REVIEW OF THE STATISTICAL DATA AVAILABLE FOR BYCATCH SPECIES

Prepared by IOTC Secretariat[1]

Purpose

To provide participants at the Assessment meeting of the 17th Session of the IOTC Working Party on Ecosystems and Bycatch (WPEB17(AS)) with a review of the status of the information available on non-targeted, associated and dependent species of IOTC fisheries ('Bycatch') defined by the IOTC Scientific Committee as:

"All species, other than the 16 species listed in Annex B of the IOTC Agreement, caught or interacted with by fisheries for tuna and tuna-like species in the IOTC area of competence. A bycatch species includes those non-IOTC species which are (a) retained (byproduct), (b) incidentally taken in a fishery and returned to the sea (discarded); or (c) incidentally affected by interacting with fishing equipment in the fishery, but not taken."

The document summarises the current information received for species or species groups other than the 16 IOTC species listed in the IOTC Agreement, in accordance with relevant Resolutions adopted by the Commission. It provides an overview of the data available in the IOTC Secretariat databases as of August 2021 for sharks, rays, seabirds, marine turtles, cetaceans, and other bycatch species. The document describes the progress achieved in relation to the collection and verification of data, identifies problem areas and proposes actions that could be undertaken to improve them.

Materials

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

Nominal catch data

Nominal catches correspond to the total retained catches (in live weight) estimated per year, Indian Ocean major area, fleet, and gear (IOTC Res. 15/02) and can be reported through IOTC form 1RC.

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

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

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

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

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Geo-referenced catch and effort data

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

Discard data

The IOTC follows the definition of "discards" adopted by FAO in previous reports and considers all non-retained catch as discarded catch, including individuals released alive or discarded dead (Alverson et al. 1994; Kelleher 2005). 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.

Furthermore, more detailed information (e.g., higher spatio-temporal resolution, fate) on discards of IOTC and bycatch species (including species of special interest) shall be collected as part of the IOTC Regional Observer Scheme (IOTC Res. 11/04) (see below).

Size frequency data

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

Regional Observer Scheme

Resolution 11/04 on a *Regional Observer Scheme* (ROS) makes provision for the development and implementation of national observer schemes among the IOTC CPCs starting from July 2010 with the overarching objective of collecting *"verified catch data and other scientific data related to the fisheries for tuna and tuna-like species in the IOTC area of competence"*. The ROS aims to cover *"at least 5% of the number of operations/sets for each gear type by the fleet of each CPC while fishing in the IOTC Area of competence of 24 meters overall length and over, and under 24 meters if they fish outside their EEZs shall be covered by this observer scheme"*. Observer data collected as part of the ROS include: (i) fishing activities and vessel positions, (ii) catch estimates with a view to identifying catch composition and monitoring discards, bycatch and size frequency, (iii) gear type, mesh size and attachments employed by the master, and (iv) information to enable the cross-checking of entries made to the logbooks (i.e., species composition and quantities, live and processed weight and location). A first technical description of the ROS data requirements is available in the document IOTC–2018–WPDCS-35 Rev_2.

The document IOTC-2020-WPEB16-08 provides a comprehensive description of the current status, coverage and data collected as part of the ROS. Although incomplete and characterized by a large variability in coverage between fisheries and over space and time, observer data include information on the fate of the catches (i.e. retained or discarded at sea) as well as on the condition of the discards. Observer data are also the main source of spatial information on interactions between IOTC fisheries and seabirds, marine turtles, cetaceans, as well as any other species encountered.

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

The ROS regional database includes a total of 87,211 interactions for the purse seine and longline fisheries having reported data to the Secretariat in electronic format (**Table 1**). Purse seine interactions (n = 50,259) cover the time period 2005-2019 and correspond to 63% of all shark interactions in the ROS regional database against 29,843 for longline. A total of 6,362 interactions with rays have been reported while few have been reported for seabirds and cetaceans, exclusively for longline fisheries.

Table 1: Number of bycatch interactions with longline and purse seine fisheries as reported in the ROS regional database

Fishery group	Species category	Initial year	Final year	Total interactions
Longline	CETACEANS	2009	2018	77
Longline	RAYS	2009	2019	5,979
Longline	SEABIRDS	2012	2016	180
Longline	SHARKS	2009	2019	29,843
Longline	TURTLES	2009	2019	302
Purse seine	RAYS	2005	2019	383
Purse seine	SHARKS	2005	2019	50,259
Purse seine	TURTLES	2006	2019	188

Methods

Data available for bycatch species

The data reporting requirements for bycatch species vary according to species category and fishing gear, and changed over time with the adoption of new resolutions (**Fig. 1**).

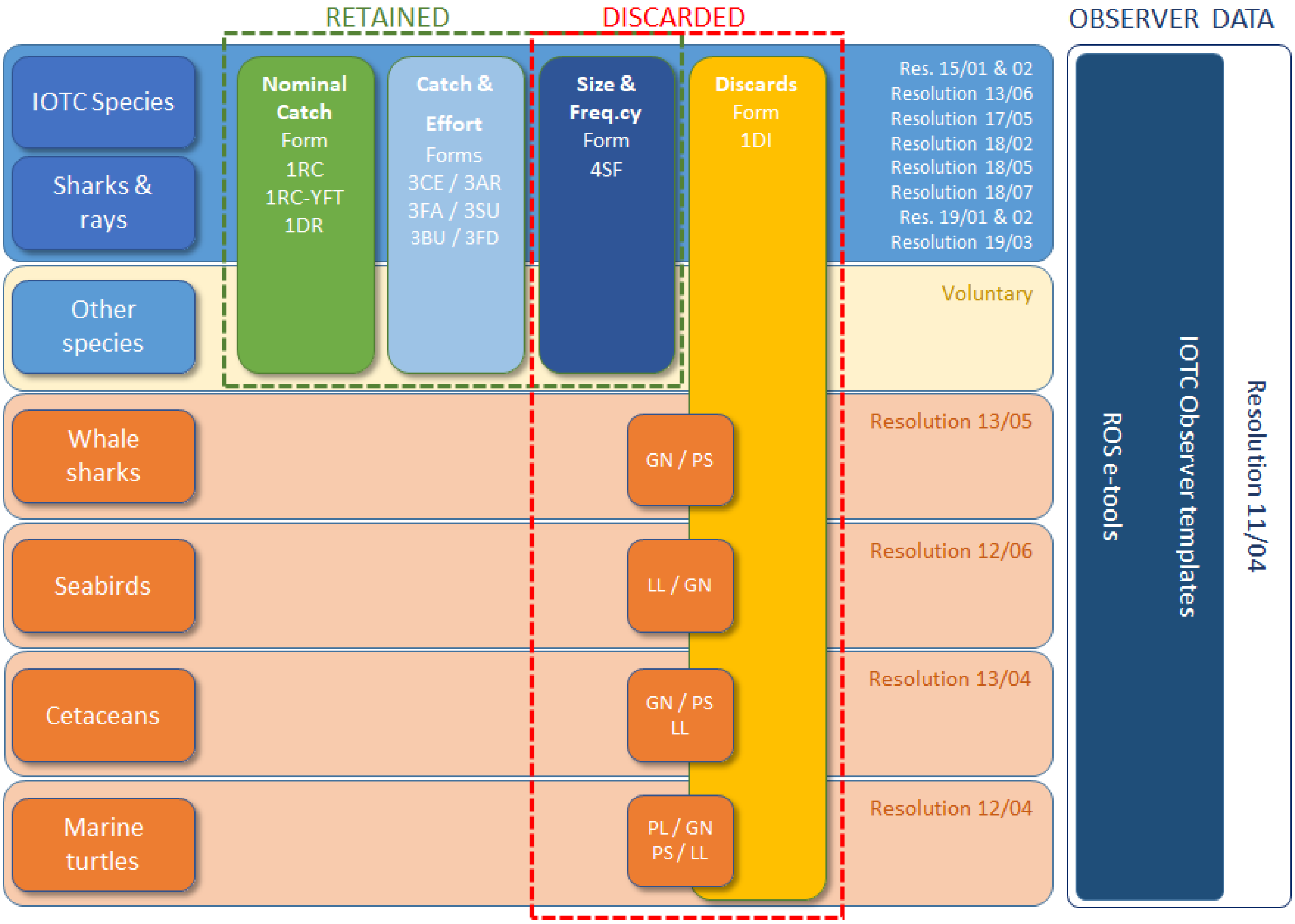


Figure 1: Overview of the data reporting requirements, including IOTC reporting forms and tools, and Resolutions for the 16 IOTC species and bycatch species caught or interacted with by fisheries for tuna and tuna-like species in the IOTC area of competence. BB = Baitboat; GN = Gillnet; LL = Longline; PS = Purse seine

The most common bycatch species with mandatory reporting requirements and other species for which reporting is encouraged are listed in **Table 2**, which summarises those bycatch species identified by the Commission as relevant for the most common gears (IOTC Res. 15/01).

Table 2: List of bycatch species of concern to the IOTC and reporting requirements by type of fishery for purse seine (PS), longline (LL), gillnet (GN), baitboat (BB), hand line (HL) and troll line (TR). Red indicates the primary species of concern and orange the optional species for which reporting is encouraged. * indicates that the Resolution only concerns fishing vessels on the IOTC Record of Authorised Vessels

Common name	Species code(s)	Resolution	PS	LL	GN	BB	HL	TR
Blue shark	BSH	18/02						
Mako sharks	MAK; SMA; LMA	15/01						
Porbeagle	POR	15/01						
Hammerhead sharks	SPN; SPL; SPK; SPZ	15/01						
Whale shark	RHN	13/05						
Thresher sharks	THR; PTH; ALV; BTH	12/09*						
Oceanic whitetip shark	OCS	13/06*						
Crocodile shark	PSK	15/01						

Common name	Species code(s)	Resolution	PS	LL	GN	BB	HL	TR
Silky shark	FAL	15/01						
Tiger shark	TIG	15/01						
Great white shark	WSH	15/01						
Pelagic stingray	PSL	15/01						
Mobula nei	RMV; RMB; RMM	19/03						
Other sharks	SKH	15/01						
Rays, stingrays, mantas	SRX	15/01						
Other marine fish nei	MZZ	15/01						
Marine turtles	TTX	12/04						
Seabirds	Table 8	12/06						
Cetaceans	Appendix I	13/04						

The present report is based on the compilation of the information derived from the data sets of bycatch species referenced in the Resolutions listed in **Table 2** that were reported to the Secretariat:

- Nominal catch data for shark and ray species, including those reported as species aggregates;
- Catch and effort data for shark and ray species, including those reported as species aggregates;
- Size frequency data for shark and ray species;
- Information on discards for shark and ray species available from the ROS;
- Fishery interactions with marine turtles, cetaceans, and seabirds derived from the ROS.

Nominal catch data for bycatch species should be considered with caution, due to several reasons (see Section Uncertainties in shark and ray catch data) that include the historically low reporting rates and a tendency to report catches for aggregated shark and ray species. Furthermore, catches of some shark and ray species that interact with coastal fisheries targeting other species than tuna and tuna-like species may not be reported to the IOTC. In addition, catches that have been reported are thought to represent only those species that are retained onboard, without taking into account discarded individuals. Finally, in many cases, the reported catches refer to dressed weights while no information is provided on the type of processing undertaken, creating more uncertainty in the estimates of catches in live weight equivalents.

Information available on the estimates of total discards collated through form 1DI was not used in the present report as the amount of data is currently very limited, with heterogeneous formats not compliant with IOTC standards, missing metadata (e.g., reason for discard, fate), and a general lack of information on sampling coverage and raising procedure.

Data processing

The preparation of the curated public-domain data sets for bycatch species follows three main data processing steps which are briefly summarized below.

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

Second, when nominal catches are not reported by a CPC, catch data from the previous year may be repeated or derived from a range of sources, e.g., the FAO FishStat database. In addition, 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. IOTC (2018).

Finally, filtering and conversions are applied to the size data reported for the most common shark and ray species in order to harmonize their format and structure, and remove data which are non-compliant with IOTC standards, e.g., provided with size bins exceeding the maximum width considered meaningful for the species (IOTC 2020). All samples collected using types of measurement other than fork length (FL; straight distance from the tip of the upper snout to the fork of the tail) are converted into FL by using the IOTC equations, considering a common range of 30-775 cm FL and constant size interval of 5 cm. If no IOTC-endorsed equations exist to convert from a given length measurement for a species to the standard FL measurement, the original size-frequency data are not disseminated, although they are kept within the IOTC databases for future reference.

Results

Overall bycatch levels & trends

Nominal catches of all species caught by Indian Ocean fisheries reported to the Secretariat have been increasing over time, with a particularly dramatic increase in the amount of tuna catches reported since the 1980s (**Fig. 2**). In 2019, the total nominal catches of all IOTC and non-IOTC species were 1,848,828 t and 223,362 t, respectively.

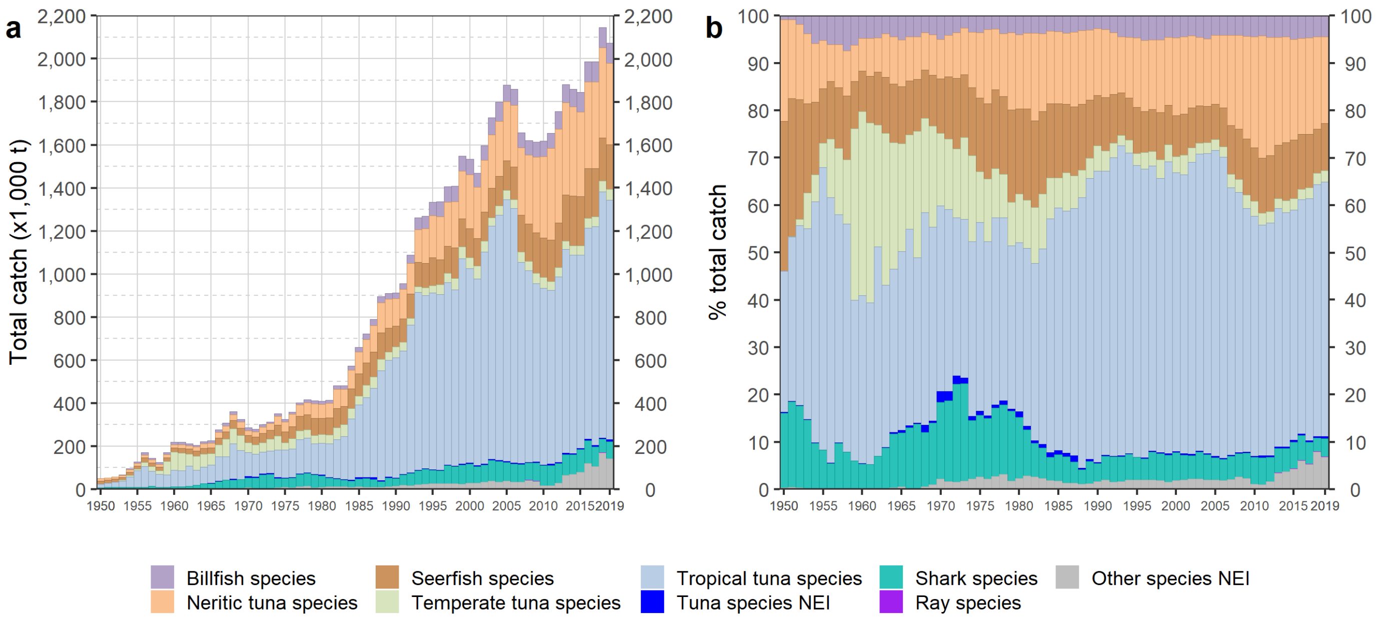


Figure 2: Annual time series of cumulative nominal absolute (a) and relative (b) catches of all IOTC tuna and tuna-like species in metric tons (t) by species category for the period 1950-2019

Reported nominal catches of species of interest to the WPEB are largely predominated by sharks with estimates from some artisanal fisheries dating back to the early 1950s (**Fig. 3**). Overall reported catches of shark and ray species have increased over time in relation to the development and expansion of tuna and tuna-like fisheries across the Indian Ocean, the increased reporting requirements for some sensitive species such as thresher and oceanic whitetip sharks, and the implementation of retention bans in some fisheries. In 2019, the total nominal catches of sharks reported to the Secretariat were 79,543 t, with rays representing a very small component of the reported bycatch and amounting to 1,813 t, i.e., about 2.2% of total reported shark and ray catches in 2019 (**Fig. 3**).

