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Commission des Thons de l'Océan Indien

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

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Executive Summary

The Second Meeting of the Working Party on Tropical Tunas (WPTT) was held in Mahé, Seychelles from 23 to 27 September 2000, involving 26 participants from 12 countries or organisations.

Although the main focus of the meeting was on a review of the status of yellowfin and skipjack tunas, the Working Party also devoted a significant amount of time to addressing the request from the Commission to identify areas, times and conditions for a moratorium on purse-seine fishing on floating objects with the objective of reducing juvenile bigeye mortality.

A review of the data situation showed significant improvements relative to the previous year, in particular with a better estimation of the catches of IUU fleets and the acquisition of more size-frequency information from longline fleets. However, there still remain a number of areas where improvements are necessary.

The lack of reliable data still limited the possibilities of conducting rigorous stock assessments; however, after considering a number of stock status indicators for yellowfin tuna, the WPTT considered that total catches of yellowfin tuna appear to have reached a plateau and may now be at or approaching MSY for the current fishing pattern. The recent trend of increased fishing pressure on juvenile yellowfin may be detrimental to the stock, as, based on analyses of the same species in the Atlantic Ocean, these fish are well below the optimum size for maximising yield per recruit. The WPTT also concluded that, if a moratorium is imposed on fishing in association with drifting objects, this is likely to also have a positive effect on yellowfin tuna stocks, as the catch of juvenile yellowfin would be reduced.

The WPTT also examined a number of indicators of the status of the skipjack tuna resource. Recent trends of these indicators are not cause for immediate concern.

The WPTT analysed a number of options for the times and areas most effective for the imposition of a moratorium on purse seine fishing on drifting objects with a view to reducing fishing mortality on juvenile bigeye tuna. The possible benefits and estimates of maximum losses were discussed and are presented for the consideration of the Scientific Committee.

In the absence of formal stock assessment for each of the species, and given the incompleteness of the information on the existing fleet capacity, the WPTT considered that it was not in a position to advise on the question of the optimum fishing capacity of the fishing fleet for the sustainable exploitation of tropical tunas in the Indian Ocean.

Finally, the WPTT discussed possible mechanisms for improving the ways in which it develops technical advice.

1. Opening Of The Meeting And Adoption Of The Agenda

The Second Meeting of the Working Party on Tropical Tunas (WPTT) opened on 23 September 2000 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 listed in Appendix II. The documents available for discussion are listed in Appendix III.

In accordance to the recommendations of the Scientific Committee, the WPTT gave priority to assessments of yellowfin and skipjack tunas. According to IOTC Resolution 99/04, the Working Party also considered:

- Various options for precise areas, periods and conditions for a moratorium on fishing with purse seines on floating objects that would bring about a reduction of the fishing mortality of juvenile bigeye, with estimates of the likely effects on the catch rates of the three species of tropical tunas and
- The best estimate, on the basis of existing data and analyses, of the optimum fishing capacity of fishing fleets which will permit the sustainable exploitation of tropical tunas.

2. Reporting and Documentation Procedures

The Chairman introduced the concept of a Permanent Report on the Status of Tropical Tunas for the Indian Ocean that would be updated on a yearly basis by the Working Party. Such a Status Report would not replace the Report of the Working Party, but would rather provide a record of the current knowledge on the biology and status of the species and document research recommendations and management measures. It would also provide a basis for the Status and Trends Reporting requested under the proposed FAO International Plan of Action. The Permanent Report should have ample diffusion and would be deposited at the Secretariat, which will post it on the IOTC web site. The first part would contain an Executive Summary on the status of the species, as requested from the Working Parties by the Scientific Committee. The Working Party considered this to be an interesting initiative but deferred further discussion until a draft version is made available for consideration.

3. Review of Data Related Issues

Report of the Secretariat

The Secretariat introduced the new database design for fisheries data that was developed and implemented during the last year. The design is based on the principle that a clear separation must exist between *raw data* (as received from reporting agencies) and *processed* or *analysed data* (as used for reporting and analysis). In addition, the database design copes nicely with some of the main problems associated to fisheries data that include:

- Highly heterogeneous stratification of information (data resolution).
- Multiple estimates of the same data.
- Changes in the stratification parameters of the data as fisheries and data collection techniques evolve.

The design is currently being used by the Secretariat for its databases of Nominal Catches (NC), Catch and Effort (CE), Size/Weight Frequencies (SF) and Vessel Registry (VR).

A historical review of nominal catches for yellowfin, bigeye and skipjack tunas was also presented as part of the report of the Secretariat.

Catches of the three species have been fully or almost fully reported since 1970. Total catches per species before that year are thought complete, although they had to be split into gears by the Secretariat. The Secretariat carried out an estimate of the catches of purse seiners and longliners NEI (Not Elsewhere Identified) in the Indian Ocean from 1985 to 1999 during the present year. These were estimated at about 100,000 tonnes for recent years; this results in a remarkable increase in the catches previously recorded in the IOTC database for bigeye, yellowfin and skipjack.

Yellowfin and skipjack tunas were caught mostly in the western IOTC area while bigeye tuna catches were more evenly distributed.

Most of the catches of yellowfin tuna reported were from purse seines, longlines and gillnets. Catches of this species increased slightly from the 1950s to the early 1980s, increasing radically afterwards.

Bigeye tuna catches come almost exclusively from industrial gears such as longlines (since the early 1950s) and purse seines (since the mid-1980s). Bigeye tuna is currently the target species for almost all longliners. The catches of the purse seine fleet are small compared to those from longliners and have been increasing, especially since the FAD fishery started operating.

Skipjack tuna catches come from purse seines, baitboats and gillnets. Significant catches are also reported from aggregated gears. The trend observed in the catches of skipjack tuna is similar to that of the yellowfin tuna.

The catch of some of these species could be slightly underestimated, as some coastal countries report species aggregates .

The nominal catches were classified into three categories, based on the source of the data and the amount of processing required before being incorporated into the database:

- **Reported**: Catch estimates provided by flag State authorities and other reliable sources were used directly.
- **Partially estimated**: Catch estimates provided by flag State authorities and other reliable sources were used, but the stratification had to be estimated. It was indicated that, in many cases, partial estimates were the result of having to re-classify catches by species, because many countries report catch data using *ad hoc* species aggregates. It was also noted that, even for data reported with species classification, there is the potential for misidentification of the species. This can be a particular problem for purse-seine catches of small bigeye and yellowfin tunas . In this respect, previous sampling studies on French and Spanish purse-seine logbook data indicate that there is a consistent species misclassification, with an overestimation of the quantity of skipjack and an underestimation of yellowfin and bigeye. However, this is corrected by port sampling for species composition.
- **Fully estimated**: The catches were completely extrapolated by the Secretariat.

Estimates of the catches of tunas by purse seine and longline vessels classified as NEI are reviewed and discussed in document WPTT-00-Inf2. The paper reports estimates of catches by purse seiners from 1986 to 1999 and by longliners from 1988 to 1999. Various sources, including the vessel registry, statistical bulletins and personal communications, were used to estimate the catches.

The NEI purse seine fleet consists of European and Russian-owned vessels. While the catches of European owned purse seiners did not need estimation, the catches of Russian purse seiners have been estimated since 1995, as this is the last year for which reported data exists. Between 9 and 10 Russian-owned purse seiners have been operating in the Indian Ocean during the last four years, with catches estimated to be between 20,000 and 40,000 t, mainly of skipjack and yellowfin tunas.

The NEI longline fleet was split into vessels above and below 100 GRT. The number of longliners above 100 GRT flying flags of convenience has increased since 1988, to reach a current level of 141 boats in operation. Catches of about 50,000 t have been estimated for the past two years, the main species being albacore, bigeye and yellowfin tunas.

NEI longliners with GRT below 100 tons are mainly Taiwanese vessels. The fleet was further classified based on the country where the base-port of the vessels are located. Catches of NEI longliners unloading to ports in Indonesia, Malaysia and Thailand were estimated for the period 1986-99 and amount to some 50,000 t/year in recent years. The estimated number of operating vessels reached its highest, some 1,200 boats, in 1993, . It is important to point out that a significant proportion of these boats have been re-flagged to the flag of the hosting country following new regulations implemented in those countries.

Review of Purse Seine Data

The statistics of the French purse seine fleet in the Indian Ocean from 1981 to 1999 are presented in document WPTT-00-20. The document gives a brief summary of the main French purse seine activities in the Indian Ocean since the beginning of the fishery in 1981. Effort, catches by species and fishing type (log and free swimming schools), catch per unit of effort and length-frequency sampling per species are described.

The authors indicated that there were problems with the 1998 and 1999 species composition and length-frequency statistics for the French, Spanish and NEI purse seine fleet and proposed that these data should not be used until the European scientists had conducted further analyses.

A summary of catch and effort statistics for the Spanish purse seine fleet in the Indian Ocean is presented in document WPTT-00-28. A similar analysis for Spanish and French purse seiners that fall in the NEI classification[1], is reviewed in document WPTT-02-29. Both documents present catch and effort by species and fishing mode, with information collected from logbooks with 100% coverage of the fleet.

A constant increase was noted in the catch of tunas and effort from the Spanish and French NEI vessels (Table 1).

Catches of the Spanish fleet in 1999 reached close to the peak levels registered in 1995-1997, with skipjack being the main component of the catch. There are no significant changes in the distribution and magnitude of effort since 1995. There has been a slight reduction in the number of positive sets since 1995. Null sets are common in free school sets (about 40% null sets), but less frequent in sets on FADs (about 4%).
A small number of supply vessels is involved in the fishing operations of these fleets (11 vessels in total). Currently no logbook data are available for supply vessels, but there are projects to put observers on these vessels for data collection. An observer programme (as part of EU's ESTHER (Efficacité des Senneurs Thoniers et Efforts Réels) research programme) has been established to collect information from one supply vessel, and the results will be reported in the next WPTT meeting.

A marked difference from year to year was pointed out in the mean weight of yellowfin tuna caught from free schools. These differences might be the result of changes in the fishing grounds or changes in the species composition of the schools, as free-swimming schools of mixed species might be composed of smaller fish than single-species schools.

Review of Longline Data

As described in WPTT/00/02, Taiwan,'s deep-sea tuna longline fishery commenced in the mid-1950s and had expanded extensively in the three Oceans by the 1960s. In 1999, Taiwan's longline fleet was composed of 341 vessels in the Indian Ocean, about the same level as in 1998. Most of those vessels (299 boats) are larger than 200 GRT. The total

[1] These are vessels belonging to French and Spanish companies but flying a flag of a non-reporting country.

Table 1. *Total catch (in t) and effort (in fishing hours) for the purse-seine fleet of European origin.*

	Spain		France		EU NEI	
	Effort	Catch	Effort	Catch	Effort	Catch
1981			87	372		
1982			263	2,063		
1983			1,475	20,089		
1984	1,713	18,802	4,936	66,587	1,414	17,070
1985	2,846	38,549	5,858	73,817	1,260	15,558
1986	2,634	40,983	5,442	86,617	539	11,623
1987	2,938	59,215	4,929	89,563	416	10,770
1988	3,331	91,565	5,293	102,335	559	15,780
1989	5,164	111,012	5,106	85,068	647	13,162
1990	5,006	96,666	4,659	78,990	994	24,152
1991	4,324	92,923	4,308	83,838	1,134	24,586
1992	4,296	89,629	4,598	95,556	1,049	20,139
1993	4,565	105,385	4,711	93,057	1,833	34,876
1994	4,463	112,433	4,648	99,909	1,950	47,115
1995	5,221	147,524	4,831	95,918	1,795	45,372
1996	5,793	139,134	4,574	82,932	2,014	39,999
1997	6,407	141,024	4,603	70,866	3,371	52,733
1998	5,644	108,725	4,329	59,572	3,229	58,972
1999	5,224	142,426	3,838	82,136	2,969	72,868

catch made by these vessels in 1999 was preliminarily estimated at 99,000 t, a decrease of about 11,000 t from 1998 level. Catches of bigeye tuna, yellowfin tuna, albacore and swordfish in 1999 were estimated at about 37,093 t, 17,686 t, 22,514 t and 14,727 t, respectively. The drop in the catch of yellowfin tuna was the main cause of the decrease relative to the previous year. Although the catch of bigeye tuna in 1999 has also decreased from the 1998 level, it was still higher than in years prior to 1998 due to the high level of fishing effort directed to bigeye tuna. There has been an intense effort on data collection and active research on the main species caught by this fishery. It was noted that information on the mean number of hooks between floats used by Taiwanese longline boats is available from data recorded in logbooks since 1995.

The importance of swordfish catches by Taiwanese boats was also noted by the Working Party, especially in areas off the coasts of Somalia, south of Madagascar and west of Australia. It is possible that some Taiwanese boats have been targeting swordfish instead of tunas in the last years.

As described in document WPTT-00-07, the Japanese longline fleet started operating in the Indian Ocean in 1952. The effort of the fleet has increased since 1971, to reach a peak in 1985 (127 million hooks). Thereafter, the effort dropped to about 50 million hooks in the early 1990s. The effort peaked again in 1996 to 126 million hooks with a new reduction of 20-28% during the past five years. The fleet concentrates its activities off South Africa and southwest Australia during the second and third quarter of the year, and to the west and south of Indonesia during the remainder of the year. The catch of the fleet peaked in 1985 at 50,000 and again in 1998 (45,000 t). Recently, four major species (yellowfin, bigeye, albacore and southern bluefin tunas) have accounted for 90% of the catch.

A major Japanese purse seine fleet also operated in the Indian Ocean. In the early 1990's, the activity of the fleet has concentrated in the western tropical area. Effort peaked in 1992 (at 2,400 days) and declined drastically to 781 days in 1996. This reduction seems more related to economic reasons rather than to inadequate catch. The fleet traditionally targets log- and FAD- associated schools. The total catches in weight show a similar trend to the effort, with a peak in 1992 (45,000 t), and decreasing to 7,000 t in 1999. The catch composition by species was 22% yellowfin, 65% skipjack and 13% bigeye for 1999. In recent years, only a few purse seiners have been operating in the Indian Ocean.

It was pointed out that the set of data presented do not include catches by Japanese boats between the 141° and 150°E, but do include data to the south of FAO areas 51 and 57.

During the last few years, there has been a reduction in the catches of bigeye tuna, coupled with an increase in catches of yellowfin tuna. This trend does not seem to be only related to a reduction in the bigeye tuna abundance; it might also be a consequence of a change in targeting practices.

The operation of 30 longliners belonging to the company Perikanan Samodra Besar (PSB) in Benoa (Indonesia) is reviewed in document WPTT-00-13. Logbook data were retrieved from 1978 to 1995. The mean number of hooks per set is between 1,000 and 1,200. The data from the fleet were split into deep and regular longliners, depending upon whether less than seven (shallow longline) or seven or more hooks between floats (deep longline) were used. Bigeye tuna is the main species caught by deep longlines while yellowfin makes up most of the catch of regular longlines. Other species caught were albacore tuna, southern bluefin tuna, billfish and sharks. Since these vessels started their operation, most of their catches have been in the eastern Indian Ocean.

The author also presented a general description of tuna fisheries in Indonesia. In the eastern Indian Ocean, tuna and tuna-like species are caught using gill nets, purse seines, troll lines and longlines. The species caught are mainly skipjack tuna (gillnet, purse seine, seine and troll line), yellowfin tuna (gillnet, purse seine, troll line and longline), bigeye tuna (longline), and other tuna and tuna-like species.

The lack of statistics for the Indonesian tuna fisheries for the last years, especially size-frequency data, was noted. It was mentioned that few size-frequency statistics have been collected in Indonesia since the end of the sampling programmes implemented by IPTP. However, it was also noted that size-frequency data are being collected through a joint research programme between RIMF (Indonesia) and CSIRO (Australia).

It was noted that the data presented in the document were from a single company (PSB), whose boats might be operating differently to vessels from different companies. Therefore, these data cannot be used as a basis for the calculation of the species composition of Indonesian longliners, as they may not adequately reflect the species composition of the total longline catches. However, it is likely that the species composition of the PSB deep longliners reflect those of the other Indonesian deep longliners.

Catches from both Indonesian and some Taiwanese longline boats have been recorded in Indonesian statistics. This needs clarification if double counting is to be avoided.

Document WPTT-00-Inf3 discusses the landings during 1999 of longline vessels with base ports located in the eastern Indian Ocean, as estimated from data recovered by the Secretariat and from the IOTC Sampling Programme in Phuket, Thailand. These vessels target fresh tuna for export to sashimi markets. The document reviews the data generously provided by two shipping agencies dealing with tuna longliners. The information obtained includes the individual weight, species and destination of all specimens unloaded per boat and landing throughout the year 1999.

About 36,000 specimens weighing in total more than 1,300 t were monitored. Bigeye and yellowfin tuna account for more than the 80% of the total landings (in number and weight). Other species recorded in the landing are swordfish, Indo-Pacific blue marlin, striped marlin, black marlin and albacore tuna. Catches per species, month, boat, landing and destination of the fish in the landing are presented, as well as the mean weight and size distributions of the species in the catch.

The importance of the data retrieved from processing companies was highlighted, and the recovery of more historical data by the Secretariat encouraged.

Review of data on the environment

The effects of the recent La Niña event on the dynamics of the purse seine fishery in the Indian Ocean are discussed in document WPTT-00-17. This document completes a similar analysis made after the 1997-98 El Niño and presented at the last WPTT Meeting (document WPTT-99-03). These two events form opposite phases of the ENSO cycle; however, a La Niña event does not necessarily follow an El Niño event. The occurrence of both events within the last three years was therefore a good opportunity to compare the fishing patterns. In the area 0° - 10°S, which encompasses a large fraction of the purse-seine fishing grounds, El Niño causes positive sea-surface temperature (SST) anomalies and a deepening of the thermocline in the western equatorial area, and negative SST anomalies associated with a reduced mixed layer in the eastern Indian Ocean. During La Niña, the equatorial area does not exhibit significant anomalies, and the environmental pattern is rather similar to normal conditions. The negative SST anomalies associated to La Niña are only observed in the south tropical region (20°S to 25°S), which is outside the surface fishery area. The outstanding feature of the last three years is an extension of the fishery area out to 100°E during the full development of El Niño, and a quick return to the classical western fishing grounds during La Niña. The CPUE indices for unassociated schools exhibited two lows, in 1992 and 1998, that coincide with strong warming events in the Indian Ocean. Conversely, CPUE values increased again in association with La Niña. It is likely than these indices reflect changes in catchability rather than in abundance. Along the 1992-1999 time series, the spatial dynamics of the fishery can be fairly well explained by some climatic indicators, such as the zonal wind stress and the sea level height deviation. These parameters could be integrated in population dynamics models incorporating habitat indices.

