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

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Abstract

The document provides an overview of the consolidated knowledge about fisheries catching swordfish (*Xiphias gladius*) 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 quality of the total retained catches of swordfish is considered to be good and overall the best among the five billfish species under IOTC mandate. The available fisheries statistics show that swordfish are mostly caught in both large-scale and coastal longline fisheries although gillnet fisheries have increased their catches over the last decade. Catches of large-scale longline fisheries have shown a steady decrease since 2004 while longline catches from the areas of national jurisdiction of Sri Lanka and India to a lesser extent have sharply increased since 2010. Information available on discarding practices collected through the IOTC Regional Observer Program shows that discarding in longline fisheries is mostly driven by size in some fleets. Discarding in coastal fisheries interacting with the species is poorly known but considered to be negligible. Information available on the spatial distribution of catch and effort has substantially improved over the last decade, particularly for coastal fisheries. Consolidated data show that swordfish are caught across all the Indian Ocean although the main fishing grounds appear to be located in the western Indian Ocean and around the coasts of Sri Lanka and India. Recent fisheries statistics, indicated catches of swordfish in the Aden Gulf. The reporting of size-frequency data has improved in recent years, particularly thanks to the data reported for the longline fisheries of Sri Lanka and Seychelles.

Keywords: billfish | swordfish | Indian Ocean | tuna fisheries

Introduction

Swordfish (*Xiphias gladius*) is the most widely distributed species of billfish, occurring in tropical, subtropical, and temperate waters throughout the world oceans. Information available from tuna Regional Fisheries Management Organisations (tRFMOs) shows the major increase in the global catch of swordfish that took place between the 1950s and 2000s when it reached a plateau at around 100,000 t (**Fig. 1a**). After a decline observed during 2008-2011 due to piracy threat in the Indian Ocean, catches of swordfish increased and peaked at about at 110,000 t during 2015-2016, before showing a strong decrease in recent years to reach about 80,000 t in 2021, the decline occurring in all oceans. The Indian Ocean represents a major fishing ground for swordfish and has contributed to about one third of the global swordfish catch during 2017-2021 (**Fig. 1b**).

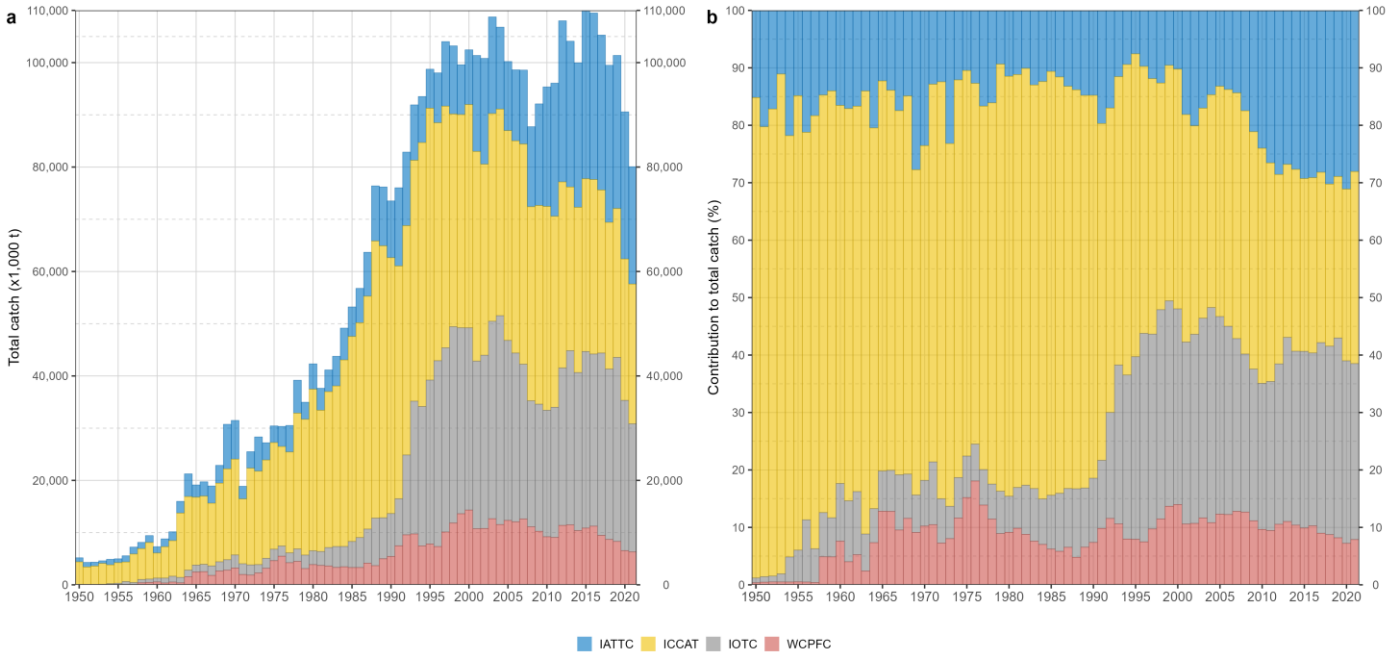

Figure 1: Annual time series of cumulative retained catches (metric tonnes; t) of swordfish by tuna Regional Fisheries Management Organisation for the period 1950-2021. IATTC = Inter-American Tropical Tuna Commission; ICCAT = International Commission for the Conservation of Atlantic Tunas; IOTC = Indian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

The overarching objective of this paper is to provide participants in the data preparatory meeting of the 21st Session of the IOTC Working Party on Billfish (WPB21) with a review of the status of the information available on swordfish in the Indian Ocean through temporal and spatial trends in catches and their main recent features, as well as an assessment of the reporting quality of the data sets. A full description of the data collated and curated by the Secretariat is available in IOTC (2023).

Total retained (nominal) catch

Historical trends (1950-2021)

Catches reported for Indian Ocean swordfish showed a sharp increase in the 1990s linked to the expansion of the high-seas longline fisheries combined with the development of several smaller-range longline fisheries targeting swordfish for the fresh market (**Figs. 2-4** and **Table 1**). Catch levels were the highest throughout the late 1990s and 2000s at about 35,000 t before they decreased to about 24,000 t between 2008 and 2011 during the period of piracy threat which prevented longliners to operate in the rich fishing grounds of the Somali basin. Catches reached the pre-piracy levels between 2013 and 2019 but showed a sharp decline in 2020-2021 (**Fig. 2a**). While industrial fisheries represented most of the reports of swordfish catch since the mid-1950s, the contribution of coastal fisheries has steadily increased since the mid-2000s (**Fig. 2a**). In 2021, coastal fisheries contributed to 46% of the total catch of retained swordfish reported to the Secretariat.

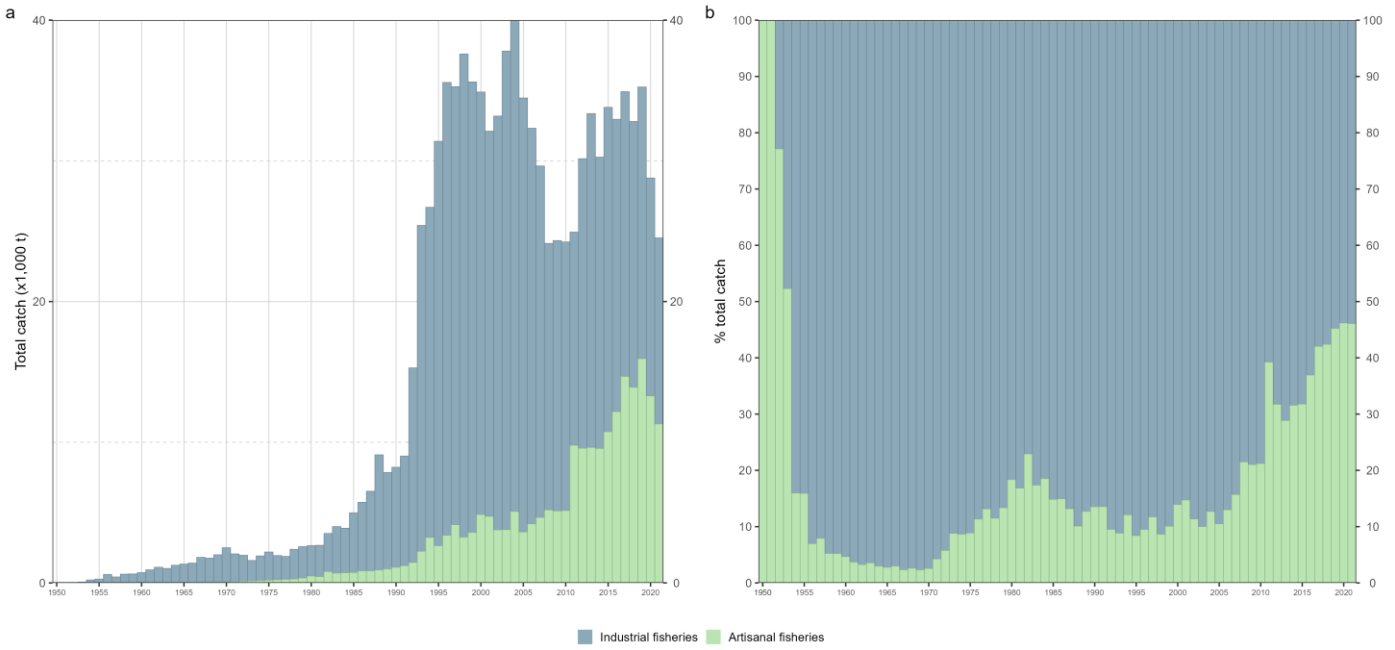

Figure 2: Annual time series of cumulative retained absolute (a) and relative (b) catches (metric tonnes; t) of swordfish by type of fishery for the period 1950-2021. Data source: best scientific estimates of retained catches

Table 1: Mean annual retained catches (metric tonnes; t) of swordfish by decade and fishery for the period 1950-2019. The background intensity color of each cell is directly proportional to the catch level. Data source: best scientific estimates of retained catches

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

Longline has been the main fishing gear catching swordfish in the Indian Ocean over the last seven decades. Prior to the 1990s, swordfish was mostly taken in deep-freezing longline fisheries targeting tunas in both temperate and tropical waters. The expansion of the activities of the Asian deep-freezing longline fisheries in the 1990s led to a substantial increase in swordfish catches which were around five times more than during the previous decade (**Table 1**). While the contribution of deep-freezing longline fisheries to swordfish catch started to decrease from the late 1990s, several longline fisheries targeting specifically swordfish developed in both the western (Taiwan,China, EU,France, EU,Spain, EU,Portugal) and eastern (Australia) Indian Ocean. Since the early 2010s, the contribution of coastal longline fisheries (mostly driven by Sri Lanka) and gillnet fisheries (dominated by Yemen in some years) has progressively increased although there are some large uncertainties associated with the quality of the data for those latter fisheries (see Uncertainties in retained catch data).

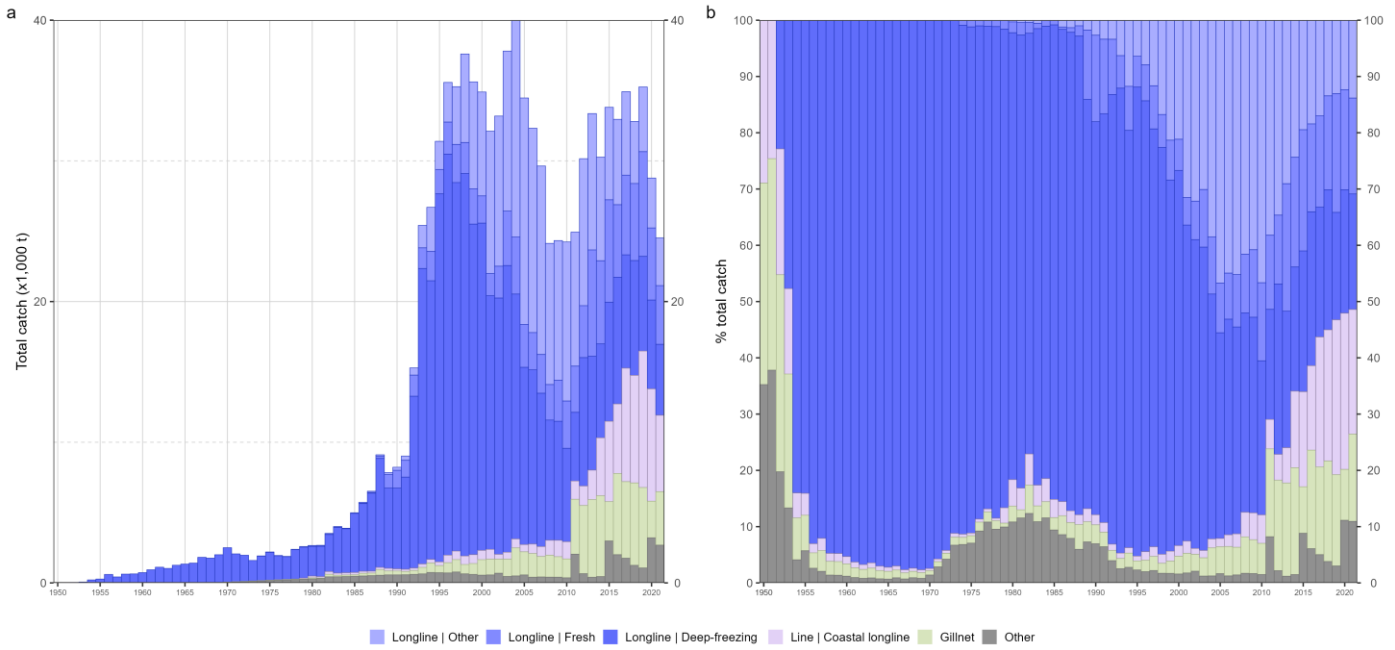

Figure 3: Annual time series of cumulative retained absolute (a) and relative (b) catches (metric tonnes; t) of swordfish by fishery for the period 1950-2021. Data source: best scientific estimates of retained catches

Table 2: Annual retained catches (metric tonnes; t) of swordfish by fishery for the period 2012-2021. The background intensity color of each cell is directly proportional to the catch level. Data source: best scientific estimates of retained catches

Fishery	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Purse seine | Other	85	99	94	96	106	807	482	78	113	90
Longline | Other	10,448	9,695	7,370	6,579	6,073	5,936	4,412	4,603	3,550	3,393
Longline | Fresh	3,694	7,557	5,904	7,283	5,152	5,666	5,478	7,439	5,127	4,178
Longline | Deep-freezing	9,123	8,096	6,677	8,458	9,008	8,056	8,158	6,729	6,310	5,039
Line | Coastal longline	1,386	2,098	4,121	5,713	4,947	8,069	7,651	9,705	7,992	5,433
Line | Trolling	121	127	96	88	962	313	119	141	53	96
Line | Handline	440	160	247	2,787	928	621	639	834	3,025	2,487
Baitboat	0	0	0	0	0	0	0	0	0	0
Gillnet	4,849	5,522	5,749	2,798	5,772	5,444	5,859	5,719	2,601	3,802
Other	10	11	10	10	9	11	8	9	12	10
Total	30,157	33,366	30,268	33,812	32,958	34,924	32,804	35,256	28,783	24,528

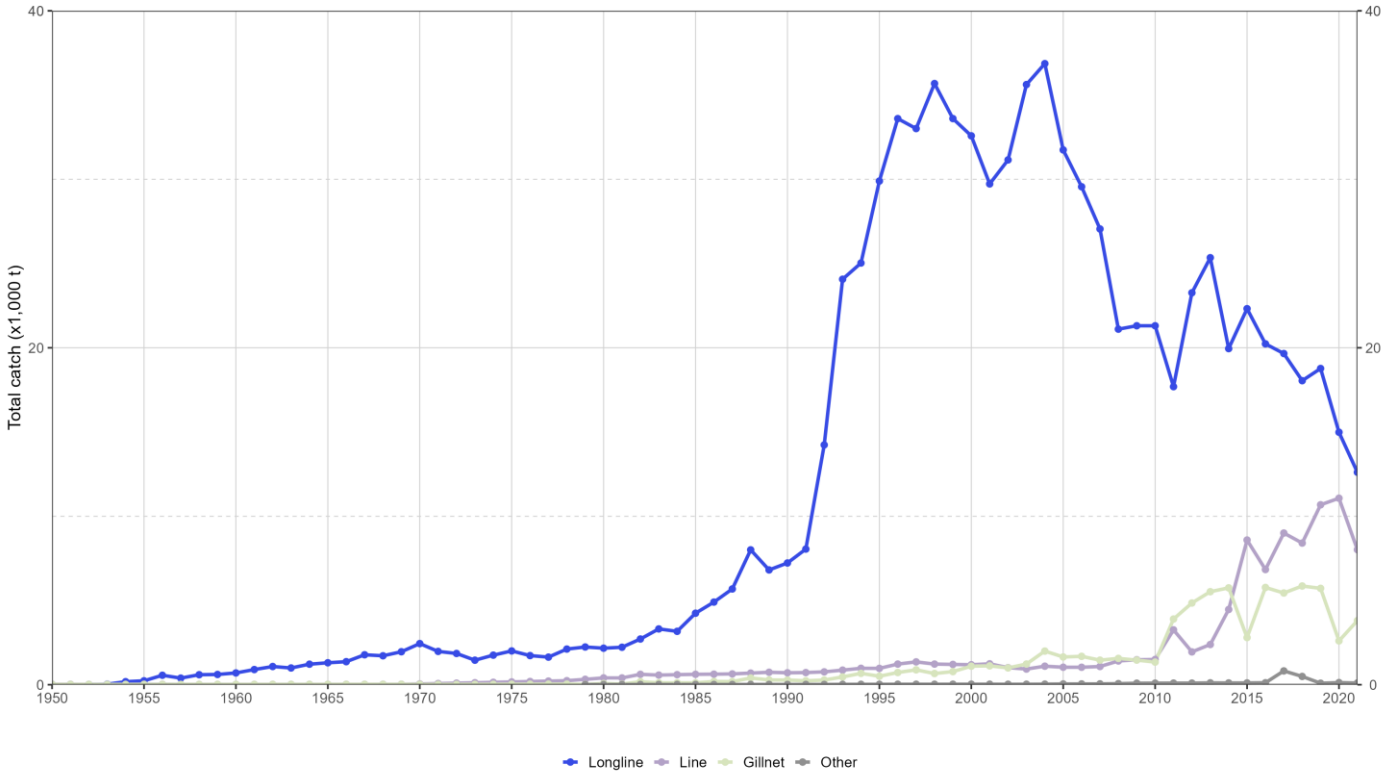

Figure 4: Annual time series of retained catches (metric tonnes; t) of swordfish by fishery group for the period 1950-2021. Data source: best scientific estimates of retained catches

Main fishery features (2017-2021)

Recently, fisheries composed of smaller longliners operating both in areas of national jurisdiction (LIC) and the high seas (LLF) have been catching as much swordfish as the deep-freezing longline fisheries. Between 2017 and 2021, these two components contributed to 43% of the total swordfish catch reported to the Secretariat (**Table. 3**).

Table 3: Mean annual catches (metric tonnes; t) of swordfish by fishery between 2017 and 2021. Data source: best scientific estimates of retained catches

Fishery	Fishery code	Catch	Percentage
Line | Coastal longline	LIC	7,770	24.9
Longline | Deep-freezing	LLD	6,858	21.9
Longline | Fresh	LLF	5,578	17.8
Gillnet	GN	4,685	15.0
Longline | Other	LLO	4,379	14.0
Other	OT	1,989	6.4

Sri Lankan fisheries took the bulk of the catch of Indian Ocean swordfish in recent years, i.e., about 30% of all swordfish catches between 2017 and 2021 (**Fig. 5**). The second most important fleet was Taiwan,China which catch swordfish with a mix of fresh and deep-freezing longliners and contributed to about 18% of all swordfish catch during that period. The other main fleets catching swordfish were EU,Spain, Seychelles, India, Yemen, Indonesia, China, I.R. Iran, and EU,Portugal (**Fig. 5**).

