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

Report of the Eighth Session of the IOTC

Working Party on Billfish

Seychelles 12 – 16 July 2010

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1. Opening of the Meeting and Adoption of the Agenda

1. The Eighth Meeting of the Working Party on Billfish (WPB) was opened on 12 July 2010 in Victoria, Seychelles. The chair, Mr. Jan Robinson, subsequently welcomed the participants (Appendix I) and the Agenda for the meeting was adopted as presented in Appendix II.

2. The WPB reiterated its concerns regarding the low level of participation of scientists to the WPB, in particular scientists from coastal countries in the IOTC Region. The WPB recalled that the Commission has agreed to the use of IOTC funds to invite scientists from the region to IOTC Technical Meetings. Having important fisheries for billfish, the WPB recommended that the Secretariat contact the following countries to ensure that at least one scientist from each country is invited to the next meeting of the WPB: Sri Lanka, Iran, Pakistan, India and Indonesia. In addition, the WPB noted that both Spain and Portugal have important fisheries for swordfish in the Indian Ocean and reiterated its concern that, in spite of the WPB efforts, no scientists from these countries have participated in meetings in recent years.

3. The WPB welcomed the participation of an invited expert (Dr. Steve Martell) from the UBC Fisheries Centre, Canada, an invitation aimed at providing critical review of the assessment process following recommendations made at the Kobe 2 meeting in Barcelona, Spain in June 2010 for greater peer-review and collaboration among RFMOs. Invitations were organised by the Chair and Secretariat but it was agreed that, in future, scientists from other member states will be involved in the selection process for invited experts.

4. The list of documents presented to the meeting is given in Appendix III.

2. Review of Statistical Data for Billfish

5. The Secretariat presented the data available for billfish in the document IOTC-2010-WPB-07.

2.1. Catch trends - nominal catch (NC) data

Swordfish

6. Swordfish is caught mainly using drifting longlines (95%) and gillnets (5%) (Figure 1). Swordfish was mainly a bycatch of industrial longline fisheries before the early 1990's. Catches increased gradually from 1950 to 1990 as the catches of targeted species (such as tropical and temperate tunas) increased. Catches increased markedly after 1990 to peaks of around 35,000 tonnes in 1998 and 36,000 tonnes in 2003 and 2004. The current catch of swordfish is around 25,000 tonnes. The increase in catch since the early 1990's is attributed to a change in target species from tunas to swordfish by part of the Taiwanese fleet, the development of longline fisheries in Australia, La Reunion, Seychelles and Mauritius targeting swordfish, and the arrival of longline fleets from the Atlantic Ocean (Portugal, Spain and other fleets operating under various flags) also targeting swordfish (Figure 2).

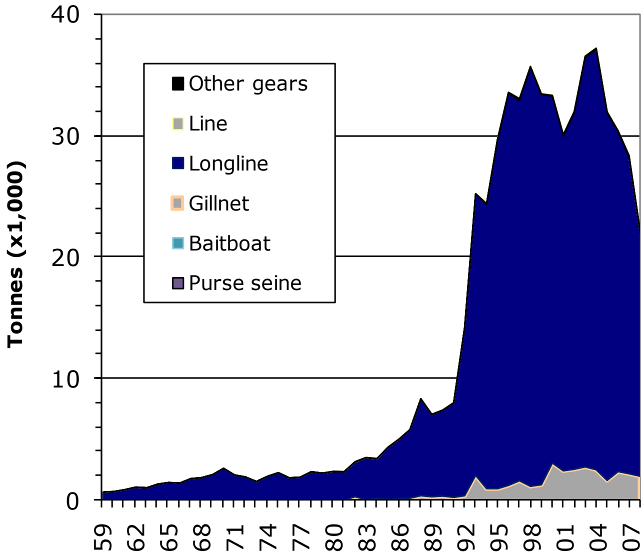


Figure 1. *Catches of swordfish in the Indian Ocean by gear type (1959-2008). From document IOTC-2010-WPB-07*

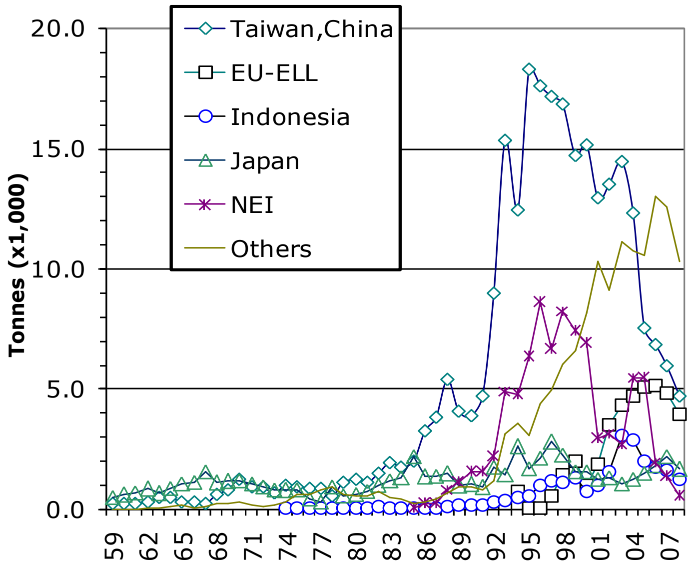
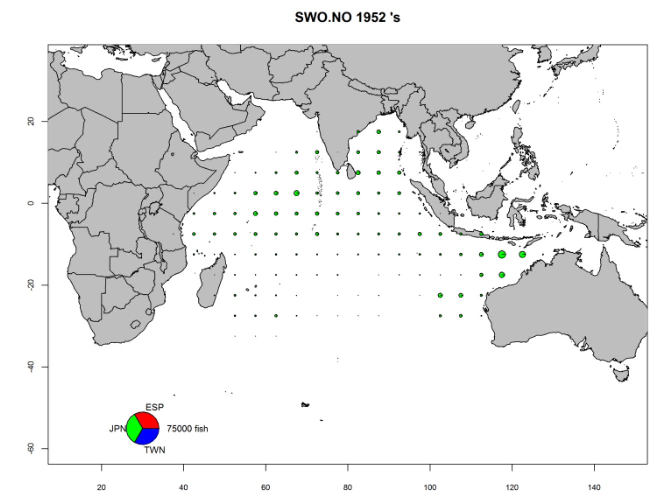
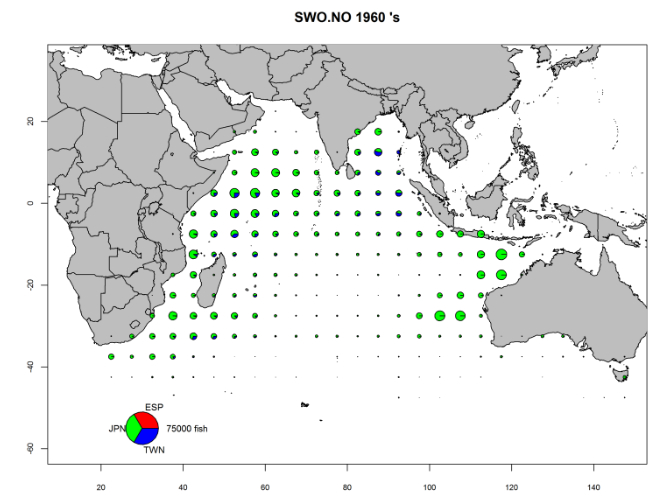
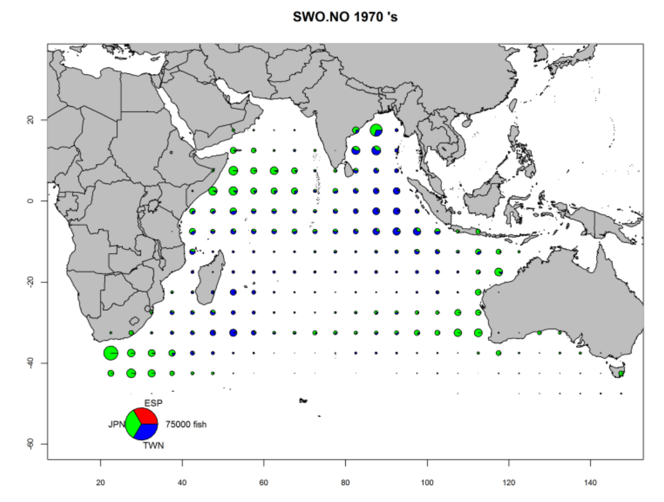
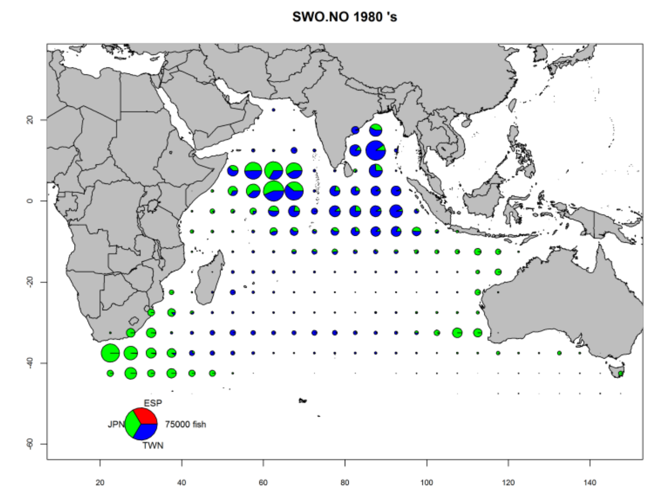


Figure 2. *Catches of Swordfish by fleet recorded in the IOTC Database (1959-2008). From document IOTC-2010-WPB-07*









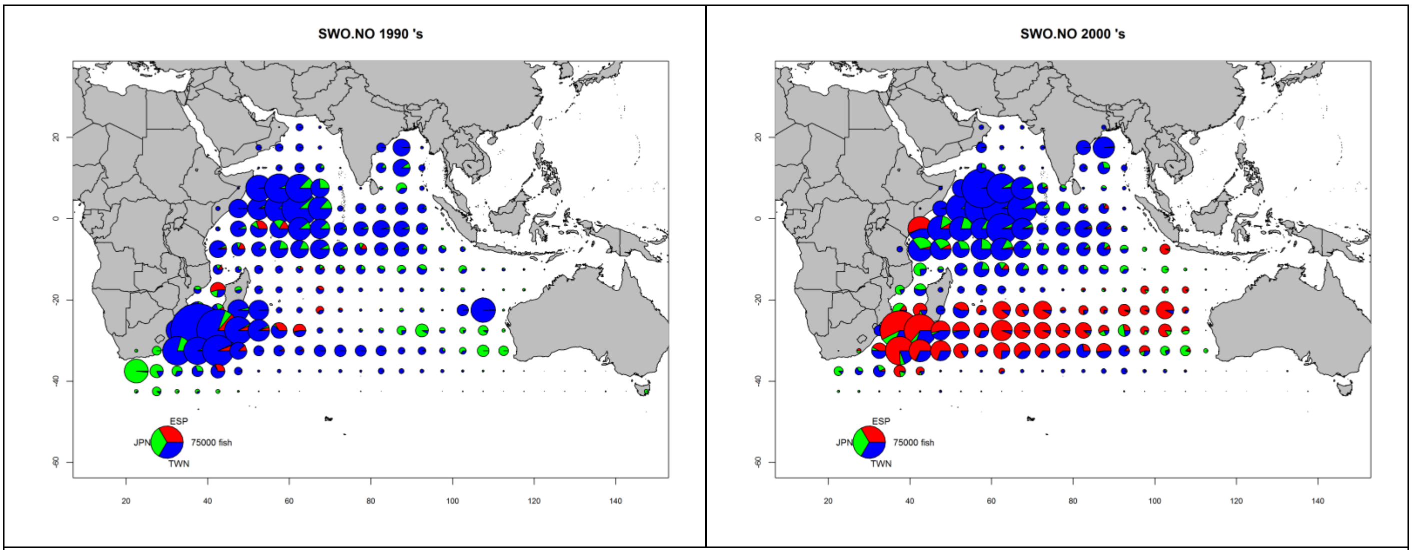


Figure 3. *Total annual catches of swordfish (number) by Taiwanese, Japanese and Spanish longline vessels operating in the Indian Ocean for the last 6 decades. From document IOTC-2010-WPB-15.*

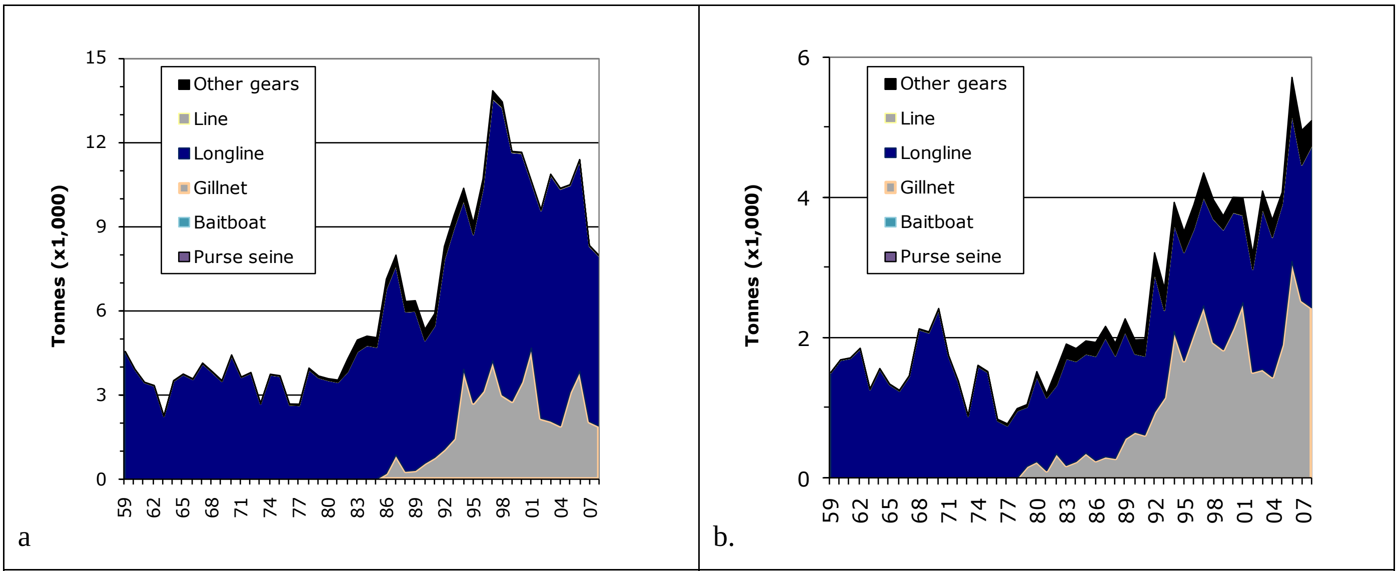
MARLINS

7. Blue, black and striped marlins are caught mainly using drifting longlines (70%) and gillnets (20%) and some troll and hand lines. These species are considered as bycatch for industrial and artisanal fisheries, but they are targeted by sport fisheries. Minimum catch estimates for the three marlin species have been derived from very small amounts of information and are therefore highly uncertain. The total catch of all marlin species varies from year to year. It reached a maximum of around 23,000 tonnes in 1997 while current catches are around 16,000 tonnes to 20,000 tonnes.

8. Catches of blue marlin are usually greater than those of black and striped marlin combined. The minimum average annual catch estimated for blue marlin for the period 2004 to 2008 is around 10,000 tonnes (Figure 4). In recent years, the fleets of Taiwan,China (longline), Japan, several NEI fleets (longline) and Sri Lanka (gillnet) are attributed with the highest catches of this species. The distribution of blue marlin catches has changed since the 1980's, with catches in the western Indian Ocean increasing and an increase in the catch by the Taiwanese fleets (Figure 5).

9. The minimum average annual catch of black marlin estimated for the period 2004 to 2008 is around 4,500 tonnes (Figure 4). The fleets of Taiwan,China, China (longline), Japan, (longline), Sri Lanka (gillnet) and Indonesia (longline and gillnet) are attributed with the highest catches of black marlin. The distribution of black marlin catches has changed since the 1980s with most of the catch now taken in the western areas of the Indian Ocean. Since the 1990s most of the longline catch has been taken by the Taiwanese fleets (Figure 6).

10. The minimum average annual catch estimated for striped marlin for the period 2004 to 2008 is around 3,000 tonnes (Figure 4). In recent years, the fleets of Taiwan,China (longline) and to a lesser extent several NEI fleets (longline) are attributed with the highest catches of this species. The distribution of striped marlin catches has changed since the 1980's with most of the longline catch now taken in the western areas of the Indian Ocean. As with the other marlin species, since the 1990's most of the longline catch has been taken by the Taiwanese fleets (Figure 7).



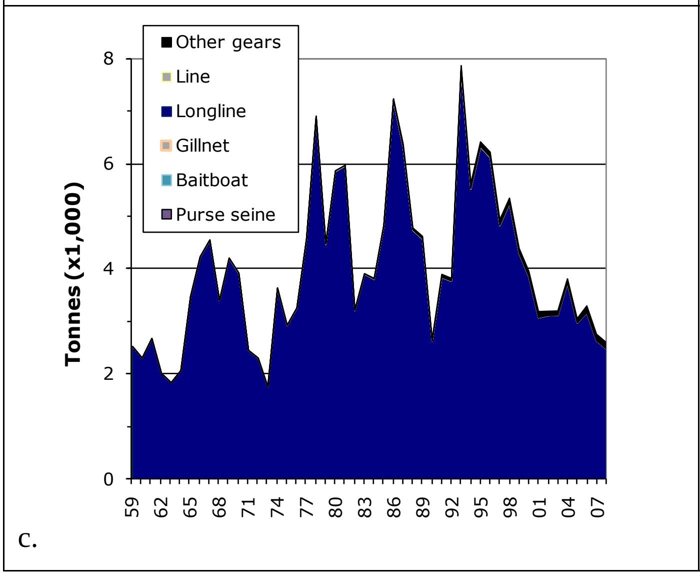
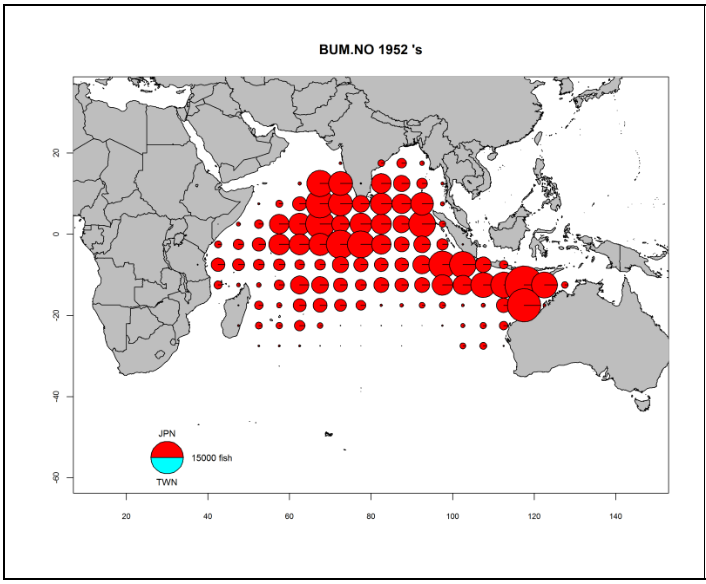
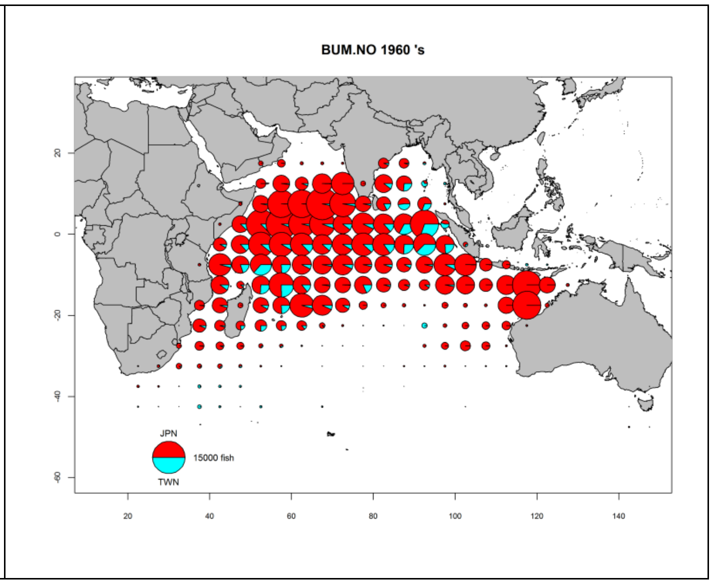


***Figure 4**. Estimated catches of marlins (a. blue marlin, b. black marlin, c. striped marlin) by gear recorded in the IOTC Database (1959-2008). From document IOTC-2010-WPB-07.*





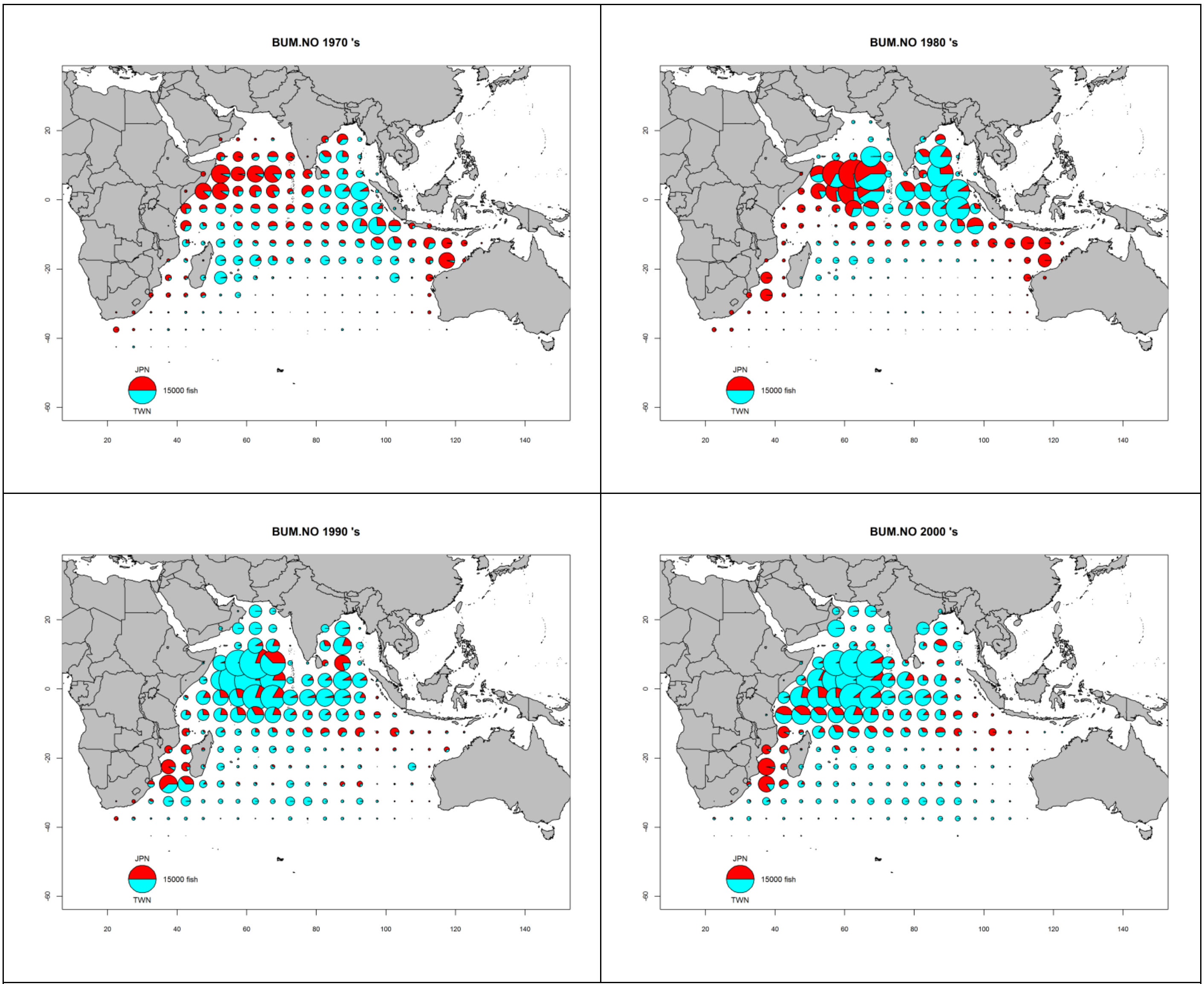
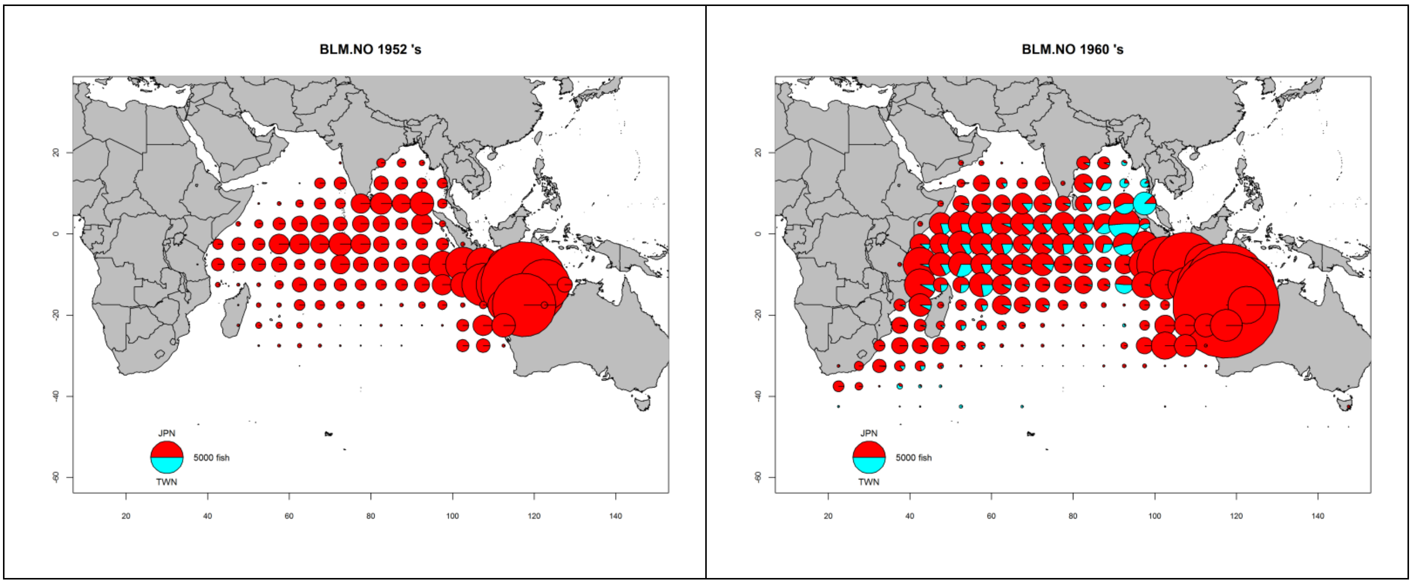


***Figure 5**. Total catches of blue marlin (number) by longline vessels operating in the Indian Ocean per decade over the period 1952 to 2008. From document IOTC-2010-WPB-15.*



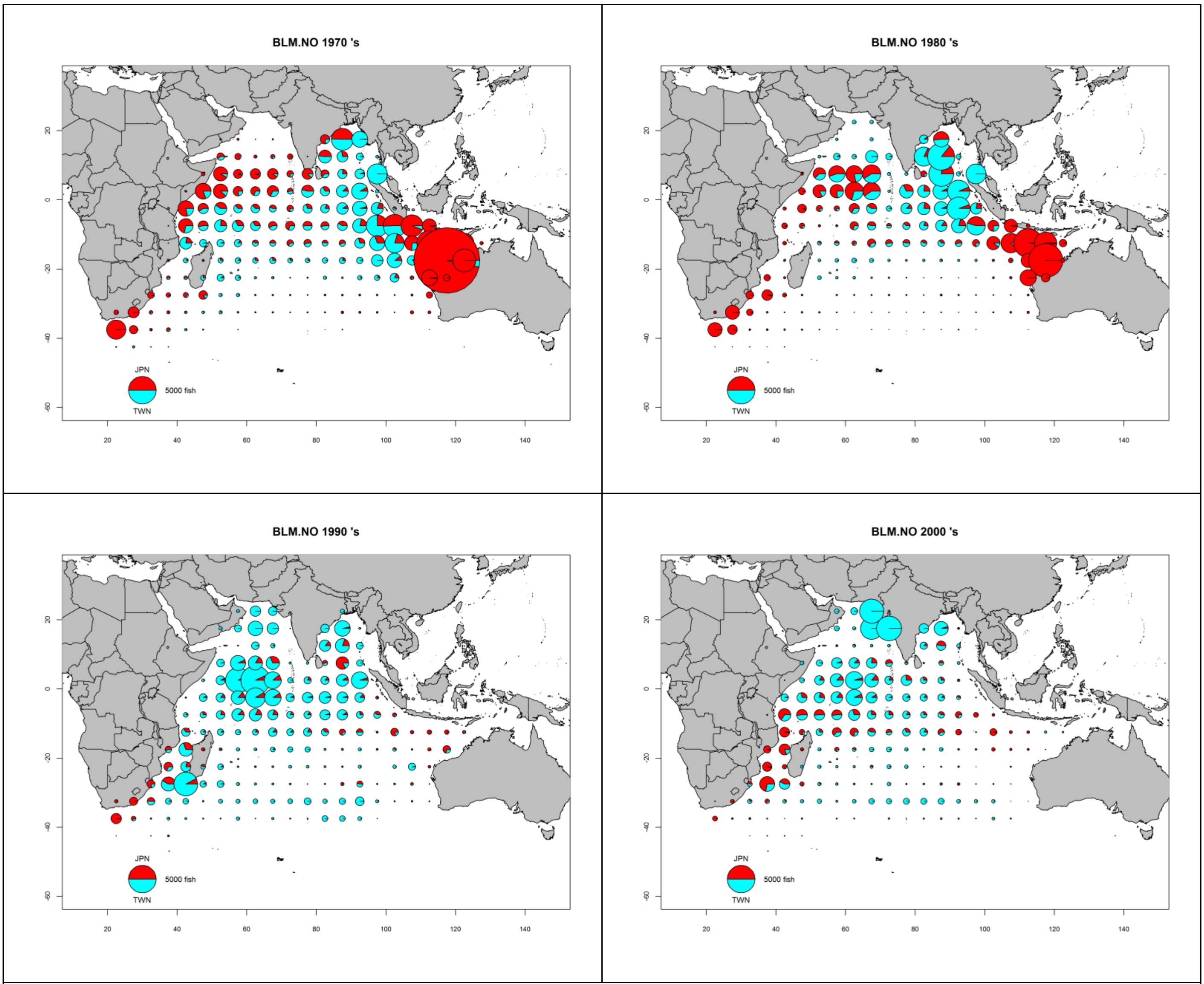
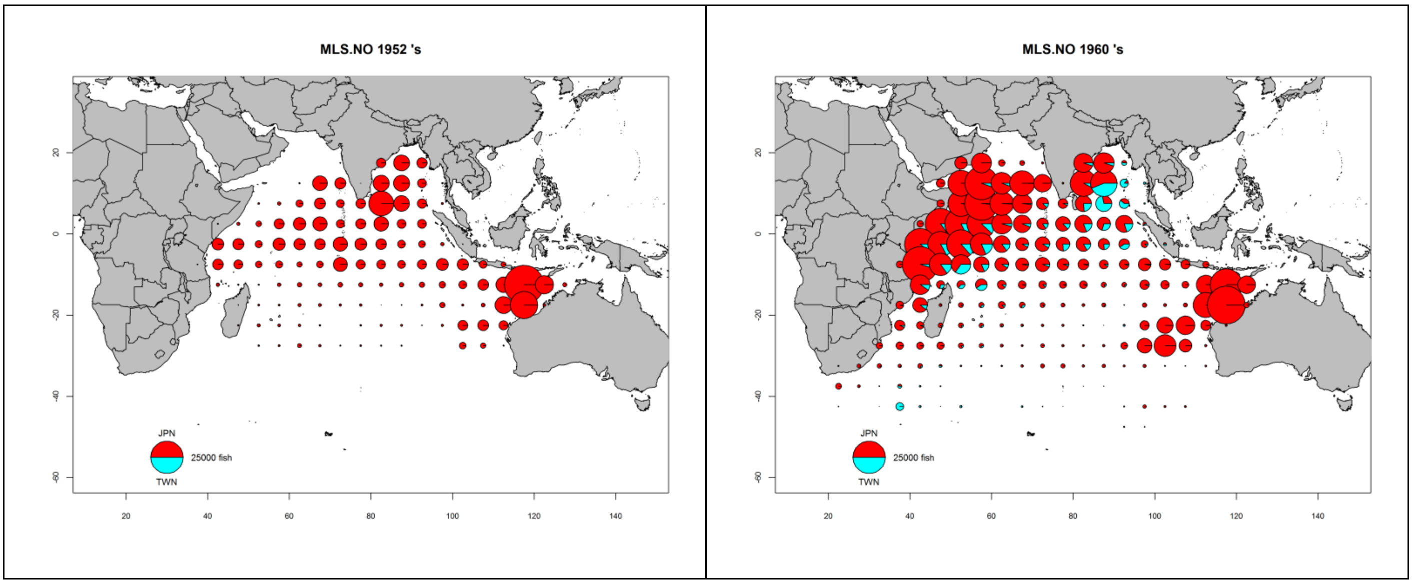


