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

Report of the Fifth Session of the IOTC Working Party on Billfish

Colombo, Sri Lanka, 27 – 31 March, 2006

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1. OPENING OF THE MEETING AND ADOPTION OF THE AGENDA

1. The Fifth Meeting of the Working Party on Billfish (WPB) was opened on 27 March 2006 in Colombo, Sri Lanka, during a welcoming ceremony in which Mr K. Haputantri, Chairman of NARA and Mr Yoshan Saddhasena, Director General, NARA pledged their support and best wishes for the work ahead.

2. In the absence of the Chairperson, Dr. John Gunn, Mr Kevin McLoughlin kindly agreed to chair the meeting in a caretaker role. Mr McLoughlin welcomed the participants (Appendix I) and the Agenda for the meeting was adopted as presented in Appendix II.

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

2. REVIEW OF STATISTICAL DATA FOR BILLFISH

2.1. Catch trends - nominal catch (NC) data

Swordfish

4. Swordfish are caught mainly using drifting longlines (95%) and gillnets (5%) (Figure 1). Swordfish were mainly by-catch of industrial longline fisheries before the early 1990's with catches slightly increasing from 1950 to 1990 proportionally to the increase in the catches of target species (tropical and temperate tunas). The catches of swordfish markedly increased after 1990 to a peak of 35,000 tonnes in 1998. Current catch levels are around 30,000 t. The change in target species from tunas to swordfish by part of the Taiwanese fleet along with the development of longline fisheries in Australia, Reunion island, Seychelles and Mauritius and the arrival of longline fleets from the Atlantic Ocean (Portugal, Spain and other fleets operating under various flags[1]), all targeting swordfish, are the main reasons for the increase (Figure 2).

Marlins

5. Blue, black and striped marlins (Figure 3) are caught mainly using drifting longlines (70%) and gillnets (20%) and some troll and hand lines. These species are generally caught as by-catch of industrial and artisanal fisheries, but are targeted by sport fisheries. Catches of blue marlin are larger (by a factor of 2) than those of black and striped marlin combined. The total catch of all marlin species varies from year to year. It reached a maximum of 17,000 t in 1998. Current catches are around 11,000 t. The bulk of the marlin catch in the Indian Ocean is taken by the Taiwanese and Japanese fleets, but recently Indonesia and several NEI fleet have begun to record significant catches.

Indo-Pacific Sailfish and Shortbill Spearfish

6. Indo-Pacific sailfish represent 99% of the data available for this group (Figure 4). Sailfish is caught mainly by gillnets (80%) with remaining catches recorded to be taken by troll and hand lines (10%), longlines (7%) or other gears). All catches of shortbill spearfish are recorded taken by drifting longlines, although this species is probably bycatch of other artisanal fisheries and mislabelled or aggregated in reporting. The catches of sailfish have greatly increased since the mid-1980's in response to the development of the gillnet / longline fishery in Sri Lanka. Current catches are around 22,000 t. The catches of both sailfish and shortbill spearfish with drifting longlines do not show any specific trends over the years. However, catches of these species are probably underreported due to both species being of little commercial value.

2.2. Data Availability and Data Quality

7. There is considerable uncertainty associated with the catch estimates for the following fisheries:

- **Sri Lankan gillnet (and longline) fishery**: The magnitude of the discrepancies between the catch estimates produced in Sri Lanka are of concern. The catches of billfish recorded in the IOTC database are similar to those used by the WPB in 2004. However, recent information indicates that the reported catches of all species might be higher than those actually harvested. The results of the first year NARA-IOTC/OFCF monitoring appear to also confirm this. It is therefore likely that the catches of billfish in Sri Lanka are two or three times lower than those recorded in the IOTC database. The data collected so far through this scheme are still incomplete, thus at this stage, the Secretariat is not able to correct the estimates for these and other species.

[1] Uruguay, Senegal, Guinea, etc.

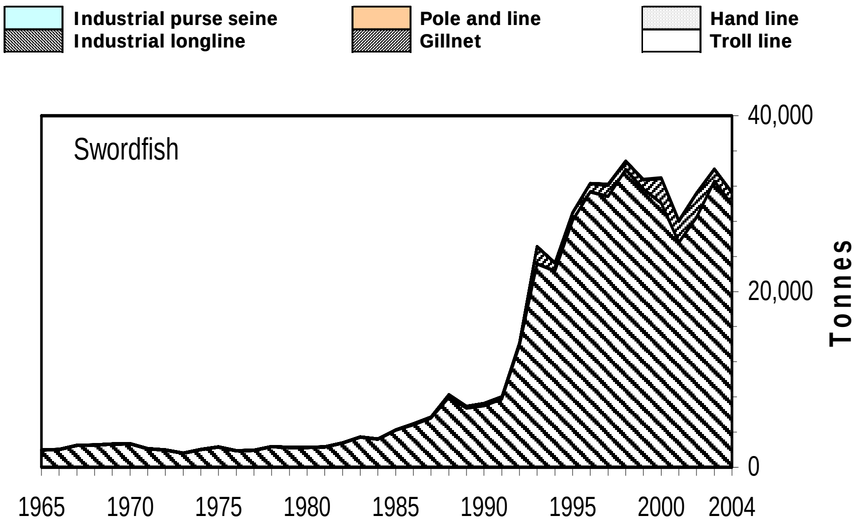

Figure 1: *Catches of swordfish in the Indian Ocean by gear type.*

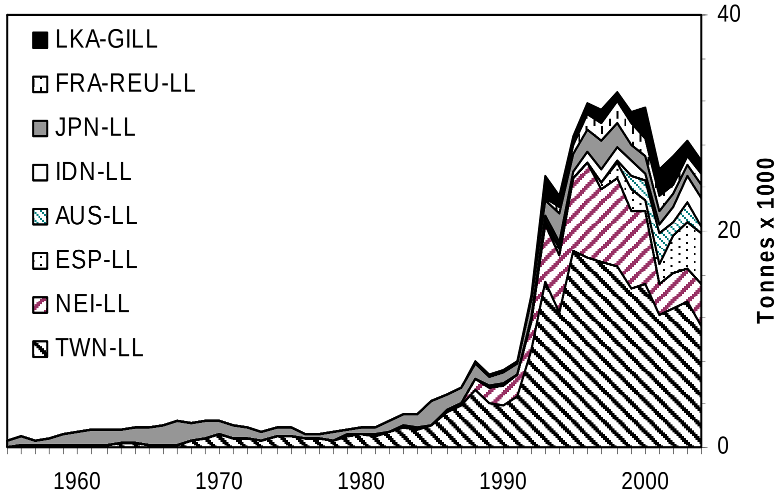

Figure 2: *Catches of swordfish in the Indian Ocean by fishing fleet.*

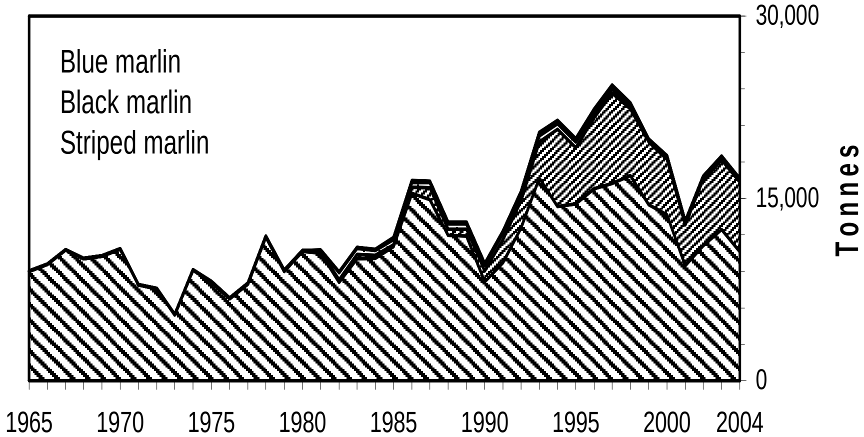

Figure 3: *Catches of marlins in the Indian Ocean by gear type.*

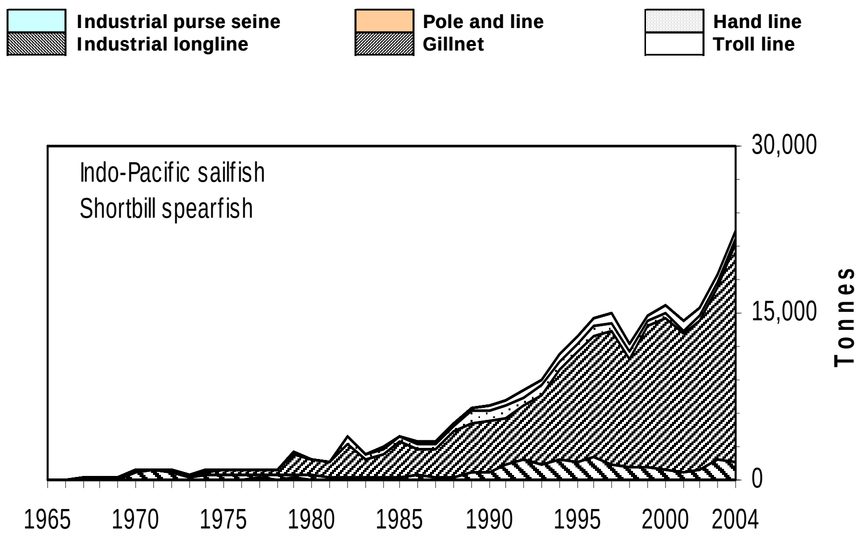

Figure 4: *Catches of sailfish and spearfish in the Indian Ocean by gear type.*

- **Estimation of catches per species:** The catches of marlins, sailfish and shortbill spearfish are usually not reported at all or not reported per species (bycatch) and therefore are usually estimated by the Secretariat. This process involves the estimation of catches amounting to as much as the 40% of the total catches for these species in recent years. The changes in the catches referred mostly to sailfish and, to a lesser extent, to marlins.
- **Mozambique and Tanzania:** Swordfish and Indo-Pacific sailfish catches reported by Mozambique between 1983 and 2002 have been erased from the IOTC Database as these data pertain to foreign fleets operating in the EEZ and are therefore are reported to IOTC by these fleets. This might also be the case with the catches of swordfish and other billfish species recorded as taken by drifting longlines in Tanzania and this is being investigated.
- **Fresh tuna longliners based in Indonesia**: The data collected since June 2002 as part of the IOTC/OFCF Project has allowed the estimation of catches of longline vessels based in Indonesia for 2003-2004.
- **Other fresh tuna longline fleets**: Although the catches of fresh tuna longline ships based in different ports of the Indian Ocean were re-estimated from data coming from past or recent sampling schemes, the precision of the catch estimates is considered to be poor, especially for those fleets operating from ports not covered by these schemes, and where past catches are estimated using recent catch levels.
- **Deep-freezing longline fleets**: The Secretariat revised catches for 1992-2004 using new information collected during 2005. These catches remain uncertain due to the many assumptions made in estimating the total catches and species breakdown. The number of vessels operating under flags of non-reporting countries has decreased markedly since 2001. The reason for this decrease is not fully known and further revisions of the catch estimates may be done as more information become available.

2.3. Estimation of catches of non-reporting fleets

8. The estimates of catches of non-reporting fleets were updated in 2005 as a result of new information becoming available during the year:

Fresh tuna longline: The catches of fresh tuna longliners were estimated according to the port where the different fleets were based. Most of the catches estimated are from Indonesian-owned or Taiwanese-owned longliners according to the information available.

- **Indonesia:** The catches of Indonesian vessels during 2002-04 were estimated from the information collected through the multilateral catch monitoring program in Indonesia. While revisions to the total catches and species composition for the years prior to 2002 are expected in the future, these data remain uncertain.
- **Thailand:** The catches of fresh tuna longliners from Taiwan,China and Indonesia in Phuket were estimated using data collected through the AFRDEC (Andaman Sea Fisheries Research and Development Centre)-OFCF (Overseas Fishery Cooperation Foundation of Japan)-IOTC Sampling Programme.

