OVERVIEW OF INDIAN OCEAN TROPICAL TUNA FISHERIES

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Introduction

Global catches of tropical tunas living in oceanic habitats, i.e., bigeye tuna (*Thunnus obesus*; BET), skipjack tuna (*Katsuwonus pelamis*; SKJ), and yellowfin tuna (*Thunnus albacares*; YFT), have steadily increased over the last decades to exceed 5 million metric tons in 2019 (FAO 2021). The contribution of the Indian Ocean to the global catch of tropical tuna also increased steadily following the development of the large-scale purse seine fishery from the early 1980s, reaching a maximum of about 28% of the total in the mid-2000s. Levels remained stable at about 20% of total catches in recent years, recording approximately 1 million metric tons in 2019 (**Fig. 1**).

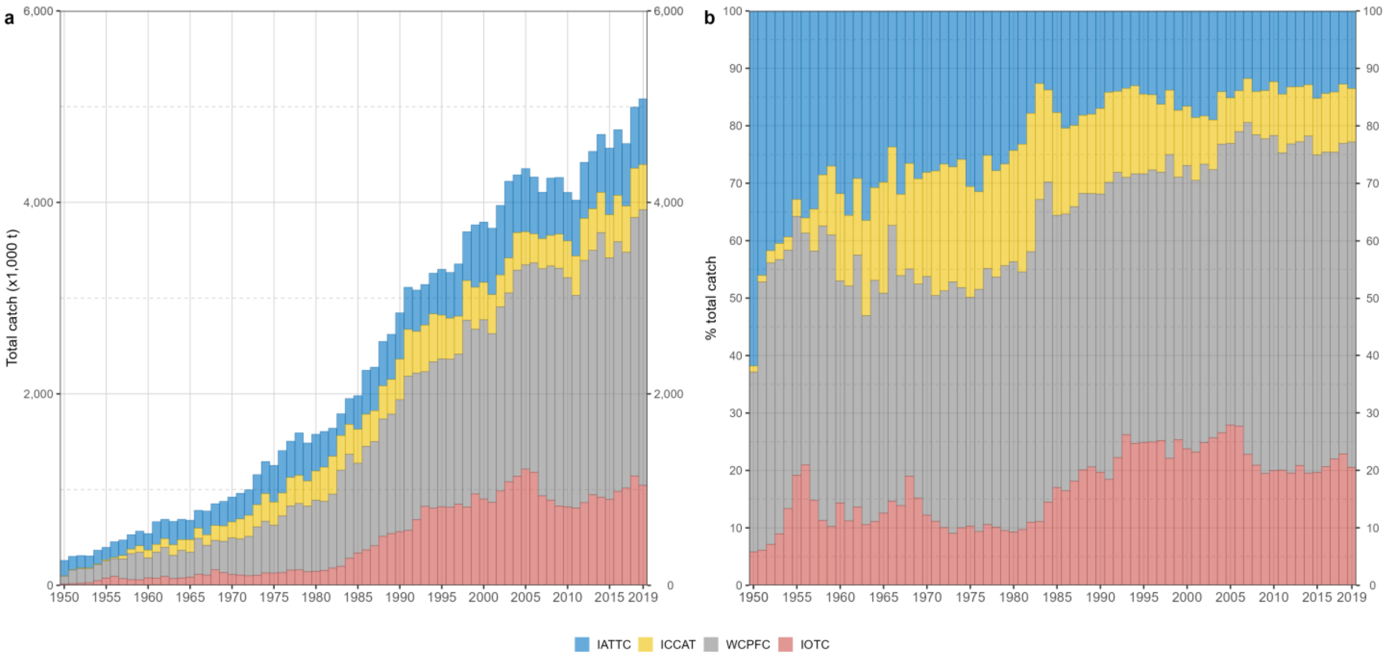

Figure 1: Annual time series of cumulative nominal catches (metric tonnes; t) of tropical tunas by tuna Regional Fisheries Management Organisation for the period 1950-2021. IATTC = Inter-American Tropical Tuna Commission; ICCAT = International Commission for the conservation of Atlantic Tunas; IOTC = Indian Ocean Tuna Commission; WCPFC = Western-Central Pacific Ocean Commission. Source: Global Tuna Atlas

The overarching objective of this summary is to provide participants at the 24th Session of the IOTC Working Party on Tropical Tunas (WPTT24) with a review of the status of the information available on Indian Ocean tropical tunas and their associated fisheries. The document provides an overview of the data sets available in the IOTC Secretariat databases as of October 2022, the methods used for processing and assessing the reporting quality of the main data sets, and a description of the main trends and features of Indian Ocean tropical tuna fisheries over the last seven decades.

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.

IOTC data requirements vary according to the size of the fishing vessels and their area of operation. Following IOTC Resolution 19/04, the IOTC maintains a record of vessels authorised to fish for tuna and tuna-like species in the IOTC area of competence (Authorized Fishing Vessels; AFVs) which includes all fishing vessels with a length overall of 24 m and over, and those under 24 m if they operate in waters outside the Exclusive Economic Zone (EEZ) of the flag state. For convenience purpose, we define the type of fishery as *industrial* when the fisheries are composed of AFVs while *artisanal* fisheries, on the opposite, refer to any fishery composed of vessels of length below 24 m and operating in areas of national jurisdiction. This in line with IOTC Resolution 15/02 whereby artisanal (or coastal) fisheries are defined as the fisheries other than longline and surface fisheries undertaken by AFVs.

Nominal catch data

Nominal catches correspond to the total retained catches (in live weight) per year, Indian Ocean major area, fleet, and fishing gear (IOTC Res. 15/02) and can be reported through IOTC form 1RC. In addition, and in order to support the monitoring of catch limits for the industrial fisheries of CPCs objecting to IOTC Resolution 21/01, IOTC Res. 19/01 requests these CPCs to submit their catches of yellowfin tuna from 2019 explicitly disaggregated by vessel length and area of operation (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 finer-scale data, usually from logbooks, reported in aggregated format and stratified by 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, and 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 collects detailed information (e.g., exact location in space and time of the sets and interactions, including the fate of observed individuals) 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 a complete reporting of size frequency data to the 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 through IOTC Form 4SF are for retained catches, CPCs can also use the same form to report size data of discarded individuals. Furthermore, additional size data (including those for individuals discarded at sea) may be collected through onboard observer programs and reported to the Secretariat as part of the ROS (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 at the Secretariat on the socio-economics of fisheries for tuna and tuna-like species (e.g., sale price, operating costs, jobs).

The Fisheries Development Division of the Pacific Islands Forum Fisheries Agency (FFA) has been collating monthly time series of tuna price data on key markets to use them as indicators of the trends in the price received by operators. Time series of price cover the period from January 2000 to December 2021 and include (i) Thai import prices for whole round frozen skipjack and yellowfin tunas (USD/t; cost and freight), (ii) Japanese import prices for fresh and frozen bigeye and yellowfin tunas caught with longline (YEN/kg; cost, insurance and freight) and (iii) US import prices for fresh (chilled) bigeye and yellowfin tunas from Oceania caught with longline (USD/kg; free on board). Fish prices were adjusted for inflation using US Consumer Price Index data to obtain real prices (Ruaia et al. 2020). These time series are considered more representative of trends in tuna price than the prices received by operators (i.e., ex-vessel prices) which may strongly depend on the markets and transport costs.

In addition, the FFA collates information on fuel price which is a major driver of costs in high seas fisheries is considered a good proxy of fishing costs (Sala et al. 2018), with the assumption that real non-fuel fishing costs have remained constant over time (Ruaia et al. 2020). The price collated by FFA is based on the arithmetic average of the Brent, Dubai, and West Texas crude oil prices and provides a global index of the value of fuel for fishing vessels. Time series of import price for tropical tunas and fuel price are given in Appendix I.

Regional Observer Scheme

Resolution 11/04 on the 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). In addition, the ROS database includes morphometric data (i.e., lengths and weights) collected at sea by fisheries observers which are of particular interest for deriving morphometric relationships.

A comprehensive description of the status, coverage, and data collected as part of the ROS is provided in IOTC (2021). 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 1,583 commercial fishing trips (886 from purse seine vessels and 697 from longline vessels of various types) made during the period 2005-2020 from 7 fleets: EU,France, Japan, Sri Lanka for longline fisheries and EU,Spain, EU,France, Republic of Korea, Mauritius, Seychelles for purse seine fisheries. In addition, observer trip reports have been submitted to the Secretariat by some CPCs (e.g., Taiwan,China) but data were not provided according to the ROS standards, *de facto* preventing their inclusion in the ROS regional database.

Tagging data

Tag 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.

Morphometric data

Different length-length and length-weight relationships have been estimated for Indian Ocean tropical tuna based on morphometric data collected through fisheries monitoring programs and research projects (**Table 1**).

Table 1: Summary of morphometric relationships available for Indian Ocean tropical tunas. FL = fork length (cm); RD = round weight (kg); GG = Gilled-and-gutted weight (kg). N = number of samples; LL = longline; GN = gillnet; PL = pole and line; PS = purse seine; OT = Other gears

Species	Equation	Gears	N	MinFL	MaxFL	a	b	Reference
BET	RD = a*FL^b	GN;PL;PS	2,156	29.5	174	2.2170e-05	3.012110	Chassot et al. 2016
	GG = a*FL^b	LL;OT	12,047	70.0	187	1.5921e-05	3.041541	Geehan and Pierre 2013
	RD = a*GG+b	LL;OT	12,047	70.0	187	1.1300e+00	0.000000	Geehan and Pierre 2013
SKJ	RD = a*FL^b	ALL	1,762	30.0	73	4.9700e-06	3.392920	Chassot et al. 2016
YFT	RD = a*FL^b	GN;PL;PS	25,386	29.0	166	2.5490e-05	2.966700	Chassot et al. 2016
	GG = a*FL^b	LL;OT	15,133	72.0	177	9.4007e-06	3.126844	Geehan and Pierre 2013
	RD = a*GG+b	LL;OT	15,133	72.0	177	1.1300e+00	0.000000	Geehan and Pierre 2013

Methods

The release of the IOTC curated data sets for tropical tunas 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 fleet (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 (**Table 2**) and gear (**Table 3**) when these are reported as *aggregates* of multiple species or gears.

Table 2: List of species groups that include one or more tropical tuna species

Species code	Species name	Species scientific name	BET	SKJ	YFT
AG10	Skipjack tuna and kawakawa	*Katsuwonus pelamis; Euthynnus affinis*		✓	
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*	✓	✓	✓
TUS	True tunas nei	*Thunnus spp*	✓	✓	✓
TUX	Tuna-like fishes nei	*Scombroidei*	✓	✓	✓

Table 3: List of gear aggregates with their component gear codes (limited to gear aggregates that have reported catches of tropical tunas)

Aggr. code	Gear aggregate	Category	BB	GILL	HAND	LIFT	LL	LLCO	PS	PSS	RR	SPOR	TRAW	TROL
BBPS	Baitboat and purse seine	Baitboat	✓						✓					
GIHT	Gillnet and hand line and troll line	Gillnet		✓	✓									✓
HATR	Hand line and Troll line	Trolling			✓									✓
HOOK	Hook and line	Trolling			✓			✓						✓
LLTR	Coastal Longline and Troll line combination	Longline						✓						✓
UNCL	Unclassified	Other	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

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 all available information, including expert knowledge, 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 catches 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. Raised data comprise estimated catches both 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 each species 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., when 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 implemented 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 the type of data set and aims to account for reporting coverage and compliance with IOTC reporting standards (**Table 4**). 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 4: Key to IOTC quality scoring system

<table>
<tr><th>Data set</th><th>Criterion</th><th>By species</th><th>By gear</th></tr>
<tr><td rowspan="3">Nominal catch</td><td>Fully available</td><td>0</td><td>0</td></tr>
<tr><td>Partially available</td><td>2</td><td>2</td></tr>
<tr><td>Fully estimated</td><td>4</td><td>4</td></tr>
<tr><td rowspan="4">Catch and effort</td><td>Available according to standards</td><td>0</td><td>0</td></tr>
<tr><td>Not available according to standards</td><td>2</td><td>2</td></tr>
<tr><td>Low coverage (<30% logbooks)</td><td colspan="2">2</td></tr>
<tr><td>Not available</td><td colspan="2">8</td></tr>
<tr><td rowspan="4">Size frequency</td><td>Available according to standards</td><td>0</td><td>0</td></tr>
<tr><td>Not available according to standards</td><td>2</td><td>2</td></tr>
<tr><td>Low coverage (<1 fish per tonne caught)</td><td colspan="2">2</td></tr>
<tr><td>Not available</td><td colspan="2">8</td></tr>
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Results

Nominal catches

Historical trends (1950-2021)

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 over 1.9 million t in 2018 (1.88 million t in 2021).

Tropical tuna have always dominated the total IOTC catch between 1950 and 2021, although their contribution to total catches has varied over time in relation to different factors such as the expansion of fisheries targeting other species, the development of the purse seine fishery starting from the 1980s, and the threats of piracy in the late 2010s.

In 2021, the total catch of tropical tuna in the Indian Ocean has been estimated at 1.16 million t, corresponding to 61.7% of catches of all IOTC species combined.

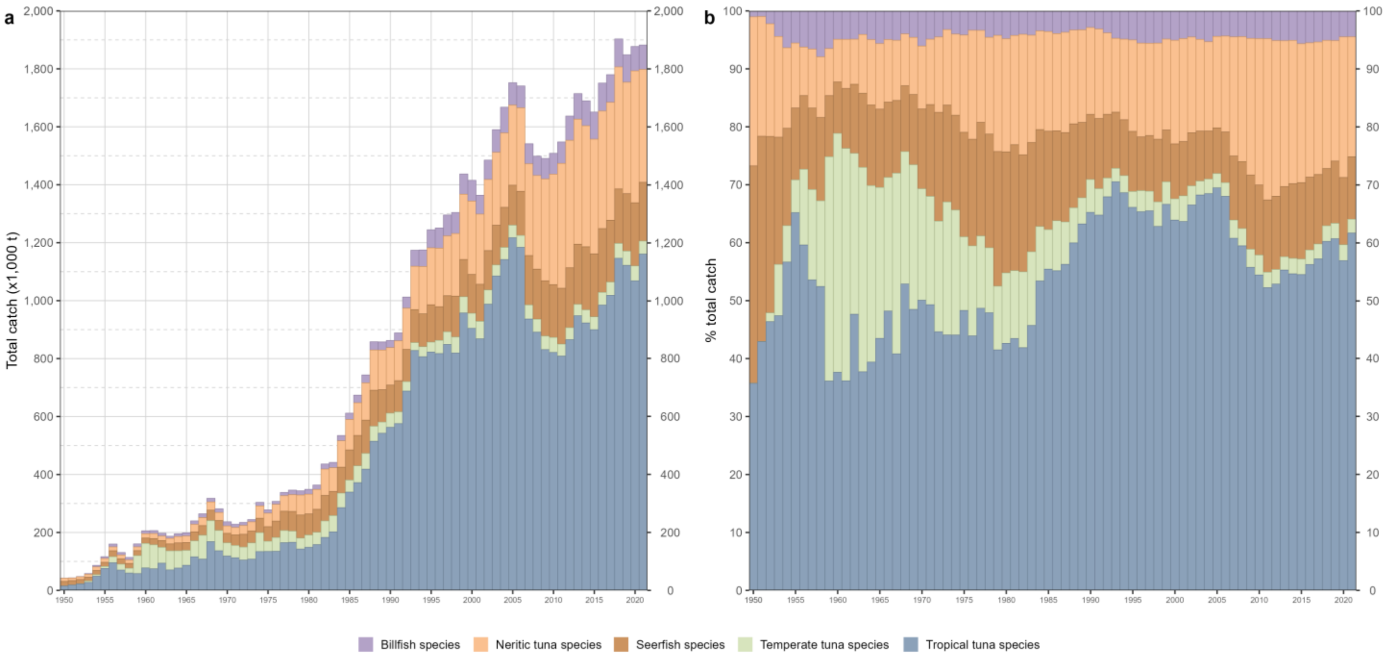

Figure 2: Annual time series of cumulative nominal absolute (a) and relative (b) catches (metric tonnes; t) of all IOTC tuna and tuna-like species by species category for the period 1950-2021

Catches of tropical tunas in the Indian Ocean show a sharp increase from the early to mid-1980s, following the arrival of purse seiners from the Atlantic Ocean and the quick development of the fishery. Eventually, purse seine catches showed a constant increase until the mid-2000s, when annual total catches from all three tropical tuna species combined exceeded 1.22 million t (**Fig. 3**).

While yellowfin tuna dominated the tropical tuna catches prior to the 1970s, its contribution decreased from over 60% in the mid-1950s to around 40% of the total catch in the early 1980s, a value that has remained fairly stable over the last four decades (**Fig. 3**). Annual catches of yellowfin tuna increased from around 28,000 t during the 1950s to around 435,000 t in recent years.

The contribution of skipjack tuna to total tropical tuna catches shows an almost continuous increase over time, from less than 30% of the totals in the mid-1950s to over 50% in recent years (**Fig. 3**). Annual catches of skipjack tuna increased from around 15,000 t during the 1950s to around 580,000 t in recent years.

Bigeye tuna has generally been the species that contributed the least to total tropical tuna catches (**Fig. 3**). In fact, its contribution shows a steady decline from 30% in the late 1970s to 10% in recent years. Annual catches of bigeye tuna increased from around 7,000 t in the 1950s to around 87,000 t between 2017 and 2021 (see IOTC-2022-WPTT24-07b - BET data for additional information).

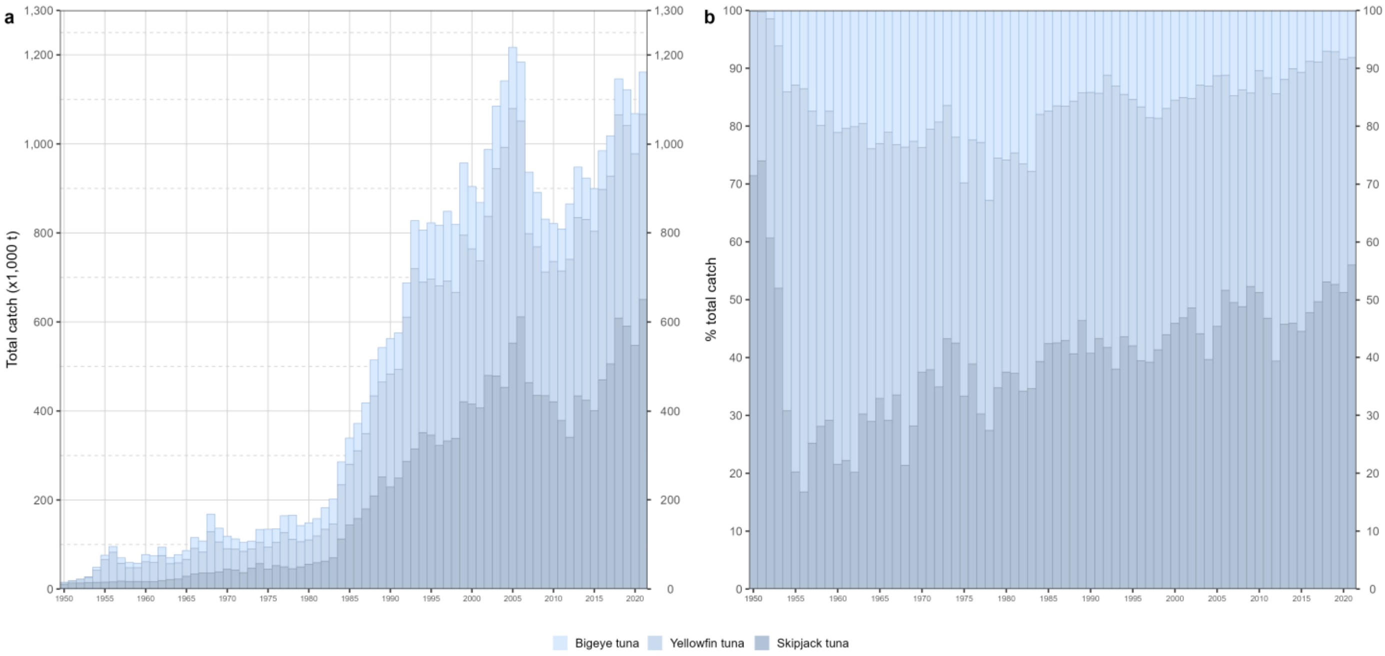

Figure 3: Annual time series of cumulative nominal absolute (a) and relative (b) catches (metric tonnes; t) of Indian Ocean tropical tuna by species for the period 1950-2021

The majority of tropical tuna has been caught by industrial fisheries from the mid-1980s throughout the 1990s and 2000s, contributing to about 64% of the total catch over that period (**Fig. 4**). In the same years, total catches of tropical tuna taken by Indian Ocean artisanal fisheries increased steadily to annual values of around 425,000 t in recent years.

