DRAFT EXECUTIVE SUMMARY: SWORDFISH

Indian Ocean Tuna Commission
Commission des Thons de l'Océan Indien
iotc ctoi

Status of the Indian Ocean swordfish (SWO: *Xiphias gladius*) resource

TABLE 1. Swordfish: Status of swordfish (*Xiphias gladius*) in the Indian Ocean.

Area[1]	Indicators		2015 stock status determination
Indian Ocean	Catch 2014: Average catch 2010–2014:	34,822 t 28,494 t	
	MSY (1,000 t) (80% CI): F_{MSY} (80% CI): SB_{MSY} (1,000 t) (80% CI): F_{2013}/F_{MSY} (80% CI): SB_{2013}/SB_{MSY} (80% CI): SB_{2013}/SB_{1950} (80% CI):	39.40 (33.20–45.60) 0.138 (0.137–0.138) 61.4 (51.5–71.4) 0.34 (0.28–0.40) 3.10 (2.44–3.75) 0.74 (0.58–0.89)	

[1]Boundaries for the Indian Ocean stock assessment are defined as the IOTC area of competence.
[1]Boundaries for southwest Indian Ocean stock assessment are defined in IOTC–2014–WPB12–07 Rev_2.

Colour key	Stock overfished(B_{year}/B_{MSY}< 1)	Stock not overfished (B_{year}/B_{MSY}≥ 1)
Stock subject to overfishing(F_{year}/F_{MSY}> 1)		
Stock not subject to overfishing (F_{year}/F_{MSY}≤ 1)		
Not assessed/Uncertain		

INDIAN OCEAN STOCK – MANAGEMENT ADVICE

Stock status. No stock assessment undertaken in 2015. Thus, the SS3 model used in 2014 (using data up until the end of 2013) is used for stock status advice, as well as indicators available in 2015. The SS3 model indicated that MSY-based reference points were not exceeded for the Indian Ocean population as a whole (F_{2013}/F_{MSY} < 1; SB_{2013}/SB_{MSY} > 1). All other models applied to swordfish also indicated that the stock is above a biomass level that would produce MSY and current catches are below the MSY level. Spawning stock biomass in 2013 was estimated to be 58–89% (from Table 1; Fig. 1) of the unfished levels. The most recent catch estimate of 29,902 t for 2014 (a decrease from 2013 catches of 30,844 t) suggests that the stock status is unlikely to have changed. Thus, the stock remains **not overfished** and **not subject to overfishing**.

Outlook. The decrease in longline catch and effort from 2005 to 2011 lowered the pressure on the Indian Ocean stock as a whole, and despite the recent increase in total recorded catches, current fishing mortality is not expected to reduce the population to an overfished state over the next decade. There is a very low risk of exceeding MSY-based reference points by 2022 if catches are maintained at current levels (<1% risk that SB_{2022} < SB_{MSY}, and <1% risk that F_{2022} > F_{MSY}) (Table 2).

***Management advice*.** Management measures are not required which would pre-empt current Resolutions and planned management strategy evaluation for swordfish.

The following key points should be noted:

- **Maximum Sustainable Yield (MSY)**: estimate for the whole Indian Ocean is 39,400 t.
- **Provisional reference points**: Noting that the Commission in 2015 agreed to Resolution 15/10 *on target and limit reference points and a decision framework*, the following should be noted:
    a. **Fishing mortality**: Current fishing mortality is considered to be below the provisional target reference point of F_{MSY} and below the provisional limit reference point of 1.4*F_{MSY} (Fig. 1).
    b. **Biomass**: Current spawning biomass is considered to be above the target reference point of SB_{MSY}, and therefore above the limit reference point of 0.4*SB_{MSY} (Fig. 1).
- **Main fishing gear** (2011–14): Longline catches are currently estimated to comprise approximately 76% of the total estimated swordfish catch in the Indian Ocean (take of the total estimated swordfish catch).
- **Main fleets** (2011–14): Taiwan,China (longline): 19%; Sri Lanka (longline/gillnet): 15%; Indonesia (longline): 15%; EU,Spain (longline): 15% (take of the total estimated swordfish catch).

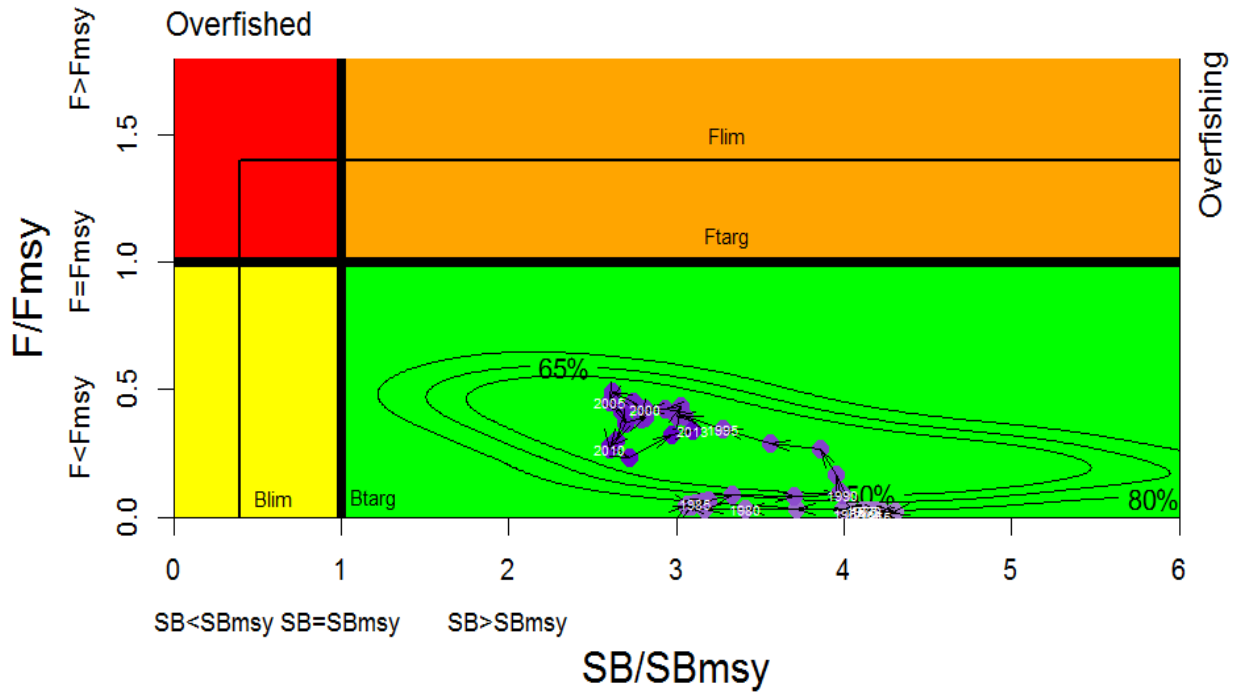


Fig. 1. Swordfish: SS3 Aggregated Indian Ocean assessment Kobe plot (contours are the 50, 65 and 80 percentiles of the 2013 estimate). Blue circles indicate the trajectory of the point estimates for the SB ratio and F ratio for each year 1950–2013. Interim target (F_{targ} and SB_{targ}) and limit (F_{lim} and SB_{lim}) reference points, as set by the Commission, are shown.

TABLE 2. Swordfish: SS3 aggregated Indian Ocean assessment Kobe II Strategy Matrix. Probability (percentage) of violating the MSY-based target (top) and limit (bottom) reference points for nine constant catch projections (average catch level from 2011–13 (27,809 t), ± 10%, ± 20%, ± 30% ± 40%) projected for 3 and 10 years.