- **Malaysia and Singapore:** The catches by fresh tuna longliners based in Malaysia and Singapore since 1992 were estimated using data from the IPTP Sampling Programme, new estimates from the Fisheries Research Institute of Penang, and vessel activity information for Singapore (Jurong).
- **Sri Lanka:** The catches by fresh tuna longliners that unload to processing plants in Sri Lanka were estimated on the basis of previous data collected by NARA (National Aquatic Resources Research and Development Agency) in Colombo and estimates from Phuket and Penang sampling.
- **Maldives:** The catches of fresh tuna longliners were estimated by using information from other landing places and data available on vessels operating in Maldives (Marine Research Center).

Deep-freezing longline - NEI: The catches by large longliners from several non-reporting countries were estimated using IOTC vessel records and the catch data from Taiwanese longliners, based on the assumption that most of the vessels operate in a way similar to the longliners from Taiwan,China. The collection of new information on the non-reporting fleets during the last year, in particular the number and characteristics of longliners operating, led to improved estimates of catches. The number of vessel operating since 1999 has decreased and this has led to a marked decrease in catch levels. The reason for this decrease in the number of vessels (and catches) operating in the Indian Ocean is not clear. Nevertheless, this decrease is somewhat proportional to an increase in the number of vessels recorded operating under flags of reporting countries, such as Philippines and the Seychelles.

2.4. Data related issues for billfish species

9. The following **problem areas** relating to the data for billfishes have been identified:

- Marked differences between the catches of Korean longliners reported as Nominal catch and catch and effort.
- Little information on the catches, effort and size-frequency from fresh tuna longline vessels, especially from Taiwan,China and several non-reporting fleets (1985-1992).
- Little information on the catches, effort and size-frequency from non-reporting fleets of deep-freezing tuna longliners, especially since the mid-1980’s.
- Lack of accurate catch, effort and size-frequency data for the Indonesian longline fishery (1973-1995).
- Little information on the catches, effort and size-frequency data for gillnet and other artisanal fisheries, especially the gillnet/longline fishery in Sri Lanka.

10. **Improvements** to the data available for billfishes have taken place in a number of areas. These include:

- **Receipt of catch and effort data** for the Taiwanese longline fishery (1990-92)
- **New size frequency data for swordfish** from the Taiwanese longline fleet for 1980-2003: Resulting in the Secretariat constructing catch-at-size tables for swordfish.
- **Disaggregation of catch data:** Revisions have been conducted at the IOTC Secretariat aiming at assigning the catches to species in the IOTC database.
- **An improved Vessel Record:** More information has been obtained on the number and type of vessels operating under flags of non-reporting parties. This information comes mostly from various licensing schemes in the Indian Ocean and has become an important element in the estimation of the catches of non-reporting fleets.
- **Improved estimation of catches of non-reporting fleets:** The collection of historical and current information on the landings of small fresh tuna longliners in ports in the Indian Ocean has improved the accuracy of earlier estimates. The more complete Vessel Record also permitted the estimation by flag of the catches of deep-freezing longliners.
- **IOTC-OFCF sampling programmes:** The collection of information on the activities of fresh tuna longliners landing in Thailand and Indonesia has continued during 2005. This has led to more complete and accurate estimates of catches of these fleets. Other valuable data collected in the scope of these programmes refer to length frequencies which will allow length-length, length-weight and weight-length relationships to be established.

- **IOTC-OFCF in Sri Lanka:** A multi-lateral cooperation between NARA (National Aquatic Resources Research and Development Agency), OFCF (Overseas Fisheries Cooperation Foundation of Japan)-IOTC was initiated in 2004. The objective of this Project is to strengthen data collection and processing systems on Sri Lankan tuna and billfish fisheries (Gillnet and longline Fishery (Offshore Fishery) and longline Fishery for large Yellowfin Tuna (Coastal Fishery) so as to allow producing more accurate effort and catch estimates per area and species and increase the amount of size frequency data collected for tropical tuna and billfish species in Sri Lanka. The first results from this program suggest that the catches of billfish recorded in the IOTC database in recent years for these species are much higher than those that actually occurred.

2.5. The current status of the data for billfish

Swordfish

11. **Nominal Catch Data:** The nominal catch data series of swordfish (SWO) is considered almost complete since 1970. The fleets catching most swordfish have been reporting catch statistics since that year, with the only exception being catches of non-reporting fleets (recorded as NEI- in the IOTC Database), and these have always been estimated by the Secretariat. The quality of the catches estimated for NEI fleets is believed to be poor due to the paucity of information available on their activities (only the total number of vessels operating per year is available in most cases). The catches of several fresh tuna longline fleets operating in the Indian Ocean (Indonesia, Thailand, Malaysia, Sri Lanka and Maldives) are also uncertain in years prior to 1992. However, these are thought to be more accurate in recent years due to the implementation of sampling programs in some of these countries to monitor the activities of fresh tuna longliners.

12. **Catch and Effort Data:** Catch and effort data are fully or almost fully available up to the early 1990s but only partially available since then due to the almost complete lack of catch and effort records from NEI fleets and Sri Lanka gillnet/longline fishery since 1992. The effort statistics are believed to be of fair quality for most of the fleets for which long catches series are available.

13. **Size Frequency Data:** Size frequency data from the longline fisheries are available from 1970 (Japan) and 1980 (Taiwan,China). In recent years, the number of specimens measured on Japanese longliners is very low in relation to the total catch, and has been decreasing year by year. The size-frequency statistics available from Korea are incomplete. Size data are also partially available for longline fleets that have been targeting swordfish since the early 1990's (Reunion, Spain, Seychelles, South Africa and Mauritius). The recovery of size data from port sampling regarding fresh tuna longline fleets operating in Phuket, Penang, Sri Lanka and, Indonesia, continued in 2004 and 2005, with many swordfish specimens measured. Size data is also available for the gillnet/longline fishery in Sri Lanka from 1988 to 2004. In general, the amount of catch for which size data for the species are available is high; however, the numbers of specimens measured per strata are low.

Marlins

14. **Nominal Catch Data:** The fleets catching most of the blue marlin (BUM), black marlin (BLM) and striped marlin (MLS) have usually reported nominal catches by species but these are considered incomplete. Marlins are usually not recorded by species (MARL for the three marlins together or BIL/BILL for marlins and other billfish together or TUX for billfish and tuna species together), or simply not recorded at all. The Secretariat has, in these cases, been trying to estimate or assign the catches of these species but this has not always been possible due to there being little information available on species making up the bycatch of the longline, gillnet or other fisheries. Furthermore, the catches of these species by non-reporting fleets or fresh tuna longline vessels in Indonesia, so far estimated by the Secretariat, are also considered important. The quality of the catch estimates for non-reporting fleets are thought to be very poor. The levels of catches of several fresh tuna longline fleets operating in the Indian Ocean (Indonesia, Thailand, Malaysia, Sri Lanka and Maldives) are also uncertain. The implementation of sampling programs to monitor the activities of these fleets has reduced this uncertainty, although the identification of marlin species through port sampling is sometimes difficult[2]. The catch estimates of marlins for the gillnet and longline fisheries of Sri Lanka are uncertain.

15. **Catch and Effort Data:** Catch and effort data are fully or almost fully available up to the early 1990s but only partially available since then, due to the almost complete lack of catch and effort records from NEI fleets and Sri

[2] Specimens of blue marlin and striped marlin are usually unloaded processed (headed and tailed), which makes it difficult to identify the species

Lanka gillnet/longline fishery since 1992 (catches per species being not available or unreliable). The effort statistics are thought to be of fair quality for most of the longline fleets for which long catches series are available, with the exception of Korea. The use of data from Korea is, therefore, not recommended. The catch and effort statistics available for the Taiwanese drifting gillnet fishery (1987-91) are also considered to be of fair quality.

16. **Size Frequency Data:** The amount of size frequency data available for marlin species is low with only regular reports from Japan (longline) and very partial reports from Taiwan,China (longline) and Sri Lanka (gillnet/longline). Some data are also available from port sampling (Sampling Programs) in recent years. In general, the amount of catch for which size data for the species are available has been decreasing since the early 1990's and the numbers of specimens measured per strata are considered to be very low. The quality of this dataset is, therefore, believed to be poor.

Indo-Pacific Sailfish and Shortbill Spearfish

17. **Nominal Catch Data:** Catches of Indo-Pacific sailfish or shortbill spearfish are usually missing from the reports. When reported, these species are usually aggregated with other billfish (BIL/BILL) or with tunas (TUX). The catch series is, therefore, considered very incomplete. Almost no catches are available for these species before 1970. The catch estimates of these species for the gillnet and longline fisheries of Sri Lanka are uncertain. Gillnet catches recorded for other countries did not usually include detailed catches of these species. The same applies to longline and other fisheries catching them.

18. **Catch and Effort Data:** The amount of catch and effort data available for Indo-Pacific sailfish or shortbill spearfish from both gillnet and longline fisheries has been very low, especially since the mid-1980's. Catch and effort data are only available from 1986 for the gillnet/longline fishery in Sri Lanka while being very scarce for other gillnet or line fisheries. For the longline fisheries, only Japan has reported statistics of the species over time. The lack of catch and effort data from all fisheries in recent years is of concern, especially taking into account the dramatic increase in the catches recorded for these species since the mid-1980's.

19. **Size Frequency Data:** The amount of size frequency data available for Indo-Pacific sailfish or shortbill spearfish has been low over time with only regular reports from Japan (longline) and partial reports from Sri Lanka (gillnet/longline). Some data is also available from port sampling (Sampling Programs) in recent years. The lack of size frequency data from most fisheries in recent years is of concern.

3. NEW INFORMATION ON BIOLOGY, ECOLOGY, OCEANOLOGY AND FISHERIES RELATING TO BILLFISH

20. Document IOTC-2006-WPB-12 described trends in the longline fishery in Sri Lanka. The pelagic longline fishery began in Sri Lanka in 1950's, slow progress was observed until late 1980's when it collapsed due to several reasons, mainly unavailability of suitable baits in required quantities. Introduction of nylon netting in early 1980's further reduced longlining effort resulting in the use of a combination of gillnet and longline in the offshore fishery. There has been a clear trend towards pelagic longlining in recent years, mainly due to increased demand for fresh/frozen fish for export market. Several local companies have started operating longliners in offshore waters with small-scale vessels size ranging from 38-52'. In this study one such company was taken as an example, which operates from Beruwala Harbour on the southwestern coast of Sri Lanka since 2002. The operation was started with a single vessel of 52' with 1,000 hooks which then expanded its fleet to 7 of a similar size by 2006. The catch landed during the year 2005 was considered in the study. Tuna (53%) and sword fish (33%) were the most important high valued species of the total landings. About half the tuna catch was bigeye tuna which was not observed in other local fishing operations with gillnet-longline combination. Typically, two to three trips were made per month by each boat with an average of 888.4 kg of fish per operation. About 80% of the catch is landed while live on the line indicating high quality of fish. Higher catch rates were recorded in these vessels compared to the local vessels using longline in combination with gillnet. Several reasons can be speculated for this. The bait used, squid or milk fish, has a major influence on catching ability of tuna or swordfish as they prefer high quality fresh bait. Although these vessels operate within the EEZ of Sri Lanka, the higher catches of swordfish and bigeye tuna could also be attributed to the greater depth at which fishing is carried out (along with the preferable bait). A recent survey revealed that about 25% of the total local fishing fleet now use only longline as the principal fishing technique. Thus an increasing trend was observed among the local fishermen of shifting towards longline fishery. Promoting longlining with necessary modifications in vessel structure and operation to concentrate on target species and to eliminate by catch will be a 'green' light in industry and will contribute in promoting environmentally friendly and sustainable fishing industry in Sri Lanka.

