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

# Report of the Seventh Session of the IOTC Working Party on Tropical Tunas

**Phuket, Thailand, 18-22 July, 2005**

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# 1. Opening of the Meeting and Adoption of the Agenda

1. The Seventh Meeting of the Working Party on Tropical Tunas (WPTT) was opened on 18 July 2005 in Phuket, Thailand, by Dr. Jaranthada Karnasuta, Deputy Director-General of Department Fisheries in Thailand and Mr Nirun Kalayamit, Phuket Deputy Governor of Phuket.

2. Chairperson, Dr. Pilar Pallarés, from the Instituto Español de Oceanografia, Spain, also welcomed the participants (Appendix I) and the Agenda for the meeting was adopted as presented in Appendix II.

3. In accordance with the instructions of the Commission, the WPTT objectives for the meeting were to review and analyse issues relevant to the fisheries and status of yellowfin tuna, and consideration to the exceptional catches of yellowfin tuna in 2003.

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

# 2. Review of Statistical Data for the Tropical Tuna Species

## *2.1. Nominal Catch (NC) data*

5. The nominal catch data series of yellowfin (YFT), bigeye (BET) and skipjack (SKJ) tunas are considered to be almost complete since 1950. Bigeye tuna are mainly caught by longlines and purse seines, while catches of yellowfin tuna are reported mainly by purse seines, longlines and gillnets and Skipjack tuna by purse seines, gillnets and pole and lines. Large increases in the catches of these three species have been noted since the mid-1980's.

6. The IOTC Secretariat conducted several reviews of the NC database during 2004. In particular, the work to disaggregate catch statistics aggregated by species and/or gear led to changes in the estimates of catches of skipjack tuna and, to a lesser extent, yellowfin tuna and bigeye tuna. Details about this work can be found in IOTC-2004-WPTT-06. There have been significant changes in the estimates of yellowfin tuna catches in recent years following reviews of the various catch series, especially that of Yemen (IOTC-2005-WPTT-04).

7. Although the quality of the information on the three tropical tunas is generally considered to be good, the completeness and accuracy of the records are compromised by:

- **Some catch data are not being available**: several countries were not collecting fishery statistics, especially in years prior to the early seventies, and others have not reported their statistics to IOTC. In most cases, the catches of tropical tunas in those countries were probably minor.
- **Poor resolution of catch data:** catches of tunas and tuna-like species are sometimes reported in an aggregated form1. The Secretariat estimates the species and gear composition of these aggregates using a range of information but the accuracy of such estimates is probably low.
- **There is considerable uncertainty associated with the catch estimates for the following fisheries:**
- **Yemen gillnet and hand line fisheries:** The catches of yellowfin tuna recorded in the FAO database for Yemen, the only existing source in the past, amount to about 800 t in recent years. This is in contradiction with reports from other sources that indicate that catches of yellowfin tuna might have been around 25,000 t in recent years. Although the catch series for this species was reviewed in 2005 and the database updated with the new estimates, the new figures are likely to be highly uncertain due to the scarce information available on catches or effort in this country.
- **Sri Lankan gillnet (and longline) fishery:** The catch series for yellowfin and skipjack tunas in Sri Lanka were re-estimated for the period 1950-2004. Marked differences between the re-estimated catches and those produced in Sri Lanka are of concern. However, the new catch series is considered to be more accurate.
- **Fresh tuna longliners based in Indonesia:** The data collected since June 2002 has allowed the estimation of the catches by longline vessels based in Benoa for 2003. The new catch estimates differ from those obtained by using the previous catch estimation procedure (CSIRO-RIMF sampling). Therefore, the catch

[1] This is the case notably when data are not reported to the Secretariat and have to be taken from the FAO nominal catch database.

series is expected to change once that new catches are estimated for 2003 (all previous estimates were based on the catches obtained through CSIRO-RIMF sampling in Benoa).

- **Other fresh tuna longline fleets:** Although the catches of fresh tuna longline vessels based in various ports of the Indian Ocean were re-estimated from data coming from past or recent sampling schemes, the accuracy of the estimates is still considered to be poor, especially for those fleets operating from ports not covered by these schemes, and where past catches have been estimated using recent catch levels.
- **Deep-freeze longline fleets:** The Secretariat re-estimated catches for the period 1992-2004 using new information collected during 2004. These catch estimates remain uncertain due to the many assumptions made in estimating total catches and the 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 revisions to the catch estimates may be undertaken when more information become available.
- **Former Soviet Union purse seiners:** The catch statistics of the nine to 11 former Soviet Union purse seiners operating under the flags of Panama and Belize in recent years are not available for the period 1995-1997. Total catches and effort for the period 1998-2002 were reported in 2003, but the new data did not include catch by species and type of school (consequently, these will have to be estimated by the Secretariat).

## *2.2. Catch-and-Effort (CE) data*

8. Catch-and-effort records are available for the main fleets fishing for tropical tunas in the Indian Ocean, namely baitboat (SKJ and YFT), purse seine (SKJ, YFT and BET) and longline (BET and YFT). Some gillnet fisheries produce substantial catches of tropical tunas, but the contribution of other gears to the total catches is small.

- **Baitboat:** Catch-and-effort statistics from the Maldives are available by species, month and atoll for 1970-1993. Only catches and effort by species, year and atoll are available for 1993-2001. Baitboat Catch-and-Effort data are not available since 2002.
- **Longline:** Catch-and-effort statistics are available since 1952 for Japan; since 1967 for Taiwan,China[2] and since 1975 for Korea. Catch and effort data for other fleets is scarce or inaccurate (e.g. there are some non-reporting fleets such as Philippines). Total longline catches by species and area are provided in Figures 1, 2 and 3

9. The catch and effort statistics provided by Japan and Taiwan,China are generally considered to be accurate. Taiwan,China provided revised CE for 1991-93. Nevertheless, some inconsistencies were found when comparing nominal catches and catch and effort data for Taiwan,China. These would indicate that either nominal catches or catches in the CE are not accurate or that size data are not representative.

10. Korean CE statistics are considered to be highly inaccurate. Many inconsistencies have been found in the data, e.g. when comparing the catches in this database with those reported as nominal catches.

- **Purse seine:** Catch-and-effort statistics are complete for European-owned purse seiners and those monitored by scientists from Europe and Seychelles. Statistics are also available for other fleets including the former Soviet purse seine fleet (1998-2002; under Belize and Panama flags), Mauritius and Japan. As is the case for the NC data, the CE data for the purse-seine fleet formerly under the Soviet Union flag are not considered to be accurate, especially the species composition and type of school fished information. Partial catch and effort data are available for the Iran purse seine fleet. Recent trends in the spatial distribution of purse seine catches are shown in Figures
- **Gillnet:** Few CE data are available for gillnet fisheries. This is of concern because gillnets have been used in both coastal waters and on the high seas in recent years.

11. Catches by gear-type are given in Figures 1, 2 and 3. Figures 4, 5 and 6 illustrate the changes to the catch estimates following recent revisions to the catch data series.

12. Figures 7 to 12 illustrate mean annual catches for the periods 1990-1999, 2000-2002 and 2003 respectively. 2003 is separated to highlight the very high catches of yellowfin that occurred in that year.

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[2] Taiwan, China refers to Taiwan province of China.

**Figure 1:** Catches of yellowfin tuna (YFT) per gear type and year in the IOTC Area from 1964 to 2003

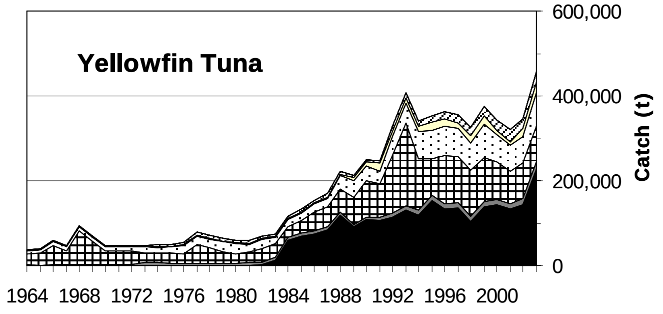
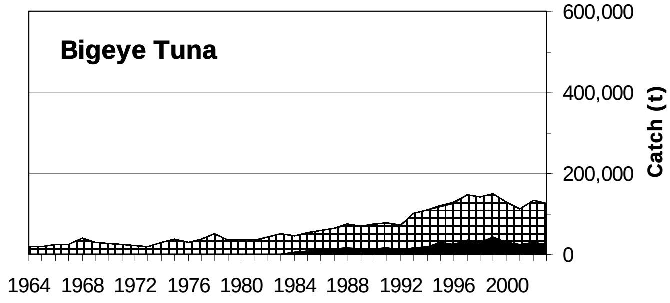



**Figure 2:** Catches of bigeye tuna (BET) per gear type and year in the IOTC Area from 1964 to 2003




**Legend:**

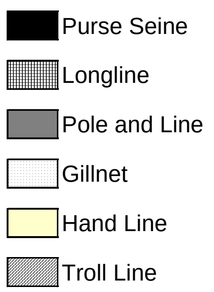
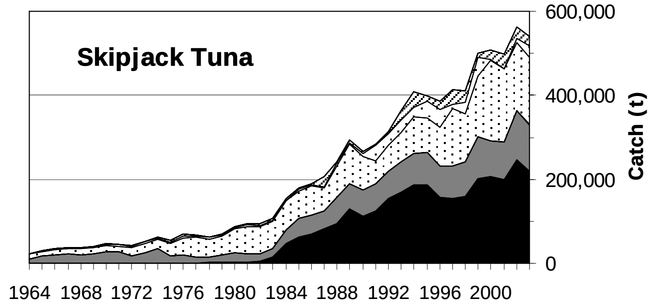



**Figure 3:** Catches of skipjack tuna (SKJ) per gear type and year in the IOTC Area from 1964 to 2003




Note that the catches series estimated during 2004-05 include catches assigned to each species after allocation of species aggregates to individual species by the Secretariat.

**Figure 4:** Yellowfin tuna catch estimates in 2005 *versus* catch estimates in 2004 (1964-2002)

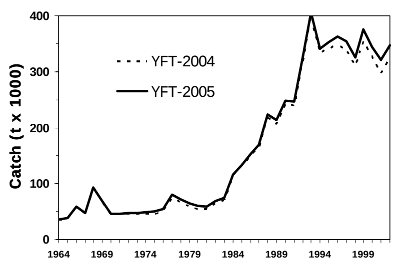



**Figure 5:** Bigeye tuna catch estimates in 2005 *versus* catch estimates in 2004 (1964 to 2002)

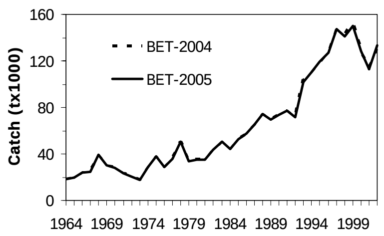
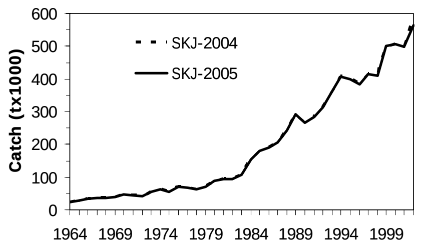



**Figure 6:** Skipjack tuna catch estimates in 2005 *versus* catch estimates in 2004 (1964-2002)




Note: Ibid. footnote Figures 1-3

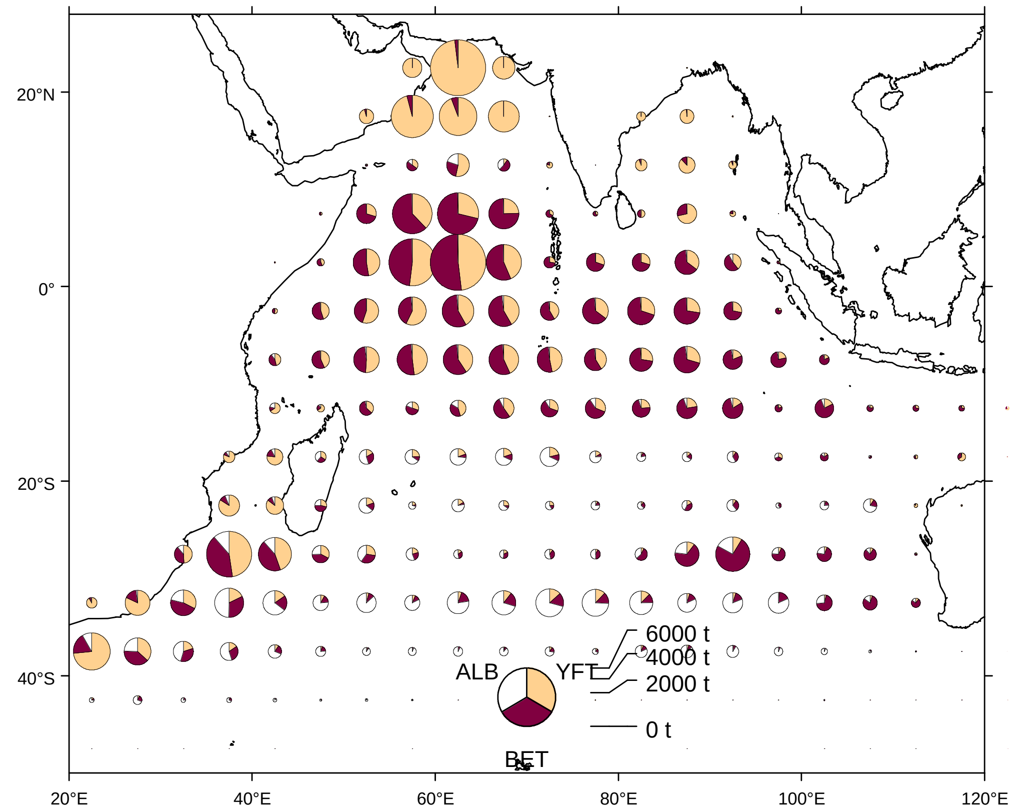



**Figure 7.** Mean of annual total catches (t) of tropical tunas: yellowfin (YFT), bigeye (BET) and albacore (ALB) by Japanese and Taiwanese long line vessels operating in the Indian Ocean over the period 1990 to 1999.

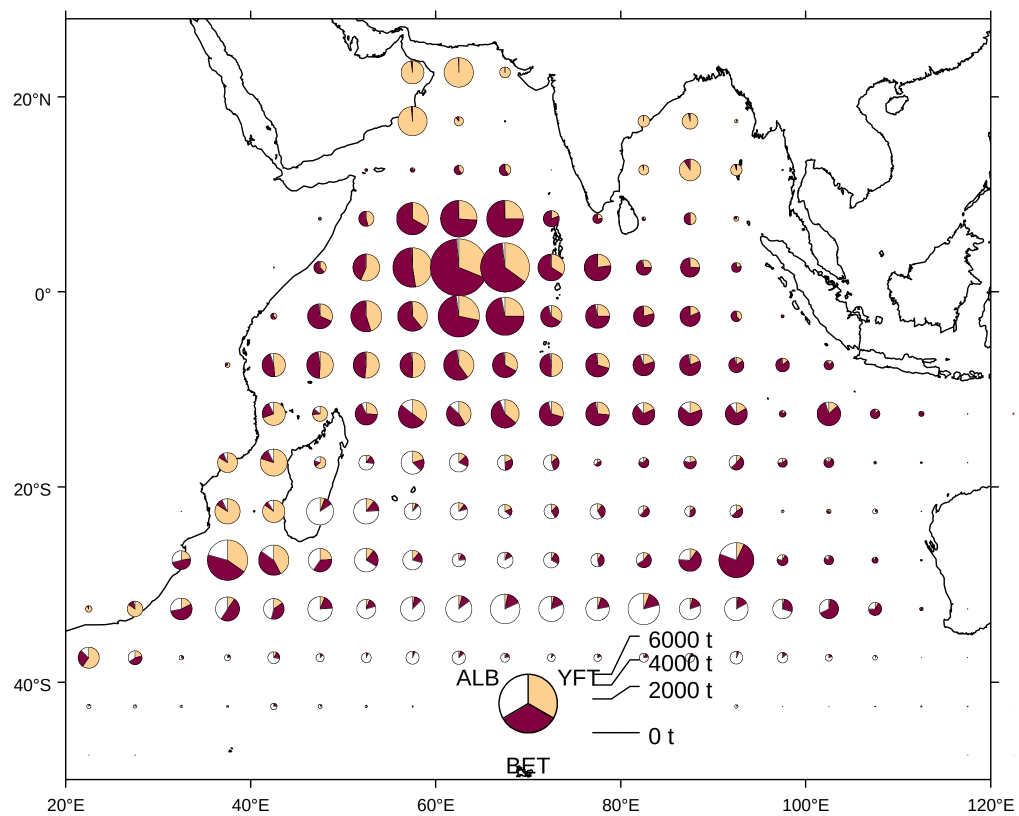



**Figure 8.** Mean of annual total catches (t) of tropical tunas: yellowfin (YFT), bigeye (BET) and albacore (ALB) by Japanese and Taiwanese long line vessels operating in the Indian Ocean over the period 2000 to 2002.

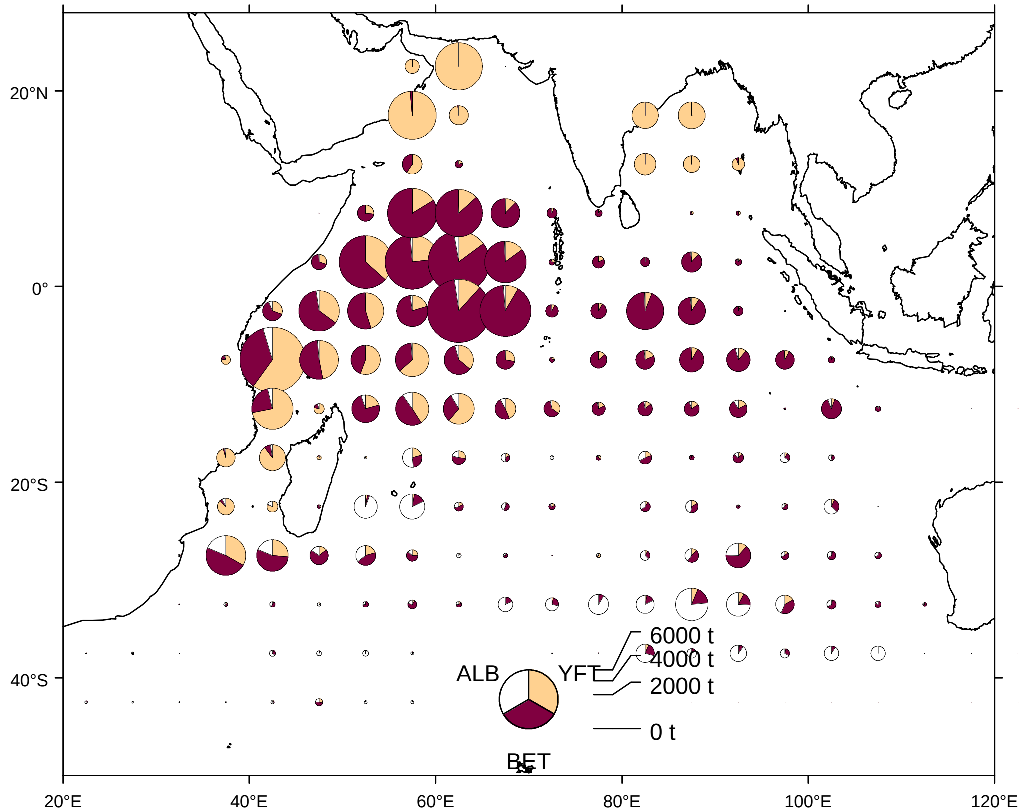



**Figure 9.** Mean of annual total catches (t) of tropical tunas: yellowfin (YFT), bigeye (BET) and albacore (ALB) by Japanese and Taiwanese long line vessels operating in the Indian Ocean in 2003.

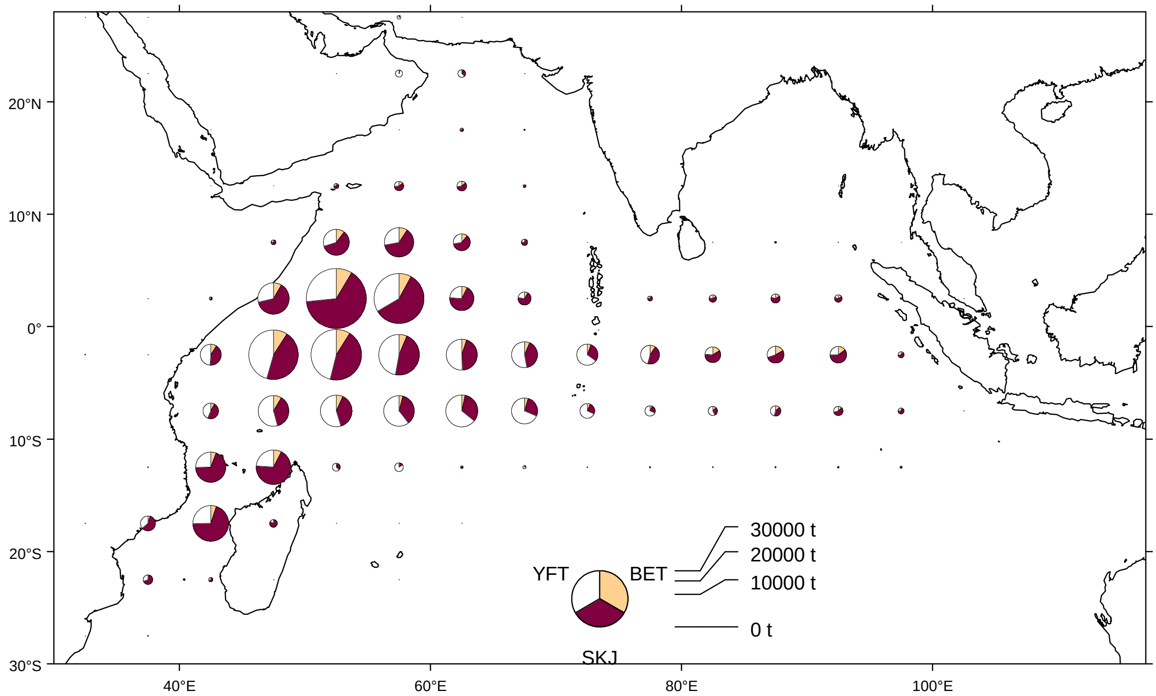



**Figure 10.** Mean of annual total catches (t) of tropical tunas: yellowfin (YFT), bigeye (BET) and skipjack (SKJ) by purse seine vessels operating in the Indian Ocean over the period 1990 to 1999.

