SWORDFISH

SUPPORTING INFORMATION

(Information collated from reports of the Working Party on Billfish and other sources as cited)

Swordfish (*Xiphias gladius*) in the Indian Ocean is currently subject to a number of Conservation and Management Measures adopted by the Commission, although none are species specific:

- Resolution 15/01: *On the recording of catch and effort by fishing vessels in the IOTC area of competence*
- Resolution 15/02: *Mandatory statistical reporting requirements for IOTC Contracting Parties and Cooperating Non-Contracting Parties (CPC's)*
- Resolution 15/11: *On the implementation of a limitation of fishing capacity of Contracting Parties and Cooperating Non-Contracting Parties*
- Resolution 14/05: *Concerning a record of licensed foreign vessels fishing for IOTC species in the IOTC area of competence and access agreement information*
- Resolution 12/11 *On The implementation of a limitation of fishing capacity of Contracting Parties and Cooperating Non-Contracting Parties*
- Resolution 11/04: *On a regional observer scheme*
- Resolution 10/08: C*oncerning a record of active vessels fishing for tunas and swordfish in the IOTC area*

FISHERIES INDICATORS

Swordfish: General

Swordfish (*Xiphias gladius*) is a large oceanic apex predator that inhabits all the world's oceans (**Fig. 1**). Throughout the Indian Ocean, swordfish are primarily taken by longline fisheries, and commercial harvest was first recorded by the Japanese in the early 1950's as a bycatch / by-product of their tuna longline fisheries. Swordfish life history characteristics, including a relatively late maturity, long life and sexual dimorphism, make the species vulnerable to over exploitation. **Table 1** outlines some of the key life history traits of swordfish specific to the Indian Ocean.

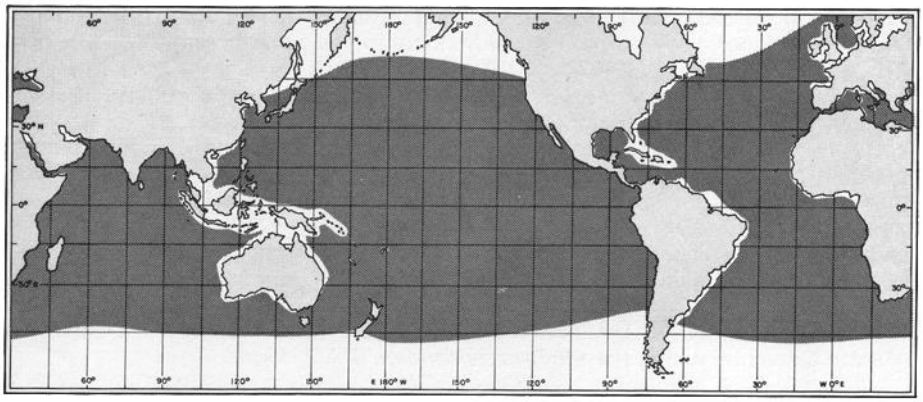


Fig. 1. Swordfish: The worldwide distribution of swordfish (Source: Nakamura 1984).

TABLE 1. Swordfish: Biology of Indian Ocean swordfish (*Xiphias gladius*).

Parameter	Description
Range and stock structure	Entire Indian Ocean down to 50˚S. Juvenile swordfish are commonly found in tropical and subtropical waters and migrate to higher latitudes as they mature. Large, solitary adult swordfish are most abundant at 15–35˚S. Males are more common in tropical and subtropical waters. By contrast with tunas, swordfish is not a gregarious species, although densities increase in areas of oceanic fronts and seamounts. Fast long-distance migrations were recorded in the Indian Ocean with average horizontal speed up to 48 km day^{-1}. Extensive diel vertical migrations, from surface waters during the night to depths of 800-1000 m during the day, in association with movements of the deep scattering layer and cephalopods, their preferred prey. A recent genetic study did not reveal any structure within the Indian Ocean with the markers used, however the hypothesis of a population structuring at the regional level cannot be discarded and needs to be investigated using different markers or approaches. Results obtained from the markers used may simply be a matter of the resolving power of the markers used, which may simply have been insufficient for detecting population subdivision. Spatial heterogeneity in stock indicators (catch–per–unit–effort trends) indicates the potential for localised depletion of swordfish in the Indian Ocean.
Longevity	30+ years
Maturity (50%)	**Age**: females 4-5 years; males 2–3 years **Size**: females ~170 cm LJFL; males ~120 cm LJFL
Spawning season	Highly fecund batch spawner. May spawn as frequently as once every three days over a period of several months in spring. Known spawning ground and season are: tropical waters of Southern hemisphere from October to April, including in the vicinity of Reunion Island.
Size (length and weight)	Maximum: 455 cm lower-jaw FL; 550+ kg total weight in the Indian Ocean. Sexual dimorphism in size, growth rates and size and age at maturity - females reach larger sizes, grow faster and mature later than males. Most swordfish larger than 200 kg are female. Recruitment into the fishery: varies by fishing method; ~50 cm LJFL for longline fisheries. By one year of age, a swordfish may reach 90 cm lower-jaw FL (~15 kg). The average size of swordfish taken in Indian Ocean longline fisheries is between 40 kg and 80 kg (depending on latitude). L-W relationships for the Indian Ocean are: females TW=0.00002409*LJFL^2.86630, males TW=0.00006289*LJFL**2.66196, both sexes mixed TW=0.00001443*LJFL^2.96267. TW in kg, LJFL in cm

Sources: Froese & Pauly 2009, Muths et al. 2009, Poisson & Fauvel 2009, Bach et al. 2011, Romanov, Romanova, 2012, Farley et al., 2016, Romanov et al., 2016

Fisheries and main catch trends

- Main fishing gear (2012–16): Longline catches[1] are currently estimated to comprise approximately 79% of total swordfish catches in the Indian Ocean. (**Table 2; Fig. 2**)
- Main fleets (and primary gear associated with catches): percentage of total catches (2012–16):
  Indonesia (fresh longline): 25%; Taiwan,China (longline): 18%; Sri Lanka (longline-gillnet): 13%; EU,Spain (swordfish targeted longline): 11% (**Fig. 3**).
- Main fishing areas: Primary: Western Indian Ocean, in waters off Somalia, and the southwest Indian Ocean. In the years between 2009 and 2011 the fishery moved eastwards due to piracy, while in current years a return to the previous fishing grounds has been detected. Secondary: Waters off Sri Lanka, western Australia and Indonesia.
- Retained catch trends:
  Before the 1990s, swordfish were mainly a non-targeted catch of industrial longline fisheries; catches increased relatively slowly in tandem with the development of coastal state and distant water longline fisheries targeting tunas.