21. Document IOTC-2006-WPB-04 updated the WPB on the La Reunion swordfish fishery and described a proposal for a multidisciplinary study to investigate the stock structure of the Indian Ocean swordfish (*Xiphias gladius*). After peaking at 35,000 t in 1998, the swordfish catch began to decrease despite an increase of the fishing effort. This could be the consequence of a decrease of the swordfish biomass particularly in the western Indian Ocean. In 2004, the total swordfish catch was around 31,000 t. In 2005, the Reunion longline fleet comprises 36 boats from 8 to 33 metres long, operating in the southwest Indian Ocean. With 1,000 t in 2005, the swordfish catch of the Reunion fleet represents 3% of the whole Indian Ocean swordfish catch. The proportion of swordfish in the catch has decreased to 32% in 2005 from 60% in 2000. As for many swordfish fisheries in the Indian Ocean, there has been a decrease in the catch of the Reunion fishery since 1998 followed by a small increase in 2004 and 2005. The catch rates have also decreased significantly since the first years of the fishery but they have stabilised in recent years. On the other hand, the mean size of the swordfish caught by the Reunion fleet during the last 12 years has remained stable without any trend to decrease.

22. The lack of knowledge on the swordfish stock structure and on the migratory behaviour limits the implementation of a sustainable management on this shared resource. A pilot study has been undertaken on 90 swordfish samples collected in four southwest Indian Ocean areas. Analysis of mtDNA and 6 microsatellite loci showed a strong heterogeneity within populations. These preliminary results indicate that there may be a unique stock in this region; however, the geographic scale and the sample size are probably too small to observe significant differences between these 4 areas. Following these preliminary results, there are plans to develop a new program encompassing the whole Indian Ocean, with more sampling sites and samples. This program will be developed on a multidisciplinary approach including genetic, otolith microchemistry, breeding, and mercury contamination.

23. The WPB acknowledged the valuable contribution this work would make to better understanding the stock structure and movements of swordfish and resoundingly endorsed the proposal and encouraged all IOTC members to participate or contribute to the project as much as possible.

24. Document IOTC-2006-WPB-05 described the evolution of the Seychelles semi-industrial longline fishery. The local pelagic longline fishery targeting swordfish started in the Seychelles in 1995. After increasing from 1 to 12 vessels in 2002, only 5 vessels were active in 2005. Fishing effort increased from 31,480 hooks in 1995 to 510,584 in 2001. Fishing was concentrated on the northern part of the EEZ, in an area of approximately 240,000 km². The reported total catch of the semi-industrial longline fishery is estimated at 3,425 t (round weight). Swordfish catches in weight represents 56% of total annual catches, followed by yellowfin tuna 16%, then bigeye tuna with 14%. By-catches constituted of sharks (8%), sailfish (3%), marlin (2%) and other species (about 1%). Since the year 2000, some local longliners changed their fishing strategies to target sharks. The annual swordfish CPUE shows a significant decreasing trend from 0.75t/ 1,000 hooks in 1998 to 0.50t/ 1,000 hooks in 2002. No significant trend is observed for tunas. On a monthly basis, high CPUE's on swordfish are obtained from April to June (0.6 to 1.0t/ 1,000 hooks) and between December and May for tunas. Monitoring of size frequency carried out since 1995 shows an increasing trend of mean length since 1997, with PAL (Pectoral Anal Length) ranging from 44 to 52 cm. There is an increase in swordfish size from March to June.

25. The WPB noted document IOTC-2006-WPB-10 (not presented). This paper presented information obtained by observers onboard Spanish longliners on the relationships between body round weight and lower jaw fork length, and sex ratio by length range for species belonging to Xiphiidae and Istiophoridae families. Covering the twelve months in 2005, two ships performed 539 sets and worked 531 916 hooks of five different kinds, baited with mackerel or squid, or squid-like species. From the 75 species / groups of species caught, billfishes comprised 40% of round weight (466t) and 9824 individuals, including 9438 SWO: *Xiphias gladius*, 126 SFA: *Istiophorus platypterus* and 168 SSP: *Tetrapturus angustirostris*. Observers weighed and measured the length of 5091 individual SWO. The length-weight relationship for SWO (both sexes combined) is described by the equation $W = 1.83 \times 10^{-6} \times L^{3,3921}$. A length-weight relationship is also described for males and females, separately. Length-weight relationships are also presented for *Istiophorus platypterus* (SFA) - combined sex from 81 individuals; and *Tetrapturus angustirostris* (SSP) - combined sex from 116 individuals. Sex and size of 6836 SWO individuals was recorded. 67% of individuals were females.

26. The WPB noted document IOTC-2006-WPB-11 (not presented). This paper presents results obtained over the last few years from research carried out on swordfish and other bycatch species from the Spanish surface longline fleet operating in the Indian Ocean. Information on the activities of this fleet for 2003 and 2004 is also given. New information on the reproduction of the swordfish is provided. Breeding grounds for swordfish appear to be restricted to western areas based on data for gonadal indices, sex-ratios at size and other available information

taken from observers. Characteristic patterns of spawning-type sex-ratio at size are also described. A review of the available information on the tagging programs conducted on the swordfish and associated species is also made, with a comparison of the recapture rates obtained. Information on by-catch species, accidental by-catches, finning practices and the reproductive parameters of *Prionace glauca* are also described.

27. Document IOTC-2006-WPB-INF01 described biological data on swordfish (and other species) gathered at the IOTC Secretariat: Basic biological data on fish size (i.e., minimum, maximum, and mean) and size relationships/conversions (i.e., length-to-weight and length-to-length) are essential for understanding growth rate, age structure, and other aspects of population dynamics. In artisanal and industrial tuna fisheries, tuna, billfish, tuna-like species and by-catch species are processed in many different ways and landed in different states (round, gilled and gutted etc). Measurements of actual size (length and weight) are recorded before processing only when observers are onboard fishing vessels or when fish are landed whole. Given that processing is common practice, being able to convert different measures of dressed and undressed fish to whole fish is essential. As information about conversion factors for fish from the Indian Ocean is limited, a review of conversion factors data available for tuna, billfish, and tuna-like species was carried out. Information has been obtained from a range of sources including, IOTC, the IOTC-OFCF project, other regional fisheries bodies and the scientific literature. The aims of this document are to present definitions of the standard and processed lengths of swordfish (and tuna and other tuna-like species), to identify the various states of fish for which measurements might be available, to highlight the data already available for the purpose of reporting size frequency and for scientific research; and to point out where deficiencies in the current databases exist.

4. UPDATE OF STOCK INDICATORS

28. Document IOTC-2006-WPB-INF02 described progress and preliminary results from a study to identify robust stock status indicators for broadbill swordfish and tropical tunas. The paper presents results from simulation models that investigate the relative sensitivity of size-based indicators to life history parameters; the effects of sexual dimorphism; the relative responsiveness of indicators to exploitation; and the time-series behaviour of indicators and their likely effectiveness in feedback decision rules. Preliminary results indicate that, in general, mean length and mean weight indicators were found to be more robust than the other indicators considered (median and 95th percentiles of length and weight in the catch; and the proportions of small, large and mature fish in the catch); and the weight based indicators were more sensitive to changes in biomass than the length-based indicators. Size-based indicators are likely to be more sensitive to changes in biomass for stocks with relatively low growth rates (k) and relatively high mortality (M). However, the steepness of the stock recruitment relationship was determined to be the most important factor. If a stock has low steepness, a size based indicator, particularly those based on length, may not be responsive enough to detect changes in biomass in time. If a stock has low steepness, a size based indicator, particularly those based on length, may not be responsive enough to detect changes in biomass in time. Even at high steepness, the expected change in indicators for a stock with high growth rate (k=0.6) is relatively small. Results examining the effect of sexually dimorphic growth implied a stronger response in indicators based on the data from the gender with the lower growth rate (females). The effect of pooling data across genders was dependent on the form of the male and female growth curves, among other factors, but ranged from the pooled indicator behaving like the female-based indicator, to behaviour in between that of the gender-specific indicators. The difference in performance of the stock under decision rules highlighted the importance of designing decision rules that are robust to uncertainty in the underlying dynamics. Further work is continuing.

4.1. *Marlins and Sailfish*

29. In the absence of detailed analyses or working papers covering these species, data held in the IOTC data base has been used to briefly describe catches of the istiophorid billfishes, Indo-Pacific sailfish and short-billed spearfish. Reported catches of the three marlin species increased throughout the 1980’s and the early 1990’s, but for all species, catches have decreased since then (Figure 3). Blue marlin catches peaked in 1997 at 15,000 t and have since fallen. Catches in 2004 were 10,600 t. Catches of black marlin also peaked in 1997, but were around 2700 t in 2004. And striped marlin catches which varied between 4,000 and 7,000 t for most of the 1980’s and 1990’s decreased to around to 3,000 t in recent years. As these species are not clearly targeted by any fishery, the catch trends could be considered a useful indicator of relative abundance, depending on the extent of the changes in global fishing effort. The catch of Indo-Pacific sailfish increased markedly during the 1990’s reaching a peak of 6,000 t in 1997 (Figure 4). In 2002 the catch had increased to 16,000 tonnes and in 2004 the catch had increased to 22,600 t.

4.2. Swordfish

30. Swordfish are mainly taken as a target or by-catch of longline fisheries throughout the Indian Ocean, and Sri Lankan gill net fisheries in the central northern Indian Ocean (Figure 5). They are rarely caught by purse seines. In the 1990's, exploitation of swordfish, especially in the western Indian Ocean, increased markedly, peaking in 1998 at around 35,000 tonnes (Figures 1 and 2). By 2002, twenty countries were reporting catches of swordfish (Figure 6). The annual total catch has averaged 31,400 t in recent years (2000-2004) and in 2004 was 31,000 tonnes. The largest catches of swordfish are taken in south western Indian Ocean areas (Figure 5 and 7).

31. Since the early 1990's China,Taiwan has been the dominant catcher of swordfish in the Indian Ocean (40-60 % of total catch – Figure 6). Taiwanese longliners, particularly in the south western and equatorial western Indian Ocean, target swordfish using shallow longlines at night. The night sets for swordfish contrast with the daytime sets used by the Japanese and Taiwanese longline fleets when targeting tunas.

32. During the 1990's a number of coastal and island states, notably Australia, La Reunion/France, Seychelles and South Africa developed longline fisheries targeting swordfish, using monofilament gear and light sticks set at night. This gear achieves higher catch rates than traditional Japanese and Taiwanese longlines and as a result, coastal and island fisheries have rapidly expanded to take over 10,000 tonnes of swordfish per annum in the late 1990's.

33. The average weight in the catch of the main longline fleets does not show any consistent trend (Figure 8).

Reunion Swordfish fishery status (IOTC-2006-WPB-04)

34. At 1,000 tonnes in 2005, the swordfish catch of the Reunion fleet represented about 3% of the entire Indian Ocean swordfish catch. While there was a decrease in the catches from around 2000 t in 1998 to 750 t in 2002, catches since have increased and in 2005 were around 1,000 t. While CPUE has generally declined since 1994, it has stabilised in recent years. The mean size of the swordfish caught by the Reunion fleet during the last 13 years has remained stable.