***Figure 6**. Total catches of black marlin (number) by longline vessels operating in the Indian Ocean per decade over the period 1952 to 2008. From document IOTC-2010-WPB-15.*



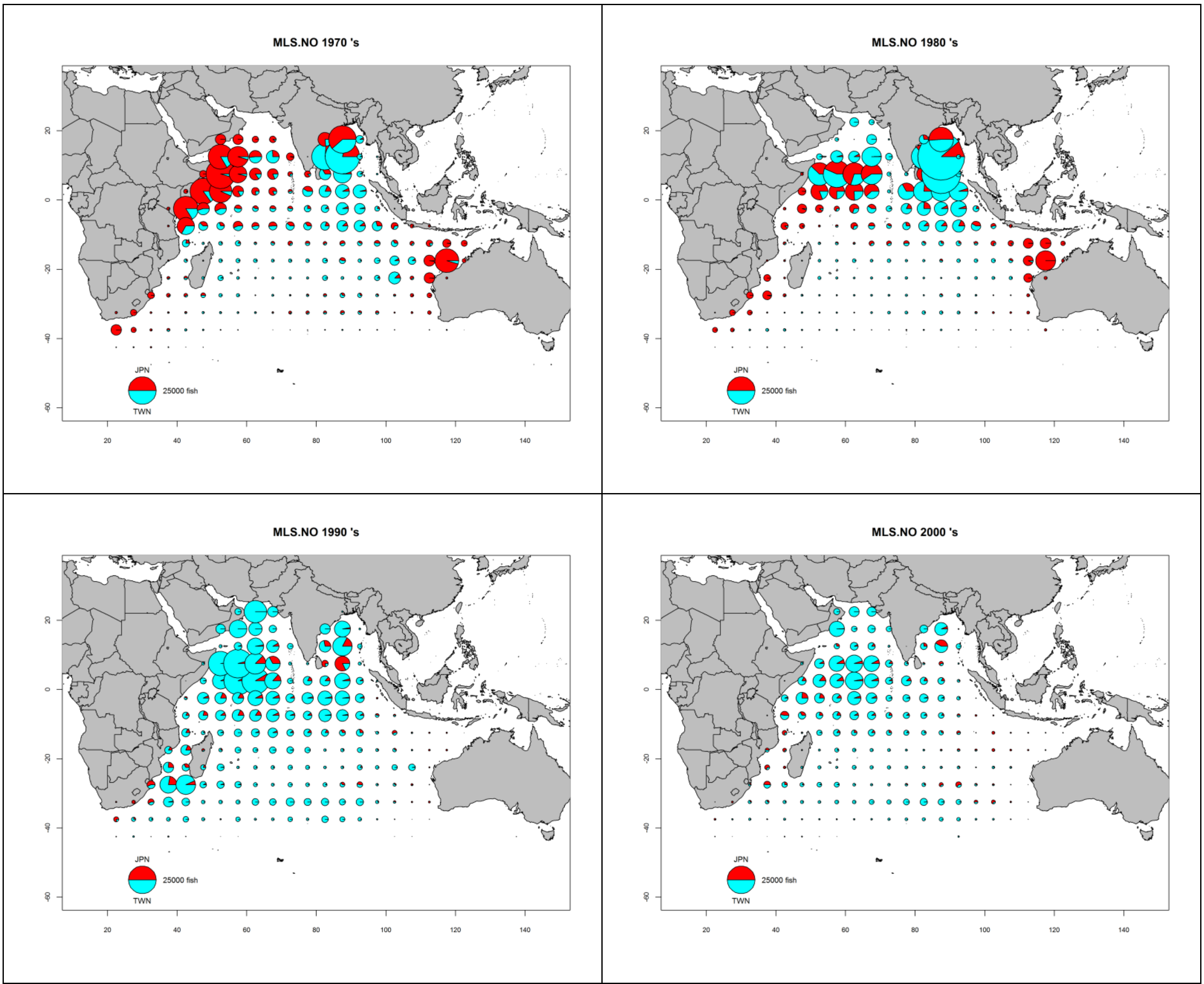


Figure 7*. Total catches of striped marlin (number) by longline vessels operating in the Indian Ocean per decade over the period 1952 to 2008. From document IOTC-2010-WPB-15.*

INDO-PACIFIC SAILFISH

11. Sailfish is caught mainly by gillnets (89%) and to a lesser extent troll and hand lines (5%), longlines (5%) and other gears (Figure 8). The catches of sailfish have greatly increased since the mid-1980s in response to the development of the gillnet / longline fishery of Sri Lanka. Minimum catch estimates have been derived from very small amounts of information and are therefore highly uncertain. The minimum average annual catch estimated for the period 2004 to 2008 is around 25,000 tonnes. In recent years, the countries attributed with the highest catches of Indo-Pacific sailfish are situated in the Arabian Sea and are Iran, Sri Lanka, India and Pakistan. Smaller catches are reported for line fishers in Comoros and Mauritius and by Indonesia longliners (Figure 8). Reports of sailfish catches from the longline fleet are recent and occur only for the Japanese fleet.

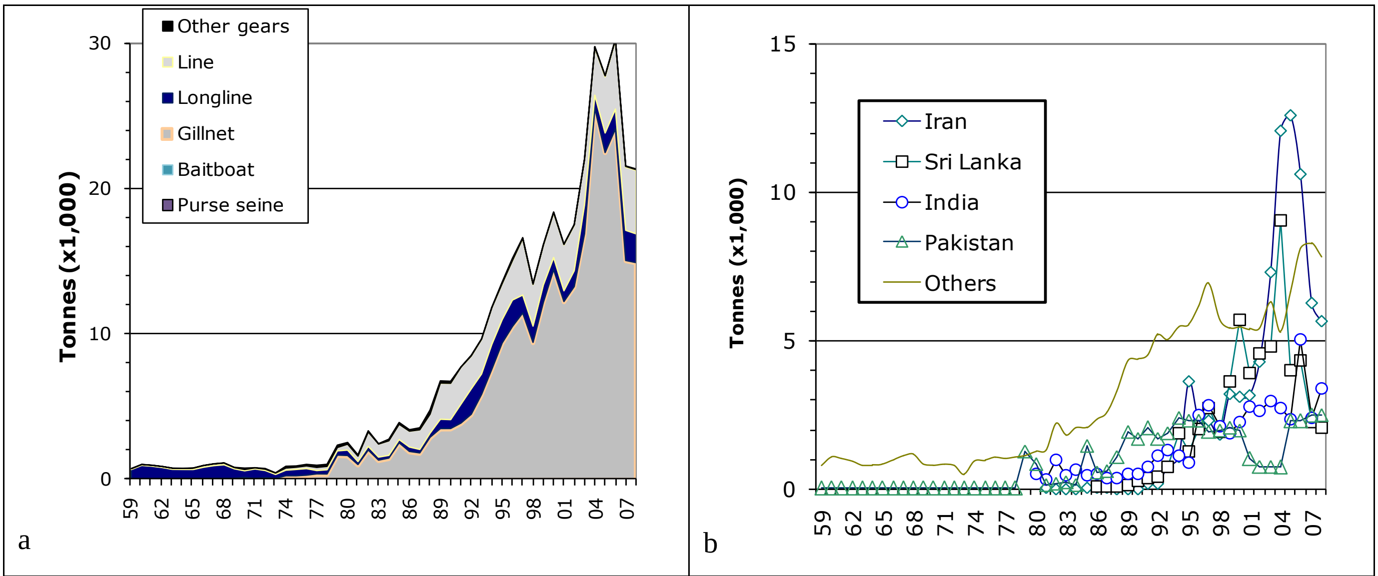


Figure 8*. Estimated catches of sailfish by (a) gear and (b) fleet recorded in the IOTC Database (1959-2008). From document IOTC-2010-WPB-07.*

2.2. The current status of data for billfish

SWORDFISH

Retained catches of the major fleets are considered to be reasonably accurate; however, uncertainties in the overall catch arise (Figure 9, Type B catch) due to:

- **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.
- **Longline** fishery of **India**: India has reported very incomplete catches and catch-and-effort data for its longline fishery.
- **Longline** fleets from **non-reporting** countries (NEI): The Secretariat has to estimate catches of swordfish for a fleet of longliners targeting tunas or swordfish and operating under flags of various non-reporting countries.

The Secretariat provided alternative catch estimates of swordfish for the fisheries of Iran (1991-2008) and Indonesia (2004-08), which represent increases in the catches of swordfish of up to 2,000t, depending on the year.

Changes to the catch series: There have not been significant changes in the catches of swordfish since the WPB in 2009.

Discard levels are believed to be low although they are unknown for most industrial fisheries.

CPUE Series: 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**[1], Non-reporting longliners (**NEI**)). In addition, catch-and-effort data are not available for the drifting gillnet fisheries of **Iran** and **Pakistan**.

Trends in average 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 size of samples and time-area coverage of longliners from **Japan**).

Catch-at-Size(Age) table: CAS are available but the estimates less certain (Figure 9) for some years and fisheries due to:

- uncertainty in the catches of swordfish for the drifting gillnet fisheries of **Iran** and the fresh-tuna longline fishery of **Indonesia**
- a lack of size data before the early-70s and from most artisanal fisheries (**Pakistan**, **India**, **Indonesia**)
- a paucity of size data available from industrial longliners since the early-1990s (**Japan**, **Philippines**, **India** and **China**)
- a lack of time-area catches for some industrial fleets (**Indonesia**, **India**, **NEI**)
- a paucity of biological data available, notably sex-ratio and sex-length-age keys

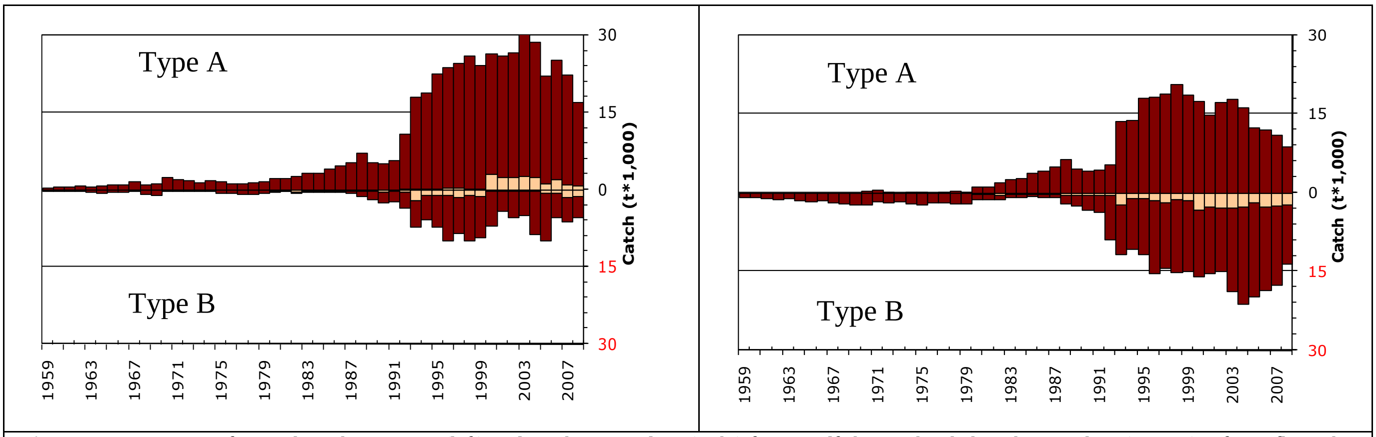


Figure 9*. Uncertainty of annual catch estimates (left) and catch at size data (right) for swordfish. Catches below the zero-line (Type B) refer to fleets that do not report catch/length data to the IOTC (estimated by the IOTC Secretariat), do not report catch/length data by gear and/or species (broken into gear and species by the IOTC Secretariat) or any of the other reasons given in document IOTC-2010-WPB-07. Catches over the zero-line (Type A) refer to fleets for which no major inconsistencies have been found to exist. Data as of June 2010 Light bars represent data for artisanal fleets and dark bars represent data for industrial fleets. From document IOTC-2010-WPB-07.*

BLUE MARLIN

Retained catches are poorly known for many fisheries (Figure 10) due to:

- catches by species not being available for many artisanal (gillnet/longline fishery of **Sri Lanka** and artisanal fisheries of **India**, **Iran** and **Pakistan**) and some industrial (longliners of **Indonesia** and **Philippines**) fisheries.
- uncertain catches for non-reporting industrial longliners (**India**, **NEI**).
- catches being incomplete for most industrial fisheries in which blue marlin is seldom the target species. No catches are available for industrial purse seiners although they are known to occur.
- conflicting catch reports: The catches of **South Korean** longliners reported as nominal catches and catches and effort are conflicting, with higher catches recorded in the CE table.
- a lack of catch data for major sport fisheries (*eg.* Mauritius, Madagascar, Reunion, Seychelles).

Changes to the catch series: There have not been significant changes to the catches of blue marlin since the WPB in 2009.

Discard levels are unknown for most industrial fisheries, mainly longliners.

[1] Catch-and-effort statistics for the fresh-tuna longline fishery of Taiwan,China are available since 2007, although logbook coverage levels are still low (≈20%).

CPUE Series: Catch and effort data are available from some industrial longline fisheries although the catch data are possibly incomplete (the catches of species other than the target species are not always recorded in the logbooks). Catch and effort are unavailable for sport fisheries, besides the sport fisheries of Kenya and South Africa, or are unavailable for other artisanal (gillnets of **Iran** and **Pakistan**, gillnet/longlines of **Sri Lanka**) or industrial fisheries (**NEI** longliners, **Taiwanese** fresh-tuna longliners and all purse seiners).

Trends in average weight can only be assessed for the longline fishery of Japan since 1970 and Taiwan,China since 1980. The number of specimens measured in recent years is, however, very low.

Catch-at-Size(Age) table: The Secretariat has not built CAS or CAA tables for blue marlin. The paucity of size data available for this species makes it difficult to estimate CAS.

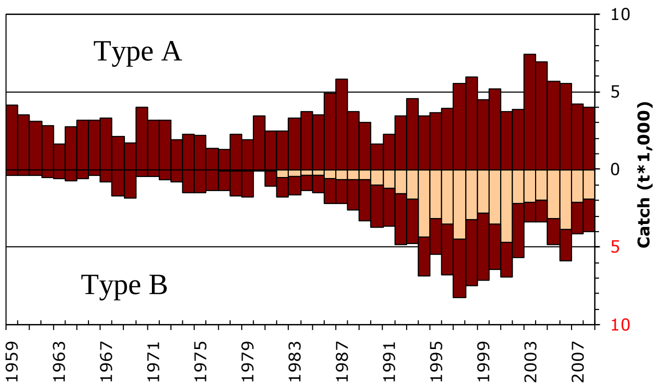


Figure 10. *Uncertainty of annual catch estimates for blue marlin. Catches below the zero-line (Type B) refer to fleets that do not report catch data to the IOTC (estimated by the IOTC Secretariat), do not report catch data by gear and/or species (broken into gear and species by the IOTC Secretariat) or any of the other reasons given in document IOTC-2010-WPB-07. 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. Data as of June 2010. From document IOTC-2010-WPB-07.*

BLACK MARLIN

Retained catches are poorly known for many fisheries (Figure 11) due to:

- catches per species not being available for many artisanal (gillnet/longline fishery of Sri Lanka and artisanal fisheries of India, Iran and Pakistan) and some industrial fisheries (longliners of Indonesia and Philippines).
- uncertain catches for non-reporting industrial longliners (India, NEI) and the gillnet fishery of Indonesia.
- catches being incomplete for most industrial fisheries for which the black marlin is seldom the target species.
- conflicting catch reports: The catches for South Korean longliners reported as nominal catches and catches and effort are conflicting, with higher catches recorded in the CE table.
- a lack of catch data for major sport fisheries (*eg.* Mauritius, Madagascar, Reunion, Seychelles).

Changes to the catch series: In 2010 India reported more detailed catches of billfish to the IOTC, including catches of marlins by species, showing a large proportion of black marlin in the catches. The IOTC Secretariat used the species composition reported to revise the estimates of catches by species and gear for India, which had not reported catches of marlins by species in the past. The revised estimates showed an increase in the catches of black marlin over the time series, especially between 1978 and 2004.

Discard levels are unknown for most industrial fisheries, mainly longliners.

CPUE Series: Catch and effort data are available for some industrial longline fisheries although the catch data may be incomplete (the catches of species other than the target species are not always recorded in the logbooks). Catch and effort are unavailable from sport fisheries, besides the sport fisheries of Kenya and South Africa, or are unavailable for other artisanal (gillnet fisheries of **Iran** and **Pakistan**, gillnet/longlines of **Sri Lanka**, gillnets of **Indonesia**) or industrial fisheries (NEI longliners and all purse seiners).

Trends in average weight can only be assessed for the longline fishery of Japan since 1970 and for Taiwan,China since 1980. The amount of specimens measured on Japanese longliners in recent years is, however, very low.

Catch-at-Size (Age) table: The Secretariat has not built CAS or CAA tables for black marlin. The paucity of size data available for this species makes it difficult to estimate CAS.

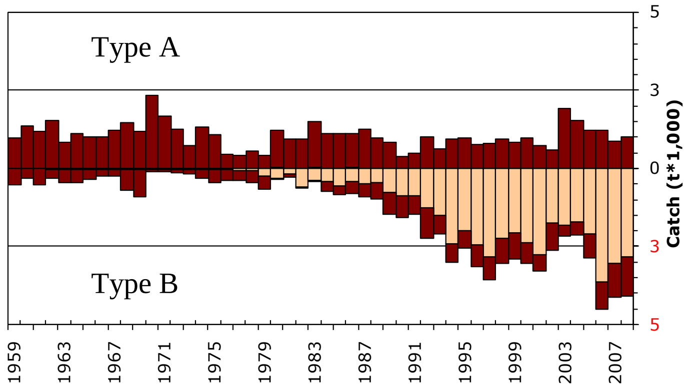


Figure 11. *Uncertainty of annual catch estimates for black marlin. Catches below the zero-line (Type B) refer to fleets that do not report catch data to the IOTC (estimated by the IOTC Secretariat), do not report catch data by gear and/or species (broken into gear and species by the IOTC Secretariat) or any of the other reasons given in document IOTC-2010-WPB-07. 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. Data as of June 2010. From document IOTC-2010-WPB-07*

STRIPED MARLIN

Retained catches are reasonably well known; however, overall catches are uncertain (Figure 12) due to:

- catches per species are not available for some industrial fisheries (longliners of Indonesia and Philippines).
- uncertain catches for non-reporting industrial longliners (India, NEI).
- catches are believed to be incomplete for many industrial fisheries as striped marlin is seldom a target species.
- conflicting catch reports: The catches for South Korean longliners reported as nominal catches and catches and effort are conflicting, with higher catches recorded in the CE table.

Changes to the catch series: There have not been significant changes to the catches of striped marlin since the WPB in 2009.

Discard levels are believed to be low although they are unknown for most industrial fisheries, mainly longliners.

CPUE Series: Catch and effort data are available for some industrial longline fisheries although the catch data are likely to be incomplete (the catches of species other than the target species are not always recorded in the logbooks). Catch and effort are unavailable for industrial fisheries (NEI longliners).

Trends in average weight can only be assessed for the longline fishery of Japan since 1970 and for Taiwan,China since 1980. The amount of specimens measured in Japanese longliners in recent years is, however, very low.

Catch-at-Size (Age) table: The Secretariat has not built CAS or CAA tables for striped marlin. The paucity of size data available for this species makes it difficult to estimate CAS.

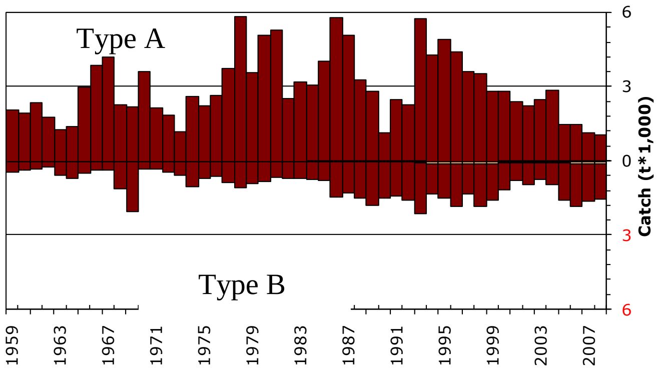


Figure 12. *Uncertainty of annual catch estimates for striped marlin. Catches below the zero-line (Type B) refer to fleets that do not report catch data to the IOTC (estimated by the IOTC Secretariat), do not report catch data by gear and/or species (broken into gear and species by the IOTC Secretariat) or any of the other reasons given in document IOTC-2010-WPB-07. 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. Data as of June 2010. From document IOTC-2010-WPB-07*

INDO-PACIFIC SAILFISH

Retained catches are poorly known for most fisheries (Figure 13) due to:

- catches per species not being available for many artisanal fisheries (mainly India and Indonesia).
- catches being very incomplete for most industrial fisheries for which this species is a bycatch and catches being incomplete for many artisanal fisheries (gillnets of Pakistan, pole and lines of Maldives) due to under-reporting.
- a lack of catch data for sport fisheries (*eg*. Mauritius, Madagascar, Reunion, Seychelles).

Changes to the catch series: There have not been significant changes to the catches of Indo-pacific sailfish since the WPB in 2009.

Discard levels are unknown for most industrial fisheries, mainly longliners (for which they are presumed to be moderate to high).

CPUE Series: Catch and effort data are available for some industrial longline fisheries but they are believed to be of poor quality (catches of sailfish are incomplete). Catch and effort are unavailable for sport fisheries besides the sport fisheries of Kenya and South Africa. The catch and effort that are available from artisanal fisheries are believed inaccurate (no data from Iran and Pakistan and poor quality effort data for the gillnet/longline fishery of Sri Lanka).

Trends in average weight can only be assessed for the longline fishery of Japan since 1970 and the gillnet/longline fishery of Sri Lanka since the late 1980s. The amount of specimens measured is, however, very low. Furthermore, the specimens discarded might not be accounted for by industrial fisheries, where they are presumed to be of smaller size (possible bias of existing samples).

Catch-at-Size(Age) table: The Secretariat has not built CAS or CAA tables for IP sailfish. The paucity of size data available for this species makes it difficult to estimate CAS.

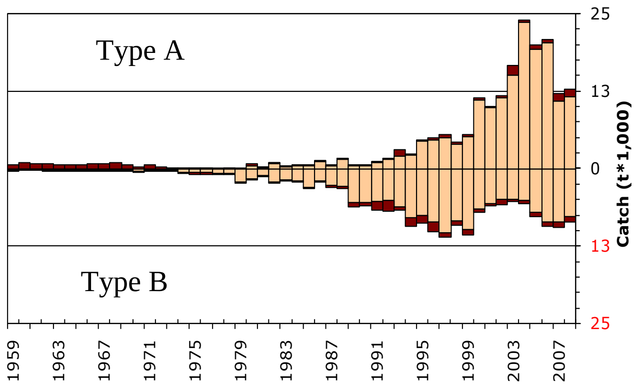


Figure 13. *Uncertainty of annual catch estimates for Indo-Pacific sailfish. Catches below the zero-line (Type B) refer to fleets that do not report catch data to the IOTC (estimated by the IOTC Secretariat), do not report catch data by gear and/or species (broken into gear and species by the IOTC Secretariat) or any of the other reasons given in document IOTC-2010-WPB-07. 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. Data as of June 2010. From document IOTC-2010-WPB-07*

WPB DISCUSSION ON DATA ISSUES

12. The WPB reiterated the need for countries having driftnet fleets to report catches of swordfish, marlins and sailfish by species to the IOTC. The WPB noted that, to date, Iran has not reported catches of billfish for its drifting gillnet fishery and Pakistan has not reported catches by species. In this regard, the IOTC Secretariat informed the WPB that it has initiated talks with the Ministry of Fisheries of Iran and a visit of IOTC staff to Iran will possibly be scheduled soon.

13. The WPB agreed on the need for further work in the preparation of minimum requirements for the collection of operational (logbook) data from gillnet fisheries. The WPB recommended that the Chair of the WPB works intersessionally with the IOTC Secretariat in the preparation of a template logbook form for gillnet fisheries, to be presented to the next session of the IOTC Scientific Committee.

14. The WPB reiterated the mandatory requirement for members to report size samples at the 5x5 degree level as per the requirements of the Commission (Resolution 10/02). Due to the paucity of information, data have historically been pooled at the 10x20 degree level, which overlaps assessment sub-areas. This situation creates a problem as size data has to be assigned subjectively to assessment sub-areas.

15. The WPB noted the paucity of information from sport fisheries in the Indian Ocean, noting that data are only held by the Secretariat for the sport fisheries of Kenya and South Africa. The WPB stressed the need for other countries having sport fisheries to collect and report this information to the Secretariat, in particular Australia, Madagascar, Maldives, Mauritius, Mozambique, Oman, La Réunion, Seychelles, Tanzania, Thailand and UAE. The WPB agreed that standardised CPUE series derived from data collected for sport fisheries may significantly improve the assessments of marlins and, especially, Indo-Pacific sailfish.

16. In this regard, Mr. Henry Riggs-Miller, a representative from The Billfish Foundation (TBF) informed the WPB that it is keen to work with the WPB to assist sport clubs in the region to provide the data required by IOTC. The WPB thanked the representative of TBF for its generous offer, agreeing to work jointly with TBF in the preparation of template forms for the collection of data from sport fisheries and of a project proposal to assist sport fishing clubs in the region in the collection and reporting of this information to the Secretariat.

17. The WPB reiterated its request for countries having important fisheries for billfish to improve data collection and reporting in the following areas:

- Species breakdown: the WPB noted that the identification of marlins and sailfish remains an issue, urging countries to take the necessary measures to ensure that billfish catches are reported by species.
- Bycatch and discards: the WPB noted that levels of reporting for bycatch and discards remain low, urging countries to incorporate estimates of bycatch and discards of billfish in their routine data reports, preferably derived from observer data.
- Length frequency data by sex: the WPB noted that the amount of length frequency data available for billfish species remains low, in spite of the recommendations in place. The WPB stressed the need for

countries having important catches of billfish to collect and report length frequency data, by species and by sex as soon as possible.

- Biological parameters: the WPB noted the paucity of length-weight and other conversion factors for billfish species, in particular for marlin species, stressing the need for more information to be collected on these species.

2.3. Preparation of the data for the stock assessments of swordfish: main issues

18. The Secretariat presented document IOTC-2010-WPB-06, which describes the methods used by the IOTC Secretariat to prepare catch tables, length-frequency samples and catch-at-size and catch-at-age tables for swordfish stock assessments. For this data preparation, estimates of total catch and the available catch-and-effort, size frequency data and other biological data were extracted from the IOTC database, covering the period 1950-2008.

19. Using information from the IOTC database, the IOTC Secretariat estimated total catches of swordfish, for the period 1950-2008, in number and weight and by year, quarter, and assessment area and fishery. Catch-and-effort and size frequency data by time-area strata were also estimated. In addition, the Secretariat prepared length-frequency samples from the size frequency data available in the IOTC databases (figure 14). The sampling unit is the proportion of space-time strata per units of 10° of latitude and 20° of longitude, quarterly time units by fleet. The Secretariat also estimated catch-at-size (figure 15) and catch-at-age tables for swordfish, again by using information available in the IOTC databases. Data preparation was affected by the lack of information for some fleets, periods and years, and, in particular, by the lack of catch and size data for most artisanal fleets and some industrial fleets.

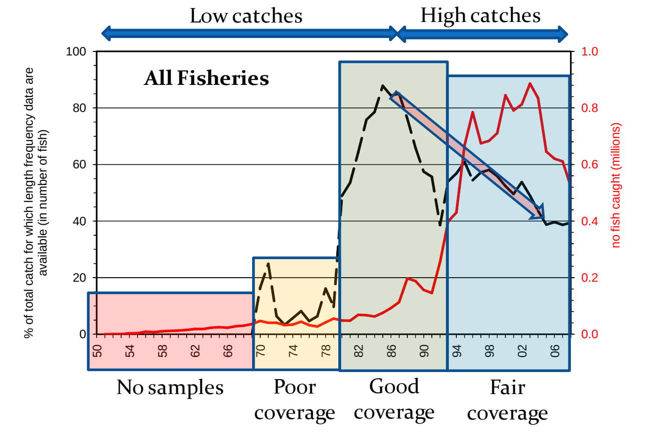


Figure 14. *Total numbers of swordfish (SWO) estimated (continuous line) and proportion (in number of fish) estimated (broken line) for strata having length frequency data (all gears combined), by year (1950-2008).*

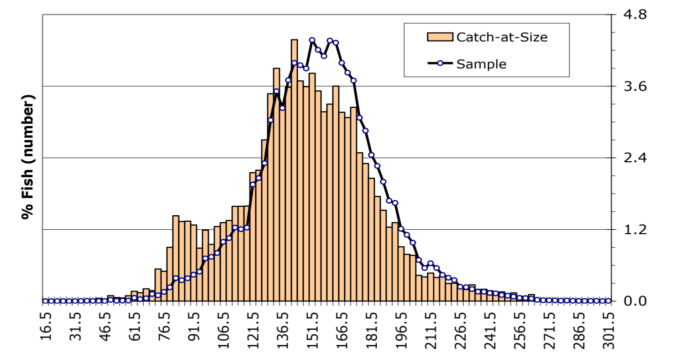


Figure 15. *Proportion that the numbers of swordfish sampled (blue line)/estimated (CAS; orange bars) under each 3cm length class (in number) make out of the total numbers of swordfish sampled/ estimated over the entire time-area series (1950-2008), all fisheries combined.*

20. The amount of catches for which length frequency samples are available has changed over time, a pattern which is detailed below in terms of different periods:

- 1950-1969: The total catches of swordfish estimated for this period are low (below 1,500t in most years). No size frequency data are available for this period. The majority of the catches of swordfish for the period come from the Japanese and Taiwanese longline fleets.

- 1970-1979: The total catches of swordfish estimated for this period range between 2,000t and 3,000t. Size frequency data are only available for the longline fishery of Japan, derived from samples collected on school training vessels and, to a lesser extent, fishing vessels. Between 3-16% of the total catches estimated (in number) are covered by size frequency sampling. Samples are not available for the longline fishery of Taiwan,China during this period.

- 1980-1991: The total catches of swordfish estimated for this period range from 2,000t to 8,000t. Samples are available for the majority of the strata having catches of swordfish, representing 55-91% of the estimated total catches of swordfish (in number), depending on the year. Samples from the longline fishery of Japan are available from both school training vessels and fishing vessels, the latter for the period 1984-90.

- 1992-2008: The total catches of swordfish estimated for this period range between 14,000t and 35,000t. Between 40-60% of the total catches estimated (in number) come from fisheries for which samples are available. The major constraints in this period are:
  - poor sample sizes and time-area coverage for the longline fishery of Japan, with samples only available from school training vessels;
  - lack of length frequency samples for the longline fisheries of Seychelles (up to 2007), India, Oman and various other flags (NEI), and
  - lack of samples or poor quality samples from gillnet and other artisanal fisheries, in particular driftnet fisheries from Iran and Pakistan.