It was noted that this type of work is important for understanding the development of the fishery, and that it would be of much interest to perform similar studies using longline data. It was observed, however, that the problems associated with computing CPUE for longliners operating in the Indian Ocean would first have to be dealt with.

The authors of this document also offered some brief comments about the development of a consolidated database of oceanographic information for the Indian Ocean. Unfortunately the development was not completed in time to be presented in this session of the WPTT, but it should be discussed during next year's WPTT meeting.

Review of data on predation by marine mammals

Predation by killer and false killer whales on Japanese longline fisheries is discussed in documents (WPTT-00-23 and WPTT-00Inf.7). The Fisheries Agency of Japan has conducted surveys of predation in longline fisheries in 1954, 1958, and from 1965 to 1981. A new predation survey started in September, involving about 450 Japanese longliners operating in three oceans (including the Indian Ocean). The authors described the form used to collect data (document WPTT-00-23) in this new survey. Previous surveys had indicated that predation is a significant problem for the Japanese longline fisheries. During the period 1977-1981, the catches damaged by predation in the eastern Indian Ocean were as high as 34% for bigeye, 26% for albacore and 29% for yellowfin, with an average of 24% for all tunas.

It was noted that predation problem affects all longline fisheries and is serious, representing losses of up to 20-30% of catches, with an average of 11.6% in the central western Pacific and 18% in the eastern Indian Ocean. Currently, there is no information regarding size selectivity of the predated fish. Given the high rate of predation, this would be an important issue for research, as it would have a noticeable effect on the estimation of removals for certain species. It was remarked that the Japanese official statistics for longline catches do not include predated fish. The Seychelles Fishing Authority (SFA) indicated that collection of information about predation rates in longliners has started, and results of the surveys will be presented to the WPTT meeting next year.

General discussion on data related issues for tropical tunas

The First Meeting of the WPTT identified a number of problem areas in the data situation for tropical tunas. These included:

- Poor knowledge of the catches, effort and size frequency from small LL vessels flying flags of convenience.
- Lack of catch, effort and size-frequency data for the Indonesian longline fishery in recent years.
- Lack of size-frequency data for the whole period of operations for the Korean longline fishery.
- Lack of catch (since 1997), effort (since 1994) and size-frequency (since 1988) data for the Taiwanese longline fishery.

In the specific case of the skipjack tuna, there was concern about the lack of reporting from important artisanal components of the fisheries directed to this species, such as those of the Maldives.

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

A better level of catch reporting: Catches and catch-and-effort information have been obtained concerning the activities of Taiwanese vessels. Maldives has provided catch and catch-and-effort information and will submit size-frequency information shortly. Philippines has provided information on the activities of its vessels in the Indian Ocean.

An improved Vessel Registry: Better 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 a very important element in the estimation of the catches of the NEI component.

Improved estimation of the NEI component: Two components are included under the NEI category: a) vessels whose activities are monitored under regular sampling programmes, such as the EU PS vessels under non-EU flag and b) vessels that are not monitored closely under any statistical system, such as small LL vessels operating under different flags or large LL (> 100 GRT) flying flags of non-reporting parties. A considerable effort has been spent in obtaining a better estimation of the second component and, as a result, the total catch of tropical tunas, in particular of bigeye and yellowfin tunas, is better known.

Improved estimation of Indonesian longline catches: New estimates were carried out during the last year regarding the historical series of catches of Indonesian longliners in the Indian Ocean based upon data on the landings of longliners in Benoa provided by the CSIRO/RIMF sampling scheme. Nevertheless, work is still needed to improve the estimation of catches from other fisheries in the country, for which only aggregated data have been reported since 1995.

Recovery of historical activity and size data from processing plants: At unloading points for small LL vessels, processing plants record individual weights for all the fish processed. Cooperation has been established with some of these operators and the Secretariat has been able to obtain copies of records for recent years covering about 36,000 specimens. Efforts to recover more of this information will continue. These historical records are an important source of information, which in some cases could go back as far as the 1970s and provide information about total catch for a fishing trip and also the size-frequency and species composition of the catches.

IOTC sampling programmes: Sampling programmes have been initiated in Thailand and Malaysia through cooperative arrangements between the Secretariat and national institutions, with the objective of obtaining information about size-frequencies, fishing operations and the total number of vessels operating from Phuket and Penang. Activities have focused on recovering past information, interviews with fishing masters and sampling of unloaded catches (about 15,000 fish have been sampled to date in Phuket). Contacts have been initiated with Indonesian and Mauritian authorities to explore the possibility of initiating similar activities in their ports.

Korean size-frequency data: Some size-frequency information has been obtained from operation of vessels from Korea. However, sample sizes are very small and no other source for this information has been identified to date. It is not clear at this time whether further data exist and this will remain a problem for any analysis that would require size information for bigeye and yellowfin tuna.

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 China(Taiwan)). Uncertainty remains for large NEI LL vessels, especially for the period 1988-1997. Artisanal catches are uncertain, although they are not considered large, with the possible exception of the gillnet/longline and other coastal fleets where the catches are reported under other species groups.

CE data: Well known in the purse-seine fisheries and the main longline operations (Japan, Korea and China (Taiwan)). Unknown for NEI longline vessels.

SF data: Data from 1999 and part of 1998 from the EU PS sampling is considered preliminary. Low sampling coverage from Japan and Korean in recent years. No SF data available from Taiwanese vessels since 1989. Little information is available on important artisanal catches (e.g. Oman, Pakistan, Comoros).

Skipjack Tuna

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

CE data: Relatively well known in the purse-seine fisheries. Little is known from the artisanal fisheries with the exception of Maldives.

SF data: Data from 1999 and part of 1998 from the EU PS sampling is considered preliminary. Information from artisanal fisheries is poor (with the exception of Maldivian BB catches and gillnet catches from Iran). There are significant catches from gillnet (Sri Lanka) and unclassified gears (Indonesia) for which no size information is available.

4. Yellowfin Tuna

Review of New Information on Yellowfin Tuna

Document WPTT-00-11 described a preliminary genetic analysis of the structure of the yellowfin stocks in the Indian Ocean. This study had been proposed by the National Research Institute of Far Seas Fisheries (NRIFSF) of Japan, and approved and recommended during the seventh Expert Consultation on the Indian Ocean and the IOTC Scientific Committee meeting in 1999. The main objective of the study was to determine whether two or more stocks of yellowfin existed in the Indian Ocean. A total of 996 tissue samples of yellowfin tunas have been received from several fishing agencies and offices, and more samples are still expected. The current study used two selected samples, taken at the westernmost and easternmost parts of the Indian Ocean. The results from the genotype comparison of the two samples indicated either the existence of a single homogeneous stock of yellowfin across the Indian Ocean or, if the stocks are heterogeneous, they cannot be discriminated with the mitochondrial DNA markers examined. Further analyses are intended, both of different samples and using different markers,.

Document WPTT-00-Inf4, a publication from 1996 on age and growth of yellowfin tuna in the western Indian Ocean based on otolith microstructure, was briefly discussed. The study analyses the deposition rate on the otoliths of 151 yellowfin tunas caught by French and Mauritian purse seiners and estimates a growth curve.

The growth curve obtained in this study is a one-stanza growth curve, rather than the two-stanza growth curve which has previously been reported for the Atlantic and Indian Ocean. Growth rates obtained in this study are consistent with those estimated for Pacific yellowfin tuna.

It was noted that differences occur frequently between the growth curves estimated from size frequency and otolith deposition data, and results from both types of studies may be difficult to consolidate. In addition, it was noted that the number of fish used in the document is relatively small.

A study on the biology of yellowfin and bigeye tunas in the eastern Indian Ocean was presented in document WPTT-00-30. The study reported size distributions; length-weight relationships and von Bertalanffy growth curve parameter estimates for both species, from samples take aboard a research vessel and Japanese purse seiners. The results indicate a growth rate of about 3 cm/month for yellowfin of one-year of age, and 2.8-2.9 cm/month for bigeye of the same age.

It was observed that the growth rates of yellowfin and bigeye seem to be very similar, and that the values reported in this study for yellowfin tuna agree well with those reported for other areas of the Indian Ocean.

It was noted that data from the tagging experiments previously carried out by the JApan MArine Resources Research Center (JAMARC) of Japan, which have not yet been analysed, should also produce additional insight regarding growth rates of yellowfin tuna. It is hoped that the results of this experiment will be reported at next year's meeting.

Document WPTT-00-05 reviewed the relationship between the distribution of yellowfin tuna caught by Japanese longliners and environmental factors, in particular temperature and dissolved oxygen. The paper concluded that (a) the optimum water temperature for catching yellowfin tuna is from 13 to 24°C; (b) the minimum dissolved oxygen at the catching depths is 1 ml/l; and (c) the depth of the upper limit of optimum water temperature (24°C) was 80 m in the equatorial region, but shallower towards the north and south. The depth of the lower limit of optimum water temperature (13°C) was about 200 m in the equatorial region, and deeper towards the north and south, reaching about 300-400 m at 20°S.

It was noted that this type of study provides important information for estimating standardized effort, and it is recommended that similar studies be performed for the purse seine fisheries.

Document WPTT-00-06 reviewed some population parameters and the feeding habits of yellowfin tuna in the Oman Sea. Yellowfin tuna constitutes about 17% of the fish landings in the Persian Gulf and Oman Sea. About 7,000 specimens caught with gillnets and about 400 specimens caught with purse seines were examined. The modal size of the specimens caught by gillnets was 80 cm, while the modal size of the specimens from purse seines was 90 cm. Von Bertalanffy growth parameters (K=0.42 y^{-1}, L_∞=189 cm and t_0=0.23 y), length-weight relationship (isometric) and total and natural mortality rates (Z=1.85 y^{-1} and M=0.6 y^{-1}) were estimated. Regarding feeding habits, the study indicated that a large percentage of the stomachs were empty (about 60% for males and females combined). For the remainder, the gut contents were dominated by squids, followed by fish and, to a lesser extent, by crabs.

It was noted that the values of K and L_∞ are very similar to those presented in WPTT-00-30. Both studies estimated growth by analysing size-frequency distributions. It was noted that the estimate of total apparent mortality may include a component due to the decreasing selectivity on larger fish by gillnets, and thereby it may overestimate the true total mortality.

The modal size of the yellowfin tuna in the study area corresponds to middle-sized yellowfin, which are under-represented in the size frequency distributions of purse seine and longline catches in the western Indian Ocean. It may be that yellowfin tuna migrate between the two areas. If so, this factor may also contribute a component to the estimated total apparent mortality rate. A tagging experiment would help to clarify this issue.

Document WPTT-00-04 presents a GLM approach to standardizing CPUE for yellowfin tuna for the Spanish purse seine fleet. The study uses logbook data from 1994-1997 in conjunction with skipper interviews that provided information on technical equipment on board purse seiners. Standardized CPUEs were estimated using standard factors such as type of school, area and season, as well as technical factors that may affect the catchability. In this latter group, factors such as net surface, use of radar and sonar, boat speed and skipper experience were considered. The study concluded that year and season were the most significant factors, confirming a strong dependency of recruitment on seasonal and oceanographic conditions. Log school catch was also an important factor and it always appeared with a negative coefficient, as expected, because this variable was entered as an indication of targeting. Sonar was a significant factor in some analyses, as also was skipper experience. The only factor that was not significant was the use of bird radar.

In discussion of this document, the conclusion that radar was not a significant factor was considered surprising, as it seems to contradict previous simulation studies. However, it was observed that similar studies in the Eastern Pacific Ocean had not shown significant effects for the use of radars, at least for the first five years. This suggests that there may be a learning effect associated with efficient use of the radar. On the other hand, it was argued that bird radars were introduced in the early nineties, so by now most skippers should be well familiar with their use. Factors like the skill of the skipper in using radar, which obviously would influence the efficiency of the device, are very hard to quantify. It may be that some of the radar effect has been captured in the skipper factor.

In this study, effort was measured in terms of fishing time, regardless of whether the effort was targeting FADs or schools. It was suggested that further analyses be carried out using different measures of effort. For example, one possible means of dealing with the targeting problem is to restrict the analysis to areas and seasons in which free schools predominate.

Document WPTT-00-10 presented the results of a GLM standardization of CPUE of adult yellowfin tunas in the Japanese longline fishery of the western Indian Ocean. The study used longline logbook data from 1975 to 1998. The western Indian Ocean was subdivided into four subareas, which were included as factors of the model. Additional factors were the type of gear, year and season. It was noted that the fitted GLM only explained a relatively low proportion of the variance. While bearing this in mind, the paper also reported that:

1. The factors most affecting nominal CPUEs in order of importance were area, number of hooks between floats, season, year and the interaction between season and area.
2. After a peak in 1977, the standardized CPUE shows a sharp decrease until 1980, after which it becomes stable (with a small reduction in 1988).
3. The catch rates in most recent years (1995-1998) have stabilized at the lowest levels observed during the period 1975-1998.

It was noted that in this, as in other studies of standardized longline CPUE over periods since the start of the fishery, there is a lack of coherence between the trends in nominal catches and the standardized CPUEs. During the first part of the period, when catches were low, both nominal and standardized CPUES fell sharply, while during the most recent years, when catches have increased sharply, the standardized CPUEs have been relatively stable. Two possible reasons for this were proposed. First, the standardization may not yet adequately deal with changes in target species which have occurred over the years. Another possibility is that the standardization method does not take account of additional environmental factors that may affect abundance and recruitment.

Document WPTT-00-26 presented estimates of GLM-standardized CPUE for yellowfin tuna caught by the Taiwanese longline fishery in the Indian Ocean from 1967 to 1998. These were used to consider the status of the stock. The results indicate that the standardized CPUE was highest in 1968 and gradually decreased until 1979, after which it stabilized. The paper considered the hypothesis of the existence of a western and eastern stock, but concluded that the most likely possibility was of a single stock having similar CPUE trends and density distribution.

When considered together, the three documents (WPTT-00-04, WPTT-00-10 and WPTT-00-26) seem to indicate some general patterns in the standardized CPUE of yellowfin tuna in the Indian Ocean:

1. It was observed that the standardized CPUE for yellowfin for both the Taiwanese and Japanese longline fleets showed some similarities. In both fisheries, there are remarkable peaks in 1977 and 1993. It was also suggested that the peaks in CPUE might be related to ENSO events, although further analysis would be needed to corroborate this.
2. All three analyses suggest that the standardized CPUE has been relatively stable for about the last fifteen years, although certainly at lower levels than in earlier years. At least from this information, there is no evidence that yellowfin tuna are overfished.
3. The apparent stability of recent standardized CPUEs contrasts with the recent rapid increase in total catches. This suggests that the current methods of CPUE standardization might not yet be producing reliable measures of relative abundance.

It was suggested that there is a strong need to take account of environmental factors during the standardization of CPUE, and other factors, such as market price of the target species, may also to play an important role.

During the meeting, there was a presentation on PROCEAN, which gives a statistical structure in a Bayesian context to a standard multi-fleet generalized production model. The model takes simultaneously into account the catchability evolution by fleet and the stock status. In this way, the approach consists in integrating the fishing effort standardization (with potential use of additional factors) into the stock assessment model. Results of applying the model to a data set for the Indian Ocean yellowfin tuna fishery were presented. Once parameters have been estimated with a maximum likelihood approach, the model is used to estimate the stock status, the overall effective effort targeting skipjack and the catchability trends by fleet. Estimated trends in fishing power are consistent with current knowledge. The comparison of different formulations and complexity levels of the models helps to better understand the fishery dynamics.

Document WPTT-00-16 addresses the problem of developing a simple indicator of the status of a fishery when effort data is not available (or, as is the case for the Indian Ocean fishery, when effective effort on the target species is hard to estimate). The study found that yellowfin catches in the Indian Ocean have increased steadily since 1984, reaching a maximum of 376,000 t in 1993. After this, they declined up to 1998, when the total catch of yellowfin was about 250,000 t. During the mid-eighties, the main fleets exploiting yellowfin tuna in the region were longliners from Japan, Taiwan, Province of China and Korea. The model proposed in the document suggests that the MSY under recent fishing patterns may be around 307,000 t. As was also the case with skipjack tuna, the recent expansion of the fishery towards the eastern Indian Ocean could possibly lead to larger MSY levels. Under current fishing patterns, however, it may be that catch levels similar to those in 1993 (i.e. about 376,000 t) are not sustainable.

In discussion, it was suggested that the estimates calculated using the proposed method do not really estimate the true MSY; rather they are estimates of equilibrium yields and the true MSY may be larger. On the other hand, however, if the estimates calculated using this method is taken as estimates of the true MSY, this could considered as equivalent to adopting a precautionary approach. It is suggested that this method needs to be subjected to considerable testing using simulated data before its properties are fully understood. Nevertheless, in cases where effort cannot be estimated reliably, it may provide a very useful alternative indicator.

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 275,000 t (all gears combined) in 1998 (Figure 1). 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 have remained stable, while those by purse seines have continued to increase.

