REVIEW OF THE STATISTICAL DATA AVAILABLE FOR INDIAN OCEAN BILLFISH (1950-2021)

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Abstract

The document provides an overview of the consolidated knowledge about fisheries catching billfish in the Indian Ocean since the early 1950s based on a range of data sets collected by the Contracting Parties and Cooperating Non-Contracting Parties (CPCs) of the IOTC and curated by the IOTC Secretariat. The reporting quality of fisheries statistics available for the five IOTC billfish species has strongly varied between 1950 and 2021, and improved substantially over the last decade. The catches from coastal gillnet and longline fisheries have steadily increased over time and now contribute to more than 60% of the total billfish catch of the Indian Ocean. Catches from industrial longline fisheries provide the bulk of the geo-referenced effort, catch, and size data available at the Secretariat. Additional details on the five billfish species under IOTC management mandate are provided in separate documents prepared for this meeting.

Keywords: billfish | Indian Ocean | tuna fisheries

Introduction

Billfish are large, highly, migratory predators that include sailfish, marlins and spearfish, which make up the family *istiophoridae*, and swordfish, sole member of the family *Xiphiidae* (**Appendix I**). Billfish have been exploited for millenia (Ward et al. 2000) but time series of fisheries statistics are only available since the early 1950s for large major fishing areas of the Food and Agriculture Organisation (FAO) and at finer spatio-temporal resolution from the tuna Regional Fisheries Management Organizations (tRFMOs) in charge of the management of billfish caught in their respective ocean basins. Data collated by FAO and tRFMOs both indicate that global catches of billfish species declined in recent years after reaching maxima in the mid-2010s. Following high catch levels of about 233,000 t between 2013 and 2016, the global billfish catch showed a substantial drop to less than 200,000 t in 2020-2021 (**Fig. 1a**). The Indian Ocean is the main fishing ground for billfish and represented 45% of the global billfish catch in recent years (**Fig. 1b**).

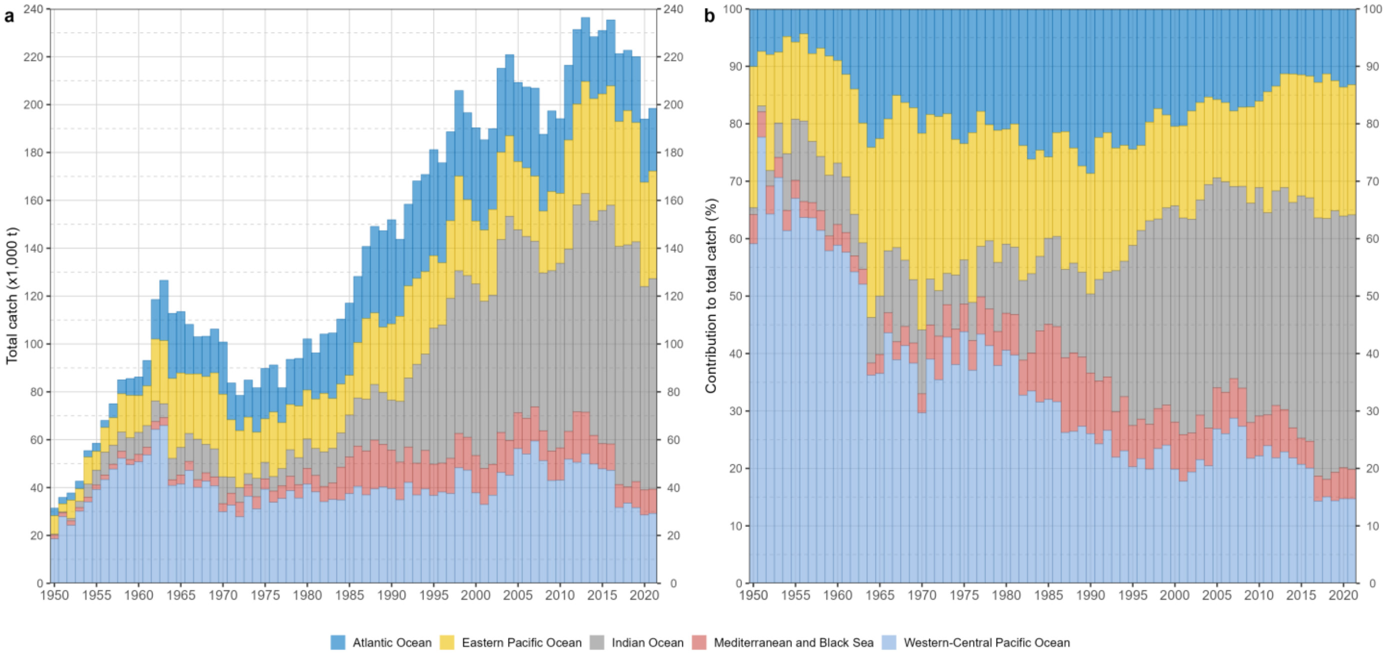

Figure 1: Annual time series of (a) cumulative retained catches (metric tonnes; t) and (b) contribution to the total retained catches (percentage; %) of billfish by ocean basin for the period 1950-2021. Source: FAO global capture production database

Five of all billfish species are currently under the management of the Indian Ocean Tuna Commission (IOTC), i.e., black marlin (*Istiompax indica*), blue marlin (*Makaira nigricans*), striped marlin (*Kajikia audax*), Indo-Pacific sailfish (*Istiophorus platypterus*), and swordfish (*Xiphias gladius*), with shortbill spearfish (*Tetrapturus angustirostris*) having been considered, in several occasions, for further inclusion under the IOTC agreement.

The overarching objective of this paper is to provide participants in the 21st Session of the IOTC Working Party on Billfish (WPB21) with a review of the status of the information available on these five species. The document provides an overview of the data sets available to the IOTC Secretariat as of April 2023, 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 billfish fisheries over the last seven decades. The short time span between the submission of last year data and the WPB21 meeting, makes it difficult to have 2022 fisheries data to be assessed this year.

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. Resolution 18/05, on the management measures for the conservation of billfish, specified catch billfish limits, which are therefore assessed against the data collected and analysed by the Secretariat. 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.

Retained (nominal) catch data

Retained catches, which refer to fish landing weight, FAO Catch and landings, 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, in order to support the monitoring of the catch limits implemented by some industrial fisheries for the CPCs having objected to IOTC Resolution 21/01 as part of the interim plan for rebuilding the yellowfin tuna stock, 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 retained 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 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, 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

Fisheries are essential to ensure food security and support economic growth of the rim countries of the Indian Ocean. This is particularly true for small island developing states (SIDS) which strongly depend on the blue economy. In this context, socio-economic statistics are key to inform decisions on the management of fisheries and assess their performance and economic contribution to the countries (Bennett 2021).

Little information is available on the socio-economic dimension of fisheries catching billfish in the Indian Ocean. The IOTC Form 7PR has been designed to voluntarily report prices of fish per type of product and market but little data have been received so far at the Secretariat with the notable exception of time series of monthly prices by species, fishing gear, and region reported by Oman since 2015, and Malaysia since 2018.

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 full description of the ROS data requirements for each fishing gear is provided in IOTC (2021a).

A comprehensive description of the status, coverage, and data collected as part of the ROS is provided in IOTC (2021b). 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 1,699 commercial fishing trips (948 from purse seine vessels and 751 from longline vessels of various types) made during the period 2005-2021 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 these data in the ROS regional database.

Morphometric data

The current length-length and length-weight IOTC reference relationships for Indian Ocean billfish mostly come from historical data collected in the eastern Pacific Ocean (Uchiyama & Kazama 2003). However, several morphometric data sets have been collected for billfish through different research and monitoring programs conducted over the last decades, including measurements taken at sea and on land (e.g., Setyadji et al. 2016, Bonhommeau et al. 2019). Hence, different morphometric relationships have been established for billfish based on data that may cover different size ranges as well as different areas and time periods (**Appendix I**)).

Methods

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

Data processing

First, standard controls and checks are performed to ensure that 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 data set and may require the submission of revised data from CPCs if the original ones are found to be incomplete.

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

a. When retained 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 global capture production 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 (IOTC 2016). Briefly, the process derives the catch proportion of each IOTC species of an aggregate in a given stratum from past reports of catches where the species and gears were reported separately following a substitution scheme.

A total of 5 species aggregates including IOTC billfish species have been used by some CPCs for reporting retained catch data between 1950 and 2021 (**Table 1**).

Table 1: Species groups including billfish species used for reporting retained catches to the IOTC Secretariat

Species code	Species name	BLM	BUM	MLS	SFA	SWO
AG01	Black marlin and striped marlin	✓		✓		
AG02	Indo-Pacific sailfish and shortbill spearfish				✓	
BIL	Marlins,sailfishes,etc. nei	✓	✓	✓	✓	✓
BXQ	Marlins nei	✓	✓	✓		
TUX	Tuna-like fishes nei	✓	✓	✓	✓	✓

A total of 5 gear aggregates including IOTC billfish species have been used by CPCs to report retained catch data of any billfish species between 1950 and 2021 (**Table 2**).

Table 2: List of gear aggregates with their component gear codes (limited to gear aggregates that have reported catches of billfish species)

Aggr. code	Gear aggregate	Category	BB	GILL	HAND	LIFT	LL	LLCO	PS	PSS	RR	SPOR	TRAW	TROL
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	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Details on the results of the estimation process used to produce the 2021 best scientific estimates and changes in time series of retained catches relative to the previous Working Party on Billfish are provided in Appendix III and Appendix IV, respectively.

Third, 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 2020). 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 2020). All size samples collected using other types of measurements are converted into FL and EFL by using the IOTC equations Appendix II, 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.

Data quality

A scoring system has been devised to assess the reporting quality of retained catch, catch and effort, and size-frequency data submitted to 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 3**). 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 data such as issues in sampling and processing as well as under- or misreporting.

Table 3: Key to IOTC quality scoring system

Data set	Criterion	By species	By gear
Retained 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

Retained catches & discards

The best scientific estimates of retained catches provide an annual view on the history of the fisheries catching billfish species in the Indian Ocean. These species are caught with a large diversity of fishing gears all over the region generally as incidental catches while swordfish is the main target of some longline fisheries.

Historical trends (1950-2021)

The contribution of catches of billfish to the total catches of IOTC species has remained fairly stable over the last decades, oscillating between 4-5% from the mid-1950s onwards (**Fig. 2**). In recent years, the five species of billfish under IOTC mandate represented 4.8% of the total catches of the 16 IOTC species.

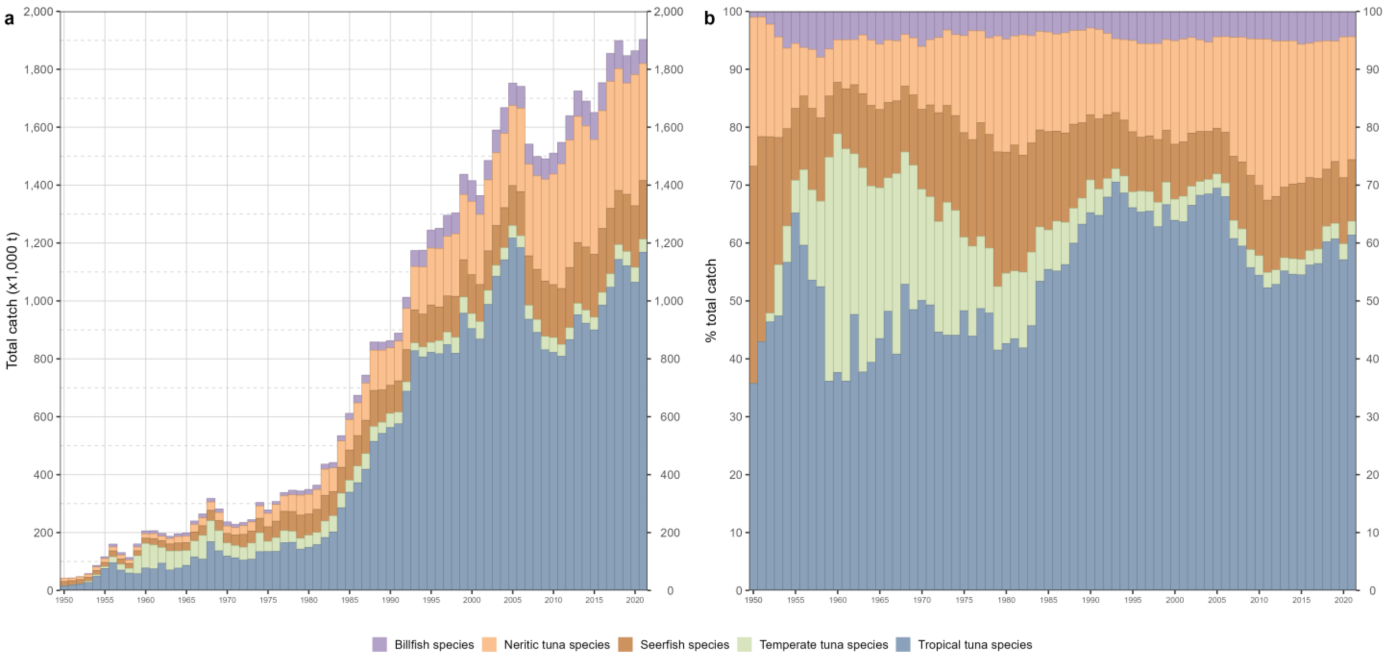

Figure 2: Annual time series of cumulative retained absolute (a) and relative (b) catches (metric tonnes; t) of all IOTC tuna and tuna-like species by species category for the period 1950-2021

Billfish are mainly caught by industrial fisheries in offshore areas using longlines and gillnets, but they are also taken with purse seines and some artisanal gears such as troll and handlines in more coastal fishing grounds. The total retained catches of the IOTC billfish species showed a major increase over the last seven decades, from an average of about 5,500 t per year in the 1950s to an average of about 88,300 t per year in the 2010s (**Table 4**). The marked increase in annual catches of billfish species caught by industrial fisheries recorded between the 1990s and the 2000s was mainly driven by the longline fisheries from Taiwan,China (**Fig. 3a**). Since then, industrial catches showed large variations with two peaks, one in 2004 at 58,700 t prior to the emergence of piracy in the Western Indian Ocean (Pillai 2012), and second in 2016 at 45,100 t, when the large longline vessels resumed their operations in the Somali basin. However, in recent years, catches of billfish by high-seas fisheries showed a declining trend to reach 28,700 t in 2021. Catches from artisanal fisheries, on the other hand, have steadily increased over time, with their contribution to the total catch of billfish increasing from less than 6% prior to the 1970s to more than 61% in recent years (**Fig. 3b**).

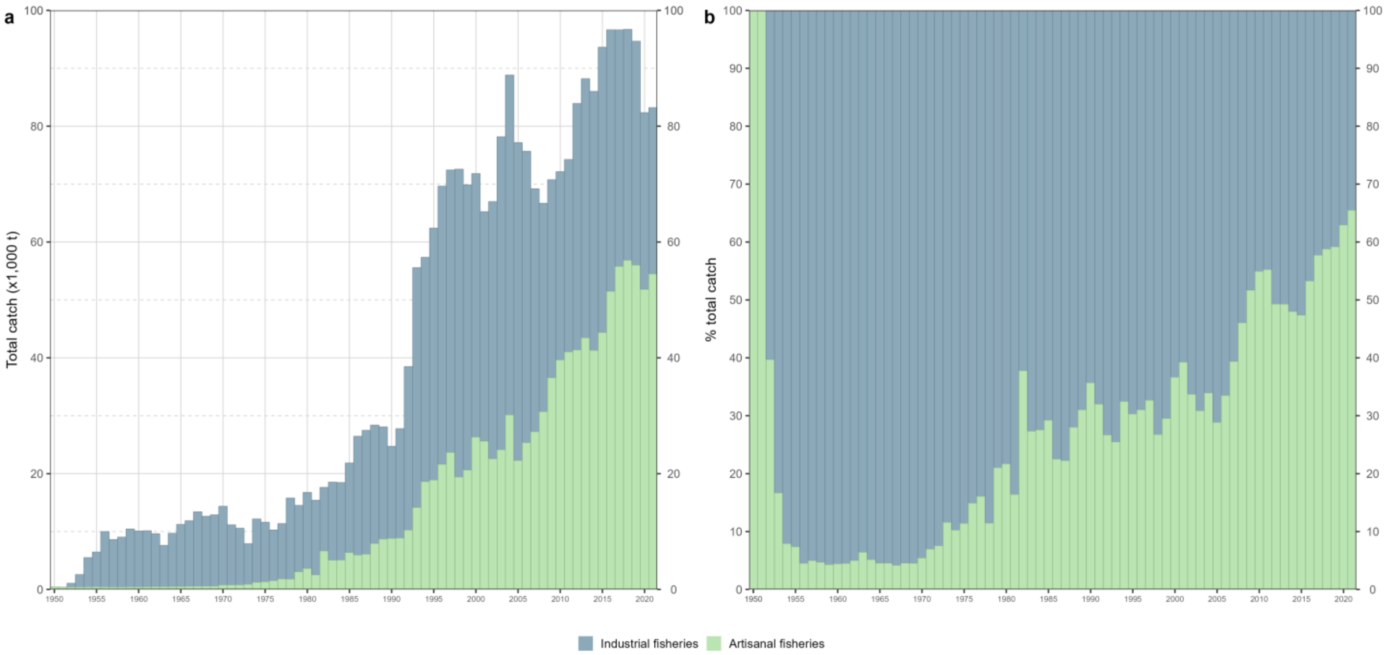

Figure 3: Annual time series of cumulative retained absolute (a) and relative (b) catches (metric tonnes; t) of IOTC billfish by fishery type for the period 1950-2021

The composition of the fisheries catching billfish varies over time and between species. While billfish have mainly been reported to be caught by longliners until the early 1990s, the contribution of gillnet and coastal line fisheries has substantially increased over the last two decades (**Table 4** & **Fig. 4**). In particular, gillnet (including both coastal and offshore fisheries) catches of billfish have steadily increased since the early 1980s to reach about 45,000 t in 2021, representing 54% of the total catches of billfish in that year.