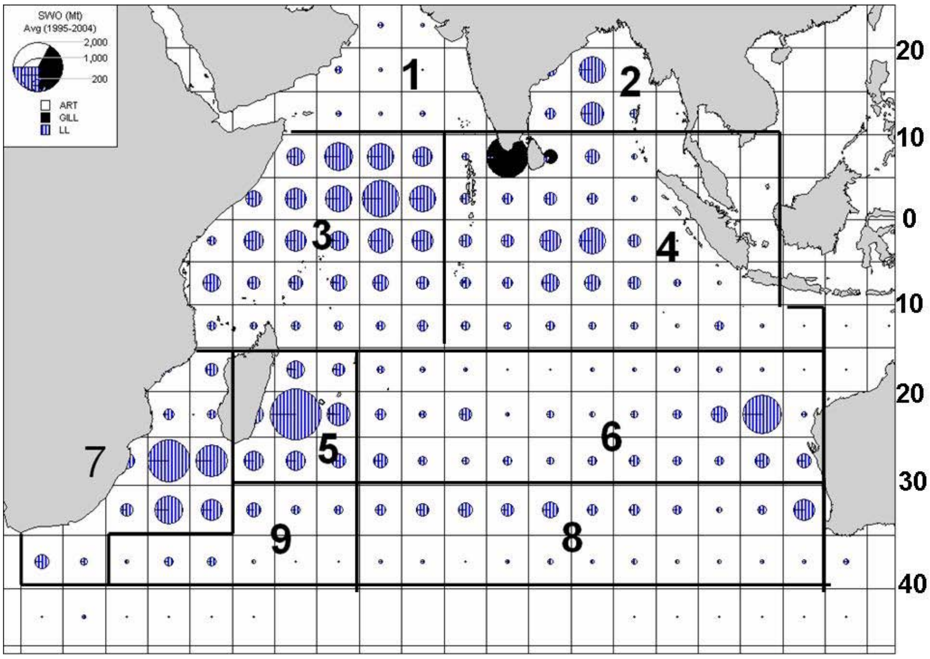

Figure 5. *Average catch of swordfish (tonnes per year) for the period 1995-2004, for longline and gillnet fisheries in the Indian Ocean. Areas used for CPUE analyses are numbered.*

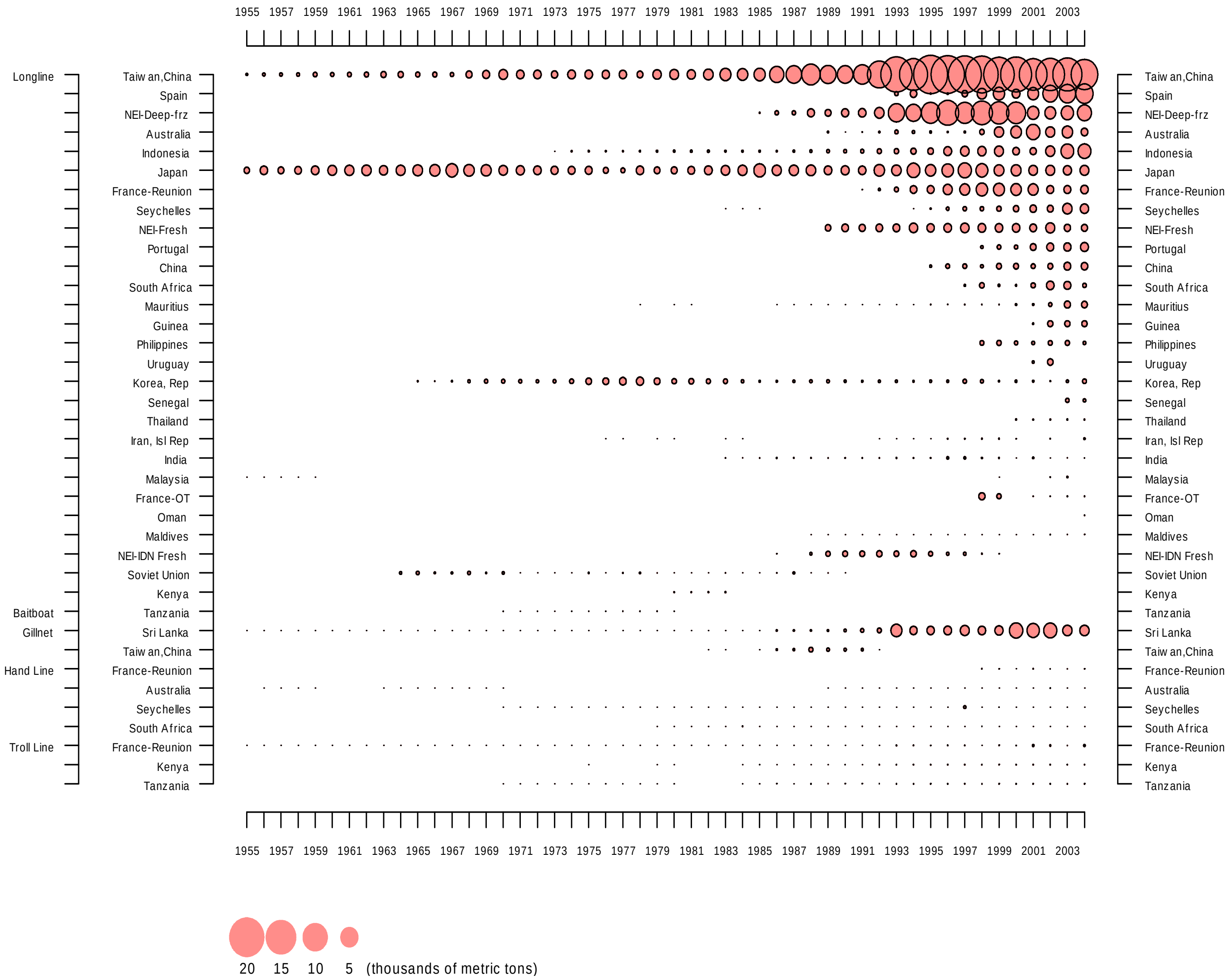

Figure 6: *Catches of swordfish in the Indian Ocean for the period 1955-2004, in thousands of tonnes by gear and country/fleet.*

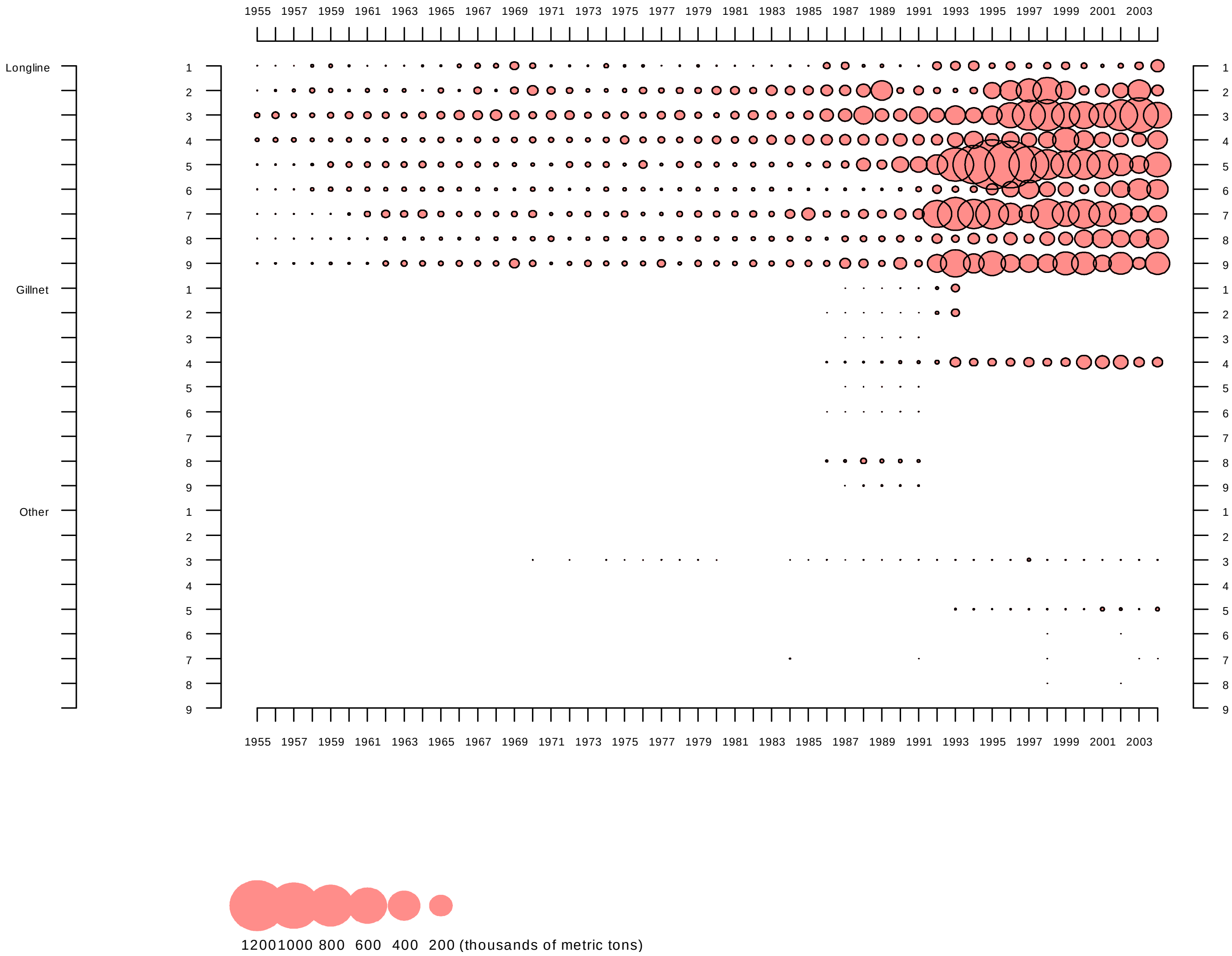

Figure 7: *Catches of swordfish by area and gear. Areas are shown in Figure 5.*

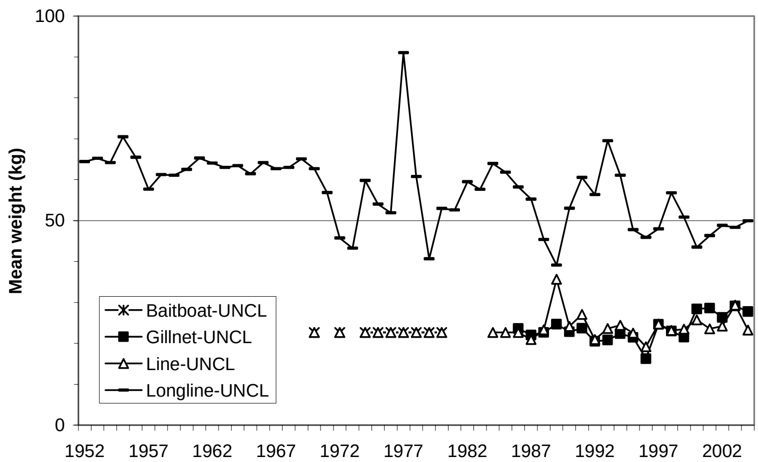

Figure 8: *Mean weight (kg) of swordfish captured by various fisheries in the Indian Ocean.*

5. STOCK ASSESSMENTS OF BILLFISH

Review of methods

35. Document IOTC-2006-WPB-08 described an overview of Current Approaches for South West Pacific Swordfish Assessment and asked “are the methods applicable for the Indian Ocean?” This paper provides a brief overview of a number of approaches that are currently under investigation for SW Pacific broadbill swordfish stock assessment. It is hoped that this will provide a helpful background for discussions about assessment options for Indian Ocean tuna. In recent years, some areas of the SW Pacific fishery have shown worrying signs of depletion and this has provided the impetus for domestic Australian management action and considerations for wider management in the South Pacific region under the auspices of the Western and Central Pacific Fisheries Commission. East coast Australian stock assessment for swordfish has historically focused on data-based indicators of catch rates and size frequency data. In the last couple years, a range of model-based assessments have been pursued to provide advice toward different management-related questions. At the simplest level, estimators of depletion and renewal have been applied to the inshore Australian fishery, in an attempt to quantify harvest rates that can be sustained without causing further decline in inshore CPUE. Spatially-structured surplus production models have been used in an attempt to link local Australian dynamics with the greater SW Pacific population. Complicated assessment models (Multifan-CL and CASAL) are being used to integrate all of the fisheries and biological data in a manner that can represent many of the relevant processes, describing age-, sex-, and area-specific details of the sub-populations and their links through migration. Concurrent with the development of assessment models, simulation testing is being undertaken to evaluate the performance and reliability of different approaches. These models will be used to formulate advice related to policies for meeting local and regional management objectives. However, it is recognized that the stock assessment methods might not deliver information at the level of precision that will be required to satisfy competing fisheries management objectives, in which case we encourage the pursuit of management strategies that are robust to the major uncertainties.

36. A stock assessment for swordfish was attempted by the WPB in 2006. Given the paucity of information currently available no assessment was attempted for marlin and sailfish species.