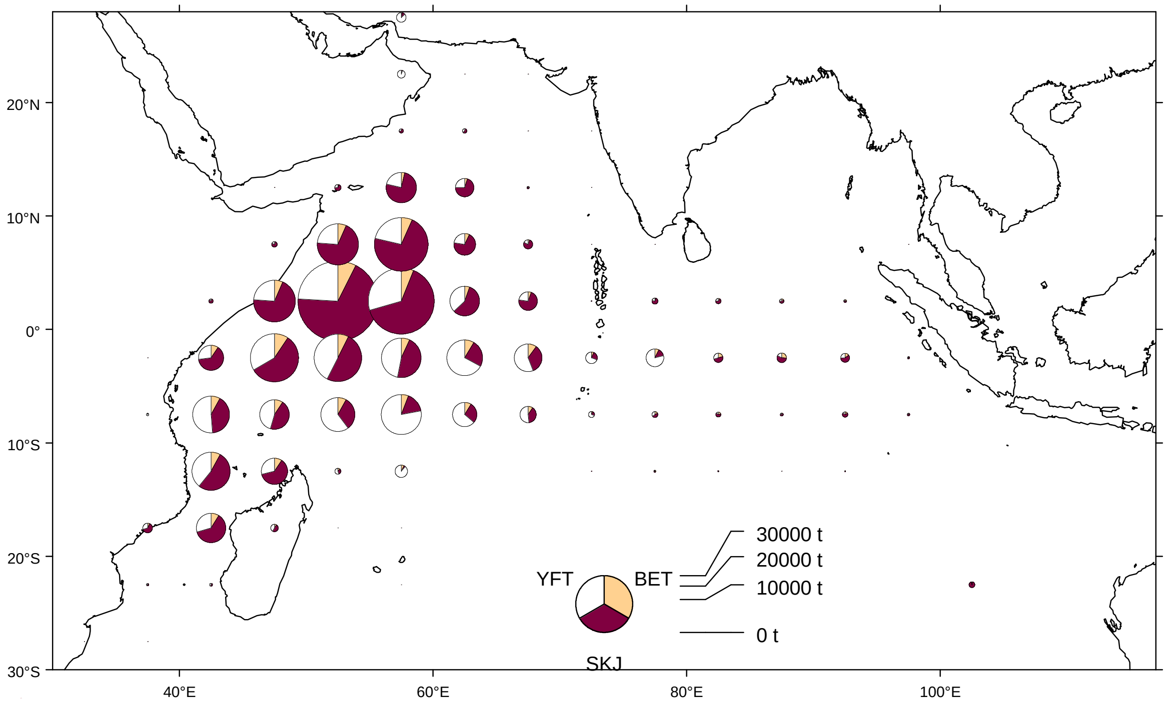



**Figure 11.** Mean of annual total catches (t) of tropical tunas: yellowfin (YFT), bigeye (BET) and skipjack (SKJ) by purse seine vessels operating in the Indian Ocean over the period 2000 to 2002.

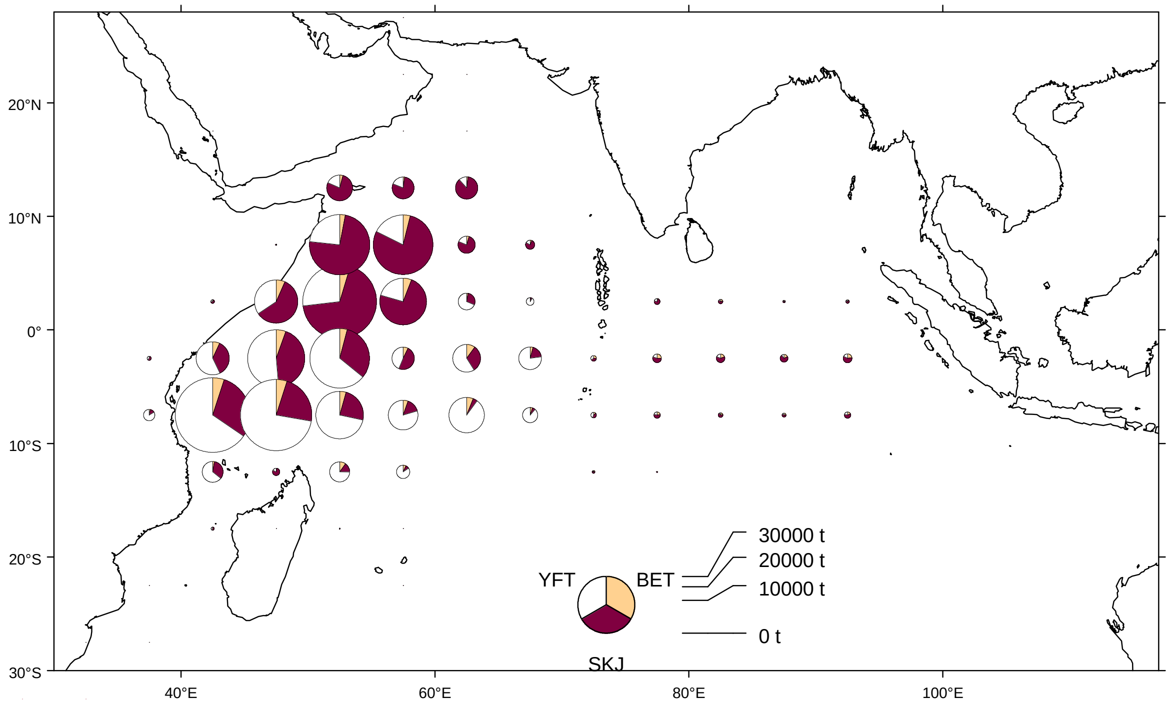



**Figure 12.** Mean of annual total catches (t) of tropical tunas: yellowfin (YFT), bigeye (BET) and skipjack (SKJ) by purse seine vessels operating in the Indian Ocean in 2003.

### 2.3. Size-Frequency (SF) data

- **Purse seine:** The quality of the purse seine data is considered to be good for fleets under European monitoring. Little or no data is available for Iranian, Japanese and former Soviet Union purse seiners. The size frequency statistics for Mauritian purse seiners since 1986 is complete.
- **Baitboat:** The completeness and quality of the sampling on baitboat fisheries (Maldives) is considered to be good up to 1998. No data are available from 1999 to 2002.
- **Longline:** Only Japan has been reporting size-frequency data since the beginning of the fishery. In recent years, the numbers of fish being measured have been very low in relation to the total catch; furthermore, they have been decreasing year by year. Coverage rates in some areas are very low. Taiwan,China provided size data on yellowfin tuna and bigeye tuna for its longline fleet for 1980-2004. The size-frequency statistics available from Korea are inaccurate (Korea), which limits their use. The recovery of size data from port sampling regarding fresh tuna longline fleets operating in Thailand and Indonesia continued in 2004 and 2005. Catch-at-size tables were estimated for fresh tuna longline vessels operating in Indonesia during 2003-04 and other ports for 1998-2004.
- **Gillnet:** Although size data are available for some important gillnet fisheries (including Iran, Sri Lanka and Oman3) sample sizes are very low.
- **Other gears:** Few size data are available for other gears.

### 2.4. Estimation of catch for non-reporting fleets

13. The catch estimates for several non reporting fleets were updated in 2003:

- **Yemen:** The catches for Yemen domestic fisheries, mainly hand line, troll line and gillnet, were re-estimated in 2005 for the period 1950-2004. The new estimates of yellowfin tuna catches are much higher than those recorded previously, especially for the last decade.
- **Other non-reporting fleets (NEI):** The high number of non-reporting fleets operating in the Indian Ocean in recent years has led to large increases in the number of catches that need to be estimated. This reduces confidence in the catch estimates for yellowfin tuna and bigeye tuna and, to a lesser extent, skipjack tuna.
- **Purse seine:** Catches for former Soviet Union purse seiners were re-estimated for 1995-2003. Total catches were estimated using to the number of vessels available, the average catches of the former Soviet Union purse seiners in previous years, and average catches available for other fleets for 1995-97 and 2003. Total catches for 1998-2002 were obtained from available catch and effort data. Total catches were assigned to species and type of school fished according to data available for European Community purse seiners during the same period (1995-2003). The new catch estimates (averaging around 30,000 t per year) are very similar to those estimated previously by the Secretariat.
- **Fresh tuna longline:** Catches by fresh tuna longliners were estimated for each port where the different fleets were based. Most of the fresh tuna longline catch appears to be taken by Taiwanese vessels.
    - **Indonesia**: The catches by Indonesian vessels during 2003-04 were estimated from the information collected through the multilateral catch monitoring program. Further changes in the total catch estimates and species composition are expected in the future, especially for years before 2003.
    - **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 of fresh tuna longliners based in Malaysia and Singapore were estimated using data from the IPTP Sampling Program, new estimates from Fisheries Research Institute of Penang and AFRDEC, and vessel activity information for Singapore (Jurong).

[3] Size frequency data of yellowfin tuna was collected during 2003 in Oman

- **Sri Lanka**: The catches of 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. Data on the number of vessels or number of vessel-unloadings have not been available since 2002.
- **Maldives:** Around 50 fresh tuna longliners are currently licensed to operate within the Maldives EEZ. Most of these vessels are, however, unloading their catches in Colombo (Sri Lanka). Catches for this fleet were estimated along with fleets operating in Sri Lanka.
- **Seychelles:** Several Indonesian and Taiwanese fresh-tuna longliners were based in Victoria (Seychelles) during 2000-02. Catch and effort data for these vessels are available from the Seychelles Fishing Authority.

• **Deep-freeze longline:** 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 fully explained. Nevertheless, this decrease is somewhat proportional to an increase in the number of vessels recorded operating under flags of reporting countries, such as Philippines, Taiwan, China and the Seychelles.

## 2.5. Documents relating to statistics

14. Document IOTC-2005-WPTT-03 provided an update on the status of the IOTC tropical tuna databases and is elaborated in Section 2 above. The IOTC Secretariat conducted several reviews of the databases during 2004. In particular, the work to disaggregate catch statistics aggregated by species and/or gear led to changes in the estimates of catches of skipjack tuna and, to a lesser extent, yellowfin tuna and bigeye tuna. Details about this work can be found in IOTC-2004-WPTT-06.

15. Document IOTC-2005-WPTT-08 provided information on the extent of size frequency data available in the IOTC database by area, year and quarter for Japan and Taiwan,China longliners that operated in the Indian Ocean during 1956-2003. It was noted that, during the last decade, areas with high catches of yellowfin tuna reported for the Japanese longline fleet have not been sampled or not sufficiently sampled. It was further noted that the quality of the Catch-at-Size data estimated upon this dataset might be compromised due to the paucity of size data.

16. Document IOTC-2005-WPTT-04 provided revised catch estimates for tuna and tuna-like species caught by artisanal boats in Yemen. The IOTC Secretariat noted that due to the paucity information available, the revised catch estimates had to be derived after much interpolation and extrapolation and by making numerous assumptions. While the new estimates are still highly uncertain, they are, arguably, much more realistic than before. In general they are much higher than those recorded by the FAO, especially for the last decade. Current catches of yellowfin tuna are estimated at around 30,000 t.

17. Document IOTC-2004-WPTT-10 provided a summary of the Korean tuna longline fishery in the Indian Ocean. 36 longliners from Korea operated in the Indian Ocean during 2004 with catches estimated at 7,735 t. The document provides also some information on a small-scale tagging programme and an observer program recently implemented on Korean longliners.

18. Document IOTC-2005-WPTT-23 provided a summary of the activities of French, Spanish, Italian, Seychelles and EU related NEI purse seine fleets (representing some 90% of the total purse seine activity in the Indian Ocean) fishing since 1981. This included effort, catch by species and fishing type (log and free swimming schools), catch per unit of effort, sampling, mean weights and size distribution for the main species. Nominal effort slightly increased in 2004, the number of free school sets dramatically increasing while the number of log sets decreased. The total catch exceeded 350,000 t in 2004. The catches of yellowfin tuna in 2004, at around 205,000 t, are the highest ever recorded.

19. Document IOTC-2005-WPTT-22 provided a summary of the French purse-seine activities in the Indian Ocean since 1981, including, effort, catch by species and fishing type (log and free swimming schools), catch per unit of effort, sampling, mean weights and size distribution for the main species. While the number of free-school sets in 2004 increased significantly, the number of log sets remained stable. Following 2003, 2004 was again an

exceptionally good year, with a total catch of 107,441 t – and the highest catches of yellowfin tuna observed since the beginning of the French fishery.

20. Document IOTC-2004-WPTT-18 provided summary statistics of the Spanish purse seine fleet fishing in the Indian Ocean from 1984 to 2004. Data included catch and effort statistics as well as some fishery indicators by species and fishing mode. While the total catches in 2004 decreased to 2002 levels the catches of yellowfin tuna are the highest recorded ever, standing at 81,000 t.

21. Document IOTC-2004-WPTT-30 provided an overview of the recent trend (2000-04) in the Indian Ocean FAD fishery for purse seine vessels operating under different EC and other flags. While the catches on FAD have shown a downward trend since 2002, catches on free schools that have been increasing. Catch rates of purse seiners operating in association with supply vessels are significantly higher than those of other purse seiners.

22. Document IOTC-2005-WPTT-06 presented the preliminary results of the Multilateral Catch Monitoring Programme on Fresh –tuna longliners operating from ports in Indonesia. Indonesia, with catches of tuna and tuna-like species exceeding the 150,000 t in recent years, is one of the major fishing countries operating in the Indian Ocean. The rapid evolution of its longline tuna fishery, especially during the last decade made it a priority for Indonesia to strengthen the monitoring activities. The fresh tuna longline catches estimated, at around 45,000 t, are thought much more accurate than previous catches estimates. The quality of the size data and other key biological information now available for this fishery is some of the best existing in the Indian Ocean for a longline fishery.

23. Document IOTC-2005-WPTT-07 provided a summary of the activities of fresh-tuna longliners operating from Phuket since 1994. The catches of fresh-tuna longliners, mainly from Taiwan,China and Indonesia have been estimated for the period 1994-2004, with current catches estimated at around 11,000 t. The collection of size frequency data in Phuket enables Catch-at-Size tables to be estimated for these fleets in the eastern Indian Ocean for 1998-2004. Other important biological information is also collected. The current activities are conducted through IOTC/OFCF-AFRDEC cooperation.

24. Document IOTC-2004-WPTT-13 provides a summary of the activities of two deep-freeze Thai longliners that have been operating in the Indian Ocean since 2000. Fishing grounds were reported in six IOTC areas, namely Bay of Bengal, west coast of Indonesia, Maldives and Chagos archipelagos, east and south of Seychelles, east coast of Somalia and southern part of the Indian Ocean. The highest catch rates were in west coast of Indonesia, followed by Maldives and Chagos archipelagos while the lowest catch rate reported in the Bay of Bengal. Yellowfin tuna made up 48 % of the total catch. It occurred in all fishing grounds, however the highest abundance was found in the east and south of Seychelles while the lowest abundance was in the southern part of the Indian Ocean. Yellowfin varied from 20 to 120 kg (mode 40 kg). Bigeye tuna comprised 31% of the total catch and was found in all fishing grounds with the highest catch in east Somalia. Bigeye varied from 20 to 150 kg (mode 50 kg). Albacore tuna comprised 11 % of the total catch, and was caught only in the southern part of Indian Ocean in 2003 and 2004. Albacore ranged from 10 to 50 kg (mode 30 kg). The rest of catch comprised swordfish (4.2%), sharks (1%), and billfish.

## 2.6. General discussion on statistics

25. The WPTT noted the progress achieved in the preparation of 'disaggregated' catch statistics for use by scientists participating to IOTC Working Parties and important reviews to catch series, such as the artisanal fishery of Yemen.

26. In view of the high catches of yellowfin tuna recently estimated for the Yemen artisanal fishery the WPTT stressed the need to collect more information on the size range of the specimens caught by this fishery. The WPTT requested that staff from the IOTC Secretariat travel to Yemen in order to collect more information on this subject. The IOTC Secretariat informed the meeting that a World Bank Programme is due to start on next October and one of its main aims is the implementation of data collection in Yemen. The IOTC Secretariat indicated that a trip to Yemen was being considered for just after the implementation of this programme.

27. The scientists from Taiwan,China noted that the discrepancies existing on the catches and effort of yellowfin tuna for 1988-92 regarding its longline fleet were due to the low logbook coverage rates that were recorded during that time. It was noted that the representativeness of the catch-and-effort data for this period may be compromised by the low coverage rates.

28. The WPTT commended Taiwan,China for supplying the size frequency data available for its longline fishery for 1980-2004. The dataset is expected to contribute greatly to the work of the WPTT.

29. The WPTT noted that the low sample size and coverage per area regarding the size frequency data available from longliners of Japan during the last decade is of concern. It was noted that the Japanese size data was used to estimate the size frequency on most non-reporting longline fleets. The WPTT stressed the need to increase the amount of size data collected on longline vessels agreeing that the use of existing data greatly compromises the quality of any Catch-at-Size tables derived from it.

30. The scientists from Taiwan,China and Japan informed the WPTT that the collection of size data on its longline vessels was voluntary, the amount of size data collected not likely to increase in the future. The scientists from Taiwan,China noted that the collection of size data through alternative methods, e.g. images of the specimens caught taken on board, was being tested and that its implementation would depend on the results of the study. Japan informed that the collection of size data through observers will improve the amount of size data collected for its fishery.

31. The WPTT commended Indonesia and Thailand for the collection of information on fresh-tuna longliners operating from ports in these countries. The WPTT stressed the need to complete the existing information through the collection of information on catches and effort per area. Indonesia informed the meeting that a pilot observer program was currently under way the implementation of a logbook system being one of its objectives.

32. Korea informed the WPTT that the catch-and-effort data was currently under review noting that more complete catch-and-effort data is expected to be available in the near future.

## *2.7. Data related issues for tropical tunas*

33. The following data related issues were highlighted by the WPTT:

- Poor knowledge of the catches, effort and size-frequency from fresh tuna longline vessels, especially from Taiwan,China, before 1998.
- Poor knowledge of 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 before 2002.
- Poor knowledge of the species composition and size-frequency data for former Soviet Union purse seine boats flying flags of convenience in recent years.
- Scarcity of data, especially size frequency data, for the Maldives hand line, troll line, gillnet and pole and line fisheries since 1998.
- Uncertainty about the catches, mainly gillnet, hand line and troll line, by domestic boats operating in Yemen and Sri Lanka.

34. Improvements have taken place in a number of areas. These include:

- **A better level of reporting:** New NC, CE and SF datasets have been obtained for Sri Lanka domestic fisheries and Taiwan,China longline fisheries. Taiwan,China provided size data for its longline fleet for 1980-2003.
- **Revision of the IOTC databases:** Several revisions have been conducted during the last year on the IOTC databases. This has led to revised NC data for some countries.
- **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. The catches of the former Soviet Union purse seiners for 1998-2002 are considered to be more accurate.
- **Estimation of catch-at-size for Indonesia, Taiwan,China and China fresh tuna longliners:** The collection of size data in Thailand, Sri Lanka and Indonesia underpins the estimates of catch-at-size for

fresh tuna longliners for 1998-2004 (longliners based in ports other than Indonesia) and 2002-04 (longliners based in Indonesia).

- **IOTC/OFCF sampling programmes:** The collection of information on the activities of fresh tuna longliners landing in Phuket and Indonesia has continued during 2004. This has led to more complete and accurate estimates of the catches by these fleets. Other valuable data collected under these programmes include length frequencies (which will allow length-length, length-weight and weight-length relationships to be updated). Size data were also obtained for Oman (Yellowfin tuna) and Maldives (skipjack tuna and yellowfin tuna) artisanal fisheries since 2003.
- **Yemen NC:** The catches of Yemen domestic fisheries were updated during 2004. New catch estimates are markedly higher than previous estimates, especially since the early 1990's.

35. The current status of the data for each of the tropical tuna species is summarised below.

### YELLOWFIN AND BIGEYE TUNA

**Nominal Catch data:** Relatively well known for most purse-seine fisheries and the main longline fleets (Japan, Korea and Taiwan,China). Catches of non-reporting longline and purse seine fleets are still uncertain, although they are believed more accurate than the estimates reported in the past.

**Artisanal catches** of bigeye tuna are negligible. By contrast, the levels of yellowfin tuna catches by artisanal gears (mainly gillnets) while uncertain are believed to have increased markedly in recent years.

**Catch and Effort data**: Well known for the purse-seine fisheries and the main longline operations (Japan, Korea and Taiwan,China). Nevertheless, the Korean data are considered to be inaccurate. No catch-and-effort statistics are available for non-reporting longline, purse seine and most gillnet fisheries.

**Size Frequency data:** Sampling coverage from Japan and Korea has been low in recent years. Size data is not available at the five degrees square resolution. The only data available for non-reporting fleets come from sampling in Phuket, Penang, Sri Lanka and Indonesia. Little information is available on important artisanal catches (e.g. Pakistan, Yemen and Comoros).

### SKIPJACK TUNA

**NC and CE data:** Relatively well known for most purse-seine fisheries. Data are available for the important artisanal fishery in Maldives although only up to 2001. Artisanal components (not well known) are important for this species. In several coastal countries (e.g. Indonesia) the catches are not reported by gear.

**SF data:** Available for reporting purse seine fleets (1984-2003), Maldivian baitboats (1983-1998 and 2003) and some gillnet fisheries and years (Pakistan, Iran, Indonesia and Sri Lanka), although sample sizes are low in some cases.

# 3. New information on biology and stock structure of tropical tunas

36. Document IOTC-2005-WPTT-28 summarised the results of the predation survey conducted by the Japanese commercial tuna longline fisheries for four years and four months from September 2000 to December, 2004. Currently about 480 longliners are cooperating in this survey. The focus is on predation by killer whales (*Orcinus orca*) and false killer whales (*Pseudorca crassidens*). The WPTT noted that the definition of predation rates used in the survey has changed from that used in the past. The number of predators observed between 2000-2004 was 1,564. Of these, 58% were sharks, 40% false killer (including killer whales) and 2 % other species. There are a few cases that squid and fur seals attacked tuna. The total number of fish attacked during the period 2000-2004 was 8,296. Yellowfin, bigeye and albacore tunas are three major species attacked by predators (47%, 27% and 14% respectively). Information on the seasonality and geographical distribution of predation events is provided. Mitigation measures are also described. Data compilation and processing will continue in 2006 and a workshop to discuss the results of the programme is tentatively scheduled for 2007.

37. Document IOTC-2005-WPTT-14 described aspects of the reproductive biology of yellowfin from the eastern Indian Ocean. Data was conducted between January 2001 and December 2003 from surface longliners that unloaded their catch at Phuket fishing port, Thailand. A total 355 ovary and 140 testis samples were collected.

