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Commission des Thons de l'Océan Indien

Report of the Third Session of the IOTC Working Party on Tropical Tunas

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Opening of the Meeting and Adoption of the Agenda

The Third Meeting of the Working Party on Tropical Tunas (WPTT) was opened on 19 June 2001 in Mahé, Seychelles by the Chairman, Dr. Geoff Kirkwood, from Imperial College, London, who welcomed the participants (Appendix I). The Agenda for the Meeting was adopted as presented in Appendix II. As recommended by the Scientific Committee, the WPTT gave priority to assessment of bigeye tuna. The documents available for discussion are listed in Appendix III.

Review of Data Related Issues

Report of the Secretariat

Document WPTT-01-01, presented by the Secretariat, reviewed the status of the data on yellowfin, skipjack and bigeye tunas held by the IOTC Secretariat.

Nominal Catch (NC) data

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

The Secretariat conducted a major review of the NC database during 2000. This revision led to slight increases in the estimates of catches of the three tropical tuna species, especially for years prior to 1970. The Secretariat also began recording the reporting country[1] in the database and assigned a code to indicate the quality of the data stored. These quality codes will flag those records that are thought incomplete and/or inaccurate, thus providing more information to the scientists and general users of the data.

Although the quality of the information on the three tropical tunas is considered in general to be fairly good, the completeness and accuracy of the records are compromised by:

- **Unreported catches**: 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. However, the catch series of NEI deep-freezing longliners is incomplete for years prior to 1998.
- **Underestimated catches**: catches of tunas and tuna-like species are sometimes reported aggregated[2]. When possible, the Secretariat estimates the species and gear composition of these aggregates but this cannot always be done reliably as the accuracy depends on the assumptions made during the estimation process. In addition, catches in several Indian Ocean coastal countries are probably underestimated as sampled landings are not raised to total catch.

Uncertainty in the catches may occur in the following cases:

- **NEI catches**: The catches of longline and some purse-seine fleets flying flags “of convenience”[3] are usually not provided by the flag country and, in some cases, need to be estimated by the Secretariat. These estimates are based on information retrieved from several sources, the most important being the IOTC sampling programmes and the Vessel Record.

[1] This refers especially to fleets flying flags "of convenience" for which the catches are not reported by the flag country but by a third party, often research institutes in the country of the vessels owners. The new country field will permit to better identify these data.

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

[3] This term is used to identify vessels flying flags of States that have an open registry and that do not report statistics related to the vessels flying their flag.

The catches of Singaporean-owned purse seiners (formerly under the Soviet Union flag) have not been reported since 1996. The catches estimated since that year and, in particular, the species allocation, are likely to be less accurate than those of previous years.

The catches of NEI longliners were estimated mainly from the types of vessel involved and the operating port. The IOTC Vessel Record and the sampling programmes that are operated in collaboration with institutions in several ports of the Indian Ocean were identified as useful tools for the estimation of these catches. The sampling programme operated in Phuket has permitted this year to estimate total catches unloaded in that port more accurately. Similar estimations will be conducted for other landing points as more information becomes available.

Indonesian catches: the last year for which Indonesian statistics were reported was 1994. Catches since that year are only available from FAO and are highly aggregated. Since 1995, the gear allocation and the species composition of the catches are estimated by the Secretariat. The accuracy of these estimates is thought to be lower in recent years due to the rapid development since 1997 of the longline fishery in Indonesia, for which information is scarce.

Catch-and-Effort (CE) data

The Secretariat reported that a review of the CE database is currently underway, including validation of the data stored in the database and the transfer of historical data that had been kept in separated databases because of variable spatial and temporal structure. The database design implemented last year permits storage of heterogeneous spatio-temporal aggregates and those data can now be incorporated into the main database. This data revision will continue in next months.

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 very small, such that the lack of CE data is not important.

Catch-and-effort statistics from the Maldives are available since 1970. Data have been reported by species, month and atoll from 1970 to 1992 but are only available by species and month since 1993. The quality of this dataset is considered to be very good.

Catch-and-effort statistics are available for the main longline fisheries, since 1952 for Japan, since 1967 for Taiwan, China[4] and since 1975 for Korea. The quality of the statistics provided by Japan and Taiwan, China are in general considered to be good. Nevertheless, some inconsistencies were found during the validation of data records for some years. These involve the Japanese CE data for 1980 and Taiwan, China data for the period 1990-92. New data series for those years were requested from the relevant institutions.

Korean CE statistics are thought to be highly inaccurate. Many inconsistencies were found in the data, when comparing the catches in this database with those reported as nominal catches, for instance. Korean authorities have been asked for clarification, but have not yet responded. The Secretariat recommends that this dataset not be used until these issues are resolved.

Catch-and-effort statistics are complete for European-owned purse seiners, including those flying flags “of convenience”, as well as those from Seychelles. Statistics are also available for other countries including Mauritius and Iran. As is the case for the NC data, the CE data for the purse-seine fleet formerly under the Russian flag are inaccurate and, at this time, are only available to IOTC for short periods of the operation of this fleet.

Size-Frequency (SF) data

The quality of the data is thought to be good for the European fleets, apart from the species and size composition for the last three years, which are likely to be less accurate due to problems in the sampling on

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

those vessels reported to the Permanent Working Party on Data Collection and Statistics by the scientists responsible. Data are also available from Iran, but not for the Japanese, ex-Russian or Mauritian purse seiners. Baitboat fisheries have also been reporting size-frequency statistics to IOTC, for which quality is thought good.

For longline fisheries, however, only Japan has been reporting size-frequency data since the beginning of the fishery. In recent years, the number of specimens measured is very low in relation to the total catch and has been decreasing year by year. The size-frequency statistics available from the two other main longline fleets are either very incomplete (Taiwan, China for which only three years are available) or inaccurate (Korea), which invalidates their use.

IOTC Sampling Programmes

Document WPTT-01-19 presents a status report of the data retrieved in the scope of the AFDEC-IOTC sampling programme, including the preliminary results obtained during the first year of operation. More than 60,000 fish of tuna and tuna-like species have been monitored in Phuket to date, including valuable information regarding size-size and size-weight distributions of tuna species (about 5,000 records gathered so far). Vessels from Taiwan, China, China mainland and Indonesia are operating from Phuket. A first estimate of the catches since the programme started was conducted, yielding about 4,500 t of tuna and tuna like fish unloaded in 2000 in Phuket, mostly of yellowfin and bigeye tunas. More than 75,000 individual historical records have been retrieved so far in the scope of the sampling programmes.

The document presented new estimates of catches for the period 1998-2000. However, this work needs to be repeated for earlier years as and when historical data are available. The use of weight-frequency rather than length-frequency data was discussed. The meeting concluded that weight samples are less reliable because they are affected by the condition of the fish and usually have more variability. Data to assess condition factors and weight-length relationship is currently being collected. However, long time series (>20 years) of weight-frequencies exist, while length-frequency series are much shorter, so using weight-frequency series could be a better option for analysis. The WP was also informed that there are currently about 5,200 length samples in the database, although these samples were not described in the document.

It was agreed that species identification in the samples was in general good, but that misidentification between blue and striped marlin was possible. The possibility of recuperating historical data for the database was also discussed.

Review of new data on purse seine fisheries

Document WPTT-01-07 presents summary statistics of the Spanish purse-seine fleet fishing in the Indian Ocean from 1984 to 2000. Data include catch by species and fishing mode (on floating objects and free-swimming schools), effort, catch rates, area explored, number of sets and distribution of sets by t caught, as well as average weight in the catch by species and fishing mode. The data show a decrease in nominal effort in 2000 (10% decrease in vessel carrying capacity compared to 1999 and a 25% decrease compared to 1997, the highest value of the series). However, catches increased to a record of 154,026 t in 2000, the increase coming from high yellowfin and skipjack catches, while the bigeye catch decreased by 25%. Consequently, the catch rates of yellowfin and skipjack tunas as well as the overall catch rate are the highest of the historical series. The large number of sets of over 100 t in the last two years was also noted.

New information about the use and operational practices of supply vessels working in tandem with Spanish purse-seine vessels operating in the Indian Ocean was reviewed in documents WPTT-01-09 and WPTT-01-11 (these documents were merged into WPTT-01-11rev). In order to know the behaviour of these vessels and the possible impact on the yield of the purse seiner, data from observers were collected and analysed both during the 1998-1999 moratorium and during the ESTHER (efficiency of tuna purse seiners and real effort) project trip during the months of July and August 2000.

The data reveal that there are two main types of supply vessels. “Anchored supplies” remain anchored on the Coco de Mer seamount and call the purse seiner when there is enough fish to make a set. “Navigating supplies” spend a significant amount of time in activities such as searching for concentrations of fish (the contribution is 75 % of the time spent searching by the "parent" purse seiner), and specially in activities related with FAD handling, such us inspection of FAD to determine whether it has fish aggregated, setting or modifying FADs and taking on board FAD owned by another vessel or its own FADs.

An analysis of the yields of the purse seiners working with and without supplies during the moratorium period indicates that the yield of the vessels working with anchored supplies is larger than for other vessels. Nevertheless, it is noted that this comparison of yields is not rigorous and the authors propose ways to expand this analysis and explore other ways to standardize the effort of the purse seiners, taking into account the effort of the supplies

As the information in WPTT-01-11 only covered from November to January during the 1999 moratorium period, the WPTT suggested that it was necessary to perform the same kind of study during the FAD-fishing season. Anchored supply vessels seem to result in increased catches, but it is not clear whether this is because the supply vessel acts as a FAD or because, in practice, an anchored supply vessel can deny access to purse seiners from other companies to the fish aggregated by the sea mount.

It is not clear yet how (and if) supply vessels increase the effective effort of purse seiners. To better assess this, it is necessary: i) to obtain historical information (possibly from logbooks) of vessels operating with and without supply vessels; ii) to have a better record of how many FADs are being deployed and tendered by supply and purse-seine vessels; and iii) to study this information on the basis of operating area and seasons, as it is likely that the effect of supply vessels on the effective effort is strongly related to these factors. It was remarked that this is an important topic for the stock assessment of tropical tunas and the WPTT encouraged further studies and analyses in this area.

Document WPTT-01-23 presents a summary of the French purse-seiner activities in the Indian Ocean since 1991. The document shows the trends in effort, catch by species and fishing method (log and free-swimming schools), catch-per-unit-effort, sampling effort and mean weight for the main species.

Document WPTT-01-08 presents a summary of the combined European-owned (French, Spanish, Seychelles and NEI) purse-seiner activities in the Indian Ocean since 1991. The document shows the trends in effort, catch by species and fishing method (log and free swimming schools), catch-per-unit-effort, sampling effort and mean weight for the main species.

The statistics seem to indicate that catch rates on FAD sets are higher for 1999 and 2000, and that the percentage of sets on FADs with large catches has increased for the Spanish fleet, especially in 2000. It was mentioned that most of the observed increases come from the fishery in the Somali basin. Whether this can be attributed to an increase in abundance, in efficiency of the fleet, or of higher fish concentration is unknown.

Review of new information on longline fisheries

The recent status of Taiwanese tuna longline fisheries operating in the Indian Ocean was reviewed in document WPTT-01-22. The number of distant water longline (DWLL) vessels operating in the Indian Ocean was, on average, about 341 during the 1998-2000 period, 90 % of which were larger than 200 GRT. The mean annual catch of tuna and tuna-like species of this fleet was about 103 thousand t from 1998 to 2000. Albacore, bigeye and yellowfin tunas accounted for more than 77 % of the total catch. The main fishing grounds of this fleet were similar in 1996, 1997 and 1998, and were distributed between 10^{o}S-10^{o}N/30^{o}E-95^{o}E and 25^{o}S-35^{o}S/30^{o}E-95^{o}E. About 1,700 fresh fish longline vessels (less than 100 GRT) were estimated to have operated from 1997 to 1999 (some operated in both the Indian Ocean and the Pacific). Catches landed in Taiwan are believed to have been mostly from vessels that operated in the Pacific. In addition to domestic landings, catches of bigeye and yellowfin tunas unloaded in foreign bases (from both Oceans) were stable (or increased slightly) and were estimated to be about 13,000 to 15,000 t and about 18,000 to 22,000 t, respectively during 1998-2000 period.

Three potential problems were pointed out by the WPTT. First, the fishing strategy of the fresh fish fleet makes the separation of catches taken from the Indian and the Pacific Oceans difficult. It was suggested that data from the non-compulsory VMS programme for these vessels could aid in the sorting of catches from each ocean. There is also a potential problem with double reporting of catches, in particular for Taiwanese-owned vessels operating in the Indonesian EEZ. New Indonesian regulations have resulted in massive re-flagging of Taiwanese vessels but some of these vessels might still be registered under both the Taiwanese and Indonesian flags. Recent contacts with fishing agents in Mauritius seem to indicate that there is a possibility that a sizable portion of the sashimi catch from the DWLL NEI fleet is being transhipped at sea, although there is no additional information to verify or estimate these transhipments.

Document WPTT-01-25 presents statistics on the China mainland longline fishing activities in the Indian Ocean during 2000. It was noted that, for 1997 and 1998, bigeye tuna catches are several times larger than yellowfin tuna catches, although landings are of similar magnitude for the remainder of the time series available. The reason for this anomaly is unknown, but misclassification could be a possible explanation.

Unusually low effort was noted during the months of July and August, possibly as a result of vessels being dry-docked or tied-up for repairs or festivities. This explanation coincides with information available from the IOTC sampling programme.