Table 4: Best scientific estimates of retained catches (metric tonnes; t) of the IOTC billfish species by decade and fishery for the period 1950-2021

Fishery	1950s	1960s	1970s	1980s	1990s	2000s	2010s
Purse seine | Other	0	0	1	11	19	39	201
Longline | Other	0	0	0	44	2,861	11,896	7,595
Longline | Fresh	0	0	15	151	1,895	2,759	5,483
Longline | Deep-freezing	260	1,301	1,905	4,128	19,686	15,017	7,581
Line | Coastal longline	10	10	16	152	363	697	4,622
Line | Trolling	2	2	8	21	34	43	212
Line | Handline	9	9	135	417	604	410	872
Baitboat	0	0	0	0	0	0	0
Gillnet	16	18	25	168	547	1,424	4,695
Other	0	0	0	1	2	4	10
Total	297	1,340	2,106	5,093	26,011	32,292	31,272

Total catches of billfish reported for line fisheries showed a marked increase from the early 2010s (**Fig. 4**), reflecting in particular the increased reporting of billfish species caught by the coastal longline fishery of Sri Lanka, that went from 37 t in 2013 to 4,426 t in 2014. This sharp increase is thought to be mainly due to an improvement in the fisheries statistics of Sri Lanka starting with the early 2010s, when a closer monitoring of the catches in multi-gear fisheries (e.g., gillnet and longline operated during the same trip) was combined with a better breakdown of longline fisheries data (i.e., separation between coastal and offshore components) (Herath & Maldeniya 2013). In parallel, the catches of billfish taken by coastal longliners operating in the areas of national jurisdiction of India have doubled over the last decade, increasing from 3,326 t in 2010 to 6,928 t in 2019. However, in 2021, billfish catches taken by coastal longline dropped by 39%.

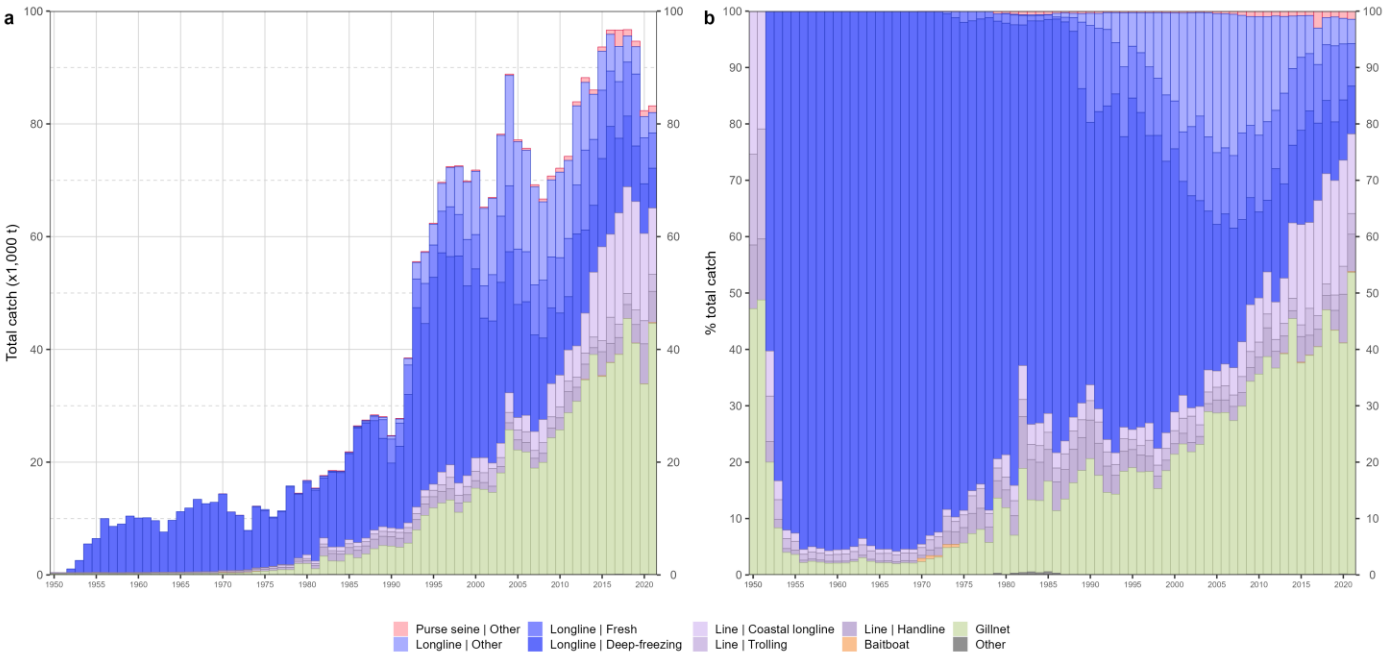

Figure 4: Annual time series of cumulative retained absolute (a) and relative (b) catches (metric tonnes; t) of IOTC billfish by fishery for the period 1950-2021

The five IOTC billfish species show different catch levels and trends over time, with a total of 2.8 million metric t of billfish reported to have been caught in the Indian Ocean since the 1950s. In terms of total catches, swordfish (SWO) represents the main billfish species, contributing to 37% of the cumulative catches of billfish available in the IOTC database, followed by Indo-Pacific sailfish (SFA) with a contribution of 25% (**Fig. 5**). Blue marlin (BUM) and black marlin (BLM) contributed about equally with cumulative catches of about 414,000 t, roughly corresponding to 15% of total billfish catches taken during that period. Striped marlin (MLS) appears to be less abundant in the catches of IOTC billfish with a maximum annual catch of 8,728 t observed between 1950 and 2021 and a total cumulative catch of about 263,000 t reported as caught over that period.

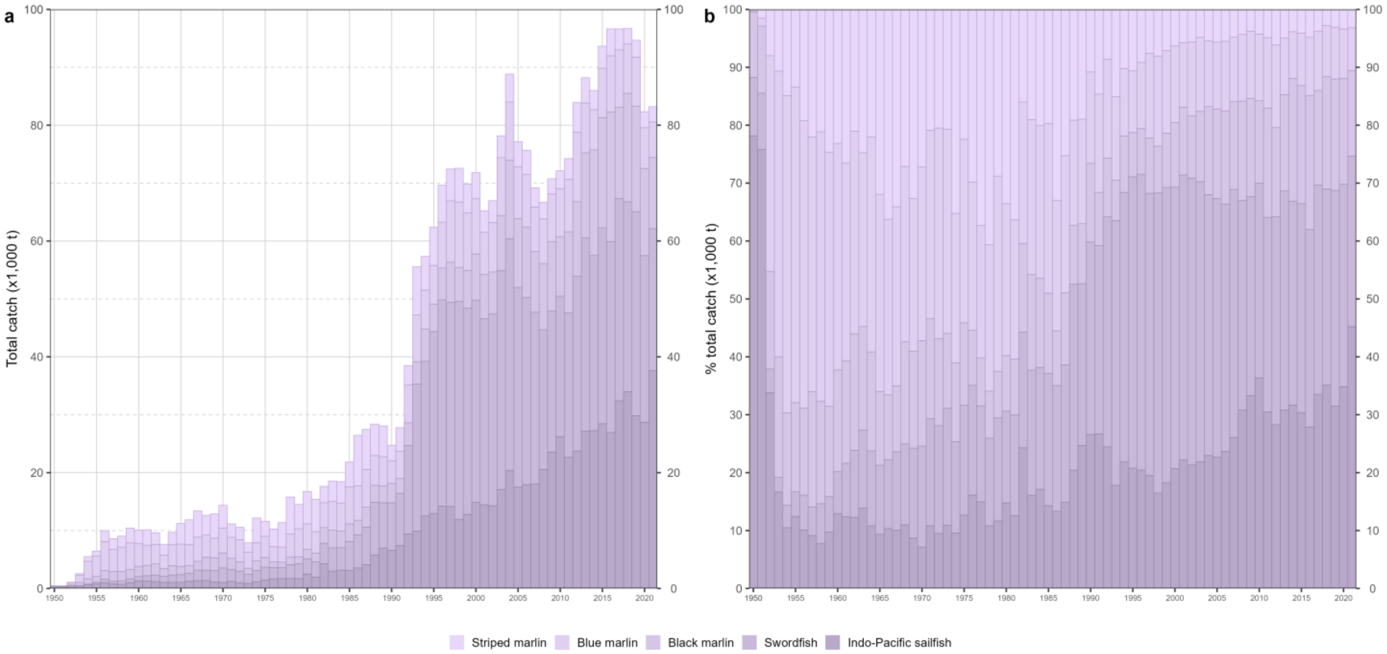

Figure 5: Annual time series of cumulative retained absolute (a) and relative (b) catches (metric tonnes; t) of IOTC billfish by species for the period 1950-2021

Black marlin (BLM) shows an increasing trend, which brought catches of the species from 3,000 t in 1991 to around 14,000 t in 2004, partly due to the development of the mixed longline-gillnet fishery in Sri Lanka (IOTC 2023a). In recent years, the majority of black marlin catches has come from coastal fisheries, particularly gillnet and coastal longline fisheries which represented 55% and 25% of the total catches of black marlin, respectively. Catches sharply increased from around 10,000 t in 2010 to over 22,000 t in 2016 – the highest catches recorded in the Indian Ocean for the species – largely due to the major increased reporting for Indian coastal fisheries in 2016 followed by a major drop in 2017 (CMFRI 2017). Following the peak in 2016, total catch of black marlin decreased and reached 12,000 t in 2021.

Catches of blue marlin (BUM) show a two-phase pattern over time, with mean annual catch levels of around 4,000 t between 1955 and 1990 and 9,000 t between 1995 and 2021 (IOTC 2023b). During that latter period, catches are marked by some major interannual variability which may be explained by the large fluctuations reported for the numbers of operating longliners from Japan and Taiwan,China which took the bulk of blue marlin catch. The increasing trend observed between 1995 and 2014 is also explained by the increased reporting of catches by the longline fishery of Indonesia. Some of the highest catches of blue marlin reported by longliners in recent years have been recorded between 2012 and 2016, and might be the consequence of higher catch rates by some longline fleets which resumed operations in the western tropical Indian Ocean following a reduction in piracy threat. Overall, catches of blue marlin are mostly dominated by longline fisheries although the contribution of line and gillnet fisheries in recent years became more marked (IOTC 2023b).

Striped marlin (MLS) shows some strong interannual variability in the retained catches between 1950 and 2021, with a progressive increase from the 1950s to the 1990s followed by a decreasing trend from a high catch of about 8,000 t of fish in 1993 to 3,000 t in 2021. Overall, the range of catch levels observed between 1990 and 2021 for striped marlin may reflect the level of reporting and the status of striped marlin as a non-target species rather than actual catches. Particularly, catches reported from longline fisheries are highly variable, with lower catch levels between 2008 and

2011 largely due to declining catches reported by deep-freezing and fresh-tuna longliners from Taiwan,China. Since 2012, catches of striped marlin have fluctuated between 3,000-5,000 t per year (IOTC 2023d).

Indo-Pacific sailfish (SFA) shows a continuous increasing trend between 1950 and 2021, driven by the gillnet fisheries that represent the large majority of the catches for this species over the entire period, with catches increasing from about 7,000 t in 1990 to 38,000 t in 2021 (IOTC 2023c). It is noteworthy that catches of Indo-Pacific sailfish reported by I.R. Iran increased from about 8,200 t in 2013 to 17,900 t in 2021, representing a 118% increase between 2013 and 2021.

After a period of slow increase between 1950 and the early 1990s, catches of swordfish (SWO) showed a massive increase mostly driven by the expansion of the longline fisheries from Taiwan,China, from about 8,000 t in 1990 to about 35,000 t per year between 1995 and 2005. The catches showed a decrease to less than 25,000 t during 2008-2011 when longline vessels had to operate far from the Somali basin due to piracy threat, and re-increased during 2012-2019 to catch levels of about 33,000 t per year. In 2020-2021, catches of swordfish have showed a marked decline mainly due to lower catches from the fisheries of Taiwan,China and Sri Lanka (IOTC 2023e).

Recent fishery features (2017-2021)

In recent years (2017-2021), total retained catches of all IOTC billfish species combined were about 90,700 t per year, with gillnet, longline, and line fisheries contributing to 15%, 53.8%, and 30.2% of all catches, respectively (**Table 5**).

Table 5: Mean annual retained catches (metric tonnes; t) of the IOTC billfish species by fishery and contribution (%) to the total catch of all IOTC billfish species between 2017 and 2021

Fishery	Fishery code	Catch	Percentage
Gillnet	GN	40,703	44.9
Line | Coastal longline	LIC	17,023	18.8
Longline | Deep-freezing	LLD	10,304	11.4
Longline | Fresh	LLF	9,360	10.3
Longline | Other	LLO	4,617	5.1
Line | Handline	LIH	4,279	4.7
Line | Trolling	LIT	2,808	3.1
Purse seine | Other	PSOT	1,452	1.6
Other	OT	118	0.1
Baitboat	BB	50	0.1

Between 2017 and 2021, the mean annual catches of IOTC billfish have been dominated by a few CPCs, to the point that about two thirds of all catches were accounted for by four distinct fleets: I.R. Iran (mostly composed of gillnet fisheries), Sri Lanka and India (described by a large diversity of fisheries and gears), and Taiwan,China (composed of an equal mix of fresh and deep-freezing longliners) (**Fig. 6**).

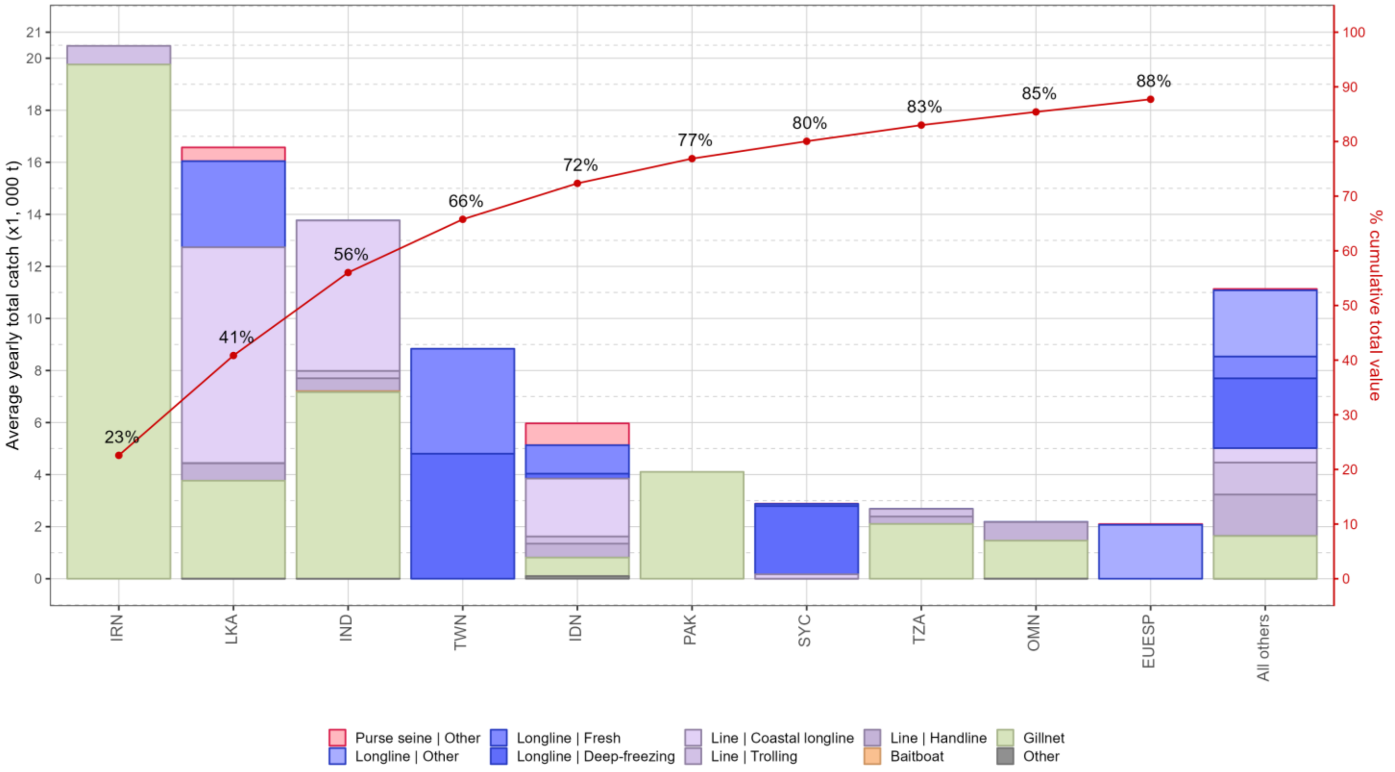

Figure 6: Mean annual catches of IOTC billfish species by fleet and fishery (metric tonnes; t) between 2017 and 2021 with indication of cumulative catches by fleet

Over the last five years of the time series (2017-2021), gillnet catches of billfish species showed a decrease followed by an increase in 2021 to reach about 45,000 t while catches reported by longline fisheries decreased from 30,000 t in 2017 to 16,900 t in 2021 (**Fig. 7**). Meanwhile, catches of billfish from line fisheries were at about 25,100 t during 2017-2020 before decreasing to 20,300 t in 2021 (**Fig. 7**). Recent catches from other fishery groups (i.e., purse seine, baitboat, and other fisheries) have been small or negligible.

