

EXECUTIVE SUMMARY: STATUS OF THE INDIAN OCEAN SWORDFISH (*XIPHIAS GLADIUS*) RESOURCE

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

Area ¹	Indicators – 2011 assessment		2011 stock status determination
			2009 ²
Indian Ocean	Catch 2010:	18,956 t	
	Average catch 2006-2010:	23,799 t	
	MSY (4 models):	29,900 t–34,200 t	
	F ₂₀₀₉ /F _{MSY} (4 models):	0.50–0.63	
	SB ₂₀₀₉ /SB _{MSY} (4 models):	1.07–1.59	
	SB ₂₀₀₉ /SB ₀ (4 models):	0.30–0.53	

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

²The stock status refers to the most recent years' data used for the assessment.

Colour key	Stock overfished (SB _{year} /SB _{MSY} < 1)	Stock not overfished (SB _{year} /SB _{MSY} ≥ 1)
Stock subject to overfishing (F _{year} /F _{MSY} > 1)		
Stock not subject to overfishing (F _{year} /F _{MSY} ≤ 1)		

INDIAN OCEAN STOCK – MANAGEMENT ADVICE

Stock status. All models suggest that the stock is above, but close to a biomass level that would produce MSY and current catches are below the MSY level. MSY-based reference points were not exceeded for the Indian Ocean population as a whole (F₂₀₀₉/F_{MSY} < 1; SB₂₀₀₉/SB_{MSY} > 1). Spawning stock biomass in 2009 was estimated to be 30–53% (from Table 1) of the unfished levels.

Outlook. The decrease in longline catch and effort in recent years has lowered the pressure on the Indian Ocean stock as a whole, indicating that current fishing mortality would not reduce the population to an overfished state. There is a low risk of exceeding MSY-based reference points by 2019 if catches reduce further or are maintained at current levels until 2019 (<11% risk that B₂₀₁₉ < B_{MSY}, and <9% risk that F₂₀₁₉ > F_{MSY}) (Table 2).

Recommendations to the Scientific Committee

The WPB agreed that:

- 1) The Maximum Sustainable Yield estimate for the whole Indian Ocean is 29,900–34,200 t (range of best point estimates from Table 2) and annual catches of swordfish should not exceed this estimate.
- 2) if the recent declines in effort continue, and catch remains substantially below the estimated MSY of 30,000–34,000 t, then management measures are not required which would pre-empt current resolutions and planned management strategy evaluation. However, continued monitoring and improvement in data collection, reporting and analysis is required to reduce the uncertainty in assessments.
- 3) The Kobe strategy matrix illustrates the levels of risk associated with varying catch levels over time and could be used to inform management actions.
- 4) Advice specific to the southwest region is provided below, as requested by the Commission.

TABLE 2. Aggregated Indian Ocean assessment - Kobe 2 Strategy Matrix, indicating a range of probabilities across four assessment approaches. Probability (percentage) of violating the MSY-based reference points for five constant catch projections (2009 catch level, ± 20% and ± 40%) projected for 3 and 10 years.

Reference point and projection timeframe	Alternative catch projections (relative to 2009) and probability (%) of violating reference point				
	60%	80%	100%	120%	140%
B ₂₀₁₂ < B _{MSY}	0–4	0–8	0–11	2–12	4–16
F ₂₀₁₂ > F _{MSY}	0–1	0–2	0–9	0–16	6–27
B ₂₀₁₉ < B _{MSY}	0–4	0–8	0–11	0–13	6–26
F ₂₀₁₉ > F _{MSY}	0–1	0–2	0–9	0–23	7–31

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

Area ¹	Indicators – 2011 assessment		2011 stock status determination
			2009 ²
Southwest Indian Ocean	Catch 2009:	6,513 t	
	Average catch 2006-2010:	7,112 t	
	MSY (3 models):	7,100 t–9,400 t	
	F ₂₀₀₉ /F _{MSY} (3 models):	0.64–1.19	
	SB ₂₀₀₉ /SB _{MSY} (3 models):	0.73–1.44	
	SB ₂₀₀₉ /SB ₀ (3 models):	0.16–0.58	

¹Boundaries for southwest Indian Ocean stock assessment are defined in IOTC–2011–WPB09–R.

²The stock status refers to the most recent years' data used for the assessment.

Colour key	Stock overfished (SB _{year} /SB _{MSY} < 1)	Stock not overfished (SB _{year} /SB _{MSY} ≥ 1)
Stock subject to overfishing (F _{year} /F _{MSY} > 1)		
Stock not subject to overfishing (F _{year} /F _{MSY} ≤ 1)		

SOUTHWEST INDIAN OCEAN – MANAGEMENT ADVICE

Stock status. Most of the evidence provided to the WPB indicated that the resource in the southwest Indian Ocean has been overfished in the past decade and biomass remains below the level that would produce MSY (B_{MSY}). Recent declines in catch and effort have brought fishing mortality rates to levels below F_{MSY} (Table 3).

