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

# Report of the First Session of the IOTC Working Party on Tagging Data Analysis

**Seychelles, 30 June to 4 July 2008**

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

1. The first meeting of the Working Party Tagging Data Analysis (WPTDA) was opened on 30 June 2008 in Victoria, Seychelles, by the Chairperson Dr Alain Fonteneau.

2. Dr Fonteneau welcomed the participants (Appendix I) and the agenda for the Meeting was adopted as presented in Appendix II.

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

# 2. Status of the Indian Ocean Tagging Programme

4. The WP was provided with a detailed description of the results and the status of the Regional Tuna Tagging Project – Indian Ocean RTTP-IO. In addition, experts that have been involved with major programmes in other oceans also made presentations to provide the WP with a comprehensive introduction into tagging programmes world-wide.

*The Regional Tuna Tagging Programme – Indian Ocean*

5. Document IOTC-2008-WPTD-10 described the status of the RTTP-IO. The project started in February 2005 and its first phase, the tagging operations, ended on September 2007. The numbers of fish tagged were outstanding as 168,163 tuna were tagged including 54,663 yellowfin, 34,570 bigeye and 78,324 skipjack (Figure 1). Double tagging to derive tag shedding rates was performed on 16.6% of the fish. 3.5 % of the fish were OTC-marked for later growth studies. Most of the tagging took place off Tanzania (Figure 2) as this area turned out to be a "Tuna hub" that was very conducive to tagging.

6. More than 24,500 fish have been recovered to-date (Figure 1), this equates to around 14% of the total fish tagged and more recoveries are expected. Recoveries for the three species are characterized by (1) a wide distribution of time-at-liberty (Figures 3 and 4); (2) a wide geographical distribution all over the purse seine fishing grounds and beyond including in the Eastern Indian Ocean; (3) long distances travelled especially for SKJ and YFT (Figure 5); (4) the overwhelming importance of purse seine recoveries (Figure 2); and (5) the importance of the Associated School Fishing Technique (i.e. maintaining an association between a tuna school and the bait boat over time) that enabled greater numbers of fish to be tagged and subsequently be available for recapture.

7. Overall the RTTP-IO achievements in tagging and recovery are making it the most successful large-scale tuna tagging project ever implemented.

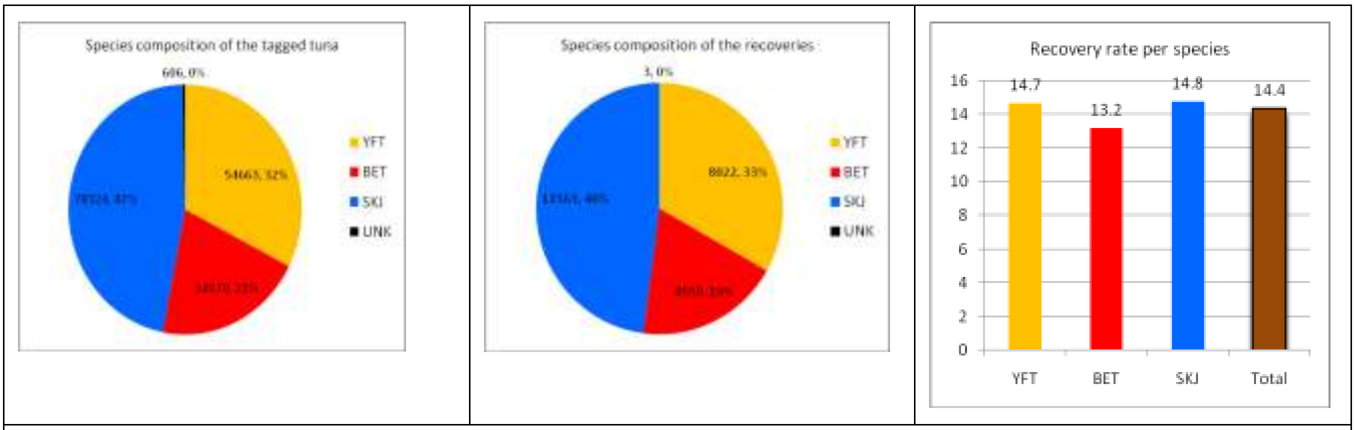
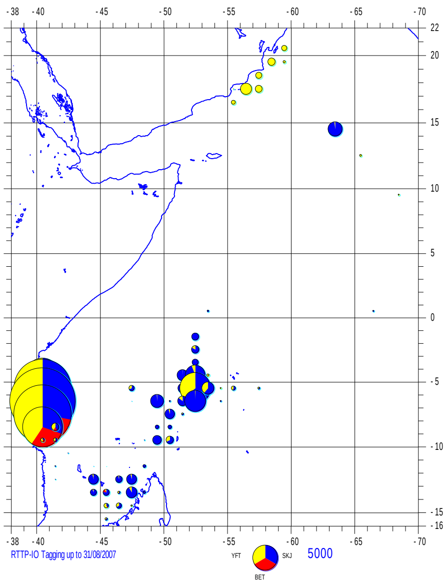



**Figure 1. Species composition of (a) tagged tuna and (b) recoveries to-date and (c) recovery rates by species. From Document IOTC-2008-WPTDA-10**

*Small-scale tagging operations in the Indian Ocean*

8. IOTC-2008-WPTDA-PRES02 described the status of the small-scale tagging operations developed by the IOTC since 2004 with funds from a range of agencies. The most recent activities have taken place in Lakshadweep and Andaman Islands (India), in Indonesia and Maldives (where tagging is ongoing). Some tagging is also undertaken in collaboration with sport fishing clubs in South Africa. The Indonesian work has been limited by environmental factors. The first operations in Maldives and Lakshadweep were very successful but the subsequent