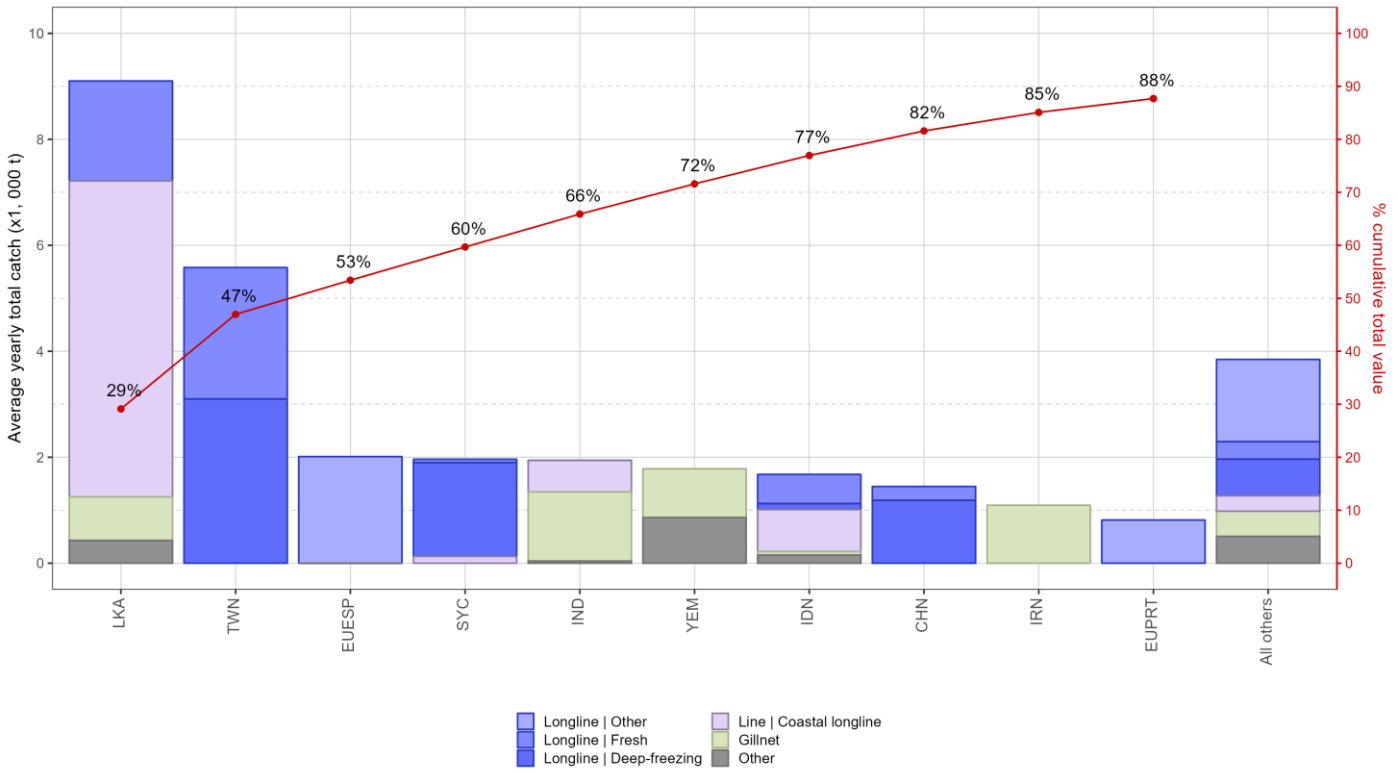

Figure 5: Mean annual catches (metric tonnes; t) of swordfish by fleet and fishery between 2017 and 2021, with indication of cumulative catches by fleet. Data source: best scientific estimates of retained catches

Recent catches of swordfish show different trends between fishery groups. Longline fisheries show an overall declining trend in recent years, from 20,000 t in 2017 to 13,000 t in 2021 (**Fig. 6**). Catches from line fisheries show more variability, following an increased catch reported for 2020 at around 11,000 t, catches declined to around 8,000 t in 2021. The third highest catch is from gillnet fisheries for which catches increased in 2021 by 46% compared to 2020 (**Fig. 6**).

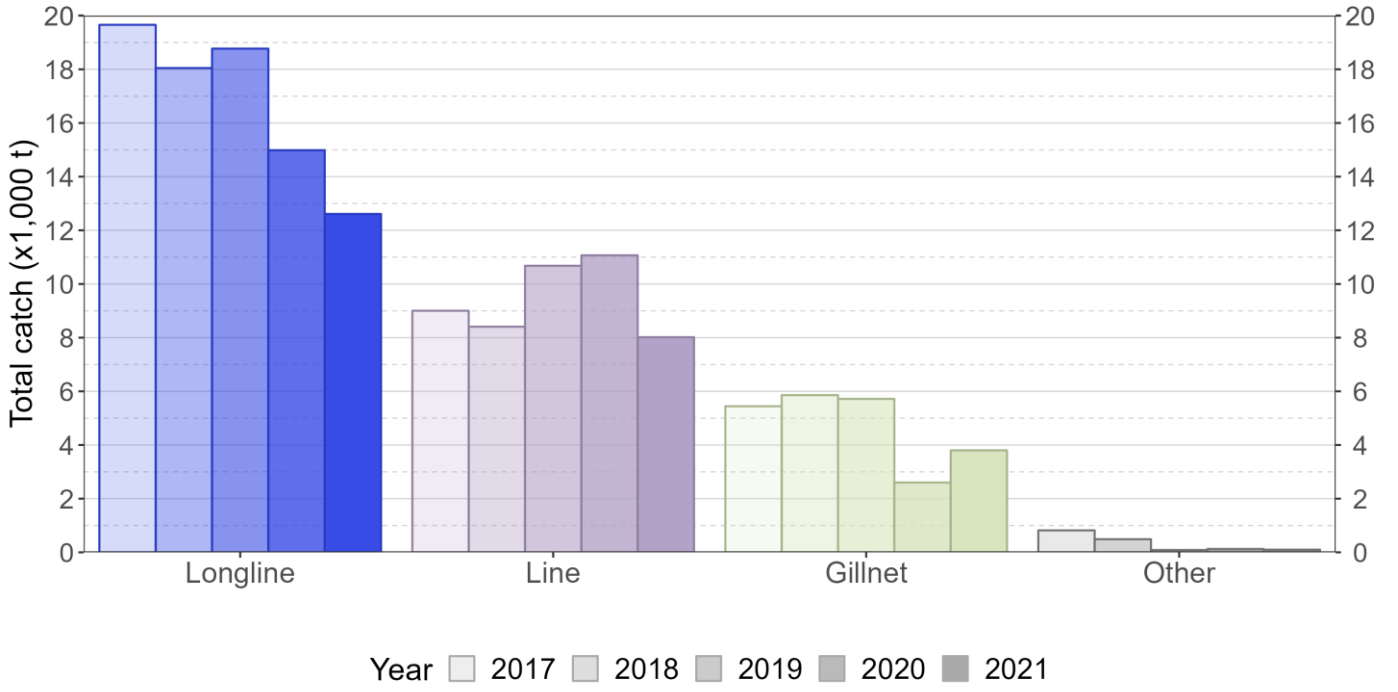

Figure 6: Annual catch (metric tonnes; t) trends of swordfish by fishery group between 2017 and 2021. Data source: best scientific estimates of retained catches

Longline fisheries from Taiwan,China, which reported the highest swordfish catch in 2017 at around 7,000 t, dropped by 50% in 2021. Besides Taiwan,China, swordfish catches decreased from all other longline fisheries (**Fig. 7b**).

Overall catches of swordfish from line fisheries indicate a slight increase in recent years. However, Sri Lankan line fisheries, with the highest catch, which caught over 8,000 t in 2019, faced a major decline, with catches reaching as low as 4,000 t in 2021. Recently, following some review by the FAO, significant catches of swordfish were reported from Yemen, averaging at 2,000 t per year (**Fig. 7c**).

Although swordfish catches from gillnet fisheries are not as high as from longline and line fisheries and the recent catch levels fluctuated for some fisheries, gillnet fisheries of India and Indonesia reported an increased catch in 2021 (**Fig. 7d**). Indonesia and Sri Lanka have other fisheries with some catches of swordfish in recent years, although the yearly average is as low as around 10 t (**Fig. 7a**).

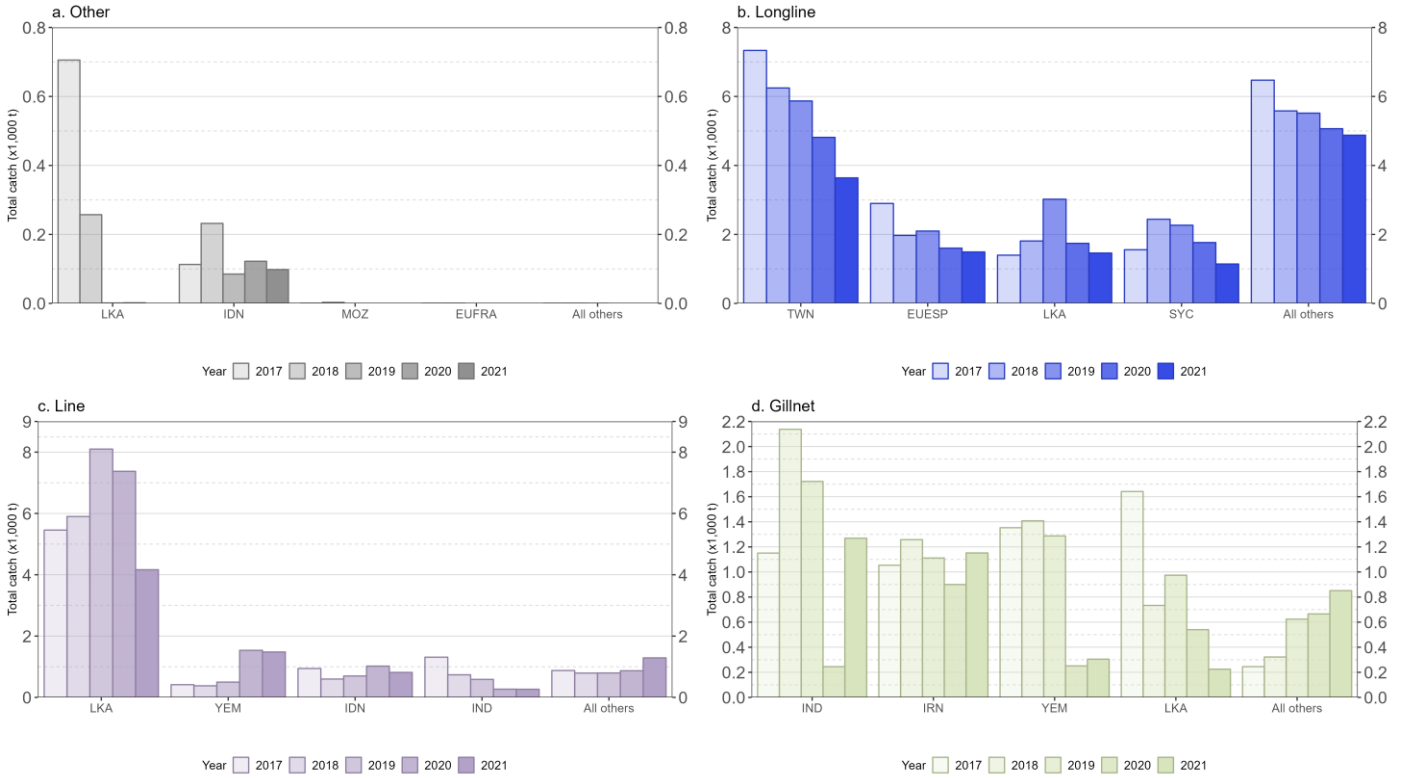

Figure 7: Annual catch (metric tonnes; t) trends of swordfish by fishery group and fleet between 2017 and 2021. Data source: best scientific estimates of retained catches

Changes from previous Working Party

Between the WPB20 and WPB21, there were revisions in the catch series which affected swordfish historical catches (**Fig. 8**). The revisions concerned a few fisheries and were performed for several reasons (see Appendix II). The major changes occurred for the historical swordfish catches reported for Yemen. Previously, the data published through the FAO global capture production database indicated that only Indo-Pacific sailfish was caught as billfish species in Yemeni fisheries. Updates for swordfish catches were reported for the period between 2011 at 3,700 t and 2021 at 1,786 t. Besides, some minor changes occurred in swordfish catches:

- Data revisions by I.R. Iran for the period 2011 to 2020;
- Updates of catch data from Kenya and Mozambique by the Secretariat based on recent published information;
- Updates of catch data from Japan based on new logbook coverage;
- Review of catch data from Indonesia based on the re-estimation of catch series between 2010 and 2017.

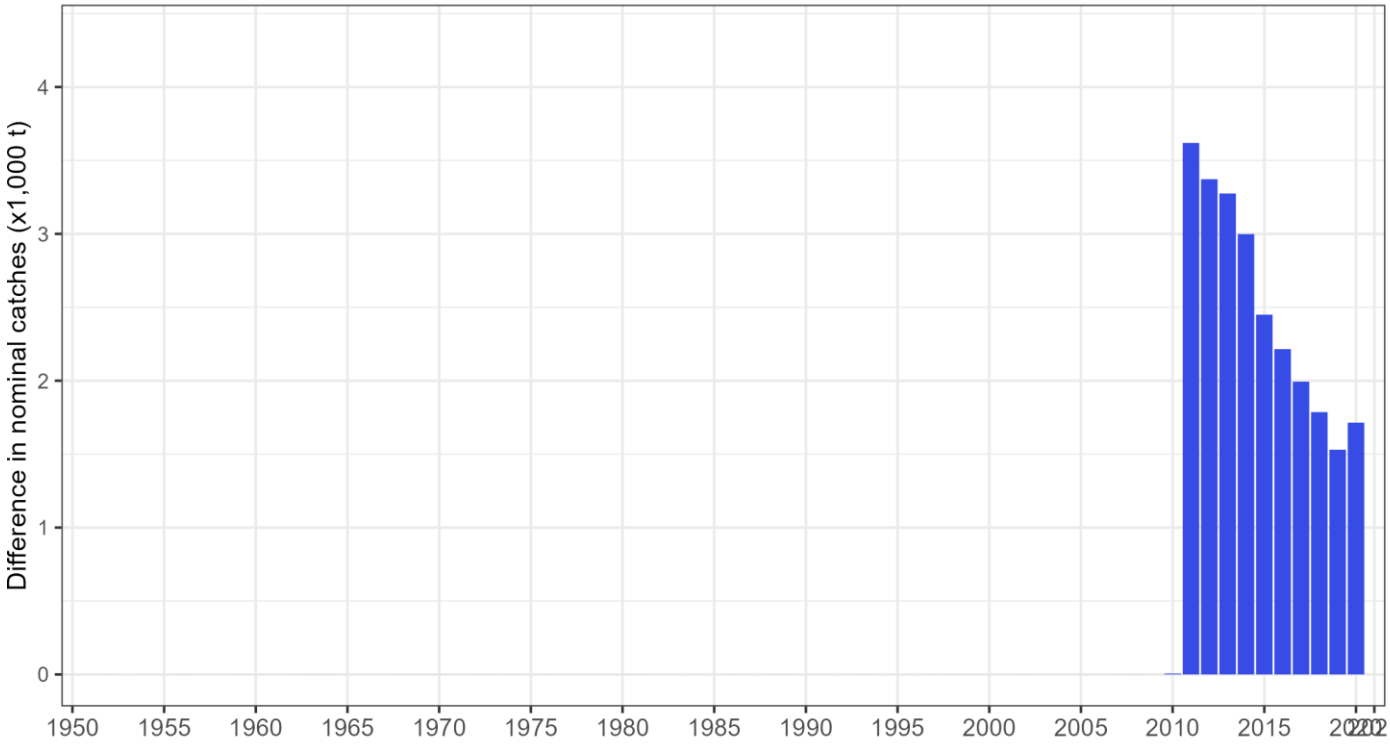

Figure 8: Differences in the available best scientific estimates of retained catches (metric tonnes; t) of swordfish between this WPB and its previous session (WPB20 meeting held in September 2022)

Uncertainties in retained catch data

The overall reporting quality of catches of retained swordfish is considered to be good as most data have been reported for industrial longline fisheries which are generally monitored with good collection and reporting systems (**Fig. 9**). The quality decreased throughout the 1990s and 2000s when some large-scale longline fisheries were found not to directly report catches to the Secretariat (Herrera 2002). In parallel, the reporting quality of total retained catches from artisanal fisheries was very low during the 1990s, with only 4.1% of the catch being fully or partially reported (**Fig. 9**). However, the quality substantially improved over the last decade, reaching an average of 90% between 2014 and 2021, mostly reflecting the improvement in reporting for Sri Lankan fisheries.

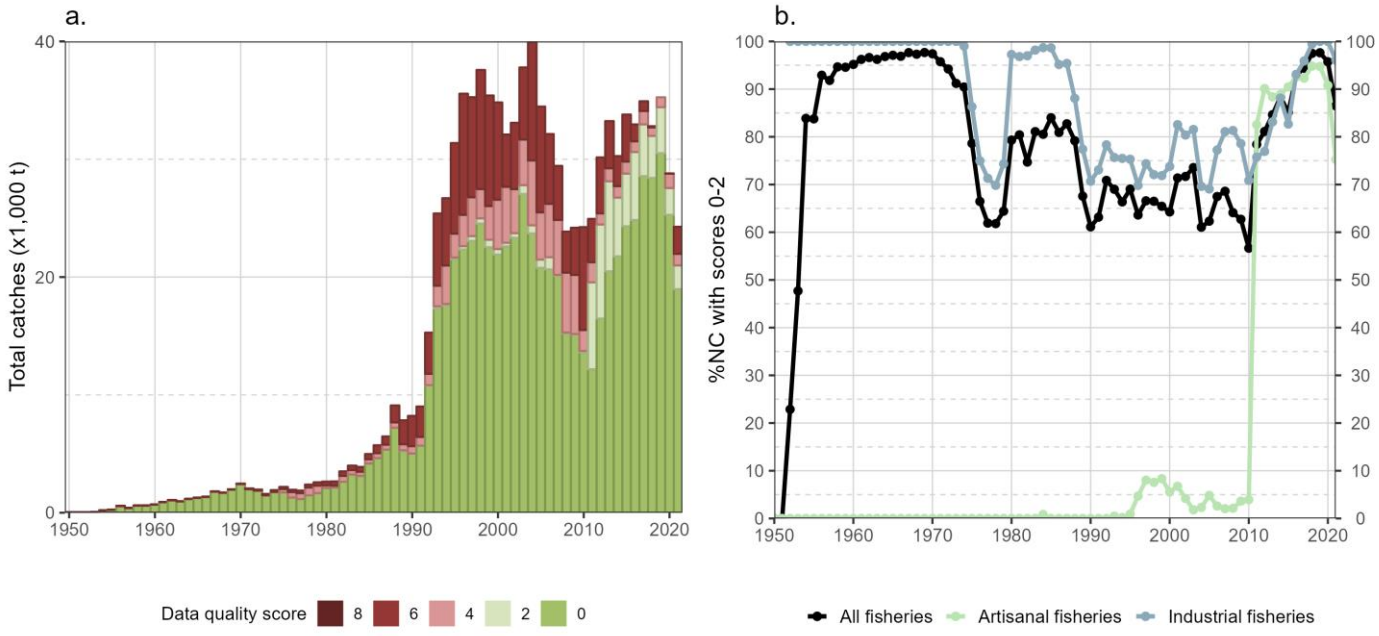

Figure 9: (a) Annual retained catches (metric tonnes; t) of swordfish estimated by quality score and (b) percentage of total retained catches fully or partially reported to the IOTC Secretariat for all fisheries and by type of fishery, in the period 1950-2021

Discard levels

The total discard levels of swordfish caught in the Indian Ocean are poorly known. Information available at the Secretariat includes: (i) discarded catch data from few fisheries through the 1DI form, which are not raised to the total and (ii) observer data collected onboard high-seas fishing vessels that only cover a few fleets (i.e., Japan and EU,France). Data from the ROS database indicate that some discards of swordfish occurred in both longline and purse seine fisheries, at higher rates for the former.

Observer data also show differences in size of discarded and retained swordfish between the two gears, although limited information is available from purse seine fisheries. While swordfish could be discarded at any size in purse seine fisheries, most swordfish discarded in longline fisheries were found to be smaller than 100 cm lower-jaw fork length (**Fig. 10**).

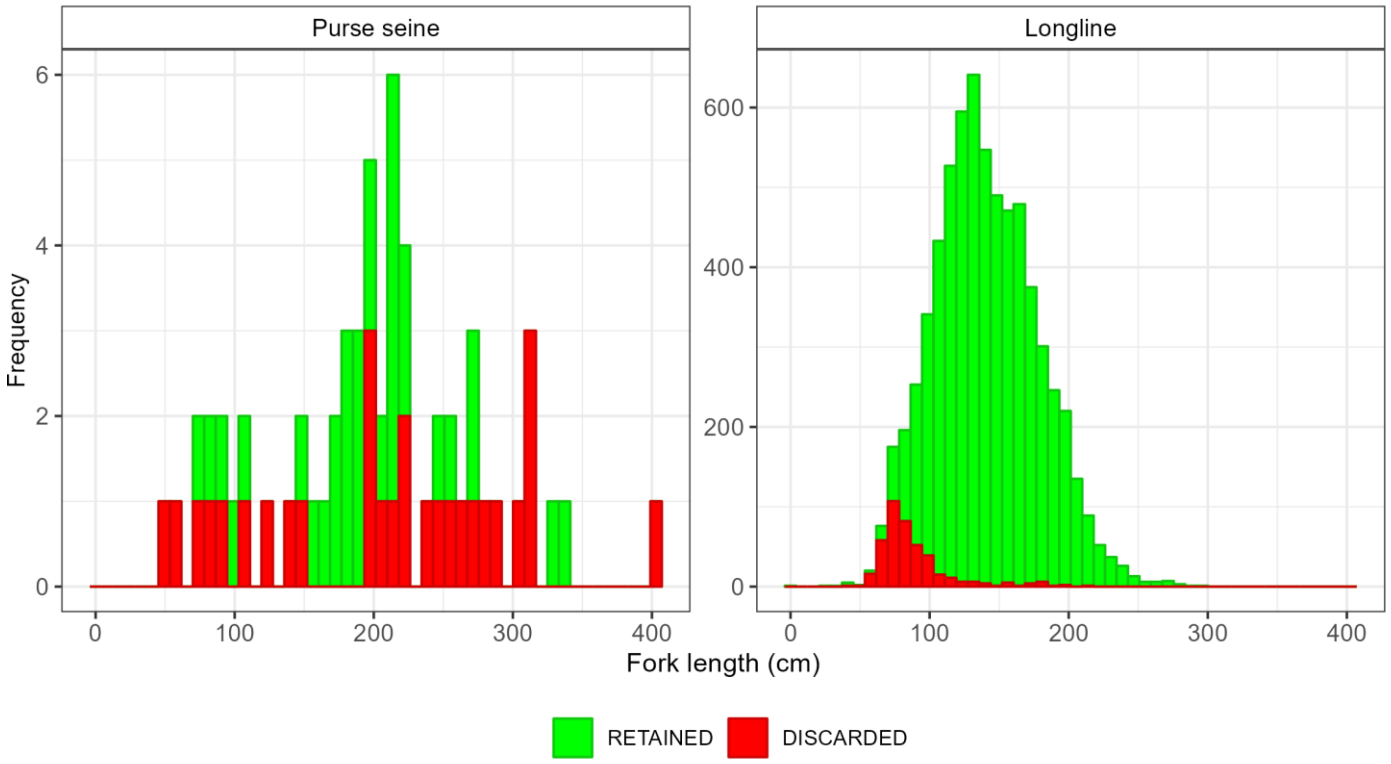

Figure 10: Size (lower-jaw fork length; cm) frequency distribution of swordfish retained and discarded at sea in purse seine and longline fisheries as available in the ROS regional database

Information on swordfish condition at release is only available from longline and purse seine fisheries having operated in the Western Indian Ocean. Although with some variability between fleets, global estimates of condition show that most swordfish were discarded dead in both types of fisheries, i.e., 84% and 95% for purse seine and longline, respectively (**Figs. 11-12**).