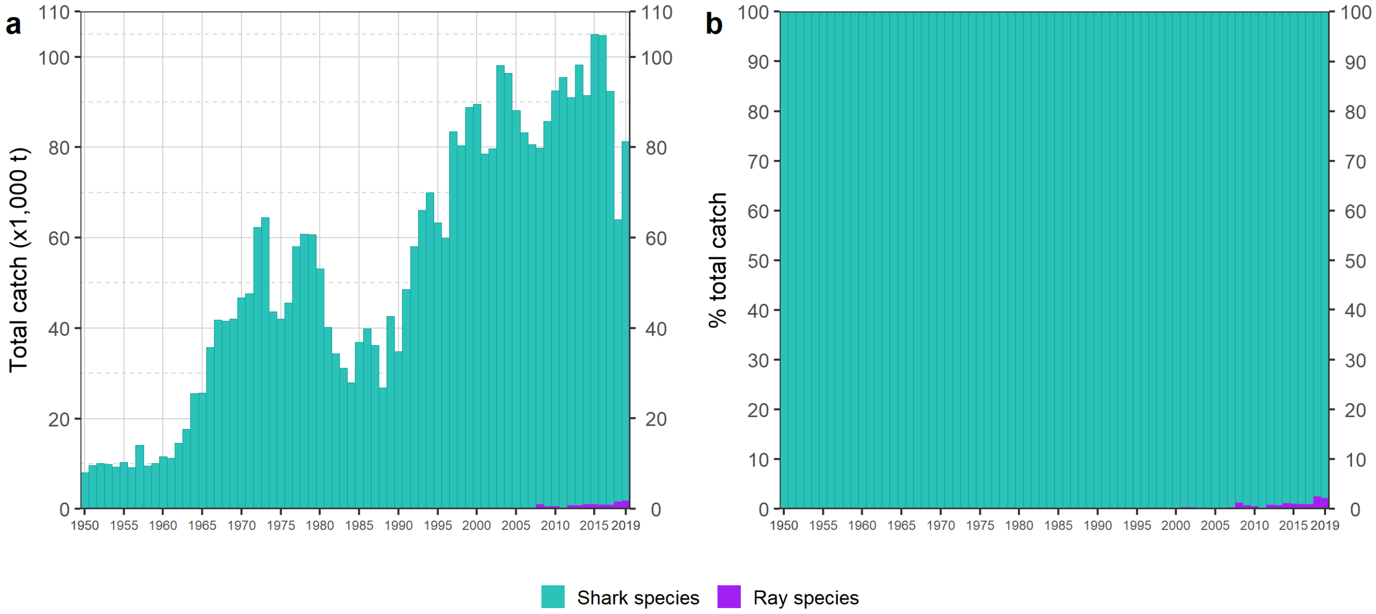


Figure 3: Annual time series of cumulative nominal absolute (a) and relative (b) catches of shark and ray species in metric tons (t) by species category for the period 1950-2019

Very few fleets reported catches of sharks and rays in the 1950s, but the number of reporting fleets has increased over time (**Fig. 4**). Total reported shark and ray catches of sharks and rays have also increased over time, reaching a peak of more than 100,000 t in 2015-2016: since then, nominal catches have decreased to about 80,000 t in 2019.

In 2018, reported catches of sharks and rays reduced declined significantly when compared with 2017 and 2019, mostly due to a complete disappearance of reported catches of aggregated shark species by India, (there that were not replaced by detailed catches by species), as well as to marked decreases in reported shark catches from other CPCs (Mozambique and Indonesia) which in some cases are thought to indicate reporting issues rather than a real reduction in catch levels. Furthermore, the revisions to Pakistani gillnet catches from 1987 onwards (endorsed by the SC in December 2019) introduced a mean annual decrease of around 17,000 t in total catches during the concerned period when compared to previously available data.

Recently, Japan provided a detailed species breakdown of retained shark catches from their deep-freezing longline fisheries for the years 1964-1993, which replaces the original re-estimates made by the IOTC Secretariat for the period concerned (Kai 2021). The revised Japanese catch series is now an integral part of the IOTC databases and is disseminated through the nominal catch data set prepared for the meeting.

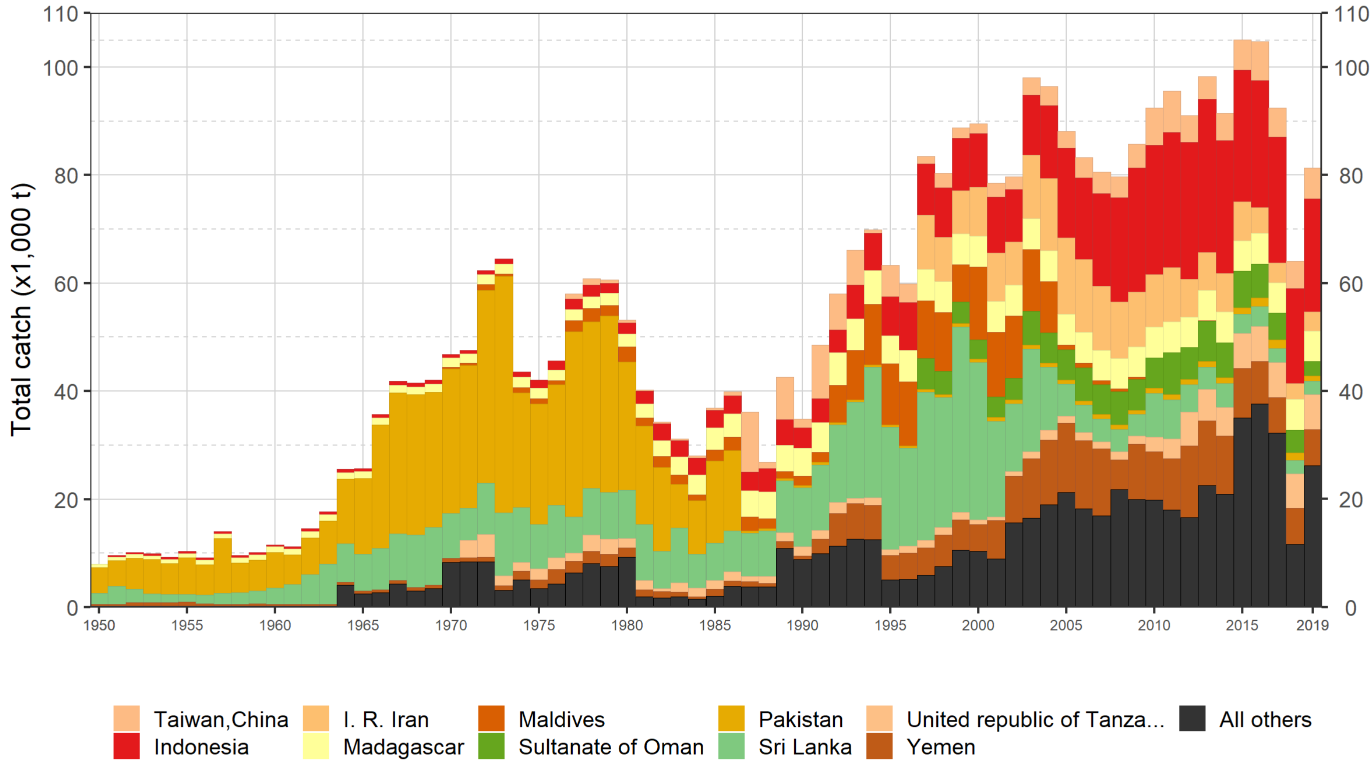


Figure 4: Annual time series of nominal catches (t) of sharks and rays by fleet during 1950–2019

Sharks and rays

Vulnerability to fisheries

Levels of reported nominal catches for sharks and rays strongly vary with fishing gear and over time, with gillnets that have historically been associated with the highest nominal catches and are currently responsible for almost 40% of reported catches of the species (**Table 3**). Of all gillnet fisheries, the majority comprise of standard, unclassified gillnets, followed by gillnets, handlines and troll lines and gillnet/longline combinations.

Table 3: Nominal catches of shark and ray species by decade and fishery in metric tons (t) for the period 1950–2019

Fishery	1950s	1960s	1970s	1980s	1990s	2000s	2010s
Purse seine | Other	0	0	0	0	0	14	360
Longline | Other	0	0	0	272	7,375	11,678	8,340
Longline | Fresh	0	0	33	187	1,697	2,980	3,376
Longline | Deep-freezing	0	2,000	1,634	1,843	4,251	5,051	6,923
Line | Coastal longline	0	0	0	1,727	5,692	11,980	21,310
Line | Trolling	783	1,262	2,379	4,168	6,220	6,242	9,437
Line | Handline	1,184	4,033	5,348	4,735	3,605	1,910	4,042
Baitboat	0	0	0	0	0	0	6
Gillnet	8,036	19,439	37,966	19,803	22,808	36,164	36,191
Other	0	0	5,846	4,198	13,684	9,960	1,664
Total	10,003	26,734	53,206	36,932	65,332	85,980	91,649

In terms of catch magnitude, gillnet fisheries are followed by longline fisheries (which contributed substantially to shark and ray catches in the 1990s) and by catches from handline and troll line fisheries, which have increased markedly in more recent years (**Fig. 5**).

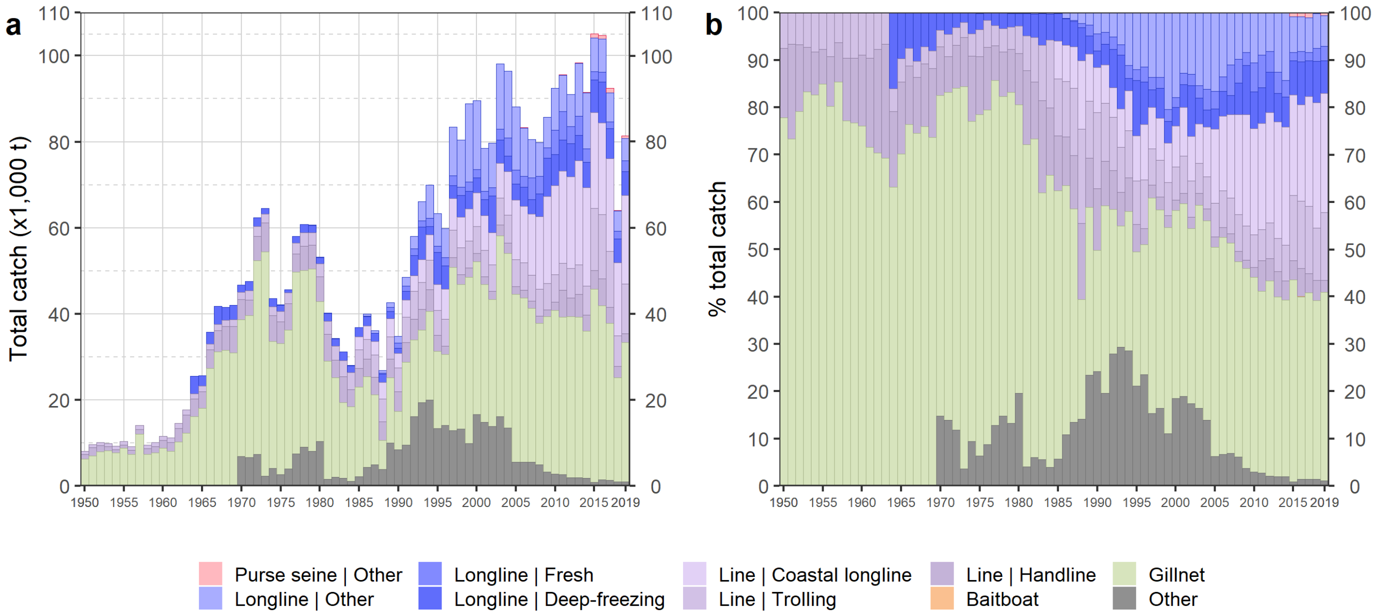


Figure 5: Annual time series of nominal absolute (a) and relative (b) catches of sharks and rays in metric tons (t) by fishery for the period 1950–2019. Other = all other fisheries combined

Overall, while industrial longliners and drifting gillnetters are known for harvesting important amounts of pelagic sharks, the same cannot be said of industrial purse seiners, pole-and-liners and most coastal fisheries.

- **Baitboat fisheries**: shark catches reported since the beginning of the time series for the pole and line fisheries of Maldives and India are very low: the extent of shark catches taken by these fisheries has been shown to be not significant (Miller et al. 2017)). In the case of Maldives, the negligible level of catches is also explained by national regulations that prevent retention of all shark species caught in their EEZ.
- **Gillnet fisheries**: the species of sharks and rays caught are thought to vary significantly depending on the area of operation of the gillnets (Moazzam 2012):
- **Gillnets operated in areas with low concentrations of pelagic sharks**: the gillnet fisheries of most coastal countries operate these gears in coastal waters, where the abundance of pelagic sharks is thought to be low.
- **Gillnets operated in areas with high concentrations of pelagic sharks**: gillnets operated in Sri Lanka, Indonesia and Yemen (waters around Socotra), despite being set in coastal areas, are likely to catch significant amounts of pelagic sharks (Fahmi and Dharmadi 2015).
- **Gillnets operated on the high seas**: vessels from Taiwan,China were using drifting gillnets (driftnets) from 1982 to 1992, before the use of this gear was banned worldwide, and catches of pelagic sharks from the fishery were very high during this period. Gillnetters from I.R. Iran and Pakistan have been fishing on the high seas since, but with lower catch rates: while initially setting in waters of the Arabian Sea, in recent years they expanded their range of operation to include the tropical waters of the western Indian Ocean and Mozambique Channel. The quantity of sharks caught by these fleets is thought to be relatively high, representing between 25–50% of the total combined catches of sharks and other species.
- **Gillnet/longline fishery of Sri Lanka**: between 1,200 and 3,200 vessels (with an average length of 12 m) operating a combination of gillnets and longlines have been harvesting important levels of pelagic sharks since the mid-1980s. The longlines are believed to be responsible for most of the catches of sharks in the period, which comprised ~45% of the total combined catch for all species in 1995, while declining to <2% in

the late 2000s. The fleet has been shifting towards predominantly longline gear in recent years, but most catches are still reported as aggregates of the combined gears.

- **Fisheries using handlines**: the majority of fisheries using hand lines and trolling in the Indian Ocean operate these gears in coastal waters, so although the total proportion of sharks caught has been historically high, the amount of pelagic sharks caught are thought to be low. The proportion of other species of sharks might change depending on the area fished and time of the day, as well as by the implementation of national regulations preventing the species from being retained onboard (e.g., Maldives).