5.1. Stock assessment for Swordfish

CPUE Indices

37. Document IOTC-2006-WPB-07 described the standardisation of swordfish CPUE from the Japanese tuna longline fisheries in the Indian Ocean spanning 1975 to 2004, based on 5° square by month data. There were insufficient data to calculate indices for areas (see Figure 5) 1, 2, 5 and 9 and observations for these areas were removed from the subsequent GLM analysis. Attempts to fit thermocline data were unsuccessful because of too many missing values. Other environmental parameters were also excluded from the model after they were found to be non-significant. The overall, standardised swordfish CPUE showed a variable but decreasing trend over time. This index generally tracked the nominal CPUE index but the standardised CPUE was consistently higher than the nominal CPUE prior to 1990 then consistently lower (Figure 9). Comparison of the standardised CPUE trends for areas (3, 4, 6, 7 and 8 – see Figure 5) suggested some inconsistencies among regions and the WPB agreed these merited further examination with respect to investigating the effects of the targeting (number of hook per basket) and localised depletion concerns

38. Document IOTC-2006-WPB-09 described the standardisation of swordfish CPUE from the Taiwanese tuna longline fisheries in the Indian Ocean spanning 1979 to 2003, based on set by set data. In the Taiwanese analysis, targeting was accounted for using three categories of swordfish composition (<8%, 8-15%, >15% of species landings in numbers) as a proxy for hooks per basket information since 1995 (a method used by the authors in previous working parties). By contrast to the Japanese CPUE trend, the Taiwanese CPUE did not show a declining trend. On the other hand the nominal index showed an increasing trend (Figure 10). The working party concluded that more work needed to be done to investigate the effects of targeting, in particular, efforts be focused on developing a the CPUE time series from 1995 when information on hooks per basket is available and obtaining information from the industry to assist with interpretation of the apparently increasing catch rates.

39. The differences in the CPUE indices from the Japanese and Taiwanese longline fisheries are poorly understood and the WPB recommended further investigations of the data from both fleets with respect to the effects of gear deployment practices (e.g. number of hooks per basket, moon phase, bait types, use of light-sticks, set time etc).

40. The WPB thanked the Japanese and Taiwanese scientists for their collaborative efforts relating to the CPUE and initial ASPIC analyses.

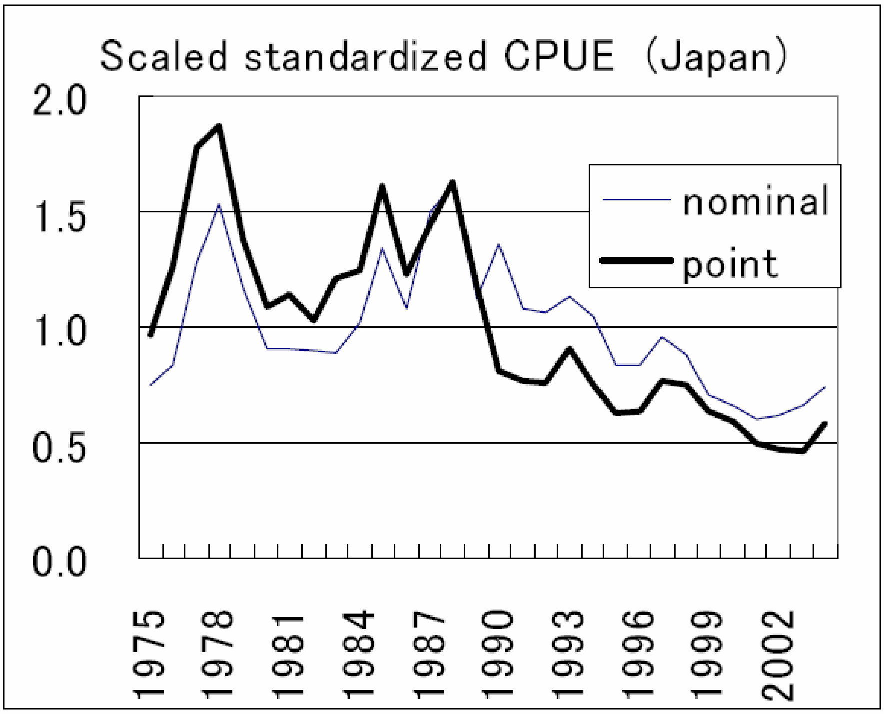

Figure 9: *Catch per unit effort indices (nominal and standardised) for swordfish caught by the Japanese fleet in the Indian Ocean (average set to 1).*

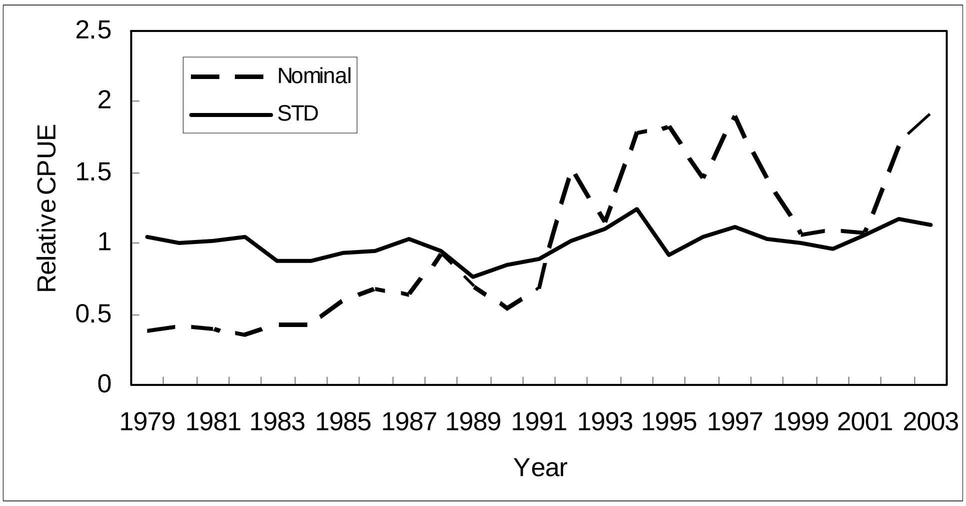

Figure 10: *Catch per unit effort indices (nominal and standardised) for swordfish caught by the Taiwanese longline fleet in the Indian Ocean. The relative values are scaled to the average estimates.*

Models

41. A quantitative stock assessment was attempted for swordfish in 2006 by the WPB using multiple age aggregated surplus production models. Document IOTC-2006-WPB-06-revised described assessment results from Fox, Schaefer and Pella-Tomlinson models (using a Stock-Production Model Incorporating Covariates (ASPIC software). These models were subsequently re-run; using revised data inputs recommended by the WPB. An alternate assessment using an independently implemented Pella Tomlinson model was also carried out during the meeting using the revised data inputs. Models were run using two separate CPUE time series: 1975 - 2004 and

1990 – 2004 derived from the Japanese longline fishery. The WPB recommended these alternative time series scenarios because changes in gear configuration and new vessels entering the fishery from 1990 onwards resulted in an increased proportion of deeper set longlines and it is unclear whether the CPUE time series before and after 1990 are compatible.

ASPIC

42. A Stock-Production Model Incorporating Covariates (ASPIC) fits several forms of surplus-production models to catch (mass) and relative abundance data, including the Schaefer logistic model, the Fox exponential-yield model, and the Pella-Tomlinson generalised model. ASPIC uses bootstrapping to provide estimates of parameter uncertainty.

43. The ASPIC model as described in document IOTC-2006-WPB-06 provided unstable results across the range of scenarios tested due to lack of convergence, obtaining biologically un-realistic results. When both the Japanese and Taiwanese CPUE series were used, they were clearly inconsistent with each other. Most of the ASPIC runs based on the 1975-2004 CPUE series were adversely affected, as were all of the ASPIC Pella-Tomlinson runs based on both time series. Based on discussions, the WPB considered the following points and further analyses were conducted accordingly:

- **Clarification of gear deployment information in CPUE series:** It is known from other swordfish fisheries around the world that gear configuration effects are a major factor influencing catch rates and typically are a major source of variation in CPUE standardisation analyses. The WPB considered that the Taiwanese standardised CPUE series were likely more biased than the Japanese series due to the lack information on gear configuration (see above). By contrast, the Japanese data did contain specific information on hooks per basket and because of this, the Japanese standardised CPUE was the only series used in the 2006 assessment.
- **Temporal discontinuity in CPUE time series:** It was agreed to use the CPUE data from sub-areas 3, 4, 6, 7, 8 (see Figure 5) combined for further analyses as the aggregate was considered to provide a more representative index for the current Indian Ocean fishery. There is a possible regime shift before and after 1990 due to the introduction of the ultra deep longlines after 1990. Thus, the consistency of the CPUEs before & after 1990 is uncertain, despite making adjustments for the targeting factor (Figure 11). The WPB decided to investigate both CPUE series as alternative plausible scenarios.

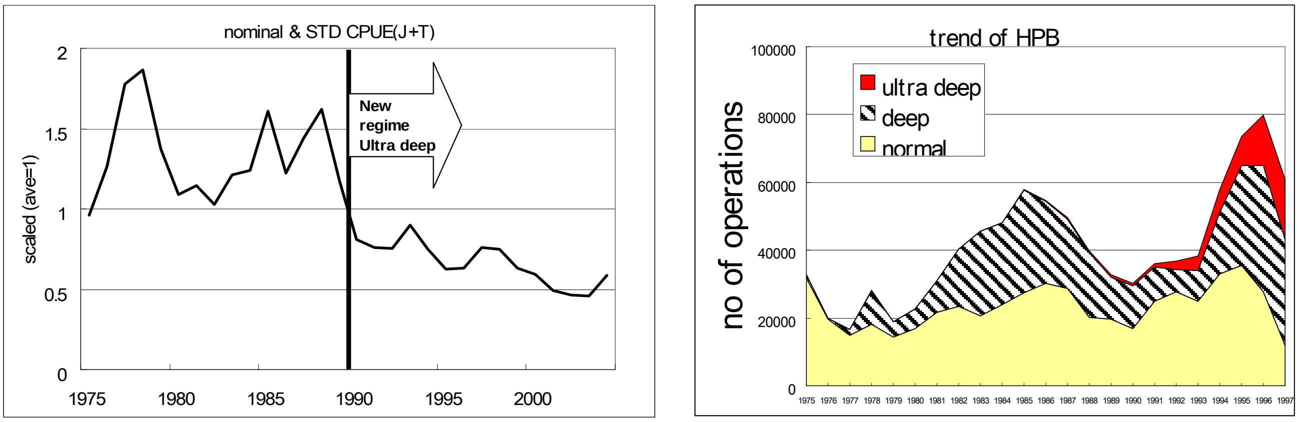

Figure 11: *Indications of a possible regime shift in catch rates related to changes in the setting practices of Japanese longliners over time. Nominal catch rates (left). Number of operations performed using normal, deep and ultra-deep longline sets (right).*

- **Incorporating a range of production scenarios:** The WPB considered that the Schaefer production model might not represent swordfish production dynamics well, therefore the use of both the Fox and Pella Tomlinson models was recommended.
- **Using the complete timeseries of catch information:** The WPB recommended using the complete time series of the Indian Ocean catch data from 1952-2004.
- **Initial biomass constraint:** It was assumed that the swordfish population was at carrying capacity in 1952 (i.e. dynamics start from an equilibrium unfished state).

Results

44. The final ASPIC model outputs (Table 1) suggest that stock biomass decreased markedly from the early 1990's corresponding to a sharp increase in fishing mortality. Based on the point estimates and confidence limits, the assessment indicates that there is probable overfishing of the swordfish stock in Indian Ocean in recent years (Fcurrent/ $F_{MSY} > 1$, Figure 12b) while the stock currently appears not to be in an overfished state (Bcurrent/ $B_{MSY} > 1$, Figure 12c). The current catch level is above the estimated MSY (Table 1).