The spawning season was between in November to April, coinciding with a period when the sex ratio was equal 1:1 (compared with the mean monthly sex ratio of 1:0.4). Size at first maturity of female and male was 109.69 cm and 104.95 cm, respectively. Small sized yellowfin (95-135 cm) comprised more females than males as did larger yellowfin (145-155 cm) but the proportion of females was slightly less. Counts of hydrated oocytes varied from 0.3 to 5.3 million oocytes, while the average diameter of oocytes was 0.56 mm.

38. Document IOTC-2005-WPTT-19 described results of a preliminary analysis on biological features of yellowfin tuna based on observer data from Chinas observer programme which began in the Indian Ocean in 2003. A total number of 746 yellowfin tuna were sampled in 2003 and 2004. The document provides length, weight, sex and stomach content information and compares the results with other studies.

39. Document IOTC-2005-WPTT-20 presents the preliminary sex ratio results for yellowfin tuna obtained by observers in an experimental Spanish longline fishery in international waters between 25º S and 35º S and 30º E and 50º E. Until now the sex of 244 yellowfin specimens has been determined, resulting in a total of 129 males (53%) and 115 females (47%). All the yellowfin specimens caught by long line in the campaign were between 110 and 170 cm LF, with 92% of the samples between 120 and 165 cm LF.

40. No new information on bigeye or skipjack tuna was available to the WPTT. New information on the biology of yellowfin tuna relevant to the stock assessment and interpretation of the high yellowfin catches in 2003 and 2004 is discussed in Section 4.

# 4. Review of new information on the status of yellowfin tuna

## *4.1. Review of the high catches of yellowfin in 2003 and their potential causes*

***Background***

41. The high catches of yellowfin observed in the Indian Ocean in 2003 and 2004 have been confirmed by the final data submitted to the IOTC. In 2003 yellowfin catches reached a record high level of 457,000 t. This was well above the average annual catch over the 10 previous years (353,000 t) and well above the previous highest catch of 406,000 t taken in 1993 (Figure 1). While the 2003 catch of yellowfin was unprecedented in the Indian Ocean, the WPTT noted that similar events have occurred in yellowfin fisheries in other oceans, e.g. the eastern and western Pacific in recent years (IOTC-2005-WPTT-21).

42. Purse seiners were responsible for the highest catches, however, some longline fleets (e.g. Japan) and by some artisanal fleets operating in the western Indian Ocean (such as those from South Africa, Iran) also experienced major increases in their catches of yellowfin.

43. Fishery data recently submitted to the IOTC on the EU purse seine and Japanese and Taiwanese LL catch and effort indicates that high catches of yellowfin were also taken in 2004. Monthly yellowfin CPUE by purse seiners during the period 1999-2004 in the Western Indian Ocean shows that CPUEs increasing from December 2002, peaking at the end of 2003 and the beginning of 2004, then decreasing back to average levels during the year 2004 in the purse seine fishery (Figure 13). Purse seine CPUEs in 2005 (provisional estimates) have been relatively low.

44. The most common size of yellowfin taken by purse seiners in 2003 and 2004 was between 110 and 150 cm (equivalent to individuals weighing 25 to 70 kg) (Figure 14).

45. For both the purse seine and longline fisheries, most of the catch of yellowfin in 2003 was taken in mainly in the south western Indian Ocean (Figure 15).

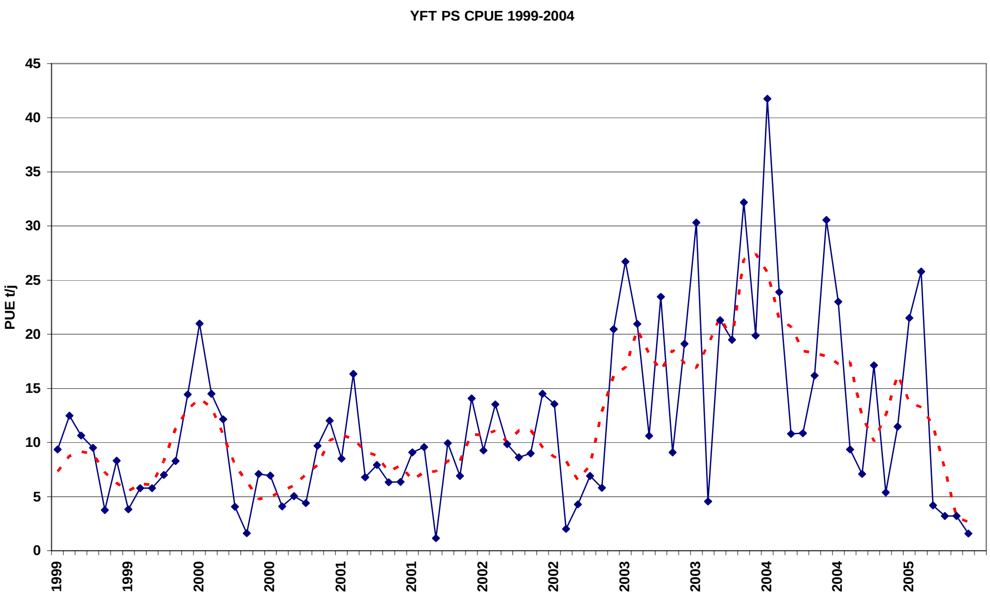



**Figure 13.** Monthly yellowfin tuna CPUE's from purse seine vessels (solid line) and smoothed average of CPUE (dotted line) for the period January 1999 to June 2005 (Note: 2005 is provisional data)

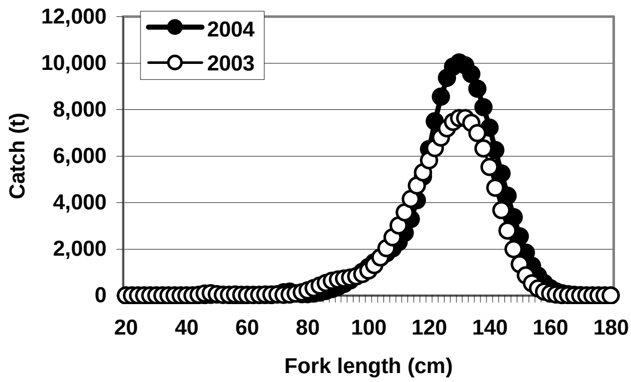



**Figure 14.** Size of yellowfin tuna taken by purse seiners in 2003 and 2004 in the Indian Ocean

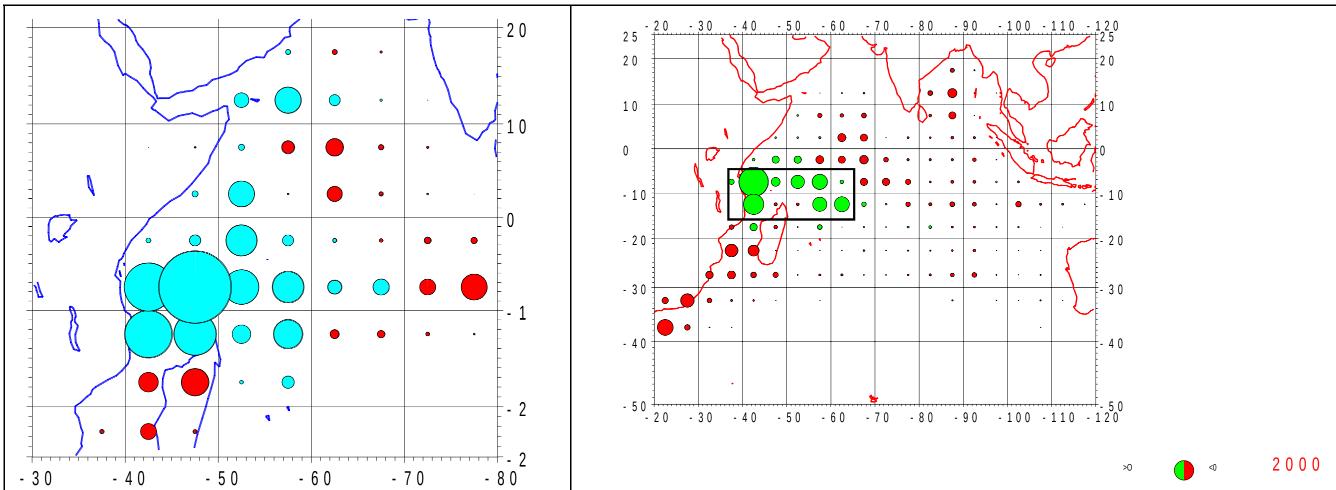



**Figure 15.** Maps showing the locations of the 2003 yellowfin catch anomalies in the purse seine (left) and Japanese longline (right) fisheries (anomalies are indicated by the relatively larger circles). Figures are from IOTC-2005-WPTT-INF04.

46. The WPTT noted that the 2003 anomaly appears to have continued into 2004 and there are signs that the purse seine and Japanese longline catches in 2004 will be similar (possibly higher) to those reached in 2003. Preliminary data shows that the 2004 high catches are being taken in the same area as those in 2003 (although it appears that in 2003 the Taiwanese longline fleet was not been targeting yellowfin in the same areas, keeping its traditional fishing zones and target species — mainly bigeye and swordfish). Verbal reports given to the WPTT indicated that Taiwanese longline fleet have taken large catches of yellowfin in the Arabian Sea in 2004 (Taiwanese yellowfin catches in 2004 being estimated to be 70% larger than in 2003), and also in 2005, but these data are not yet available to the IOTC.

47. The WPTT also noted from an analysis of the preliminary 2005 data that the yellowfin catches and catch rates by purse seiners during the first months of 2005 are relatively low (Figure 13), indicating that the 2003-2004 anomaly of high yellowfin catches may not be repeated in 2005.

***Why did the 2003-2004 anomalies occur ?***

48. In 2004 the Scientific Committee (IOTC-2004-SC-R) considered that the high catches could be explained by various mechanisms and causes, mainly:

- An increase of adult stock biomass due to an increased recruitment e.g. the presence of one or several large recruitments entering into the adult stock. Such increased recruitment could for instance have been due to favourable environmental conditions in the spawning/nursery areas in the late 1990's/early 2000's. However, it was noticed that catch rates of juveniles in the purse seine fishery do not show any very large year class during the period 2000-2001 (when in other yellowfin fisheries, such as in the Atlantic and Pacific oceans, these large classes tend to be "visible" at early ages in the purse seine fishery). This could indicate (1) either that juveniles of these large cohorts could have been outside the purse seine fishing zones, for instance in the eastern Indian Ocean (2) or that these recent cohort were at average levels.
- An increased catchability of the yellowfin stock, e.g. an increased fishing mortality due to certain conditions present in 2003 and 2004. The potential sources of increased catchability were listed and discussed in the various documents and some of these potential causes were considered as being more likely than others: (1) the increased efficiency of the purse seine fleet due to new sonars recently implemented, (2) the effect of the crustacean *Natosquilla* a new shallow species that is now frequently eaten by yellowfin in the western Indian Ocean and potentially facilitating the capture of yellowfin schools by purse seine; large biomass of a deep swimming crab was also noticed by Japanese longline fishermen in the same area and it may have concentrated the yellowfin biomass in the area, (3) the geographical concentration of the yellowfin stock in a peculiar area, where the yellowfin adult stock could have been more easily caught by purse seine and by longline, (4) the increased efficiency and better local targeting on yellowfin by Japanese longline.

49. New information submitted to the WPTT in 2005 (IOTC-2005-WPTT-27) discussed the potential effects of ecological anomalies on recruitment and catchability. This paper showed that various environmental anomalies (in the thermocline depth and primary productivity) have been observed in the western Indian Ocean, and may have played a role in the high yellowfin catches due primarily to an increased catchability of the stock. The same paper also discussed a new hypothesis that the recent deployment of noisy and massive war navy fleets in the north-west Indian Ocean could have produced a displacement of the northern yellowfin tuna biomass towards the southern Indian Ocean.

50. The conclusion of this document is that the 2003 high yellowfin catches were probably due to a combination of increased recruitments and increased catchability in the adult yellowfin stock (due to a combination of fishery and environmental factors).

51. A preliminary examination of various environmental parameters was also presented (IOTC-2005-WPTT-35). This paper described the seasonal variability and interannual trends of SST, chlorophyll s and it showed that various cycles and anomalies have been observed in these environmental parameters which could have influenced yellowfin.

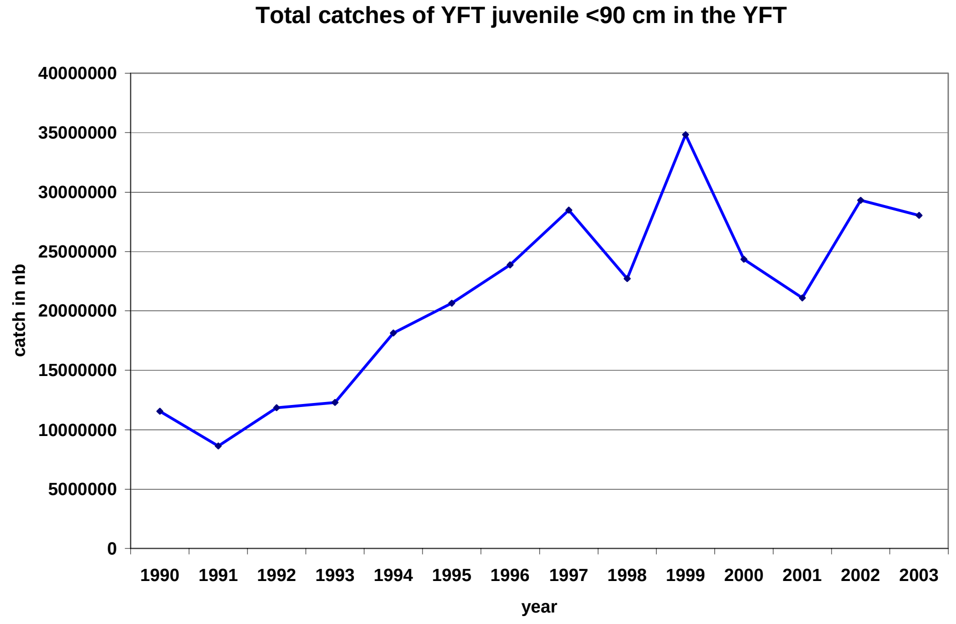



**Figure 16.** Total catches (numbers) of yellowfin juveniles <90 cm fork length.

52. Various environmental information on wind speed, sea surface temperature and upwelling were also examined in document IOTC-2005-WPTT-26. This information indicated that conditions were highly favourable for good recruitment in the area during the late 1990's, and these favourable conditions could explain the large recruitment of adult yellowfin in the 2003 and 2004 fishery. However, the same data set would also indicate that the environmental conditions could have been quite poor since 2000, then potentially producing poor recruitments in subsequent years. These potential low levels of yellowfin recruitment have not yet been identified in the fisheries of juvenile yellowfin, total catches of juvenile yellowfin (sizes <90cm, Figure 16) being estimated to be quite stable during recent years.

### *Conclusions on the 2003-2004 high YFT catches*

53. The data examined by the WPTT lead to the conclusion that the recent high yellowfin catches taken by purse seine and to less degree by other fleets in the South Western Indian Ocean were probably due a combination of factors

(1) one or two **high recruitments** entering into the adult stock; these increased recruitments should lead to an increased MSY if they could be maintained at high levels in the long run. If there was only a recruitment anomaly with 1 or 2 large year classes, the previously estimated MSY would still be valid.

(2) simultaneous **increased catchability** of the stock due to several additive factors (linked with fishery technology and behaviour, as well as a peculiar behaviour and biology of yellowfin tuna during this period). If real, this increased catchability of the yellowfin stock could temporarily lead to increased catches (as it would simply produce an **increased F at constant nominal effort**), but such increased catch would not be maintained in the long run, as the basic MSY of the stock would stay unchanged (the preliminary 2005 PS data tend to indicate such decline towards lower levels of catches).

54. These conclusions are simply based on the examination of various fishery and environmental data and qualitative information, and not upon a comprehensive stock assessment, but they would tend to indicate that the high 2003-2004 catches are probably not sustainable in the long run, being mainly driven by two large year classes and an increased catchability of the yellowfin stock, but not by a long term improvement of its biological productivity.

55. Such complex situation should preferably be analysed using complex integrated analytical assessment models, as they are the only suitable models to precisely evaluate the exact roles played by the various factors linked in peculiar geographical areas to changes in stock catchability and stock size.

## *4.2. Data for input to stock assessments*

#### CATCH AND EFFORT

56. A comparative overview of tuna stocks worldwide, in terms of biology, catches, population status and stock assessment, was presented (IOTC-2005-WPTT-21). Comparisons of a range of variables and indicators across all four yellowfin tuna areas (Indian, Atlantic, and western and eastern Pacific Oceans) were made. The various ways the scientific communities involved with the four stocks are dealing with common problems were also highlighted. The WPTT recognised the usefulness of such comparisons across stocks and paid special thanks the author for his hard work.

#### CATCH AT SIZE

57. Catch by length data for all fisheries were generated by Mrs. V. Nordstrom (IOTC-2005-WPTT-INF05). The WPTT thanked Mrs. Nordstrom for her good work. Questions were raised on the level of extrapolation necessary when generating this dataset. Unfortunately, sampling levels in many fisheries is very low, and it is even going down in some of them. This is the case, for example, of the Japanese longline fishery. The quality of the size frequency data needs also to be taken into account. For some fleets, sizes in the catch are measured by the crew while in others a complex sampling programme, stratified by area, season and vessel type, is in place. However, the generation of a complete catch-at-size matrix is absolutely necessary for the application of both length and age based assessment methods.

#### GROWTH CURVES AND REVISED LENGTH-AGE KEY

58. Document IOTC-2005-WPTT-32 re-examined the growth model for yellowfin tuna in the Indian Ocean using an analysis of length frequencies from purse seiners and in the Taiwanese longliners and Iranian gillnets between 2000 and 2004. A two stanza growth model was fitted. Growth appeared to be correctly described until 140 cm FL. L infinity was constrained in order to have result more realistic than the Stéquert growth curve or the Lumineau growth curve used in the previous assessment. Questions were raised about the implications of the growth curve proposed. The differences observed with the growth curves estimated for other oceans could be explained by the differences in methodology, or could arise from real differences between the various oceans where yellowfin is present. If this was the case, the use of natural mortality rates estimated in other oceans for the Indian ocean yellowfin stock could be misleading.

59. An ad hoc ‘Task Force on biological parameters’ was formed to discuss the pros and cons of the various growth curves available for use in the yellowfin stock assessment (the full report of the group is given in Appendix IV). The group made a comparison of the various growth models available in the Indian Ocean (based on modal progressions such as the Lumineau and Viera models, and otolith readings such as the Stequert models), comparing them to models used in other oceans for yellowfin stock assessments. The conclusion by the group was that the age reading done by Stequert was highly relevant but his growth parameters using his best fit of an L infinity at 2.60 m should not be used in a stock assessment. The WG reprocessed the Stequert data, and it was found that alternative growth model fitted to the two stanza growth model with an L infinity fixed at a realistic biological level of 1.65 m (e.g. at the 99% highest sizes taken by the historical longline fisheries). The fit of this new growth curve was nearly identical in statistical terms to the original Stequert curve;

60. The new growth curve fitted to the Stequert 1998 data with a L infinity = 1.65 m using a 2 stanza model was called the revised Stequert growth curve. For fish sizes > 70 cm, this new growth curve shows good agreement in growth curves obtained from modal progression. However, the WPTT could not reach a consensus on which of the revised Viera or revised Stequert growth curves best describe growth of yellowfin <70 cm.

61. The final conclusion by the WPTT was to use:

(1) two alternate growth curves for YFT <60 cm: i.e. the revised Stequert and Viera (noting that there is a difference of 12 month or 1 year in the absolute age of the 60 cm fishes ).
(2) the revised Stequert growth curve for YFT over 60 cm

62. It was noted that the usefulness of Stequert's original growth curve was limited by the unrealistic estimate of L_infinity obtained when fitting a growth curve to data with a limited length range. A model was thus fitted to the original data that fixed the value of L_infinity to 165 cm. The fit obtained was equally valid as the original one, and the group considered this to be a better approach.

### CATCH AT AGE

63. Given that both the revised Stequert and Viera's curves were markedly different from what was used for generating the previous catch-at-age matrix, new matrices were derived using both growth curves (Figure 17). Assessment models were thus re-run using one or both of these new matrices.

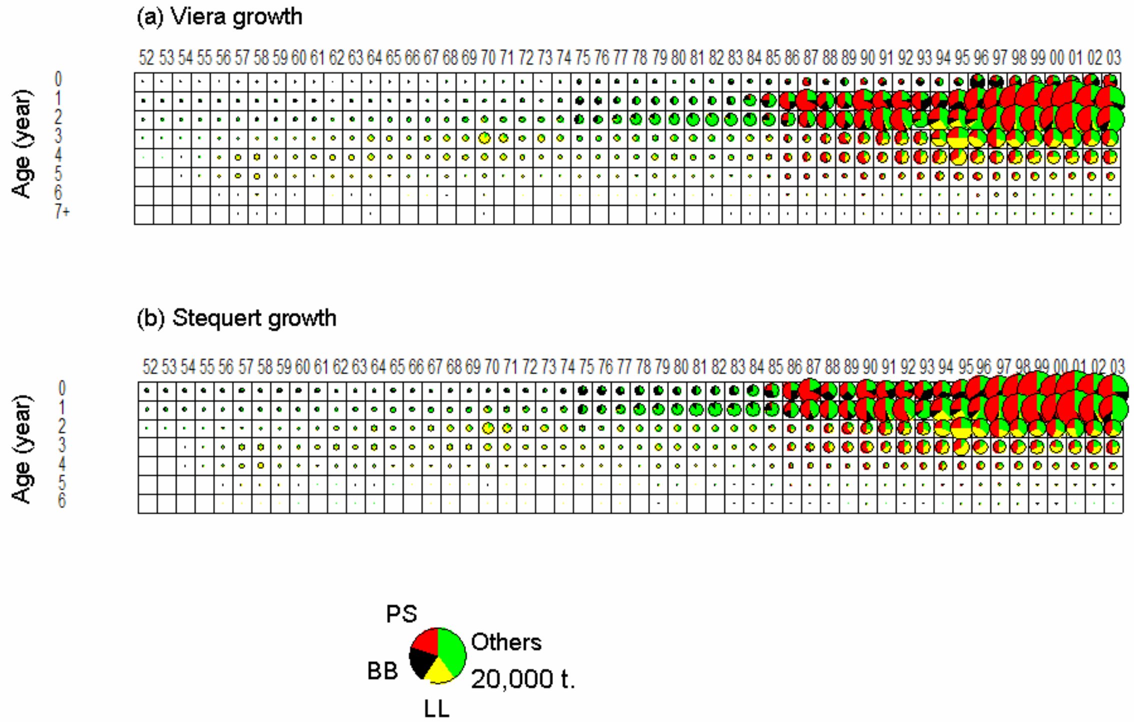



**Figure 17.** Catch at age (tonnes) for yellowfin tuna caught in the Indian Ocean (a) estimated using the revised Viera growth curve (b) estimated using the revised Stequert growth curve. PS: purse seine; BB: bait boat; LL: longline fishing.