Following the major decline of the catches by industrial fisheries in the late 2000s, catch levels of artisanal and industrial fisheries remained comparable at about 448,000 t per year between 2010 and 2015, when a new increase in industrial catches saw their contribution reach 61% of the total tropical tuna catch, i.e., about 678,000 t as recorded in recent years (**Fig. 4**).

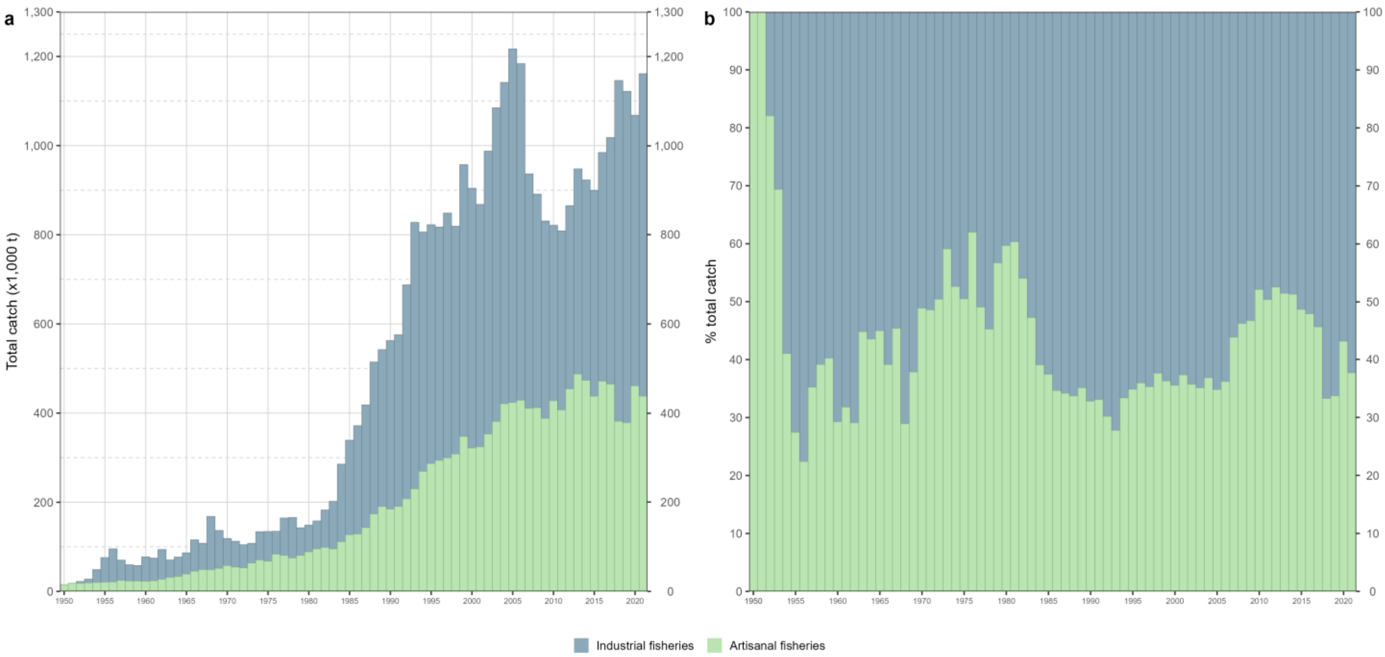

Figure 4: Annual time series of nominal catches (metric tonnes; t) of Indian Ocean tropical tuna by fishery type for the period 1950-2021

Tropical tunas are harvested by a large diversity of fisheries and fishing gears, and except longline fisheries and purse seine fisheries catching free-swimming schools, all other fisheries have shown an increasing trend in their total catch over the last decades (**Fig. 5a**). The contribution of the different fisheries to the total tropical tuna catch has showed major changes over time in relation with the development, expansion, or decline of the fisheries between 1950 and 2021 (**Fig. 5b**).

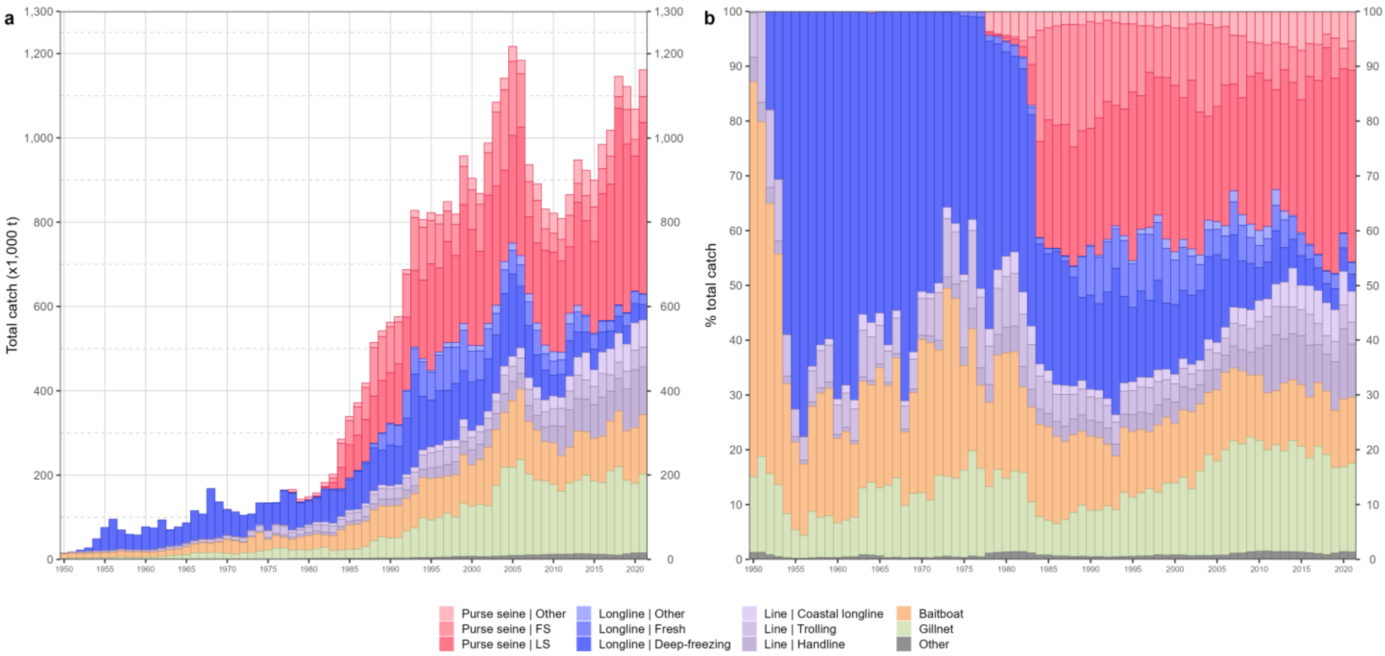

Figure 5: Annual time series of nominal catches (metric tonnes; t) of Indian Ocean tropical tuna by fishery for the period 1950-2021

Main fishery features (2017-2021)

Purse seines, gillnets, and pole and lines contribute to the large majority of tropical tuna catch in the Indian Ocean. In recent years, purse seine on tuna schools associated with drifting floating objects has been the dominant fishing gear, representing about one third of the total tropical tuna catch estimated by the IOTC Secretariat for the years between 2017 and 2021 (**Table 5**). Over the same period, gillnets and pole and lines have contributed to 17% and 11.6% of the total catch, respectively. Catches from coastal line fisheries are also substantial in the Indian Ocean (18.7% for all combined line fisheries) while longline fisheries now represent a small part of the tropical tuna catch, i.e., 6.3% for all combined longline fisheries.

Table 5: Mean annual catches (metric tonnes; t) of Indian Ocean tropical tuna by fishery between 2017 and 2021. LS = schools associated with floating objects; FS = free-swimming schools

Fishery	Fishery code	Catch	Percentage
Purse seine | LS	PSLS	382,992	34.7
Gillnet	GN	187,201	17.0
Baitboat	BB	128,125	11.6
Line | Handline	LIH	99,358	9.0
Line | Coastal longline	LIC	65,253	5.9
Purse seine | Other	PSOT	59,881	5.4
Purse seine | FS	PSFS	55,618	5.0
Line | Trolling	LIT	42,465	3.8
Longline | Deep-freezing	LLD	41,493	3.8
Longline | Fresh	LLF	26,262	2.4
Other	OT	13,000	1.2
Longline | Other	LLO	1,473	0.1

Tropical tunas are currently caught at high levels by several fleets, with EU,Spain ranking first during the period 2017-2021 thanks to the high productivity of its large-scale purse seiners (**Fig. 6**). The other major fishing nations (according to their recent catch reports) are Indonesia, Maldives, and Seychelles, which are described by very different profiles in terms of fishery composition. These four countries together have contributed to 54.1% of the total tropical tuna catch of the Indian Ocean between 2017 and 2021.

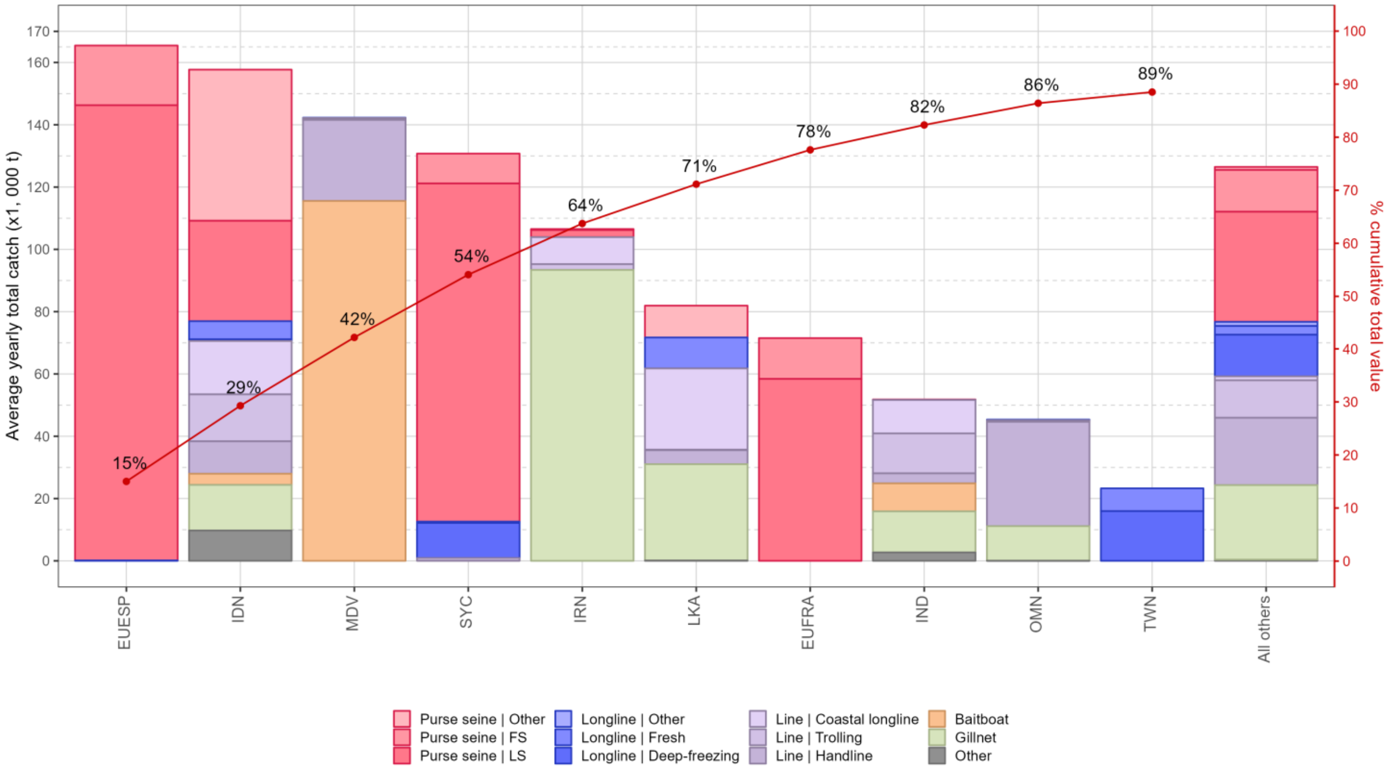

Figure 6: Mean annual catches (metric tonnes; t) of Indian Ocean tropical tuna by fleet and fishery between 2017 and 2021, with indication of cumulative catches by fleet. FS = free-swimming schools; LS = schools associated with floating objects

Fig. 7 and **Fig. 8** present the recent temporal trends in nominal catch of tropical tuna by fishery group and fleet in the years between 2017 and 2021. Overall, catch levels strongly vary across fishery groups while the main fleets display different interannual changes in catches within each fishery group.

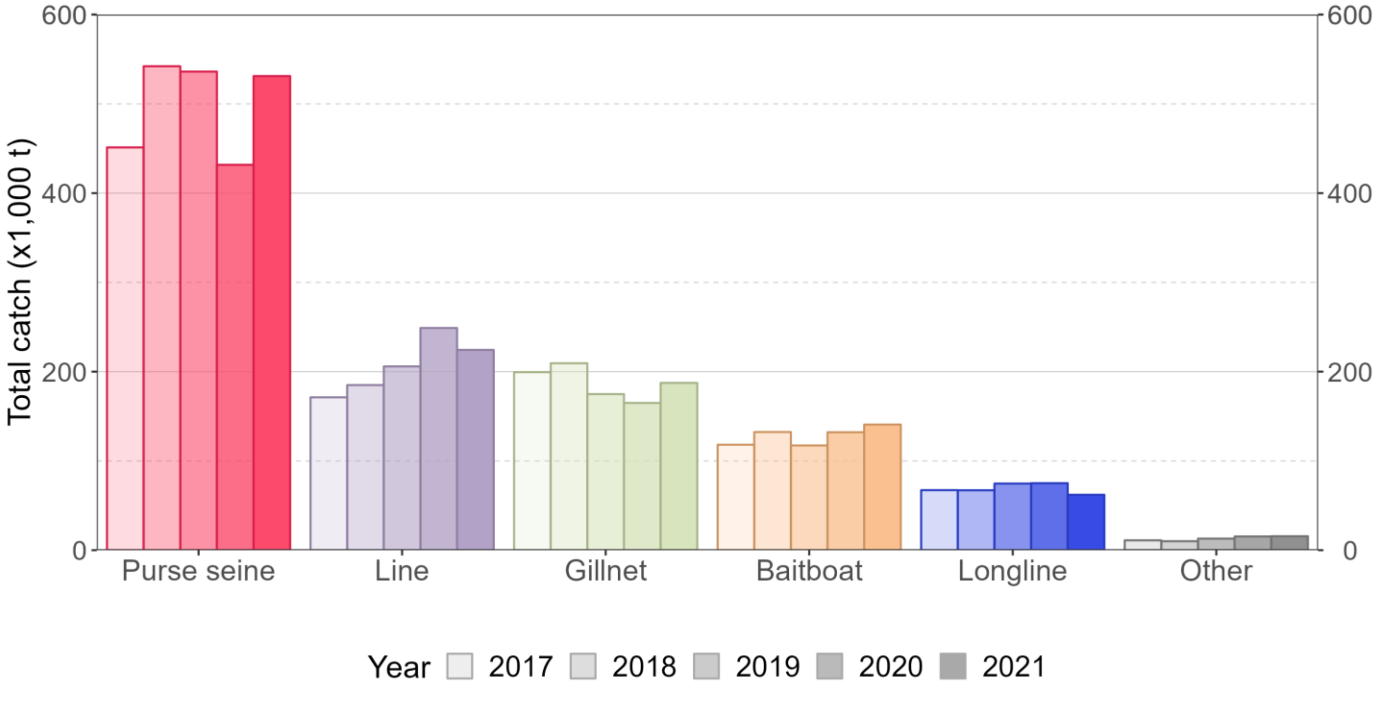

Figure 7: Annual catch (metric tonnes; t) trends of Indian Ocean tropical tuna by fishery group between 2017 and 2021

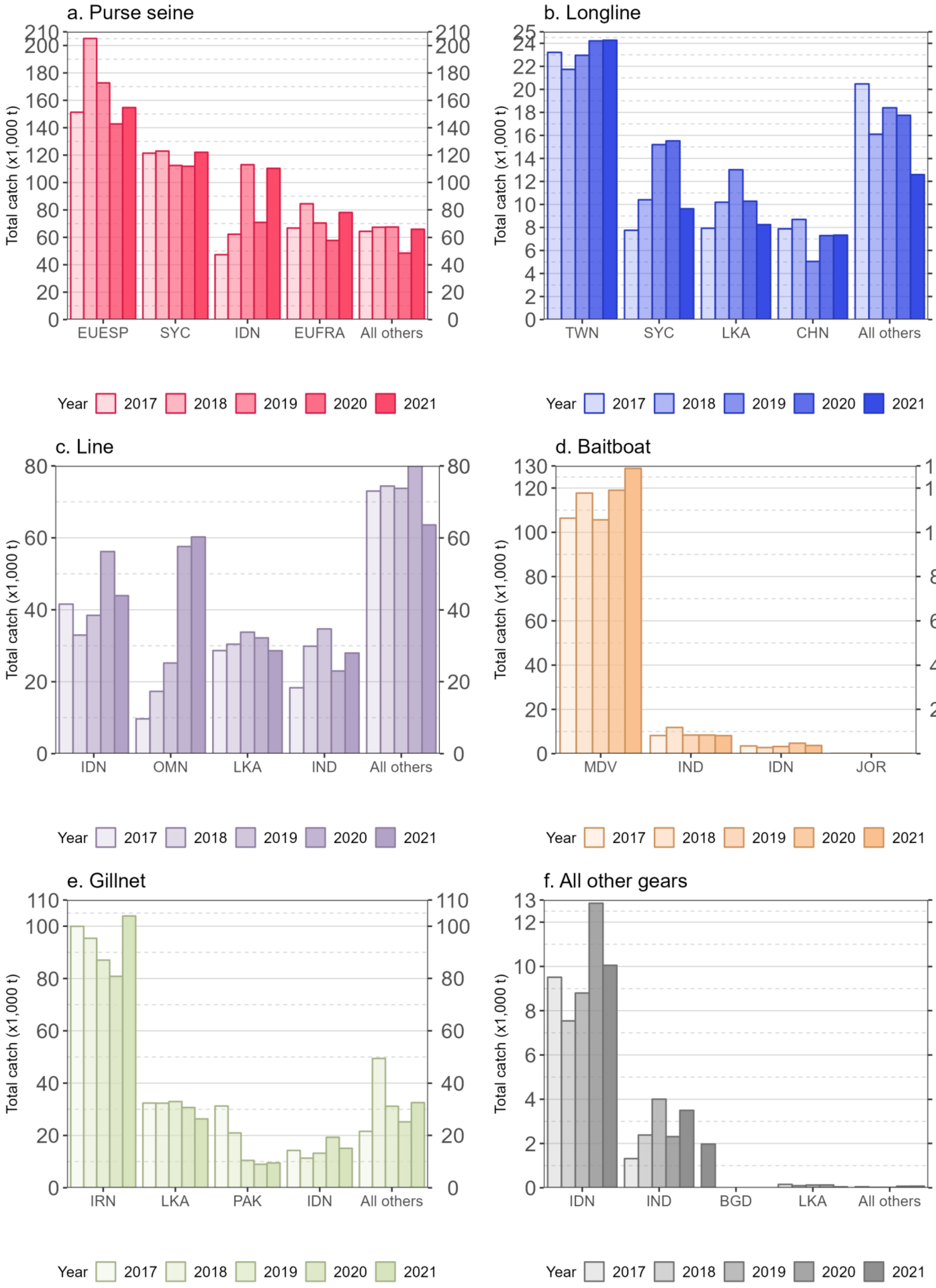

Figure 8: Annual catch (metric tonnes; t) trends of Indian Ocean tuna by main fishery group and fleet between 2017 and 2021

Reporting quality of nominal catch data

The quality of the nominal catch data reported for tropical tuna to the IOTC Secretariat shows major variability over the years (**Fig. 9**). As expected, the overall reporting quality for industrial fisheries is better than for artisanal fisheries, mostly because larger vessels are generally monitored with logbooks and landing recording systems. The collection of fisheries data for coastal small-scale and semi-industrial fleets is generally more difficult from a logistical point of view, since it generally requires the implementation of routine stratified catch assessment surveys combined with regular boat frame surveys and data processing systems (Caddy & Bazigos 1985, Stamatopoulos 2002). The reporting quality of the nominal catch data has shown an increasing trend over the last decade although it decreased in 2019-2020, partly due to the COVID-19 pandemic. In 2021, the percentage of tropical tuna catches fully or partially reported to the Secretariat was 86%.