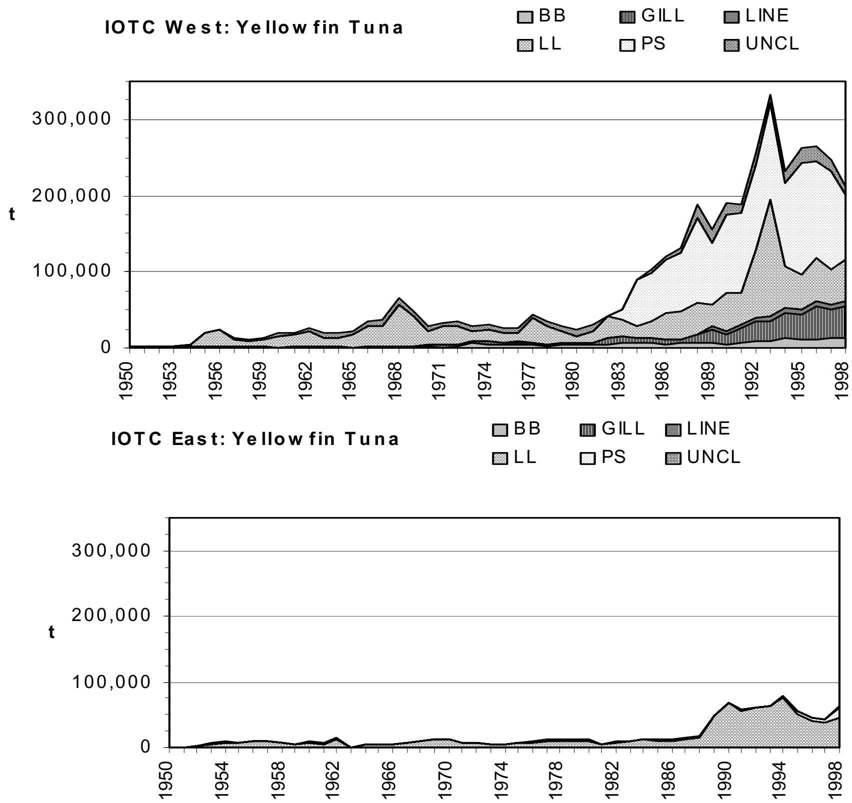


Figure 1: *Recent trends in catch of yellowfin tuna by gear in the western (upper panel) and eastern (lower panel) Indian Ocean*

Recent Trends in Fishing Capacity in the Western Indian Ocean Purse-Seine Fishery

In 1981, some of the purse seine vessels originally fishing in the Atlantic Ocean shifted their activities to the Indian Ocean. Since then, there has been a fast and steady increase in the number of purse seine vessels in the area, and this has become the dominant gear. The number of purse seine vessels peaked at 58 in 1997, with a total fishing capacity of about 56,000 t. Starting Since 1997, there has been small reduction in the number of boats to a total of 52 vessels with fishing capacity of about 51,000 t in 1999 (Figure 2).

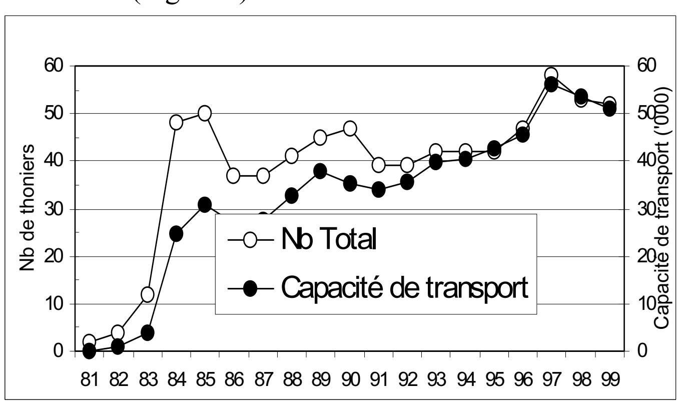


Figure 2. *Trend in fishing capacity in the purse-seine fishery.*

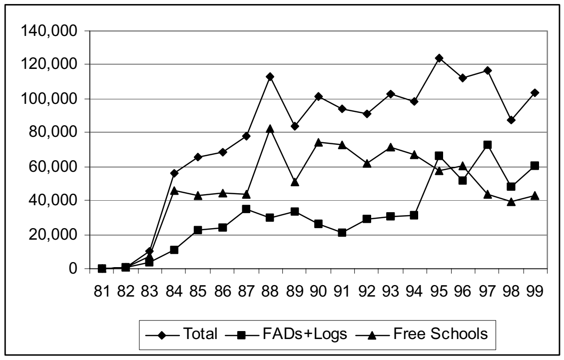


Figure 3: *Trend in purse-seine catches of yellowfin tuna by fishing mode.*

Recent Trends in Catches in the Western Indian Ocean Purse-Seine Fishery

Since 1982, purse seine catches in the Western Indian Ocean have increased rapidly to a maximum of about 124,000 t in 1995, after which they decreased, although the provisional data for 1999 may indicate a change in this recent trend (Figure 3). Catches on free schools have been decreasing, while the proportion of catches from floating objects has increased steadily.

Recent Trends in Effort in the Western Indian Ocean Purse-Seine Fishery

Purse seine effort increased rapidly between 1981 and 1985, after which it increased steadily up to a peak in 1997, after which it decreased slightly (Figure 4). It is important to note, however, that the number of sets on free schools has remained quite steady since 1984, whereas the number of sets on floating objects (most of which are FADs) has increased continually since 1981. Sets on floating objects have been the dominant type of set since 1996 (Figure 5).

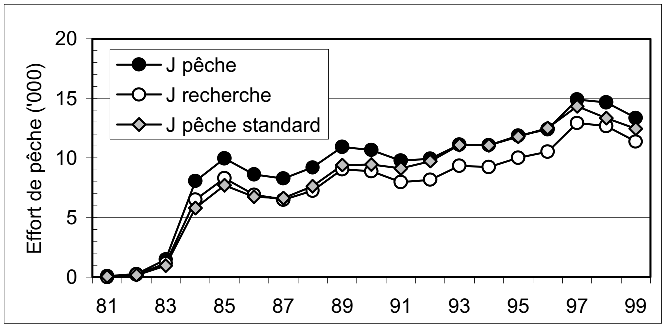


Figure 4. *Trend in fishing effort for the main purse-seine fleets.*

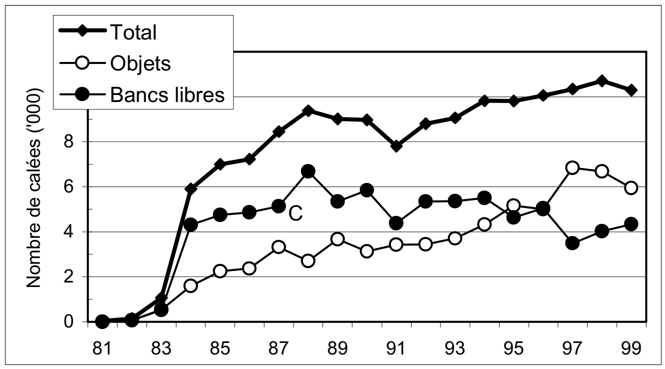


Figure 5*. Trend in the number of sets by set type in the main purse-seine fleets.*

Stock Status Indicators

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

1) Standardized CPUE for the Japanese and Taiwanese longline fisheries indicates a reduction to historically lowest levels in recent years, but it seems to have either remained stable or decreased slightly over the last 10-15 years (see Figures 6 and 7).

   For the purse seine fishery, nominal total CPUE has remained relatively stable since around 1987, although there has been a decrease in recent years. During that period, nominal CPUEs on free schools have tended to decline, while those on FADs have increased (Figure 8). It is important to note, however, that the values of nominal CPUEs have not been standardized, nor are they corrected for likely increases in efficiency. Figure 9 shows the same data after correction for an assumed 3% annual increase in efficiency (for all set types). Even with this correction, the trends shown do not give rise to particular concern.

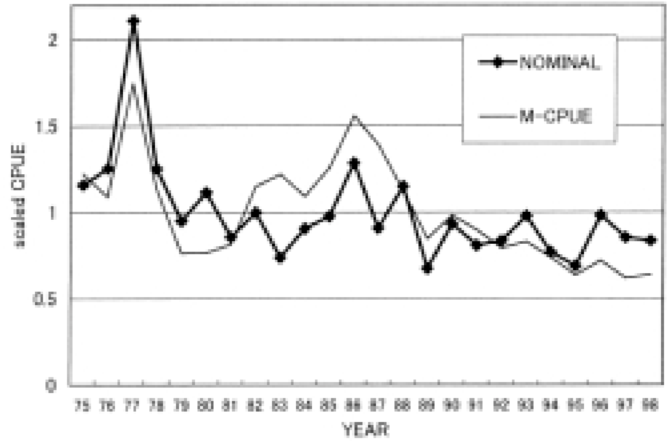


Figure 6. *Standardized and nominal CPUE for the Japanese longline fishery (from WPTT-00-10).*

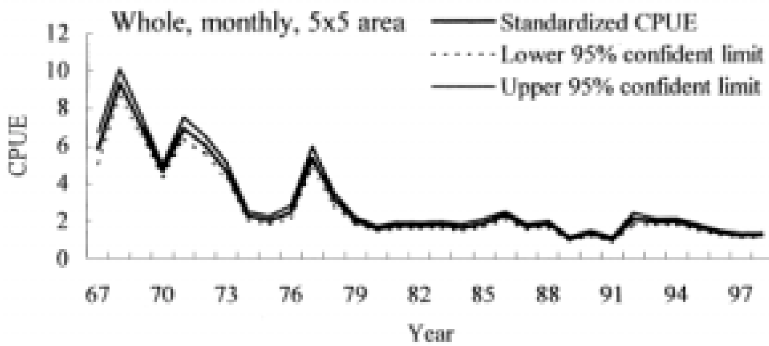


Figure 7. *Standardized CPUE for the Taiwanese longline fishery (from WPTT-00-26).*

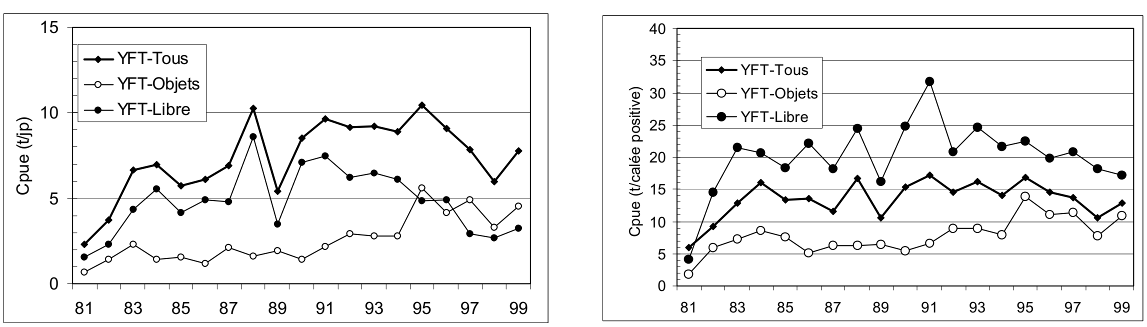


Figure 8. *CPUE for the main purse-seine fleets.*

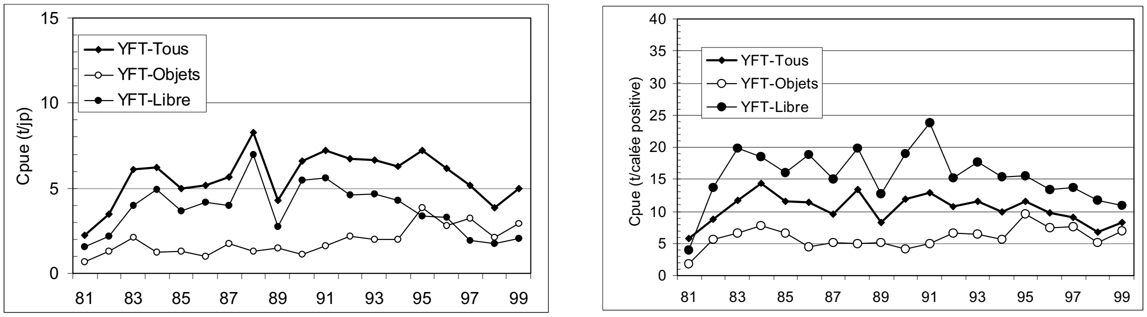


Figure 9. *Purse-seine CPUE with effort efficiency assumed to increase by 3% each year since the beginning of the fishery.*

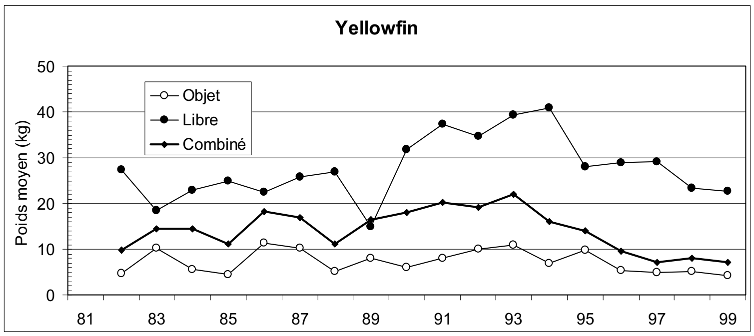


Figure 10. *Average weight of yellowfin tuna in the catch of the main purse-seine fleets.*

2) The average weight of yellowfin caught on school sets increased until 1993, after which it has been declining, while the average weight of fish caught on objects has remained relatively stable, perhaps with a slight tendency to decrease (Figure 10). When both type of sets are taken together, the tendency in recent years is towards catches of smaller average weight, but this probably reflects the increased proportion of sets on floating objects during the past few years.

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

4) Using the methods of document WPTT-00-15 described above to analyse trends in total catches in circumstances in which effort has been continuously increasing, the maximum sustainable yields available under current fishing patterns may be around 300,000 t.

5) Yield-per-recruit calculations for yellowfin tuna in the Atlantic Ocean suggest that the optimum mean age-at-first-capture for these species is between 2.5 and 3 years, depending on the exploitation rate (Figure 11). Figure 12 illustrates the results of preliminary calculations for yellowfin tuna in the Indian Ocean, based on the size-at-age data reported in WPTT-00-Inf.4 and a natural mortality scheme similar to that assumed for yellowfin in the eastern Pacific (Figure 13). These calculations suggest that the critical age (the age at which, in absence of fishing, a cohort would reach its maximum biomass) would be around 2.5 years, which corresponds to an average weight of fish in the catch of 23 kg.

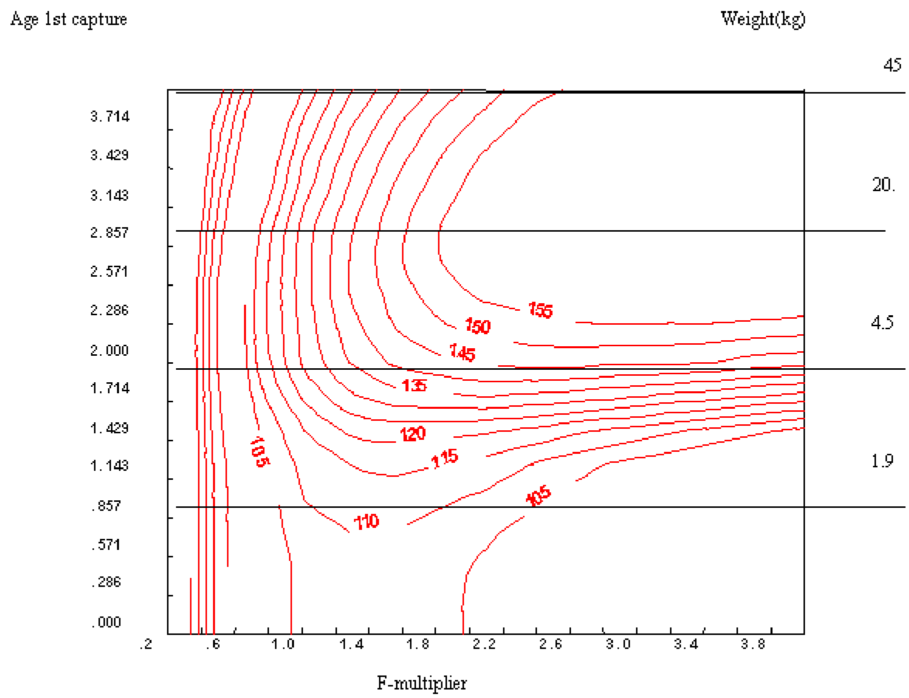


Figure 11. *Typical yield-per-recruit analysis for a yellowfin tuna (example with data from the Atlantic Ocean yellowfin tuna)*

Technical Advice

Considering all these stock status indicators, as well as the recent trends in effort and total catches of yellowfin, the Working Party considered that:

1) The current trend for increased fishing pressure on yellowfin of smaller sizes may be detrimental to the stock if it continues, as fish of these sizes are well below the optimum size for maximizing yield per recruit, based on analyses of the same species in the Atlantic.
2) If a time-area moratorium is imposed on purse-seine fishing on floating objects, with a view to reducing fishing mortality on juvenile bigeye tuna, it is likely to also have a positive effect for yellowfin tuna, as catches of juvenile yellowfin on floating object sets would also be reduced.
3) Total catches under current fishing patterns appear to have reached a plateau and they may now be at or approaching MSY. In these circumstances, any substantial increase in fishing effort should be avoided.