### INDICES OF ABUNDANCE

#### *Longline fisheries*

64. Document IOTC-2005-WPTT-11 described recent trends of the Japanese longline fishery in the Indian Ocean with special reference to the targeting and asked the question “is the target shifting from bigeye to yellowfin ?”. Since the late 1990s, the proportion of yellowfin in the total bigeye and yellowfin combined catch has increased in the Indian Ocean. – especially in the western areas. Distribution of catch by species, species composition, CPUE were analysed in an attempt to determine whether the target species has been changing. The proportion of yellowfin has probably increased due to one or a combination of factors: 1) a shift of fishing ground (distribution of effort concentration) to a yellowfin dominant region in the western Indian Ocean; 2) an introduction of more than 17 hooks between floats and use of Nylon materials since 1990; 3) a decrease of bigeye abundance (CPUE) and increasing or flat level in yellowfin CPUE in the last 10 years in the tropical Indian Ocean.

65. Document IOTC-2005-WPTT-12 described the estimation of longline gear configuration using species composition data from the Japanese longline fisheries 1975 to 2002. In the four species combinations tested, the combination of six species (BET, YFT, ALB, SWO, MLS and BUM) resulted in the highest correct estimation ratio. By substitution of the strata whose species composition could not determined for one or both gear types, the ratio of un-judged observation decreased from 0.464 to 0.300. In the estimation using composition of six species and applying the substitution, the correct estimation ratio averaged about 63%. When the estimated and actual gear configurations were applied into GLM, both of estimated and actual NHFCLs had a significant effect on the bigeye CPUE standardization, although the difference of effects between estimated NHFCLs (regular and deep longlines) was smaller than that observed between actual gear types.

66. Document IOTC-2005-WPTT-29 described the results of a study to examine the affects of Japanese tuna prices on targeting practices and CPUE of yellowfin tuna and bigeye tuna exploited by Japanese and Taiwanese tuna longline fisheries in the Indian Ocean. The results indicated that some changes in the fishery may have occurred as a result of prices around 1980.

67. Nominal CPUE is illustrated for the period 1953-2003 (Figure 18). Standardised CPUE analyses using the same analytical approach were reported for the Japanese longline fishery (Figure 19) and the Taiwanese longline fisheries (Figure 20), respectively. In the analysis of the Taiwanese data (IOTC-2005-WPTT-16), environmental factors were included in the model for the first time this year. For the Japanese analysis (IOTC-2005-WPTT-15), the GLM model incorporated both environmental and of technological factors.

68. The group discussed the relative merits and shortcomings of each of those indices, concentrating on their suitability for the purposes of stock assessment. Doubts were raised on the need for such a complex GLM-based standardisation for the LL fleets, specially the Japanese, when they did not differ greatly from the nominal. Also the WPTT generally agreed that too many parameters tend to be incorporated in the GLM models.

69. IOTC-2005-WPTT-INF03 informed the WPTT that in Japan basic tuna price (fresh & frozen) data are available in more than 200 fishing ports since 1961. It is not clear whether these data are electronic at this stage. The WPTT suggested that the price data might be digitized so that they can be utilized in the CPUE standardization. When tuna price data are used for the analyses, however, four points need to be taken care, i.e., (a) to use fresh(or frozen) tuna prices as the representative tuna price statistics in Japan, (b) to use tuna price data in major 6-10 cities to represent average situation because tuna prices are different among cities (or landing ports) in Japan, (c) to apply the inflator to standardize tuna prices using consumer price indices (CPI) and (d) to apply the exchange rates (US$-Japan yen) to standardize tuna prices.

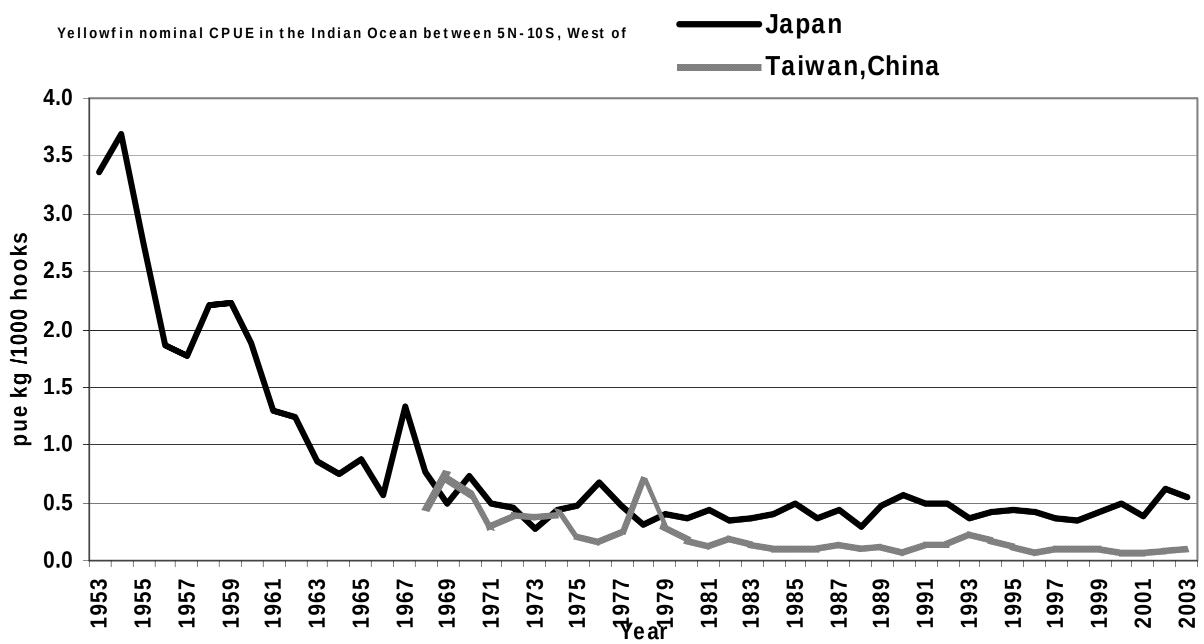



**Figure 18.** Nominal CPUE for yellowfin in the Indian Ocean for longline fleets from Japan and Taiwan,China.

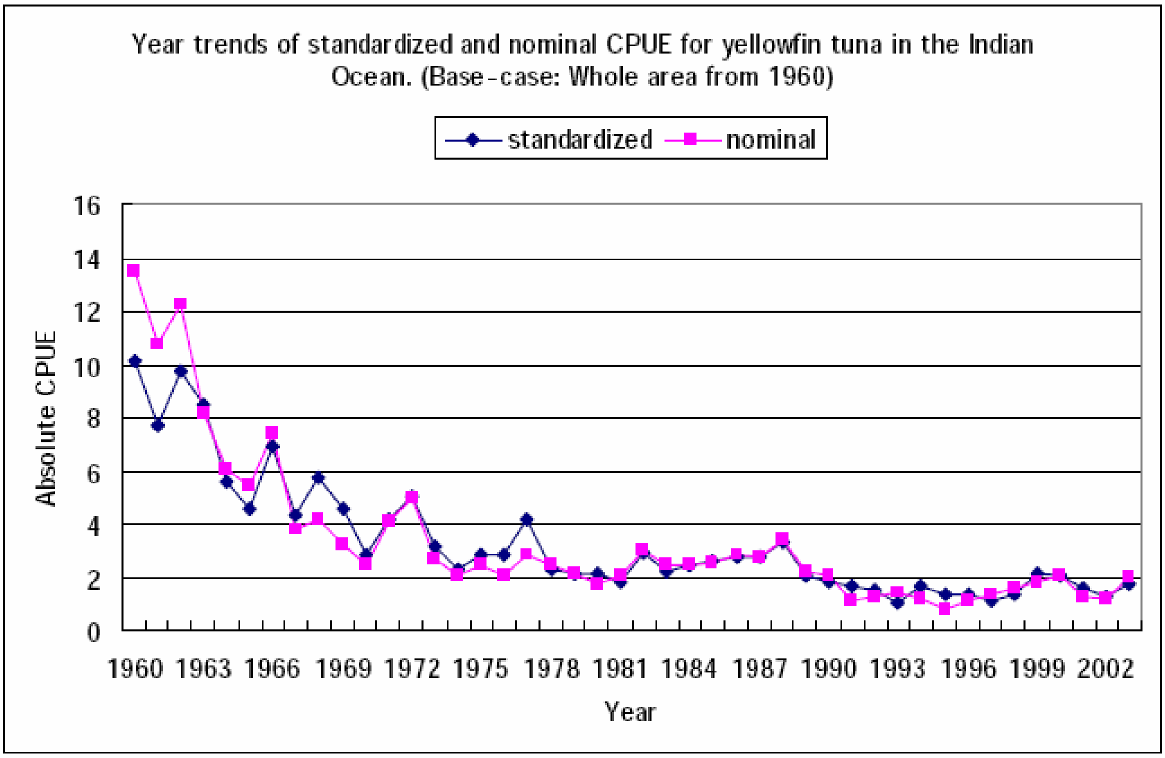



**Figure 19.** Standardised CPUE index: Japanese longline fishery.

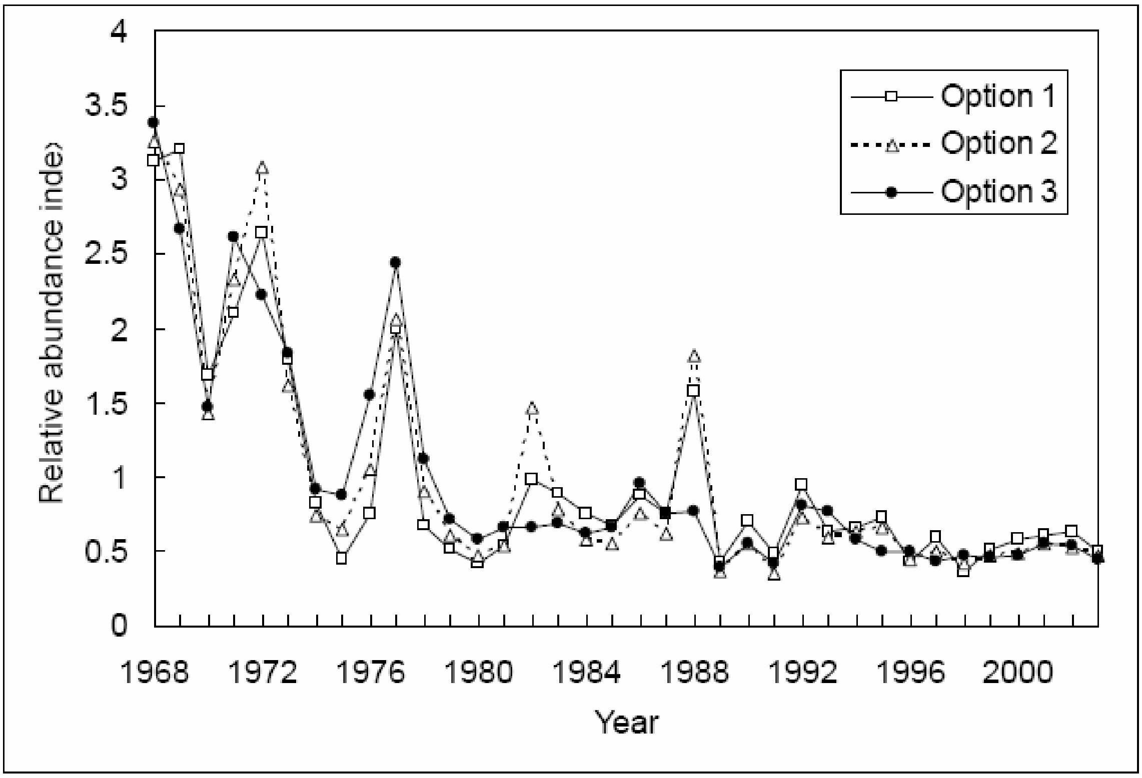



**Figure 20.** Standardised CPUE index: Taiwanese longline fishery for a range of options. Option 1 is a full model, option 2 is excluding area x the effect of mix layer depth, and option 3 excludes the effect of SST.

***Purse seine fisheries***

70. Document IOTC-2005- WPTT-17 described a standardization of yellowfin purse seine catch rates using GLM. Two sources of data were considered in the analyses: catch and effort data by 1ºx1º square and month, from the IOTC data base, as well as more detailed logbooks data at boat level. The standardized catch rates resulting of the different models were unlikely to be representative of yellowfin abundance. In all the cases, the increasing trend showed by the indexes seemed to be more related with trends in efficiency than abundance. The European PS index was clearly recognised as needing to be standardised, given the known technological changes this fleet has been involved with. The group acknowledged the effort of the team behind this work but conceded that the present data on technological and procedure changes, as well as the knowledge of the effect and interaction among them, was too limited to permit the use of the presented index of abundance for assessment purposes.

## 4.3. Stock assessments

71. A comprehensive assessment was attempted for yellowfin tuna in 2005 by the WPTT. Two papers presenting assessment results were presented, one using the age structured production model (ASPM) method and one using a new Bayesian two-age-class production model. Additional assessments were carried out during the WPTT meeting using agreed data sets and the following methods: the PROCEAN method, the CATAGE trend (statistical catch at age analysis) method, ASPM, and the Bayesian two-age-class production model.

***Age-structured production model ASPM***

72. A stock assessment on yellowfin tuna was presented using the stochastic age-structured production model, ASPM (IOTC-2005-WPTT-09 and addendum 1). This ASPM model assumes that the catchability coefficients relating the longline fleet CPUEs to abundance are constant over time. Results of several model runs were presented that used various combinations of input parameters such as indices of abundance (JPN and TWN, starting 1960 or 1968), stock-recruitment relationships and natural mortality vectors.

73. Although this model was used in the previous yellowfin assessment and its behaviour is well known, there the WPTT noted certain limitations and these were discussed. A problem appeared to be present with the stock-recruitment parameters. For example, steepness was not reliably estimated from the current data, as shown by the tendency of the model fix on a estimate of 0.99 i.e. the upper limit of possible values and not considered by the WPTT to be realistic. Estimation of steepness in the S/R relationship appears to be extremely complex for many tuna stocks. A suggestion was made that runs could be attempted by fixing the steepness parameter to an agreed value, so that the estimation of MSY and their related reference points would be more successful, but this was apparently not possible in the present model implementation.

74. The ASPM model outputs showed a marked decline in SSB and a singular pattern in recruitment. This appeared to be motivated by the sharp decline implied by the longline indices of abundance at the start of the fishery, when catches were relatively low. In the ASPM, assuming a constant q, the only possible explanation for such a decline in CPUE is that it was due to a parallel decline in recruitment. The biological reasons for such a decline in recruitment are not clear, and no indication of a decline has been detected.

***Bayesian age-structured production model***

75. Document (IOTC-2005-WPTT-24) presented a Bayesian age-structured production model, modelling two age groups, juveniles and adults, to avoid the problems introduced by the uncertainty in growth. The cutoff point between the two age groups was 85 cm fork length, a length were the FAD fishery catches separate from the free school and Longline fisheries, and close enough to the assumed length at maturity. A mean weight was then estimated for each age group. Catch-at-length in numbers and the Japanese longline index of abundance for the 1968-2003 period were used. A catchability coefficient that was constant over time was assumed for relating the Japanese longline index to abundance. A Beverton-Holt stock-recruitment relationship was assumed, where steepness was fixed at a value of 0.9, and only virgin recruitment was estimated.

76. The population trends detected by this model were in general agreement with those of the ASPM: a stable or slightly declining SSB until the early 1970s, when the decline of adult biomass started. Recruitment (in the form of its proxy here of the abundance of age 0 and 1 fish) appeared stable until recent years. Even with a very weak SR relationship, the current level of exploitation of the stock appears to start having an impact on recruitment, albeit a minor one.

77. The model predicted that ongoing catches at the level of those in 2003 are not sustainable in the short or medium term. A constant catch scenario at the levels of 2003, and incorporating the uncertainty in the estimate of SSB, and an alternative were catches of both ages are reduced by 25% in weight were presented.

***CATAGE***

78. CATAGE-TREND is a multi-fleet statistical catch-at-age model which includes both observation error and process error on both catchabilities and selectivities for each fleet. The process error model for catchabilities combines a random walk that allows for slow trends in fishing power and a robust error that allows for high frequency random variability in annual catchabilities. The model uses a Bayesian approach that allows for the use of prior probability distributions for parameters such as natural mortality and recruitment variability. The likelihood approach used enables different levels of model complexity to be compared and permits the extraction of the maximum amount of information from the data. A Monte Carlo Markov Chain (MCMC) algorithm is used to integrate the posterior density function of the model and to provide the posterior probability distributions for model parameters (e.g. natural mortality, abundances and fishing mortalities) and derived parameters of interest (e.g. reference points and projections).

79. Results of applying CATAGE-TREND to yellowfin tuna data covering the period 1953-2003 are presented in IOTC-2005-WPTT-33. Estimated trends in SSB and recruitment matched those of the other models, especially the declines in recent decades. The apparent jump in recruitment in the 1998-99 was discussed with respect to its possible contribution to the high catches observed in 2003. However, it was noted that the five year gap was too long to realise the sizes of fish observed in the 2003 catches, even considering the uncertainty in growth and aging. Estimates of catchability for the longline fleets showed strong decreasing trends for the first 20 – 30 years of the fishery and then increases since 1990. For the purse-seine fleets, there were strong increases in estimated catchabilities since the early to mid-1980s.

***PROCEAN***

80. PROCEAN (PROduction Catch/Effort ANalysis) is a multi-fleet non-equilibrium Pella and Tomlinson model which includes both observation error and process error on both the carrying capacity of the stock and the catchability for each fleet. The process error model for catchabilities combines a random walk that allows for slow trends in fishing power and a robust error that allows for high frequency random variability in annual catchabilities. PROCEAN uses a Bayesian approach that allows for the use of prior probability distributions for the biomass at time zero ($B_0$) and other model parameters such as the intrinsic growth rate (r), the shape parameter (m), and the carrying capacity (K), or alternatively on the MSY and $F_{MSY}$. A Monte Carlo Markov Chain (MCMC) algorithm is used to integrate the posterior density function of the model and to calculate posterior probability distributions for the estimated model parameters, derived parameters (e.g. $F_{MSY}$, MSY), and other variables of interest (e.g. reference points, projections, etc). The objective of the model is not to propose a very realistic representation of the fishery. Rather, it is a tool to explore data sets and extract the maximum amount of information from the data set by structuring it according to a simple and well established theoretical model.

81. Results of applying PROCEAN to yellowfin tuna data covering the period 1953-2003 are presented in IOTC-2005-WPTT-33. Estimates of catchability for the longline fleets showed strong decreasing trends for the first 20 – 30 years of the fishery and then slower increases since the mid-1980s. For the purse-seine fleets, there were strong increases in estimated catchabilities since the early to mid-1980s. In the runs conducted, the data were well fitted by the model. The fishery is estimated to be below $F_{MSY}$ although the current position relative to $F_{MSY}$ is poorly determined. The 2003 catch was above the MSY, but the mean catch for the five previous years was in the vicinity of the MSY.

***Summary of model results***

82. Although there were differences in the details of results from the different assessments, the overall picture they presented was consistent, particularly in terms of estimated trends in stock biomass and fishing mortality rates. Estimates of catchability using the PROCEAN and CATAGE trend methods, which allow for time-varying catchability, show a strong increasing trend since the mid-1980s for both the longline fleets and the purse-seine fleets. The assessment runs considered at this meeting consistently indicated that fishing mortality rates between 1992 and 2002 have been close to or at levels of F corresponding to the $F_{MSY}$ estimated by the most plausible ASPM assessment. Catches during this period were in the vicinity of, or possibly above, the MSY levels estimated by PROCEAN and the most plausible ASPM assessment. Estimated catches in 2003 and 2004 were well above

those MSY levels, and projections carried out indicate that these are not sustainable unless supported by very high recruitments.

83. There remain strong uncertainties in each of the assessments conducted. In particular, none are yet able to consistently explain the trends in standardized CPUEs in the early years of the fishery without using trends in catchabilities or recruitment for which there is no evidence. Consequently, the implications drawn from them regarding current stock status are also uncertain.

## 4.4. Technical advice on yellowfin tuna

84. A comprehensive assessment was attempted for yellowfin tuna in 2005 by the WPTT and the Executive Summary of the status of the yellowfin tuna resource was updated. The Management Advice section of the executive summary is reproduced below. The complete Executive Summary is given in Appendix V.

Considering all the stock indicators and assessments, as well as the recent trends in effort and total catches of yellowfin, the Scientific Committee considered that:

1) Fishing mortality rates between 1999 and 2002 were probably slightly below or around Fmsy, and total catches during that period, at an average level of 347,000 t, were probably close to, or possibly above MSY. Total catches in 2003 and 2004 were substantially above MSY; see below for interpretation of the possible reasons for and possible effects of these catches. In these circumstances, any further increase in both effective fishing effort and catch above average levels in 1999 - 2002 should be avoided.
2) The current fishing pressure on juvenile yellowfin by both purse seiners fishing on floating objects and artisanal fisheries is likely to be detrimental to the stock if it continues, as fish of these sizes are well below the optimum size for maximum yield per recruit estimated in 2002.
3) The Scientific Committee also noted that juvenile yellowfin tuna are caught in the purse-seine fishery that targets primarily skipjack tuna. Some measures to reduce the catches of juvenile yellowfin tuna in the FAD fishery will be accompanied by a decrease in the catches of skipjack tuna.

While there was greater consistency in the assessment results considered at this meeting than in 2002, the Scientific Committee emphasized that there remain considerable uncertainties in the assessments, as none as yet are able to fully explain the observed trends in standardized longline CPUEs over the duration of the fishery.

In interpreting the high catches of 2003 and 2004, the Scientific Committee noted that if the hypothesis of one or two high recruitments entering the adult stock is correct, the increased catches from these year classes are unlikely to be detrimental to the stock, but these catches would not be sustainable in the longer term unless supported by continued high recruitments.