- **Deep-freezing tuna longliners and fresh-tuna longliners**: catches of sharks are thought to represent between 10–40% of the total combined catch for all species in these fleets (Huang and Liu 2010; Oliver et al. 2015). However, the catches of sharks recorded in the IOTC database only make up a small proportion of the total catches of all species by industrial longline fleets. These catch series for sharks are therefore thought to be very incomplete. Nevertheless, levels of reporting have improved in recent years, following the implementation of catch monitoring schemes in different ports of landing of fresh-tuna longliners, and the recording of catches of main species of sharks in logbooks and observer programmes. The catches estimated, however, are unlikely to represent the total catches of sharks for these fisheries due to the paucity of information on levels of discards of sharks, which are thought to be high in some areas and for some species.

- **Freezing (fresh) swordfish longliners**: catches of sharks are thought to represent between 40–60% of the total combined catch for all species in these fleets (Ariz et al. 2006; Petersen et al. 2009). The amount of sharks caught by longliners targeting swordfish in the IOTC area of competence has been increasing since the mid 1990s, with catches of sharks recorded for these fleets thought to be more realistic than those recorded for other longline fisheries. The high catch levels are thought to be due to:

  – **Gear configuration and time fished**: vessels targeting swordfish use surface longlines and set the lines at dusk or during the night. Many pelagic sharks are thought to be abundant at these depths and most active during dusk or night hours.

  – **Area fished**: fleets targeting swordfish have been deploying most of the fishing effort in the Southwest Indian Ocean, in the vicinity of South Africa, southern Madagascar, Reunion and Mauritius. High amounts of sharks are thought to occur in these areas.

  – **Changes in the relative amounts of swordfish and sharks in the catches**: some vessels are known to alternate between targeting swordfish and sharks (particularly blue sharks) depending on the season, or when catch rates of swordfish are poor.

- **Industrial tuna purse seiners**: catches of sharks are thought to represent less than 0.5% of the total combined catch for all species and vary according the type of school association (Amandè et al. 2012; Fonteneau et al. 2013; Clavareau et al. 2020). Limited nominal catch data have been reported for the purse seine fleets but a large amount of information is available from observations of discards at sea (Ruiz et al. 2018; Grande et al. 2019).

- **Trolling fisheries**: the majority of fisheries trolling in the Indian Ocean operate in coastal waters, so the amounts of pelagic sharks caught are thought to be low. The proportion of the total catch of tuna and tuna-like species that other species of shark make up might change depending on the area fished and the time of day.

Species-specific trends (1950-2019)

The resolution of the nominal catch data of sharks and rays has improved over time. The proportion of reported catches identified to species or genus level has steadily increased since the 1980s to reach more than 43% in 2019 (**Fig. 6**). In 2018 there was a large reduction in the percentage of shark catch data reported as aggregated compared with the previous years (2016-2017) during which India reported more than 20,000 t of aggregated sharks annually. In 2019, more than 15,000 t of unclassified shark species were again reported to have been caught in the gillnet and line fisheries of India.

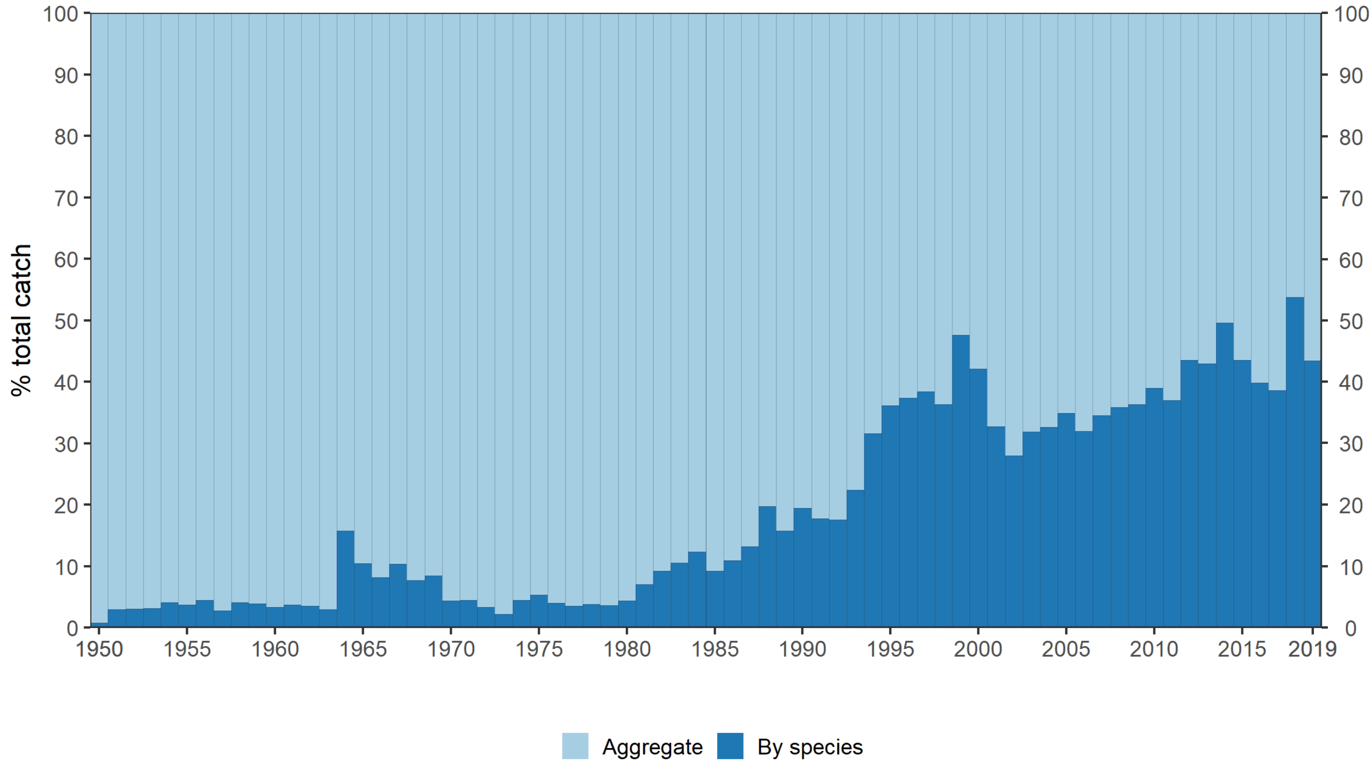


Figure 6: Annual percentage of shark and ray catches reported as aggregated or by species

Of the 53 shark and ray species reported at the species level (Appendix A), blue shark (BSH) forms the greatest proportion, comprising about 62% of catches during 1950-2019. Over the entire period covered by the time series, silky shark (FAL) and shortfin mako shark (SMA) represented 23% and 5% respectively of total sharks and rays catches reported at species level, with all remaining species combined contributing to a very small percentage overall. When shark species reported at the genus level are considered, i.e. by including catches reported for the codes SPN (standing for *Sphyrna* spp.), THR (for *Alopias* spp.), and MAK (for *Isurus* spp), the overall contribution of blue shark decreases to 50% over the period. The genera *Sphyrna* (SPK, SPL, SPN, SPZ), *Alopias* (ALV, BTH, PTH, THR), and *Isurus* (MAK, SMA, LMA) represent 10%, 9%, and 8% of the total shark and ray catches reported at species and genus level, respectively (**Fig. 7**).

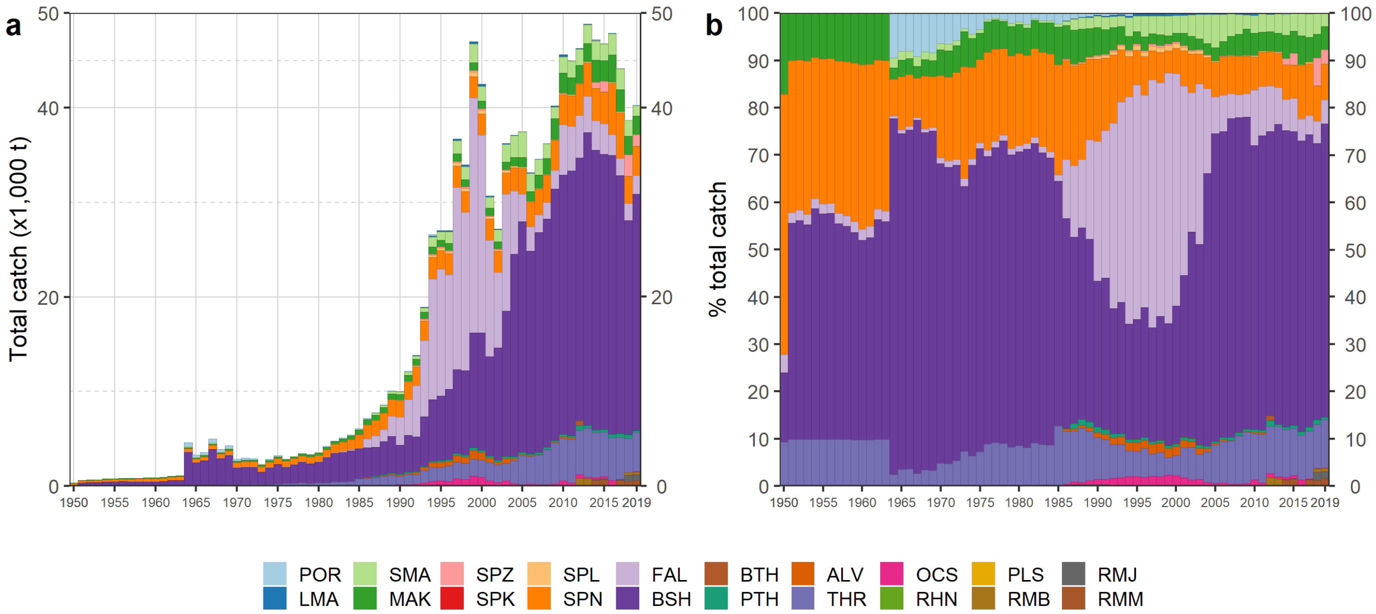


Figure 7: Annual time series of nominal absolute (a) and relative (b) catches of sharks and rays in metric tons (t) by species for the catch component of the main sharks and rays reported at species and genus level for the period 1950–2019

The temporal species-specific trends in annual nominal catches of sharks and rays reported to the Secretariat strongly differ between species (**Fig. 8**). Blue shark shows a steady increase in reported catches from the early 1950s, exceeding 30,000 t in 2013 before showing a drop to about 25,000 t in 2019. It is noteworthy that the catches of BSH are predominantly reported by coastal longliners of Indonesia which are estimated by the Secretariat from the total reported catches of sharks by applying an average species composition derived from historical literature and catch samples (White 2007; Moreno et al. 2012). A similar temporal trend observed in the nominal catch series of silky shark (FAL), oceanic whitetip shark (OCS), common thresher (ALV), scalloped hammerhead (SPL), and longfin mako (LMA) is driven by the Sri Lankan longline-gillnet fisheries. For these species, catches show an increasing trend from the early 1990s that reached a peak in 1999, before showing a steady decline in relation to the adoption of management measures imposing the requirement for fins to be landed with the shark carcasses (Herath 2012).

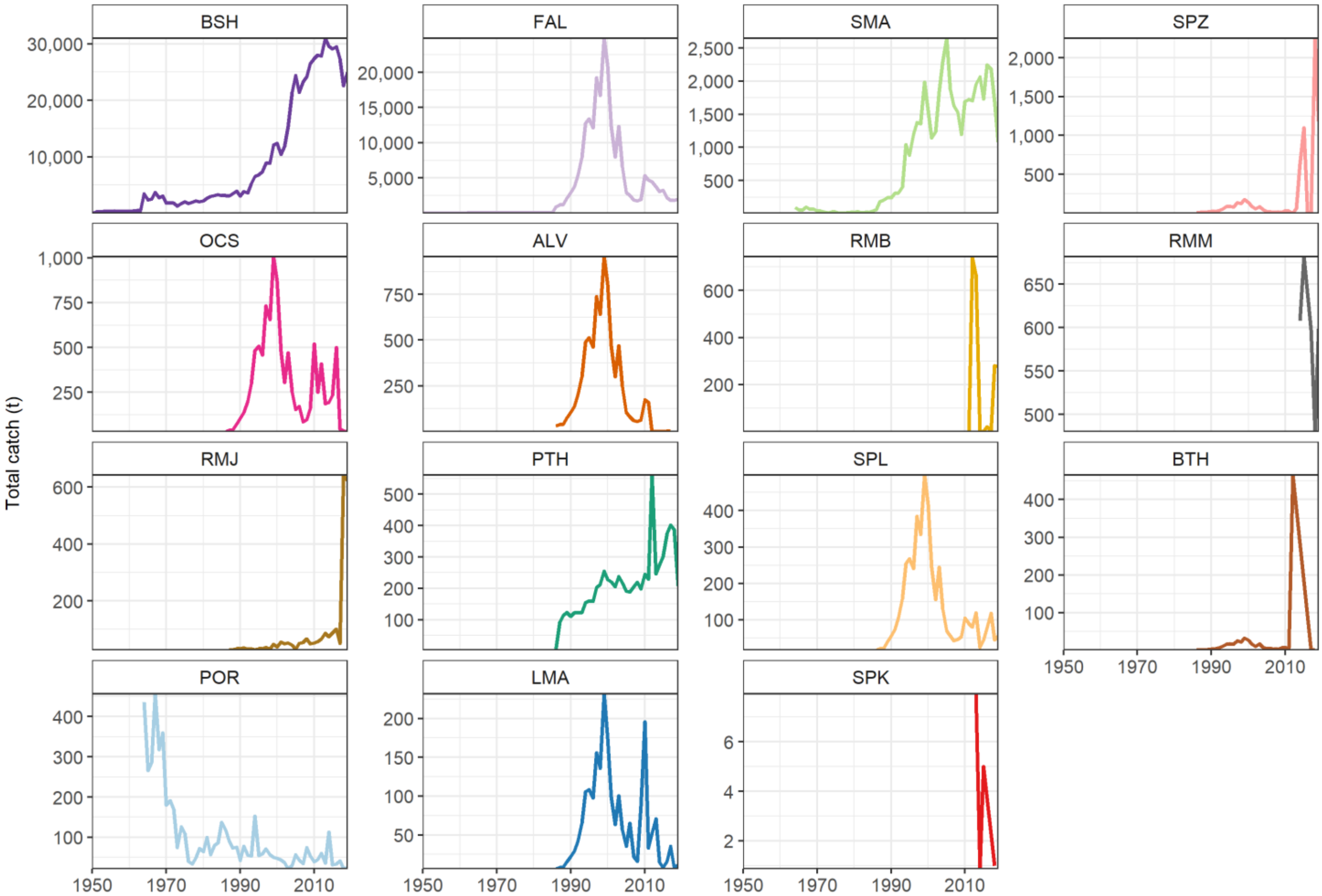


Figure 8: Total nominal catches (t) of the main sharks and rays reported at species level for all fleets (1950-2019)

Longline fleets reported predominantly blue shark catches, followed by mako and silky sharks, with catches of handline gears also being dominated by blue shark, followed by thresher sharks. Purse seine catches are dominated by silky shark while troll lines reported relatively high catches of hammerhead sharks. Reporting by species is very uncommon for gillnet fleets, where the majority of shark catches are reported as aggregates.