21. The estimated length frequency distributions (catch-at-size) for some fisheries and periods differ significantly from the length frequency samples in the case of:

- the longline fisheries of Japan and Taiwan,China for the period 2000-08.
- artisanal fisheries over the entire period.

22. The following factors may explain these discrepancies:

- **Different shapes of the length frequency distributions available for Taiwanese longliners for 2000-03 and 2004-07, with sample coverage considerably higher for the period 2004-07:** During 2009-10, scientists from Taiwan, China conducted a review of the length frequency data for the Taiwanese longline fishery for 2004-07, with new data provided for this period. It was indicated that the previous dataset for the swordfish contained a significant number of specimens of striped marlin that had been mislabelled as swordfish. In addition, the new dataset contains new lengths of swordfish as derived from the logbooks available from Taiwanese longliners, with sample sizes in recent years amounting to as much as 40% of the total catches for this fishery. The new length distributions reported are compared with those used in previous WPB meetings in Figure 16.

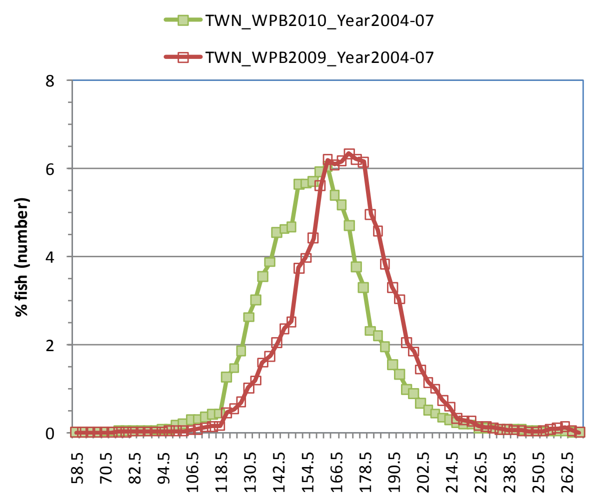


Figure 16. *Length frequency distributions of swordfish for the period 2004-07 (represented as the % of fish (in number) by length class) used by the WPB in 2009 (red line) and new dataset provided for the WPB in 2010 (green line).*

- **No weighting applied in the aggregation of samples under the strata selected for the assessment:** No weighting procedure is used in the allocation of the individual samples available to the fishery, area and period concerned. The samples available for each assessment area, fishery, year and quarter are aggregated by summing up all the specimens sampled by length class from all the fleets and gears concerned and over the entire area and period. However, the sample weights derived from the samples may represent various levels of coverage, depending on the strata involved.
- **Catches at size derived from samples containing a low number of specimens:** The shape of some CAS distributions tends to suggest that the number of specimens from which the catches at size were derived is too low. The minimum number of specimens needed for a sample to be raised to total catches, 30 specimens, is the same for all species. This number may be insufficient for species having a wide length frequency distribution, as it is the case with the swordfish.

- **Samples not representative of the fishery:** In recent years, the majority of the samples available for the longline fishery of Japan come from training vessels (Figure 17). There is uncertainty as to whether the samples collected on training vessels are representative of the fishery, as these vessels do not necessarily operate the same areas or use the same fishing techniques as the commercial vessels from Japan and tend to catch swordfish of larger length (Figure 18).

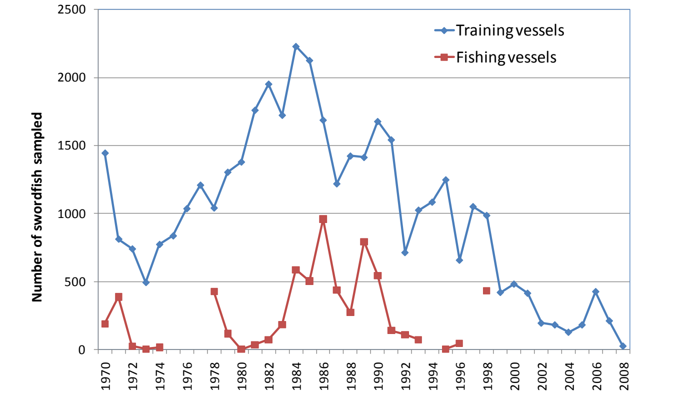


Figure 17. *Number of swordfish lengths measured onboard Japanese training vessels versus the number of swordfish weights reported by Japanese commercial vessels (1970-2008)*

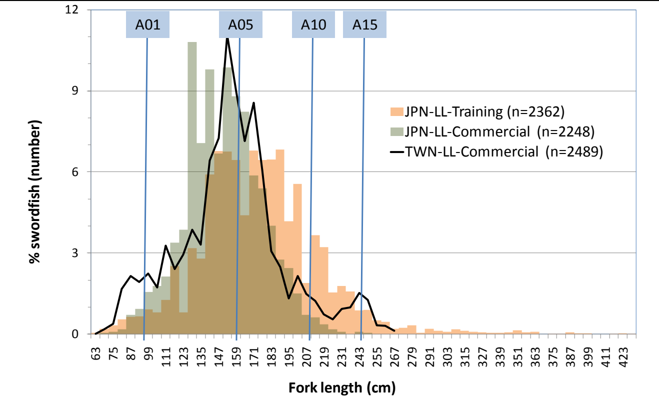


Figure 18. *Length frequency distributions of swordfish derived from samples taken onboard commercial longline vessels from Japan and Taiwan,China and samples from Japanese training vessels. The length frequency distributions represent the proportion (%) of fish (in number) by length class (6cm) over the period 1984-90. Only the strata having samples from the three fisheries were used. A01-A15 represents the lengths corresponding to Ages 1, 5, 10 and 15 estimated (deterministic) using the length-age function available.*

- **Samples not representative of the area:** As noted in section 2.3, the samples of swordfish available from Japanese and Taiwanese longliners refer to 10 degrees latitude by 20 degrees longitude areas and quarter, which are not the IOTC standards (5 degree square grid and month). In consequence, as much as 40% of the swordfish sampled comes from areas that overlap two or more of the areas used for the assessment (Figure 19). The samples concerned, or the CAS derived from them, are assigned by area using the time-area catches available within each 5 degree square and month. Figures 20 show the proportion of fish sampled that comes from 10-20 areas that fall fully within one of the assessment areas, by fishery, year and assessment area.

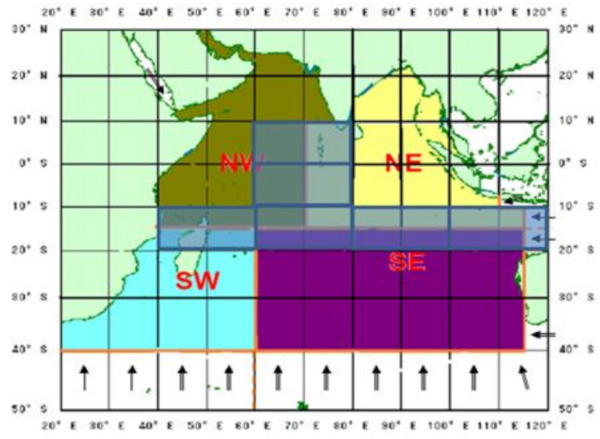


Figure 19. *10-20 areas (grey shading) that overlap two or more of the assessment areas used for Indian Ocean swordfish.*

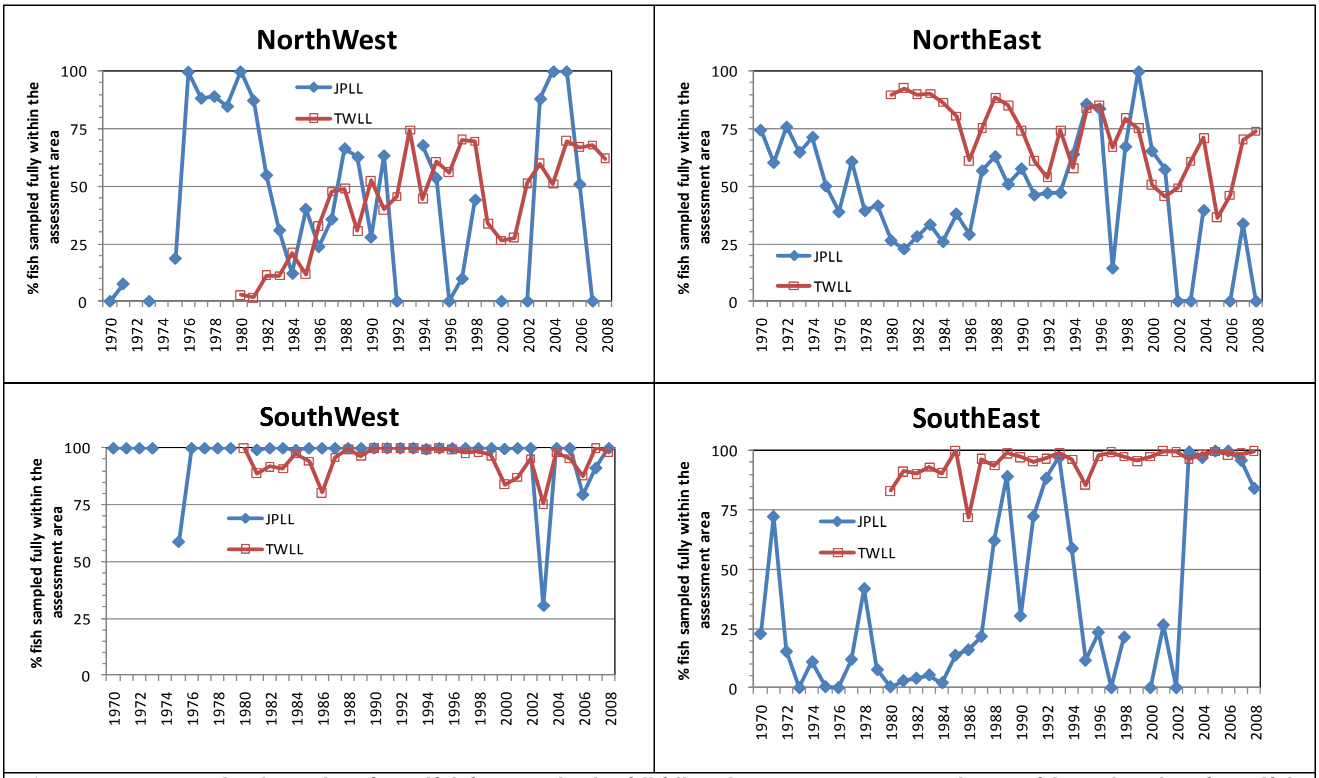


Figure 20. *Proportion that the number of swordfish from samples that fall fully within an assessment area makes out of the total number of swordfish allocated to the area (following the disaggregation of samples from areas overlapping two or more assessment areas (Figure 34)), by assessment area and year. Data are presented for the fisheries of Japan (JPLL) and Taiwan (TWLL).*

23. In addition, certain length classes (120-123cm; 207-210cm) are poorly represented in the length frequency distributions derived from both the samples and the CAS for Japan over the entire time series. These gaps originate in the conversion (deterministic) of swordfish lengths from measurements of eye-fork length to lower-jaw fork length, as the measurements reported by Japan refer mostly to eye-fork length measurements aggregated into 5cm length classes.

24. The WPB noted the issues identified above and stressed the need for countries having fisheries catching significant amounts of swordfish to revise their sampling schemes to incorporate the collection of length frequency data by sex. The WPB further noted that the decrease in sample size in recent years is a concern and urged countries, in particular Japan (longline), India (all fisheries), Oman (longline), Iran (driftnet), Pakistan (driftnet) and Taiwan,China (fresh-tuna longline), to increase sampling coverage to ensure that the size data collected are representative of the fishery concerned. In addition, the WP recommended that Japan and Taiwan,China provide the entire size frequency data series for their longline fisheries as per the IOTC standards.

25. The WPB expressed concerns about the effects that the above issues may have on the assessments of swordfish. A list including the main issues identified by the WPB can be found in Appendix IV

26. The WPB acknowledged the work undertaken by the Secretariat in the preparation of data.

3. Information on Biology, Ecology, Oceanography and Fisheries Relating to Billfish

3.1. IOSSS.

27. The Indian Ocean Swordfish Stock Structure (IOSSS) project provided an update on the collection of genetic, isotope and stomach sampling. Samples have been collected from several regions including La Réunion, Seychelles, Sri Lanka, and the Java Sea. Additional opportunities in Pakistan are being pursued. It is expected that the project will be able to provide new information of stock structure in 2011/12.

3.2. Tagging studies

28. Australia and South Africa have active programmes to deploy pop-up satellite archival tags (PSATs). Australia has a total of 15 GPS (PSAT) tags to deploy on swordfish through the west coast longline fishery observer programme. Several of these tags have been deployed to date, but release times have typically been very short, with none of the attachments exceeding two months. Tracks reported to date do not indicate any basin-scale movements.

29. The South West Indian Ocean Fisheries Project (SWIOFP) conducted a tagging cruise in the Mozambique Channel in April 2010 intending to deploy PATs on swordfish but was unsuccessful due to the poor condition of the fish. A second cruise is planned in October 2010 off South Africa with training in tagging swordfish provided by CSIRO, Australia.

3.3. Swordfish age and growth

30. Document IOTC-2010-WPB-08 was presented, describing the age and growth analysis of swordfish based on the specimens collected by the Taiwanese observer programme implemented on the Taiwanese tuna longline fleet in the Indian Ocean during 2007-2008 (figure 21). Since the relationships between length (lower jaw fork length; LJFL) and weight (round weight; RW) were not statistically different between sexes, the length-weight relationship was estimated by sex-pooled data and the relationship is $RW = 9.133\times10^{-6} LJFL^{3.012}$. Age determination was based on the annuli of the cross sections of the second rays of the first anal fin. The parameters of von Bertalanffy growth function were estimated by fitting to the sex-specific back-calculated lengths-at-age and the growth functions were statistically different between males and females. The results of spatial comparisons revealed that the growth function were statistically different between eastern and western sub-groups for both sexes. Among sub-group, the growth functions were also statistically different between males and females. The estimates of the parameters of von Bertalanffy growth functions are listed in Table 1.

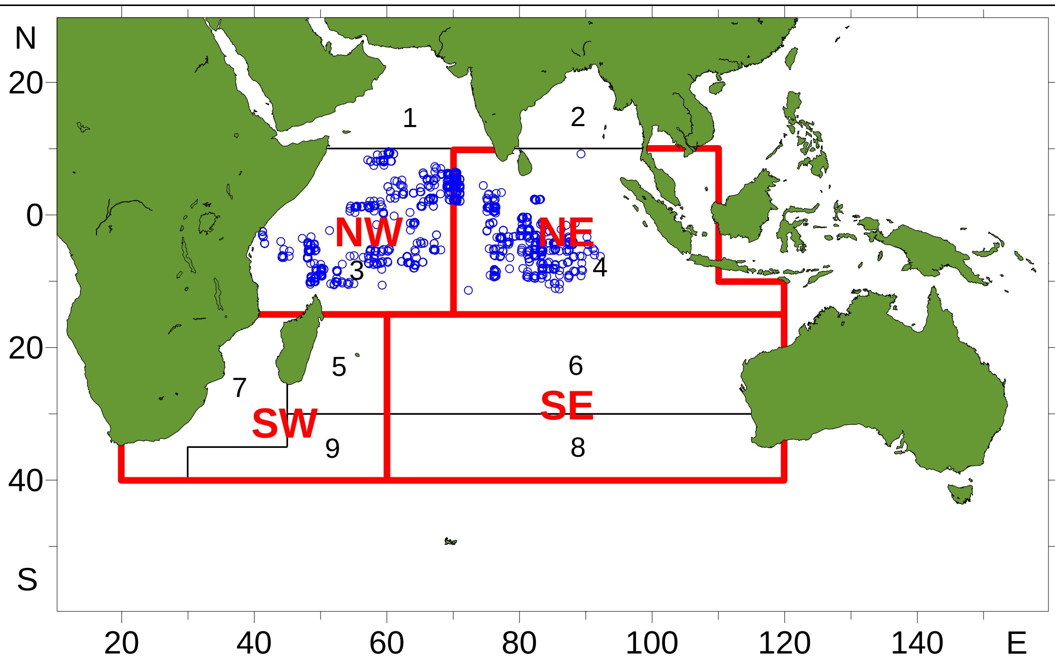


Figure 21. *Distribution of swordfish specimens collected by Taiwanese observer programme deployed in the Indian Ocean during 2007-2008.*

Table 1. *The parameter estimates of von Bertalanffy growth function based on swordfish specimens collected by Taiwanese observer programme deployed in the Indian Ocean.*

Group	L_∞	K	t_0
Male	234.002	0.169	-2.181
Female	274.855	0.138	-1.998
Eastern sub-group			
Male	270.809	0.125	-2.407
Female	276.518	0.143	-1.613
Western sub-group			
Male	199.887	0.259	-1.629
Female	267.315	0.144	-2.053

31. The WPB welcomed the addition of new growth parameters, length-weight relationships and age-length keys provided by the analyses, which addresses an ongoing recommendation. The participants compared the growth parameter estimates with those previously used in stock assessments and several models used in the current assessments adopted these new parameters. It was recommended that further research is still needed to validate that fin ray bands correspond to annual growth increments (*i.e.* annuli). Further, the WPB suggested that samples collected by the Taiwanese observer programme may provide material for genetic analyses and collaboration with the IOSSS programme is strongly recommended.

3.4. Seychelles semi-industrial longline fishery

32. Document IOTC-2010-WPB-10 provided an update on fisheries data for the Seychelles semi-industrial longline fishery with data current to 2009. The fishery is locally owned and operated, and started in 1995. In 2009, a total of 119 longline fishing trips were conducted by 9 vessels targeting swordfish and tuna, with both the number of trips and vessels increasing over the previous year (by 60% and 29%, respectively). The increase in trips and vessels resulted in an increase in effort in 2009 with over 483,000 hooks compared to 345,237 hooks the previous year (figure 22). This increase in effort resulted primarily from amendments to the fuel incentive scheme in 2008, as reported last year, and occurred in spite of the increasing threat of piracy on the fishery in 2009.

33. In 2009, the catch by the fleet increased by 40% compared to the previous year, reaching 329 t (figure 23). Swordfish dominated the catch in 2009, accounting for 52%, while yellowfin and bigeye tuna accounted for 21% and 17%, respectively (figure 24). Bycatch constituted sharks (4%), sailfish (4%), marlins and other species (2%). Nominal swordfish CPUE remained low in 2009, at 0.35t/1000 hooks (figure 26). The number of swordfish sampled for size frequency data has increased substantially in the past year, with the sample size in 2009 more than double that of the total for the prior 5 years (figure 25). Nominal CPUE values for yellowfin and bigeye tuna decreased slightly in 2009 compared to the previous year and were substantially lower than 2007 (figure 26).

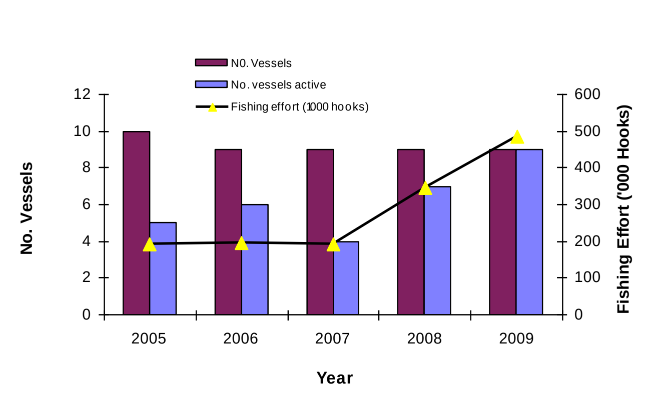


Figure 22. *Number of vessels active and fishing effort of semi Industrial fishery, 2005- 2009. From document IOTC-2010-WPB-10*

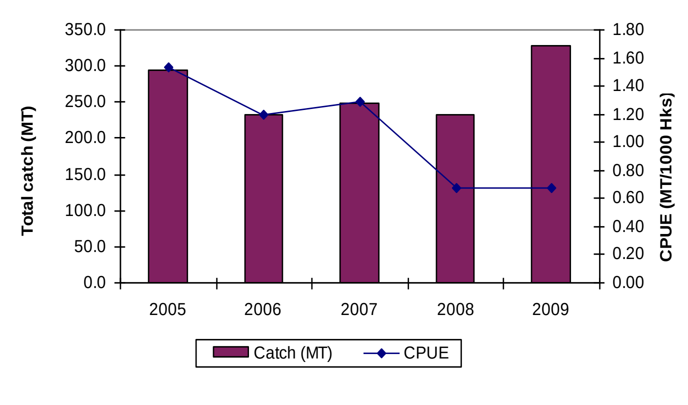


Figure 23. *Catch and catch rate of semi Industrial fishery targeting swordfish or tuna, 2005- 2009. From document IOTC-2010-WPB-10*

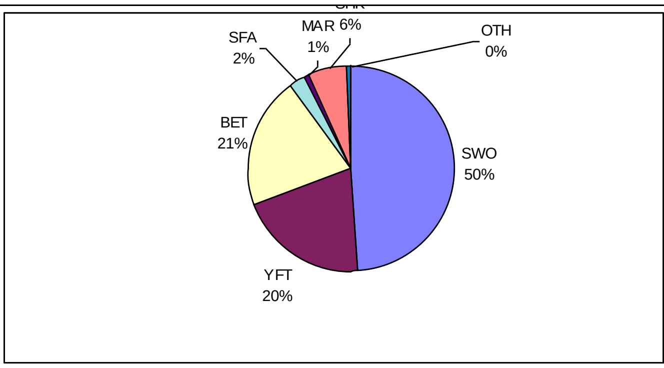


Figure 24. *Average Species composition of semi Industrial fishery for the 2005 - 2009 period. From document IOTC-20010-WPB-10*

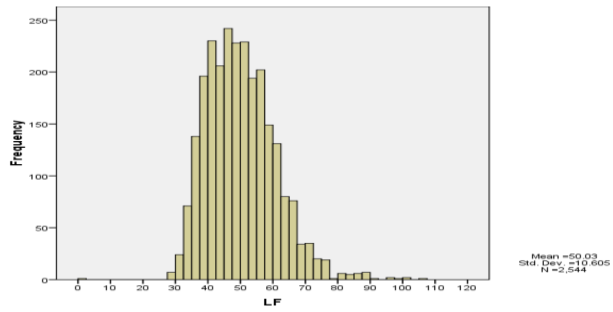


Figure 25. *Swordfish size frequency distributions (PAL in cm) from fish landed by Seychelles' longliners in Victoria for the period 2005 - 2009 (n=2,544). From document IOTC-2010-WPB-10*

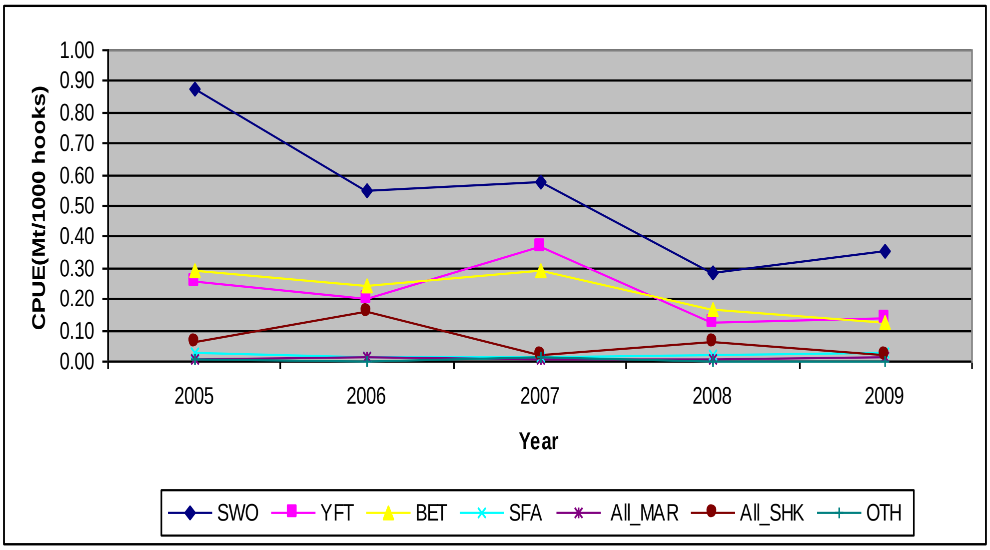


Figure 26. *Catch rate (t/1000 hooks) by species of Seychelles semi-industrial fishery, 2005- 2009. From document IOTC-2010-WPB-10*

34. Continuing from 2008, the number of longline vessels that reported targeting sharks decreased substantially, with only 1 vessel declaring 4 shark trips in 2009. Consequently, the amount of shark carcasses (1.8t) and fins (0.9t) landed in 2009 declined by 91% and 92%, respectively, compared to 2008. However, it is considered that the new fuel incentive criteria introduced in 2008 (*i.e.* that fuel rebates are not given for trips with shark catches in excess of 15% of the total catch) has led to significant misreporting and underreporting, possibly mediated through the transhipment at sea of shark fins and carcasses to artisanal vessels – the artisanal fishery recorded a substantial increase in shark catches in 2009.

35. The WPB thanked Seychelles for the information provided and enquired for further clarification in the meeting next year regarding estimation of logbook size sampling coverage relative to total catch based on the new recommendations of sampling the first 20 fish per set. It was reiterated that Seychelles should report, as well, on its industrial longline fleet at the WPB.

4. Update of stock indicators

4.1. Swordfish

Catch Trends

36. After the beginning of the Japanese longline fishery in the Indian Ocean in 1952, catches of swordfish increased slowly and reached around 4,000 tonnes by 1985. Due to large increases in effort and changes in

targeting practices, catches significantly increased from the mid-1980s to the mid-1990s, after which time they stabilized at between 30,000 and 33,000 tonnes per year, with a reported catch of around 22,000 tonnes in 2008 (figure 1).

CPUE INDICES

37. Intersessional collaborative work on the catch rate standardization for the Japanese and Taiwanese swordfish fleets was undertaken in 2010 to address a number of recommendations from previous meetings of the WPB. Four main objectives were targeted:

a. **Revisit the fishery definitions**. The Taiwanese and Japanese fleets have undergone substantial changes over time, largely in relation to species targeting changes, such that the merging of heterogeneous regions in large spatial units could be introducing biases to the CPUE time series. As an alternative approach in 2010, analyses were restricted to relatively small regions that have been fished the most consistently over the historical record. These regions were defined by examining graphical summaries of the number of consistently fished years and quarters on a 1x1 degree grid. The analysis revealed that both fleets are highly mobile among years, but reasonably consistent core areas were evident. One area was selected for each of the 4 Indian Ocean regions for each fleet (figure 27). The 3 regions were the same for Japan and Taiwan in the NW, NE, SW, but differed in the SE. Regions for the Seychelles and La Réunion CPUE series are included for comparison.

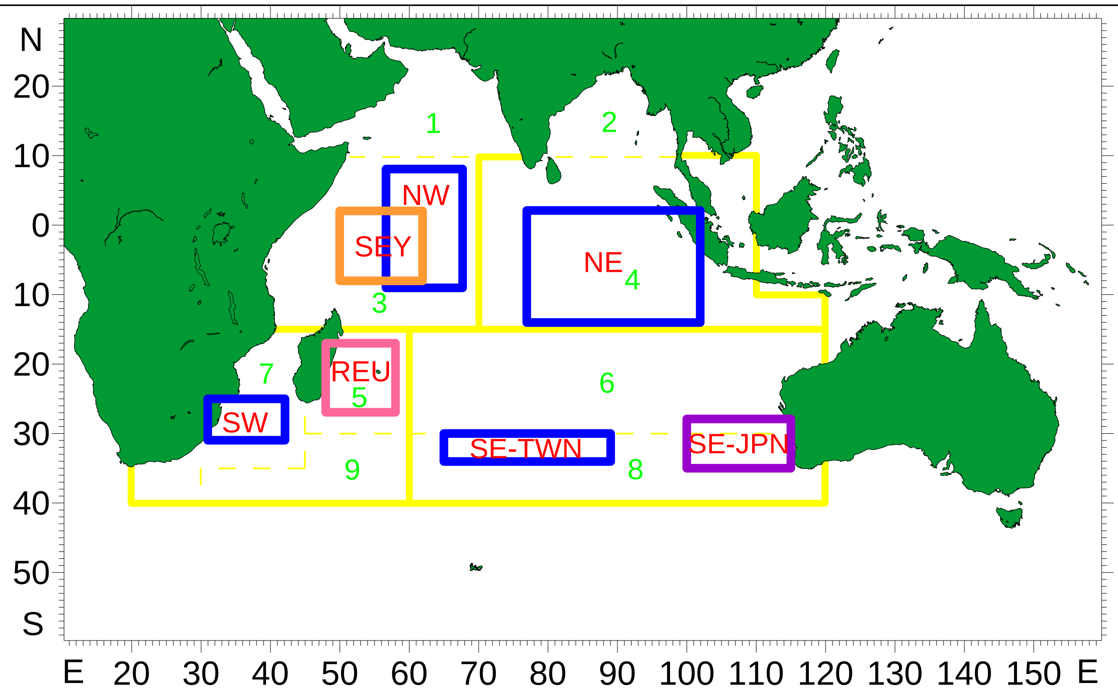


Figure 27. *Map showing the core areas of (relatively) consistently fished areas for the Japanese (1980-2008) and Taiwanese (1994-2008), La Reunion (1995-2008) and the Seychelles industrial (2001-2008) fleets. The region of the Seychelles semi-industrial fleet is a very restricted central region within the box indicated for the Seychelles industrial fleet.*

b. **The influence of extreme outliers in nominal and GLM-standardized time series** was examined by comparing selective filtering of very high observations, and using robust statistical methods (*e.g.* plotting medians instead of means). The group decided to eliminate the small number of observations with CPUE > 100 fish/3000 hooks. This had a big influence on a small number of strata, but many highly irregular CPUE patterns remained in the time series despite several approaches.

c. **Treatment of zeroes**. There are a large number of observations (30-40% by year) with positive effort and zero swordfish catch. The traditional approach of adding a small constant to the lognormal CPUE model was compared with the delta-lognormal model. This latter approach is a two stage process in which the probability of obtaining a zero catch is modelled as a binomial process, and then the positive CPUE is subsequently modelled with the traditional lognormal model. The two models are integrated to estimate the time series of annual relative abundance. The two approaches were compared for the Taiwanese fleet, using a relatively simple and relatively complex model structure. The effect on the estimated time series trends was insubstantial (figure 28) and the WPB agreed that the traditional lognormal model would be sufficient for this year.

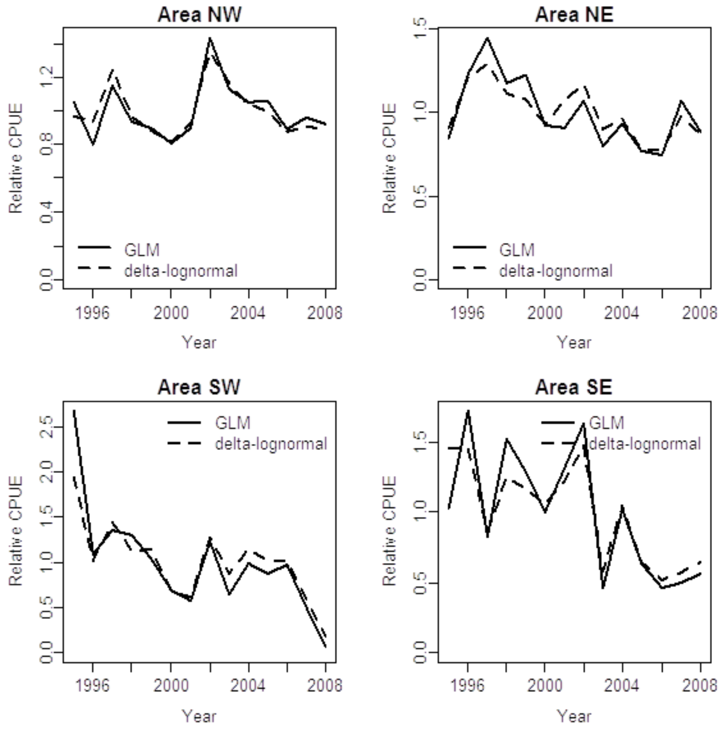


Figure 28. *Comparison of the relative abundance indices estimated from the Taiwanese CPUE standardization using the lognormal and delta-lognormal GLMs (CPUE ~ Y + Q + A + Y:A).*

d. **Selection of independent variables**. In 2009, there were 37 predictive terms in the final CPUE model, including 26 2-way and 3-way interactions. In 2010, simpler models were explored in which the only interactions across GLMs were year-area effect and temperature gradient-area effect (and in one case the mainline-NHBF interaction). The variables included Year, Area, Quarter, NHBF, main line material (the latter two as a proxy for depth/targeting), individual vessel identifier (to consider that fishing master skill probably influences catchability in ways that may not be quantified by the logbook fields), and a suite of environmental variables.