Outlook. The decrease in catch and effort over the last few years in the southwest region has reduced pressure on this resource. There is a low risk of exceeding MSY-based reference points by 2019 if catches reduce further or are maintained at current levels (<25% risk that B₂₀₁₉ < B_{MSY}, and <8% risk that F₂₀₁₉ > F_{MSY}). There is a risk of reversing the rebuilding trend if there is any increase in catch in this region (Table 4).

Recommendations to the Scientific Committee

The WPB agreed that:

- 1) The Maximum Sustainable Yield estimate for the southwest Indian Ocean is 7,100–9,400 t (range of best point estimates from Table 3).
- 2) Catches in the southwest Indian Ocean should be maintained at levels at or below those observed in 2009 (6,600 t) [6,678], until there is clear evidence of recovery and biomass exceeds B_{MSY}.
- 3) The Kobe strategy matrix illustrates the levels of risk associated with varying catch levels over time and could be used to inform management actions.

TABLE 4. Southwest Indian Ocean assessment - Kobe 2 Strategy Matrix, indicating a range of probabilities across three assessment approaches. Probability (percentage) of violating the MSY-based reference points for five constant catch projections (2009 catch level, ± 20% and ± 40%) projected for 3 and 10 years.

Reference point and projection timeframe	Alternative catch projections (relative to 2009) and probability (%) of violating reference point				
	60%	80%	100%	120%	140%
B ₂₀₁₂ < B _{MSY}	0-15	0-20	0-25	0-30	12-32
F ₂₀₁₂ > F _{MSY}	0-1	0-5	0-8	0-18	13-34
B ₂₀₁₉ < B _{MSY}	0-15	0-20	0-25	0-32	18-34
F ₂₀₁₉ > F _{MSY}	0-1	0-5	0-8	0-18	19-42

SUPPORTING INFORMATION

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

CONSERVATION AND MANAGEMENT MEASURES

Swordfish in the Indian Ocean are currently subject to a single conservation and management measure adopted by the Commission: Resolution 09/02 *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 2010 and 2011.

- Resolution 08/04 *concerning the recording of catch by longline fishing vessels in the IOTC area.*
- Resolution 09/02 *On the implementation of a limitation of fishing capacity of contracting parties and cooperating non-contracting parties.*
- Resolution 10/02 *mandatory statistical requirements for IOTC Members and Cooperating non-Contracting Parties (CPC's).*
- Resolution 10/03 *concerning the recording of catch by fishing vessels in the IOTC area.*
- Resolution 10/07 *concerning a record of licensed foreign vessels fishing for tunas and swordfish in the IOTC area.*
- Resolution 10/08 *concerning a record of active vessels fishing for tunas and swordfish in the IOTC area.*
- Recommendation 10/13 *On the implementation of a ban on discards of skipjack tuna, yellowfin tuna, bigeye tuna, and non targeted species caught by purse seiners.*
- Recommendation 11/06 *Concerning the Recording of Catch by Fishing Vessels in the IOTC Area of Competence.*

FISHERIES INDICATORS

General

Swordfish (*Xiphias gladius*) is a large oceanic apex predator that inhabits all the world's oceans. 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.

TABLE 5. Biology of Indian Ocean swordfish (*Xiphias gladius*).

Parameter	Description
Range and stock structure	Northern coastal state waters 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. For the purposes of stock assessments, one pan-ocean stock has been assumed. However, 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 lower-jaw FL; males ~120 cm lower-jaw FL
Spawning season	Highly fecund batch spawner. May spawn as frequently as once every three days over a period of several months in spring. Spawning occurs from October to April 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; ~60 cm lower-jaw FL for artisanal fleets and methods. 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).

SOURCES: Froese & Pauly (2009); Poisson & Fauvel (2009)

Catch trends

Swordfish are caught mainly using drifting longlines (95%) and gillnets (5%) (Fig. 1). 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 (Figs. 1 and 2). 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).

Since 2004, annual catches have declined steadily (Fig. 1), 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. 3).