Pella Tomlinson surplus production model

A Pella-Tomlinson surplus production model was applied to the Indian Ocean swordfish fishery as a preliminary attempt to gain insight into the stock status and productivity potential (IOTC-2006-WPB-14). The insight and recommendations obtained in relation to the ASPIC runs were also adopted for this model as itemised below. Given the paucity of life history information for swordfish in the Indian Ocean, information from other areas and pelagic species were adopted as bounds. Key assumptions included:

- Catch (t) from the entire Indian Ocean 1952-2004 is assumed to be known without error.
- GLM Standardised CPUE from the Japanese fleet (areas 3,4,6,7,8 see Figure 5 combined) is assumed to be proportional to abundance (with lognormal observation errors). A potential discontinuity in fishing methods around 1990 (related to set depths) was recognised by considering two alternative CPUE time series: 1975-2004 and the truncated 1990-2004.
- Stock production dynamics (combined growth + recruitment – natural mortality) are deterministic, iterated on an annual time step, starting from an unfished state.
- 2 surplus production curves (as defined by shape parameters: B_{MSY}/K, MSY/K) were imposed as constraints that bound a range of plausible life history parameters
- Production curves were estimated from the equilibrium yield curves resulting from the age-structured dynamics of a relatively productive population (high stock recruitment curve steepness and high natural mortality, possibly resembling yellowfin tuna or bigeye tuna), and a less productive population (low steepness, low mortality possibly resembling Southern Bluefin Tuna), each combined with fishery selectivity resembling Pacific swordfish stock estimates. Growth characteristics (length at age, weight at age) and fisheries selectivity was derived from Pacific Ocean swordfish.
- Four model scenarios were considered with equal plausibility (i.e. we did not consider that the type of information incorporated in the model had the capacity to distinguish plausibility among scenarios on the basis of the fit to the data):
    - Low productivity; CPUE 1975-2004
    - High productivity; CPUE 1975-2004
    - Low productivity; CPUE 1990-2004
    - High productivity; CPUE 1990-2004
- 3 free parameters are estimated for each model scenario: Carrying capacity (K), catchability, CPUE observation error variance.
- When the parameters governing the shape of the productivity curve were not constrained, the model tended to estimate a curve with MSY at extremely low biomass (i.e. corresponding to a stock with extremely high stock recruitment curve steepness and very high natural mortality, the latter seems qualitatively incompatible with observed swordfish age structures).
- When the maximum productivity was unconstrained, models using the long CPUE series(1975-2004) tended toward an upper bound on productivity. When unbounded, the 1990-2004 CPUE time series did not estimate extremely high productivity.
- Statistical uncertainty quantification consisted of 95% confidence bounds calculated using the multivariate normal approximation from the inverse Hessian matrix (and delta method for derived parameters)

Results

45. All scenarios suggest that overfishing is likely to be occurring (current exploitation rates are likely above F_{MSY} (Table 1). The decline in the stock since 1952 estimated using the long CPUE series is much more severe than that estimated using the short CPUE series (Figure 12a). The low productivity scenarios suggest that the stock might be overfished relative to B_{MSY} and current catches appear to be above the estimated MSY. The depletion estimators are very similar among models because relative abundance closely tracks the CPUE trend, while the MSY-related indicators are sensitive to the functional form of the surplus production curve (which cannot be reliably estimated from the available data).

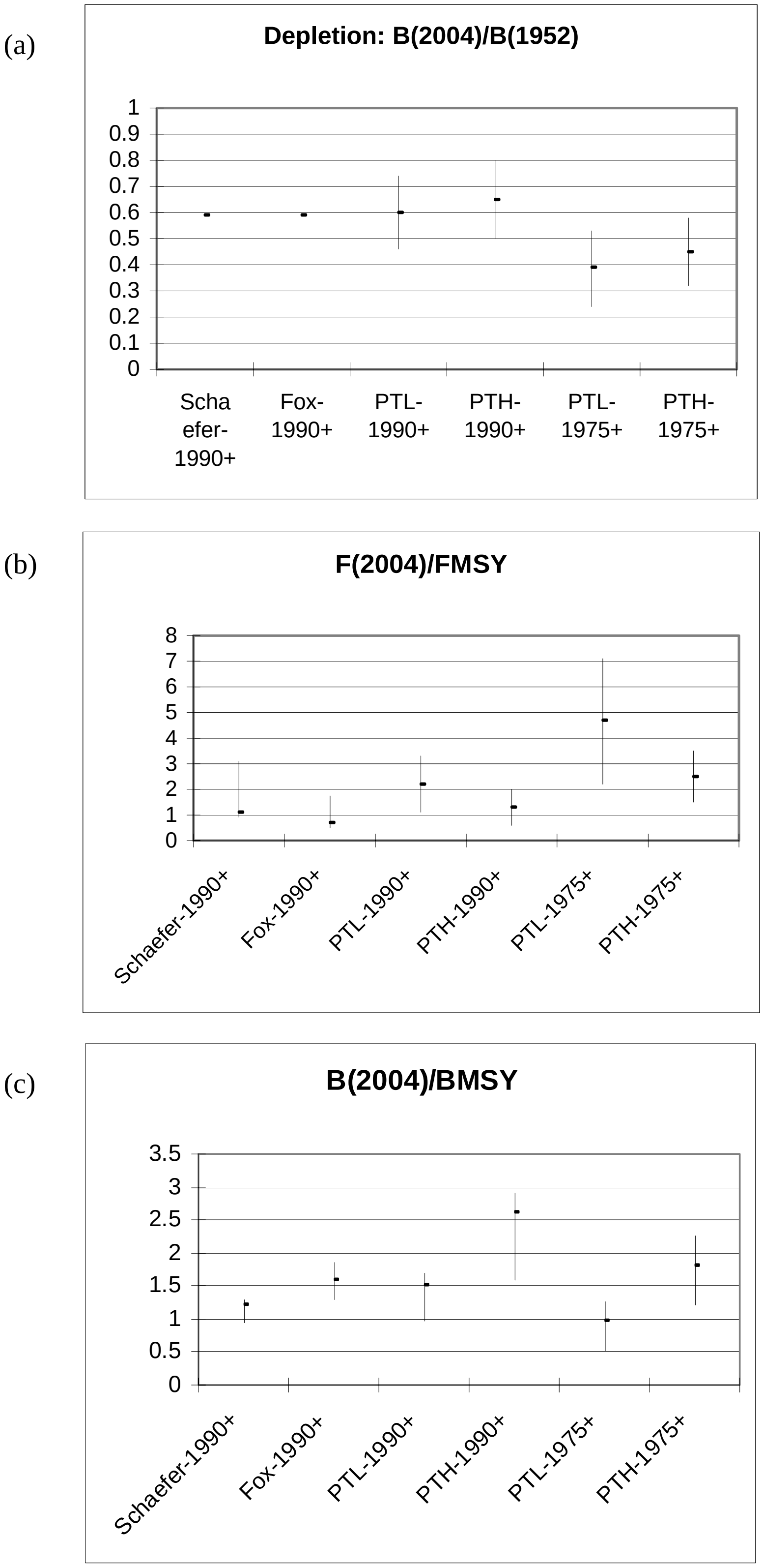

Figure 12. *2006 Indian Ocean swordfish stock assessment results. Stock status estimates from the six successful production model fits. (a) Current biomass levels as a proportion of the biomass in 1952 (when the stock was considered to be at carrying capacity i.e. at equilibrium in an unfished state (b) Current fishing mortality relative to the level of fishing mortality at MSY (c) current biomass relative to the estimated biomass at MSY. Confidence limits are 80% for the Fox and Schaefer models (Confidence limit estimates are not available for the depletion estimates) and 95% for the Pella-Tomlinson models.*

Table 1. SUMMARY OF MODEL RESULTS

CPUE 1975-2004

	ASPIC		**Pella Tomlinson**	**(± 95% CI)**
	Schaffer model	**Fox model**	**High productivity**	**Low productivity**
MSY (t)	*	*	27,954 (24487 – 31421)	17340 (14686 – 19994)
Catch in 2004	*	*	31,288	31,288
B(MSY)	*	*	45,570 (41098 – 52769)	138650 (118980 – 161571)
B(2004)	*	*	84,196 (49447 – 118945)	134590 (64140 – 205040)
B(2004)/B(MSY)	*	*	1.81 (1.20 – 2.25)	0.97 (0.54 – 1.27)
F(MSY)	*	*	0.15 (0.15 – 0.15)	0.05 (0.05 – 0.05)
F(2004)	*	*	0.37 (0.22 – 0.52)	0.23 (0.11 – 0.35)
F(2004)/F(MSY)	*	*	2.48 (1.46 – 3.50)	4.65 (2.22 – 7.08)

* Numerical convergence problems

CPUE 1990-2004

	ASPIC	**(± 80% CI)**	**Pella Tomlinson**	**(± 95% CI)**
	Schaffer model	**Fox model**	**High productivity**	**Low productivity**
MSY (t)	23,540 (9,329 – 28,460)	27,000 (9,574 – 32,610)	37,332 (25,579 – 49,085)	23,665 (17,081 – 30,249)
Catch in 2004	31,288	31,288	31,288	31,288
B(MSY)	224,800 (139,600 – 534,800)	179,000 (126,500 – 373,100)	62,237 (45,404 – 85,310)	189,228 (143,264 – 249,939)
B(2004)	263,000	286,000	161,990 (73,964 – 250,016)	285,790 (138761 – 432819)
B(2004)/B(MSY)	1.17 (0.95 – 1.34)	1.60 (1.31 – 1.85)	2.60 (1.63 – 2.93)	1.51 (0.97 – 1.73)
F(MSY)	0.105 (0.021 – 0.179)	0.151 (0.032 – 0.282)	0.150 (0.147 – 0.153)	0.050 (0.049 – 0.050)
F(2004)	0.119	0.111	0.193 (0.088 – 0.298)	0.109 (0.053 – 0.166)
F(2004)/F(MSY)	1.13 (0.91 – 3.10)	0.74 (0.50 – 1.75)	1.29 (0.59 – 1.99)	2.19 (1.06 – 3.32)

Summary of Stock Assessment results

46. While the stock assessments represent a major advance in the assessment of Indian Ocean swordfish the results are considered preliminary. Considerable uncertainties remain, including:

- Uncertainty in the utility of the CPUE index as an estimate of relative abundance. In particular, there is a need to better understand the effects of changing gear configuration and setting practices over time and space.
- Uncertainty in the catch time series. In particular, data from the Taiwanese fleet from the SW Indian Ocean (20-30S) seems to be missing.
- The production models used in the assessment have limited flexibility to represent many potentially important aspects of fisheries dynamics, including recruitment variability and transient age structure effects. The simple models cannot directly include additional data relating to size frequencies, sex composition or spatial dynamics.
- Unknown stock structure.
- For the Pella-Tomlinson model, the use of life history and production parameters derived from Pacific Ocean swordfish in the Indian Ocean assessment might not be appropriate.

47. It remains unclear whether the short (1990-2004) or long (1975-2004) time series of CPUE is more appropriate for swordfish assessment. The ASPIC software did not converge reliably for the long time series, but in itself this is not sufficient for discarding the longer time series.

48. Notwithstanding these uncertainties in the assessment and in the details of the results, the overall picture they presented was consistent, particularly in terms of the current levels of fishing mortality and stock biomass levels.

49. Stock biomass decreased markedly from the early 1990's corresponding to a sharp increase in fishing mortality. Based on the point estimates and confidence limits, on balance the assessment model results indicate that there is probable overfishing of the swordfish stock in Indian Ocean in recent years (Fcurrent/FMSY > 1, Figure 12b) while the stock currently appears not to be in an overfished state (Bcurrent/ BMSY > 1, Figure 12c). The current catch level is above the estimated MSY and probably not sustainable.

5.2. Technical advice on swordfish

50. The WPB considered a range of information in formulating its technical advice in 2006.

51. The overall standardized CPUE of swordfish for the Japanese fleet for all areas of the Indian Ocean showed a variable but continuous decline over time. However, this result appears to be driven by the declining trend in the areas north of the equator (areas 3 and 4 combined) as the CPUE trend from the areas south of the equator (areas 6, 7 and 8 combined) appears to have stabilised in recent years. Catch rates following 1990 are markedly lower than those prior to this time (particularly in southern areas) and this may be due to an apparent regime shift in fishing practices after 1990. This marked decrease in CPUE also follows substantial increases in catches throughout the 1990's, particularly in the western Indian Ocean.