38. The Japanese and Taiwanese series show somewhat different trends in the different regions, though the aggregate trends for all regions suggest declines from 1995-2008 as detailed below.

The Japanese longline fishery

39. Document IOTC-2010-WPB-09 described the standardization of swordfish CPUE for the Japanese tuna longline fisheries in the Indian Ocean over the period 1980-2008, using generalized liner models (GLM). As in the last Session, the 4 sub-areas were used in the GLM, but for this year the core fishing area within each sub area was defined and used to obtain stable nominal CPUE for standardization. The aggregate CPUE series was calculated by weighting the core areas according to the relative areas of the 4 larger sub-areas.

40. In the past, 5x5 degree catch and effort data have been used. However, it was recognized that such low resolution is not sensitive to fine-scale environmental data such as moon phase, sea temperature, salinity, shear currents and ocean fronts; the use of such environmental information for CPUE standardization has been recommended by IOTC Scientific Committees. In addition, it was recommended during the 2008 meeting of the WPB that daily moon phase data be used. Therefore, to match environmental data, daily set-by-set catch and effort data have been used since the WPB of 2009. In the GLM, 9 scenarios were attempted and the 7th scenario with five effects was identified as the best. The five effects were MAIN (year, quarter and sub-area), HBF (number of hooks between float), ENV (8 environmental factors), V (vessel) and one interaction (TG: ocean front*A: sub-area) (Table 2).

Table 2. *Nine scenarios used in Japanese longline CPUE standardization with BIC scores.*

GLM Model	BIC	R^2	
(1) Y+Q+A+YA	287209	13.4	
(2) Y+Q+A+YA+HBF	286908	13.6	
(3) Y+Q+A+YA+HBF+V	283683	20.9	3rd
(4) Y+Q+A+YA+ENV	286394	14.1	
(5) Y+Q+A+YA+HBF+ENV	286083	14.3	
(6) Y+Q+A+YA+HBF+ENV+V	283107	21.4	2nd
(7) Y+Q+A+YA+HBF+ENV+V+TG*A	282775	21.7	Best
(8) Y+Q+A+YA+HBF+ML	297437	4.5	NG
(9) Y+Q+A+YA+HBF*ML	297767	4.1	NG

41. GLM results suggested that the abundance index (AI) rapidly increased from 1980 to 1988, then decreased until 2006, followed by increases in 2007-2008. Using daily fine scale CPUE (set by set) data, it was found that nominal CPUE is significantly affected by the following factors (by order of statistical significance): 'number of hooks between floats', 'environmental data [moon phases, ocean fronts, temperature & salinity at 45m depth where SWO are primarily caught]' and 'main factors (area and season)'. Such findings, especially relating to environmental information, could not be obtained when the coarse scale (5x5) nominal CPUE were used in the past. This demonstrates the effectiveness and importance of fine-scale CPUE and environmental data. In addition, it was also found that V (vessel effects) significantly affects nominal CPUE, implying that there are different levels of catchability among vessels due to the skipper's skills.

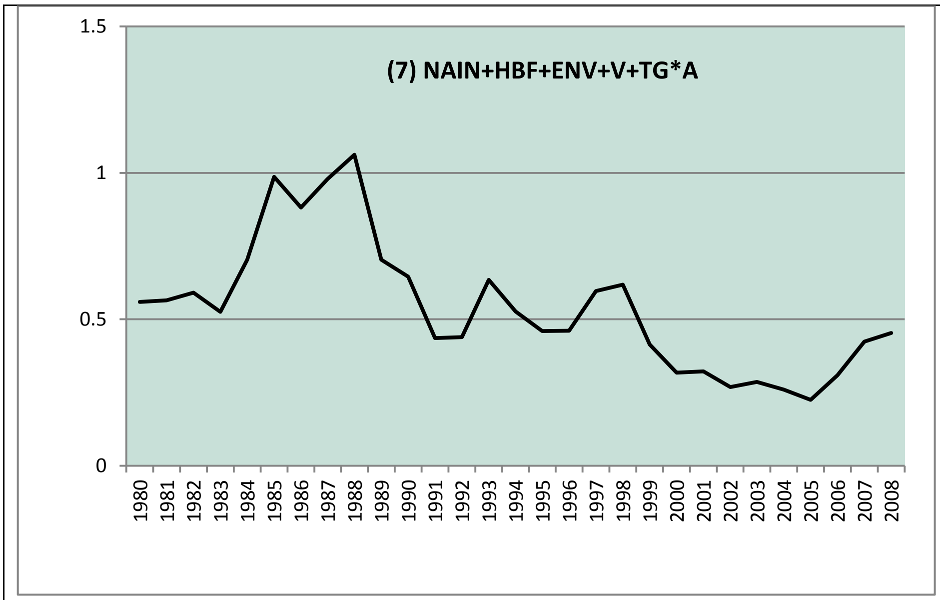
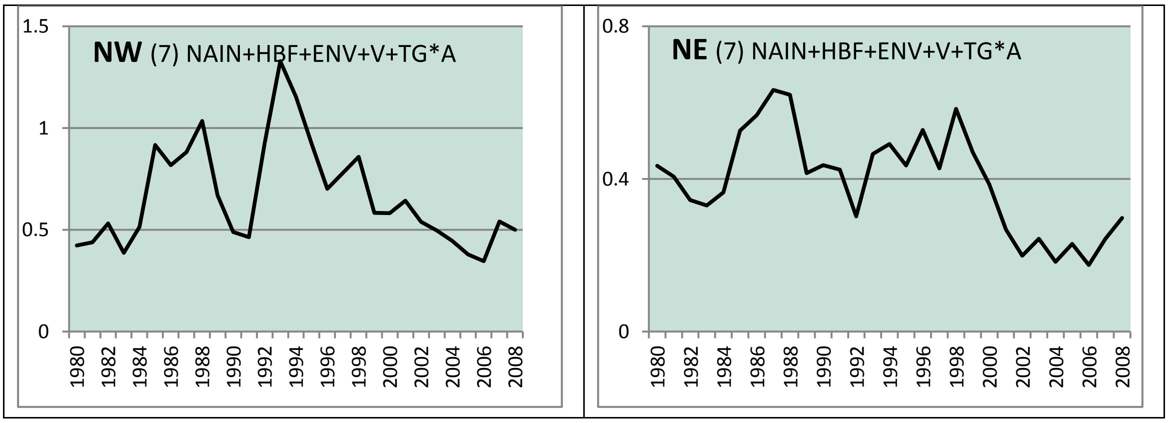


Figure 29. *Estimated AI (abundance index) based on the Japanese longline CPUE by the GLM analyses.*



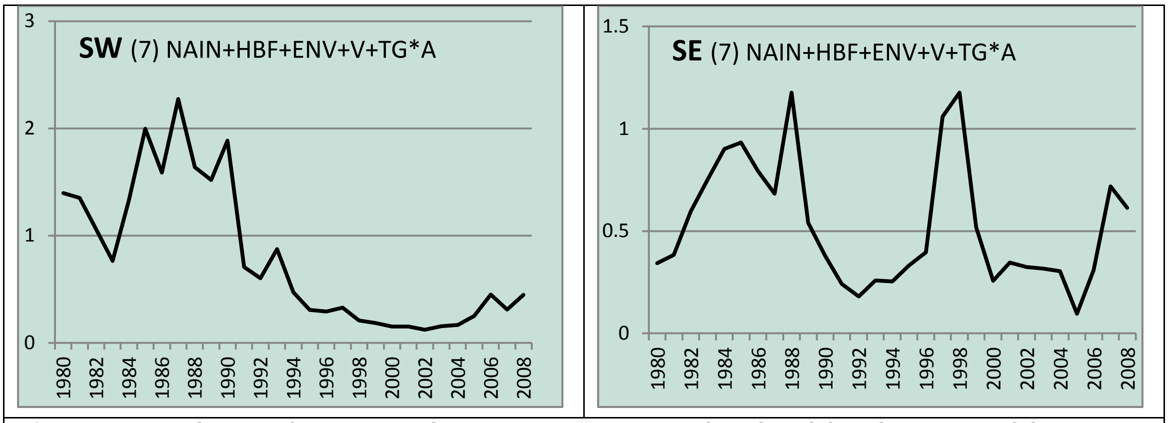


Figure 30. *Estimated AI in 4 sub-areas. AI trends in recent years in NW, NE and SW showed sharp decreasing trends but starting in different years.*

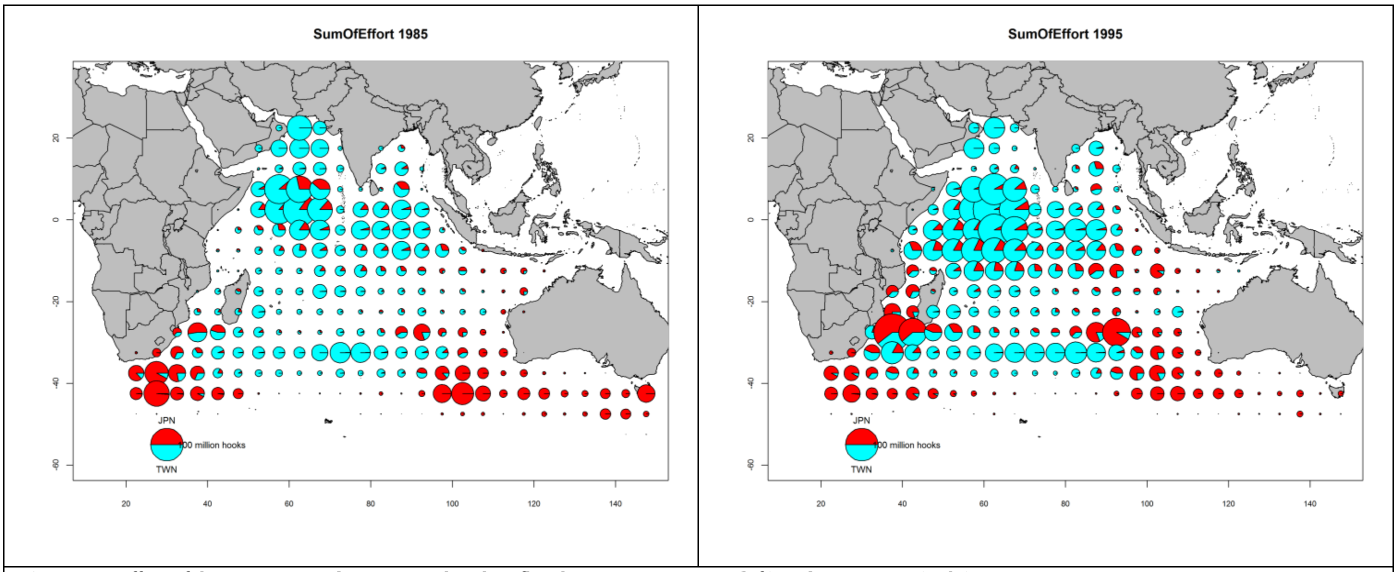


Figure 31. *Effort of the Japanese and Taiwanese longline fleet between 1985-1994 (left) and 1995-2008 (right).*

The Taiwanese longline fishery

42. Document IOTC-2010-WPB-11 was presented, describing the CPUE standardization for swordfish caught by the Taiwanese longline fishery in the Indian Ocean (for 1995-2008), using GLM based on data sets extracted from the core fishing area. Including interactions with the year effect would invalidate the year effect as an index of abundance and high autocorrelation would occur among environmental effects. Therefore, only the interactions year-area and temperature gradient-area were considered in the model (table 3). Except for the SE area, standardized CPUE series reveal continuous declining trends for recent years, especially for the SW area where the CPUE decreased sharply after 1995 (figure 32). Although there was an obvious peak in 2002, the standardized CPUE-aggregated by area (weighted by relative area of the larger sub-regions) reveals a gradual decreasing trend since 1995 (figure 33).

Table 3. *The values of BIC and R2 for seven models.*

sn	MODEL	BIC	Δ_{BIC}	R^2 (%)
1	Y+Q+A+Y×A	596847	-	11.94
2	Y+Q+A+Y×A+NHBF	596620	-226	12.06
3	Y+Q+A+Y×A+NHBF+V	579945	-16901	20.23
4	Y+Q+A+Y×A+ENV	596137	-710	12.30
5	Y+Q+A+Y×A+NHBF+ENV	595939	-908	12.41
6	Y+Q+A+Y×A+NHBF+ENV+V	579315	-17531	20.52
7	Y+Q+A+Y×A+NHBF+ENV+V+TG×A	579272	-17575	20.54

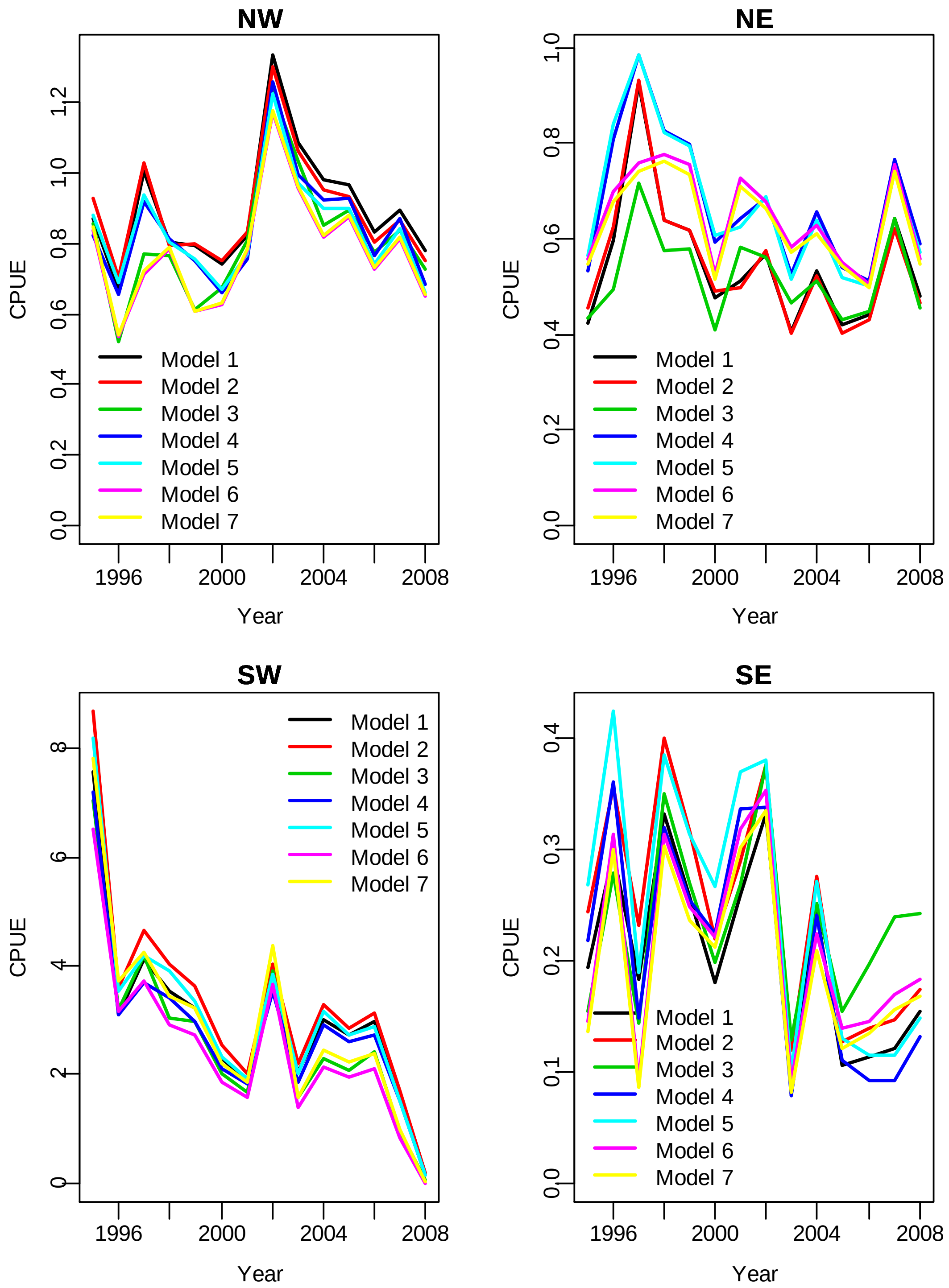


Figure 32. *Area-specific standardized CPUE of swordfish caught by the Taiwanese longline fishery in the Indian Ocean.*

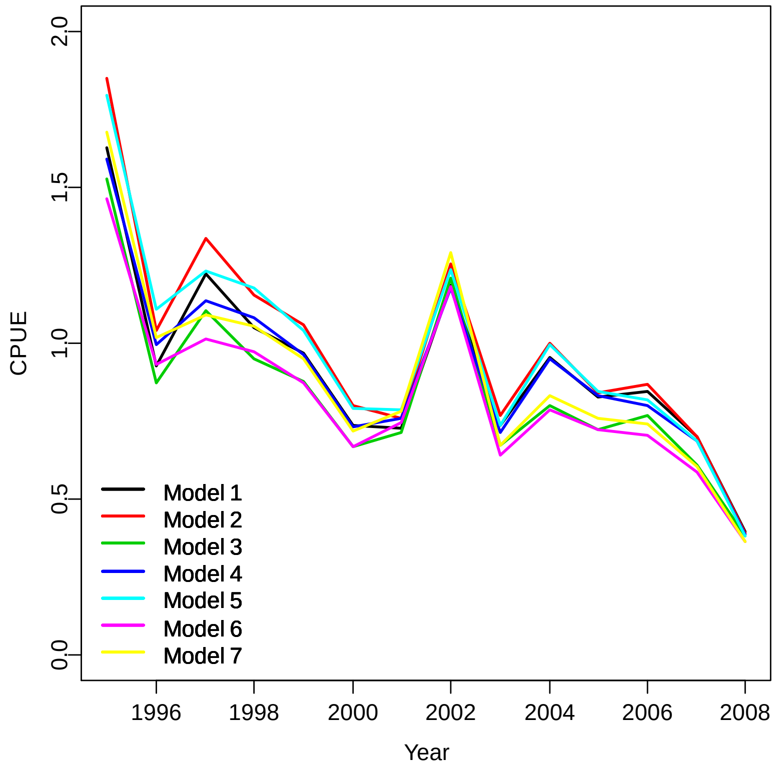


Figure 33. *Area-aggregated standardized CPUE of swordfish caught by the Taiwanese longline fishery in the Indian Ocean.*

Comparison of Japanese and Taiwanese CPUE series

43. The standardized Japanese and Taiwanese CPUE series from the 7th WPB (2009) and the 8th WPB (2010) are compared in figure 35, and Table 4. The historical problem of conflicting trends is illustrated in figure 34. The WPB noted that the general trends in the TWN and JPN series were more consistent in the 8th WPB (2010) than in the previous year. This may indicate that the core area approach is removing some of the biases due to spatial heterogeneity and targeting effects that are associated with spatial changes. The group recommended that the core area approach be pursued further in future meetings.

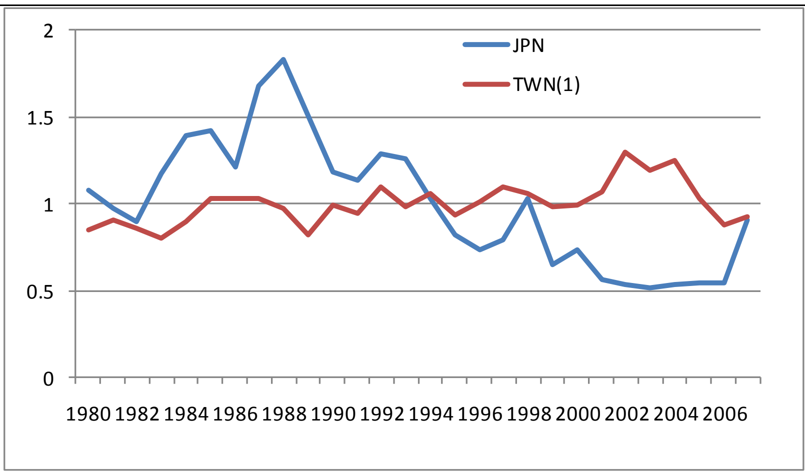
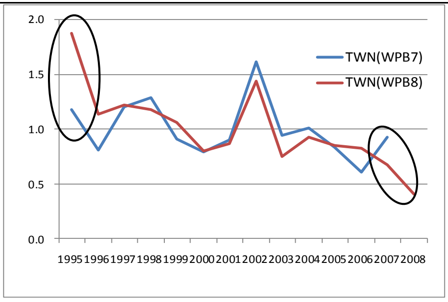
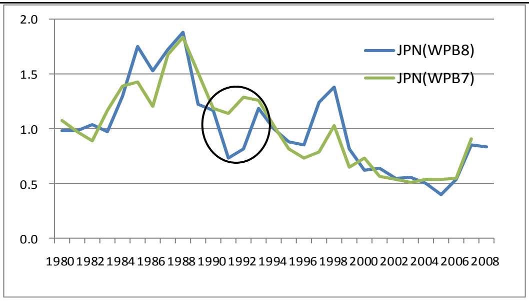


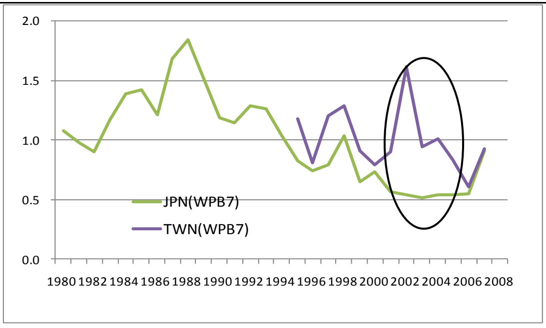
Figure 34. *Comparison of TWN and JPN CPUE over the long term (from WPB7 2009) when TWN uses "spp. comp" for targeting corrections (1980-1994) & "NHBF"(1995-2007), while JPN uses "NHBF" for the whole time period.*



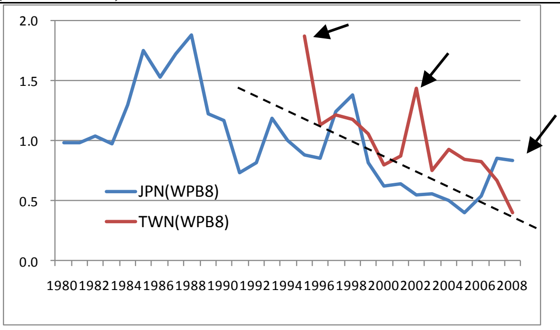
TWN (WPB7-2009 vs. WPB8-2010): *Similar except 1995 and 2006-2007*



JPN (WPB7-2009 vs. WPB8-2010): *Similar except 1991-1992 (low in WPB8)*



TWN vs. JPN (WPB7-2009): *Trends are similar in 1995-2000 & 2006-2007,but large discrepancies in 2001-2005*



TWN vs. JPN (WPB8-2010): *General decrease trends are similar, but there are jumps in 1995 & 2002 and also discrepancies in 2006-2008.*

Figure 35. *Comparison between Japanese and Taiwanese standardized CPUE in 2009 (using large areas and NHBF targeting factors) and 2010 (using core areas and NHBF targeting factors).*

Table 4. *Comparison between the input data between WPB7 (2009) and WPB8 (2010) for TWN & JPN). Note both JPN & TWN use the set by set data in 2010 (but only the 1995-2008 period is included for TWN.*

	WPB7 (2009)	WPB8 (2010)
No. of ENV co-variates	37	10
Individual Vessel ID	no	Yes
Area	4 large areas	4 core areas

44. The WPB welcomed the new analyses on core fishing areas of the Japanese and Taiwanese fleets and encouraged future investigation. In particular, the use of operational data continued to improve CPUE standardization, although further investigation into the optimal model size is required. The WPB recognised the sensitivity regarding the presentation of spatial distribution of fine-scale effort as maps.

45. The WPB noted the uptake by Japan of the recommendation, made during the 2006 meeting, that set by set data be used for the CPUE standardization, and discussed the improvements that use of detailed data has provided for the integration of environmental data in the model. It was recommended that Japan continue to use the set by set data in the future.

46. The WPB noted the significant decline in the AI for the SW area (starting 1991) and identified that this could be a consequence of various factors including the environmental heterogeneity of the area, targeting issues, shifting fishing areas over time (figure 30 and 32) and specification of the model (*e.g.* interactions between environmental factors and spatial patterns in the fishery). Technological changes leading to an increase in tuna catch rates (e.g. changes in longline fishing depth, number of hooks between floats) might have had a potential negative impact on swordfish catchability and CPUE.

47. The WPB noted that the steep downward trend observed in the Japanese CPUE for the SW region was shifted from 1994-95 (7^{th} WPB, 2009) to 1991-92 (8^{th} WPB, 2010) using the core areas selected in this analysis. This suggests that the decline may be partly an artefact of the shifting spatial distribution of effort and/or targeting in the SW region.

48. The WPB identified that the spike in Taiwanese CPUE in 2002, notable in the NW and SW areas and which in turn influenced the area-aggregated series, may possibly have been caused by the low logbook coverage in that year, which tended to inflate the high CPUE in the affected areas. It was noted that removing 2002 from the data series, an approach that was adopted in last year’s assessment, does not affect the overall trend and it should not be omitted from the series without further justification.

49. The WPB recognised the potential usefulness of the environmental variables derived from the general circulation models, which are well established in that many published papers now use these data. Hence, the WPB suggested that CPUE standardisation should continue using the best environmental data available while recognising their characteristics. The WPB recognised that further investigation is required to improve the way that fine scale oceanographic features are predicted using general circulation models and alternative remote-sensing based products.

50. The spatial partitioning of core areas might have helped to identify homogenous fisheries, but it seems likely that targeting shifts are still occurring within these regions. Further work should be done to partition the fleets according to the species composition (which is somewhat different from the troublesome approach of using other species as a factor in the GLM). Alternatively, it may be worth splitting the CPUE series into different time periods when targeting shifts can be identified.

51. The environmental covariates included in the model might be removing the effects of relative abundance rather than catchability (*i.e.* higher CPUE in cooler waters could reflect a temperature preference for cooler water, rather than higher catchability). Examining inter-annual anomalies from the average seasonal cycles might be a more appropriate way to identify environmental effects that are relevant for describing interannual variability in CPUE. This work should be pursued during the intersessional period.

52. Assuming a linear response in catchability might be inappropriate for some variables (*e.g.* a dome shaped response might be more appropriate for some environmental covariates). To solve this problem, it may be appropriate to use general additive modelling approaches.

53. Many of the environmental covariates might appear to be statistically significant for spurious reasons. For example due to the spatially and temporally correlated nature of oceanographic data. To test for this possibility, a number of GLMs were fit for the Seychelles industrial fleet using the same environmental fields as were used for Japan and Taiwan. Highly significant relationships were identified when the environmental data were arbitrarily shifted in time (by 20 years) and space (30 degrees of longitude and latitude), and different variables were identified each time this process was repeated. In this case, including fixed spatial effects (sub-areas) provided more explanatory power. Further investigation is required to understand the real environmental mechanisms that impact catchability.

54. The environmental effects may act differently in different regions and this would be easier to examine if analyses were conducted for different areas independently.

55. Presentation of the parameter estimates is essential for the WPB to review the proposed mechanisms linking environmental factors to catchability.

Seychelles semi-industrial and industrial longline fisheries

56. Document IOTC-2010-WPB-04 describes exploratory work on standardization of swordfish CPUE series from the Seychelles semi-industrial (SEMI) and industrial (IND) longline fisheries using GLM. The SEMI fleet is localized and operates primarily around the periphery of the Mahé Plateau with little evidence of spatial expansion since its development in the mid-1990s (figure 36). The IND fleet consists of large, long range vessels and operates over a much larger area than the SEMI fleet; however, it is assumed that they are targeting the same swordfish population in the vicinity of the Seychelles. Patterns in catch, effort and nominal CPUE for the SEMI fleet (figure 37) are highly influenced by disruptions to the fishery between late 2002 and early 2005 caused by restrictions on exports to the EU due to issues related to cadmium levels.

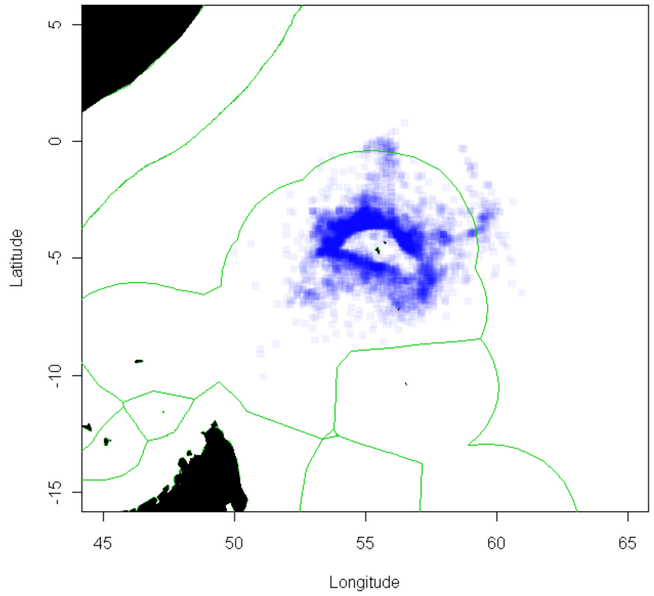


Figure 36. *Location of Seychelles semi-industrial longline fleet logbook sets 1995-2009. Full colour saturation indicates 20 or more sets.*

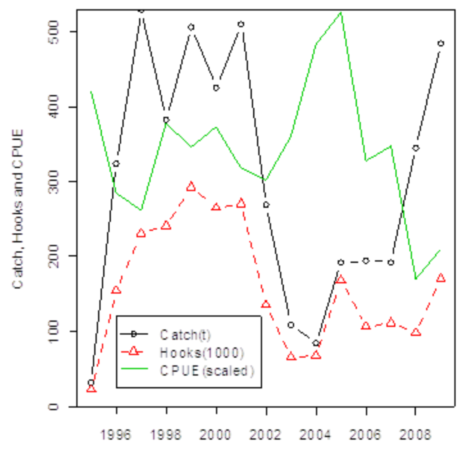


Figure 37. *Time series of total catch, total hooks and total Catch/total hooks (rescaled to fit on the same axes) for the SEMI fleet.*

57. GLM models examined year, quarter, area and moon phase effects in the SEMI fleet. First, the influence of zero CPUE observations was assessed using lognormal, Box-Cox transformation, and delta-lognormal approaches applied to models with the simplest combination of explanatory variables. As there were no major differences among the time series estimated by the three models, lognormal models were applied in subsequent model development (figure 38). Due to the short duration of most vessels in the fishery, vessel effects were examined through introduction of factors based on vessel ID and experience (in years and sets), and using subsets of the data for only the most experienced vessels. Due to a lack of targeting parameters in the dataset, proxies based on non-target species composition were introduced through factors or data subsets.