The document reports about 120 vessels, which fished between 5,000 and 6,000 t per year. The WP suggested a comparison of this catch estimate with the current estimates from the IOTC sampling programmes for the same fleet.

Review of new information on the biology and environment of tropical tunas

Document WPTT-01-16 presented the results of a genetic analysis performed on yellowfin tuna to examine genetic differentiation between samples from the western and eastern Indian Ocean, The document indicates that the method failed to detect significant differences between the DNA of both samples in spite of the results of other studies that have reported the existence of two or three morphometrically different stocks of yellowfin tunas in the Indian Ocean. The WP suggested that mixing rates would tend to reduce the ability of genetic studies to differentiate between stocks and that a tagging programme could provide useful information regarding mixing rates and migration. It was noted that CSIRO[5] has conducted a similar study on bigeye tuna. No differences were detected between the stocks of bigeye tuna from the west coast of Australia and from the rest of the Indian Ocean. Therefore, the hypothesis of a single stock of yellowfin tuna in the Indian Ocean cannot be rejected.

Document WPTT-01-05 discussed the use of different indices to appraise environmental fluctuations in the Indian Ocean. The main focus of the document is on simple indices that can be used as reliable indicators of the ocean response to climate forcing that could be included as environmental factors in standardized CPUE models. The document indicates that the Sea-Level Pressure (SLP) and Sea-Surface Temperature Anomalies (SSTA) are relatively easy to obtain and could be readily incorporated as factors in the generalized linear model (GLM) used to compute standardized CPUE. In particular, the authors suggested that the newly defined Indian Oscillation Index (IOI) for the western Indian Ocean, Arabian Sea and South East tropical Indian Ocean would better reflect large-scale events related to ENSO events, while the Southern Oscillation Index (SOI) would be a better proxy for eastern Indian Ocean environmental fluctuations.

The WPTT noted that environmental factors affect catchability as well as local abundance, distribution and survival of larvae, and therefore recruitment. The effect of these factors on catchability would be more easily assessed than on recruitment. It was mentioned that SSTA could be a good proxy for environmental conditions affecting catchability, while wind stress could be a proxy for conditions affecting larval survival and recruitment. Other studies have shown time-lags between CPUE and factors such as primary productivity, and this possibility should be considered if SSTA is to be included as a factor in the standardized CPUE analyses.

Document WPTT-01-10 discusses factors affecting distribution of adult yellowfin tuna and its reproductive ecology in the Indian Ocean, based on data and survey information from the Japanese longline fishery.

[5] Commonwealth Scientific and Industrial Research Organization (Australia)

Data from the Japanese tuna longline fishery from 1953 to 1997 were analysed in the study, including hooking rates, sexual maturity and larval density, and compared with environmental conditions, including oxygen, salinity, water temperature and nutrients. Water temperature, dissolved oxygen and depth of the thermocline were shown to influence the distribution of adult yellowfin tunas and their larvae, while water temperature and dissolved oxygen seem to be the most influential factors on yellowfin spawning activities.

It was suggested that future research in this area needs more rigorous statistical analyses. The effects of environmental factors on catchability could be particularly confusing in interpreting the correlation between environmental factors and spatio-temporal distribution of adults.

Preliminary results of a study on tuna diet in the western equatorial Indian Ocean are reported in document WPTT-01-03. This study is part of the THETIS project and presents the results of analysing 112 stomach samples collected during a single trip onboard a purse seiner. The study indicates a high proportion of empty stomachs in FAD-associated fish as compared with unassociated fish, with a higher proportion of empty stomachs in small fish. The species composition in the stomach contents differs between species, with crustaceans appearing as the dominant diet item for skipjack tuna. For yellowfin tuna, the dominant diet item was fish, while for bigeye tuna the dominant item was cephalopods. It was noted that these results could be linked to different behavioural patterns and vertical migrations between species (and between sizes of individuals of the same species).

It was noted that the study does not consider important factors such as spatial distribution of prey items, which would probably influence the results. The results of the study seem to agree with the accepted idea of tunas being visual predators, in particular as tuna caught in early-morning FAD sets showed high proportion of empty stomachs. This could also indicate a possible digestion time of less than eight hours. It was agreed that interpretation of results from this kind of study could be clarified by determining the distribution of forage species and tunas around FADs. In this sense, acoustic surveys were necessary to determine the availability of preys and the position and movement of tuna schools around FADs.

Review of new data on predation by marine mammals

Documents WPTT-01-15 and WPTT-01-17 present the results of predation surveys carried out on Japanese longline vessels. Document WPTT-01-17 is a completed version of a preliminary document presented during the WPTT in 2000. Document WPTT-01-15 reports on data collected in year 2000.

As logbooks for the Japanese longline fleet have not yet been processed for 2000, document WPTT-01-15 presents total predation, indicating that only about 5 fish per set are lost to predation. According to the document, the largest portion of predation is the result of killer whale activities. The discussion suggested that the surveys performed on the longline fleets of Seychelles and Australia indicate that predation is mostly by false killer whales, and it was recommended that Japanese survey forms and methodology be revised to ensure correct species identification. The average predation rate of all species combined (17%) in the Indian Ocean (WPTT-01-15) is slightly lower than the one in WPTT-01-17(page 11)(22%) in the eastern Indian Ocean and Pacific Ocean. The former case is based on the data only when there are predations, while the latter case includes the cases where no predation occurred. If the no-predation data in the latter case,it is expected that two figures would become closer.

General discussion on data related issues for tropical tunas

A number of problem areas were identified in the data situation for tropical tunas:

- Poor knowledge of the catches, effort and size-frequency from fresh tuna longline vessels, especially from Taiwan, China and several flags of convenience.
- Poor knowledge of the catches, effort and size-frequency from deep-freezing tuna longliners flying flags of convenience, especially since the mid-eighties.
- Lack of catch, effort and size-frequency data for the Indonesian longline fishery in recent years.

- Poor knowledge of the catches and lack of effort and size-frequency data for ex-Russian purse seine boats flying flags of convenience in recent years.

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

A better level of reporting: NC and CE information have been obtained for deep-freezing Taiwanese vessels. The submission of NC, CE and SF statistics from Maldives is currently complete. Sets of CE and SF statistics have been provided by Korea, although the SF data have not been integrated into the database due to numerous problems found during the validation process. It is important to note also the submission by Pakistan and Vanuatu of NC statistics for recent years.

Revision of the IOTC databases: Several revisions have been conducted during the last year on the IOTC databases. This has led to new datasets being input, especially regarding CE and SF statistics and to new series of 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 the NEI component.

Improved estimation of the NEI component: 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 will also permit the estimation by flag of the catches of deep-freezing longliners.

Recovery of historical activity and size data from processing plants: The collection of historical information from operators in different ports of the Indian Ocean has continued since last year. Some 120,000 individual fish weight records by species have been retrieved to date for 1998 to 2001.

IOTC sampling programmes: The collection of information on the activities of fresh tuna longliners landing in Phuket and Penang has continued during 2001. This has permitted an estimate of the catches unloaded for these vessels in Phuket for the first time. Other valuable data collected in the scope of these programmes refer to length frequencies which will allow length-length, length-weight and weight-length relationships to be established. Sampling will also soon start in Sri Lanka, where fresh tuna longliners have been operating since the early nineties.

Korean size-frequency data: Korea has reported SF statistics for yellowfin and bigeye tunas since 1990. Nevertheless, the data are scarce and inaccurate and cannot be used as many errors were found during validation.

Maldives NC, CE and SF data: Maldives has submitted all pending statistics this year. Only the 1999 size frequencies and the 1993-99 detailed CE statistics are pending submission.

Sri Lanka nominal catch and size-frequency data: the reporting of catches has improved for vessels operating with gillnet and longline gears. SF and CE statistics are also recorded and will soon be submitted.

The status of the current data situation for each of the species can be summarised as follows:

Yellowfin and Bigeye Tuna

NC data: Relatively well known for most purse-seine fisheries and the main longline fleets (Japan, Korea and Taiwan, China). Catches of large NEI LL vessels are still uncertain, especially for the period 1988-1997. Artisanal catches are uncertain, although they are not considered large, with the possible exception of gillnet/longline and other coastal fleets where the catches are reported under “other species” groups, especially for early years.

CE data: Well known in the purse-seine fisheries and the main longline operations (Japan, Korea and Taiwan, China). Nevertheless, the Korean data are thought inaccurate. No catch-and-effort statistics are available for NEI longline and purse seine vessels.

SF data: Data since 1997 from the EU PS sampling is considered less accurate. Sampling coverage from Japan and Korean is low in recent years. No SF data are available from Taiwanese vessels since 1989. Little information is available on important artisanal catches (e.g. Oman, Pakistan and Comoros).

Skipjack Tuna

NC data: Relatively well known for most purse-seine fisheries. Data are available for the important artisanal fishery in Maldives. Artisanal components (not well known) are important for this species. In several coastal countries the catches are not reported by gear.

Review report and recommendations of the Working Party on Methods

The WPTT was briefed about the conclusions and recommendations produced by the *ad hoc* Working Party on Methods (WPM), which met earlier this year. The briefing was documented by the report of the WPM, listed as IOTC-SC-01-04E.

Although the WPTT noted that, unfortunately, it has been unable to solve all the problems, it acknowledged the progress of the WPM and endorsed all the recommendations listed in the report. It also recognized that the recommendations had resulted in new information being produced by the scientists involved and presented at this meeting.

Assessment of the stock of bigeye tuna

Standardization of longline CPUE data

The WPTT, recognizing the importance of agreeing on the indices of abundance to be used in the stock assessment, decided to assign to a small subgroup the task of looking at possible additional analyses of the datasets available. The purpose of these analyses was to better understand the trends of the different indices proposed and to improve the indices where possible.

Prior to the work of the subgroup, documents relevant to the calculation of indices of abundance were reviewed by the WPTT.

In document WPTT-01-04, catch and effort data from the Taiwanese longline fleet are used to obtain indices of abundance using GLM methods. A method is proposed for partitioning fishing effort, based on species composition and area to account for targeting of different species.

The WPTT noted that the catches of yellowfin tuna in the north Arabian Sea were rather surprising, given the low dissolved oxygen content of those waters. It was suggested that shallow sets with monofilament gear could explain these catches. The WPTT also discussed the differences in CPUE trends between the Japanese and Taiwanese longline fleets. Over time, the Japanese CPUE series shows a decreasing pattern, while the Taiwanese series shows increasing CPUE indices. It was argued that, although there is some overlap in the fishing grounds of both fleets, they fish mostly in different areas. The largest increases in the Taiwanese CPUE might be due to a spatial expansion the area of operations to an area (described as Area 2 in the document) not usually fished by the Japanese fleet. This area alone accounts for about one third of the total catch of the Taiwanese fleet.

Document WPTT-01-21 presents the use of environmental factors in GLM analyses for standardization of Japanese longline CPUE for bigeye tuna in the Indian Ocean. Japanese longline CPUE for bigeye tuna from was standardized by GLM, up to 1999. In this study, in order improve the standardization, new sub-area definitions and environmental factors (sea-surface temperature and the Southern Oscillation index) were applied in the models. Judging from value of Akaike's Information Criterion (AIC), the model including environmental factors showed better fit than that of other models without environmental factors, indicating that the application of environmental factors in to the model improved the fit of model significantly. Although the same model was applied to both of number- and weight-based CPUEs, there was no remarkable difference between the standardized CPUEs derived from them. The model including

Year-Area interaction as well as environmental factors was also tested and resulted in a better fit with the inclusion of the Year-Area interaction. In the end, the model including environmental factors and Year-Area interaction was chosen as the final model because this showed the smallest value of AIC among the models tested and the distribution of standardized residuals was close to a the normal distribution. Age-specific CPUEs were also developed using final model and catch-at-age information described in WPTT-01-20 in order to provide possible input data as abundance indices for the age-structured production model analysis described in WPTT-01-18.

The WPTT agreed that this document should be thoroughly discussed during the meetings of the sub-group computing bigeye CPUEs and conducting stock assessment. During discussion in the plenary session, it was noted that the GLM did not include factors to account for changes in gear efficiency, which would affect catch rates, the possible effects of changes in fish prices, which would affect targeting, or the use of stranded *vs*. monofilament lines. It was agreed, however, that the large sample and the length of the lines could *average* the effects of varying efficiency. It was indicated that monofilament lines are neutrally buoyant, and their fishing depth is highly dependent on the setting speed and the use of line-throwers. They also allow a larger number of hooks at the same depth than do stranded lines.

Document WPTT-01-13 presents a large number of analyses that summarize various aspects of the Japanese longline catch-and-effort data in the Indian Ocean since 1952. In particular, the analyses highlight the large spatial and temporal changes in the fishery over time and which need to be accounted for in stock assessments. The document shows that the fishery in the tropical regions of the Indian Ocean expanded rapidly throughout the 1950s and continued to expand spatially throughout the temperate regions until around 1970. There have also been large changes in the species composition of the total catch which indicate that significant changes in the spatial distribution of effort and targeting practices have occurred over time. Since 1970 fishing has occurred in around 150 five-degree squares each year, although the spatial distribution of the squares fished can change significantly between years as does the spatial distribution of effort and catch rates. For most years, 95 % of the bigeye catch is taken in around 50 five-degree squares (or about one-third of the total area fished). The document also highlights the fact that most five-degree squares have been fished infrequently over time. Furthermore, on a quarterly basis, the amount of effort deployed in five-degree squares is highly skewed, with most squares having little effort. For example, 21 % of squares have less than 10,000 hooks (approx 3-4 sets). The extreme differences in the amount of effort within five-degree/quarter strata indicates that very large differences exist in the relative precision of catch rates and that, for a large number of strata, relative abundances are not well estimated. This problem is worse if one considers five-degree/month strata.

