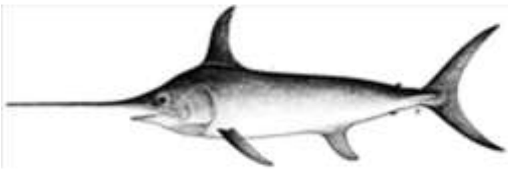
# DRAFT: EXECUTIVE SUMMARY: SWORDFISH

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 | | 2014 stock status determination |
|---|---|---|---|
| Indian Ocean | Catch 2013:<br>Average catch 2009–2013: | 31,804 t<br>26,510 t | |
| | MSY (1,000 t) (80% CI):<br>$F_{MSY}$ (1,000 t) (80% CI):<br>$SB_{MSY}$ (80% CI):<br>$F_{2013}/F_{MSY}$ (80% CI):<br>$SB_{2013}/SB_{MSY}$ (80% CI):<br>$SB_{2013}/SB_{1950}$ (80% CI): | 39.40 (33.20–45.60)<br>0.138 (0.137–0.138)<br>61.4 (51.5–71.4)<br>0.34 (0.28–0.40)<br>3.10 (2.44–3.75)<br>0.74 (0.58–0.89) | |

[1]Boundaries for the Indian Ocean stock assessment are defined as the IOTC area of competence.

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

### INDIAN OCEAN STOCK – MANAGEMENT ADVICE

***Stock status.*** The SS3 model, used for stock status advice 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 31,804 t in 2013 indicate 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. Management measures are not required which would pre-empt current Resolutions and planned management strategy evaluation for swordfish. 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). **NOTE:** Advice specific to the southwest region is provided below, as requested by the Commission.

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 2013 agreed to Resolution 13/10 *on interim 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** (2010–13): Longline catches are currently estimated to comprise approximately 85% of the total estimated swordfish catch in the Indian Ocean.
- **Main fleets** (2010–13): Taiwan,China: 18%; Sri Lanka: 16%; Indonesia: 15%; EU,Spain: 14%.
- **Improvements required**: Continued monitoring and improvement in data collection, reporting and analysis is required to reduce the uncertainty in the assessments.

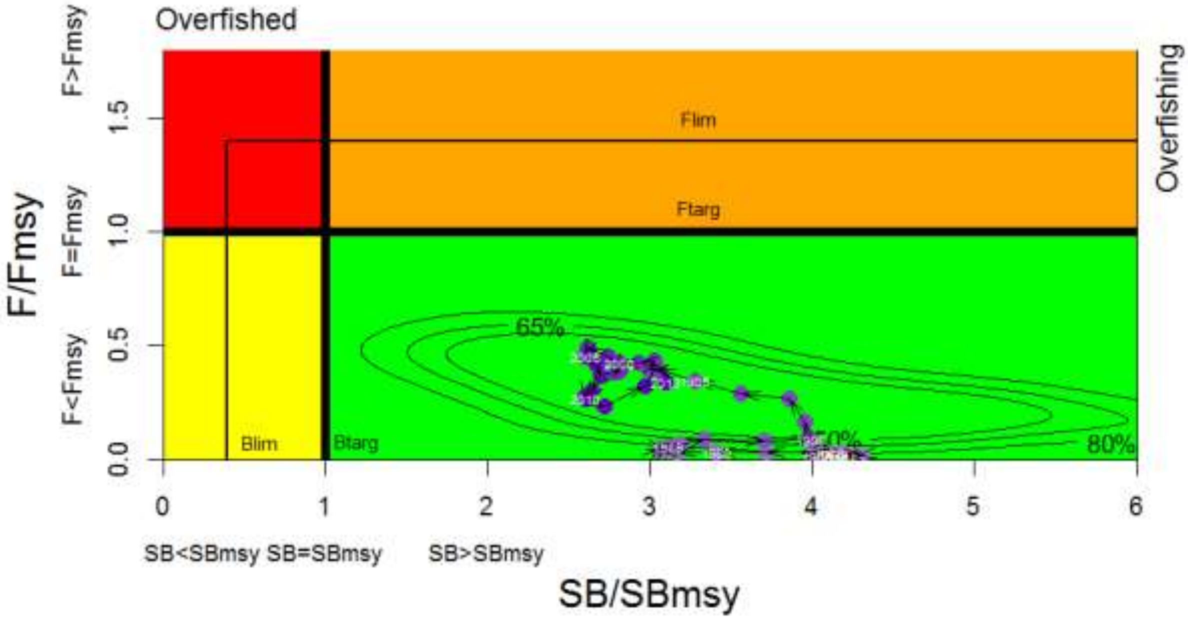



**Fig. 1.** Swordfish: SS3 Aggregated Indian Ocean assessment Kobe plot (contours are the 50, 65 and 80 percentiles of the 2013 estimate). Blue circles indicate the trajectory of the point estimates for the SB ratio and F ratio for each year 1950–2013. Interim target ($F_{targ}$ and $SB_{targ}$) and 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%** | **70%** | **80%** | **90%** | **100%** | **110%** | **120%** | **130%** | **140%** |
| $SB_{2016} < SB_{MSY}$ | 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%** | **70%** | **80%** | **90%** | **100%** | **110%** | **120%** | **130%** | **140%** |
| $SB_{2016} < SB_{Lim}$ | 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 |

**Note**: As detailed in Recommendation 14/07, the colour coding used above, and refers to 25% probability levels (Green: 0–25; Yellow: >25–50; Orange: >50–75; Red: >75–100) associated with the interim target and limit reference points set by the Commission.

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# 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 | | 2014 stock status determination |
|---|---|---|---|
| Southwest Indian Ocean | Catch 2013:<br>Average catch 2009–2013: | 7,349 t<br>7,265 t | |
| | MSY (1000 t) (80% CI):<br>$F_{MSY}$ (80% CI):<br>$B_{MSY}$ (1000 t) (80% CI):<br>$F_{2013}/F_{MSY}$ (80% CI):<br>$B_{2013}/B_{MSY}$ (80% CI):<br>$B_{2013}/B_{1950}$ (80% CI): | 9.86 (9.11–10.57)<br>0.63 (0.59–0.70)<br>12.68 (12.52–12.78)<br>0.89 (0.61–1.14)<br>0.94 (0.68–1.23)<br>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 ($B_{year}/B_{MSY}$≥ 1) |
|---|---|---|
| Stock subject to overfishing($F_{year}/F_{MSY}$> 1) | | |
| Stock not subject to overfishing ($F_{year}/F_{MSY}$≤ 1) | | |
| Not assessed/Uncertain | | |

***NOTE: The following advice is provided on the basis of the following:***

***Commission request:*** *The Commission* ***REQUESTED*** *that the southwest region continue to be analysed as a special resource, as it appears to be highly depleted compared to the Indian Ocean as a whole.*

***Scientific Committee:*** *The SC* ***NOTED*** *that although the results of the IOSSS project 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.*

***NOTE: Comment from the 12th Working Party on Billfish:***

*The WPB* ***NOTED*** *that information received after the last stock assessment carried out in 2011, indicated that there is no evidence for a separate stock in the southwest Indian Ocean (Paper IOTC–2012–WPB10–15 and published as Muths et. al 2013 (see IOTC–2013–WPB11–10). Hence, from a biological point of view, it does not make sense to conduct a separate assessment for this region.*

***Working Party on Billfish:*** Paragraph from the WPB10 Report on the two papers cited above*: The WPB* ***RECOMMENDED*** *that the SC note that although the results of the IOSSS project 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*. (para. 127 of the WPB10 Report).