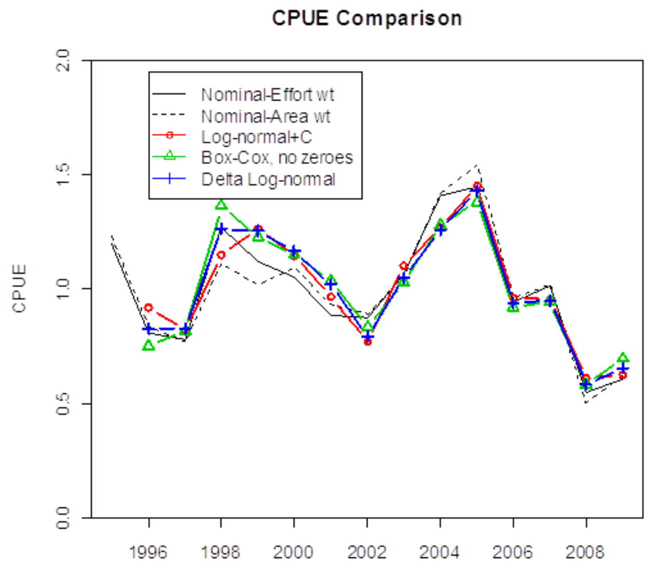


Figure 38. *Comparison of SEMI CPUE series, including the nominal series and the different error models (semiLN0, semiBC0, semiDL0) with the main space-time effects*

58. Individual vessel effects were important and analyses were somewhat sensitive to different species targeting assumptions. Across models (figures 39 and 40), the standardized CPUE series had robust features shared with nominal CPUE, notably the decline leading up to the cadmium related issue in late 2003, followed by recovery during the export ban up to early 2005, and a subsequent continuous decline in CPUE to the end of the series. Model semiLN9 was selected on the basis of the BIC (Bayesian Information Criterion) score. However, due to doubts about the appropriateness of the non-swordfish targeting index in semiLN9, model semiLN21 was recommended for consideration by the WPB.

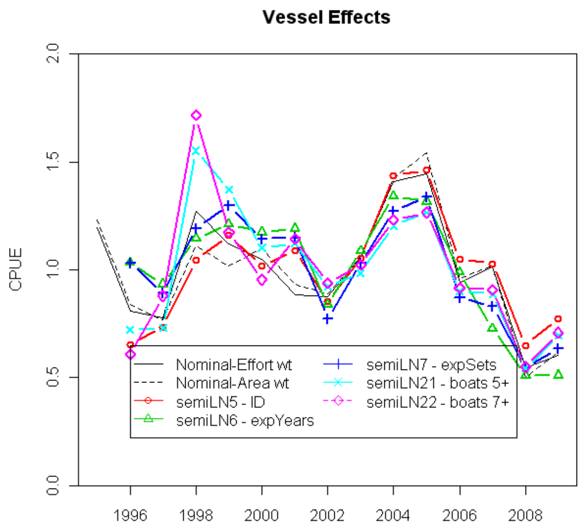


Figure 39. *Comparison of Seychelles SEMI swordfish CPUE models that examine different vessel effects.*

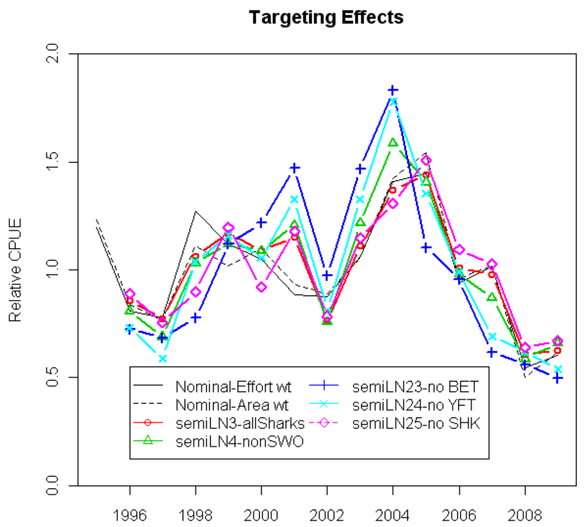


Figure 40. *Comparison of Seychelles SEMI swordfish CPUE time series when different approaches are used to identify the effects of shifting targeting.*

59. The standardized swordfish CPUE series from the Seychelles industrial fleet (IND) was robust to treatment of the comparatively high zero observations (figure 41) and was stable over the period (2004-2008) of analysis, differing from the declines observed in SEMI series over the same period (figure 42). Series indDL1 was selected.

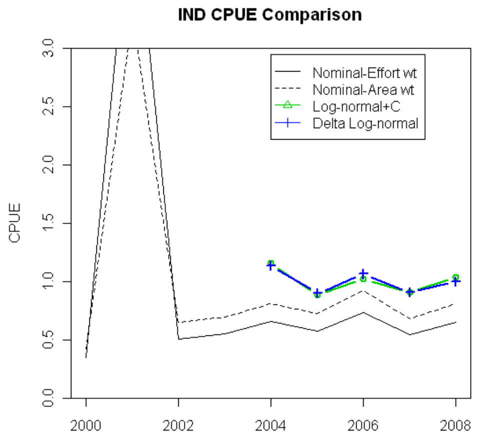


Figure 41. *Comparison of the nominal and standardized CPUE series for the IND fleet in the SEZ region (normalized to a mean of unity).*

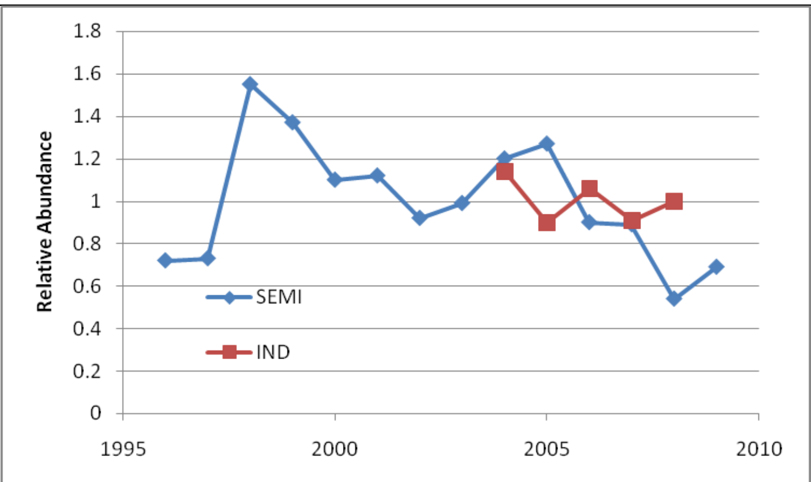


Figure 42. *Comparison of the recommended swordfish relative abundance time series from the Seychelles semi-industrial (SEMI) and industrial (IND) longline fleet CPUE series (normalized to a mean of unity).*

60. The WPB discussed potential problems arising from the inclusion of the standardized CPUE series from the Seychelles semi-industrial fleet in the stock assessments. The spatial extent of the fishery is limited and the fleet is probably not targeting a wide area of the stock distribution. Processes of highly localized depletion and renewal, and possibly gear interactions, may be influencing the CPUE series. Until the mechanisms are better understood, attempts to include the series will largely be exploratory.

La Reunion longline fishery

61. Working paper IOTC-WPB-2010-03 was presented, describing the GLM-based catch rate analysis for the La Reunion fishery. Three different logbook datasets were available for analysis. The data from 1993-2000 were the most useful, as they included records at a set by set resolution with many operational details. The data from 2005-8 were also useful, but included fewer fields and were not entirely consistent with the 1993-2000 period. The data from the 2001-2004 period were aggregated at the level of the trip, and did not include location or effort in hooks, and hence were not used at this time. Standardization was restricted to the core spatial region within roughly 5 degrees of La Reunion, as more distant regions were only fished sporadically (figure 43). With the exception of the models that included Year:Quarter or Year:Area interaction terms, the time series estimated by the standardization proved to be very similar to the nominal series (figure 44), and very robust to the choice of explanatory variables used in the model and the exclusion of data on the basis of positive tuna catches (the most extreme case omitted 95% of observations) (figure 45). The models from the extended time series (1993-2000 plus 2005-8) suggested that: i) there is very little difference between the nominal and standardized CPUE series, ii) The CPUE in the latter period is substantially lower than the earlier period, and iii) there is no evidence for a

trend within the 2005-8 period. However, there is doubt as to whether the two data series are compatible, for several reasons: i) anecdotal evidence suggests that the fishery has changed between the two time periods (e.g. there is a large increase in bigeye nominal CPUE between the two time periods that is the opposite of the swordfish decline), ii) operational data which might be useful to quantify the targeting shift are not available, and iii) the units of catch differ between the two time series, and the conversion factor from catch in mass to numbers might not have been appropriate. The CPUE series from the period 1993-2000 was recommended for inclusion in the 2010 stock assessment.

62. The WPB endorsed the use of the Reunion CPUE series 1994-2000 in the assessment this year. The WPB recommended that La Reunion implement logbook and observer programmes to improve data collection, including the recording of high resolution operational data, so that this potentially useful time series can be used in the future.

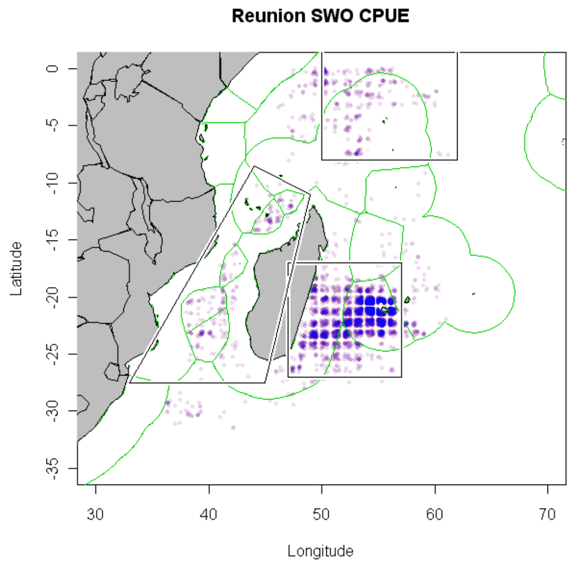


Figure 43. *Location of Reunion longline fleet sets 1993-2001. Full colour saturation indicates 20 or more sets. The standardization was conducted on the box that encompasses the island of La Reunion.*

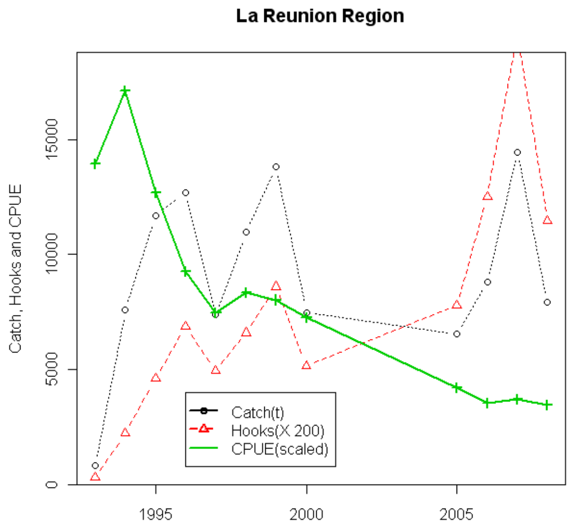


Figure 44. *Time series of logbook-reported Total Catch, Total Hooks and nominal CPUE (Total Catch / Total Hooks, scaled to fit on the same axes) for the REU region (1993-2008, with 2001-4 omitted)***.**

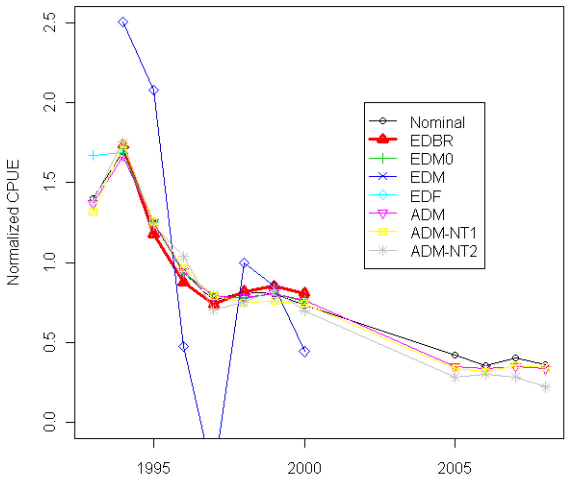
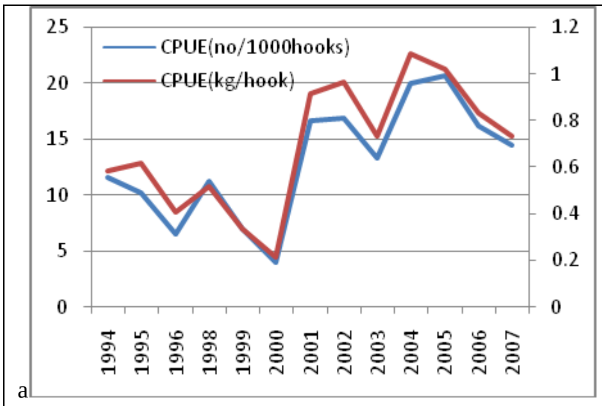


Figure 45. *Nominal and standardized CPUE series for the La Reunion fleet (scaled relative to their respective means over the 1994-2000 period). Model EDBR was recommended for inclusion in the stock assessment models.*

Nominal Spanish CPUE in the SW Indian Ocean

63. The nominal swordfish CPUE series for the Spanish fleet is provided as an additional indicator in the SW region (figure 46a). There is a strong increase in CPUE between 2000 and 2001 that has been attributed to increased catchability, through the adoption of 'American-style' gear. There may be a declining trend over the

last 4 years, but given the level of noise in the series, it is difficult to conclude that there is any consistent trend since 2001. The last update of the Spanish longline CPUE time series was presented in 2008 (IOTC-2008-WPB-06), based on both the SW and SE regions (figure 46b).



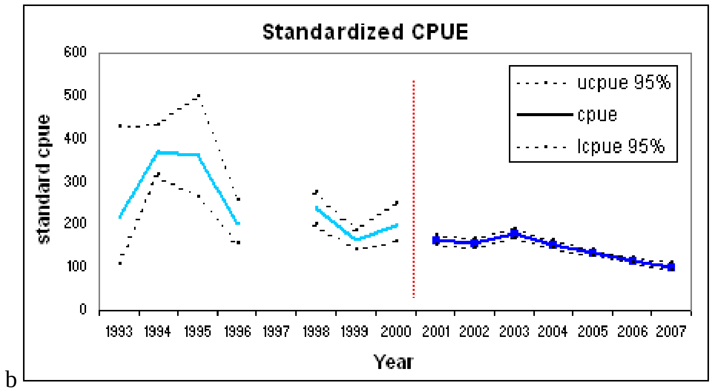
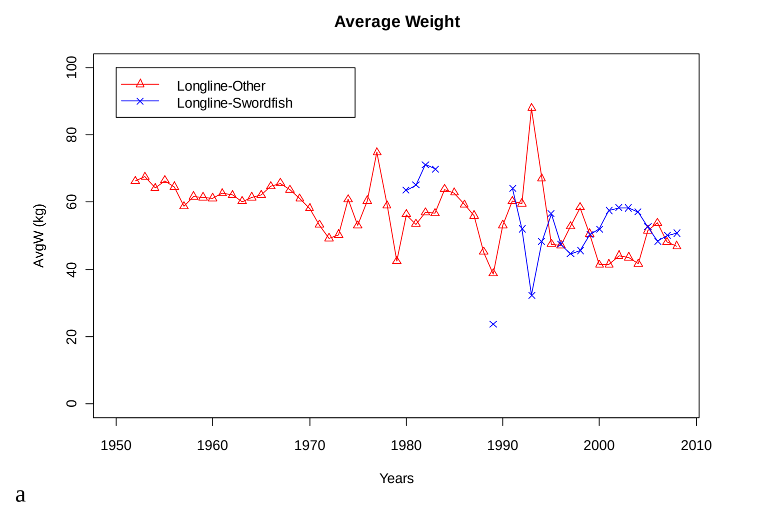


Figure 46. *Nominal and standardized Spanish swordfish CPUE in the SW Indian Ocean.*

AVERAGE WEIGHT TRENDS

64. The annual average weights of swordfish have been variable over time (Figure 47). The annual average weight for swordfish reported by longline fleets appears to show a decreasing trend, from around 60kg in 1970 to 50kg in recent years. Average weights estimated for other gears, especially gillnet, are around 20kg (not shown).

65. The WPB noted the numbers of swordfish being measured by the major fleets catching this species (Figure 47b) and reiterated its concern about the lack of size data being reported by some fisheries (as shown in Figure 14); detecting any trend in average size is likely to be influenced by low sample sizes, representativeness of samples for the Japanese fishery (as shown in Figure 17), discard practices and area fished.



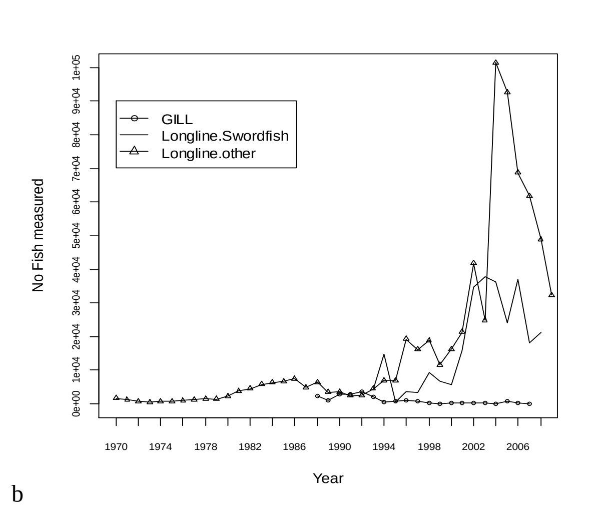


Figure 47. *(a) mean weights of swordfish estimated from longline samples reported by fleets targeting swordfish (Longline-Swordfish, fleets targeting only swordfish: Australia, EU-Spain, EU-Portugal, EU-UK, Kenya, Madagascar, Seychelles, Mauritius…) and other fleets (Longline-Other), including Japanese and Taiwanese longliners (b) and numbers of fish measured. Data as of June 2010. Broken lines represent linear trends estimated for each fishery. From document IOTC-2010-WPB-11.*

LENGTH FREQUENCY DISTRIBUTIONS FROM CATCH SAMPLES

66. There have been no major trends in the length composition of swordfish catches over time (figure 48); in particular, reductions in the numbers of large swordfish are not apparent. Most fish measured are between 135-195 cm long.

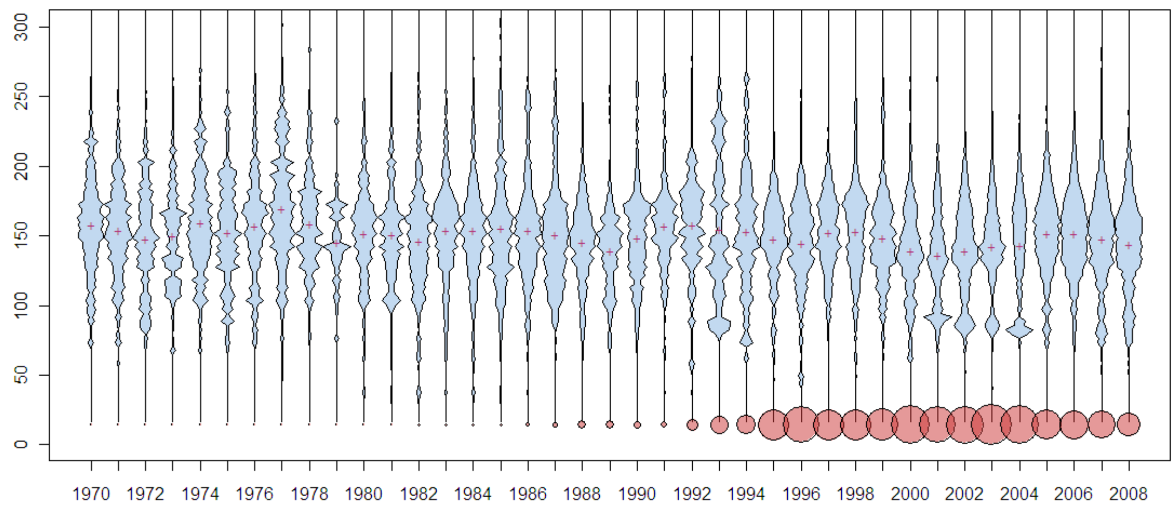


Figure 48. *Catch-at-size over time (violins) and total catch (red circles).*

The Reunion longline fishery

67. The mean annual average size of swordfish in the domestic fishery of Reunion (France) showed no trend over the period 1993-2008. The sample size for swordfish has, however, been decreasing steadily in the framework of the new sampling scheme; the number of swordfish sampled dropped from an annual average of 3,125 individuals sampled between 1994 and 2001 to 850 individuals between 2001 and 2008 (figure 49). Moreover, taking into account size fluctuation by season and by area, this index should be considered with caution. Increasing sample sizes by strata is recommended.

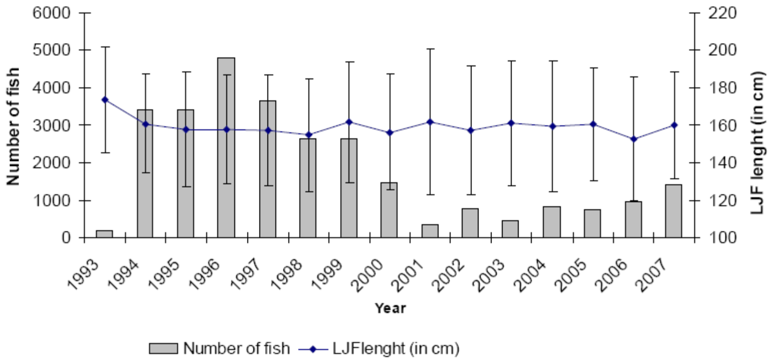


Figure 49. *Evolution of the mean size of the swordfish caught by the Reunion-based longline fleet between 1993 and 2007 (SIH Ifremer).*

TOTAL EFFORT

68. The total effort in hooks over time by the major longline fleets is illustrated in figure 50. The most notable recent trend is the halving of Taiwanese effort over the past three years.

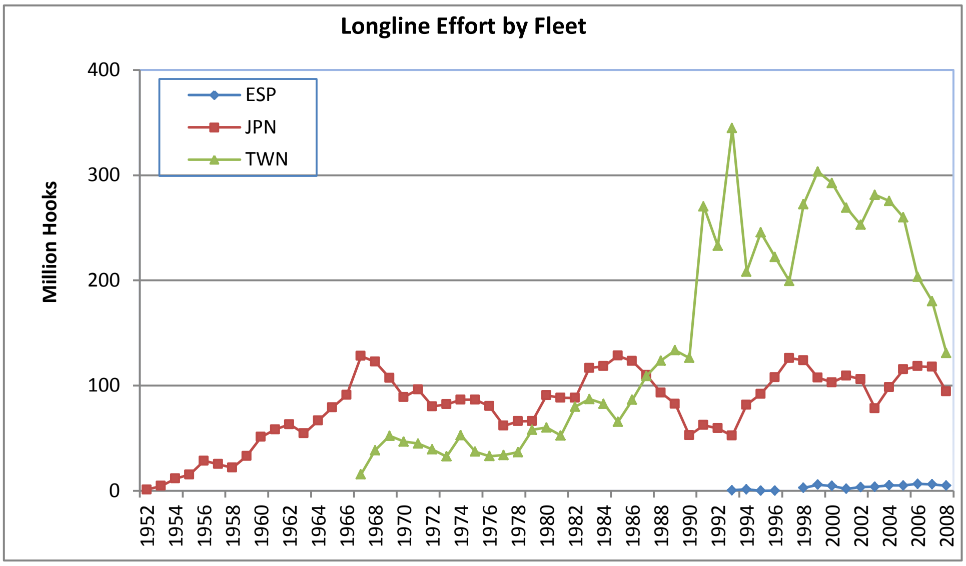
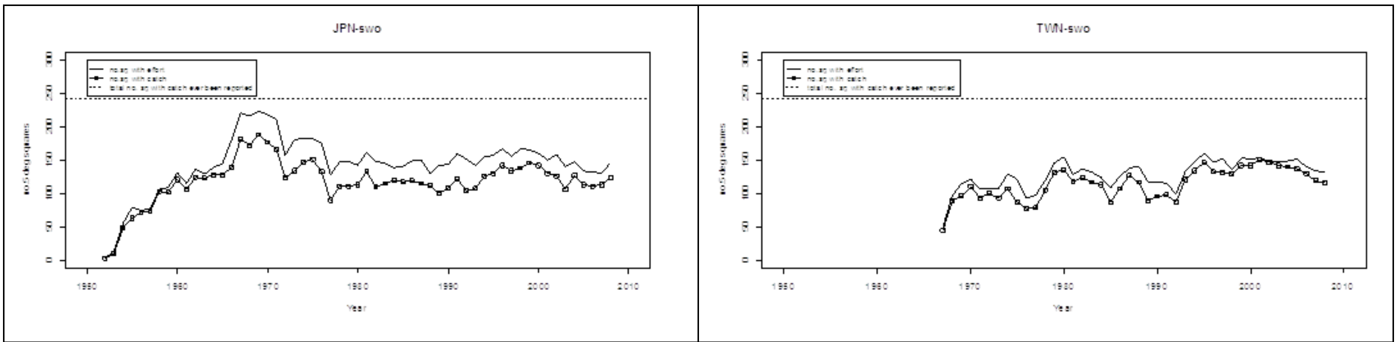


Figure 50. *Trends in effort over time for the Taiwanese, Japanese and Spanish longline fleets in the Indian Ocean.*

AREAS FISHED

69. The WPB noted that the expanding and contracting nature of the swordfish fishery over time might have important implications for the interpretation of CPUE as an index of relative abundance. Examination of the numbers of 5degree squares fished with swordfish catches compared to the total number of 5 degree squares fished (figure 51) shows that the Japanese and Taiwanese fishing grounds are of a similar size. In the case of Japan the change in area fished over time arise from an initial exploratory period and changing numbers of vessels. In the case of Taiwan,China, changes in the area fished may be influenced by the levels of logbook coverage over time. The gap between the two lines may reflect targeting practices. When the lines are close, this may indicate that swordfish is the target species. This is apparent for the Spanish fleet where the number of areas fished and number of areas having catches of swordfish are identical because swordfish is the target of this fleet.



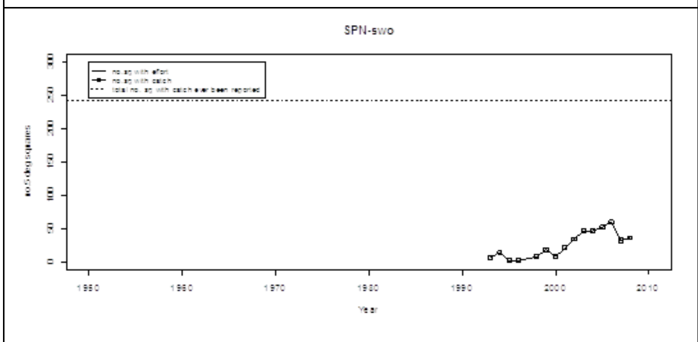


Figure 51. *The numbers of 5deg squares fished and with catches of swordfish reported by the major longline fleets catching swordfish in the Indian Ocean. From document IOTC-2010-WPB-11*

4.2. *Marlins and Sailfish*

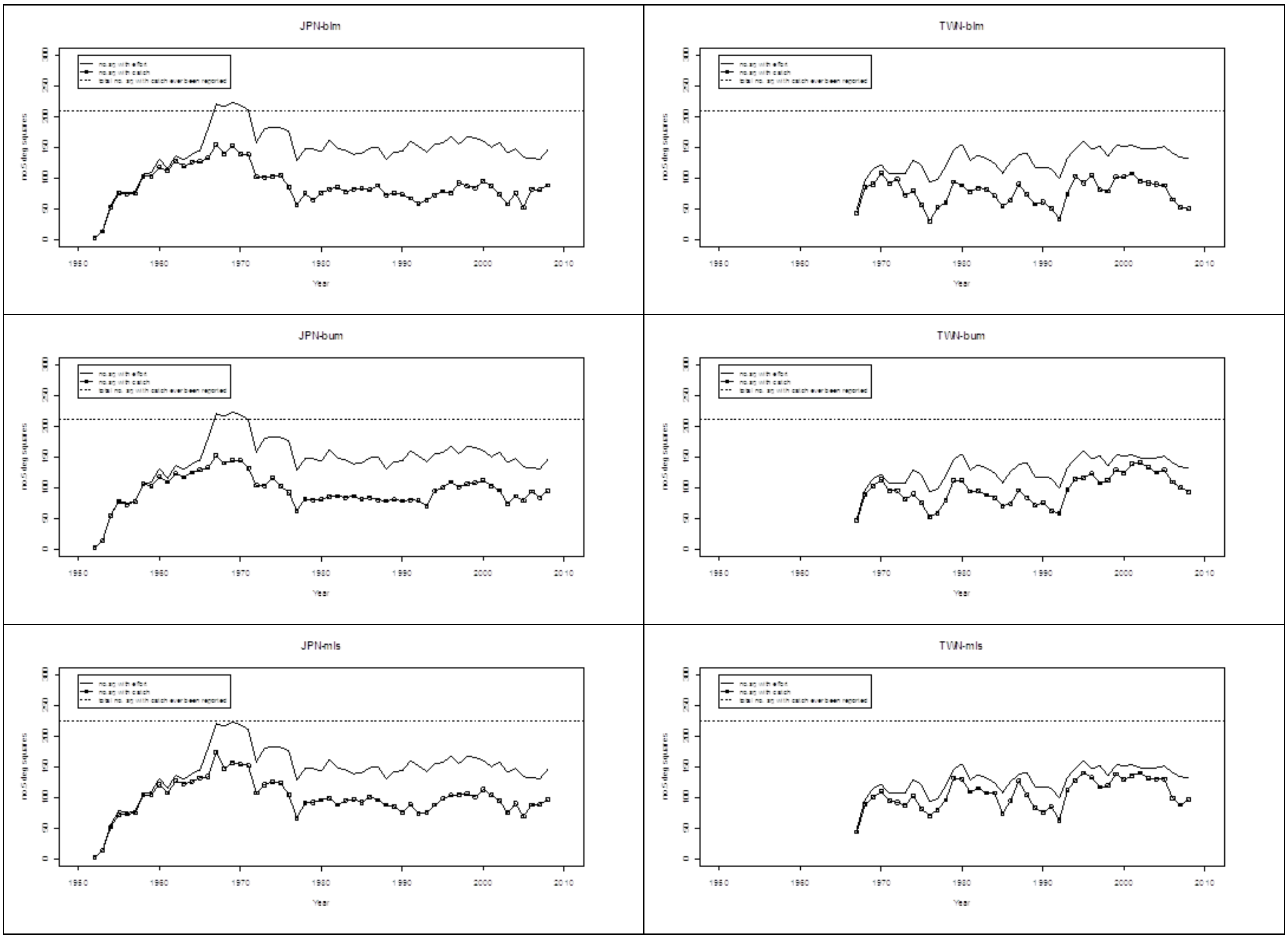
70. Marlins and sailfishes are highly migratory species taken in relatively minor quantities in the Indian Ocean compared to tunas and swordfish. They are not typically targeted by commercial fisheries, but they are targeted by many sport fisheries. Marlins and sailfish are large predators that play an important role in pelagic ecosystems as they may influence the abundance, distribution and behaviour of a wide range of pelagic species.

71. Given the paucity of data and the intermittent nature of the fisheries exploiting marlins and sailfish, many of the quantitative stock assessment approaches used by scientists for tunas and swordfish cannot be used on these species and a range of more qualitative stock status indicators invariably become the only available means to follow the status of these populations.

72. Following a request from the WPB in 2008, stocks status indicators have been developed for marlins and sailfish.

i. Blue and black marlins are mainly caught by longlines and gillnets. Their catches, stable from the beginning of the longline fishery until the mid 1980s, increased dramatically during the early 1990s (figure 4a and 4b). Record catches of blue marlin where observed in 1997, while the catches of black marlin peaked at around 5,500 tonnes in 2006 with catches in 2007-08 at around 5,000 tonnes. For striped marlin, mainly caught by the longline fleets, the level of catches has been highly variable since 1958, but showing a slight increasing trend up to the mid-1990's (figure 4c). Catches dropped in recent years with current catches at around 3,000 tonnes.

ii. Annual percentage of fishing effort by area: figure 52 describes the number of squares fished and number of squares with catch of the 3 species of marlins and sailfish for both the Japanese and Taiwanese fleets. Proportionally, the Taiwanese fleet bycatch of marlins more closely reflects the distribution of effort than the Japanese fleet, which might be a consequence of differences in gear configuration, fishing practices, spatial distribution of effort and sample sizes (fleet size). This indicator shows that the population of marlins (bycatch species) are widely distributed.



