REVIEW OF THE STATISTICAL DATA AVAILABLE FOR INDIAN OCEAN BILLFISH (1950-2022)

Author: IOTC Secretariat

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

Definitions of a billfish species vary, and could depend on the characteristics and appearance of the species. Billfish foundation described billfish species as the fish species with spear-like rostrum of "bill", and (Collette et al. 2006) description is based on molecular data, stating billfish as sister of Scombrodei. Billfish species which are large, highly, migratory predators, are categories 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 235,000 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 43% of the global billfish catch in recent years (**Fig. 1b**).

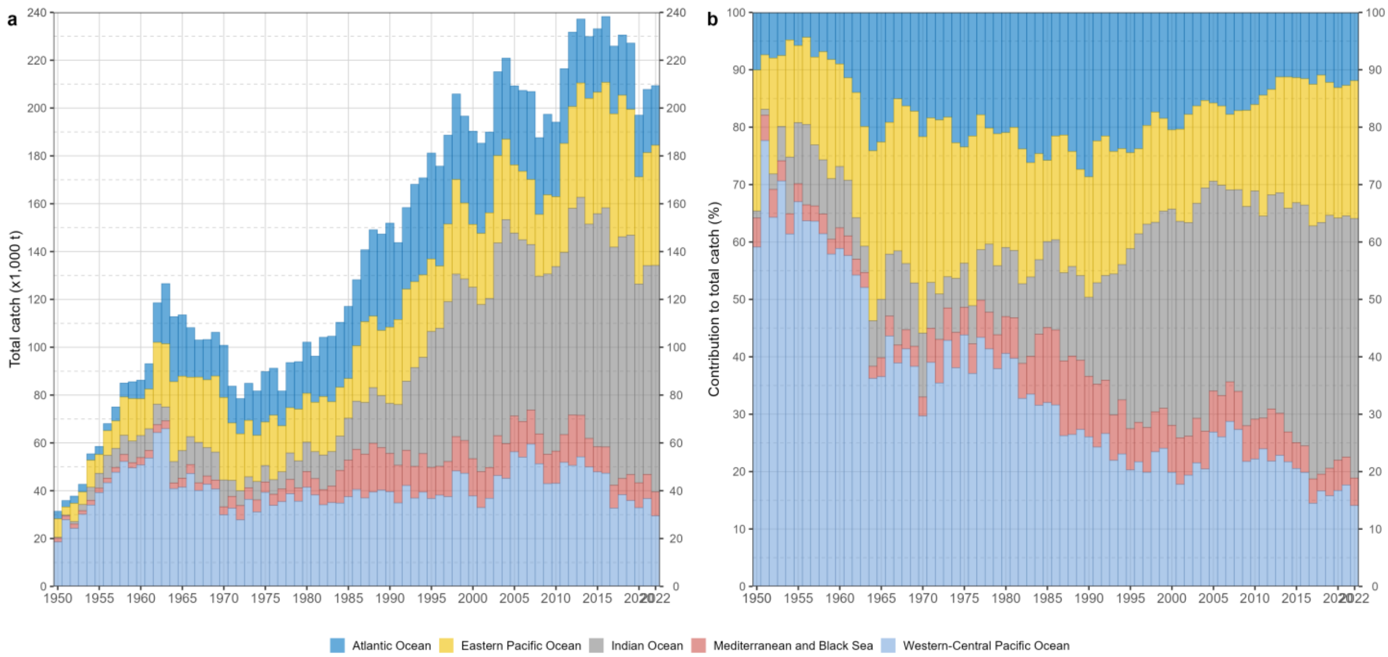

Figure 1: Annual time series of (a) cumulative retained catches (metric tonnes; t) and (b) contribution to the total retained catches (percentage; %) of billfish by ocean basin for the period 1950-2021. Source: FAO global capture production database

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 fundamental objective of this paper is to provide participants in the 22nd Session of the IOTC Working Party on Billfish (WPB22) with a review of the status of the information available on these five species. The datasets used for this document are for the period 1950 to 2022, available to the IOTC Secretariat as of June 2024. This document review 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.It is challenging to include the 2023 submitted data in the WPB22 meeting due to the following reasons: (i) Short Time Span: The brief interval between the submission of last year's data and the WPB22 meetin; (ii)Incomplete Submissions: Some fisheries submissions were incomplete; and (iii) Post-Assessment Submissions: Data was submitted after preliminary assessments had already been conducted.

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). Particularly, as required by IOTC Res. 15/02 and 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(**18/05?** doc).

The Secretariat is improving the information providing to CPCs to enhance the quality of data reporting. The new online IOTC Reporting guidelines and online detailed IOTC forms description and requirement, are the latest guiding tools developed by the Secretariat, and at the disposal of all countries operating in the Indian Ocean. The use of the forms for data submission will facilitate data curation and management by the Secretariat.

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). The retained catch data reporting requirements are described in 1RC form webpage and can be reported through IOTC form 1RC template.

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.

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. Nonetheless, descriptions of the discarded data requirements are explained in 1DI form webpage, and data can be usbmitted through 1DI form template. The final data should be extrapolated to represent the total level of discards by fisheries, fleet, species concerned, including turtles, cetaceans, and seabirds for the year

Nevertheless, discard data reported to the Secretariat through the 1DI form template 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. 22/04) 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).

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 reporting requirements for the catch and effort are described in 3CE form webpage, if for submission of all fisheries through the 3CE form template. Otherwise for updated submissions, descriptions in 3CE form update, and submission through 3CE form update webpage. Furthermore, CPCs with surface fisheries should collect and report geo-reference on the use of fish aggregating devices (FADs), depending on the type of FAD used. Activities related to anchored FADs the requirements are described in 3DA form webpage and submission through the 3DA form template. Whereas for activities on drifting floating objects, detailed description of the requirements are in 3DA form webpage, and submission through 3DA form template

To support the reporting of effort from support vessels that assist industrial purse seiners, CPCs should use the 3CE form template, which provide the required fields for reporting geo-reference effort data.

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. Detailed descriptions of the data reporting requirements for size frequency data are in 4SF form webpage for the submission of full data for all fisheries and species, through the 4SF from template. However, CPCs can also provide updated information for several reasons, with the requirements descriptions in 4SF form upate webpage, and submitting the data updated data through 4SF form update template. The new format allows CPCs to report several information related to size frequency as requested by IOTC Res. 15/02, including type of data, if retained or discarded, source of data (logbook, research institutions or observers) and the sex of the species.

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). The analysis of the socio-economic data in fisheries management are proven useful particularly in setting-up fishing quota, as indicated in the TCAC document (**TCAC_AR23?**).

Little information is available on the socio-economic dimension of fisheries catching billfish in the Indian Ocean. Currently, the IOTC Secretariat is only collecting fish price from various sources on a voluntary basis, through the IOTC Form 7PR, however, minimal information are reported for tuna species, and no information on billfish prices. 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

IOTC Res. 22/04 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 Secretariat (2021a).

A comprehensive description of the status, coverage, and data collected as part of the ROS is provided in IOTC Secretariat (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.

The Secretariat recently developed new template to address issues with reporting of ROS data. Although several CPCs submitted ROS reports, not all could be uploaded in the ROS regional database due to reporting format. The new template, in excel would capture more of the data reporting requirement and ease the pressure of processing the data. To date, the ROS regional database contains information for a total of 1,764 commercial fishing trips (1013 from purse seine vessels and 751 from longline vessels of various types) made during the period 2005-2022 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, in the past, 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. Currently, more CPCs, including Taiwan,China, are using the new template to report the ROS data.

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

The Secretariat has recently developed tools enable CPCs to conduct preliminary checks on the data, ensuring the accuracy of reference codes and completeness before submission. Once the Secretariat received the submissions additional control checks are performed, as detailed below. 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 Secretariat (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 2022 (**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 2022 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 Secretariat 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 Secretariat 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 (1950-2022)

Game fishing involving billfish were common long ago, although scarcity of historical information on billfish are available (Big rock history – the big rock tournament 2022). 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 4.7% of the total catches of the 16 IOTC species.

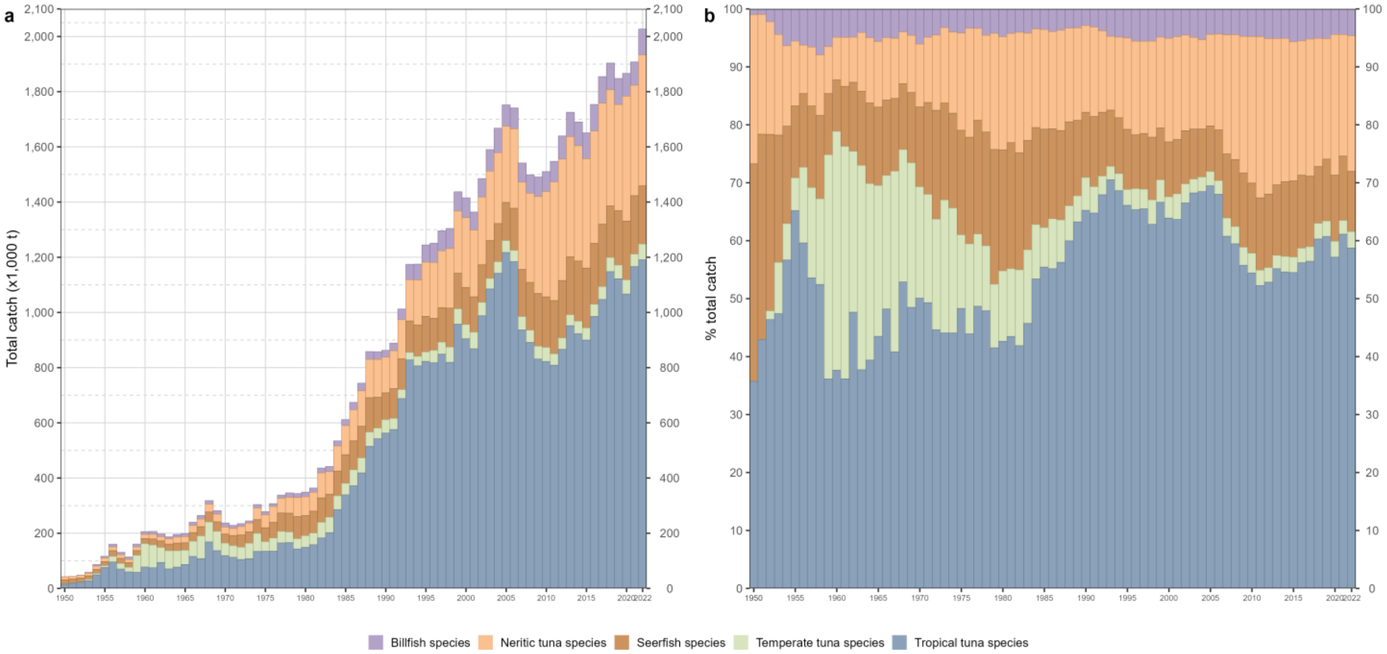

Figure 2: Annual time series of cumulative retained absolute (a) and relative (b) catches (metric tonnes; t) of all IOTC tuna and tuna-like species by species category for the period 1950-2022

Historically, billfish species were caught by industrial fisheries, contributing around 73% between 1950 and 2007 (**Fig. 3a**), with catches mainly from longline fisheries from 1950s and industrial gillnet fisheries in recent years (**Table 4**). The trend changed in late 2000s, when longline fisheries reduced operation in Western Indian Ocean, and gillnet fisheries operating more within their Area National Jurisdiction (ANJ), targeting less large pelagic species. Although significant catches of billfish were from industrial fisheries, some coastal fisheries also caught billfish species. Catches of billfish from coastal fisheries were more evenly split between the two IOTC areas of competence, whereas from the industrial fisheries, over 67% were from Western Indian Ocean.The drop of billfish catches from 2009, resulting from reduced number of longline vessels operating in the Western Indian Ocean was the effect if the emergence of piracy in Western Indian Ocean (Pillai 2012), and in general, the fishing efforts and economies of industrial fisheries in the Western Indian Ocean (Chassot et al. 2012). Despite the emergence in later 2000s, catches of billfish in the Indian Ocean show increasing trend from 1950, with periodic fluctuations and significant increase from coastal fisheries, contributing more than 60% in recent years (**Fig. 3b**).Hence, in 2022 total catch of billfish reached 93,500 t, increasing by 11 %,compared to 2021 catch.