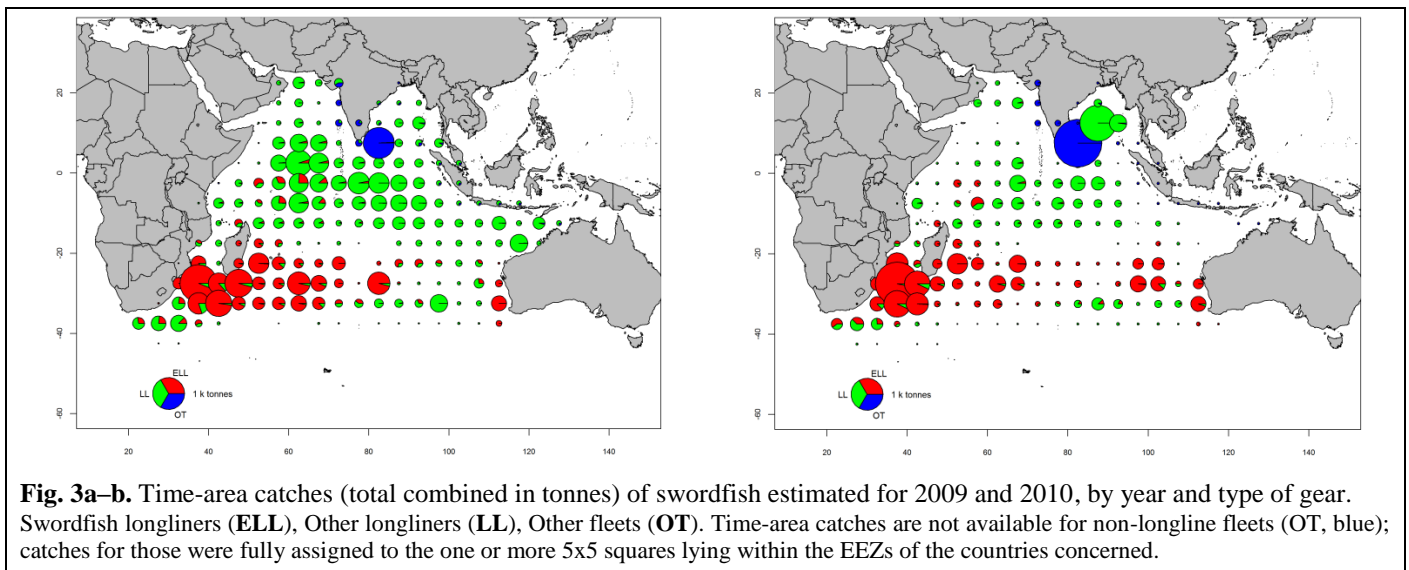
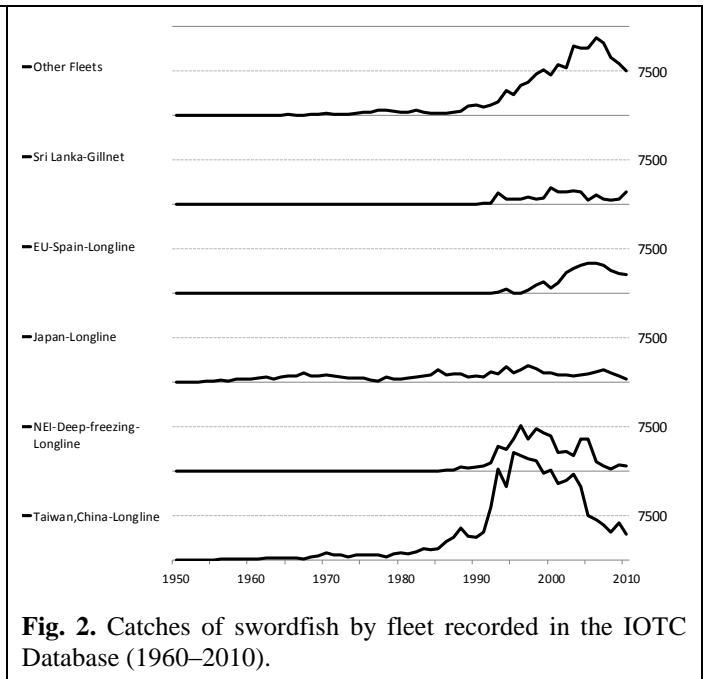
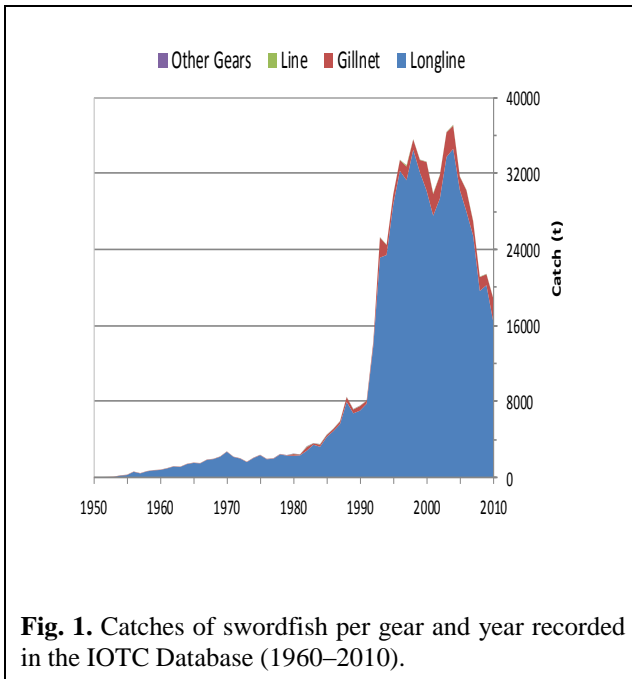


TABLE 6. Best scientific estimates of the catches of swordfish by type of fishery for the period 1950–2009 (in metric tons). Data as of October 2011.