## SOUTHWEST INDIAN OCEAN – MANAGEMENT ADVICE

***Stock status.*** The assessments carried out in 2014 produced substantially conflicting results (ASIA, BBDM and ASPIC). However, the ASPIC model runs are presented here just 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 2013, 7,349 t of swordfish catches were recorded from this region, which equals 110% of the recommended maximum catch of 6,678 t agreed to by the SC in 2011 (Table 3). If catches are maintained at 2013 levels, the probabilities of violating target reference points in 2016 are ≈ 81% for $F_{MSY}$ and ≈ 40% for $B_{MSY}$ (Table 4). 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 2013 catches exceeded the maximum recommended by the WPB09 and SC14 in 2011 (6,678 t). The WPB10 estimated that there is a low to moderate risk of exceeding MSY-based reference points by 2023 if catches are reduced by 20% from 2013 levels (≈ 1% risk that $B_{2023} < B_{MSY}$, and ≈ 5% risk that $F_{2023} > F_{MSY}$) (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).

The following key points should be noted:

- **Maximum Sustainable Yield (MSY)**: estimate for the southwest Indian Ocean is 9,100–10,400 t (Table 3). Catches in the southwest Indian Ocean should be maintained at levels at or below those observed in 2009 (6,678t), until there is clear evidence of recovery and biomass exceeds $B_{MSY}$.
- **Provisional reference points**: Noting that the Commission in 2013 agreed to Resolution 13/10 *on interim 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 hence, below the provisional limit reference point of $1.4*F_{MSY}$ (Fig. 1).
    b. **Biomass**: Current spawning biomass is considered to be below the target reference point of $SB_{MSY}$, but above the limit reference point of $0.4*SB_{MSY}$ (Fig. 1).
- **Main fishing gear** (2010–13): Longline catches are currently estimated to comprise approximately 85% of the total estimated swordfish catch in the Indian Ocean.
- **Main fleets** (2010–13): Taiwan,China: 18%; Sri Lanka: 16%; Indonesia: 15%; EU,Spain: 14%.
- **Improvements required**: Continued monitoring and improvement in data collection, reporting and analysis is required to reduce the uncertainty in the assessments.

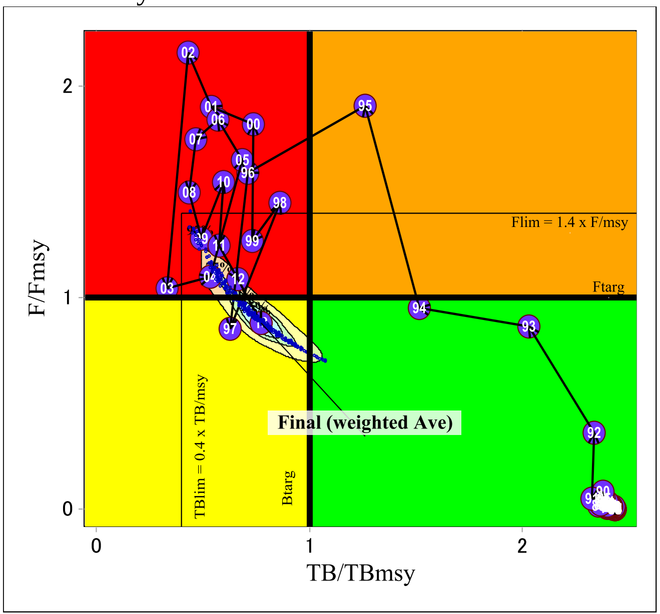


**Fig. 2.** Swordfish: ASPIC southwest Indian Ocean assessment Kobe plot (The horizontal blue line represents $F_{LIM}$ and the vertical blue line represents $B_{LIM}$). The results are from a preferred model option: Model weighted average using the inverse of the Root Mean Square errors across models (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%** | **70%** | **80%** | **90%** | **100%** | **110%** | **120%** | **130%** | **140%** |
| $B_{2016} < B_{MSY}$ | 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%** | **70%** | **80%** | **90%** | **100%** | **110%** | **120%** | **130%** | **140%** |
| $B_{2016} < B_{Lim}$ | 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 |

**Note**: As detailed in Recommendation 14/07, the colour coding used above, and refers to 25% probability levels (Green: 0–25; Yellow: >25–50; Orange: >50–75; Red: >75–100) associated with the interim target and limit reference points set by the Commission.

## 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 13/03 on the recording of catch and effort by fishing vessels in the IOTC area of competence
- Resolution 13/07 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 10/02 *mandatory statistical requirements for IOTC Members and Cooperating non-Contracting Parties (CPC's)*
- 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.

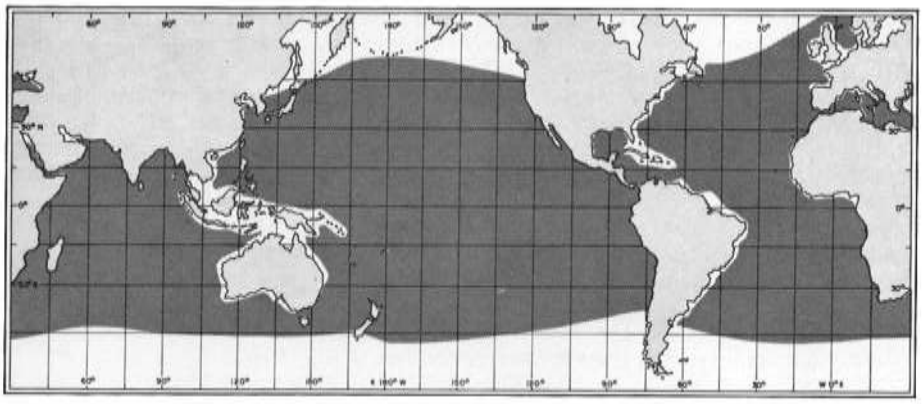

**Fig. 3.** Swordfish: The worldwide distribution of swordfish (Source: Nakamura 1984)

**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<br>**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.<br>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).<br>L-W relationships for the Indian Ocean are: females TW=0.00002409*LJFL^2.86630,<br>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: Catch trends***

Over 90% of swordfish are caught mainly using drifting longlines (>85%) (Fig. 4), on longline fisheries directed to tunas (Table 6, LL) or swordfish (Table 6, ELL), while the remaining the catches are taken by other fisheries, in particular drifting gillnets. Between 1950 and 1980, catches of swordfish in the Indian Ocean slowly increased in tandem with the level of coastal state and distant water fishing nation longline effort targeting tunas. Swordfish were mainly a bycatch of industrial longline fisheries before the early 1990's with catches slightly increasing from 1950 to 1990 proportionally to the increase in the catches of target species (tropical and temperate tunas).

The catches of swordfish markedly increased after 1990, from around 8,000 t in 1991 to a peak of 36,000 t in 1998 and 37,000 t in 2004. The change in target species from tunas to swordfish by part of the fleet of Taiwan,China along with the development of longline fisheries in Australia, Reunion island, Seychelles and Mauritius and the arrival of longline fleets from the Atlantic Ocean (EU,Portugal, EU,Spain the EU,UK and other fleets operating under various flags[1]), all targeting swordfish, are the main reasons for this significant increase.