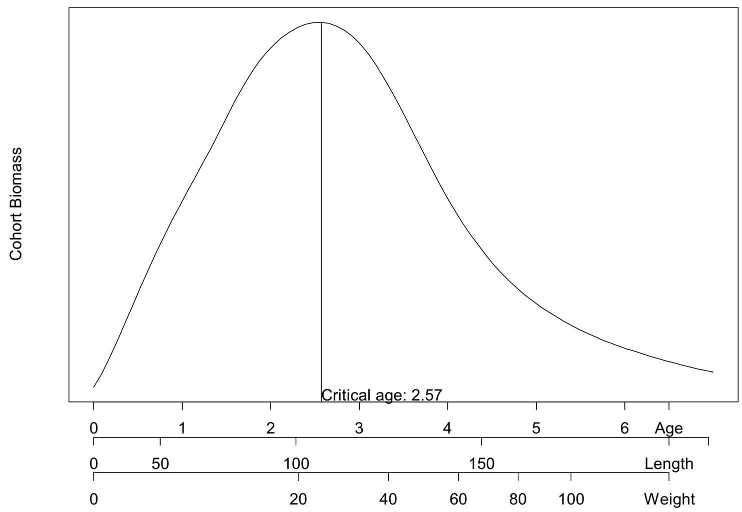


Figure 12. *Preliminary calculations on the critical age estimated for the Indian Ocean yellowfin tuna. Additional axes indicate the equivalent length and weight*

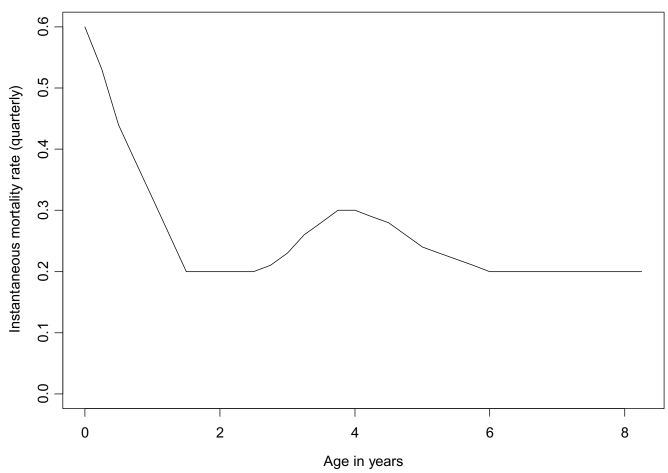


Figure 13. *Scheme of quarterly instantaneous natural mortality rate assumed in the calculations for Figure 12.*

5. Bigeye Tuna

Review of New Information on Bigeye Tuna

Document WPTT-00-01 presented some preliminary studies of age and growth of bigeye tuna in the western Indian Ocean, as investigated using both, otolith and first dorsal spine. Micro-increments, considered as daily depositions, were observed on transverse sections of sagittal otoliths of 154 bigeye tunas. A von Bertalanffy growth curve was estimated. The fish reaches 58 cm at 1 year, 91 cm at 2 years and 120 cm at 3 year of age. The growth was also studied by analysing marks on the first dorsal spine of 140 fish. For fish that are 1 and 2 years old, the results obtained with spines and otoliths are comparable, but they are different for older fish.

It was observed that the growth rate estimated in this paper is comparable to those found in the Pacific. It was also indicated that this growth rate seem to be slower than the one reported by Tankevich (1982), which was used last year for the estimation of catches-at-age. The Working Party suggested that a more detailed comparison between both studies should be done to better identify differences between them.

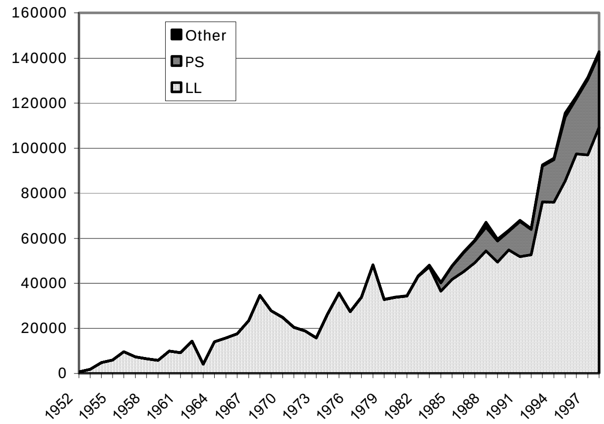


Figure 14. *Trend in catches of bigeye tuna (in t) in the Indian Ocean by major gear types.*

A length-at-age relationship for the bigeye tuna is presented in paper WPTT-00-30 (this document was also discussed in the section related to yellowfin tuna). It was noted that the lengths-at-age reported in this paper for bigeye tuna were smaller than those obtained by Tankevich (1982).

Review of indices of abundance

Results of standardization of bigeye tuna CPUE for the Japanese longline fishery using GLMs is presented in document WPTT-00-08. This updated a similar analysis presented last year.

It was agreed that the considerable jump in both the nominal and the standardized BET CPUE between 1976 and 1977 that was discussed last year and was still seen in the new analyses presented in WPTT-00-08, was unlikely to reflect a change in biomass of that magnitude in such a short time. Increases in the biomass of the yellowfin tuna ranging from 10 to 30% over a single year have been reported in other oceans. However, given that fewer age classes can be expected in LL caches of yellowfin tuna than of bigeye, it would be far more difficult for these changes to have occurred in the biomass of bigeye tuna over a single year.

As was the case last year, it was hypothesised that this jump in CPUE resulted from some factor associated with the gear or targeting that has not been accounted for in the standardization process. The Working Party proposed that additional factors should be incorporated into future standardizations, such as changes in environmental conditions. In the mean time, the Working Party agreed that the standardized CPUE should be corrected to remove the jump, as it was done in the previous meeting.

It was also recommended that in the future, a presentation of the residuals from the GLM as a function of time should be made to help in the interpretation of the results of the model

Production Models

Document WPTT-00-09 describes a stock assessment of bigeye tuna based on production modelling using the program ASPIC and the Japanese longline standardized CPUE and total catch by longline and purse seine fisheries. The analyses were carried out by fixing the B_1 ratio at a value of 2.0 and excluding the CPUE during the first five years (1952-56) because the trend during those years was assumed to be anomalous and unstable. Therefore, four combinations were used for calculation. For one of the four combinations, confidence intervals were estimated through a bootstrap procedure. The estimates of MSY derived from these analyses ranged between 45,000 t and 74,000 t. The predicted CPUE showed a declining trend. The B-ratio is approaching 1.0 in recent years and the F-ratio has already exceeded 1.0.

The value of MSY closely agreed with that of Okamoto and Miyabe (1996), in which catch and CPUE data until 1994 were included, but the current B-ratio was somewhat smaller, while the F-ratio was higher than in the previous study. Considering these results, the present catch level seems to be excessive and it is necessary to reduce the catch and monitor the stock more carefully.

The authors recognized that it is necessary to include purse seine catches in the stock assessment. The age composition of purse seine catches is quite different from that of longline catches, and the increase in purse seine catches changes the selectivity of the entire fishery. These changes cause a large bias in a simple stock assessment such as that using a production model. In consequence, it is desirable in future studies to conduct analyses by using age-structured models.

In response to a comment on the adequacy of assuming a Schaefer model for the dynamics of the population, the authors mentioned that this was a preliminary study and that further research will be carried out on this subject.

An application of an age-structured production model was presented in the document WPTT-00-25. This document also includes GLM-based indices of abundance for the Taiwanese, Japanese and Korean longline data. The results suggest that the yield for the most recent year in the assessment (1996) is close to the MSY estimated with the age-structured production model (about 116,000 t).

In response to a question about the assumed selectivity of the purse seine fishery, the author noted that the catches of bigeye tuna by purse seiners have been assumed to be composed of fish of ages 1 and 2.

Concerns were also expressed regarding the value of the steepness parameter of the stock recruitment relationship, which suggested that the relationship was not very strong.

The Working Party also noted the large differences between the MSY estimated (116,000 t) in this document and that presented in WPTT-00-09 (45,000-74,000 t). Further research is necessary to clarify the reasons for such discrepancies.

In a general discussion concerning the application of production models, it was noted that a change in selectivity-at-age patterns would result in changes in the apparent productivity that cannot be well estimated by a standard production model. Such changes, which occurred as a consequence of the expansion of the FAD fishery on bigeye tuna, mean that the results of fitting simple production models should be interpreted cautiously.

The trends in the catches of bigeye tuna in the Atlantic and Indian oceans were compared. Large increases in the catches of bigeye tuna occurred both in the Atlantic and in the Indian oceans. It was also noted that catches in the Atlantic Ocean had remained more or less stable for three years, even though the estimated MSY was much lower than the observed level of catches, suggesting that there is still uncertainty concerning the actual MSY.

A number of suggestions for ways to improve the analyses were put forward by the Working Party:

- Environmental variables should be included as factors in the standardization procedure.
- As targeting of bigeye tuna by the longline fishery seems to be affected by market prices, the effect of including price information in the effort standardization procedure should be explored.
- Use of an age- or size-structured production model, which might better account for changing selectivity, could result in an improvement in the assessments.

Technical Advice

The Working Party did not consider any new technical advice relating to the status or management of bigeye tuna. Technical advice relating to time-area closures of the purse seine fishery on floating objects is given in section 7.

6. Skipjack Tuna

Review of New Information on Skipjack Tuna

A plan to study the genetic structure of skipjack tuna stocks in the Indian Ocean is proposed in document WPTT-00-27. The plan is to be coordinated and implemented between the National Research Institute of Far Fisheries (NRIFSF) from Japan, and the Marine Research Centre of the Ministry of Fisheries, Agriculture and Marine Resources of Maldives.

Tuna fisheries are the mainstay of the Maldivian economy, with skipjack contributing an average of 67% of the entire national fish catch and about 78% of the total tuna catch for recent years (1995-1999). There is great concern that the Maldivian skipjack catches would be negatively affected by the increased fishing effort on the species elsewhere in the Indian Ocean. Currently, the average size of skipjack caught in the northwest of the Maldives has declined. However, it is not clear whether this is due to changing oceanographic conditions or the high fishing pressure in other areas of the Indian Ocean. It is necessary to understand the stock structure in order to perform meaningful stock assessments needed to manage the resource and the genetic (DNA) studies of this plan would help elucidate this. The agencies implementing the study will request assistance (in the form of tissue samples of skipjack) from other regional fishing agencies and officers.

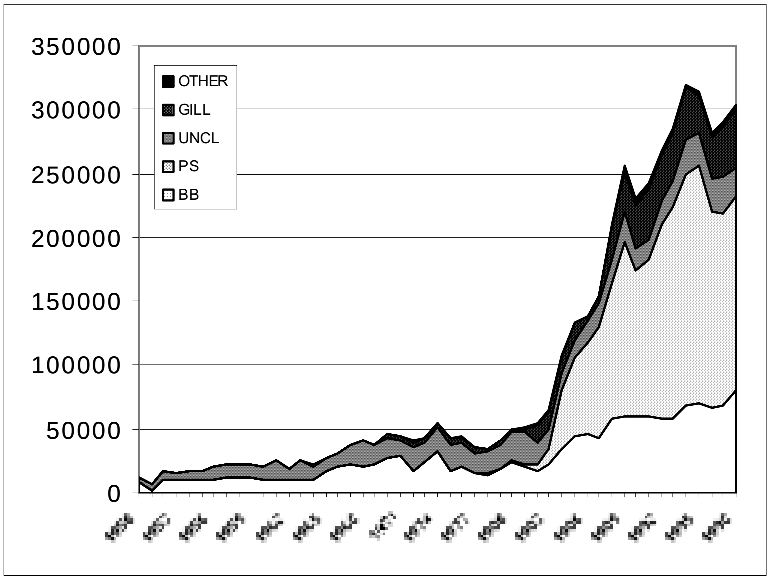


Figure 15. *Catches of skipjack tuna (in t) in the Indian Ocean by gear.*

It was observed that tagging studies previously made by IPTP and the Marine Research Section in the Maldives seem to indicate little exchange between the Maldivian stocks and those in rest of the Indian Ocean. However, it was generally agreed that this cannot be considered conclusive, as some of the tags were recovered off Sri Lanka and the fish tagged were mainly associated to stationary (anchored) FADs, which usually have a high retention rate. No oceanic specimens were tagged, so it is not possible to assess whether there is an influx of other stocks into the Maldivian basin. Finally, most of the recoveries came shortly after tagging, and this might not have been long enough to resolve exchange rates that usually take place over longer periods of time.

It was also indicated that historically, local catches of skipjack in the Maldives have increased several fold, and this certainly would have affected the abundance of a hypothetical local stock.

Document WPTT-00-21 discussed the growth rate of skipjack from tagging studies in the Maldives in comparison to those of the Atlantic and Pacific Oceans. This document also introduced a new software tool (PLOTREC) that can be used as a visualization aid to compare growth rates computed from tagging data to theoretical growth curves. The document indicates that the growth rate of skipjack in the Maldives seems similar to that of Atlantic skipjack (similar K, although a slightly lower L_∞), and is lower than those of the eastern and western Pacific.

It was observed that several studies (and in particular those that treat otolith deposition rates) seem to indicate that the growth rates of skipjack are highly variable, possibly with strong dependence on environmental conditions; life history; factors such as the location of the fish at the moment of tagging may have important influence in the apparent growth rate computed after recovery. However, in general it is agreed that even having an average growth rate can be useful for stock assessments.

Document WPTT-00-16 was reviewed again in relation to information regarding skipjack. The document indicates that skipjack catches in the Indian Ocean remained stable at around 50,000 t from the mid-sixties to 1983, most catches coming from Sri Lankan and Maldivian baitboats. After 1984, the development of purse seine fishing resulted in a continuous increase in catches, reaching a peak of 313,000 t in 1994, after which they declined to about 280,000 t. Based on the model presented in this paper, MSY for skipjack in the Indian Ocean is estimated to be about 288,000 t, but the estimate could be larger if new fishing grounds for skipjack are identified.

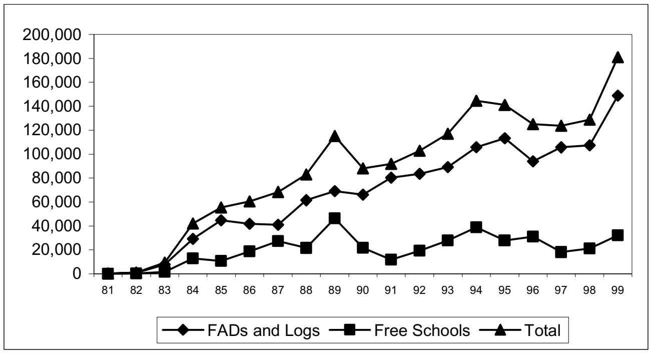


Figure 16. *Catches of skipjack tuna by the main purse-seine fleets by fishing mode.*

The Chairman provided a verbal summary of yet-to-be published research (Adam, S., MS. 1999. Ph.D. thesis, Univ. of London) on skipjack tuna caught in the Maldivian basin. The main relevant conclusions are:

- Standard methods used to estimate growth rates using tag-recapture data might be biased. In particular, they might underestimate K and overestimate L_∞. The main problem is that these methods do not take proper account of uncertainty in the age distribution of fish at tagging, or of the extent that the fish length at tagging differs from that predicted by the mean growth curve. Use of consistent growth parameter estimators suggests that the von Bertalanffy growth rate parameter K is likely to be in the range 1.0 – 1.5 y^{-1}, similar to that found for the South Pacific
- Catches and catch rates of skipjack in the Maldives have levelled off in recent years. It is not known, however, whether this reflects increasing levels of local exploitation or whether it is related to the development of a purse seine fishery for skipjack offshore. Some of the tagged fish released in the Maldives were recovered in Sri Lanka and in oceanic waters southeast of the Maldives, indicating some level of exchange between the high seas and local stocks. However, reliable estimation of the extent of interaction between the high seas and Maldivian fisheries requires that tagged fish be released in both fisheries.
- The results of a fitting of a production model to standardised Maldivian catch-and-effort data suggest that, if the skipjack tuna in Maldividian waters can be considered to be a closed population, then this population is probably close to being fully exploited or possibly overexploited..

Recent trends in fishing capacity

Until 1981, the fishery of skipjack tuna in the Indian Ocean was dominated by baitboats, with total catches remaining more or less stable around 25,000 t/year. For a general discussion of the trends in purse-seine fishing capacity, see the yellowfin tuna section.

Recent trends in catches

The increase in purse seine fishing has been accompanied with a general increase in total catches of skipjack, which peaked at about 320,000 t (all gears combined) in 1994, and was followed by a small reduction to about 305,000 t in 1998 (Figure 16).

The major component of the skipjack catch comes from the purse seine fishery. Figure 17 shows the trend of the catches of skipjack by set type for purse seiners. Catches from free schools have remained stable for the past years, while catches from floating objects have increased, particularly for the period 1998-1999. It should be noted, however, that catches for 1999 might need correction due to possible errors in the data collection.

Recent trends in effort

For a discussion of trends in effort in the main purse-seine fishery, see the section on yellowfin tuna.

Stock status indicators

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

1. Purse seine CPUE for skipjack declined from 1994 to 1997, but increased again 1997. In 1999, it seems to have reached levels comparable to those in 1994 (Figures 17 and 18).

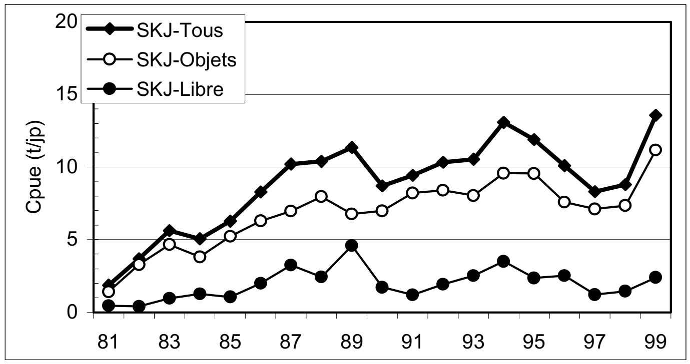


Figure 17 *. CPUE in tonnes per fishing day of skipjack tuna in the main purse-seine fishery.*

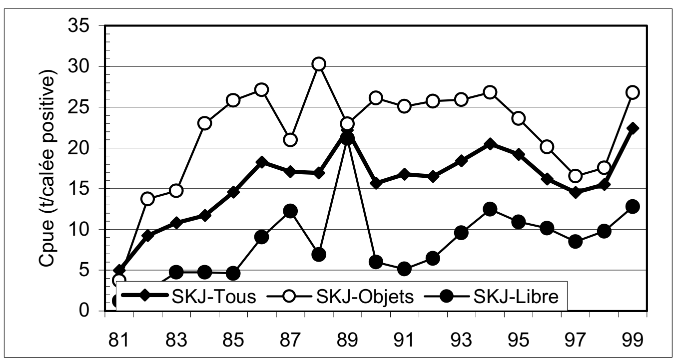


Figure 18 . CPUE in tonnes per positive set of skipjack tuna in the main purse-seine fishery

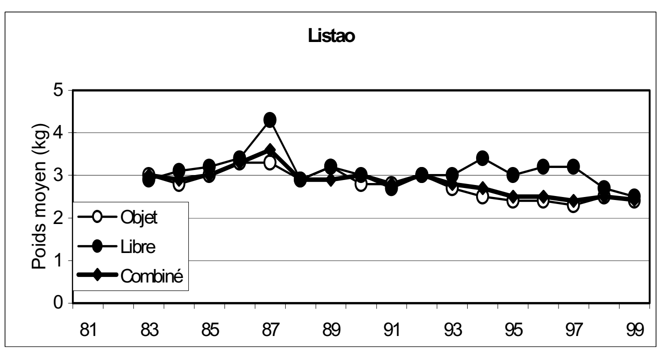


Figure19. *Average weight (in kg) of skipjack tuna caught in the main purse-seine fishery by different fishing modes.*

2. The average weight of purse seine skipjack catches has declined slightly, but seems to be stable (Figure 19), in particular for skipjack caught on floating objects.