Fishery	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
ELL				9	1,842	10,439	7,970	8,927	10,727	13,414	15,645	13,629	12,008	8,579	8,423	8,113
LL	282	1,426	2,135	4,337	21,580	17,475	19,600	20,453	23,032	21,206	14,630	14,350	13,443	11,064	11,825	8,373
OT	40	41	53	317	1,094	2,121	2,381	2,514	2,646	2,531	1,461	2,305	1,600	1,515	1,200	2,470
Total	322	1,467	2,188	4,664	24,516	30,035	29,950	31,893	36,405	37,152	31,735	30,285	27,051	21,157	21,448	18,956

Fisheries: Swordfish longline (ELL); Other longline (LL); Other fisheries (OT)

TABLE 7. Best scientific estimates of the catches of swordfish by fishing area for the period 1950–2009 (in metric tons). Data as of October 2011.

Area	By decade (average)						By year (last ten years)									
	1950s	1960s	1970s	1980s	1990s	2000s	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
NW	117	551	650	1,469	7,245	9,820	7,969	12,281	15,108	12,276	10,865	10,355	8,719	6,625	4,998	2,204
SW	14	256	405	620	8,599	7,591	8,887	7,359	3,969	6,293	9,680	8,833	7,349	6,188	6,678	6,513
NE	122	405	725	2,017	5,787	6,352	6,379	5,783	8,166	7,775	4,680	6,138	4,973	4,753	6,661	7,393
SE	27	167	271	342	2,518	5,644	6,051	5,737	8,297	9,729	5,753	4,337	5,258	3,507	3,014	2,788
OT	41	88	137	215	368	628	664	734	864	1,079	757	621	752	84	97	58
Total	322	1,467	2,188	4,664	24,516	30,035	29,950	31,893	36,405	37,152	31,735	30,285	27,051	21,157	21,448	18,956

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. 4); however catches are uncertain for:

- Drifting gillnet fisheries of Iran and Pakistan: To date, Iran has not reported catches of swordfish for its gillnet fishery. Although Pakistan has reported catches of swordfish they are considered to be too low for a driftnet fishery.
- Longline fishery of Indonesia: The catches of swordfish for the fresh tuna longline fishery of Indonesia may have been underestimated in recent years due to insufficient sampling coverage. Although the new catches estimated by the Secretariat are thought to be more accurate, swordfish catches remain uncertain, especially in recent years.
- Longline fishery of India: India has reported very incomplete catches and catch-and-effort data for its longline fishery. Although the new catches estimated by the IOTC Secretariat are thought to be more accurate, catches of swordfish remain uncertain.
- 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.
- Changes to the catch series: There have not been significant changes to the catch series of swordfish since the WPB in 2010. Changes since the last WPB refer to revisions of historic data series for the artisanal fisheries of Indonesia and India. These changes, however, did not lead to significant changes in the total catch estimates.
- Discards are 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 Iran, as this species has no commercial value in this country.

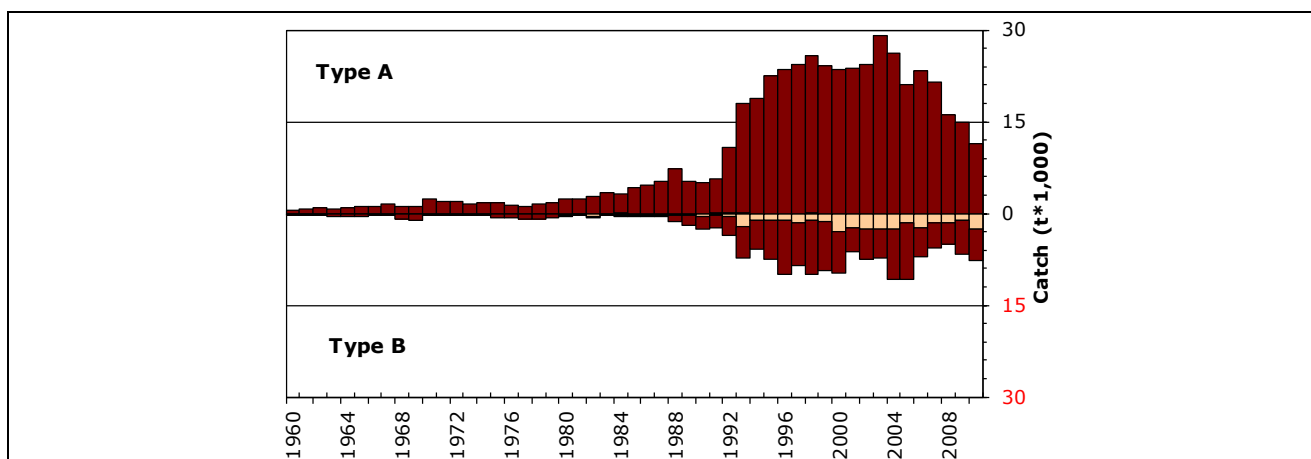


Fig. 5. Uncertainty of time-area catches for swordfish (Data as of October 2011).