52. The apparent fidelity of swordfish to particular areas is a matter for concern as this can lead to localised depletion. In previous years, localised depletion was inferred on the basis of decreasing CPUEs following fine scale analyses of the catch effort data. While no fine scale analyses of CPUE were carried out in 2006, the WPB could not discount that localised depletion was still occurring in some areas. Localised depletion has occurred in other parts of the world where swordfish have been heavily targeted.

53. The annual average sizes of swordfish in the respective Indian Ocean fisheries are variable but show no trend. It was considered encouraging that there are not yet clear signals of declines in the size-based indices, but these indices should be carefully monitored. It was noted that since females mature at a relatively large size, a reduction in the biomass of large animals could potentially have a strong effect on the spawning biomass.

54. Notwithstanding the uncertainties in the 2006 assessments using surplus production models, the overall results were consistent, particularly in terms of the current levels of fishing mortality and stock biomass levels. Stock biomass decreased markedly from the early 1990's corresponding to a sharp increase in fishing mortality. Based on the point estimates and confidence limits, on balance the assessment model results indicate that there is probable overfishing of the swordfish stock in Indian Ocean in recent years (Fcurrent/ FMSY > 1) while the stock currently

appears not to be in an overfished state (Bcurrent/ B_{MSY} > 1). The current catch level (around 31,500 t) is above the MSY and probably not sustainable.

55. The WPB considered that any increase in the catch of, or fishing effort on, swordfish should not be allowed. Furthermore, management measures focussed on controlling and/or reducing effort, especially in the south-west Indian Ocean are recommended.

6. RESEARCH RECOMMENDATIONS AND PRIORITIES

6.1. Priorities

Response to the request from the Commission at S9 in relation to apparent localised Swordfish depletions

56. Following the presentation of the 2004 report of the Scientific Committee (IOTC-2004-SC-R) to the Commission at S9, the Commission noted (para 21) the technical recommendations made by the SC regarding the status of the swordfish resource and agreed that the issue of local depletion was serious and requested the SC to undertake area-specific analyses, with particular emphasis for the southwest Indian Ocean, for the Commission's future consideration. The 2006 WPB was unable to undertake any work on this matter and agreed to make it a priority task for the next WPB meeting.

6.2. Recommendations in general

57. Despite having advanced the stock assessment for swordfish, the WPB acknowledged that many of the recommendations made in 2004 had not been addressed and as a consequence most of these recommendations are carried forward in this report. Several new recommendations have been made as a result of the stock assessment modelling.

6.3. Recommendations concerning data

1) Taiwanese data: The WPB recognized the valuable contribution in new data and analyses provided by Taiwanese scientists, particularly in relation to information on gear configuration of Taiwanese longliners (e.g. hooks per basket) and the heterogeneity of the configuration among vessels. It was noted that these data were only collected after 1995. In the Taiwanese analyses, data prior to 1979 were aggregated by 5x5 degree areas. Taiwan,China reported that since 2003 their longline vessels logbooks has included a field for time of setting the line, which the WPB noted was critical for evaluating the targeting practices of this important fleet. It is also recommended that data related to the use of lightsticks and bait types should be recorded for catch rate standardization. Catch, effort and size data for the Taiwanese deep-freezing longline fleet were made available for use at the meeting, and a Taiwanese scientist provided valuable scientific support to the WPB. These efforts are acknowledged and appreciated.

2) Marlins and sailfishes: there is a critical lack of statistical data for this group of fishes. It is strongly recommended to better estimate catches and discards by species and by gear, by size and sex.

3) Purse seine landings: It is strongly recommended that past and future catches of marlins taken as by-catches by purse seiners be estimated. The historical yearly landing of marlins by tropical purse seiners could be estimated from observer data, and in the future, landings data should be monitored (preferably by species and by size). It is also recommended to develop permanent observer programmes on these fleets, at least at a small scale, in order to better estimate by-catches of billfishes.

4) Sex ratio by size: It is desirable to sample the size of swordfish and marlins as a function of their sex whenever possible.

5) IOTC-OFCF project: The WPB emphasizes its support to the IOTC-OFCF project and recommends that priority be given to countries with substantial catches of swordfish and billfishes which are not properly monitored or are reported as aggregates (e.g.: Sri Lanka gillnet fisheries).

6) Written statistical reports should be obtained from scientists from each fishing country on all fisheries, even when a country cannot participate in the working group meeting. The IOTC Secretariat should request these reports before WPB meetings**.**

7) Billfishes length measurements: Length data should be reported to the IOTC in a standard format to facilitate comparison of data from different countries. When these lengths are collected in a non-standard way, they should be converted to the standard form of reporting using robust methods. The basic data used to establish these conversions should be kept by IOTC. The WPB strongly recommends that size measurements should be always taken in straight length, never in round length (this is because the condition factors and shapes of fishes are highly variable at a given size between time and area strata).

6.4. Research recommendations

1) Swordfish stock structure and migratory range — using genetics techniques: Analysis of mtDNA and 6 microsatellite loci showed a strong heterogeneity within populations. These preliminary results indicate that there may be a unique stock in this region; however, the geographic scale and the sample size are probably too small to observe significant differences between these 4 areas. Following the results from a pilot genetic study (outlined in IOTC-2006-WPB-04), there are plans to develop a new program encompassing the whole Indian Ocean, with more sampling sites and samples. This program will be developed on a multidisciplinary approach including genetic, otolith microchemistry, reproductive biology, and mercury contamination to improve knowledge on the swordfish stock structure and migratory range. The WPB encouraged IOTC members to participate or contribute to the project as much as possible.

2) Swordfish stock structure and movement rates — using tagging techniques: The WPB considered tagging swordfish was a useful method to examine stock structure, and in particular to make realistic hypotheses on movement rates between strata. It was recognized that tagging of swordfish is a difficult and expensive task. However, taking into account the absolute need to validate growth and to determine stock structure, the WPB strongly recommend conducting swordfish tagging in the IOTTP (as was planned in the original IOTTP). Such tagging could be done in various ways such as:

- Scientific tagging, primarily with electronic tags, using small chartered longliners with short sets of few hooks.
- Encouraging longline fishermen to tag small swordfish. Such tagging is already conducted in Australia and could be done by observers.

3) Swordfish growth: The WPB recommended researchers to try to validate the growth studies already done, and to conduct similar comparative studies in other areas.

4) Size data analyses: The following additional analyses of Taiwanese size data are recommended:

- Conversion of lengths to ages using different assumptions on sex ratios at size/age.

5) Stock status indicators: Further research is recommended concerning the definition and estimation of stock indicators that reflect the status of stocks of billfish species. Special attention should be given to the choice of indicators which could best measure changes in abundance of older fishes (which are the first to disappear in case of overfishing) and changes in the geographical patterns of the fisheries. The various stock indicators recommended by the WPB in 2001 should be calculated in advance of the WPB meeting in cooperation between scientists from fishing countries and the IOTC Secretariat; and these indicators should be available at the beginning of the WPB meetings.

The WPB noted that although much of the technical advice on swordfish in this document is presented relative to MSY reference points, this does not suggest that these should be adopted as target reference points for the species. Investigation of appropriate reference points is a research priority.

6) Analysis of apparent movement of swordfish based on fishery data: The analysis of size specific CPUE by sex and by time and area strata, together with biological data on feeding, sex ratio, reproductive condition etc offer potential to indirectly evaluate the apparent movement and stock structure of swordfish. These studies are highly recommended.

7) CPUE Standardization: Following analyses at the 2004 and 2006 WPB the following further efforts towards standardization of the CPUE series from Taiwanese and Japanese fleets are recommended, including:

- Spatial and temporal analyses of the number of hooks per basket (Shallow, normal, deep and ultra deep LL) and their relationships to the SWO distribution need to be studied to understand the effect of the number of hook per basket on the SWO CPUE.
- Research to examine if nominal SWO CPUE in the normal LL and the deep LL are overestimated and the one for the ultra deep LL are less affected.

- Improving the definition of variables that could be used as a proxy for targeting. In addition to hooks per basket considerations, this should include examining the effects of set-times, moon-phase, light-sticks and bait-types.
- Consideration of alternative ways of combining area-specific indices into a global index using different weighting schemes.
- Consideration should be given to defining area strata that take into account environmental factors and fishery distribution and characteristics.
- Many of these factors might be examined by using the Japanese shot by shot data that already exists. For other fleets additional data collection might be required to duplicate these analyses.

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

Efforts should be made to provide additional CPUE series from other fisheries (e.g. La Réunion, Seychelles) for the next WPB.

8) Stock assessment: Further development of stock assessment models for swordfish and undertaking research to reduce the uncertainties in the following areas (highlighted during the 2006 assessment):

- Uncertainty in the utility of the CPUE indices as an estimate of relative abundance. In particular, there is a need to better understand the effects of changing gear configuration and setting practices over time and space.
- Uncertainty in the total catch time series.
- The production models used in the assessment have limited flexibility to represent complicated fisheries dynamics, including recruitment variability and transient age structure effects. And they cannot include additional data relating to size frequencies, sex composition or spatial dynamics. The explicit use of age- and sex- and/or spatially-structured models to represent these characteristics realistically however, is not recommended given the paucity of input data.
- Unknown stock structure.
- Uncertainty in the representativeness of life history and production paramenters derived from Pacific Ocean swordfish.

9) Research on biology of Istiophorids: The WPB recommended that following research on istiophorids be undertaken.

- Genetic studies of the main istiophorid species, concentrating on obtaining robust sample sizes from widely separated locations in the Indian Ocean. If genetic studies cannot commence in the near future, samples should still be collected and preserved.
- Hard parts from billfish (marlin, sailfish) should be collected and preserved for future age estimation studies. The third (largest) anal spine is probably best for this purpose, but this needs to be verified for each species (with respect to the extent of the matrix in larger fish).
- Popup satellite tagging experiments should be conducted on blue ,black and striped marlins to provide information on many aspects of their biology, including long-term vertical behaviour, movement and mixing rates.
- Increased tagging of billfish in the Indian Ocean should be encouraged on an opportunistic basis. This may be achieved through a coordinated, Indian Ocean wide sport fishery tagging programme, if initiated, as recommended by a recent IOTC consultancy. The IOTTP will ensure widespread publicity and offers of rewards for tag returns, enhancing such a sport fishing based tagging programme.
- Improved catch and effort statistics should be collected for artisanal fisheries of coastal countries with the help of IOTC and of the IOTC-OFCF project. This applies to all Istiophorids, but especially sailfish in areas of high recent catches such as Sri Lanka, Iran and Indonesia.
- Selected catch and effort statistics should be collected from key billfish sport fishing areas to provide CPUE indices.

- Selected indicators of stock status should be better identified, selected and prepared before the next WPB meeting and be made available to the WPB allowing to evaluate stocks trends, independently of stock assessments analysis.

7. OTHER BUSINESS

IOTC-OFCF project

58. A presentation was provided on the current IOTC-OFCF project in Sri Lanka relating to monitoring and assessment of the offshore gillnet and longline fisheries (IOTC-2006-WPB-13). The data collection programme started in 1982 and has been supported by IPTP, FAO/TCP and IOTC-OFCF through its history. The fishers mainly target the tuna, marlins, seerfish, swordfish, sailfish, sharks and rays The current programme uses a stratified random sampling approach and 18 data collectors covering a range of landing sites (seven zones around Sri Lanka) and vessels (there are more than 1700 offshore fishing vessels). The data collectors record daily effort, catch and effort, biological data and information. The presentation described some of the results to-date and discussed problems and ways being used overcome them.