[1] Senegal, Guinea, etc.

Since 2004, annual catches have declined steadily, largely due to the continued decline in the number of active Taiwan,China longliners in the Indian Ocean. Annual catches since 2004 have been dominated by the Taiwan,China and EU fleets (Spain, UK, France and Portugal), with the fishery extending eastward due to the effects of piracy actions (Fig. 5).

Catches of swordfish of up to 6,000 t have been recorded in recent years for a fleet of deep-freezing and fresh tuna longliners operating under flags of non-reporting countries (Not Elsewhere Included (NEI)). The catches have been low since 2007, at around 1,000 t.

The catches of Swordfish of industrial longliners from Japan have increased proportionally to those of yellowfin tuna, the target species of this fleet during the first years of the fishery, and have remained stable until the early 1990’s. The average annual catches over the last two decades have amounted to around 1,600 t, rising to over 2,500 t in 1994 and 1997, although most recently in 2012 and 2013 catches of between 600 t to 700 t have been reported.

Sri Lanka swordfish catches have ranged between 2,400 and 5,500 t over the last decade, with the highest catches recorded in 2013. These are taken mostly by vessels that use a combination of drifting gillnets and longlines. Results from the sampling conducted by NARA[2] during 2005 and 2006 with the support of the IOTC-OFCF[3] Project in different locations in Sri Lanka led to a re-estimation of the historical catch series in 2012[4].

The catches of Indonesian fresh-tuna longliners operating in Indian Ocean waters increased steadily until 2003 (3,400 t), and have decreased since then. It is, however, likely that the catches recorded for the swordfish are incomplete, as the statistics for years before 2003 are thought to be more uncertain (as port sampling was only initiated in 2003), and coverage of the frozen component of catches from port sampling, which is likely to contain substantial amounts of swordfish, was not sufficient. Catch estimates for 2012 and 2013 are three-fold those in 2011 and remain uncertain.

During the last two decades, several domestic longline fisheries targeting swordfish started to operate in Reunion (EU,France), Australia, Seychelles, South Africa and, more recently, Mauritius, with total accumulated catches estimated to be between 2,000 t and 3,000 t in recent years (see ‘All other fleets, Fig. 5).

EU longliners flagged to Spain, Portugal and the UK coming from the Atlantic Ocean have been operating in the Indian Ocean since the early 90s with current accumulated catches around 5,000 t. Around 25% of the catches of swordfish in the Indian Ocean have been taken by vessels operating under EU flags in recent years.

The annual catches of swordfish by longliners from the Rep. of Korea, recorded since 1965, have rarely exceeded 1,000 t. The highest catch, 1,100 t, was recorded in 1994. In 2010 the IOTC Secretariat revised the catches of swordfish for Rep. of Korea over the time-series using catches reported as nominal catches and catch-and-effort.

Swordfish is mostly exploited in the western Indian Ocean (Fig. 6), in waters off Somalia, and in the southwest Indian Ocean. Other important fisheries operate in waters off Sri Lanka, Western Australia and Indonesia. In 2009–11 the catches of swordfish in the western tropical Indian Ocean have dropped considerably, especially in areas off Somalia, Kenya and Tanzania, from around 13,000 t in 2005 to 6,500 t in 2008, and in particular 2,500 t in 2011. The drop in catches is the consequence of a drop in fishing effort in the area by longline fisheries, due to either piracy or decreased fish abundance, or a combination of both. Catches in 2012 in this area were three-fold those in 2011.

[2] National Aquatic Resources and Development Agency of Sri Lanka

[3] Overseas Fisheries Cooperation Foundation of Japan

[4] Moreno et al. (2012). Pilot project to improve data collection for tuna, sharks and billfish from artisanal fisheries in the Indian Ocean. Part II: Revision of catch statistics for India, Indonesia and Sri Lanka (1950-2011). Assignment of species and gears to the total catch and issues on data quality. Document presented at the 15th Session of the IOTC Scientific Committee, Seychelles, 10-15 December 2012. IOTC–2012–SC15–38