Reference point and projection timeframe	**Alternative catch projections (relative to the average catch level from 2011–13) and probability (%) of violating MSY-based target reference points ($SB_{targ} = SB_{MSY}$; $F_{targ} = F_{MSY}$)**								
	60% (16,685 t)	**70%** (19,466 t)	**80%** (22,247 t)	**90%** (25,028 t)	**100%** (27,809 t)	**110%** (30,590 t)	**120%** (33,371 t)	**130%** (36,152 t)	**140%** (38,933 t)
$SB_{2016} < SB_{MSY}$	0	0	0	0	0	0	0	0	0
$F_{2016} > F_{MSY}$	0	0	0	0	0	0	0	0	2
$SB_{2023} < SB_{MSY}$	0	0	0	0	0	0	0	0	0
$F_{2023} > F_{MSY}$	0	0	0	0	0	0	0	0	4
Reference point and projection timeframe	**Alternative catch projections (relative to the average catch level from 2011–13) and probability (%) of violating MSY-based limit reference points ($SB_{lim} = 0.4\ SB_{MSY}$; $F_{Lim} = 1.4\ F_{MSY}$)**								
	60% (16,685 t)	**70%** (19,466 t)	**80%** (22,247 t)	**90%** (25,028 t)	**100%** (27,809 t)	**110%** (30,590 t)	**120%** (33,371 t)	**130%** (36,152 t)	**140%** (38,933 t)
$SB_{2016} < SB_{Lim}$	0	0	0	0	0	0	0	0	0
$F_{2016} > F_{Lim}$	0	0	0	0	0	0	0	0	4
$SB_{2023} < SB_{Lim}$	0	0	0	0	0	0	0	0	0
$F_{2023} > F_{Lim}$	0	0	0	0	0	0	0	0	4

Status of the southwest Indian Ocean swordfish (SWO: *Xiphias gladius*) resource

TABLE 3. Swordfish: Status of swordfish (*Xiphias gladius*) in the southwest Indian Ocean.

Area[1]	Indicators		2015 sub-regional status determination
Southwest Indian Ocean	Catch 2014: Average catch 2010–2014:	8,276 t 7,661 t	
	MSY (1,000 t) (80% CI): F_{MSY} (80% CI): B_{MSY} (1,000 t) (80% CI): F_{2013}/F_{MSY} (80% CI): B_{2013}/B_{MSY} (80% CI): B_{2013}/B_{1950} (80% CI):	9.86 (9.11–10.57) 0.63 (0.59–0.70) 12.68 (12.52–12.78) 0.89 (0.61–1.14) 0.94 (0.68–1.23) 0.16 (n.a.)	

[1]Boundaries for southwest Indian Ocean stock assessment are defined in IOTC–2014–WPB12–07 Rev_2.

Colour key	Stock overfished($B_{year}/B_{MSY}< 1$)	Stock not overfished ($B_{year}/B_{MSY}\geq 1$)
Stock subject to overfishing($F_{year}/F_{MSY}> 1$)		
Stock not subject to overfishing ($F_{year}/F_{MSY}\leq 1$)		
Not assessed/Uncertain		

SOUTHWEST INDIAN OCEAN – MANAGEMENT ADVICE

Sub-regional status. No assessment undertaken in 2015 as the Commission has agreed that no further stock assessment needs to be undertaken until the completion of the IOTC stock structure project. Thus, the models used in 2014 (using data up until the end of 2013) are used for sub-regional status advice, as well as indicators available in 2015. The assessments carried out in 2014 produced conflicting results (ASIA, BBDM and ASPIC). ASPIC is presented here for consistency with the previous advice. The southwest Indian Ocean region has been subject to localised depletion over the past decade and biomass remains below the level that would produce MSY (B_{MSY}). Declines in catch and effort brought fishing mortality rates to levels below $F_{MSY.}$ In 2014, 7,107 t of swordfish were recorded caught from this region, which equals 106% of the recommended maximum catch of 6,678 t agreed to by the SC in 2011 (Table 3). Thus, the resource remains **not subject to overfishing** but **overfished**.

Outlook. The decrease in catch and effort over the last few years in the southwest region has reduced pressure on this resource. However, from 2010 to 2014 catches exceeded the maximum recommended by the WPB09 and SC14 in 2011 (6,678 t). If catches are maintained at 2011–13 levels, the probabilities of violating target reference points in 2016 are ≈ 81% for F_{MSY} and ≈ 40% for B_{MSY} (Table 4). There is however a high risk of reversing the rebuilding trend if there is any increase in catch in this region (Table 4).

Management advice. A precautionary approach to the management of swordfish in the southwest Indian Ocean should be considered by the Commission, to reduce catches below 6,000 t to ensure the population in this area may rebuild.

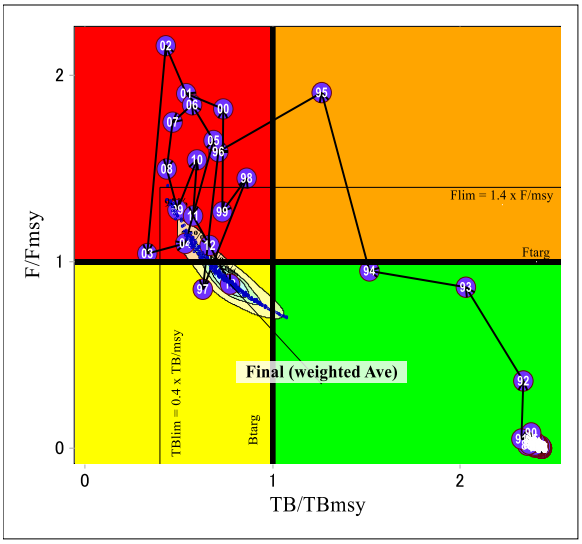


Fig. 2. Swordfish: ASPIC southwest Indian Ocean assessment Kobe plot (The horizontal blue line represents F_{LIM} and the vertical blue line represents B_{LIM}). The results are from a preferred model option: Model weighted average using the inverse of the Root Mean Square errors across models (scenario) 2 and 4 (IOTC–2014–WPB12–24 Rev_2).

TABLE 4. Swordfish: ASPIC **southwest** Indian Ocean assessment Kobe II Strategy Matrix. Probability (percentage) of violating the MSY-based reference points for nine constant catch projections (average catch level from 2011–13 (7,236 t), ± 10%, ± 20%, ± 30% and ± 40%) projected for 3 and 10 years.

Reference point and projection timeframe	**Alternative catch projections (relative to the average catch level from 2011–13) and probability (%) of violating MSY-based target reference points ($B_{targ} = B_{MSY}$; $F_{targ} = F_{MSY}$)**								
	60% (4,342 t)	**70%** (5,065 t)	**80%** (5,789 t)	**90%** (6,512 t)	**100%** (7,236 t)	**110%** (7,960 t)	**120%** (8,683 t)	**130%** (9,407 t)	**140%** (10,130 t)
$B_{2016} < B_{MSY}$	9	13	19	28	40	53	65	82	86
$F_{2016} > F_{MSY}$	3	6	30	56	81	91	98	99	100
$B_{2023} < B_{MSY}$	0	0	1	3	14	41	87	100	100
$F_{2023} > F_{MSY}$	0	0	5	67	92	98	99	100	100
Reference point and projection timeframe	**Alternative catch projections (relative to the average catch level from 2011–13) and probability (%) of violating MSY-based limit reference points ($B_{lim} = 0.4\ B_{MSY}$; $F_{Lim} = 1.4\ F_{MSY}$)**								
	60% (4,342 t)	**70%** (5,065 t)	**80%** (5,789 t)	**90%** (6,512 t)	**100%** (7,236 t)	**110%** (7,960 t)	**120%** (8,683 t)	**130%** (9,407 t)	**140%** (10,130 t)
$B_{2016} < B_{Lim}$	4	6	8	14	20	23	40	45	65
$F_{2016} > F_{Lim}$	3	6	15	15	20	33	45	67	100
$B_{2023} < B_{Lim}$	0	0	0	6	24	26	49	74	100
$F_{2023} > F_{Lim}$	0	0	0	10	22	45	67	96	100

APPENDIX I

SUPPORTING INFORMATION

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

Swordfish in the Indian Ocean is currently subject to a single direct Conservation and Management Measure adopted by the Commission: Resolution 12/11 *On The implementation of a limitation of fishing capacity of Contracting Parties and Cooperating Non-Contracting Parties.* This Resolution applies a freezing of fishing capacity for fleets targeting swordfish in the Indian Ocean to levels applied in 2007. The Resolution limits vessels access to those that were active (*effective presence*) or under construction during 2007, and were over 24 metres overall length, or under 24 meters if they fished outside the EEZs. At the same time the measure permits CPCs to vary the number of vessels targeting swordfish, as long as any variation is consistent with the national fleet development plan submitted to the IOTC, and does not increase effective fishing effort. This Resolution is effective for 2012 and 2013. Swordfish is also subject to the following non species-specific Conservation and Management Measures adopted by the Commission:

- 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 11/04 *on a regional observer scheme*
- Resolution 10/08 *concerning 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. 3**). 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/byproduct 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 5** outlines some of the key life history traits of swordfish specific to the Indian Ocean.