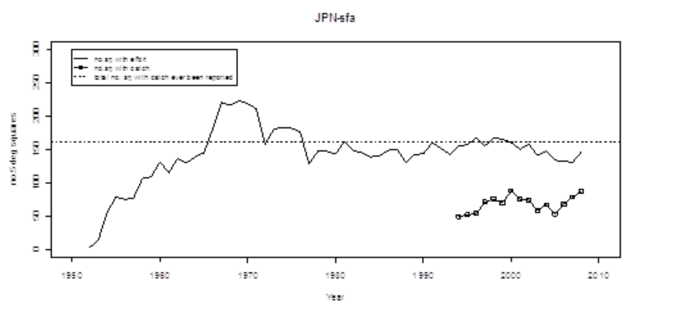


Figure 52. *The numbers of 5deg squares fished and with catches of blue marlin (BUM), black marlin (BLM), striped marlin (MLS) and sailfish (SFA) reported by the major longline fleets in the Indian Ocean. From document IOTC-2010-WPB-11*

73. Figure 53 shows the trends of nominal CPUE for marlins in two of the major historical fishing zones of the Indian Ocean. A continual decline in this indicator over time may signal that the stock is being depleted. Around the Seychelles, CPUE's show a variable but decreasing trend for each species since the start of industrial fisheries in 1952. A similar trend is exhibited for marlins in north-west Australia (another of the major historical fishing zones).

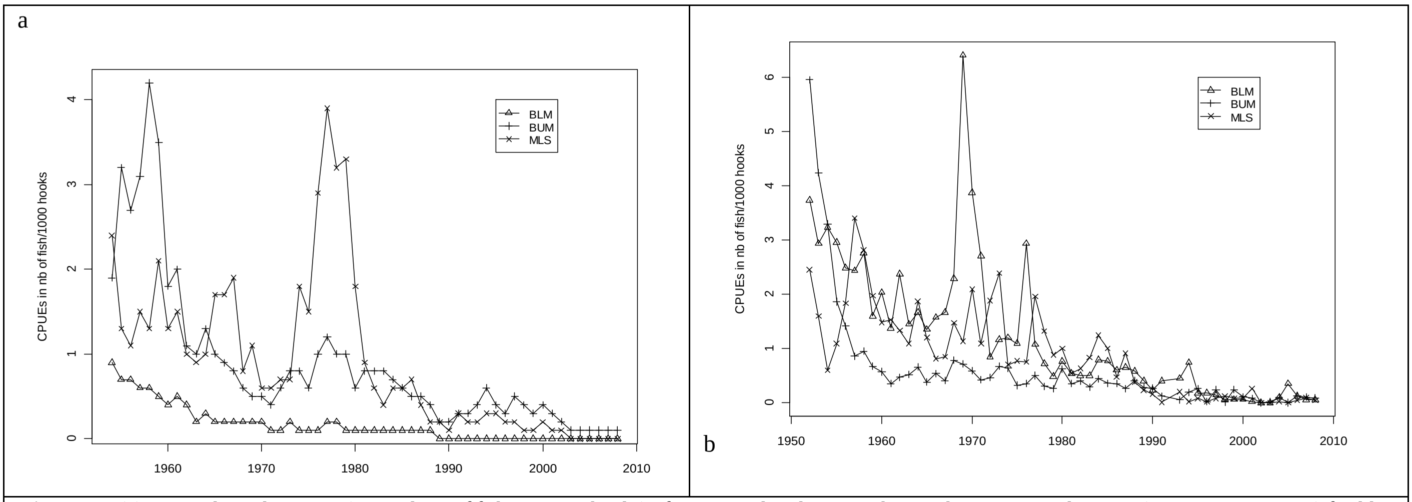


Figure 53. *(a) nominal yearly CPUE (in numbers of fishes / 1000 hooks) of Japanese longliners in the North West Australia area (10-20°S,110-120°E) for blue marlin (BUM), striped marlin (MLS) and black marlin (BLM) (b) nominal yearly CPUE (in numbers of fishes / 1000 hooks) of Japanese longliners in the area around Seychelles Islands (10°N-10°S,50-70°E). From document IOTC-2010-WPB-11*

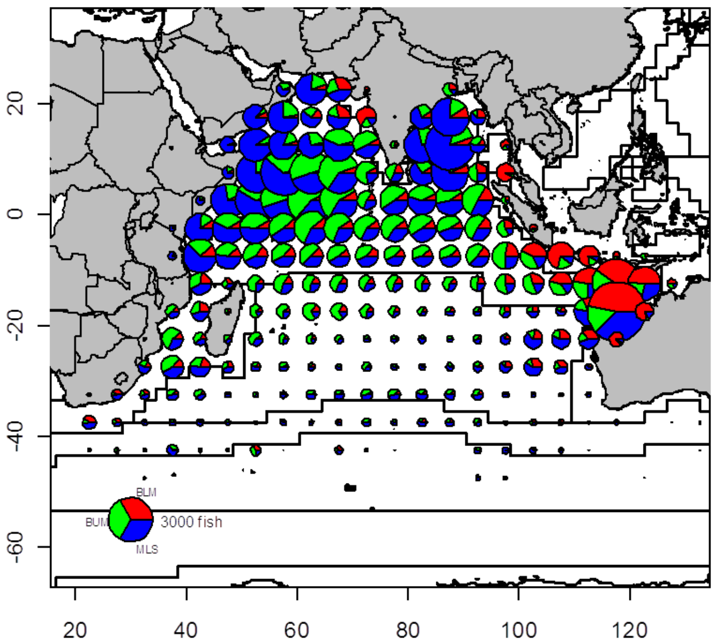


Figure 54. *Average yearly catches of marlins in the IO reported by longline fleets during the 1952-2008 period*

74. Figure55 illustrates an indicator for each marlin species based on the annual total of 5 degree squares in which at least 10 fish were caught. For all species, the index increased from 1952 to 1967, then declined until 1976-77. Since the late 1970s, the index has been variable and without clear trends. The black marlin index is typically lower than those of the other marlins, while the trends of blue marlin and striped marlin indices are similar. A continual decline in this indicator over time may signal that the stock is being depleted.

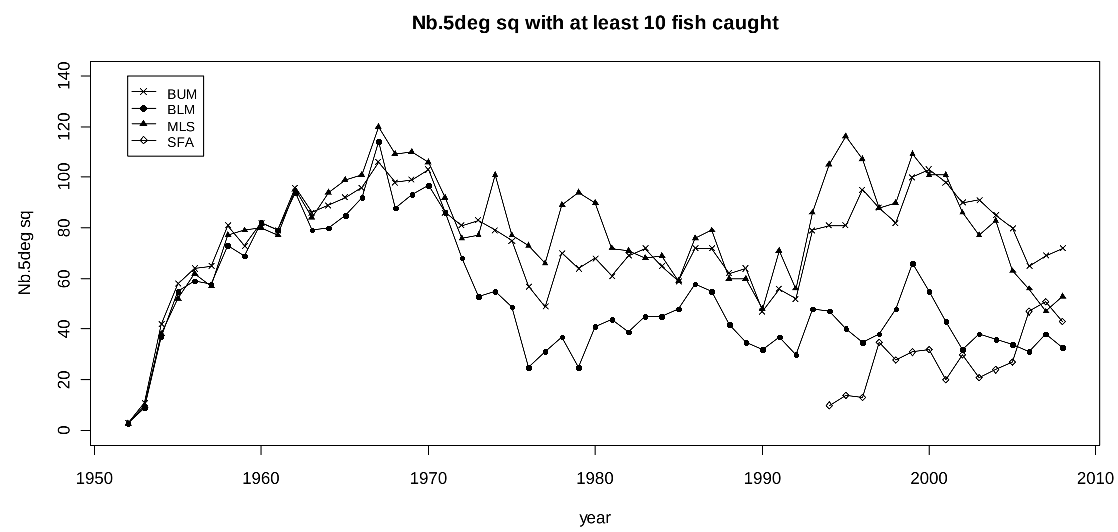
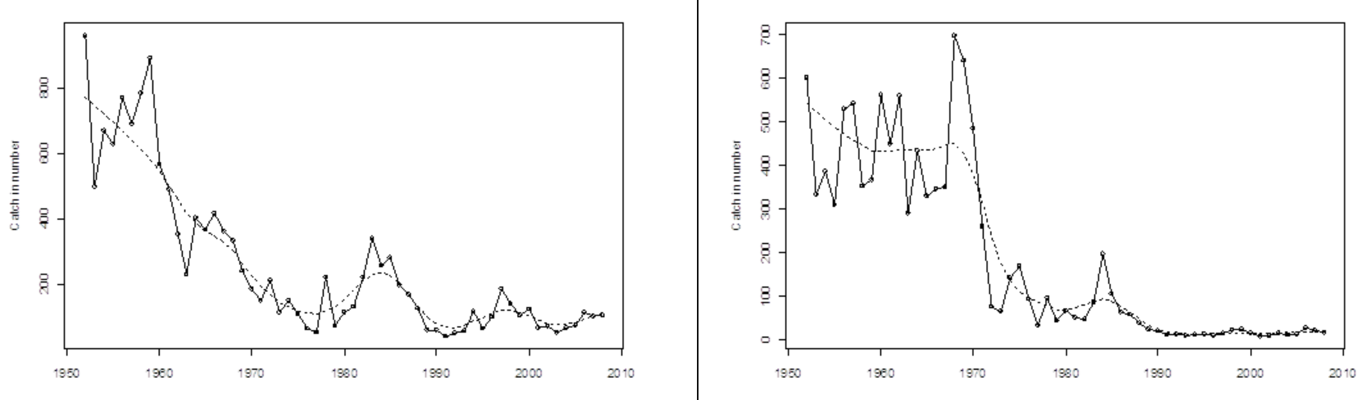


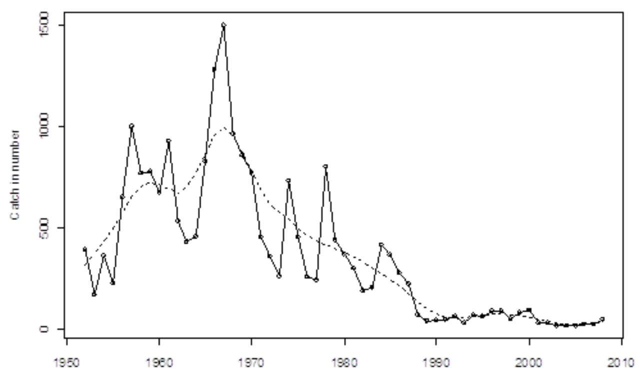
Figure 55. *Number of 5° squares with a minimal catch of at least 10fish of black (BLM), blue (BUM) and striped marlin (MLS) and Indo-Pacific sailfish (SFA) in the Indian Ocean. From document IOTC-2010-WPB-11*

75. Figure 56 illustrates trends in the annual mean of the three highest monthly catches of each marlin species by Japanese longliners taken by 5 degree squares by month across the entire Indian Ocean. A continual decline in this indicator over time may signal that the stock is being depleted. Each marlin species is showing a variable but declining trend in this indicator since the start of the industrial fishery.



a

b



c

Figure 56. *Annual mean of the 3 highest monthly catches of blue marlin (a) black marlin (b) and striped marlin (c)by Japanese longliners taken by 5° squares (in numbers of fishes) for the period 1952-2008, with the general trend showed by a Friedman super-smoother. From document IOTC-2010-WPB-11*

76. The status of all marlin stocks remains uncertain. While these species are not important for their market value, they are of great interest for scientists, due to their potential role in pelagic ecosystems (as billfishes are probably playing a keystone role in some areas), and also for sport fisheries which often provide a major input to local economies.

77. The WPB noted that the updated indicators presented this year for the marlins are still very preliminary and their interpretation should proceed with caution. There was considerable uncertainty about the degree to which the indicators represent abundance.

78. Bearing in mind the uncertainties in catch data, the trend of total yearly catches does not show significant declines for the blue and black marlins in recent years in spite of increasing trends in fishing effort exerted by the combined artisanal and industrial fisheries. However, striped marlin catches have been declining since the early 1990s, possibly indicating overfishing.

79. Conflicting trends between marlin catches and CPUEs may be explained by several factors, in particular:

- poor data quality: under reporting and miss-identification of marlins are currently overarching concern.
- changes in fishing areas: movement of some effort towards areas with lower concentration of marlins.
- gear configuration and targeting practices: technological changes targeting an increase of tuna catch rates (*eg.* changes in longline fishing depth, number of hooks between floats) may have had a potentially negative impact on billfish catchability and CPUEs.
- changes in billfish behaviour

80. Current catch of sailfish in the Indian Ocean has declined from a high of 30,000 tonnes. However, this species continues to be widely underreported by both industrial and artisanal fleets. In addition to the general lack of catch and effort data, the historical catch and effort data of the Japanese longline fleet include a mixture of Indo-Pacific sailfish (*Istiophorus platypterus*) and short spearfish (*Tetrapurus angustirostris*)

81. The WPB identified that these trends are similar to the major declines observed early in the development of the Indian Ocean longline fisheries, for which the underlying causes remain uncertain, a situation which also applies in the analysis of the WPB. However, aspects of the biology, productivity and fisheries for these species, combined with the lack of data on which to base a more formal assessment, is a cause for considerable concern. The WPB recalled its recommendation in 2009 that a major research project on billfish be developed for the Indian Ocean as soon as possible, which should include improved statistical data collection for industrial and artisanal fisheries, collection of data for the sport fisheries, biological research (*i.e.* growth, reproduction and studies of stock structure using tagging techniques among others), and development of stock assessment techniques dedicated to these species (Appendix IV). The WPB agreed to work with The Billfish Foundation and other interested parties in the preparation of a Project Proposal focusing on sport fisheries, and to identify possible donors for its execution.

5. STOCK ASSESSMENTS OF BILLFISH

5.1. *2010 stock assessment for Swordfish*

82. A range of quantitative modelling methods were applied to the swordfish assessment in 2010, 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-2010-WPB-05, 12, 13 and 14. Each model is summarized in the sections below.

AGE-AGGREGATED PRODUCTION MODEL (ASPIC) IOTC-2010-WPB-12

83. During the 2010 WPB, an Age-Structured Production Model Including Covariates (ASPIC ver. 5.05) was applied to a stock assessment of swordfish in the Indian Ocean (1980-2008). Using standardized CPUE (Japan, Taiwan and La Réunion, all weighted equally in the model fitting) (figure 57), ASPIC analyses were conducted.

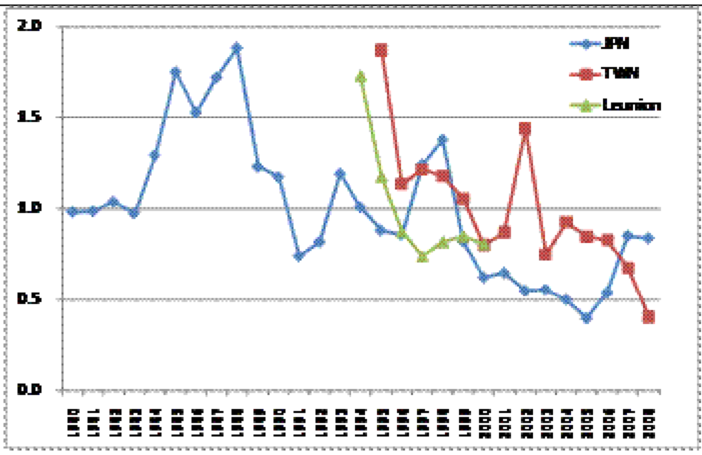
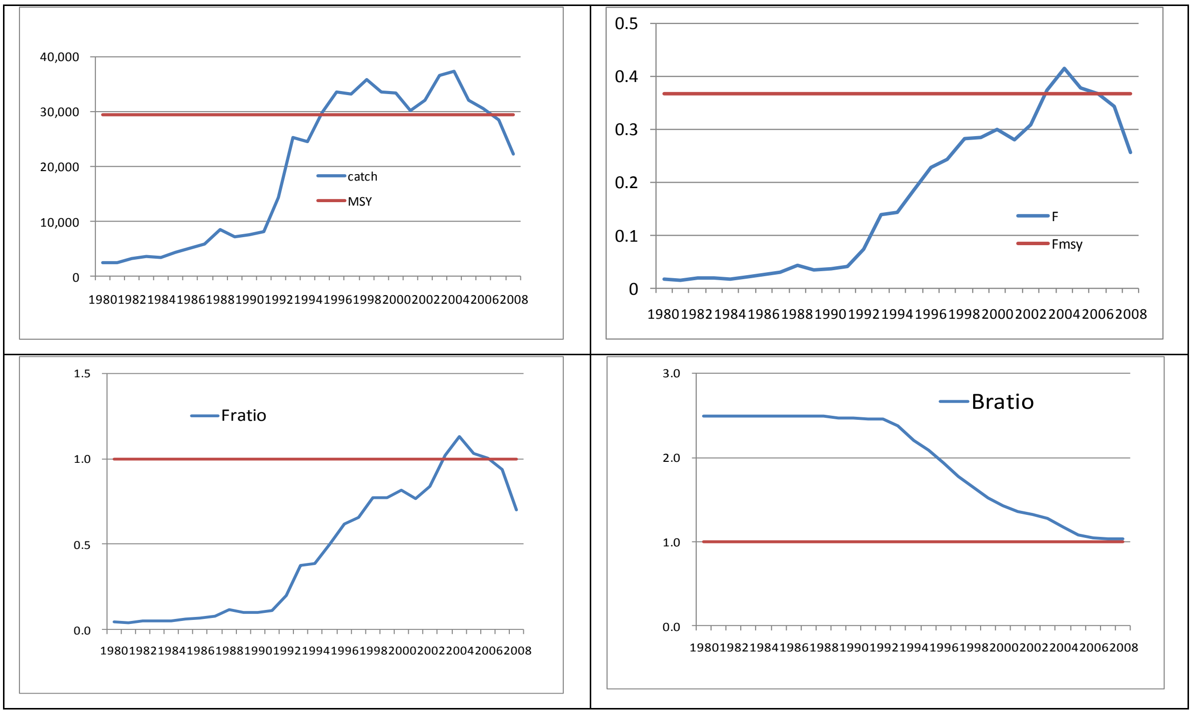
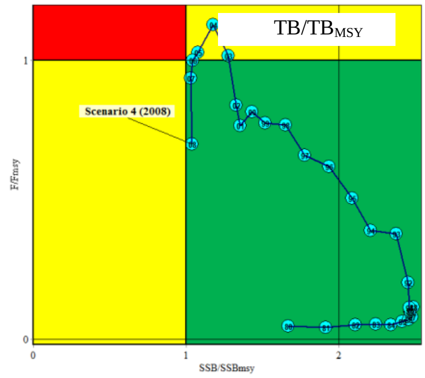


Figure 57. *Three standardized AI (Abundance Index) (Japan, Taiwan and Ra Reunion) used in the stock assessment by ASPIC. AI is scaled by its average value.*

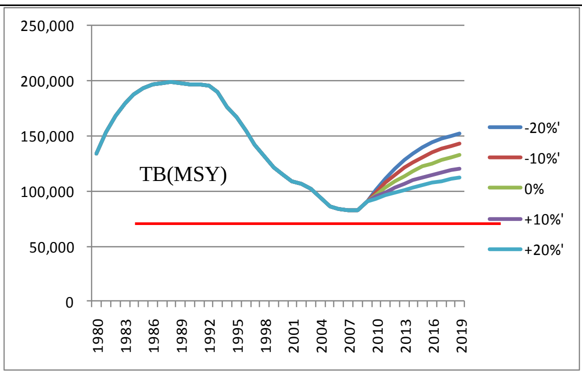
84. The model results indicate that in 2008, MSY=29,420t, F=0.257, F_{MSY}=0.368, F(ratio)=0.699, TB(Total Biomass)=83,200 t, TB_{MSY}=73,759 t, B(ratio)=1.128. Figure 58 shows results of the stock assessment by ASPIC and figure 59 shows future projection for 10 years (2009-2019) based on 5 catch scenarios. Based on these results, over-fishing does not appear to be occurring (due to the low catch level in 2008), however the total biomass is close to the B_{MSY} level. At the current level of catch, the stock will remain above B_{MSY}.



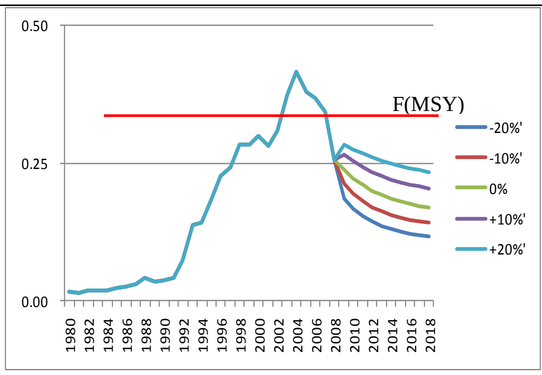


Stock trajectory (Kobe diagram)

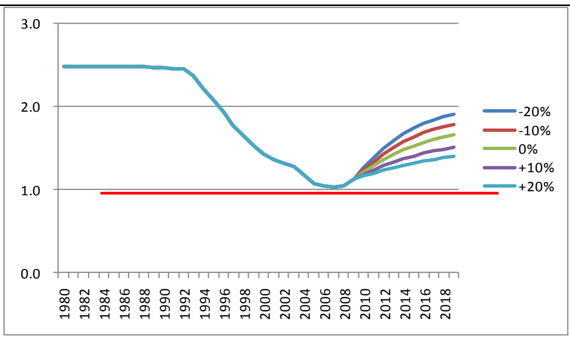
Figure 58. *Results of the stock assessment by ASPIC*



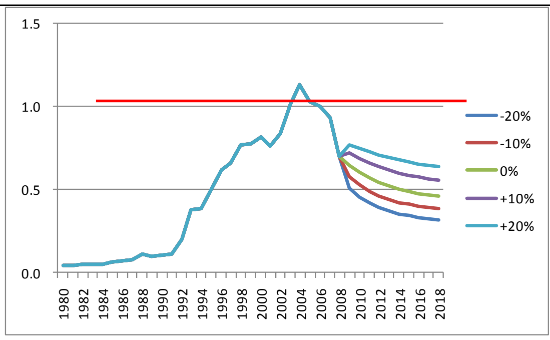
Total biomass



F



TB ratio



F ratio

Figure 59. *Future projection (2009-2019) by 5 catch scenarios (+20%, +10%, 0%, -10%, -20%) of the 2008 catch (22,335t)*

85. There is a high probability of not exceeding MSY reference levels, even with a 20% increase in catch sustained over the next 10 years, due to the current status of the stock which has shown an improved prognosis given recent levels of effort (figure 50), catch and fishing mortality (Table 5).

86. The WPB noted that the results obtained in the 2010 assessment were similar to the previous year. In terms of the biomass growth trends early in the early 1980's, it was recognised that this was an artefact of the model caused by the very low catches at the start of the series, as identified by other studies using this model, and does not affect the current stock status estimates.

Table 5. *Kobe 2 Strategy Matrix for comparing management options based on ASPIC. Table entries are the probability of violating the MSY-related reference points for three constant catch projections, i.e. current catch level (2008; i.e. 0% change), catches 20% less than current and catches 20% above current catch, reported for 3 year and 10 years in the future. The catch levels are provided in brackets.*

Stock status Reference Point	Projection Time frame	Alternative Catch Projections			Data Rich/Data Poor
		C(2008) -20%	C(2008) (22,333	C(2008)+20%	

		(17,866 t)	t)	(26,800 t)	
P(Ft>Fmsy)	In 3 years	0.001	0.004	0.22	Moderate
	In 10 years	0.001	0.004	0.14	Moderate

Stock status Reference Point	Projection Time frame	Alternative Catch Projections			Data Rich/ Data Poor
		C(2008) -20% (17,866 t)	C(2008) (22,333 t)	C(2008)+20% (26,800 t)	
P(Sbt<SBmsy)	In 3 years	0.158	0.194	0.260	Moderate
	In 10 years	0.028	0.050	0.160	Moderate

AGE-STRUCTURED INTEGRATED ANALYSIS (ASIA) IOTC-2010-WPB-13

87. Document IOTC-2010-WPB-13 described the updated application of an age-structured assessment model to swordfish in the Indian Ocean. This study explored estimation of the exploitation rates and the spawning biomass by fitting the model to all catch and length-frequency, CPUE series of Taiwan, Japan, La Reunion and Seychelles, and biological parameters (growth, sex ratio and maturity). The fleet-aggregated fishing intensity increased substantially to more than 50% of FMSY since the early 1990s due to increasing catch, and this resulted in an decrease of spawning biomass (figure 60). Based on the sensitivity analysis for different assumption of natural mortality (M) and steepness of stock-recruitment relationship (h), the results indicated that current fishing intensity was about 44-77% of FMSY and the spawning biomass maintained at about 40-60% of S0 and about double of SMSY. The most pessimistic stock status occurred when assuming a relatively high value of M and a relatively low value of h (Table 6). Based on the Kobe plot, however, the results of this study indicated that the stock status of swordfish in the Indian Ocean might not be in a condition of overexploitation (figure 61).

Table 6. *The value of the MPD estimates of the quantities of management interest for the base-case analysis and the sensitivity analyses.*

	MSY	S_{MSY}	S_{2008}/S_0	S_{2008}/S_{MSY}	F_{2008}/F_{MSY}
Base-case	34210	72132	0.44	2.00	0.51
M = 0.15	37644	207182	0.59	2.39	0.44
M = 0.30	33025	47616	0.39	1.89	0.54
h = 0.95	35900	63181	0.44	2.25	0.47
h = 0.8	31201	87502	0.44	1.70	0.59
h = 0.6	25442	119343	0.46	1.40	0.77

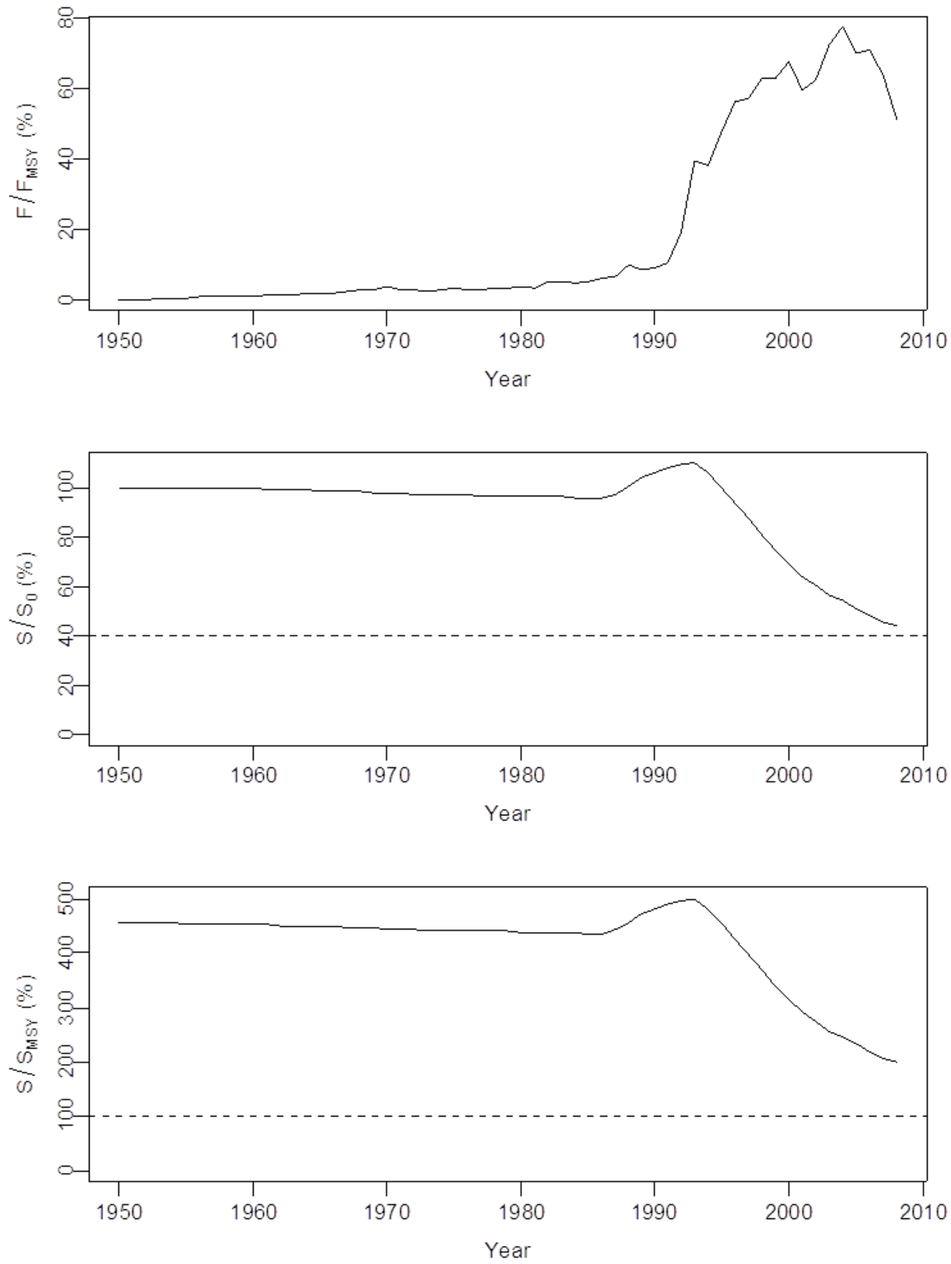


Figure 60. *Time trajectories of MPD estimates for the spawning biomass as a ratio of the unexploited spawning biomass (S2008 /S0), the spawning biomass as a ratio of SMSY (S2008/SMSY) and the fleet-aggregated fishing intensity as a ratio of that at which MSY is achieved (F2008/FMSY) for base-case analysis.*

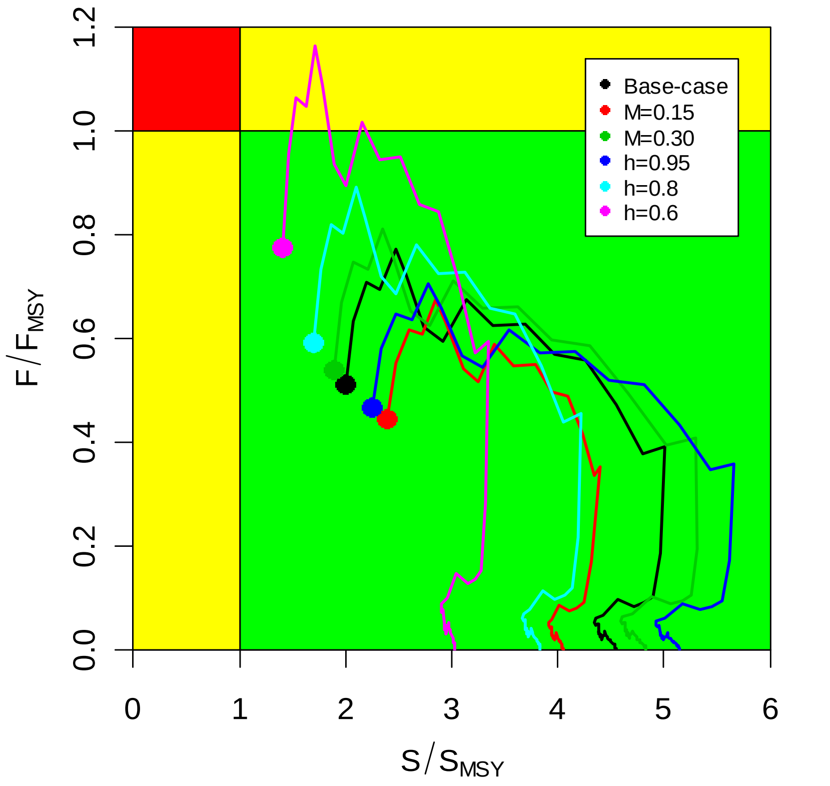


Figure 61. *Kobe plot for swordfish in the Indian Ocean based on different assumptions of natural mortality and stepness of the stock-recruitment relatonship.*

88. The WPB noted the relatively poor fits to the CPUE series by the model but recognised that this was an inherent problem resulting from the inclusion of a large number of fisheries with conflicting trends in CPUE.