Thorough discussion of this document was delegated to the CPUE sub-group. However, several general issues were raised and discussed during the plenary session. In particular, it was noted that, during the forth quarter of 1976 and 1977, there was a significant change in the spatial distribution of the catch. This brought to the fore that, although the analyses indicate that, in most cases, areas fished one year are more likely to be fished in the following year, there were large-scale changes in the spatial pattern of the effort in the 70s, possibly as a result of increased targeting of southern bluefin tuna. In consequence, the possible effect of these changes should be considered carefully in the interpretation of the CPUE trends.

Document WPTT-01-14 presents several alternative methods for calculating annual indices of bigeye abundance using Japanese longline catch-and-effort data in the Indian Ocean. Three different 'core' bigeye fishing areas are used to limit the data used in the models and simple sum indices are calculated together with several GLM-based indices. In calculating indices based on models which allow for Year-Area interactions, a protocol is described for estimating catch rates in those areas which remain unfished in any year. The results show that the annual indices are relatively invariant to the core area used. Finally, a novel approach is described which allows for the spatial areas used in the models to vary from year to year. For this purpose, only the data within the top 49 catch squares in any year are used in an attempt to limit the analysis to a core habitat of bigeye in each year. The annual indices were found to show temporal trends that were significantly different from those based on the more traditional approaches

The WPTT agreed that analyses similar to those presented in WPTT-01-13 and WPTT-01-14 should be conducted with data from other fleets, in particular the Taiwanese fleet. The WPTT also agreed that this document should be thoroughly discussed during the meetings of the CPUE sub-group. In particular, the WPTT explicitly requested the sub-group to consider issues related to the possible contraction of the spatial range of the species, as well as changes in the distribution of the fleet, inside the areas studied in this document, (i.e. some areas are big enough for possible changes in the concentration of effort to be diluted). It was noted that using smaller spatial strata, perhaps 5x5 degrees, would help resolve some of these concerns.

Review of stock assessment models

Document WPTT-01-06 presented an attempt to evaluate the current status of the Indian Ocean bigeye stock using sequential population analysis. A first step was to estimate the catch-at-size for both the longline and purse-seine fisheries. The yearly catches at age are estimated using this catch-at-size table, assuming the growth curve estimated for bigeye tuna in the Western Pacific (as bigeye growth in the Indian Ocean is poorly known) and a simple slicing method. This catch at age is later analysed using Murphy's equation and hypotheses of natural mortality at age and of recruitments/terminal fishing mortality (F). The results obtained are the trend in biomass and the fishing mortality by age of each of the two gears. This analysis indicates a fast increase of fishing mortality by both main gears during recent years. The present catches appear to be at levels which are probably much higher than the maximum equilibrium productivity of the stock and which are not sustainable. Although the author cautions that these results should be considered highly provisional, because of the uncertainties in the data and methods used, he concluded that many of its results are probably realistic and could be useful in better understanding the current status of the stock and its uncertainties.

The WPTT acknowledged the effort to develop this type of analysis in the context of its assessments, but made some general comments applicable to all such methods. It noted that catch-at-size and catch-at-age data will not be well estimated provided the scarce size-frequency data available for the Japanese longline fleet. Concern was also expressed about the assumptions made in the estimation of other parameters, such as the use of a constant recruitment over time, the high natural mortality value assumed for age 0 and the use of Japanese size frequency data to estimate catches at size of other longline fleets for which the fishing grounds exploited and the target species had been different (Taiwan, China). These problems will affect most methods similar to the one presented.

Selectivity-at-age

In document WPTT-01-20, the author attempts to provide selectivity-at-age information on bigeye tuna in the Indian Ocean. A separable VPA (Pope and Shepherd 1982) was separately applied to catch-at-age of the Japanese longline fishery and the total purse seine fishery after catch-at-size data were converted to catch-at-age using the growth equations of Tankevich (1982). The resulting selectivity for the Japanese longline fishery increases with age. The selectivity for the total purse seine fishery (combined for all types of set) was somewhat high for ages 0 and 1, lower at intermediate ages and the highest for age 6. Since the latter observation is very different from current perceptions, the author concluded that further investigation and verification might be necessary in data and estimation procedures.

The WPTT agreed to recalculate the selectivity-at-age for the purse seine fleets because of the unrealistic results obtained. It was agreed that the analysis should be repeated, excluding the catches of bigeye tuna on free schools which have been negligible over time if compared with those under floating objects. It was also agreed that a different set of natural mortalities-at-age should be used when recalculating selectivities-at-age.

The WPTT reiterated its concern regarding the decrease in the number of specimens sampled on Japanese longliners over time and the very low sample sizes of recent years. The issue of training vessels being the source for most of these data was also raised, as this was considered a source of potential bias. The Japanese scientists agreed that, while the fishing grounds used by training and regular longliners could be somewhat different, it is unlikely that those differences introduced a significant bias as the gear and fishing techniques used were almost the same in both types of vessel.

Growth

The WPTT also assessed the lack of information on bigeye tuna growth. Modal progression (especially in the early stages), age reading from hard parts and tagging were identified as the three main techniques for bigeye tuna ageing, and further research was recommended using these techniques. French and Australian scientists reported on age determination studies currently underway in Réunion and on bigeye tuna from the Indian and Pacific oceans in Australia. The first results of these programmes will be probably available next year. In the conversion of catch-at-size to catch-at-age data, it was agreed that, in the future, methods of modal separation that account for individual variability were more suitable techniques than cohort slicing.

Natural mortality

The WPTT also recognized the uncertainty in the values used for natural mortality at age. It was suggested that, considering the lack of information on this subject, several vectors should be used in all analyses to assess the dependency of the results on this parameter.

Assessment model

In document WPTT-01-18, the authors describe an analysis of the status of the bigeye tuna stock using an age-structured production model (ASPM), as suggested by the WPM. As a result of various runs assuming different scenarios, two base cases were selected which could be considered as two extremes under the current uncertain situation. The 'pessimistic' base case (Run 1) provided MSY=83,000 t and F(ratio)=0.88, while for the 'optimistic' case (Run 3), MSY=149,000 t and F(ratio)=0.35. Considering the current sharp decrease of the longline CPUE and the sharp increase of the catch by both purse seine and longline fisheries, the current stock status was considered to be close to the situation described by the 'pessimistic' base case. Therefore, the authors suggested that the catch should be decreased from the current level (143,000 t) to the MSY level (83,000 t) estimated in Run 1 as the minimum level.

The WPTT agreed that the flat shape of the CPUE used, from which no clear trend could be assessed, was unrealistic, although it was impossible to determine the reason for these results. The WPTT suggested the use of an index based on the tropical areas only, instead of the whole Indian Ocean, as a possible solution to this problem, since targeting of bigeye tuna prevails in the tropical region. It was noted that this assessment used a different growth curve than the assessment presented in WPTT-01-06 and it was agreed that the sensitivity to an alternative growth formulation be investigated during the meeting, together with an alternative vector of natural mortality at age.

In document WPTT-01-24 the author presented the methodology adopted to test the PROCEAN (PROduction Catch-Effort Analysis) model and to construct priors for its parameters. Because this work is still under progress, only preliminary simulations were presented. The PROCEAN model is a statistical catch/effort analysis framework based on a generalized production model. The use of such a production model could be useful in IOTC where reliable size data are missing for stock assessment. Nevertheless, the highly complex characteristics of Indian Ocean tuna fisheries put in question the ability of PROCEAN to produce reliable results.

In the ensuing discussion, and to the question of why nominal instead of standardized effort had been used, the author explained that the standardization was not clear for the purse seine vessels. Nevertheless, the European scientists confirmed that all effort data provided to IOTC were somewhat standardized and, therefore, that no nominal effort had been used as such.

The six-fold increase in the efficiency of the purse seiners since they started operating was considered questionable, despite the increasing trend in the catch rates observed throughout the period.

Document WPTT-01-02 presents the preliminary results of a study on age and growth of tropical tunas using daily increment of otoliths. The document describes the extraction, preparation and morphology of otoliths of tropical tunas and presented relationships useful for converting between different measurement of yellowfin and bigeye tunas. These relationships were calculated using data obtained the IOTC sampling programme in Phuket, Thailand.

The WPTT agreed that this type of work is important and should be encouraged. The use of tagging as an alternative method to validate ageing and to develop growth curves was raised again. It was agreed that, although tagging could provide useful information on growth rates, it is not a replacement for ageing studies. The authors of the document also indicated that logbook collection programmes were being implemented for freezer- and the smaller ice-longliners.

Stock Assessment

CPUE Indices

The results of the models used to compute standardized CPUE were presented, including a review of the main issues discussed by the sub-group assigned to compute these indices.

It was agreed that there is an anomaly in the CPUE data for the Japanese fleet during the 70s, which show a peak in the nominal CPUE for age 4+ in 1977. The index obtained after standardization by GLM still shows large values for 1977 and 1978. The reasons behind this anomaly are still not completely understood, but the evidence seems to indicate that this peak might be related to spatial shifts in fishing patterns and changes in the concentration of effort and is not likely to represent an increase in abundance. It was agreed that different runs of the stock assessment model may be need to include cases using unmodified standardized CPUE series, as well as series in which the CPUE for 1977 and 1978 have been weighted down.

An attempt was made to compute standardized CPUE for the Taiwanese longline fleet. Several important issues were raised:

(i) There are some possible quality problems for the data provided by Taiwan, China to IOTC. In particular, it was found that, for some areas, the reported nominal catches are smaller than the reported catches by effort.

(ii) From 1990 to 1992, the coverage is very low. It was suggested that the large fluctuations in CPUE during these same years might be related to low coverage, rather than to changes in abundance of bigeye.

(iii) Data on hooks per basket are not available for this fleet before 1995, so the standardized CPUE cannot reliably account for targeting effects.

(iv) Some data was available regarding sea-surface temperature for the Japanese fleet as 5°x5°-month values, based on daily temperature records. This information was incorporated in analyses of the Taiwanese data carried out during the meeting but, because there are differences in the areas fished by each fleet, temperature information is not available for a subset of the Taiwanese data.

At least one stock assessment run should include CPUEs from the Taiwanese fleet for comparison, although the results should be interpreted taking into account the data quality issues described above.

The standardized CPUE analyses for the Japanese longline fleet were computed for the whole Indian Ocean and for the tropical areas (south of 15°S) only. In general, the abundance indices computed for the tropical areas are lower and show some yearly differences with those computed for the whole Indian Ocean. It was agreed that the stock assessment model should be run with the CPUE series computed for the whole Indian Ocean.

Two documents (WPTT-01-14 and WPTT-01-21) presented different options for standardized indices of abundance. The results presented by the sub-group charged with standardizing CPUE show that indices based on traditional GLM models have similar trends and that differences between them are minor. On the other hand, the indices based on the 'variable areas' method showed significantly different temporal trends. The WPTT decided to use the indices based on the traditional GLM standardisation method described in WPTT-01-21, as the reasons for the differences noted in the 'variable areas' index were not fully understood. Species targeting was determined using the number of hooks per basket, which seems to be an appropriate proxy, but it was noted that this information is not available for sets before 1975. However, it is believed that there was little or no deep longlining prior to that time as bigeye and yellowfin tunas had the same price.

The WPTT discussed the results of age-specific standardized CPUE. It was agree that two series representing CPUE for juvenile (2-3 year-class) and adult (4+ year-classes) fish should be used for the stock assessment.

There are a small number of 5°x5° areas that were fished but for which not enough data are available, in part because areas with low sampling densities (i.e. less than 10,000 hooks) were not included in the standardized CPUE analyses.

The selection of an appropriate model for weight-length conversion was discussed. No major issues were raised during the discussion and the WPTT decided that the stock assessment should use the model presented in Document WPTT-01-18.

Two possible options were discussed for selection of the growth model to estimate weight-at-age in the stock assessment between the model proposed by Tankevich (1982)[6], with the modifications proposed in WPTT-01-18 and the model proposed by Lehodey *et al*. (1999)[7] based on data for bigeye tuna from the western Pacific Ocean. It was agreed that the Tankevich model could be used for the base case for the stock assessment.

The WPTT considered that the assumptions for fecundity-at-age proposed in document WPTT-01-18 were suitable and decided, in view of the lack of any additional data for this parameter, to adopt them for the current stock assessment.

Selectivity-at-age

The Working Party decided to run an ASPM using the two growth curves (Tankevich and Lehodey) proposed in documents WPTT-01-06, WPTT-01-18 and WPTT-01-20. The Working Party also considered that the selectivity at age calculated in document WPTT-01-20 for the purse seiners might be biased as the calculations were conducted using a constant natural mortality value for all ages. Because of uncertainties in natural mortality (M), the Working Party decided to try the M-at-age vector used for bigeye by ICCAT (0.8 for ages 0 and 1 and 0.4 for age 2 and more) and SPC (1.2 for age 0, 0.8 for age 1 and 0.4 for age 2 and more). New calculations were thus conducted to obtain sets of selectivity by age for the different scenarios of growth and M considered. The periods retained for the longline fishery were those defined in document WPTT-01-20 (1965-76, 1977-91 and 1992-99); for the purse seine fishery, selectivity was calculated for the period 1991-99.