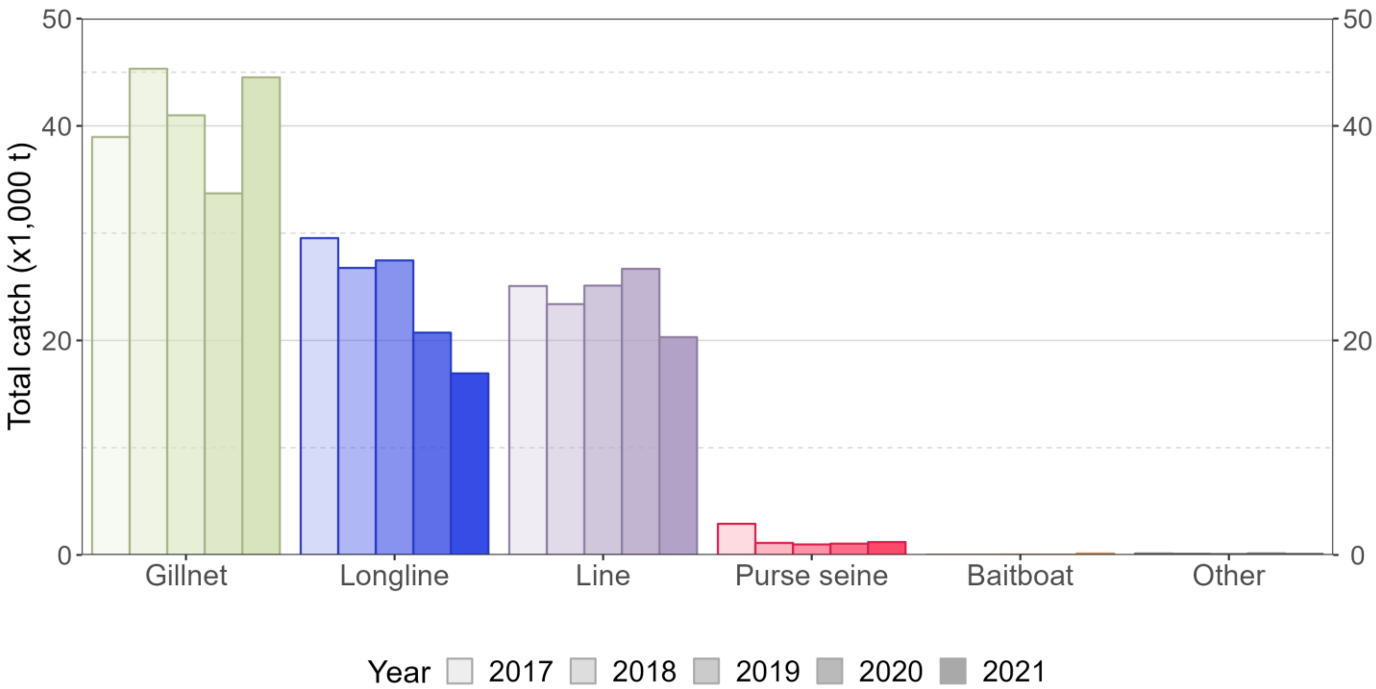

Figure 7: Annual catch (metric tonnes; t) trends of IOTC billfish species by fishery group between 2017 and 2021

Annual trends observed in the catches of billfish in recent years vary between fleets and fishery groups. The increase observed in gillnet catches in 2021 was mainly driven by the fisheries of I.R. Iran and India (**Fig. 8a**). In recent years, catches from Sri Lankan gillnetters declined from 5,000 t to 2,000 t, which could be due to the reduction of fishing vessels in operation. Longline catches of billfish showed a major decrease for all fisheries since 2017, i.e., Taiwan,China, Sri Lanka, Seychelles, and EU,Spain (**Fig. 8b**). Meanwhile, major line fisheries of Sri Lanka and India showed some major decline in catch in 2021 (**Fig. 8c**).

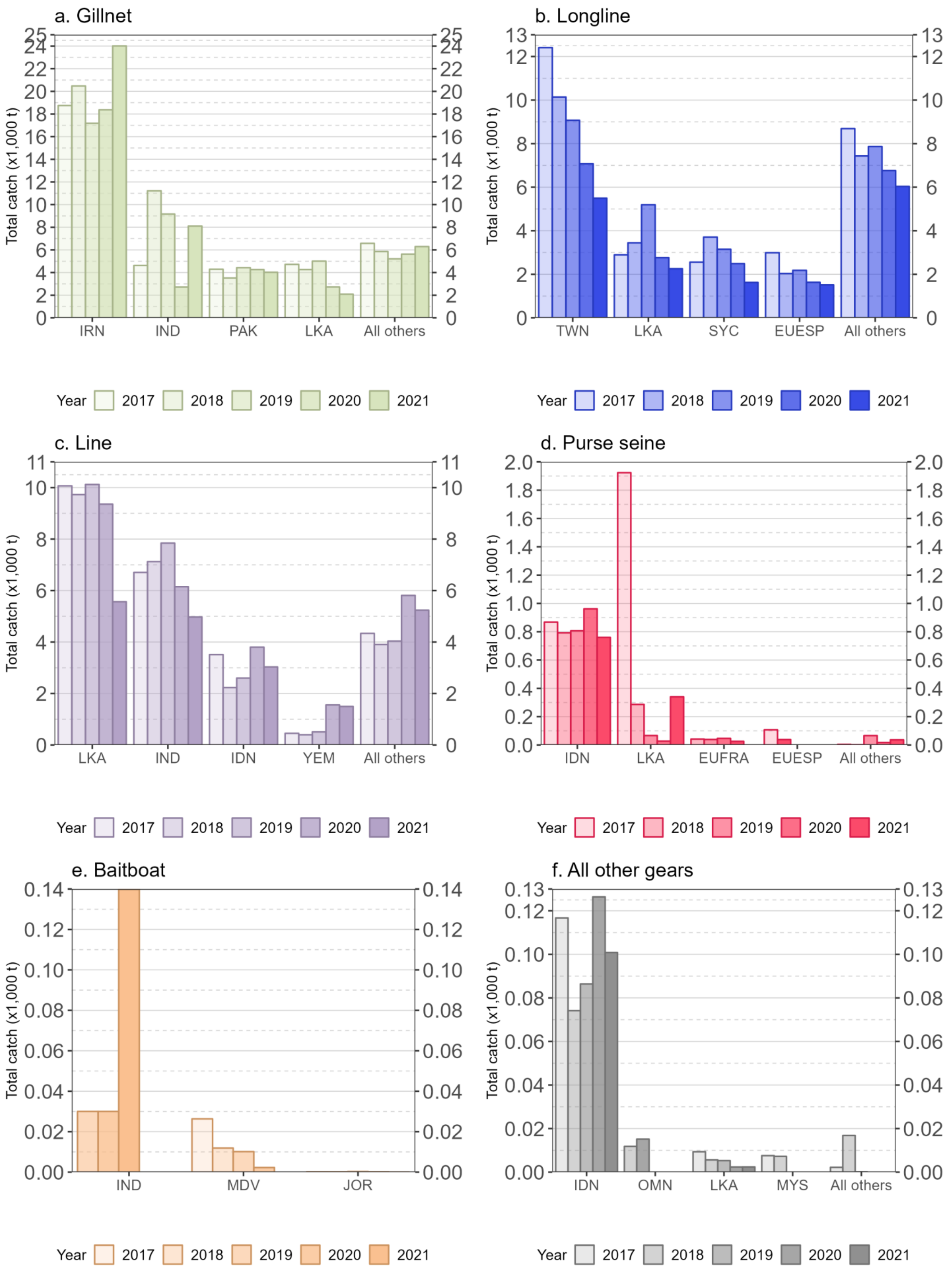

Figure 8: Annual catch (metric tonnes; t) trends of IOTC billfish species by fishery group and fleet between 2017 and 2021

Changes from previous Working Party

Some changes occurred in the catch time series of the IOTC billfish species since the release of the data set of best scientific estimates of retained catches produced for the 20th session of the Working Party on Billfish (WPB20) held in 2022. The changes concern the last decade and represent an additional catch of about 2,000 t per year on average between 2011 and 2020 (**Fig. 9**). These changes are mostly due to data improvements made by some CPCs and the Secretariat, including:

- Data revisions by I.R. Iran for the period 2011-2020;
- Updates of catch data from Kenya and Mozambique by the Secretariat based on recent published information;
- Review of catch data from Indonesia based on the re-estimation of catch series between 2010 and 2017;
- Updates in time series of the FAO global capture production database for non-CPC coastal states (United Arab Emirates, Jordan, and Yemen), which are used in absence of data reported to the Secretariat.

Significant changes of billfish catches concern Yemen for which the series made available by FAO included for the first time some catch of swordfish for the period 2011-2020, which amounted between 1,800-3,700 t. Also, the historical review of fisheries statistics performed by I.R. Iran resulted in a decline of billfish catches in 2020 by 1,500 t. Changes from other fisheries were found to be minor. The differences in the catch between the two working parties are detailed in Appendix IV.

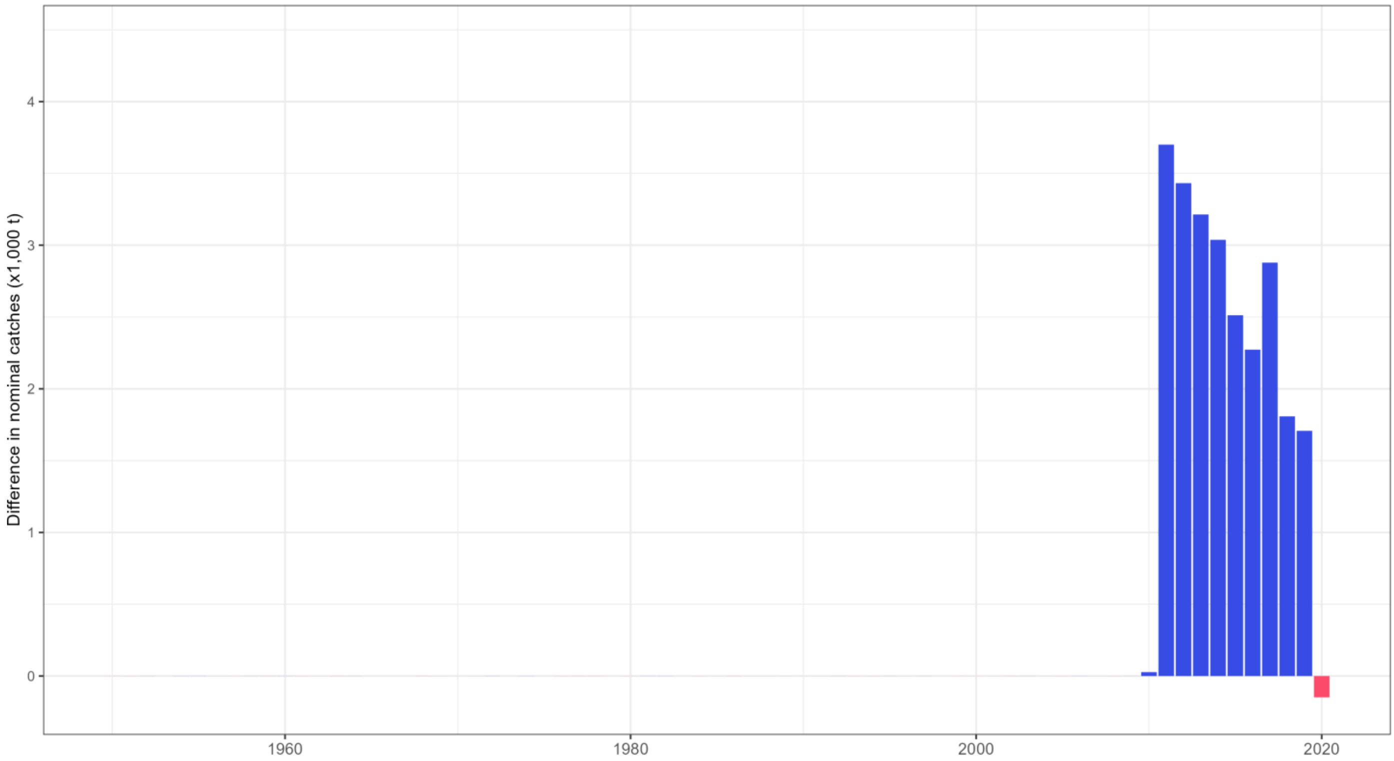

Figure 9: Differences in the available best scientific estimates of retained catches (metric tonnes; t) of billfish between the 20th and 21st sessions of the IOTC Working Party on Billfish

Uncertainties in retained catch data

Different processes may affect the quality of the statistical data reported to the IOTC Secretariat, depending on the complexity of the fisheries and the systems in place to collect, process, and manage the data at national level. The accuracy and precision of the catches may be affected by under-reporting or misreporting, low sampling coverage, poor data resolution (e.g., due to mis-identification of species), and errors in processing and reporting.

The overall quality of retained catches for the five IOTC billfish species with regards to IOTC reporting standards has strongly varied between 1950 and 2021, and improved substantially over the last decade. The percentage of retained catches fully or partially reported to the Secretariat (i.e., scores between 0 and 2; **Table 3**) showed large variations over time, decreasing from more than 90% prior to the 1970s, when the catches were dominated by industrial longline fisheries, to less than 44% in the late 2000s (**Fig. 10**). The quality of data improved for the Iranian fisheries thanks to additional information provided from 2011, and also to better quality data reported for Sri Lankan fisheries from 2014. Since then, the reporting quality improved for both industrial and artisanal fisheries with the overall percentage of data fully or partially reported to the Secretariat reaching 85% in 2021 (**Fig. 10**).

The reporting quality of retained catch data varies between species and over time and information on quality is available on a species-specific basis from the data review papers on black marlin (IOTC 2023a), blue marlin (IOTC 2023b), striped marlin (IOTC 2023d), Indo-Pacific sailfish (IOTC 2023c), and swordfish (IOTC 2023e).

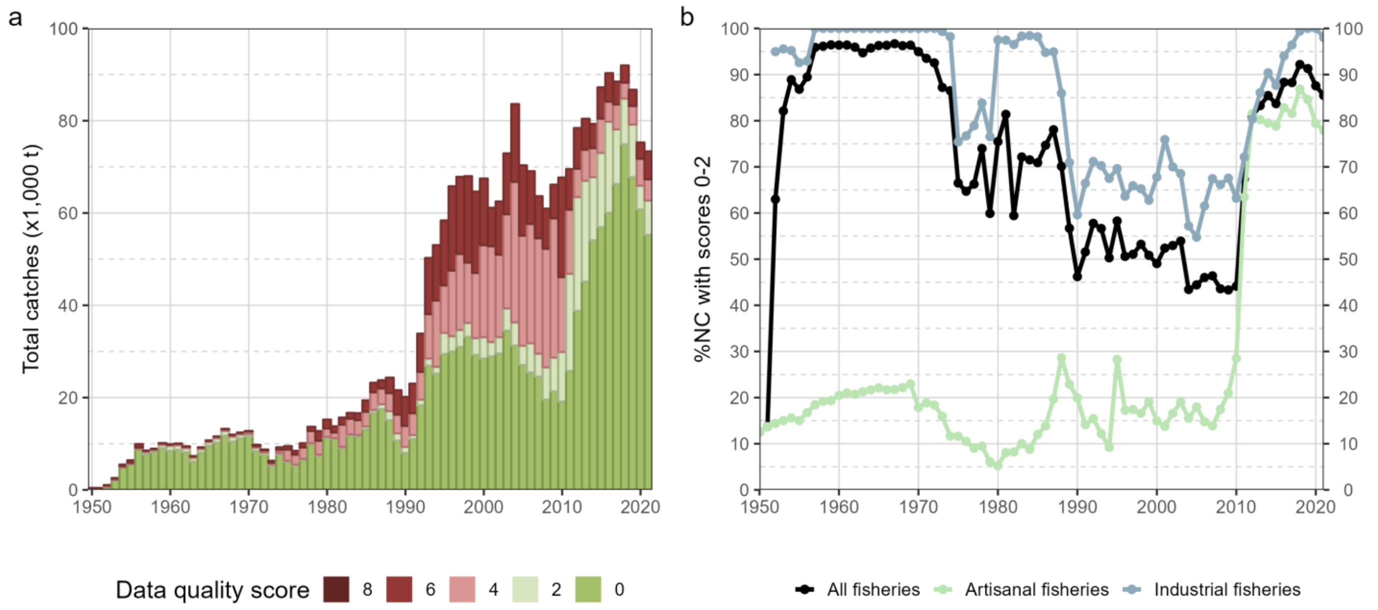

Figure 10: (a) Annual retained catches (metric tonnes; t) of IOTC billfish species estimated by quality score and (b) percentage of retained catches fully or partially reported to the IOTC Secretariat for all fisheries and by type of fishery, in the period 1950-2021

In 2021, 75% of the retained catches of billfish was fully reported to the Secretariat while the rest had to be partially or fully estimated. Part of the catches was derived from alternative sources of catch data for both non-IOTC members and IOTC CPCs that have not reported data to the Secretariat (Appendix III). In addition, a re-estimation process was applied to the catches from the artisanal fisheries of India and Indonesia, which are known to be affected by data quality issues, in particular regarding the reporting of catch data for species and gear aggregates.