3. Although there has been an increase in the catches of small skipjack in the recent years (Figure 20), it should be noted that this increase is consistent with an increase in the number of sets on floating objects. In addition, the small skipjack modal value (45-47 cm) mirrors that found in the Atlantic Ocean for sets on floating objects and is well above the size for the average age of maturity and first age of recruitment.

Technical Advice

The Working Party considered that the stock status indicators and the trends in catch effort and fishing capacity did not give rise to immediate concern regarding the status of the skipjack tuna stocks in the Indian Ocean.

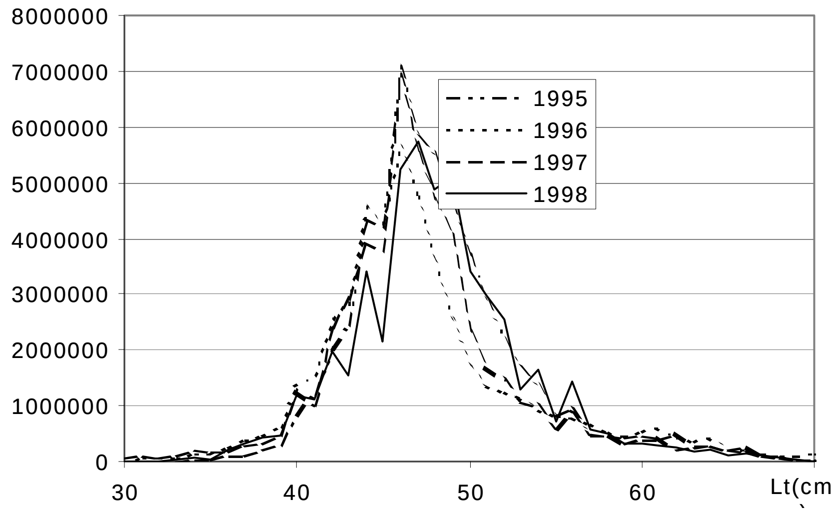


Figure 20. *Catch of skipjack tuna (in numbers by size) by the main purse-seine fleets in the Indian Ocean in recent years.*

7. Time and area closure of the Purse Seine Fishery on Floating Objects

At the 4th Session of IOTC, the Commission instructed the Scientific Committee to provide advice on:

- Precise areas, periods and conditions for a moratorium on fishing with purse seines on floating objects that would bring about a reduction of the fishing mortality of juvenile bigeye. The Scientific Committee should present various options, with estimates of their likely effects on the catch rates of the three species of tropical tunas.

In accordance to these instructions, the Working Party reviewed information relevant to the provision of such advice.

Previous experience with time-area closures

Information on the characteristics and effects of the voluntary time-area closures on fishing on tuna schools associated with drifting objects implemented by the Spanish and French tuna boat associations in the Atlantic and Indian Oceans was presented to the Working Party, along with information on the catch and by-catch species composition.

In 1997, 1998 and 1999, the French and Spanish tuna-boat owners associations conducted time-area closures for fishing on drifting objects in the Atlantic Ocean and in 1998 in the Indian Ocean. Observers were onboard each of the tuna purse-seiners. Preliminary conclusions about the effects of the closures on the fleets and on the tuna stocks can be drawn from data collected by the observers and landing statistics.

In the Atlantic Ocean, the closures resulted in a spatial redistribution of the fishing effort of the fleet that implemented the moratorium (French and Spanish owned vessels), a reduction in the number of sets on logs and a decrease of one third in the landings from those fleets during the moratorium period compared to those recorded in the immediately preceding years during the same months, especially for skipjack and bigeye tuna. The closures led to a decrease in the partial fishing mortality of juvenile bigeye tuna (for those fleets) by 45% for age-0 fish, 30% for age-1 fish and 10% for age-2 fish.

In the Indian Ocean, the French and Spanish purse seine boat owners associations implemented a voluntary time-area closure from 15 November 1998 to 15 January 1999 in an area extending from the African coast to 55°E and from the Equator to 5°N. Unfortunately, it appears that time chosen for the closure was inappropriate.

It was noted that, as is the case in the Atlantic, the drifting objects fishery in the Indian Ocean is mainly concentrated in specific times and areas, as opposed to the situation in the Eastern Pacific Ocean, where the use of drifting objects does not show any seasonal pattern. This may explain why studies by IATTC have suggested that time-area closures would not be an effective means of reducing fishing mortality on bigeye tuna within that region.

Analysis of statistical information

An analysis of the statistical data regarding the moratorium on the fishing on objects by purse seiners in the Indian Ocean was presented in document WPTT-00-15. This document discussed the data and prospects relative to the project for a moratorium on FAD fishing by tuna purse seiners in the Indian Ocean, the main goal of which is to reduce the mortality of juvenile bigeye. The document reviewed the trend of catches in association with drifting objects by purse seiners and identified the areas and seasons where these catches are important. Ten areas were considered in the analysis (Figure 21). Of these areas, the East Somalia region shows the largest concentration of catches in association with drifting objects in recent years during a period that goes approximately from August to November. The NW Seychelles and the Mozambique Channel areas also show important catches from this fishing strategy, although not at the same levels or with the same consistency from year to year as the E Somalia region (Figure 22). Within the East Somalia region, the area located between the African coast and 60°E, during a four-month period centred each year in September and October, is identified in WPTT-00-15 as an area that shows the potential to be effective in reducing the catches in association with drifting objects (Figures 23 and 24). Such a potential moratorium could reduce total tuna catches in a range between 10,000 and 40,000 t, but the fishing mortality on juvenile bigeye could be reduced in a range between 20 and 40%. Unfortunately, the available data and analyses do not allow estimating the future long-term consequences of such moratoria

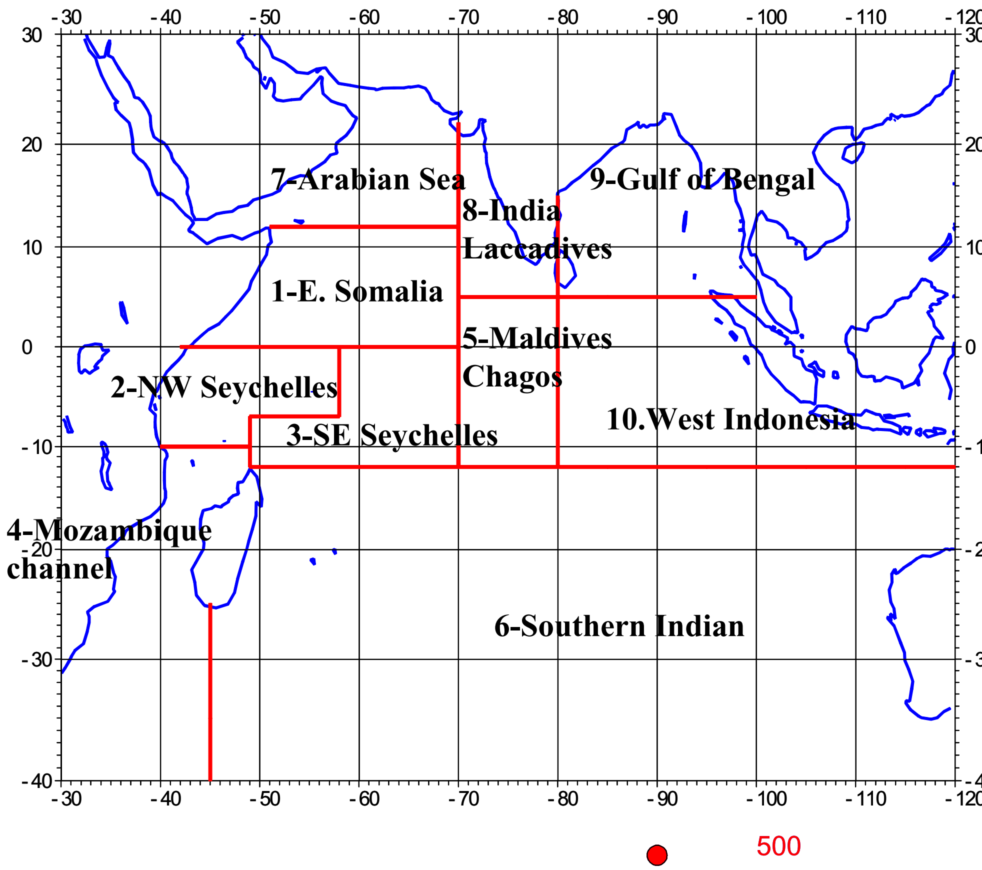


***Figure 21**. Areas used in the analyses described in document WPTT-00-15*

5.

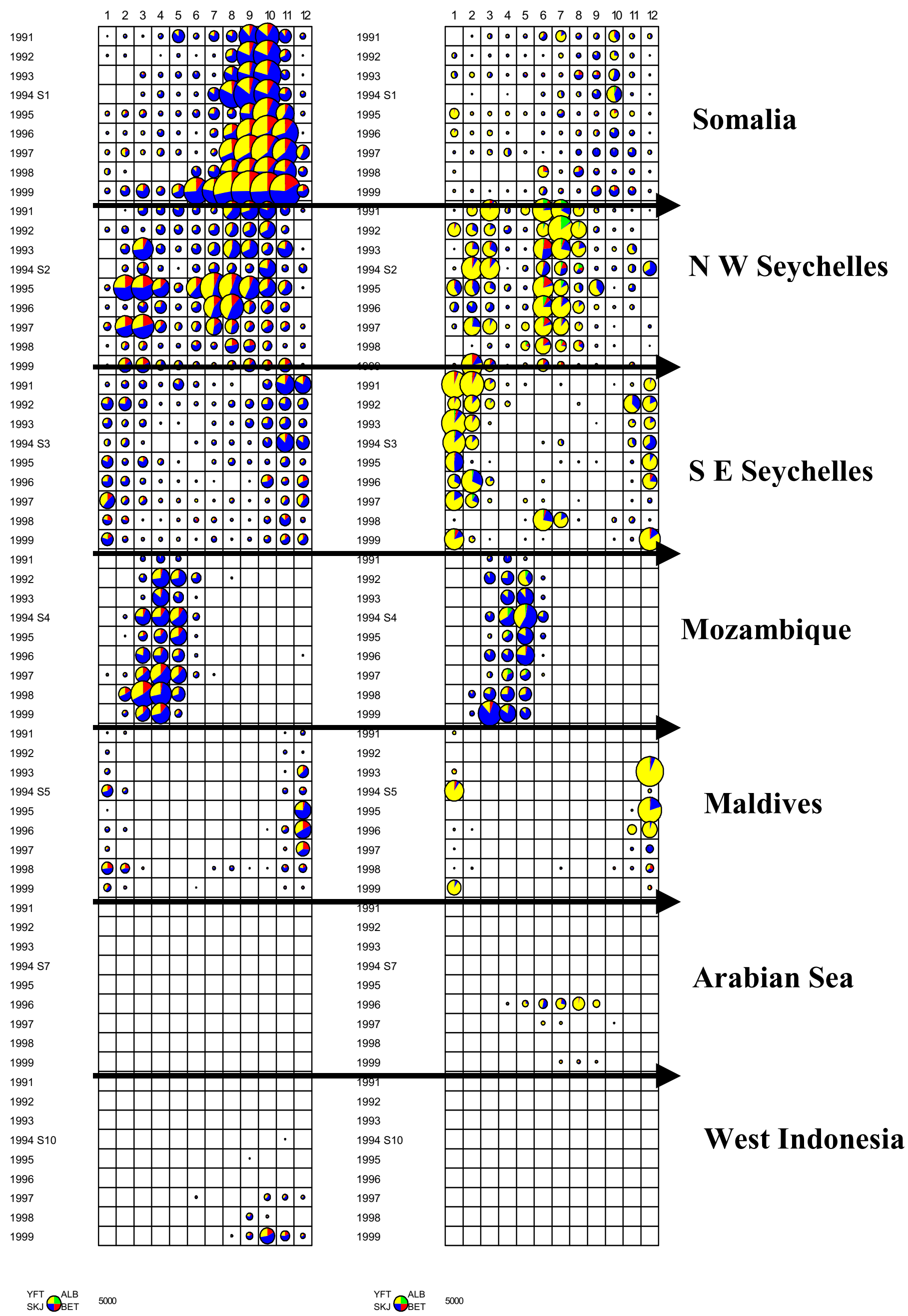
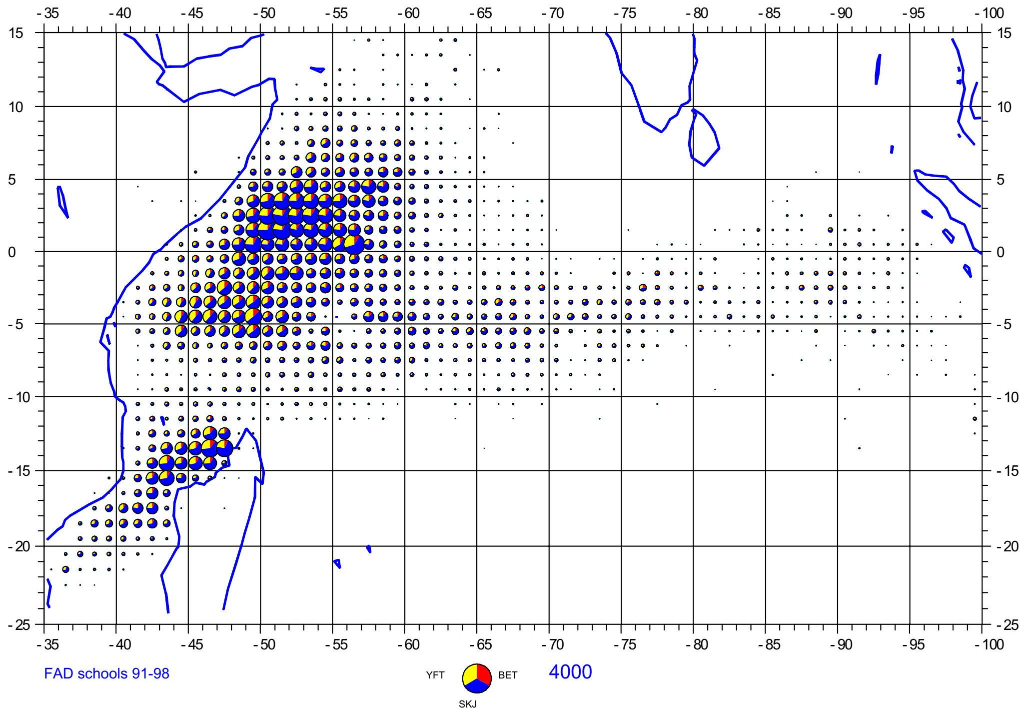


Figure 22. *Catches of tunas in the main purse-seine fishery by year, area, month and species. The left panel shows the catches in association with drifting objects, while the right panel shows catches of free-swimming schools.*



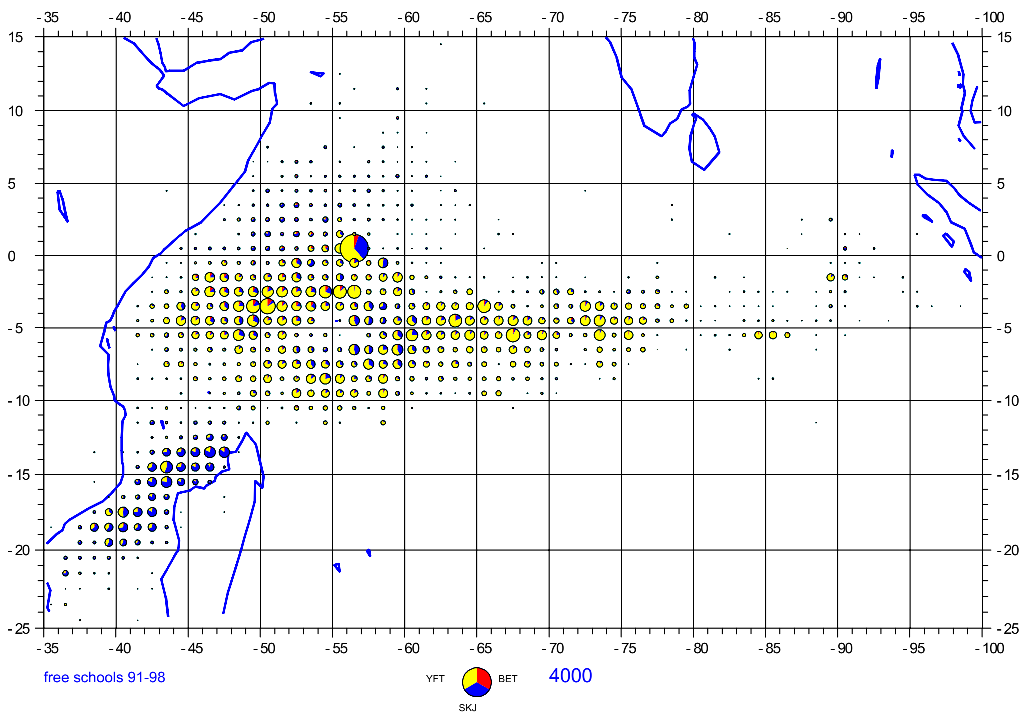


Figure 23. *Catches of the main species of tuna by the main purse-seine fleets by fishing mode for the period 1991-98. The upper panel shows catches in association with drifting objects and the lower panel shows catches of free-swimming schools.*