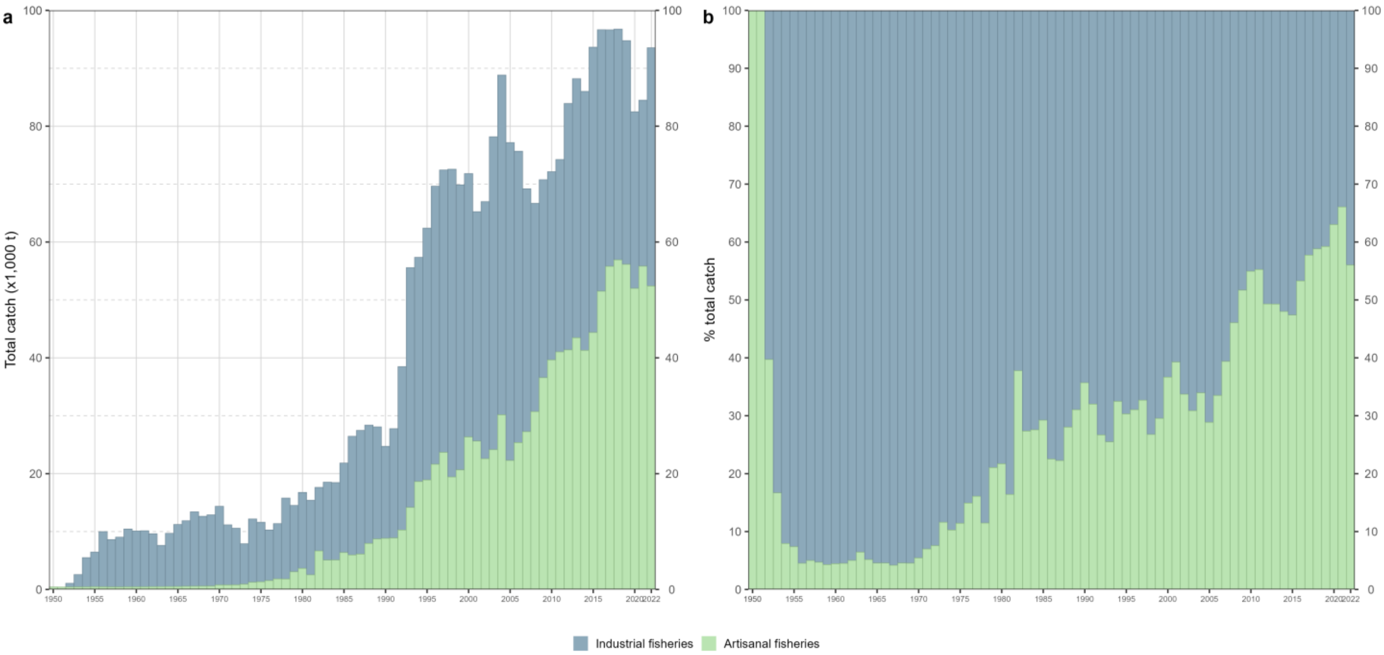

Figure 3: Annual time series of cumulative retained absolute (a) and relative (b) catches (metric tonnes; t) of IOTC billfish by fishery type for the period 1950-2022

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 49,000 t in 2022, representing 53% 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 1950-2022

Fishery	1950s	1960s	1970s	1980s	1990s	2000s	2010s
Purse seine | Other	0	0	8	122	167	337	1,030
Longline | Other	0	0	0	115	4,503	15,433	9,224
Longline | Fresh	0	0	112	569	6,326	9,040	10,904
Longline | Deep-freezing	5,015	10,404	10,451	15,360	30,031	22,227	13,730
Line | Coastal longline	88	87	107	722	1,434	3,083	12,484
Line | Trolling	96	149	272	624	1,235	1,889	2,282
Line | Handline	40	39	278	1,256	1,788	1,440	2,863
Baitboat	0	0	29	0	0	0	35
Gillnet	213	241	712	3,090	9,576	19,558	35,645
Other	0	0	3	42	23	45	105
Total	5,451	10,920	11,972	21,900	55,083	73,052	88,301

During the 2010s, several gillnet fisheries were converted into longline fisheries and operating mainly into ANJ areas or offshore in countries like Sri Lanka to maximise tuna-like species caught in various seasons, and selling better quality of fish(Jathunga et al. 2015, Sri lanka - national report 2018 IOTC 2018).Hence, for a period of time catches of billfish increased in line fisheries. Total catches of billfish reported for line fisheries showed a marked increase from the early 2010s (**Fig. 4**), particular from Sri Lanka coastal longline fisheries, that went from 37 t in 2013 to 4,426 t in 2014. This sharp increase is attributed to the increase in line fisheries and 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 3,373 t in 2010 to 6,928 t in 2019. However, in 2022, billfish catches taken by coastal longline increased slightly, compared to catches in 2021, although lower than the peak in 2017 (by 37%).

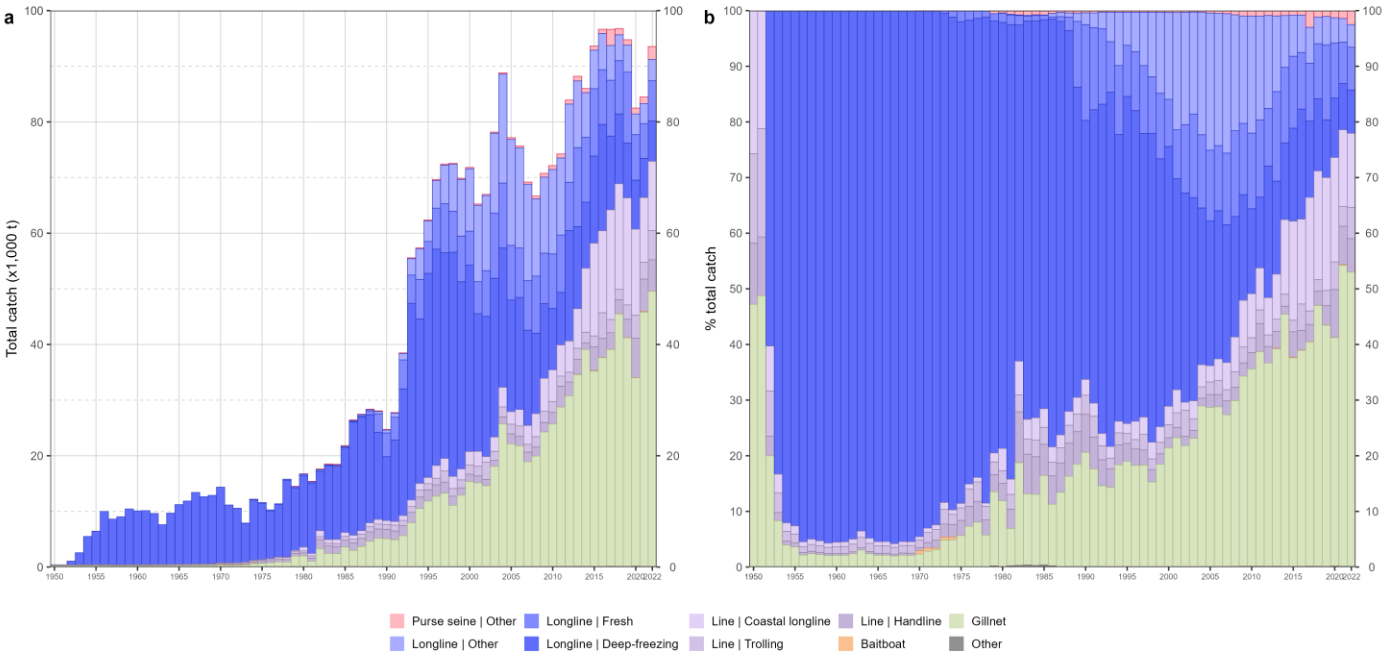

Figure 4: Annual time series of cumulative retained absolute (a) and relative (b) catches (metric tonnes; t) of IOTC billfish by fishery for the period 1950-2022

Among the five billfish species managed by the IOTC, swordfish is the main target since the 1950s, contributing 36% of the total cumulative 2.9million metric t of billfishes caught in the Indian Ocean between 1950 and 2022 (**Fig. 5**). The second most caught billfish species is sailfish, representing 25%, of which 80% are from coastal fisheries. Black, blue and stripped marlins are least caught, contributing 15%, 14% and 9%, respectively, by which are mainly caught from offshore fisheries (with 71% cumulatively caught by industrial fisheries).

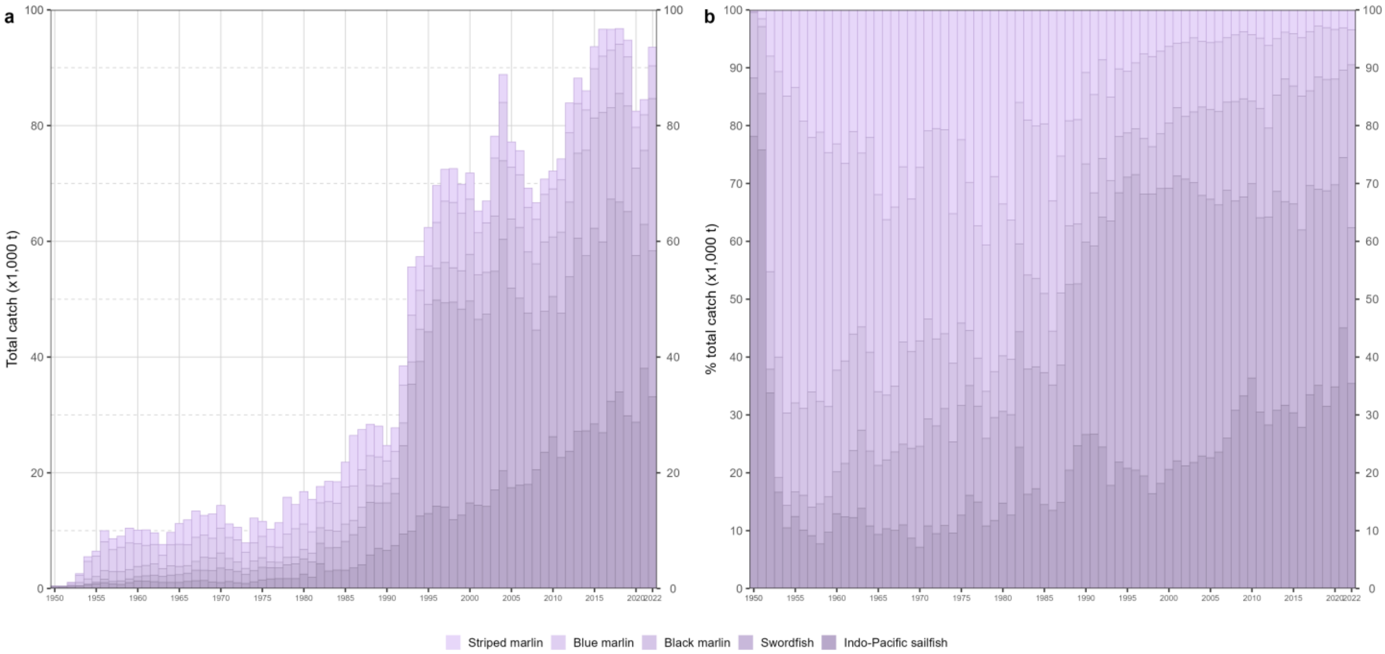

Figure 5: Annual time series of cumulative retained absolute (a) and relative (b) catches (metric tonnes; t) of IOTC billfish by species for the period 1950-2022

Catch trend of black marlin (BLM) fluctuated between 1950 and 2022, although showing 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 (**IOTC2024a?**). Catches remained at an average of 18,000 between 2015 and 2020, by which majority of the catch are from gillnet and line fisheries. Gillnet fisheries of Iran caught on average 6,000 t of black marlin, and India line fisheries on the other hand, caught 3,000t in the same period. The increasing trend in Indian catch reflects the major reported catch from Indian in 2016 (CMFRI 2017). Following a drop in 2021, black marlin catch peaked in 2022 to 26,000t, through which, Iran contributed 60% (**Fig. ??a**).

Catch trend of blue marlin (BUM) shows variations, with 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 2022 (**IOTC2024b?**). Industrial longline fisheries is the major blue marlin fisheries, particularly from Asian fleets operating in the Indian Ocean in the early periods. Nonetheless, the catch trend reflect the moving of industrial longline vessels in and out of the Indian Ocean. Japan was the major longline fleet from 1950, with over 82% of the blue marlin catch between 1950 and 1970, whereas Taiwan,China which started catch blue marlin from 1960, is currently the main fleet catching blue marlin, with around 7,000 in 2012, representing 55% total blue marlin catch. The increase catches of blue marline from 2012, reflects the resuming operation of some longline fleets in Western Indian Ocean following the reduction of piracy threat. In recent years, there are significant drop in catches from longline fisheries, contrary to coastal line and gillnet, where catches of blue marlin showed increasing trends (**Fig. ??b**).

Striped marlin is the least caught billfish in the Indian Ocean, yet shows strong interannual variability in the trend from 1950 and 2022 (**Fig. ??c**). Although the catch peaked at 9,000 in 1986, catch dropped significant in early 1990s, and increased substantially in 1995, before reducing again. Similar to blue marlin, striped marlin were mainly caught by industrial longline fisheries, with around 98% between 1950 and 2000. The emergence of gillnet fisheries from late 1990s, increased catches from coastal fisheries, showing continuous increasing trend until recently. Japan and

Taiwan,China were the main fleets catching striped marlin from 1950s to 1990s, contributed 78% of total striped marlin. Primary fisheries and fleet catching striped marlin shifted from 2000s to gillnet fisheries of Iran and Pakistan, with 51% of total striped marlin catch between 2014 and 2022. the average catch of striped marlin in recent years is around 3,000t, which lower than catches reported in the 1990s (IOTC Secretariat 2023d).

Comparing with other billfish species, catches of Indo-Pacific sailfish (SFA) shows a steady increasing trend between 1950 and 2022, with majority of the catch from coastal fisheries. Indo-Pacific sailfish catch increased from an average of 11,000t in the 1990s to 3,000t in recent years (IOTC Secretariat 2023c). Gillnet fisheries remained the principal fisheries, through which, Iranian gillnet contributed 39% and Indian gillnet 23% between 2015 and 2022. catches of SFA from Iranian gillnet fisheries dropped in 2022 to 15,000t, following a peaked in 2021 of about 18,000t (**Fig. ??d**). It is noteworthy that catches of SFA from line fisheries showed increasing trend in recent years, peaked at 12,000t in 2022.

Swordfish was the primary billfish species in the 1990s, following the expansion of longline fleets, particularly, Taiwan,China in the same period. Substantial increased from 8,000 t in 1990 to an average 35,000t between 1995 and 2005 (**Fig. ??e**). However, catches declined from 2007 to 2011, and increased again from 2012, at an average 32,000t between 2012 and 2020. Longline fisheries remain the principal fishery for catch swordfish, although gillnet and line fisheries are recording high catches of billfish species in recent years. Following the peak average catches from Taiwan,China in the 1990s, caches of swordfish from Taiwan,China dropped to an average of 6,000t between 2014 and 2020. Whereas catches from Sri Lankan fisheries average at around8,000t in the same period. Overall catch of swordfish dropped from 2021 reaching 25,000 t in 2022, which represent a decrease of 29% from 2019, mainly from low catches from Taiwan,China and Sri Lanka (IOTC Secretariat 2023e).