  After 1990, catches increased sharply (from around 8,000 t in 1991 to 36,000 t in 1998) as a result of changes in targeting from tunas to swordfish by part of the Taiwan,China longline fleet, along with the development of longline fisheries in Australia, France(La Réunion), Seychelles and Mauritius and arrival of longline fleets from the Atlantic Ocean (EU,Portugal, EU,Spain the EU,UK and other fleets operating under various flags[2]).

  Since the mid-2000s annual catches have fallen steadily, largely due to the decline in the number of Taiwanese longline vessels active in the Indian Ocean in response to the threat of piracy; however since 2012 catches appear to show signs of recovery as a consequence of improvements in security in the area off Somalia.

[1] Including deep freezing longline (LL), exploratory longline (LLEX), fresh longline (FLL), longlines targeting sharks (SLL), and swordfish targeted longline (ELL).

[2] E.g., Senegal, Guinea, etc.

- Discard levels: Low, although estimates of discards are unknown for most industrial fisheries, mainly longliners. Discards of may also occur in the driftnet fishery of I.R. Iran, as this species has no commercial value in this country.

TABLE 2. Swordfish: best scientific estimates of catches by type of fishery for the period 1950–2016 (in metric tons).

Fishery	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
ELL	-	-	-	9	1,841	9,736	10,996	7,655	7,637	9,031	6,835	7,643	7,876	7,420	6,618	6,441
LL	260	1,301	1,920	4,313	22,692	20,085	16,123	13,511	13,810	12,419	10,976	17,466	17,186	21,477	23,419	23,722
OT	37	39	186	807	1,989	2,819	2,809	3,261	3,019	3,033	4,061	4,068	5,275	7,881	9,602	9,614
Total	**297**	**1,340**	**2,106**	**5,130**	**26,521**	**32,640**	**29,928**	**24,427**	**24,466**	**24,483**	**21,872**	**29,177**	**30,338**	**36,778**	**39,639**	**39,777**

Definition of fisheries: Swordfish targeted longline (**ELL**); Longline (**LL**); Other gears (includes longline-gillnet, handline, gillnet, gillnet-longline, coastal longline, troll line, sport fishing, and all other gears) (**OT**).

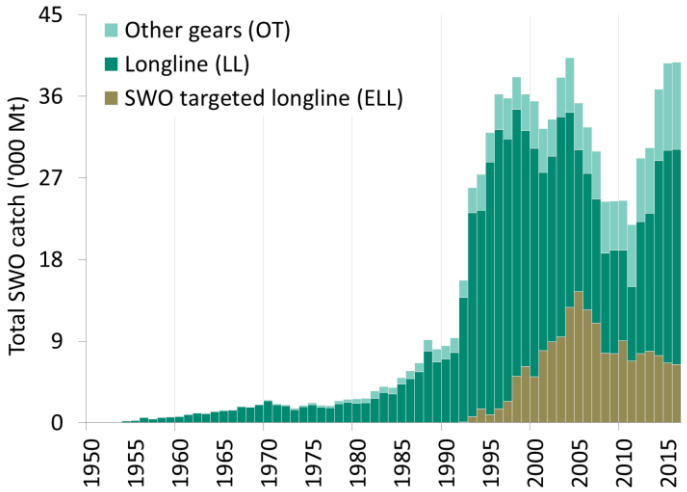


Fig. 2. Swordfish: catches by gear and year recorded in the IOTC Database (1950–2016).
Notes: Other gears includes: longline-gillnet, handline, gillnet, coastal longline, troll line, sport fishing, all others.

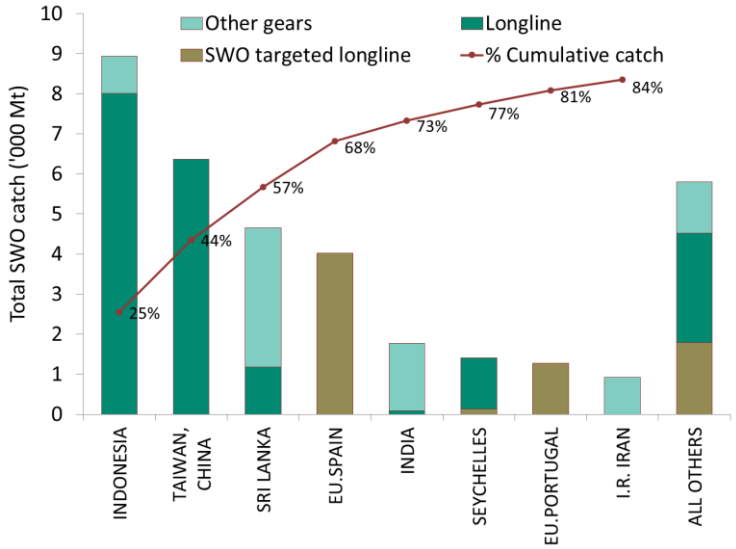


Fig. 3: Swordfish: average catches in the Indian Ocean over the period 2012–16, by fleet and gear. Fleets are ordered from left to right, according to the volume of catches reported. The red line indicates the (cumulative) proportion of catches of swordfish for the fleets concerned, over the total combined catches reported from all fleets and gears.