Recent fishery features (2015-2019)

Most tuna and tuna-like fisheries of the Indian Ocean show a decline in the catches of shark and ray species reported to the IOTC in recent years, with particularly low levels of nominal catches of sharks and rays reported by India for 2018 for their gillnet, line, and purse seine fisheries operating in Indian coastal waters. The decrease observed in gillnet nominal catches of sharks and rays during 2015-2019 concerns most gillnet fisheries, with the exception of Yemen and Tanzania for which catches in recent years have been repeatedly estimated to be at the same constant levels in absence of data officially reported to the Secretariat (**Fig. 9a**). Catches from line fisheries, dominated by Indonesia, and catches from longline fisheries also show a decrease between 2015 and 2019 (**Fig. 9b,d**).

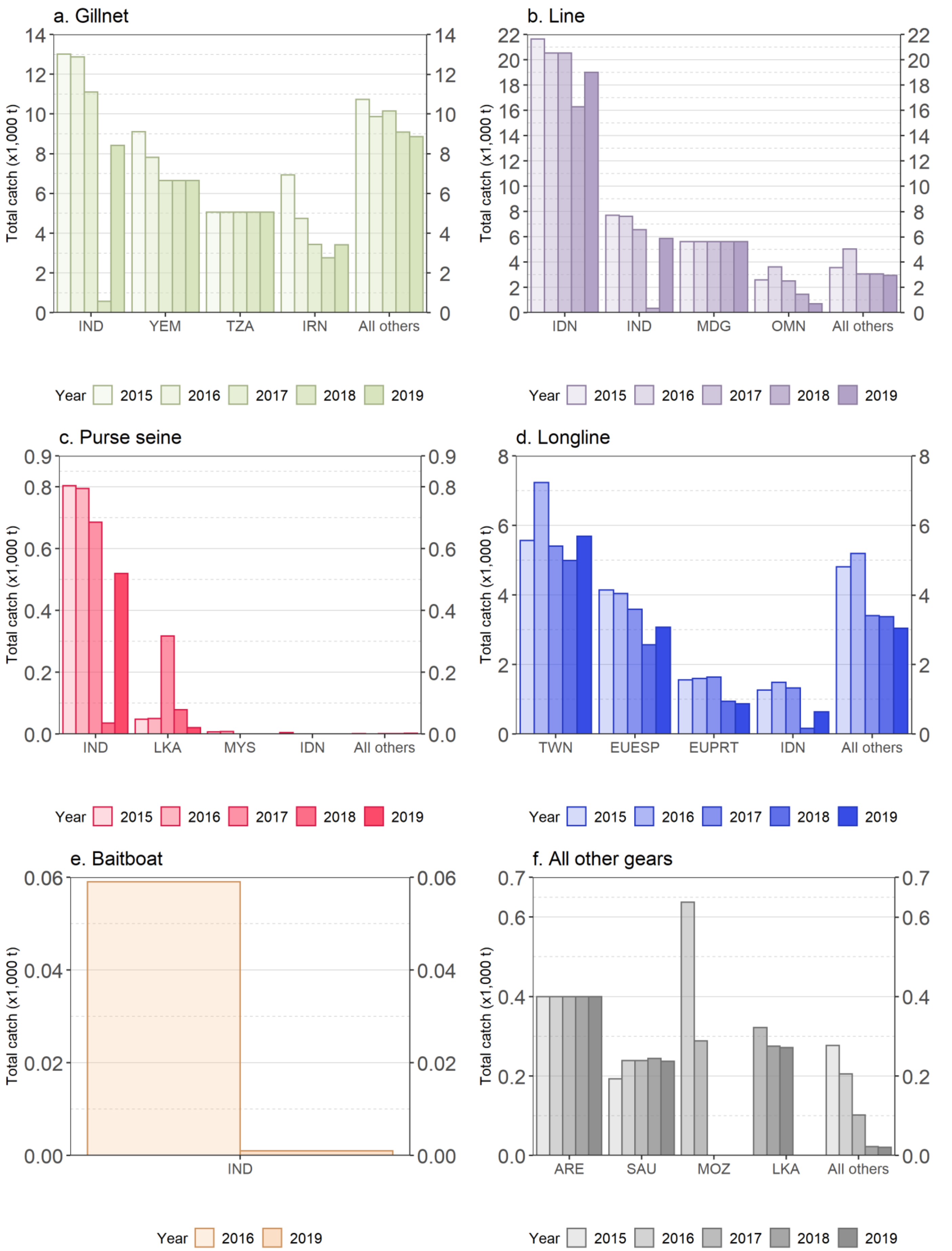


Figure 9: Annual catch trends of shark and ray species by fishery group in metric tons (t) between 2015 and 2019

During 2015-2019, Indonesian fisheries contributed an average of about 25% of total retained catches of sharks and rays, with a mean annual catch of about 22,000 t mainly caught by coastal longliners (**Fig. 10**). India also accounts for relatively high levels of catches of sharks (15,000-23,000 t per year, excluding 2018) which were mainly caught with gillnets and trolling lines. Nominal catches of sharks from the coastal fisheries of Yemen and Tanzania (gillnets, hand lines and trolling lines) are also thought to be important although highly uncertain.

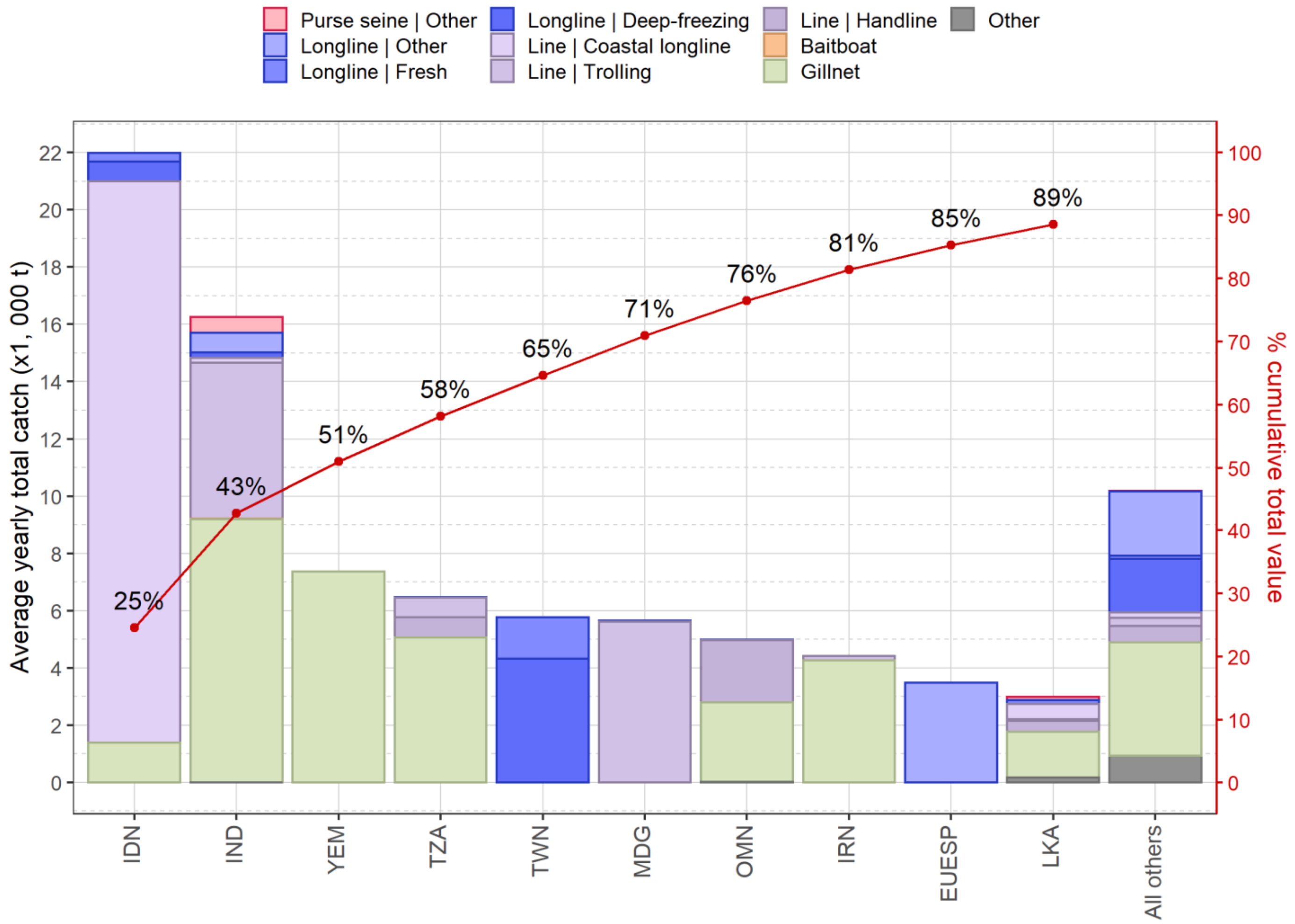


Figure 10: Mean nominal catches (t) of sharks and rays over the period 2015–2019, by fishery and fleet ordered according to the importance of catches. The solid line indicates the cumulative percentage of the total combined catches of the species for the fleets concerned

Discarding practices

In the absence of data on total discard for most fisheries (see section Uncertainties in catch data), information on discarding practices can be inferred from observer data collected by the ROS programme. The distribution of shark interactions with pelagic longline fisheries, as available through the ROS data for the period 2009-2019 only covers a small part of the longline fishing grounds (**Fig. 11**). This is mainly due to the non-availability of observer data (in a format suitable for analysis) from major longline fisheries such as Taiwan,China, China, EU,Spain, EU,Portugal, Seychelles, and Korea as well as an almost complete lack of observer data from minor longline fisheries. 8% of the interactions in this data set refers to species reported in aggregate form (e.g., “various sharks NEI”). Furthermore, information on fate and condition at release is lacking for more than 8% and 3% of the records, respectively.

The species composition of the longline catch appears to vary between the western and eastern parts of the Indian Ocean, with blue shark dominating the catches in all areas (**Fig. 11a**). Most sharks are discarded at sea and the fate of the species seems to depend on the fishery and fishing grounds, with most sharks discarded around Reunion Island and Madagascar and in the eastern Indian Ocean to a lesser extent, while most sharks were retained when fishing occurred in the waters off South Africa (**Fig. 11c**). Information collected by the observers on the condition at release indicates that about 75% of all sharks discarded at sea were alive: little information is known about post-release survival rates in Indian Ocean longline fisheries but experiments conducted in other oceans with satellite tags have shown that the mortality of the most common sharks discarded at sea varies around 15-20% (Musyl and Gilman 2018; Schaefer et al. 2021).

Pelagic stingray largely dominates the longline catches of rays by contributing to 99% of all interactions with rays observed at sea (**Fig. 11b**). A very large majority of them are reported to have been discarded at sea with less than 50% of the individuals being released alive (**Fig. 11d**).

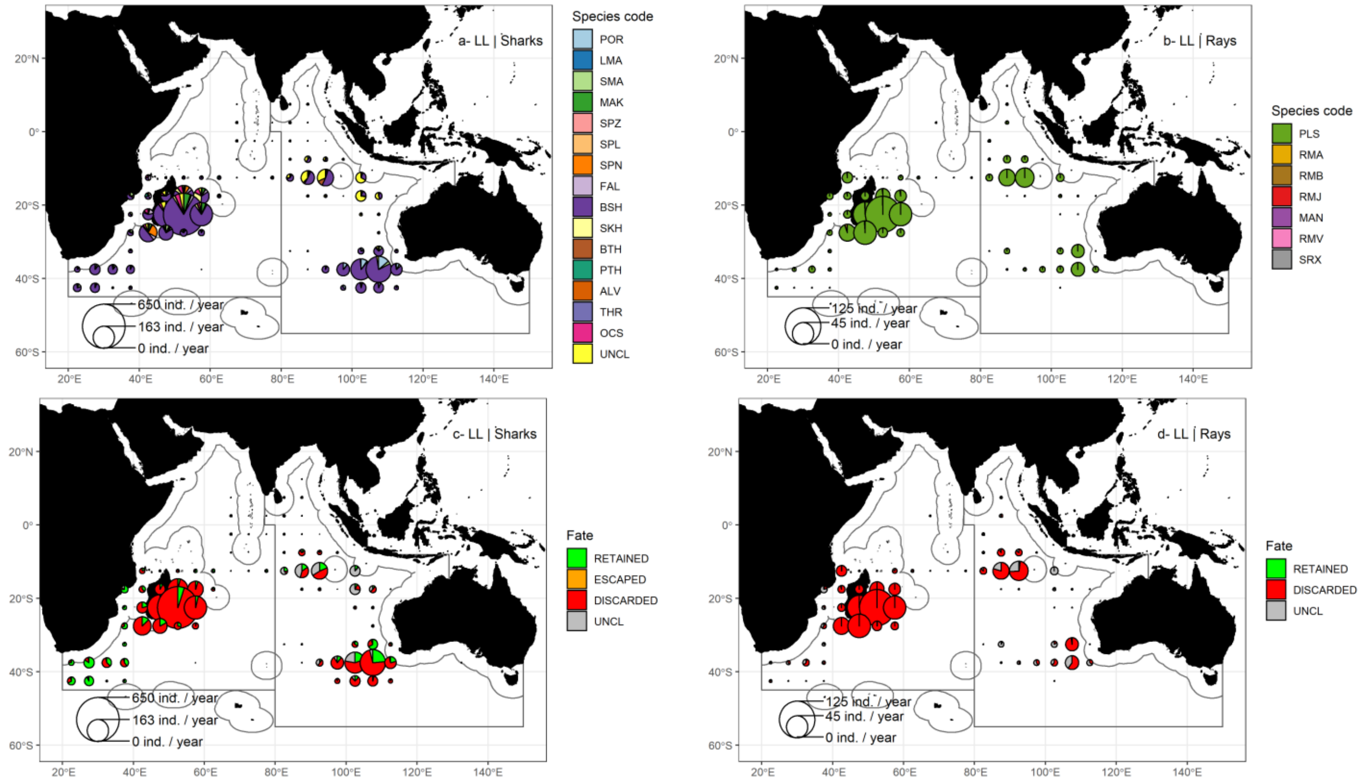


Figure 11: Mean annual number of shark and ray interactions (numbers of individuals per year) with deep-freezing longline fisheries by species (a & b) and fate (c & d) as reported to the Secretariat during the period 2009-2019

Observer data collected onboard purse seiners show the large dominance of silky shark in shark interactions for the fishery, representing 97% of all interactions recorded in the data available to the Secretariat for the period 2005-2019 (**Fig. 12a**). Oceanic whitetip shark comes second with 771 observations of occurrence in the purse seine catches, i.e. about 1.5% of all shark interactions, while most reports of bycatch of bull shark are due to errors of species identification. Most sharks are discarded at sea (**Fig. 12c**) following the guidelines of best practices developed over the last decade by the fishing companies (Poisson et al. 2014a; Grande et al. 2019). The overall mortality rate of silky sharks caught with purse seine in the Indian Ocean has been estimated to be at around 80%, including a mortality rate of about 50% for the sharks released alive at sea (Poisson et al. 2014b).

Overall, few interactions with rays are observed in the purse seine fishery (**Fig. 12b**) and almost all rays are discarded at sea (**Fig. 12d**). As for longline, pelagic stingray is the dominant species with a total of 162 interactions reported. Among the pelagic stingrays for which the condition at release was known and recorded, the percentage of dead individuals was more than 60%, an apparent mortality rate (i.e. excluding the additional mortality after release) consistent with that reported for this species from a larger observer data set collected onboard the EU and associated purse seine fishery (Clavareau et al. 2020). Purse seine interactions with mobulid rays, i.e. devil fish (RMA), giant manta (RMB), Alfred manta (RMA), and Chilean devil ray (RMT), also occur in the Indian Ocean (Martin 2020), with an apparent mortality of about 35% among the 188 mobulid rays reported with a known condition at release.