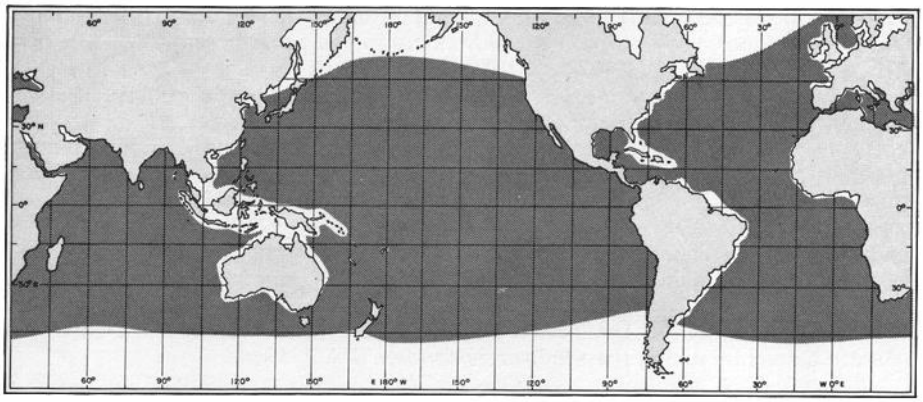


Fig. 3. Swordfish: The worldwide distribution of swordfish (Source: Nakamura 1984).

TABLE 5. 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. Extensive diel vertical migrations, from surface waters during the night to depths of 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 6–7 years; males 1–3 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

Swordfish: Fisheries and main catch trends

- Main fishing gear (2011–14): Longline catches[1] are currently estimated to comprise approximately 76% of total swordfish catches in the Indian Ocean. (**Table 5, 6; Fig. 4**)
- Main fleets (and primary gear associated with catches): percentage of total catches (2011–14):

  Taiwan,China (longline): 19%; Sri Lanka (longline-gillnet): 15%; Indonesia (fresh longline): 15%; EU,Spain (swordfish targeted longline): 15% (**Fig. 5**).
- Main fishing areas: Primary: Western Indian Ocean, in waters off Somalia, and the southwest Indian Ocean. In recent years (2009 – 2011) the fishery has moved eastwards due to piracy, a decrease in fish abundance, or a combination of both. 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 (**Figs. 6, 7**).
- 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.

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

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

***Changes to the catch series*:** no major changes to the catch series since the WPB meeting in 2014.

TABLE 5. Swordfish: best scientific estimates of catches by type of fishery for the period 1950–2014 (in metric tons). Data as of November 2015.

Fishery	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
ELL	-	-	-	9	1,841	9,993	12,740	14,965	13,009	11,543	8,173	8,106	9,510	7,686	8,337	8,785
LL	282	1,425	2,136	4,372	22,689	20,048	24,204	17,390	17,129	16,080	13,497	13,726	11,740	10,332	17,484	17,575
OT	37	39	186	807	1,998	2,846	3,324	3,337	2,936	2,810	3,482	3,019	3,020	3,545	4,237	5,445
Total	**297**	**1,340**	**2,106**	**5,130**	**26,521**	**32,868**	**35,693**	**33,102**	**30,434**	**24,895**	**24,850**	**24,908**	**22,174**	**29,723**	**30,844**	**34,822**

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**).

TABLE 6. Best scientific estimates of the catches of swordfish by fishing area for the period 1950–2014 (in metric tons). Data as of November 2015.

Area	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
NW	93	501	704	1,867	8,276	10,174	12,254	10,794	8,430	6,256	4,506	2,739	2,553	8,593	8,421	9,779
SW	13	232	368	600	8,622	7,678	9,791	9,002	7,423	6,370	6,381	8,427	7,204	7,272	7,127	8,276
NE	156	414	686	2,143	6,502	9,291	7,976	9,282	9,359	8,798	10,862	10,157	9,406	11,665	12,112	13,671
SE	35	186	278	382	3,033	5,706	5,656	4,017	5,207	3,466	3,097	3,574	3,005	2,190	3,184	3,095
OT	-	7	69	138	88	20	16	6	15	5	5	12	7	3	1	2
Total	**297**	**1,340**	**2,105**	**5,130**	**26,521**	**32,869**	**35,693**	**33,101**	**30,434**	**24,895**	**24,851**	**24,909**	**22,175**	**29,723**	**30,844**	**34,822**

Areas: Northwest Indian Ocean (**NW**); Southwest Indian Ocean (**SW**); Northeast Indian Ocean (**NE**); Southeast Indian Ocean (**SE**); Southern Indian Ocean (**OT**)

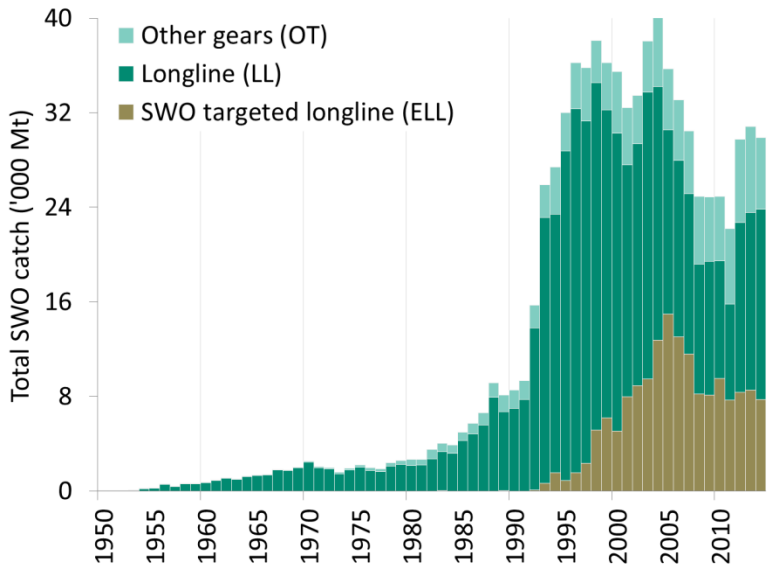


Fig. 4. Swordfish: catches by gear and year recorded in the IOTC Database (1950–2014). Other gears includes: longline-gillnet, handline, gillnet, coastal longline, troll line, sport fishing, and all other gears.

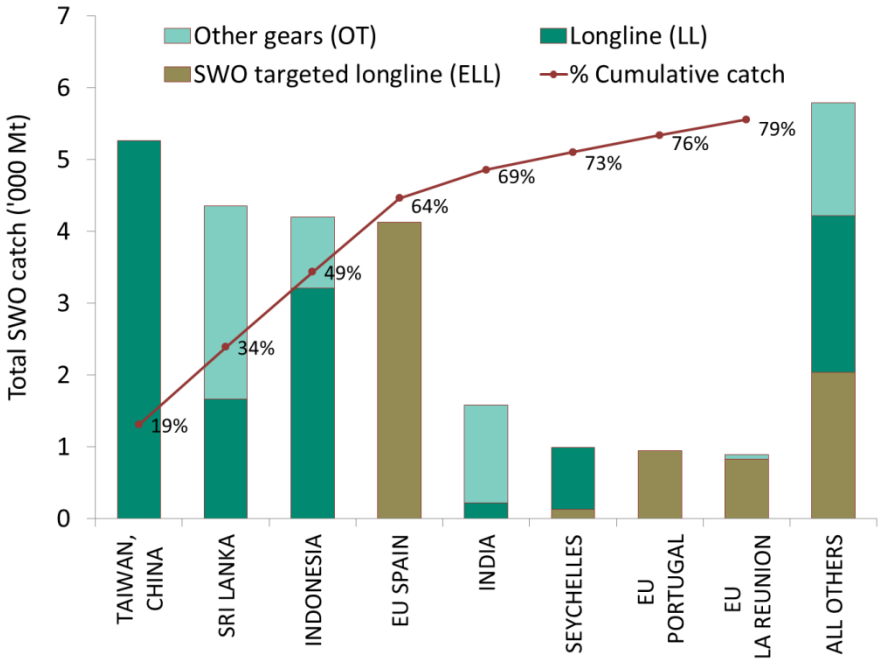


Fig. 5. Swordfish: average catches in the Indian Ocean over the period 2011–14, by fleet and gear. Fleets are ordered from left to right, according to the volume of catches reported. The red line indicates the (cumulative) proportion of catches of swordfish for the fleets concerned, over the total combined catches reported from all fleets and gears.