Selectivities were estimated using the Separable VPA model (Pope & Shepherd, 1982[8]) included in the FishLab (CEFAS, 1998) software. Initial results indicated that using a different variable M-vector had an effect on the selectivity of the purse-seine fleet, the longline catch of ages 0 and 1 fish being negligible. Even for the purse seine catch, the main effect was found in the case of using the Lehodey growth curve for ageing as the catch of age 0 from the Tankevich growth curve is minor. Other conclusion from these first results were that the selectivities for longline considering the Tankevich growth curve were very sensitive to the number of ages used. Finally, it was evident that for all the periods considered for the

[6] TANKEVICH, P. B.1982. Age and growth of the bigeye tuna, *Thunnus obesus* (Scombridae) in the Indian Ocean. *J. Ichthyology*. 22(4):26-31.

[7] LEHODEY P., J. HAMPTON AND B. LEROY, 1999. Preliminary results on age and growth of bigeye tuna (*Thunnus obesus*) from the western and central Pacific Ocean as indicated by daily growth increments and tagging data. *Standing Committee on Tuna and Billfishes, Tahiti, June 1999.*

[8] POPE, J. G., AND J.G. SHEPHERD .1982. A simple method for the consistent interpretation of catch-at-age data. *J. Cons. Explor. Mer*. 40:176-184.

longliners that the selectivity vectors were completely different when using either the Tankevich or the Lehodey growth equations.

Taking into account this evidence, the Working Party decided:

- To use the selectivity at age (ages 0 to 8+) presented in document WPTT/01/20 for the longline catch, with age determination based on the Tankevich growth curve.
- For the longline catch with age determination based on the Lehodey growth curve, to use the selectivities for ages 0 to 3 estimated, consider age 8 as the plus group and assume a flat selectivity for ages more than 3.
- For the purse seine catch, use two different selectivities for each growth option (Tankevich and Lehodey), one for each of the natural mortality vectors considered. In all the cases selectivities were estimated for ages 0 to 8+.

Table V.2 in Appendix V shows the selectivities used in the different ASPM runs.

ASPM

Following suggestions of the participants, the assessment presented in WPTT-01-18, based on a stochastic age-structured production model implemented by the ASPM software was further explored during the meeting in order to assess the status of the bigeye tuna stock.

Two growth curve options were used to provide weights-at-age and to estimate selectivity using the SVPA method implemented in the FISHLAB software. The first growth equation was that of Tankevich (1982) with modifications as described in WPTT-01-20 and the second described in Lehodey *et al* (1999) and currently assumed in SPC assessments (see Table V.1 in Appendix V).

Two vectors of mortality-at-age were tried, differing only in the mortality assumed for fish younger than one year old. The first vector, following current assumptions in ICCAT assessments, assumed that the mortality is 0.8, while the second is similar to that assumed in SPC assessments, assigning a value of 1.2 to the youngest fish.

The WPTT discussed the selection of suitable natural mortality rates based on the current literature, as no recent estimations are available for the Indian Ocean. It appears that mortality of juveniles (in particular 0 and 1 years-old) is high, while mortality for fish aged 2 and above remains relatively low. Based on the results from previous analyses performed by the SPC, the WPTT decided that the stock assessment should use the natural mortality vector proposed in document WPTT-01-06. This vector has values of M=0.8 for ages 0 and 1 and M=0.4 for fish age 3 and older.

Given the limited time available, the model was fitted to the index of abundance obtained from the Japanese LL fishery for the whole Indian Ocean and for all ages pooled, obtained as described in Appendix IV. Additional assumptions for the ASPM run included a value of 0.25 for autocorrelations in the recruitments and an assumed variance of 0.4 for the logarithm of the estimated recruitments.

The estimating procedure failed to reach convergence in the runs incorporating the SPC growth curve. The runs based on the Tankevich growth curve indicated no important difference between the two mortality-at-age vectors and, for the sake of simplicity, it was agreed to base further discussions on the results obtained using the ICCAT mortality-at-age vector. Assumptions and basic results from this assessment are shown in Table V.2 in Appendix V.

The results suggest that the population is currently above the MSY level (estimated to be at about 90,000 t) but has been declining since the late 1980s (Appendix V, Figure V.1). The overall fishing mortality is estimated to be currently just below that expected at the MSY level, but recent catches have exceeded the MSY and, therefore, do not seem sustainable.

The recruitment parameters estimated by the model suggest a very weak dependency of the recruitments on the spawning biomass level. There is a slight increasing trend in the estimated recruitments for the period considered (Appendix V, Figure V.1), although it was noted that they might actually be due to a trend in catchability not accounted for in the model formulation.

Current uncertainties in the assessment

A number of uncertainties in the assessment conducted were identified by the WPTT, including:

- The lack of a growth curve for the Indian Ocean that adequately represents growth for fish of all sizes caught by longline and purse-seine fisheries, in particular in light of the sensitivity of some of the results to the different curves assumed.
- The lack of adequate size information for the catches of longline fisheries, especially in recent years, which affects the estimation of the catch-at-size and catch-at-age data required to estimate selectivities for the ASPM.
- Uncertainty about the natural mortality at various life stages.
- Uncertainty about the increase in efficiency of the different fisheries involved, especially in the purse-seine fishery. The WPTT noted that future consideration of an increase in efficiency could result in a more pessimistic appraisal of the stock status. For example, it is possible that the fishing mortality that would result in the MSY has already been exceeded.
- There are still unresolved questions in the index of abundance based on the Japanese longline data, in particular the large values for the years 1977 and 1978. Further work is required to analyse data from other fisheries and, in particular, to obtain an index from the purse-seine fishery.

The WPTT acknowledged that, although there is scope for improvement in the current assessment, it is unlikely that these uncertainties will be substantially reduced for the next assessment cycle.

Other assessments

The WPTT also attempted to conduct an assessment based on a catch-at-age model incorporating the possibility of estimating selectivity-at-age, natural mortality and trends in catchability, in addition to recruitments by year[9]. Results from preliminary runs indicated that additional constraints, for example, in the value of the mean fishing mortality at age, would be required to achieve a better estimation of the parameters. The WPTT agreed that such work would not be possible in the limited time available during the meeting and, therefore, it was decided to concentrate its discussion on the results from the ASPM run, although the WP noted with interest that this model suggests that there has been a shift in the selectivity of the purse-seine fishery resulting in increasing catches of one-year old fish.

Likely future trends under alternative exploitation scenarios

Forward projections were conducted for the period 2000-2010 on the basis of the results of the ASPM assessment, assuming three different scenarios:

- A constant catch scenario, where the catches are maintained at 1999 levels throughout the projected period.
- A constant fishing mortality scenario, in which the fishing mortality is assumed to remain constant at the levels estimated for 1999.
- An increasing fishing mortality scenario, in which fishing mortality is assumed to continue to increase at a rate of 6 % per year during the projected period.

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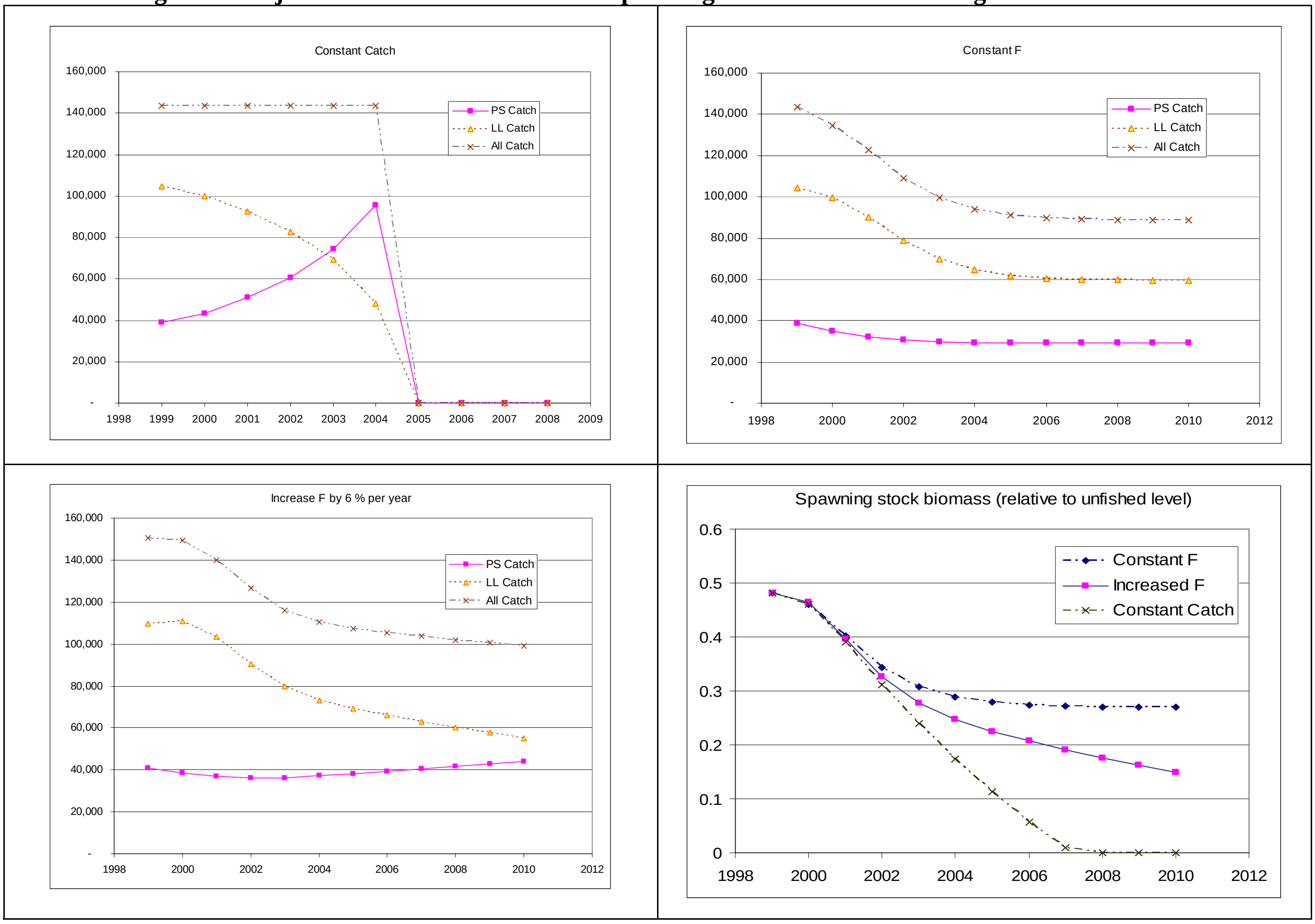
[9] This model is decribed in a document entitled “A multi-fleet are-structured model to assess fishery dynamics in a bayesian context” presented to ICCAT as SCRS/00/87.

Figure 1. Projected trends in catches and in spawning stock biomass according to three scenarios



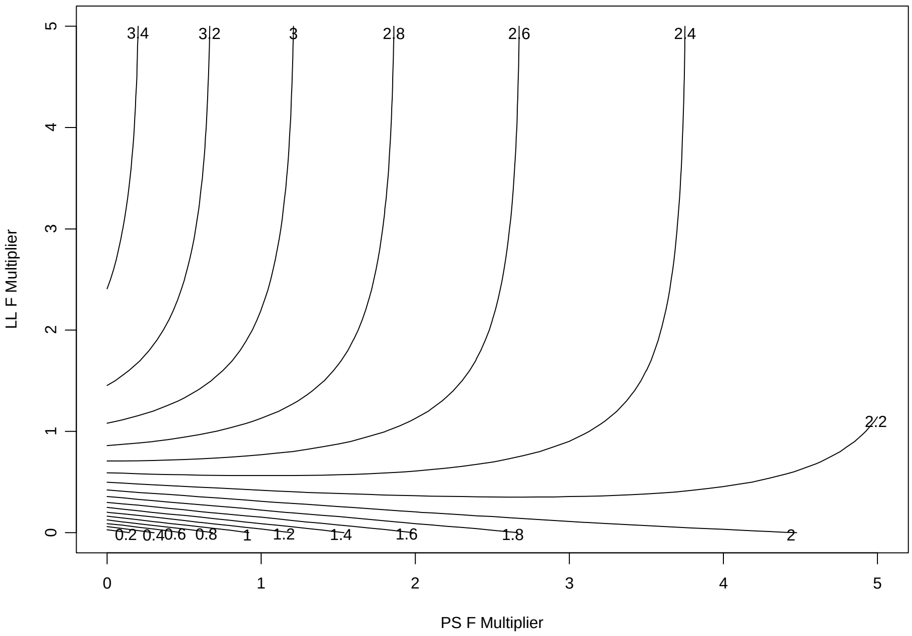
The constant-catch scenario predicts a rapid decline of the spawning stock biomass and the catches, until the population become severely over-exploited after the year 2006. However, it is unlikely that the fishery would be able to maintain such catch levels as the population diminishes in time and, for this reason, this is considered a low-probability scenario.

Projections under the constant F scenario indicate that the population would be reduced to a level slightly above MSY, with catches being reduced over time and reaching an equilibrium slightly below the MSY of about 90,000 t. This is a direct consequence of the assumed fishing mortality for the projected period which has been estimated by the ASPM assessment to be at 85 % of the fishing mortality level that would produce MSY.