Update on tuna tagging activities in the Indian Ocean

59. A verbal update was provided on the progress to-date at the start of the Regional Tuna Tagging Project. To date 34,670 tunas have been tagged (8352 YFT, 1377 BET, 24888 SKJ, and 53 unknown). The vessels for the moment are over their target, however the proportion of skipjack is too high and the vessels were asked to concentrate more on yellowfin and bigeye. To-date 854 tagged fish have been returned to the IOTC in Seychelles. A tag recovery scheme has recently been launched in the major ports of unloading in the Western Indian Ocean (Seychelles, Madagascar, Kenya and Mauritius). The small-scale tagging projects (e.g. Mayotte, India, Maldives…) were not pursued this year due to lack of funding. A new project is being developed to tag fish in the Eastern Indian Ocean. This project which is designed in collaboration with RCCF, CSIRO and NRIFSF is supposed to start in August with 8 weeks of trials on the West coast of Sumatra. The target of the first leg of this project is to tag 5000 fish (mainly yellowfin and bigeye) off the west coast of Sumatra. All the countries are asked for their full cooperation in this tagging project and to spread the word among their local agency. To signal any recovery, please contact Teresa Athayde, Publicity and Tag Recovery Officer (ta@iotc.org). For any questions on the tagging projects, please contact Jean-Pierre Hallier, Chief Coordinator of the RTTP-IO (jph@iotc.org) or Julien Million, IOTC Tagging Assistant (jm@iotc.org).

Update on tuna tagging activities being undertaken by SEAFDEC

60. A brief verbal update was provided on the tagging activities currently being undertaken by SEAFDEC.

Tribute to the late Dr Geoffrey Kirkwood

61. The Working Party was greatly saddened to learn of the sudden death of Dr Geoffrey Kirkwood (the current Chair of the IOTC Scientific Committee) during the week of the meeting. The working group reflected on the Geoff’s good humour, the major influence he had in fisheries science world-wide and his untiring contributions for the IOTC working parties, the Scientific Committee and the Commission.

8. ADOPTION OF THE REPORT

62. The Report of the Fifth Session of the Working Party on Billfish was adopted on the afternoon of Friday 31 March, 2006. Thanks were conveyed to NARA for their generosity, hospitality and tireless support over the course of the meeting.

APPENDIX I. LIST OF PARTICIPANTS

Champa Amarasiri
Head, Marine Biological Division
National Aquatic Resources Research and Development Agency (NARA)
Crow Island
Colombo 15
SRI LANKA
Tel.+94 112 521000 ext 104
e-mail: champa@nara.ac.lk

Chamari Dissanayake
Research Officer
National Aquatic Resources Research and Development Agency (NARA)
Crow Island
Colombo 15
SRI LANKA
Tel.+94 112 521000 ext 143 or 167
e-mail: chamari@nara.ac.lk

Juliette Dorizo
Seychelles Fishing Authority
P.O. Box 449
Fishing Port
Victoria
SEYCHELLES
e-mail: jdorizo@sfa.sc

Shunji Fujiwara
IOTC-OFCF Project
P.O.Box 1011
Fishing Port
Victoria
SEYCHELLES
e-mail: sf@iotc.org

H. P. K. Hewapathirana
Fishery Biologist
Maligawatte Fisheries Secretariat
Colombo 10
SRI LANKA
Tel.+94 11 2381367

J. A. D. B. Jayasooriya
Chief, Fisheries Statistical Unit
Ministry of Fisheries and Ocean Resources
Maligawatte Fisheries Secretariat
Colombo 10
SRI LANKA
Tel.+94 11 2381367
Fax +94 11 2329440
e-mail: jadbjayasooriya@fisheries.gov.lk

Dale Kolody
Fisheries Scientist
CSIRO
AUSTRALIA
Tel.+61 62325121
email: dale.kolody@csiro.au

Shiu Ling Lin
Fisheries Agency
No.2, Chaochow Street
Taipei
TAIWAN,CHINA
Tel.+886 2 24622192
email: shiuling@ms1.fa.gov.tw

Kevin Mcloughlin
Senior Fisheries Scientist
Department of Agriculture Fisheries and Forestry
AUSTRALIA
Tel.+61 262724015
Fax +61 262724014
e-mail: kevin.mcloughlin@brs.gov.au

Dominique Miossec
Biologiste
IFREMER
BP 60
rue Jean Bertho
Le Port 97822 CEDEX
LA REUNION
Tel:+02 62 42 03 40,
Fax:+02 62 43 36 84
e-mail:
Dominique.Miossec@ifremer.fr

Tsutomu (Tom) Nishida
Research Coordinator for Ocean and Resources
National Research Institute of Far Seas Fisheries
5-7-1, Shimizu – Orido, Shimizu, Shizuoka
JAPAN
e-mail: tnishida@affrc.go.jp

Chris O'Brien
Deputy Secretary
Indian Ocean Tuna Commission
P.O.Box 1011
Victoria
SEYCHELLES
e-mail: cob@iotc.org

François Poisson
Fisheries Statistician
Indian Ocean Tuna Commission
P.O. Box 1011
Fishing Port
Victoria
SEYCHELLES
Tel:+248 225591,
Fax:+248 224364
e-mail: francois.poission@iotc.org

Sutee Rajruchithong
Division Head
SEAFDEC
Suksawadi RD. Laemphrapha Phasamutjadi
Samutprakarn
THAILAND
Tel.+662 4256170
Fax.+622 4256110
e-mail: sutee@seafdec.org

David Ray
Manager
Apollo Marine International
SRI LANKA
Tel.+94 33 22 82426
email: david@apollo-marine.com

Koichi Sakonju
IOTC-OFCF Project Manager
Indian Ocean Tuna Commission
P.O. Box 1011
Fishing Port
Victoria
SEYCHELLES
e-mail: ks@iotc.org

E.K.V. Samaraweera
Research Officer
National Aquatic Resources Research and Development Agency (NARA)
Crow Island
Colombo 15
SRI LANKA
Tel.+94 112 521000 ext 143 or 167
e-mail: visaka@nara.ac.lk

Somboon Siriralesophon
Head of Research Division.
Southeast Asian Fisheries Development Center (SEAFDEC)
P.O.BOX 97
Sumutprakan
THAILAND
Tel.+662 4256140
Fax.+622 4256110
e-mail:somboon@seafdec.org

Marc Taquet
Chef de Laboratoire RH
IFREMER
BP 60
rue Jean Bertho
Le Port 97822 CEDEX
LA REUNION
Tel.+02 62 42 03 40
Fax.+02 62 43 36 84
e-mail: Marc.Taquet@ifremer.fr

Sheng-Ping Wang
Fisheries Agency
No.2, Chaochow Street
Taipei
TAIWAN,CHINA
Tel.+886 2 33437255
email: shenping@ms1.fa.gov.tw

APPENDIX II. AGENDA OF THE MEETING

1. **REVIEW OF THE DATA**
   - Review of the statistical data available for the billfish species (Secretariat)
2. **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
3. **REVIEW OF NEW INFORMATION ON THE STATUS OF BILLFISH**
   - Stock status indicators for marlins, sailfish and swordfish.
     - C*atch and effort*
     - *CPUE*
     - *Changes in fishing area*
     - *Trends in size distributions of the catch*
   - Stock assessments
     - Assessment methods
     - Any new assessments on billfish species
   - Selection of Stock Status indicators and Likely future trends under alternative exploitation scenarios
4. **RESPONSE TO THE REQUEST FROM THE COMMISSION AT S9 IN RELATION TO APPARENT LOCALISED SWORDFISH DEPLETIONS**

   Following the presentation of the 2004 report of the Scientific Committee (IOTC-2004-SC-R) to the Commission at S9, the Commission noted (para 21) the technical recommendations made by the SC regarding the status of the swordfish resource and agreed that the issue of local depletion was were serious and requested the SC to undertake area-specific analyses, with particular emphasis for the southwest Indian Ocean, for the Commission's future consideration.
5. **DEVELOP TECHNICAL ADVICE ON THE STATUS OF THE STOCKS**
   - Marlins and sailfish
   - Swordfish
   - Update of the Executive Summary for Swordfish
6. **RESEARCH RECOMMENDATIONS AND PRIORITIES**
7. **OTHER BUSINESS**

APPENDIX III. LIST OF DOCUMENTS PRESENTED TO THE MEETING

DOCUMENT	TITLE
IOTC-2006-WPB-01	WPB 2006 Agenda
IOTC-2006-WPB-02	WPB List of documents
IOTC-2006-WPB-03	Status of IOTC databases for billfish species. *IOTC Secretariat*
IOTC-2006-WPB-04	Assessment of the stock structure of the Indian Ocean swordfish (*Xiphias gladius*): apropsal for a multidisciplinary study. *C. Jean, J Bourjea, D Miossec and M. Taquet.*
IOTC-2006-WPB-05	Evolution of the Seychelles semi-industrial longline fishery. *V. Lucas, J. Dorizo and C. Gamblin*
IOTC-2006-WPB-06	Stock assessment of swordfish *(Xiphias gladius)* in the Indian Ocean by A Stock-Production Model Incorporating Covariates (ASPIC). *T. Nishida and Y. Shiba*
IOTC-2006-WPB-07	Standardization of swordfish *(Xiphias gladius)* CPUE of the Japanese tuna longline fisheries in the Indian Ocean (1975-2004). *T. Nishida, and S-P. Wang*
IOTC-2006-WPB-08	Overview of Current Approaches for South West Pacific Swordfish Assessment: Are the Methods Applicable for the Indian Ocean? *D. Kolody*
IOTC-2006-WPB-09	CPUE standardization of Indian Ocean swordfish from Taiwanese longline fishery for Data up to 2003. *S-P. Wang, S-K. Chang, T. Nishida and S-L. Lin.*
IOTC-2006-WPB-10	Analyses of sex ratio, by length-class and length-weight relationships for several species of Family Xiphiidae (*Xiphias gladius*, Linnaeus 1758) and Istiophoridae (*Istiophorus platypterus*, Shaw 1792) and *Tetrapturus angustirostris*, Tanaka 1915) caught from experimental cruise on Spanish longliners in the South Western Indian Ocean during 2005. *J. Ariz, A. Delgado de Molina, M. L. Ramos and J.C. Santana.*
IOTC-2006-WPB-11	An overview of research activities on swordfish (*Xiphias gladius*) and the by-catch species, caught by the spanish longline fleet in the Indian Ocean. *J. Mejuto, B. García-Cortés and A. Ramos-Cartelle.*
IOTC-2006-WPB-12	Trends in the Sri Lankan longline fishery. *E.K.V. Samaraweera, D.C.T. Dissanayake and C. Amarasiri.*
IOTC-2006-WPB-13	Monitoring and assessment of offshore (gillnet/longline) fishery in Sri Lanka. *D.C.T. Dissanayake, C. Amarasiri, E.K.V. Samaraweera, U. Adikari, C. Perera (NARA) and, F. Poisson (IOTC-OFCF).*
IOTC-2006-WPB-14	A methodological description of the Pella-Tomlinson Production Model used for exploratory Indian Ocean swordfish assessment at the 5th IOTC WPB. *D. Kolody*.
IOTC-2006-WPB-INF01	Biological data on tuna and tuna-like species gathered at the IOTC Secretariat: Status Report presented to the IOTC Working Party on Tropical Tunas in 2005 (IOTC-2005-WPTT-05).
IOTC-2006-WPB-INF02	Progress and preliminary results of a study to develop robust stock status indicators for broadbill swordfish and tropical tunas). *M. Basson and N. Dowling.*
IOTC-2006-WPB-INF03	Age and growth of the swordfish (*Xiphias gladius* L.) in the waters around Taiwan determined from anal-fin rays. *C-L. Sun, S-P. Wang and S-Z. Yeh.*
IOTC-2006-WPB-INF04	Sex Ratios and Sexual Maturity of Swordfish *(Xiphias gladius L.)* in the Waters of Taiwan. *S-P. Wang, C-L. Sun and S-Z. Yeh.*
IOTC-2006-WPB-INF05	Sex-specific yield per recruit and spawning stock biomass per recruit for the swordfish, Xiphias gladius, in the waters around Taiwan. *C-L. Sun, S-P. Wang, C. E. Porch and S-Z. Yeh.*
IOTC-2006-WPB-INF06	Evaluation of a sex-specific age-structured assessment method for the swordfish, Xiphias gladius, in the North Pacific Ocean. *S-P. Wang, C-L. Sun, A. E. Punt and S-Z. Yeh.*