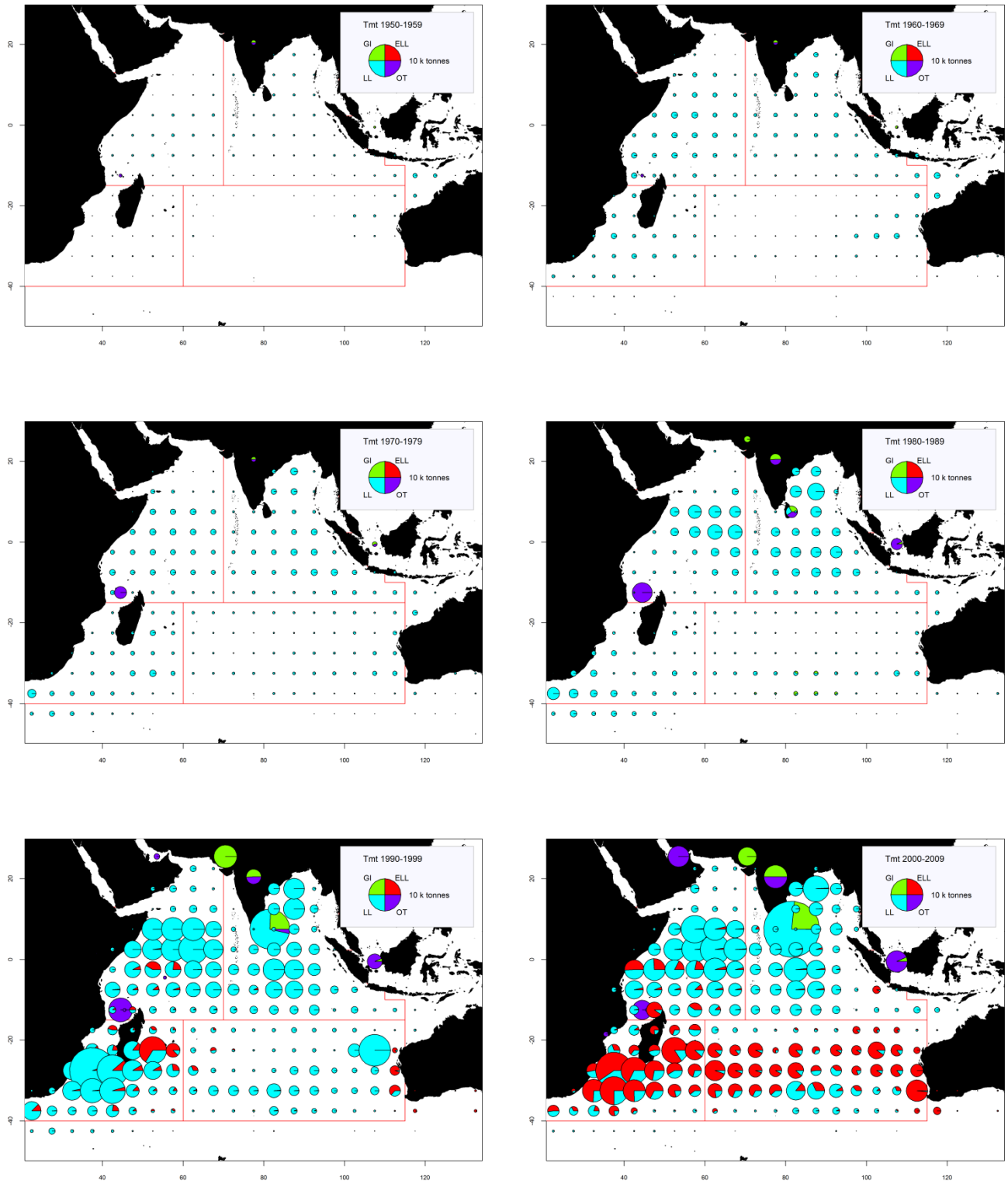


Fig. 6a-f: Swordfish: Time-area catches (total combined in tonnes) as reported for longline fisheries targeting swordfish (**ELL**), other longline fisheries (**LL**), gillnet fisheries (**GI**), and for all other fleets combined (**OT**), for the period 1950-2009, by decade and type of gear. Red lines represent the areas used for the assessments of swordfish.

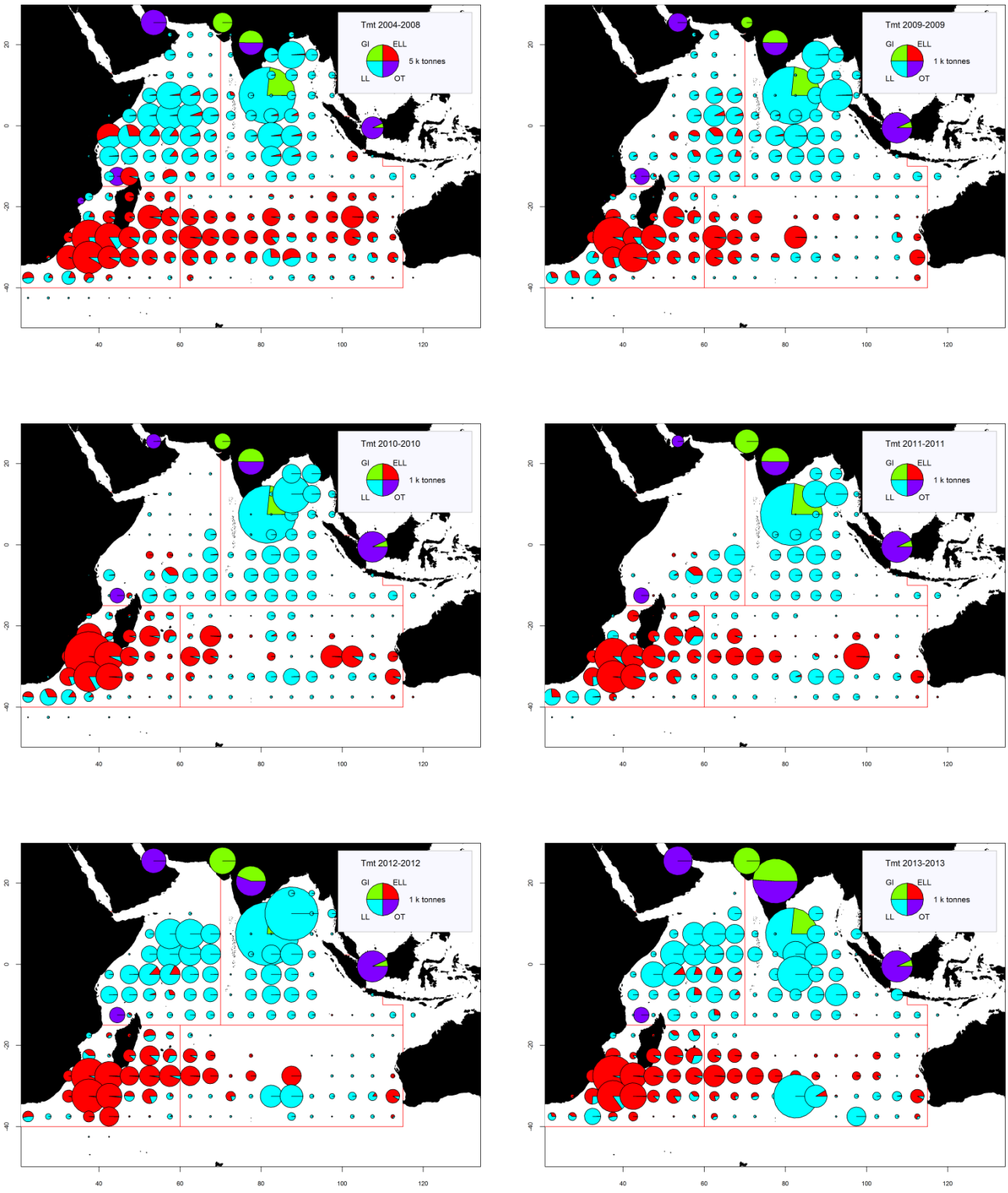


Fig. 7a-f: Swordfish: Time-area catches (total combined in tonnes) for longline fisheries targeting swordfish (**ELL**), other longline fisheries (**LL**), gillnet fisheries (**GI**), and for all other fleets combined (**OT**), for the period 2004-2008 by type of gear and for 2009-13, by year and type of gear. Red lines represent the areas used for the assessments of swordfish.