89. Following the sensitivity analyses conducted at the WPB in 2009, and based on subsequent recommendations, dome-shaped selectivity was adopted in 2010, which was considered to have improved the model in terms of fits to size data.

SS3 – SPATIALLY DISAGGREGATED INTEGRATED ANALYSIS (IOTC-2010-WPB-05)

90. An update of the Indian Ocean swordfish (*Xiphias gladius*) stock assessment using "Stock Synthesis 3" (SS3) software was presented. The fish population is disaggregated by age, sex, and 24 fleets in 4 regions, iterated on a quarterly time-step from 1950-2008. Parameters are estimated by fitting to catch-at-length data from 18 fleets and 10 sub-regional CPUE series (Japan and Taiwan in all areas plus La Reunion in the SW and Seychelles in the NW). The approach was initially developed as an integrated framework to explore the relationships and identify the conflicts among the disparate sources of data and biological assumptions. The current application is presented as an assessment, with emphasis on uncertainty in key parameters that are poorly quantified and difficult to estimate for this species (steepness, M, growth rates, reliability of different relative abundance indices). The model is spatially structured with very low migration between areas, and a shared spawning population. There are annual recruitment deviations, but the estimated distribution of recruits among areas is constant over time.

91. Table 7 lists the MPD estimates for reference points from 6 specifications. Table 8 provides the constant catch projection results for a typical model (7, chosen as a central reference case that is most similar to the ASIA life history assumptions). The MSY reference points are highly variable among the model specifications, while the depletion estimates are much more stable. Aggregate B and F time series are shown by model in figure 62 and by sub-region for model 7 in figure 63. While all models suggest that the stock status is currently reasonable with respect to MSY reference points, the projections from the least productive specification (steepness=0.7, slow growth, low M and late maturity) suggests that current catches may not be sustainable. Kobe plots for the most optimistic and pessimistic models (3,5) are shown in figure 64. Given the biological uncertainty and the poor fits among several conflicting CPUE trends, the uncertainty in this analysis is not well represented. The most notable

problem is the failure to explain the CPUE declines estimated in the SW region for all fleets (*e.g.* figure 65). It appears that the dynamics of the SW region need to be further decoupled from the rest of the Indian Ocean (in terms of spawning, recruitment, and possibly migration) to explain the conflicting signals (though much of the problem is probably attributable to biases in the CPUE series).

Table 7. *Alternative SS3 specifications applied to the whole Indian Ocean swordfish population*

Model	F/F_{MSY}	B/B_{MSY}	B/B_0	*MSY*
2 Steepness=0.9, slow life history	0.45	3.14	0.47	26
3 Steepness=0.7, slow life history	0.78	1.86	0.47	19
4 Steepness=0.9, slow life history, TWN CPUE down-weighted	0.51	3.03	0.46	25
5 Steepness=0.9, fast life history	0.33	2.15	0.52	46
6 Steepness=0.9, size data down-weighted	0.49	2.68	0.40	26
7 Steepness=0.9, intermediate life history, (i.e. consistent with ASIA)	0.32	3.29	0.55	32

Table 8. *Results from deterministic projections from SS3 model 7.*

Catch Projection	B_{2011}/B_{MSY}	B_{2018}/B_{MSY}	B_{2011}/B_{2008}	B_{2018}/B_{2008}	B_{2011}/B_0	B_{2018}/B_0
0.8 C(2008)	3.12	3.25	0.95	0.99	0.52	0.54
0.9 C(2008)	3.10	3.07	0.94	0.93	0.52	0.51
1.0 C(2008)	3.08	2.89	0.94	0.88	0.51	0.48
1.1 C(2008)	3.06	2.71	0.93	0.83	0.51	0.45
1.2 C(2008)	3.03	2.53	0.92	0.77	0.51	0.42

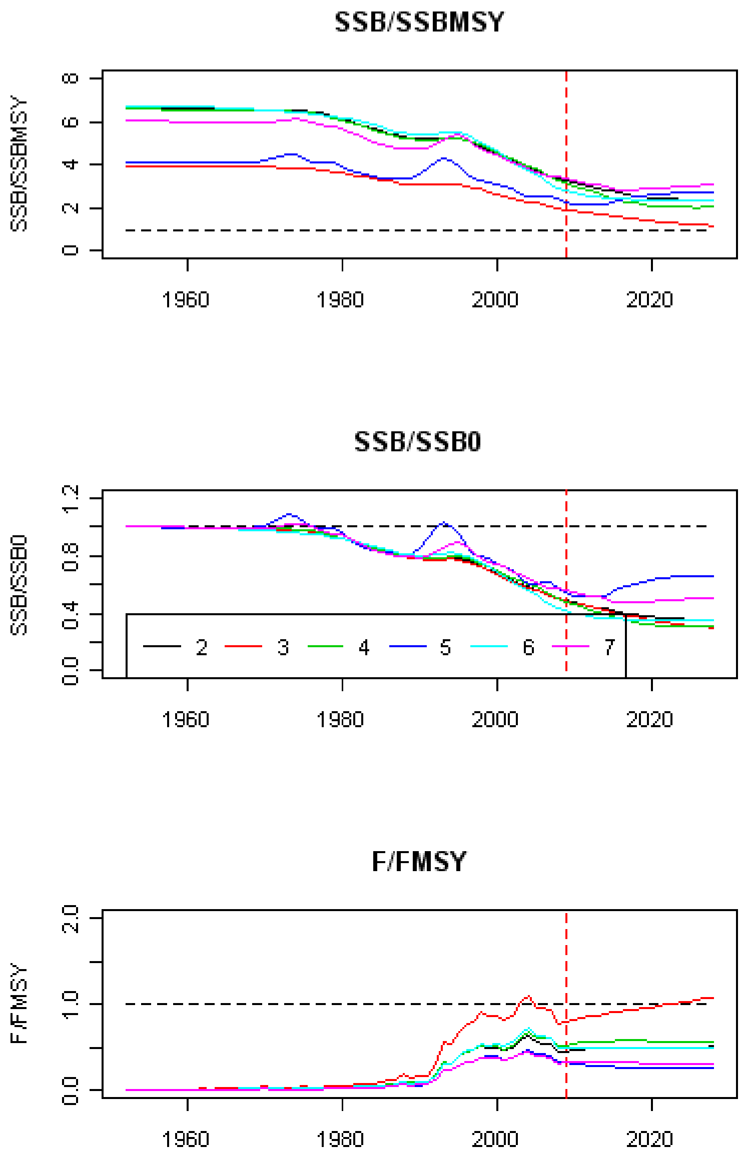


***Figure 62.**. Time series of B and F reference points from the 6 SS3 models described in **Table 7**including 20 years of current catch projections (starting at the red broken line in 2009).*

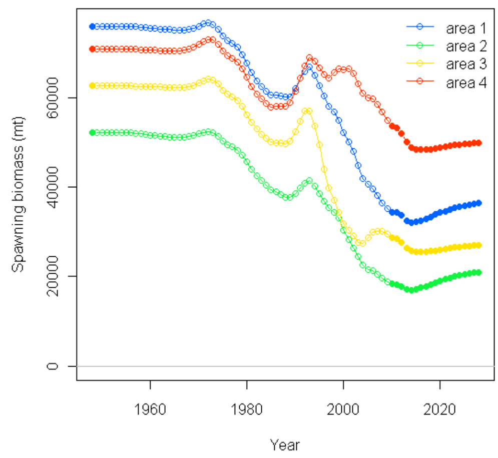


***Figure 63.**. Estimated spawning biomass by region over time (including 20 year current catch projections, solid points) for SS3 model 7.*

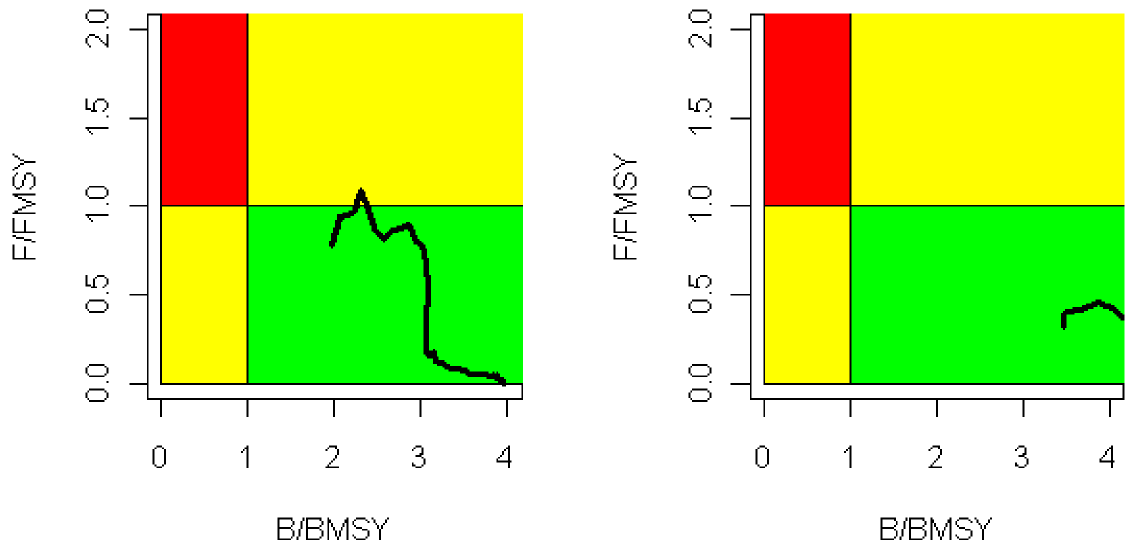
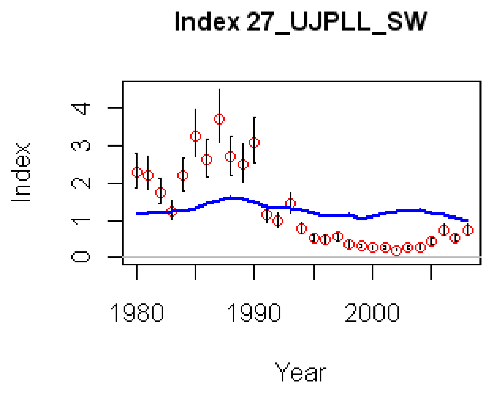
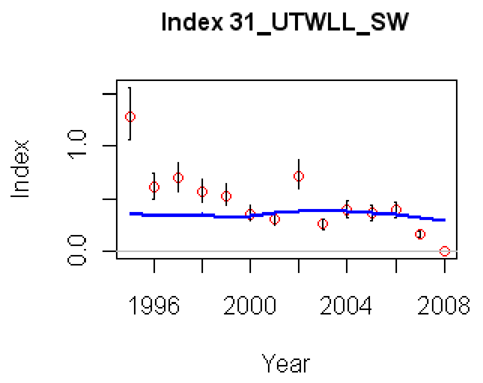


Figure 64.. *Kobe plots for the MPD estimates from the most pessimistic (model 3) and optimistic (model 5) SS3 specifications (i.e. lowest and highest MSY).*





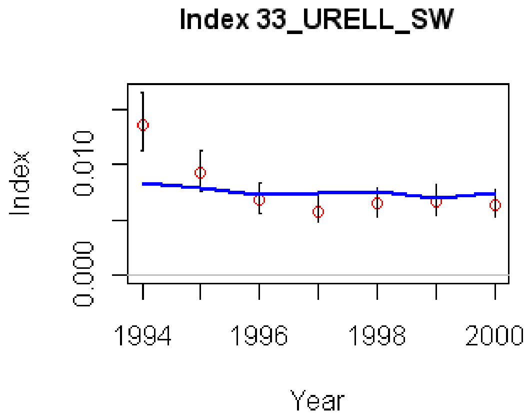


Figure 65.. *Example fit to the CPUE series in the problematic SW region for the SS3 models (model 7 illustrated). Top left is the Japanese, top right Taiwanese and bottom left La Reunion.*

92. The WPB noted that the aggregate stock status estimates were generally similar to ASIA and ASPIC, but that the poor fit to the SW region CPUE remained a concern. Alternative methods for examining the depletion in the SW were encouraged.

SCAM – STATISTICAL CATCH-AT-AGE MODEL (IOTC-2010-WPB-14)

93. During the WPB, a statistical catch-age model (SCAM) was fit to catch and CPUE data in the SW region of the Indian Ocean. This model was not fit to catch-at-age or catch-at-length (composition data) due to time constraints; therefore, age-selectivity was assumed and not estimated internally. A logistic function was used to model age-specific selectivity with the 50% vulnerability fixed at age 3, and a standard deviation of 0.75 years.

94. The following assumptions were made:

- M = 0.23 and is age-independent and time invariant.
- Growth and weight at age is constant.
- All CPUE indices are proportional to abundance with lognormal errors and a coefficient of variation arbitrarily set at 0.1.
- Recruitment follows a Beverton-Holt form with an informative prior on steepness, Beta (alpha=8,beta=5).
- Age selectivity is logistic with a mean age of 3 years and a standard deviation of 0.75 years.

95. Two alternative scenarios for the SW Indian Ocean were presented: CPUE indices from JPN LL, TWN LL and the La Réunion fishery were all fit, with the exception of the 2008 index for the TWN LL fishery. In the second scenario, the entire TWN LL CPUE index was removed from the fitting. Kobe plots of spawning stock biomass relative to SB_{msy} and fishing mortality relative to F_{msy} are shown in Figure 67a and b.

96. Scenario 1 (figure 66a) resulted in a median estimate for MSY 6,258t (and 90% credible interval, or CI of 5,455t and 7,138t), with corresponding estimates of F_{msy} and SB_{msy} of 0.367 (0.29 and 0.45 CI) and 4,717t (3,000 t and 7,277t CI), respectively (note these estimates result in an extremely productive stock with a steepness value of 0.978). Median estimates of spawning biomass depletion (SB_t/SB_0) were 3.2% with a 90% CI of 1.8% to 5.5%.

97. Scenario 2 (figure 66b) resulted in a similar median estimate for MSY of 6,357t (5,500 t and 7,266t CI) as that of Scenario 1. Median estimates of F_{msy} were 0.39 (0.31 and 0.48 CI) and median estimates of SB_{msy} were 4,160t (2,667t and 6,292t CI). Estimates of the steepness parameter for Scenario 2 are also similar to Scenario 1 at 0.984. Estimates of spawning biomass depletion were 8.0% (5.34% to 11.35% CI).

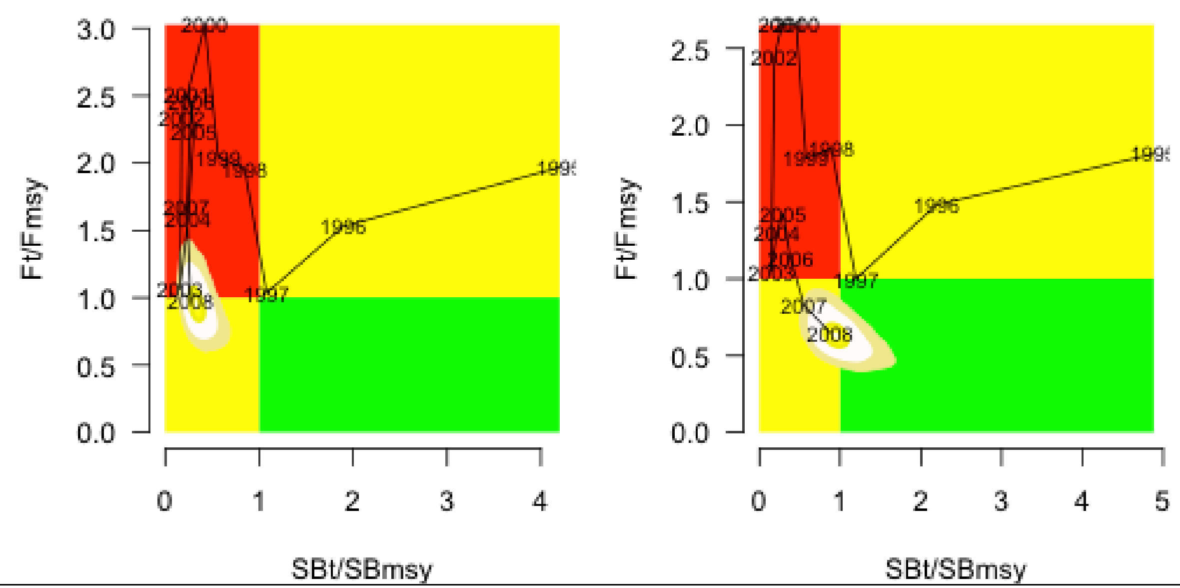


Figure 66. Kobe plots illustrating the results of Scenario 1 (a) and Scenario 2 (b) of the SCAM model for swordfish in the SW region of the Indian Ocean. The fried egg represents uncertainty (obtained from posterior integration using a Metropolis Hastings algorithm), where each color change spans the 5th, 25th, 75th and 95th percentiles

98. Future projections of spawning stock biomass and fishing mortality rate scenarios are based on 5 catch levels ranging from -20%, -10%, 0, 10% and 20% changes in the 2008 catch level. Probabilities of exceeding MSY based reference points are based on posterior samples and future recruitment variability based on a CV of 0.4.

99. A Strategy matrix for setting management measures based on Scenario 1 (S1) and Scenario 2 (S2) is presented in Table 9. The top part of the table is the probability of exceeding the F_{msy} fishing mortality rate for a fixed catch level and the bottom table is the probability of the spawning biomass falling below the SB_{msy} in 2011 and 2018 for a fixed catch level.

Table 9. *Kobe 2 Strategy Matrix for Setting Management Measures based on SCAM for the SW region. Table entries are the probability of violating the MSY-related reference points for three constant catch projections, i.e. current catch level (2008; i.e. 0% change), catches 20% less than current and catches 20% above current catch, reported for 3 year and 10 years in the future. The catch levels are provided in brackets*

Stock status Reference Point	Projection Time frame	Alternative Catch Projections			Data Rich/ Data Poor
		C(2008) -20% 5,140 t	C(2008) 6,426 t	C(2008)+20% 7,711 t	
P(Ft>Fmsy)	In 3 years	S1<0.01 S2 <0.01	S1 0.494 S2 0.031	S1 0.242 S2 0.206	Moderate
	In 10 years	S1 0.0255 S2 0.016	S1 0.145 S2 0.110	S1 0.522 S2 0.481	Moderate

Stock status Reference Point	Projection Time frame	Alternative Catch Projections			Data Rich/ Data Poor
		C(2008) -20% 5,140 t	C(2008) 6,426 t	C(2008)+20% 7,711 t	
P(Sbt<SBmsy)	In 3 years	S1 0.107 S2 <0.01	S1 0.200 S2 <0.01	S1 0.343 S2 <0.01	Moderate
	In 10 years	S1 0.031 S2 0.016	S1 0.132 S2 0.092	S1 0.422 S2 0.387	Moderate

100. The WPB discussed the issue with the latter points in the Taiwanese series and the contradiction with the Japanese series in recent years. While only 80% of the logbooks had been returned in 2008, CPUE declined by more than 95% between 2007 and 2008, a decline which may not change substantially on full returns. Until the full data are available, the WPB thought that the 2008 data point should be ignored (scenario 1). The other consideration was that very low effort in 2008 and preceding years (figure 50) may be influencing CPUE, particularly considering the spatial restriction of the core area analysis.

101. The WPB noted that the timing of the steep decline in the SW Japanese CPUE series in the early-mid 1990s is sensitive to the assumptions in the standardization process, and hence it is not clear to what extent this series provides a measure of relative abundance versus targeting.

102. The WPB recognized that further work was required to determine if the size composition data was consistent with the very high depletion levels predictions from the SCAM model. Notably, the absence of a trend in mean size in the Reunion fishery (Figure 49) did not seem to be consistent with the high levels of depletion estimated for this fishery.

5.2. Summary of the assessment results

103. Table 10 provides an overview of key features of the different models, Table 11 summarizes key concerns about the use of each model and Table 12 summarizes key reference points.

Table 10. *Summary of model features as applied to Indian Ocean swordfish in 2010.*

	ASPIC	**ASIA**	**SS3**	**SCAM**
Population spatial structure Areas	IO 1 area	IO 1 area	IO 4areas	SouthWest IO 1 area
Number CPUE Series	3	10	10	2 or 3
Uses Catch-at-length		Yes	Yes	
Age-structured		Yes	Yes	Yes
Sex-structured			Yes	
Number of Fleets	4 (effectively 1)	18	24 (effectively 18)	1
Stochastic Recruitment		Yes	Yes	Yes

Table 11. *List of known problems associated with different models applied to the Indian Ocean swordfish assessment in 2010.*

<table>
<tr><th></th><th>ASPIC</th><th>SCAM</th><th>ASIA</th><th>SS3</th></tr>
<tr><td>CPUE Series</td><td colspan="4">• conflicting series indicate that catchability is not constant for at least one of the fleets (despite standardization)
• appropriate weighting factors among areas is uncertain (and resulting scaled CPUE series from Japan and Taiwan,China are not consistent across areas)</td></tr>
<tr><td>Size composition data</td><td></td><td></td><td colspan="2">• Sampling poor in some fleets
• Trends are not consistent between fleets which suggests non-random sampling or changing selectivity for at least some fleets</td></tr>
<tr><td rowspan="2">Selectivity assumptions</td><td rowspan="2"></td><td>selectivity assumed</td><td></td><td></td></tr>
<tr><td colspan="3">selectivity assumed constant over time despite apparent targeting shifts</td></tr>
<tr><td rowspan="2">Model Complexity Issues</td><td>cannot represent time lags, high recruitment variability or effects of variable selectivity among fleets</td><td colspan="3">• depend on uncertain biological assumptions (M, growth rates, steepness)</td></tr>
<tr><td colspan="3">assumes single homogenous population and cannot quantify localized abundance changes</td><td>Can represent depletion by sub-region, but spawning is aggregated and movement assumptions are poorly quantified</td></tr>
</table>

Table 12. *Summary of key stock status reference points from the different models that the Working Party considered plausible. MPD = Maximum Posterior Density (or equivalent best point estimate).*

	ASPIC	ASIA	SS3	SCAM
Population spatial structure / Areas	IO / 1 area	IO / 1 area	IO / 4areas	SouthWest IO / 1 area
Uncertainty	MPD (80% CI Bootstrap)	Base case (MPD Range)	MPD Range	MPD range
B_{MSY} (1000t)	74 (51-146)	72 (47-207)	59 - 143	4.1 - 4.7
B_{2008}/B_0	0.42 (NA)	0.44 (0.39-0.56)	0.40 – 0.55	0.0241 – 0.070
B_{2008}/B_{MSY}	1.13 (0.93-1.36)	2.0 (1.4 – 2.39)	1.86 – 3.29	0.269 – 0.88
F_{2008}/F_{MSY}	0.70 (0.53-0.94)	0.51 (0.44 – 0.70)	0.32 – 0.78	0.64 - 0.98
MSY (1000t)	29 (24-32)	34 (25-37)	19 - 46	6.2 - 6.3

104. The WPB agreed on the following:

- The overall downward CPUE trend remains for the period 1995-2008. The last 3-5 years of the spatially-aggregated CPUE series have seen a divergence in trends between Japan (increasing) and Taiwan (decreasing). This has implications for recent estimated population trends.
- When examined by the assessment sub-areas, the conflicts between the Japanese and Taiwanese CPUE series were amplified.
- The ASPIC, ASIA and SS3 results for the whole Indian Ocean suggest that the current status of the stock relative to MSY reference points (Fmsy, Bmsy) are relatively consistent and not showing any major signs of overfishing. It is possible that overfishing occurred in the recent past (early to mid-2000's) but due to recent declines in catch and effort, this is not considered to be an urgent concern if current effort levels are sustained. Catch declines are largely attributable to effort declines in the Taiwanese fleet over the past 4 years (figure 50), with a possible influence of piracy in recent years, particularly in the NW region.
- The model-based assessment of the SW region alone (SCAM) supported previous concerns regarding elevated levels of depletion in that region, *i.e.* the standardized series from Japan, Taiwan,China (using the

HBF data available since 1995), La Réunion and the Spanish fleet (figure 46) are all trending generally downward since the 1990s.

- The SW result was generally consistent regardless of which CPUE series was used to index that region. The level of depletion estimated is a serious concern. However, these results are tempered by a number of unresolved conflicts in the data, being:
  - It was noted that the CPUE series for all fleets in 2010 were derived from very small areas, under the assumption that they would be representative of the larger SW assessment region
  - There is evidence for major targeting shifts within the Japanese and Taiwanese fleets that may be exaggerating the rate of estimated swordfish decline (particularly in the SW region). These issues have not been fully resolved and the time series are sensitive to alternate assumptions regarding the fishery definition. The Taiwanese series suggests a strong decline over the last 5 years, whereas the Japanese series suggests an increase. The nominal CPUE trends from La Reunion and Spain in the SW in the last 5 years (neither of which were used in the model) did not show substantial trend.
  - The last year of data for the Taiwanese fleet is considered incomplete. The targeting data available for the Taiwanese fleet is limited, and there are reasons to think that efficiency could be increasing for some portions of this fleet (possibly underestimating the biomass decline).
  - The SCAM model does not use the size composition data. However, it does predict size composition and visual comparisons of the distributions between 1994 and 2007 indicated large declines in mean size, which were not evident in the La Réunion size data (which is very stable over time, figure 48).
  - The SCAM model results estimate the large biomass decline to be a combined effect of fishing mortality and anomalous recruitment (a decline immediately preceded by a peak in recruitment). This has also not been confirmed in the size composition data.
- The spatially-disaggregated SS3 model did not seem to adequately describe the dynamics of the SW region. It appears that the dynamics of the SW region(s) need to be decoupled from the rest of the Indian Ocean to explain the CPUE patterns and further investigation of localised models is encouraged for this region.
- There remains considerable uncertainty in life history parameters and stock structure for swordfish in the Indian Ocean. Studies of stock structure remain a priority for research and management of swordfish.
- In general, the size composition data were not considered to be very informative because there is no modal structure to indicate year class strength, and conflicting trends suggest that either selectivity has been changing, or the sampling is biased for at least some of the fleets. Variation in catch size composition within strata may depend on fine-scale targeting and is common to swordfish fisheries (*e.g.* Atlantic fishery).

6. MSE SUMMARY

105. The concepts from working paper IOTC-2010-WPB-15 were discussed in relation to a Management Strategy Evaluation (MSE) example from the Australian Pacific longline fishery. MSE is a quantitative tool, pioneered (in the fisheries context at least) in the International Whaling Commission in the 1980s and since then applied in many fisheries around the world, that is judged to be more likely to achieve effective management than the traditional approach used in most tuna RFMOs.

106. The traditional approach involves an iterative cycle: i) an assessment step, in which some sort of quantitative fishery model(s) is employed to estimate the effect of the fishing fleet on the fish population, ii) management advice is formulated based on these perceptions of stock status and fishing mortality using a more or less ad hoc decision to (attempt to) modify the activity of the fishery, and iii) repeat. MSE involves a somewhat different approach to reach the same objectives. In essence, the MSE approach aims to evaluate the expected performance of decision rules that will be translated into future management actions. The decision rules (and data requirements) are agreed in advance, but are designed to interpret incoming data in a way that provides sensible management actions to a broad range of possible responses by the fish population. The decision rules are tested and compared on the basis of simulations, using operating models that represent the major uncertainties in the fishery.

107. MSE is often promoted on the basis of the following advantages:

i) MSE development normally increases the level of engagement between scientists, managers and industry. Explicit quantification of management trade-offs are illustrated, which allows objectives to be prioritized in a much more effective way than can typically be achieved if they are discussed independently.

ii) MSE emphasizes the development of decision rules that are robust (i.e. likely to perform reasonably well under a broad range of situations and avoid catastrophe in the most pessimistic scenarios) rather than optimal decision rules (which can be designed to work very well provided that there is little uncertainty about the underlying dynamics). In this sense, MSE directly incorporates the principles of the precautionary approach.
iii) Decision rules are designed to operate effectively for several years. This adds certainty to the decision process that can help industry with strategic investment plans.
iv) The MSE framework is useful for identifying the value of information, and helping to design data collection and research requirements (e.g. is it better to age 10000 fish every year or hold a tagging programme once every 10 years?).

108. However, MSE is not an all purpose panacea. It will not remove the need for quality data, and it will not remove the difficult decisions that need to be made when fishing effort has to be reduced. There is initially an increased demand for scientific resources and stakeholder meetings to cooperatively develop the MSE (typically a 2-3 year time period), but there should be a longer term advantage of freeing up resources from the usual stock assessment process, allowing them to be focused on more strategic research.

109. The WPB recognized the potential benefit of adopting an MSE approach. However, it was also recognized as a resource intensive process involving not only scientists but also many other stakeholders. The broader SC would have to consider the relative priorities among IOTC species if this approach was to be adopted for swordfish.

7. TECHNICAL ADVICE ON BILLFISH

7.1. Swordfish

110. The WPB considered it beneficial to have had several different assessment approaches tabled, as they provided different perspectives and a cross-check of results. This section represents a qualitative summary across all models and data-based indicators.

111. The stock status reference points from the range of models for the aggregate Indian Ocean were generally consistent, in that the point estimates suggested $B>B_{MSY}$ and $F<F_{MSY}$ for all models (Table 12), although there was a range in the uncertainty estimates, with ASPIC the most pessimistic, SS3 the most optimistic, and ASIA intermediate. The central tendency of the depletion and MSY estimates are very similar, and the variability is mostly in the degree of uncertainty expressed. All of the models suggest that depletion is moderate, within the range 0.39 – 0.56 (B_{2008}/B_0). MSY estimates varied from 19000 to 46000 tonnes, with many models having point estimates of ~30 000 tonnes. The WP considered that the Kobe plot for the ASPIC model provided a useful descriptive summary of the general trends of all the Indian Ocean models (although the uncertainty is understated relative to the full range of results and B/B_{MSY} is on the lower end of the range).

112. The SW region represents an important exception to the main points above. It is uncertain whether this region represents a distinct sub-population, but this hypothesis cannot be discarded on the basis of current evidence. In the last 5 years, the SW CPUE trends conflict (increases for the Japanese fleets, decreases for the Taiwanese fleets, relatively stable for La Reunion and Spain). This reflects an elevated uncertainty in a sub-population which is believed to be the most depleted, following targeted fishing in the 1990s (during which all CPUE series declined considerably). The CPUE-based models suggest that this sub-population is highly depleted (whichever series is given the most weight). There are reasons for not being alarmist in the interpretation of these results (*i.e.* stock structure and movement rates are not known, the results may not be consistent with the size composition data, and the Japanese CPUE series is sensitive to assumptions about spatial/targeting preferences). However, until there is further evidence to reduce the uncertainty, it would be prudent to proceed under the assumption that this sub-population is heavily depleted and may not be rebuilding under current effort levels.

113. Kobe-2 strategy matrices are provided for the aggregate Indian Ocean swordfish population (Table 5), based on ASPIC bootstrap projections, and for the SW population under the assumption that it may represent an independent stock (Table 9), based on SCAM MCMC projections). These tables attempt to quantify the future outcomes from a range of management options. The tables describe the probability of the fishery being in an undesirable state at some point in the future, where 'undesirable' was assigned the default definitions of $F>F_{MSY}$ or $B<B_{MSY}$. The timeframes represent 3 and 10 year projections (from the last data in the model), which corresponds to predictions for 2011 and 2018. The management options represent three different levels of constant catch projection: catches 20% less than 2008, equal to 2008 and 20% greater than 2008. These options

and reference points were selected for illustrative purposes, and can easily be changed next year to reflect the requirements of the Commission.