In addition to the reporting issues, several other key elements of concern emerge from the available retained catches of some CPCs, that need to be noted and addressed to improve the fisheries statistics of the five IOTC billfish species:

- Artisanal fisheries (including sport fisheries)
  - Billfish catches for Indonesian artisanal fisheries have been estimated at very high levels in the last decade, reaching around 10-15% of the total catches of billfish in the Indian Ocean. In 2012 the Secretariat revised the retained catch dataset for Indonesia, using information from various sources, including official reports (Moreno et al. 2012). While Indonesia is implementing a number of improvements to the collection and validation of data for artisanal fisheries, such as electronic logbooks and complete enumeration of catches at key landing sites, catches are still considered to be uncertain for Indonesian small-scale fisheries. Although all the effort in data collection, irregularities and inconsistencies in estimating the final retained catches remained. The Secretariat is currently working with Indonesia to review and improve the current estimation process;
  - Sport fisheries of Australia, France (La Réunion), India, Indonesia, Madagascar, Mauritius, Oman, Seychelles, Sri Lanka, Tanzania, Thailand and United Arab Emirates: data have either never been submitted, or are available for only a limited number of years for sport fisheries in each of the referred

CPCs. Sport fisheries are known to catch billfish species, and are particularly important for catches of blue marlin, black marlin and Indo-Pacific sailfish. Although some data are available from sport fisheries in the region (e.g., Kenya, Mauritius, Mozambique, South Africa), the information cannot be used to estimate levels of catch for other fisheries. In 2017 the IOTC Secretariat commissioned a pilot project to develop tools and training materials for CPCs to improve the collection and reporting of catch-and-effort and size frequency from sport fisheries in the Western Indian Ocean (Pepperell et al. 2017). The project focused on trialling specifically-developed data collection tools on a small number of CPCs, including La Réunion, Kenya, Mauritius and Seychelles – however data reporting continues to be an on-going issue for sports and recreational fisheries.

- The gillnet fisheries of I.R. Iran and Pakistan are estimated to account for around 22,000 t of catches of billfish (equivalent to about 24% of the total billfish catches in the Indian Ocean) annually in recent years. However, catches for these components remain uncertain for several reasons:
  - In recent years (from 2011 onwards) I.R. Iran has reported catches of marlins and swordfish for their gillnet fishery which significantly revised the species-specific catch previously estimated by the Secretariat. While the IOTC Secretariat has used the new catch reports to re-build the historical series for its offshore gillnet fishery (pre-2011), the resulting estimates are thought to be highly uncertain;
  - In 2019, the IOTC WPDCS and SC endorsed the revised catch series (from 1987 onwards) officially provided by the Pakistan government for its gillnet fleet, based on the results of the work from the data collection programme supported by WWF-Pakistan. These revised catch series introduced large differences in the reported catches of billfish species, in particular for swordfish, striped marlin and Indo-Pacific sailfish that are now far lower than what originally reported (IOTC 2019). As a consequence, current catch estimates for Pakistan account for around 6% of the total catches of billfish in the Indian Ocean, and still suffer from the lack of detailed per-species information for several years, using “generic” billfish species to report for billfish catches. However, from 2018, Pakistan began submitting catches of individual billfish species.
- Industrial longline fisheries
  - Following issues with the reliability of catch estimates of Indonesia’s fresh longline fleet in recent years, in 2018 the IOTC Secretariat developed in collaboration with Indonesia a new methodology of catch estimation that mostly affects Indonesia’s catches of swordfish, striped marlin, and blue marlin (Geehan 2018). The revised catches are significantly lower for Indonesia’s fresh longline fleet in recent years, compared to previous IOTC estimates, while total catches across all fleets have also been revised downwards by as much as 30% for each species as a consequence of the new estimation methodology. The methodology has not been applied to the industrial component of Indonesian longline catches since 2018;
  - Despite a decrease in the number of fresh-longline vessels from Taiwan,China by around 30% between 2013-2016, catches have remained at similar levels, or even marginally increased as average catches per vessel have risen from 100 t per vessel in 2013 to around 175 t per vessel in 2016. Over the same period, the proportion of swordfish reported by the fresh longline fleet from Taiwan,China has risen from around 8% to over 30% - due to improvements in the estimation of catches by species, according to official sources. Both these issues (i.e., the sharp increase in average catches per vessel and changes to the species composition) require further clarification to ensure that the recent increase in average catches is valid.
- Industrial purse seine fisheries
  - Although considered to be small, catches of billfish recorded by all industrial purse seiners are thought to be a fraction of those retained on board. Due to the species being a bycatch, catches are seldom recorded in the logbooks although information collected through the ROS shows that some purse seine fleets do retain billfish for marketing.

Discard levels

The total amount of billfish species 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, the implementation of IOTC Res. 18/05 that bans the release of specimens of billfish smaller than 60 cm lower jaw fork length may have modified discarding practices in recent years. Despite the lack of information available, discarding of billfish species is overall considered to be limited in most coastal and industrial fisheries targeting tuna and tuna-like species in the IOTC area of competence.

Purse seine fisheries

The levels of bycatch of billfish in Indian Ocean large-scale purse seine fisheries have been shown to be low and dominated by marlins, although sailfish may occasionally be caught (Romanov 2002, Ruiz et al. 2018). Part of the billfish has been shown to be discarded at sea despite the entry in force of IOTC Res. 19/05 that bans the discard of non-targeted species caught with purse seine.

Information available from the ROS regional database covers the period 2005-2021 and the whole fishing grounds of the purse seine fishery (**Fig. 11**). Data show that only ~26% of billfish caught are discarded, indicating that a substantial component of billfish catch is retained onboard, particularly marlin species (**Fig. 11**). Based on a large data set of observations at sea collected during the period 2008-2017, the annual catch levels of billfish in the main component of the Indian Ocean purse seine fishery were estimated to vary between 100 and 400 t per year (Ruiz et al. 2018), providing an upper limit for the discard levels.

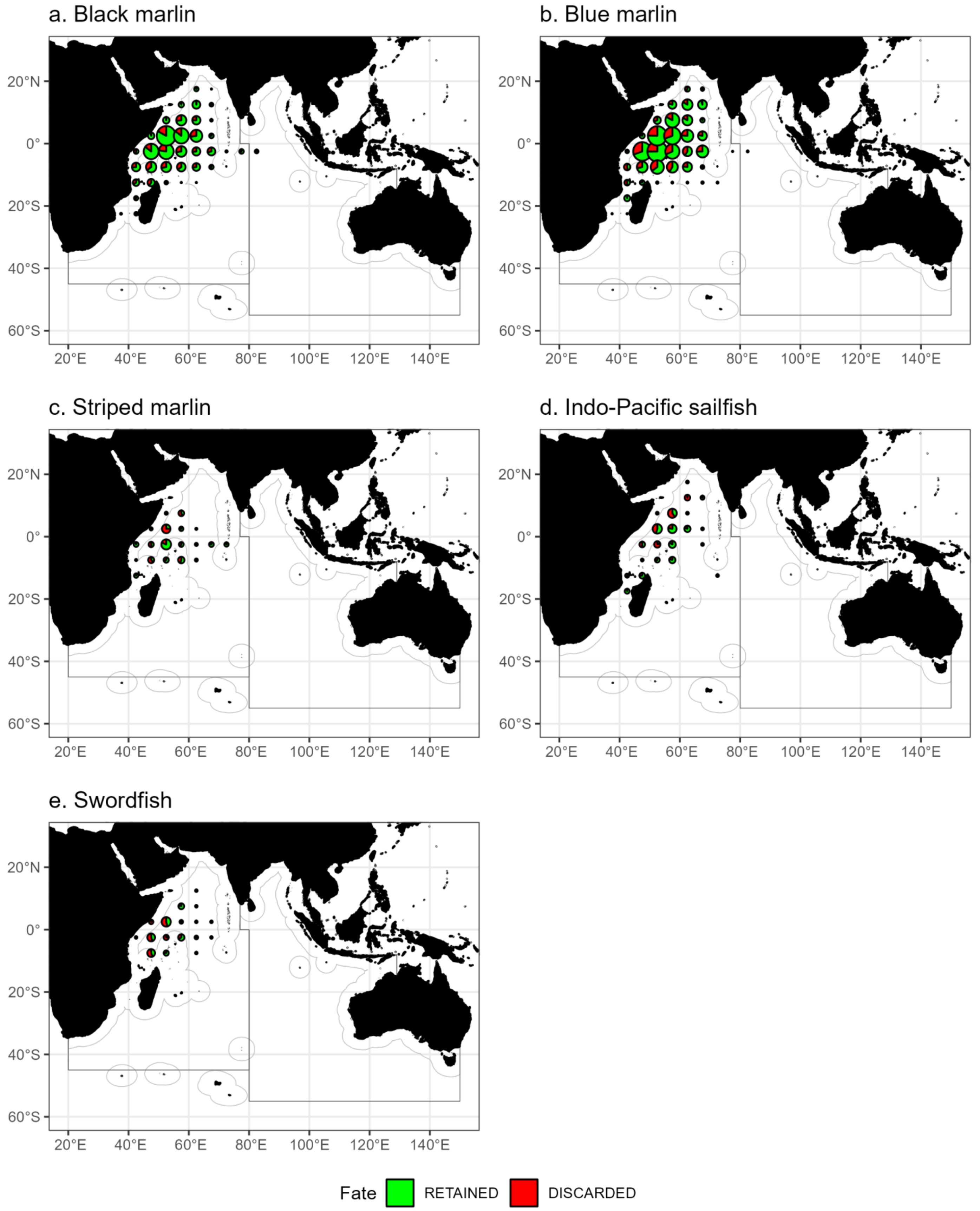

Figure 11: Distribution of all observations of billfish caught in the western Indian Ocean purse seine fishery with information on fate (i.e., retained or discarded) as available in the ROS regional database

ROS data show that purse seine discards are dominated by black and blue marlins while discards of Indo-Pacific sailfish and swordfish are very small, in line with their bycatch levels. Data collected by observers further show that the very large majority of the discarded billfish end up dead (~95.3%). Interestingly, the data also show that the level of discarding depends on the fleet, with an overall percentage of discarding of 42.1% for EU,France and 13.6% and 18.9% for Seychelles and EU,Spain, respectively. For the three fleets, the proportion of discards shows a decrease over time, indicating the growing tendency of the industry for marketing billfish species.

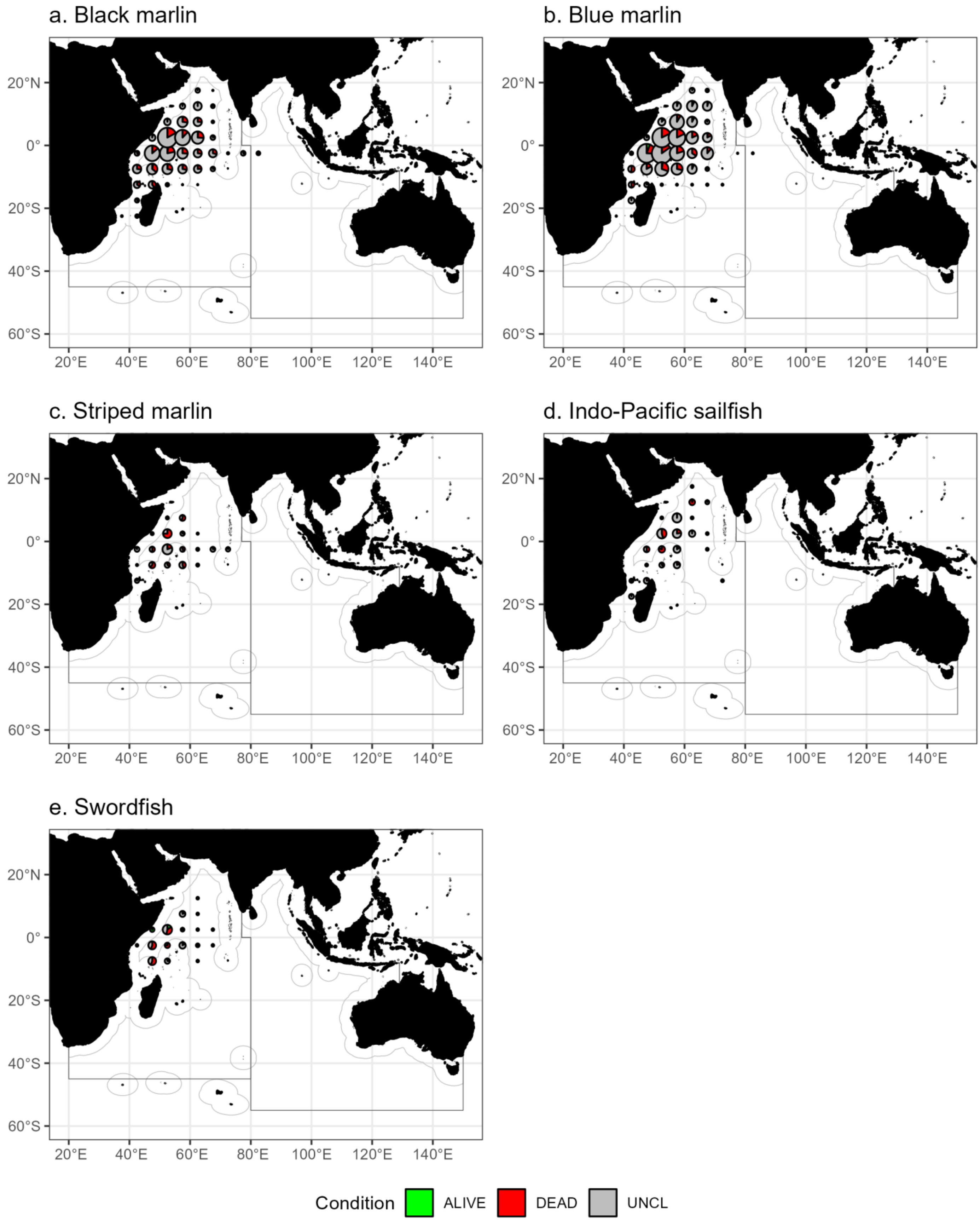

Figure 12: Distribution of all observations of billfish discarded at sea in the western Indian Ocean purse seine fishery with information on condition as available in the ROS regional database

Size data collected by observers at sea for billfish caught in the purse seine fishery show no significant difference between retained and discarded specimens (**Fig. 13**). The size of the three marlin species is very similar across species. The median fork length is about 215-230 cm, with the capture of the largest individuals showing larger sizes in black marlin (75% quantile = ~270 cm FL), followed by blue marlin (75% quantile ~250 cm FL), and striped marlin (75% quantile = ~235 cm FL). The median sizes of Indo-Pacific sailfish and swordfish are 178.5 cm FL and 202 cm FL, respectively.