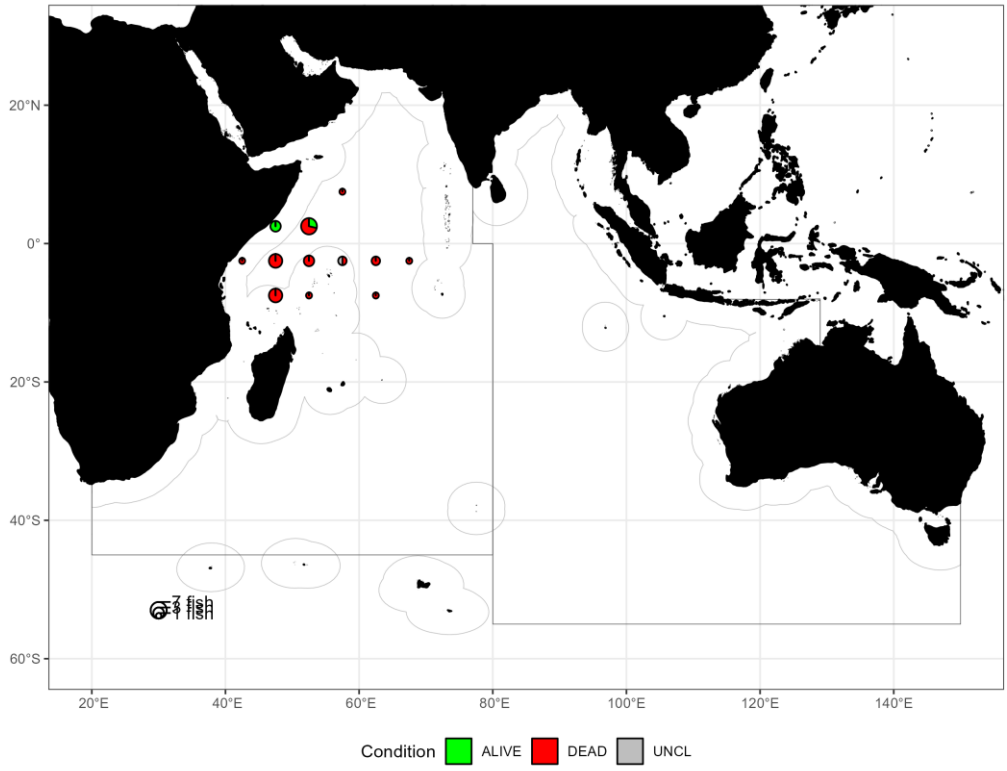

Figure 11: Distribution of swordfish discarded at sea in the western Indian Ocean purse seine fisheries with information on condition at release as available in the ROS regional database

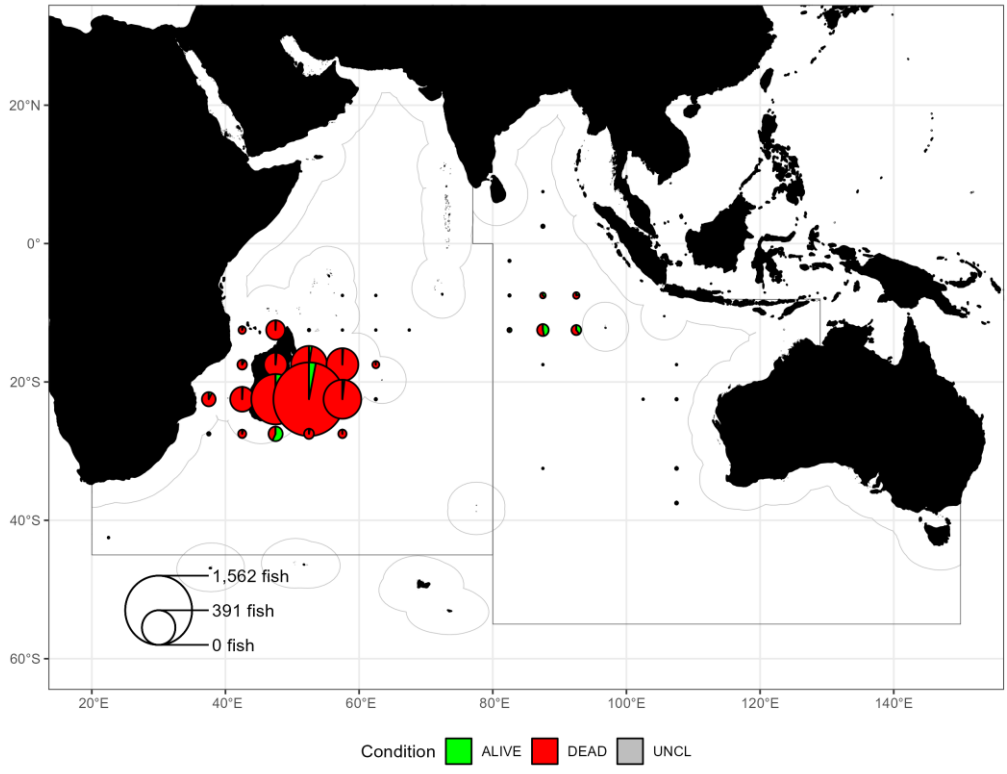

Figure 12: Distribution of swordfish discarded at sea in the Indian Ocean longline fisheries with information on condition at release as available in the ROS regional database

Geo-referenced catch

Spatial distribution of catches

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

Geo-referenced catches show the spatial expansion and major changes that took place in the fisheries catching swordfish over the past decades (**Fig. 13**). Spatial catch data in weight (t) are available since the 1970s, while only catch in numbers are available at the beginning of the time series. **Fig. 13** shows the expansion of the deep-freezing longline fisheries catching swordfish around South African waters and in the northwestern Indian Ocean from the 1990s. Significant catches were reported from gillnet fisheries in Sri Lankan waters throughout the 1990s and 2000s. Longline fisheries that caught swordfish from the 2000s in the south Indian Ocean changed to other types of longliners, switching their target species and moving operations mainly towards the north Indian Ocean.

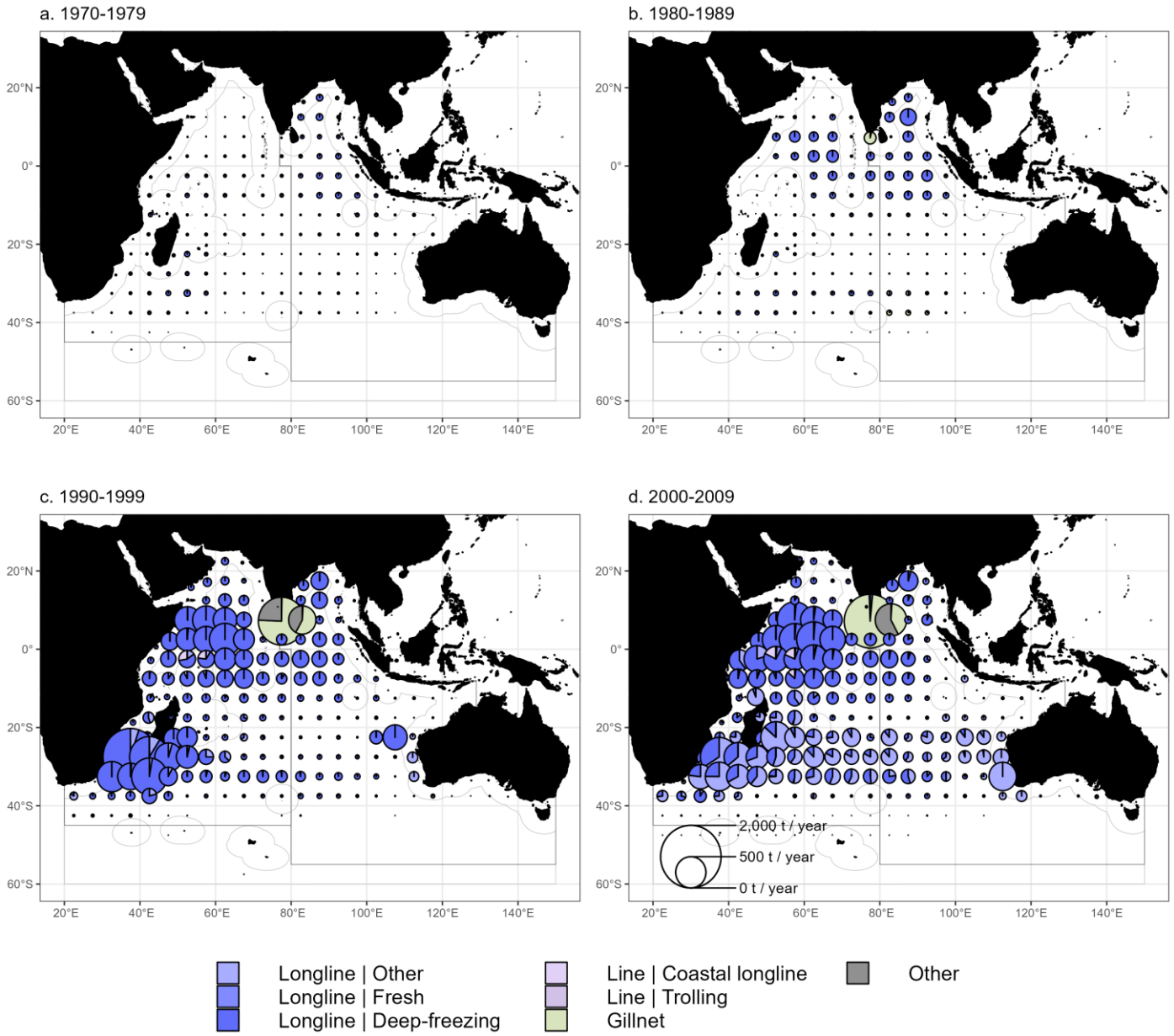

Figure 13: Mean annual time-area catches in weight (metric tonnes; t) of swordfish, by decade, 5x5 grid, and fishery. Data source: time-area catches

Geo-referenced catch data in number show that the distribution of swordfish catches from longline fisheries spans over the whole Indian Ocean since the 1970s (**Fig. 14**). Catches substantially increased from the 1980s with higher levels reported for the north Indian Ocean. The increased number of Taiwanese and Japanese deep-freezing longline vessels operating around South Africa in the 1990s increased the catches of swordfish in the southwestern Indian

Ocean. Throughout the 2000s, a different longline fishing method, specifically targeting swordfish, was found to occur more frequently in the south Indian Ocean.

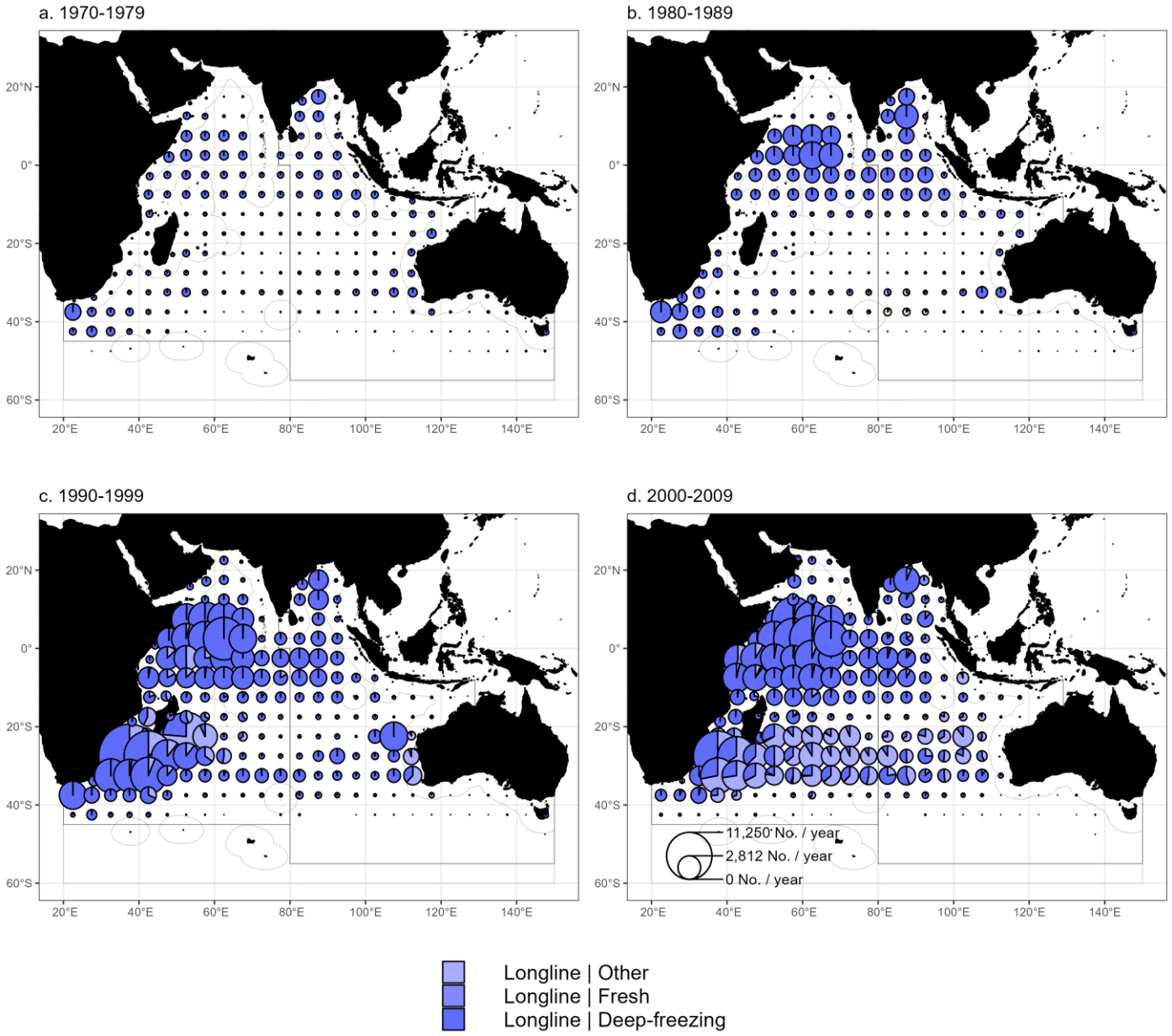

Figure 14: Mean annual time-area catches in numbers of swordfish, by decade, 5x5 grid, and fishery. Data source: time-area catches

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

During the last five years, the annual distribution of swordfish catch in weight showed some variability, with coastal longline catches increasing in the north Indian Ocean, mostly around Sri Lanka. Geo-referenced data also show some important catches from purse seine and gillnet fisheries distributed around the north Indian Ocean in recent years. The distribution patterns between 2017 and 2021 differ from the 2010s, with a continuous distribution in the south of the catches from longline fisheries (**Fig. 15**).

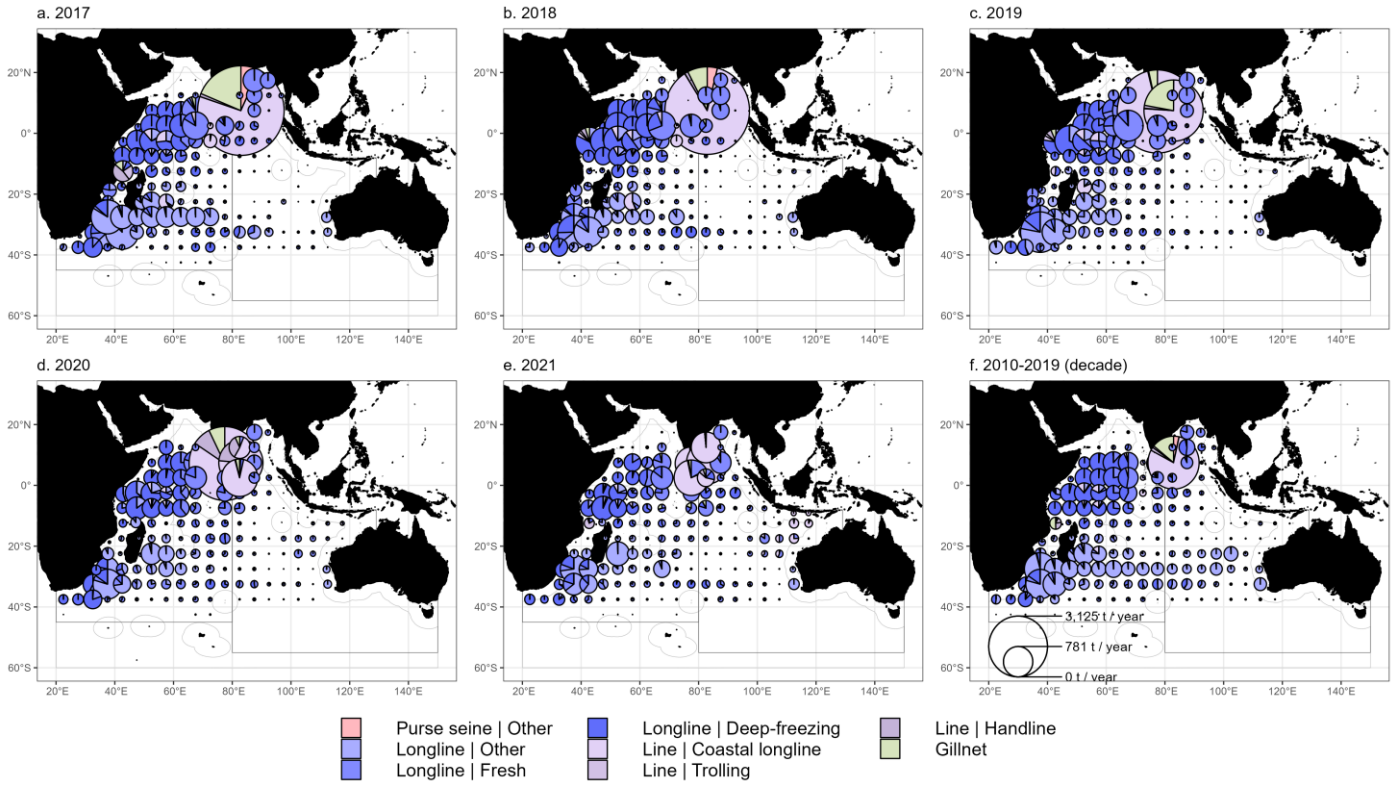

Figure 15: Mean annual time-area catches in weight (metric tonnes; t) of swordfish, by year / decade, 5x5 grid, and fishery. Data source: time-area catches

Contrary to the geo-referenced catch in weight, catches in numbers of fish are only available from longline fisheries in recent years. The distribution pattern indicates an increase in catch from 2017 from the fresh and other longline fisheries in the western Indian Ocean. Similar to the information provided through the catch in weight, less catches were reported from deep-freezing longline fisheries operating in the south, as compared to the distributions observed during previous decades (**Fig. 16**).

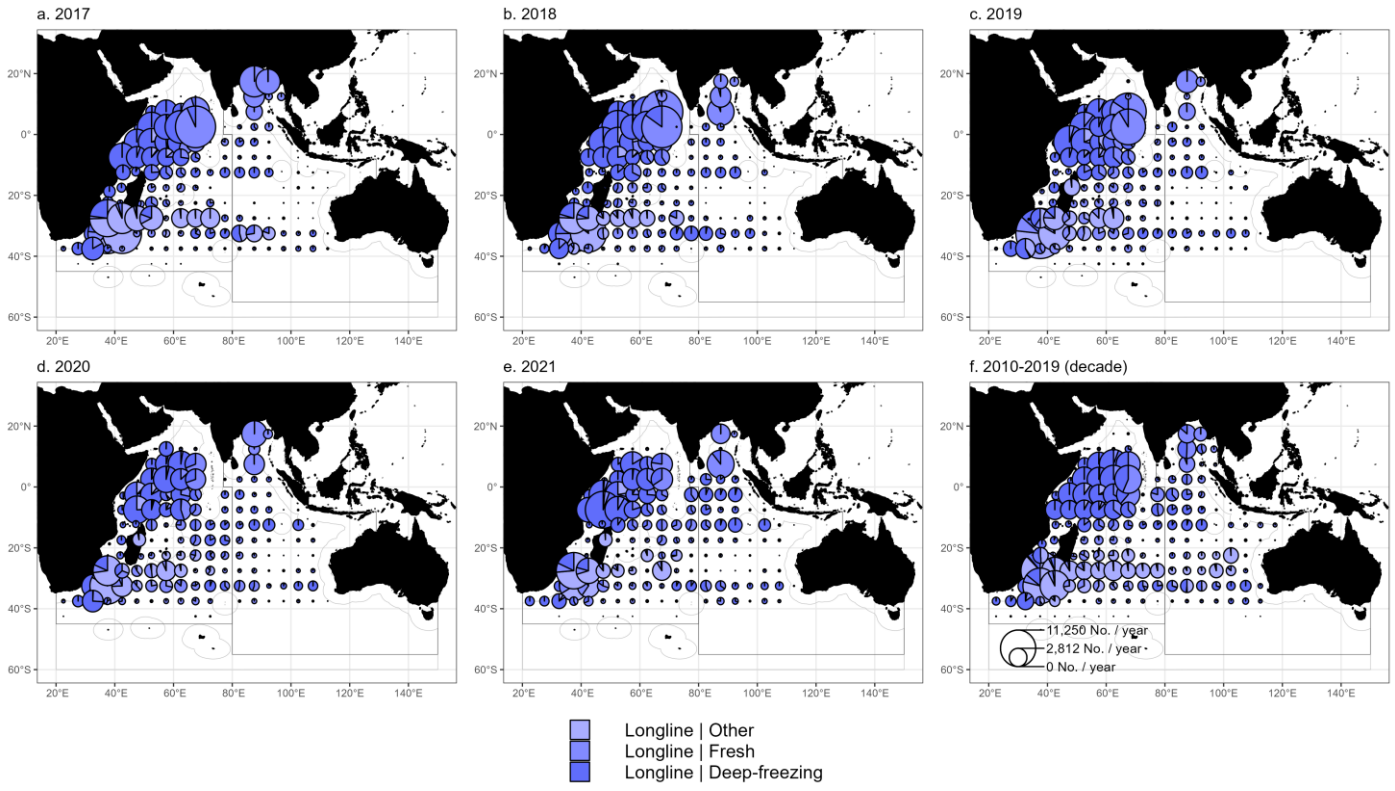

Figure 16: Mean annual time-area catches in numbers of swordfish, by year / decade, 5x5 grid, and fishery. Data source: time-area catches

Uncertainties in catch and effort data

Swordfish catch and effort data are available from the early 1950s and the quality was good as the species were mainly caught by industrial longline fisheries mostly described by good data collection and reporting systems. The overall quality started to deteriorate when other fisheries, particularly when smaller fisheries began targeting swordfish, which had limited capacity to submit catches, especially with spatial information. Hence, although some information on fishing effort became available, the reporting quality was found to be poor. Furthermore, some fisheries that were known to have catches of swordfish did not record geo-referenced catch and effort data.