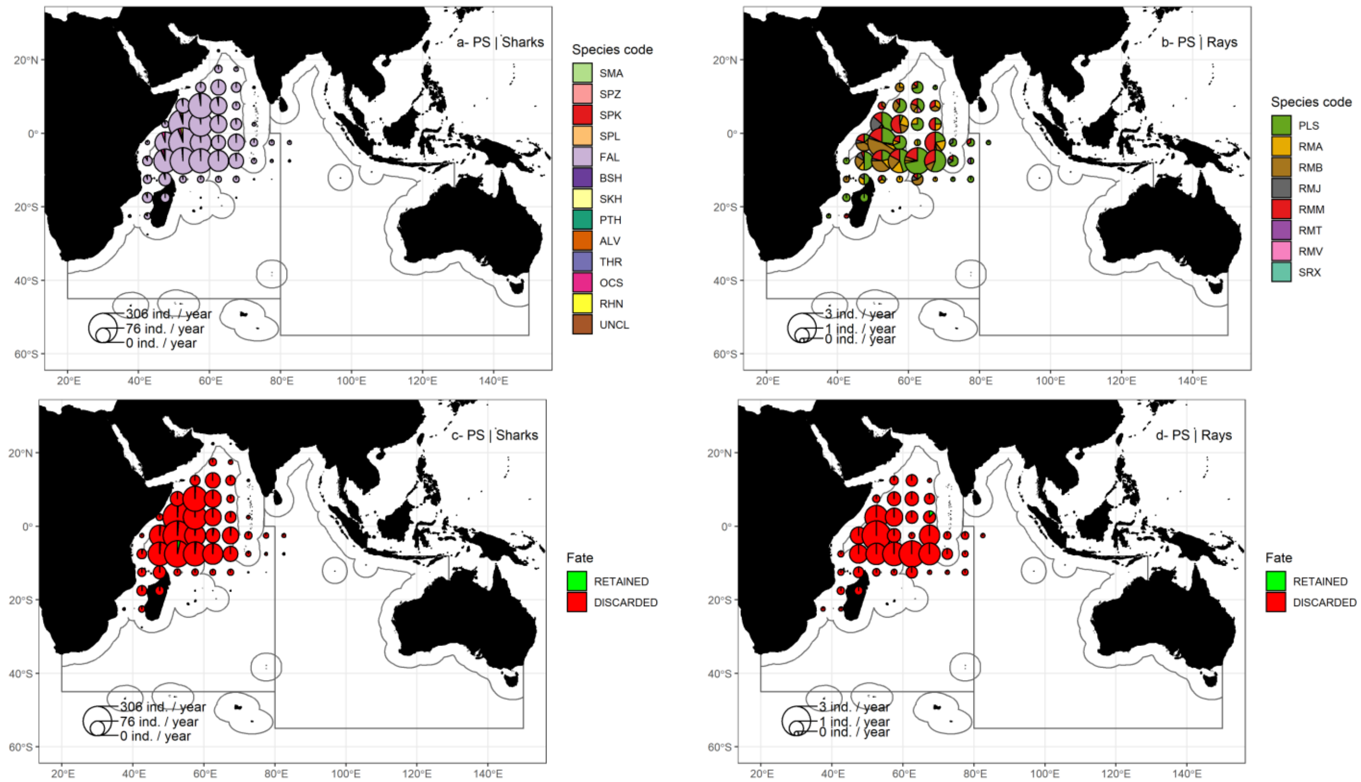


Figure 12: Mean annual number of shark and ray interactions (numbers of individuals per year) with large-scale purse seine fisheries by species (a & b) and fate (c & d) as reported to the Secretariat during the period 2005-2019

Size composition of the catch

There are two major reporting sources of size data for sharks and rays: (1) length/weight data by species, type of fishery and 5 degree grid area and month strata as per IOTC Res. 15/02 to be reported according to the IOTC guidelines and through the recommended form 4SF and (2) length/weight data collected through the Regional Observer Scheme programme (Res. 11/04). Size data can be collected at sea by fishermen or observers and at landing sites by staff from research institutions or the industry. No size data derived from the analysis of pictures or videos collected with Electronic Monitoring systems is currently available to the IOTC Secretariat. It is worth recalling that Res. 15/02 states that *"size data for longline fleets may be provided as part of the Regional Observer Scheme where such fleets have at least 5% observer coverage of all fishing operations"*. Size data collected by observers may then be reported twice to the Secretariat, although at different levels of spatio-temporal resolution, i.e. once per year, aggregated by month and grid in the standard annual submissions and when available, through the more detailed ROS data sets (by day / hour and exact location of capture).

The number of size samples for sharks and rays reported according to Res. 15/02 greatly varies between species, fisheries, and fleets, with 19% of available size data collected by observers at sea. Blue shark, which are mainly caught with longline, represent 81% of all size samples (n = 226,615). About 15,000 size samples are available for shortfin mako and silky shark while the number of samples decreases dramatically for the other shark species and almost no size sample is available for rays (**Table 4**). Also, a total of 18,929 samples have been reported for species groups (SKH, MSK, MAK, THR), which is of limited use when the species composition of the aggregates is unknown.

Table 4: Total number of fish size samples collected as per Res. 15/02 and reported at species level for shark and ray species covering the period 2005-2019 through IOTC forms 4SF or equivalent. Only species with more than 20 samples are shown. N_STD = number of samples collected by fishermen or enumerators at landing; N_OBS = number of samples collected by observers)

Species code	Species name	Initial year	Final year	N_STD	N_OBS	N_TOT	%
BSH	Blue shark	2005	2019	181,290	45,325	226,615	80.7
SMA	Shortfin mako	2005	2019	11,221	4,189	15,410	5.5

Species code	Species name	Initial year	Final year	N_STD	N_OBS	N_TOT	%
FAL	Silky shark	2005	2019	14,596	600	15,196	5.4
POR	Porbeagle	2007	2019	623	1,874	2,497	0.9
CCL	Blacktip shark	2007	2019	473	0	473	0.2
OCS	Oceanic whitetip shark	2007	2019	232	233	465	0.2
BLR	Blacktip reef shark	2007	2017	335	0	335	0.1
PLS	Pelagic stingray	2013	2018	163	56	219	0.1
BTH	Bigeye thresher	2005	2019	81	97	178	0.1
PTH	Pelagic thresher	2013	2018	144	9	153	0.1
PSK	Crocodile shark	2007	2017	8	127	135	0.0
SPL	Scalloped hammerhead	2007	2019	88	4	92	0.0
SPZ	Smooth hammerhead	2016	2018	64	2	66	0.0
DUS	Dusky shark	2015	2015	56	0	56	0.0
LMA	Longfin mako	2007	2019	2	36	38	0.0

For the shark species with a substantial sample size, the fork length distributions show strong variability and spikes for some fisheries, particularly for the data collected for blue shark caught by longline fisheries other than deep-freezing and “fresh,” i.e., those targeting swordfish and sharks (**Fig 13**). Size data from deep-freezing longliners are consistent between observer and non-observer data for both blue shark (BSH) and porbeagle (POR), indicating a median fork length of about 170 cm (i.e., ~30.7 kg) and 90 cm (i.e., ~9.2 kg), respectively (**Fig 13a-b**). Blue shark caught by coastal longliners of Sri Lanka and Indonesia are dominated by small sharks, mostly of less than 150 cm in fork length and described by a median fork length of about 120 cm (~10 kg) (**Fig 13a**).

Size data collected for shortfin mako (SMA) by observers onboard deep-freezing longliners show a distribution described by a median fork length of 177.5 cm, which is larger than the median of the sizes collected by other enumerators (162 cm) (**Fig 13c**). Spatial information shows that most observer samples for this species come from southern latitudes (south of 20°S) while the other size data mainly come from the central and south western Indian Ocean, which might explain the differences in distributions and suggest some size-dependent variability in the spatio-temporal distribution of shorfin mako that needs further investigation.

Finally, size data collected for silky shark (FAL) caught with deep-freezing and fresh longline show quite similar distributions described by a median fork length of about 145 cm (~31.9 kg) (**Fig 13d**). Recent information available for silky sharks (FAL) caught by Sri Lankan coastal longliners and gillnetters shows the sharks are smaller than those caught with longline, with median fork lengths of about 130 cm (~23.2 kg) and 115 cm (~16.2 kg), respectively.

Few data are available at the IOTC Secretariat for silky sharks caught and discarded at sea by purse seiners: those available indicate that measured individuals are all juveniles with a median fork length of about 90 cm (~7.9 kg). This pattern is confirmed by a larger data set (>20,000 fish) collected onboard EU purse seiners during 2005-2017 which indicates that most silky sharks are caught with purse seine when in association with drifting floating objects dominated by FADs (Clavareau et al. 2020).

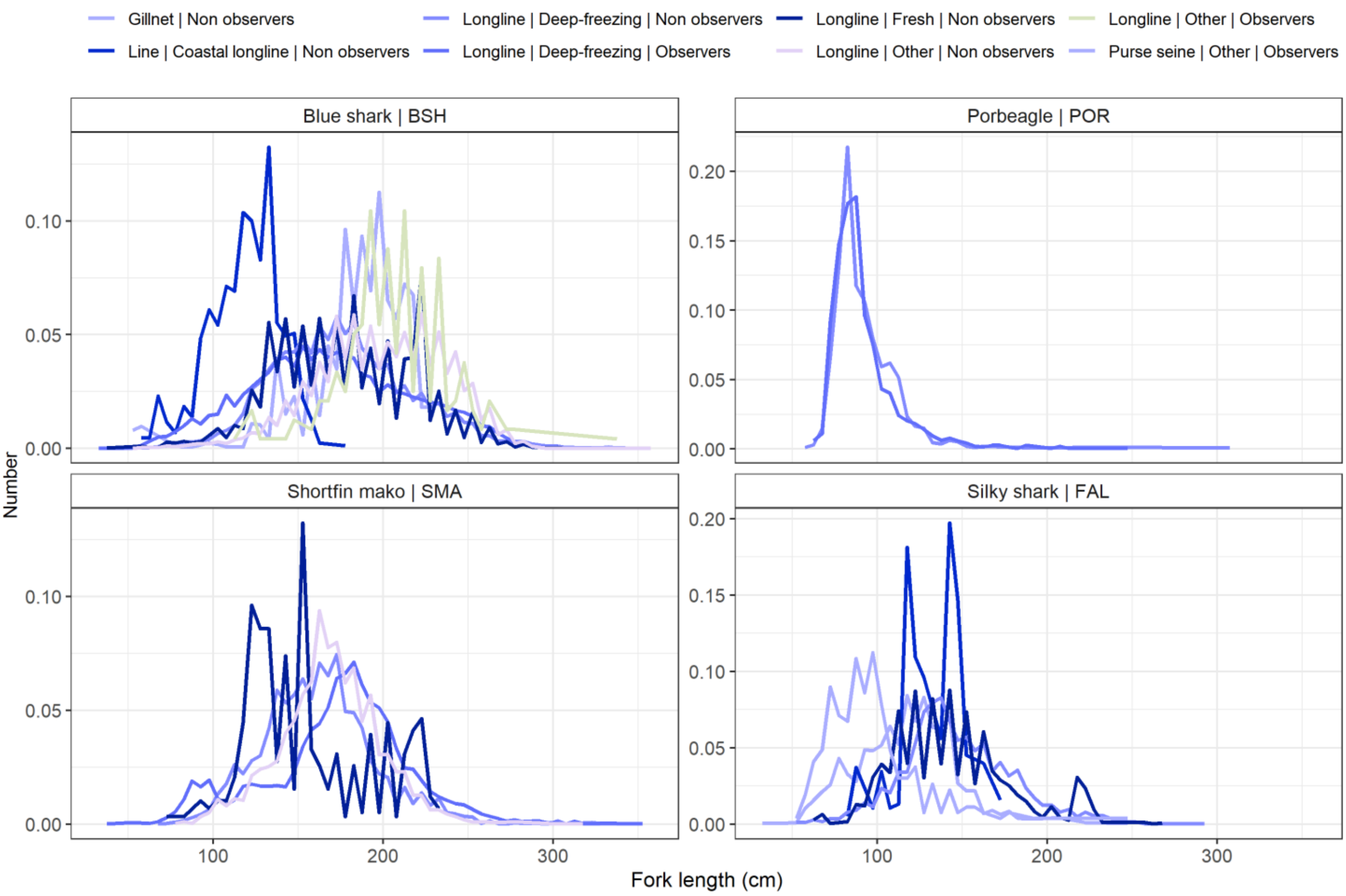


Figure 13: Relative distribution of fork lengths (cm) by 5 cm classes by fishery and source of information (i.e., observers vs. fishermen or enumerators) for the four shark species with more than 200 fish samples by fishery available after conversion of raw size data into fork length when required

There are some major outstanding issues in the reporting of size data:

- Gillnet fisheries of I.R. Iran and Pakistan: to date, I.R. Iran and Pakistan have not reported size frequency data for their gillnet fisheries;
- Longline fisheries of India, Malaysia, Oman: to date, these countries have not reported size frequency data for their longline fisheries. Madagascar reported size frequency data for blue shark and smooth hammerhead shark for 2018 in their longline fisheries;
- Coastal fisheries of India, Indonesia, Madagascar and Yemen: to date, these countries have not reported size frequency data for their coastal fisheries. Madagascar reported size frequency data for blue shark and smooth hammerhead shark for 2018 in their coastal fisheries. Fresh tuna longline fishery: Indonesia have provided size frequency data for sharks for the fresh longline fleet for 2018 based on observer data

Furthermore, the IOTC Secretariat has to use length-age keys, length-weight keys, ratios of fin-to-body weight, and processed weight-to-live weight keys for sharks from other oceans due to the limited amount of biological data available: this situation could be potentially addressed in the medium term to long term with the steady increase in scientific observer data submissions according to ROS standards and requirements.

Spatial information on sharks and rays' catches

Geo-referenced catches of sharks and rays are reported in both number of fish and total weight, and generally represent only a subset of the nominal catches reported by fleet and gear for each species. Due to the general lack of information on the size composition of the catch, these cannot be converted into a common unit and therefore spatial distribution maps of catches are provided both in numbers and in weight. Overall, the distribution of the catches of sharks and rays shows the increasing improvements of data reporting over time, with data becoming available for more shark and ray species from an increasing number of CPCs and fisheries over the last four decades.

During the 1980s and 1990s, most spatial information available on retained catches of sharks and rays came from longliners of Taiwan,China and Korea and from gillnetters of Pakistan (**Figs. 14-15a-b**). All nominal catches reported during the 1980s were aggregated sharks (SKH) while catches started to be reported at species and genus levels throughout the 1990s for blue shark (BSH), oceanic whitetip shark (OCS), silky shark (FAL), shortfin mako (SMA), thresher sharks (THR), and hammerhead sharks (SPN).

During the 2000s, important levels of sharks and rays catches were reported for the handline fishery of Yemen in addition to the catches taken by longline and gillnet fisheries from several other CPCs (**Figs. 15c**). The number of CPCs reporting information on retained catches of sharks and rays increased throughout the 2000s and 2010s as well as the proportion of catch reported at species level (**Figs. 16-17**). In 2019, aggregated species represented less than 10% of the total geo-referenced catches reported in number and less than 20% of the catches reported in weight.