Recent fishery features (2018-2022)

Billfish catches show fluctuation in recent years, with steep dropped from 95,000 t in 2019 to 82,000 t , which could be due to less operations during COVID period. The total retained catches of billfish species combined (2018-2022), were about 90,400 t per year, with gillnet, longline, and line fisheries contributing to 47.7%, 24.4%, and 26.3% 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 2018 and 2022

Fishery	Fishery code	Catch	Percentage
Gillnet	GN	43,103	47.7
Line | Coastal longline	LIC	15,545	17.2
Longline | Deep-freezing	LLD	9,106	10.1
Longline | Fresh	LLF	8,788	9.7
Line | Handline	LIH	4,861	5.4
Longline | Other	LLO	4,131	4.6
Line | Trolling	LIT	3,385	3.7
Purse seine | Other	PSOT	1,339	1.5
Other	OT	112	0.1
Baitboat	BB	45	0.0

In recent years (2018 and 2022), three main coastal fleets dominated the catches of billfish species, namely Iran, India and Sri Lanka, averaging 24,000 t, 14,000 t and 14,000 t respectively, with mainly gillnet and line fisheries operating in ANJ and ABNJ areas (**Fig. 6**).

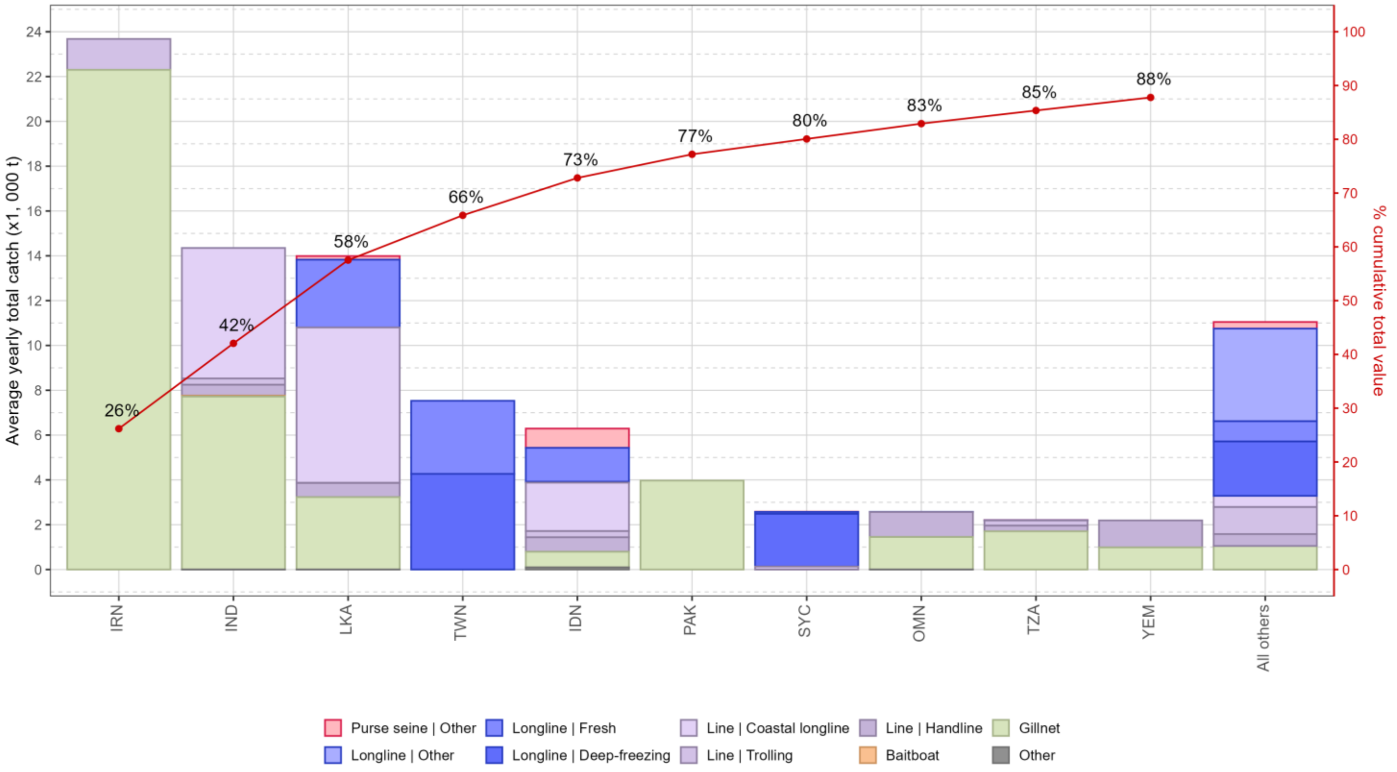

Figure 6: Mean annual catches of IOTC billfish species by fleet and fishery (metric tonnes; t) between 2018 and 2022 with indication of cumulative catches by fleet

Over the last five years of the time series (2018-2022), gillnet catches of billfish species decreased from 2018 to 2020, followed by an increased trend to reach about 49,000 t while catches reported by longline fisheries decreased from 27,000 t in 2018, and remained below 20,000 t in the last two years. to 18,300 t in 2022 (**Fig. 7**). Meanwhile, catches of billfish from line fisheries, slightly increased to 23,000 t in 2022, after declining in 2021 (at 20,000 t). Nonetheless catches from line fisheries averaged about 23,800 t in recent years (**Fig. 7**). Recent catches from other fishery groups (i.e., purse seine, baitboat, and other fisheries) have been small or negligible.

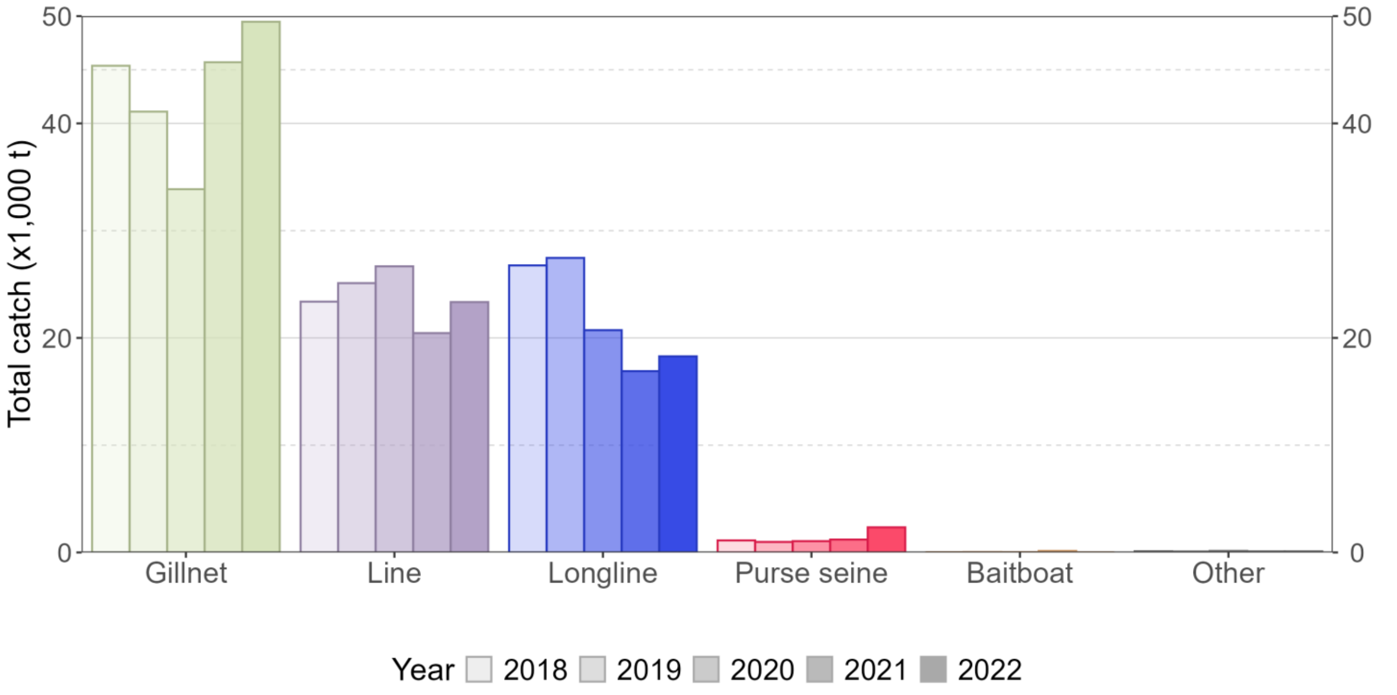

Figure 7: Annual catch (metric tonnes; t) trends of IOTC billfish species by fishery group between 2018 and 2022

Annual trends observed in the catches of billfish in recent years vary between fleets and fishery groups. Sharp increased from gillnet fisheries of I. R Iran in 2022, and India gillnet, although lower catch compared to I. R Iran, also increased in last 2021 and 2022 (**Fig. 8a**). Longline and line fisheries, which also recorded significant catches of billfish, showed declining trends from major fleets.Longline fisheries of Taiwan,China catches remained below 6000 t from 2021, compared to high catch of 10,000t in 2018. Similar trends are observed from longline fisheries of Sri Lanka and Seychelles (**Fig. 8b**). Billfish catches of Sri Lanka also declined from line fisheries, reaching its lowest value of 3,000t in 2022. Contrary to Sri Lanka, catches from line fisheries of India, Indonesia and I. R Iran indicated increased trends overall in recent years (**Fig. 8c**).

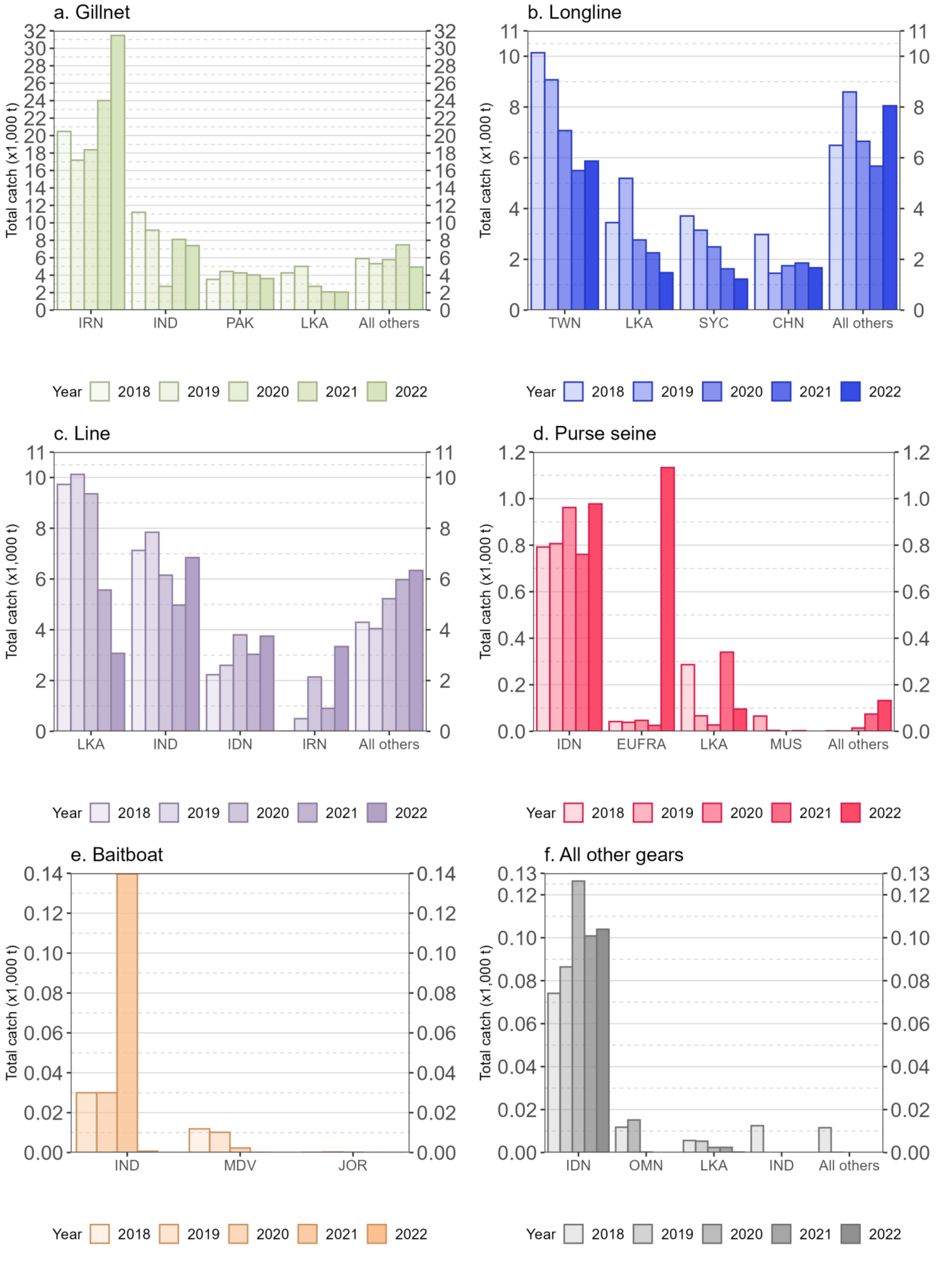

Figure 8: Annual catch (metric tonnes; t) trends of IOTC billfish species by fishery group and fleet between 2018 and 2022

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 (WPB21) held in 2023. The changes concern the last decade and represent an additional catch of about 147 t per year on average between 2011 and 2021 (**Fig. 9**). These changes are mostly due to updates by some CPCs and the SEcretariat including:

- Review of catch by Bangladesh;
- Updates by Japan on recovery of logbooks;
- Historical review by EU for the purse seine fisheries, including bycatch data of billfish
- 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.

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

The quality of data collected and reported to the Secretariat can be influenced by a range of factors. As fisheries become more diverse and complex, the challenges associated with data collection and reporting increase. Additionally, the socio-economic impact of fisheries on a country underscores the critical importance of accurate data collection.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 quality of billfish data is significantly influenced by the type of fishery involved. Data collection methods vary, and these variations impact data accuracy. Artisanal fisheries often face challenges in data recording, particularly when data is collected only at landing sites. In contrast, fisheries that utilize logbooks and on-board recording systems generally produce higher-quality data. This discrepancy arises because many billfish are processed (e.g., headed) before landing, making accurate identification and data collection more difficult in artisanal fisheries.