On the other hand, there could be serious consequences if the hypothesis that there was an increased catchability during 2003 and 2004 is correct. In this case, the very large catches would represent a much higher fishing mortality and certainly would not be sustainable. Furthermore, they could lead to a sudden decline of the existing adult biomass of yellowfin tuna, potentially reducing the stock to below MSY levels. If such is the case, management action might be needed to reduce catches and fishing mortality to below the levels prevailing in 1999 – 2002 to allow the stock to recover.

If, as the Scientific Committee believes, the most likely cause of the exceptional catches is a combination of these factors, then some reduction of stock biomass is to be expected in the future. However, the extent of any such reduction will only become apparent in several years following detailed stock assessments.

# 5. Research Recommendations and priorities

85. At the 9th Session of the IOTC, the Commission requested (via IOTC Resolution 05/01 On conservation and management measure for bigeye tuna) that the Scientific Committee be tasked to provide advice on;

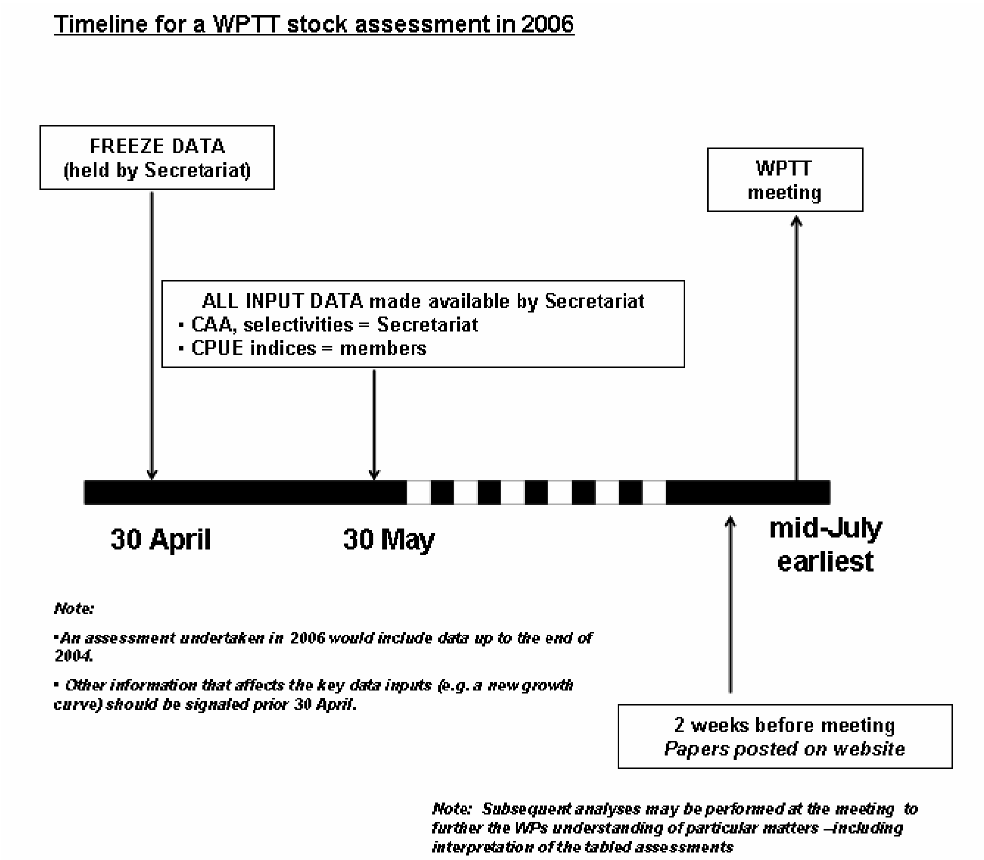
- the effects of different levels of catch on the SSB (in relation to MSY or other appropriate reference point)
- the impact of misreported and illegal catch of bigeye tuna on the stock assessment and required levels of catch reduction
- evaluation of the impact of different levels of catch reduction by main gear types.

86. The WPTT agreed that that ASPM model, as used by Japan in 2004 would be re-run using updated fisheries data and the biological and fisheries parameters used in 2004. The results of this assessment will be made available to WPTT prior to the Scientific Committee meeting in November 2005 and new technical advice on bigeye would be prepared for the Commission by the Scientific Committee based on the results of the up-dated assessment. The WPTT requested that the Secretariat coordinate the delivery of the assessment in conjunction with Japanese scientists.

# 6. Other business

***Timeline for future stock assessments***

87. Concerns were raised by members about the short amount of time that was available in which to produce stock assessments and/or review the results of comprehensive assessments prior to the meeting . The WPTT agreed that the main problem lay with the unavailability of the key data inputs until near the start of the meeting. To improve the situation in 2006, the WPTT recommended that the Secretariat works closer to the those member scientists that provide the various datasets and ultimately be responsible for providing the basic data including catch at size and catch at age data –estimated using standard- agreed procedures. The WPTT concluded adherence to the timeline below should greatly benefit the work of the Working parties in 2006 and future years.



***Election of WPTT chair***

88. The WPTT noted with regret that the current WPTT chair (Dr. Pilar Pallarés) would not be available for consideration for re-election for 2006 and 2007. On behalf of the WPTT, the Chair of the SC, thanked the Dr Pallarés for her expert guidance over the last biennium and her considerable contribution to the success of the WP process over that time. The meeting noted that a new WPPT chair needed to be elected and agreed that this matter should be addressed at the Scientific Committee meeting in November 2005.

***Update on tuna tagging activities in the Indian Ocean***

89. Document IOTC-2005-WPTT-25 described the small scale and pilot tagging projects involving IOTC being carried out in Maldives, Mayotte and India, and progress to-date at the start of the Regional Tuna Tagging Project.

# 7. Adoption of the report

90. The Report of the Seventh Session of the Working Party on Tropical Tunas as reviewed by correspondence between 10 and 26 August. This final version reflects the comments received from that review.

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# APPENDIX II. AGENDA OF THE MEETING

1. **REVIEW OF THE DATA**

   Review of the statistical data available for the tropical tuna species

2. **REVIEW OF NEW INFORMATION ON THE STATUS OF YELLOWFIN**

   Investigations on the cause of the extraordinary large catches on YFT in 2003, 2004

   Data for input into stock assessments:

   - Catch and effort
   - Catch at size
   - Growth curves and revised age-length key
   - Catch at age
   - CPUE

   Stock assessments

   Selection of Stock Status indicators

3. **NEW INFORMATION ON BIOLOGY AND STOCK STRUCTURE OF TROPICAL TUNAS**

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

4. **DEVELOP TECHNICAL ADVICE ON THE STATUS OF THE STOCKS**

   Yellowfin

5. **RESEARCH RECOMMENDATIONS AND PRIORITIES**

6. **OTHER BUSINESS**

# APPENDIX III. LIST OF DOCUMENTS PRESENTED TO THE MEETING

| DOCUMENTS | TITLES |
|---|---|
| IOTC-2005-WPTT-01 | WPTT 2005 Agenda |
| IOTC-2005-WPTT-02 | WPTT List of documents |
| IOTC-2005-WPTT-03 | Status of IOTC databases for Tropical Tunas. *IOTC Secretariat* |
| IOTC-2005-WPTT-04 | Revised catch estimates for tuna and tuna-like species caught by artisanal boats in Yemen *Secretariat* |
| IOTC-2005-WPTT-05 | Biological data on tuna and tuna-like species gathered at the IOTC Secretariat *Secretariat* |
| IOTC-2005-WPTT-06 | Preliminary results of the multilateral catch monitoring programme on fresh-tuna longliners operating from ports in Indonesia. *DGCF, RCCF, CSIRO, ACIAR, IOTC, OFCF*. |
| IOTC-2005-WPTT-07 | Fresh tuna longline fishery in Thailand. *Praulai Nootmorn* |
| IOTC-2005-WPTT-08 | Availability of size frequency data for yellowfin tuna and bigeye tuna from the major longline fleets operating in the Indian Ocean. *Secretariat* |
| IOTC-2005-WPTT-09, add1 | Stock assessment of yellowfin tuna (*Thunnus albacares*) resources in the Indian Ocean by the age structured production model(ASPM) analyses. *Tom Nishida and Hiroshi Shono* |
| IOTC-2005-WPTT-10 | Korean tuna longline fishery in the Indian Ocean. *Won Seok Yang* |
| IOTC-2005-WPTT-11 | Recent trend of Japanese longline fishery in the Indian Ocean with special reference to the targeting. *Hiroaki Okamoto* |
| IOTC-2004-WPTT-12 | Estimation of longline gear configuration using species composition in the operations of which the gear structure are already known. *Hiroaki Okamoto, Kotaro Yokawa and Shui-Kai Chang* |
| IOTC-2004-WPTT-13 | Thai Tuna Fishery by Mook Andaman Longliners in the Indian Ocean during 2000-2004. *Sampan Panjarat, Praulai Nootmorn, Smith Thummachua* |
| IOTC-2004-WPTT-14 | Reproductive Biology of Yellowfin Tuna in the Eastern Indian Ocean. *Praulai Nootmorn* |
| IOTC-2005-WPTT-15 | Standardised CPUE for yellowfin tuna (*Thunnus albacares*) of the Japanese longline fishery in the Indian Ocean up to 2003 by generalised linear models (GLM (1960-2003). *Hiroshi Shono, Hiroaki Okamoto, Tom Nishida* |
| IOTC-2005-WPTT-16 | Standardization of CPUE for yellowfin tuna caught by Taiwanese longline fishery in the Indian Ocean using generalised linear model (Draft). *Sheng-Ping Wang and Shui-Kai Chang* |
| IOTC-2005-WPTT-17 | Standardized catch rates for yellowfin (*Thunnus albacares*) for the European purse seine fleets (1982-2003) *Soto M., D. Gaertner, A. Fonteneau, J. Dorizo, P. Pallarés1, A. Delgado de Molina and J. Ariz* |
| IOTC-2005-WPTT-18 | Statistics of the purse seine Spanish fleet in the Indian Ocean (1984-2004) *Delgado de Molina, A., P. Pallares, J.J. Areso and J. Ariz 4* |
| IOTC-2005-WPTT-19 | Preliminary analysis on biological features of yellowfin tuna (*Thunnus albacares*) based on observers' data in the Indian Ocean. *Xu Liuxiong and Zhu Guoping*. |
| IOTC-2005-WPTT-20 | Preliminary yellowfin tuna sex-ratio analysis from observer data obtained during the experimental cruise on Spanish longliners in the Southwestern Indian Ocean. *J.Ariz , A. Delgado de Molina, Mª L. Ramos and P.Pallarés* |
| IOTC-2005-WPTT-21 | An overview of yellowfin tuna stocks, fisheries and stock status worldwide. *Alain Fonteneau* |
| IOTC-2005-WPTT-22 | French purse-seine tuna fisheries statistics in the Indian Ocean, 1981-2003. *Pianet R., V. Nordstrom and P.Dewals*. |
| IOTC-2005-WPTT-23 | Statistics of the main purse seine fleets fishing in the Indian Ocean (1981-2003). *Pianet R., P. Pallares, A. Delgado de Molina, V. Nordstrom, P. Dewals and V. Lucas* |
| IOTC-2005-WPTT-24 | Stock assessment of Indian Ocean yellowfin tuna using a Bayesian implementation of a two-age structured model. *Iago Mosqueira & Richard Hillary.* |
| IOTC-2005-WPTT-25 | Summary of the different tagging activities of the Indian Ocean tuna tagging programme (IOTTP). *Secretariat* |

| | |
|---|---|
| IOTC-2005-WPTT-26 | Developing a index of area suitable for recruitment. *Olivier Maury* |
| IOTC-2005-WPTT-27 | Did ecological anomalies cause 1993 and 2003-2004 high catches of yellowfin tuna (*Thunnus albacares*) in the western Indian Ocean? And - review of other possible causes (strong recruitments, high catchabilities and excess fishing efforts). *Tom Nishida, Hiroshi Matsuura, Yukiko Shiba, Miyako Tanaka, Masahiko Mohri and Shui-Kai Chang* |
| IOTC-2005-WPTT-28 | Report of the predation survey by the Japanese commercial tuna longline fisheries (September, 2000 – December, 2004). *Tom Nishida and Yukiko Shiba* |
| IOTC-2005-WPTT-29 | Study on affect of Japanese tuna prices on targeting practices and CPUE of tuna longline fisheries - Case study for yellowfin tuna (*Thunnus albacares*) & bigeye tuna (*Thunnus obesus*) in the Indian Ocean. *Tom Nishida, Arata Izawa and Shui-Kai Chang* |
| IOTC-2005-WPTT-30 | Recent trend in fad fishing activities by purse seiners licensed to fish inside of the Seychelles EEZ. *V. Lucas, and J. Dorizo* |
| IOTC-2005-WPTT-31 | Preliminary result of the CAPPES (CAPturabilité des grands PElagiques exploités à la palangre dérivante dans la Zone Economique Exclusive des Seychelles) research program. *V. Lucas and P. Bach* |
| IOTC-2005-WPTT-32 | Study of the growth of yellowfin tuna (*Thunnus albacares*) in the Indian Ocean based on length frequency data from 2000 to 2004. *Antony Viera* |
| IOTC-2005-WPTT-33 | Outputs from CATAGE-TREND (statistical catch at age analysis program -Maury 2000). *Olivier Maury* |
| IOTC-2005-WPTT-34 | PROCEAN results. *Olivier Maury* |
| IOTC-2005-WPTT-35 | Examining environmental factors and yellowfin catch rates in the Indian Ocean. *Marco Garcia.* |
| IOTC-2005-WPTT-INF01 | Spatial and Temporal Distribution Patterns of Bigeye Tuna (*Thunnus obesus*) in the Indian Ocean. *Pei-Fen Lee, I-Ching Chen and Wann-Nian Tzeng* |
| IOTC-2005-WPTT-INF02 | Incorporating spatial autocorrelation into the general linear model with an application to the yellowfin tuna (*Thunnus albacares*) longline CPUE data. *Tom Nishida and Ding-Geng Chen* |
| IOTC-2005-WPTT-INF03 | Tuna price statistics in Japan. *Tom Nishida and Arata Izawa* |
| IOTC-2005-WPTT-INF04 | The Indian Ocean yellowfin stock and fisheries in 2003: overview and discussion of the present situation. *Alain Fonteneau, Javier Ariz, Jean Pierre Hallier, Vincent Lucas, Pilar Pallares and Michel Potier* |
| IOTC-2005-WPTT-INF05 | Processing of YFT catch by size data (06/2005). *V. Nordstrom* |
| IOTC-2005-WPTT-INF06 | On accuracy of the estimated fish school weights by sonar specialists. *H. Shono and T. Nishida* |

# APPENDIX IV. REPORT OF THE BIOLOGICAL PARAMETER TASK FORCE

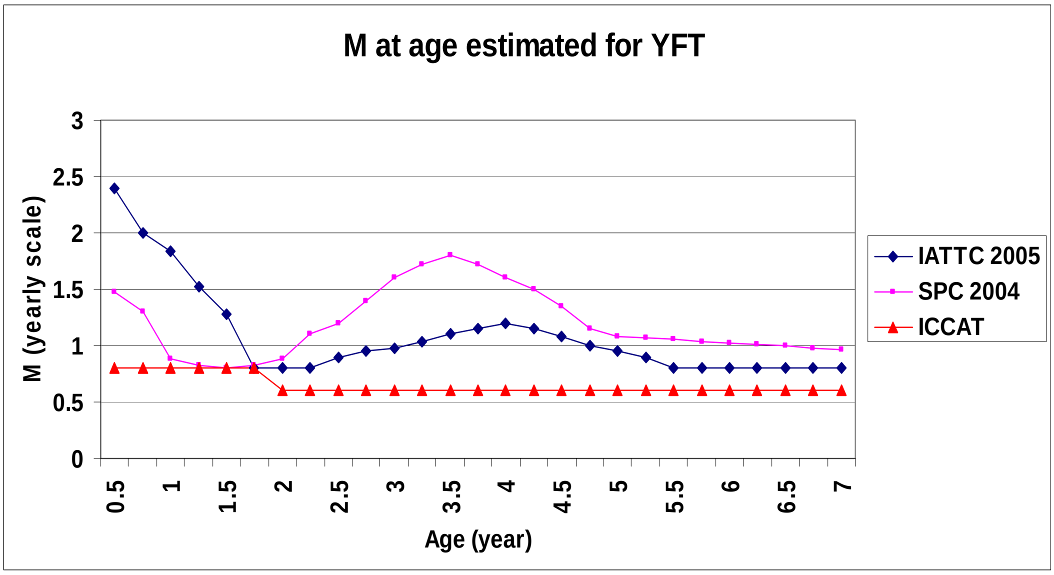
The *ad hoc* Task Force on the biological parameters to be used by the WPTT in its stock assessment held its meeting after the abalone dinner. Its work has been targeting on 2 key parameters used in analytical stock assessment.

**(1) Natural mortality at age**

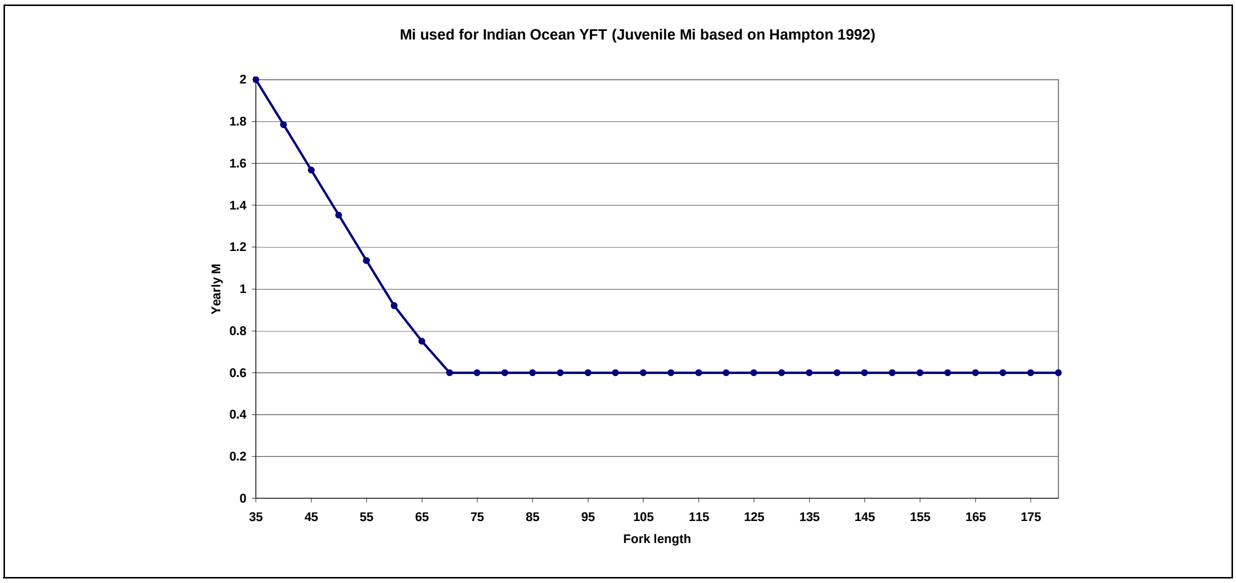
This parameter tend to be of key importance in all analytical stock assessment, when it remains widely uncertain. The WG made a comparison between various M at age vectors used nowadays by other tuna commissions and by the IOTC. A summary of these vector is shown by figure 1.

After an extensive discussion the group reached a consensus that age structure production models could well use the 3 types of hypothetical Mi, a single vector of Mi should be selected in analytical models.

The group reached the conclusion that a vector Mi combining the initial shape and level of




The Mi at size estimated by Hampton 2001, showing a pattern that is very similar to the IATTC Mi, was selected as being the best Mi to be used in the 2005 stock assessment, followed by a low ICCAT type Mi at 0.6; The change between the high and low M would be fixed at a given size of 70 cm, e. g. at 6.5 kg, this age would be variable as a function of the age estimated at this 70 cm size, as shown by figure 2 (see the discussion on growth).

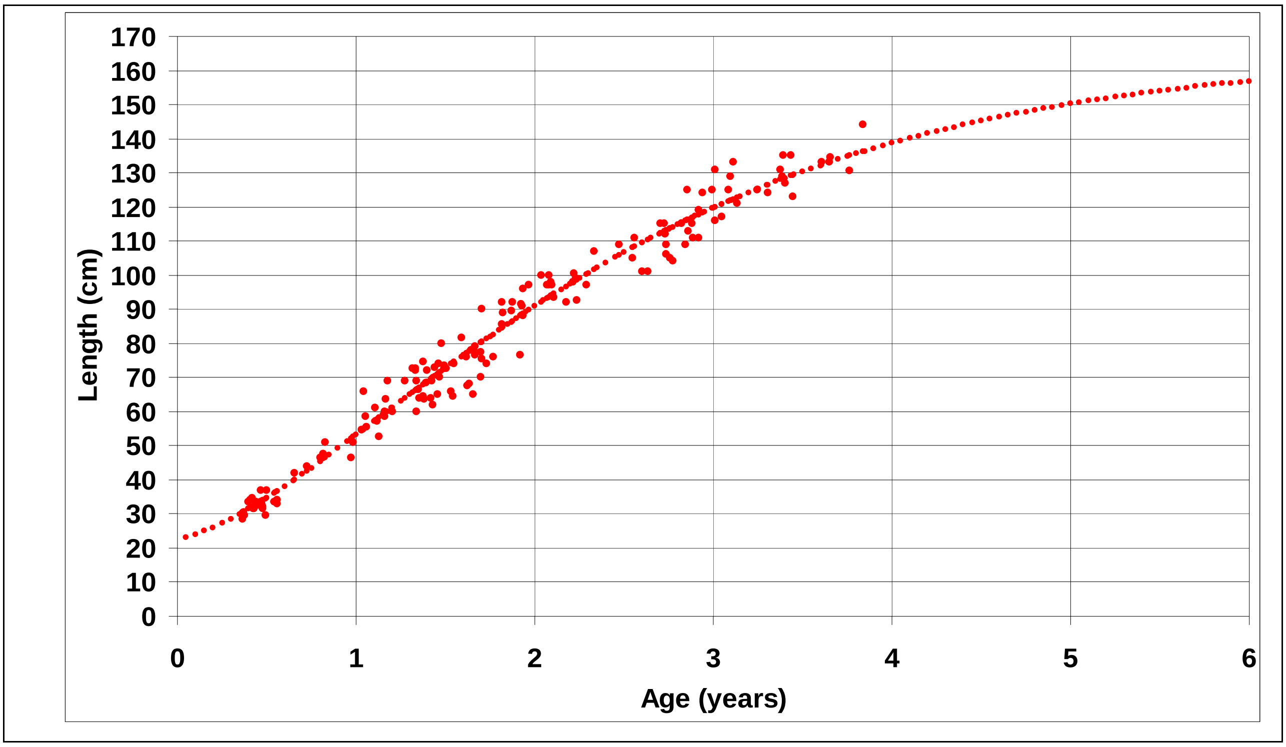


**(2) Growth**

The WG made a comparison of the various growth models available in the Indian Ocean (based on modal progressions such as the Lumineau 2002 and Viera 2005 models, and based on otolith readings such as the Stequert 1998 models), comparing them to models used in other oceans for YFT stock assesments.