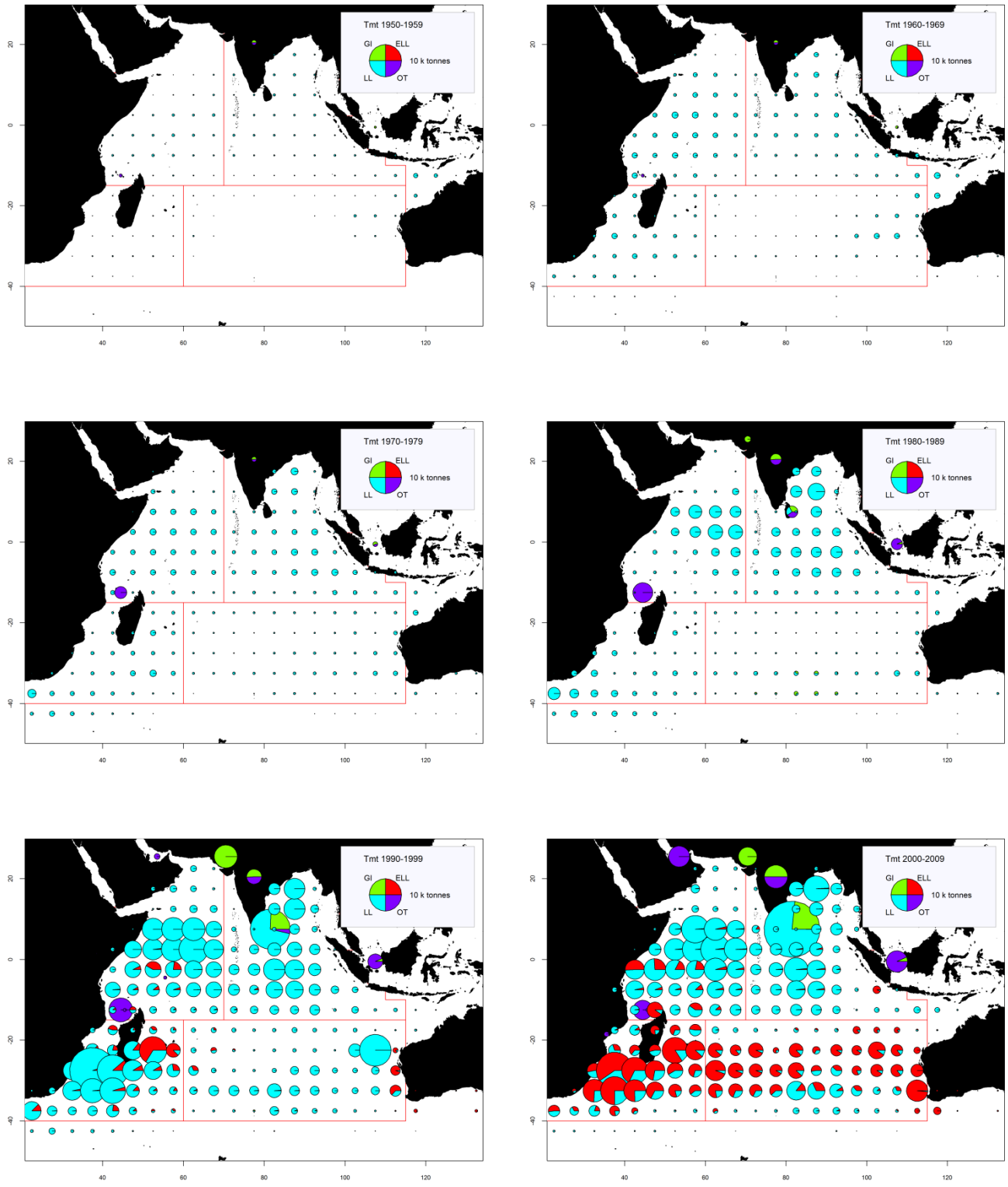


Fig. 4a-f: Swordfish: Time-area catches (total combined in tonnes) as reported for longline fisheries targeting swordfish (**ELL**), other longline fisheries (**LL**), gillnet fisheries (**GI**), and for all other fleets combined (**OT**), for the period 1950-2009, by decade and type of gear. Red lines represent the areas used for the assessments of swordfish.