Andaman tagging and the second operation in Maldives, while ongoing, have been limited as tuna abundance has been low. **The WP noted that funds from the Japanese Government are still available, and recommended that further pop-up tagging continue in Maldives (2 popup tags have already been deployed).**

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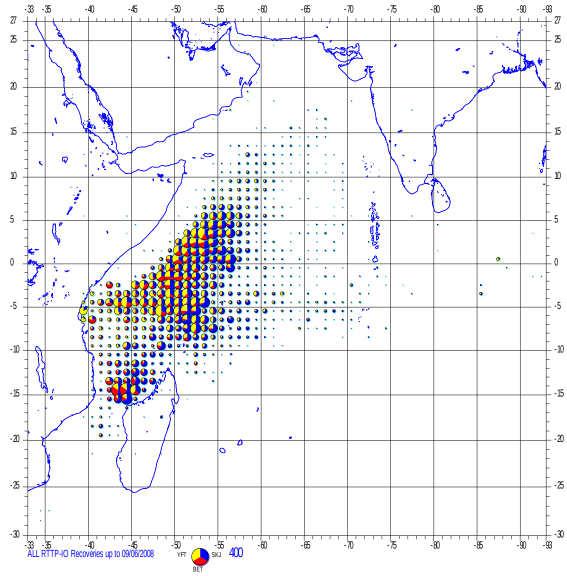


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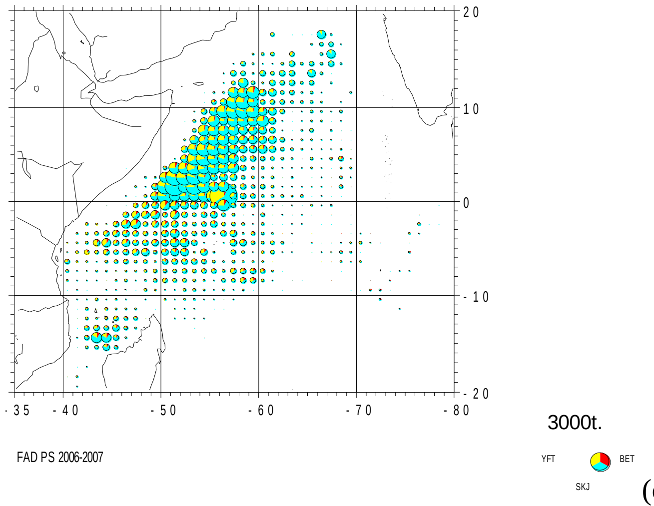



(c)

**Figure 2. Locations where (a) tagging took place and (b) recoveries were made and (c) the location of fishing by the purse seine fleet on FADs – the fleet from which most recoveries were made. The maps depict the western Indian Ocean with the coastline of Africa in blue. Yellow circles represet yellowfin, blue represents bigeye and red represents skipjack. The diameter of the circles represent the following: (a) 5000 fish (b) 400 fish (c) 3000 t of catch. From Document IOTC-2008-WPTDA-10**

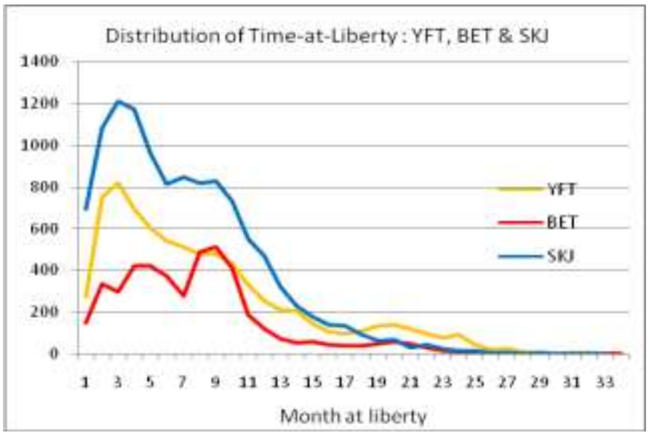



**Figure 3. Time at liberty travelled for tagged fish fish. Y-axis represents numbers of fish. From Document IOTC-2008-WPTDA-10**