The conclusion by the WG was that if the age reading done by Stequert were highly valuable, his growth parameters using his best fit of an L infinity at 2.60 m should not be used in a stock assessment. The WG reprocessed the Stequert data, and it was found that alternative growth model fitted to a Gascuel et al 1992 model with an L infinity fixed at a realistic biological level of 1,65 m (e.g. at the 99% highest sizes taken by the historical LL fisheries). The fit of this new growth curve was nearly identical in statistical terms to the original Stequert curve;

This new growth curve fitted to the Stequert 1998 data with a L infinity = 1.65 m using a 2 stanza model will be later kept as the revised Stequert growth curve.




This new growth curve also shows at sizes over 70 cm a good agreement in its growth pattern with the growth obtained from modal progression (Lumineau 2002 or Viera 2005)

However, the WG could not reach a consensus upon growth of YFT <70 cm as various studies in all oceans, and including in the IO, have shown that these young YFT are showing a slower growth than preadults, and a much slower growth than expected from the Von Bertalanffy model.

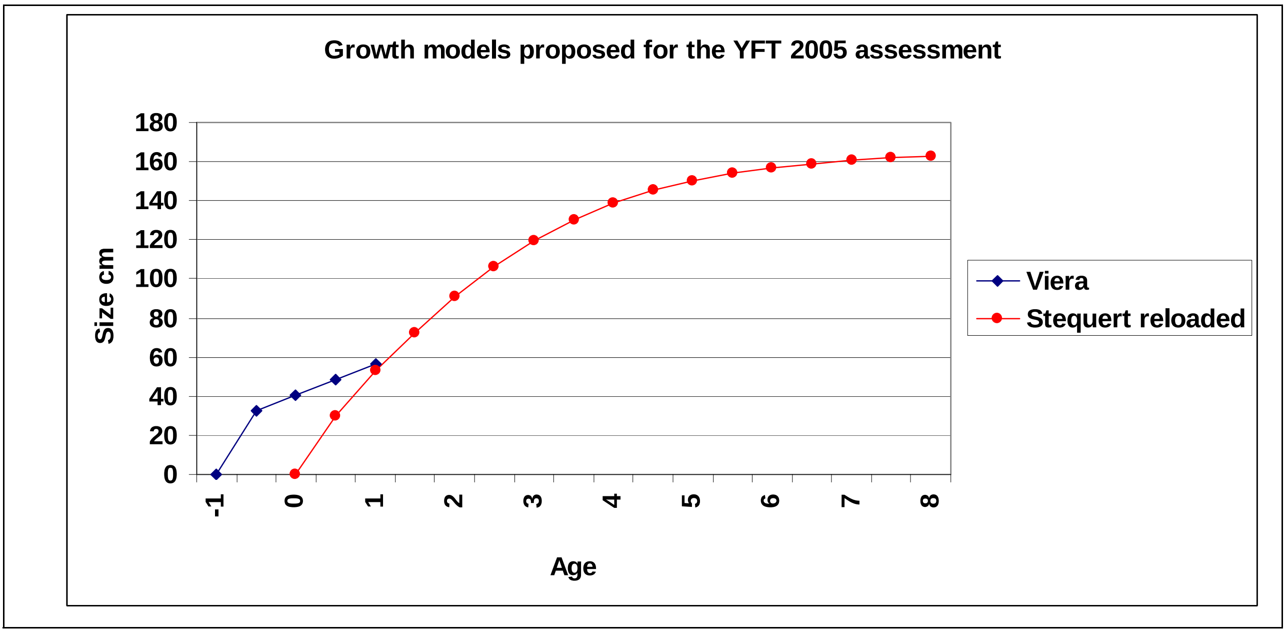
In the Indian Ocean such slow growth pattern has been repeatedly and strongly suggested by the slow modal progressions analysed by Lumineau 2002 and Viera 2005.

The final conclusion by the WG was to use:

(3) 2 alternate growth curves should be used for YFT <60 cm: Stequert reloaded and Viera (noting that there is a difference of 12 month or 1 year in the absolute age of the 60 cm fishes ).

(4) the Stequert reloaded growth curve should solely be used for YFT over 60 cm

These 2 recommended assessment growth curves are summarised by the following figure.




**NB: an important point should also be noted in the further analysis of the subsequent catch at age matrices obtained following these 2 growth curves: in both cases, the catches of YFT the year of recruitment in the fisheries at age 0, are taken at sizes greater than 30 cm, then starting both at an age of about 6 month and during a duration of only 6 months during this first year (e.g. a half year interval, when all the other catches are taken during entire full years). Therefore the catch equations working during this age "zero" should be processed in an ad hoc correct semi annual way.**

The corresponding table of Mi to be used in subsequent analytical studies are given in the following table:

| Age | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| Stequert | 1.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 |
| Viera/Stequert | 1.8 | 1.3 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 |

# APPENDIX V. EXECUTIVE SUMMARY OF THE STATUS OF THE YELLOWFIN TUNA RESOURCE

## BIOLOGY

Yellowfin tuna is a cosmopolitan species distributed mainly in the tropical and subtropical oceanic waters of the three major oceans, where it forms large schools. The sizes exploited in the Indian Ocean range from 30 cm to 180 cm fork length. Smaller fish (juveniles) form mixed schools with skipjack and juvenile bigeye tuna and are mainly limited to surface tropical waters, while larger fish are found in surface and sub-surface waters. Intermediate age yellowfin are seldom taken in the industrial fisheries, but are abundant in some artisanal fisheries, mainly in the Arabian Sea.

Stock structure is unclear, and a single stock with complete mixing is usually assumed for stock assessment purposes. Longline catch data indicates that yellowfin are distributed continuously throughout the entire tropical Indian Ocean, but some more detailed analysis of fisheries data suggests that the stock structure may be more complex and that mixing may be incomplete. A study of stock structure using DNA was unable to detect whether there were subpopulations of yellowfin tuna in the Indian Ocean.

Spawning seems to occur mainly from December to March in the equatorial area (0-10°S), with the main spawning grounds between 50° and 70°E. However, secondary spawning grounds are known to exist, for instance off Sri Lanka and the Mozambique Channel and in the eastern Indian Ocean off Australia. Yellowfin size at first maturity has been estimated at around 100 cm, and recruitment occurs predominantly in July. Newly recruited fish are primarily caught by the purse seine fishery on floating objects. Males are predominant in the catches of larger fish at sizes than 150 cm (this is also the case in other oceans).

A new growth study fitting a two-stanza growth curve to length frequency data was presented to the WPTT. In addition, the Working Party refitted a two-stanza growth curve to the Stequert otolith data. Both growth curves suggested similar growth rates for fish over 70 cm, but growth rates differed substantially for smaller fish. The two growth curves are illustrated in Figure 7.

There are no direct estimates of natural mortality (M) for yellowfin in the Indian Ocean. In stock assessments, new estimates of M at length based on those from other oceans have been used. These were then converted to estimates of M at age using the two growth curves. This indicated a higher M on juvenile fish than for older fish.

There is little information on yellowfin movement patterns in the Indian Ocean, and what information there is comes from analysis of fishery data, which can produce biased results because of their uneven coverage. However, there is good evidence that medium sized yellowfin concentrate for feeding in the Arabian Sea. Feeding behaviour is largely opportunistic, with a variety of prey species being consumed, including large concentrations of crustacea that have occurred recently in the tropical areas and small mesopelagic fishes which are abundant in the Arabian Sea.

## FISHERY

Catches by area, gear, country and year from 1950 to 2003 are shown in Table 1 and illustrated in Figure 1. Contrary to the situation in other oceans, the artisanal fishery component in the Indian Ocean is substantial, taking approximately 20-25% of the total catch.

The geographical distribution of yellowfin tuna catches in the Indian Ocean in recent years by the main gear types (purse-seine, longline and artisanal) is shown in Figure 2. Most yellowfin tuna are caught in Indian Ocean north of 12°S and in the Mozambique Channel (north of 25°S).

Although some Japanese purse seiners have fished in the Indian Ocean since 1977, the purse seine fishery developed rapidly with the arrival of European vessels between 1982 and 1984. Since then, there has been an increasing number of yellowfin tuna caught although a larger proportion of the catches is made of adult fish, when compared to the case of the bigeye tuna purse-seine catch. Purse seine catches of yellowfin with fork lengths between 30 and 180 cm increased rapidly to around 131,000 t in 1993. Subsequently, they have fluctuated around that level, until 2003 when they increased substantially to 227,000 t.

The purse seine fishery is characterized by the use of two different fishing modes: the fishery on floating objects (FADs), which catches large numbers of small yellowfin in association with skipjack and juvenile bigeye, and a fishery on free swimming schools, which catches larger yellowfin on mixed or pure sets. Between 1995 and 2003, the FAD component of the purse seine fishery represented 48-66% of the sets undertaken (60-80% of the positive sets) and took 36-63% of the yellowfin catch by weight (59-76% of the total catch). Since 1997, the proportion of log sets has steadily decreased from 66% to 48%.

The longline fishery started in the beginning of the 1950's and expanded rapidly over the whole Indian Ocean. It catches mainly large fish, from 80 to 160 cm fork length, although smaller fish in the size range 60 cm – 100 cm have been taken by longliners from Taiwan, China since 1989 in the Arabian Sea. The longline fishery targets several tuna species in different parts of the Indian Ocean, with yellowfin and bigeye being the main target species in tropical waters. The longline fishery can be subdivided into an industrial component (deep-freezing longliners operating on the high seas from Japan, Korea and Taiwan, China) and an artisanal component (fresh tuna longliners). The total longline catch of yellowfin reached a maximum in 1993 (196,000 t). Since then, it has declined, and in 2003 was 83,500 t.

Artisanal catches, taken by bait boat, gillnet, troll, hand line and other gears have increased steadily since the 1980s. In 2003, the total artisanal yellowfin catch was 51,000 t, while the catch by gillnets (the dominant artisanal gear) was 79,000 t.

Yellowfin catches in the Indian Ocean were much higher than previous levels during 2003 and 2004, while skipjack and bigeye catches remained at their average levels. Purse seiners currently take the bulk of the yellowfin catch — mostly from the western Indian Ocean. In 2003, their total catch was 227,000 t — over 48% more than the previous largest purse seine catch, which was recorded in 1995. Artisanal yellowfin catches were also near their highest level in 2003. Japanese longliners also recorded higher than normal catches in the tropical western Indian Ocean in 2003. Preliminary data suggest that purse seine and longline catches during 2004 are even higher than 2003.

Yellowfin catches in number by gear (purse seine, longline and bait boat) are reported in Figure 3. Current estimates of annual mean weights of yellowfin caught by different gears and by the whole fishery are shown in Figure 4. After an initial decline, mean weights in the whole fishery remained quite stable from the 1970s to the early 1990s. Since 1993, mean weights in the catches in the industrial fisheries have declined. Prior to 2003, although total catch in biomass has been stable for several years, catches in numbers have continued to increase, as there has been more fishing effort directed towards smaller fish. As described above, this situation changed during 2003 and 2004; where most of the very large catches were obtained from fish of larger sizes.

#### AVAILABILITY OF INFORMATION FOR ASSESSMENT PURPOSES

The reliability of the estimates of the total catch has continued to improve over the past few years, and the Secretariat conducted several reviews of the nominal catch databases during 2004. This has led to marked increases in estimated catches of yellowfin tuna since the early 1970s. A comparison of time series of estimates of total catches made by the Secretariat in 2004 and in 2005 is given in Figure 5. In particular, the estimated catches for the Yemen artisanal fishery have been revised upwards sharply, based on new information, but they still remain highly uncertain. In 2005, Taiwan, China provided size data for yellowfin tuna by IOTC area for 1980 – 2003, thereby substantially improving the information available to estimate catches by size.

Estimates of annual catches at size for yellowfin were calculated using the best available information prior to the 2005 WPTT meeting. A number of papers dealing with fisheries data, biology, CPUE trends and assessments were discussed by the WPTT in 2005, and additional data analyses were performed during that meeting. Estimated catches at age were calculated (Figure 6) using the catch-at-size data and two alternative growth curves (a refitted Stequert growth curve and a new two-stanza growth model) are shown in Figure 7. The two growth curves were used to develop two sets of natural mortality at age, maturity at age and average weight at age schedules. M was assumed to be higher on juvenile than adult fish.

Standardized CPUE series for both Japanese and Taiwanese longline data were presented and used during the assessments. Standardised purse seine CPUE analyses were also presented and discussed, but these were not used during the assessments because it was believed that they still did not fully account for the increases in purse seine catching efficiency over time.

The two standardized longline CPUE series showed similar trends, with an initial steep decline, over a period when catches were relatively low and stable, followed by stable standardized CPUEs since the late 1970s, a period during which catches have increased strongly following the development of the purse seine fishery (Figure 8). The observed pattern of standardised longline CPUEs does not correspond well with the expected response of CPUE to changes in catch and biomass, if standardized CPUE is directly proportional to the abundance of the part of the stock exploited by the gear concerned. There are several possible explanations for this, such as changes in catchability or behaviour, or the population existing in two fractions with differential availability to purse seine and longline gears, or a substantial decrease in the accumulated biomass in the oldest age groups in the early years. However, current analyses are unable to distinguish which, if any, of these explanations is correct.

**STOCK ASSESSMENT**

A full assessment was attempted for yellowfin tuna in 2005 by the WPTT. Two papers presenting assessment results were presented, one using the age structured production model (ASPM) method and one using a new Bayesian two-age-class production model. Additional assessments were carried out during the WPTT meeting using agreed data sets and the following methods: the PROCEAN method, the CATAGE trend (statistical catch at age analysis) method, ASPM, and the Bayesian two-age-class production model.

Although there were differences in the details of results from the different assessments, the overall picture they presented was consistent, particularly in terms of estimated trends in stock biomass and fishing mortality rates. Estimated trends in the fishing mortality rates are shown in Figure 9. Estimates of catchability using the PROCEAN and CATAGE methods show a strong increasing trend since the mid-1980s for both the longline fleets and the purse-seine fleets (Figure 10). The assessment runs considered at this meeting consistently indicated that fishing mortality rates between 1992 and 2002 have been close to or at levels of F corresponding to the Fmsy estimated by the most plausible ASPM assessment. Catches during this period were in the vicinity of, or possibly above, the MSY levels estimated by PROCEAN and the most plausible ASPM assessment. Estimated catches in 2003 and 2004 were well above those MSY levels, and projections carried out indicate that these are not sustainable unless supported by very high recruitments.

The Scientific Committee emphasized, however, that there remain strong uncertainties in each of the assessments conducted. In particular, none are yet able to consistently explain the trends in standardized CPUEs in the early years of the fishery without using trends in catchabilities or recruitment for which there is no evidence. Consequently, the implications drawn from them regarding current stock status are also uncertain.

Since the early-1980s there has also been an increase in both purse seine fishing on floating objects and artisanal fisheries which has led to a rapid increase in the catch of juvenile yellowfin. The rapid expansion, particularly on juvenile fish, is cause for concern, since it displays all the symptoms of a potentially risky situation. The increases in catches in general has not been as a result of geographic expansion to previously unfished areas, but rather as a result of increased fishing pressure on existing fishing grounds.

**EXCEPTIONAL CATCHES DURING 2003 AND 2004**

Yellowfin catches in the Indian Ocean were very high during 2003 and 2004. The total catch in 2003 was substantially higher than the previous highest catch (in 1993) and 33% higher than the average catch in the previous

5 years. Preliminary indications are that the 2004 catch will be substantially higher still. These anomalous catches occurred all over the western Indian Ocean, in particular in a small area off eastern Africa, although the anomaly extended over a much wider area, from the Arabian Sea to South Africa, in both industrial (purse seine on free-swimming schools and longline) and artisanal fisheries. The fish caught were of large sizes (100-150 cm FL).The Scientific Committee discussed two possible hypotheses explaining the observed high catches, noting that it is possible that a combination of factors was responsible for this event. There are two main categories of factors:

**Increase in the biomass of the population:**

According to this hypothesis, several large recruitments to the population in the late 1990's or early 2000's could be responsible for the large increase in yellowfin catches. In these years, environmental conditions favourable to good recruitment may have occurred in the Indian Ocean. But recruitment is not the only process by which the biomass could increase. Additional explanations could be reduced natural mortality during some critical life stage and/or increased growth rates related to favourable environmental conditions.

The Scientific Committee noted there is no evidence from existing data of unusually large numbers of small fish being caught in the surface fisheries in the early 2000's. This could indicate that either the juveniles from these large cohorts were present, but outside the normal purse seine fishing grounds (e.g. in the eastern Indian Ocean), or that the recent cohorts were only at average levels.

**An increase in catchability due to a concentration of the resource and/or an increase in the fishing efficiency:**

It is also possible that during 2003 and 2004, the catchability of large yellowfin tuna had increased. Possible factors that could have caused this include aggregation of large yellowfin tuna over a relatively small area and/or depths that made it easier for purse seiners and longliners to catch them in large quantities and technological improvements on purse-seiners that could have the schools more vulnerable to fishing. No technological improvements have been reported for industrial longliners during this period.

While these factors might explain the high catches of industrial fisheries in a small area off eastern Africa, there are also reports of exceptionally high catches by the commercial and artisanal fisheries from Yemen, Oman, Iran, South Africa and Maldives.

Large concentrations of the shallow water crustacean *Natosquilla investigatoris* and swimming crab *Portunus trituberculatus*, were reported to have occurred in 2003 and 2004 in the western Indian Ocean, and yellowfin tuna were observed feeding voraciously on them. New information on anomalies in the thermocline depth and primary productivity in 2003 also supported the hypothesis that there may have been an increased catchability due in some part to environmental factors.

By the end of 2002, most purse seine vessels had new sonar equipment installed. These devices potentially enable skippers to locate schools at distances up to 5 km, both night and day. This could make schools more vulnerable to fishing, and catches could be expected to increase. However, there is no indication of similar increases in efficiency in the Atlantic Ocean, where vessels were also fitted with the same equipment. In addition, higher catches also occurred in artisanal and longline fisheries for which there is no indication of recent technological advances.

The Scientific Committee agreed that it was most likely that the increased catches were due to a combination of these two sets of factors, increased recruitment in the early 2000s and increased catchability of large yellowfin tuna during 2003 and 2004.

**MANAGEMENT ADVICE**

Considering all the stock indicators and assessments, as well as the recent trends in effort and total catches of yellowfin, the Scientific Committee considered that:

1) Fishing mortality rates between 1999 and 2002 were probably slightly below or around Fmsy, and total catches during that period, at an average level of 347,000 t, were probably close to, or possibly above MSY. Total catches in 2003 and 2004 were substantially above MSY; see below for interpretation of the possible reasons for and possible effects of these catches. In these circumstances, any further increase in both effective fishing effort and catch above average levels in 1999 - 2002 should be avoided.
2) The current fishing pressure on juvenile yellowfin by both purse seiners fishing on floating objects and artisanal fisheries is likely to be detrimental to the stock if it continues, as fish of these sizes are well below the optimum size for maximum yield per recruit estimated in 2002.
3) The Scientific Committee also noted that juvenile yellowfin tuna are caught in the purse-seine fishery that targets primarily skipjack tuna. Some measures to reduce the catches of juvenile yellowfin tuna in the FAD fishery will be accompanied by a decrease in the catches of skipjack tuna.

While there was greater consistency in the assessment results considered at this meeting than in 2002, the Scientific Committee emphasized that there remain considerable uncertainties in the assessments, as none as yet are able to fully explain the observed trends in standardized longline CPUEs over the duration of the fishery.

In interpreting the high catches of 2003 and 2004, the Scientific Committee noted that if the hypothesis of one or two high recruitments entering the adult stock is correct, the increased catches from these year classes are unlikely to be detrimental to the stock, but these catches would not be sustainable in the longer term unless supported by continued high recruitments.

On the other hand, there could be serious consequences if the hypothesis that there was an increased catchability during 2003 and 2004 is correct. In this case, the very large catches would represent a much higher fishing mortality and certainly would not be sustainable. Furthermore, they could lead to a sudden decline of the existing adult biomass of yellowfin tuna, potentially reducing the stock to below MSY levels. If such is the case, management action might be needed to reduce catches and fishing mortality to below the levels prevailing in 1999 – 2002 to allow the stock to recover.

If, as the Scientific Committee believes, the most likely cause of the exceptional catches is a combination of these factors, then some reduction of stock biomass is to be expected in the future. However, the extent of any such reduction will only become apparent in several years following detailed stock assessments.

## YELLOWFIN TUNA SUMMARY

| | |
|---|---|
| Maximum Sustainable Yield (MSY) | Approximately 300,000 - 350,000 t |
| Current (2003) Catch | 458,000 t |
| Mean catch over previous five years (1998 – 2002) | 343,000 t |
| Current Replacement Yield | |
| Relative Biomass $B_{cur}$/ Bmsy | |
| Relative Fishing Mortality $F_{cur}$/Fmsy | |
| Management Measures in Effect | None |

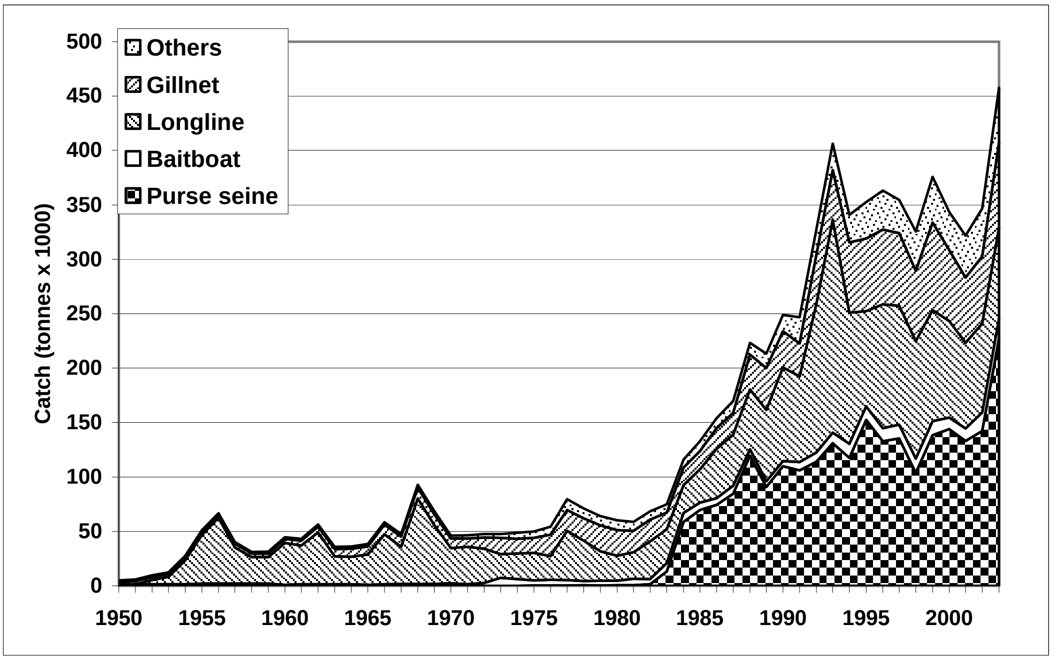
# Table 1. Catches of yellowfin tuna by gear and main fleets for the period 1966 to 2003. 2004 is provisional data only.