Improvement in data collection and reporting could be assessed through the improved quality of data reported between 1950 and 2022 . Level of reporting with quality scores between 4 and 6 (**Table 3**)), which mainly relate to aggregated catch of billfish by species and gear, and the need for estimation by the Secretariat, only represent 10% in recent years, compared to 53 (**Fig. 10**)%. The improvement reflects (i) better quality data reported by I. R. Iran in recent years, which is a major contributor of billfish species; (ii) continuous improvement in data reported by Sri Lanka; and (iii) disaggregation of billfish species by Pakistan; hence reducing the uncertainty of reported billfish data, by which 92% in 2022 (**Fig. 10**) are fully of partially available.

While the quality of total retained catch data of billfish indicated less uncertainty in recent years, nonetheless, the quality of individual species might varies over time depending on the fisheries and fleet targeting the each billfish species. Detailed information on certainty of species-specific could be found in review papers of each species:black marlin (**IOTC2024a?**), blue marlin (**IOTC2024b?**), striped marlin (**IOTC2024c?**), Indo-Pacific sailfish (**IOTC2024d?**), and swordfish (**IOTC2024e?**).

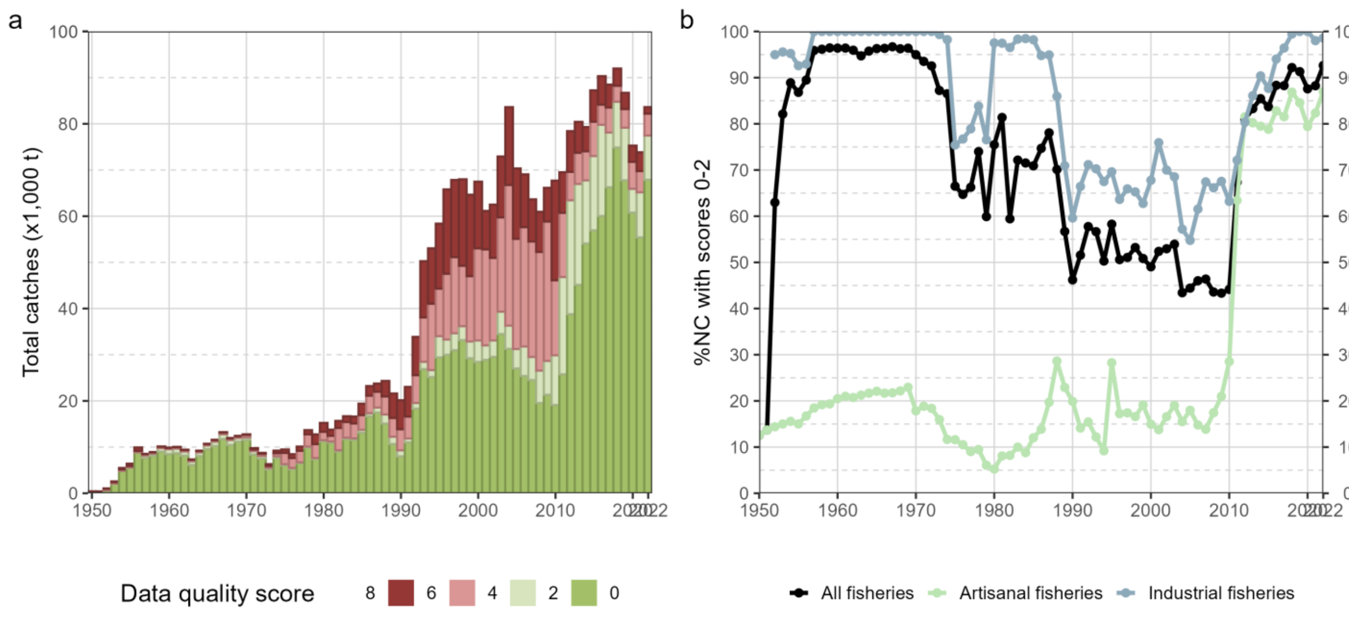

Figure 10: (a) Annual retained catches (metric tonnes; t) of IOTC billfish species estimated by quality score and (b) percentage of retained catches fully or partially reported to the IOTC Secretariat for all fisheries and by type of fishery, in the period 1950-2022

In 2022, 81% 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.

Recently, some CPCs are working closely with the Secretariat in revising the estimation methodologies used to derive catches by species and fisheries, for both industrial and artisanal fisheries, namely Indonesia and I. R. Iran. Despite these liason, concern still emerge from some retained catch data reported that need to be noted and addressed:

- Artisanal fisheries (including sport fisheries)

  +High level estimation of billfish catches for Indonesia and India. Both fisheries catches are estimated using methodology derived in 2012 by a consultant for secveral fisheries in the Indian Ocean (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. India, on the contrary, does not have close collaboration with the Secretariat to address the issues.

- 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 pre-2011 and Pakistan historical catches are estimated on the account of revised improved quality data submitted for 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 Secretariat 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 2005-2022 and the whole fishing grounds of the purse seine fishery (**Fig. 11**). Data show that only ~28% 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.

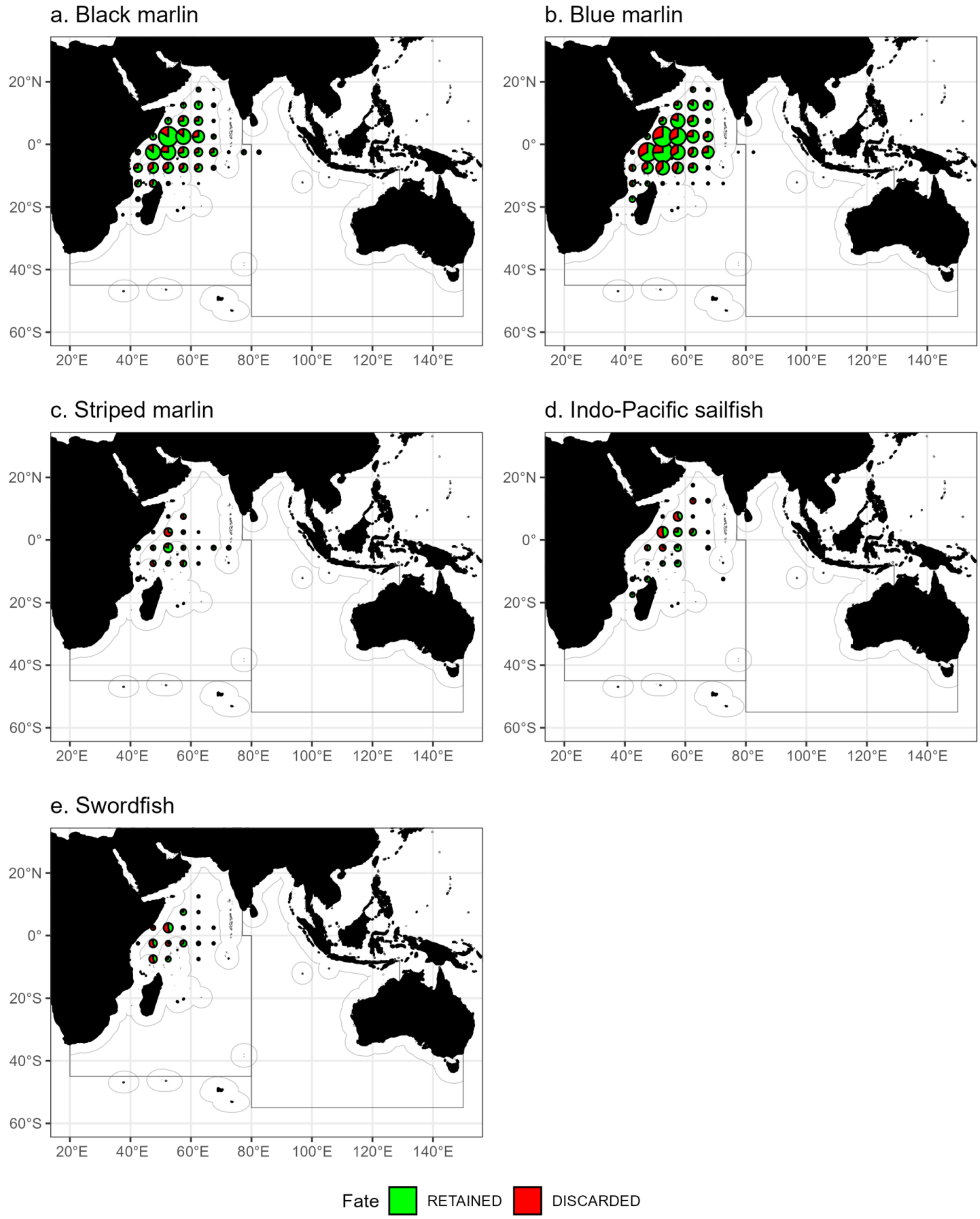

Figure 11: Distribution of all observations of billfish caught in the western Indian Ocean purse seine fishery with information on fate (i.e., retained or discarded) as available in the ROS regional database

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 (~95.8%). 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 25.5% 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.

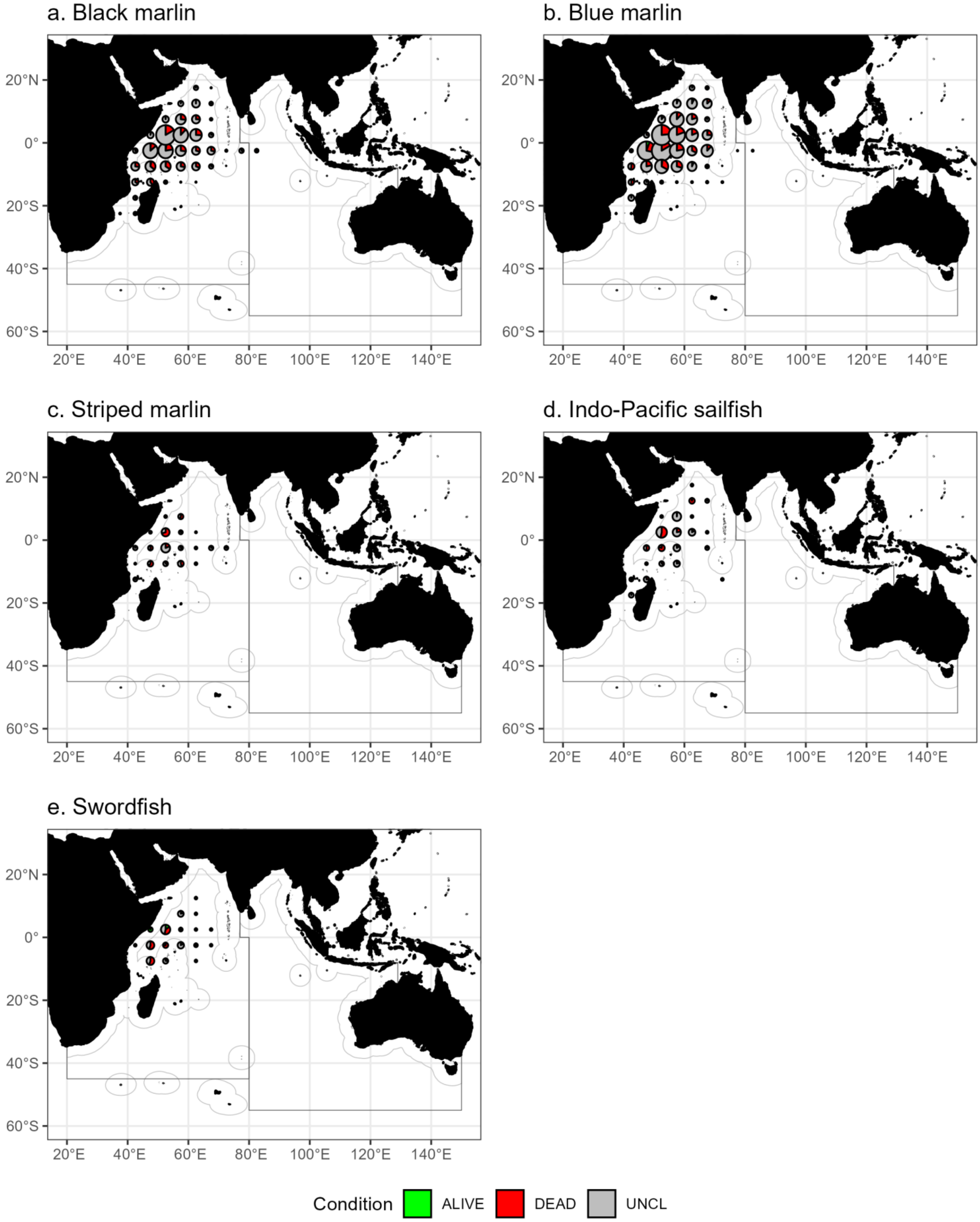

Figure 12: Distribution of all observations of billfish discarded at sea in the western Indian Ocean purse seine fishery with information on condition as available in the ROS regional database

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 177.5 cm FL and 202 cm FL, respectively.