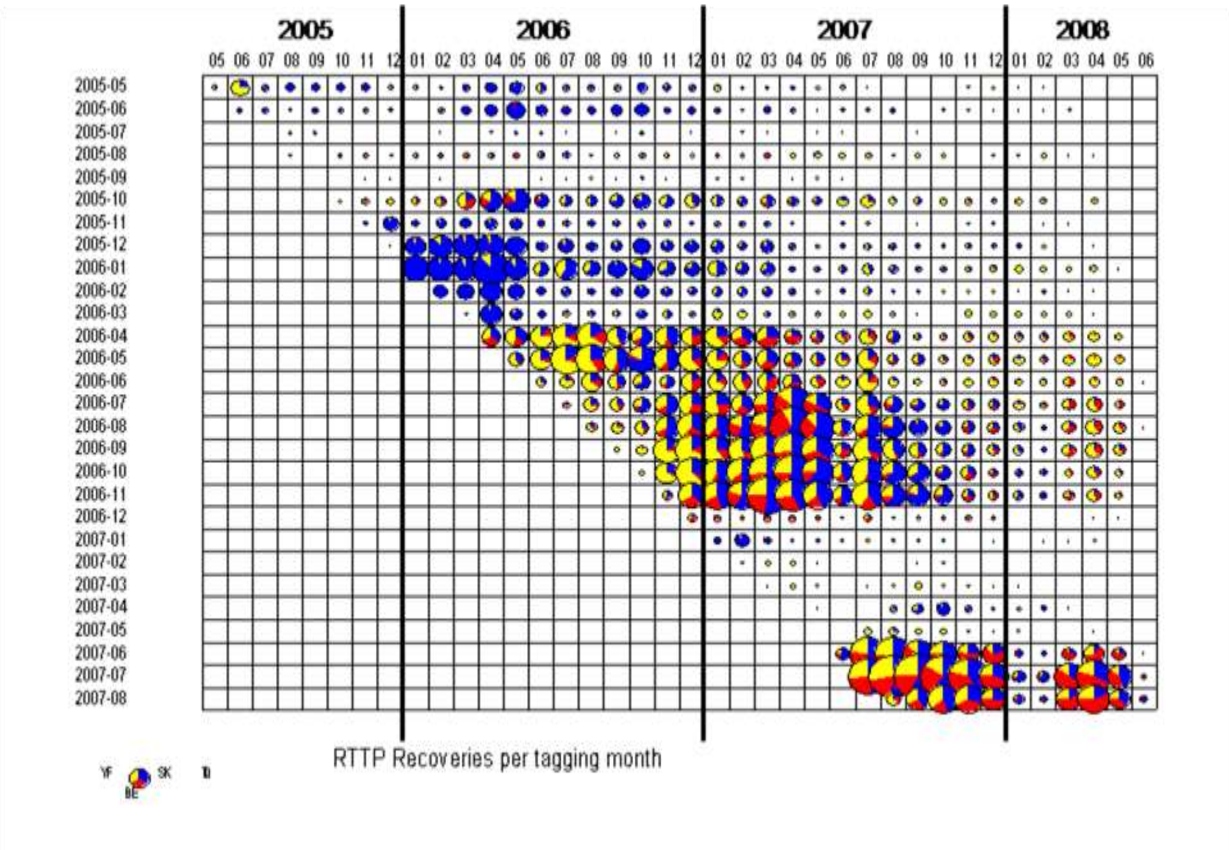



**Figure 4. Numbers of tags recovered over time (by year-month). Yellow circles represet yellowfin, blue represents skipjack and red represents bigeye. The diameter of the circle in the legend represents 10 fish. From Document IOTC-2008-WPTDA-10**

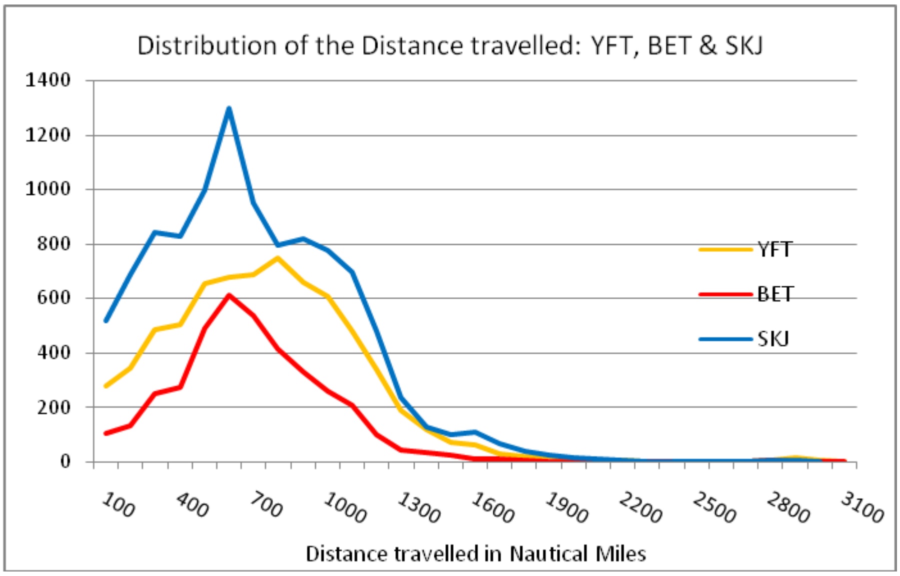



**Figure 5. Distance travelled by individual fish betwwen being tagged and being recovered, Y-axis represents numbers of fish. This distance is a striaght-line estimate of distance travel as the exact route taken beween the two points by the individal fish is not known. From Document IOTC-2008-WPTDA-10.**

9. Recoveries from small-scale tagging have been registered locally but some showed up in the purse seine fishery. Altogether, 15,242 tagged tuna have been released so far (12,025 SKJ, 3,122 YFT, 40 BET & 55 Unknowns) and more than 300 fish have been recovered.

*SPC tagging programmes in the western and central Pacific Ocean*

10. Dr John Hampton provided an overview of SPC tagging programmes in the western and central Pacific Ocean (IOTC-2008-WPTDA-PRES03). Three large-scale programmes have been conducted: (1) the Skipjack Survey and Assessment Programme (SSAP) in the late 1970s – early 1980s; (2) the Regional Tuna Tagging Project (RTTP) in the late 1980s – early 1990s; and (3) the Pacific Tuna Tagging Programme (PTTP), the field work for which began in mid-2006 and is expected to continue until 2009. The SSAP targeted skipjack, releasing ~140,000 tuna for ~7,000 recoveries. The RTTP targeted skipjack, yellowfin and bigeye, releasing ~150,000 tuna for ~18,000 recoveries. The PTTP is also targeting all three species of tropical tunas. In phase 1 of the PTTP, in Papua New Guinea and Solomon Islands, ~100,000 tuna have been released and ~11,000 recoveries received to date. The programme is now continuing in Micronesia, Philippines and Indonesia, with an additional 100,000 releases targeted. Plentiful numbers of skipjack and yellowfin have been tagged, but it has proved difficult to tag sufficient numbers of bigeye tuna. An experimental cruise in the central tropical Pacific using a chartered handline vessel was however successful, tagging almost 2,000 bigeye (including 50 archival tag releases) in about 2 weeks of fishing. This operation targeted aggregations of tuna associated with the TAO oceanographic moorings, and it is hoped that the numbers of bigeye tag releases can be enhanced by further fishing on such aggregations.