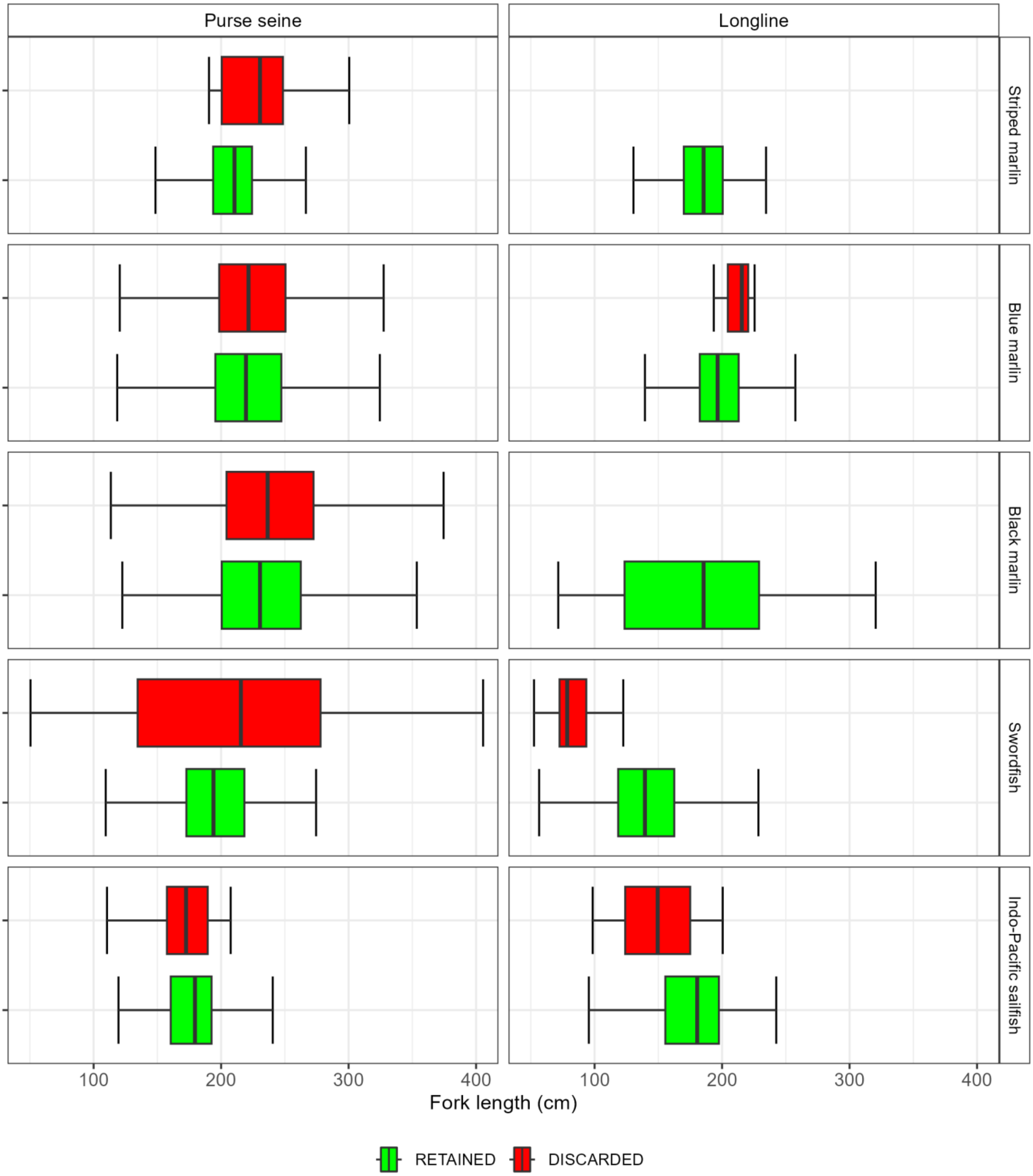

Figure 13: Boxplots of size measurements (fork length; cm) of billfish species discarded at sea in purse seine and longline fisheries as available in the ROS regional database

Longline fisheries

Information from the literature indicates that levels of discards of billfish are low in Indian Ocean longline fisheries (Huang & Liu 2010, Gao & Dai 2016). Discarding is mainly due to under size, damaged condition, and depredation by whales and sharks that has been shown to be substantial in some longline fisheries of the western Indian Ocean (Munoz-Lechuga et al. 2016, Rabearisoa et al. 2018).

Information available in the ROS regional database for longline fisheries covers the period 2009-2021 and a small part of the longline fishing grounds as the data are limited to EU,France, Japan, and Sri Lanka. The discards of billfish in these fisheries appear to be low for billfish, i.e., from 0% discard in the longline fishery of Sri Lanka to a maximum of about 5% for blue marlin and swordfish in the longline fishery of Japan. Discarding appears to be the highest for swordfish in the swordfish-targeted longline of Reunion Island where the overall discarding rate during 2009-2019 was about 14.3%. This apparent high discard rate may be partly explained by the high levels of depredation observed in this fishery (Romanov et al. 2013, Rabearisoa et al. 2018). However, size data available in the ROS show a significant difference between the swordfish retained and discarded in the fishery, with the latter being ~60 cm smaller than the former, on average (**Fig. 13**). Further analysis accounting for the variability of discarding in space and time and other factors such as vessel attributes (e.g., size) is required to accurately assess the extent of and causes of discarding in this fishery and other longline fisheries when data become available.

Gillnet fisheries

In absence of market value, marlins and swordfish have been assumed to be discarded in some important gillnet fisheries such as from I.R. Iran although information available for this fishery suggests that most billfish may be retained and landed (Rajaei 2013, Shahifar et al. 2013).

Geo-referenced catch and effort

Time series of nominal effort

Some information is available on nominal effort for both artisanal and industrial fisheries having caught billfish species over the last seven decades. Nevertheless, the completeness and continuity of the time series of effort reported to the Secretariat greatly varies between fisheries and fleets. Furthermore, several different units of effort may have been used over time for some fisheries, and the spatial-temporal resolution and reporting coverage for a given fleet may vary between years (**Tables 6-7**).

Table 6: Geo-referenced data on artisanal fishing effort available at the IOTC Secretariat for each fishery group with information on the number of years and spatial fishing grounds used for reporting the data. FDAYS = Fishing days; FHOURS = fishing hours; MD = men-day; MH = men-hours

Fishery type	Fishery group	Unit	Years	Start year	End year	Fishing grounds
Artisanal fisheries	Purse seine	FDAYS	2	2020	2021	1
		SETS	1	2021	2021	3
		TRIPS	9	1986	2021	8
	Line	BOATS	10	2001	2013	8
		DAYS	26	1985	2019	26
		FDAYS	22	2000	2021	121
		FHOURS	4	2012	2016	1
		HOOKS	27	1995	2021	349
		MD	1	2016	2016	1
		MH	1	2021	2021	1
		TRIPS	17	1985	2021	18
	Baitboat	FDAYS	7	2013	2020	29
		TRIPS	1	1987	1987	1
	Gillnet	BOATS	3	2011	2013	5
		DAYS	5	1979	2018	11
		FDAYS	5	1987	1991	1
		SETS	1	2019	2019	2
		TRIPS	35	1985	2021	21
	Other	BOATS	2	2011	2012	3
		DAYS	1	2002	2002	1
		TRIPS	31	1985	2021	7

Table 7: Geo-referenced data on industrial fishing effort available at the IOTC Secretariat for each fishery group with information on the number of years and spatial fishing grounds used for reporting the data. FDAYS = Fishing days

Fishery type	Fishery group	Unit	Years	Start year	End year	Fishing grounds
Industrial fisheries	Purse seine	FDAYS	1	2021	2021	47
		SETS	7	2013	2021	85
		TRIPS	8	2014	2021	97
	Longline	BOATS	2	2010	2011	1
		DAYS	10	1998	2008	184
		FDAYS	16	1998	2015	631
		HOOKS	70	1952	2021	1,350
		SETS	5	2003	2008	37
		TRIPS	20	2001	2021	64
	Line	FDAYS	4	2018	2021	16
		TRIPS	3	2014	2016	9
	Baitboat	FDAYS	3	2018	2020	8
	Gillnet	NETS	6	1986	1991	76
		TRIPS	15	2007	2021	457

Information on fishing effort is generally missing for the artisanal fisheries catching billfish in the areas of national jurisdiction of India and Pakistan. Time series of effort data have been collected and reported by the coastal gillnet fisheries of I.R. Iran (2007-2021), Indonesia (2018-2021) and Sri Lanka (1987-2021), with the effort expressed in number of fishing trips for Iranian and Sri Lankan fleets, although the duration of the trips may strongly vary between vessels and over the years (Fu et al. 2019). In addition, fisheries from Sri Lanka use a combination of longline and gillnet gears without systematic information collected on the breakdown of these gears over time (Herath & Maldeniya 2013), which affects the accuracy of the effort time series available. As for Indonesia, efforts are expressed in multiple types from fishing days to sets.

Beside those fleets, little information on effort is available for other fisheries catching billfish except for the longline fisheries of Australia, EU,Spain, EU,France (Reunion), EU,Portugal, Seychelles, and Mauritius that mostly target swordfish but may have switched to other species such as sharks or tunas in some time periods. Hence, most time series of catch per unit effort (CPUE) for billfish are only available for industrial longline fisheries and described by high proportions of zeros that need to be accounted for in the standardisation process (Lin et al. 2022, Matsumoto et al. 2022).

Spatial distribution of the catch

Geo-referenced catch data for billfish species have been reported to the Secretariat in numbers, weights, or both. Data provided by CPCs have not been systematically raised to the total catches although IOTC Res. 15/02 explicitly calls for data raising and documents describing in detail the adopted extrapolation procedures. Consequently, maps of catch distribution in numbers and weights presented below mainly aim at describing the spatial patterns of the fisheries and should be interpreted with care as the reporting coverage may vary between years and species. Species-specific maps of catch are available from the data review papers on black marlin (IOTC 2023a), blue marlin (IOTC 2023b), striped marlin (IOTC 2023d), Indo-Pacific sailfish (IOTC 2023c), and swordfish (IOTC 2023e).

Most spatial information available on billfish catches between 1950 and 1999 comes from large-scale longline fisheries of Japan, Taiwan,China, and Korea while few geo-referenced catch data have been reported for the most important artisanal fisheries, with the notable exception of Sri Lankan coastal gillnet and longline fisheries from the mid-1980s (**Figs. 14-15**). Historical maps of catch show the large distribution of billfish across the whole Indian Ocean with a major "hotspot" of catches of black and blue marlins identified in northwestern Australia throughout the 1950s and 1960s (**Fig. 14**). The importance of this "hotspot" decreased throughout the following decades, while catch levels started to become particularly high off the coasts of Somalia during the 1990s and 2000s.

In the last decade, reported geo-referenced catches of billfish taken in longline fisheries have been mainly concentrated off the coasts of Somalia and around the Seychelles. However, there has been a major decline in catches of the species during recent years in the area identified as a marlin hotspot, with the main longline fishing grounds appearing to be located more south of the area in 2018-2019 (i.e., between 20°S and the equator and 40-70°E) (**Figs. 16-17**).

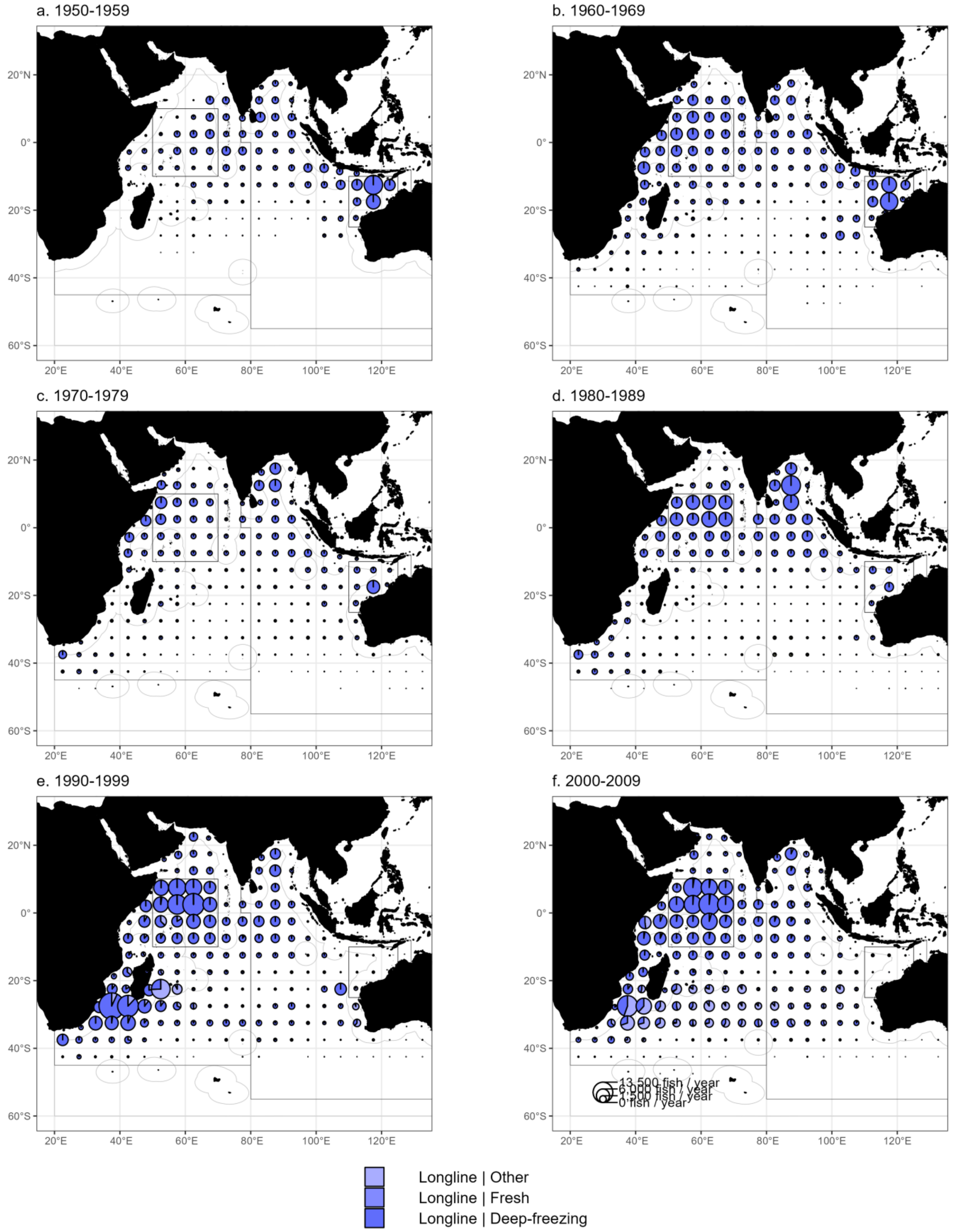

Figure 14: Mean annual time-area catches (in number of fish) of billfish for the period 1950-2009, by decade and fishery. Black solid lines represent the marlin main longline fishing grounds identified by the IOTC WPB

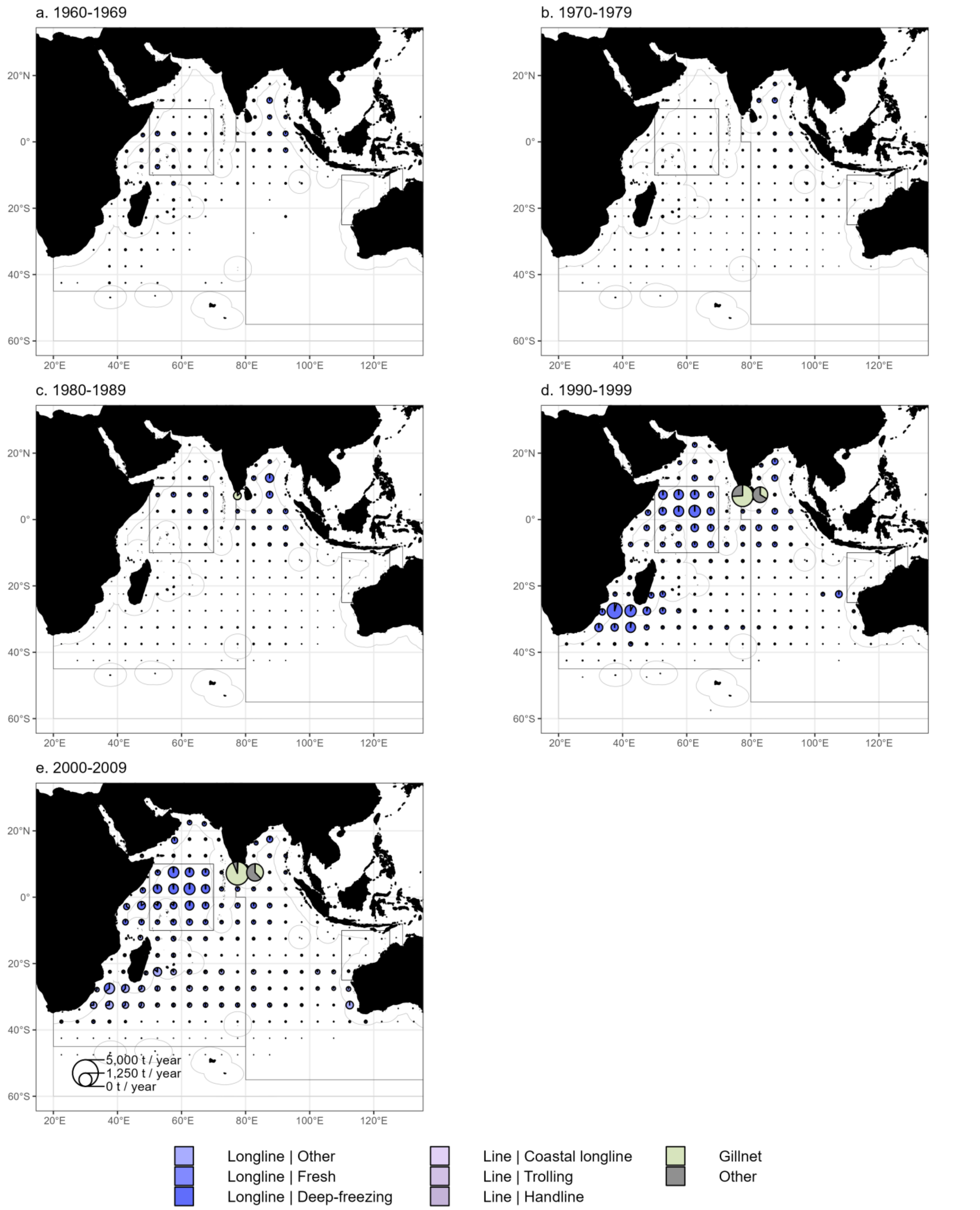

Figure 15: Mean annual time-area catches (metric tonnes; t) of billfish for the period 1950-2009, by decade and fishery. Black solid lines represent the marlin main longline fishing grounds identified by the IOTC WPB