Catches below the zero-line (Type B) refer to fleets that do not report catch-and-effort data to the IOTC, do not report catch-and-effort data by gear and/or species or any of the other reasons provided in the document. Catches over the zero-line (Type A) refer to fleets for which no major inconsistencies have been found to exist. Light bars represent data for artisanal fleets and dark bars represent data for industrial fleets.

Effort trends

Total effort from longline vessels flagged to Japan, Taiwan, China and EU, Spain by five degree square grid from 2007 to 2010 are provided in Fig. 6, 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 2007 to 2010 are provided in Fig. 7.

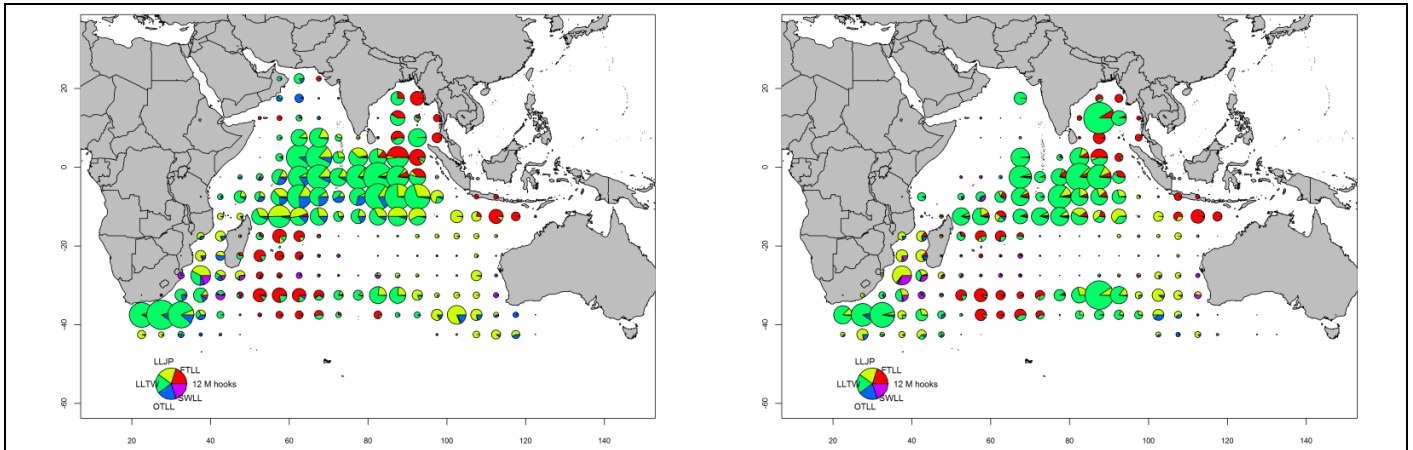


Fig. 6. Number of hooks set (millions) from longline vessels by five degree square grid and main fleets, for the years 2009 (left) and 2010 (right) (Data as of August 2011).

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)