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. 8a**), 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 12% 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 is thought to be low and does 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.

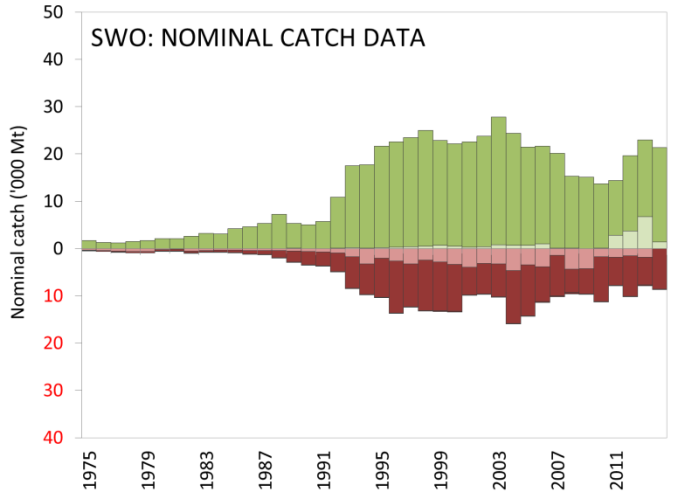
For most other fisheries, catch-and-effort are either not available (e.g., gillnet and longline fishery of Sri Lanka and drifting gillnet fisheries of I.R. Iran and Pakistan), or they are considered poor quality – especially since the early-1990s (e.g., Indonesia, Taiwan,China fresh-tuna longliners,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

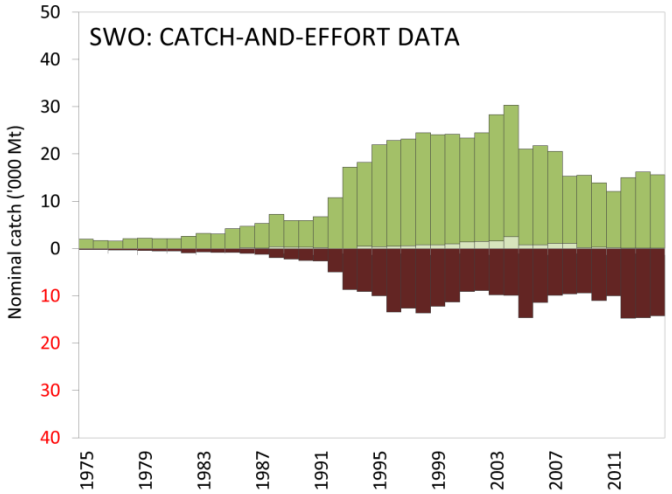
Swordfish – Fish size or age trends (e.g., by length, weight, sex and/or maturity)

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. 9c**)

- 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 to a 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.





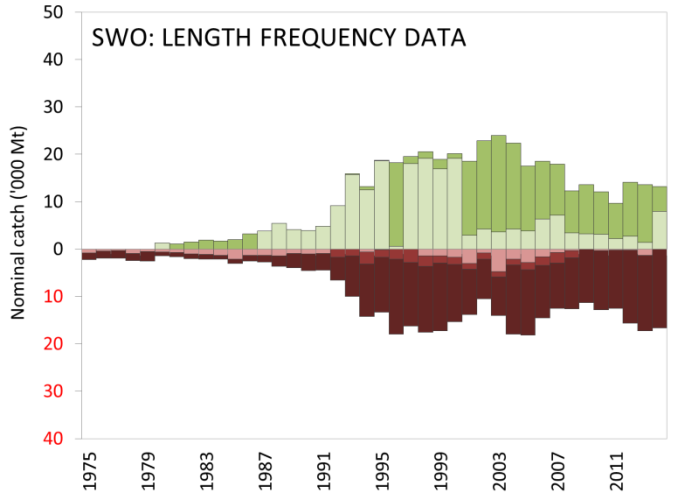


Fig. 8a-c. Swordfish: data reporting coverage (1975–2014).

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.

Data as of August 2015.

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)

.

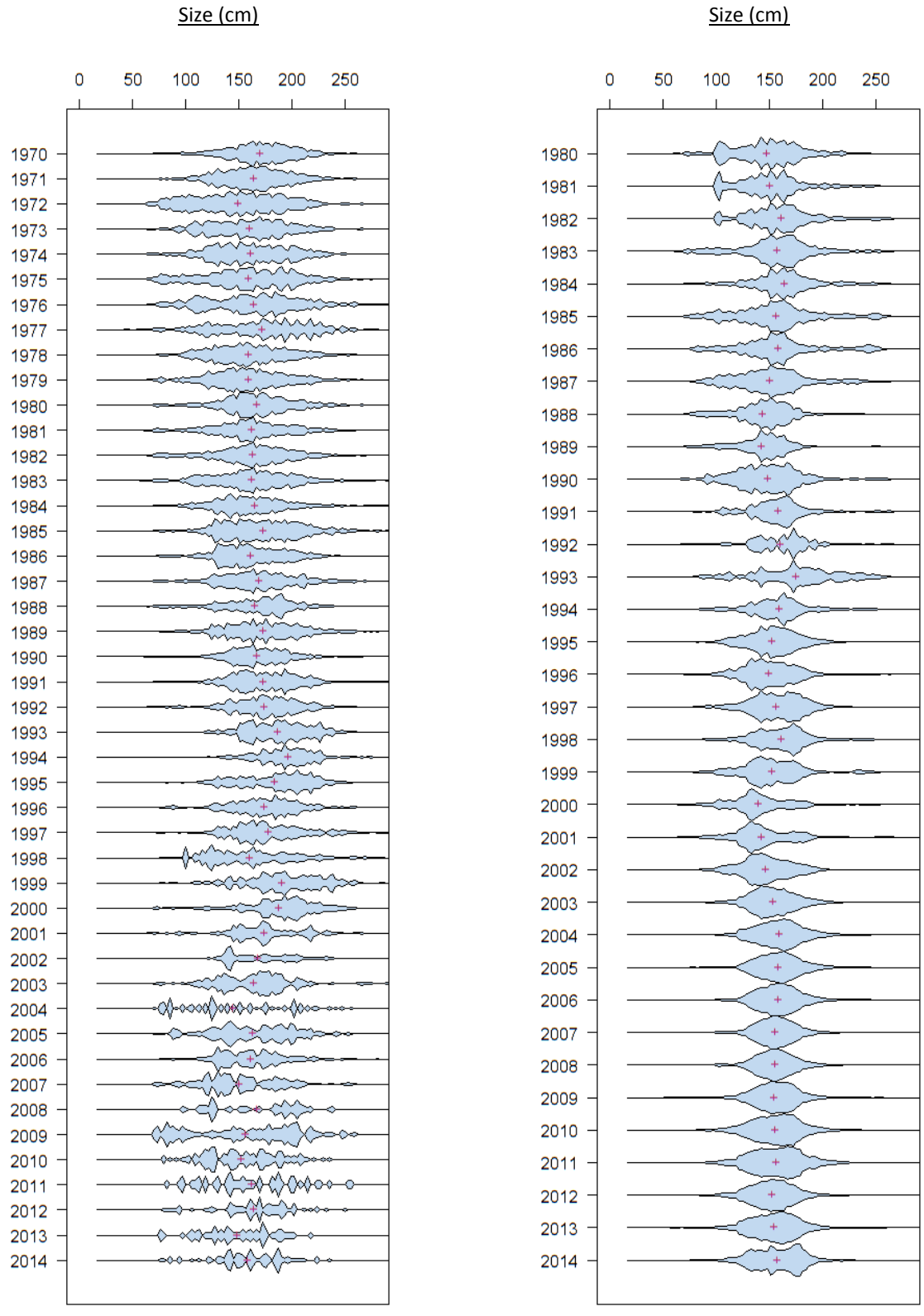


Fig. 9. Swordfish: Longline catch-at-size length distributions for Japan (left) and Taiwan,China (right) (Data as of September 2015).