The quality of geo-referenced catch and effort data improved from 2014, with improvement in the data collected by some coastal fisheries, particularly Sri Lanka, with significant catches of swordfish from coastal fisheries. Besides Sri Lanka, Indonesia submitted geo-referenced catch and effort, although with a low coverage (<30%). In recent years, spatial data with good quality (scoring 0-2) declined to as low as 49% in 2012 overall. Following the worsening in quality of the data received from industrial fisheries which targeted swordfish, between 2010 and 2015 to about 75%, and artisanal remaining low at around 16%. The quality improved to 83% in 2019 due to significant reports of geo-referenced data from coastal fisheries catching swordfish. However, as many fisheries are recovering from the effect of the COVID-19 pandemic, the rate of reporting geo-referenced data declined in 2021 to 72% overall, with the reporting quality of artisanal fisheries reduced to 48% (**Fig. 17**).

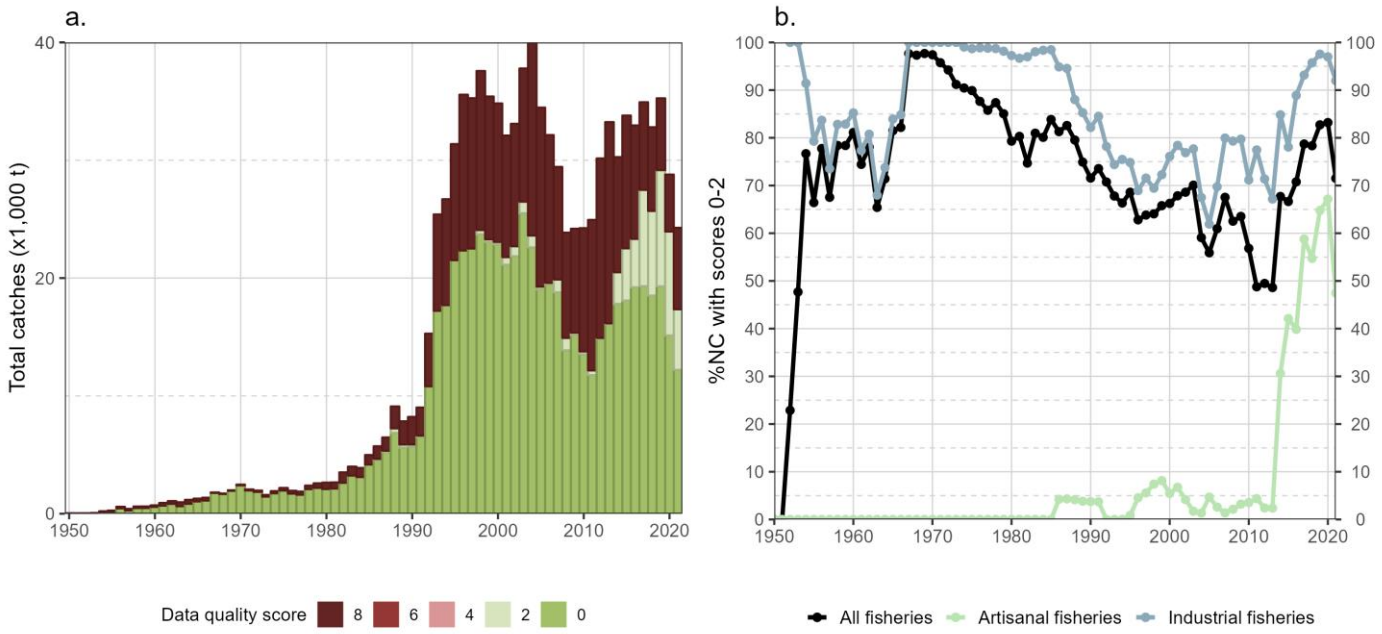

Figure 17: (a) Annual retained catches (metric tonnes; t) of swordfish estimated by quality score and (b) percentage of total retained catches for which geo-referenced catches were reported to the IOTC Secretariat in agreement with the requirements of Res. 15/02 for all fisheries and by type of fishery, in the period 1950-2021

Size composition of the catch

Samples availability

The sample trend indicates that most swordfish samples collected are from longline fisheries, representing about 97.4% of all size samples available at the Secretariat, although with some variation in the trend. The peak of swordfish samples collected was in the mid-2000s with a substantial number from longline fisheries of EU-Spain, which target swordfish. However, in recent years, fewer samples of swordfish were reported for several reasons:

(i) less large longline vessels targeting swordfish operated in the Indian Ocean;

(ii) small longline vessels do not sample large quantities of fish;

(iii) inconsistencies in the coverage of small fisheries catching swordfish;

(iv) smaller fishing vessels catching swordfish do not have observers on-board.

The total number of swordfish sampled reached a lower peak in recent years at 27,244 in 2020, reflecting the impact of the CoViD-19 pandemic leading to (i) less data collected, (ii) no observers on board vessels, and (iii) minimum fishing activities. Besides longline fisheries, swordfish samples are also collected from gillnet and line fisheries (**Fig. 18**).

By fishery group

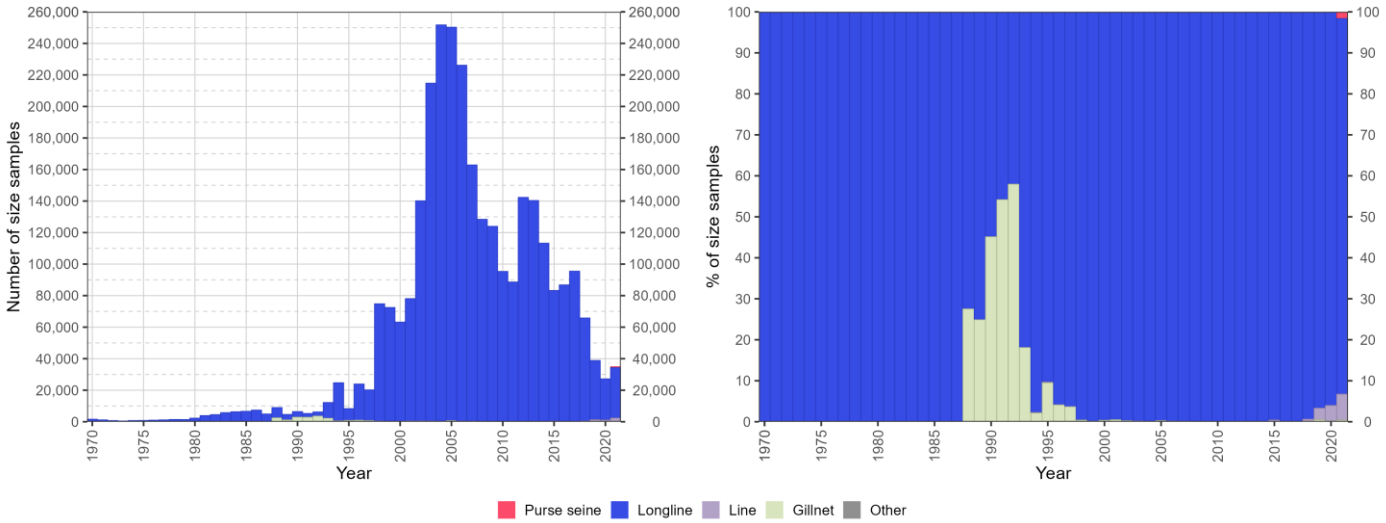

Figure 18: Availability of swordfish size-frequency data as absolute number of samples (left) and relative number of samples (right) per year and fishery group. Data source: standardized size-frequency dataset

Samples distribution

The distributions of swordfish samples by fisheries indicate that samples from longline fisheries are coming from across all the Indian Ocean, with high concentrations in the southwest Indian Ocean around southern African waters, northern Indian Ocean, Somalian waters, and western Australia (**Fig. 19**).

Limited samples are available from line and gillnet fisheries. Swordfish caught from gillnet fisheries are low compared to longline and line fisheries, which are also reflected in the level of samples collected from gillnet fisheries. Samples from gillnet fisheries are distributed around the northern Indian Ocean, as only Sri Lanka reported size-frequency data of swordfish from gillnet fisheries in recent years (**Fig. 20**). Distributions of swordfish samples collected from line fisheries are high around the coasts of Sri Lanka and Indonesia, and less in Western Indian Ocean (**Fig. 21**). Purse seine fisheries, contrary to other fisheries, are not sampling swordfish, although there are evident from observers' data that swordfish interacted in purse seine fisheries. In 2021, however, Tanzania measured some swordfish from its coastal purse seine fisheries (**Fig. 22**).

Longline fisheries

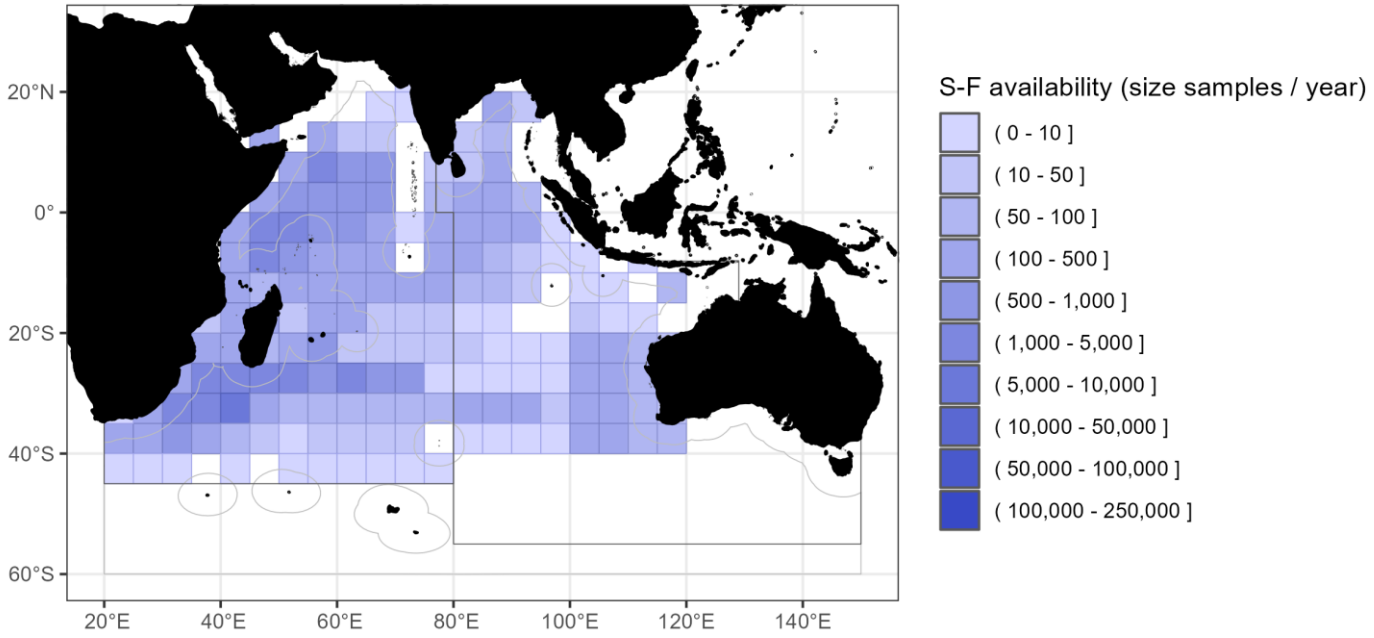

Figure 19: Spatial distribution (average number of samples per grid per year) of available swordfish size-frequency data for longline fisheries in the period 2017-2021. Data source: standardized size-frequency dataset

Gillnet fisheries

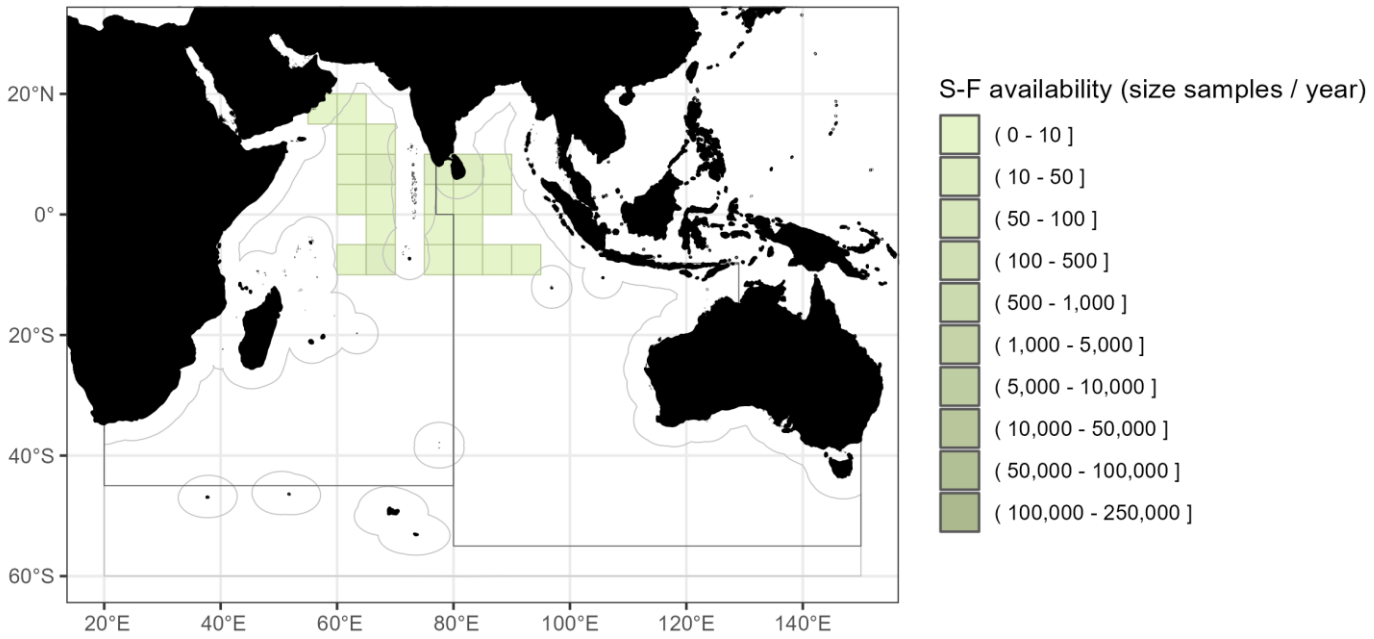

Figure 20: Spatial distribution (average number of samples per grid per year) of available swordfish size-frequency data for gillnet fisheries in the period 2017-2021. Data source: standardized size-frequency dataset

Line fisheries

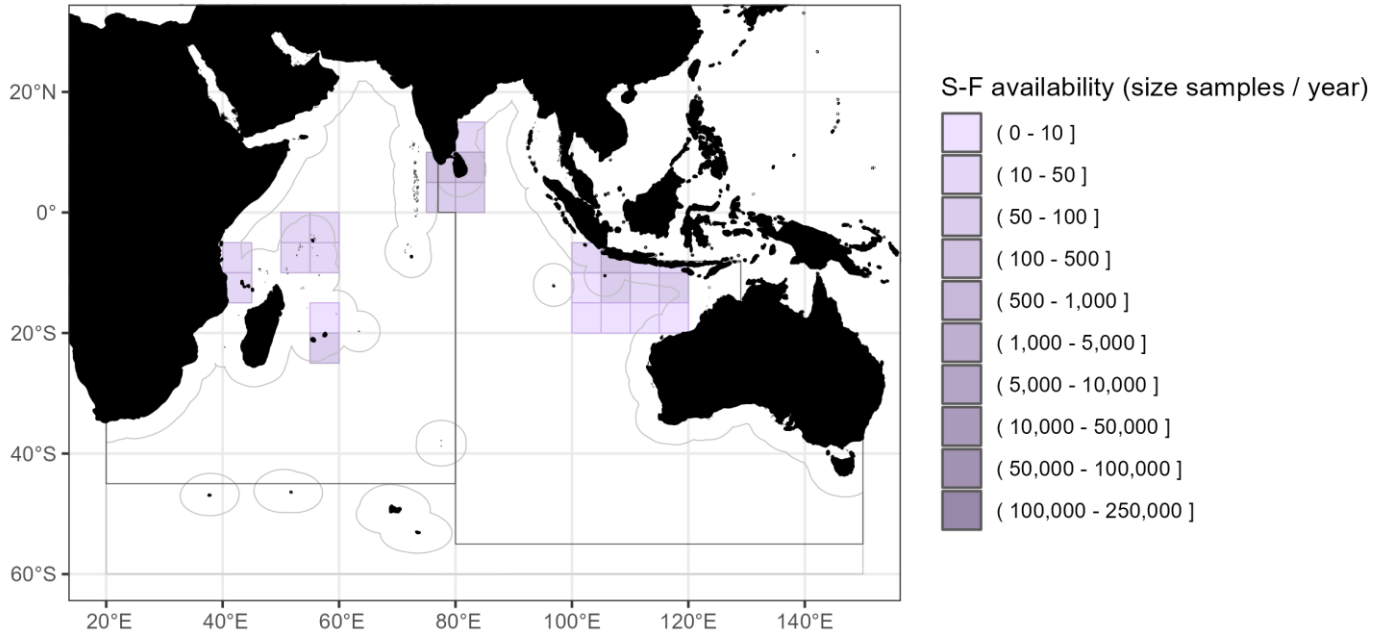

Figure 21: Spatial distribution (average number of samples per grid per year) of available swordfish size-frequency data for line fisheries in the period 2017-2021. Data source: standardized size-frequency dataset

Purse seine fisheries

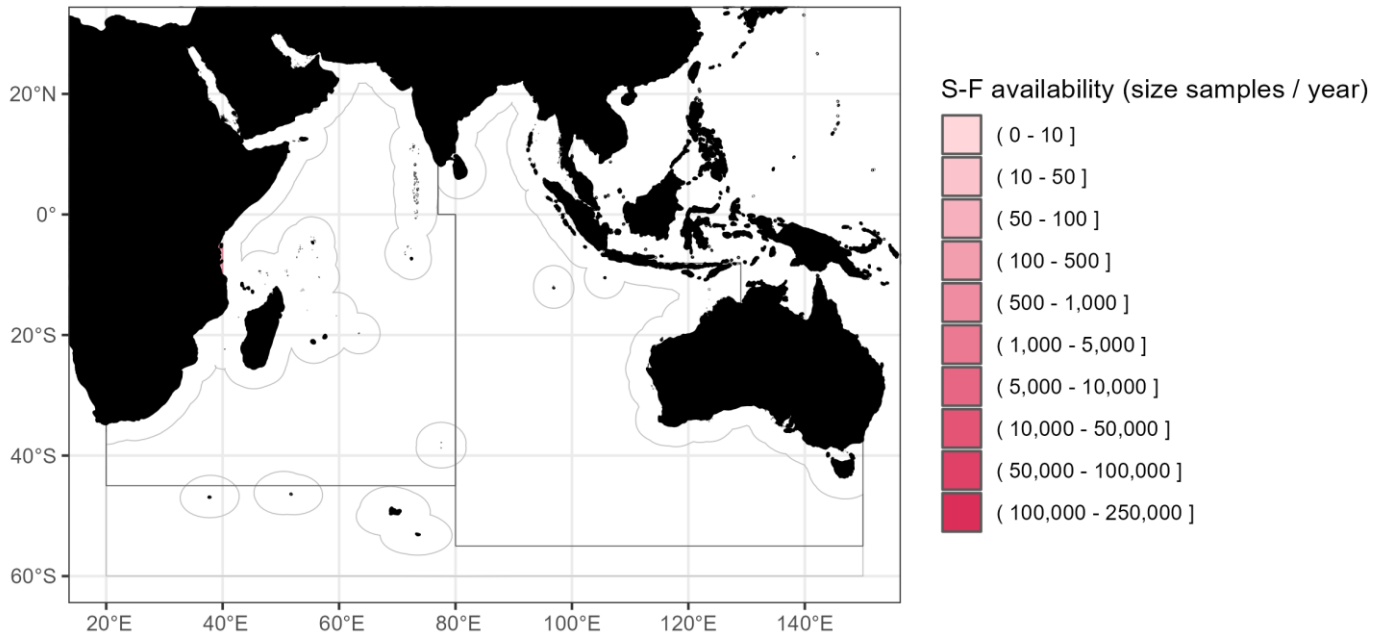

Figure 22: Spatial distribution (average number of samples per grid per year) of available swordfish size-frequency data for purse seine fisheries in the period 2017-2021. Data source: standardized size-frequency dataset

By fishery

Spatial distribution and availability of swordfish samples by fishery types denote the shift of number of samples collected by deep-freezing longliners in the past to more samples from other longline fisheries in recent years (**Fig. 24**). Samples taken by deep-freezing longline vessels are mainly distributed in the western Indian Ocean (**Fig. 25**), and likewise from fresh longine fishery, with further samples collected in eastern Sri Lanka (**Fig. 26**). Purse seine fisheries on free-swimming schools and schools associated with drifting floating objects recorded samples of swordfish in the western Indian Ocean (**Figs. 29- 30**). Line fisheries with increased catch of swordfish in recent years, samples collected by coastal longline fisherise are distributed around Indonesia, Sri Lanaka, and small island fisheries in western Indian, i.e., Mauritius, Seychelles, and Reunion island (**Fig. 32**), around Mozambique, Tanzania and Indonesia by handline fisheries (**Fig. 33**), and collected by trolling fisheries in Comoros (**Fig. 34**).