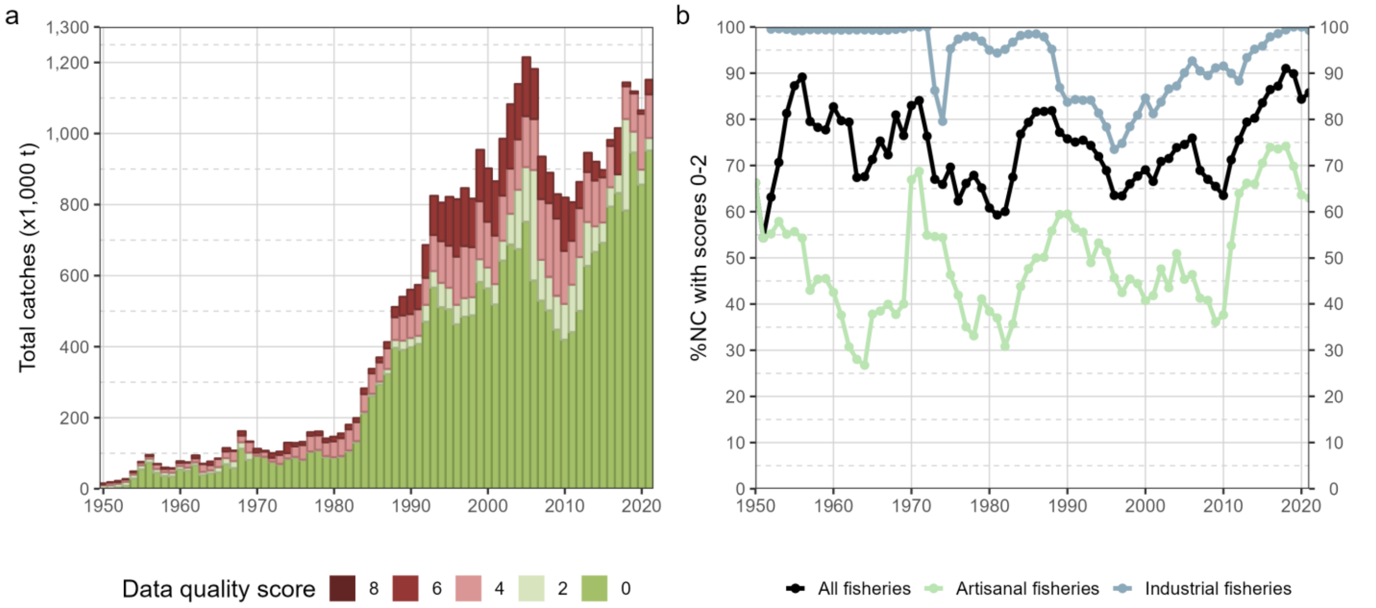

Figure 9: (a) Annual nominal catches (metric tonnes; t) of Indian Ocean tropical tuna estimated by quality score and (b) percentage of nominal catch fully or partially reported to the IOTC Secretariat for all fisheries and by type of fishery, in the period 1950-2021

Further details on potential bias in species composition for some industrial purse seine fleets

The Working Party on Tropical Tuna at its 21st session in October 2019 highlighted how the relative composition of tropical tuna 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 (IOTC 2019b).

In particular, it was noted how the percentage of bigeye tuna 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 accounted for 25.08% of total catches in the same year (average: 30.76%), while skipjack tuna contribution remained quite stable at 64.53% (average: 62.8%).

In October 2022, under the advice of the Working Party on Tropical Tunas, the IOTC Secretariat re-estimated the species composition of purse seine catches on FOB-associated schools reported by the Spanish component of the EU fleet in 2018, with the view of harmonizing the results with those reported in recent years by comparable fleets (including the rest of the EU).

The re-estimation reduced the fraction of bigeye tuna for 2018 while increasing back yellowfin and skipjack tuna catches to level comparable to previous and following years (at least until 2019). The results of this re-estimation are summarized in **Fig. 10a** (all EU flags combined) and **Fig. 11a** for the Spanish component.

Originally, the disproportion in EU bigeye tuna catches compared to previous years was more evident in the Spanish component of the fleet, and reached a peak of 12.24% in 2018 compared to an average of 6.8% for all other years.

Now, with the re-estimation applied by the IOTC Secretariat, the species composition appears to be more uniform, at least until 2019. Slightly higher-than-average values for the proportion of bigeye are reported by EU,Spain in 2020 and 2021, at the expenses of the relative proportions of skipjack in 2019 and yellowfin in 2020 (**Fig. 11a**).

Until 2021, neither the French component of the EU purse seine fleet (**Fig. 11b**) nor any of the EU-assimilated purse seine fleets (i.e., Seychelles and Mauritius, **Figs. 12a-b**) appeared to show the same anomaly encountered for EU,Spain in 2018 in terms of species composition.

Conversely, EU,France reported in 2021 a higher-than-average fraction of bigeye tuna and skipjack tuna compared to previous year, with yellowfin tuna dropping to less than 30% of total purse-seine catches on FOB-associated schools for the first time in recent years.

Same appear to be the case for Seychelles (**Fig. 10a**) which in 2021 reported a higher-than-average fraction of bigeye tuna and skipjack compared to previous years, with yellowfin tuna dropping to less than 25% of total purse-seine catches on FOB-associated schools for the first time in recent years, and skipjack reaching almost 70% of total catches of tropical tuna reported by the fleet.

a. European Union

Year	BET (%)	YFT (%)	SKJ (%)
2016	6.6	33.1	60.2
2017	6.0	30.4	63.6
2018	5.4	30.5	64.1
2019	5.2	25.8	69.0
2020	7.3	29.4	63.3
2021	7.5	23.8	68.7

b. Assimilated fleets

Year	BET (%)	YFT (%)	SKJ (%)
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
2021	8.6	21.4	70.0

Figure 10: Annual species composition (in % of catches by species) of the three tropical tunas as reported by the FOB-associated component of (a) the European Union and (b) assimilated purse seine fleets, all flags combined, for the years 2017-2021. The background intensity colour 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)

a. EU,Spain

Year	BET (%)	YFT (%)	SKJ (%)
2016	7.0	32.2	60.8
2017	6.2	28.6	65.2
2018	5.3	29.1	65.6
2019	5.3	22.9	71.8
2020	8.3	28.6	63.1
2021	8.1	22.3	69.7

b. EU,France

Year	BET (%)	YFT (%)	SKJ (%)
2016	5.7	35.5	58.8
2017	5.5	34.8	59.7
2018	5.8	34.2	60.1
2019	5.0	33.5	61.5
2020	4.5	31.5	64.0
2021	6.4	26.8	66.8

Figure 11: Annual species composition (in % of catches by species) of the three tropical tunas as reported by the FOB-associated component of the European Union (a) Spain and (b) France-flagged purse seine fleet for the years 2017-2021. The background intensity colour 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)

a. Seychelles

Year	BET (%)	YFT (%)	SKJ (%)
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
2021	8.8	21.7	69.5

b. Mauritius

Year	BET (%)	YFT (%)	SKJ (%)
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
2021	8.2	28.6	63.3

Figure 12: Annual species composition (in % of catches by species) of the three tropical tunas as reported by the FOB-associated component of the (a) Seychelles and (b) Mauritius purse seine fleet for the years 2017-2021. The background intensity colour 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)

The fleet-specific ternary diagrams of reported species compositions for catches on FOB-associated schools in the years 2010-2021 indicate a tendency (which became more evident from 2019 onwards) at decreasing the proportion of yellowfin in favour of skipjack and bigeye tuna (**Fig. 13**).

While this can be a consequence of the measures put in place to fulfil the requirements of Res. 19/01 (superseded by Res. 21/01 for those CPCs that haven't objected to the latter), further clarity is required from all involved CPCs to better understand the factors contributing to this evident shift in species composition detected in recent years, and more specifically to clarify the impact of changes to the statistical procedures for the calculation of final catch estimates.

Furthermore, the issues encountered with the original species composition of tropical tuna catches reported by the FOB-associated component of the European Union purse seine fleet have been temporarily dealt with by implementing the re-estimation of concerned geo-spatial catches in agreement with IOTC (2019a).

In July 2022 the Seychelles Fishing Authority (SFA) officially informed the IOTC Secretariat that "(…) *After continuous revision and remodelling, the Authority and the Ministry have found that T3 skews the resultant data upward, to some extent close to 20% on individual vessel. We have sought assistance of some experts involved in the original design of T3 and it has been concluded that for 2021 with the current change in fishing technique, frequency, lack of sampling due to Covid, species mix composition, etc. the reliability and accuracy of this model is no longer what it used to be and therefore, redundant in a certain way. For the 2021 data, the Authority (Flag State) has submitted its figures based on the landings and actual declarations of the Logbooks, rather than T3. This seems to bear more weight and more realistic from what we have been following, tracking and trending.* (…)".

Therefore, current purse seine catches for the statistical year 2021 submitted by Seychelles reflect the statement above, and this might potentially explain the detected differences in species composition compared to previous years.

It is worth recalling that Res. 15/02 (para. 4a) requires all CPCs to routinely submit "*documents describing the extrapolation procedures (including raising factors corresponding to the logbook coverage)*" as part of the annual data reporting cycle of fisheries statistics: at the time of writing, no detailed information in this regard was submitted by Seychelles and the EU to the IOTC Secretariat and therefore caution is advised when comparing recent catch data (2021) with previous years.

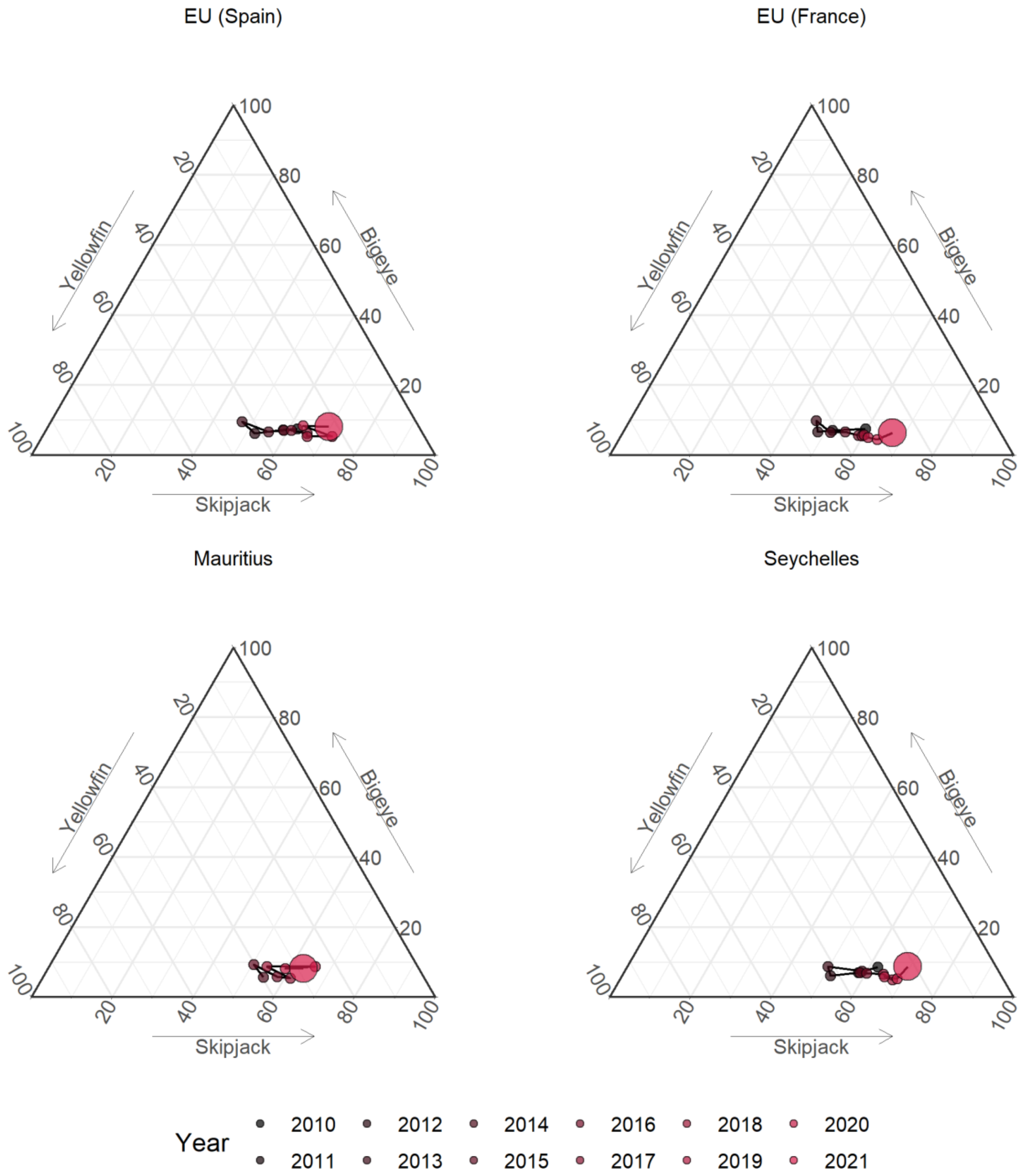

Figure 13: Ternary diagrams of trends in average annual relative catches by species as reported by the FOB-associated component of the major purse seine fleets for the period 2010-2021. The larger circle indicates the final year 2021. Data source: re-estimated [time-area catch dataset for purse seine fisheries](#) (Res. 15/02)

Spatial distribution of effort

Longline fisheries

By decade (1950-2009)

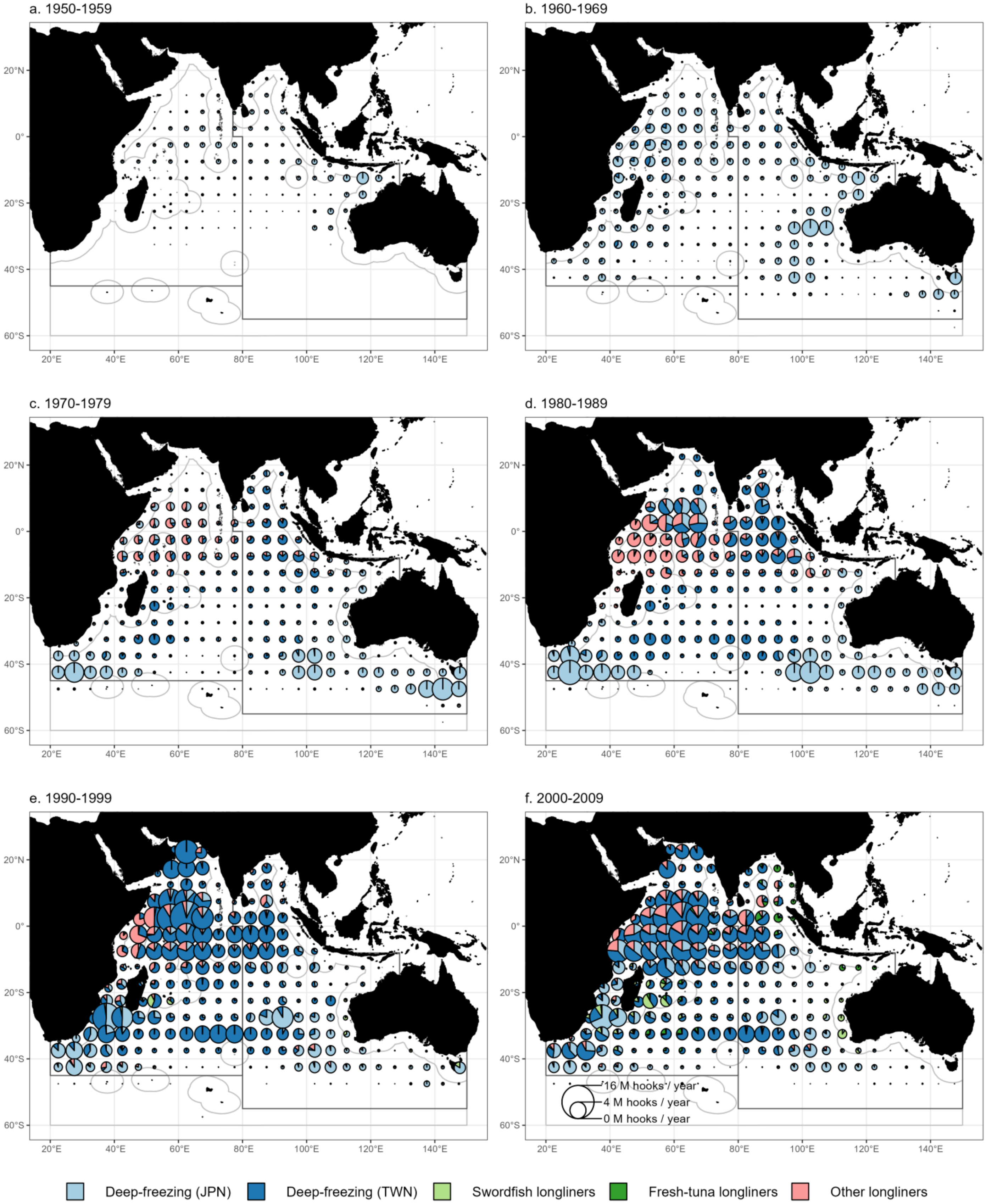

Figure 14: Mean annual effort (millions hooks deployed) exerted by industrial longline fleets by decade, 5x5 grid, and fleet. Data source: time-area effort dataset for longline fisheries (Res. 15/02)

By last years (2017-2021) and decade (2010-2019)