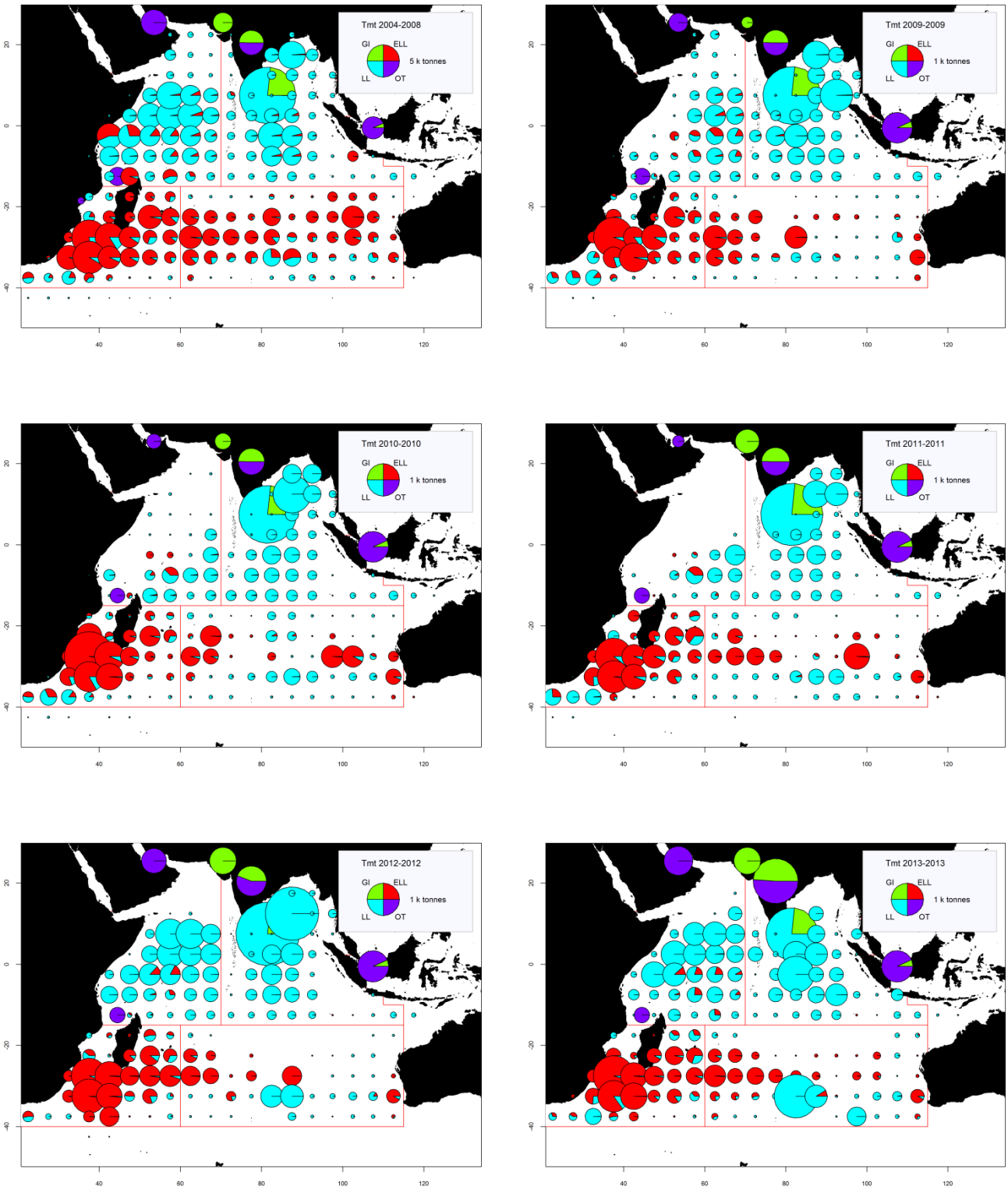


Fig. 5a-f: Swordfish: Time-area catches (total combined in tonnes) for longline fisheries targeting swordfish (**ELL**), other longline fisheries (**LL**), gillnet fisheries (**GI**), and for all other fleets combined (**OT**), for the period 2004-2008 by type of gear and for 2009-13, by year and type of gear. Red lines represent the areas used for the assessments of swordfish.

Source: IOTC catch and effort data (raised time area catches).

Swordfish: estimation of catches – data related issues

Retained catches – while the proportion of catches estimated, or adjusted, by the IOTC Secretariat are relatively low (**Fig. 6a**), there are uncertainties for the following fisheries/fleets:

- I.R. Iran and Pakistan (Gillnet): the IOTC Secretariat used the catches of swordfish and marlins reported by I.R. Iran for the years 2012 and 2013 to rebuild historical catch series of billfish for this fishery. However, catch rates

and species composition for the Iranian and Pakistani gillnet fisheries differ significantly from each other in terms of the species composition, and in the case of Pakistan, the catches by species and are also in contradiction with other estimates derived from WWF funded sampling conducted Pakistan in recent years.

- Indonesia (Longline): Catches possibly underestimated due to insufficient sampling coverage – especially in recent years (where they represent around 25% of the total catches).
- India (Longline): Incomplete catches and catch-and-effort data, especially for its commercial longline fishery. Catches in recent years represent less than 4% of the total catches of swordfish.
- Non-reporting fleets (NEI) (Longline): Catches estimated by the IOTC Secretariat, however the proportion of total catches associated with this fishery are thought to be low and do not have a significant impact on the overall catch series.

Swordfish – Catch-per-unit-effort (CPUE) trends

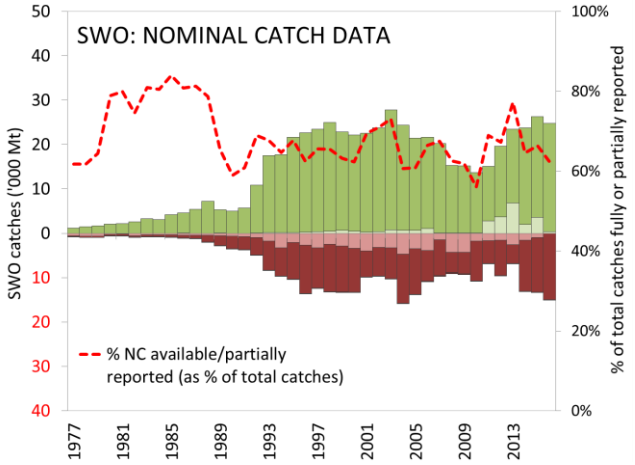
- Availability: Catch-and-effort series are available for some industrial longline fisheries.

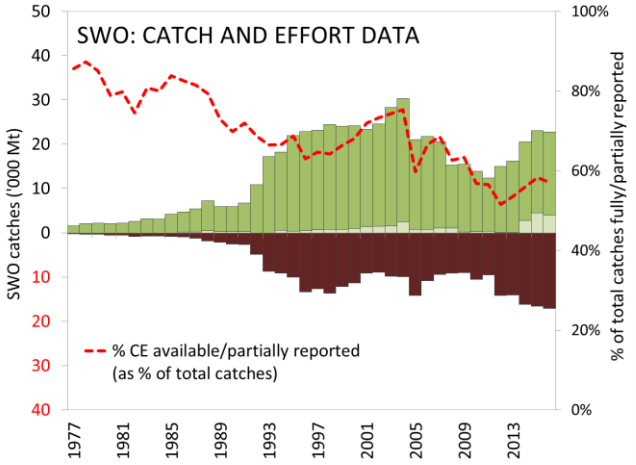
For most other fisheries, catch-and-effort are either not available (e.g., longline fisheries of Indonesia, drifting gillnet fisheries of Iran and Pakistan), or they are considered poor quality – especially since the early-1990s (e.g., gillnet and longline fisheries of Sri Lanka, Taiwan,China fresh-tuna longliners, Non-reporting longliners (NEI)).