Gillnet fisheries

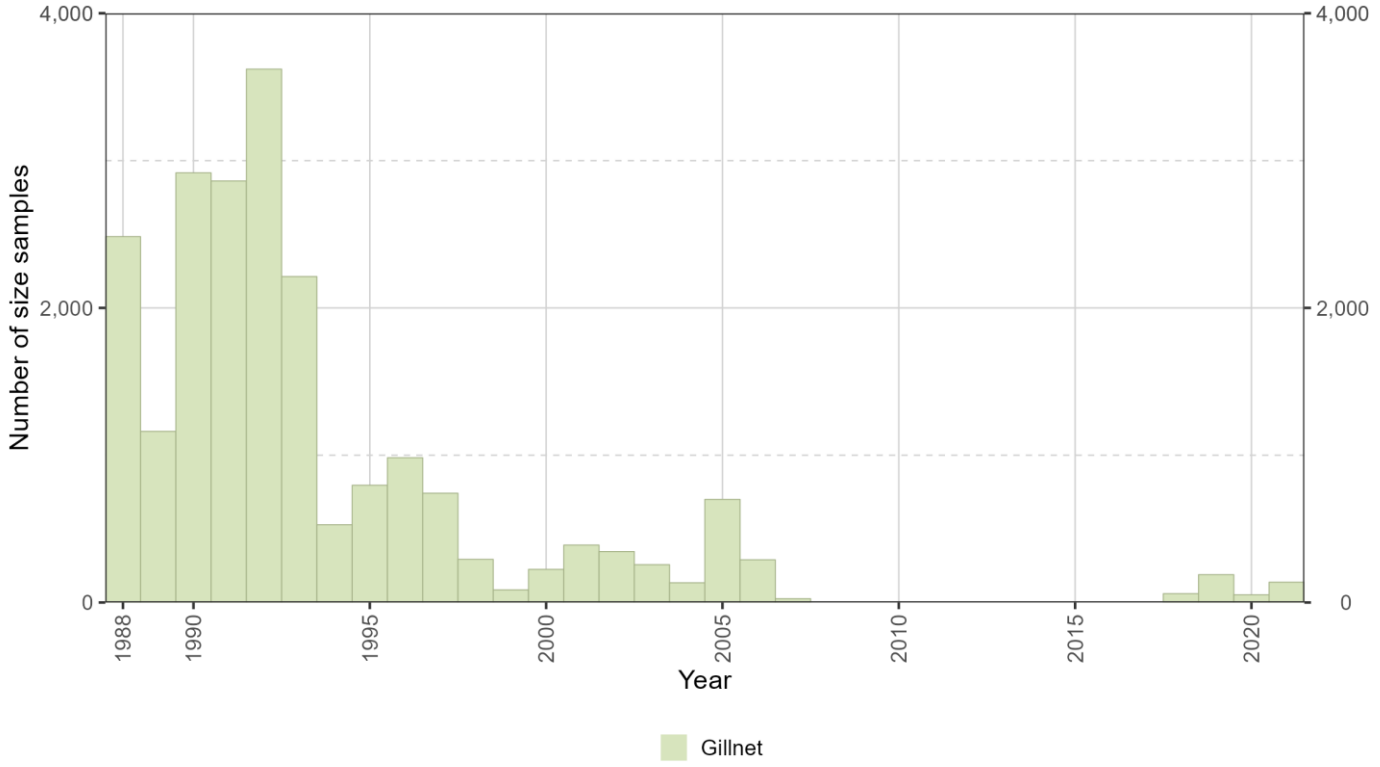

Figure 23: Availability of swordfish size-frequency data as absolute number of samples per year in gillnet fisheries. Data source: standardized size-frequency dataset

Longline fisheries

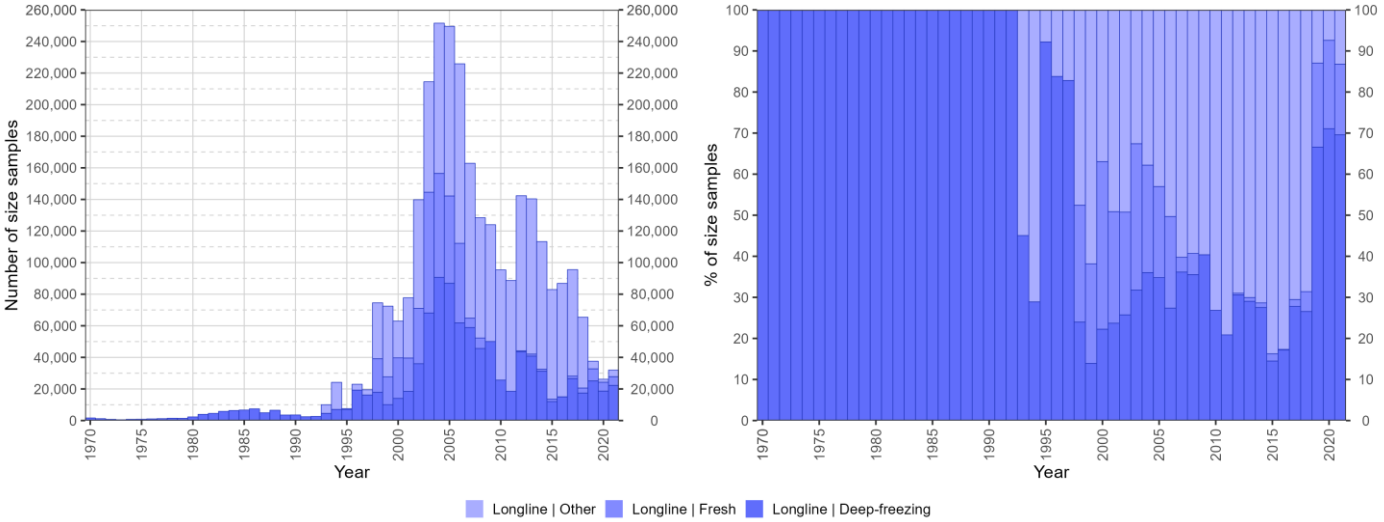

Figure 24: Availability of swordfish size-frequency data as absolute number of samples per year and longline fishery. Data source: standardized size-frequency dataset

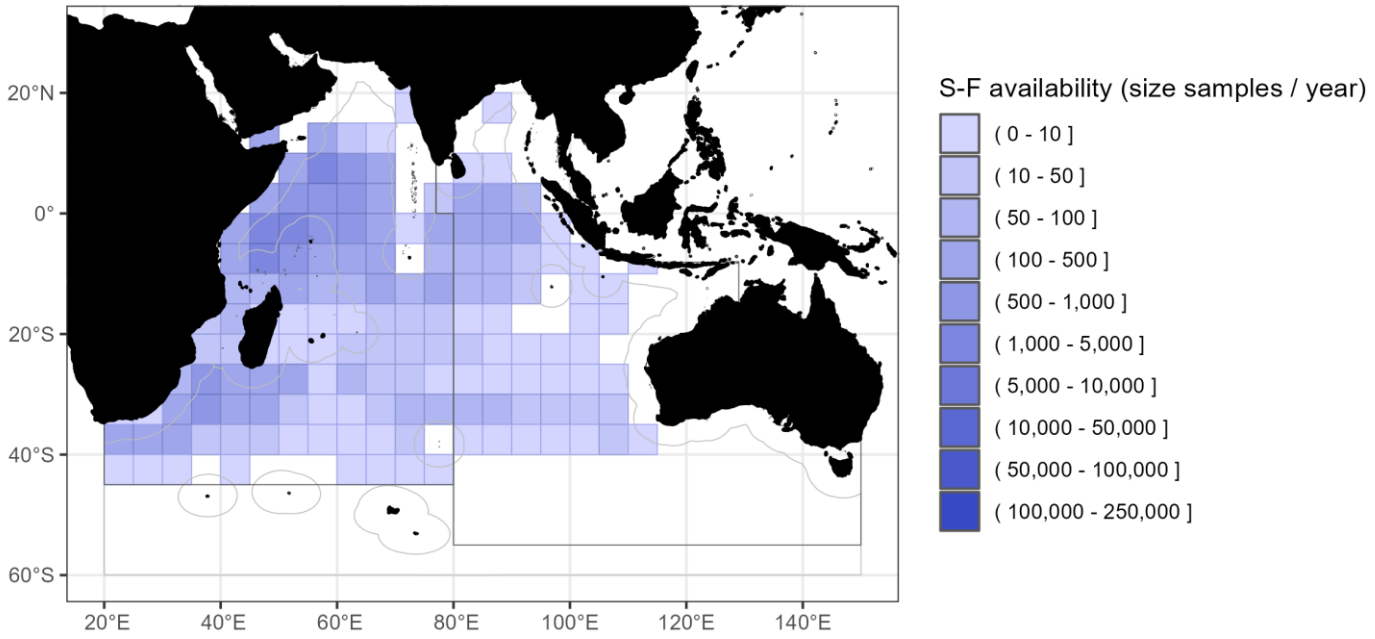

Figure 25: Spatial distribution (average number of samples per grid per year) of available swordfish size-frequency data for deep-freezing longline fisheries (LLD) in the period 2017-2021. Data source: standardized size-frequency dataset

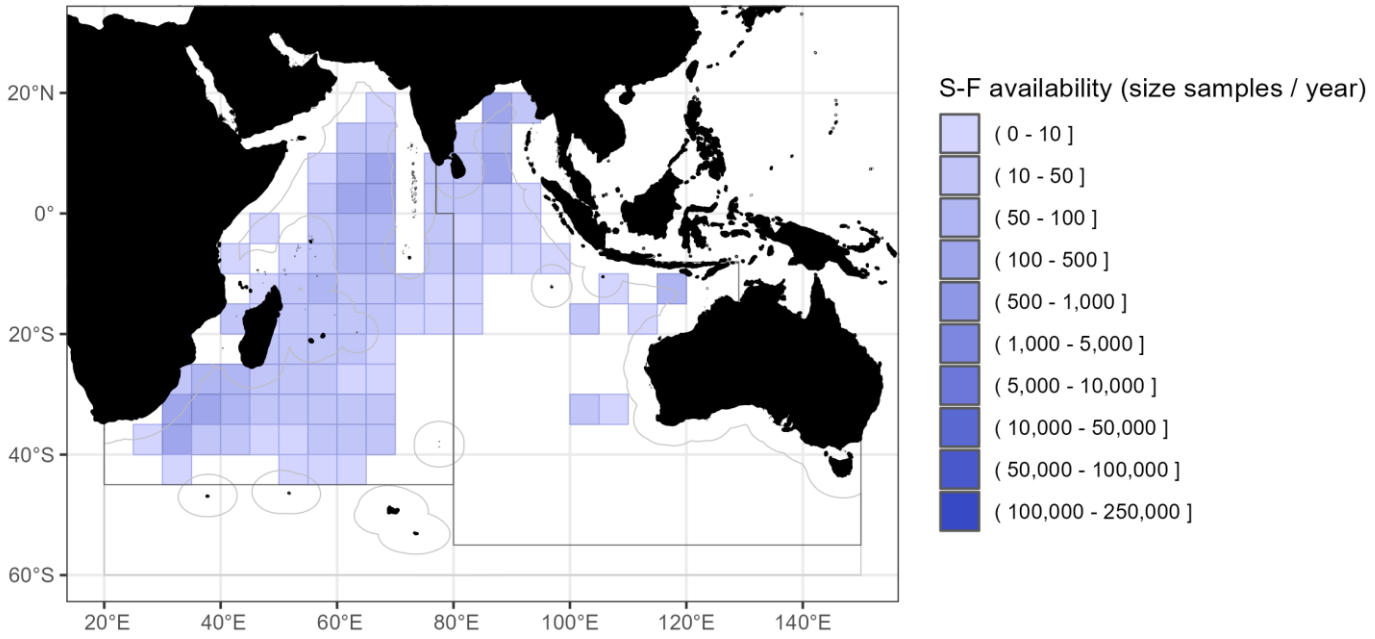

Figure 26: Spatial distribution (average number of samples per grid per year) of available swordfish size-frequency data for fresh longline fisheries (LLF) in the period 2017-2021. Data source: standardized size-frequency dataset

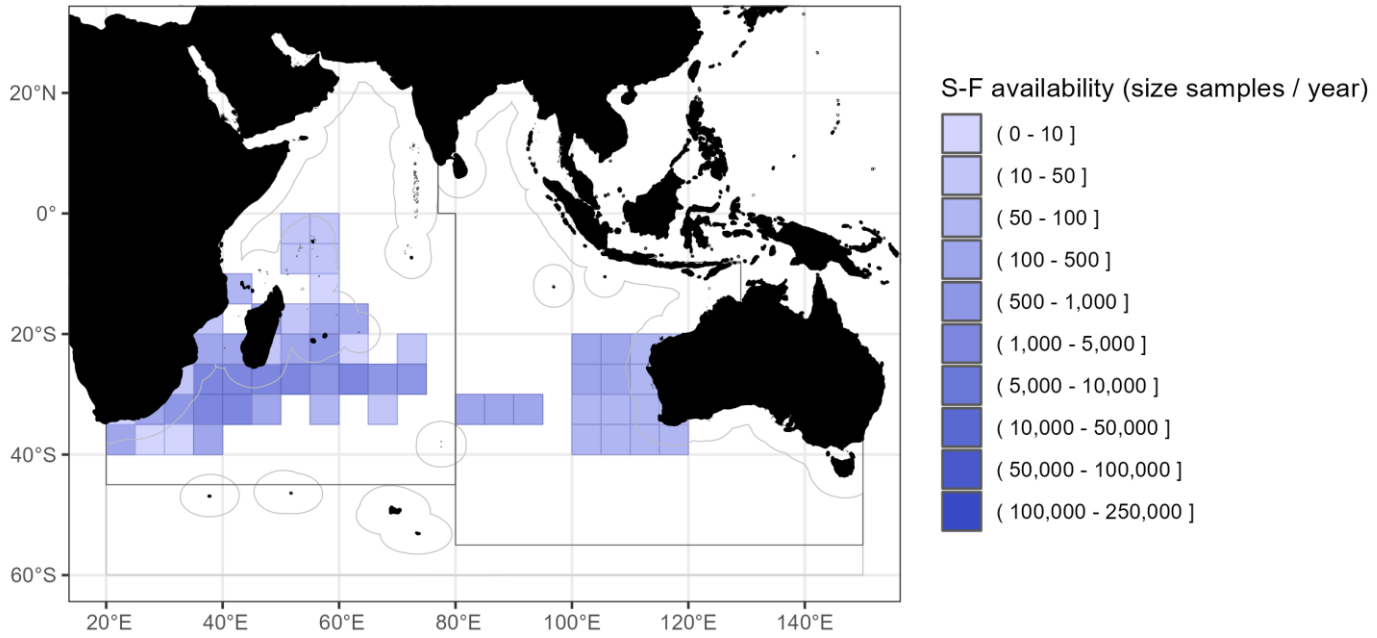

Figure 27: Spatial distribution (average number of samples per grid per year) of available swordfish size-frequency data for swordfish and shark-targeted longline fisheries (LLO) in the period 2017-2021. Data source: standardized size-frequency dataset

Purse seine fisheries

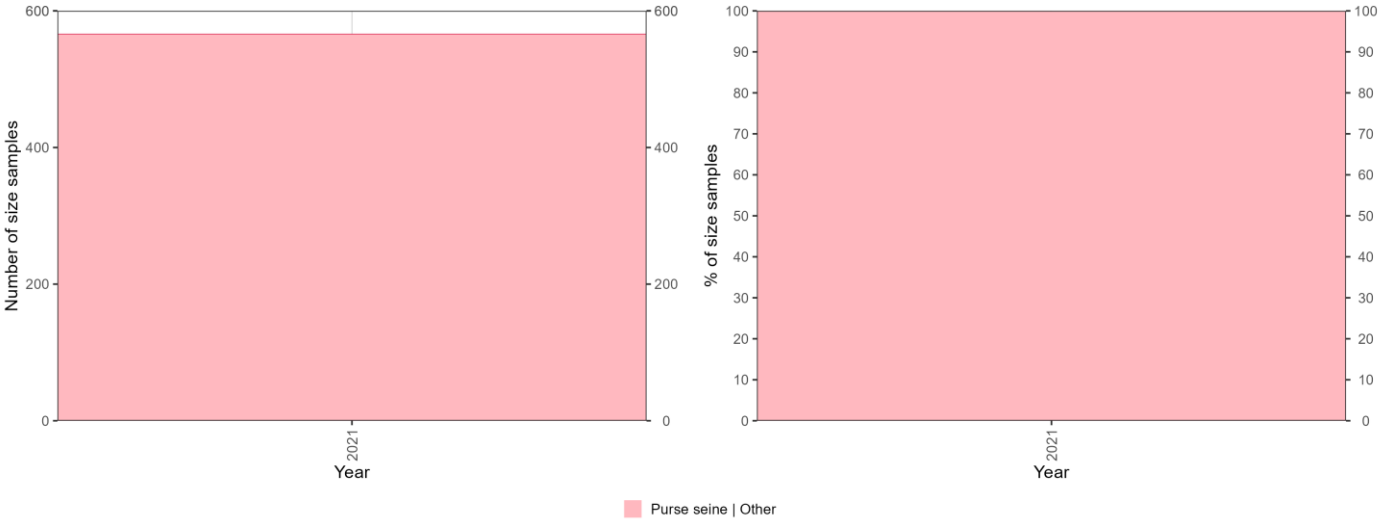

Figure 28: Availability of swordfish size-frequency data as absolute number of samples per year and purse seine fishery. FS = free-school; LS = school associated with drifting floating object. Data source: standardized size-frequency dataset

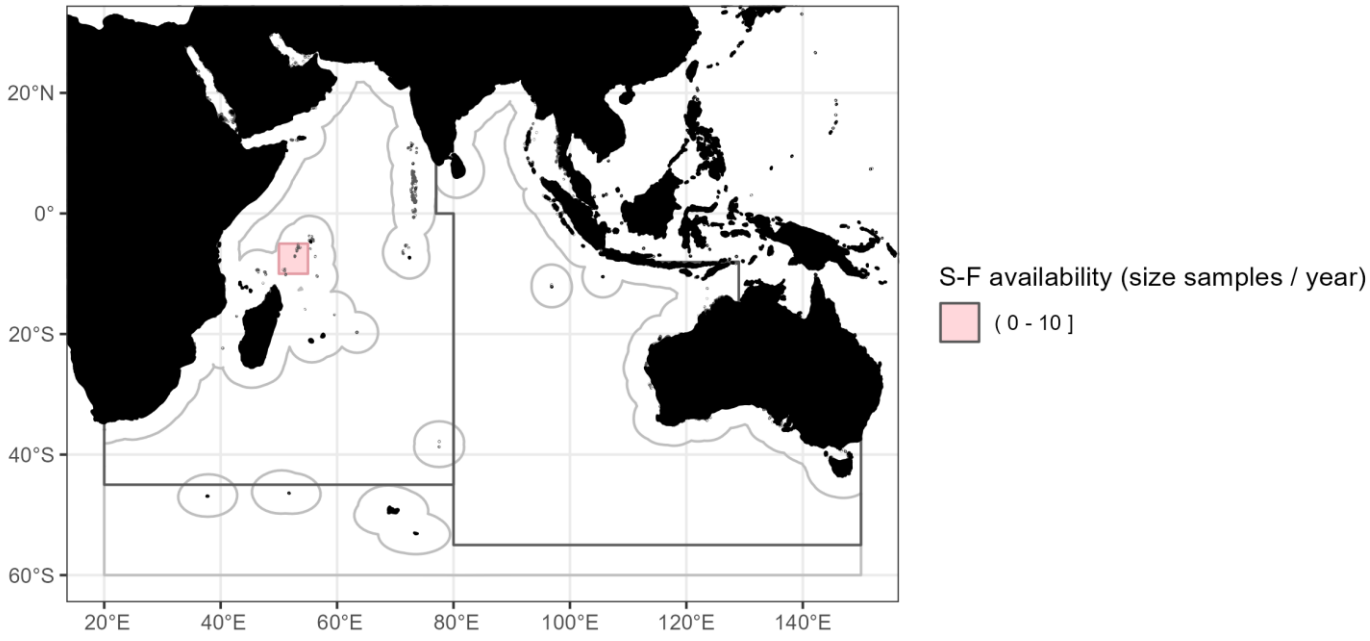

Figure 29: Spatial distribution (average number of samples per grid per year) of available swordfish size-frequency data by purse seine fisheries on free-swimming schools (PSFS) in the period 2017-2021. Data source: standardized size-frequency dataset