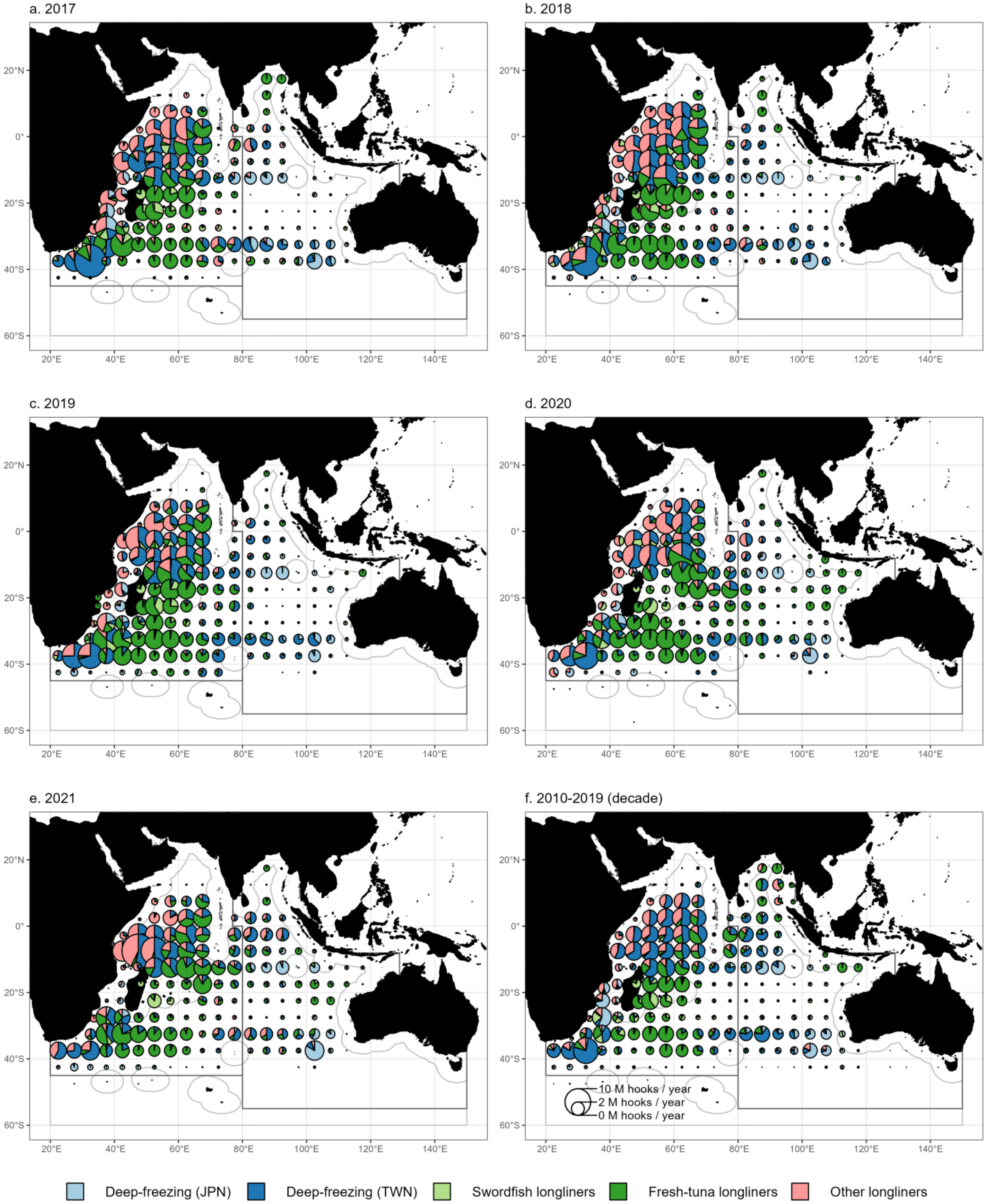

Figure 15: Mean annual effort (millions hooks) exerted by industrial longline fleets by year / last decade, 5x5 grid. and fleet. Data source: time-area effort dataset for longline fisheries (Res. 15/02)

Purse seine fisheries

All, by decade (1980-2009)

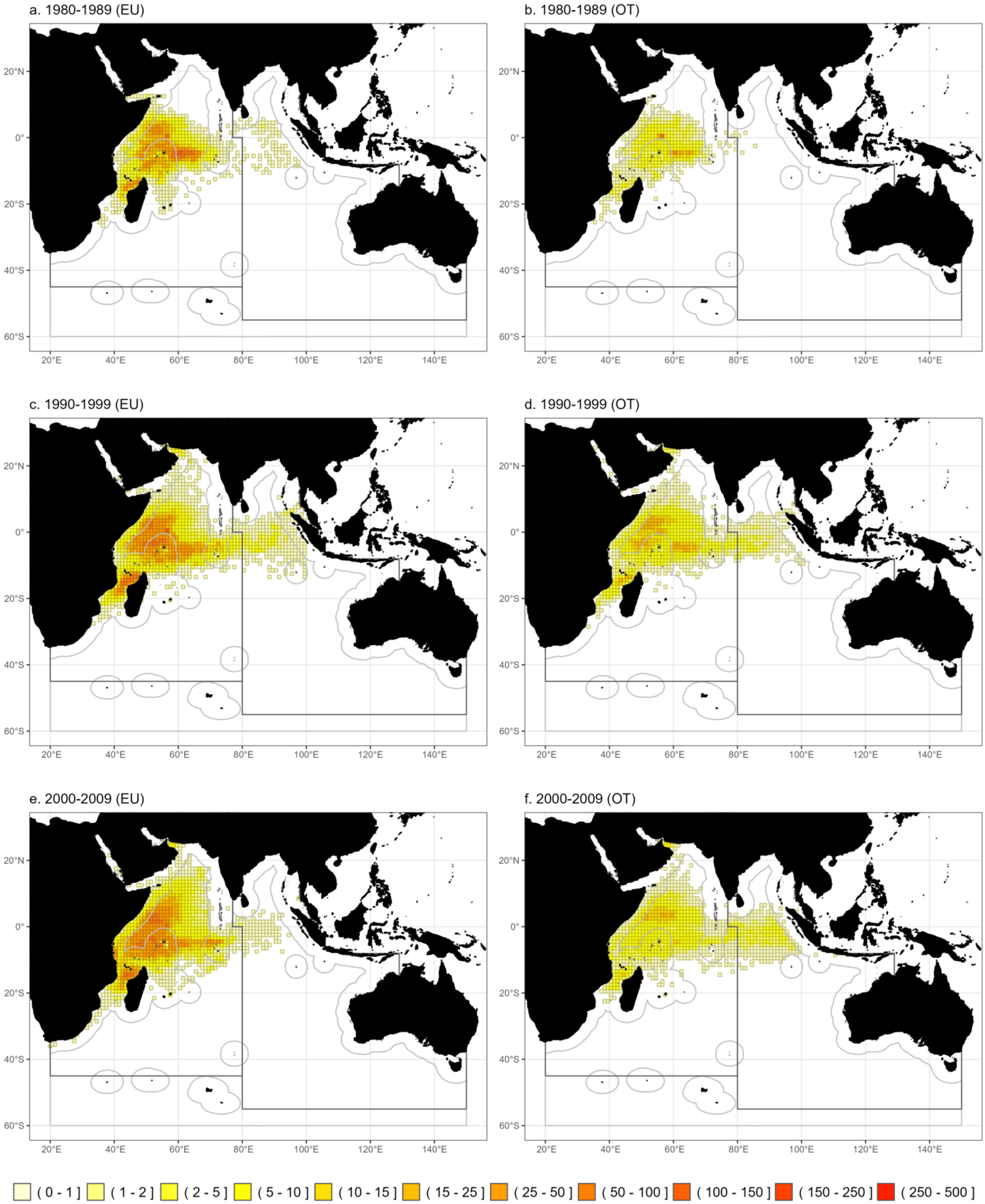

Figure 16: Mean annual effort (fishing days) exerted by the industrial purse seine fleets of the European Union and assimilated flags (EU) vs. all other flags (OT) by decade, 1x1 grid, and fleet. Data source: [time-area effort dataset for purse-seine fisheries](#) (Res. 15/02)

European Union, by last years (2017-2021) and decade (2010-2019)

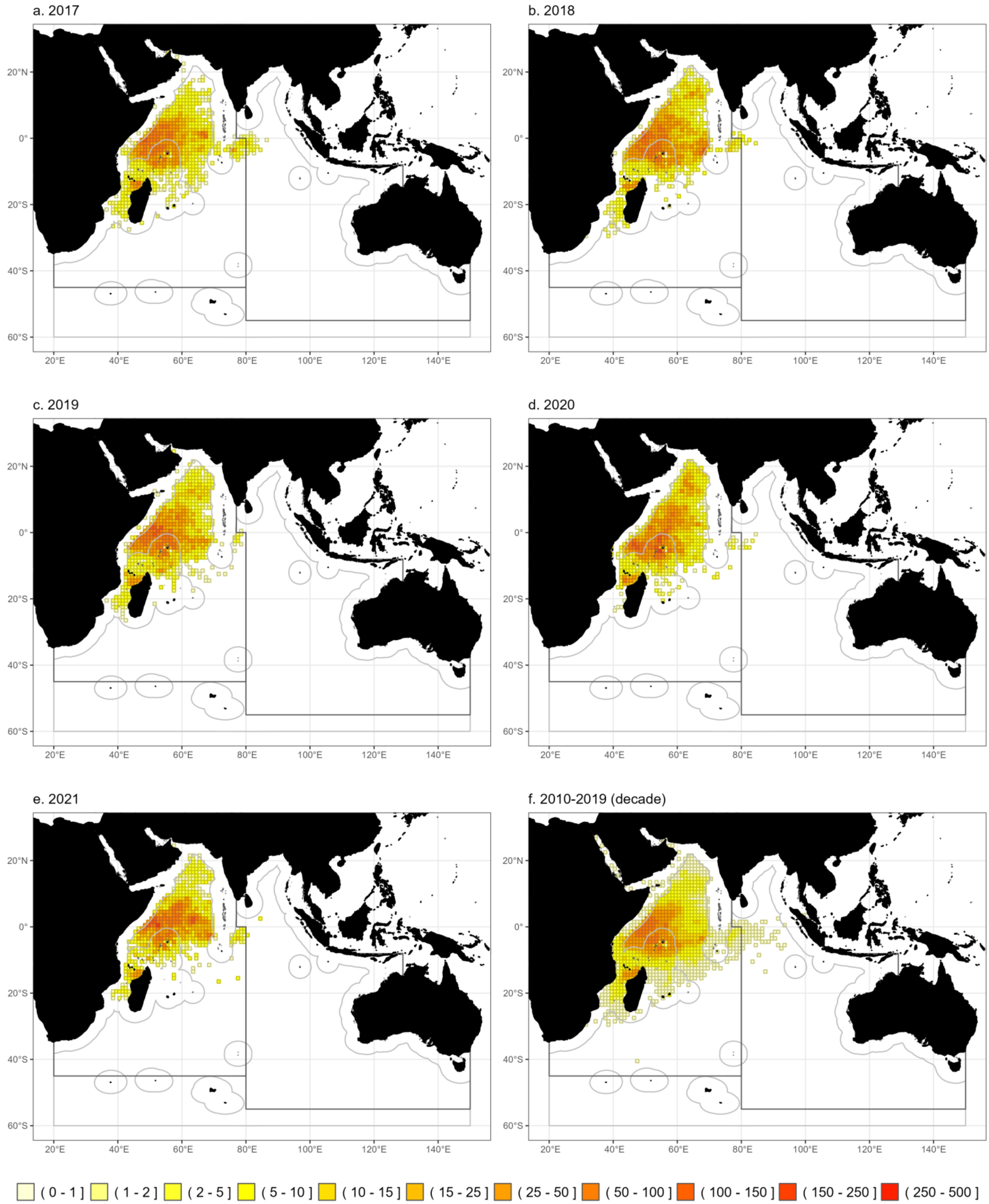

Figure 17: Mean annual effort (fishing days) exerted by the industrial purse seine fleets of the European Union and assimilated flags (EU) by year / decade and 1x1 grid. Data source: time-area effort dataset for purse-seine fisheries (Res. 15/02)

All others, by last years (2017-2021) and decade (2010-2019)

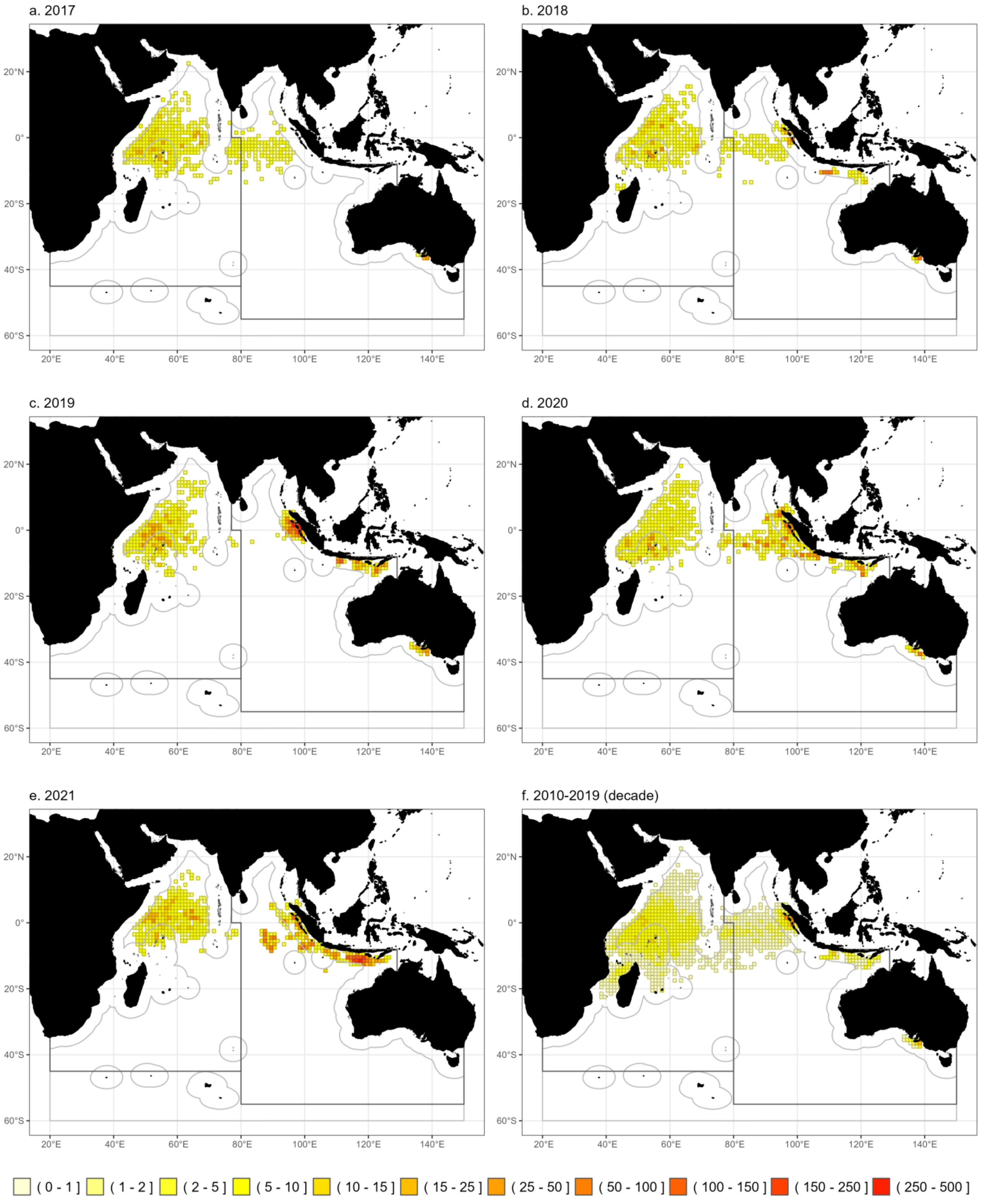

Figure 18: Mean annual effort (fishing days) exerted by the industrial purse seine fleets from other flags (OT) by year / decade and 1x1 grid. Data source: time-area effort dataset for purse-seine fisheries (Res. 15/02)

Spatial distribution of catch

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

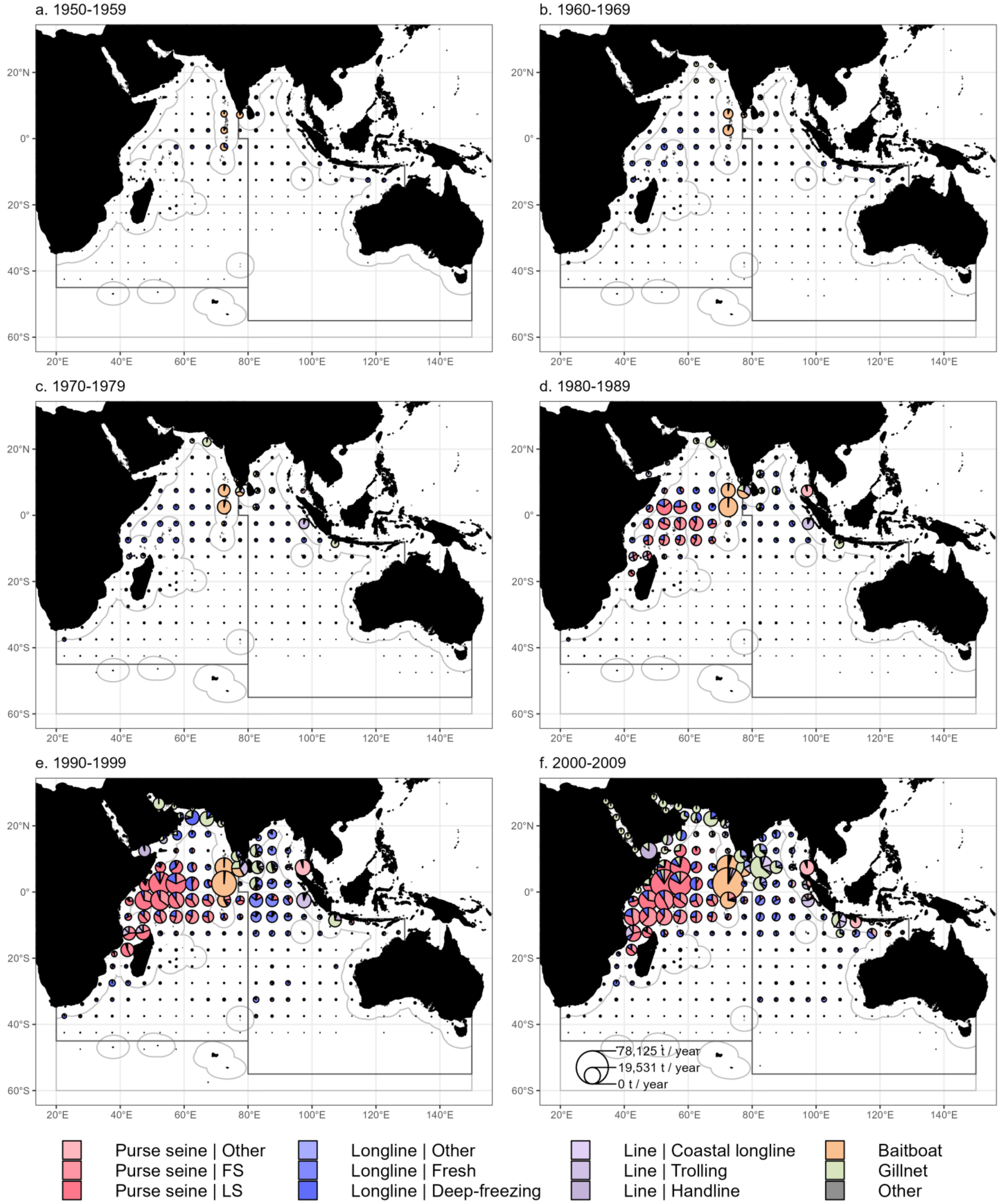

Figure 19: Estimated mean annual time-area catches (metric tonnes; t) of Indian Ocean tropical tuna by decade, 5x5 grid, and fishery. Data source: tropical tuna raised time-area catches

Geo-referenced catches by fishery, last years (2017-2021) and decade (2010-2019)