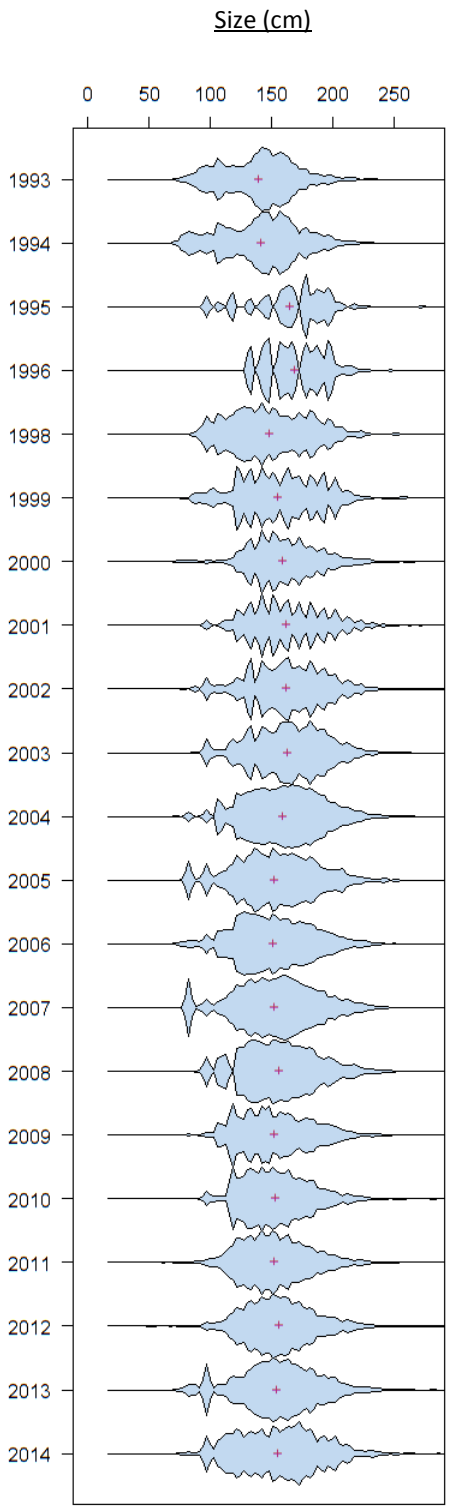


Fig. 9. Swordfish: Longline catch-at-size length distributions for combined EU,Spain, and EU,Portugal vessels (Data as of September 2015).

Swordfish: Effort trends

Total effort from longline vessels flagged to Japan, Taiwan,China and EU,Spain by five degree square grid in 2013 and 2014 are provided in **Fig. 10**, and total effort from purse seine vessels flagged to the EU and Seychelles (operating under flags of EU countries, Seychelles and other flags), and others, by five degree square grid and main fleets, for the years 2012 and 2013 are provided in **Fig. 11**.

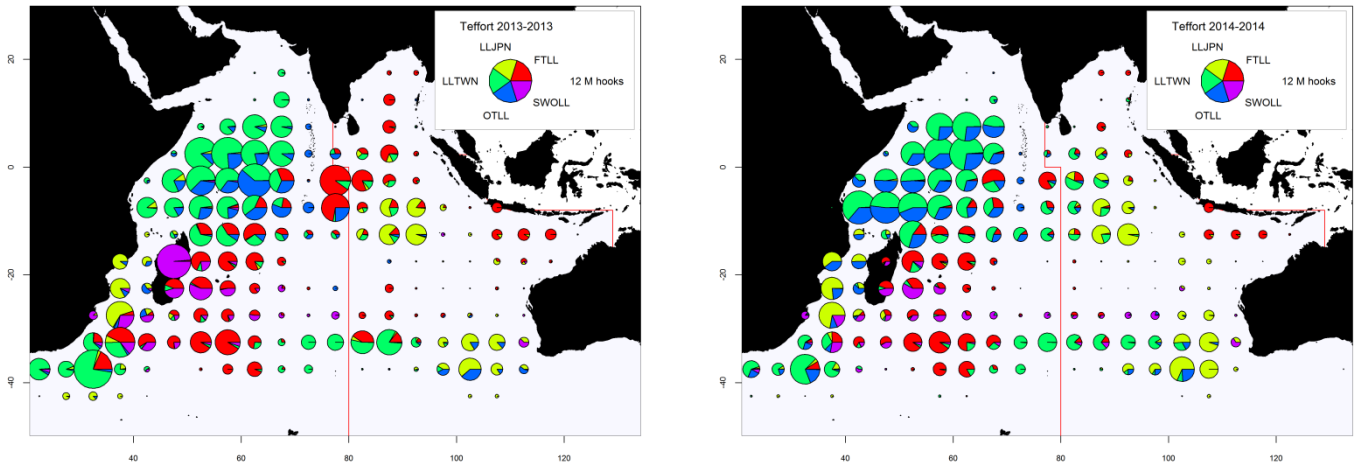


Fig. 10. Number of hooks set (millions) from longline vessels by five degree square grid and main fleets, for the years 2013 (left) and 2014 (right) (Data as of September 2015). **LLJP** (light green): deep-freezing longliners from Japan; **LLTW** (dark green): deep-freezing longliners from Taiwan,China; **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).

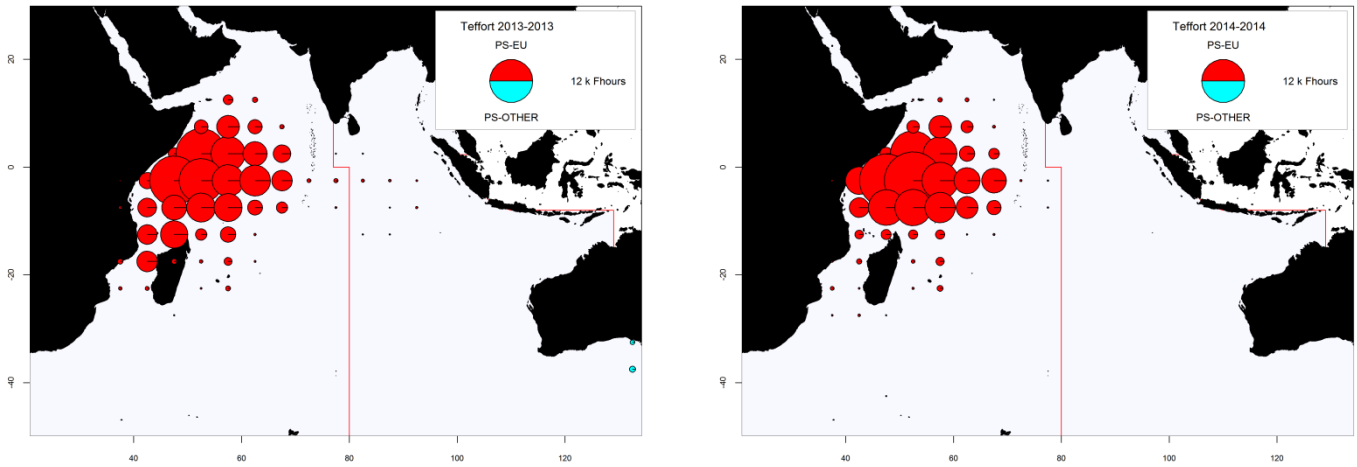


Fig. 11. Number of hours of fishing (Fhours) from purse seine vessels by 5 degree square grid and main fleets, for the years 2013 (left) and 2014 (right) (Data as of September 2015). **PS-EU** (red): Industrial purse seiners monitored by the EU and Seychelles (operating under flags of EU countries, Seychelles and other flags); **PS-OTHER** (green): Industrial purse seiners from other fleets (includes Japan, Mauritius and purse seiners of Soviet origin) (excludes effort data for purse seiners of Iran and Thailand).