Swordfish – Fish size or age trends (e.g., by length, weight, sex and/or maturity)

In general, the amount of catch for which size data for the species are available before 2005 is still very low and the number of specimens measured per stratum has been decreasing in recent years (**Fig. 6c**)

- Average fish weight: can be assessed for several industrial fisheries, although they are incomplete or poor quality for most fisheries before the early-80s and also in recent years (due low sampling coverage and time-area coverage of longliners from Japan). The average weights of swordfish are variable but show no clear trend.
- Catch-at-Size (Age) table: data are available but the estimates are thought to have been compromised for some years and fisheries due to:
    i. uncertainty in the length frequency data recorded for longliners of Japan and Taiwan,China: average weights of swordfish derived from length frequency and catch-and-effort data are very different;
    ii. uncertainty in the catches of swordfish for the drifting gillnet fisheries of I.R. Iran and the longline fishery of Indonesia;
    iii. the total lack of size data before the early-70s and poor coverage before the early-80s and for most artisanal fisheries (e.g., Pakistan, India, Indonesia);
    iv. the paucity of size data available from industrial longliners since the early-1990s (e.g. Japan, Philippines, India and China);
    v. the lack of time-area catches for some industrial fleets (e.g. Indonesia, India, NEI fleets);
    vi. the paucity of biological data available, notably sex-ratio and sex-length-age keys.
- Sex ratio data: have not been provided to the Secretariat by CPCs.





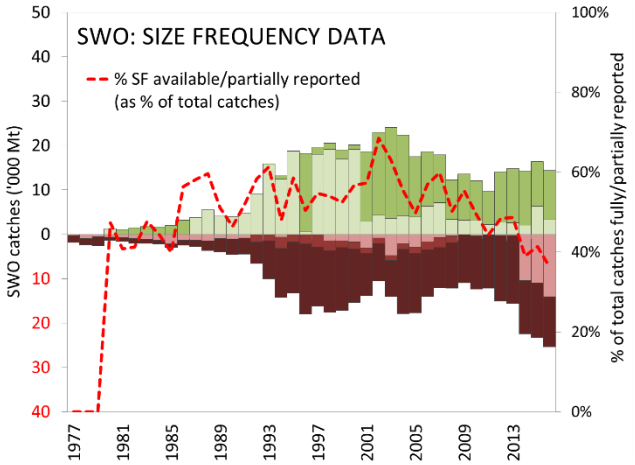


Fig. 6a-c. Swordfish: data reporting coverage (1977–2016).

Each IOTC dataset (nominal catch, catch-and-effort, and length frequency) are assessed against IOTC reporting standards, where:

- *Score 0: indicates the amount of nominal catch associated with each dataset that is fully reported according to IOTC standards;*
- *Scores: 2 – 6 refers to the amount of nominal catch associated with each dataset that is partially reported by gear and/or species (i.e., adjusted by gear and species by the IOTC Secretariat) or any of the other reasons provided in the document;*
- *Score: 8 refers to the amount of nominal catch associated with catch-and-effort or size frequency data that is not available.*

The red dotted line indicates the proportion of data (in terms of total catches) fully or partially reported for each dataset.

Key to IOTC Scoring system

Nominal Catch	By species	By gear
Fully available	0	0
Partially available (part of the catch not reported by species/gear)*	2	2
Fully estimated (by the IOTC Secretariat)	4	4

*Catch assigned by species/gear by the IOTC Secretariat; or 15% or more of the catches remain under aggregates of species

Catch-and-Effort	Time-period	Area
Available according to standards	0	0
Not available according to standards	2	2
Low coverage (less than 30% of total catch covered through logbooks)	2	
Not available at all	8	

Size frequency data	Time-period	Area
Available according to standards	0	0
Not available according to standards	2	2
Low coverage (less than 1 fish measured by metric ton of catch)	2	
Not available at all	8	

Key to colour coding

- Total score is 0 (or average score is 0-1)
- Total score is 2 (or average score is 1-3)
- Total score is 4 (or average score is 3-5)
- Total score is 6 (or average score is 5-7)
- Total score is 8 (or average score is 7-8)