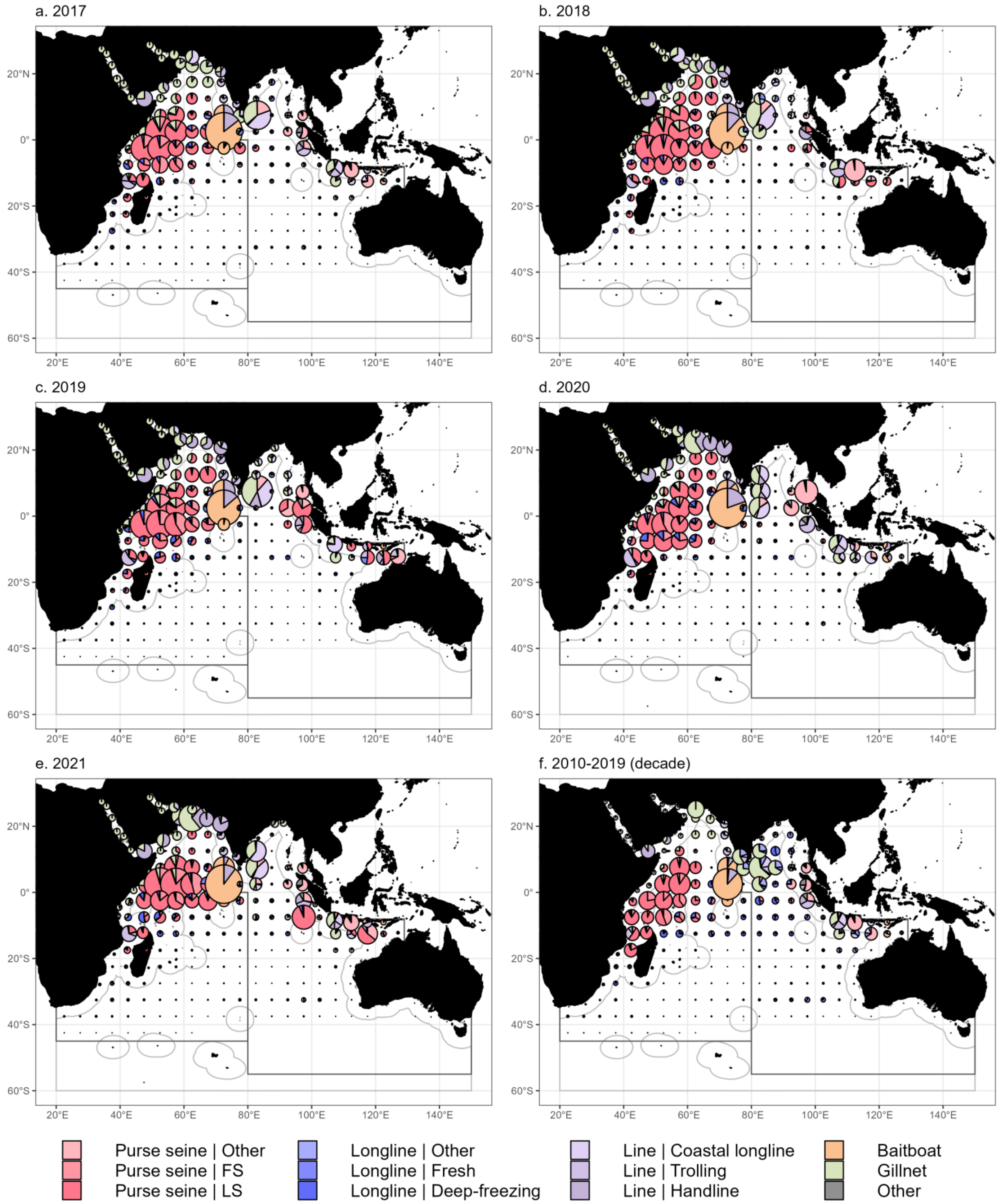

Figure 20: Estimated mean annual time-area catches (metric tonnes; t) of Indian Ocean tropical tuna by year / decade, 5x5 grid, and fishery. Data source: Tropical tuna raised time-area catches

Reporting quality of catch and effort data

The quality of the geo-referenced catch and effort data reported for tropical tuna to the IOTC Secretariat shows major variability over the years (**Fig. 21**). Similarly to the nominal catch data, industrial fisheries show better reporting quality than artisanal fisheries, mostly due to the availability of logbook systems for the former as required by IOTC Resolution 15/01. Since the 1960s, geo-referenced catch and effort data considered to be of good quality (i.e., scores 0-2; **Table 4**) have represented a mean annual average of about 67% of the total nominal catch of tropical tuna. In 2021, the percentage of nominal catches for which good geo-referenced catch and effort data were available at the Secretariat was 83%.

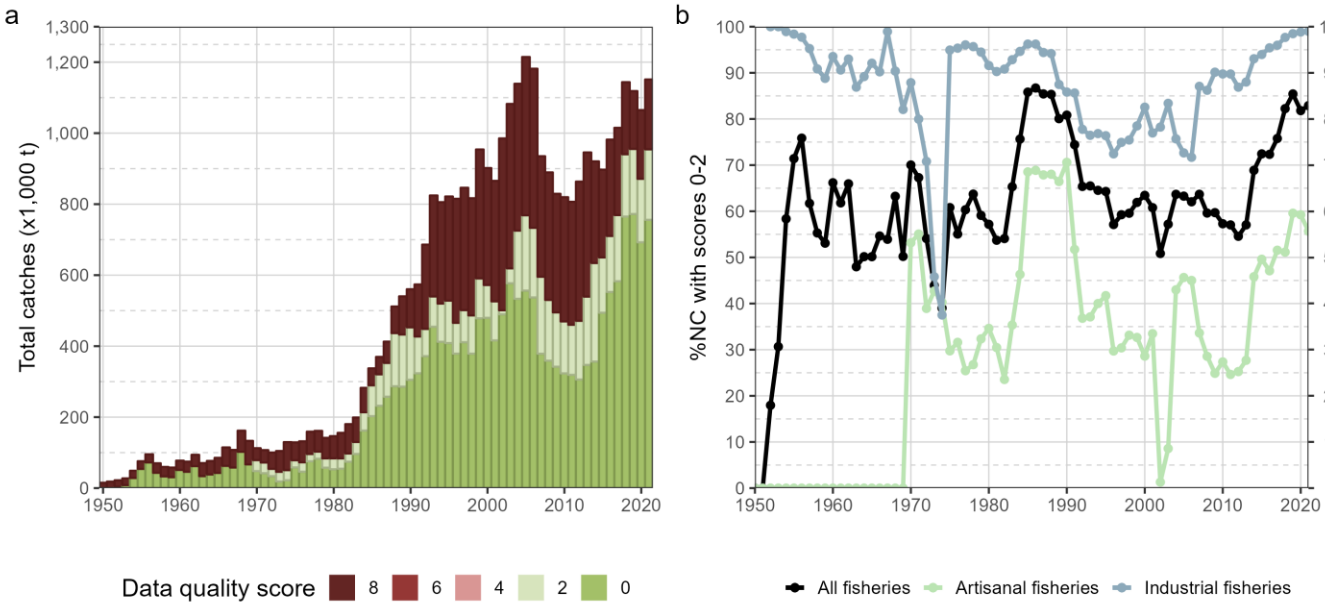

Figure 21: (a) Annual nominal catches (metric tonnes; t) of Indian Ocean tropical tuna estimated by quality score and (b) percentage of geo-referenced catches reported to the IOTC Secretariat in agreement with the requirements of Res. 15/02 for all fisheries and by type of fishery, in the period 1950-2021

Further details on potential bias in species composition for some industrial purse seine fleets

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 the catches on FOB-associated schools reported for 2018 by the Spanish component of the EU purse seine fleet. In fact, the 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, even more evident when compared with other purse seine fleets operating in the same areas and with comparable strategies.

This information originated directly from the geo-referenced time-area catches provided to the Secretariat by the EU purse seine fleet, and therefore an analysis was attempted to explore the relative proportion of the two tropical tuna species (bigeye and yellowfin tuna) to the level of resolution available for this data set, i.e., on regular grids of 1° in size (IOTC 2022a).

The results of this analysis show indeed that the proportion of bigeye tuna compared to yellowfin tuna as reported by EU,Spain in 2018 was particularly high in several 1°x1° grids. Furthermore, and recalling how species composition for the European Union and assimilated fleets were generally 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 was considered as a side-effect of the T3 process. In the specific case of EU,Spain, the area where the preponderance of bigeye tuna was clearly evident (for 2018) corresponded to the *EU PS statistical area 3 - Southeast Seychelles*.

The issue was also addressed from a different perspective, i.e., by correlating rounded values of reported proportions of bigeye vs. yellowfin tuna (as percentages) with the fraction of regular grids where that given proportion value was found.

This analysis performed prior to the re-estimation of the species composition by the IOTC Secretariat (IOTC 2022a) resulted in the identification of a higher-than-average number of grids in which EU,Spain reported (for 2018) 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 did not exceed 50%, with generally less than 4% of grids reporting each possible value up to that maximum.

A similar result can be inferred from the ternary diagrams of relative species composition by grid in **Figs. 24**, **27**, **30**, and **33**, which show the evolution of the reported species composition over the years by each of the concerned fleets.

Geo-referenced catch and effort data for the purse seine fleet of EU,Spain (2018) have currently been re-adjusted by the IOTC Secretariat in agreement with IOTC (2019a), and therefore similar analysis performed on the re-estimated data (**Figs. 22c** and **23c**) did not yield the same results (for the statistical year 2018) as in IOTC (2022b).

While the apparent discrepancies with species composition reported by the purse seine fleet of EU,Spain in 2018 have now been partially addressed (at least from a scientific point of view), recent data seem to indicate that for the years between 2019 and 2021 comparable issues still affect EU,Spain (**Fig. 22d-f**) as well as EU,France (**Fig. 25d-f**) and Seychelles (**Fig. 28d-f**).

In fact, a simple spatial analysis of the relative proportion of bigeye tuna vs. yellowfin tuna reported in recent years by these three fleets now shows a generalized increase of the former during the period concerned, although at lower levels compared to what originally identified for EU,Spain in 2018.

The analysis of the grid vs. species percentage distribution (number of grids with a given proportion of bigeye tuna vs. yellowfin tuna) also appears to confirm a potential issue with the data for 2021 and previous years officially reported by these fleets (**Figs. 23**, **26**, and **29**).

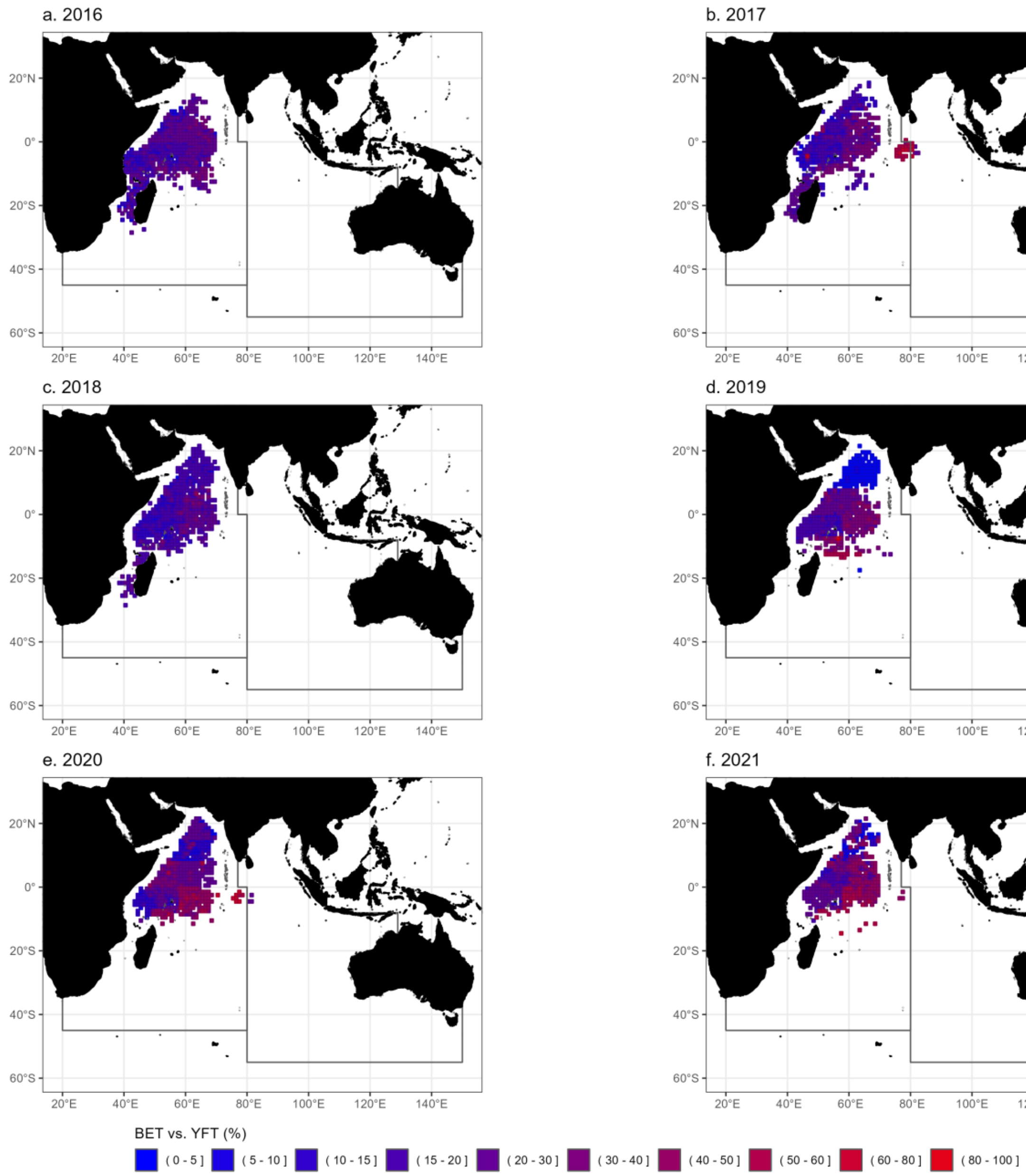

Figure 22: Relative percentages of catches of bigeye tuna vs. yellowfin tuna reported by the Spanish FOB-associated component of the European Union purse seine fleet for the period 2016-2021. Data source: re-estimated [time-area catch dataset for purse seine fisheries] (Res. 15/02)

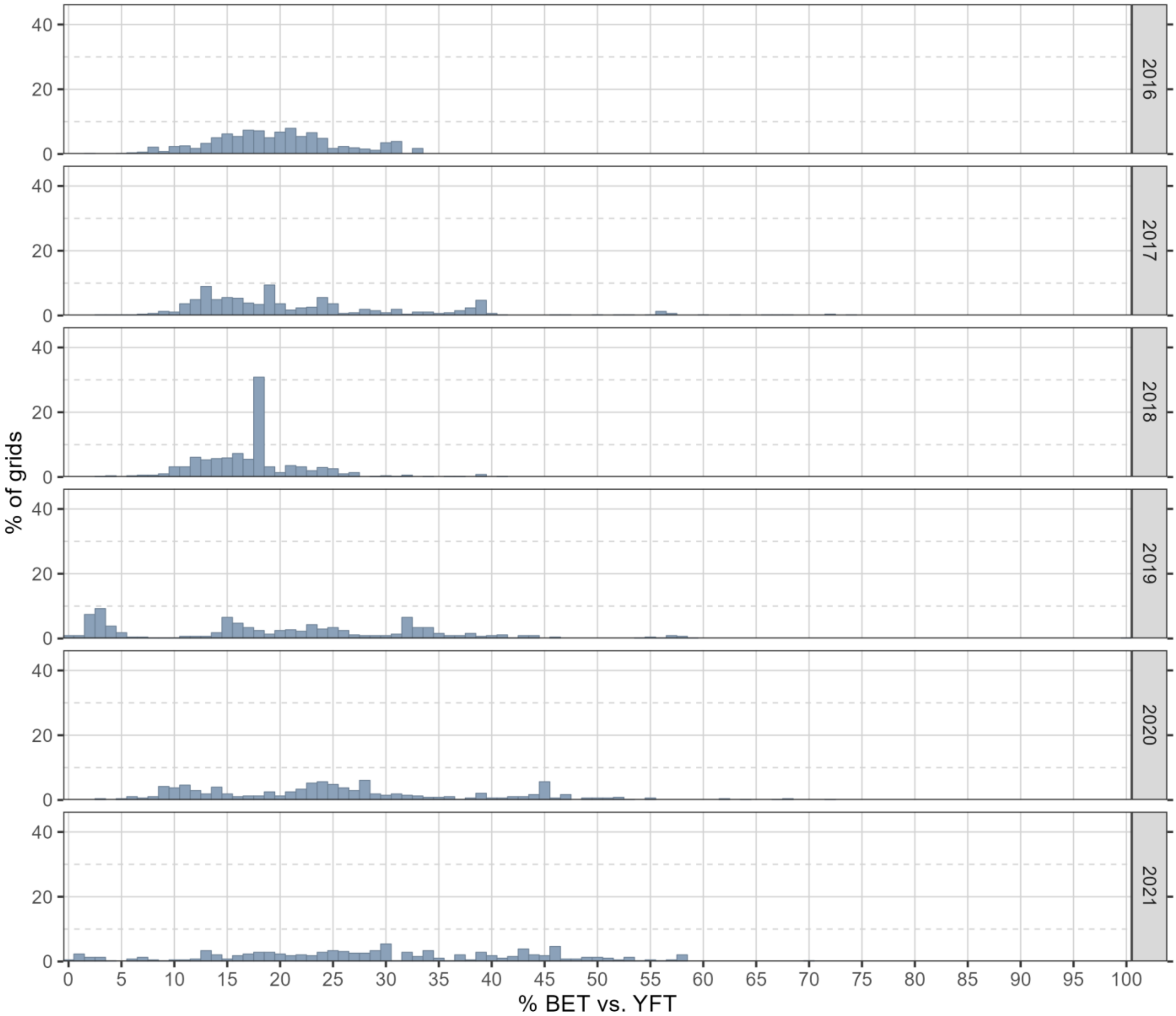

Figure 23: Percentages of 1°x1° grids by relative fraction of catches of bigeye tuna vs. yellowfin tuna reported by the Spanish FOB-associated component of the European Union purse seine fleet for the period 2016-2021. Data source: re-estimated time-area catch dataset for purse seine fisheries (Res. 15/02)

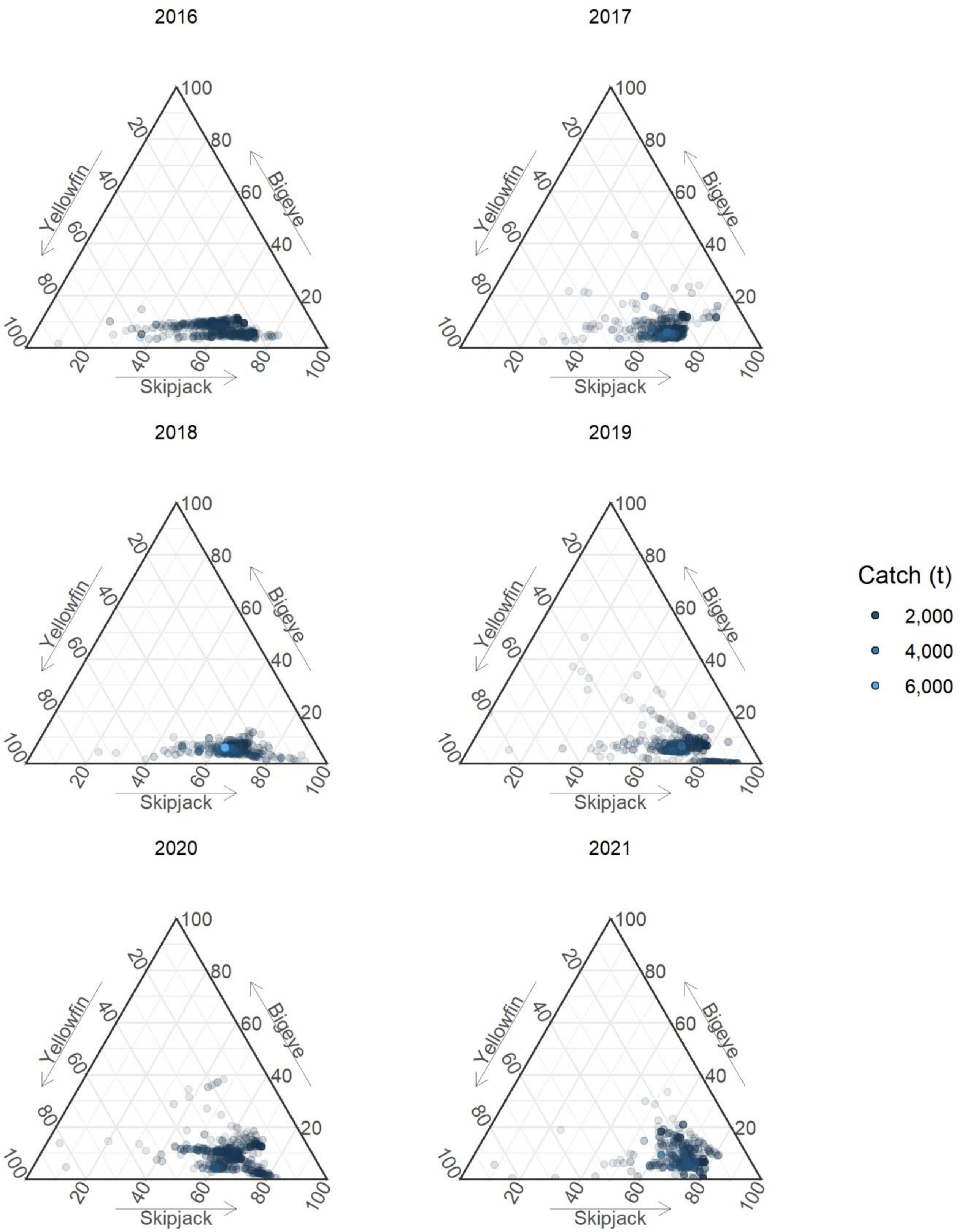

Figure 24: Ternary diagram of relative catches by species for each 1°x1° grids reported by the Spanish FOB-associated component of the European Union purse seine fleet for the period 2016-2021. Data source: re-estimated time-area catch dataset for purse seine fisheries (Res. 15/02)