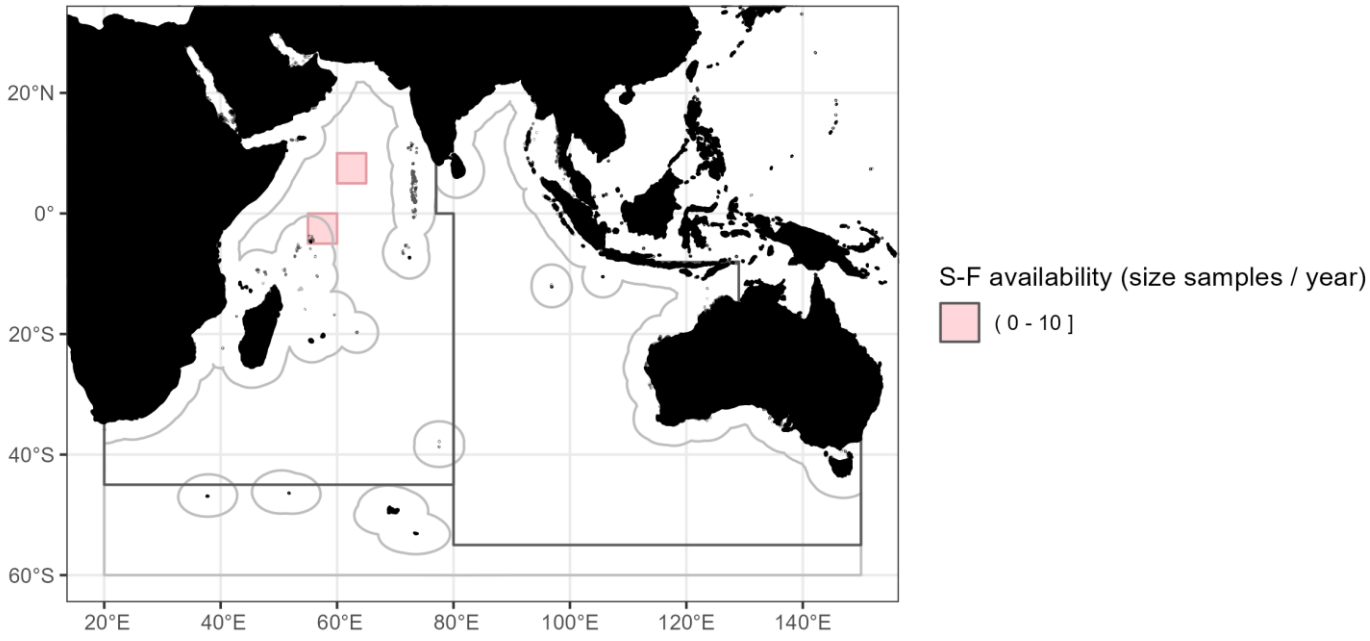

Figure 30: Spatial distribution (average number of samples per grid per year) of available swordfish size-frequency data by purse seine fisheries on schools associated with drifting floating objects (PSLS) in the period 2017-2021. Data source: standardized size-frequency dataset

Line fisheries

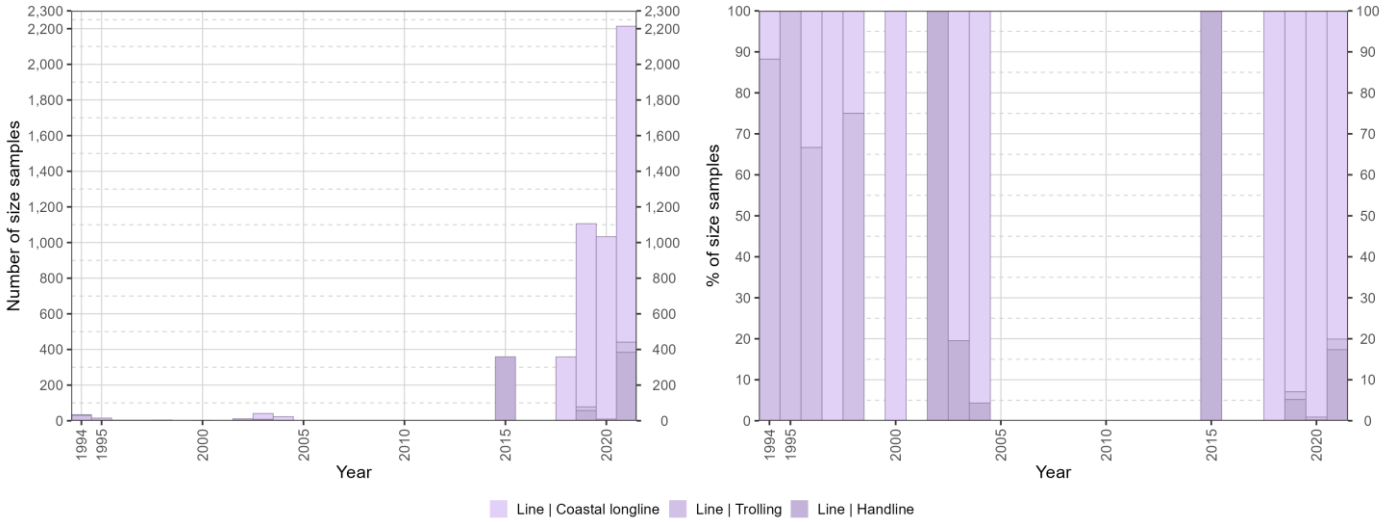

Figure 31: Availability of swordfish size-frequency data as absolute number of samples (left) and relative number of samples (right) per year and type of line fishery. Data source: standardized size-frequency dataset

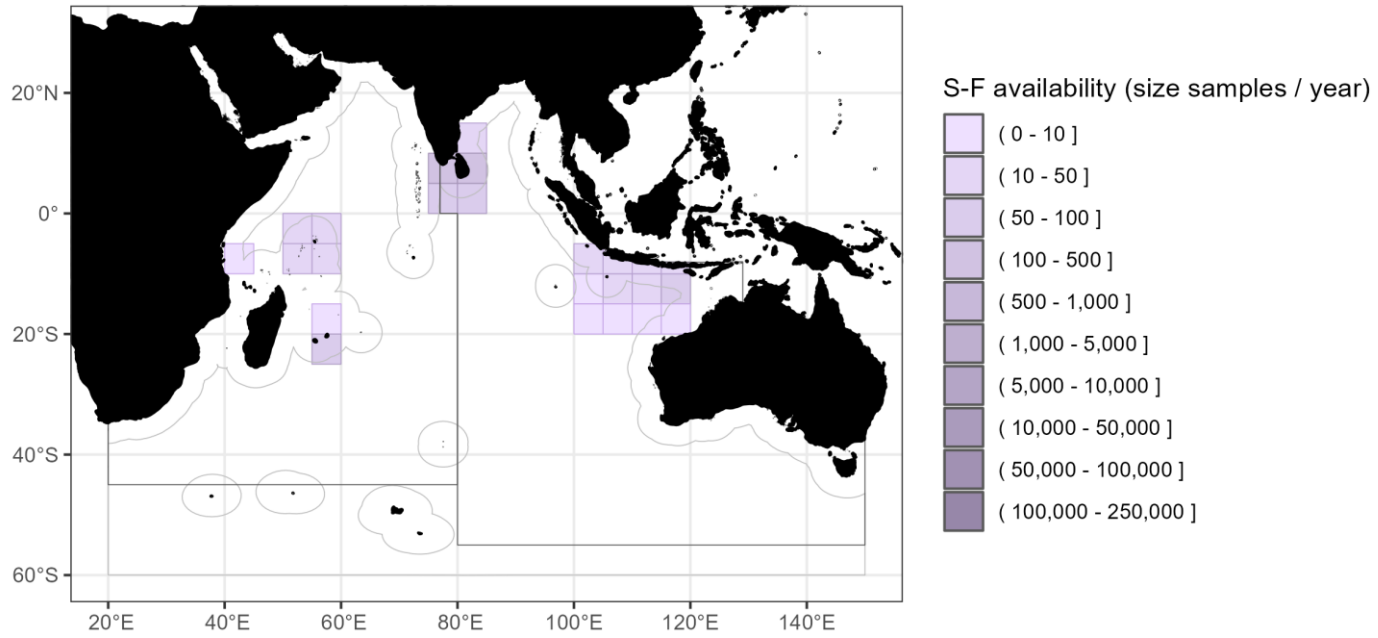

Figure 32: Spatial distribution (average number of samples per grid per year) of available swordfish size-frequency data by line (coastal longline) fisheries in the period 2017-2021. Data source: standardized size-frequency dataset

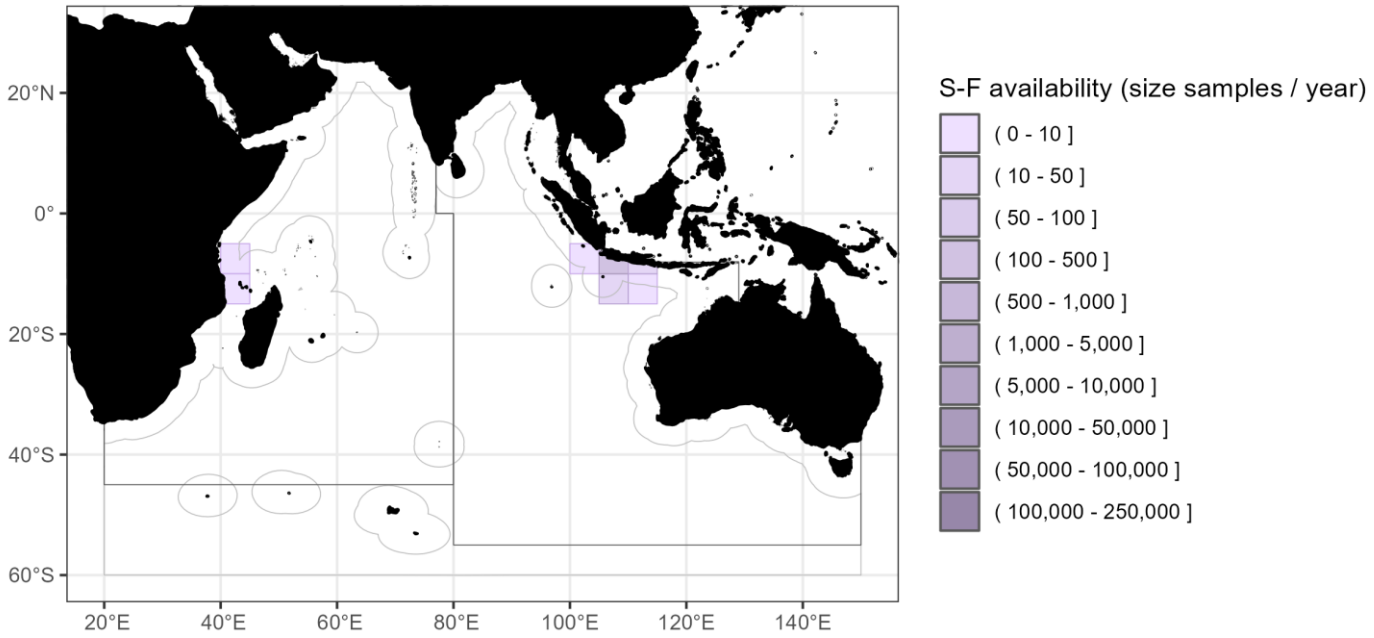

Figure 33: Spatial distribution (average number of samples per grid per year) of available swordfish size-frequency data by line (handline) fisheries in the period 2017-2021. Data source: standardized size-frequency dataset

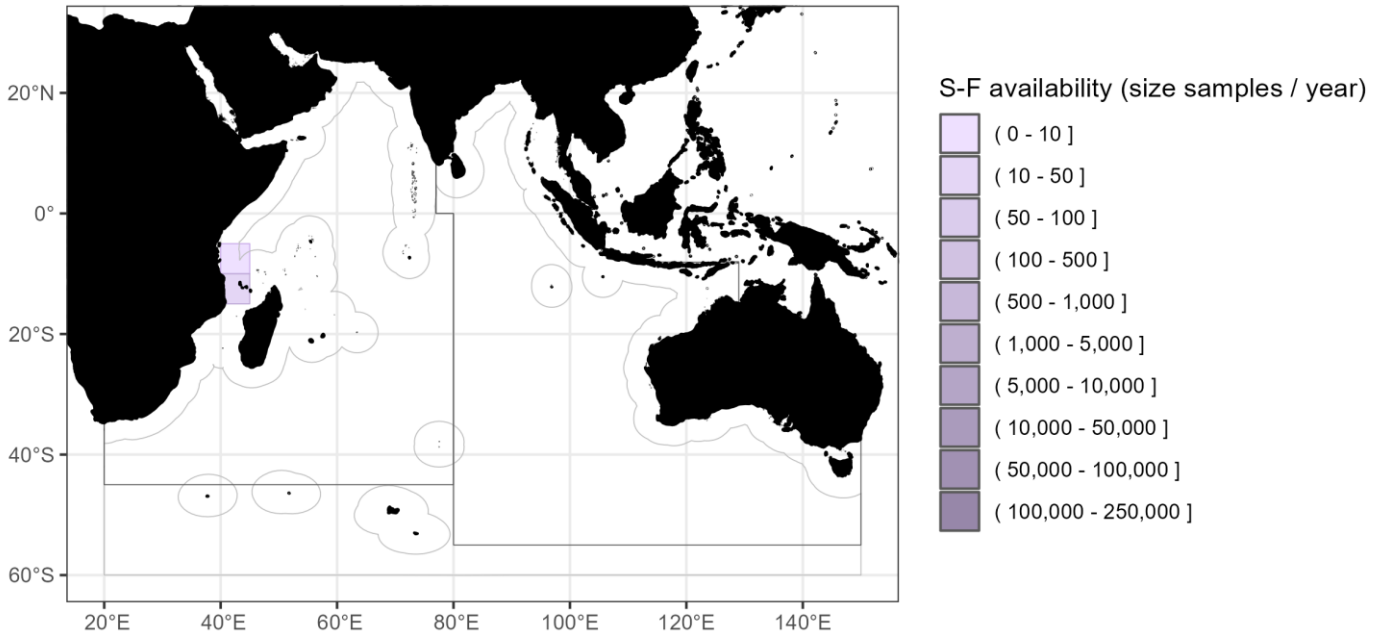

Figure 34: Spatial distribution (average number of samples per grid per year) of available swordfish size-frequency data by line (trolling) fisheries in the period 2017-2021. Data source: standardized size-frequency dataset

Other fisheries

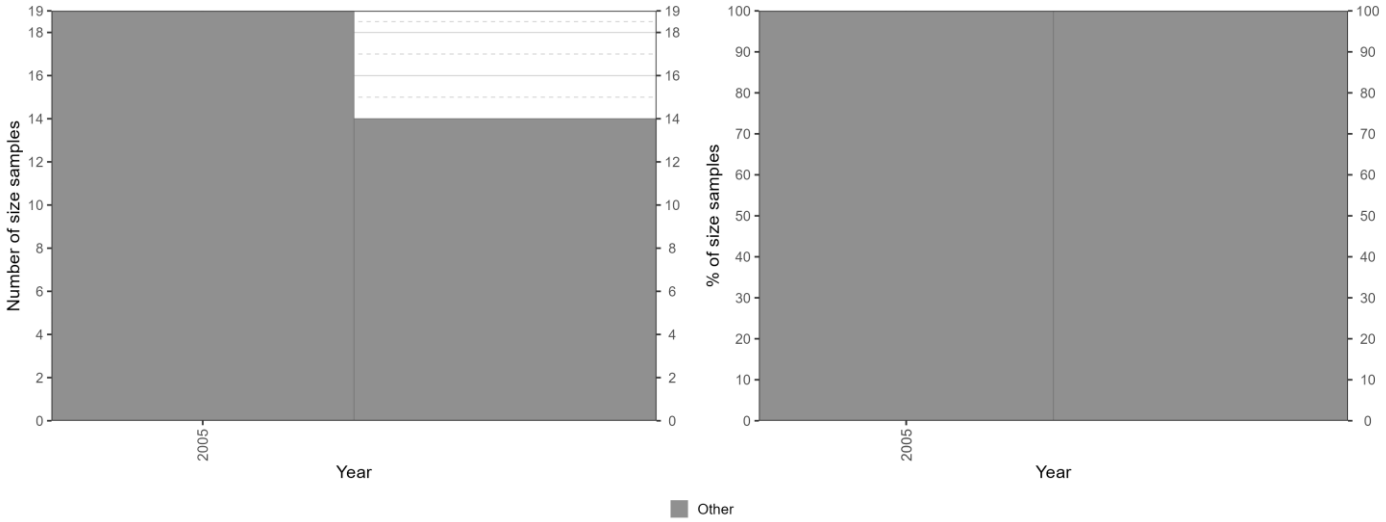

Figure 35: Availability of swordfish size-frequency data as absolute number of samples (left) and relative number of samples (right) per year and 'other' fishery type. Data source: standardized size-frequency dataset

Temporal patterns and trends in size distributions

The samples collected indicate variation in sizes by fisheries and over time. Temporal patterns indicate that samples from longline fisheries are around 100 to 200 cm, with high frequency distribution around of 150 cm for all longline fisheries. The patterns for line and gillnet differ from longline fisheries and do not have a consistent frequency. In the past, samples collected from line had high frequency around 90 and 150 cm, however in recent years, the median values varied between 100 and 200 cm. Like line fisheries, gillnet fisheries size-frequency distributions in recent years differ to the size-frequency distributions available prior to 2008. The median values of gillnet samples in recent years vary between 90 and 160 cm, while in the past they were between 100 and 150 cm (**Fig. 36**).

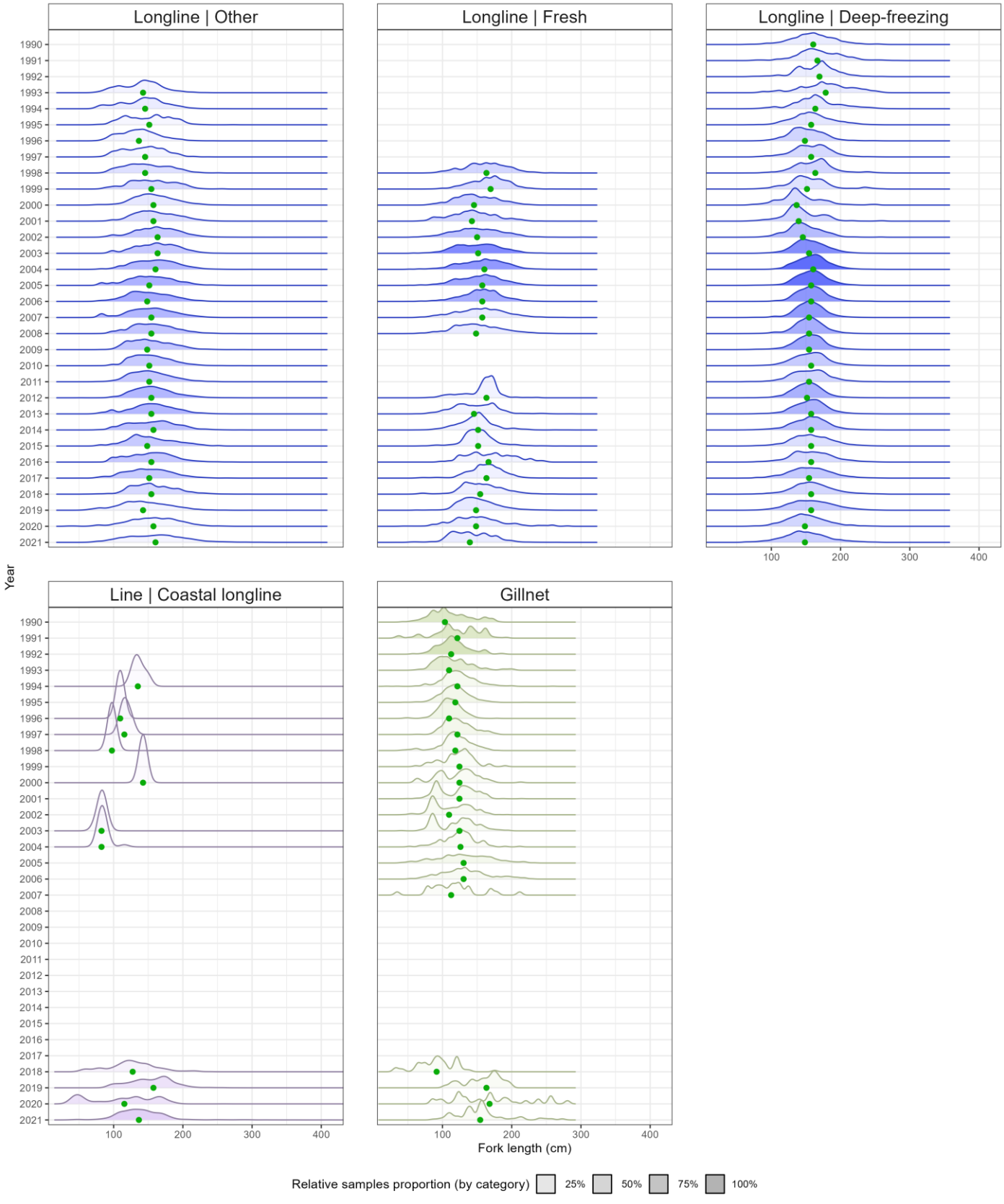

Figure 36: Relative size distribution (fork length; cm) of swordfish caught by longline and gillnet fisheries. Fill intensity is proportional to the number of samples recorded for the year, while the green dot corresponds to the median value. Data source: standardized size-frequency dataset

Size distribution by fishery and fleet

Fleet-wise, Taiwan,China and Japan deep-freezing longline fleets sampled swordfish since the early 1990s and had the same general distribution patterns. Most of the deep-freezing longline fisheries have size frequency distributions between 100 and 200 cm, besides the Korean deep-freezing longline fleet which measured some larger swordfish in recent years (over 300 cm) (**Fig. 37**).