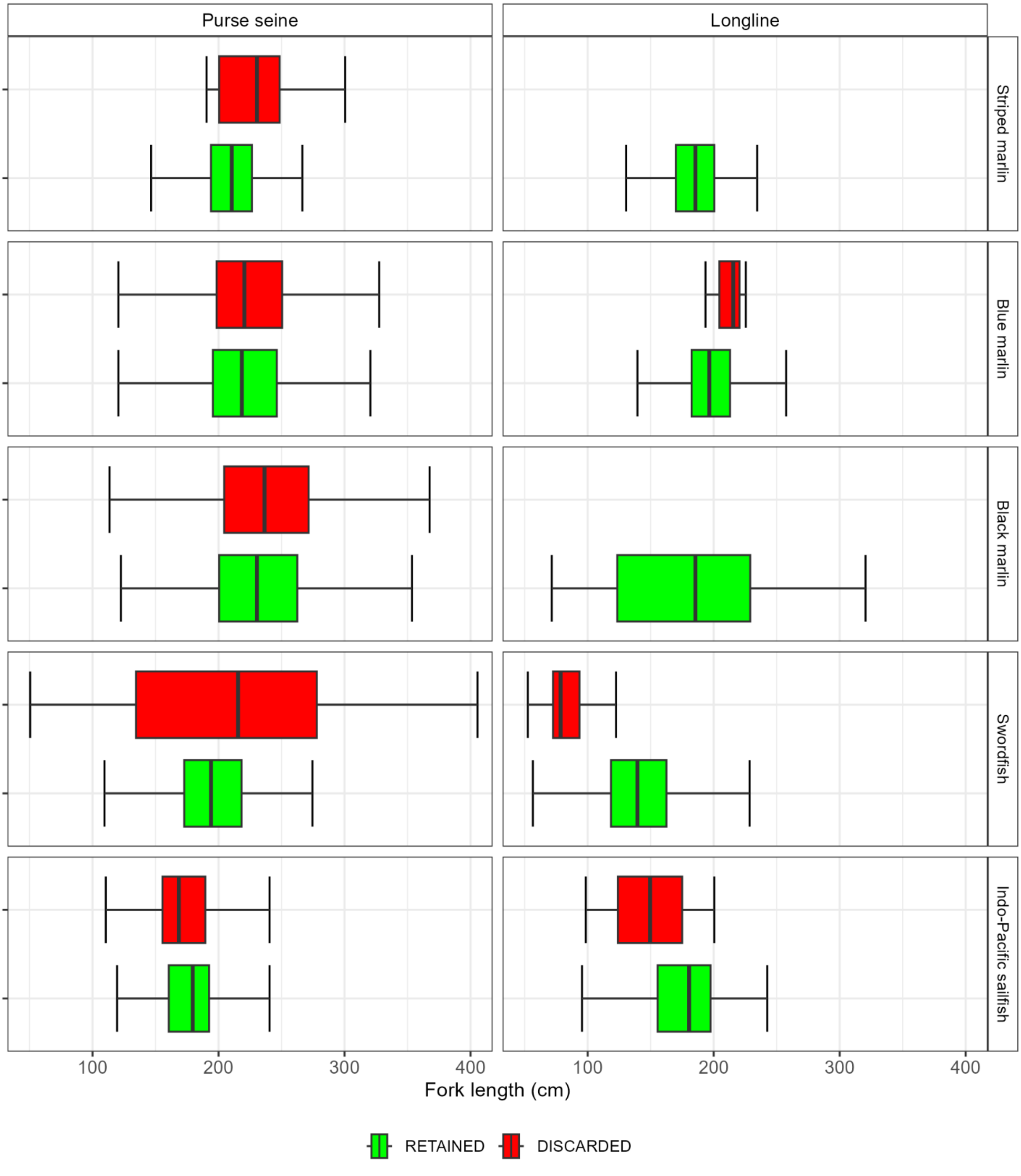

Figure 13: Boxplots of size measurements (fork length; cm) of billfish species discarded at sea in purse seine and longline fisheries as available in the ROS regional database

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

Availability of nominal effort for both artisanal and industrial fisheries with catches of billfish varies, in time series and type of effort measured. Although there are some continuous collection of data for some artisanal fisheries, type of effort measured could varies over time, posing some challenges to assess the level of effort applied over time for some fleets. Besides the time series and type of effort, spatial-temporal resolution and coverage are altered across 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	3	2020	2022	4
		SETS	1	2021	2021	3
		TRIPS	10	1986	2022	8
	Line	BOATS	10	2001	2013	8
		DAYS	27	1985	2022	27
		FDAYS	23	2000	2022	140
		FHOURS	4	2012	2016	1
		HOOKS	28	1995	2022	349
		MD	1	2016	2016	1
		MH	1	2021	2021	1
		TRIPS	18	1985	2022	18
	Baitboat	FDAYS	8	2013	2022	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	36	1985	2022	21
	Other	BOATS	2	2011	2012	3
		DAYS	1	2002	2002	1
		TRIPS	32	1985	2022	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	2	2021	2022	75
		SETS	10	2013	2022	338
		TRIPS	9	2014	2022	104
	Longline	BOATS	2	2010	2011	1
		DAYS	10	1998	2008	184
		FDAYS	16	1998	2015	631
		HOOKS	71	1952	2022	1,384
		SETS	5	2003	2008	37
		TRIPS	21	2001	2022	64
	Line	FDAYS	5	2018	2022	17
		TRIPS	3	2014	2016	9
	Baitboat	FDAYS	4	2018	2022	9
	Gillnet	NETS	6	1986	1991	76
		TRIPS	16	2007	2022	487

Despite the fact that several coastal fisheries are recording billfish, not all fleets report the fishing effort from the artisanal fisheries catching billfish. India and Pakistan, which are catching around 18320.6543639t in recent years, however, there are no effort data reported from 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 (2007-2022), Indonesia (2018-2022) and Sri Lanka (1987-2022), 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). Past temporal-spatial data form fisheries of 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 (**IOTC2024a?**), blue marlin (**IOTC2024b?**), striped marlin (**IOTC2024c?**), Indo-Pacific sailfish (**IOTC2024d?**), and swordfish (**IOTC2024e?**).

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**).While geo-referenced catches of billfish from longline fisheries reduced Western Indian Ocean in recent years, there are increasing geo-referenced catches from gillnet and line fisheries in the North of Indian Ocean between 2018 and 2022.

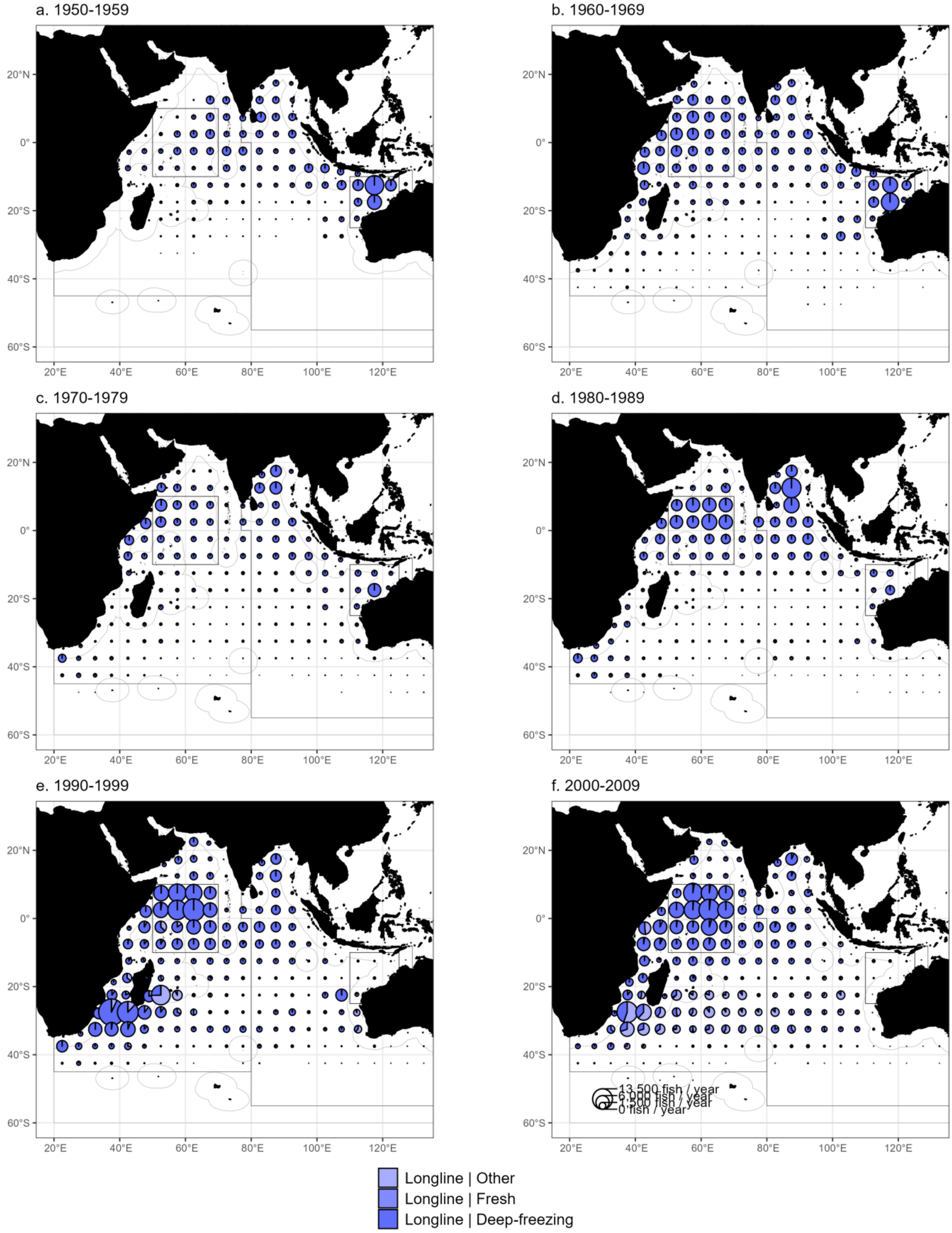

Figure 14: Mean annual time-area catches (in number of fish) of billfish for the period 1950-2009, by decade and fishery. Black solid lines represent the marlin main longline fishing grounds identified by the IOTC WPB

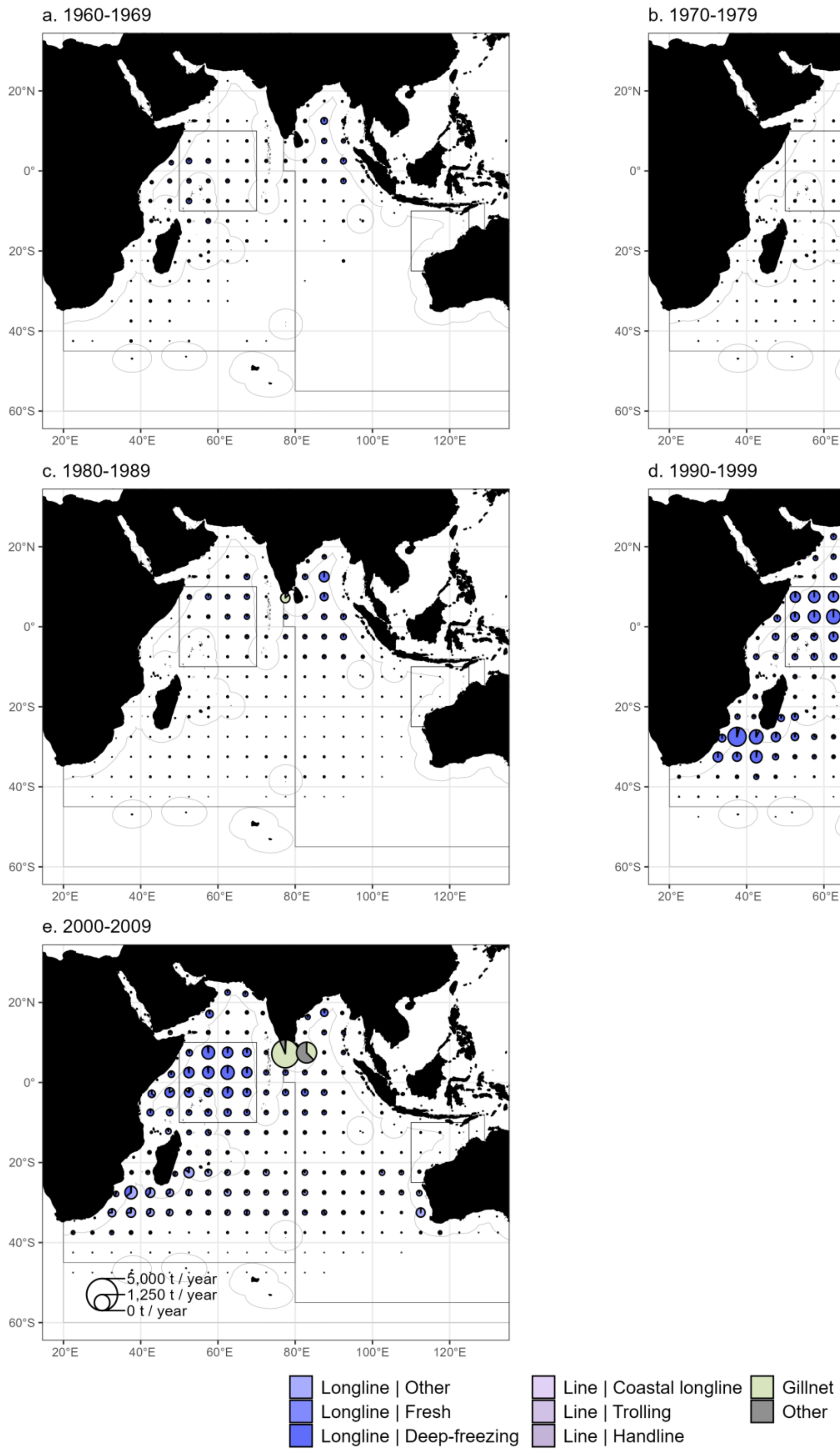

Figure 15: Mean annual time-area catches (metric tonnes; t) of billfish for the period 1950-2009, by decade and fishery. Black solid lines represent the marlin main longline fishing grounds identified by the IOTC WPB