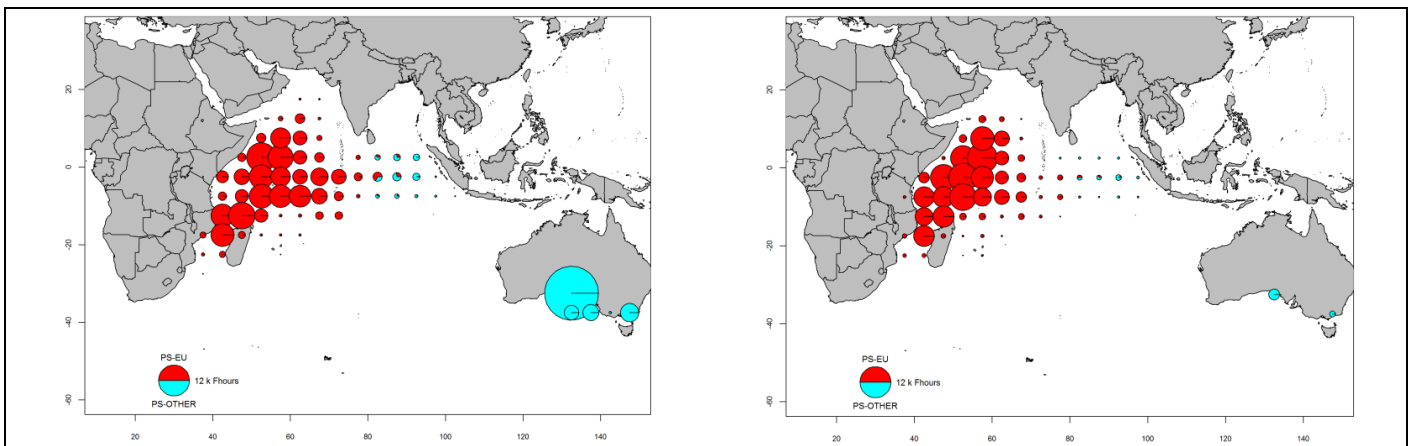


Fig. 7. Number of hours of fishing (Fhours) from purse seine vessels by 5 degree square grid and main fleets, for the years 2009 (left) and 2010 (right) (Data as of August 2011).

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)

Catch-per-unit-effort (CPUE) trends

The following CPUE series were used in the stock assessment models for 2011 (Figs. 8 and 9), while the relative weighting of the different CPUE series would be left to the individual analyst to determine and justify to participants:

- Japan data (1980–2009): Series 3.2 from document IOTC–2011–WPB09–14, which includes fixed latitude and longitude effects, plus environmental effects.
- Taiwan,China data (1995–2009): Model 10 from document IOTC–2011–WPB09–23, which includes fixed latitude and longitude effects, plus environmental effects.
- EU,Spain data (2001–2009): Series 5 from document IOTC–2011–WPB09–23, calculated for the southwest area only (includes sub-region factors and species ratio factors) area and run 1 for the assessment of whole Indian Ocean.
- EU,La Reunion data (1994–2000): Same series as last year (IOTC–2010–WPB–03).

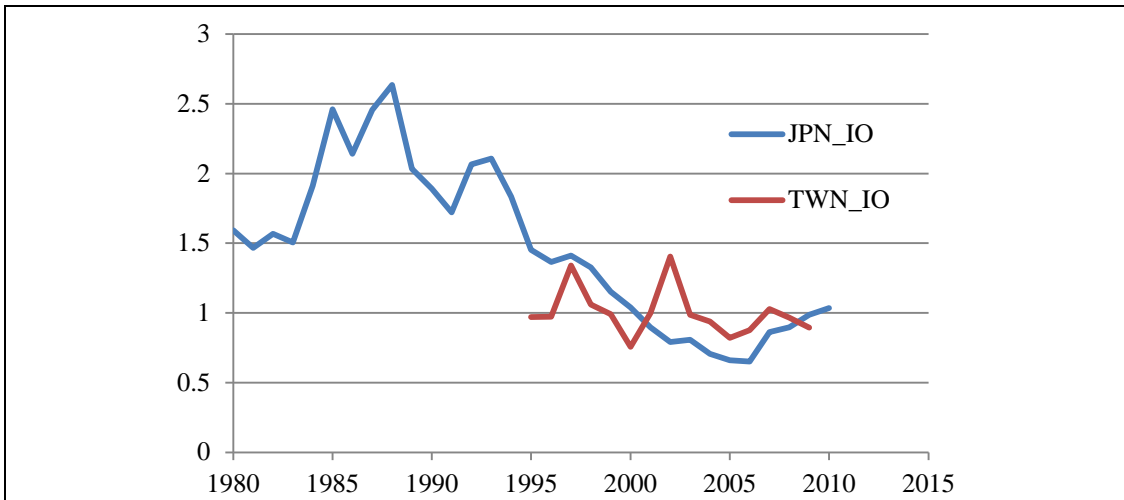


Fig. 8. Aggregate Indian Ocean CPUE series for swordfish. Series have been rescaled relative to their respective means from 1995–2009.