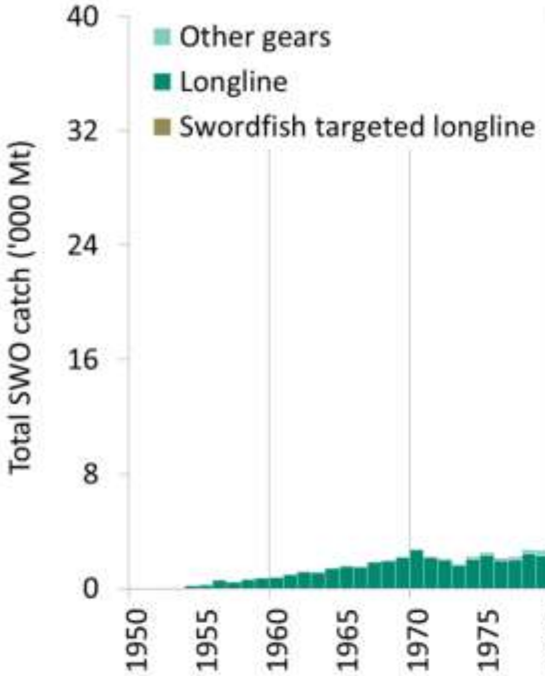


**Fig. 4** Swordfish: Catches of swordfish by gear and year recorded in the IOTC Database (1950–2013).

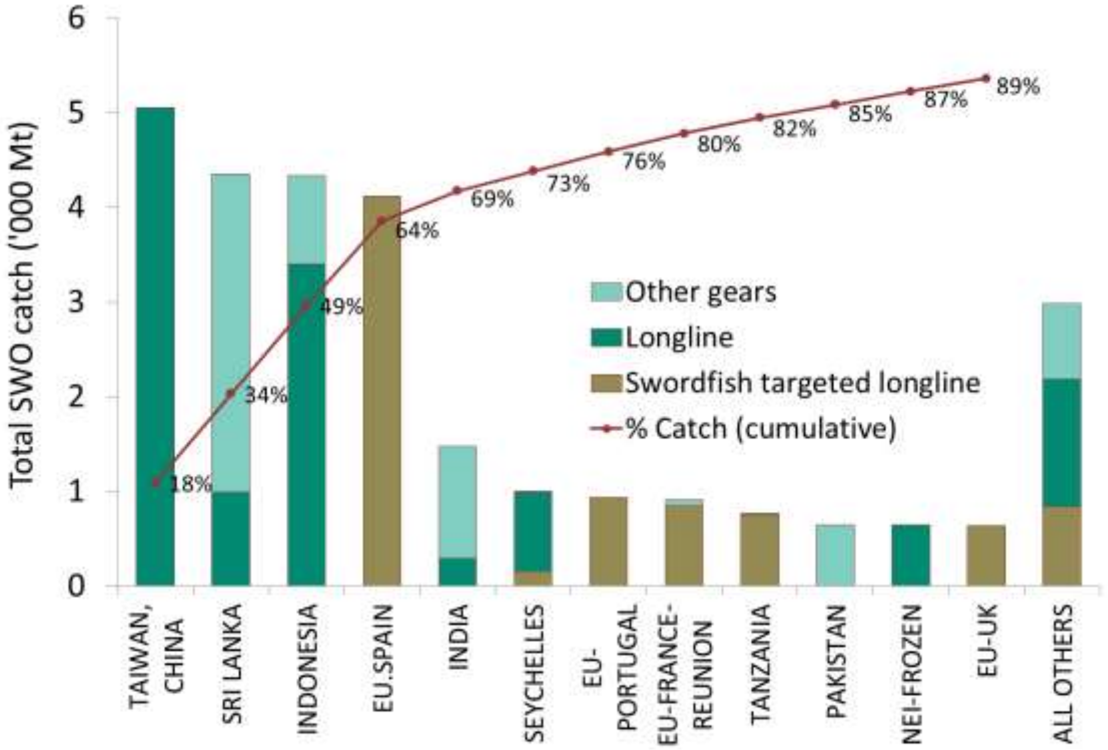


**Fig. 5**. Swordfish: average catches in the Indian Ocean over the period 2010–13, by fleet or country, ordered from left to right, according to the importance of catches of swordfish reported. The red line indicates the (cumulative) proportion of catches of swordfish for the fleets or countries concerned, over the total combined catches of this species reported from all fleets or countries and fisheries.

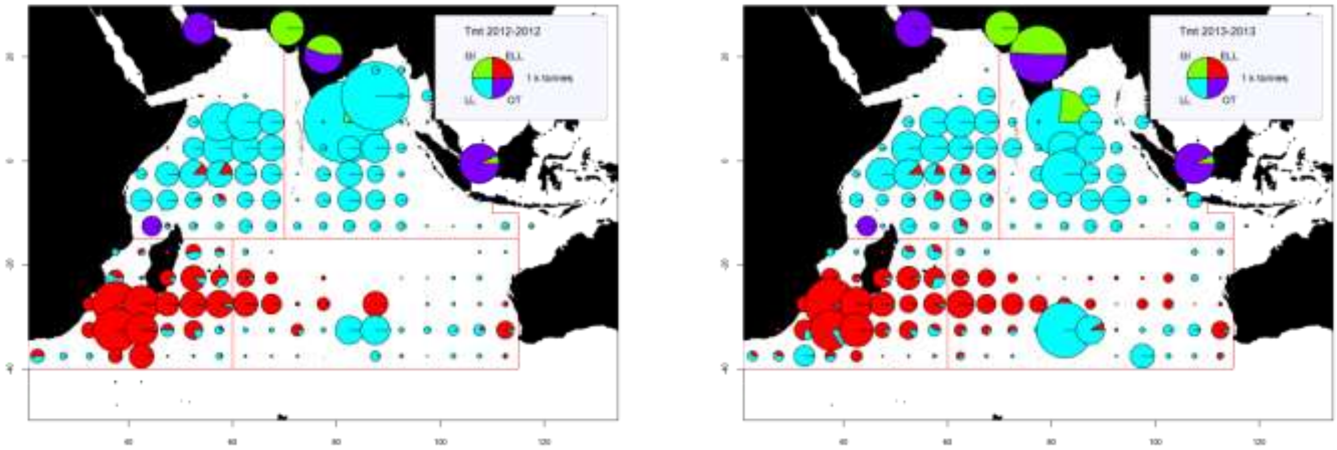

**Fig. 6a–b.** Swordfish: Time-area catches (total combined in tonnes) of swordfish for longline fisheries targeting swordfish (ELL), other longline fisheries (LL), gillnet fisheries (GI), and for all other fleets combined (OT), for the period 2004–08 by type of gear and for 2009–13, by year and type of gear. Red lines represent the areas used for the assessments of swordfish.

**TABLE 6**. Swordfish: Best scientific estimates of the catches of swordfish by type of fishery for the period 1950–2013 (in metric tons). Data as of September 2014.

| Fishery | By decade (average) | | | | | | By year (last ten years) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1950s | 1960s | 1970s | 1980s | 1990s | 2000s | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
| 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** | **320** | **1,465** | **2,322** | **5,189** | **26,527** | **32,886** | **40,267** | **35,693** | **33,074** | **30,433** | **25,153** | **24,852** | **24,270** | **21,564** | **30,058** | **31,804** |

**Fisheries:** Swordfish longline (**ELL**); Longline (**LL**)**;** Other gears (**OT**)

**TABLE 7**. Swordfish: Best scientific estimates of the catches of swordfish by fishing area for the period 1950–2013 (in metric tons). Data as of September 2014

| Area | By decade (average) | | | | | | By year (last ten years) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1950s | 1960s | 1970s | 1980s | 1990s | 2000s | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
| NW | 100 | 547 | 776 | 1,888 | 8,278 | 10,180 | 12,868 | 12,254 | 10,785 | 8,430 | 6,321 | 4,506 | 2,668 | 2,483 | 8,690 | 8,683 |
| SW | 14 | 254 | 406 | 606 | 8,624 | 7,682 | 6,325 | 9,791 | 8,995 | 7,423 | 6,437 | 6,381 | 8,211 | 7,005 | 7,354 | 7,349 |
| NE | 168 | 453 | 756 | 2,168 | 6,504 | 9,296 | 11,400 | 7,975 | 9,275 | 9,359 | 8,889 | 10,862 | 9,896 | 9,147 | 11,796 | 12,489 |
| SE | 37 | 203 | 307 | 387 | 3,034 | 5,709 | 9,641 | 5,656 | 4,014 | 5,207 | 3,502 | 3,097 | 3,483 | 2,923 | 2,215 | 3,283 |
| OT | 0 | 8 | 76 | 140 | 88 | 20 | 33 | 16 | 6 | 15 | 5 | 5 | 11 | 6 | 4 | 1 |
| **Total** | **320** | **1,465** | **2,322** | **5,189** | **26,527** | **32,886** | **40,267** | **35,693** | **33,074** | **30,433** | **25,153** | **24,852** | **24,270** | **21,564** | **30,058** | **31,804** |

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

### *Uncertainty of time–area catches*

**Retained catches:** are fairly well known (Fig. 7a); however catches are uncertain for:

- **Drifting gillnet** fisheries of IR Iran and Pakistan: The IOTC Secretariat used the catches of swordfish and marlins reported by IR Iran for the years 2012 and 2013 to rebuild historical catches of billfish for this fishery. However, catch rates and species composition for the Iranian and Pakistani gillnet fisheries differ and they are also in contradiction with other estimates, derived from sampling in Pakistan. Estimates of catches of swordfish by drifting gillnet in Pakistan and IR Iran have represented over 4% of the total combined catches of swordfish reported, from all fisheries.
- **Longline** fishery of Indonesia: The catches of swordfish for the longline fishery of Indonesia may have been underestimated over the time series due to insufficient sampling coverage. Although the new catches estimated by the IOTC Secretariat for the period 2003–09 are thought to be more accurate, swordfish catches remain uncertain, especially in recent years (where they represent around 12% of the total catches of swordfish in the Indian Ocean).
- **Longline fishery of India:** India has reported very incomplete catches and catch-and-effort data for its commercial longline fishery. Although the new catches estimated by the IOTC Secretariat are thought to be

more accurate, catches of swordfish remain uncertain (catches of swordfish in recent years represent less than 4% of the total catches of swordfish in the Indian Ocean).