The samples collected from fresh tuna longline fleets are fewer compared to deep-freezing longliners, and predominantly from Taiwan,China, Indonesia, and other non-identified fresh tuna longline fleets in the past. Recently, various other fresh tuna longline fleets have been sampling swordfish. Despite the differences between fleets, size distributions from fresh tuna longline fisheries remained between 100 and 200 cm. However, smaller swordfish samples were recorded from Seychelles and Malaysia fresh tuna longline fisheries, which measured around 15 cm (**Fig. 38**).

Fisheries that target swordfish and sharks sampled significant number of swordfish prior to 2018, and less in recent years (**Fig. 39**) . There are two types of longline fisheries targeting swordfish and sharks, the larger vessels operating on the high seas and smaller vessels operating in the EEZ. Despite the variation in operation, slight differences in the distribution patterns are observed. EU-Spain, which targeted swordfish using the American-style monofilament longline (García-Cortés & Mejuto 2005) reported raised size frequency of swordfish between the late 1990s and late 2010s, with a distribution pattern between 48 cm and 348 cm. The Spanish Institute of Oceanography (IEO), which conducted at-sea sampling program, suspended the program in 2020 due to COVID-19 pandemic and other administrative issues (Instituto Español de Oceanografía & Pesca 2022). EU-Reunion has stable swordfish fisheries compared to other small island nations with longline targeting swordfish. Hence, the size frequency distribution from EU-Reunion maintained some consistency in the sampling from the late 1990s to recent years, with distribution patterns ranging between 33cm and 345 cm, although some outliers in 2018 (around 400 cm). EU,Portugal on the contrary, collected sampling through observer programme from 2011.

Following some marketing problems for swordfish faced by Seychelles due to too high contents of cadmium and mercury, the semi-industrial longline fishery shifted toward targeting tunas recently. The sampling of swordfish from the Seychelles swordfish-longline fishery varies both in the number of samples collected and size distribution patterns over the years. Similar patterns have been observed from the semi-industrial longline fishery of Mauritius, which has stopped its operations in 2021. In the eastern Indian Ocean, Australia had a longline fishery targeting swordfish from 2000 to 2007. Thereafter, there were some variations in the sampling intensity, reflecting the reduction in swordfish catches from Australia due to a substantial decline in the number of longline vessels from 2005. The number of samples increased from 2015 with an average distribution range comprised between 63 cm and 288 cm in recent years.

Sampling of swordfish from gillnet fisheries are only collected by Sri Lanka (**Fig. 40**). Although the sampling program began in the 1990s, the distribution patterns and number of swordfish measured vary over time, possibly due to a combination of changes in the type of fishing gear and fishing grounds. Sri Lanka gillnet size frequency collected between 2018 and 2021 averaged at 110 fish per year. The size-frequency distribution patterns reported for 2020 and 2021 are between 75 cm and 306 cm, which differ with samples collected between 2018 and 2019 (30 cm and 294 cm). #### Deep-freezing longline fisheries

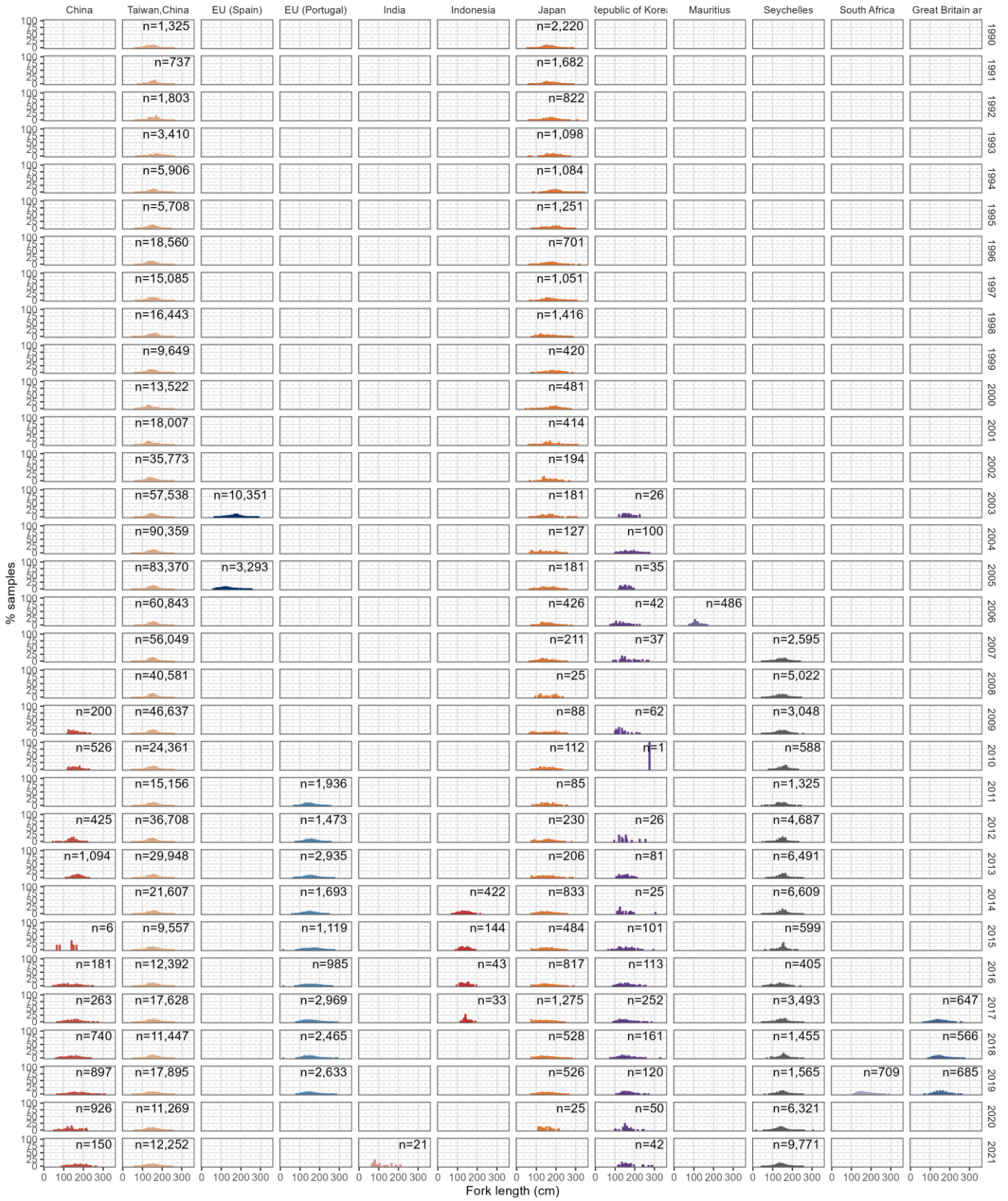

Figure 37: Relative size distribution of swordfish (fork length; cm) recorded for deep-freezing longline fisheries (LLD) by year and main fleet. Data source: [standardized size-frequency dataset]

Fresh longline fisheries

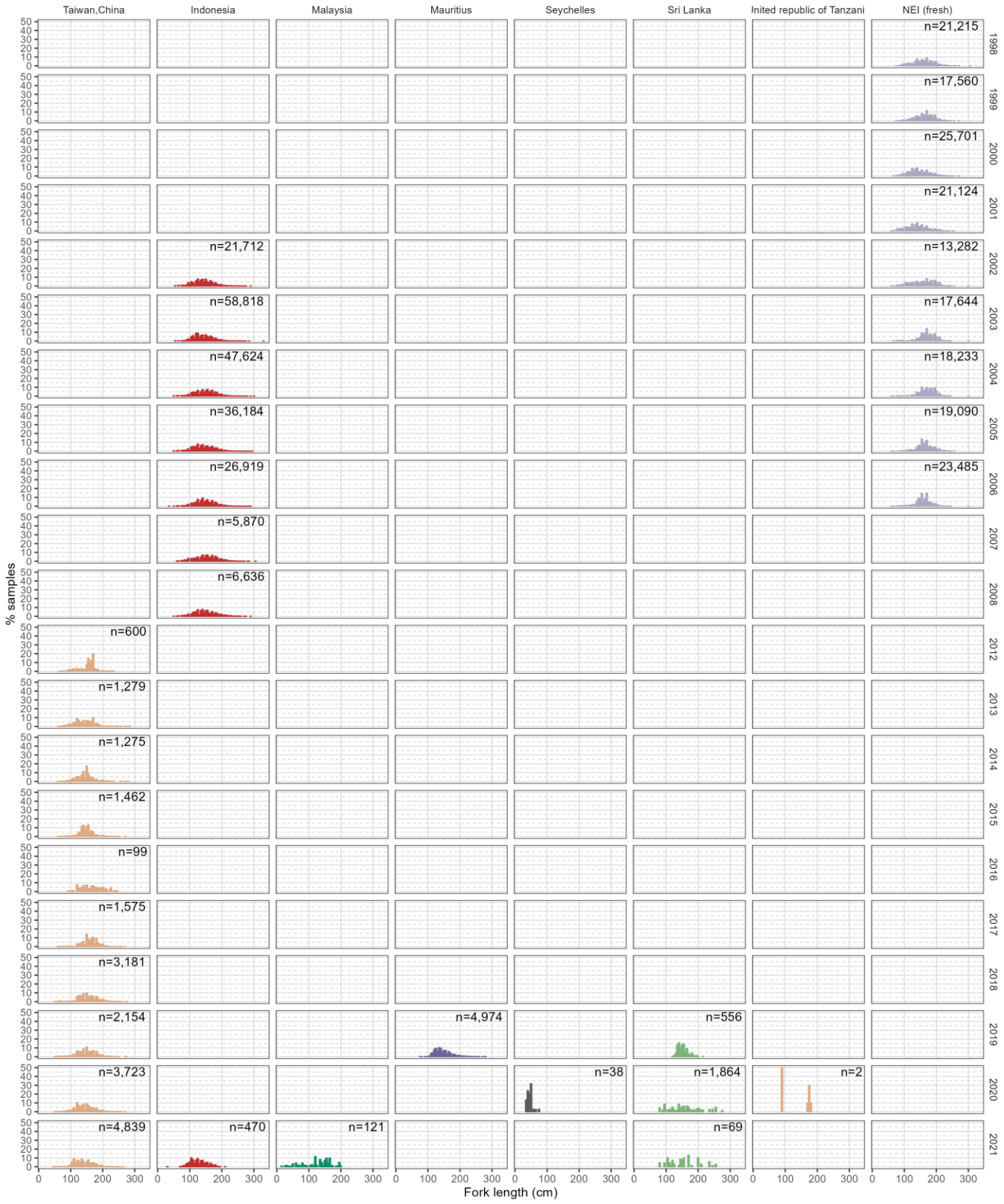

Figure 38: Relative size distribution of swordfish (fork length; cm) recorded for fresh longline fisheries (LLF) by year and main fleet. Data source: standardized size-frequency dataset

Swordfish and sharks-targeted longline fisheries

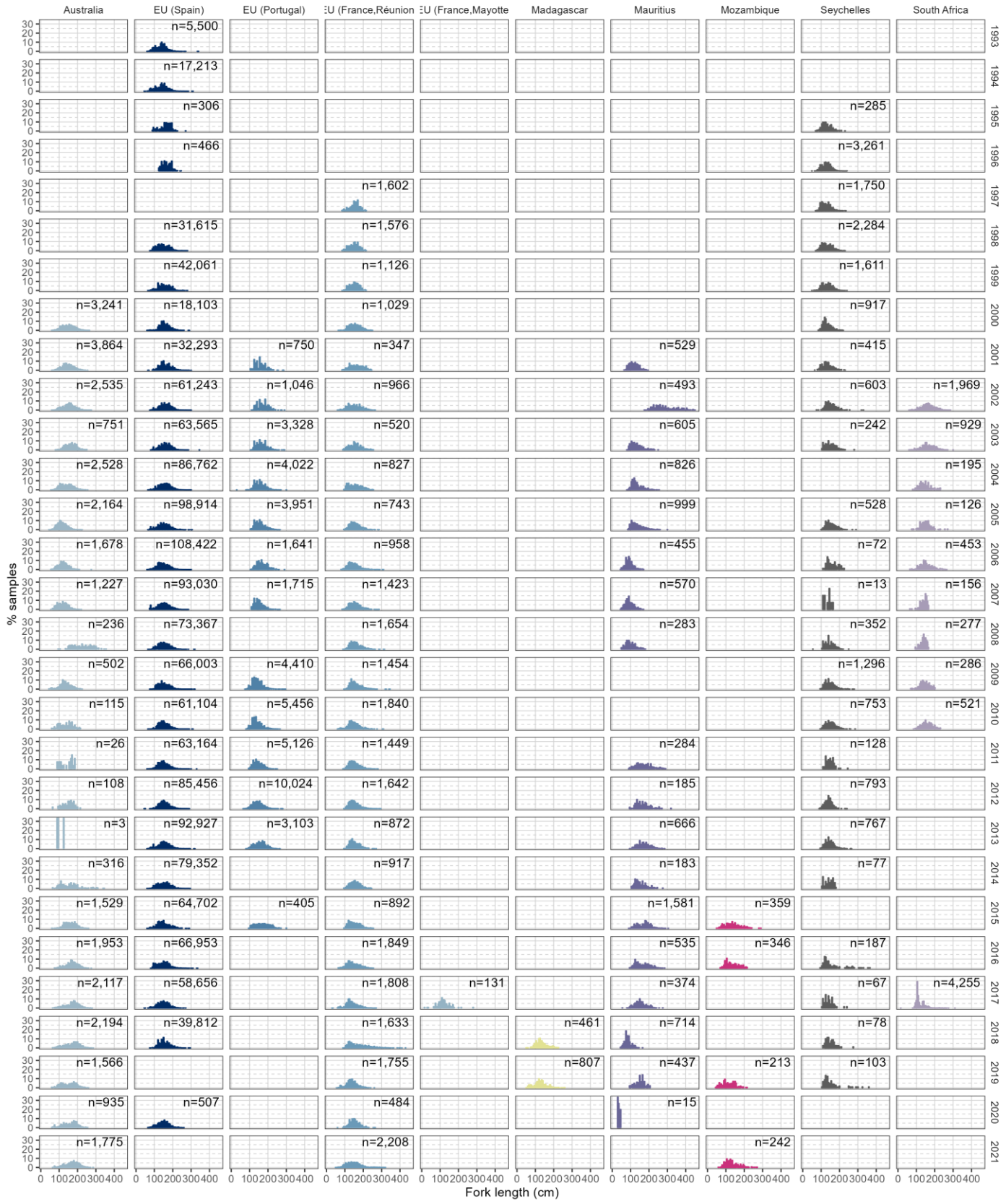

Figure 39: Relative size distribution of swordfish (fork length; cm) recorded for swordfish and shark-targeted longline fisheries (LLO) by year and main fleet. Data source: standardized size-frequency dataset

Gillnet fisheries

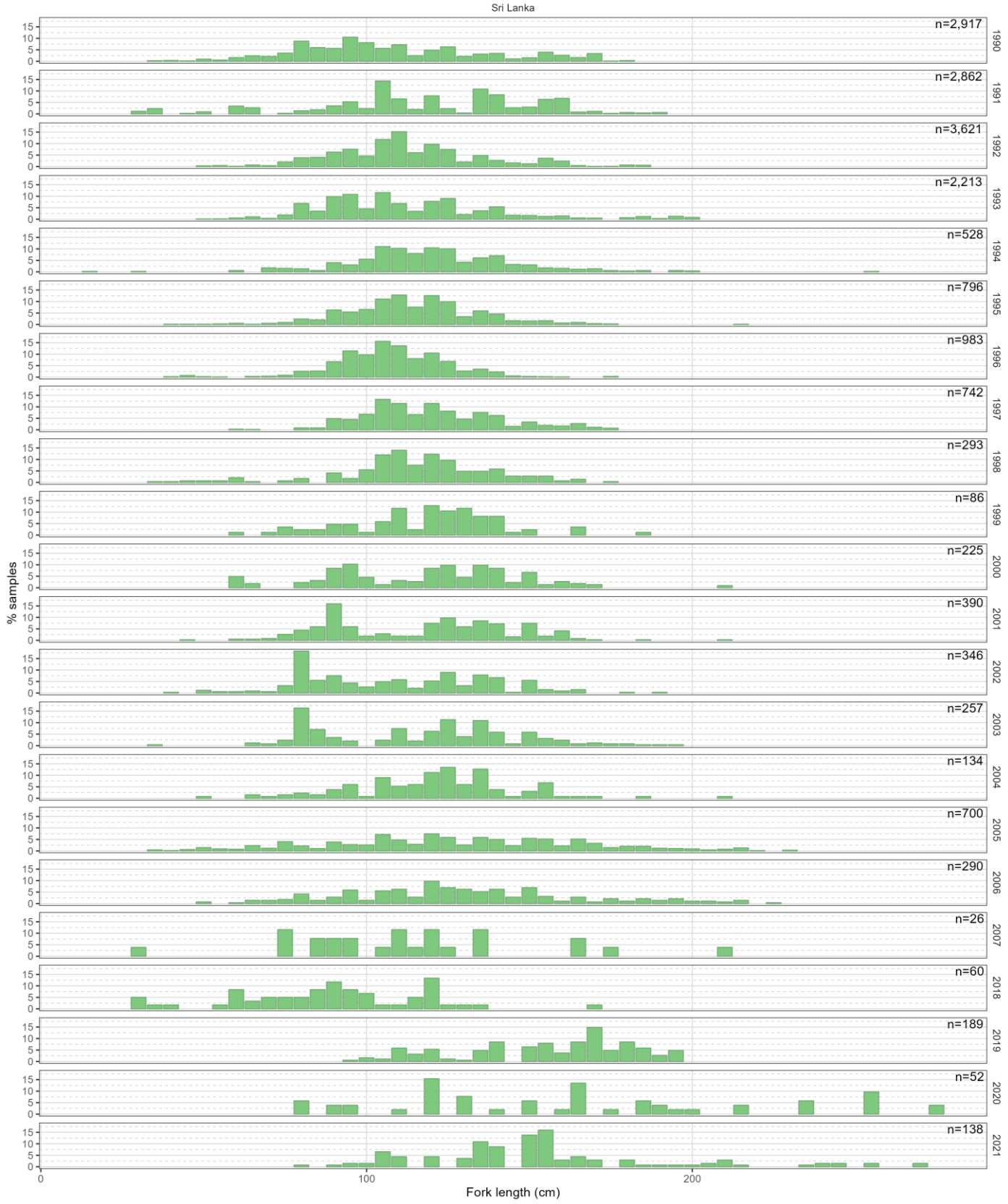

Figure 40: Relative size distribution of swordfish (fork length; cm) recorded for gillnet fisheries by year and main fleet. Data source: standardized size-frequency dataset

Uncertainties in size-frequency data

The quality of geo-referenced size-frequency data of swordfish shows inadequate data are available in relation to the retained catch data of swordfish. Limited swordfish size-frequency data was available before 1980 and with poor

quality. Since the 1980s, the quality of size data began to improve, whereby more fleets started to report data, particularly from industrial fisheries. Good quality size-frequency data (scoring between 0-2), in relation to retained catch data of swordfish was at 48% in 1980 and fluctuated around the same level thereafter. The quality improved in recent years to reach 73% overall, with recent improvement in the quality of size frequency data from coastal fisheries (**Fig. 41**).

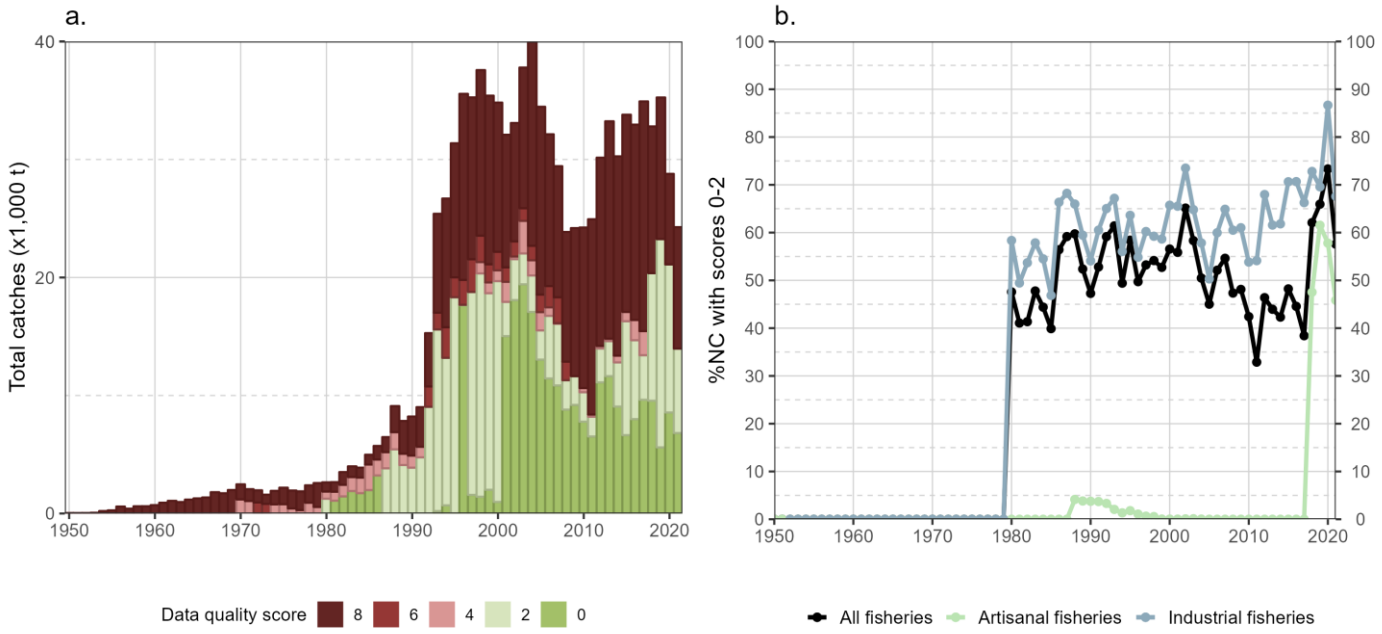

Figure 41: (a) Annual retained catches (metric tonnes; t) of swordfish estimated by quality score and (b) percentage of retained catches for which geo-referenced size-frequency data were reported to the IOTC Secretariat in agreement with the requirements of Res. 15/02 for all fisheries and by type of fishery, in the period 1950–2021

Temporal trends in estimated average weights

Trends in the average weights of swordfish can be derived from the raised time-area catches in weight and numbers. While they can be estimated for the entire time series and for each fishery, due to the lack of original samples for several strata (especially in the early periods of the fisheries) they are considered accurate only for those periods for which actual samples are available and cover strata that correspond to at least 50 t of retained catches per year.