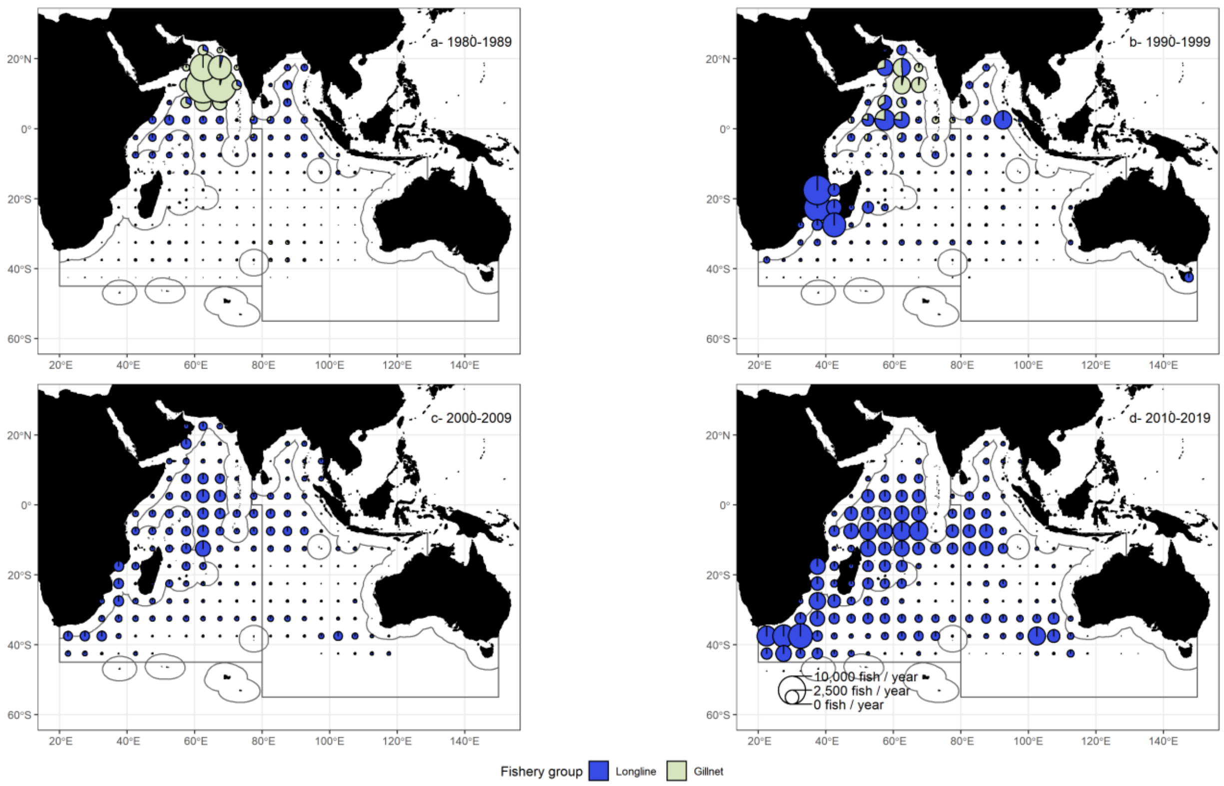


Figure 14: Mean annual retained catches by number of sharks and rays by fishery group and decade reported to the Secretariat covering the period 1980-2019

Figure 15: Mean annual retained catches by weight (t) of sharks and rays by fishery group and decade reported to the Secretariat covering the period 1980-2019

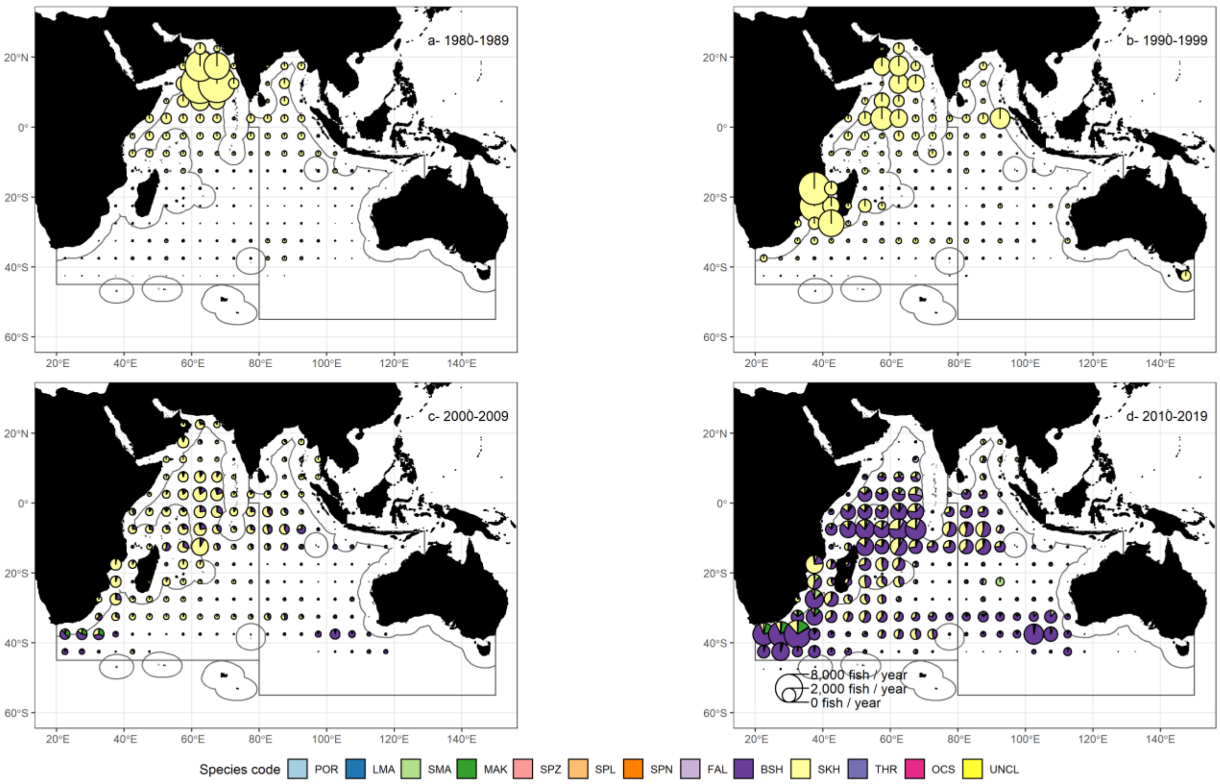


Figure 16: Mean annual retained catches by number of sharks and rays by species and decade reported to the Secretariat covering the period 1980-2019

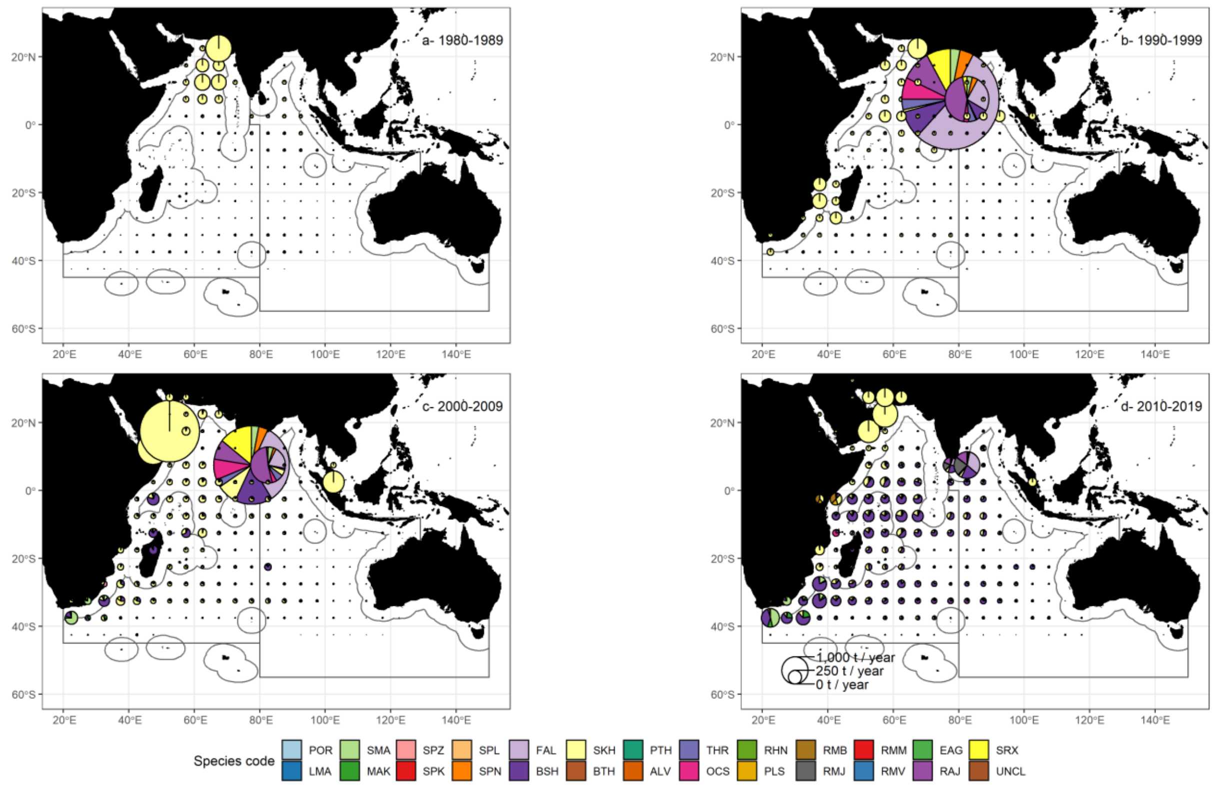


Figure 17: Mean annual retained catches by weight (t) of sharks and rays by species and decade reported to the Secretariat covering the period 1980-2019. Sri Lanka reported high levels of shark catches during the 1990s

Uncertainties in catch and effort data

The estimation of catch and effort for sharks and rays in the Indian Ocean is compromised by the paucity and inaccuracy of the data originally reported by some CPCs.

Unreported catches

Although some fleets have been operating since the early 1950s, there are many cases where historical catches have gone unreported as many countries were not collecting fishery statistics in years prior to the 1970s. It is therefore thought that important catches of sharks and rays might have gone unrecorded in several countries. Also, there still are several fleets not reporting on their interactions with bycatch species, despite data showing that other fleets using similar gears report high catch rates of bycatch species.

Some fleets have also been noted to report distinct catches only for those species that have been specifically identified by the Commission and do not report catches of other species – not even in aggregate form: this creates problems for the estimation of total catches of all sharks and rays and hinders the possibility of further disaggregating catches originally provided as species groups.

Errors in reported catches

For the fleets that do report interactions, there still are several issues with estimates of total volumes of biomass caught. In fact, reported data tend to refer only to retained catches rather than total catches, with discard levels that are often severely under-reported or not available at all. While IOTC Res. 15/02 explicitly calls for the provision of discard data for the most commonly caught elasmobranch species, very little information has been received so far by the Secretariat. To date the EU (Spain, UK), Japan and Taiwan,China, have not provided estimates of total discards of sharks by species for their longline fisheries, although all are now reporting discards in their observer data. As for industrial purse seine fisheries, I.R. Iran, Japan, and Thailand have not provided estimates of total quantities of discards of sharks and rays by species for industrial purse seiners under their flag. EU,Spain and Seychelles are now reporting discards in their observer data and EU,Spain reported total discards for its PS fleet in 2018.

Errors are also introduced by the processing of retained catches undertaken at national level: these create further problems in the estimation of total weight or numbers, as sometimes dressed weight might be recorded instead of live weights. For high levels of processing such as finning, where the carcasses are not retained, the estimation of total live weight is extremely difficult and prone to errors.

Poor data resolution

Historically, shark catches have not been reported by species but simply as an aggregated total. However, the proportion of catches reported by species has increased substantially in recent years (see section Historical trends in catches (1950-2019)). Mis-identification of shark species is also common and additional data processing might introduce further problems related to proper species identification, requiring a high level of expertise and experience to be able to accurately identify specimens. The level of reporting by gear type is much higher, and catches reported as allocated to gear aggregates are only a small proportion of the total.

Catch and effort data

For all the aforementioned reasons, the geo-referenced catch and effort data sets available at the Secretariat for shark and ray species are of overall poor quality, with very little information available to derive time series of abundance indices that are essential for conducting stock assessments. The main issues vary with gear and fleet:

- **Gillnet fisheries**
  - Driftnet fishery of Taiwan,China (1982–92): data not reported to IOTC standards (no species-specific catches);
  - Gillnet fisheries of Pakistan: revised nominal catch data have been provided from 1987 onward, with species-specific shark data available from 2018 only. However catch and effort data have not been provided for any years;
  - Gillnet fisheries of I.R. Iran: spatially disaggregated catch and effort data are now available from 2007 onwards, although not fully reported to IOTC standards (do not include catches by shark species, which are instead available as nominal catches during the same period);
  - Gillnet fisheries of Oman: data not reported to IOTC standards.

- **Longline fisheries**
  - Historical catches of sharks from major longline fisheries (Japan, Taiwan,China, Indonesia, and Rep. of Korea): data not reported to IOTC standards for years before 2006 (no species-specific catches);
  - Fresh-tuna longline fisheries (Malaysia): data not provided or not reported to IOTC standards. Indonesia has reported catch and effort data since 2018 but the level of coverage is very low with only minor reported catches of blue shark;
  - Deep-freezing longline fisheries (EU,Spain, India, Indonesia and Oman): data not provided or not reported to IOTC standards (for the periods during which these fisheries were known to be active).
- **Coastal fisheries**
  - Coastal fisheries of India and Yemen: data not provided;
  - Coastal fisheries of Oman: data not reported to IOTC standards;
  - Coastal fisheries of Madagascar: data provided since 2018 but with a very low coverage and not reported to IOTC standards;
  - Coastal fisheries of Indonesia: catch and effort data has been reported since 2018 for coastal fisheries but coverage is very low with minor reported catches of some shark and ray species.

Catch estimation process

For some fisheries characterized by outstanding issues in terms of data collection and management, the composition of the catch may be derived from a data processing procedure that relies on constant proportions of the catch assigned to shark species over time (e.g., Moreno et al. 2012). Also, revisions of historical data aimed at estimating species-specific time series of catch may rely on assumptions of constant species composition (e.g. Kai 2021), although more complex approaches exist (Martin et al. 2017). The use of constant catch proportions conceals the variability in catches inherent to changes in abundance and catchability and strongly depends on the original samples used for the processing. Recently, a revision of gillnet catches by Pakistan from 1987-2018 has impacted the mean shark catches of the CPC to the point where these are close to negligible, whereas they previously accounted for the second highest mean annual catch from all CPCs (IOTC 2019).

Marine turtles

Main species and fisheries concerned

Six species of marine turtles have been involved in interactions with pelagic fisheries (**Table 5**). The overall abundance and IUCN status varies by species, ranging from data deficient (flatback turtle) to critically endangered (hawksbill turtle).