Projections assuming increasing F at an annual rate of 6 % (the average rate of increase in overall fishing mortality in the late 1990s as estimated in the assessment) suggest that a decline in the total catch over the projected period would be slightly less than that under the constant F scenario. However, the decline in longline catches is more pronounced in this scenario, while catches in the purse-seine fishery actually increase during the period. This latter projection depends strongly on the assumption that recruitment is almost independent of spawning stock. Of particular concern is the predicted reduction by the year 2010 of the spawning stock biomass to about 20 % of the virgin state, a value that is often considered as a limit reference point.

Given that the current assessment suggests that recruitment is almost independent of spawning stock biomass, the results of the projections reflect mostly yield-per-recruit effects, which could also be evaluated using a multi-gear yield-per-recruit analysis such as the one depicted in Figure 2. This calculation was done on the basis of the results and assumptions on input values from the ASPM assessment.

Figure 2. Multi-gear yield-per-recruit calculations, in kg/recruit, with the growth, natural mortality and fishing mortality assumptions from the base case in the ASPM assessment.



The projections can also be used to address the question posed by the Commission in its Fourth Session regarding the long-term effects of a time-area closure with the goal of reducing the fishing mortality of juvenile bigeye tuna. Table 1 shows the results of the calculations under two assumptions for reductions in fishing mortality, expressed in terms of the percentage change in projected yield in 2010 under different scenarios for reducing fishing mortality relative to projected yield under current fishing mortalities.

Table 1. Percentage change in projected yield in 2010 under different scenarios for reducing fishing mortality relative to projected yield with current fishing mortalities.

Gear	No reduction	Moratorium with 20 % reduction in fishing mortality	Moratorium and 20 % reduction in longline fishing mortality
Purse seine	0%	-16%	-16%
Longline	0%	+10%	-10%
Total	0%	+2%	-11%

The first assumption considers that there is a reduction of 20 % in purse-seine fishing mortality. Such a reduction is compatible with the proposals for a time-area closure discussed at the last meeting. The second hypothesis assumes that there is, in addition to the reduction in purse-seine effort, a reduction of a similar magnitude in longline catches.

The WPTT stressed the fact that the caveats and uncertainties expressed about the assessment apply even more strongly to the results of the projections. These calculations are meant to be interpreted as an example of what are possible trends in the fishery if the actual situation of the resource is well approximated by the results of the assessment. As such, the predictions regarding actual catch levels and their rates of change over time should be taken with considerable caution. For example, the assessment predicts that recruitment is almost constant since, according to the assessment, there is no data on the level of recruitment at reduced spawning biomass levels. If recruitment is actually reduced as a consequence of a decline in spawning biomass in the future, reductions in population levels and on catches will be more pronounced than in the current projections.

Other status indicators

As in past meetings, the WPTT also discussed the evolution of other potential indicators of stock status.

1. **Trends in total catch:** The large increase in catches noted by the WPTT meeting in 1999 have continued in the last two years, which is similar to the overall trend seen in other oceans (Figure 3). There was consensus that such trends are not sustainable, as seems to be the case in the other oceans.

Figure 3. Catches of bigeye tuna in the three oceans for the period 1950-1999.

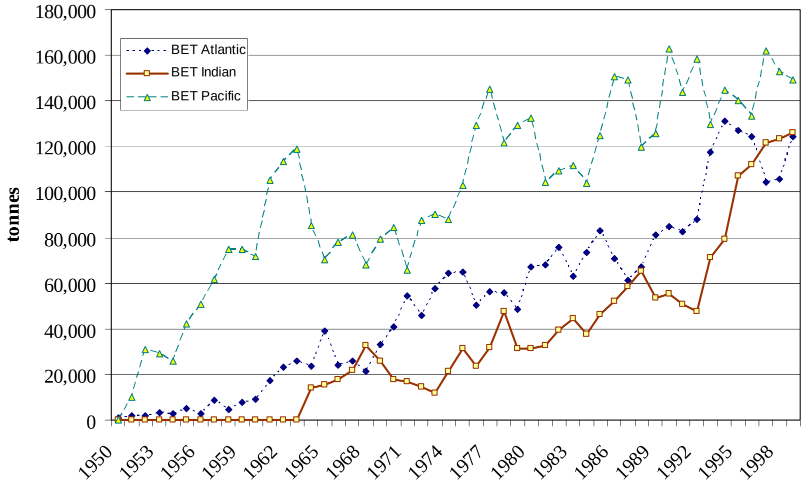
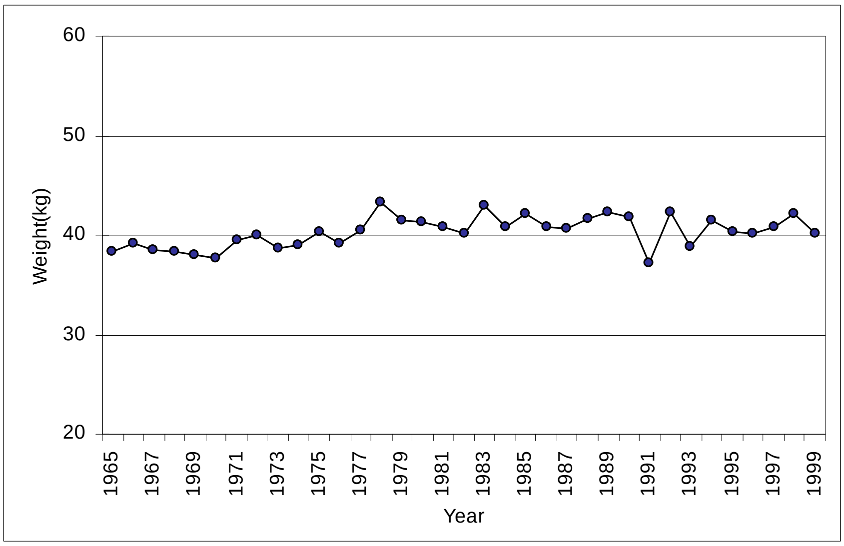
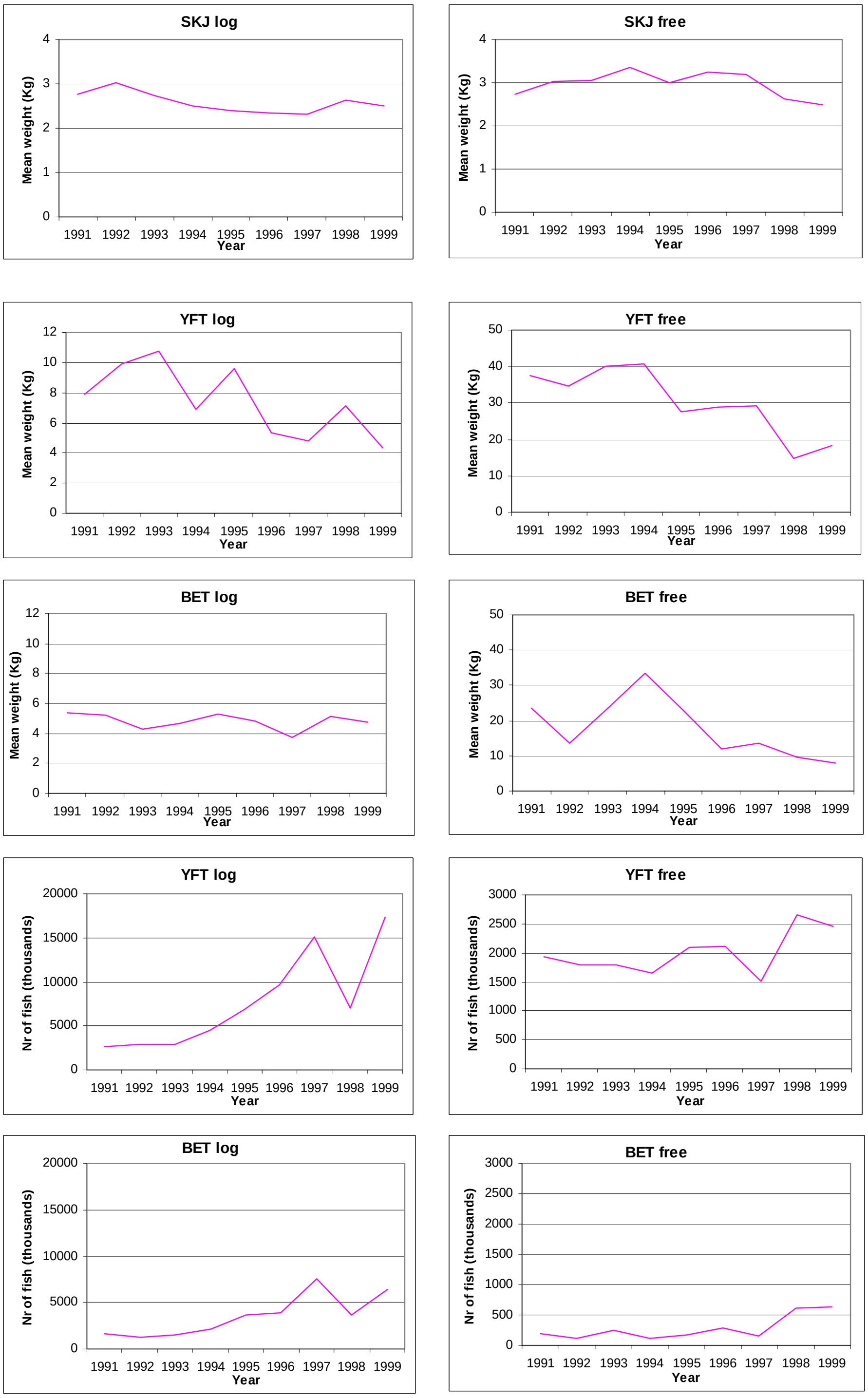


Figure 4. Average weight of bigeye tuna in the catch of the Japanese longline fleet.



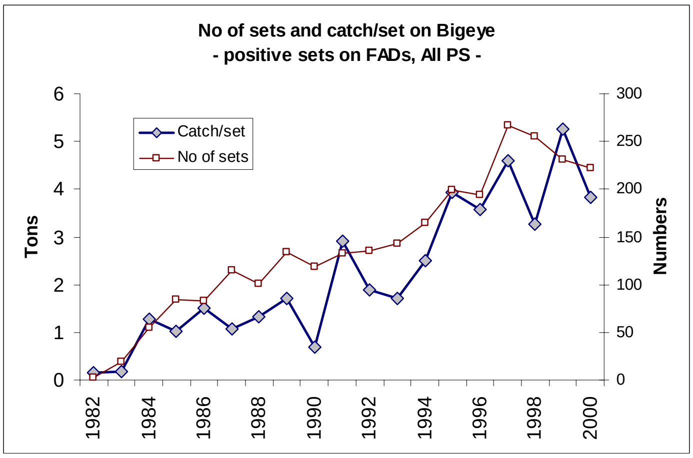
2. **Trends in mean weight**: the trend in average weight in the Japanese LL fishery continues to increase, as noted during the WPTT meeting in 1999 (Figure 4). The WPTT considered that the current assessment results would suggest that this trend is likely to be the result of more effective targeting towards fish of larger sizes, rather than as a change in average size in the population. In the purse-seine fishery, the average weight of fish caught in association with floating objects has been stable or declining (Figure 5), while the average size of fish caught in free-swimming schools suggests an increasing trend (Figure 5). However, it should be noted that the catches of bigeye tuna in free-swimming schools are very small and that this observation is subject to considerable uncertainty.

Figure 5. Average weight in the catch and number of individuals in the catch of the main purse-seine fleets.



3. **Trends in catch-per-successful-set:** The catch per successful set in the purse-seine fishery has shown a continuously increasing trend since the beginning of the fishery (Figure 6). It was suggested that this pattern could be interpreted as a continuous improvement in the technology associated with the use of FADs.

Figure 6. Catch of bigeye tuna per successful set and number of sets for the main purse-seine fleets



Technical advice

The WPTT had already noted with concern the rapid increase of catches of bigeye tuna at its meeting in 1999. Since then, catches have continued to increase. Taking into account the results of the current assessment, which represents the best effort to date to analyse the available data in a formal context, it is likely that current catches are well above MSY.

Bearing in mind those considerations and the need for a precautionary approach, the WPTT recommended that a reduction in catches of bigeye tuna from all gears should be effected as soon as possible.

The WPTT briefly discussed some of the actions that could achieve these goals. Possible means of reducing fishing mortality on juvenile bigeye tuna from the purse-seine fishery on floating objects were discussed by the WPTT at its last two meetings. In particular, options for time-area closures were addressed in detail in 2000, when it was noted that this measure could also impact catches of skipjack as bigeye tuna is not the main target of the fishery on floating objects. Further advice on possible long-term effects of time-area closures is given above.

The WPTT recognized that, given the uncertainty in the relationship between nominal effort and fishing mortality for purse seiners, it will be very difficult to achieve a reduction in catches by attempting to reduce purse-seine effort. An obvious alternative is to control catches of bigeye tuna directly (e.g. by setting catch quotas), but this also poses practical problems, given the difficulty in distinguishing between juvenile yellowfin and bigeye tunas.

In principle, a reduction in longline catches of bigeye tuna could be achieved by reducing the numbers of longline vessels operating in the Indian Ocean. However, the WP noted that a number of longline fleets operating in the Indian Ocean were targeting temperate tuna or billfish, and therefore taking at most only a very small bycatch of bigeye tuna. Even for the longline fleets targeting tropical tunas, bigeye tuna almost always represent a minority of the catch. Thus a blanket management measure such as this could have unintended consequences on fisheries for other species.