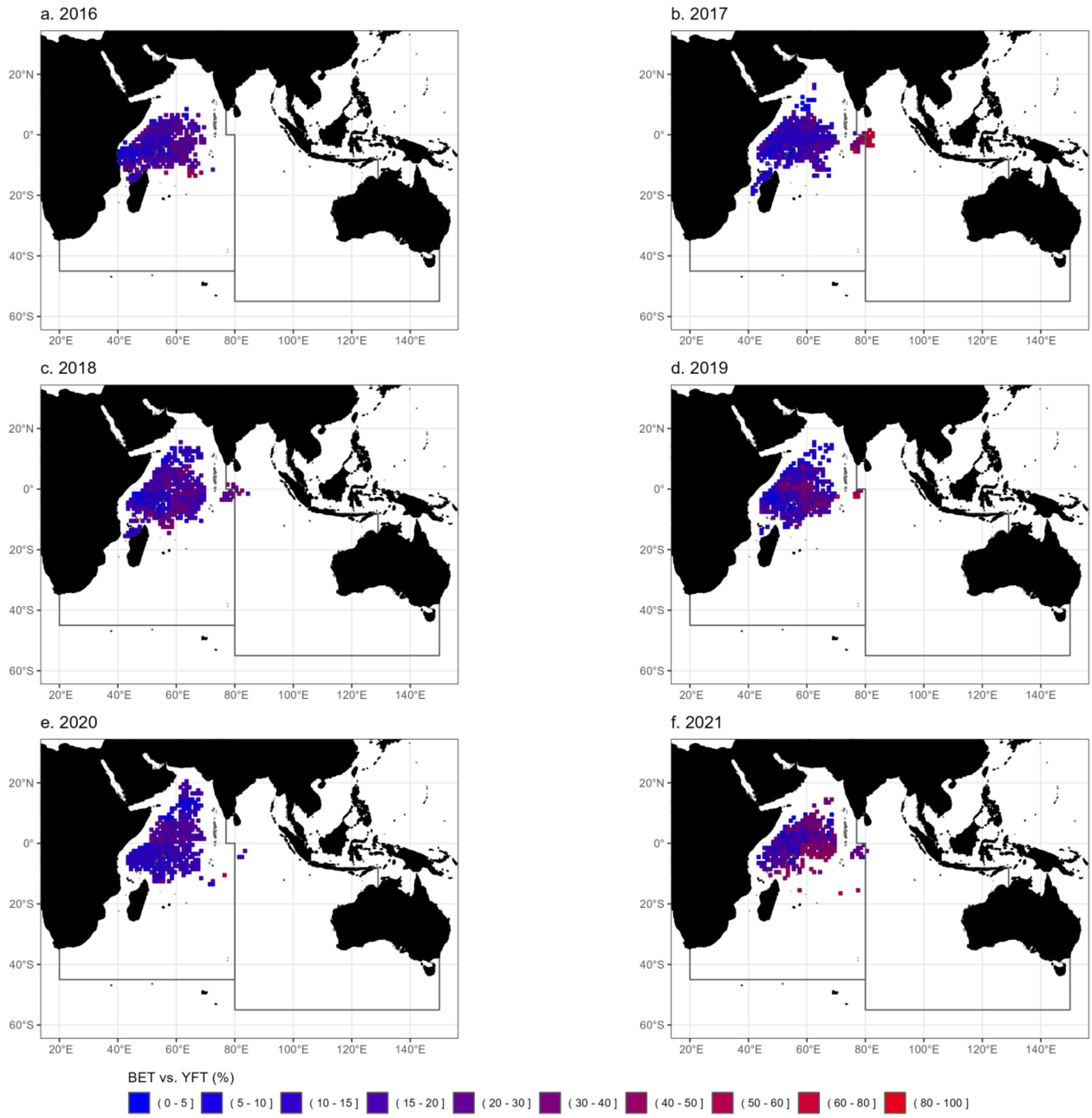

Figure 25: Relative percentages of catches of bigeye tuna vs. yellowfin tuna reported by the French FOB-associated component of the European Union purse seine fleet for the period 2016-2021. Data source: re-estimated time-area catch dataset for purse seine fisheries (Res. 15/02)

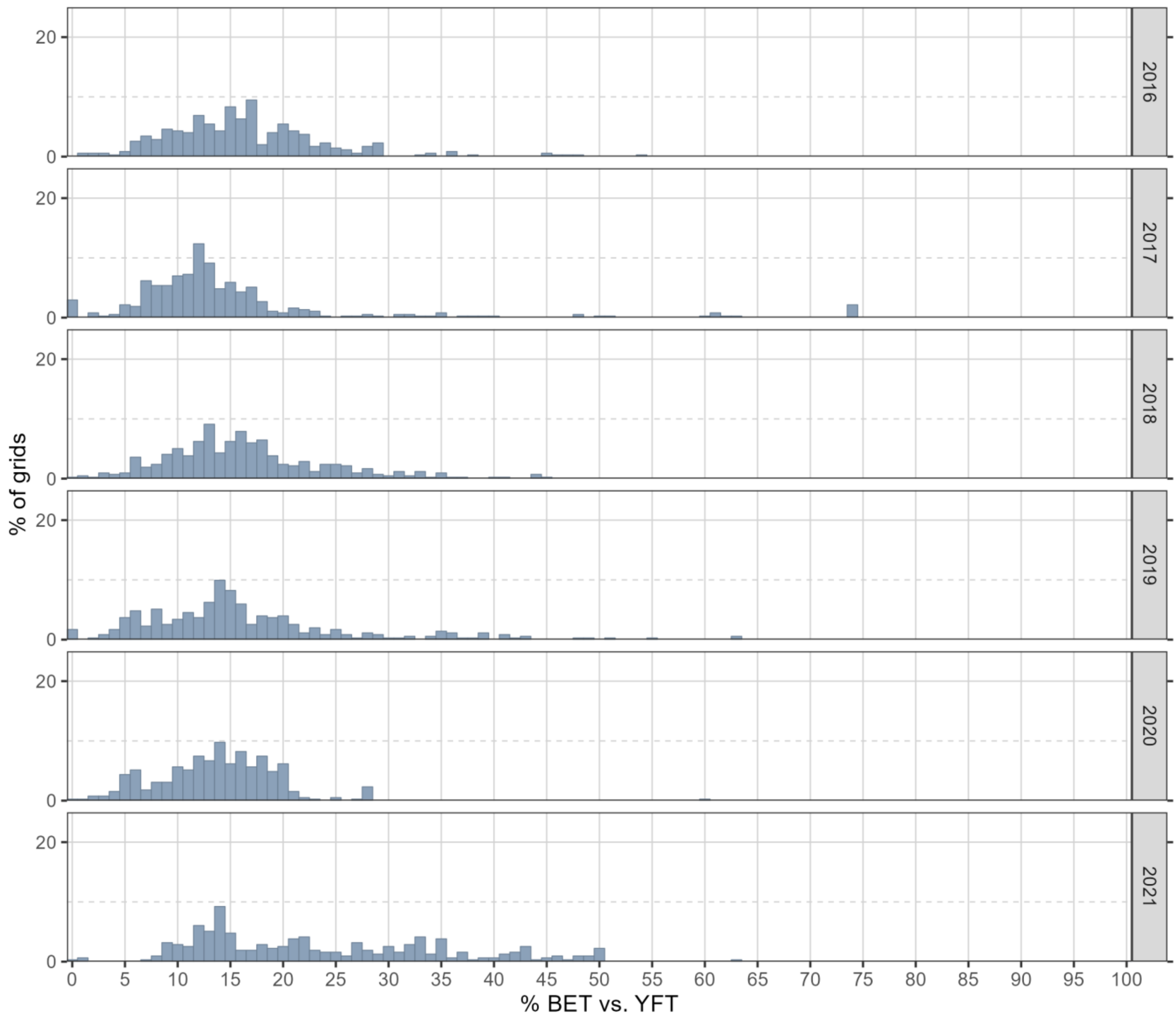

Figure 26: Percentages of 1°x1° grids by relative fraction of catches of bigeye tuna vs. yellowfin tuna reported by the French FOB-associated component of the European Union purse seine fleet for the period 2016-2021. Data source: re-estimated time-area catch dataset for purse seine fisheries (Res. 15/02)

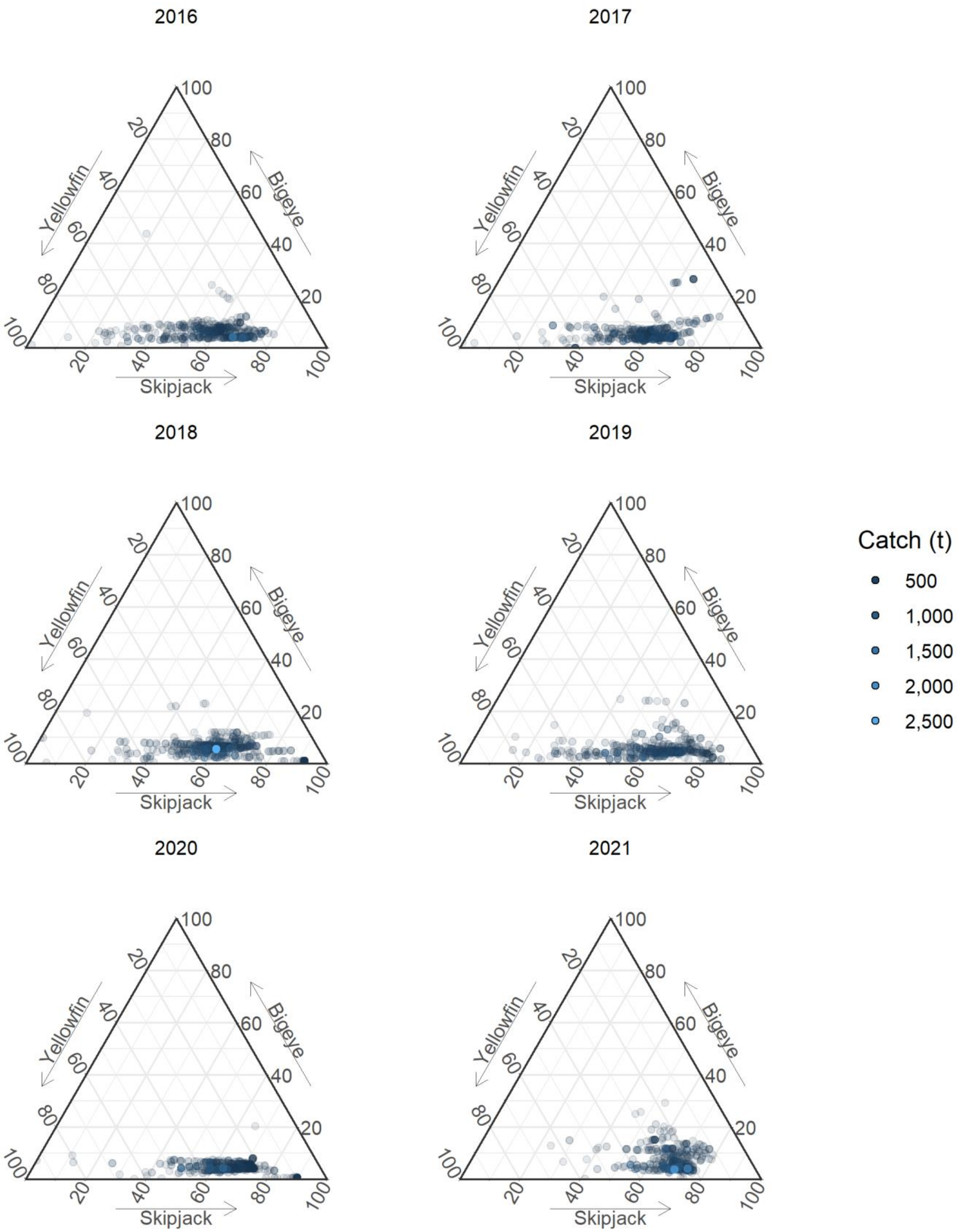

Figure 27: Ternary diagram of relative catches by species for each 1°x1° grids reported by the French FOB-associated component of the European Union purse seine fleet for the period 2016-2021. Data source: re-estimated time-area catch dataset for purse seine fisheries (Res. 15/02)

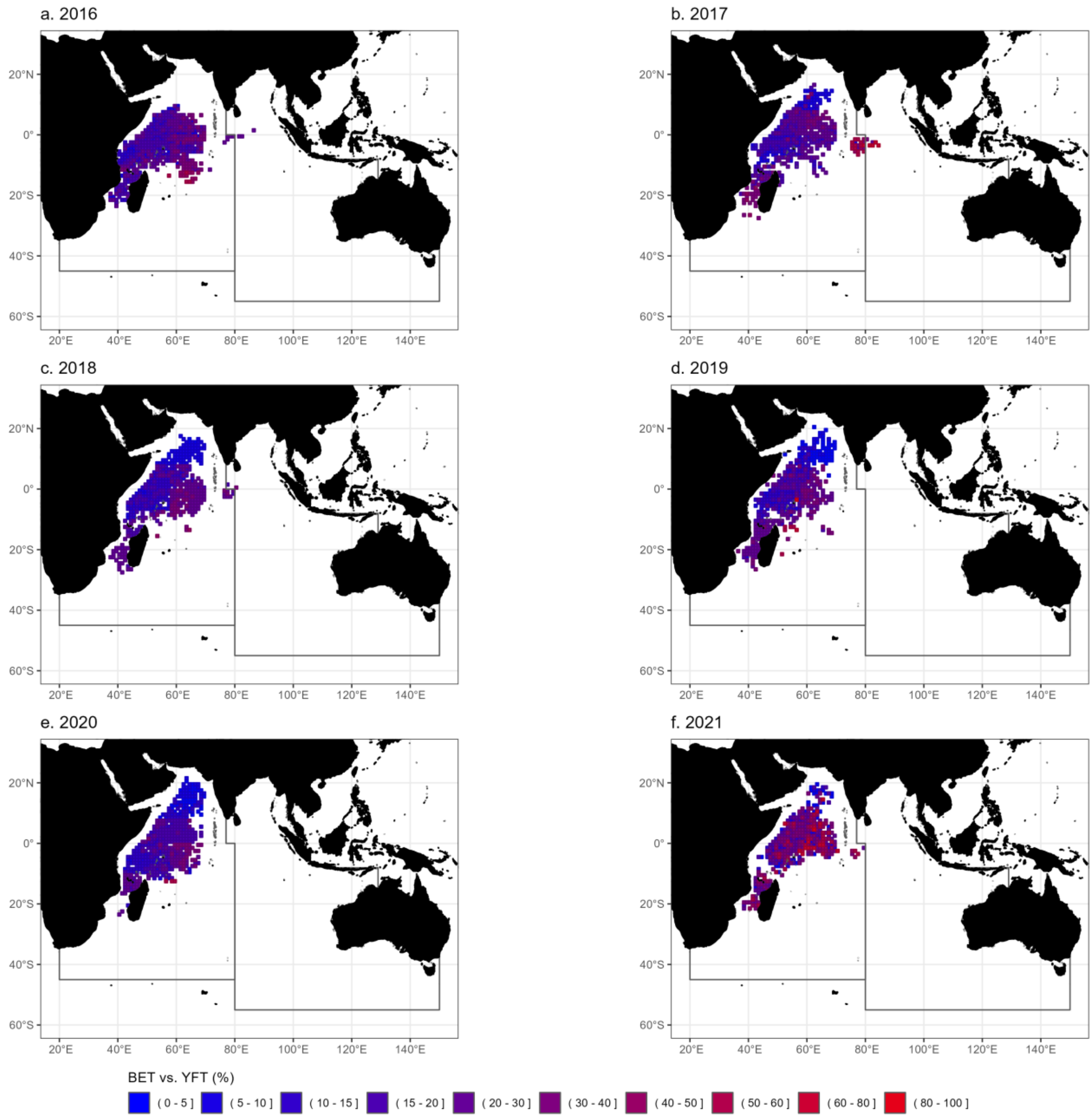

Figure 28: Relative percentages of catches of bigeye tuna vs. yellowfin tuna reported by the FOB-associated component of the Seychelles purse seine fleet for the period 2016-2021. Data source: re-estimated time-area catch dataset for purse seine fisheries (Res. 15/02)

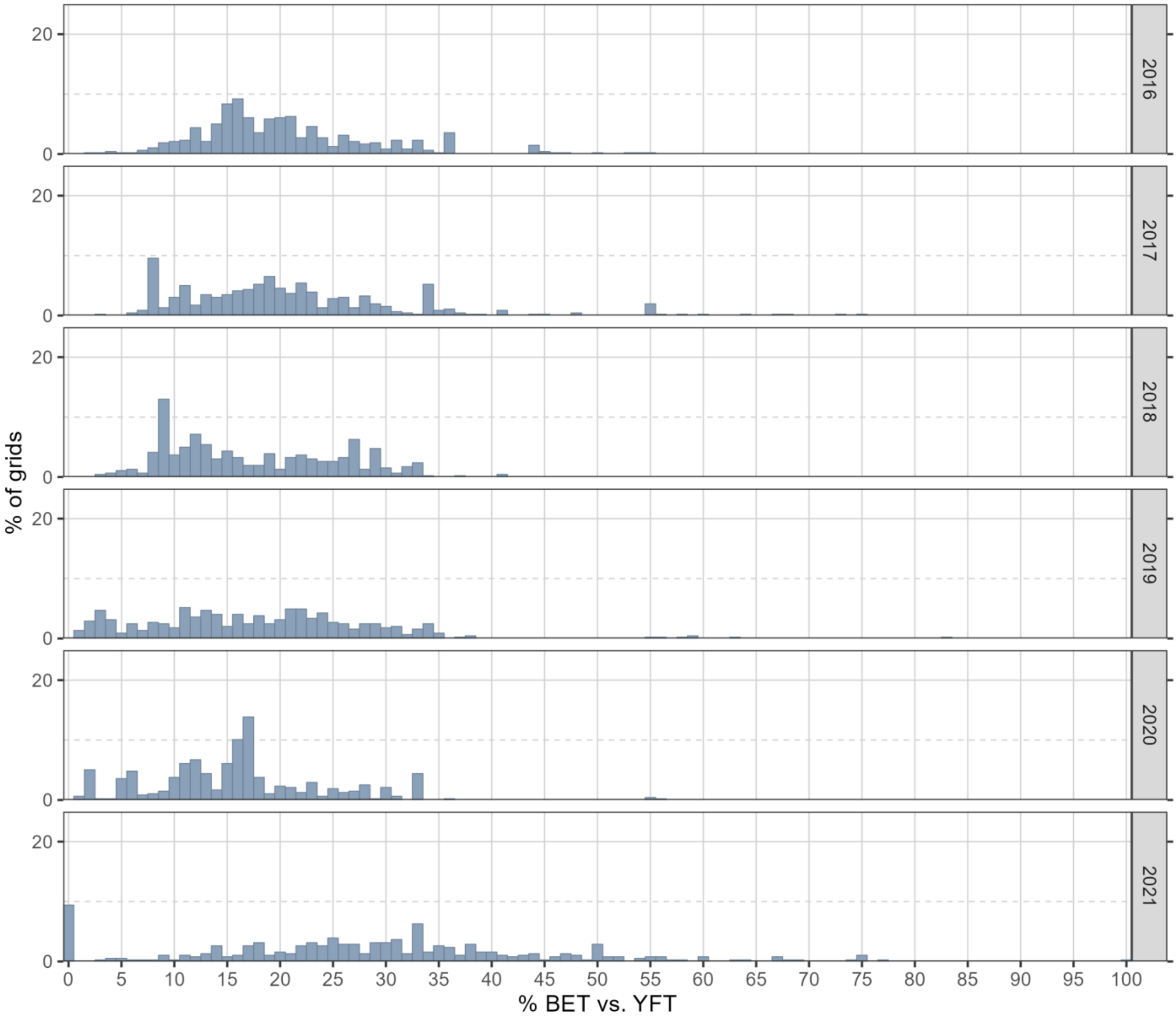

Figure 29: Percentages of 1°x1° grids by relative fraction of catches of bigeye tuna vs. yellowfin tuna reported by the FOB-associated component of the Seychelles purse seine fleet for the period 2016-2021. Data source: re-estimated [time-area catch dataset for purse seine fisheries](#) (Res. 15/02)