From the above figures of the spatial and temporal distribution of catches, effort and catch rates, it is clear that there are areas (and times) where catches of young bigeye tuna and yellowfin tuna taken on drifting objects are particularly high. A moratorium would obviously be most effective in reducing fishing mortality on young bigeye and yellowfin if it restricted fishing on drifting objects in one of these areas. The Working Party therefore considered three potential areas for a moratorium:

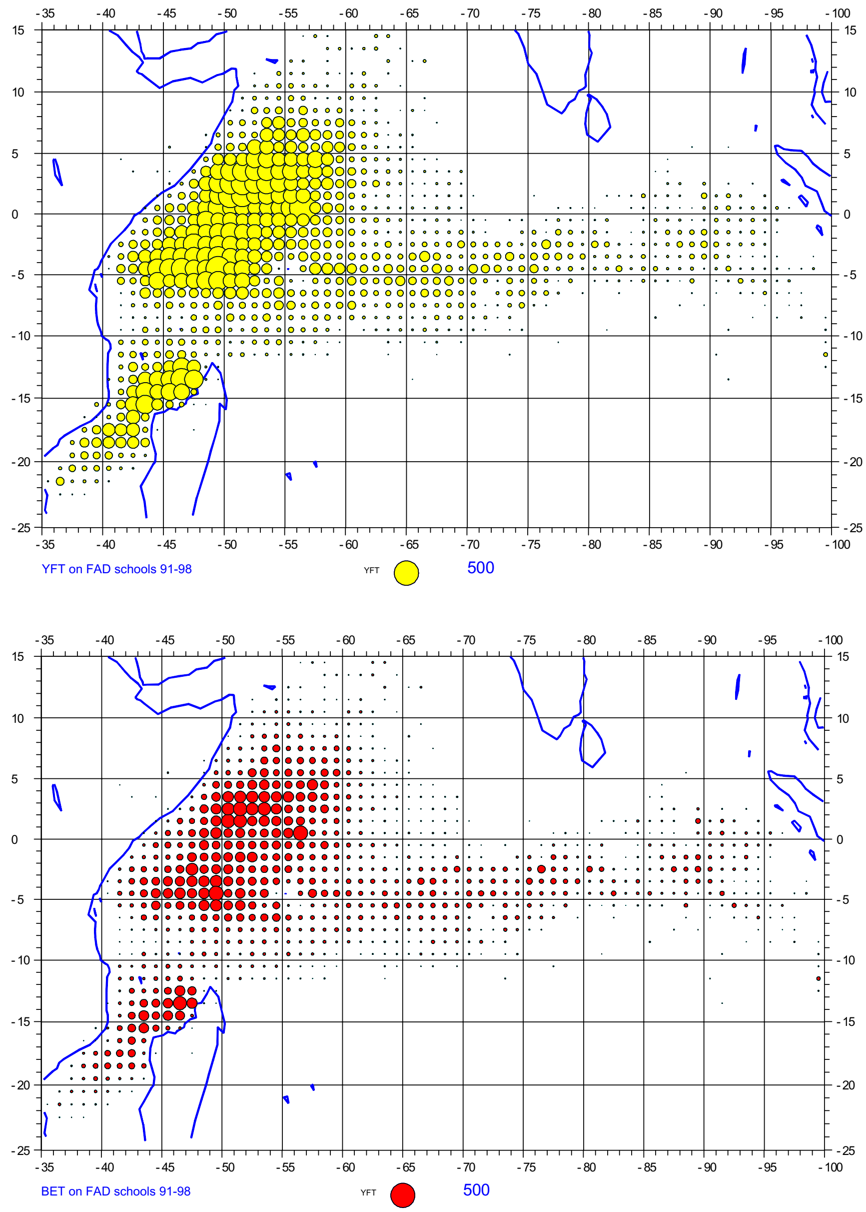


Figure 24*. Catches of yellowfin tuna (upper panel) and bigeye tuna (lower panel) by the main purse-seine fleets in association with drifting objects for the period 1991-1998.*

Mozambique Channel: Total catches on drifting objects in this area amounted to 13% of the total catches on logs by purse seiners. In addition, catches on free schools amounted to about the 50% of the total catches in this area. This would imply a high loss of catch for relatively little reduction of juvenile bigeye fishing mortality if a total moratorium on fishing in the area was to be implemented.

West Seychelles: Total catches in this area amounted to 28% of the total catches on logs by purse seiners. However, there were large variations in catches on drifting objects in this area, both between years and between months within each year. Consequently, it is likely that a closure of this area to fishing on drifting objects for a limited number of months would have a very limited and inconsistent effect.

Somalia: Purse seine annual catches on drifting objects off Somalia represent approximately 45% of the total purse seine catches on drifting objects. The FAD fishery is concentrated in this area each year for several months, with more or less stable catches on drifting objects across years. Furthermore, the number of free school sets in this area is small, compared with the total catches.

The Working Party agreed that, of these three areas, the area off Somalia was by far the most suitable for an area closure for a limited time period. Two possible areas within this region were examined further:

- The area proposed in WPTT-00-15, extending from 60°E to the African coast and from the equator to 5°N.
- A larger area extending from 60°E to the African coast and from the equator to 10°N.

Five options for time strata were examined by the Working Party:

- From September to October (two months)
- From October to November (two months)
- From August to October (three months)
- From September to November (three months)
- From August to November (four months)

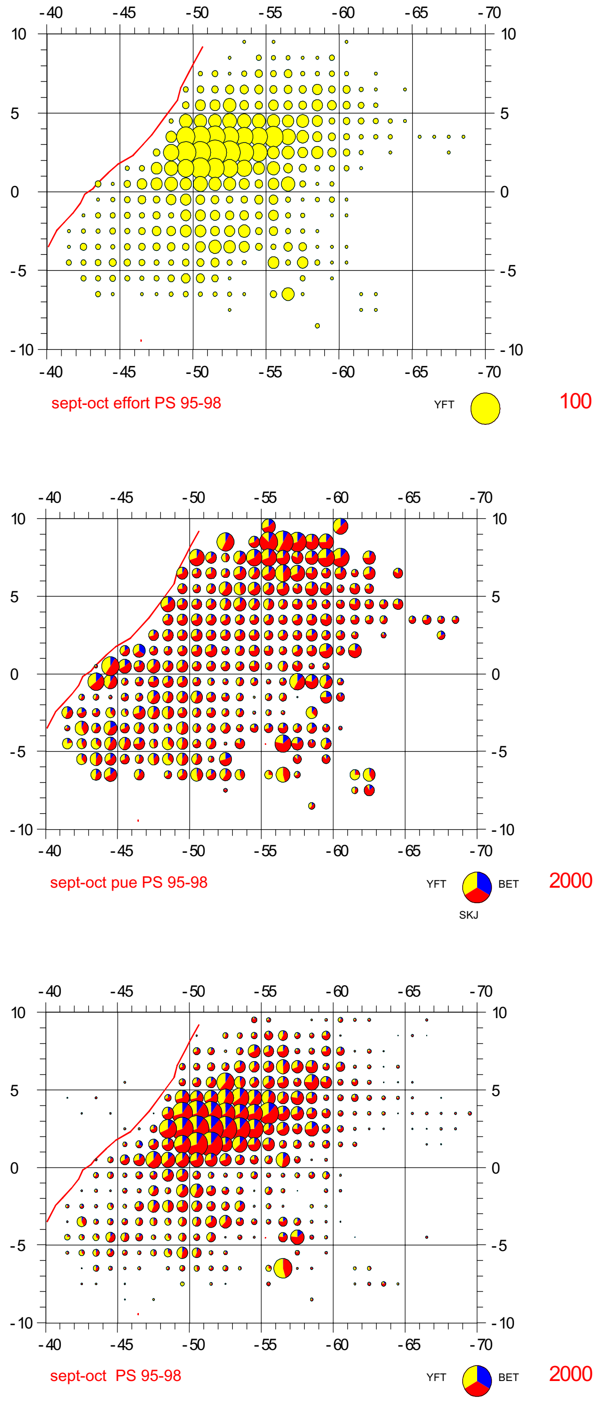


Figure 25. *Total effort (upper panel), CPUE (central panel) and total catch by species for the main purse-seine fleets during the period 1995-98.*

It was noted that the average time required for a drifting object to cross the area proposed should be of the order of 40-60 days. It is necessary to take this element into account in order to avoid drifting objects being deployed outside the area, drifting through the area concentrating fish and leaving it during the closure period with the fish aggregated, as this would reduce the effectiveness of the moratorium. For the smaller area considered, this condition might not be met in respect of north-south drift.

When assessing the costs (in terms of loss of catch to the fishermen) and benefits (in terms of reduction of fishing mortality on small bigeye and yellowfin tuna) of the moratorium, two hypotheses were considered:

- H1: The effort within the area will be relocated outside the area and the vessels will achieve the same catch rates as those recorded for previous years in the areas to which they had relocated.

EFFECTS IN THE CATCH OF THE DIFFERENT OPTIONS OF MORATORIA					
AVERAGE 1995-98		AREA			
		0-5N 20-60E		0-10N 20-60E	
PERIOD	SPECIES/CAT	%	NUMBER	%	NUMBER
Sep-Oc	YFT< 5kg	17%	1,595,088	21%	1,960,054
	YFT> 5kg	18%	299,451	22%	377,567
	BET< 10kg	15%	751,187	18%	926,489
	BET> 10kg	17%	44,399	21%	54,645
	SKJ	16%	6,992,883	20%	8,821,851
Aug-Nov	YFT< 5kg	26%	2,464,791	33%	3,139,676
	YFT> 5kg	27%	461,156	34%	589,359
	BET< 10kg	22%	1,150,489	28%	1,476,574
	BET> 10kg	24%	64,936	31%	81,686
	SKJ	25%	10,853,434	32%	13,980,352
Aug-Oc	YFT< 5kg	21%	2,005,277	26%	2,461,164
	YFT> 5kg	21%	363,209	26%	450,575
	BET< 10kg	19%	994,372	23%	1,476,574
	BET> 10kg	20%	52,449	24%	81,686
	SKJ	21%	8,943,414	25%	11,099,644
Sep-Nov	YFT< 5kg	22%	2,054,602	28%	2,638,566
	YFT> 5kg	23%	397,398	30%	516,352
	BET< 10kg	18%	907,303	23%	1,230,398
	BET> 10kg	21%	56,886	27%	63,339
	SKJ	21%	8,902,903	27%	11,702,559
Oc.-Nov	YFT< 5kg	15%	1,332,447	19%	1,780,367
	YFT> 5kg	17%	296,455	23%	391,896
	BET< 10kg	11%	506,721	14%	688,903
	BET> 10kg	16%	41,534	20%	53,753
	SKJ	14%	5,849,404	18%	7,932,311
% refers to the percentage of the number of specimens of each species/category caught in the area and period considered versus the total number of specimens of the species/category caught during the whole year					

Table 2. *Estimation of the effects of different options for the moratorium on fishing on drifting objects: the figures indicate the decrease in catch* ***in number*** *under the assumptions of H2.*

- H2: The loss of the catch in the moratorium area will not be offset by catches in other areas (i.e. all vessels that previously had fished on drifting objects in the defined region stop fishing for the period of the moratorium).

After completing initial analyses of the data needed to assess the implications of H1, the Working Party recognised that this scenario may yield unrealistic predictions of possible catches outside the area of the moratorium. This is because the catch rates that would be likely to be achieved by the displaced effort in areas surrounding the moratorium area are very difficult to predict. For example, historical catch rates in some localities outside the moratorium area are high, suggesting that perhaps there might be little loss in catch if effort is displaced to those locations. The observed catch rates on drifting objects outside the moratorium area are based on low levels of effort and it is unclear how the catch rates will be affected in these areas if the level of effort is increased substantially. It is plausible that the low level of fishing effort on drifting objects in these localities is linked to the fisher's knowledge that high catch rates are not sustainable in these areas, however there are no data to support this supposition.

As the Working Party was unable to predict the catches resulting from fishing outside the moratorium area, results are presented only for H2. The Working Party emphasised that in practice there would be, almost certainly, less loss of catch and a lower reduction in juvenile fishing mortality than that suggested by H2, but it was unable to estimate their extent.

The Working Party agreed to carry out the analysis taking into account only the catches on drifting objects in the moratorium areas, on the grounds that the catches on free schools in the moratorium areas have been very low during recent years.

Short-term consequences of the different options for the moratorium were assessed in terms of the following species and size categories, based on historical size-frequency distributions for yellowfin and bigeye tunas taken on drifting objects:

- Yellowfin tuna (below and above 5 kg)
- Bigeye tuna (below and above 10 kg),
- Skipjack (all sizes)

EFFECTS IN THE CATCH OF THE DIFFERENT OPTIONS OF MORATORIA					
AVERAGE 1995-98		AREA			
		0-5N 20-60E		0-10N 20-60E	
PERIOD	SPECIES/CAT	%	WEIGHT	%	WEIGHT
Sep-Oc	YFT< 5kg	17%	4,657	21%	5,699
	YFT> 5kg	15%	5,074	19%	6,623
	BET< 10kg	14%	2,538	17%	3,140
	BET> 10kg	16%	878	20%	1,062
	SKJ	18%	18,140	22%	22,813
Aug-Nov	YFT< 5kg	26%	7,201	33%	9,146
	YFT> 5kg	23%	7,749	29%	10,035
	BET< 10kg	21%	3,871	27%	4,979
	BET> 10kg	24%	1,285	29%	1,600
	SKJ	27%	28,132	35%	36,096
Aug-Oc	YFT< 5kg	21%	5,816	26%	7,109
	YFT> 5kg	19%	6,205	23%	7,955
	BET< 10kg	18%	3,334	23%	4,137
	BET> 10kg	20%	1,048	23%	1,244
	SKJ	22%	22,977	27%	28,467
Sep-Nov	YFT< 5kg	22%	6,042	28%	7,736
	YFT> 5kg	19%	6,618	25%	8,704
	BET< 10kg	17%	3,076	22%	3,983
	BET> 10kg	21%	1,115	25%	1,418
	SKJ	23%	23,296	29%	30,442
Oc.-Nov	YFT< 5kg	22%	4,011	28%	5,321
	YFT> 5kg	19%	4,625	25%	6,260
	BET< 10kg	17%	1,745	22%	2,372
	BET> 10kg	21%	797	25%	1,027
	SKJ	23%	15,707	29%	21,064
% refers to the percentage of the weight of each species/category caught in the area and period considered versus the total weight of the species/category caught during the whole year					

Table 3. *Estimation of the effects of different options for the moratorium on fishing on drifting objects: the figures indicate the decrease in catch* ***in weight*** *under the assumptions of H2.*

Short-term losses and gains resulting from closing an area to fishing on floating objects for a specified number of months were calculated for different species-size categories, both in terms of numbers (Table 2) and weight (Table 3). In these tables, the percentages refer to the decrease in catches of each species-size category, measured as a percentage of the historical (1991-1998) average annual total catch in the whole Indian Ocean for that species-size category.

In the tables below, decreases in catches of bigeye tuna less than 5 kg and of yellowfin tuna less than 10 kg are to be interpreted as benefits in terms of reductions of fishing mortality on small fish. Decreases in catches of skipjack tuna and of larger yellowfin and bigeye tuna are to be interpreted as costs, in terms of loss of catches. In Figure 26, the trade-offs of the different proposed options for the moratorium are illustrated graphically.

These are estimates of short-term losses and gains only, as the effects of the reductions in fishing mortality will flow through other segments of the population in later years and these effects are not taken into account into the calculation. A complete evaluation of the effects of the time-area closure would require a set of population projections to be carried out. However, a complete stock assessment is a prerequisite for such projections.