Considering the limitations in the original data and in the process that produces this estimation, it should be noted that the average weights calculated for the longline fisheries of Japan and Taiwan,China between 2000 and 2021 fluctuated at around 55 kg and 50 kg respectively (**Fig. 43**). With Japan reaching the minimum average weight 31 kg in 2008, due to significant decrease in catches and sample collected in the Northwest Indian Ocean during piracy time. Taiwn,China however, the average weight peaked at 93 kg in 1990s, when a high number of Taiwanese longliners operated in Western Indian Ocean.

The average weight in the catch of fisheries other than longline fisheries from Japan and Taiwan,China was around 38 kg between 2000 and 2021, when there were more reliable samples. The average weights prior to the mid-1990s (at 39 kg) were estimated as no samples were available during that period (**Fig. 43**).

The trend for all fisheries catching swordfish in the Indian Ocean since 1950s show an average weight of 44 kg between 2000 and 2021. However, in the early 1990s the average weight peaked to 80 kg, reflecting the high average weight from the Taiwanese longline fishery in that period.

Figure 42: Combined estimated swordfish average weight (kg/fish) in the catch by fishery and year. Semi-transparent points correspond to years for which the original size samples cover strata with reported catches (by year and fishery) **lower** than 50 t. Longline | Japan = includes data from longliners flagged by Japan, Rep. of Korea, Oman and Thailand; Longline | Taiwan = includes data from longliners flagged by Taiwan,China and other longliners operating similarly or ex-Taiwan,China longliners; and Other fisheries not otherwise mentioned. Data source: raised time-area catches

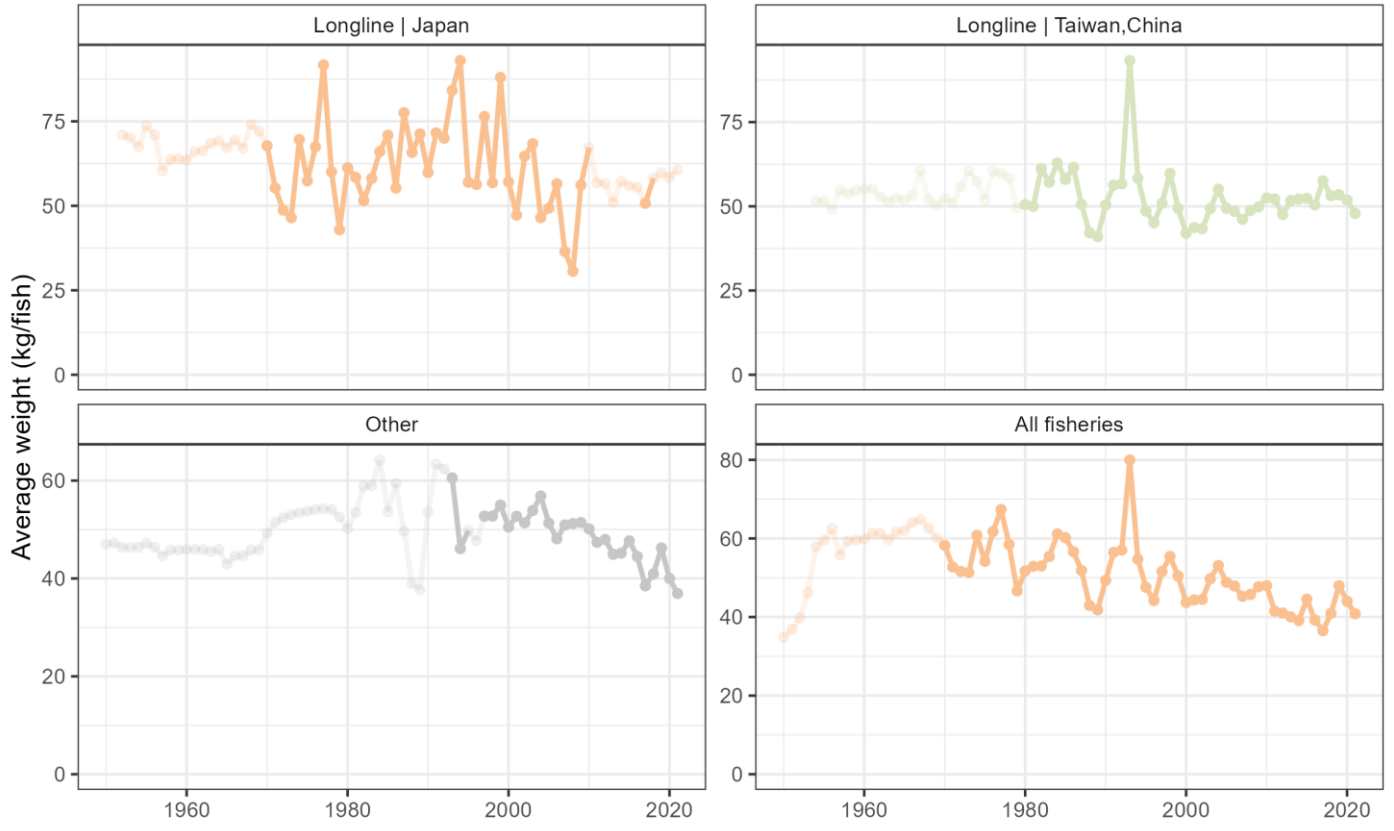

Figure 43: Estimated swordfish average weight (kg/fish) in the catch by fishery and year. Semi-transparent points correspond to years for which the original size samples cover strata with reported catches (by year and fishery) **lower** than 50 t. Longline | Japan = includes data from longliners

flagged by Japan, Rep. of Korea, Oman and Thailand; Longline | Taiwan = includes data from longliners flagged by Taiwan,China and other longliners operating similarly or ex-Taiwan,China longliners; and Other fisheries not otherwise mentioned. Data source: raised time-area catches

Overall, the trend in average weights that results from combining data for all fisheries together shows a slow decrease in the size of fish caught since the beginning of the 2000s, which can be explained by the generalized decline from longline fisheries targeting swordfish in recent years (**Fig. 42**).

Spatial distribution of average weights

Estimated average weights by decade (1950-2019)

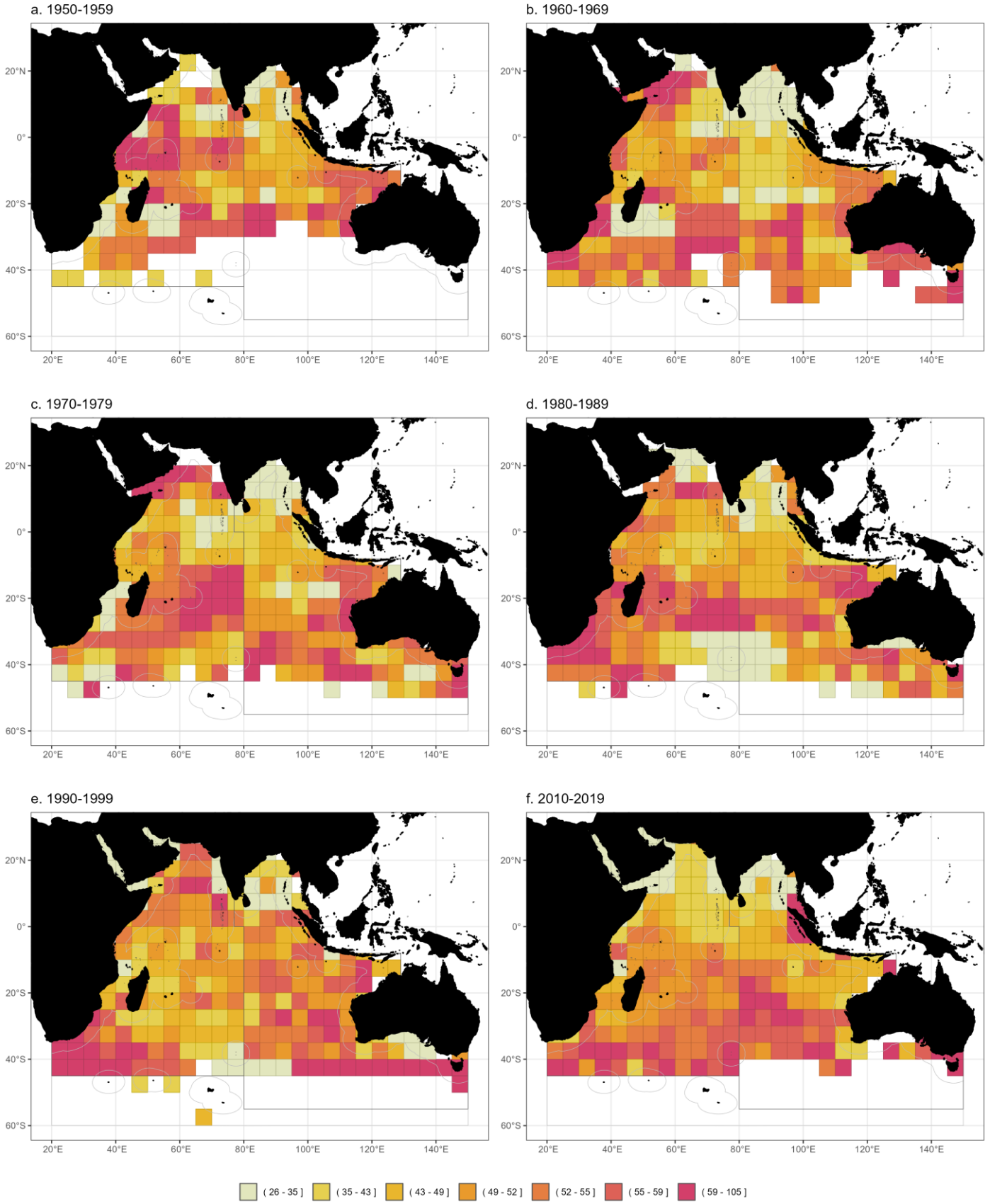

Figure 44: Estimated swordfish average weight (kg/fish) in the catch by decade and 5x5 grid, for all fisheries combined for the period 1950-2019. Data source: raised time-area catches

Estimated average weights by year (2017-2021) and last decade (2010-2019)

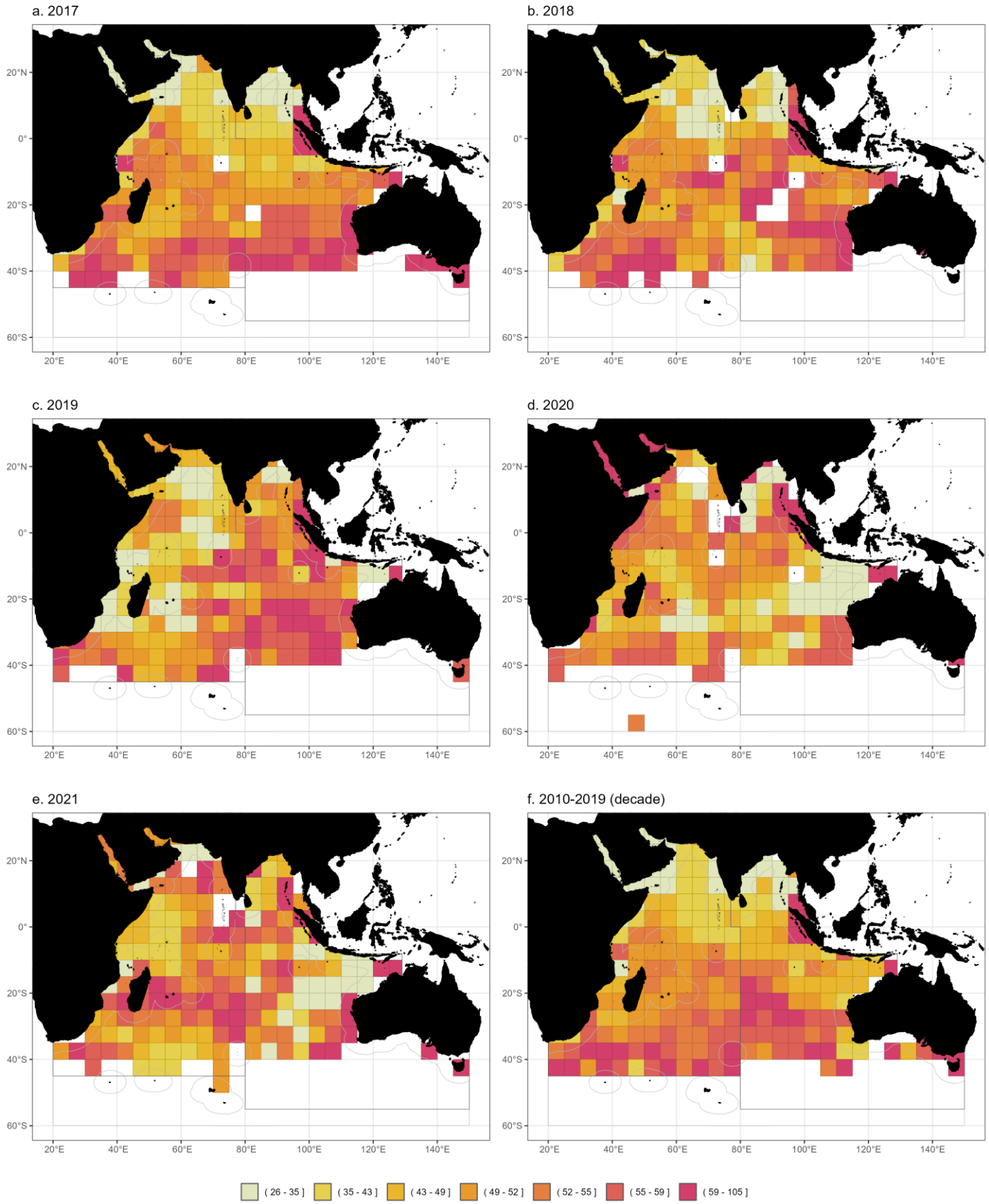

Figure 45: Estimated swordfish average weight (kg/fish) in the catch by year and 5x5 grid, for all fisheries combined for the period 2017-2021 and for the decade 2010-2019. Data source: raised time-area catches

Estimated average weights by fishery group in recent years (2017-2021)

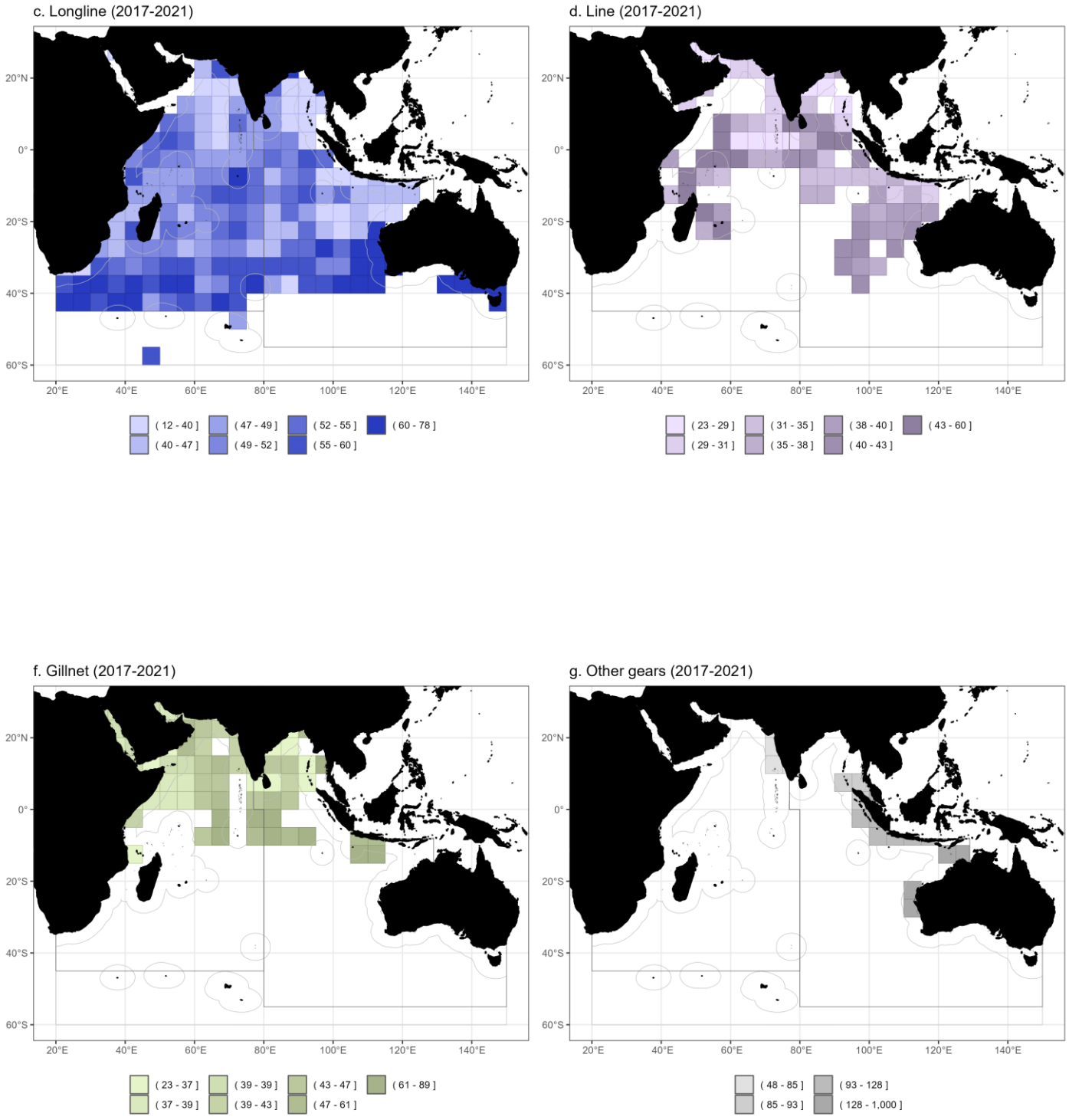

Figure 46: Estimated swordfish average weight (kg/fish) in the catch by 5x5 grid and fishery group for the period 2017-2021. LS = schools associated with floating objects; FS = free-swimming schools. Data source: raised time-area catches

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Appendices

Appendix I: Taxonomy

Rank	Taxon
Kingdom	*Animalia*
Subkingdom	*Bilateria*
Infrakingdom	*Deuterostomia*
Phylum	*Chordata*
Subphylum	*Vertebrata*
Infraphylum	*Gnathostomata*
Superclass	*Actinopterygii*
Class	*Teleostei*
Superorder	*Acanthopterygii*
Order	*Perciformes*
Suborder	*Xiphioidei*
Family	*Xiphiidae*
Genus	*Xiphias*
Species	*Xiphias gladius*

Appendix II: Changes in best scientific estimates of retained catches from previous WPB

Some improvements were made to the best scientific estimates of retained catches of swordfish since the 20th session of the IOTC Working Party on Billfish (WPB20), with overall small modifications in the time series of annual catches (**Fig. 8**). The changes covering the period 2017-2020 were due to: (i) updates of billfish catches by Yemen (YEM) as available in the FAO global capture production database and (ii) some minor catch revision for some fisheries of Indonesia, Japan, I.R. Iran, and Kenya (**Table 4**).

Table 4: Changes in best scientific estimates of annual retained catches (metric tonnes; t) of swordfish by year, fleet, fishery group and main Indian Ocean area, limited to absolute values higher than 10 t

Year	Fleet	Fishery group	Area	Current (t)	Previous (t)	Difference (t)
2020	KEN	Gillnet	Western Indian Ocean	96	61	35
		Line	Western Indian Ocean	41	154	-113
	YEM	Gillnet	Western Indian Ocean	251	0	251
		Line	Western Indian Ocean	1,535	0	1,535
2019	IRN	Gillnet	Western Indian Ocean	1,111	1,380	-268
	JPN	Longline	Western Indian Ocean	147	136	11
	YEM	Gillnet	Western Indian Ocean	1,287	0	1,287
		Line	Western Indian Ocean	499	0	499
2018		Gillnet	Western Indian Ocean	1,408	0	1,408
		Line	Western Indian Ocean	378	0	378
2017	IDN	Gillnet	Eastern Indian Ocean	76	61	15
		Line	Eastern Indian Ocean	943	755	188
		Purse seine	Eastern Indian Ocean	101	81	20
	YEM	Gillnet	Western Indian Ocean	1,353	0	1,353
		Line	Western Indian Ocean	415	0	415