- **Longline** fleets from non-reporting countries (NEI): The IOTC Secretariat had to estimate catches of swordfish for a fleet of longliners targeting tunas or swordfish and operating under flags of various non-reporting countries. The catches estimated since 2006 are, however, low (they represent around 3% of the total catches of swordfish in the Indian Ocean).

**Discards:** believed to be low although they are unknown for most industrial fisheries, mainly longliners. Discards of swordfish may also occur in the driftnet fishery of IR Iran, as this species has no commercial value in this country.

**Changes to the catch series:** There have been relatively minor revisions to the catches of swordfish since the WPB meeting in 2013. Any differences in the data series since the last WPB are relatively small changes to the nominal catch as a result of reallocation of catch reported as other billfish species or as aggregated species groups reported by Sri Lanka, and Pakistan to a lesser extent. These changes, however, did not lead to very significant changes in the total catch estimates for swordfish.

**Catch–per–unit–effort (CPUE) Series** (Fig. 7b): Catch and effort series are available from some industrial longline fisheries. Nevertheless, catch and effort are not available from some fisheries or they are considered poor quality, especially since the early 90s (Indonesia, fresh-tuna longliners from Taiwan,China[5], Non-reporting longliners (NEI)). In addition, catch-and-effort data are not available for the gillnet and longline fishery of Sri Lanka and the drifting gillnet fisheries of IR Iran and Pakistan.

**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. 7c).

- **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 in recent years (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)** (Figs. 8, 9): data are available but the estimates are thought to have been compromised for some years and fisheries due to:

- the uncertainty in the length frequency data recorded for longliners of Japan and Taiwan,China, for which average weights of swordfish derived from length frequency data and catch-and-effort data are very different.
- the uncertainty in the catches of swordfish for the drifting gillnet fisheries of IR Iran and the longline fishery of Indonesia.
- the total lack of size data before the early-70s and poor coverage before the early-80s and for most artisanal fisheries (Pakistan, India, Indonesia).
- the paucity of size data available from industrial longliners since the early-1990s (Japan, Philippines, India and China).
- the lack of time-area catches for some industrial fleets (Indonesia, India, IR Iran, Pakistan, NEI).
- the paucity of biological data available, notably sex-ratio and sex-length-age keys.

[5] Catch-and-effort statistics for the fresh-tuna longline fishery of Taiwan,China are available since 2007, although logbook coverage levels are still low.

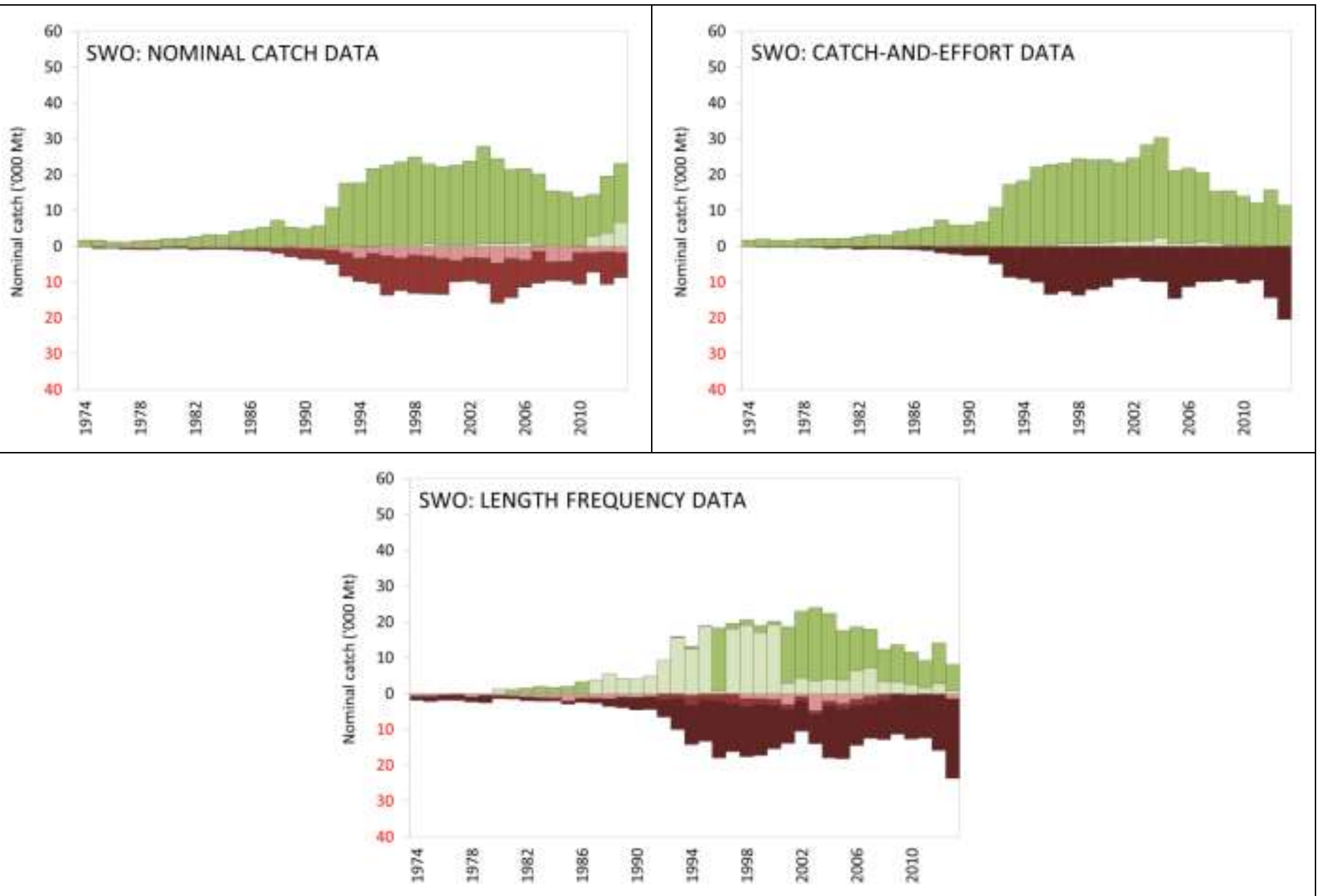


**Fig. 7a-c.** Swordfish: data reporting coverage (1974–2013). a) nominal catch data; b) catch-and-effort data; c) length frequency data. *Each IOTC dataset (nominal catch, catch-and-effort, and length frequency) are assessed against IOTC reporting standards, where: a score of 0 indicates the amount of nominal catch associated with each dataset that is fully reported according to IOTC standards; a score of between 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; a score of 8 refers to the amount of nominal catch associated with catch-and-effort data that is not available. (Data as of September 2014)*

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)