*Recent tuna tagging experiments in the eastern Pacific Ocean by the Inter-American Tropical Tuna Commission*

11. Dr Kurt Schaefer informed the WP that the Inter-American Tropical Tuna Commission (IATTC) began tagging tropical tunas in the eastern Pacific Ocean in the early 1950s and continued regional tuna tagging experiments through the 1970s into the early 1980s (IOTC-2008-WPTDA-PRES04). The results obtained from those studies have been useful to the IATTC for inclusions in stock assessments including information on movements, stock structure, growth, mortality, and exploitation.

12. A tagging project was initiated by the IATTC in 2000 focused on bigeye tuna in the equatorial eastern Pacific Ocean. The background information and justification for this project were: (1) development and rapid expansion of purse-seine fishing on drifting fish aggregation devices (FADs) in the EPO in 1994 resulted in substantial increases in catches of bigeye from about 5,000 to 50,000 t by 1996 (2) declining trend in the Japanese longline bigeye catch in the EPO from about 100,000 t to less than 5,000 t by 1996 (3) concern that the bigeye longline fishery is being indirectly affected by the purse-seine fishery on FADs (4) lack of scientific information on bigeye population structure, movements, mortality, and growth in the EPO (5) essential to quantify these and other life history information for inclusion in stock assessments of bigeye in the EPO.

13. During the period of 2000-2006 the conventional plastic dart tag releases in the equatorial EPO and returns were the following: bigeye releases 19,174, returns 8,249 (43.0%), skipjack releases 3,425, returns 563(16.4%), yellowfin releases 2,234, returns 405 (18.1%). The overall distribution of the bigeye tag recaptures shows limited dispersion primarily restricted to the equatorial EPO. The linear displacement patterns of bigeye, skipjack, and yellowfin are quite similar after 30 days at liberty. During the period of 2000-2005 the bigeye archival (data storage) tag releases in the equatorial EPO and returns were 323 and 163 (50.5%), respectively. The most probable movement paths based on processing the archival tag data with the unscented Kalman Filter with sea-surface temperature integrated for 98 bigeye which were at liberty for greater than 30 days indicate the movements are primarily confined to the equatorial EPO.

14. Analyses of both conventional and archival tag data have provided invaluable information about movements, stock structure, and exploitation for bigeye in the EPO. Results from these experiments indicate restricted movements and regional fidelity of bigeye tagged and released in the equatorial EPO.

*Overview of southern bluefin tuna tagging programmes*

15. Dr Tom Polacheck provided an overview of the southern bluefin tuna tagging programme that has been in existence for over 40 years (IOTC-2008-WPTDA-PRES05). SBT is a long-lived (up to age 40), with age at maturity 8+ years. It is highly migratory, with distribution spanning southern ocean from South Africa to New Zealand. It has a single spawning ground in northeast Indian Ocean south of Indonesia. Major conventional tagging experiments have been conducted in 1960s (1959-1969), 1980 (1983-84), 1990s (1991-1997) and 2000s (2001-2007). Over 206,000 tags have been released and ~24,000 recovered. There have been three periods of archival tag deployments (1993-1995, 1998-2000 and 2002-2007).

16. Growth rates of SBT have increased over the 40 year study. The report describes reporting and shedding rate estimates. Current fishing mortality rates for age 3 and 4 fish found in the Great Australian Bight area appear extremely high and are substantially greater than those in the 1990's. Movement and migration patterns of juvenile SBT have changed between the 1960 and 1980/90 and between the 1990's and 2000s.

## 3. STATUS OF THE RTTP-IO AND SMALL-SCALE TAGGING PROJECT DATA

17. IOTC-2008-WPTDA-11 described the current status of the RTTP-IO databases. The major activities are:

- Quality control, an everyday follow-up on the quality of the data collected.
- Validation and storage

18. These operations will continue until the end of the project. With respect to validation and storage, these tasks have been delayed until recently due to tagging commitment. However, for the last four months a special effort was made in order to get the database as clean as possible for the WPTDA. The WP noted also that documentation of the recovery database is in preparation and should be ready soon**. The WP recommended that lengths not be calculated when weight data only are available.**

19. Following discussions on the importance of recovering tags from longline fleets, the WP was informed about the efforts deployed by the RTTP for the collection of recoveries from longliners.

20. The WP was informed that other tagging programmes found that the numbers of tag returns increased markedly when landings were monitored by programme staff and recommended that the RTTP-IO continue to employ this monitoring approach to the extent possible. The WP was also informed that observers are soon to be deployed by IOTC as part of the programme to monitor transhipments at sea, and these people may be able to assist in the return of tags.

21. **The WP acknowledged the improvements in the quality of the databases and recommended work continue in order to obtain the best possible databases before the meeting of the WP on Tropical Tunas in October 2008.**

22. The WP noted that all small-scale recoveries have already been entered into the database; however, as other tagging data remain to be added, the Recovery data base from the small-scale tagging programme is currently incomplete.

## 4. ESTIMATING GROWTH

23. A brief introduction to growth of IO tuna was provided by the Chairman.

24. Document IOTC-2008-WPTDA-03 described exploratory attempts of integrating the otolith data (when available) and the tagging data into a growth estimation framework for yellowfin and bigeye species. With respect to these species, when integrating the growth increments from the tagging data into a probability model with the otolith data the von Bertalanffy model did not fit the tagging information. When moving to a more complex form of growth model that accommodates a two-stage growth behaviour the ability to estimate an unequivocal maximum likelihood estimate for the parameters is lost. Also, there is a clear disparity at the younger ages between what the tagging and the otolith data indicate about length-at-age.

25. For the skipjack data, the growth rate and asymptotic length parameters of the von Bertalanffy model were estimated using a simple growth increment form of this model and using the tag data only, given no otolith data exist for this species. In this case the MLE was robust to different starting values and displayed none of the instability seen in the more complex yellowfin and bigeye models. The resultant parameter estimates did not appear to be different to those estimated for Maldivian skipjack.