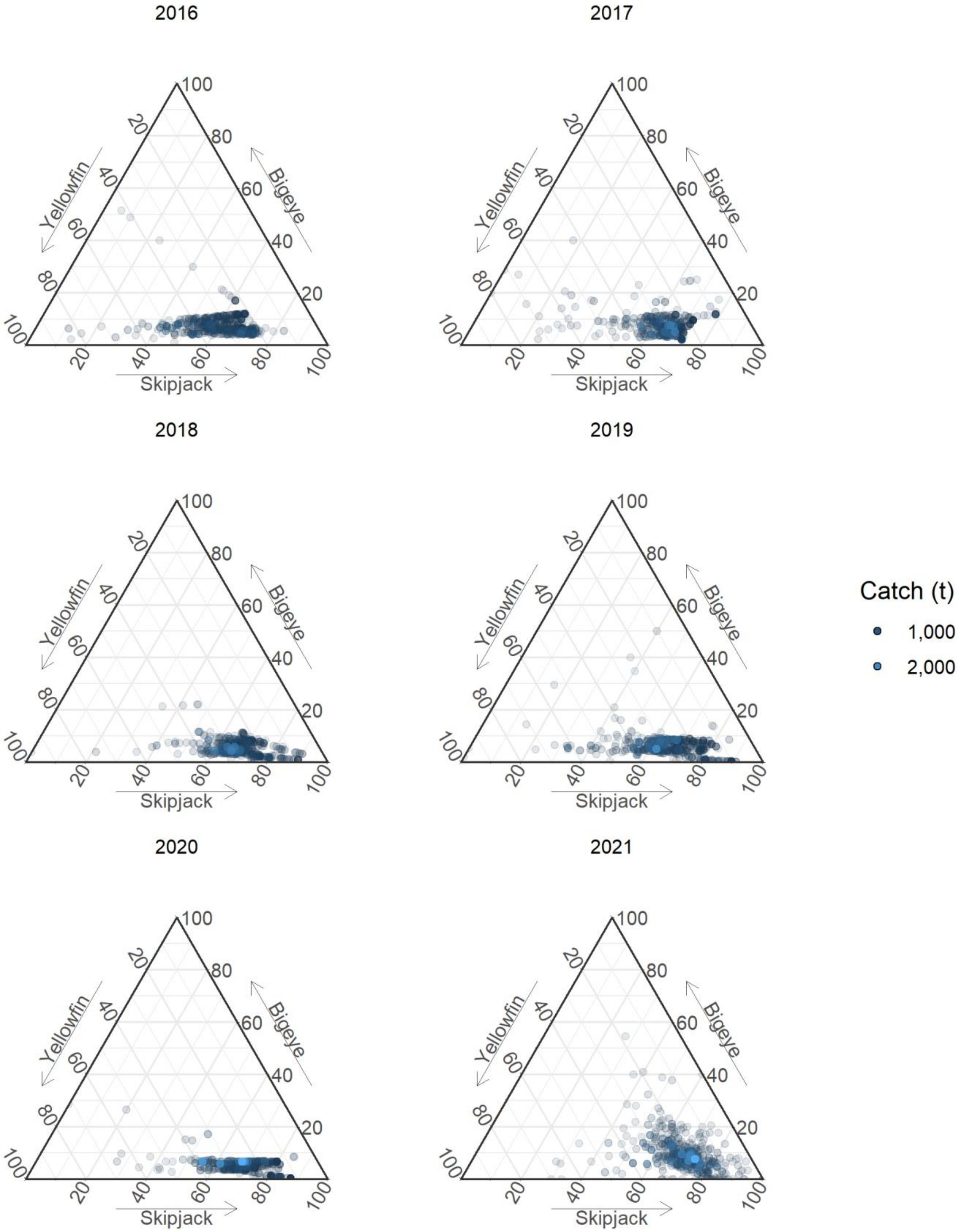

Figure 30: Ternary diagram of relative catches by species for each 1°x1° grids reported by the FOB-associated component of the purse seine fleet of Seychelles for the period 2016-2021. Data source: re-estimated time-area catch dataset for purse seine fisheries (Res. 15/02)

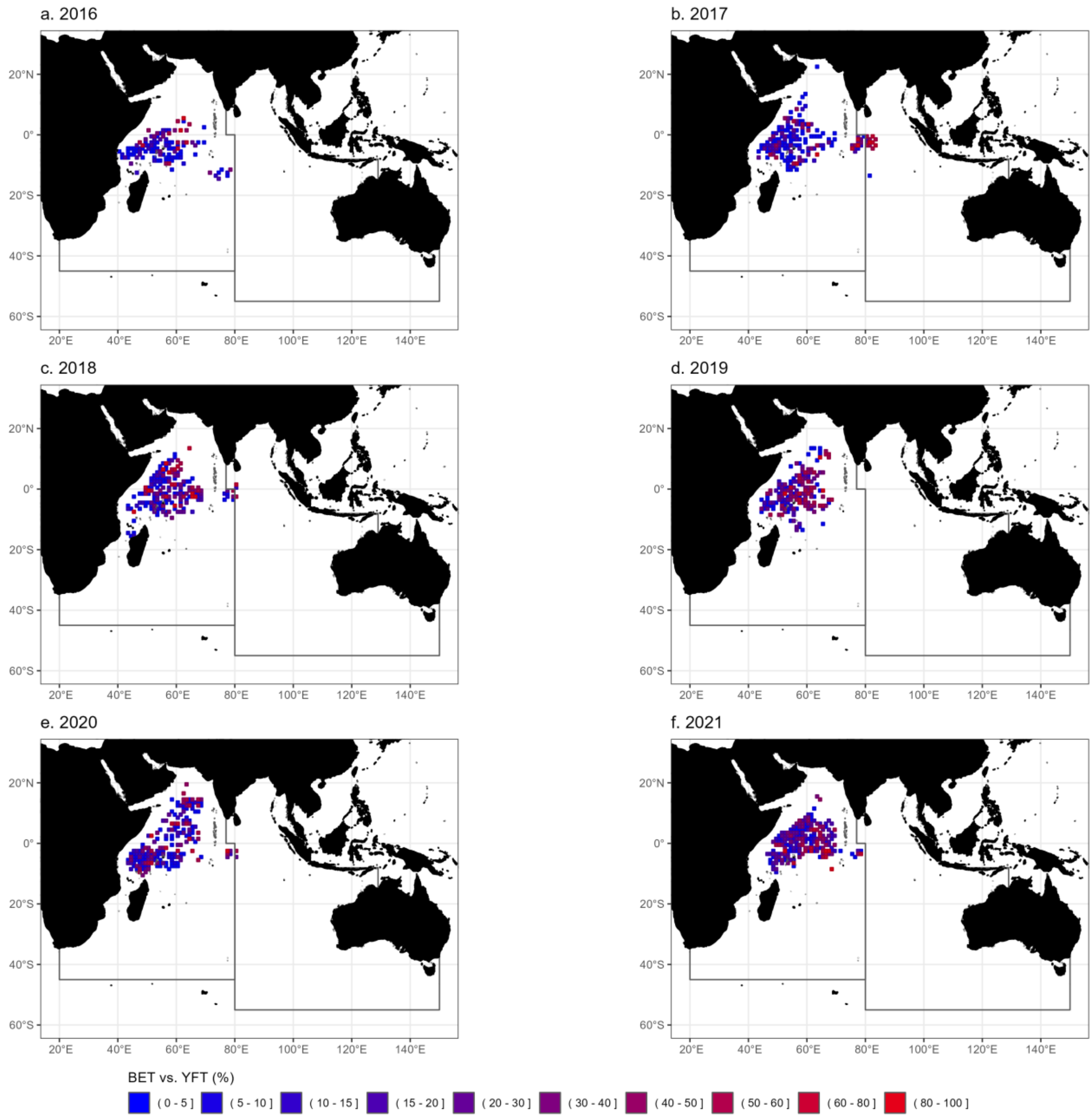

Figure 31: Relative percentages of catches of bigeye tuna vs. yellowfin tuna reported by the FOB-associated component of the Mauritius purse seine fleet for the period 2016-2021. Data source: re-estimated time-area catch dataset for purse seine fisheries (Res. 15/02)

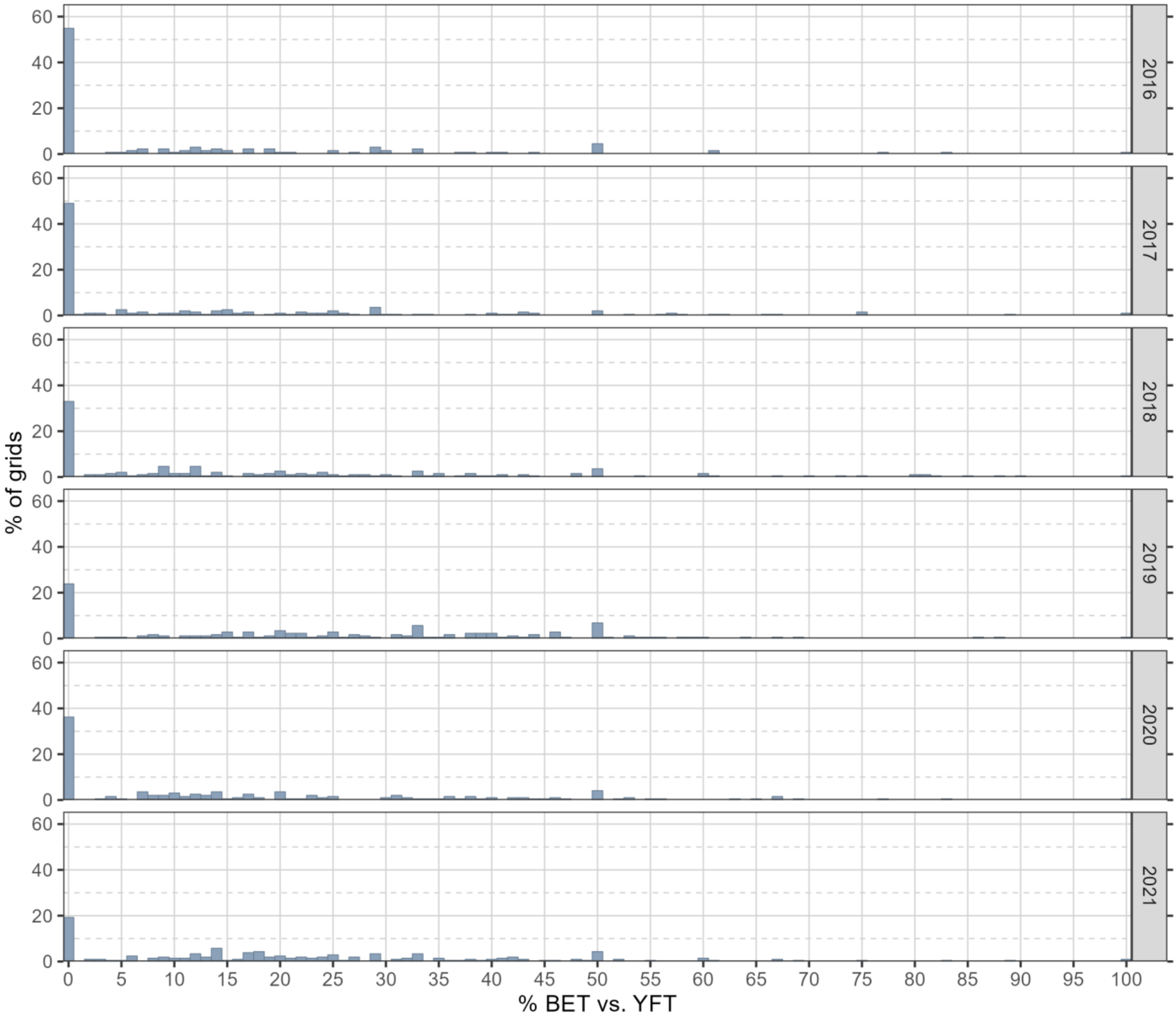

Figure 32: Percentages of 1°x1° grids by relative fraction of catches of bigeye tuna vs. yellowfin tuna reported by the FOB-associated component of the Seychelles purse seine fleet for the period 2016-2021. Data source: re-estimated time-area catch dataset for purse seine fisheries (Res. 15/02)

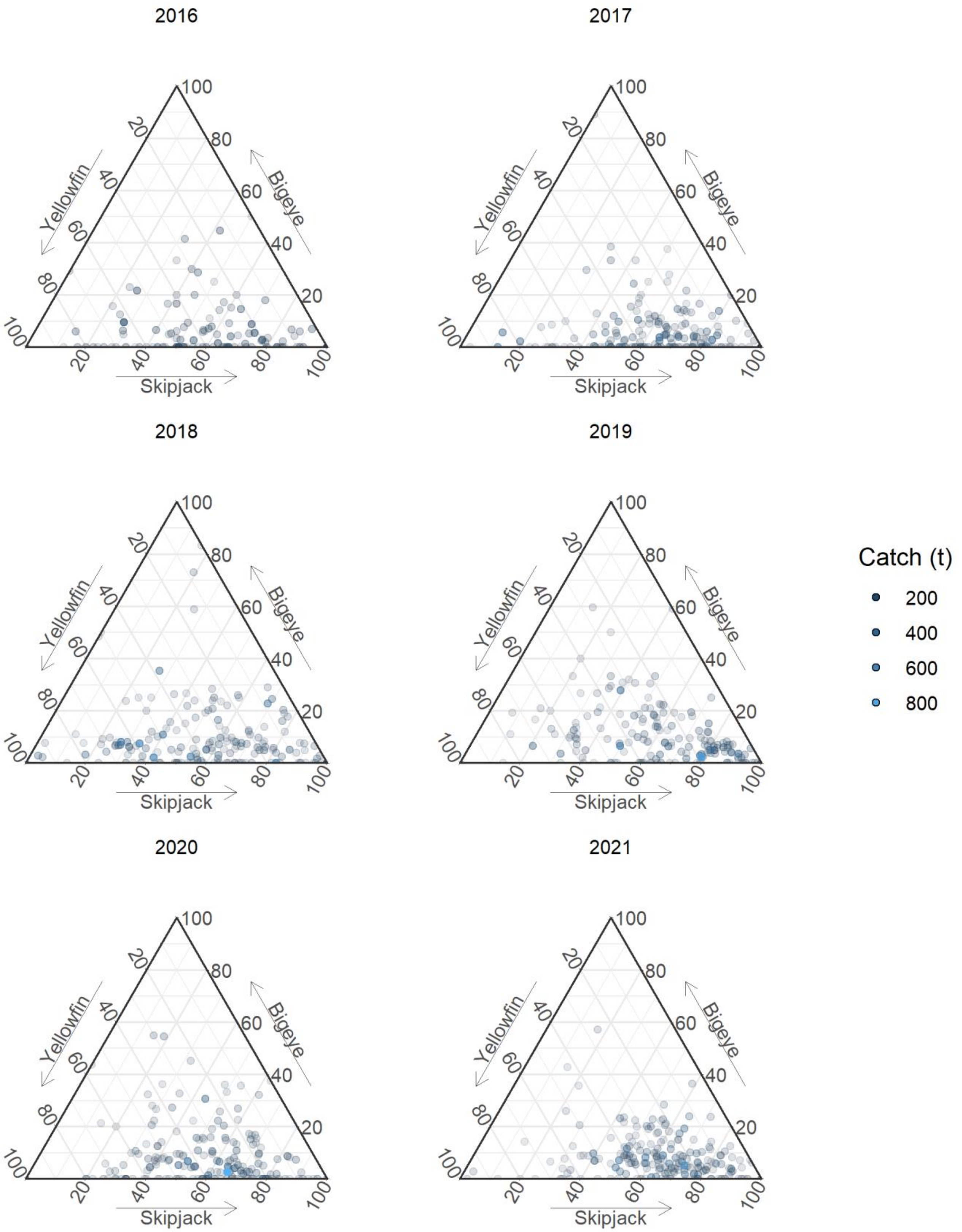

Figure 33: Ternary diagram of relative catches by species for each 1°x1° grids reported by the FOB-associated component of the purse seine fleet of Mauritius for the period 2016-2021. Data source: re-estimated time-area catch dataset for purse seine fisheries (Res. 15/02)

The results emerging from this preliminary analysis (and already recalled in a previous section of this document) are corroborated by the fact that Seychelles explicitly informed the IOTC Secretariat of changes introduced in their estimation procedures for the statistical year 2021, and also by the well-known practice adopted by the European

Union purse seine fleet of incorporating samples from comparable fleets, including Seychelles, when estimating species composition and catch-at-size of tropical tunas caught by their vessels.

In any case, evident changes in the relative proportions of tropical tuna species reported in recent years has been identified for the major purse seine fleets operating in the Indian Ocean, and therefore further clarity should be sought from the original data providers to confirm that these changes reflect more accurately the reality of their fisheries rather than being mere statistical artifacts caused by updates to their estimation procedures.

Size-frequency

Reporting quality of size-frequency data

The quality of the geo-referenced size frequency data reported for tropical tuna to the IOTC Secretariat is low but has shown an improvement over the last decade (**Fig. 34**). Almost no size data are available prior to the 1980s. Over the last four decades, size data have not been available for more than half of the nominal catch estimated by the Secretariat. In 2021, the percentage of nominal catch data for which good size data were available at the Secretariat was 70%.