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

Of the CPUE series available for assessment purposes, the Japan, Taiwan,China, EU,Portugal and EU,Spain series were used in the final stock assessment models investigated in 2014, for the reasons discussed above (**Figs. 12**, **13**).

- EU,Portugal data (2000–2013): Model 2 from IOTC–2014–WPB12–19
- EU,Spain data (2001–2012): Run 4 from document IOTC–2014–WPB12–20 Rev_1 and Run 2 for the assessment of whole Indian Ocean.
- Japan data (1971–2013): Case 5 (SWO cluster, SWO data) and case 3 (NHBF, all data) from document IOTC–2014–WPB12–21 Rev_1.
- Taiwan,China data (1980–2012): Series 2 from document IOTC–2014–WPB12–22.

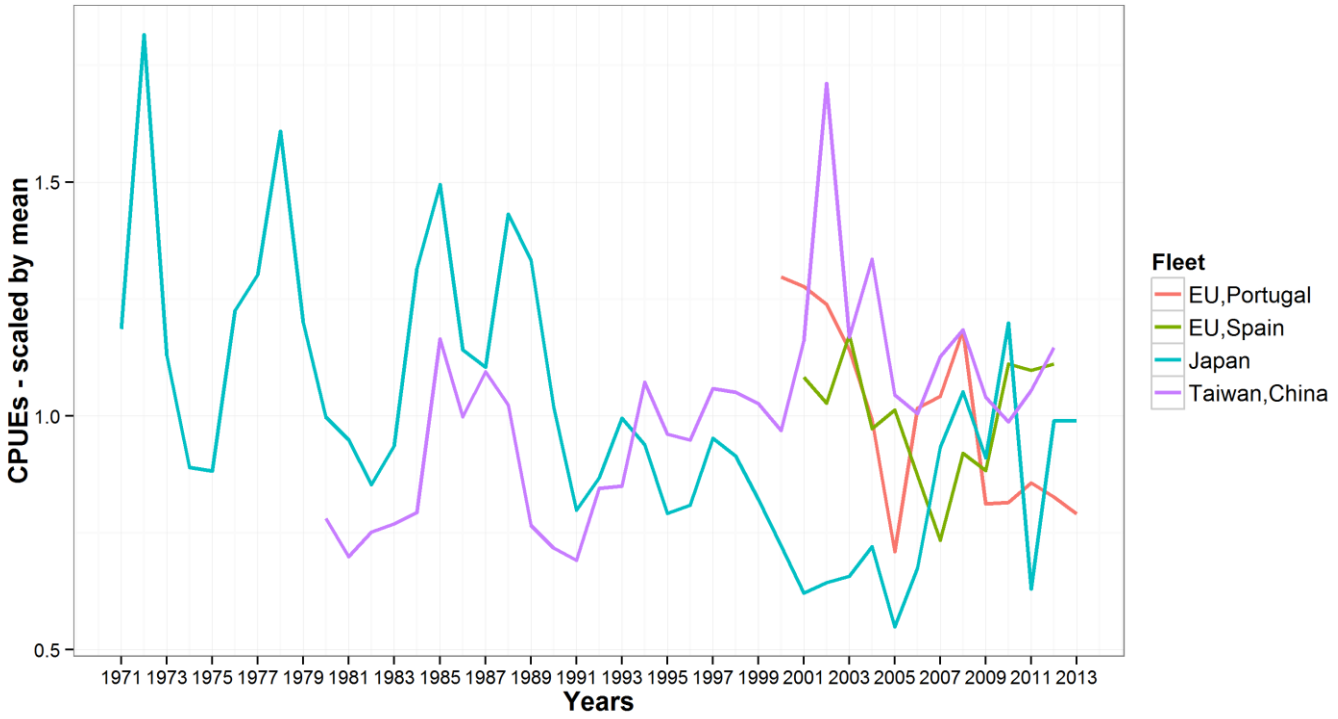


Fig. 12. Aggregate whole Indian Ocean Swordfish: CPUE series for the Indian Ocean swordfish assessments (ASIA, ASPIC and BBDM) in 2014. Series have been rescaled relative to their respective means (for different overlapping time periods).

The Japan, Taiwan,China, EU,Portugal and EU,Spain series, by area, were used in the final SS3 stock assessment model to develop management advice (**Fig. 13**).

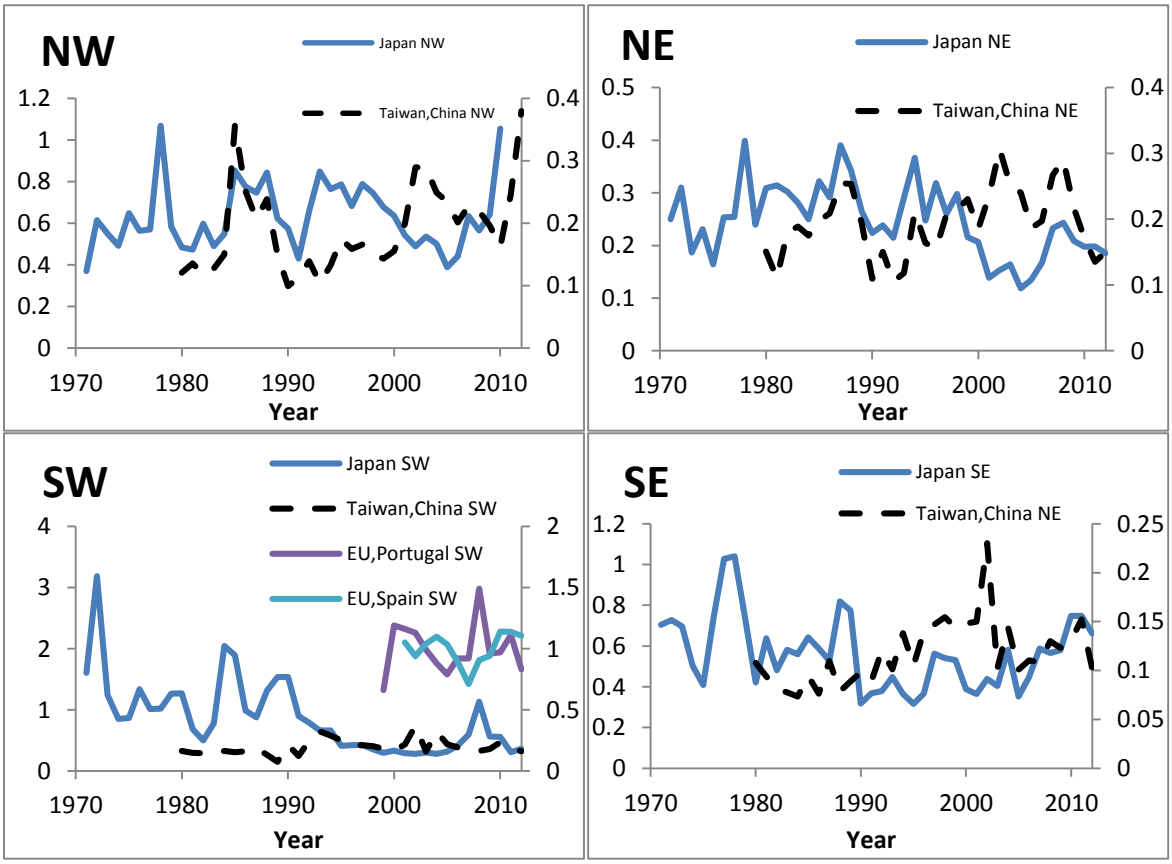


Fig. 13. Swordfish: CPUE series used in the final SS3 stock assessment model in 2014 by sub-region. Series have been rescaled relative to their respective means (for different overlapping time periods). NW – north-west; SW – southwest; NE – northeast; SE – southeast Indian Ocean.

Southwest Indian Ocean CPUE summary

The CPUE series used in the southwest Indian Ocean stock assessment models for 2014 (shown in **Fig. 14**). Of the CPUE series available for the southwest Indian Ocean for assessment purposes, listed below, the Japanese case (scenario) 3 in paper IOTC–2014–WPB12–21 Rev_1 (**Fig. 14**) was used in the final stock assessment model for management advice.