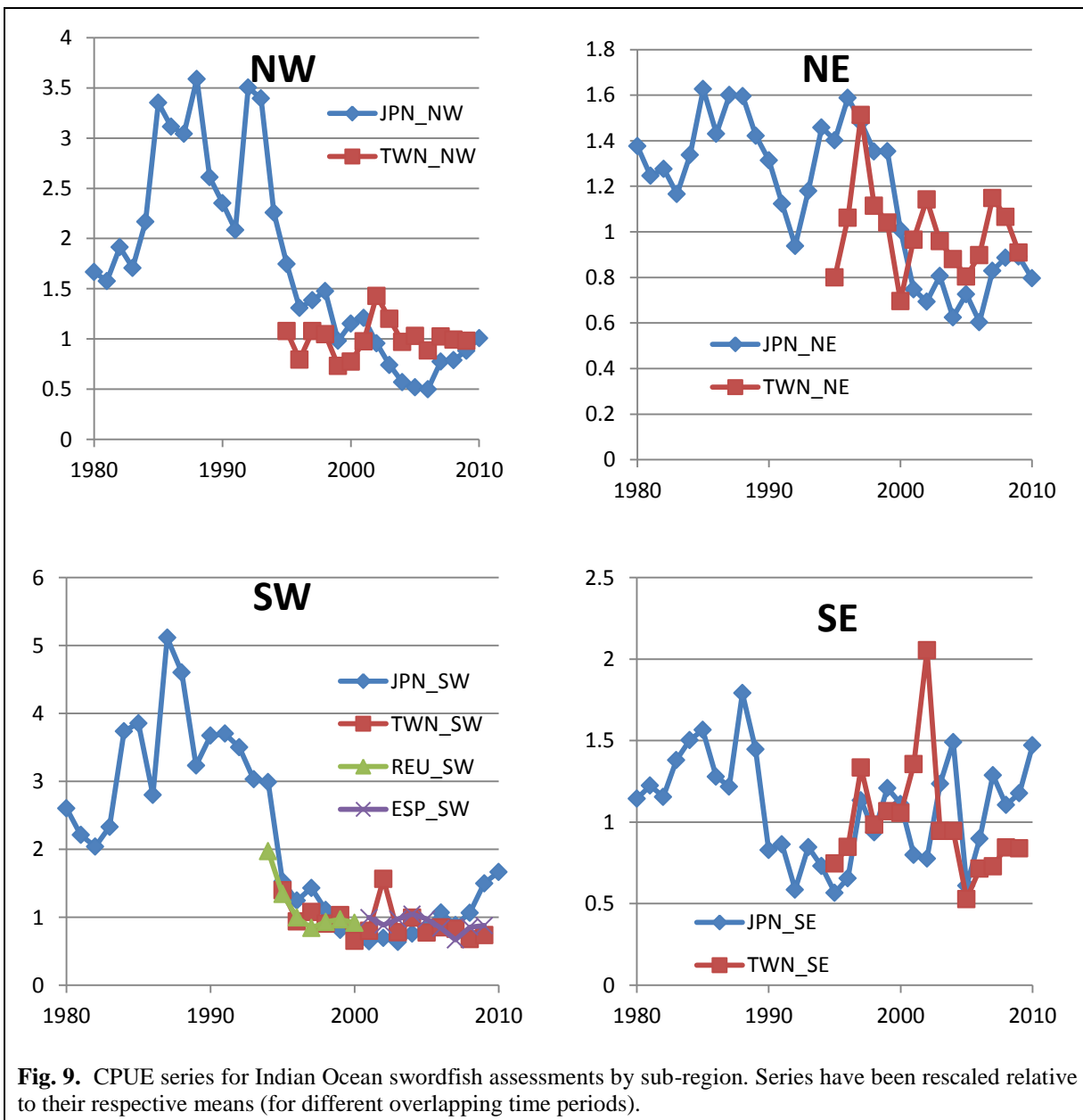


Fig. 9. CPUE series for Indian Ocean swordfish assessments by sub-region. Series have been rescaled relative to their respective means (for different overlapping time periods).

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.

- 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 (Fig. 10). It is considered encouraging that there are no clear signals of declines in the size-based indices, but these indices should be carefully monitored, as females mature at a relatively large size, therefore, a reduction in the biomass of large animals could potentially have a strong effect on the spawning biomass.
- Catch-at-Size(Age) data are available but the estimates are thought to have been compromised for some years and fisheries due to:
 - the uncertainty in the catches of swordfish for the drifting gillnet fisheries of Iran and the fresh-tuna 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, NEI).
 - the paucity of biological data available, notably sex-ratio and sex-length-age keys.