Other species

Review of yellowfin tuna

The Working Party did not develop a formal stock assessment for this species, but the following stock status indicators were reviewed:

Recent Trends in Catches by Gear

Catches of yellowfin tuna by all gears combined have increased rapidly since 1981, when a portion of the purse seine fleet previously operating in the Atlantic started operation in the Indian Ocean. Revised estimates indicate that catches peaked in 1993, with a catch of about 398,000 t (all gears combined) and have declined since then, with catches of about 300,000 t (all gears combined) in 1999 (Table IV. The peak in 1993 was the result of exceptionally high catches by the Taiwanese longline fleet in the Arabian Sea. For the most recent years, catches by longliners and purse seiners have remained more or less stable.

Stock Status Indicators

The Working Party did not conduct a formal stock assessment for yellowfin tuna, but the following stock status indicators were reviewed:

(i) The **average weight of yellowfin caught in school sets** increased until 1993, after which it has been declining, while the average weight of fish caught on floating objects has remained relatively stable, perhaps with a slight tendency to decrease (Figure 5). When both types of sets are taken together, the tendency in recent years is towards smaller average weight of fish in the catches, but this probably reflects the increased proportion of sets on floating objects during the past few years.

(ii) The **size compositions in all catches** indicate that small fish are being caught in greater numbers in recent years. Again, this is probably the result of increased effort on yellowfin associated with floating objects.

(iii) Since 1982, **purse seine catches** have increased rapidly to a maximum of about 150,000 t in 1995, after which they decreased but recorded a new increase in 1999 to 130,000 t (Table IV.1). Catches on free schools have been decreasing, while the proportion of catches from floating objects has increased steadily. Total catches reached maximum values in 1993 and have been decreasing since then. The group agreed that this could be interpreted as a sign of overexploitation, with catches of yellowfin tuna above the MSY since that year.

Review of skipjack tuna

Recent trends in fishing capacity

Until 1983, the fishery of skipjack tuna in the Indian Ocean was dominated by baitboats, with total catches remaining more or less stable around 50,000 t/year. For a general discussion of the trends in purse-seine fishing capacity, see the yellowfin tuna section.

Recent trends in catches

The major component of the skipjack catch comes from the purse seine fishery. The increase in purse seine fishing has been accompanied with a general increase in total catches of skipjack, which peaked in 1999, at about 400,000 t (Table IV.3). Catches from free schools have remained stable for the past years, while catches from floating objects have increased, particularly for the 1998-1999 period.

Stock status indicators

The Working Party did not develop a formal stock assessment for skipjack, but the following stock status indicators were reviewed:

(i) The **average weight** of skipjack in purse seine catches has declined slightly, but seems to be stable and larger than the average weight caught in other oceans (Figure 5), in particular for skipjack caught on floating objects.

(ii) Although there has been an **increase in the catches of small skipjack** in the recent years, it should be noted that this increase is consistent with an increase in the number of sets on floating objects.

Technical advice on optimal fishing capacity

The WPTT concurred with the view of the WPM on the issues involved in providing advice on optimal fishing capacity. The WPTT noted that this was a difficult problem for a number of reasons. Any estimate of overall fishing capacity needs to be able to estimate the relative effects of different vessels and gear on the stock (e.g. to estimate relative fishing power or what the fishing mortality rate for a specific combination of vessel types and number would generate). The information required to generate reliable estimates of vessel-specific fishing power are not available. Fishing power often changes markedly over time, with an increasing trend and, as such, fishing capacity, if measured in terms of number of vessels, will not be a static quantity. In addition, different combination of number and types of vessels can have comparable effects on the stock (in terms of the effect of their removals on the dynamics of the stock). As such, when a variety of vessel types and sizes exist in a fishery, there is no unique combination of vessels that would yield "optimal" performance in terms of normal stock assessment performance criteria (e.g. MSY, F_{msy}, risk statistic). Other criteria (often economic and social) come into consideration. Other data and methods that are outside the scope of the normal fishery assessment work are required to undertake evaluations against such criteria.

Research Recommendations and Priorities

General

1. *Developments in fishing practices and gear technology need to be fully documented and their effects on fishing power need to be assessed for all major fleets. The European scientists are encouraged to continue retrieving information on these subjects.*
2. *All parties with longline vessels fishing for tropical tunas in the Indian Ocean should make every possible effort to improve the size sampling coverage*
3. *The size-frequency information for fish caught by vessels from Taiwan, China should be made available according to the IOTC data requirements as soon as possible.*
4. *Japanese scientists should make every possible effort to assess the availability of historical data gathered by vessel skippers on individual weights of the species caught by longlines.*
5. *The IOTC Secretariat is requested to continue gathering information on the activities of non-reporting longline fleets through implementation of sampling schemes in the ports where these fleets are based.*
6. *The IOTC Secretariat is requested to continue efforts to retrieve historical records on the individual weights of tuna and tuna-like species from landings of fresh tuna longliners to Indian Ocean ports.*
7. *A major tagging experiment is required in order to estimate levels of mixing of between the tuna stocks of the western and eastern parts of the ocean. Tagging experiments are also thought helpful to estimate tropical tuna growth rates.*
8. *Scientists are encouraged to further research on the spatial distribution of tropical tuna in the Indian Ocean in order to define new areas more in accordance with the tropical tuna habitats.*

Stock Assessment

1. *All scientists are encouraged to further research on methods leading to the standardization of the Japanese longline CPUE, including studies to improve the knowledge on targeting practices by skippers of these vessels.*
2. *Scientists should continue to include environmental data in the calculation of indices of abundance.*
3. *Scientists are encouraged to further research on the dynamics of tunas in the Indian Ocean, especially research to develop indices of abundance for tuna associated with fish aggregating devices.*
4. *Work is encouraged towards development of an operational model and appropriate simulation models for testing methods of analysis to be applied to Indian Ocean tropical tunas.*

Bigeye Tuna

1. *Scientists from Réunion and Australia are encouraged to continue collecting biological data to allow the estimation of bigeye tuna growth rates.*

Yellowfin Tuna

1. *Tagging is necessary to investigate stock structure, migrations, fishery interactions, growth and mortality parameters.*
2. *The IOTC Secretariat is requested to make every possible effort to improve the situation regarding the catch and effort and size frequency statistics available on this species.*

Skipjack Tuna

1. *Tagging is necessary to investigate stock structure, migrations, fishery interactions, growth and mortality parameters.*
2. *The possibility of interactions between fisheries for skipjack tuna and, in particular, between the western Indian Ocean purse-seine fishery and the Maldivian artisanal fishery, should be investigated by analysing fishery data on purse seines and baitboats from Maldives.*

Recommendations on organization of future work

The WPTT agreed that priority should be given to yellowfin tuna in next assessments.

The need of a Working Party on Methods to be held before the next WPTT meeting was discussed by the group. It was agreed that the same methods used to carry out the assessment of the bigeye tuna could be used for the yellowfin tuna and, therefore, that there was no need to have a WPM if this species was chosen. It was also agreed that such a meeting will be needed if the assessment is to be carried out on skipjack tuna.

The Working Party also agreed that the preliminary assessment of the yellowfin tuna could be conducted by a small group of scientists working between sessions who will report on the results to the next meeting. The WPTT noted that the deficiencies in catch data will be more pronounced in the case of yellowfin tuna than for bigeye tuna, as there are catches of yellowfin tuna from gears for which reporting of data is poor.

The group also agreed that making papers available before the meeting, especially those regarding stock assessment, would avoid consuming time during the meeting in reading and understanding the methods used. Nevertheless, the Secretariat pointed out that, despite all efforts to have the WPTT documents at least two weeks in advance, most of the scientists attending the WPTT did not provide papers until one or two days before the meeting, making it impossible for this proposal to be accomplished.

Election of the Chairman for the next biennium

The WPTT unanimously re-elected the current chairman of the WPTT, Dr. Geoffrey Kirkwood, to continue in his functions for the next biennium.

Arrangement for Next Meeting and Adoption of the Report

The WPTT unanimously accepted the invitation of the Chinese authorities to host the next meeting and agreed that, pending confirmation by the Scientific Committee, the next meeting will take place in Shanghai, China, during the month of June 2002.

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Appendix II: Agenda of the Meeting

1. *Review the statistical data for the tropical tuna species and the situation in reporting countries on data acquisition, for reporting to the WPDCS.*
2. *Review new information on the biology and stock structure of tropical tunas, their fisheries and related environmental data.*
3. *Review report and recommendations of the WPM*
4. *Undertake stock assessment for bigeye tuna.*
    - 4.1. *Standardization of longline CPUE data*
    - 4.2. *Review stock assessment models*
    - 4.3. *Stock assessment*
    - 4.4. *Likely future trends under alternative exploitation scenarios*
5. *Develop technical advice on management options, their implications and related matters with priority given to the situation of bigeye tuna.*
6. *Identify research priorities, and specify data and information requirements, necessary for the Working Party to fulfil its responsibilities.*
7. *Any other business*
8. *Election of Chairperson for 2002-3*
9. *Adoption of the Report*

Appendix III: List of Documents

WPTT-01-01	Report on the status of the YFT, SKJ and BET statistics gathered at IOTC. *IOTC Secretariat*
WPTT-01-02	Preliminary Results on Age and Growth Determination, Daily Increment, of Tropical Tunas. *Nootmorn, Praulai and Sampan Panjarat*
WPTT-01-03	Preliminary results of tuna diet studies in the West equatorial Indian Ocean. *Potier M., Sabatié R., Ménard F. and Marsac F.*
WPTT-01-04	On targeting problem, partitioning fishing effort and abundance index of bigeye tuna for Taiwan longline fishery in the Indian Ocean. *Hsu Chien-Chung and Dr. Liu*
WPTT-01-05	Climate and oceanographic indices appraising the environmental fluctuations in the Indian Ocean. *Marsac, F.*
WPTT-01-06	Tentative use of sequential population analysis to analyse the status of Indian Ocean bigeye stock. *Fonteneau, A.*
WPTT-01-07	Statistics of the Spanish purse seine fleet (1984-2000). *Delgado, A. and Pallares, P.*
WPTT-01-08	Statistics Of The Main Purse Seine Fleets Fishing In Eastern Indian Ocean (1991-2000). *Pallares, P., A. Delgado de Molina, R. Pianet, J. Ariz and V. Nordstrom*
WPTT-01-09	See WPTT-01-11rev.
WPTT-01-10	Factors affecting distribution of adult yellowfin tuna (*Thunnus albacares*) and its reproductive ecology in the Indian Ocean based on Japanese tuna longline fisheries and survey information. *Romena, November A.*
WPTT-01-11rev.	Analysis of the activities of supply vessels in the Indian Ocean from observers data. *Arrizabalaga, H., J.Ariz, X. Mina, A. Delgado de Molina, I. Artetxe, P. Pallares, and A. Iriondo*
WPTT-01-13	Exploratory Analyses of Japanese Longline Catch And Effort Data in the Indian Ocean. *Campbell, Robert, Natalie Dowling and Tom Polacheck*
WPTT-01-14	Calculation of annual abundance indices for bigeye tuna in the Indian Ocean using Japanese longline catch and effort data.. *Campbell, Robert and Natalie Dowling*
WPTT-01-15	Report of the predation survey by the Japanese commercial tuna longline fisheries (September-October, 2000). *Nishida, T. and Mariko Tanio*
WPTT-01-16	RFLP analysis on single copy nuclear gene loci in yellowfin tuna (*Thunnus albacares*) to examine the genetic differentiation between the western and eastern samples from the Indian Ocean. *Nishida, T., Seinen Chow, Susumu Ikame and Shojiro Kurihara*
WPTT-01-17	Summary of the predation surveys for the tuna longline catch in the Indian and the Pacific Ocean based on the Japanese investigation cruises (1954, 1958 and 1966-81). *Nishida, T. and Mariko Tanio*
WPTT-01-18	Stock assessment of bigeye tuna (*Thunnus obesus*) resources in the Indian Ocean by the age structured production model (ASPM) analyses. *Nishida, T., Naozumi Miyabe, Hiroshi Shono, Takashi Matsumoto and Chien-Chung Hsu*
WPTT-01-19	IOTC Sampling Programmes, Status Report. *Nootmorn, Praulai and Miguel Herrera*
WPTT-01-20	Estimation of Selectivity at Age for Bigeye Tuna in the Indian Ocean. *Miyabe, Naozumi*
WPTT-01-21	GLM analyses for standardization of Japanese longline CPUE for bigeye tuna in the Indian Ocean applying environmental factors. *Okamoto, Hiroaki, Naozumi Miyabe and Takayuki Matsumoto*
WPTT-01-22	Recent Status of Taiwanese Tuna Longline Fisheries Operate in the Indian Ocean. *Wang Shyh-Bin*
WPTT-01-23	Statistiques de la pêcherie thonière des senneurs français dnas l'Océan Indien, 1991-2000. *Pianet R. et V.Nordstrom*
WPTT-01-24	A Simulation Framework For Testing The Procean Model And Developping Bayesian Priors. Preliminary Results.. *Maury, Olivier et Emmanuel Chassot*
WPTT-01-25	China's Tuna Fishery In IOTC Waters In 2000. *Xu Liu Xiong and Dai Xiao Jie*
IOTC-SC-01-03	Report of the *ad hoc* IOTC Working Party on Methods. *IOTC*

Appendix IV – Recent catches of tropical tunas by flag

Table IV.1. Yellowfin tuna catches (in thousands of tonnes).