Table 5: List of marine turtle species reported to occur in the Indian Ocean with the most recent status of the IUCN Red List

Number	Species code	Species name	Scientific name	IUCN status
1	DKK	Leatherback turtle	*Dermochelys coriacea*	Vulnerable
2	FBT	Flatback turtle	*Natator depressus*	Data deficient
3	LKV	Olive ridley turtle	*Lepidochelys olivacea*	Vulnerable
4	TTH	Hawksbill turtle	*Eretmochelys imbricata*	Critically endangered
5	TTL	Loggerhead turtle	*Caretta caretta*	Vulnerable
6	TUG	Green turtle	*Chelonia mydas*	Endangered

The interaction between marine turtles and IOTC fisheries is likely to be significant only in tropical areas, involving both industrial and artisanal fisheries, notably for:

- Industrial purse seine fisheries, in particular on sets using fish aggregating devices (EU, Seychelles, Mauritius, Korea, Japan, I.R. Iran) (Bourjea et al. 2014; Ruiz et al. 2018);
- Gillnet fisheries operating in coastal waters or on the high seas (Sri Lanka, I.R. Iran, Pakistan, Indonesia) (Gilman et al. 2010; Shahid et al. 2015);
- Industrial longline fisheries operating in tropical areas (China, Taiwan,China, Japan, Indonesia, Seychelles, India, Oman, Malaysia and the Philippines) (Huang 2016).

Status of data on marine turtles' bycatch

Overall, the reported data available on marine turtles caught in the IOTC area of competence are considered to be of low to poor quality, sparse and not standardised. All information related to marine turtles' interactions was extracted from the data currently incorporated in the ROS regional database. Although some CPCs tend to report (limited) information on incidental catches of marine turtles through their national reports, these are not integrated in the present study due to their incompleteness and lack of standardization. It is important to recall that the current version of the ROS database includes only a fraction of the data expected from longline fisheries.

A total of 490 turtle interactions with tuna fisheries were reported through the ROS, with loggerhead (n = 155) and Olive ridley turtles (n = 138) being the most frequent incidentally caught species in longline and purse seine fisheries, respectively (**Table 6**). Only 2 flatback turtles were reported to have interacted with tuna fisheries, notably by the longline fishery of Sri Lanka.

Table 6: Number of turtle interactions by species with longline and purse seine fisheries as reported in the ROS regional database during the period 2006-2019

Fishery group	Species code	Species name	Interactions
Longline	DKK	Leatherback turtle	41
Longline	FBT	Flatback turtle	2
Longline	LKV	Olive ridley turtle	58
Longline	TTH	Hawksbill turtle	13
Longline	TTL	Loggerhead turtle	127
Longline	TTX	Marine turtles nei	19
Longline	TUG	Green turtle	42
Purse seine	DKK	Leatherback turtle	2
Purse seine	LKV	Olive ridley turtle	80
Purse seine	TTH	Hawksbill turtle	40
Purse seine	TTL	Loggerhead turtle	28
Purse seine	TTX	Marine turtles nei	6
Purse seine	TUG	Green turtle	32

The spatial distribution of turtle interactions with longline fisheries is limited to very few areas due to the small size of the longline observer data set while the purse seiner observer data cover the purse seine fishing grounds well (**Fig. 18**). Most turtles were released (as expected) except for a few injured individuals caught by Reunion-based longliners that were brought back to the Kelonia turtles observatory and care center. The survival rate appeared to be lower in longline fisheries (~70%) than in purse seine fisheries (>95%) although data from other longline fisheries are required to confirm this pattern.

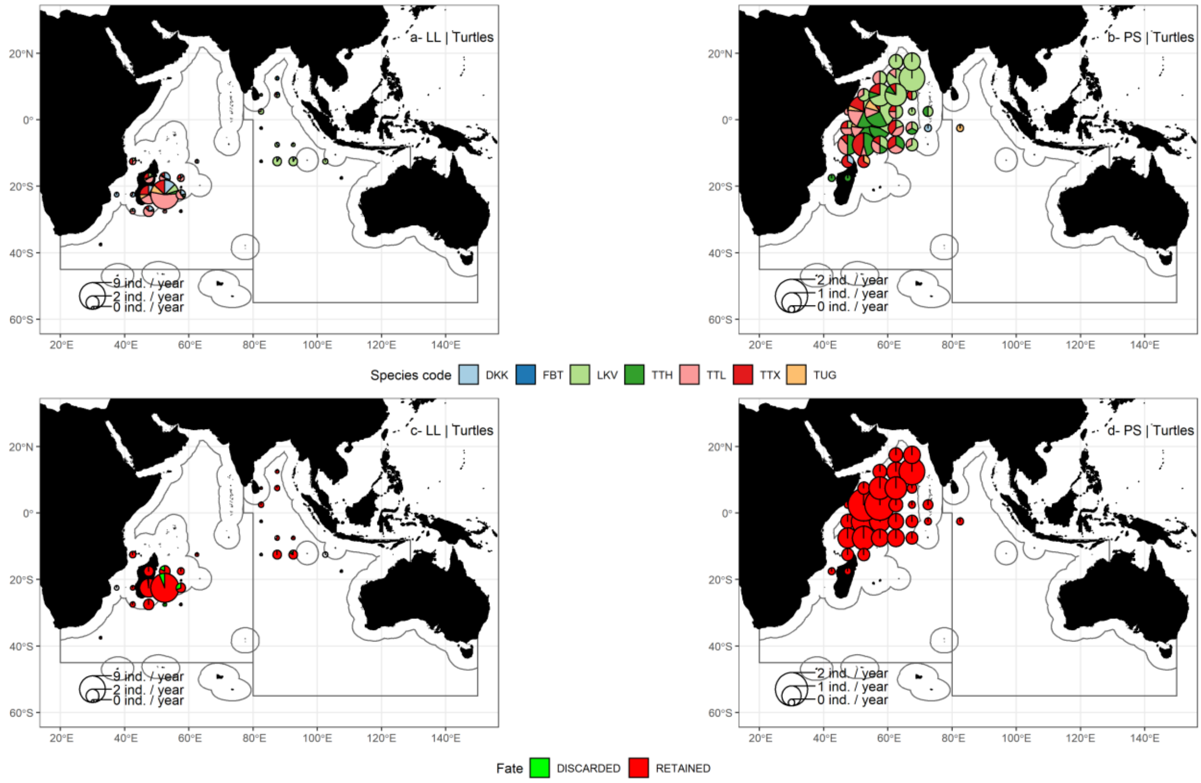


Figure 18: Mean annual number of marine turtle interactions (numbers of individuals per year) with pelagic fisheries by species (a & b) and fate (c & d) as reported to the Secretariat during the period 2005-2019

Incidental catches of marine turtles

- Gillnet fisheries of Pakistan and Indonesia: to date, there have been no reported incidental catches of marine turtles for these gillnet fisheries;
- Longline fisheries of Malaysia, Oman, India, Philippines and Seychelles: to date, these countries have not reported incidental catches of marine turtles for their longline fisheries;
- Purse seine fisheries of Japan, I.R. Iran and Thailand: to date these countries have not reported incidental catches of marine turtles for their purse seine fisheries, including incidental catches of marine turtles on Fish Aggregating Devices. Seychelles provided data on discards of marine turtles from their purse seine fleet for 2018.

While a number of CPCs have been mentioned specifically here, as they have important fisheries or have not provided any information, there are still many CPCs that are providing data that are not consistent with the IOTC minimum reporting standards.

Cetaceans

Data availability and fisheries concerned

Reporting of interactions between IOTC fisheries and cetaceans has been extremely limited to date, and interactions are expected to vary greatly by fishing gear, gear configuration, time-area strata, and environmental conditions. The full lists of whale and dolphin species susceptible to interactions with tuna and tuna-like species fisheries are given in Appendix I. The overall expected levels of interactions are as follows:

- Few interactions occur between purse seine and cetaceans although tuna schools associated with whales could have been targeted prior to the entry in force of IOTC Resolution 13/04 as was the case for schools associated with whale sharks. Those sets represented a small component of all sets and the animals were released alive in most cases (Escalle et al. 2015). Very few cases of dolphin-associated schools have been reported in the Indian Ocean while they are more common in the Pacific Ocean;

- Most interactions between longline and cetaceans stem from the animals being attracted mainly to longlines as a source of food, possibly resulting in incidental entanglement, injury, and mortality (Gilman et al. 2006; Hamer et al. 2012). The extent of these interactions and associated levels of mortality are poorly known although several studies have focused on depredation in the Indian Ocean (Romanov et al. 2013; Munoz-Lechuga et al. 2016);
- Gillnet (or driftnet) is considered to be the main fishing gear responsible for direct mortality of cetaceans through entanglement (Anderson et al. 2020)
- Artisanal fisheries may be responsible for some bycatch of small cetaceans, with different fishing gears involved, including gillnet (Temple et al. 2018)

Status of data on cetaceans' bycatch

A total of 77 cetacean interactions with tuna fisheries has been reported through the ROS (**Table 7**). Most interactions were reported for the fresh pelagic longline fishery of Reunion Island (85% of all observations) and are limited to the south-western Indian Ocean, east of Madagascar (**Fig. 19**). The interactions observed for this fishery were dominated by Risso's dolphins that were all released alive. Overall, 97% of the cetaceans having interacted with the fishery were assessed to be alive at release. Remaining interactions were reported from Japanese longliners operating in the eastern part of the Indian Ocean (9 toothed whales with about 90% of them released alive) while only 2 observations of common dolphins were reported for Sri Lankan longliners without information on their condition at release (**Fig. 19b**).

Table 7: Number of cetacean interactions by species with longline fisheries as reported in the ROS regional database from 2009-2018

Species code	Species name	Scientific name	Interactions
DRR	Risso's dolphin	*Grampus griseus*	53
ODN	Toothed whales nei	*Odontoceti*	11
FAW	False killer whale	*Pseudorca crassidens*	3
HUW	Humpback whale	*Megaptera novaeangliae*	3
DCO	Common dolphin	*Delphinus delphis*	3
SHW	Short-finned pilot whale	*Globicephala macrorhynchus*	2
MIW	Minke whale	*Balaenoptera acutorostrata*	1
DBO	Bottlenose dolphin	*Tursiops truncatus*	1

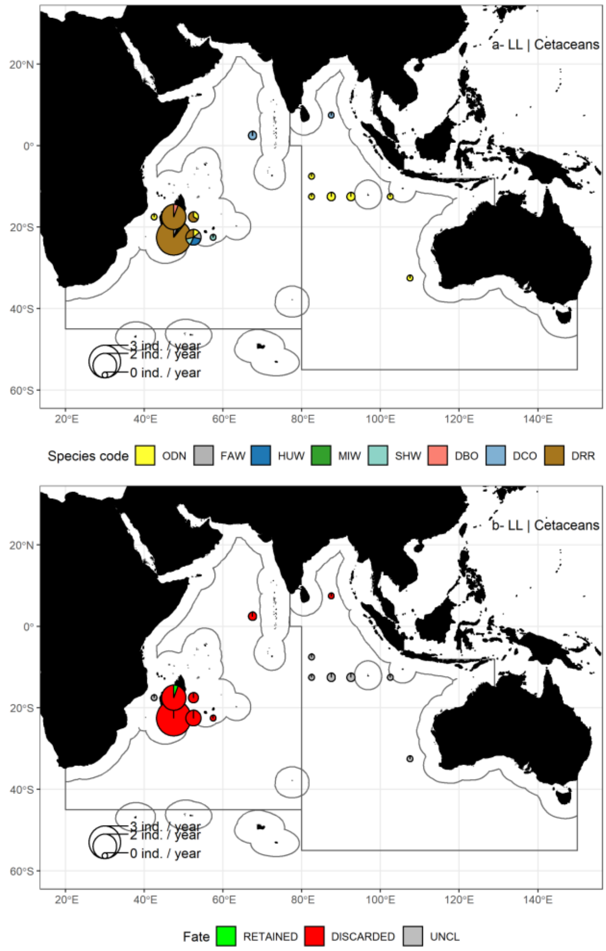


Figure 19: Cetacean interactions (numbers of individuals) with pelagic longline fisheries by species and fate as reported to the Secretariat during the period 2005-2019

Seabirds

Longline vessels fishing in southern waters

The interaction between seabirds and IOTC fisheries is likely to be significant only in southern waters (south of 25°S), an area where most of the effort is exerted by longliners (ACAP 2007). Spatial information available on longline fishing effort shows the dominance of vessels from Japan and Taiwan,China in this area since the mid-1950s, with a progressive decline in the effort exerted by the Japanese fleet since the mid-2000s and an increased effort of the Taiwan,China fleet starting from the 2010s (**Fig. 20**). In recent years (2017-2019), Taiwan,China represented about 70% (~80 million hooks) of the total reported longline effort of about 115 million hooks deployed annually in southern waters.

With more than 11 million hooks deployed annually, Japanese longliners contribute to about 10% of the total effort while the fleets of China, Seychelles, EU,Spain, and Malaysia deploy between 2.8 and 7.3 million hooks annually. The fishing effort might actually be incomplete for some reporting fleets while a number of other longline fleets may also operate in this area as suggested by the presence of temperate species in their catch data (e.g., Indonesia).

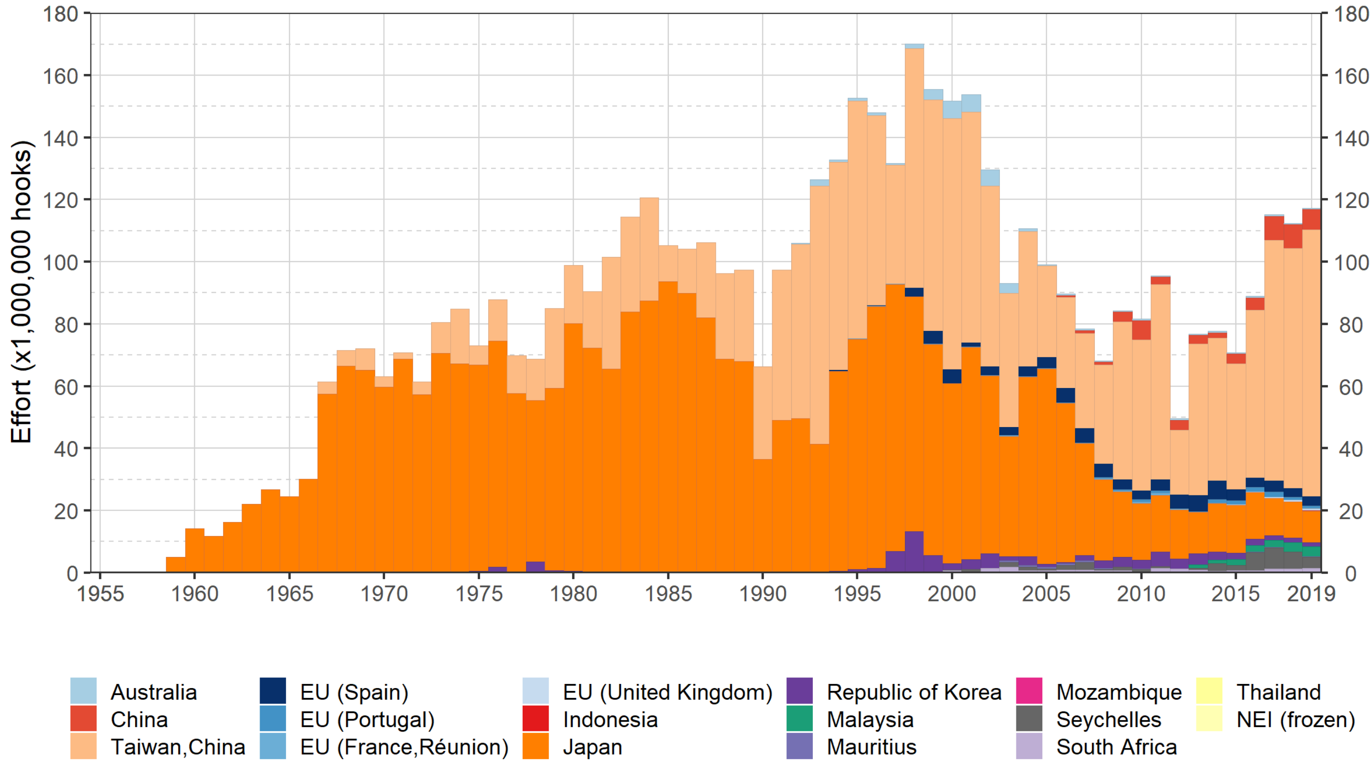


Figure 20: Reported longline effort (hooks) for fleets operating south of 25°S between 1955 and 2019

Main species concerned

Among the 24 species of petrels and albatrosses known to occur in the IOTC area of competence (ACAP 2007), 19 species have been reported to interact with longline fisheries according to the ROS regional database (**Table 8)**. It is important to note that the ROS data set only includes data from Japan over the time period 2012-2016 and no other data of interactions with seabirds have been reported to date using reporting formats suitable for automated data extraction according to the ROS data standards.