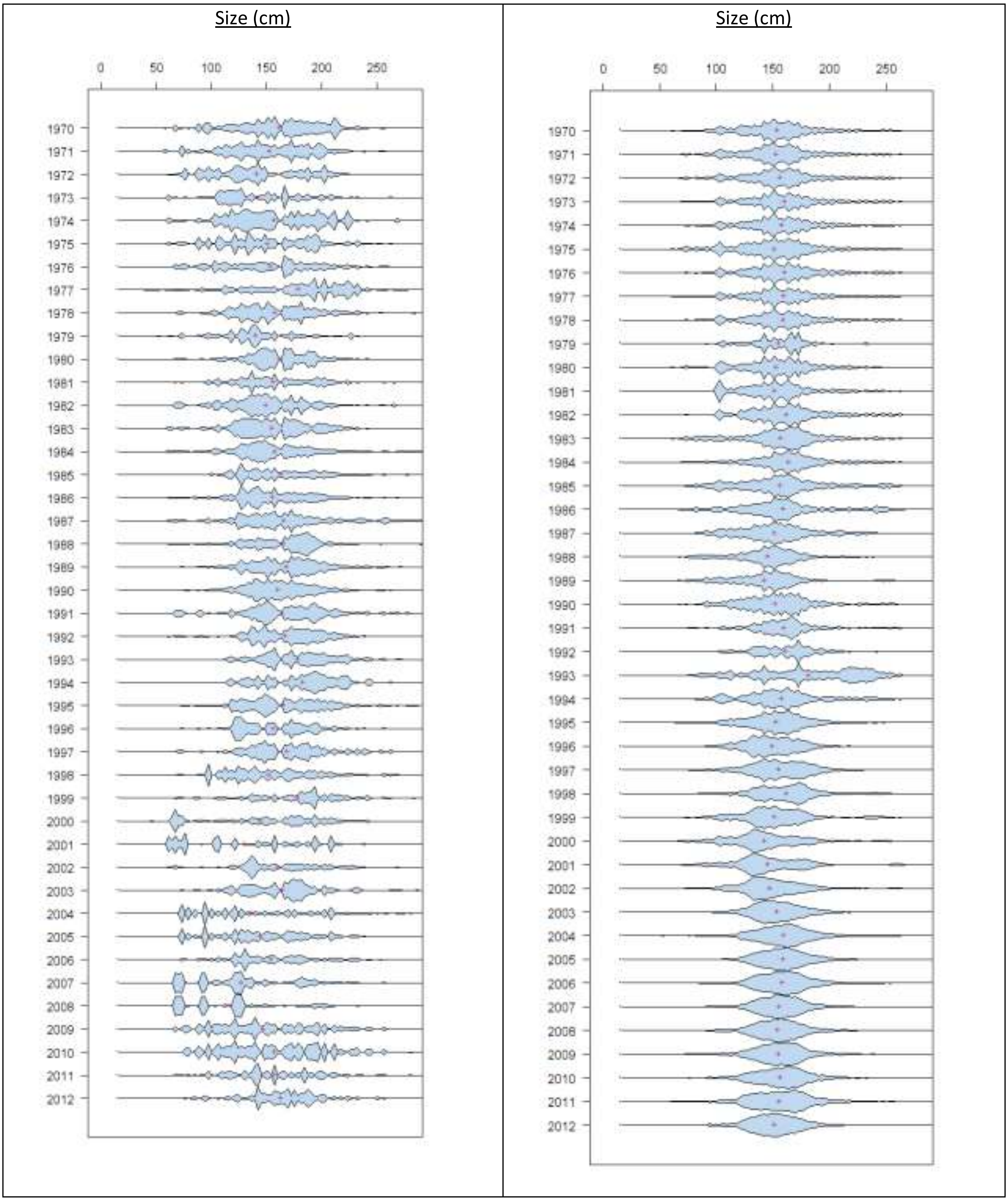


**Fig. 8.** Swordfish: Longline catch-at-size length distributions for Japan (left) and Taiwan,China (right) (Data as of September 2014)

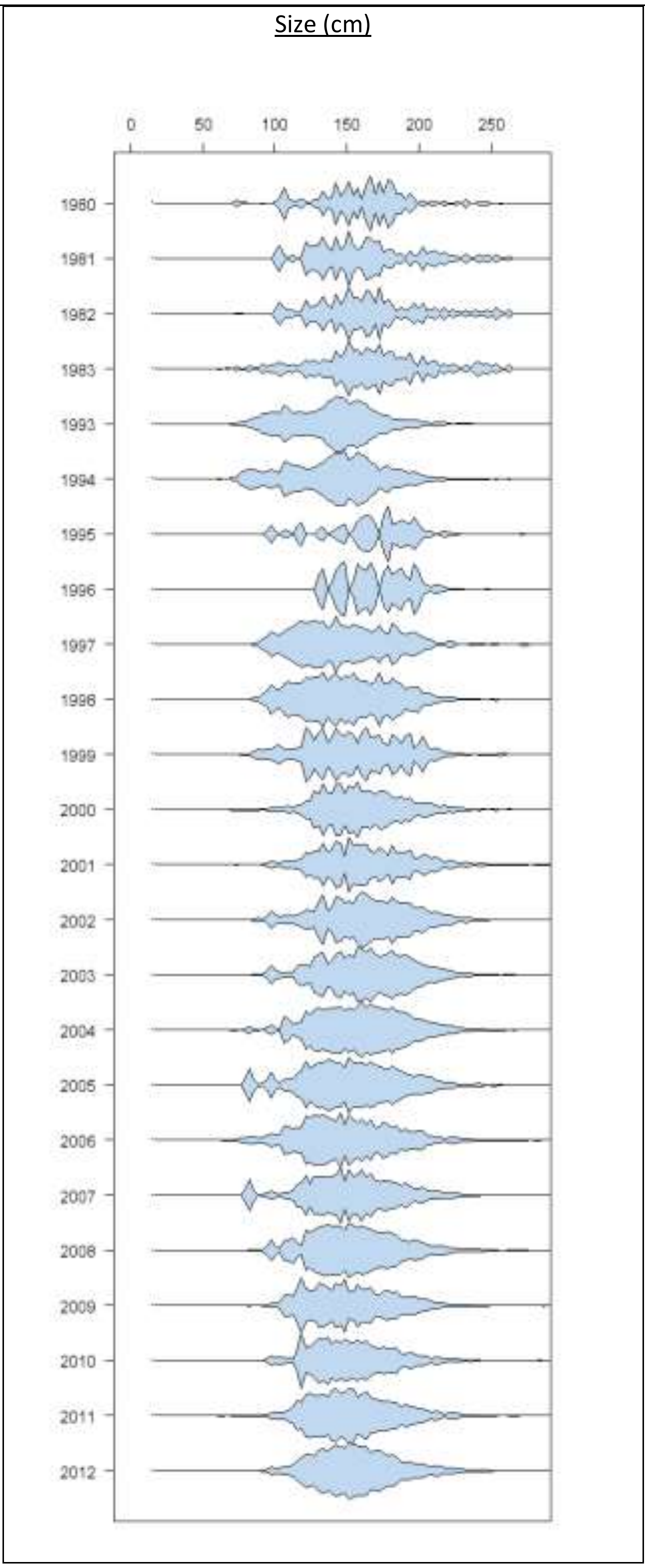


**Fig. 9.** Swordfish: Longline catch-at-size length distributions for combined EU,Spain, EU,Portugal and EU,UK vessels (Data as of September 2014)

***Swordfish: Effort trends***

Total effort from longline vessels flagged to Japan, Taiwan,China and EU,Spain by five degree square grid in 2012 and 2013 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.