YFT

| Gear | Fleet | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Purse seine | Total | | | | | | | | | 0.0 | 0.0 | 0.0 | | | | | | | | | 0.1 | 0.2 | 0.2 | 0.3 | 0.5 | 0.4 | 0.5 |
| Baitboat | Maldives | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.5 | 1.5 | 1.5 | 1.5 | 1.0 | 1.5 | 1.7 | 1.7 | 1.8 | 2.3 | 1.4 | 2.5 | 6.9 | 5.0 | 4.6 | 5.2 | 4.9 | 3.8 | 4.4 | 4.4 |
| | Other Fleets | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.6 | 1.2 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Total | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.0 | 1.5 | 1.5 | 1.5 | 1.5 | 1.0 | 1.5 | 1.7 | 1.7 | 1.8 | 2.3 | 1.4 | 2.6 | 7.4 | 6.2 | 4.8 | 5.2 | 4.9 | 3.8 | 4.4 | 4.4 |
| Longline | China | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Taiwan,China | 0.7 | 1.1 | 1.3 | 1.8 | 2.4 | 2.2 | 2.9 | 3.5 | 3.4 | 2.9 | 2.2 | 4.4 | 3.4 | 22.7 | 21.1 | 14.9 | 11.9 | 11.8 | 5.7 | 4.4 | 4.6 | 3.4 | 8.1 | 4.2 | 3.7 | 3.8 |
| | Indonesia | | | | | | | | | | | | | | | | | | | 0.1 | 0.3 | 0.7 | 1.0 | 1.3 | 1.3 | 1.4 | 2.1 |
| | Japan | 44.2 | 59.5 | 31.9 | 22.6 | 22.2 | 36.1 | 32.7 | 44.2 | 22.0 | 22.2 | 24.9 | 40.8 | 30.2 | 48.3 | 23.1 | 10.3 | 13.4 | 7.9 | 3.9 | 4.9 | 6.4 | 2.8 | 2.1 | 4.6 | 3.3 | 3.2 |
| | Korea, Republic of | | | | | | | | | | | 0.1 | 0.1 | 0.4 | 5.3 | 9.1 | 5.2 | 7.4 | 10.3 | 10.8 | 13.1 | 13.3 | 13.7 | 33.1 | 26.5 | 18.0 | 13.2 |
| | Other Fleets | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.3 | 0.5 | 0.5 | 0.1 | 2.3 | 0.6 | 1.9 | 1.6 | 1.5 | 1.1 | 0.7 | 0.2 | 1.1 | 0.9 | 0.2 | 0.4 | 0.5 |
| | Total | 44.9 | 60.6 | 33.1 | 24.5 | 24.6 | 38.3 | 35.6 | 47.7 | 25.4 | 25.3 | 27.7 | 45.7 | 34.0 | 78.6 | 53.9 | 32.3 | 34.3 | 31.5 | 21.7 | 23.5 | 25.3 | 21.9 | 45.4 | 37.0 | 26.9 | 22.8 |
| Gillnet | Sri Lanka | 0.7 | 0.8 | 1.0 | 1.1 | 1.2 | 1.5 | 1.8 | 2.7 | 3.5 | 3.4 | 3.2 | 3.6 | 4.1 | 4.5 | 5.0 | 3.9 | 2.8 | 4.4 | 5.3 | 4.7 | 3.8 | 6.9 | 6.3 | 6.7 | 7.4 | 8.2 |
| | Oman | 0.7 | 0.5 | 0.5 | 0.5 | 0.7 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 | 0.6 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.8 | 0.9 | 2.9 | 3.4 | 3.8 | 4.0 | 4.4 | 4.1 | 5.0 |
| | Pakistan | 0.6 | 0.5 | 1.4 | 0.7 | 0.7 | 0.9 | 0.8 | 1.2 | 1.8 | 2.5 | 2.7 | 3.6 | 3.5 | 3.5 | 3.2 | 2.9 | 2.4 | 2.8 | 2.2 | 3.0 | 3.3 | 3.1 | 2.8 | 1.6 | 2.8 | 1.3 |
| | Indonesia | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.5 | 0.6 | 0.6 | 0.6 | 0.7 | 0.7 | 0.7 | 0.7 | 0.8 | 0.6 | 0.6 | 1.1 | 1.1 | 1.0 | 1.1 | 1.6 | 3.3 | 4.2 | 4.7 | 4.3 |
| | Other Fleets | 0.3 | 0.4 | 0.3 | 0.3 | 0.3 | 0.5 | 0.7 | 0.2 | 0.4 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.3 | 0.7 | 1.3 | 1.3 | 5.4 | 1.8 | 2.2 | 4.3 | 2.7 | 3.5 | 4.8 | 4.7 |
| | Total | 2.7 | 2.7 | 3.6 | 3.1 | 3.2 | 3.8 | 4.3 | 5.2 | 6.9 | 7.4 | 7.6 | 8.9 | 9.4 | 9.9 | 10.1 | 8.8 | 7.9 | 10.4 | 14.9 | 13.4 | 13.8 | 19.7 | 19.0 | 20.6 | 23.9 | 23.5 |
| Line | Yemen | 0.3 | 0.2 | 0.2 | 0.2 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.3 | 0.3 | 0.7 | 0.8 | 0.9 | 1.0 | 1.0 | 1.0 | 1.1 |
| | Comoros | | | | | | | | | | | | | | | | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 |
| | Indonesia | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 | 0.5 | 0.3 | 0.6 | 0.7 | 0.5 |
| | Other Fleets | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.5 | 0.7 | 0.9 | 0.8 | 0.8 | 0.9 | 1.1 | 1.2 | 1.3 | 1.3 | 1.3 | 1.6 | 1.8 | 1.8 | 1.5 | 2.3 | 4.9 | 3.3 | 3.0 | 3.2 |
| | Total | 0.6 | 0.6 | 0.6 | 0.7 | 0.7 | 0.7 | 0.8 | 1.0 | 1.2 | 1.2 | 1.2 | 1.3 | 1.5 | 1.7 | 1.8 | 1.8 | 1.8 | 2.2 | 2.4 | 2.9 | 2.8 | 3.9 | 6.3 | 5.1 | 4.7 | 4.9 |
| All | Total | 50.1 | 65.9 | 39.4 | 30.2 | 30.5 | 43.8 | 42.3 | 55.5 | 35.1 | 35.4 | 37.5 | 57.4 | 46.7 | 91.9 | 67.7 | 45.2 | 45.4 | 46.6 | 46.4 | 46.0 | 46.9 | 50.9 | 75.9 | 66.9 | 60.3 | 56.0 |

| Gear | Fleet | Av00/04 | Av55/04 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 00 | 01 | 02 | 03 | 04 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Purse seine | Spain | 62.1 | 19.3 | | | | 11.5 | 18.4 | 20.0 | 26.3 | 44.9 | 41.1 | 43.7 | 44.0 | 37.8 | 47.8 | 43.1 | 65.1 | 59.4 | 61.0 | 38.6 | 51.9 | 49.4 | 47.7 | 53.4 | 79.0 | 80.8 |
| | France | 47.0 | 17.5 | 0.2 | 1.0 | 10.5 | 36.7 | 39.1 | 43.3 | 46.8 | 59.9 | 38.4 | 45.3 | 38.1 | 45.3 | 39.5 | 35.8 | 39.6 | 35.6 | 31.2 | 22.4 | 30.8 | 37.7 | 34.1 | 36.4 | 63.3 | 63.5 |
| | Seychelles | 24.6 | 2.9 | | | | | | | | | | | 0.4 | 0.2 | | | | | 2.8 | 7.4 | 9.8 | 11.6 | 12.9 | 16.6 | 33.3 | 48.8 |
| | NEI-Other | 20.0 | 6.3 | | | 0.7 | 8.4 | 9.4 | 6.3 | 5.2 | 7.9 | 4.5 | 11.9 | 11.9 | 8.1 | 15.5 | 19.7 | 19.3 | 16.7 | 21.9 | 20.3 | 25.8 | 27.1 | 19.4 | 19.1 | 24.5 | 10.1 |
| | NEI-Ex-Soviet Union | 8.5 | 2.3 | | | | | | | | | | 0.8 | | 5.2 | 8.7 | 5.8 | 14.6 | 11.7 | 9.8 | 5.3 | 11.8 | 10.9 | 9.8 | 6.8 | 15.1 | |
| | Other Fleets | 7.8 | 3.9 | 0.4 | 0.6 | 2.1 | 2.3 | 2.6 | 4.7 | 6.4 | 6.7 | 6.7 | 8.0 | 11.8 | 17.4 | 19.5 | 13.0 | 13.8 | 9.4 | 8.8 | 9.6 | 8.1 | 7.2 | 9.1 | 10.0 | 12.3 | 0.3 |
| | Total | 170.0 | 52.1 | 0.6 | 1.6 | 13.2 | 58.9 | 69.5 | 74.3 | 84.7 | 119.5 | 90.7 | 109.7 | 106.2 | 114.0 | 131.0 | 117.5 | 152.5 | 132.9 | 135.5 | 103.6 | 138.2 | 143.9 | 133.0 | 142.2 | 227.4 | 203.5 |
| Baitboat | Maldives | 10.9 | 5.7 | 5.6 | 4.5 | 7.7 | 8.2 | 6.9 | 6.2 | 7.4 | 5.9 | 5.5 | 4.9 | 7.0 | 8.0 | 9.3 | 12.4 | 11.8 | 11.5 | 12.2 | 13.0 | 12.6 | 10.0 | 11.1 | 16.3 | 17.2 | |
| | Other Fleets | 0.6 | 0.2 | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.5 | 0.5 | 0.4 | 0.4 | 0.5 | 0.5 | 0.4 | 0.5 | 0.6 | 0.5 | 0.6 | 0.6 | 0.4 |
| | Total | 11.5 | 5.9 | 5.9 | 4.6 | 7.7 | 8.2 | 6.9 | 6.2 | 7.4 | 5.9 | 5.5 | 4.9 | 7.5 | 8.5 | 9.8 | 12.8 | 12.2 | 12.0 | 12.7 | 13.4 | 13.1 | 10.6 | 11.6 | 16.9 | 17.8 | 0.4 |
| Longline | China | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Taiwan,China | 26.2 | 14.9 | 4.1 | 4.7 | 5.6 | 5.8 | 7.3 | 16.2 | 22.3 | 22.7 | 22.4 | 31.6 | 30.7 | 56.0 | 88.2 | 34.1 | 23.1 | 27.9 | 18.4 | 23.4 | 17.7 | 17.4 | 18.9 | 27.7 | 24.8 | 42.3 |
| | Indonesia | 23.5 | 7.0 | 2.6 | 2.7 | 0.8 | 0.8 | 0.8 | 0.7 | 1.3 | 2.3 | 3.8 | 4.6 | 5.5 | 9.3 | 10.8 | 14.8 | 16.7 | 31.8 | 38.2 | 35.7 | 41.7 | 29.6 | 28.4 | 24.2 | 20.2 | 15.0 |
| | Japan | 16.4 | 16.4 | 4.9 | 7.3 | 7.8 | 7.9 | 9.5 | 10.7 | 8.3 | 9.3 | 4.6 | 6.3 | 4.4 | 5.7 | 5.7 | 9.7 | 8.0 | 12.8 | 15.6 | 16.8 | 14.7 | 15.5 | 13.9 | 14.0 | 17.3 | 21.3 |
| | NEI-Fresh Tuna | 8.4 | 4.6 | | | | | | | | | 11.9 | 16.6 | 14.4 | 16.7 | 16.5 | 23.7 | 17.1 | 17.7 | 21.2 | 16.6 | 14.8 | 13.0 | 7.9 | 7.4 | 8.3 | 5.4 |
| | NEI-Deep-freezing | 3.3 | 2.5 | | | | | 0.1 | 1.1 | 1.2 | 3.4 | 3.2 | 6.7 | 5.9 | 8.9 | 23.8 | 9.9 | 6.9 | 12.1 | 5.9 | 9.8 | 7.4 | 6.6 | 3.2 | 4.0 | 2.6 | |
| | Korea, Republic of | 2.0 | 7.0 | 12.4 | 19.3 | 16.2 | 10.2 | 12.5 | 15.4 | 13.2 | 14.1 | 8.7 | 7.5 | 3.2 | 4.4 | 4.3 | 4.0 | 2.7 | 4.0 | 4.2 | 2.6 | 1.0 | 2.0 | 1.5 | 0.3 | 2.1 | 4.1 |
| | NEI-Indonesia Fresh Tuna | 0.0 | 2.0 | | | | | | 0.1 | | 2.7 | 10.3 | 12.6 | 12.9 | 15.6 | 12.6 | 16.3 | 8.9 | 3.7 | 4.0 | 0.3 | 0.0 | | | | | |
| | Other Fleets | 4.7 | 2.5 | 0.4 | 0.4 | 0.7 | 0.7 | 0.3 | 1.1 | 0.7 | 0.5 | 0.5 | 0.1 | 1.9 | 20.1 | 33.7 | 8.2 | 4.2 | 3.8 | 1.9 | 2.6 | 4.6 | 4.6 | 4.7 | 4.2 | 8.1 | 2.1 |
| | Total | 84.6 | 56.8 | 24.4 | 34.5 | 31.1 | 25.5 | 30.4 | 45.3 | 47.0 | 55.0 | 65.3 | 86.1 | 78.8 | 136.7 | 195.7 | 120.7 | 87.6 | 113.8 | 109.2 | 107.8 | 101.9 | 88.7 | 78.6 | 81.9 | 83.5 | 90.1 |
| Gillnet | Sri Lanka | 24.9 | 10.1 | 9.4 | 9.2 | 8.9 | 6.3 | 6.8 | 7.0 | 7.3 | 7.6 | 8.2 | 9.4 | 11.5 | 13.7 | 16.4 | 21.3 | 18.6 | 23.4 | 29.2 | 28.9 | 36.7 | 33.3 | 27.8 | 29.9 | 33.5 | |
| | Iran, Islamic Republic | 16.0 | 4.9 | | | | | | | | | 1.0 | 2.3 | 3.2 | 12.1 | 13.3 | 19.5 | 22.5 | 28.5 | 20.0 | 18.0 | 24.3 | 13.5 | 18.0 | 19.0 | 29.5 | |
| | Oman | 5.5 | 5.1 | 4.8 | 3.5 | 1.6 | 4.6 | 2.3 | 2.5 | 5.9 | 15.6 | 16.2 | 14.4 | 9.0 | 13.5 | 11.5 | 19.2 | 21.4 | 11.6 | 9.9 | 11.3 | 7.4 | 7.1 | 6.3 | 5.3 | 8.8 | |
| | Pakistan | 3.8 | 2.8 | 2.0 | 2.5 | 0.8 | 0.9 | 1.5 | 2.6 | 2.4 | 3.8 | 8.6 | 3.3 | 4.9 | 3.9 | 2.6 | 2.4 | 2.1 | 3.2 | 3.9 | 3.9 | 9.4 | 5.3 | 4.0 | 3.3 | 3.5 | 3.2 |
| | Indonesia | 2.7 | 1.9 | 2.5 | 3.2 | 3.1 | 3.3 | 4.3 | 6.2 | 2.7 | 4.2 | 3.3 | 2.2 | 0.9 | 0.9 | 0.8 | 1.3 | 1.3 | 1.1 | 2.7 | 1.5 | 1.8 | 5.0 | 3.1 | 3.1 | 2.3 | |
| | Other Fleets | 1.0 | 1.3 | 0.9 | 1.5 | 0.7 | 1.0 | 1.9 | 0.9 | 1.4 | 0.8 | 1.2 | 1.7 | 0.9 | 1.0 | 0.9 | 0.9 | 0.8 | 0.9 | 1.0 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 | 0.8 |
| | Total | 53.9 | 25.9 | 19.5 | 20.0 | 15.1 | 16.0 | 16.7 | 19.1 | 19.8 | 32.0 | 38.5 | 33.2 | 30.4 | 45.2 | 45.6 | 64.6 | 66.7 | 68.7 | 66.7 | 64.5 | 80.5 | 65.3 | 60.0 | 61.5 | 78.5 | 4.1 |
| Line | Yemen | 27.2 | 6.0 | 0.8 | 0.8 | 1.5 | 2.3 | 3.1 | 3.9 | 4.6 | 5.4 | 6.2 | 6.9 | 7.7 | 8.5 | 7.6 | 8.3 | 13.2 | 15.0 | 17.0 | 19.1 | 21.1 | 23.1 | 25.2 | 27.2 | 29.2 | 31.3 |
| | Comoros | 4.6 | 1.6 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 3.7 | 3.7 | 3.7 | 5.0 | 5.0 | 5.9 | 5.9 | 5.8 | 5.6 | 5.6 | 5.4 | 5.9 | 5.4 | 5.8 | 6.1 | |
| | Indonesia | 3.3 | 2.3 | 0.1 | 0.5 | 0.4 | 0.3 | 1.7 | 1.1 | 2.3 | 1.5 | 0.2 | 0.9 | 9.1 | 6.5 | 8.3 | 7.9 | 11.2 | 11.9 | 4.9 | 8.9 | 12.3 | 1.5 | 2.3 | 4.3 | 8.3 | |
| | Other Fleets | 4.8 | 2.3 | 3.9 | 3.4 | 2.9 | 2.3 | 2.2 | 2.1 | 2.2 | 2.4 | 2.3 | 2.6 | 3.0 | 3.4 | 3.3 | 3.0 | 3.1 | 3.0 | 3.0 | 2.7 | 3.0 | 4.5 | 5.4 | 6.9 | 7.0 | 0.4 |
| | Total | 39.9 | 12.2 | 5.0 | 4.9 | 5.1 | 5.1 | 7.1 | 7.3 | 9.4 | 9.5 | 12.4 | 14.1 | 23.5 | 23.3 | 24.2 | 25.1 | 33.4 | 35.7 | 30.5 | 36.3 | 41.9 | 35.0 | 38.3 | 44.2 | 50.5 | 31.7 |
| Other | Total | 0.0 | 0.0 | | | | | | | | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | | 0.0 | 0.0 | 0.0 | 0.0 | |
| All | Total | 359.9 | 153.0 | 55.5 | 65.6 | 72.2 | 113.7 | 130.8 | 152.2 | 168.2 | 222.0 | 212.4 | 248.1 | 246.4 | 327.7 | 406.2 | 340.7 | 352.4 | 363.0 | 354.6 | 325.6 | 375.6 | 343.5 | 321.6 | 346.7 | 457.8 | 329.9 |

(a)




(b)