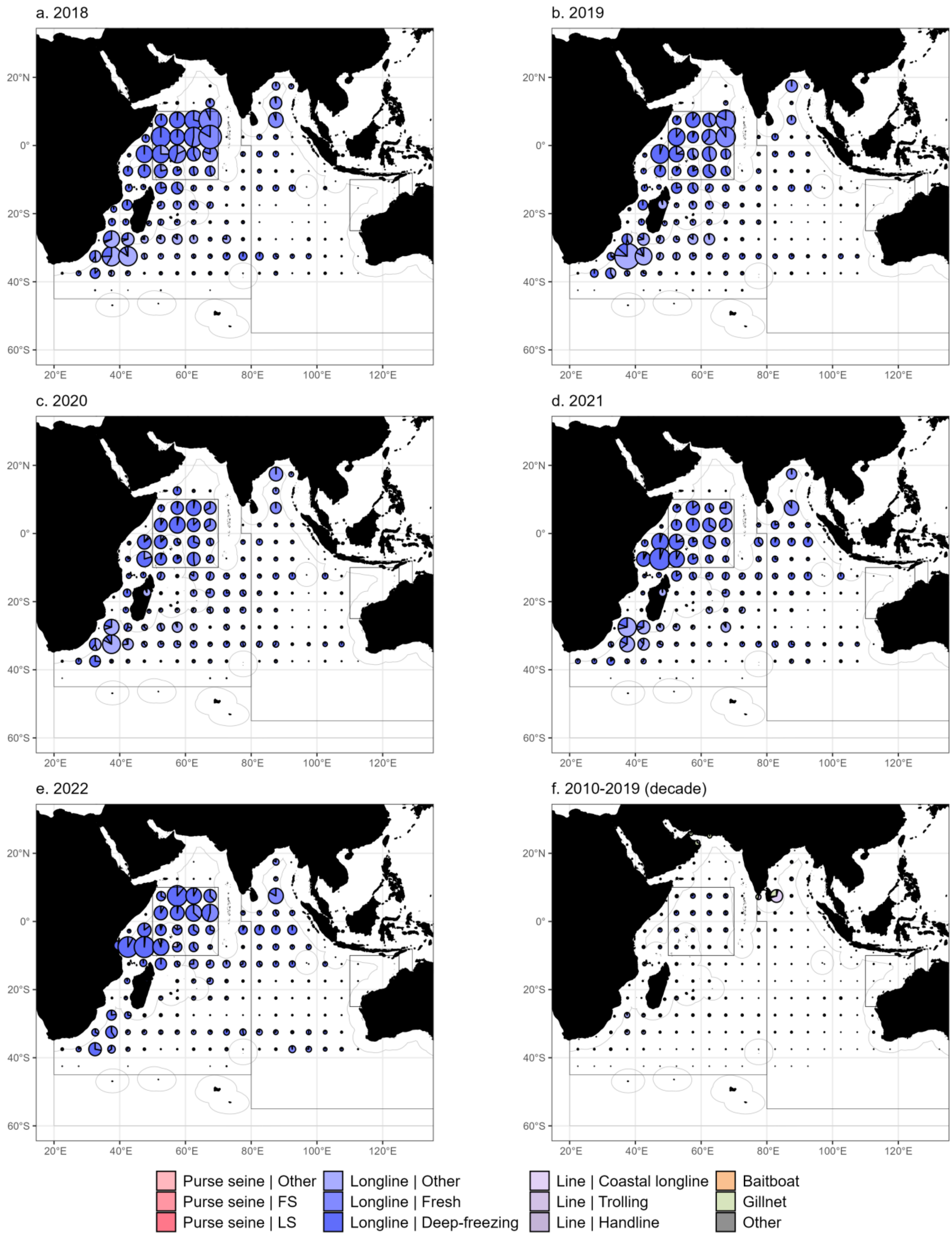

Figure 16: Mean annual time-area catches (in number of fish) of billfish for the last decade 2010-2019 and each year during the recent period 2018-2022. Black solid lines represent the marlin main longline fishing grounds identified by the IOTC WPB

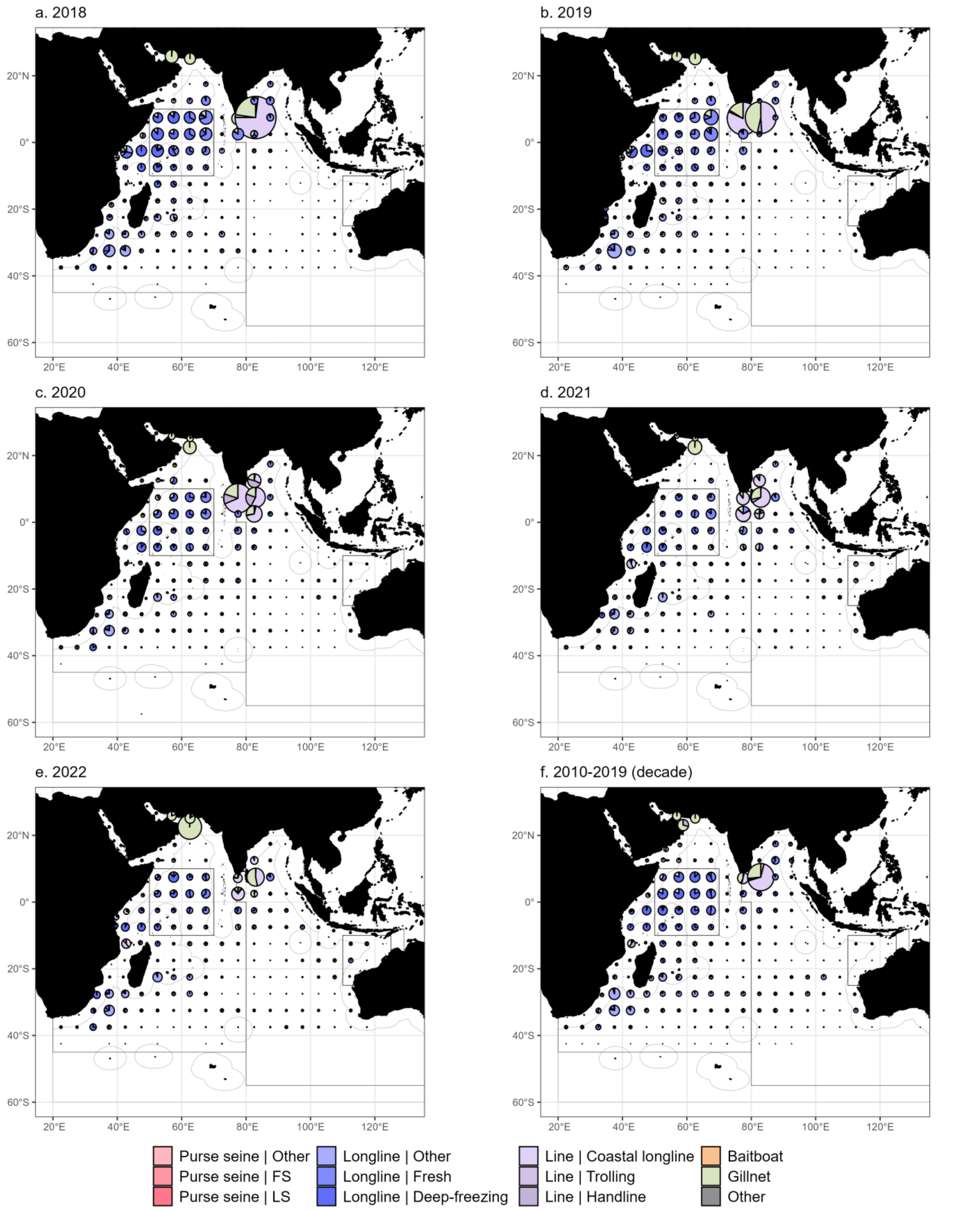

Figure 17: Mean annual time-area catches (metric tonnes; t) of billfish for the last decade 2010-2019 and each year during the recent period 2018-2022. Black solid lines represent the marlin main longline fishing grounds identified by the IOTC WPB

Uncertainties in catch and effort data

The quality of geo-referenced catch of billfish is influenced by the type of fisheries, as data quality varies by fisheries. The general trend depict the availability of billfish from the fisheries, by which, the increasing catches of billfish from artisanal fisheries in recent years, are poorly available in spatial area (**Fig. 18**). In the early decades, where billfish were mainly caught by industrial fisheries, over 65% of geo-referenced data were available. The rise of billfish from artisanal fisheries from 2000 led to decline quality, with around 20% of geo-referenced catch available as compared to total retained billfish data. The improvement in data collection from Sri Lanka, I. R Iran, and more recently Indonesia providing some geo-referenced data, shifted the quality of data, with 66% availability of geo-referenced catch. 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 (**IOTC2024a?**), blue marlin (**IOTC2024b?**), striped marlin (**IOTC2024c?**), Indo-Pacific sailfish (**IOTC2024d?**), and swordfish (**IOTC2024e?**).

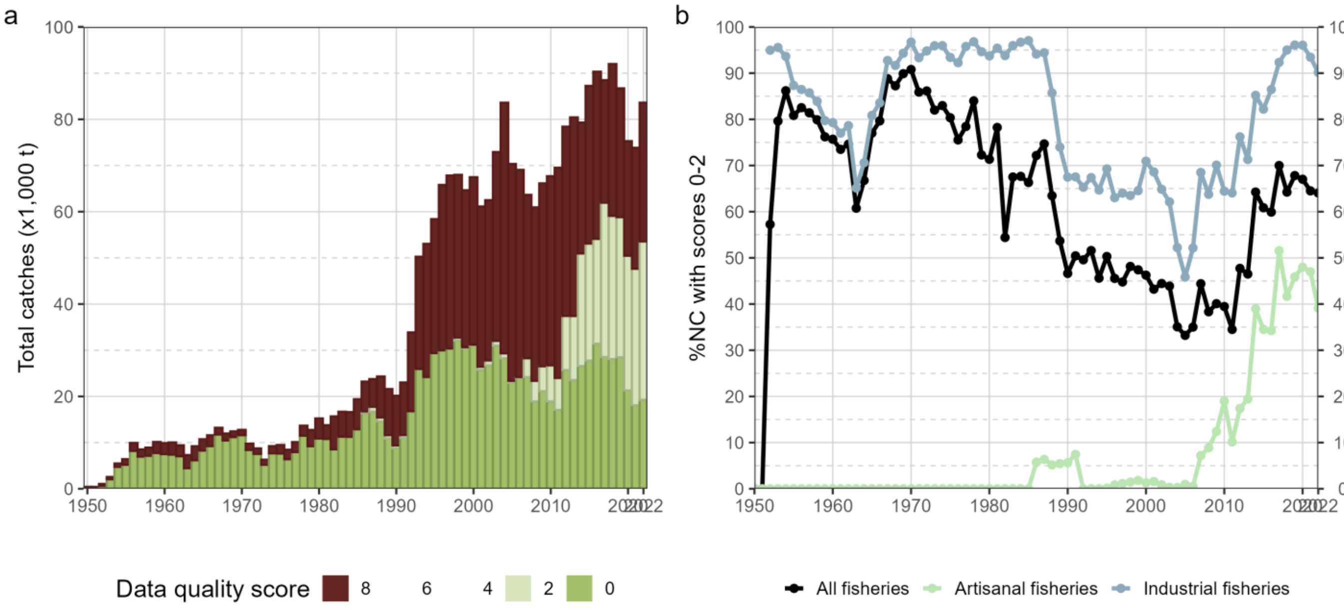

Figure 18: (a) Annual retained catches of IOTC billfish species (metric tonnes; t) estimated by quality score and (b) percentage of retained catches by type of fishery with good quality information (i.e., logbook coverage >30% and compliant with IOTC standards) for the corresponding geo-referenced catch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

Size composition fo the catch

Size sample availability

The characteristic of data collection from artisanal fisheries hinder the availability of sample data collected for billfish species. Sampling offish from coastal fisheries are done mainly during landing, where enumerators collect biological data on landing site. Landing of billfish species are mainly processed fish, headed. Hence, the CPCs argument is that the processing of billfish before landing makes it difficult to identify the species for recording biological information. CPCs like I. R. Iran, Sri Lanka, India and Pakistan, with 62t in recent years, do no collect size frequency of billfish species. The dominant fisheries with size frequency of billfish remained longline fisheries from fleets like China, Taiwan,China, Seychelles, Korea, and EU, representing 97.3%, although the number of sample collected decline substantially in recent years, which is in agreement with the decline in retained catches (see section Retained catches and discards). Between 1980s and 1990s there were some sample size collected from gillnet fisheries as part of Indo-Pacific Tuna Program (IPTP) in Sri Lanka (**Fig. 19**). Recently, sampling of billfish species are collected from some coastal longline and gillnet, despite being at a very low rate.

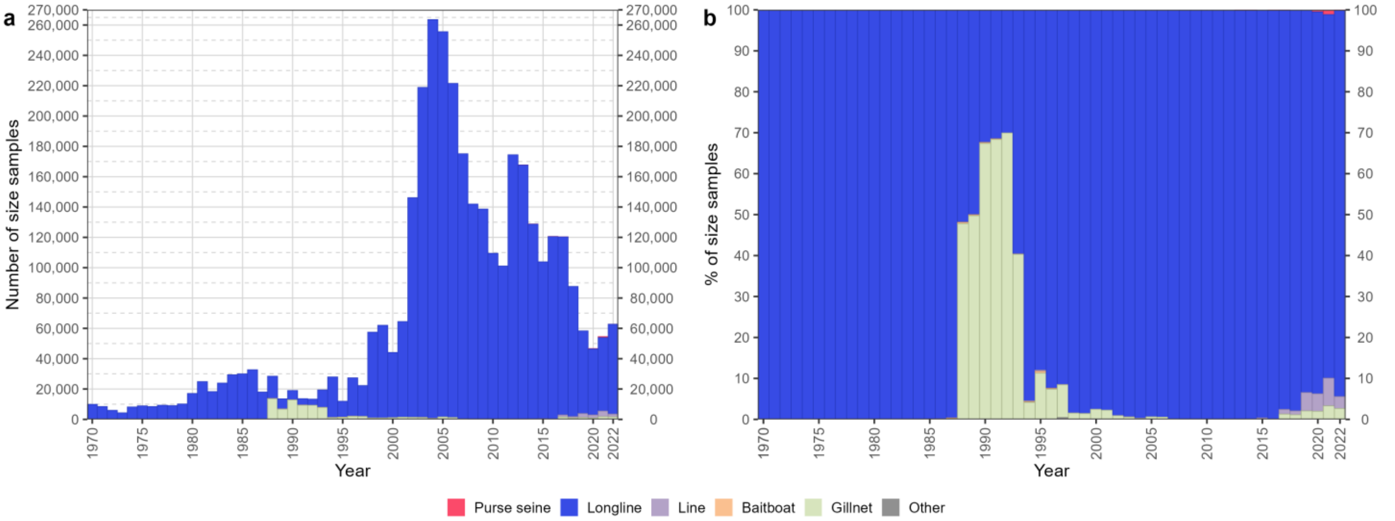

Figure 19: (a) Annual number and (b) relative proportion (%) of billfish standard size samples available by fishery group at the IOTC Secretariat

Size sample available by species are not representative of the level of retained catches by species. Sailfish which in recent years dominated the billfish catch, is the least sampling species with only 2% of total size sample available. Size sample available for swordfish on the contrary, is 79% (**Fig. 20**), reflecting the high catches of SWO from industrial longline, for which data sets reporting requirements are well observed.