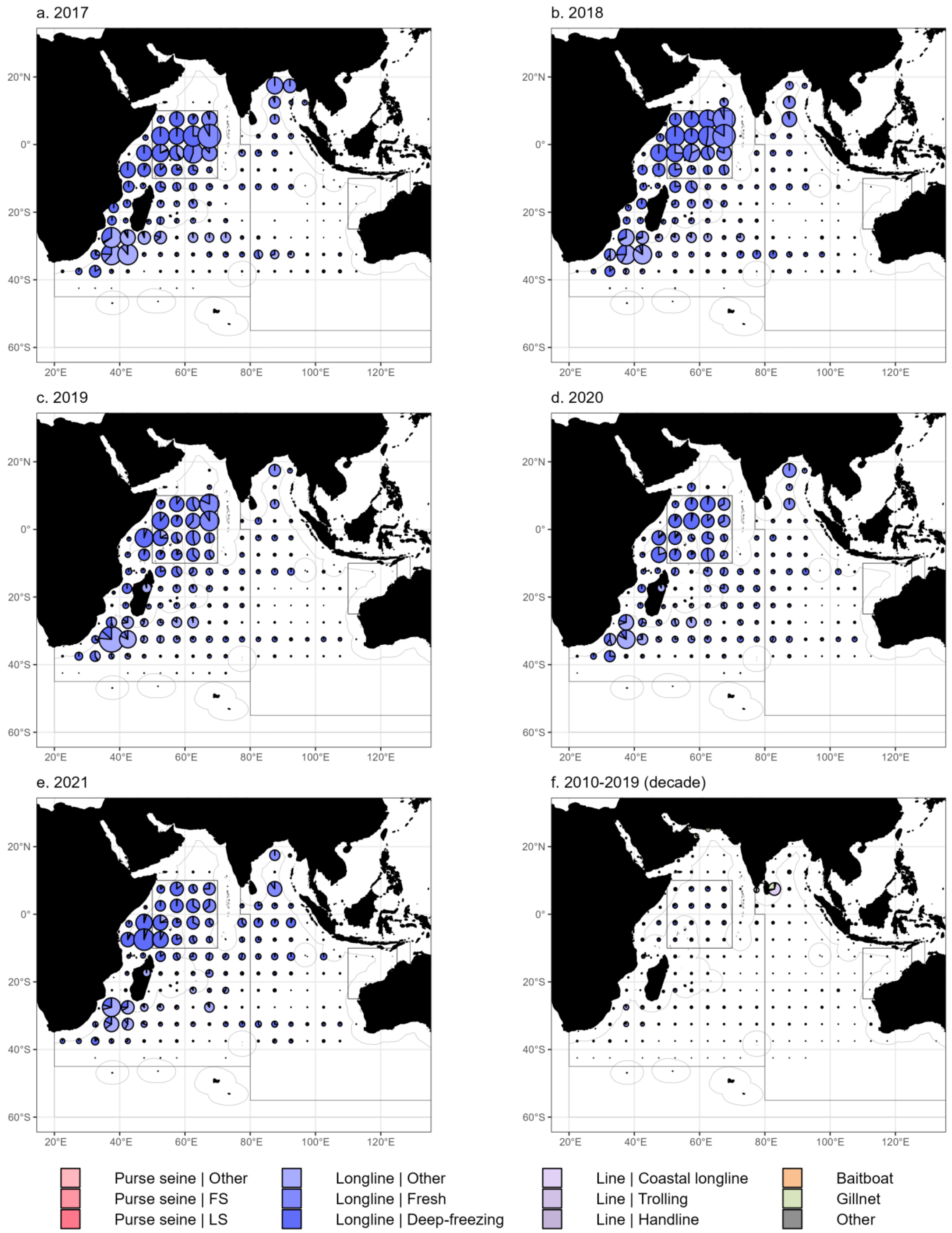

Figure 16: Mean annual time-area catches (in number of fish) of billfish for the last decade 2010-2019 and each year during the recent period 2017-2021. Black solid lines represent the marlin main longline fishing grounds identified by the IOTC WPB

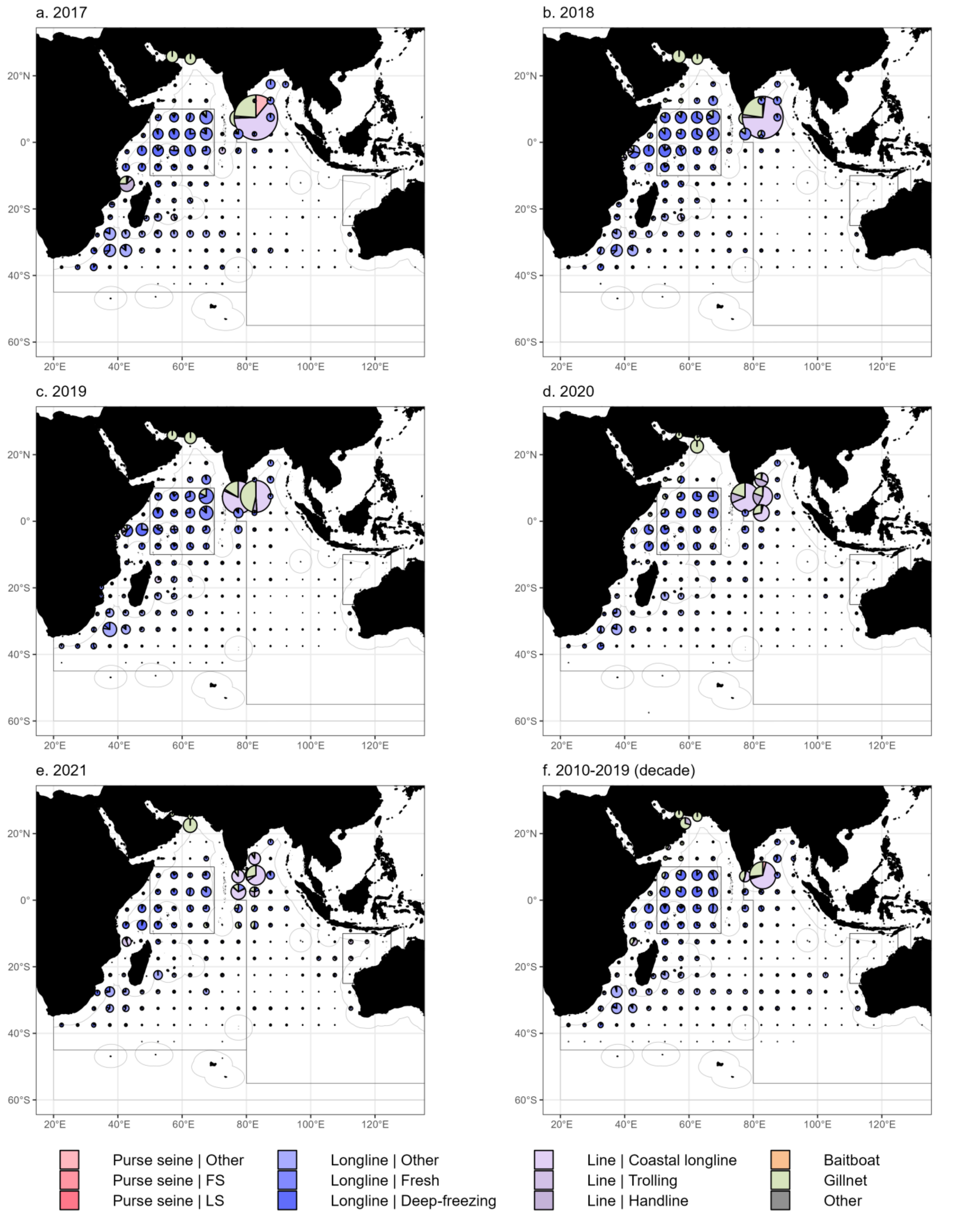

Figure 17: Mean annual time-area catches (metric tonnes; t) of billfish for the last decade 2010-2019 and each year during the recent period 2017-2021. Black solid lines represent the marlin main longline fishing grounds identified by the IOTC WPB

Uncertainties in catch and effort data

Overall, the general trend in quality is driven by the changes in fishing patterns that occurred in the Indian Ocean over the last decades, reflecting the increased contribution of artisanal fisheries to the total catches of billfish species over time (**Fig. 18**). The reporting quality shows a decreasing trend between the mid-1950s and early-2010s before sharply increasing over the last decade. The percentage of good-quality catch and effort data (scores of 0-2; **Table 3**) decreased from more than 80% in the late 1950s to a minimum of about 30% in the mid-2000s (**Fig. 18**). The situation has however improved over the last decade with the increasing reporting of catch and effort for some artisanal fisheries (e.g., Indonesia, Sri Lanka), although the logbook coverage used to derive the spatial distribution of the catch for these fisheries is generally reported to be low (<30%). The overall reporting quality of geo-reference data in recent years (2017 to 2021) remained low, around 67%, and in 2021 the overall quality of reporting was 65%. The reporting quality of geo-referenced catch and effort data varies between species and over time and information on quality on a species-specific basis is available from the data review papers on black marlin (IOTC 2023a), blue marlin (IOTC 2023b), striped marlin (IOTC 2023d), Indo-Pacific sailfish (IOTC 2023c), and swordfish (IOTC 2023e).

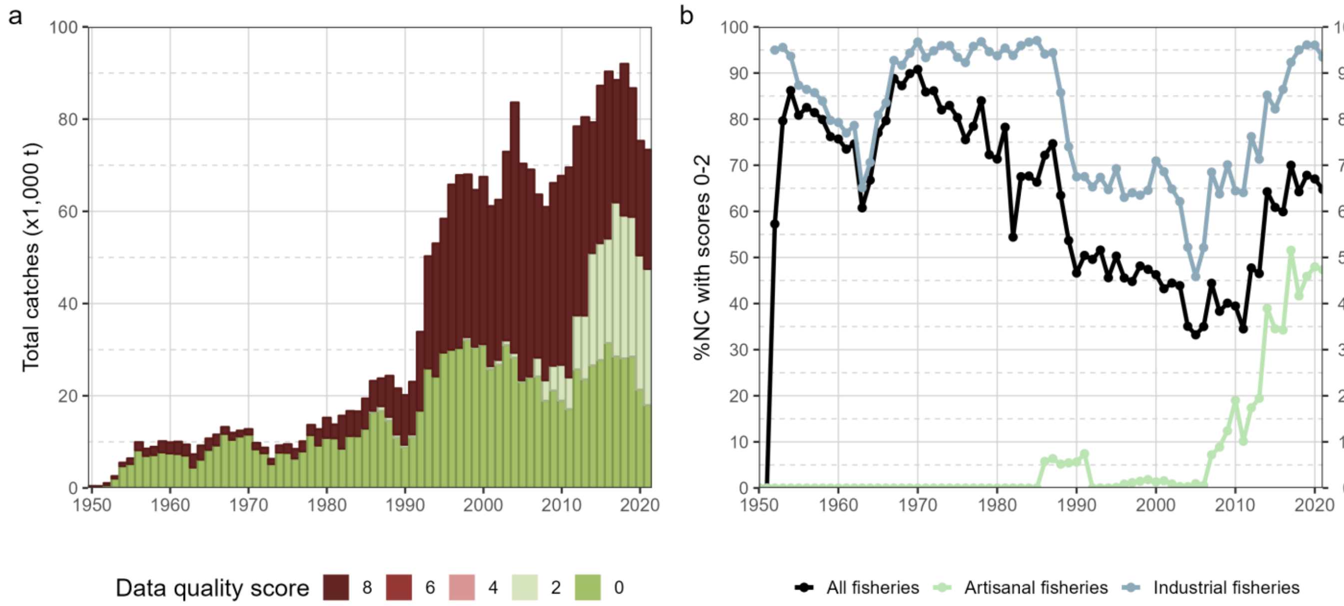

Figure 18: (a) Annual retained catches of IOTC billfish species (metric tonnes; t) estimated by quality score and (b) percentage of retained catches by type of fishery with good quality information (i.e., logbook coverage >30% and compliant with IOTC standards) for the corresponding geo-referenced catch and effort data reported to the IOTC Secretariat

Size composition fo the catch

Size sample availability

The number of billfish sampled for size is largely dominated by longline fisheries which represent 97.4% of all size data available in the IOTC database for billfish species. While large numbers of samples were collected from longline fisheries in the mid-2000s, the sampling showed a major decreasing trend thereafter, in agreement with the decline of the catch reported for this fishery group (see section Retained catches and discards). Some size data were collected in large numbers (~10,000 samples per year) between the late 1980s and mid-1990s in the gillnet fishery of Sri Lanka through the Indo-Pacific Tuna Program (IPTP), representing the main source of samples from gillnets during that period (**Fig. 19**). The number of samples collected in this fishery substantially decreased to about 1,000 fish per year thereafter, with very few samples having been collected for all other fisheries since the 1950s.

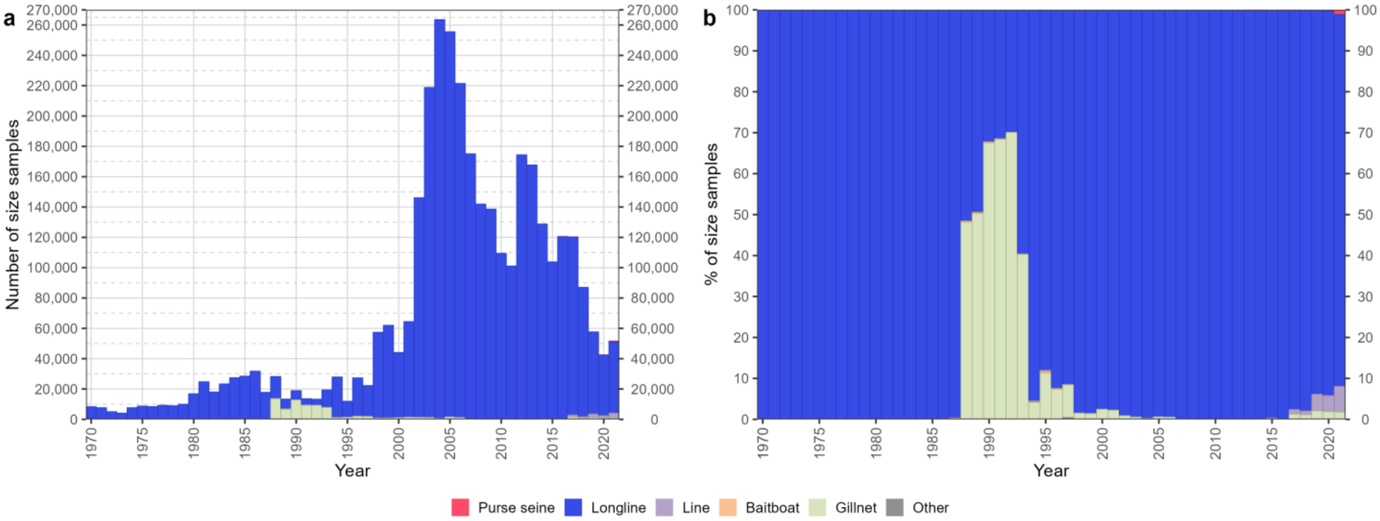

Figure 19: (a) Annual number and (b) relative proportion (%) of billfish standard size samples available by fishery group at the IOTC Secretariat

The number of size samples available for billfish species is very unbalanced and not representative of the importance of each species in the total retained catches reported to the Secretariat. About 80% of all samples are available for swordfish (**Fig. 20**). The high number of swordfish sampled, compared to other billfish species, may be explained by the fact that most longline fisheries operating near-surface target swordfish and catch few of the other billfish species.

Figure 20: Percentage of size samples by species for all standard size samples available at the IOTC Secretariat

The aggregation of all size-frequency data available for billfish collated by the Secretariat through regular data submissions provides an overview on the differences in size composition of the catch between fisheries, e.g., billfish caught in longline fisheries are generally larger than when caught with drifting gillnets and coastal line fisheries (**Fig. 21**). Cumulative size-frequency distributions show some good consistency in the general patterns of marlins and swordfish caught with longlines although occurrences of spikes observed in fresh longline fisheries suggest some issues in sampling and/or reporting. It is important to note that a comprehensive review of the longline size data collected for tropical tunas showed some issues and inconsistencies in the data that prevent their use for stock assessments

(Hoyle et al. 2021). A similar study would be instrumental to assess the quality of billfish size data and their interest for scientific analysis.