In 2016, six CPCs (Australia, EU-Portugal, EU-Spain, EU-France, Japan, Rep. of Korea, Taiwan,China and South Africa) submitted data in response to a call for data submission on seabirds following the dissemination of the IOTC Circular 2016-043 (IOTC 2016). Although some of the interactions with seabirds were reported in aggregate form, 16 species were recorded to have interacted with longline fisheries in the compiled data set covering the period 2009-2015, including six in additional to those available from the ROS (**Table 8)**.

In addition, some CPCs have also reported seabird interactions through their national reports. For instance, Taiwan,China reported a total of 40 interactions with their longline fishery operating south of 25°S for 8 species of seabirds in 2018: black-browed albatross (1), wandering albatross (2), Salvin's albatross (1), light-mantled sooty albatross (1), sooty albatross (7), white-chinned petrel (17), white-capped albatross (5), and yellow-nosed albatross (6). In the same year, Korea reported the incidental catch of three grey-headed albatrosses and one sooty albatross.

Table 8: List of seabird species reported to have interacted with longline fisheries in the Indian Ocean with the most recent status of the IUCN Red List. ROS = Regional Observer Scheme; 2016-043 = IOTC Circular 2016-043

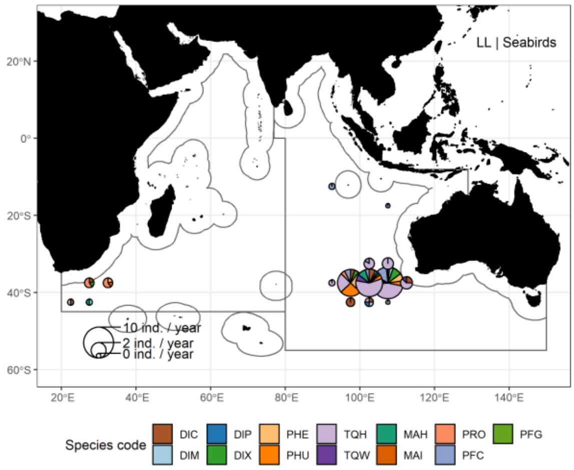
Species code	Species name	Scientific name	IUCN status	Source
DCR	Atlantic yellow-nosed albatross	*Thalassarche chlororhynchos*	Endangered	2016-043
DCU	Shy albatross	*Thalassarche cauta*	Near threatened	2016-043
DIC	Grey-headed albatross	*Thalassarche chrysostoma*	Endangered	ROS
DIM	Black-browed albatross	*Thalassarche melanophris*	Least concern	ROS
DIP	Southern royal albatross	*Diomedea epomophora*	Vulnerable	ROS

Species code	Species name	Scientific name	IUCN status	Source
DIQ	Northern royal albatross	*Diomedea sanfordi*	Endangered	2016-043
DIX	Wandering albatross	*Diomedea exulans*	Vulnerable	ROS
MAH	Hall's giant petrel	*Macronectes halli*	Least concern	ROS
MAI	Antarctic giant petrel	*Macronectes giganteus*	Least concern	ROS
MWE	Cape gannet	*Morus capensis*	Endangered	2016-043
PFC	Flesh-footed shearwater	*Ardenna carneipes*	Near threatened	ROS
PFG	Sooty shearwater	*Ardenna grisea*	Near threatened	ROS
PFT	Short tailed shearwater	*Ardenna tenuirostris*	Least concern	2016-043
PHE	Light-mantled sooty albatross	*Phoebetria palpebrata*	Near threatened	ROS
PHU	Sooty albatross	*Phoebetria fusca*	Endangered	ROS
PRO	White-chinned petrel	*Procellaria aequinoctialis*	Vulnerable	ROS
TQH	Indian yellow-nosed albatross	*Thalassarche carteri*	Endangered	ROS
TQW	Campbell albatross	*Thalassarche impavida*	Vulnerable	ROS
TWD	White-capped albatross	*Thalassarche steadi*	Near threatened	2016-043

Status of data on seabirds' bycatch

The data available on seabirds caught in the IOTC area of competence are generally fairly limited: the information collected through circular 2016-043 highlighted some general trends in seabird bycatch rates across the Indian Ocean, with higher catch rates at higher latitudes – even within the area south of 25°S – and higher catch rates in the coastal areas in the eastern and western parts of the southern Indian Ocean (IOTC 2016). Data also showed that the mortality rates were generally high for most species, and the mean mortality rate across all years and fleets was higher than 70%.

To date, properly structured data on seabird interactions collected as part of the ROS are only available for the Japanese longline fishery: a total of 180 interactions was reported during 2012-2016, with an average of 36 interactions per year and all birds reported as dead, when the information on condition at capture was available. Regarding the overall low observer coverage and very few data currently available on seabird interactions, no estimation of the total bycatch of seabirds from the longline fishery south of 25°S was undertaken.



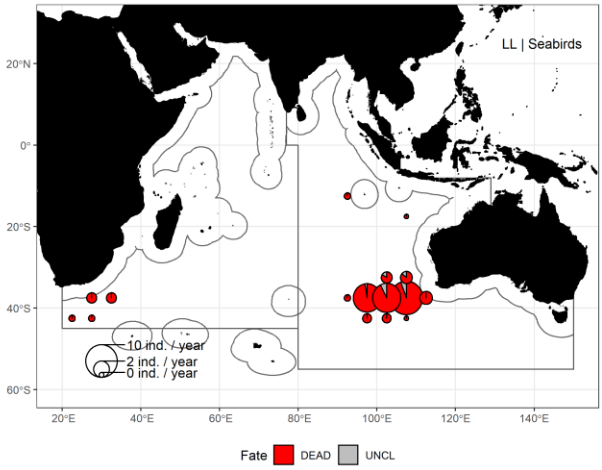


Figure 21: Mean annual number of seabird interactions (number of individuals per year) with deep-freezing longline fisheries by species and fate as reported to the Secretariat during 2012-2016

The longline fisheries of Seychelles, Malaysia, and Mauritius that operate or have operated in areas with high densities of seabirds have not reported incidental catches of seabirds for longliners under their flag.

Other bycatch species categories

The reporting of non-IOTC species other than sharks is extremely poor and where it does occur, this is often in the form of patchy information which is not submitted according to IOTC data reporting procedures, is non-standardized and often lacking in clarity. Formal submissions of data in an electronic and standardized format using the available IOTC templates, in combination with observer data reported in the context of the ROS programme, will considerably improve the quality of data obtained and the type of regional analyses that these data can be used for.

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Appendices

Appendix A: List of bycatch species interacting with tuna fisheries

Table 9: List of shark species reported at species level in the nominal catch data for the period 1950-2019

Number	Species code	Name	Scientific name	IUCN status
1	AGN	Angelshark	*Squatina squatina*	Critically endangered
2	ALS	Silvertip shark	*Carcharhinus albimarginatus*	Vulnerable
3	ALV	Thresher	*Alopias vulpinus*	Vulnerable
4	BLR	Blacktip reef shark	*Carcharhinus melanopterus*	Vulnerable
5	BRO	Copper shark	*Carcharhinus brachyurus*	Vulnerable
6	BSH	Blue shark	*Prionace glauca*	Near threatened
7	BTH	Bigeye thresher	*Alopias superciliosus*	Vulnerable
8	CCB	Spinner shark	*Carcharhinus brevipinna*	Vulnerable
9	CCD	Whitecheek shark	*Carcharhinus dussumieri*	Endangered
10	CCE	Bull shark	*Carcharhinus leucas*	Near threatened
11	CCG	Galapagos shark	*Carcharhinus galapagensis*	Least concern
12	CCL	Blacktip shark	*Carcharhinus limbatus*	Near threatened
13	CCM	Hardnose shark	*Carcharhinus macloti*	Near threatened
14	CCO	Finetooth shark	*Carcharhinus isodon*	Least concern
15	CCP	Sandbar shark	*Carcharhinus plumbeus*	Vulnerable
16	CCQ	Spottail shark	*Carcharhinus sorrah*	Near threatened
17	CCW	Grey reef Shark	*Carcharhinus amblyrhynchos*	Endangered
18	CCY	Graceful shark	*Carcharhinus amblyrhynchoides*	Near threatened
19	CLD	Sliteye shark	*Loxodon macrorhinus*	Least concern
20	CTU	Gummy shark	*Mustelus antarcticus*	Least concern
21	DUS	Dusky shark	*Carcharhinus obscurus*	Endangered
22	FAL	Silky shark	*Carcharhinus falciformis*	Vulnerable
23	GAG	Tope shark	*Galeorhinus galeus*	Critically endangered
24	GAM	Mouse catshark	*Galeus murinus*	Least concern
25	HAY	Lined catshark	*Halaelurus lineatus*	Least concern
26	HCM	Hooktooth shark	*Chaenogaleus macrostoma*	Vulnerable
27	HEE	Snaggletooth shark	*Hemipristis elongata*	Vulnerable
28	LMA	Longfin mako	*Isurus paucus*	Endangered
29	NTC	Broadnose sevengill shark	*Notorynchus cepedianus*	Vulnerable
30	OCS	Oceanic whitetip shark	*Carcharhinus longimanus*	Critically endangered
31	OSF	Zebra shark	*Stegostoma fasciatum*	Endangered
32	OXY	Angular roughshark	*Oxynotus centrina*	Vulnerable

Number	Species code	Name	Scientific name	IUCN status
33	POR	Porbeagle	*Lamna nasus*	Vulnerable
34	PSK	Crocodile shark	*Pseudocarcharias kamoharai*	Least concern
35	PTH	Pelagic thresher	*Alopias pelagicus*	Endangered
36	RHA	Milk shark	*Rhizoprionodon acutus*	Vulnerable
37	RHN	Whale shark	*Rhincodon typus*	Endangered
38	SBL	Bluntnose sixgill shark	*Hexanchus griseus*	Near threatened
39	SCK	Kitefin shark	*Dalatias licha*	Vulnerable
40	SHM	Shark mackerel	*Grammatorcynus bicarinatus*	Least concern
41	SMA	Shortfin mako	*Isurus oxyrinchus*	Endangered
42	SMD	Smooth-hound	*Mustelus mustelus*	Vulnerable
43	SPK	Great hammerhead	*Sphyrna mokarran*	Critically endangered
44	SPL	Scalloped hammerhead	*Sphyrna lewini*	Critically endangered
45	SPZ	Smooth hammerhead	*Sphyrna zygaena*	Vulnerable
46	TFM	Whiskery shark	*Furgaleus macki*	Least concern
47	TIG	Tiger shark	*Galeocerdo cuvier*	Near threatened
48	TRB	Whitetip reef shark	*Triaenodon obesus*	Vulnerable
49	WSH	Great white shark	*Carcharodon carcharias*	Vulnerable

Table 10: List of ray species reported at species level in the nominal catch data for the period 1950-2019

Number	Species code	Name	Scientific name	IUCN status
1	PLS	Pelagic stingray	*Pteroplatytrygon violacea*	Least concern
2	RMB	Giant manta	*Mobula birostris*	Endangered
3	RMJ	Spinetail mobula	*Mobula japanica*	Endangered
4	RMM	Devil fish	*Mobula mobular*	Endangered

Table 11: List of whale species susceptible to interactions with tuna and tuna-like species fisheries in the IOTC area of competence

Number	Species code	Species name	Scientific name	IUCN status
1	BAW	Arnoux's beaked whale	*Berardius arnuxii*	LC
2	BBW	Blainville's beaked whale	*Mesoplodon densirostris*	LC
3	BCW	Cuvier's beaked whale	*Ziphius cavirostris*	LC
4	BDW	Andrews' beaked whale	*Mesoplodon bowdoini*	DD
5	BHW	Hector's beaked whale	*Mesoplodon hectori*	DD
6	BLW	Blue whale	*Balaenoptera musculus*	EN
7	BNW	Longman's beaked whale	*Indopacetus pacificus*	LC
8	BRW	Bryde's whale	*Balaenoptera edeni*	LC
9	BSW	Sherpherd's beaked whale	*Tasmacetus shepherdi*	DD
10	BYW	Gray's beaked whale	*Mesoplodon grayi*	LC
11	CPM	Pygmy right whale	*Caperea marginata*	LC
12	DWW	Dwarf sperm whale	*Kogia sima*	LC
13	EUA	Southern right whale	*Eubalaena australis*	LC
14	FAW	False killer whale	*Pseudorca crassidens*	NT
15	FIW	Fin whale	*Balaenoptera physalus*	VU
16	HUW	Humpback whale	*Megaptera novaeangliae*	LC
17	KIW	Killer whale	*Orcinus orca*	DD
18	KPW	Pygmy killer whale	*Feresa attenuata*	LC
19	MIW	Minke whale	*Balaenoptera acutorostrata*	LC
20	PIW	Long-finned pilot whale	*Globicephala melas*	LC
21	PYW	Pygmy sperm whale	*Kogia breviceps*	LC
22	SHW	Short-finned pilot whale	*Globicephala macrorhynchus*	LC
23	SPW	Sperm whale	*Physeter macrocephalus*	VU
24	SRW	Southern bottlenose whale	*Hyperoodon planifrons*	LC
25	TGW	Ginkgo-toothed beaked whale	*Mesoplodon ginkgodens*	DD
26	TSW	Strap-toothed whale	*Mesoplodon layardii*	LC

Table 12: List of dolphin species susceptible to interactions with tuna and tuna-like species fisheries in the IOTC area of competence

Number	Species code	Species name	Scientific name	IUCN status
1	CMD	Commerson's dolphin	*Cephalorhynchus commersonii*	LC
2	DBO	Bottlenose dolphin	*Tursiops truncatus*	LC
3	DCO	Common dolphin	*Delphinus delphis*	LC
4	DDU	Dusky dolphin	*Lagenorhynchus obscurus*	LC
5	DHI	Indo-Pac. hump-backed dolphin	*Sousa chinensis*	VU
6	DPN	Pantropical spotted dolphin	*Stenella attenuata*	LC
7	DRR	Risso's dolphin	*Grampus griseus*	LC
8	DSI	Spinner dolphin	*Stenella longirostris*	LC
9	DST	Striped dolphin	*Stenella coeruleoalba*	LC
10	FRD	Fraser's dolphin	*Lagenodelphis hosei*	LC
11	HRD	Hourglass dolphin	*Lagenorhynchus cruciger*	LC
12	IRD	Irrawaddy dolphin	*Orcaella brevirostris*	EN
13	RSW	Southern right whale dolphin	*Lissodelphis peronii*	LC
14	RTD	Rough-toothed dolphin	*Steno bredanensis*	LC