26. For all three species, there was strong evidence for an increase in the variation in growth with both time-at-liberty and length-at-release, both of which could be considered as proxy effects for an increased variation in growth with age and length. However, one of the problems with the estimates of asymptotic length in this work and in previous such studies is that model estimates are rarely consistent with observed catch-at-length data.

27. In summary, the analyses presented in this paper were insufficient to establish a robust growth curve for yellowfin and bigeye tuna at this stage. By contrast, for skipjack, a robust and sensible growth model which can be

used for the construction of a length transition matrix was derived. A range of suggestions for future work are described in the paper.

28. Document IOTC-2008-WPTDA-07 described an application of a recently developed approach for estimating growth behaviour from tagging data (release length, recapture length and days at liberty (Figure 6), for yellowfin, bigeye and skipjack. Results (Figure 7) are presented from fitting growth models to the tagging data for each species using both Fabens method and the method of Laslett, Eveson and Polachek[1]. The results suggest that the two-stage 'VB log k' growth function, which accommodates a change in the underlying growth curve at a given age, is appropriate for the yellowfin and bigeye data. For the skipjack data, a standard VB model appears to be adequate. It is important to note that the tagging data, at present, contain very limited information about growth of older fish. However, this situation should improve in future as tags are returned from fish that have been at liberty for longer periods.

29. Document IOTC-2008-WPTDA-08 described results from some analyzes of growth of yellowfin, skipjack and bigeye tagged and recovered in the Indian Ocean as a function of their sizes. This work was based on the provisional recovery data released in June 2008 by the IOTC Secretariat. The first step of the study described the criteria used to eliminate various potential errors in this provisional recovery file. The analysis concentrated on the estimation of the apparent growth rates of the three species, as a function of their average sizes between tagging and recovery. The analysis did not aim to fit a theoretical growth model to the recovery data but produced growth curves based on growth rates for the three species and provided size/age relationships which may be suitable as an input of assessment models. It was proposed that these observed results may be more realistic than a theoretical growth obtained through an inadequate growth model. The results were compared with the growth patterns previously estimated by scientists and used by the IOTC for its stock assessments. The comparison showed that yellowfin and bigeye growth appears to be consistent with a complex 2 stanza model multi-staged growth and not Von Bertalanffy-type models, as these species are showing slower growth rates at their early juvenile stages (Figure 8). It was noted that growth rates of yellowfin and bigeye appear to be very similar for juvenile fishes under 60 cm (and 4 kg), but are different for older fish, e.g. yellowfin showing a much faster growth than bigeye. These results (Figure 9) were consistent with those reported by Marsac in 1991[2] (based on modal progression) using Petersen methods.

30. Further to this work, growth rates were re-estimated using the same methods on an agreed 'cleaned' data set specifically derived for growth analyses (see Appendix V for criteria). The results (IOTC-2008-WPTDA-PRES19) were similar to those reported above and show a clear two-stanza growth pattern for YFT and BET (Figure 9).

31. The WP noted that this method could introduce bias into the estimates of growth rate at size. Sensitivities were conducted by simulation during the meeting in order to evaluate this matter and the results indicated that bias, while relatively minor for small and medium sized fish, increased with fish size (Appendix IV). The WP noted that the use of a non-model, empirical based approach for analysing growth may provide useful insights and the basis for developing transition probabilities for use in a size-based modelling approach. It was further noted that the current approach does not allow for the statistical properties of the values estimated. Consideration should be given to further work to develop a statistically based approach.

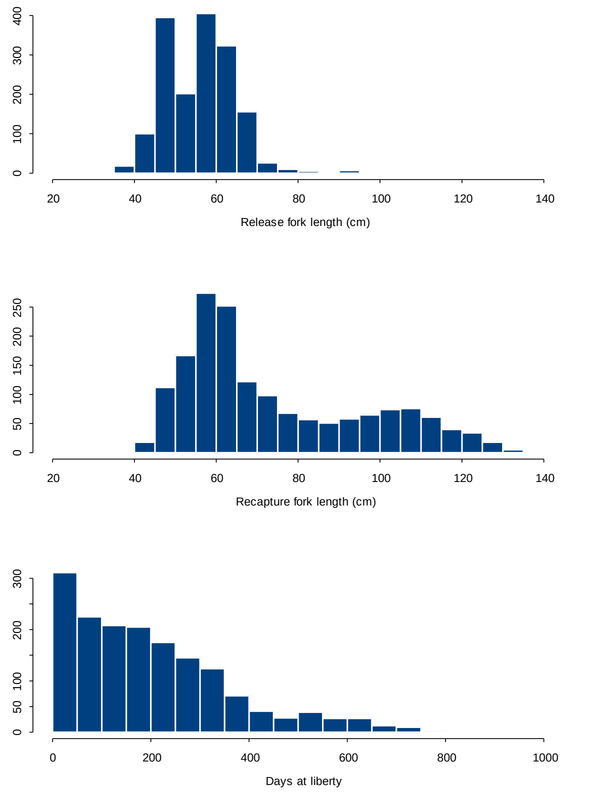
32. The WP recommended that the cleaned data set also be analysed using the Laslett, Eveson and Polachek method (Document IOTC-2008-WPTDA-07) and the results be used in the tropical tuna stock assessments planned for October 2008.