Besides regular data submission by the CPCs, the Secretariat also holds size-frequency data collected at sea by scientific observers, which provide size information on billfish taken in industrial purse seine and longline fisheries (see section Discard levels). Information on size sample availability and distribution on a species-specific basis is available from the data review papers on black marlin (IOTC 2023a), blue marlin (IOTC 2023b), striped marlin (IOTC 2023d), Indo-Pacific sailfish (IOTC 2023c), and swordfish (IOTC 2023e).

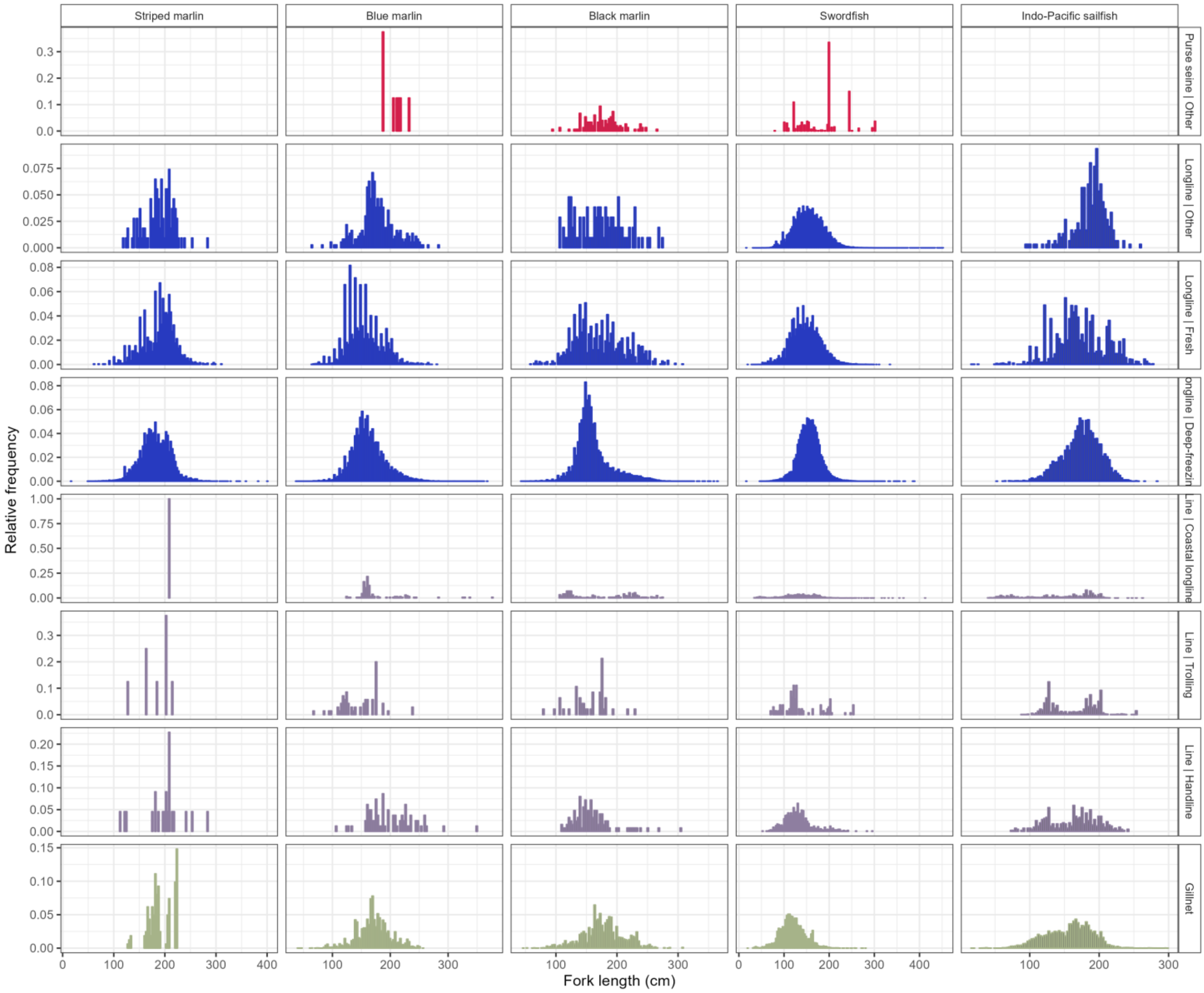

Figure 21: Relative size distributions (fork length; cm) by billfish species and fishery based on all samples available at the Secretariat. Fisheries with less than 500 samples are not shown

Uncertainties in size-frequency data

The overall reporting quality of geo-referenced size data is poor for all five IOTC billfish species. In fact, almost no size data are available prior to the 1980s and the few data available during the 1970s for industrial longliners from Japan are characterized by low sampling coverage (<1 fish per t) and are not compliant with IOTC reporting standards.

Some size data became available from longliners from Taiwan,China and gillnetters from Sri Lanka during the 1980s and later on from the swordfish-targeting fresh longline fisheries of EU,Spain, EU,France (La Réunion), and Seychelles, which developed and expanded throughout the 1990s. The availability of size data sharply declined from the mid-2000s, mostly due to the major decrease in catches of swordfish reported by the deep-sea longline fisheries of Taiwan,China, and swordfish longline fisheries (**Fig. 22**). It increased in very recent years with the reporting of size data by Sri Lanka for its coastal longline fishery. The overall quality of size-frequency data available for billfish species increased between 2019 and 2020 to around 41%, but due to less sampling and few observer operations following the COVID-19 pandemic, the quality reduced to 30% in 2021.

The reporting quality of geo-referenced size-frequency data varies between species and over time and information on quality on a species-specific basis is available from the data review papers on black marlin (IOTC 2023a), blue marlin (IOTC 2023b), striped marlin (IOTC 2023d), Indo-Pacific sailfish (IOTC 2023c), and swordfish (IOTC 2023e).

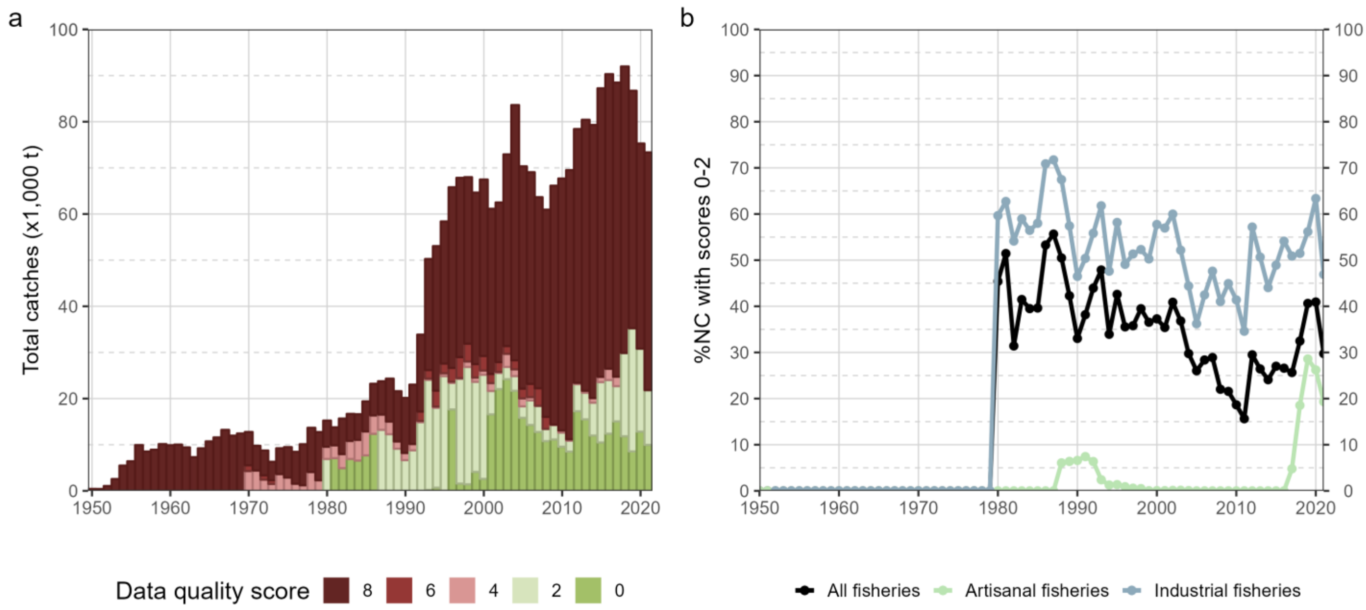

Figure 22: (a) Annual retained catches of IOTC billfish species (metric tonnes; t) estimated by quality score and (b) percentage of retained catches by type of fishery with good quality information (i.e., >1 fish per t caught and compliant with IOTC standards) for the corresponding geo-referenced size-frequency data reported to the IOTC Secretariat

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IOTC (2023c) Review of the statistical data available for Indian Ocean Indo-Pacific sailfish (1950-2021). IOTC, La Saline-les-Bains, Réunion, 06-09 September 2023, p 34

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Appendices

Appendix I: Taxonomy

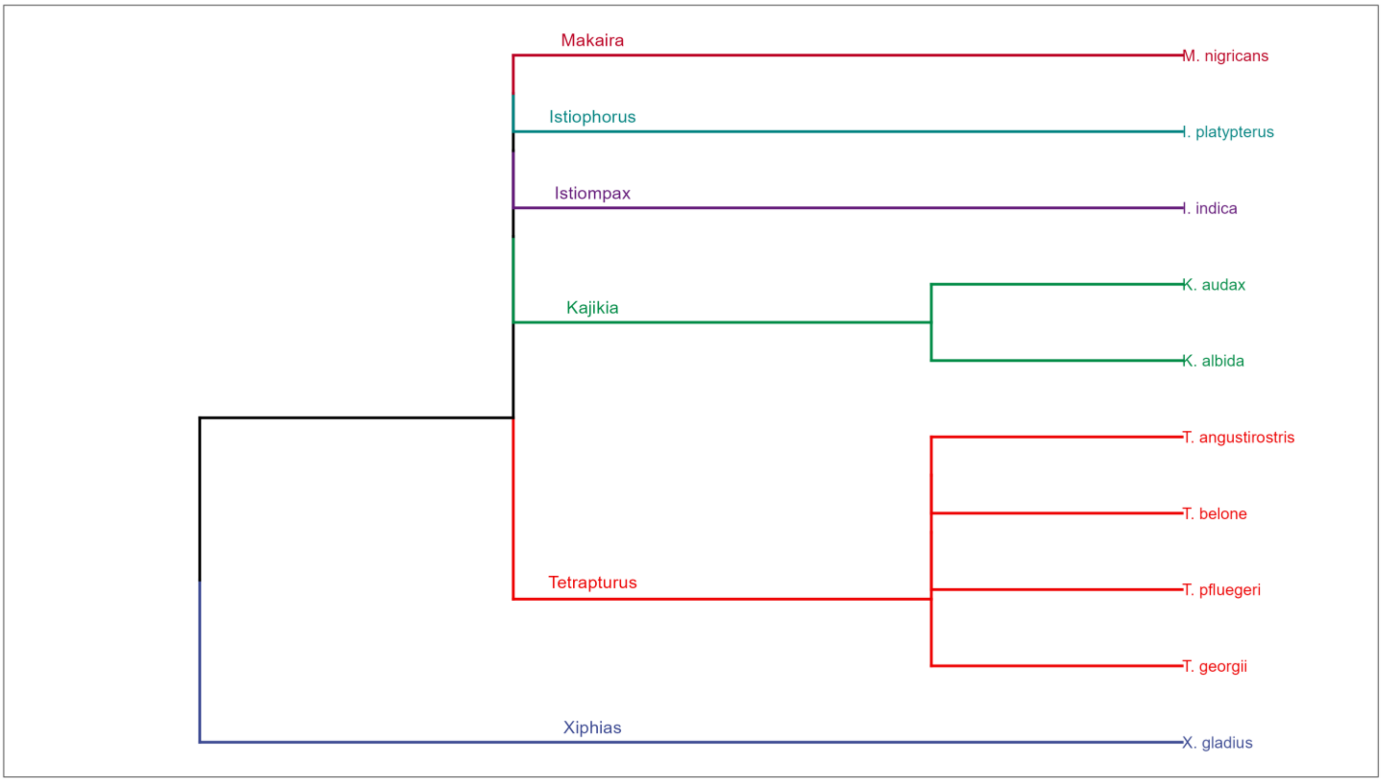

Figure 23: Phylogenetic dendogram of billfish species where Atlantic sailfish (*Istiophorus albicans*) is considered to be synonym of Indo-Pacific sailfish (*Istiophorus platypterus*) according to Collette et al. (2006). Source: Integrated Taxonomic Information System

Appendix II: Morphometrics for billfish

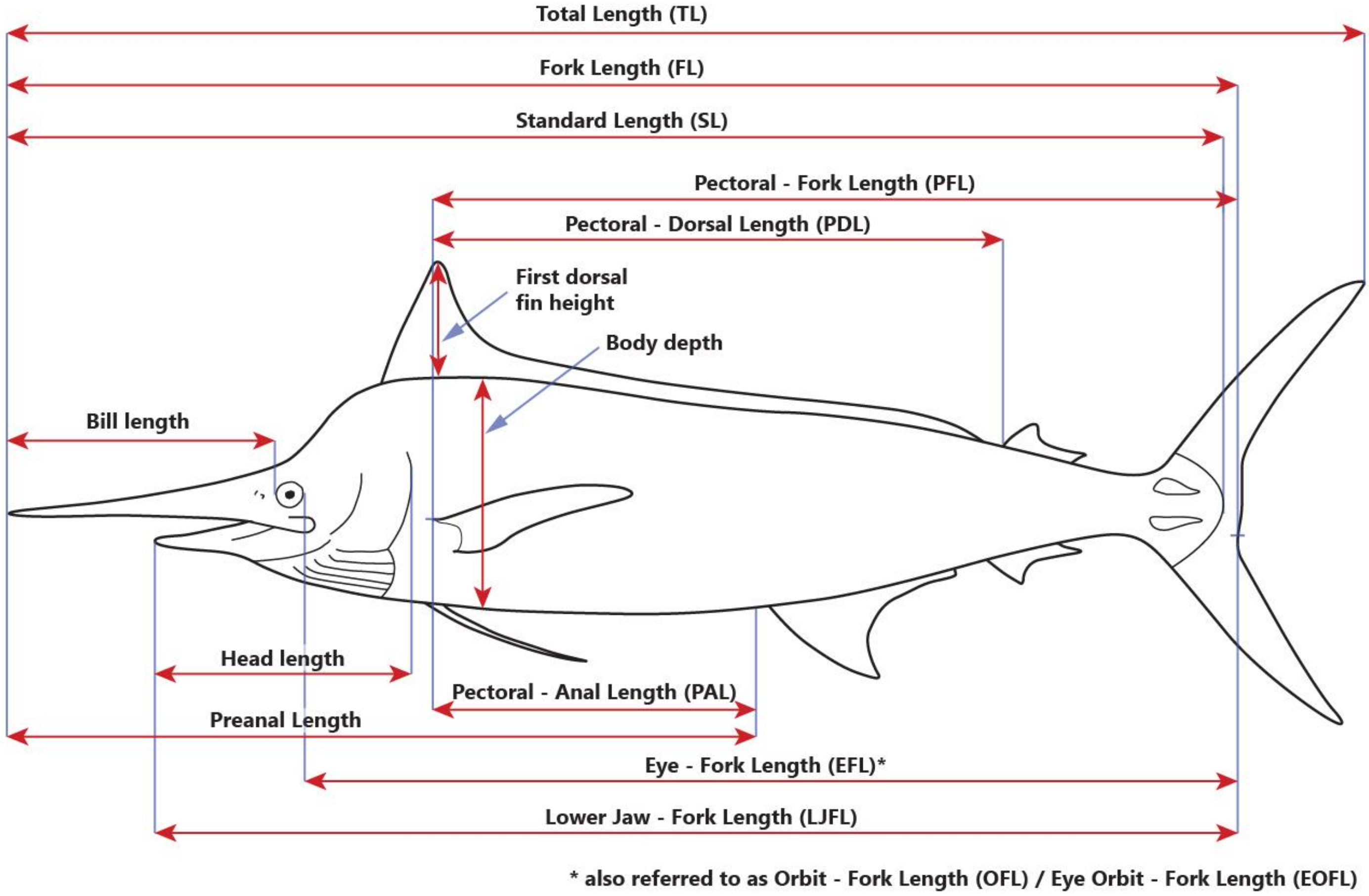

Figure 24: Types of length measurements used for billfish (source: Fishider)

Table 8: Length-length linear relationships for billfish (see Fig. 24 for definitions of measurement types). * indicates current IOTC relationships