Flag	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Spain							0.4	0.1		11.5	18.4	20.0	26.3	44.9	41.1	43.7	44.0	37.8	47.7	43.2	65.2	59.4	60.9	38.6	51.8
France	0.3	0.3	0.3	0.4	0.3	0.3	0.4	1.2	10.7	36.9	39.3	43.5	47.0	60.1	38.6	45.5	38.4	45.6	39.8	36.3	39.6	36.1	31.8	23.0	31.3
China																					0.1	0.5	1.7	2.2	2.3
Taiwan,China	4.6	3.4	8.1	4.2	3.7	3.8	4.1	4.7	5.6	5.8	7.3	16.2	22.4	22.8	22.4	31.6	30.7	56.0	88.0	34.0	23.1	27.9	18.4	23.4	17.7
NEI[1]											0.0	1.0	0.5	5.1	27.2	39.6	33.2	40.4	49.3	43.4	42.9	39.0	29.9	35.6	32.5
Korea, Republic of	11.7	12.8	31.4	25.2	17.8	12.5	11.8	18.7	15.3	9.9	12.0	14.9	12.6	13.4	8.1	7.0	3.0	4.1	4.7	3.6	2.4	3.4	3.6	2.3	0.9
Indonesia	0.2	0.4	1.0	1.5	2.3	1.9	0.2	5.2	4.0	4.4	4.2	5.0	7.4	7.3	14.3	30.4	25.4	24.2	23.8	23.5	21.6	16.3	17.5	18.9	19.9
Sri Lanka	6.6	6.9	5.7	5.4	6.2	6.9	7.7	8.4	9.0	6.4	6.7	7.4	7.2	8.6	10.1	7.9	12.1	10.4	11.6	11.9	8.7	12.9	15.8	19.7	27.5
Japan	4.7	2.7	2.1	4.2	2.1	3.4	4.7	6.5	7.2	7.7	9.3	11.1	7.8	8.9	4.5	9.2	8.9	15.7	14.3	12.3	12.7	15.9	16.1	16.7	15.5
Oman											2.2	2.5	5.8	15.5	16.9	18.3	10.2	15.4	21.9	22.0	28.6	20.7	15.9	14.9	7.4
Iran, Islamic Rep.		0.9	0.7		0.4	0.4									1.0	2.3	3.2	14.6	21.6	27.2	27.2	30.2	21.3	21.5	26.9
Maldives	3.7	4.7	4.3	3.5	4.2	4.1	5.1	3.9	6.1	6.8	5.7	5.1	6.4	6.2	5.8	5.0	7.2	8.3	9.6	12.6	12.0	11.8	12.5	13.6	13.7
Pakistan	3.3	3.1	2.7	1.6	2.8	1.3	2.0	2.5	0.8	0.9	1.5	2.5	2.3	3.7	8.6	3.2	6.5	23.4	30.8	4.6	5.1	5.3	3.8	3.8	8.9
Panama										2.5	3.3	3.4	4.0	4.1	2.0	8.0	10.0	6.9	8.9	10.0	10.7	8.8	6.0	3.7	6.1
Belize										0.2	1.2	1.1							3.5	9.6	8.1	8.0	7.4	7.4	9.4
Comoros	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	3.3	3.3	3.3	4.7	4.7	5.6	5.6	5.5	5.3	5.3	5.2
Mauritius				0.0		0.0	0.0		1.1	1.3	0.9	0.9	1.7	1.4	1.8	1.4	2.7	2.3	2.5	1.9	1.7	0.7	1.1	1.4	0.8
Seychelles	0.1	0.1	0.1	0.1	0.1	0.4	0.9	0.5	0.2	0.1	0.2	0.0	0.0	0.0		0.0	0.4	0.2			0.0	0.1	2.9	7.5	9.9
Malta										0.2	1.3	1.1	1.3	3.8	2.5	3.9	1.9	1.1	3.0		0.5				
Soviet Union									0.2	0.1	0.7	2.9	3.6	4.2	3.1	2.4	3.1								
Liberia																		5.1	8.1	5.8					
India									0.0	0.0	0.1	0.6	0.2	0.1	0.0	0.0	0.0	0.0	0.2	0.2	0.2	7.3	4.1	3.6	2.1
Netherlands Antilles																							3.3	7.0	7.6
Yemen						0.0	0.0	0.0	0.0	0.2	2.4	0.8	0.5	1.6	0.7	0.7	0.8	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Côte d'Ivoire									0.7	5.6	3.6	0.8													
Italy																							1.3	2.3	2.6
Honduras															0.1	0.1	0.1	0.1	2.5	1.5	1.9				
St. Vincent & Gren.																							3.8		
Australia			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.1	0.6	0.3	0.1	0.3	0.3	0.5
Madagascar	0.2																								
Kenya						0.1	0.2	0.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Philippines																								0.6	0.6
Cayman Islands																0.8									
South Africa									0.2				0.0	0.0		0.1	0.0	0.0	0.0	0.0	0.0				
Mozambique									0.0	0.2	0.0														
TOTAL	35.4	35.4	56.5	46.1	39.9	35.1	37.6	51.9	61.6	100.8	120.6	141.0	157.1	212.0	212.2	264.6	245.4	317.3	397.7	310.8	319.1	310.8	285.6	274.0	301.9

1 The following flags are included under NEI (not elsewhere included): Belize, Cambodia, 'Taiwan,China', Cote d'Ivoire, Equatorial Guinea, Guinea, Honduras, Liberia, Panama, Malta and Saint Vincent and the Grenadines.

Table IV.2. Bigeye tuna catches (in thousands of tonnes).

Flag	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
China																					0.1	0.5	0.8	0.4	2.2
Taiwan,China	5.3	4.2	6.2	4.9	7.4	8.9	6.8	11.3	11.3	10.9	12.2	17.1	17.7	21.3	20.4	20.9	29.1	24.0	39.5	27.7	32.6	29.8	34.1	39.7	37.1
Korea, Republic of	24.7	21.0	24.6	32.9	21.2	18.7	18.9	18.9	16.7	11.5	12.4	11.4	13.9	16.5	11.7	10.3	2.1	4.5	7.1	8.2	6.2	10.8	10.2	3.2	1.3
Japan	5.6	2.1	3.0	10.4	4.2	5.9	8.4	11.7	18.5	13.7	16.7	16.3	14.9	12.4	7.5	10.4	8.4	6.5	8.9	18.7	19.5	16.7	17.7	16.7	15.3
NEI[1]												0.1	0.1	2.8	7.7	7.6	8.0	9.8	11.0	12.9	18.1	26.8	20.2	33.1	29.7
Indonesia								0.9	0.6	0.5	0.5	0.4	2.8	3.5	3.1	6.7	5.5	9.1	8.9	10.2	11.7	14.9	16.0	17.3	18.2
Spain										0.8	1.3	1.8	5.0	6.8	5.9	4.9	6.0	3.6	5.4	5.9	12.2	11.4	15.8	11.2	16.1
France							0.0	0.0	0.2	2.3	4.3	7.1	7.0	6.2	3.6	4.6	5.4	3.8	5.0	5.3	7.3	7.0	7.9	6.5	8.7
Panama										0.1	0.1	0.8	0.5	0.6	0.4	0.7	1.2	0.6	0.9	1.2	1.8	1.6	1.8	1.0	1.7
Belize											0.1								0.5	1.2	1.5	1.8	2.1	1.8	2.8
Mauritius						0.0		0.1	0.3	0.2	0.7	0.5	0.7	0.8	1.3	0.8	1.1	0.9	0.7	0.7	0.6	0.3	0.5	0.2	0.3
Maldives	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.1	0.2	0.4	0.3	0.2	0.3	0.3	0.3	0.3	0.5	0.4	0.5	0.5	0.5	0.6	0.5	0.6	0.6
Sri Lanka												0.0	0.0	0.0	0.1	0.1	0.0	0.2	1.0	1.0	2.1	0.5	0.6	0.7	0.5
Seychelles									0.0	0.1	0.1						0.0	0.0			0.0	0.1	0.9	2.1	3.1
Netherlands Antilles																							1.0	1.7	2.2
Philippines																								1.6	1.9
India									0.0	0.0	0.0	0.0	0.0						0.9	1.1	1.1			0.0	
Malta											0.1	0.1	0.3	0.3	0.1	0.4	0.4	0.2	0.6		0.0				
Italy																							0.5	0.6	0.8
Australia								0.0	0.0	0.0	0.0	0.0	0.0		0.0		0.0	0.1	0.5	0.1	0.1	0.0	0.1	0.2	0.5
Liberia																		0.4	1.0	0.3					
Iran, Islamic Rep.																						0.2	0.3	0.4	0.6
Soviet Union												0.2	0.0	0.3	0.1	0.2	0.2								
St. Vincent & Gren.																							0.8		
Kenya						0.2	0.2	0.2	0.3																
Côte d'Ivoire									0.0	0.4	0.3	0.1													
Honduras															0.1	0.1	0.1	0.1	0.1	0.2	0.0				
Comoros															0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
South Africa																	0.0	0.0							
Cayman Islands																0.0									
Mozambique									0.0	0.0															
TOTAL	35.8	27.4	33.9	48.3	32.9	33.8	34.5	43.2	48.1	40.9	49.2	56.3	63.0	71.8	62.3	68.0	68.1	64.3	92.5	95.4	115.5	122.9	131.7	139.0	143.4

1 The following flags are included under NEI (not elsewhere included): Belize, Cambodia, 'Taiwan,China', Cote d'Ivoire, Equatorial Guinea, Guinea, Honduras, Liberia, Panama, Malta and Saint Vincent and the Grenadines.

Table IV.3. Catches of skipjack tuna (in thousands of tonnes).

Flag	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Maldives	14.9	20.1	14.3	13.8	18.1	23.6	20.6	15.9	19.7	32.0	42.6	45.4	42.1	58.5	58.1	59.9	58.9	58.6	58.7	69.4	70.3	66.5	69.0	78.4	92.9
Spain							0.2	0.0		6.4	18.6	19.1	27.9	39.7	63.9	47.9	41.8	46.8	51.4	61.6	69.6	66.3	63.1	58.7	74.3
France	0.1	0.1	0.0	0.1	0.1	0.0	0.2	1.1	9.4	27.3	29.9	36.1	35.6	36.1	43.1	29.1	39.4	45.2	48.3	58.5	49.2	40.2	31.4	30.4	42.8
Sri Lanka	15.2	12.2	11.4	11.0	8.3	12.7	13.8	13.3	14.0	11.6	12.1	17.4	16.9	20.3	24.5	25.1	28.8	24.1	24.8	21.5	18.3	22.8	27.8	34.7	51.9
Indonesia	3.9	5.5	4.0	4.1	8.6	9.0	8.1	13.3	13.4	10.4	11.4	11.2	12.0	13.7	19.2	14.7	15.1	17.0	19.0	22.0	23.6	23.5	25.2	27.3	28.6
Japan	0.0	0.0	0.1	0.9	0.6	0.4	0.1	0.5	0.6	0.7	0.3	0.6	0.9	2.3	3.5	10.9	15.9	31.5	31.3	20.1	16.1	7.0	6.7	5.8	4.6
Pakistan	4.5	4.2	3.7	2.2	3.8	1.7	2.7	3.3	1.1	1.2	2.0	1.5	3.7	5.5	7.5	7.6	7.4	6.1	6.9	8.1	7.1	4.1	4.5	4.4	4.5
Panama										1.2	2.6	3.9	3.3	3.7	3.4	6.0	7.7	8.2	8.5	10.7	11.8	8.8	6.8	5.8	8.2
India							1.8	2.4	2.8	3.6	3.3	4.3	5.9	5.1	6.4	5.8	4.6	4.9	5.0	9.3	6.6	6.9	6.1	1.0	5.7
NEI[1]														0.0	0.0			0.0	0.0	0.0	22.1	16.3	12.3	13.9	18.2
Belize										0.0	1.6	1.2							4.2	13.7	10.2	9.6	8.8	12.5	12.1
Mauritius				0.0	0.0	1.0	1.7	2.4	1.4	2.5	2.0	1.9	4.4	5.0	5.6	4.1	6.5	6.1	6.9	5.2	3.8	1.9	3.1	1.7	2.4
Comoros	1.3	1.3	1.3	1.3	1.3	1.3	1.4	1.5	1.6	1.6	1.7	1.7	1.7	1.7	3.8	3.8	3.8	1.8	1.8	2.2	2.2	2.2	2.1	2.1	2.0
Iran, Islamic Rep.															0.3	0.8	1.1	4.3	4.4	7.4	1.1	3.2	6.0	6.7	16.6
Seychelles	0.0	0.0	0.0	0.0	0.0												1.8	0.6					4.9	10.7	15.9
Malta											1.4	1.1	1.5	3.3	4.6	4.9	3.2	2.6	4.6		0.2				
Liberia																		10.0	8.0	8.2					
Netherlands Antilles																							4.0	9.9	9.7
Soviet Union									0.1	0.6	1.0	2.0	4.7	2.7	2.7	3.9	5.6								
Madagascar	1.6																								
Australia	0.5	0.4	0.1	0.0	0.1	0.0	0.0	0.3	0.1	0.0	0.1	0.6	0.9	0.1	0.0	0.6	0.8	0.3	0.0	1.2	0.5	0.3	0.9	2.2	5.0
Côte d'Ivoire									0.4	7.0	2.8	0.2													
Italy																							1.8	3.0	3.4
St. Vincent & Gren.																							3.0		
Oman																				0.4	0.8	0.4	0.7	0.2	0.3
Korea, Republic of	0.2	0.1	0.6	0.8	0.4	0.0	0.0	0.1	0.0					0.0	0.0							0.0			
China																									
Taiwan,China				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.2	0.1	0.1	0.1	0.0	0.1	0.0
Cayman Islands																0.7									
Yemen						0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
Mozambique									0.1	0.2	0.1														
South Africa									0.0							0.0		0.0	0.0	0.0	0.0				
Honduras																			0.0		0.0				
Kenya							0.0	0.0	0.0																
TOTAL	42.2	43.8	35.7	34.3	41.2	49.8	50.6	54.0	64.7	106.5	133.6	148.2	161.5	197.9	246.7	226.0	242.5	268.2	284.2	319.7	313.6	280.1	288.2	309.5	399.3

1 The following flags are included under NEI (not elsewhere included): Belize, Cambodia, 'Taiwan,China', Cote d'Ivoire, Equatorial Guinea, Guinea, Honduras, Liberia, Panama, Malta and Saint Vincent and the Grenadines.