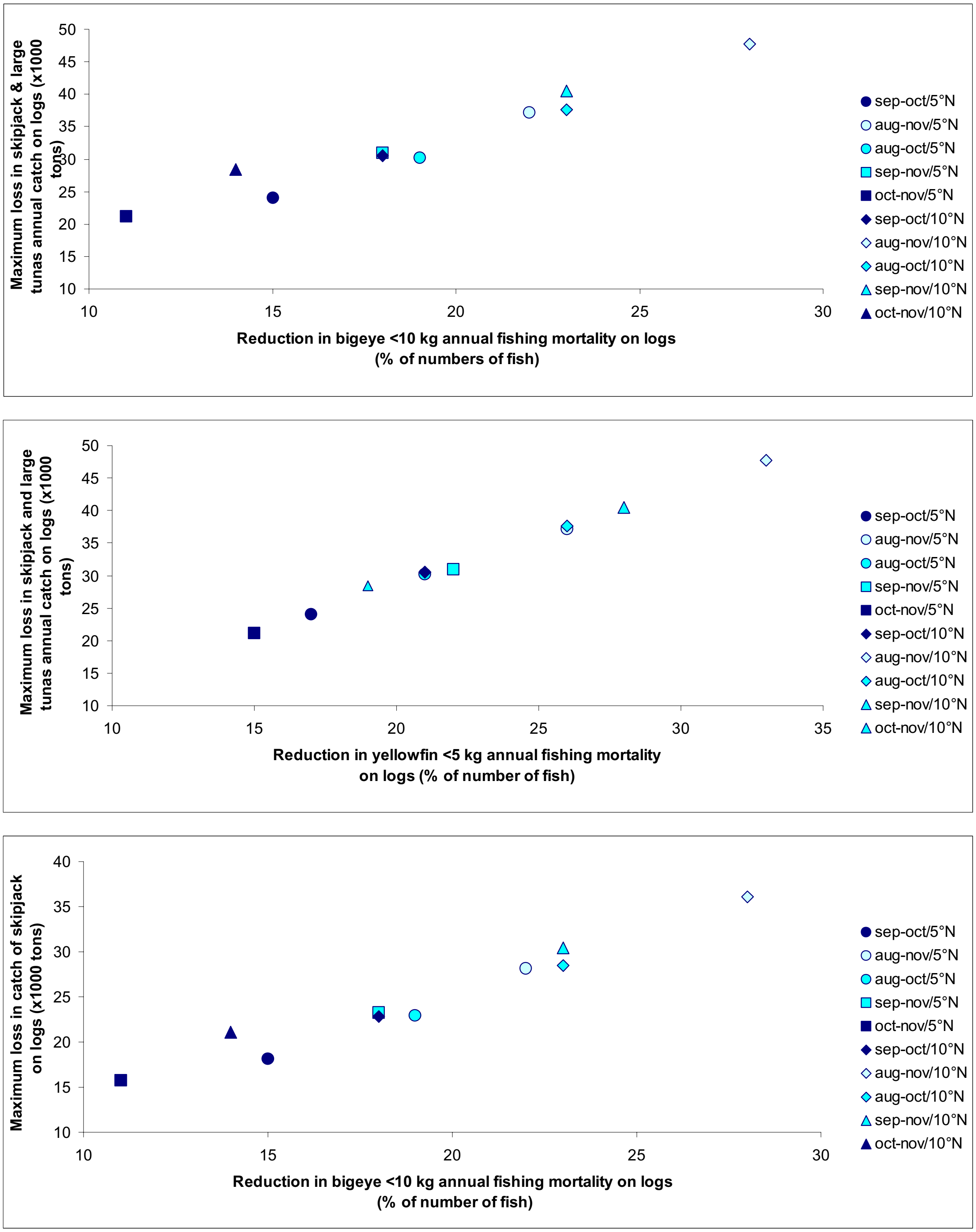
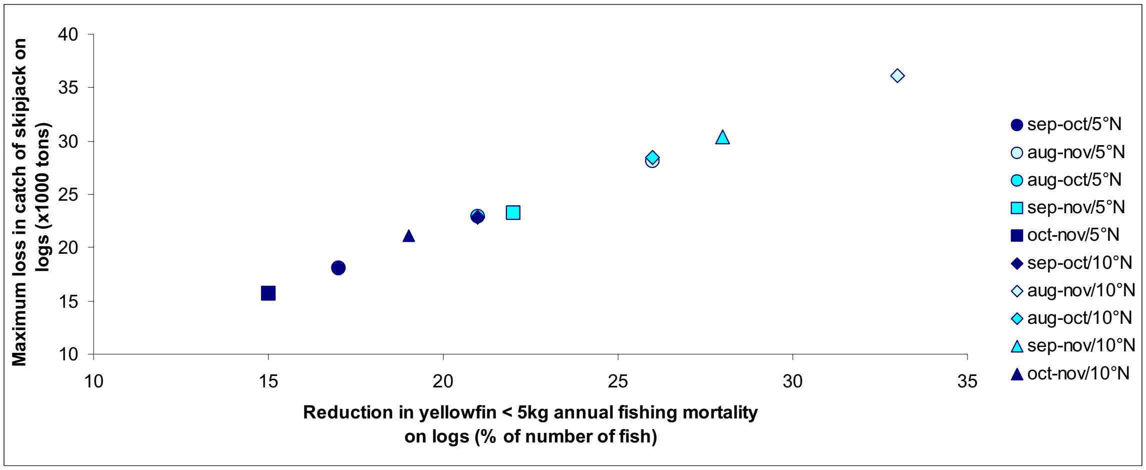


Figure 26*. Estimated trade-offs between reduction in fishing mortality and loss in catches of different options for the moratorium under the assumptions of H2.*



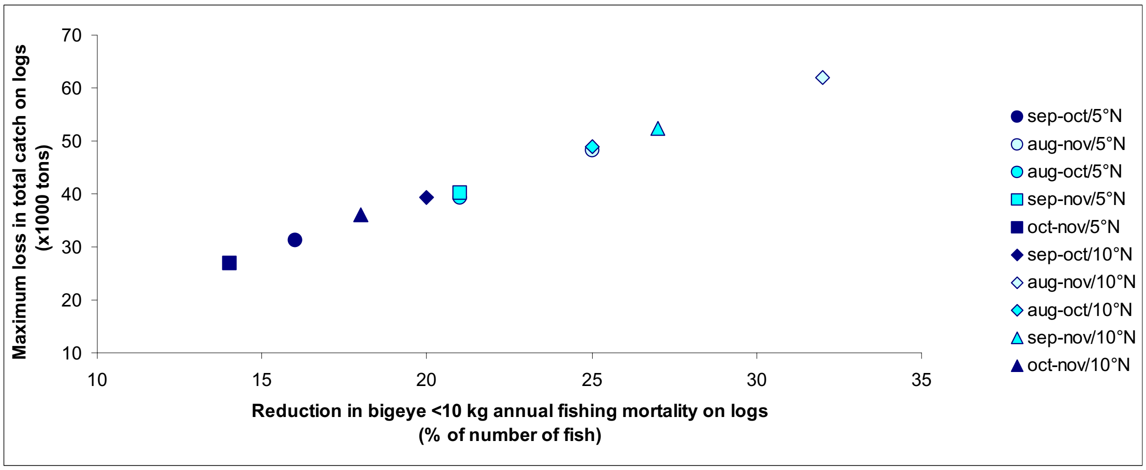


Figure 26(cont). *Estimated trade-offs between reduction in fishing mortality and loss in catches of different options for the moratorium under the assumptions of H2.*

Bycatch and discards from FAD-associated schools

Bycatch from sets of Soviet tuna purse seine boats on FAD-associated schools in the northwest Indian Ocean (0-10°N, 45-70°E) between August and November are reviewed in document WPTT-00-31. Scientific observers aboard Soviet/Russian/Liberian tuna purse seiners in the western Indian Ocean (WIO) collected data from 1986 to 1992. A total of 108 sets on FAD-associated schools were analysed. More than 40 fish species and of marine animals were recorded, of which only two species, yellowfin and skipjack tuna, were target species. Average levels of bycatch were 1.9 t per set (non-tuna by-catch 0.9 t per set), or 97 t (non-tuna bycatch 46 t) per 1,000 t of target species. The most important species in the bycatch were bigeye tuna, pelagic oceanic sharks, rainbow runner, triggerfish and dolphinfish. Discards were estimated to 0.9 t per set (all species) or 44 t per 1,000 t of target species. Potential discards (which included small skipjack, yellowfin, bigeye and all frigate and bullet tunas) were estimated at 0.16 t per set or 8.3 t per 1,000 t of target species.

It was noted that the areas fished and the types of operation of Russian and European owned purse seiners were similar.

Data collected by 40 observers on board 30 Spanish purse seiners operating in the Indian Ocean from 15 November 1998 to 15 January 1999 are reviewed in WPTT-00-03. Data reviewed include areas fished, effort (total number of sets and number of positive sets), species composition of the catch and discards, catch per set and total discards. A total of 396 fishing operations were observed during the period. During the month of November, most of the operations were sets in association with drifting objects (84%). This pattern changed towards fishing predominantly on free-swimming schools in December 1998, with 63% of sets on unassociated schools, and January 1999, when 86% of the sets were on unassociated schools. Data on total discards indicate difference in the level of discards between fishing modes. A total of 9.76% of the catch was discarded in FAD-associated sets in comparison with 0.08% in sets on free-swimming schools.

Benefits from implementing a moratorium

The Working Party agreed that the moratorium would have the following beneficial results:

- Improve the long-term yield per recruit. It was noted that, in case of stocks that are fully exploited or overexploited, (e.g. bigeye tuna), or for stocks that may be approaching full exploitation (e.g. yellowfin tuna), a reduction in the catch of juveniles would lead to an increase in yield per recruit and spawning stock size for both species. In the case of yellowfin tuna, the benefits would flow to both the purse seine and longline fisheries, while for bigeye tuna the main beneficiary would be the longline fishery.
- Decrease the total discards from the fishery.

Information on alternative management measures

The time-area closure on floating objects on which IOTC requested advice from the Scientific Committee involved a moratorium only on fishing on floating objects, with no restrictions being placed on fishing on free schools. In principle, this would allow fishermen to fish on free-swimming schools in the moratorium area, as such schools do not contain small fish. However, enforcement of this measure would require the presence of inspectors on board all vessels.

An alternative means of implementing the moratorium would be to close the area to all fishing (on both free schools and floating objects) for a specified time period. Such a total closure could be enforced through a VMS system, without placement of inspectors, on all vessels that have a VMS system installed. It does, however, impose a restriction on fishing free schools, which is not necessary to achieve a reduction in fishing mortality on juvenile bigeye tuna.

The Working Party also briefly discussed new information concerning the other options considered at its previous meeting for reducing fishing mortality on juvenile bigeye:

a) **Introduction of quota measures**: No new information was available on this option. However, the Working Party reaffirmed its views of last year that quotas are difficult to monitor and certainly require the use of inspectors on board fishing vessels, in particular because of the difficulties in discriminating between small individuals of yellowfin and bigeye tunas.

b) **Establishing minimum sizes for bigeye tuna**: Evidence suggests that it is possible for fishermen to know the approximate size of the fish in a school prior to setting. If so, they may be able to refrain from setting on schools of small fish. It is clear, however, that this measure could only be properly enforced if all boats carry inspectors on board. As was demonstrated by ICCAT's experience with similar regulations, the Working Party believed that it is not possible to implement this management measure effectively.

c) **Ban of supply vessels**: A comparison of the catches of Spanish and French purse seiners on drifting objects was presented to the Working Party. This emphasized the difference in BET catch rates of the Spanish and French purse seiners since 1994, the year when a Spanish supply vessel first operated in the fishery. It was suggested that the higher catch rates obtained by the Spanish fleet were a direct consequence of the use of supply vessels. Catch rates during the years before 1994 were similar for the Spanish and French boats, as both fleets were operating in the same way.

The Working Party recommended that more research be conducted on this topic. European scientists informed the Working Party that data were available for some trips of observers on supply vessels and that results from the analysis of these data will be presented to the Scientific Committee.

It was also recommended that more effort be spent in obtaining data on the number of supply vessels operating in each year, on the number of purse seiners using these vessels, and on which purse seiners were using supply vessels, in order to improve the preliminary analysis presented. A scientist from the Seychelles Fishing Authority confirmed that they could also provide data regarding the number of supply vessels licensed to operate in the Seychelles EEZ.

Other measures that could lead to a decrease in the catches of juvenile BET were briefly discussed:

a) **Reduce the depth of the nets**: The extent to which use of deeper nets leads to greater catches of juvenile bigeye tuna is currently not clear enough to support such a measure. However, it was agreed that more research needed to be carried out on this subject.

b) **Reduce the number of drifting objects:** Monitoring the number of drifting objects deployed by purse seiners would imply having inspectors on board permanently. Furthermore, at this stage there is no information about the relation between the number of drifting objects deployed and the resulting catches.

c) **Keeping all discards on board**, thereby reducing the hold capacity for carrying the commercial catch: As in the previous option, enforcing this would require having inspectors on board permanently. On the other hand, experience from observer programmes conducted on purse seiners indicates that the amount of discards is low. The benefit of applying such a measure will not then be great.

d) **Restrictions on fishing on seamounts**: Catches from seamounts have sizes and species compositions that are similar to those taken on drifting objects, so restrictions on fishing on seamounts may reduce the fishing mortality on small fish. Purse seine fishing does occur on the Coco de Mer seamount, however the total catch is so small (about 5,000 t per year) that a ban on this activity would not reduce juvenile bigeye tuna mortality significantly.

Other Recommendations

If a moratorium on fishing on floating objects were to be imposed by IOTC, the Working Party **strongly recommended** that actions be taken to ensure that all purse seine and associated supply vessels operating in the Indian Ocean, including those from non-Contracting Parties, comply with the moratorium. Otherwise, the intended benefits might not be attained.

8. Consideration of the Question of Optimum Fishing Capacity

At the 4th Session of IOTC, the Commission instructed the Scientific Committee to provide advice on:

- The best estimate, on the basis of existing data and analyses, of the optimum fishing capacity of the fishing fleet that will permit the sustainable exploitation of tropical tunas.

The Working Party noted that assessing the optimum fishing capacity of tuna fleets would only be possible when reliable assessments had been conducted on each of the tropical tuna stocks. Furthermore, better data regarding the current fishing capacity situation are needed. Although we have an idea of the fishing capacity of purse seiners, we lack knowledge about other fleets, in particular of longliners. It was noted that few countries have to date provided the Secretariat with the data requested on foreign flag vessels licensed by them or using their harbours called for in Resolution 98/03.

From the information we currently have regarding total catch and CPUE, it seems there is a tendency for catches to level off. It therefore seems sensible that further increases in fishing capacity be avoided.

It was observed that there is an effort to document the current status of purse seiner technology[2], and in particular those devices that can have a direct effect in the effort efficiency. It was suggested that the Working Party might consider collaborating with such efforts.

9. Research Recommendations and Priorities

Progress on the implementation of recommendations from the first WPTT Meeting

The Working Party reviewed the progress regarding the recommendations made at WPTT-99:

General

1. *Developments in fishing practice and gear technology need to be fully documented and their effects on fishing power need to be assessed for all major fleets.*

New data regarding the number and activities of supply vessels are presented in documents WPTT-00-03 and WPTT-00-28. The Working Party was informed of new studies currently under way, the results of which will be presented to the Scientific Committee if time allows.

2. *Size-frequency data from the Korean longline fishery during 1974-90, if they exist, should be made available to IOTC.*

Korea submitted all size frequency data available for Korean longliners operating in the Indian Ocean recently. These data are, unfortunately, highly aggregated, and the sample sizes are so small that their usefulness is questionable.

[2] by David Itano.

3. *Catch, effort and size-frequency data from the Taiwanese longline fishery in recent years, if they exist, should be made available to IOTC.*

Catch and effort statistics have now been reported up to 1998. Size frequency data exist but have not been reported so far since 1988.

4. *Catch, effort and size-frequency data from the Indonesian longline fishery in recent years, if they exist, should be made available to IOTC.*

Document WPTT-00-13 includes valuable information on part of the Indonesian longline tuna fishery. Nevertheless, the total catches are still uncertain and much more effort is needed to retrieve current and historic information.

Stock Assessment

1. *In order to facilitate the calculation of indices of apparent biomass, the IOTC Secretariat is to approach Japan requesting that the catch-and-effort data for the Japanese longline fleet be provided, aggregated by the number of hooks between floats. These data, together with the already available size data, will then be provided through the IOTC to scientists willing to undertake the calculation of the required indices (in particular, age-specific). Scientists undertaking this work should make their results available through the IOTC website.*

The Japanese data on the mean number of hooks between floats used by longliners operating in the Indian Ocean by 5-degree square have been deposited with the Secretariat.

2. *Scientists should include environmental data in the calculation of indices of apparent biomass.*

Some such analyses have been already undertaken and preliminary results were presented to the Working Party.

3. *The IOTC Secretariat is to coordinate further work with interested scientists to facilitate the calculation and provision of the necessary catch-at-age data sets required for stock assessment purposes. Once calculated, these data sets should be posted on the IOTC website.*

The Secretariat was unable to undertake this task due to lack of time.

4. *The IOTC Secretariat is to list recommended biological parameters to be used for stock assessment purposes on the IOTC website. A list of recommended methods, models and programs (drawing on the work of other tuna commissions such as ICCAT and IATTC) should also be made available through the IOTC website.*

It was recognised that it was not up to the Secretariat to recommend which methods to use or what programs or models to run. Rather, this should be done by the Working Party itself. Mechanisms to achieve this need to be developed.

5. *The IOTC Secretariat will assist in the dissemination of environmental data useful for stock assessment purposes. The Secretariat will provide through its Web site a list of contacts and Internet addresses of primary sources for this type of data. Scientists are invited to send to the Secretariat information about such sources together with a short summary of the data available from the sites.*

The Secretariat informed the Working Party that links already exist in the IOTC website giving access to this information. Members agreed to notify the Secretariat of new links as they become available.

6. *Scientists from the various organisations with an interest in undertaking stock assessments on the tropical tunas in the Indian Ocean are encouraged to make use of the data and methods which will be posted on the IOTC website. Scientists undertaking such work are also encouraged to make their results available through the IOTC website and seek comments back on their work. In this manner, much of the preliminary work required to undertake stock assessments could be undertaken before the annual meeting of the WPTT.*

The Secretariat agreed to list all methods that were recommended by the Working Party in the IOTC Website.

7. *Scientists are encouraged to explore and develop the use of new methods and models applicable to the assessment of tropical tunas in the Indian Ocean. Such models should explicitly incorporate uncertainty in the data and model structure and include consideration to spatial and environmental structure and interactions between species.*

8. *Individual scientists are encouraged to assist the IOTC Secretariat to achieve each of the above recommendations.*

Both of these recommendations are being acted upon.

Bigeye Tuna

1. *Countries and fisheries scientists should support the Australian CSIRO initiative to investigate genetic stock structure of Indian Ocean bigeye tuna by supplying appropriate tissue samples.*

An Australian scientist present at the meeting advised that assistance in obtaining samples has been provided.

2. *Comparative studies of bigeye fisheries in the Indian Ocean and those in other oceans may shed light on developments within the Indian Ocean and are therefore encouraged.*

Comparative studies have already been undertaken.

3. *Catch and effort data from Mauritian purse seiners (which are believed to have concentrated on FAD fishing with deep nets since the beginning of their operations) should be analysed to provide comparative information on the changing catch composition of the EU purse seine fleet, which has engaged more recently on such fishing.*

Although direct studies of the Mauritian purse seine data have not yet been carried out, some studies are underway on related issues.

4. *A major tagging experiment is required in order to address the stock structure of bigeye tuna in the Indian Ocean and to estimate levels of mixing of between the stocks of the western and eastern parts of the ocean.*

5. *Tagging experiments and otolith studies are also thought to be the best ways to estimate bigeye tuna growth rates.*

Tagging is a major priority that will be addressed in detail by the Working Party on Tagging. It was also noted that tagging could be considered useful to interpret catch and effort data.

