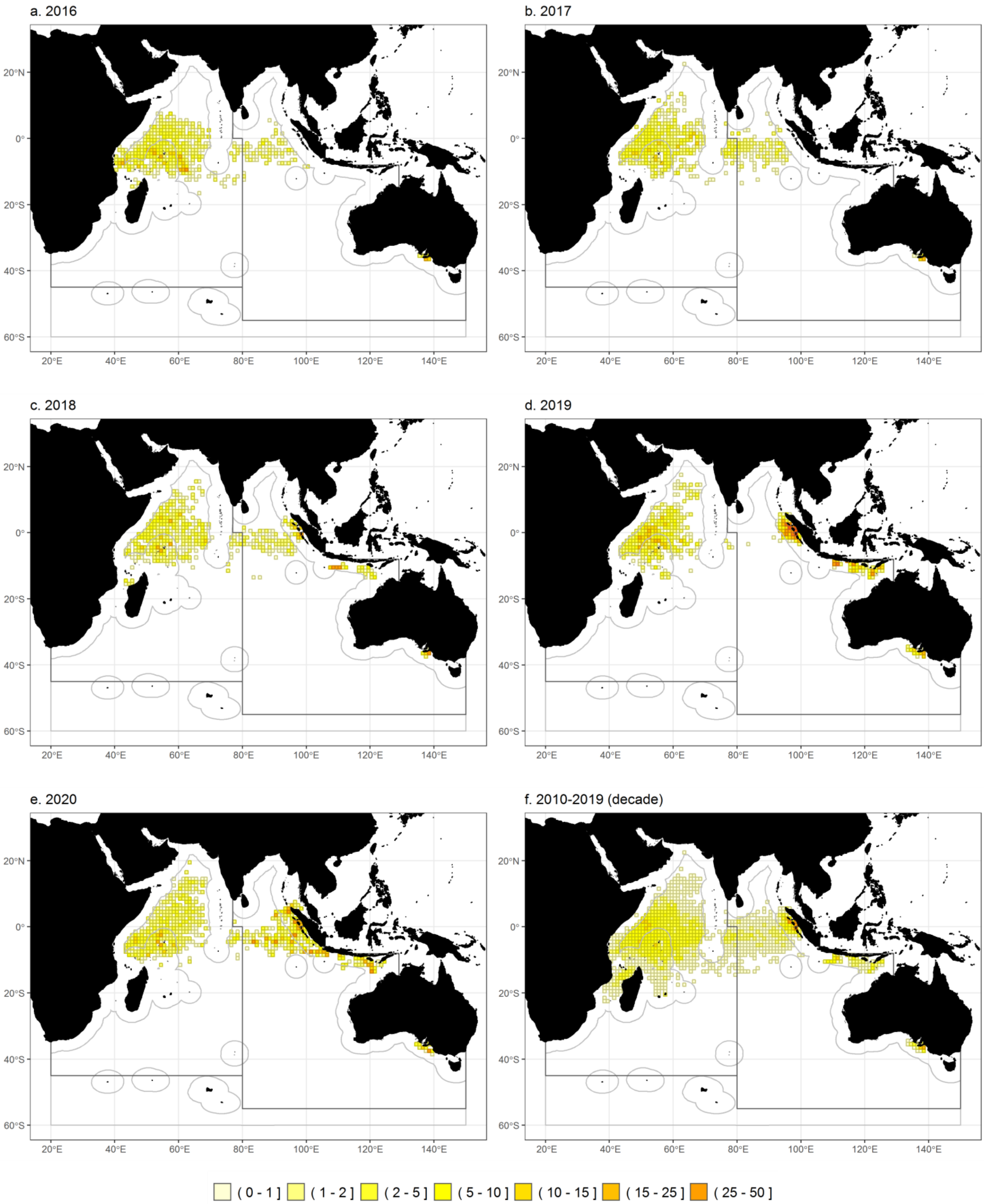

Figure 38: Average annual effort exerted by the industrial purse seine fleets from other flags (OT) in fishing days / year, by year / decade and 1x1 grid. Data source: time-area effort dataset for purse-seine fisheries (Res. 15/02)

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