33. The growth pattern of yellowfin tuna provoked much discussion. In the past, the data (from model progression and otolith studies) have been ambiguous, and could not distinguish convincingly between two possible growth patterns: a classic VB type growth, and a more complex two-stage growth (with slow growth in small 40-65cm fish being followed by faster growth in intermediate-sized fish). New data from tagging provides support for the two-stage growth hypothesis. However, although yellowfin of commercial lengths do show two-stage growth, pre-recruits have fast growth, so over their entire lifespan yellowfin actually have a 'three-stage' or 'complex' pattern of

[1] Laslett, G.M., Eveson, J.P., and Polacheck, T. 2002. A flexible maximum likelihood approach for fitting growth curves to tag-recapture data. Can. J. Fish. Aquat. Sci. 59: 976-986.

[2] Presented at the Workshop on stock assessment of yellowfin tuna in the Indian Ocean, organised by the IPTP in Colombo (7-12 October 1991). Document TWS/91/17.

growth. Perhaps for this reason, two-stage mathematical models do not fit the data particularly well, and more complex models (as shown in Figure 9) may be required.

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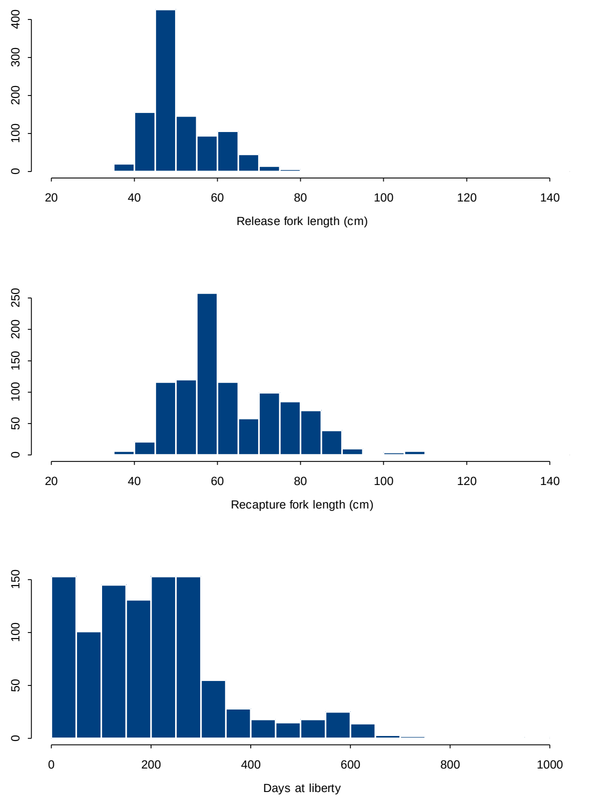


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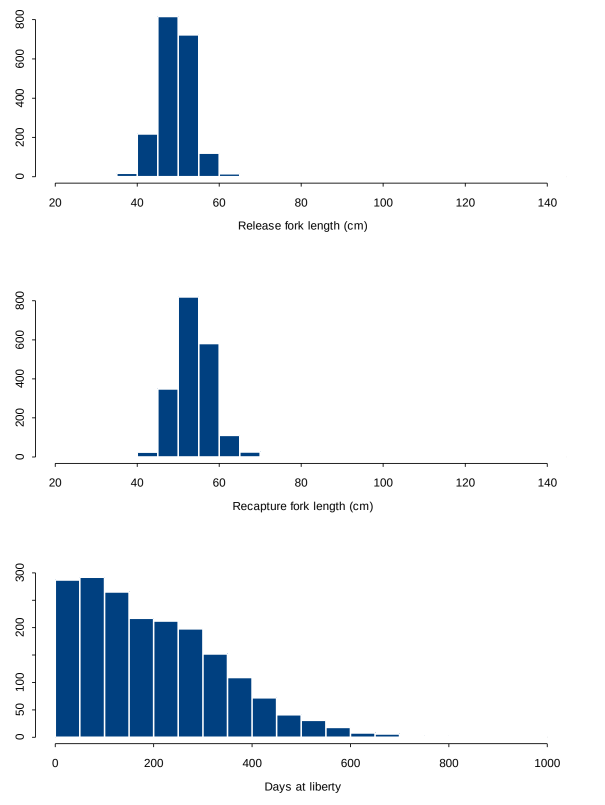


**Figure 6. Histograms of release lengths, recapture lengths and days at liberty for recaptured (a) yellowfin tuna (b) bigeye and (c) skipjack. From document IOTC-2008-WPTDA-07**

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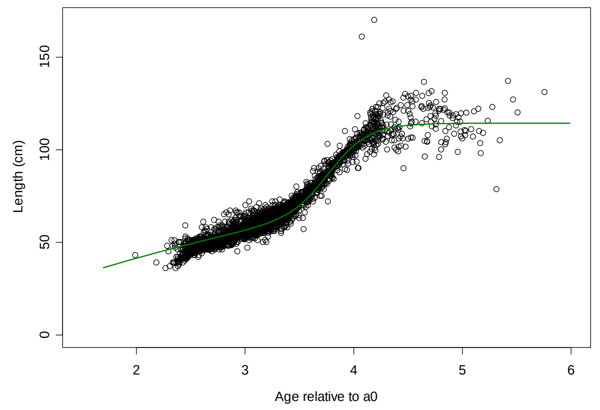
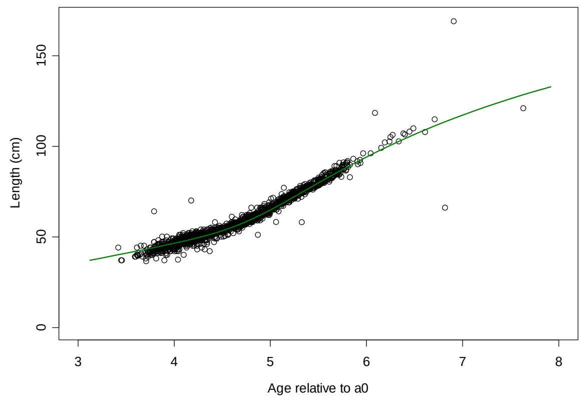
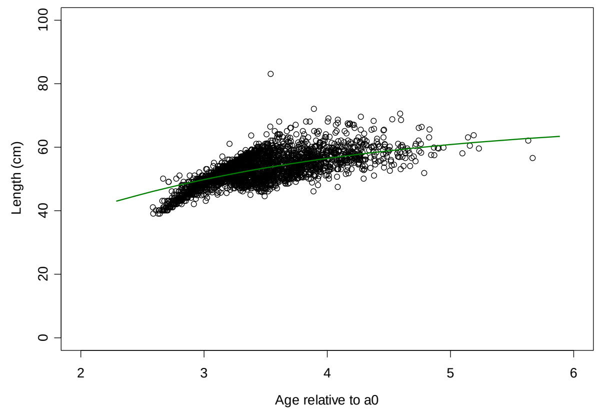