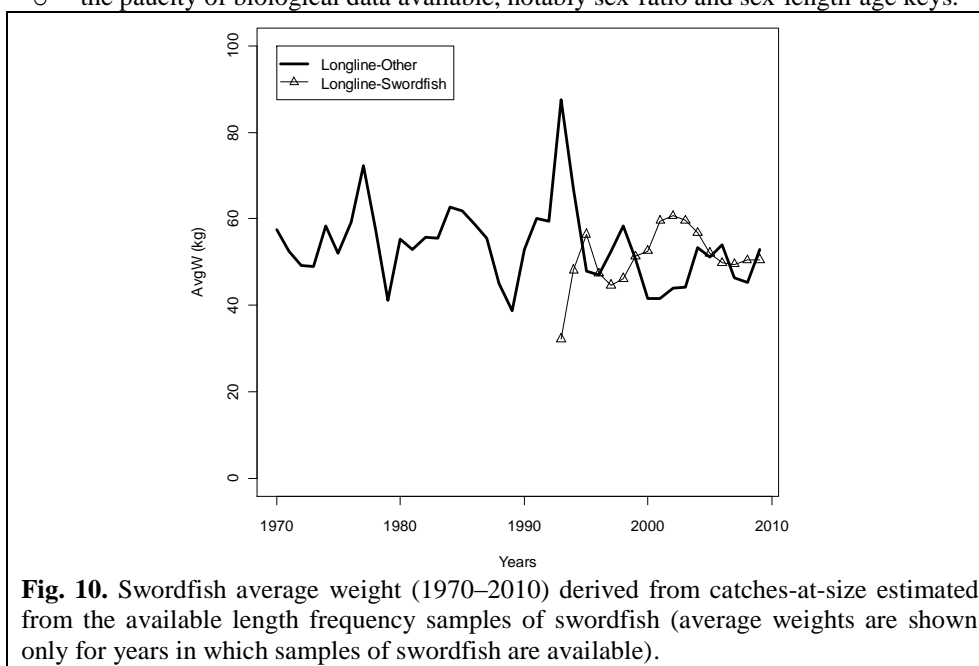


Fig. 10. Swordfish average weight (1970–2010) derived from catches-at-size estimated from the available length frequency samples of swordfish (average weights are shown only for years in which samples of swordfish are available).

STOCK ASSESSMENT

The stock structure of the Indian Ocean swordfish resource is under investigation, but currently uncertain. The southwest region was identified as a management unit of particular concern, because it seems to be more depleted than other regions in the Indian Ocean, and may have limited mixing with other regions.

A range of quantitative modelling methods were applied to the swordfish assessment in 2011, ranging from the highly aggregated ASPIC surplus production model to the age-, sex- and spatially-structured SS3 analysis. The different assessments were presented to the WPB in documents IOTC–2011–WPB09–17, 18, 19 and 20.

There is value in comparing different modelling approaches. 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 swordfish stock status was determined by qualitatively integrating the results of the various stock assessments undertaken in 2011 (Tables 1 and 8).

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

- There was more confidence in the abundance indices this year due to the additional CPUE analyses from Japan and Taiwan, China, and the addition of the EU, Spain series. This has led to improved confidence in the overall assessments and the southwest in particular.
- The southwest region should continue to be analysed as a special resource, as it appears to be highly depleted compared to the Indian Ocean as a whole. However the difference in depletion does not appear to be as extreme as analyses in previous years have suggested. A review of the spatial assumptions should be conducted following the final results of the IOSSS project.
- Further analysis is required on the appropriate way to use the size composition data in the integrated models. In particular, consideration of the large discrepancies between size composition data and mean weight data for Japanese and Taiwan, China fleets is needed.
- There is large uncertainty in swordfish growth rate estimates, and this has important implications for the integrated assessments. Most of these differences seem to be attributable to the interpretation of fin spine annulus counts, which have not been directly validated. Further information might be sought from growth increment data from the Atlantic tagging programs.
- It was recognised that the effects of depredation (at least from the southwest), and discarding should be examined in future analyses.
- 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. It was suggested that truncating the catch and CPUE time series would allow more options to be explored. However, some participants of the WPB suggested that it would be more appropriate to consider the model rather than discarding potentially informative data (e.g. the generation time of swordfish is such that a relatively long time series is required to make inferences about productivity).

TABLE 8. Key management quantities from the Stock Synthesis 3 assessments, for the aggregate and southwest Indian Ocean. Values represent the 50th (5th–95th) percentiles of the (plausibility-weighted) distribution of maximum posterior density estimates from the full range of the models examined.

Management Quantity	Aggregate Indian Ocean	Southwest Indian Ocean
2009 catch estimate (1000 t)	21.5	6.6 [6.7]
Mean catch from 2005–2009 (1000 t)	26.4 [26.3]	7.8 [7.7]
MSY (1000 t)	31 (20–55)	9.4 (6.5–13.5)
Data period used in assessment	1951–2009	1951–2009
F_{2009}/F_{MSY}	0.50 (0.23–1.08)	0.64 (0.27–1.27)
B_{2009}/B_{MSY}	–	–
SB_{2009}/SB_{MSY}	1.59 (0.94–3.77)	1.44 (0.61–3.71)
B_{2009}/B_0	–	–
SB_{2009}/SB_0	0.35 (0.22–0.42)	0.29 (0.15–0.43)
$B_{2009}/B_{0, F=0}$	–	–
$SB_{2009}/SB_{0, F=0}$	–	–

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- Kolody D, 2009. *An exploratory 'stock synthesis' assessment of the Indian Ocean swordfish fishery 1950–2007*, Seychelles, 6–10 July 2009, IOTC-2009-WPB-10.
- Poisson F and 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 Resources*, vol. 22, pp. 45–58.