6. *Many basic biological parameters are poorly known and further study is required in order to refine estimates of:*
   - *Growth rates, particularly of large fish*
   - *Length-weight relationships*
   - *Natural mortality rates*
   - *Age (and/or size) at first maturity*

Document WPTT-00-30 provided some new estimates on biological parameters. The sampling programmes currently under way in Phuket and Penang will also provide new information in this respect.

7. *Some data relating to biological parameters are available with national or other agencies (e.g. maturity data from BIOT and gonad index data from the Japanese longline fishery). These should be submitted to IOTC as soon as possible.*

Biological data from observers aboard vessels operating in the British Indian Ocean Territory (BIOT) area were provided this year.

8. *Port sampling of bigeye catches will be necessary in order to obtain the size-frequency data required for stock assessment. In order to determine the optimum disposition of sampling sites, it is recommended that heterogeneity analysis be carried out. In considering the adoption of statistical units, it would be appropriate to adopt ecologically meaningful sub-areas (e.g. based on Longhurst's areas).*

Weights of about 50,000 specimens of tuna and billfish have been already recorded in Phuket and Penang. Document WPTT-00-Inf. 3 reviews the progress regarding the sampling programmes conducted in those ports.

9. *VPA by size, rather than age, may be useful, especially if it reduces assumptions about growth parameters and addresses the problem of missing size compositions.*

In addition to these methods, it was agreed that general size-based statistical models should be investigated.

10. *It is necessary to obtain data on the sex ratio by size in the catch. In the future, this information could be used to carry out stock assessments by sex.*

Some information on this topic is provided in document WPTT-00-30, but this recommendation is regarded as having low priority.

Yellowfin Tuna

1. *Countries and fisheries scientists from the region should support the Japanese NRIFSF initiative to investigate stock structure of Indian Ocean yellowfin tuna by supplying appropriate tissue samples.*

Document WPTT-00-11 presents the first results obtained regarding the genetic analysis conducted on yellowfin tuna. It also includes a list of cooperating scientists.

2. *Tagging is necessary to investigate stock structure, migrations, fishery interactions and growth and mortality parameters.*

There was consensus that tagging remains an important tool to achieve a reliable stock assessment.

Skipjack Tuna

1. *The stock structure of Indian Ocean skipjack tuna should be investigated as soon as possible.*

No specific studies have been carried out to date, but a research plan addressing this subject was presented in document WPTT-00-27.

2. *Tagging is necessary to investigate stock structure, migrations, fishery interactions and growth and mortality parameters.*
3. *The cause(s) of the recent decline in skipjack catches on FADs by purse seiners should be investigated.*

It was noted that since the declining trend in skipjack catches has been reversed in the latest year for which data are available, this recommendation is no longer necessary.

4. *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.*

The Working Party noted the current incompleteness of Maldivian statistics available to date at the Secretariat. However, the Secretariat informed the Working Party that these data have been submitted by Maldives and are expected to arrive shortly. Studies of interactions based on Maldivian tagging experiments were carried out in the PhD thesis of Dr. S. Adam, a copy of which is held by the Secretariat. The Working Party noted, however, that interactions could not be considered fully without widespread tagging throughout the region. This requirement has been taken into account in current plans for tagging experiments to be discussed by the Working Party on Tagging.

Management Recommendations

Management Recommendations specific to each species were reviewed in previous sections.

Recommendations on organization of future work

The Working Party noted that in neither last year's nor this year's meetings has it been possible to conduct a comprehensive assessment of any of the species under its responsibility. The various reasons for this were discussed and a number of suggestions were made for improving the process.

It was recognized that four days does not provide sufficient time to deal with the assessment of the three species under the responsibility of the Working Party, in particular considering that the desirable goals include an extensive data review, complete data analysis and modelling, discussion of the results and the production of a detailed report. Therefore, it was proposed that as far as possible the Working Party should concentrate exclusively on one species during each meeting, and that the duration of each meeting should be extended to a full week.

In reaching this conclusion, the Working Party recognised that it was still required to advise WPDCS on data-related issues each year, and that from time to time it would be required to answer specific questions posed by IOTC that may not relate to the species under consideration. This may divert some time from work on the single species.

It is essential that all public domain data in the IOTC database should be made available to the scientists well in advance of the meeting, in order to allow sufficient time to conduct preliminary analyses. These data could possibly be provided in the form of flat ASCII files contained on a CD. Data regarding the species to be dealt should be reviewed before the Working Party meeting. This will permit the Working Party to have a clear picture on the situation well before the meeting. The Working Party Chairman or a designate (e.g. a scientist designated to coordinate the work for the species being considered) should be responsible for ensuring that the necessary data are available and distributed on time.

A good selection of software for stock assessment should be made available to the participants. Tasks and analytical work should be planned in advance and assigned during the Working Party meeting to task forces, made up of groups of 2 to 4 scientists. During the meeting, working sessions would be conducted by the task forces in separate rooms, alternating with plenary sessions. It was noted that this might raise occasional scheduling problems, since often individual scientists present at the meeting have experience in a number of areas that have been assigned to different task forces.

The results of this work of the Working Party should be described in detailed reports, providing a wide range of figures, models and results. The report from the WP should include comprehensive sections concerning data availability and completeness and background information on the data used in the analyses and models presented. Such a report could serve as the input for the planned Permanent Report on the status of the stock.

The Working Party recognised the relevance of these recommendations for the functioning of other species' Working Parties and agreed that a more detailed proposal should be prepared for consideration by the Scientific Committee.

Several other possible actions were discussed that would facilitate the conduct of analyses for future meetings of the WPTT:

a) **Establishing dedicated groups to carry out stock assessment for each species**: The Working Party expressed concerns about the difficulties that would be created by having additional meetings, particularly considering other commitments of most of the scientists. Furthermore, it was noted that stock assessment activities are already part of the mandate of this Working Party.

b) **Establishing a Working Group on Methodology**: There was no consensus on whether such a Group would be of help in conducting stock assessment, although it was agreed that an *ad hoc* group could provide guidance on how to deal with specific problems raised in the context of the species Working Parties.

c) **Establishing an interagency Working Group on Methodology**: It was noted that the Scientific Committee recommended, in its last session, to propose the creation of such a group in cooperation with other tuna regional bodies. However, given the different approaches to the problem taken by other tuna bodies, it does not seem possible at this time to find an arrangement satisfactory to all parties. However, it was agreed that the participation of invited scientists from other tuna Commissions would bring an important additional expertise to the Working Party.

Option c) received considerable support, but the Working Party recognised that such a working group could not be formed in the near future. Despite an extended discussion, the Working Party did not reach consensus on either of the first two options.

New General Recommendations

1. The Secretariat should maintain a catalogue in the website about the availability and quality of all data in the IOTC database, including size frequency and catch and effort data.

New Recommendations regarding yellowfin, skipjack and bigeye tunas

1. Studies should be carried out through observer programmes in order to obtain more information on bycatch and discards of the most important fleets operating in the region.

10. Arrangement for Next Meeting and Adoption of the Report

The Working Party unanimously agreed that the next meeting should take place in Seychelles during the third week of June 2001.

Appendix I: List of Participants

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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 of stock assessment for each tropical tuna species.*
4. *Develop technical advice on management options, their implications and related matters.*
    - *4.1.1. Bigeye Tuna*
    - *4.2. Provide technical advice on times and areas proposed for closure of fishing in association with floating objects, with the objective of reducing the fishing mortality of juvenile bigeye tuna.*
    - *4.3. Yellowfin Tuna*
    - *4.4. Skipjack Tuna*
5. *Consider the question of the optimum fishing capacity of the fishing fleet.*
6. *Identify research priorities, and specify data and information requirements, necessary for the Working Party to fulfil its responsibilities.*
7. *Any other business*
8. *Adoption of the Report*

Appendix III: List of Documents

WPTT-00-01	Preliminary studies of age and growth of Bigeye tuna (*Thunnus obesus*) in the Western Indian Ocean. *Stequert, B. and F. Conand*
WPTT-00-02	Catch Status of Tropical Tunas and Swordfish by Taiwan Deep-Sea Tuna Fishery in the Indian Ocean n 1999. *Chang, S-K.. and H-C. Liu*
WPTT-00-03	Preliminary analysis of observers data available from the 1998-1999 moratorium in the Indian Ocean. *Arrizabalaga, H. and I.Artetxe*
WPTT-00-04	Standardized Catch Rates For Yellowfin (*Thunnus albacares*) From The Spanish Purse Seine Fleet (1984-1995). *Soto, M., Morón, J. And Pallarés, P.*
WPTT-00-05	Consideration on distribution of adult yellowfin tuna (*Thunnus albacares*) in the Indian Ocean based on Japanese tuna longline fisheries and survey information. *Mori, M. andTt. Nishida*
WPTT-00-06	Population Parameters and Feeding Habits of Yellowfin tuna (*Thunnus albacares*) in the Oman Sea. *Kaymaram, F., H.Emadi, and B.Kiabi*
WPTT-00-07	Japanese Tuna Fisheries in the Indian Ocean, up to 1999. *Matsumoto, T., T.Nishida and H.Okamoto*
WPTT-00-08	Standardized CPUE for bigeye caught by the Japanese longline fishery in the Indian Ocean, 1952-1999. *Matsumoto, T.*
WPTT-00-09	Preliminary sock assessment of bigeye tuna in the Indian Ocean by a non-equilibrium production model. *Matsumoto, T.*
WPTT-00-10	Standardisation of the Japanese longline catch rates of adult yellowfin tuna (*Thunnus albacares*) in the western Indian Ocean by General Linear Model(1975 - 1998). *Nishida, T.*
WPTT-00-11	A preliminary genetic analysis on yellowfin tuna stock structure in the Indian Ocean using mitochondrial DNA variation. *Chow, N., K.Hazama, T.Nishida, S.Ikame, and S.Kurihara*
WPTT-00-13	Analyses of the Indonesian tuna longline fisheries data in the Indian Ocean (1978-94). *Gafa B., Sofri Bahar, IR., Anung, A, Iskandar, B., Mahiswara, Rachmat, E., Susanto, K, Uktolseja, J., Radiarta, IN. and T. Nishida*
WPTT-00-14	Marine Explorer (GIS software) demo. *Environmental Simulation Laboraory, Inc.(Itoh K. and T.Nishida)*
WPTT-00-15	Analyse des données statistiques concernant le projet de moratoire de la pêche sous objets flottant dans L'Océan Indien. *Fonteneau, A., Delgado, A., Nordsorm, V., Pallarés, P., and Pianet, R.*
WPTT-00-16	Use of a simple fishery indicator to assess the status of the tropical tuna fisheries in the Indian Ocean. *Gaertner, D. and Fonteneau, A.*
WPTT-00-17	ENSO cycle and purse seine tuna fisheries in the Indian Ocean with emphasis on the 1998 - 1999 La Niña. *Marsac, F. and J-L. Le Blanc*
WPTT-00-20	Overview of the French purse seiners fishery statistics (catch, effort and sizes) in the Indian Ocean during the period 1982-1999. *Pianet, R.and Nordstrom, V.*
WPTT-00-21	PLOTREC, a graphic software for plotting the apparent growth of recovered fishes in association with theoretical growth curves. *Fonteneau. A., and V.Nordstrom*
WPTT-00-23	Predation survey on the Japanese tuna longline catch. *NRIFSF*
WPTT-00-25	The Current Status of bigeye tuna (*Thunnus obesus*) in the Indian Ocean by a stochastic age-structured production model based on longline fishery data. *Hsu, C-C., and H-C., Liu.*
WPTT-00-26	Stock Assessment of the Indian Ocean yellowfin tuna. *Lee Y-C and H-C., Liu.*
WPTT-00-27	Research plan to study stock structure of skipjack (*Katsuwonnus pelamis*) in the Indian Ocean by genetic analyses. *NRIFSF (Japan) and MRC (Maldives)*
WPTT-00-28	Statistics of the purse seine Spanish Fleet in the Indian Ocean (1984-1999). *Pallarés, P., Delgado de Molina, A. and J.Ariz*
WPTT-00-29	Statistics of the purse seine NEI fleet in the Indian Ocean (1984 -1999). *Pallarés, P., Delgado de Molina, A., Pianet, R., Ariz, J. and V. Nordstorm*

WPTT-00-30	Some Biological study of Yellowfin tuna (*Thunnus albacares*) and Bigeye Tuna (*Thunnus obesus*) in the Indian Ocean. *Tantivala C.*
WPTT-00-31	Bycatch in the Soviet purse seine fisheries on FAD-associated schools in North Equatorial Area of the Western Indian Ocean. *Romanov, E.V.*
WPTT-00-Inf1	Spatial tuna resources analyses using GIS (Geographical Information System):Current situation and prospects. *Nishida, T.,T. Meaden and T. Booth*
WPTT-00-Inf2	Calculation of the nominal catches by vessels Not Elsewhere Included (NEI) within the western and eastern IOTC Areas. *IOTC Secretariat*
WPTT-00-Inf3	Landings of small fresh tuna longline vessels to ports in the eastern Indian Ocean during the year 1999. *Herrera, M., P. Nootmorn, M. Mhd. Isa and S. Panjarat*
WPTT-00-Inf4	Age and growth of Yellowfin tuna (*Thunnus albacares*) from the western Indian Ocean, based on otolith microstructure. *Stequert, B., J. Panfili and J-M Dean*
WPTT-00-Inf6	Atlas of the conventional tag release-recapture information based on the Nippon-maru survey cruises (1980-2000). *Nishida t., M.Ogura and K. Yano*
WPTT-00-Inf7	Summary of predation surveys and research on Tuna longline fishing in the Indian and Pasific Ocean based on the Japanese investigation cruises (1954, 1958, and 1966-81). *Nishida, T.*
WPTT-00-Inf8	Ecological and fisheries data relevant to determination of the southern boundary between the IOTC and MHLC areas of competence. *Kalish, J.*

Appendix IV: List of Current Recommendations from the WPTT

General

Developments in fishing practice and gear technology need to be fully documented and their effects on fishing power need to be assessed for all major fleets.

Size-frequency data from the Taiwanese longline fishery in recent years, if they exist, should be made available to IOTC.

Catch, effort and size-frequency data from the Indonesian longline fishery in recent years, if they exist, should be made available to IOTC.

Studies should be carried out through observer programmes in order to obtain more information on bycatch and discards of the most important fleets operating in the region.

Stock Assessment

The Secretariat should maintain a catalogue in the website about the availability and quality of all data in the IOTC database, including size frequency and catch and effort data.

Scientists should include environmental data in the calculation of indices of apparent biomass.

The IOTC Secretariat should coordinate further work with interested scientists to facilitate the calculation and provision of the necessary catch-at-age data sets required for stock assessment purposes. Once calculated, these data sets should be posted on the IOTC website.

The IOTC Secretariat should list recommended biological parameters to be used for stock assessment purposes on the IOTC website. A list of recommended methods, models and programmes (drawing on the work of other tuna commissions such as ICCAT and IATTC) should also be made available through the IOTC website.

The IOTC Secretariat should assist in the dissemination of environmental data useful for stock assessment purposes. The Secretariat will provide through its Web site a list of contacts and Internet addresses of primary sources for this type of data. Scientists are invited to send to the Secretariat information about such sources together with a short summary of the data available from the sites.

Scientists from the various organisations with an interest in undertaking stock assessments on the tropical tunas in the Indian Ocean are encouraged to make use of the data and methods which will be posted on the IOTC website. Scientists undertaking such work are also encouraged to make their results available through the IOTC website and seek comments back on their work. In this manner, much of the preliminary work required to undertake stock assessments could be undertaken before the annual meeting of the WPTT.

Scientists are encouraged to explore and develop the use of new methods and models applicable to the assessment of tropical tunas in the Indian Ocean. Such models should explicitly incorporate uncertainty in the data and model structure and include consideration to spatial and environmental structure and interactions between species.

Individual scientists are encouraged to assist the IOTC Secretariat to achieve each of the above recommendations.

Bigeye Tuna

Countries and fisheries scientists should support the Australian CSIRO initiative to investigate genetic stock structure of Indian Ocean bigeye tuna by supplying appropriate tissue samples.

Catch and effort data from Mauritian purse seiners (which are believed to have concentrated on FAD fishing with deep nets since the beginning of their operations) should be analysed to provide comparative information on the changing catch composition of the EU purse seine fleet, which has engaged more recently on such fishing.

A major tagging experiment is required in order to address the stock structure of bigeye tuna in the Indian Ocean and to estimate levels of mixing of between the stocks of the western and eastern parts of the ocean.

Tagging experiments and otolith studies are also thought to be the best ways to estimate bigeye tuna growth rates.

Many basic biological parameters are poorly known and further study is required in order to refine estimates of:

- *Growth rates, particularly of large fish*
- *Length-weight relationships*
- *Natural mortality rates*
- *Age (and/or size) at first maturity*

Some data relating to biological parameters are available with national or other agencies (e.g. gonad index data from the Japanese longline fishery). These should be submitted to IOTC as soon as possible.

Port sampling of bigeye catches will be necessary in order to obtain the size-frequency data required for stock assessment. In order to determine the optimum disposition of sampling sites, it is recommended that heterogeneity analysis be carried out. In considering the adoption of statistical units, it would be appropriate to adopt ecologically meaningful sub-areas (e.g. based on Longhurst's areas).

VPA by size, rather than age, may be useful, especially if it reduces assumptions about growth parameters and addresses the problem of missing size compositions.

It is necessary to obtain data on the sex ratio by size in the catch. In the future, this information could be used to carry out stock assessments by sex.

Yellowfin Tuna

Tagging is necessary to investigate stock structure, migrations, fishery interactions and growth and mortality parameters.

Skipjack Tuna

The stock structure of Indian Ocean skipjack tuna should be investigated as soon as possible using, among other techniques, analyses of genetic structure.

Tagging is necessary to investigate stock structure, migrations, fishery interactions and growth and mortality parameters.

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.