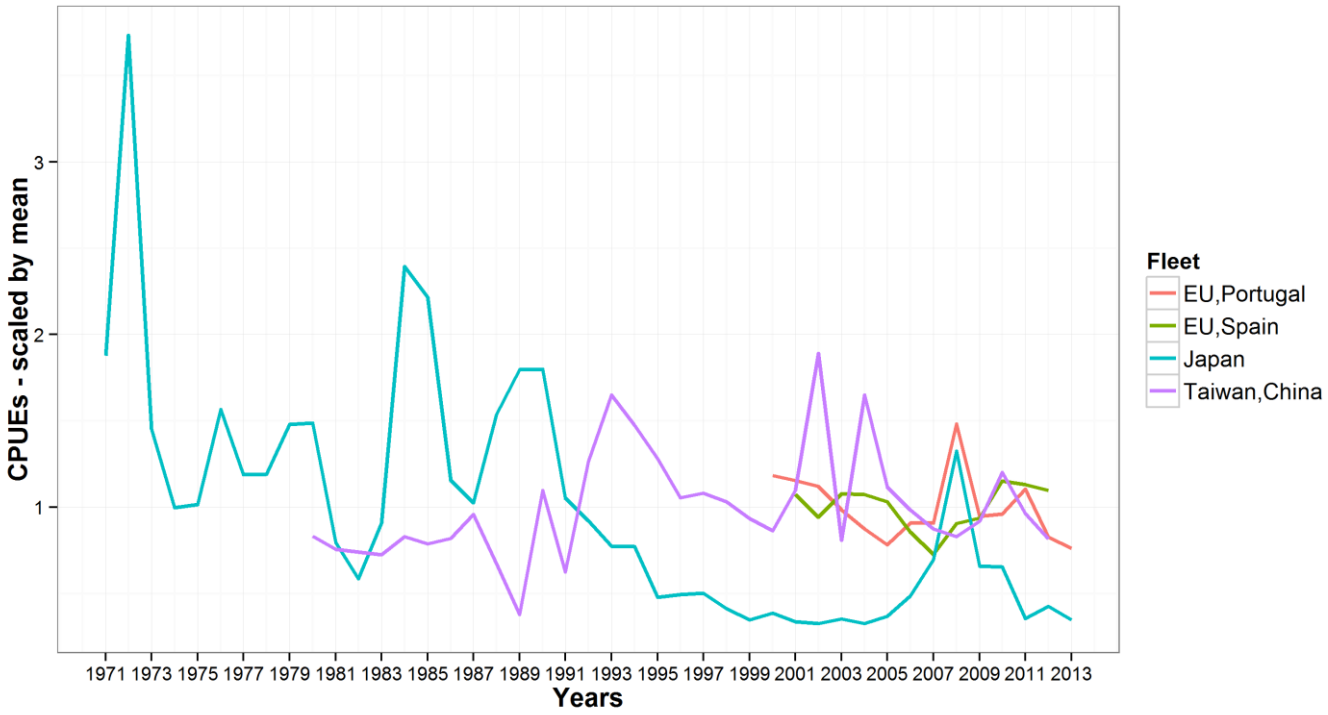


Fig. 14. Swordfish: CPUE series for the **southwest** Indian Ocean swordfish assessments in 2014. Series have been rescaled relative to their respective means (for different overlapping time periods).

STOCK ASSESSMENT

The following should be noted with respect to the various modelling approaches used in 2014:

- There was more confidence in the abundance indices this year due to the additional exploratory CPUE analyses from Japan and Taiwan,China. This has led to improved confidence in the overall assessments.
- The Japan longline CPUE series is more likely to closely represent swordfish abundance at this time, because a substantial part of the Japan longline fleet has a long term series of swordfish bycatch even though it has never targeted swordfish. In addition, it is the only CPUE series that decreases as catch increases.
- Conversely, the Taiwan,China CPUE seems to demonstrate very strong targeting shifts away from swordfish in the core area and back towards swordfish in recent years.
- CPUE series should not be averaged across series with different trends as this is likely to result in spurious trends. Thus, only series which are considered to be most representative of abundance, in this case the Japan longline series, should be the primary CPUE series used in stock assessments while further work is carried out on the other series (Taiwan,China, EU,Spain and EU,Portugal).
- It was recognised that the deterministic production models were only able to explore a limited number of modelling options. The structural rigidity of these simple models causes numerical problems when fit to long time series for some cases.

The swordfish stock status for the aggregate Indian Ocean is determined from the SS3 stock assessment undertaken in 2014 as it was considered most likely to numerically and graphically 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. However, there are a lot of uncertainties in basic swordfish biology (e.g. growth rates, M, stock recruitment relationship), and it is difficult to represent all of these uncertainties. In contrast, the production models often provide robust estimates regardless of uncertainties in basic biological characteristics. However, sometimes the ASPIC model can have difficulty fitting long time series, and production models in general cannot represent some important dynamics (e.g. arising from complicated recruitment variability).

The southwest Indian Ocean assessments had substantial conflicting results based on the different model runs (ASIA, BBDM and ASPIC: **Table 7**).

TABLE 7. Swordfish: Key management quantities from the SS3 assessment for aggregate Indian Ocean, using a base case with the growth curve from paper IOTC–2010–WPB08–08 Rev_1, M=0.25, and steepness=0.75, ESS=200, and all CPUE data used for point estimates). CI values are 80% from the base case run; and from the ASPIC assessment for the southwest Indian Ocean.

Management Quantity	Aggregate Indian Ocean	Southwest Indian Ocean
2013 catch estimate	31,804 t	7,349
Mean catch from 2009–2013	26,510 t	7,265
MSY (1,000 t) (80% CI)	39.40 (33.20–45.60)	9.86 (9.11–10.57)
Data period used in assessment	1950–2013	1950–2013
F_{MSY} (80% CI)	0.138 (0.137–0.138)	0.63 (0.59–0.70)
SB_{MSY} (1,000 t) (80% CI)	61.4 (51.5–71.40)	12.68 (12.52–12.78)
F_{2013}/F_{MSY} (80% CI)	0.34 (0.28–0.40)	0.89 (0.61–1.14)
B_{2013}/B_{MSY} (80% CI)	n.a.	0.94 (0.68–1.23)
SB_{2013}/SB_{MSY} (80% CI)	3.10 (2.44–3.75)	n.a.
B_{2013}/B_{1950} (80% CI)	n.a.	0.16 (n.a.)
SB_{2013}/SB_{1950} (80% CI)	0.74 (0.58–0.89)	n.a.
$B_{2013}/B_{1950, F=0}$ (80% CI)	n.a.	n.a.
$SB_{2013}/SB_{1950, F=0}$ (80% CI)	n.a.	n.a.

LITERATURE CITED

Bach P, Romanov E, Rabearisoa N, Sharp A (2011) Note on swordfish catches collected during commercial operations and research cruises onboard pelagic longliners of the La Reunion fleet from 2006 to 2010. IOTC–2011–WPB09–INF11_Pres

Froese R, Pauly DE (2009) *FishBase*, version 02/2009, FishBase Consortium, <www.fishbase.org>

Kolody D (2009) An exploratory 'stock synthesis' assessment of the Indian Ocean swordfish fishery 1950–2007, Seychelles, 6–10 July 2009, IOTC–2009–WPB07–10, p 58

Muths D, Le Couls S, Evano H, Grewe P, Bourjea J (2009) Microsatellite and mtDNA markers were unable to reveal genetic 1 population structure of swordfish (*Xiphias gladius*) in the Indian Ocean. Tenth Working Party on Billfish, Cape Town, South Africa, 11–15 September 2012. IOTC–2012–WPB10–15, p 28

Nakamura I (1985) FAO species catalogue. Billfish of the world. An annotated and illustrated catalogue of marlins, sailfishes, spearfishes, and swordfishes known to date. FAO Fish.Synop.125(5), p 65

Poisson F, Fauvel C (2009)'Reproductive dynamics of swordfish (*Xiphias gladius*) in the southwestern Indian Ocean (Reunion Island), part 1, Oocyte development, sexual maturity and spawning', Aquatic Living Res 22, pp. 45–58

Romanov E, Romanova N (2012) Size distribution and length-weight relationships of some billfish (marlins, spearfish and swordfish) in the Indian Ocean. IOTC–2012–WPB10–18, p 12.