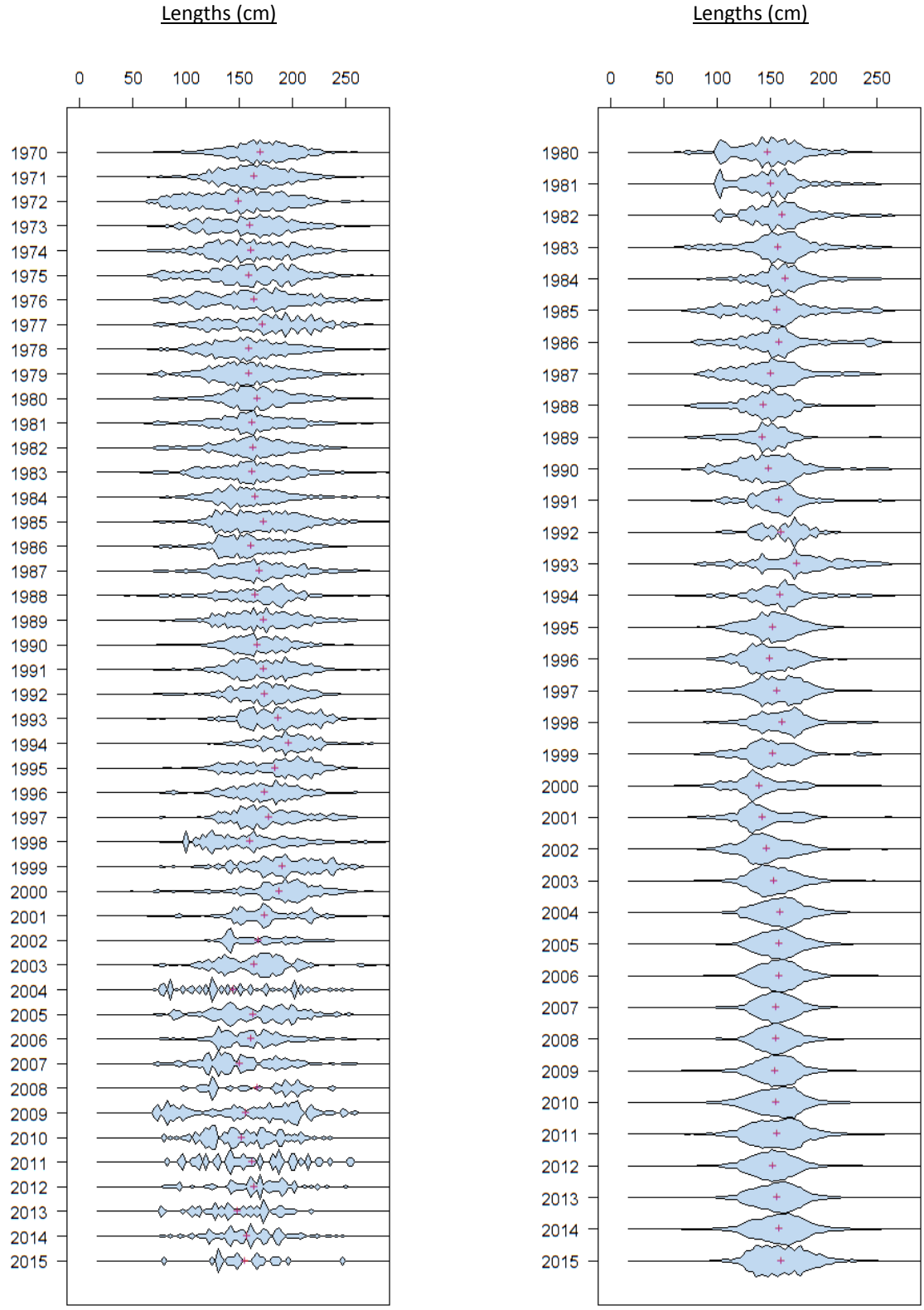


Fig. 7. Swordfish: Longline length frequency distributions for Japan (left) and Taiwan,China (right).

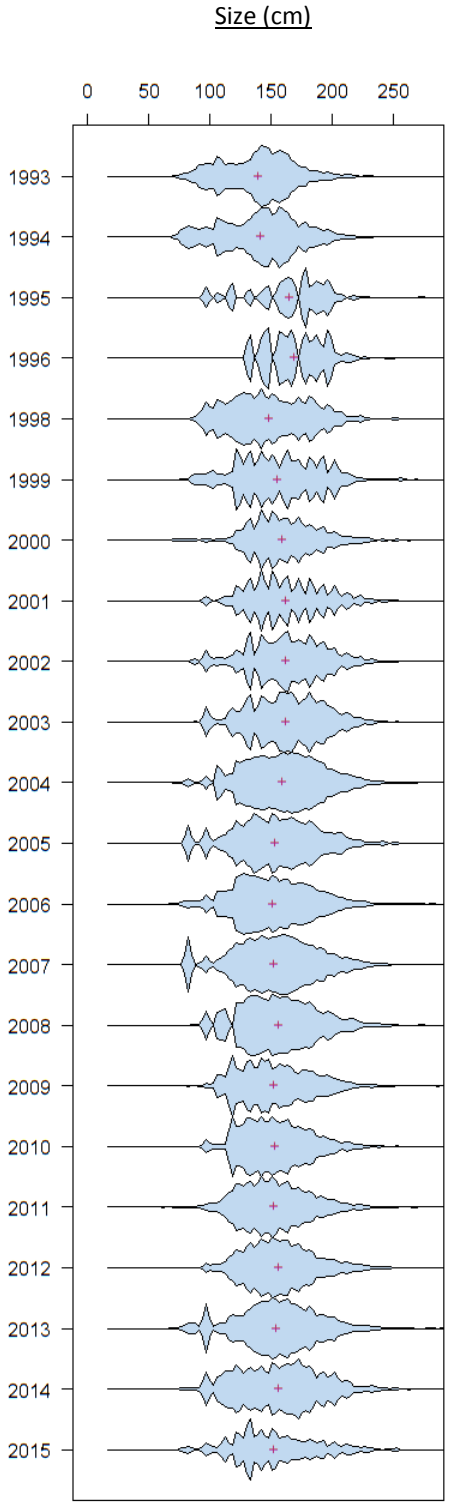


Fig. 8. Swordfish: Longline (targeted swordfish) length frequency distributions for combined EU,Spain, and EU,Portugal vessels (data as of September 2016).