**(a) Yellowfin**

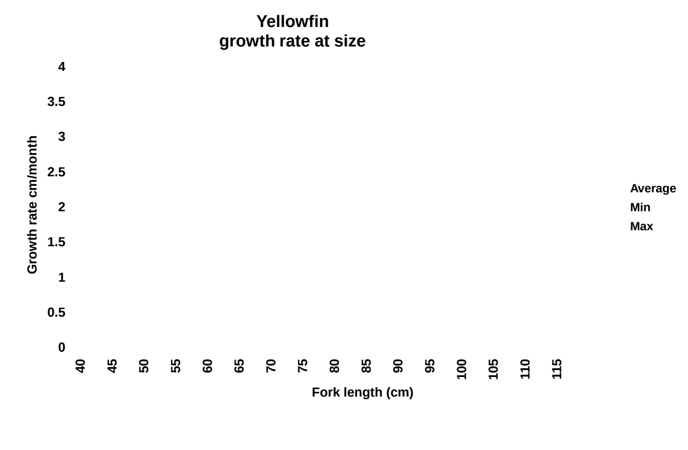


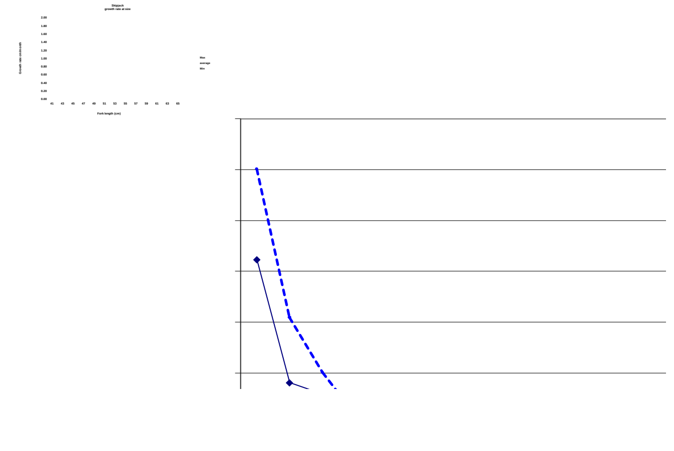

**(b) Bigeye**




**(c) Skipjack**

**Figure 7. Release and recapture lengths plotted against estimated age (relative to a0), with the mean fitted growth curve for (a) yellowfin – using a VB log k growth function (b) bigeye – using a VB log k growth function (c) skipjack using a VB growth function. From document IOTC-2008-WPTDA-07**