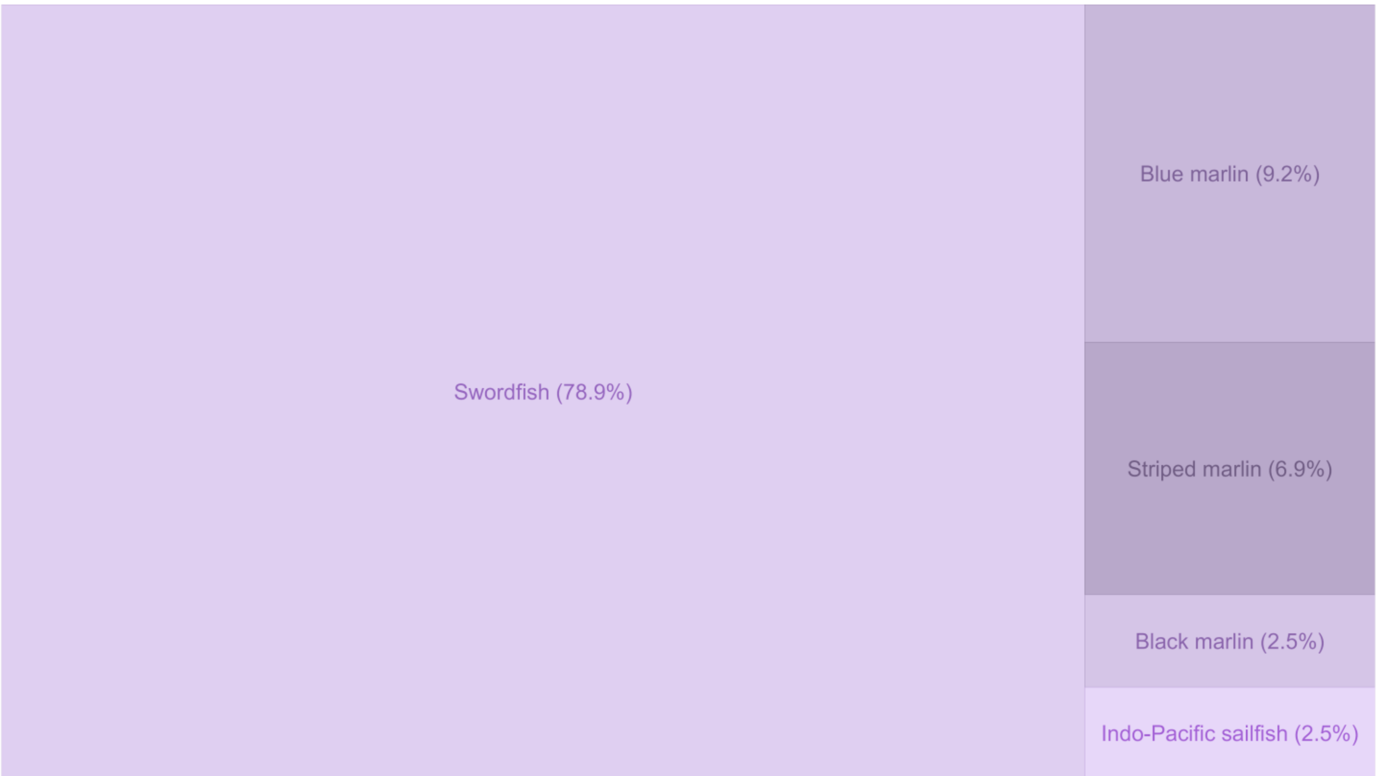

Figure 20: Percentage of size samples by species for all standard size samples available at the IOTC Secretariat

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 Secretariat 2023a), blue marlin (IOTC Secretariat 2023b), striped marlin (IOTC Secretariat 2023d), Indo-Pacific sailfish (IOTC Secretariat 2023c), and swordfish (IOTC Secretariat 2023e).

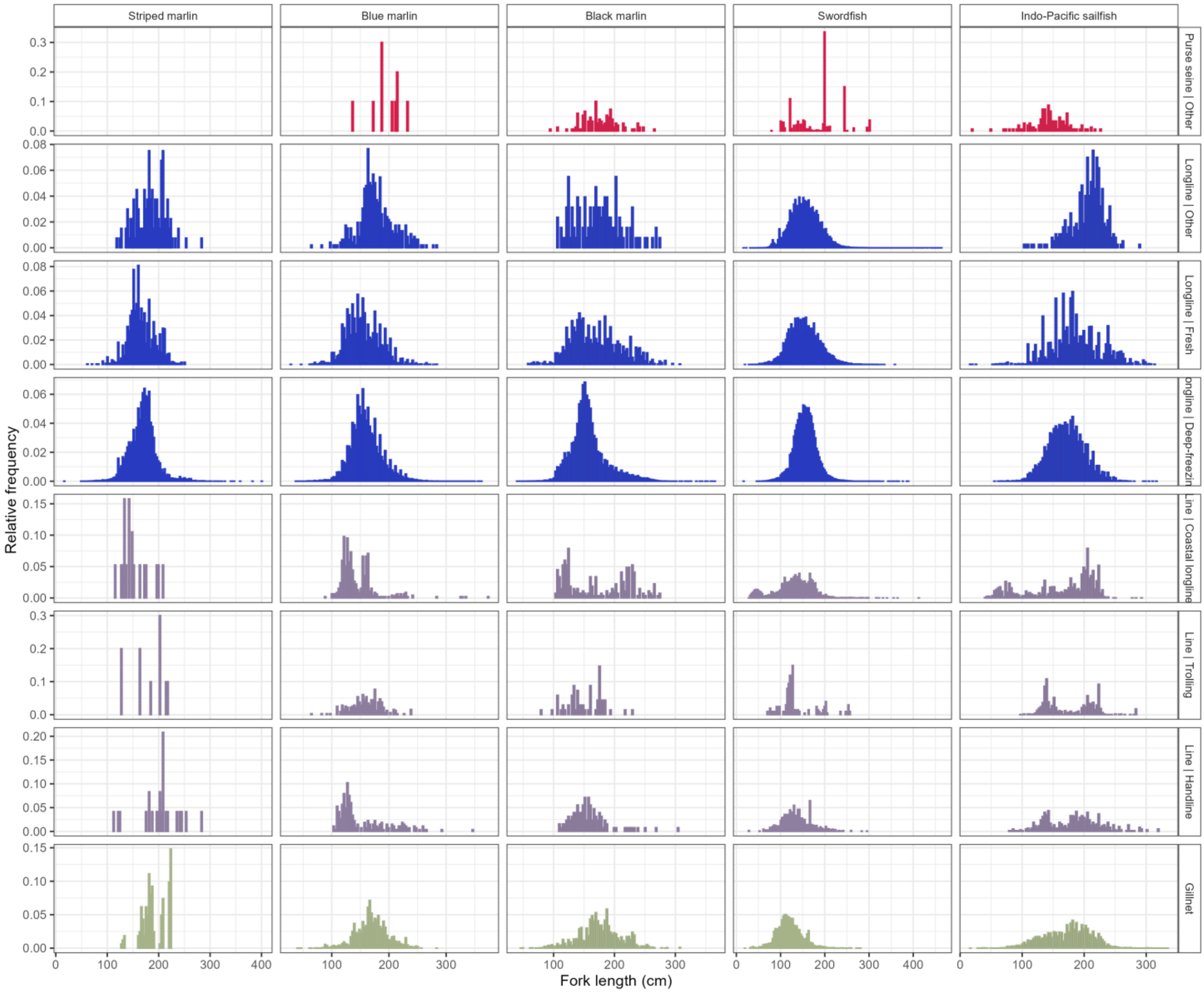

Figure 21: Relative size distributions (fork length; cm) by billfish species and fishery based on all samples available at the Secretariat. Fisheries with less than 500 samples are not shown

Uncertainties in size-frequency data

Geo-referenced size information from main fleets catching billfish species was not available between 1950s and 1970s, due to lack of billfish species sampling at that time, and poorly available in recent years, as the main fisheries catching billfish species collect limited size samples. Furthermore, the geo-referenced data available in the 1970s and 1980s were 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, Indonesia, Seychelles, EU.France for there coastal longline fisheries, Sri Lanka gillnet fisheries. 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 21% in 2022.

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 (IOTC2024a?), blue marlin (IOTC2024b?), striped marlin (IOTC2024c?), Indo-Pacific sailfish (IOTC2024d?), and swordfish (IOTC2024e?).

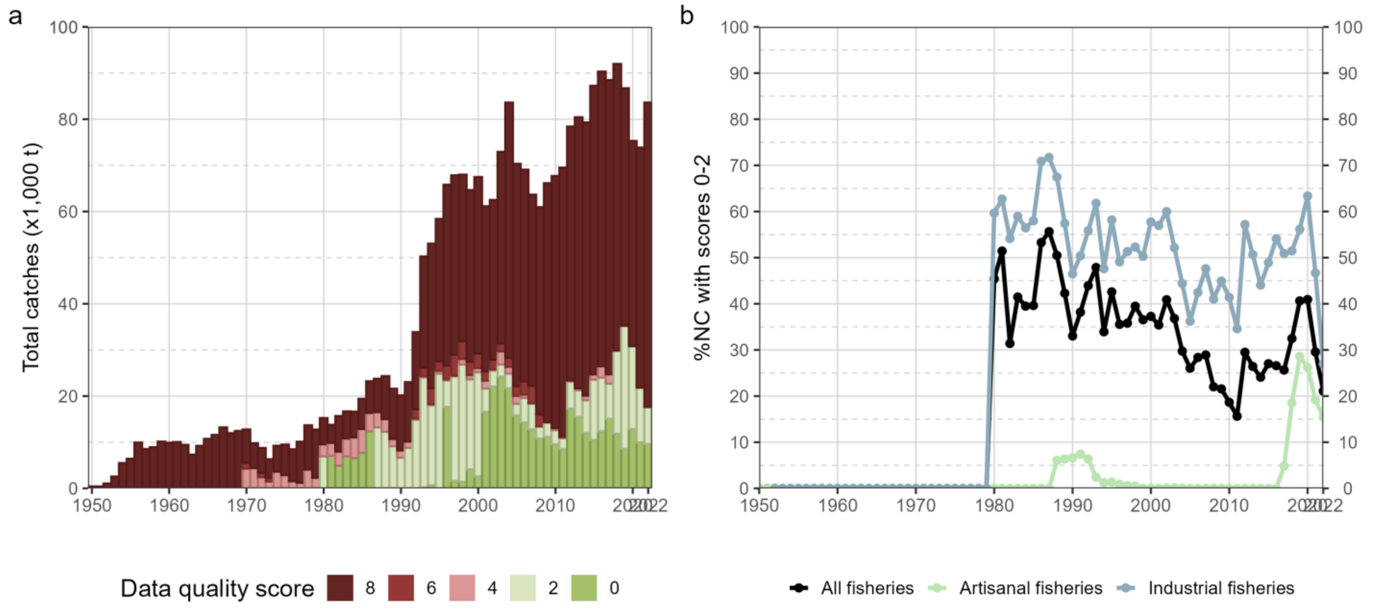

Figure 22: (a) Annual retained catches of IOTC billfish species (metric tonnes; t) estimated by quality score and (b) percentage of retained catches by type of fishery with good quality information (i.e., >1 fish per t caught and compliant with IOTC standards) for the corresponding geo-referenced size-frequency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

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IOTC Secretariat (2023c) Review of the statistical data available for indian ocean indo-pacific sailfish (1950-2021). IOTC, La Saline-les-Bains, Réunion, 6 - 9 September 2023, p 34

IOTC Secretariat (2023d) Review of the statistical data available for indian ocean striped marlin (1950-2021). IOTC, La Saline-les-Bains, Réunion, 6 - 9 September 2023, p 24

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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

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

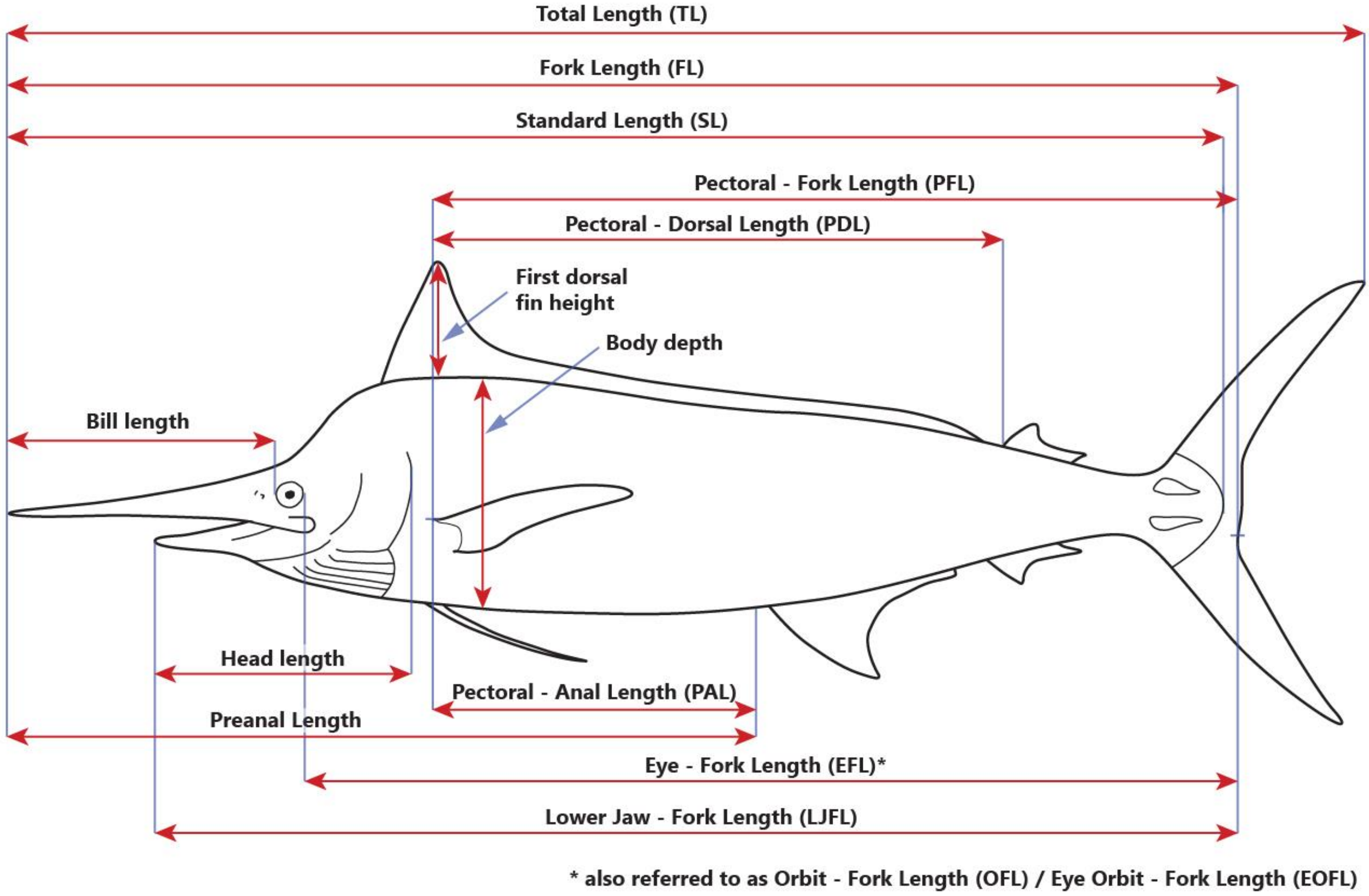

Figure 24: Types of length measurements used for billfish (source: Fishider)