Swordfish: Effort trends

Total effort from longline vessels flagged to Japan, Taiwan,China and EU,Spain by five degree square grid in 2014 and 2015 are provided in **Fig. 9.**

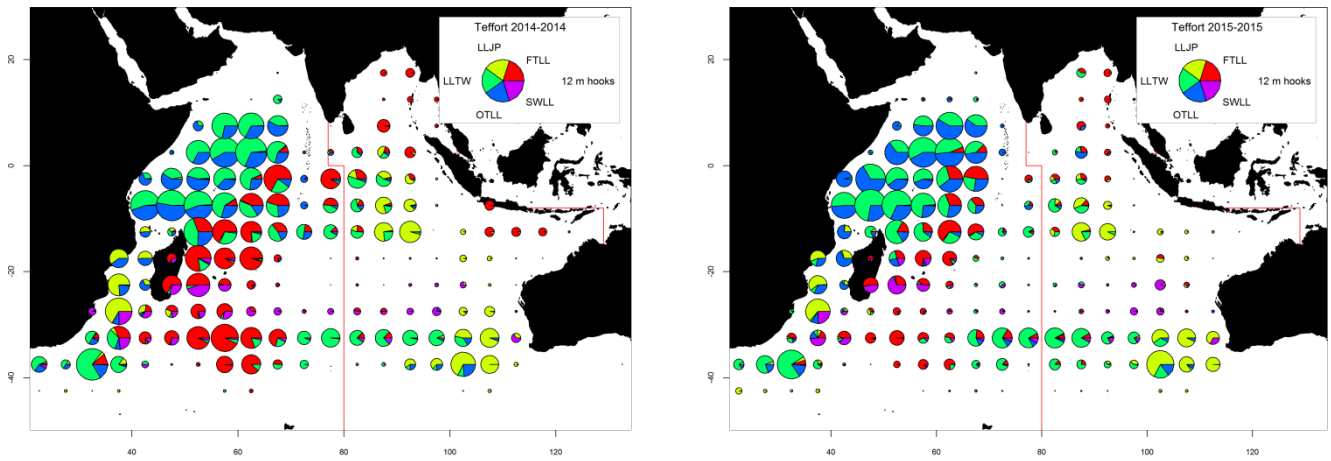


Fig. 9. Number of hooks set (millions) from longline vessels by five degree square grid and main fleets, for the years 2014 (left) and 2015 (right) (data as of September 2016). **LLJP** (light green): deep-freezing longliners from Japan LLTW (dark green): deep-freezing longliners from Taiwan,China; **SWLL** (turquoise): swordfish longliners (Australia, EU, Mauritius, Seychelles and other fleets); **FTLL** (red) : fresh-tuna longliners (China, Taiwan,China and other fleets); **OTLL** (blue): Longliners from other fleets (includes Belize, China, Philippines, Seychelles, South Africa, Rep. of Korea and various other fleets).

Swordfish: Standardised catch–per–unit–effort (CPUE) trends

The following CPUE series were available for assessment purposes (**Fig. 10**), and the Japan, EU,Portugal series were used in the final stock assessment models investigated in 2017:

- EU,Portugal data (2000–2015): from IOTC–2017–WPB15–14
- Indonesia data (2005–2015): from IOTC–2017–WPB15–15
- EU,Spain data (2001–2015): from IOTC–2017–WPB15–16
- Taiwan,China data (1979–2015): from IOTC–2017–WPB15–17
- Japan data (1976–2015): from IOTC–2017–WPB15–19