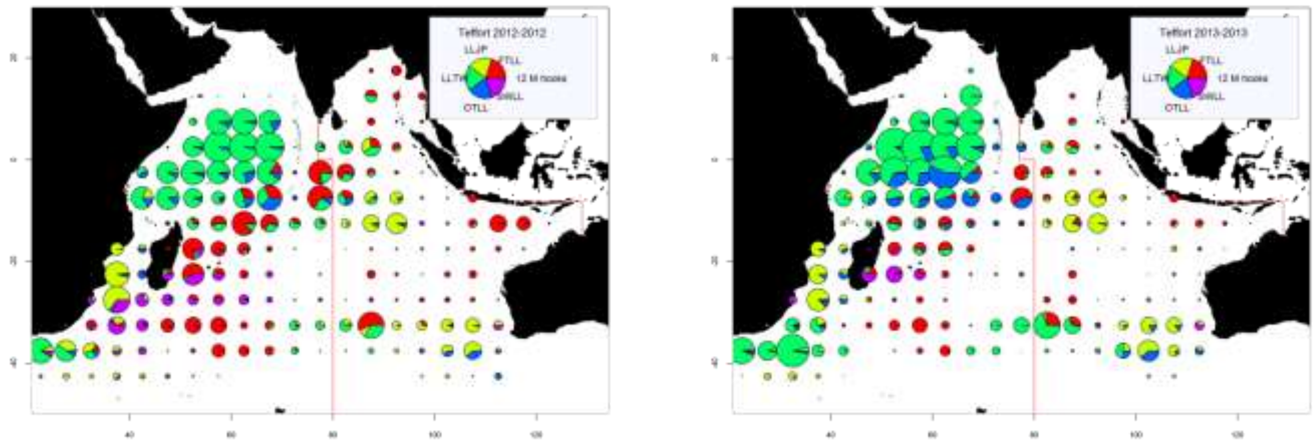

**Fig. 10.** Number of hooks set (millions) from longline vessels by five degree square grid and main fleets, for the years 2012 (left) and 2013 (right) (Data as of September 2014).
LLJP (light green): deep-freezing longliners from Japan
LLTW (dark green): deep-freezing longliners from Taiwan,China
SWLL (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)

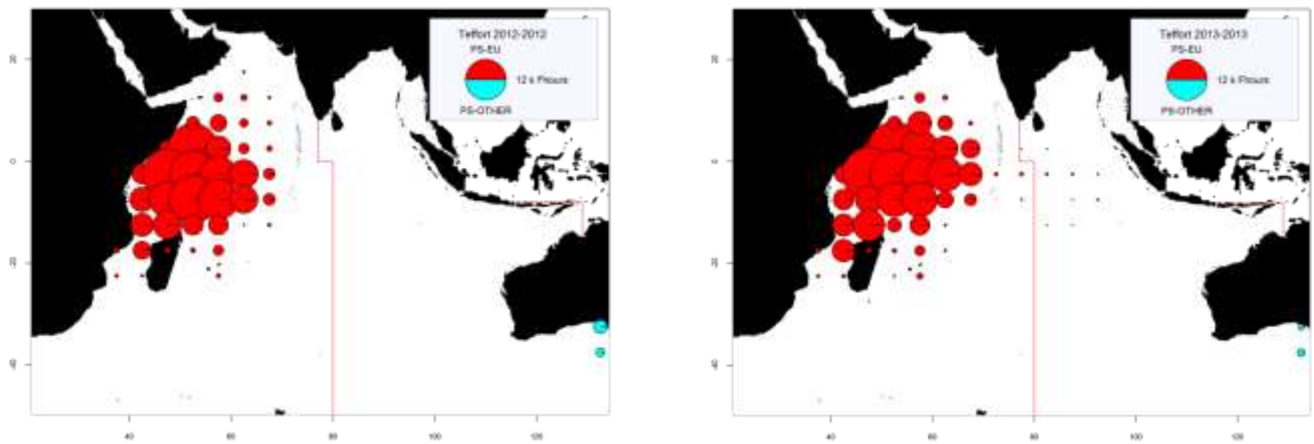

**Fig. 11.** Number of hours of fishing (Fhours) from purse seine vessels by 5 degree square grid and main fleets, for the years 2012 (left) and 2013 (right) (Data as of September 2014)
PS-EU (red): Industrial purse seiners monitored by the EU and Seychelles (operating under flags of EU countries, Seychelles 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: 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.

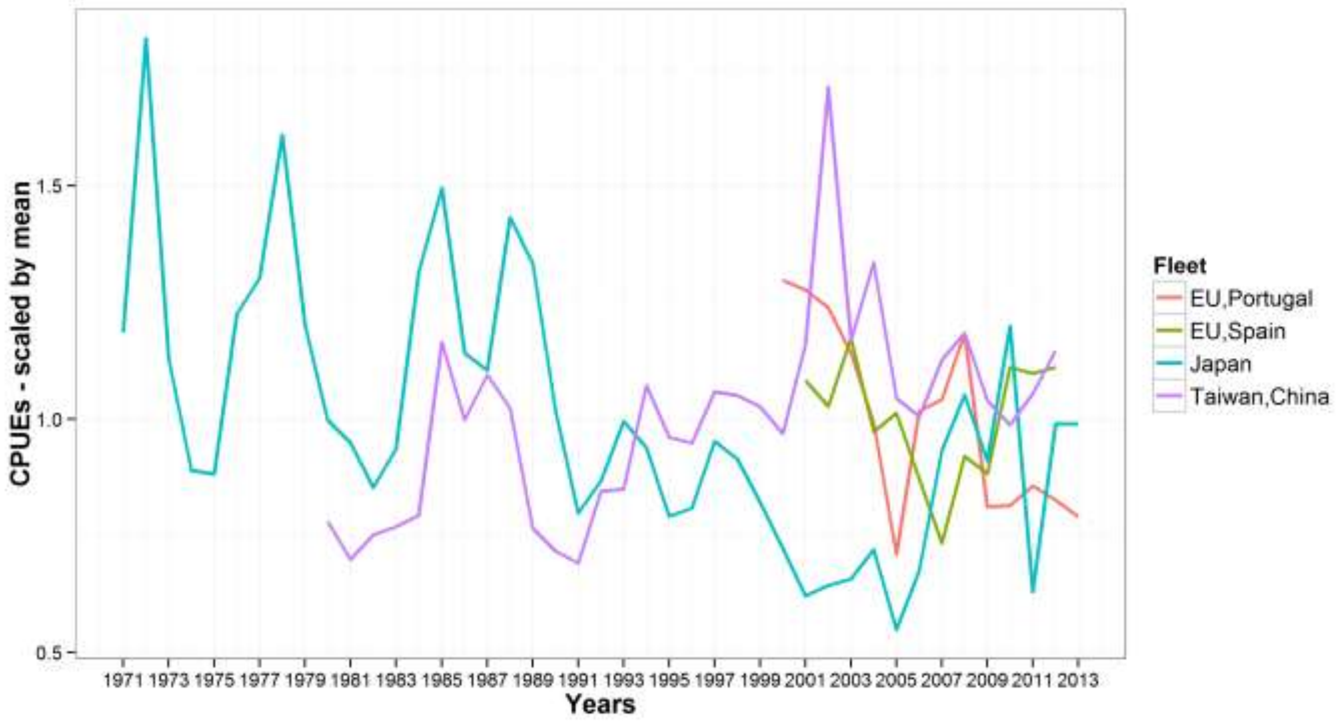


**Fig. 12.** Aggregate whole Indian Ocean Swordfish: CPUE series for the Indian Ocean swordfish assessments (ASIA, ASPIC and BBDM) in 2014. Series have been rescaled relative to their respective means (for different overlapping time periods).