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	Indian	LJFL = a*EFL+b	1.334000	0.839500	443	Ward (pers. com)
		Western-Central Pacific	LJFL = a*EFL+b	1.120000	7.330000	397	Sun et al. 2011
		Western-Central Pacific	LJFL = a*EFL+b	0.834000	36.610000	301	Kopf et al. 2011
BUM	Blue marlin	Atlantic	LJFL = a*TL+b	0.763000	2.000000	258	Prager et al. (1995)
		Atlantic	LJFL = a*PFL+b	1.261000	7.696000	732	Prager et al. (1995)
		Atlantic	LJFL = a*EFL+b	1.096000	8.887000	250	Prager et al. (1995)
		Atlantic	LJFL = a*PAL+b	2.156000	61.656000	453	Prager et al. (1995)
		Indian	LJFL = a*EFL+b	0.983000	28.630000	53	Setyadji et al. (2016)
		Indian	LJFL = 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	LJFL = a*EFL+b	1.106317	8.018586	26	Ward (pers. Com)*
BLM	Black marlin	Indian	LJFL = a+EFL*b	5.202073	1.114579	13	Ward (pers. Com)*
		Indian	LJFL = a*PFL+b	1.249000	11.299000	37	Setyadji et al. 2016
		Indian	LJFL = 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)
SWO	Swordfish	Indian	LJFL = a*EFL+b	1.060000	9.027000	160	Setyadji et al. (2016)
		Indian	LJFL = 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)
		Indian	LJFL = a*EFL+b	1.066000	10.449000	123	Poisson and Taquet (2001)
		Indian	LJFL = a*CKL+b	1.541100	19.605000	801	Poisson and Taquet (2001)*
		Indian	LJFL = a*PAL+b	2.540700	25.698000	1,806	Poisson and Taquet (2001)*
SFA	Indo-Pacific sailfish	Western-Central Pacific	LJFL = a*EFL+b	0.884500	-3.702500	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	GUT = a*EFL^b	3.0393e-06	3.329	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*LJFL^b	3.2000e-07	3.56	170	Shimose et al. 2013
		Western-Central Pacific	RD = a*LJFL^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)
		Indian	GUT = a*EFL^b	1.0000e-05	3.064	324	Setyadji et al. (2016)
		Pacific	RD = a*EFL^b	2.7223e-06	3.31	154	Uchiyama and Kazama (2003)*
BLM	Black marlin	Indian	GUT = 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)*
		Western-Central Pacific	RD = a*FL^b	6.6100e-06	3.336	117	Speare (2003)
SWO	Swordfish	Atlantic	GUT = a*LJFL^b	8.5703e-08	3.918	16	Garcia-Cortés and Mejuto 2002
		Indian	GUT = a*PFL^b	3.0000e-05	2.94	1,429	Setyadji et al. (2016)
		Indian	GUT = a*LJFL^b	5.8641e-06	3.085	334	Poisson and Taquet (2001)*
		Indian	RD = a*LJFL^b	3.8150e-06	3.188	3,608	Mejuto et al. (1998)*
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 2022

The overall amount of retained catches fully estimated in 2022 is 4,205 t, for 8 distinct fleets, representing 4.5% 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 2022 or whose catches were available from other sources. For non-members (i.e., Djibouti) 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 Kenya) for some of their fisheries in 2022, retained catches were repeated from 2021 (**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 2022

Fleet code	Fleet	Status	Source	Catch
DJI	Djibouti	NM	FAO	44
EGY	Egypt	NM	FAO	3
ERI	Eritrea	MP	FAO	18
JOR	Jordan	NM	FAO	35
YEM	Yemen	MP	FAO	2,685
KEN	Kenya	MP	IOTC	554
MDG	Madagascar	MP	IOTC	24
MDG	Madagascar	MP	IOTC	842
ALL	All fleets	-	-	4,205

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 2022, the total catch of billfish taken by India was 14,236 t, by which catches taken in coastal longline and gillnet fisheries are estimated by gear. 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 14,510 t (reported through official submissions) to 8,367 t (estimated), with catches increasing for swordfish and decreasing for the four other species (**Fig. 25**).

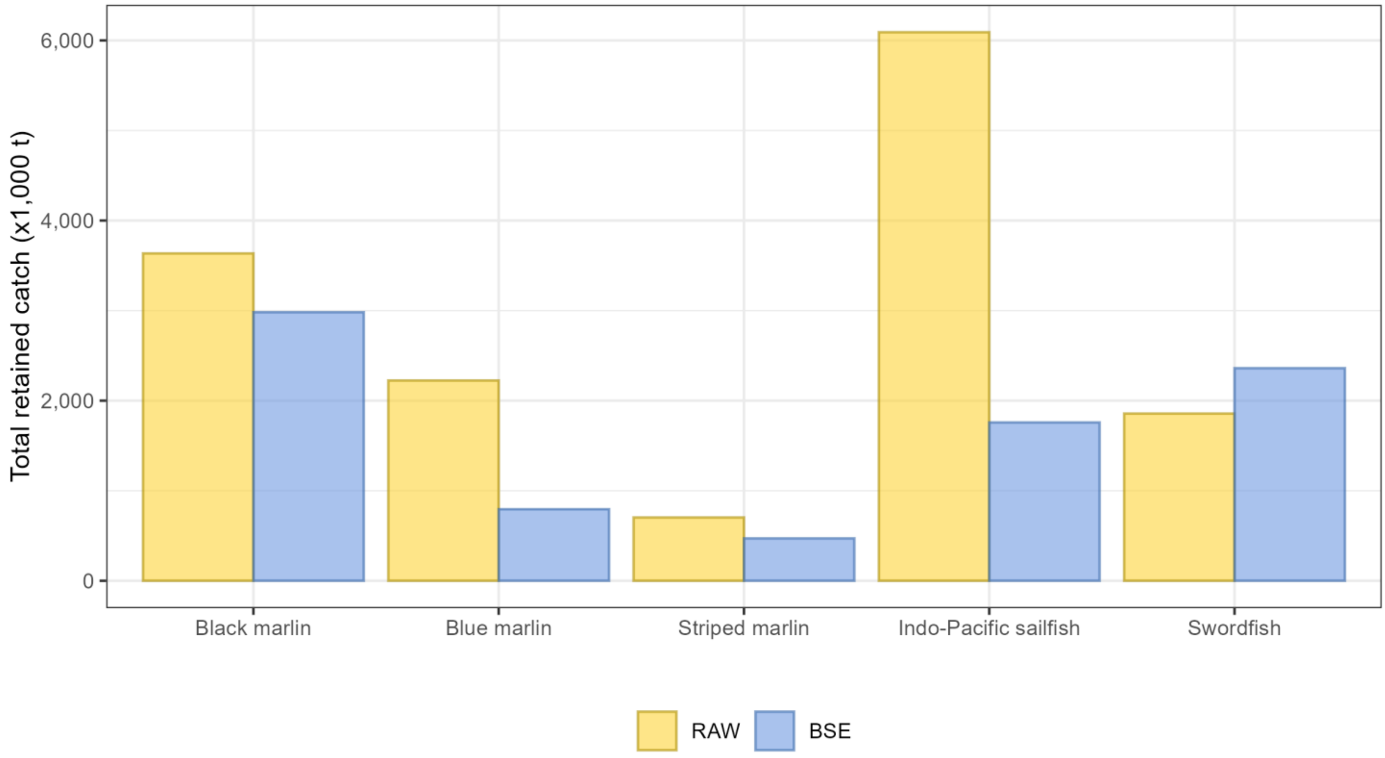

Figure 25: Comparison between the total catches (metric tonnes; t) of IOTC billfish by Indonesia as submitted to the Secretariat (RAW) and estimated following the current methodology used to derive the best scientific estimates (BSE)

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 2022, this breakdown by species resulted in the addition of a total of 9,929 t to the catches reported at species level for the five species of interest, corresponding to 10.6% of the final catch estimates (**Fig. 26**).

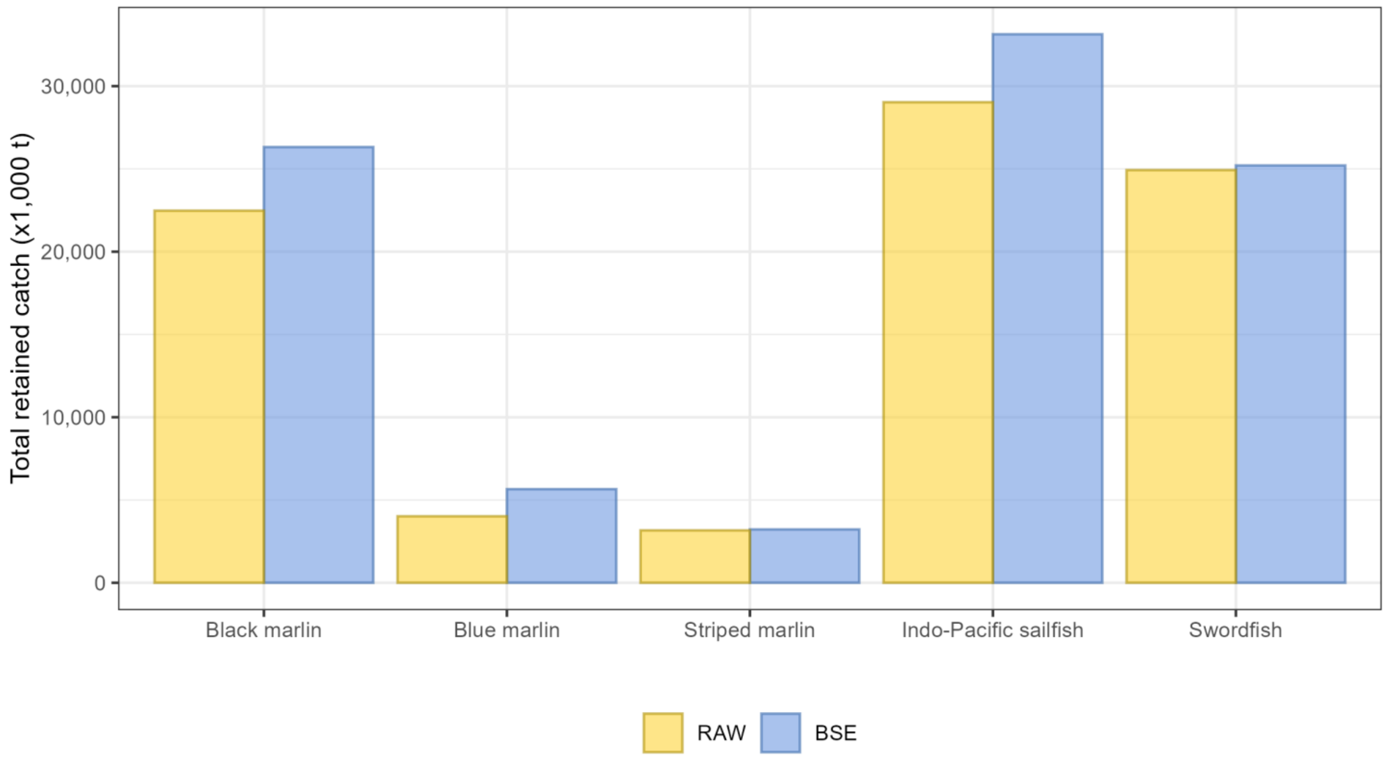

Figure 26: Total catches (metric tonnes; t) of IOTC billfish species as reported (RAW) and estimated (BSE) after accounting for the catches added through the breakdown of species aggregates

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 2019 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)
2021	BGD	Gillnet	Eastern Indian Ocean	1,329	260	1,068
		Line	Eastern Indian Ocean	0	123	-123
	JPN	Longline	Western Indian Ocean	107	123	-15
	MYS	Longline	Eastern Indian Ocean	187	268	-81
		Longline	Western Indian Ocean	138	58	81
	TMP	Gillnet	Eastern Indian Ocean	24	0	24
	YEM	Gillnet	Western Indian Ocean	572	486	86
		Line	Western Indian Ocean	1,763	1,496	267
2020	TMP	Gillnet	Eastern Indian Ocean	153	0	153
2019		Gillnet	Eastern Indian Ocean	106	0	106
2018		Gillnet	Eastern Indian Ocean	48	0	48