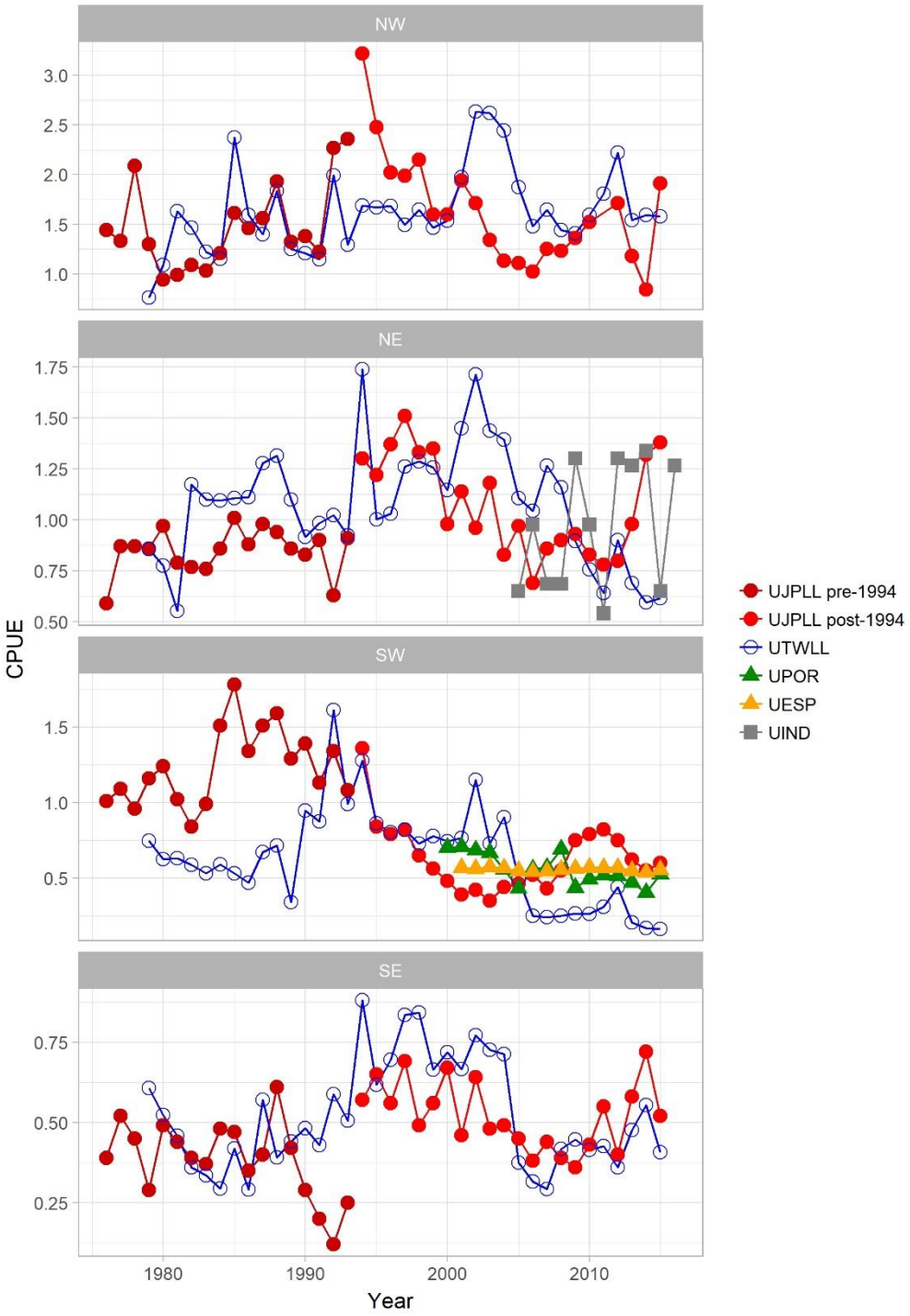


Fig. 10. Swordfish: CPUE series used in the SS3 stock assessment model in 2017 by sub-region. Series have been rescaled relative to their respective means (for different overlapping time periods). NW – north-west; SW – southwest; NE – northeast; SE – southeast Indian Ocean.

Starting from WPB14, Swordfish is treated as a single stock and separate sections related to Swordfish for the southwest Indian Ocean have been removed from the executive summary and from the summary of available data for all billfish species.

STOCK ASSESSMENT

The swordfish assessment was undertaken in 2017 using a number of models including SS3, ASPIC, SCAA, and BSP. The swordfish stock status for the Indian Ocean is determined from the SS3 stock assessment as it was considered most likely to represent the current status of swordfish in the Indian Ocean (Table 3). The other analysis were treated as being informative of the results. There is value in undertaking a number of different modelling approaches to facilitate comparison. The structured models are capable of a more detailed representation of complicated population and fishery dynamics, and integrate several sources of data and biological research that cannot be considered in the simple production models.

The SS3 assessment uses a spatially disaggregated, sex explicit, and age structured model. The assessment includes catch data grouped into 12 separate fisheries covering the period from1950 through to 2015. The final base case reference case used the Japanese CPUE from 1994 to 2015, except that in SW region, the Japanese indices from 2000 to 2015 were dropped and the Portugal indices from 2000-2015 were used instead. A grid approach was used to quantify the uncertainties where the model is running over permutations of parameters and/or assumption options. The reference grid included 24 MPD runs covering three values of steepness (0.7, 0.8, and 0.9), two growth/maturity options (otoliths-based estimates from the SW Pacific by Farley et al. (2016), spine-based estimates from Indian Ocean by Wang et al. (2010)), two recruitment variability (sigma = 0.2 or 0.4), and two assumed effective sample size for length composition data (capped at 20 or 2).

The following should be noted with respect to the various modelling approaches used in 2017:

- The depletion estimated by the Japanese series has been more consistent with the swordfish exploitation history than the Taiwanese series, and this interpretation has generally been given more weight in the assessment and management advice.
- The operations of Japanese and Taiwanese fleets have changed historically, with large shifts in targeting that are poorly quantified. The trend in the early CPUE series (pre-1994) for both fleets cannot be explained by the catch or other plausible dynamics. It is widely known that the catch efficiency of swordifih has experienced dramatic changes in the late 1980s and early 1990s with the deveopment of fresh-chill longline fleets which have further improved on catch rates through refinements to fishing gear in this period (Ward & Elscot 2000).
- The Portuguese and Spanish series are probably more reliable than the others because: i) these fleets seem to have operated consistently over the recent time period, and ii) the standardization analyses were very robust to different assumptions. The CPUE from the South African domestic fleet showed a similar trend to the Portuguese CPUE.
- The validity of the assumption that swordfish density is uniform within each large sub-region is questionable, and the changes in the CPUE standardization methodologies is likely to result in very different estimates of regional weighting factors.
- The swordfish catch from the Indonesian Fresh Tuna Longliners was estimated using the Taiwanese fresh longline as a proxy for gear/species disaggregation, resulting in a nearly two-fold increase in the swordfish catch for the LL_NE fishery in 2014 and 2015, which is considered to be very unlikely. Therefore the assessment used the average catch between 2011 and 2013 as an estimate for the Indonesian Fresh Tuna Longline catch for the last two years.

Table 3. Swordfish: Key management quantities from the SS3 assessment for aggregate Indian Ocean, using a base case reference gird included 24 MPD runs covering three steepness (0.7, 0.8, and 0.9), two growth/maturity options (otoliths-based estimates from the SW Pacific by Farley et al. (2016), spine-based estimates form Indian Ocean by Wang et al. (2010)), two recruitment variability (sigma=0.2 or 0.4), and two assumed effective sample size for length composition data (capped at 20 or 2). CI values are 80% from the base case run.

Management Quantity	**Aggregate Indian Ocean**
2015 catch estimate	32,130 t
Mean catch from 2011–2015	28,490 t
MSY (1,000 t) (80% CI)	31.59 (26.30–45.50)
Data period used in assessment	1950–2015
F_{MSY} (80% CI)	0.17 (0.12–0.23)
SB_{MSY} (1,000 t) (80% CI)	43.69 (25.27–67.92)
F_{2015}/F_{MSY} (80% CI)	0.76 (0.41–1.04)
B_{2015}/B_{MSY} (80% CI)	n.a.
SB_{2015}/SB_{MSY} (80% CI)	1.50 (1.05–2.45)
B_{2015}/B_{1950} (80% CI)	n.a.
SB_{2015}/SB_{1950} (80% CI)	0.31 (0.26–0.43)
$B_{2015}/B_{1950,\ F=0}$ (80% CI)	n.a.
$SB_{2015}/SB_{1950,\ F=0}$ (80% CI)	n.a.

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