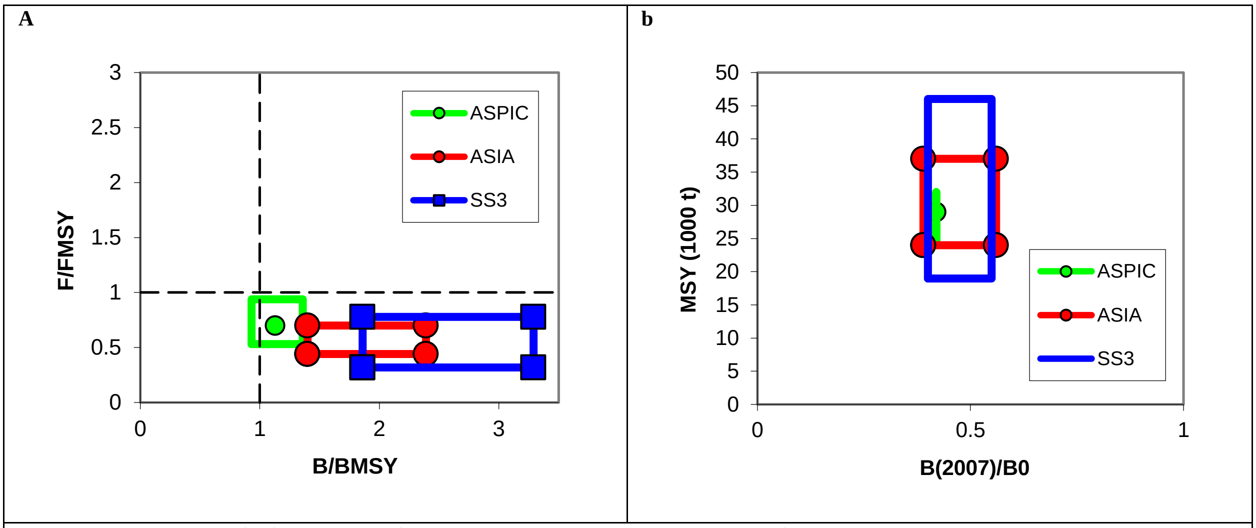


Figure 67. *Comparison of reference points from the aggregate Indian Ocean models defined in Table 10 - Table 12. It is noted that the boxes only bound the range of the uncertainty in each dimension independently, and do not reflect the (typically banana-shaped inverse) correlation between reference points.*

7.2. Marlins and sailfish

114. No quantitative stock assessment is currently available for marlins and sailfish in the Indian Ocean, and due to a lack of fishery data for several gears, only preliminary stock indicators can be used. Therefore stock status remains uncertain. However, aspects of the biology, productivity and fisheries for these species combined with the lack of data on which to base a more formal assessment are a cause for considerable concern. Research emphasis on improving indicators and exploration of stock assessment approaches for data poor fisheries are warranted.

115. In 2009, the WPB recommended that the development of a dedicated project on billfish should be considered as a priority. The participants to the current meeting considered that development of a global project addressing all constraints relating to these species and their fisheries may be ambitious in the short-term, but that aspects of the proposed project could be tackled through collaboration with other projects and a wider stakeholder group. As a first step, development of a project between IOTC, The Billfish Foundation and sport fishing centres was recommended as a way to approach issues relating to sport fisheries.

8. Research and Data Recommendations

116. The WPB revised the status of implementation of recommendations arising from previous meetings of the WPB, noting that, to date, many of the recommendations standing have not been addressed by the parties concerned, particularly in terms of recommendations relating to improving data available to IOTC. As a result, the WPB urged countries having fisheries for which recommendations have been addressed to consider implementing the recommendations as soon as possible. In this regard, the WPB requested the IOTC Secretariat to liaise with the countries concerned in order to assess the way in which the recommendations can be implemented in a timely manner. Full details of the new and standing recommendations are provided in Annex IV). The status of implementation of recommendations arising from previous WPB meetings is revised in Annex V.

8.1. Recommendations to improve the data available to IOTC

117. With regards to data acquisition and availability, the WPB agreed that the following issues have to be addressed **as a matter of priority**:

a. Acquisition of statistics from drifting gillnet fisheries in Iran and Pakistan, in particular catch-and-effort and size data

b. Identification of marlins by species and increase in sampling coverage in the artisanal fisheries of Sri Lanka, especially offshore fisheries
c. Acquisition of catch-and-effort and size data from sport fisheries. Preparation and dissemination of reporting forms to Sport Fishing Centres in the region.
d. Acquisition of statistics of billfish not reported by longline fleets, by species, in particular India, Philippines, Malaysia, Oman and Indonesia.
e. Implementation of sampling for the collection of biological data for billfish, in particular sex-ratio by length, length - weight and non-standard size – standard length conversion relationships and resulting keys

118. In 2010, the WPB identified the following new issues concerning the statistics available for billfish species, urging the parties concerned to address these issues as a matter of priority. The WPB requested the IOTC Secretariat to assist developing countries in the IOTC region in addressing the issues identified, where required.

119. Artisanal fisheries of Indonesia: The catches of billfish reported by Indonesia for its artisanal fisheries in recent years are considerably higher than those reported in the past. The quality of the dataset for the artisanal fisheries of Indonesia is thought to be very poor.

120. Longline fishery of Indonesia: The catches of swordfish and marlins estimated for the fresh tuna longline fishery of Indonesia may have been underestimated in recent years due to them not being sampled in port.

121. Gillnet fisheries of Iran and Pakistan: To date, Iran and Pakistan have not reported size frequency data for their gillnet fisheries.

122. Gillnet/longline fishery of Sri Lanka: Although Sri Lanka has reported length frequency data for swordfish and marlins in recent years, the lengths reported are considered highly uncertain, due to mislabelling of marlins and likely sampling bias (large specimens of swordfish and marlins are highly processed and not sampled).

123. Longline fishery of Indonesia: Indonesia has reported size frequency data for its fresh-tuna longline fishery in recent years. However, the samples cannot be fully broken by month and fishing area (5x5 grid) and refer mostly to the component of the catch that is unloaded fresh. The quality of the samples in the IOTC database is for this reason uncertain.

124. In addition, the WP recommended that Japan and Taiwan,China provide the entire size frequency data series for their longline fisheries as per the IOTC standards.

125. The WPB recommended that the Chair of the WPB works intersessionally with the IOTC Secretariat in the preparation of a template logbook form for gillnet fisheries, to be presented to the next session of the IOTC Scientific Committee.

8.2. Research Recommendations

126. With regards to research, the WPB agreed that the following issues have to be addressed **as a matter of priority**:

a. Based on recommendations last year and the assessments conducted in 2010, the WPB still considered determination of stock structure as a research priority as the information available tends to indicate localized depletion in certain areas, notably the SW. Ongoing initiatives, such as IOSSS and SWIOFP, should provide better information on the stock structure in 2011/2012. IOSSS and Taiwan,China to discuss collaboration on genetic analyses regarding the large scale biological sampling conducted by the observer programme in tropical areas in 2009. The WPB continued to encourage the countries in the region to cooperate with those initiatives. These programmes should also be complemented by support to tagging programmes in both longline and sport fisheries.
b. The WPB welcomed the introduction of standardised CPUE series in 2010 from La Reunion and Seychelles but identified Spain and Portugal as potentially having useful series for inclusion in assessments in 2011, particularly to further explore the SW area. The WPB recommended the ongoing development of the spatially disaggregated approach.
c. The WPB recommended investigation the historical coverage of logbooks for Taiwan,China.

127. In 2010, the WPB identified the following new issues concerning research on billfish species.

128. The WPB recommended examining inter-annual anomalies as an appropriate way to identify environmental effects that are relevant for describing inter-annual variability in CPUE and that this work should be pursued in the inter-sessional period.

129. The WPB recommended continued exploration of the apparent depletion in the SW area.

9. OTHER BUSINESS

130. None.

10. ADOPTION OF THE REPORT

131. The Report was adopted in the main on Friday 16 July 2010 and finalised by correspondence on 11th October 2010. Thanks were conveyed to Seychelles Fishing Authority for the use of the SFA Training Room.

APPENDIX I
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APPENDIX II
AGENDA OF THE WORKING PARTY ON BILLFISH

1. OPENING OF THE MEETING

2. ADOPTION OF THE AGENDA

3. REVIEW OF THE DATA

- Review of the statistical data available for the billfish species (Secretariat)

4. NEW INFORMATION ON BIOLOGY, ECOLOGY AND FISHERIES OCEANOGRAPHY RELATING TO BILLFISH

- Review new information on the biology, stock structure of billfish, their fisheries and associated environmental data

  Papers as provided by Members

5. REVIEW OF NEW INFORMATION ON THE STATUS OF BILLFISH

- Stock status indicators for marlins, sailfish and swordfish.
- Stock assessments

  - *Assessment methods*
  - *Review and presentation of projection results (Kobe 2 Strategy Matrix)*

6. MANAGEMENT STRATEGY EVALUATION

- Discussion of methods, applications in fisheries management

7. DEVELOP TECHNICAL ADVICE ON THE STATUS OF THE STOCKS

  - *Marlins – new Executive Summary*
  - *Sailfish – new Executive Summary*
  - *Swordfish – update the Executive Summary*

8. RESEARCH RECOMMENDATIONS AND PRIORITIES

9. OTHER BUSINESS

APPENDIX III
LIST OF DOCUMENTS

Document	Title	Availability
IOTC-2010-WPB-01	Draft agenda of the Working Party on Billfish	✓
IOTC-2010-WPB-02	WPB List of documents	✓
IOTC-2010-WPB-03	Reunion Longline Swordfish Catch Rate Standardization, Kolody, D., F. Poisson, J. Bourjea	✓
IOTC-2010-WPB-04	Swordfish Catch Rate Standardization for the Seychelles Semi-Industrial and Industrial Longline Fleets, Kolody, D., J. Robinson and V. Lucas	✓
IOTC-2010-WPB-05	A Spatially-Structured Stock Synthesis Assessment of the Indian Ocean Swordfish Fishery 1950-2008, including Special Emphasis on the SW Region. Kolody, D.	✓
IOTC-2010-WPB-06	Preparation of data input files for the stock assessments of Indian Ocean Swordfish. Herrera, M., Pierre, L.	✓
IOTC-2010-WPB-07	Status of IOTC databases for billfish. Herrera, M., Pierre, L.	✓
IOTC-2010-WPB-08	Age and growth analysis of swordfish (Xiphias gladius) in the Indian Ocean based on the specimens collected by Taiwanese observer programme. Wang, S.-P., Chi-Hong, L. and W-C Chiang.	✓
IOTC-2010-WPB-09	Estimation of the Abundance Index (AI) of swordfish (Xiphias gladius) in the Indian Ocean (IO) based on the fine scale catch and effort data in the Japanese tuna longline fisheries (1980-2008). Nishida, T and SP Wang	✓
IOTC-2010-WPB-10	Status of Seychelles Semi Industrial Longline Fishery. Assan, C. And N. Bristol.	✓
IOTC-2010-WPB-11	CPUE standardization of swordfish (Xiphias gladius) caught by Taiwanese longline fishery in the Indian Ocean during 1995-2008. Wang, S.P. and T. Nishida.	✓
IOTC-2010-WPB-12	Stock assessment of swordfish (Xiphias gladius) in the Indian Ocean by ASPIC (1980-2008). Nishida, T and S.-P. Wang	✓
IOTC-2010-WPB-13	Update of the application of an age-structured assessment model to swordfish (Xiphias gladius) in the Indian Ocean. Wang, S.-P., and T. Nishida	✓
IOTC-2010-WPB-14	SCAM Swordfish Stock Assessment. Martell, S.	✓
IOTC-2010-WPB-15	Billfish Indicators 2010. Herrera, M.	✓
IOTC-2010-WPB-INF01	Effects of lunar cycle and fishing operations on longline-caught pelagic fish: fishing performance, capture time, and survival of fish. Poisson, F. et al.	✓
IOTC-2010-WPB-INF02	Comparing three indices of catch per unit effort using Bayesian geostatistics. Pereira, J.C. et al	✓
IOTC-2010-WPB-INF03	Introduction to Management Strategy Evaluation. Kolody, D., and A. Anganuzzi	✓

APPENDIX IV
MAIN ISSUES IDENTIFIED BY THE WPB CONCERNING DATA AND STATISTICS

Catch-and-Effort data from Artisanal Fisheries:

1. Drifting gillnet fisheries of Iran and Pakistan: To date, Iran has not reported catches of swordfish and marlins for its gillnet fishery. Although Pakistan has reported catches of swordfish and black marlin, they are considered to be too low for a driftnet fishery and the catches of black marlin are thought to contain other marlins (mislabelling).
2. Gillnet/longline fishery of Sri Lanka: Although Sri Lanka has reported catches of marlins by species for its gillnet/longline fishery, the catch ratio blue marlin:black marlin has changed dramatically over time. This is thought to be a sign of mislabelling rather than the effect of changes in catch rates for this fishery.
3. Artisanal fisheries of Indonesia: The catches of billfish reported by Indonesia for its artisanal fisheries in recent years are considerably higher than those reported in the past. The quality of the dataset for the artisanal fisheries of Indonesia is thought to be very poor.
4. Artisanal fisheries of India: To date, India has not reported catch-and-effort data for its artisanal fisheries.
5. Catch-and-Effort data from Sport Fisheries:
6. Sport fisheries of Australia, France (La Reunion), India, Indonesia, Madagascar, Mauritius, Oman Seychelles, Sri Lanka, Tanzania, Thailand and UAE: To date, no data have been received from any of the referred sport fisheries.
7. Catch-and-Effort data from Industrial Fisheries:
8. Longline fishery of Indonesia: The catches of swordfish and marlins estimated for the fresh tuna longline fishery of Indonesia may have been underestimated in recent years due to them not being sampled in port.
9. Longline fishery of India: India has reported very incomplete catches and catch-and-effort data for its longline fishery.
10. Longline fishery of the Republic of Korea: The nominal catches and catch-and-effort data series for billfish for the longline fishery of Korea are conflicting, with nominal catches of swordfish and marlins lower than the catches reported as catch-and-effort for some years.
11. Longline fishery of EU-Spain: To date, the Secretariat has not received catch-and-effort data for marlins and sailfish for the longline fishery of EU-Spain.
12. Purse seine fisheries of EU, Seychelles, Thailand, Iran and Japan: To date, the referred countries have not reported catches of billfish from purse seiners.
13. Size data from All Fisheries:
14. Gillnet fisheries of Iran and Pakistan: To date, Iran and Pakistan have not reported size frequency data for their gillnet fisheries.
15. Gillnet/longline fishery of Sri Lanka: Although Sri Lanka has reported length frequency data for swordfish and marlins in recent years, the lengths reported are considered highly uncertain, due to mislabelling of marlins and likely sampling bias (large specimens of swordfish and marlins are highly processed and not sampled).
16. Longline fisheries of India and Oman: To date, India and Oman have not reported size frequency data for their longline fisheries.
17. Longline fishery of Indonesia: Indonesia has reported size frequency data for its fresh-tuna longline fishery in recent years. However, the samples cannot be fully broken by month and fishing area (5x5 grid) and refer mostly to the component of the catch that is unloaded fresh. The quality of the samples in the IOTC database is for this reason uncertain.
18. Fresh-tuna longline fishery of Taiwan,China: To date, Taiwan,China has not provided size frequency data for its fresh-tuna longline fishery.
19. Longline fishery of Japan: Japan has not reported samples for its commercial fishery since 2000 and the number of samples reported from training vessels has dropped dramatically since that time.

20. Artisanal fisheries of India and Indonesia: To date, India and Indonesia have not reported size frequency data for their artisanal fisheries.
21. Biological data for all billfish species:
22. Industrial longline fisheries, in particular Taiwan,China, Indonesia, EU, China and the Republic of Korea: The Secretariat had to use length-age keys, length-weight keys, and processed weight-live weight keys for billfish species from other oceans due to the general paucity of biological data available from the fisheries indicated.
23. Industrial longline fisheries, in particular Taiwan,China, Indonesia, EU, China and the Republic of Korea: There has not been regular reporting of length frequency data by sex from any of the referred fisheries.

APPENDIX IV *(CONTINUED)*
MAIN ISSUES IDENTIFIED BY THE WPB CONCERNING RESEARCH

1. Swordfish stock structure and migratory range — using genetics techniques: The WPB encourages IOTC members to participate or contribute to the planned IOSSS project as much as possible, in particular in the collection of samples for analysis by the project. Samples from northern areas of the Indian Ocean are of particular importance.
2. Swordfish stock structure and movement rates — using tagging techniques: Including:
    - The EC, Taiwan,China, Japan, Seychelles, Indonesia and the EC to initiate conventional tagging of swordfish specimens by longline fishermen and observers, in particular tagging of small swordfish specimens, and where possible inject fish with OTC for validation of ageing methods.
    - Use of the RTTP-IO tag recovery scheme to collect swordfish tags.
    - Collaborate with SWIOFP in the implementation of its 2009/2010 programme to tag swordfish using PAT tags, in particular tag recovery and analysis of the results.
3. Swordfish growth: The IOTC Secretariat to promote the growth studies undertaken by Reunion (EC-France) and Taiwan,China scientists and comparison of the results obtained through those and other projects.
4. Size data analyses: The IOTC Secretariat to coordinate studies on the conversion of swordfish lengths into ages by using different assumptions on sex ratios at size/age for the Taiwan,China, Japan and EC fleets size data.
5. Stock status indicators: The IOTC Secretariat to further coordinate the exploration of indicators from available data and report these to next meetings of the WPB.
6. CPUE Standardization:
    - China and Taiwan,China to report the results of their ongoing TDR studies (relationship between the number of hooks per basket and hook depth) to the next meeting of the WPB. The IOTC Secretariat to provide the results of a TDR study conducted by Australia at the next meeting of the WPB.
    - Japan, Taiwan,China, EC, Seychelles and Indonesia to conduct research studies intended to improve the definition of variables that could be used as a proxy for targeting of swordfish, in particular changes in the number of hooks per basket set-times, area fished, moon-phase, use of light-sticks, bait-types and species composition. The WPB to review the results of these studies at its 2012 meeting. The WPB to review the standard IOTC requirements for logbook data on the basis of the results of these studies.
    - Japan and Taiwan,China to examine the influence of zero catches in CPUE analyses through sensitivity analysis using delta log-normal models and report the results of these analysis to the next meeting of the WPB.
    - Japan, Taiwan,China and the EC to conduct studies to ascertain that the areas used for the assessment are appropriate, in particular analysis of the influence of environmental heterogeneity at sub-regional scales and the combination of area-specific indices into a global index using different weighting schemes
    - The EC and Seychelles to use set by set data in the standardization of the CPUEs for its longline fisheries and to report the results to the next meeting of the WPB. The IOTC Secretariat to assist Seychelles with this study, where required.

Given the importance of these recommended actions to the swordfish assessment, the WPB encourages that a collaborative approach to the work be taken.

7. Stock assessment: The IOTC Secretariat to promote further development of stock assessment models for swordfish, in particular development of the models used by the WPB in 2010.
8. Research on Istiophorids: The WPB showed concern about the paucity of the biological data available for marlins and Indo-Pacific sailfish noting the consequences that this is having on the assessments of the species. In order to overcome these problems the WPB recommended the implementation of a Large Scale Research Programme to collect the information required for these species, in particular biometric and

morphometric data, marlins and sailfish movements, growth, and other information required for stock assessment (Appendix IV). The WPB agreed to address this request to the IOTC SC.

APPENDIX V
STATUS OF IMPLEMENTATIONS OF RECOMMENDATIONS FROM PREVIOUS WPB MEETINGS

A. Data and statistics

Recommendation	Addressed To	Year Issued	Implemented
Members having artisanal fisheries for swordfish and marlins to improving their collection and reporting of species and gear information *Remarks: Sri Lanka to increase sampling coverage to 2005-06 levels, including identification and reporting of marlins by species. The IOTC-OFCF Project has plans to assist Sri Lanka to strengthen sampling effort on its coastal and off-shore fisheries in late 2010.* *Follow-up: IOTC-OFCF Project* *Deadline: Next WPB Meeting*	Sri Lanka	2001	Ongoing
Members having artisanal fisheries that catch substantial amounts of billfish to providing catch and effort and size data for those fisheries, including catches of billfish disaggregated by species *Remarks: Iran, India and Pakistan to provide catch-and-effort data and size data for billfish, including gillnet fisheries. The IOTC Secretariat has initiated contacts with Iran and Pakistan. The IOTC Secretariat is planning to visit Iran to assess the status of data collection and processing in this country, including implementation of pilot sampling activities to assess the quality of the statistics collected from gillnet fisheries in Iran. A mission to Iran will be planned depending on the situation in this country.* *Follow-up: The IOTC Secretariat to proceed with its plans in Iran and Pakistan and contact the IOTC Liaison Officer in India* *Deadline: Next WPB Meeting*	Iran India Pakistan	2008 2008 2008	Ongoing No Ongoing
The Secretariat to coordinate catch-and-effort data collection from major sport fishing bodies in the Indian Ocean and analysis of the information retrieved (CPUE and size data) *Remarks: A representative of the Billfish Foundation attended the WPB. The WPB agreed to work closely with the BF in the design of a Project Proposal for the collection of data from sport fisheries in the region.* *Follow-up: The Chair of the WPB to coordinate future work in cooperation with the IOTC Secretariat and the Billfish Foundation* *Deadline: Next WPB Meeting*	Secretariat	2001	Ongoing
Members having industrial fisheries for swordfish, marlins and sailfish to improving their collection and reporting of species information. This should include tools to assist fishers and data collectors to correctly identify billfish species *Remarks: Need for countries to implement the standard IOTC longline logbooks; the Secretariat created and disseminated in 2010 new forms and Guidelines for the Reporting of fisheries statistics to the IOTC, intended to improve reports from all parties.* *Follow-up: The Secretariat to urge countries to report data as specified in the referred Guidelines* *Deadline: Next WPB Meeting*	All CPC's	2001	Partially
India to report catch-and-effort and size data for billfish species for its commercial longline fishery. *Remarks: India reported very incomplete catch-and-effort statistics for its longline fishery in 2010; to date, no size data has been reported for commercial*	India	2003	Partially

longliners *Follow-up: The IOTC Secretariat to liaise with India in order to improve the quality of the data reported* *Deadline: Next WPB Meeting*			
The Republic of Korea to revise its catch-and-effort data series as soon as possible *Remarks: The IOTC Secretariat revised in 2009 the nominal catch data series of Korea using the existing nominal catches and catch-and-effort data* *Follow-up: The IOTC Secretariat to liaise with the Republic of Korea to inform about the new nominal catches estimated for its longline fishery* *Deadline: Next WPB Meeting*	Korea, Rep.	2003	Partially
The IOTC Secretariat to follow-up on the logbook programmes initiated by Indonesia and Taiwan,China for the collection of catch-and-effort data from their fresh-tuna longline fleets *Remarks: Taiwan,China reported catch-and-effort data for the years 2007-09 for the first time in 2010, with logbook coverage at around 20%. It was indicated that logbook coverage will increase in the future. Indonesia started implementation of logbooks on vessels under its flag in 2009. However, to date the Secretariat has not received catch-and-effort data from Indonesia.* *Follow-up: The IOTC Secretariat to assist Indonesia in the reporting of catch-and-effort data, if required* *Deadline: Next WPB Meeting*	Indonesia Taiwan,China	2003 2003	Ongoing Yes
Taiwan,China to collect and provide size data from its fresh tuna longliners *Remarks: Taiwan,China has not reported size data for its fresh-tuna longline fishery to date.* *Follow-up: IOTC Secretariat* *Deadline: Next WPB Meeting*	Taiwan,China	2003	No
The EC-Spain LL to provide catch-and-effort and size data of marlins and sailfish by time and area strata *Remarks: The EU-Spain has reiterated that it has no plans to report catch-and-effort or size data for species other than the swordfish. Need to address this issue to the SC* *Follow-up: WPB to address to the SC* *Deadline: Next WPB Meeting*	EU-Spain	2003	No
The EC-Portugal, EC-UK, Kenya, Guinea, Senegal and Tanzania to collect and report size data for billfish species for its longline fleets *Remarks: No data has been received so far* *Follow-up: IOTC Secretariat* *Deadline: Next WPB Meeting*	EU(Portugal, UK) Kenya Guinea Senegal Tanzania	2009	No No No No No
The Secretariat to request EC-Portugal to provide more information on the activities of longliners under its flag, especially concerning the limited fishing area covered by year *Remarks: EU-Portugal reported the information requested*	EU-Portugal	2009	Fully
Japan to increase size sampling coverage (to cover a minimum of 10% of the catch (in number) by quarter by 10deg latitude – 20 deg longitude area) from its longline fleet. *Remarks: Japan initiated implementation of a observer programme on its commercial fishery in July 2010; size data will be collected through observers*	Japan	2003	Ongoing

Follow-up: IOTC Secretariat *Deadline: 2011*			
Members ensuring that logbook coverage is appropriate to produce acceptable levels of precision (CV to be initially set at less than 20%) in their catch and effort statistics for billfish species. The Secretariat to request countries to include levels of precision in their reports of catch-and-effort for billfish species *Remarks: The WPDCS agreed to set minimum levels of coverage for industrrial fisheries at 5% of the fishing activity (e.g. 5% of the vessels operating or trips to be sampled for catch data). In addition, the WPDCS set miimum coverage rates for length data to 1 fish per ton caught for both industrial and artisanal fisheries.* *Follow-up: CPC's to assess if the above levels of coverage are sufficient for billfish species, bearing in mind that, initially, the CV should be less than 20% for all billfish species and fisheries.*	All CPC's	2008	Ongoing
Members with observer programmes to analyse the data collected to estimate discards of billfish species and the precision of these estimates *Remarks: Discards of billfish have been estimated for industrial purse seiners of the EU* *Follow-up: The Secretariat to request countries to provide estimates of discard levels of billfish species, including levels of precision for these estimates* *Deadline: Next WPB Meeting*	All CPC's	2003	Partially
The WPB to address a request to the next meeting of the WPDCS to establish the levels of precision that are adequate for catches and size data of billfish, by species, fishery and time-area strata *Remarks: The WPDCS agreed to set minimum levels of coverage for artisanal fisheries at 5% of the fishing activity (e.g. 5% of the vessels operating or trips to be sampled for catch data). In addition, the WPDCS set miimum coverage rates for length data to 1 fish per ton caught for both industrial and artisanal fisheries.Follow-up: CPC's to assess if the above levels of coverage are sufficient for billfish species, bearing in mind that, initially, the CV should be less than 20% for all billfish species and fisheries.* *Deadline: Next WPB Meeting*	All CPC's	2008	Partially
Conversion relationships: The Secretariat to request CPC's having important fisheries for billfish to collect and provide the basic data that would be used to establish length-age keys and non-standard measurements to standard measurements keys for billfish species, by sex and area *Remarks: Taiwan,China provided the WPB with new information, including a length-weight conversion relationship and age-length keys by sex derived from samples collected in the tropical Indian Ocean. No new data received since the last WPB meeting. In 2010 the Secretariat compiled and disseminated new conversion relationships from different sources, the information coming in most cases from other oceans. The Secretariat to request this information to countries having important fisheries for billfish, including the raw data* *Follow-up: The IOTC Secretariat* *Deadline: Next WPB meeting*	All CPC's	2001	Ongoing
Obtaining sex ratio information by size and area *Remarks: The Secretariat to request this information to countries having important fisheries for billfish, including the raw data* *Follow-up: The IOTC Secretariat* *Deadline: Next WPB meeting*	All CPC's	2001	Partially
Japan and Taiwan to analyse the size samples collected from their longline fisheries for swordfish and marlins in order to verify if the length frequencies derived from such samples are representative of their fisheries. *Remarks: Taiwan,China and Japan have not conducted such studies to date. The*	WPB	2008	Partially

Secretariat presented to the WPB a comparison of swordfish lengths for Japanese training and commercial vessels. The length distributions obtained tend to indicate that the size data used for Japan, the majority derived from samples collected on from training vessels, are not representative of the fishery. *Follow-up: The IOTC Secretariat* *Deadline: Next WPB meeting*			

B. Research			
Recommendation	Addressed To	Year Issued	Implemented
Swordfish stock structure and migratory range — using genetics techniques IOTC CPC's to participate or contribute to the planned IOSSS project *Remarks: No results expected until 2011 and the final project will be concluded by October 2011. New partnerships have been formed and are needed to obtain samples from northern Indian Ocean.*	All CPC's	2000	Ongoing
Swordfish stock structure and movement rates — using tagging techniques • The EU, Taiwan,China, Japan, Seychelles and Indonesia to initiate conventional tagging of swordfish specimens by longline fishermen and observers, in particular tagging of small swordfish specimens, and where possible inject fish with OTC. • Use of the RTTP-IO tag recovery scheme to collect swordfish tags • Collaborate with SWIOFP in the implementation of its 2009/2010 programme to tag swordfish using PAT tags, in particular taqg recovery and analysis of the results *Remarks: Secretariat to encourage voluntary conventional tagging by fleets through EU and other CPCs, including small swordfish tagging and OTC marking for growth studies and validation. PAT tags for swordfish attempted in Mozambique channel in 2010 under SWIOFP but no swordfish caught in good enough condition for tagging. New cruise planned for October 2010. Discussions with sport fishing representatives (The Billfish Foundation) were held at the meeting with regards to the potential for collaborative tagging of swordfish using PATs.*	All CPC's	2000 2008 2008	No Ongoing Ongoing
Swordfish growth: The IOTC Secretariat to promote the growth studies undertaken by Reunion (EU-France) and Taiwan,China scientists and comparison of the results obtained through those and other projects. *Remarks: There are plans to analyze the Reunion swordfish growth data. Swordfish growth studies are being conducted in Taiwan,China based on samples from Taiwanese observer programme and preliminary results were presented at the WPB. No known studies on sailfish or marlins.*	Reunion Taiwan,China	2001	Ongoing
Size data analyses: The IOTC Secretariat to coordinate studies on the conversion of swordfish lengths into ages by using different assumptions on sex-ratios at size/age for the Taiwan,China, Japan and EU fleets size data *Remarks: Secretariat will coordinate this work*	Taiwan,China Japan EU	2008	No
Stock status indicators: The IOTC Secretariat to further coordinate the exploration of indicators from available data and report these to the next meeting of the WPB *Remarks: Indicators updated in 2010 but no new indicators introduced. Work to*	Secretariat	2008	Ongoing

be continued			
CPUE Standardization: • Examine the relationship between the number of hooks per basket and hook depth *Remarks: China and Taiwan,China conducting current TDR studies and data will be reported at future meetings. Australian TDR study results to be sourced by Secretariat.* • Improving the definition of variables that could be used as a proxy for targeting. *Remarks: Consistencies between Japan and Taiwan,China improving due to the increasing time-series of Taiwanese data on NHBF. Taiwan only used data from 1995 for assessments in 2010 as no new proxy variables. Species proxies could be examined through introduction/exclusion of subsets of data in 2011, as attempted with Seychelles/La Reunion in 2010.* *Secretariat to review standard logbook requirements to include relevant variables* • Examine methods to better account for the influence of zero catches in CPUE analyses *Remarks: Sensitivity analyses using delta log-normal models have been attempted by Taiwan,China at the WPB meeting. Japan will present results to the next WPB. CPUE standardization for Taiwan,China, Seychelles and La Reunion were undertaken in 2010 assessments.* • Consideration of alternative ways of combining area-specific indices into a global index using different weighting schemes. Consider alternative methods of estimating fish densities in areas across the species range that have not been fished consistently over time. • La Reunion, Spain and Seychelles to use set by set data in the standardization of the CPUEs for its longline fisheries *Remarks: Done for all except Spain*	China Taiwan,China Japan Taiwan,China EU Seychelles Indonesia Taiwan,China Japan Japan Taiwan,China EU Seychelles	2001	Ongoing Ongoing Partially No Partially
Stock assessment: Further development of stock assessment models for swordfish, in particular development of the models used by the WPB in 2008 and 2009 *Remarks: SS3, SCAM, ASPIC and ASIA all undertaken in 2010 with ASIA and SCAM applied to SW area in addition to all areas. Seychelles and La Reunion CPUE series were included in 2010.*	WPB	2003	Ongoing
Research on Istiophorids: The WPB recommended the implementation of a Large Scale Research programme to collect the information requi8red for these species, in particular biometric and morphometric data, marlins and sailfish movements, growth and other information required for stock assessment. *Remarks: The WPB addressed the request to the IOTC Scientific Committee. The WPB The WPB agreed to work closely with the Billfish Foundation in the design of a Project Proposal for the collection of data from sport*	All CPC's	2001	Ongoing

fisheries in the region.			