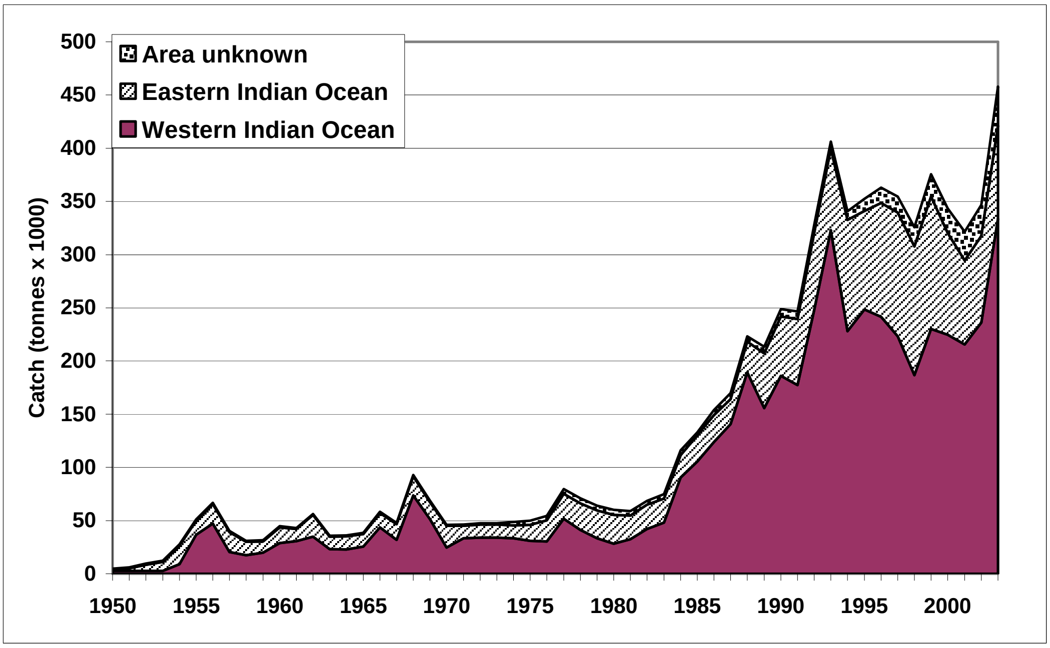



**Figure 1.** Yearly catches (tonnes x 1000) of yellowfin by (a) gear and (b) area from 1960 to 2003.

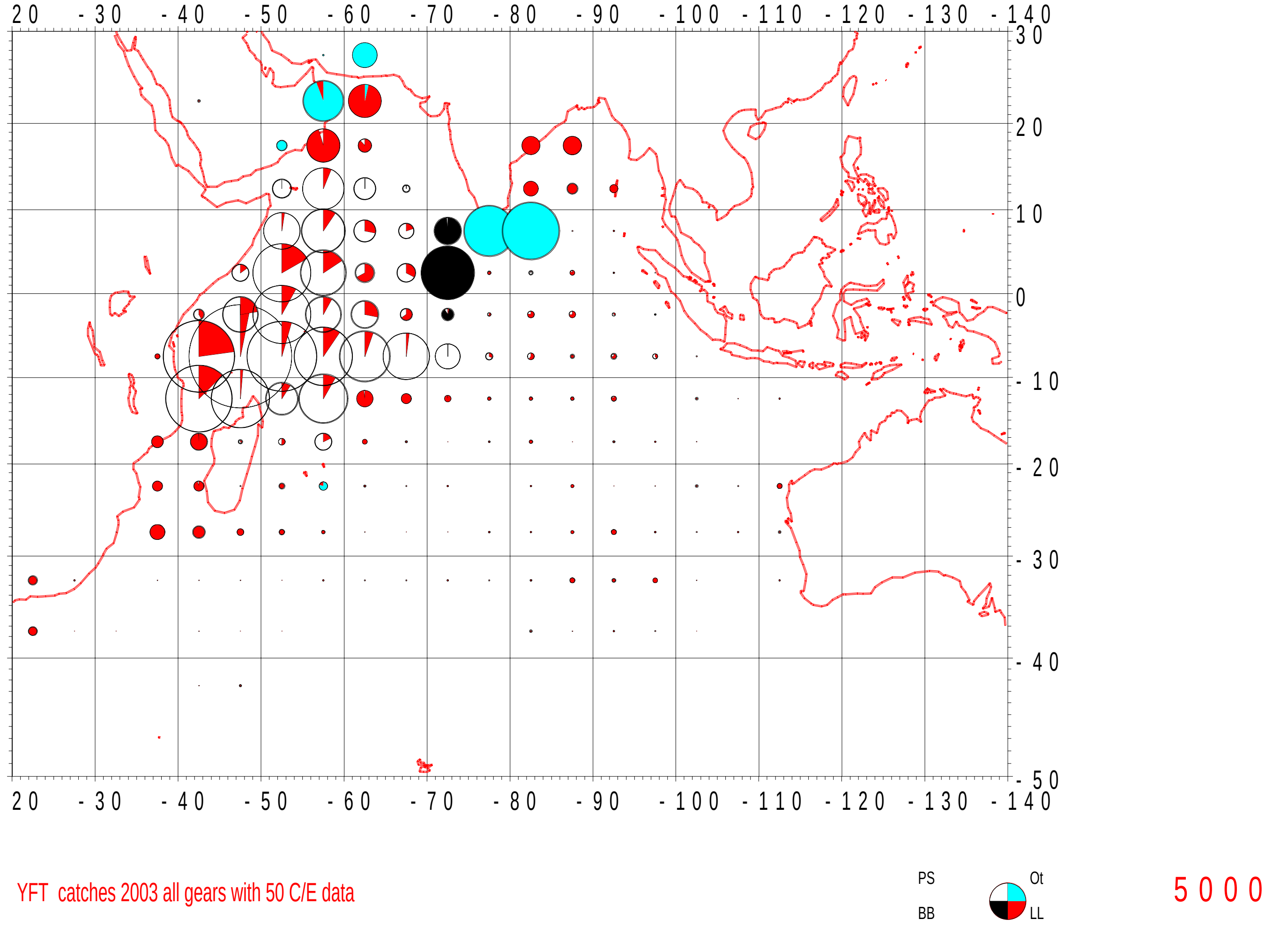



**Figure 2.** Location of yellowfin catches taken in the Indian Ocean in 2003. Legend circle equivalent to 5000 tonnes.

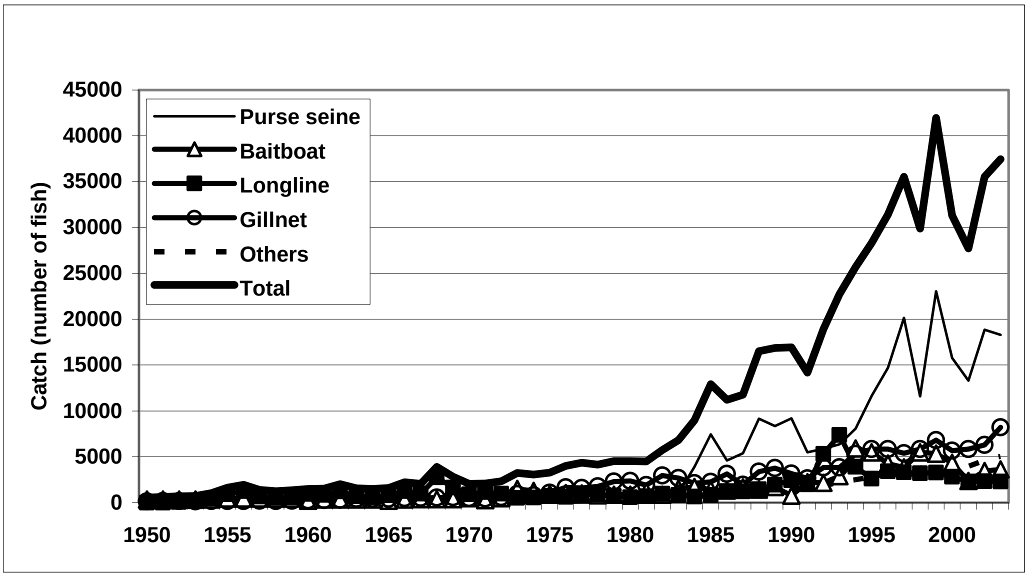



**Figure 3.** Numbers of yellowfin caught by gear-type.

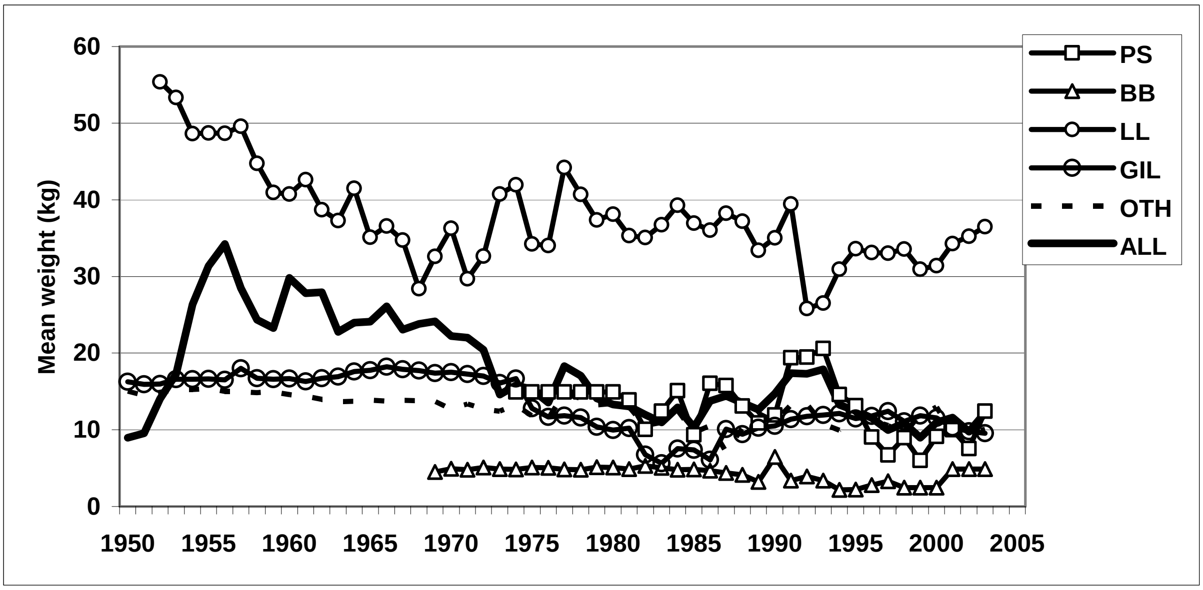



**Figure 4.** Mean weight (kg) of yellowfin individuals in the catch by gear and for all gear-types (estimated from the total catch at size). PS: purse seine, BB: bait boat, LL: longline, GIL: gillnet, OTH: other.

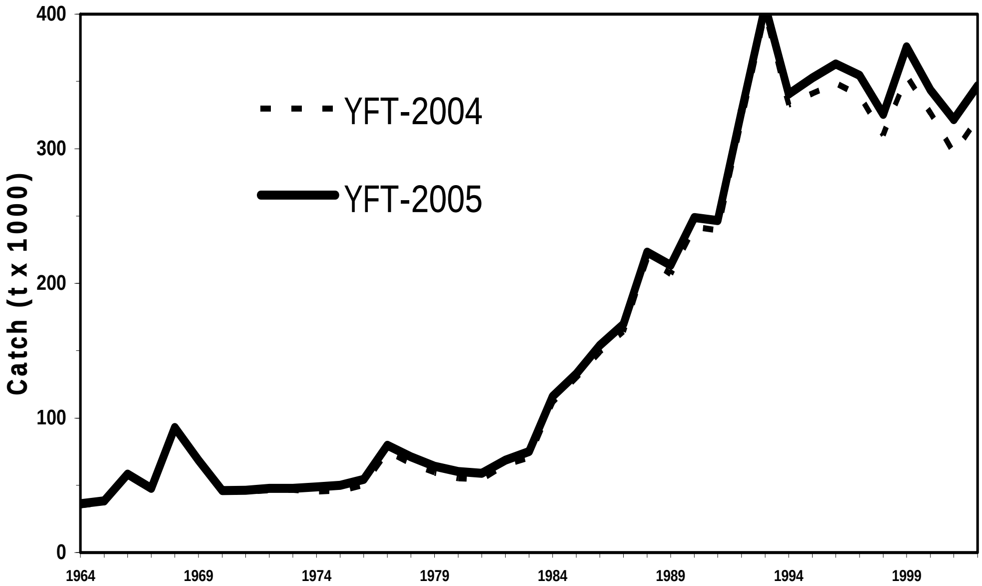



**Figure 5:** Yellowfin tuna catch estimates in 2005 following a review of the data by the IOTC Secretariat versus catch estimates in 2004 (1964-2002)

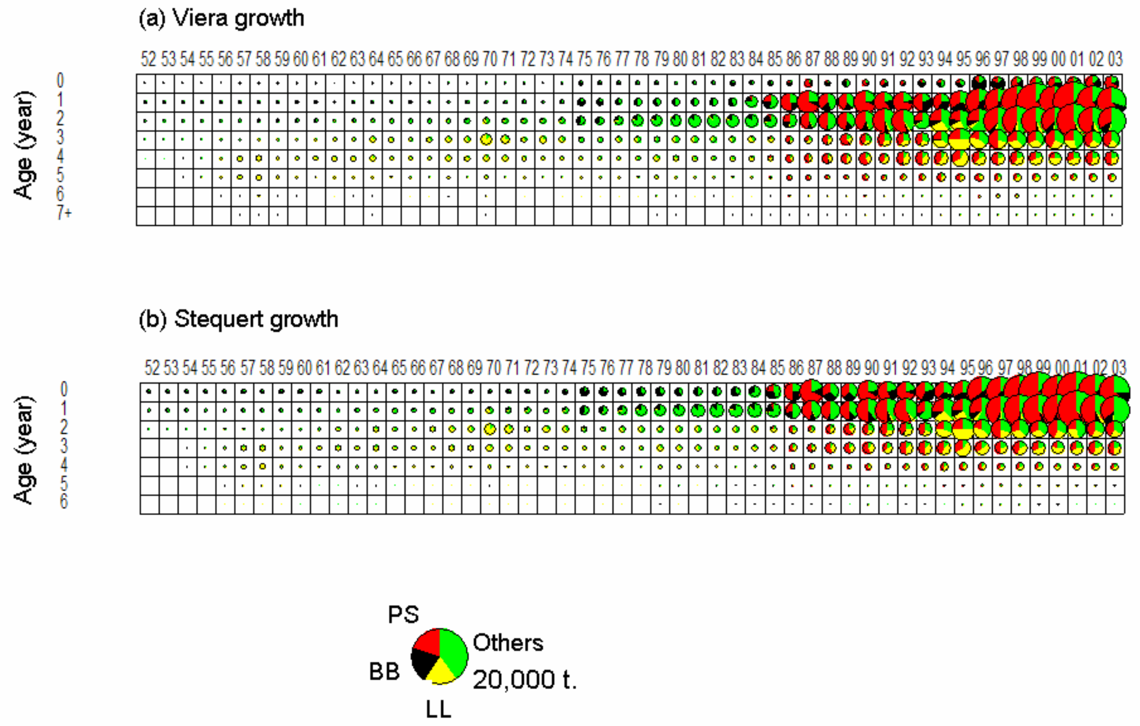



**Figure 6.** Catch at age (tonnes) for yellowfin tuna caught in the Indian Ocean (a) estimated using the revised Viera growth curve (b) estimated using the revised Stequert growth curve. PS: purse seine; BB: bait boat; LL: longline fishing.

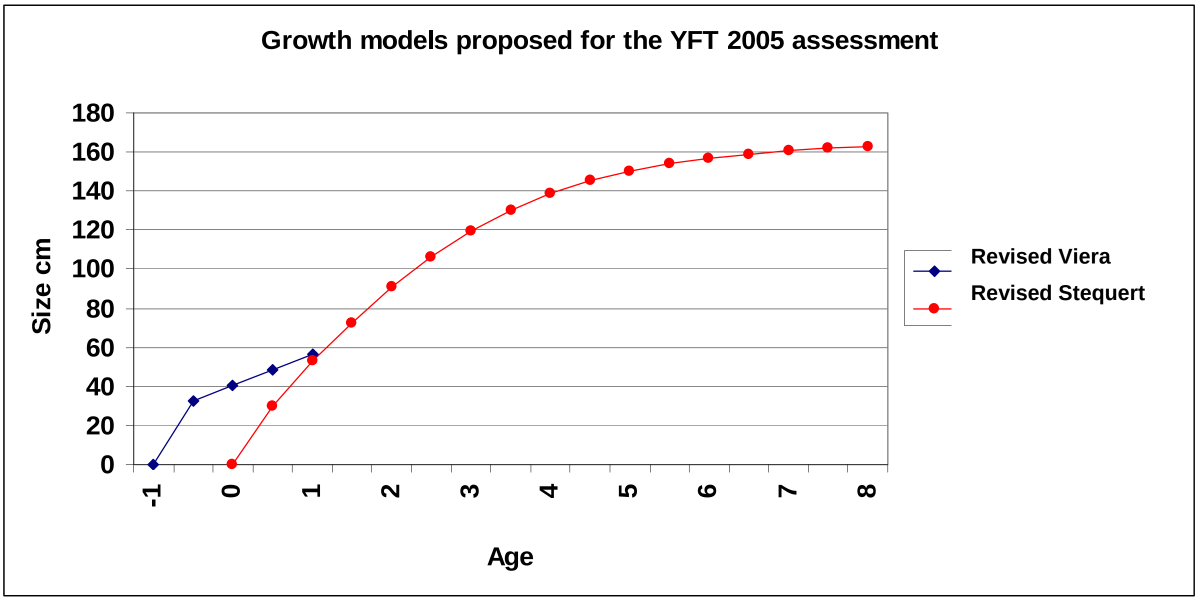



**Figure 7.** Yellowfin tuna growth curves used in the 2005 stock assessments.

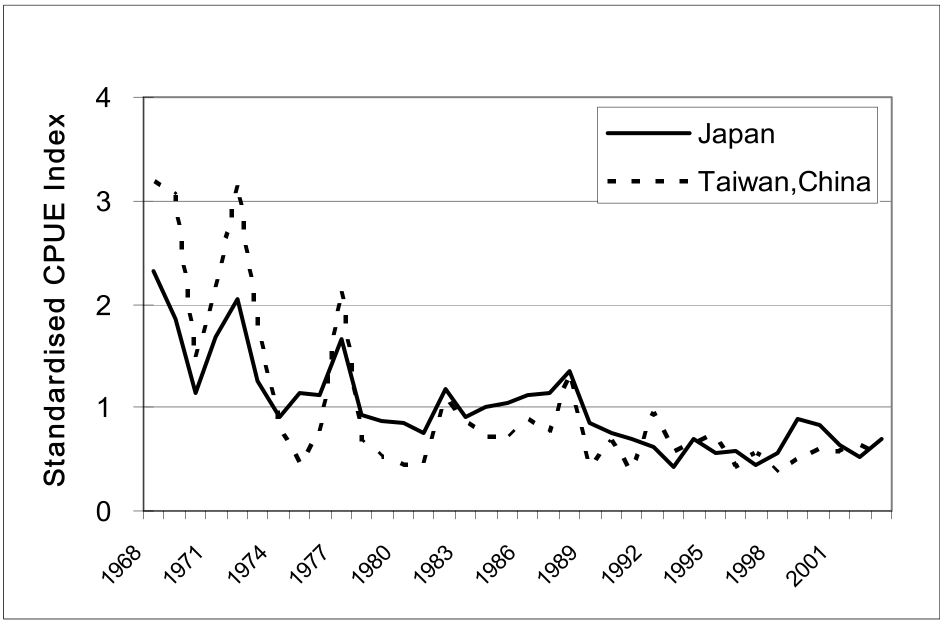



**Figure 8.** Yearly standardised CPUE indices for yellowfin tuna based on the Japanese and Taiwan,China longline catch rates in the Indian Ocean

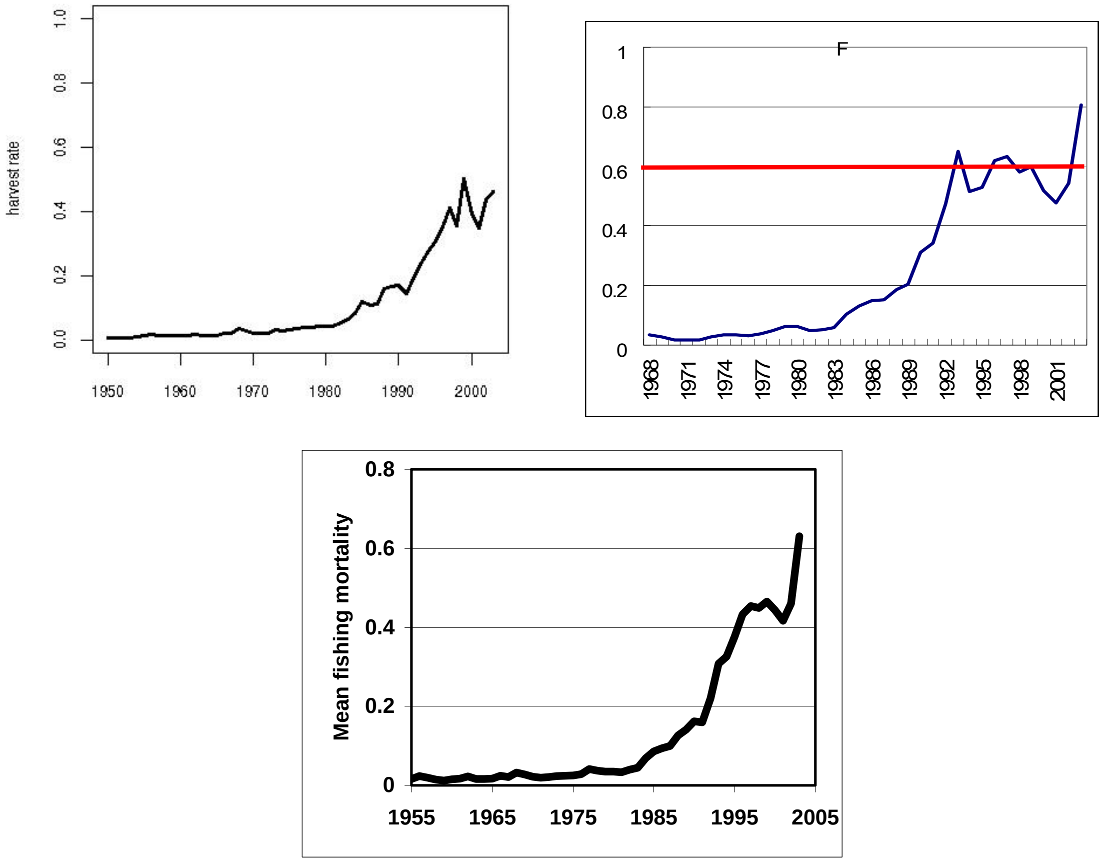



**Figure 9.** Yellowfin fishing mortality rate trends from each of the models in 2005. Bayesian (top left), ASPM (top right) and CATAGE (bottom).

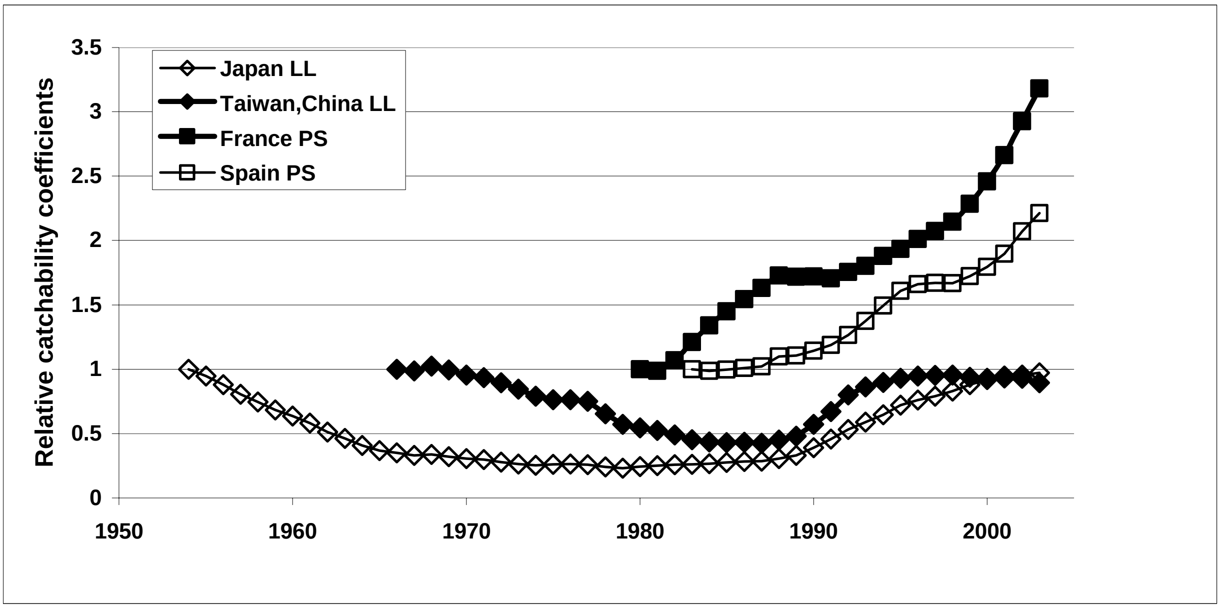



**Figure 10.** Mean yearly relative catchability coefficients estimated from CATAGE for Japanese longline (LL), Taiwan,China longline, French purse seine (PS) and Spanish purse seine.