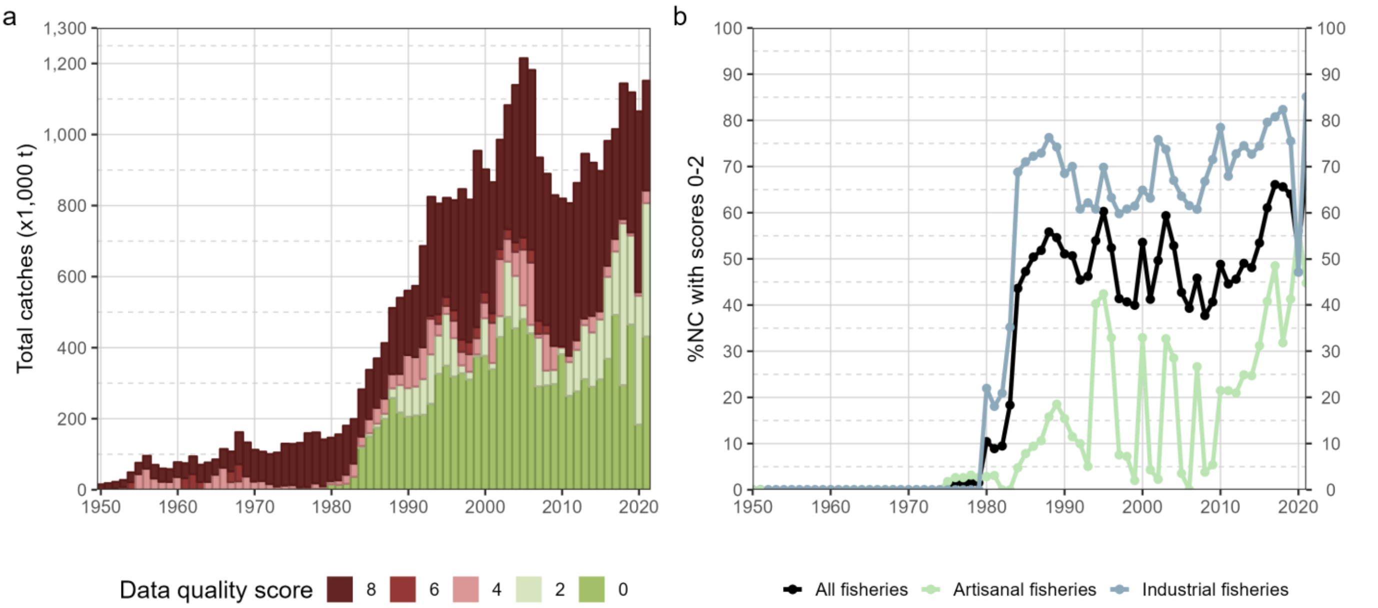

Figure 34: Annual nominal catches (metric tonnes; t) of Indian Ocean tropical tuna estimated by quality score (barplot) and percentage of geo-referenced size-frequency data reported to the IOTC Secretariat in agreement with the requirements of Res. 15/02 (lines with dots) for all fisheries (a) and by type of fishery (b), in the period 1950–2021

Appendix I: Monthly time series of tropical tuna import prices and crude oil prices, 2000-2021

Frozen purse seine, Thai import prices (canning grade)

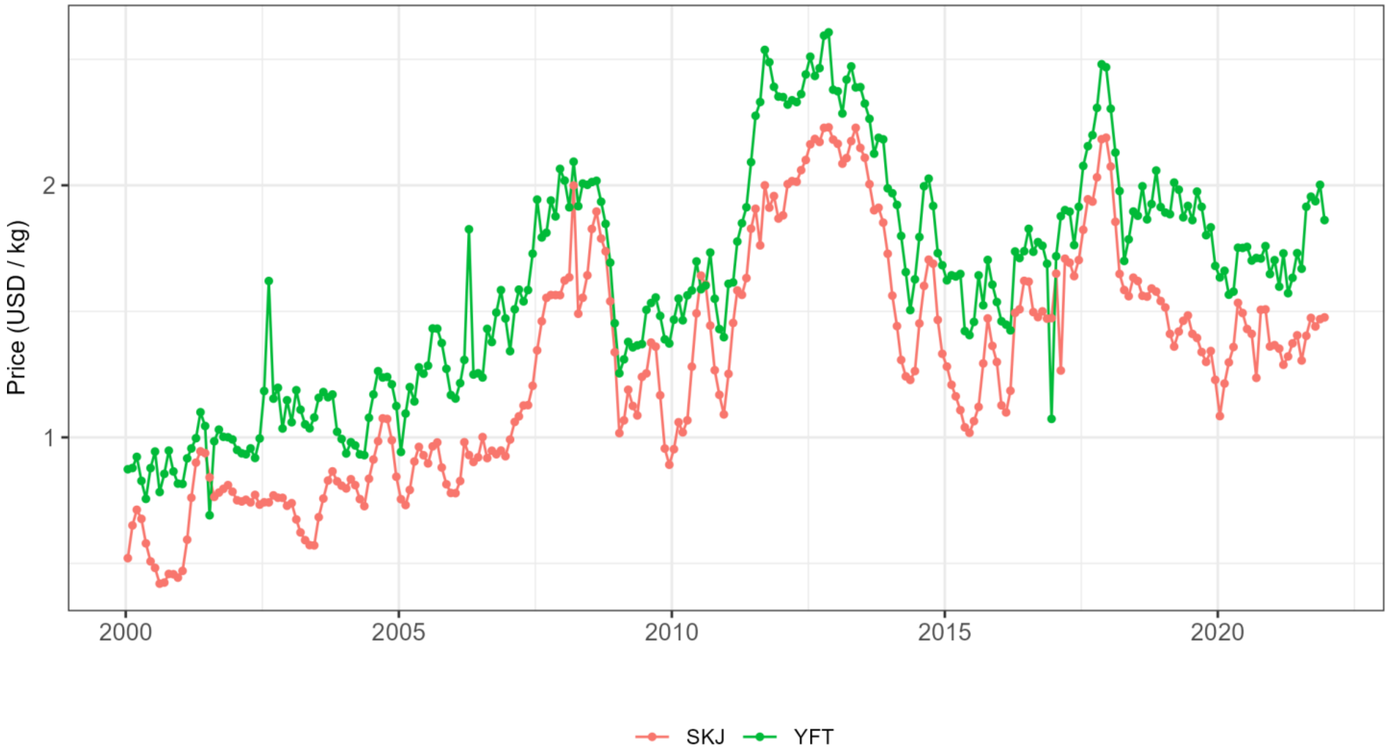

Figure 35: Monthly time series of import prices (USD/kg) in Thailand for canning-grade frozen skipjack and yellowfin tunas during the period 2000-2021. Data sourced from Thailand customs, compiled, and curated by the FFA Fisheries Development Division (Ruaia et al. 2020)

Frozen longline, Japanese import prices (sashimi grade)

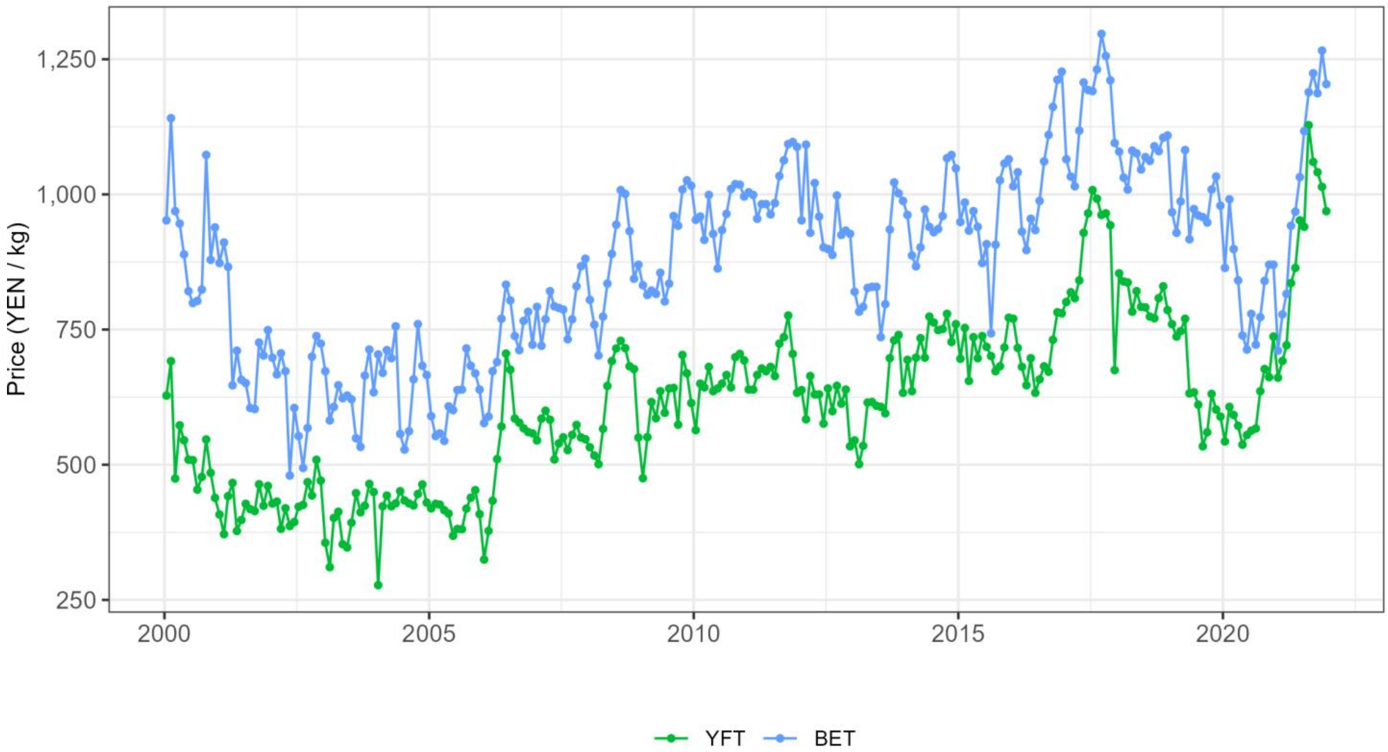

Figure 36: Monthly time series of import prices (YEN/kg) in Japan for sashimi-grade frozen during the period 2000-2021. Data sourced from Japanese customs, compiled, and curated by the FFA Fisheries Development Division (Ruaia et al. 2020)

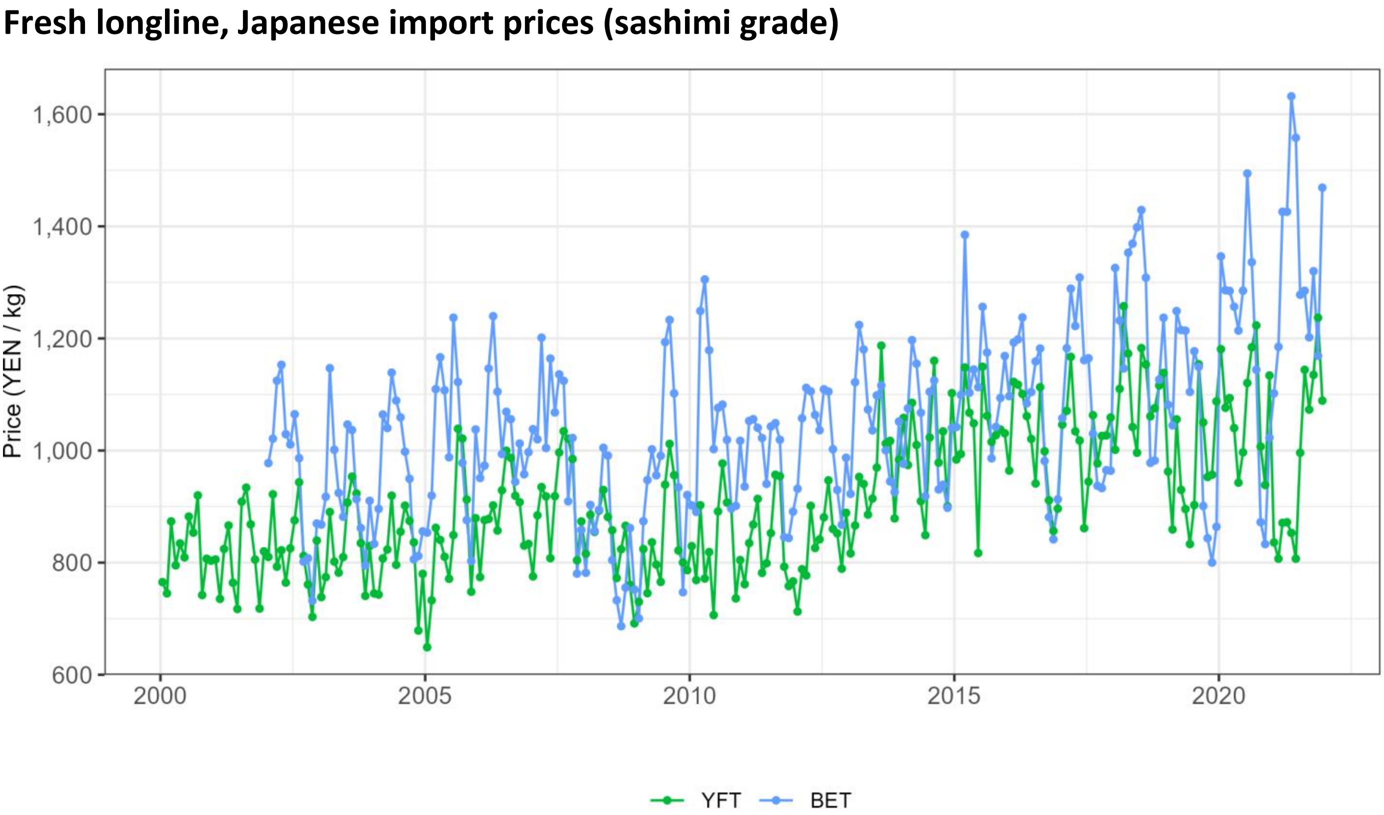

Figure 37: Monthly time series of import prices (USD/kg) in Thailand for canning-grade frozen during the period 2000-2021. Data sourced from Japanese customs, compiled, and curated by the FFA Fisheries Development Division (Ruaia et al. 2020)

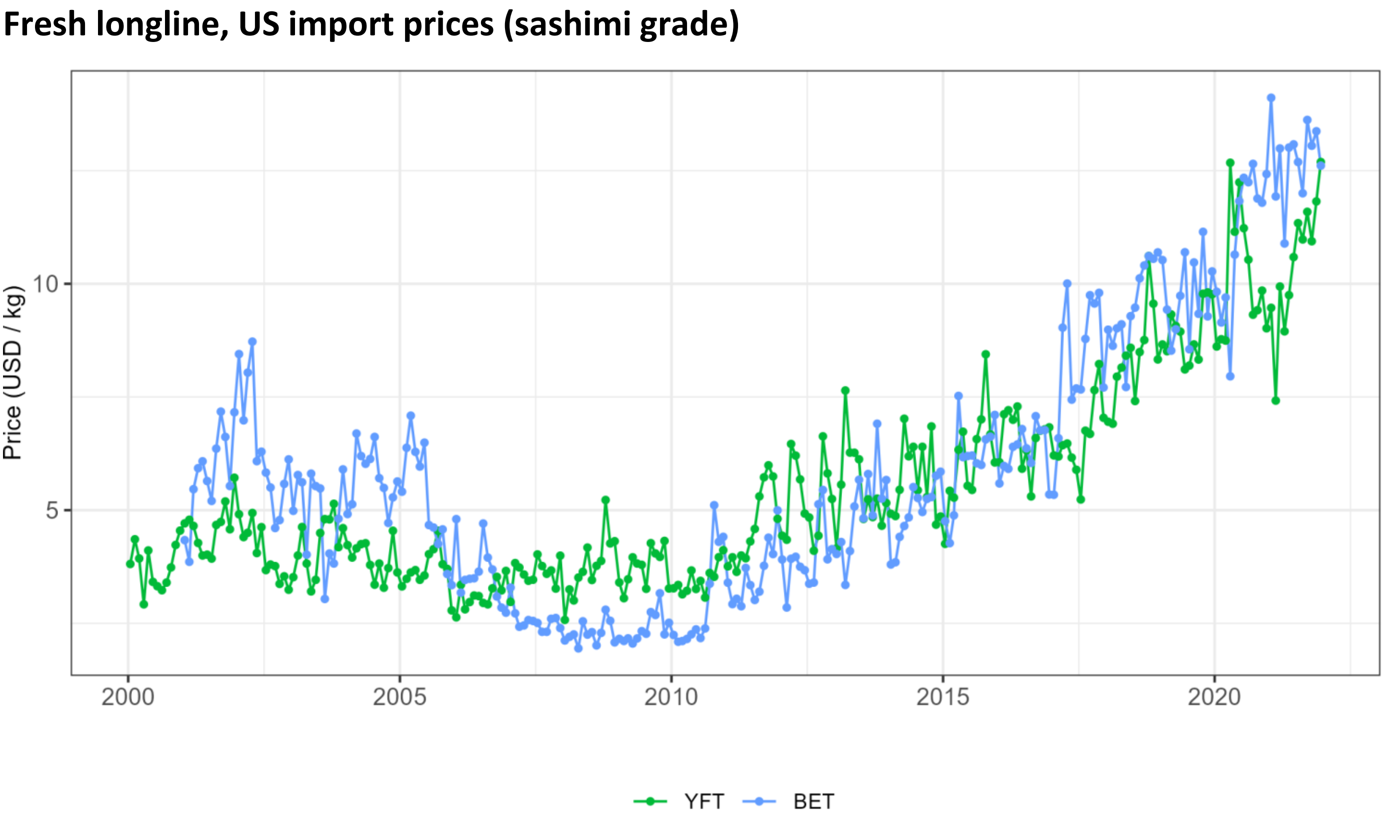

Figure 38: Monthly time series of import prices (USD/kg) in Thailand for canning-grade frozen during the period 2000-2021. Data sourced from USA customs, compiled, and curated by the FFA Fisheries Development Division (Ruaia et al. 2020)

Crude oil price

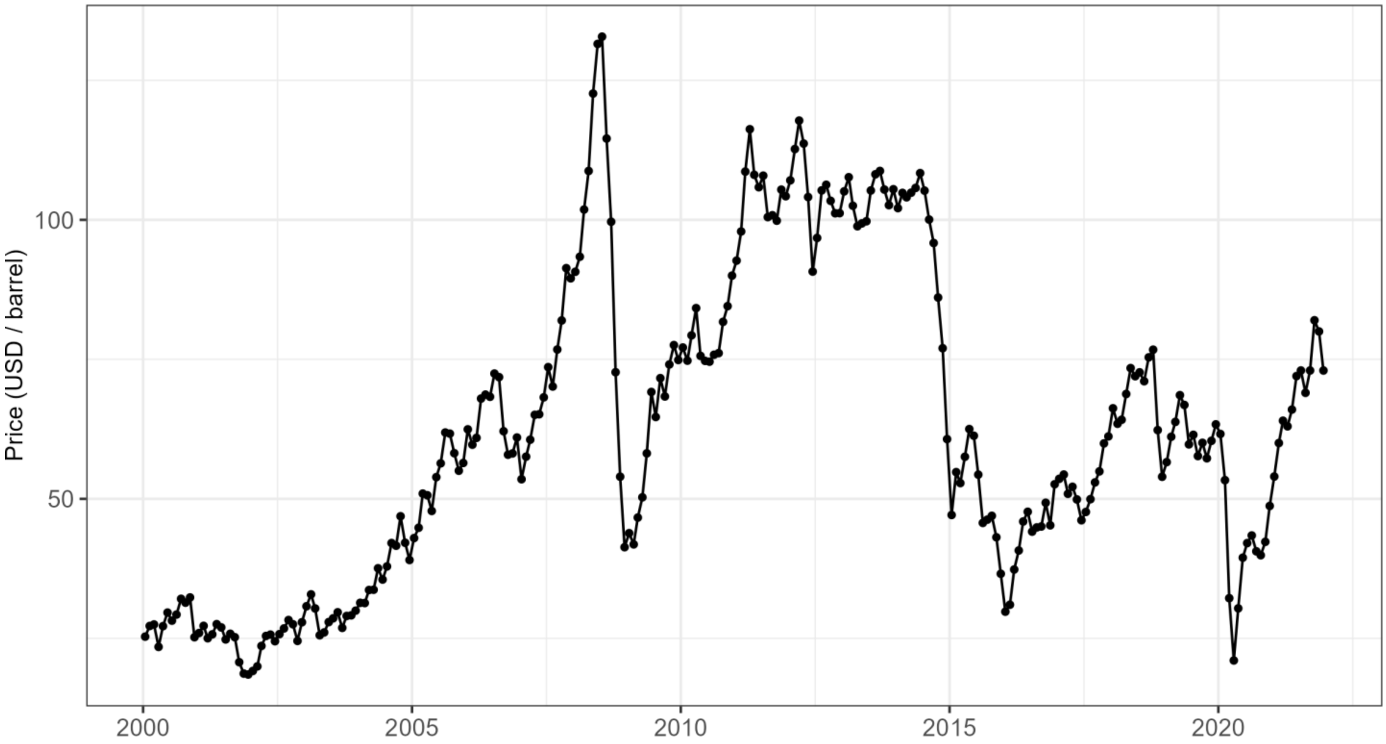

Figure 39: Monthly time series of crude oil spot price (USD/barrel) during the period 2000-2021. Data sourced from the spot prices of Brent, Dubai, and West Texas, compiled, and curated by the FFA Fisheries Development Division

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