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).

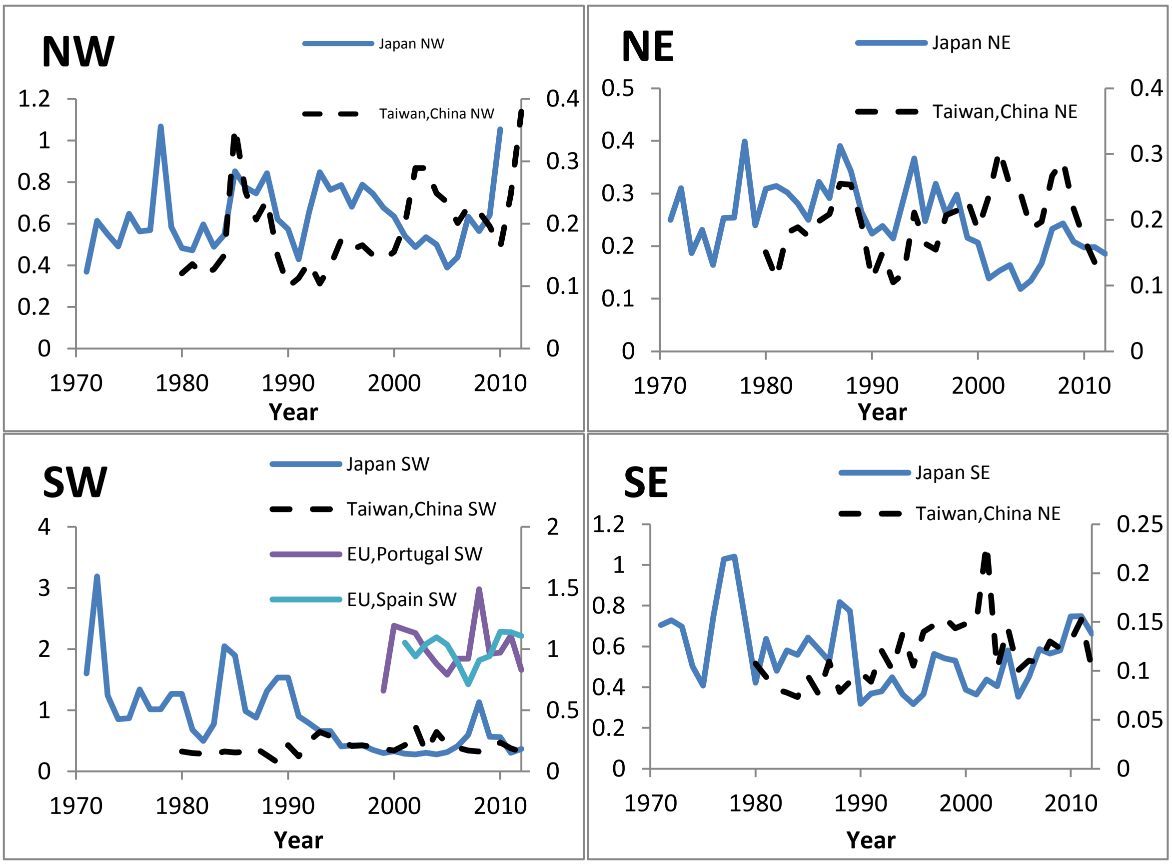

**Fig. 13.** Swordfish: CPUE series used in the final SS3 stock assessment model in 2014 by sub-region. Series have been rescaled relative to their respective means (for different overlapping time periods). NW – north-west; SW – southwest; NE – northeast; SE – southeast Indian Ocean.

***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.

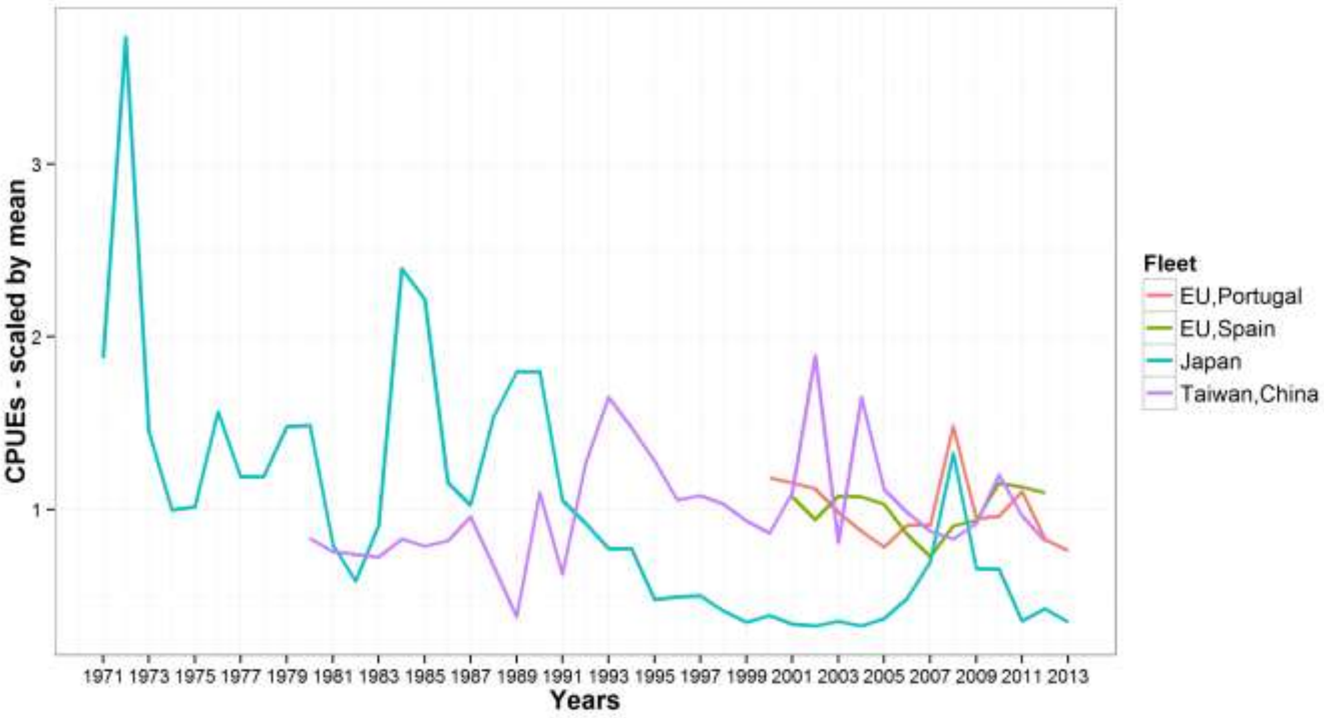


**Fig. 14.** Swordfish: CPUE series for the **southwest** Indian Ocean swordfish assessments in 2014. Series have been rescaled relative to their respective means (for different overlapping time periods).

## 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 8). 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 8).

**TABLE 8.** 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 (1000 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) |
| $SB_{MSY}$ (1000 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. |

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