Code	Species	Ocean	Equation	a	b	N	Reference
MLS	Striped marlin	Western-Central Pacific	FL = a*EFL+b	1.120000	7.330000	397	Sun et al. 2011
		Western-Central Pacific	EFL = a*FL+b	0.834000	36.610000	301	Kopf et al. 2011
BUM	Blue marlin	Atlantic	FL = a*TL+b	0.763000	2.000000	258	Prager et al. (1995)
		Atlantic	FL = a*PFL+b	1.261000	7.696000	732	Prager et al. (1995)
		Atlantic	FL = a*EFL+b	1.096000	8.887000	250	Prager et al. (1995)
		Indian	FL = a*EFL+b	0.983000	28.630000	53	Setyadji et al. (2016)
		Indian	EFL = a*PFL+b	1.115000	31.674000	53	Setyadji et al. (2016)
		Indian	EFL = a*PFL+b	1.163000	-1.019000	53	Setyadji et al. (2016)
		Indian	EFL = a*FL+b	0.903900	-7.248000	26	Ward (pers. Com)*
BLM	Black marlin	Indian	EFL = a+b * FL	-4.667300	0.897200	13	Ward (pers. Com)*
		Indian	FL = a * PFL+b	1.249000	11.299000	37	Setyadji et al. 2016
		Indian	FL = a * EFL+b	1.060000	14.185000	37	Setyadji et al. (2016)
		Indian	EFL = a * PFL+b	1.195000	-4.367000	37	Setyadji et al. (2016)
		Pacific	FL = a * EFL+b	1.088100	9.510000	586	Sun et al. 2015
		Pacific	FL = a * EFL+b	1.120400	4.632700	3,799	Sun et al. 2015
SWO	Swordfish	Indian	FL = a*EFL+b	1.060000	9.027000	160	Setyadji et al. (2016)
		Indian	EFL = a*PFL+b	1.241000	12.440000	160	Setyadji et al. (2016)
		Indian	EFL = a*PFL+b	1.168000	3.532000	160	Setyadji et al. (2016)
SFA	Indo-Pacific sailfish	Western-Central Pacific	EFL = a*LJFL+b	-4.185981	1.130582	1,166	Chiang et al. (2004)*

Table 9: Length-weight power relationships for billfish (see Fig. 24 for definitions of measurement types). * indicates current IOTC relationships

Code	Species	Ocean	Equation	a	b	N	Reference
MLS	Striped marlin	Pacific	RD = a*EFL^b	1.3326e-06	3.413	17	Uchiyama and Kazama (2003)
		Pacific	RD = a*EFL^b	NA	NA	1,427	Uchiyama and Kazama (2003)*
		Western-Central Pacific	RD = a*EFL^b	4.6800e-06	3.16	1,037	Sun et al. 2011
		Western-Central Pacific	RD = a*FL^b	3.2000e-07	3.56	170	Shimose et al. 2013
		Western-Central Pacific	RD = a*FL^b	1.0120e-07	3.55	214	Kopf et al. 2011
BUM	Blue marlin	Atlantic	RD = a*FL^b	1.1955e-06	3.366	5,245	Prager et al. (1995)
		Pacific	RD = a*EFL^b	2.7223e-06	3.31	154	Uchiyama and Kazama (2003)*
BLM	Black marlin	Indian	HG = a * PFL^b	9.0000e-06	3.118	390	Setyadji et al. (2016)
		Pacific	RD = a * EFL^b	1.4422e-06	2.989	24	Uchiyama and Kazama (2003)*
		Pacific	RD = a * FL^b	2.0000e-05	2.895	586	Sun et al. 2015
		Pacific	RD = a * FL^b	3.0000e-06	3.193	3,799	Sun et al. 2015
		Western-Central Pacific	RD = a * FL^b	6.6100e-10	3.336	117	Speare (2003)
SFA	Indo-Pacific sailfish	Indian	RD = a*EFL^b	4.0000e-05	2.52		Kar et al. (2015)
		Indian	RD = a*LJFL^b	5.0000e-05	2.589	101	Hoolihan (2006)
		Pacific	RD = a*EFL^b	6.9010e-05	2.524	35	Uchiyama and Kazama (2003)

Appendix III: Best scientific estimates of retained (nominal) catches for 2021

The overall amount of retained catches fully estimated in 2021 is 5,584 t, for 9 distinct fleets, representing 6.71% of total catches of IOTC billfish species for the final year of the time series (**Table 10**).

The estimation of the catch data includes three processing steps. First, retained catches are estimated by the Secretariat for IOTC CPCs as well as non-members that either did not report any catch for 2021 or whose catches were available from other sources. For non-members (i.e., Djibouti), Eritrea and Yemen, catches were preferentially extracted from the FAO Global Capture Production database and further broken down into species (when necessary) and fishing gears based on knowledge of the fisheries present in each of the countries (**Table 10**). For IOTC members with inconsistent data (Madagascar and Tanzania) for some of their fisheries in 2021, retained catches were repeated from 2020 (**Table 10**).

Table 10: Data source and final estimates of catches (metric tonnes; t) of IOTC billfish species for non-members (NM) and members (MP) of the IOTC that reported no or inconsistent data for some or all of their fisheries for the year 2021

Fleet code	Fleet	Status	Source	Catch
DJI	Djibouti	NM	FAO	34
ERI	Eritrea	MP	FAO	8
JOR	Jordan	NM	FAO	35
MDG	Madagascar	MP	IOTC	842
SYC	Seychelles	MP	IOTC	1
TZA	Tanzania	MP	IOTC	2,105
TZA	Tanzania	MP	IOTC	287
TZA	Tanzania	MP	IOTC	290
YEM	Yemen	MP	IOTC	1,982
ALL	All fleets	-	-	5,584

Second, a re-estimation process was applied to catches reported by the artisanal fisheries of India and Indonesia which builds on a comprehensive review conducted in the early 2010s with the purpose of revising the time series of catch from these specific artisanal fisheries and improve the information available to the IOTC (Moreno et al. 2012). In the case of India, the process modifies the catch composition of the gears by Indian Ocean major area for the gillnet, hook and line, and trolling fisheries. In 2021, the total catch of billfish taken by India was 13,213 t, with most of it estimated to have been taken in coastal longline and gillnet fisheries. In the case of Indonesian coastal fisheries, a fixed proportion of total catch for each species and fishing gear is used to derive the catches of each of the IOTC billfish species based on samples of catch composition available for the period 2003-2011 (Moreno et al. 2012). The process results in a decrease of total billfish catches from 15,490 t (reported through official submissions) to 5,315 t (estimated), with catches increasing for swordfish and decreasing for the four other species (**Fig. 25**).

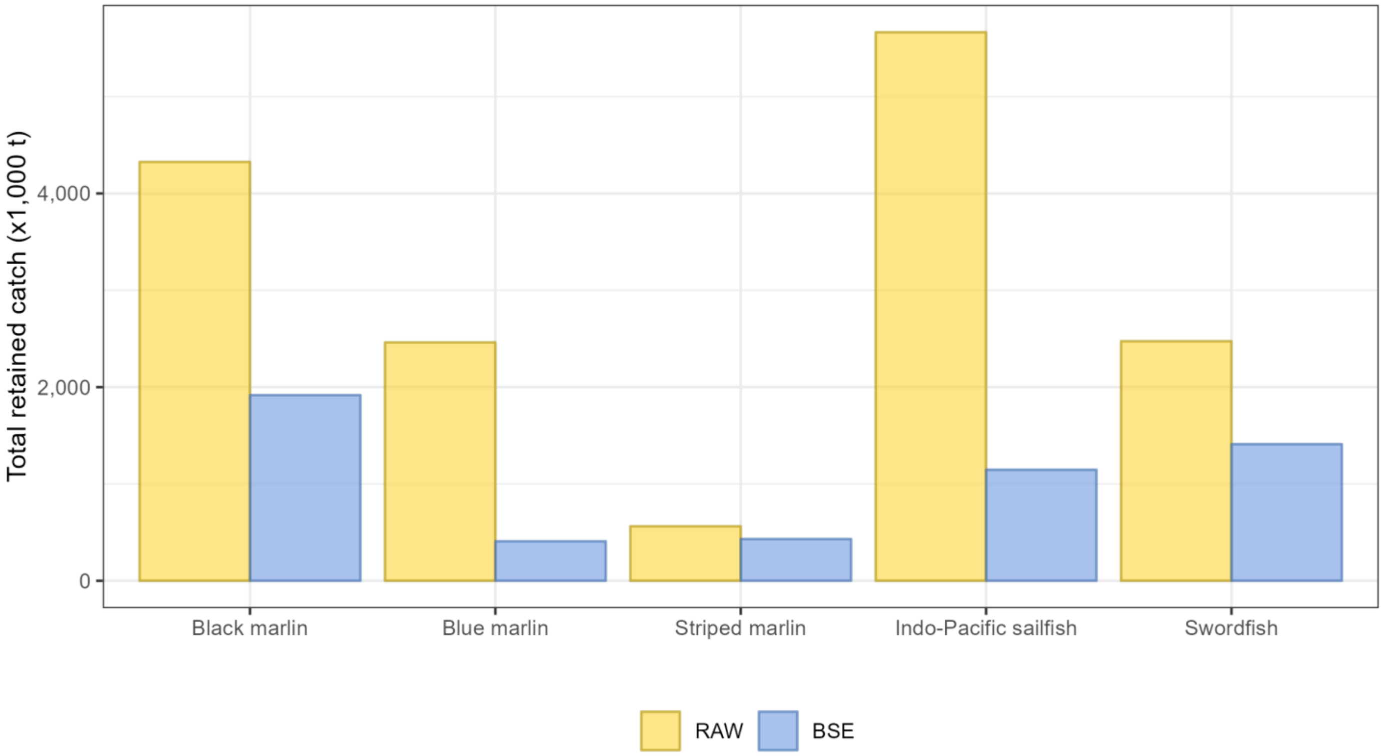

Figure 25: Comparison between the total catches (metric tonnes; t) of IOTC billfish by Indonesia as submitted to the Secretariat (RAW) and estimated following the current methodology used to derive the best scientific estimates (BSE)

Third, nominal catches reported as species aggregates including IOTC billfish species are further broken down into their single species components to generate the IOTC best scientific estimates (**Table 1**). In 2021, this breakdown by species resulted in the addition of a total of 9,836 t to the catches reported at species level for the five species of interest, corresponding to 11.8% of the final catch estimates (**Fig. 26**).

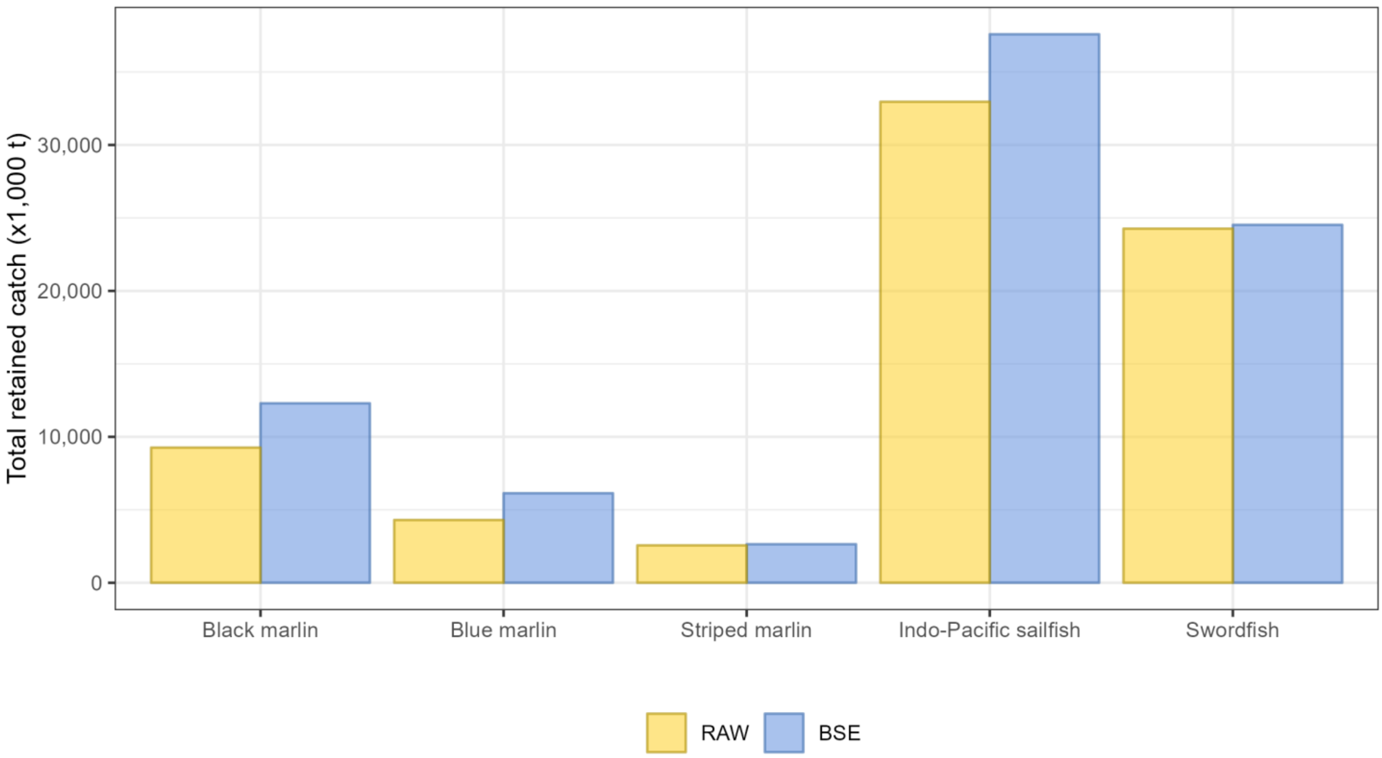

Figure 26: Total catches (metric tonnes; t) of IOTC billfish species as reported (RAW) and estimated (BSE) after accounting for the catches added through the breakdown of species aggregates

Appendix IV: Changes in best nominal catches from previous Working Party

Table 11: Changes in best scientific estimates of retained catches (metric tonnes; t) of billfish by year, fleet, fishery group, and main Indian Ocean area, limited to absolute values higher than 10 t. Data source: best scientific estimate of retained catches as estimated annually from 2012 to 2022 for the preceeding statistical year (https://www.iotc.org/WPB/21/Data/03-NC)

Year	Fleet	Fishery group	Area	Current (t)	Previous (t)	Difference (t)
2020	ARE	Gillnet	Western Indian Ocean	60	86	-26
	IRN	Gillnet	Western Indian Ocean	18,370	20,924	-2,554
		Line	Western Indian Ocean	2,142	1,071	1,071
	JOR	Gillnet	Western Indian Ocean	23	1	23
	KEN	Gillnet	Western Indian Ocean	154	182	-27
		Line	Western Indian Ocean	106	459	-353
	MOZ	Line	Western Indian Ocean	24	92	-68
	YEM	Gillnet	Western Indian Ocean	426	175	251
		Line	Western Indian Ocean	1,556	21	1,535
2019	ARE	Gillnet	Western Indian Ocean	69	86	-17
	IRN	Gillnet	Western Indian Ocean	17,179	17,686	-507
		Line	Western Indian Ocean	499	82	418
	JOR	Gillnet	Western Indian Ocean	31	0	30
	YEM	Gillnet	Western Indian Ocean	1,473	186	1,287
		Line	Western Indian Ocean	509	10	499
2018	ARE	Gillnet	Western Indian Ocean	60	86	-26
	JOR	Gillnet	Western Indian Ocean	45	0	45
	YEM	Gillnet	Western Indian Ocean	1,585	177	1,408
		Line	Western Indian Ocean	397	19	378
2017	IDN	Gillnet	Eastern Indian Ocean	824	660	164
		Line	Eastern Indian Ocean	3,511	2,813	698
		Other	Eastern Indian Ocean	117	94	23
		Purse seine	Eastern Indian Ocean	868	696	173
	JOR	Gillnet	Western Indian Ocean	44	0	43
	YEM	Gillnet	Western Indian Ocean	1,511	158	1,353
		Line	Western Indian Ocean	453	38	415
2016	IRN	Line	Western Indian Ocean	0	257	-257
	JOR	Gillnet	Western Indian Ocean	28	0	28

Year	Fleet	Fishery group	Area	Current (t)	Previous (t)	Difference (t)
	KEN	Gillnet	Western Indian Ocean	317	92	224
		Line	Western Indian Ocean	255	71	184
	YEM	Gillnet	Western Indian Ocean	1,664	197	1,468
		Line	Western Indian Ocean	646	33	612
2015	JOR	Gillnet	Western Indian Ocean	55	0	55
	YEM	Line	Western Indian Ocean	2,740	290	2,450
2014	JOR	Gillnet	Western Indian Ocean	46	0	45
	YEM	Gillnet	Western Indian Ocean	3,247	342	2,905
		Line	Western Indian Ocean	98	3	95
2013	IDN	Gillnet	Eastern Indian Ocean	803	778	25
		Line	Eastern Indian Ocean	3,422	3,315	107
		Purse seine	Eastern Indian Ocean	846	820	26
	IRN	Purse seine	Western Indian Ocean	0	224	-224
	JOR	Gillnet	Western Indian Ocean	27	0	27
	YEM	Gillnet	Western Indian Ocean	3,294	193	3,100
		Line	Western Indian Ocean	326	187	140
2012	IDN	Line	Eastern Indian Ocean	2,929	2,905	24
	JOR	Gillnet	Western Indian Ocean	27	0	27
	YEM	Gillnet	Western Indian Ocean	2,917	0	2,917
		Line	Western Indian Ocean	867	420	447
2011		Gillnet	Western Indian Ocean	2,042	0	2,042
		Line	Western Indian Ocean	1,908	250	1,658