Appendix IV Standardisation of CPUE

A small group was convened to discuss the choice of standardisation models in order to calculate indices of abundance for input into the stock assessment models. The recommendations of this group are given here.

i). Time period for the analysis: 1960-1999. As shown in WPTT-01-13, the Japanese longline fishery underwent a rapid spatial expansion in the years before 1960. The group therefore agreed that changes in CPUE for these years may not adequately represent changes in abundance.

ii) Area Effects: The spatial areas to be used in the model are those described in WPTT-01-21.

iii) Model Structure: The model is to assume a log-normal error structure and the small constant to add to each CPUE is taken to be 10 % of the mean CPUE over the entire data set. The model to be used to be that described as the 'best model' in WPTT-01-21. Models using a temporal effort by quarter instead of month are also to be tested.

iv) Changes in Targeting: Changes in the number of hooks-per-basket (hpb) are to be used as a proxy for changes in targeting practices. It was noted that the trend toward the use of more than 15 hpb (as shown in WPTT-01-13) during the 1990s in the Japanese longline fishery may have been due to changes in fishing gears not related to increased targeting on bigeye. In consequence, the Group recommended the use of the following categorization:

- 1960-1975: All sets considered to be shallow.
- 1975-1993: Shallow sets those with 5-9 hpb. Deep sets those with 10+ hpb.
- 1994-1999: Shallow sets those with 5-12 hpb. Deep sets those with 13+ hpb

v) Environmental Influences. The following factors are to be included in the model: Sea-surface temperature (or anomaly) in each 5-degree square, monthly Southern Oscillation Index (SOI) and the corresponding monthly Indian Ocean Oscillation Index (IOI).

v) Observations to include. All catch/effort records with less than 10,000 hooks are not to be included in the analysis to avoid possible bias due to the low precision of CPUE based on small amounts of effort.

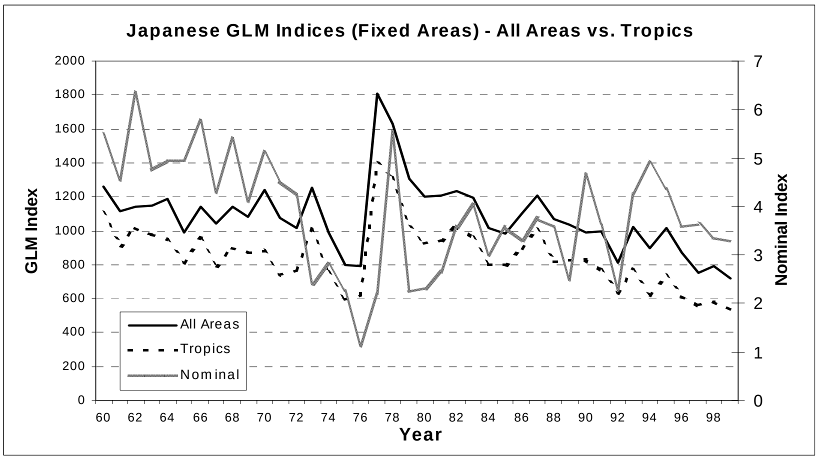
vi) Unfished Strata. Estimation of CPUE in missing area/time strata are to be performed using the protocol described in WPTT-01-14.

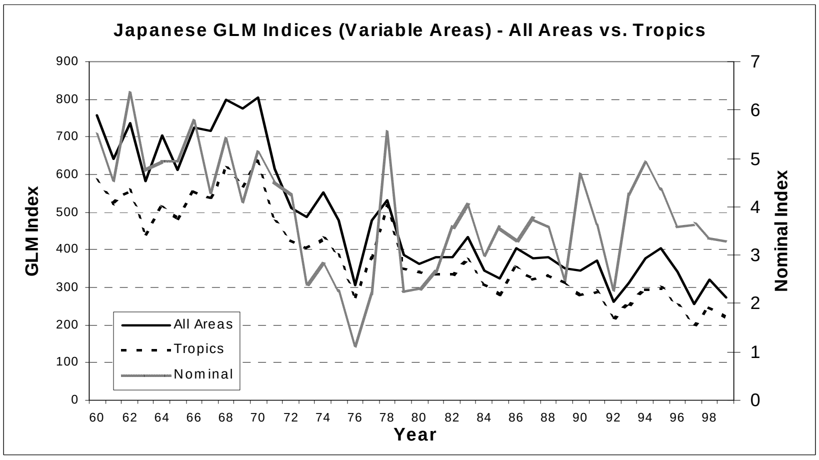
vii) Age Classes. Together with indices for all ages aggregated, indices for the two age-specific groups are also to be calculated: juveniles (2-3 year classes) and adults (4-8 year classes).

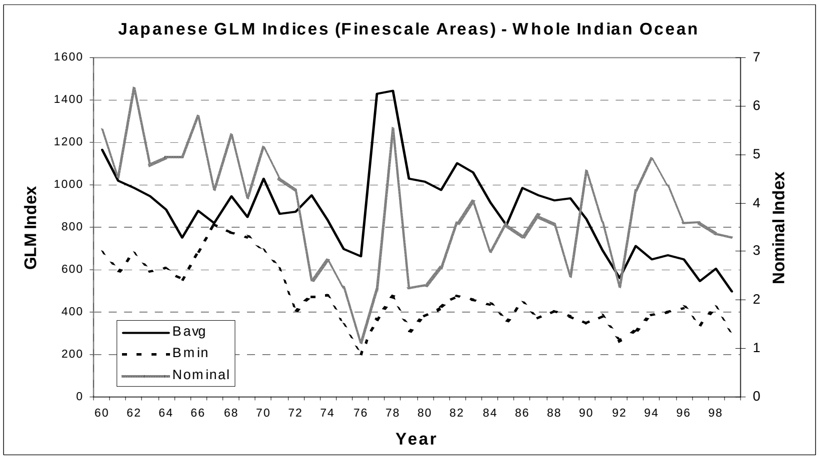
viii) Coverage: A standardised index for the entire Indian Ocean is to be calculated (Areas 1-7) together with an index for the tropical regions alone (Areas 1-5).

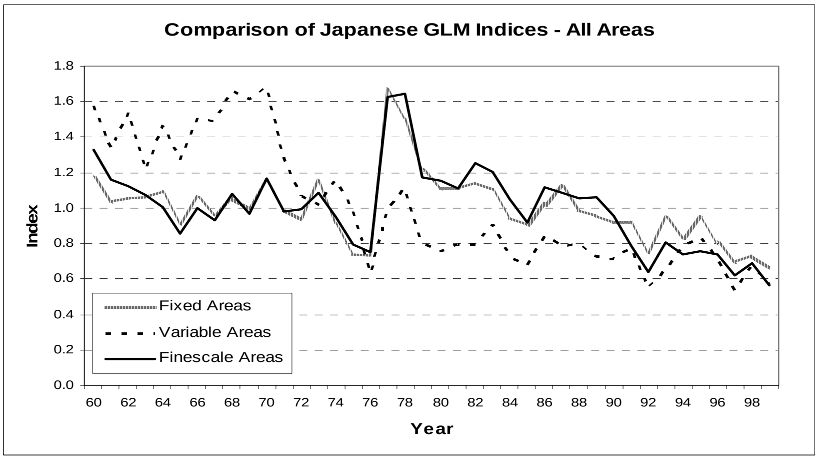
viii) Data Sets. Indices to be calculated using the Japanese longline data (1960-1999) for all three age classes. Several other indices [simple sum, variable area, GAMS and GLMs using fine scale (5-degree squares) area effects] are also to be calculated for comparative purposes. Indices using the Taiwanese longline data (1967-1998) are to be calculated for all ages combined and for the tropical region only.

Several of the indices based on the above recommendations are shown in the following figures.


Japanese GLM Indices (Fixed Areas) - All Areas vs. Tropics
GLM Index
Nominal Index
Year
All Areas
Tropics
Nominal


Japanese GLM Indices (Variable Areas) - All Areas vs. Tropics
GLM Index
Nominal Index
Year
All Areas
Tropics
Nominal


Japanese GLM Indices (Finescale Areas) - Whole Indian Ocean
GLM Index
Nominal Index
Year
Bavg
Bmin
Nominal


Comparison of Japanese GLM Indices - All Areas
Index
Year
Fixed Areas
Variable Areas
Finescale Areas

Appendix V. Results of the ASPM stock assessment

Table V.1 Assumed values for the ASPM runs

Length-weight relationship

For fork length < 80 cm : $W = (2.74 \times 10^{-5}) l^{2.908}$ Poreeyanond (1994) (Indian Ocean)

For 80cm <=fork length: $W = (3.661 \times 10^{-5}) l^{2.90182}$ Nakamura and Uchiyama (1966) (Pacific Ocean)

Growth curves

a) Tankevich (1982):

Females : $L_{t(cm)} = 209.8\left(1 - e^{-0.171[t-(-0.86)]}\right)$

Males : $L_{t(cm)} = 423.0\left(1 - e^{-0.058[t-(-1.773)]}\right)$

NB: The equation for females was used for fish of age < 3.5 and the average of both equations for age <=3.5 yrs.

b) Lehodey et al. (1999)

All fish: $L_{t(cm)} = 166.3\left(1 - e^{-0.349[t-(-0.389)]}\right)$

Weight-at-age key

Age	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5
(kg)	0.7	1.6	4.1	6.3	14.0	18.1	25.9	31.2	40.9	47.1	58.0	64.9	76.8	84.2	96.8	104.5	138.8	146.8

Table V.2. Assumed vectors of selectivity-at-age. See details of calculations for the different options in Table V.3.

Runs 1 and 2

	Period	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8+
LL	1960-1976	0	0.004	0.046	0.137	0.329	0.618	0.848	1	1
	1977-1991	0	0.003	0.042	0.181	0.414	0.703	0.918	1	1
	1992-1999	0	0.001	0.067	0.276	0.514	0.816	0.97	1	1
PS	All Years	0.188	1	0.432	0.272	0.206	0.248	0.113	0.025	0.025

Runs 3 and 4

	Period	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8+
LL	1960-1976	0.001	0.148	0.536	0.999	1	1	1	1	1
	1977-1991	0.001	0.148	0.65	1	1	1	1	1	1
	1992-1999	0	0.166	0.679	1	1	1	1	1	1
PS	All Years	1	0.795	0.502	0.468	0.439	0.368	0.258	0.197	0.126

Table V.3 . Summary Results for the ASPM Runs

Run no.	**1**	**2**	**3**	**4**
INPUT DATA				
Catch	LL (All) & PS (log & free combined)			
Growth curve	Tankevich(1982)		Lehodey et al (1999)	
M	M(0)=0.8; M(1-8+)=0.4	M(0)=1.2;M(1-8+)=0.4	M(0)=0.8; M(1-8+)=0.4	M(0)=1.2;M(1-8+)=0.4
Area	All Indian Ocean			
Selectivity	LL (WPTT-01-20) PS (M(0)=0.8;Tankevich)	LL (WPTT-01-20) PS (M(0)=1.2; Tankevich)	LL (Calculated in the Meeting, 8+) PS (M(0)=0.8; Tankevich)	LL (Calculated during the Meeting) PS (M(0)=1.2; Tankevich)
Stock recruitment	Beverton-Holt model (stochastic option)			
CPUE index	All ages pooled; All Indian Ocean (calculated in the meeting)			
RESULTS				
MSY (t)	89,090	89,267	(Not converged)	(Not converged)
Virgin biomass (million t)	0.794	0.787		
-ln (likelihood)	-92.63	-92.65		
Steepness	0.99	0.99		
F(ratio)= F1999/F(MSY)	0.85=0.587/0.694	0.83=0.597/0.719		
Bratio(SSB)= B1999/B(MSY) (million tonnes)	2.11=0.374/0.177	2.15=0.370/0.172		
B ratio(total)= B1999/B(total) (million t)				
B1 ratio = B1999/B(1960) (million t)	0.58	0.59		

Figure V.1. Results of runs 1 (left column) and run 2 (right column) from the ASPM analyses. Assumptions and data used are described in Table V.3.