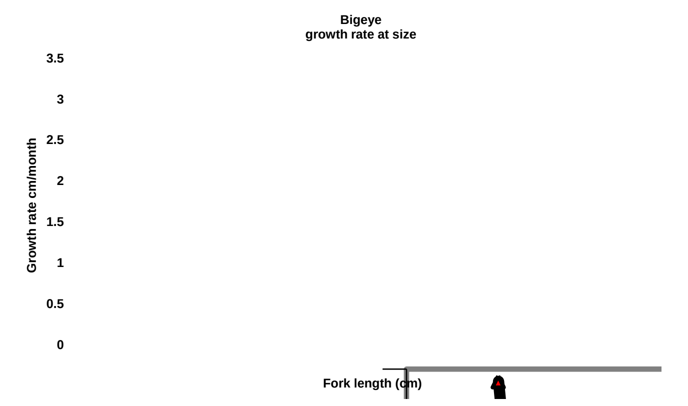



**Figure 8. Growth rates at size for yellowfin, bigeye and skipjack described in document from IOTC-2008-WPTDA-08.**

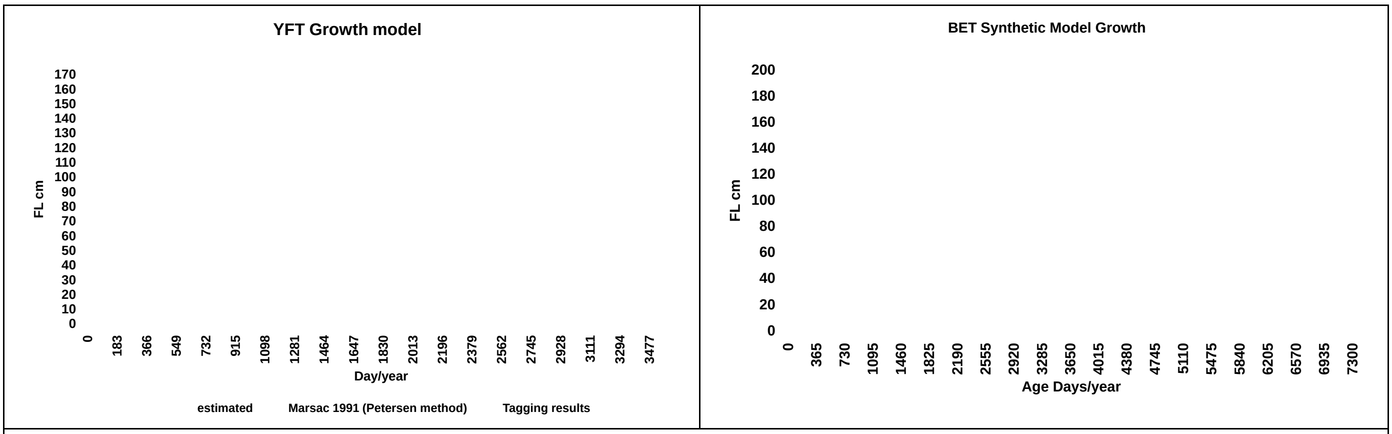



**Figure 9. Growth rates at size for yellowfin and bigeye described from IOTC-2008-WPTDA-PRES19.**

34. Document IOTC-2008-WPTDA-09 described results from a range of growth studies. The paper indicated that the coverage of the tagging data and the commercial data needs to be similar in order to avoid potential bias in models and results. There was also some discussions at this point comparing the apparent two-stanza growth of yellowfin and bigeye with that of human growth and some participants suggested that some aspects of human growth functions might be applicable to tuna growth.

35. IOTC-2008-WPTDA-PRES10 described very preliminary results on estimating age from otoliths collected as part of the RTTP-IO. Although the numbers of otoliths that have been examined is low (<100), some differences in the estimated length at age of the RTTP-IO samples and the historical Stequert samples were apparent.

36. The WP acknowledged that there could be a range of reasons for these apparent differences, including spatial and temporal effects and possible difference in the methods or equipment used to examine the otoliths. **The WP recommended that the current and historical methods used to examine the otoliths be compared; and if**

**possible, some of the historical otoliths be re-read by the workers currently examining the RTTP-IO otoliths.**

37. **The WP also recommended that it was important that the validation of otoliths be carried out across the full size range of fish being aged. Furthermore, the variance of age estimates should be evaluated to determine whether statistically significant differences exist between readers and for individual readers.**

38. Document IOTC-2008-WPTDA-12 described an analysis of skipjack growth analysis using tagging data. The results from the conventional Fabens' method were compared with a new method which combines the tagging data and parameters of growth of skipjack from isolated studies in the World Ocean. The main advantage of the new approach was to account for the form of the relationship between the historical growth parameters and to express $L\infty$ as a bioenergetic function of K. The influence of the penalties in the partial objective functions of the Log-likelihood were compared between an unweighted combined likelihood and a sample size weighted likelihood. Results produced estimates of K at 0.26 and Linf of 77.66. These were similar to those derived using the Fabens method and consistent with values reported for skipjack in the world's oceans (Appendix VI).

39. The WP discussed the issue of weighting of data-sets in non-linear estimation and agreed that it may be useful in resolving some of the issues observed when trying to fit the growth curves. It was noted that a split with respect to observation/measurement and process error should, to some degree, deal with the internal weighting of the data both pre- and post-estimation.

40. The WP noted the following historical estimates of length at 6 months: 34 cm for yellowfin in the western Pacific Ocean[3]; 32 cm for yellowfin in the eastern Pacific Ocean[4], and 36 cm for bigeye in the eastern Pacific Ocean[5].

*Measurement errors from tagging*

41. The WP also noted that shrinkage in tuna length occur post-mortem and with freezing (and further that different freezing methods produce different changes). While these changes in length are relatively small, they will produce biases in growth estimates. It is necessary to conduct shrinkage experiments (for example refer to Schaefer and Fuller (2006) [6] in order to be able to adjust the recapture lengths of the fish to those expected at the time of recapture. **The WP recommended investigations to quantify post-mortem shrinkage in tuna length caused by freezing.**

42. Preliminary analyses of the tagged fish recaptured by the tagging vessel during tagging operations were conducted during the meeting to get an indication of the extent of measurement error at the time of tagging (Appendix VII). The data used in the analyses were from tagged fish that were recaptured by the tagging vessel within five days of their release to ensure that measurement error was isolated from growth. The estimated measurement error is largest for skipjack, and smallest for bigeye, although the differences in the latter case are small. The differences in the measurement error are in accordance with the expectation of those who have undertaken tagging of the three different species based on differences in the behavioural characteristics of the three species in the tagging cradle. When outliers in the difference between the initial and subsequent length measurements are excluded (i.e. differences of 10cm or greater), the estimates for the standard deviation in the initial length measurements were 0.75, 0.50 and 0.47 for skipjack, yellowfin and bigeye respectively. The results of the analyses in Appendix VII (or subsequent refinements) can be used to provide estimates of the magnitude of the initial length measurement for use in the estimation of growth from the RTTP-IO tag increment data.

*General comments*

[3] Stéquert,B., Panfili, J., Dean, J.M., 1996. Age and growth of yellowfin tuna, *Thunnus albacares*, from the western Indian Ocean, based on otolith microstructure. Fish. Bull. 94, pp. 124-134.

[4] Wild, A. 1986. Growth of yellowfin tuna *T. albacores* in the Eastern Pacific Ocean based on otolith increments. *IATTC Bull.*, **18**, 423-482.

[5] Schaefer, K.M. and Fuller, D.W. 2006. Estimates of age and growth of bigeye tuna (*Thunnus obesus*) in the Eastern Pacific Ocean, based on otolith increments and tagging data. *IATTC Bull.*, **23**(2), 31-77.

[6] Schaefer, K.M. and Fuller, D.W. 2006. Estimates of age and growth of bigeye tuna (*Thunnus obesus*) in the Eastern Pacific Ocean, based on otolith increments and tagging data. *IATTC Bull.*, **23**(2), 31-77.

43. The issue of whether the changes in purse-seine selectivity relating to fish size may influence the observed two-stage growth pattern was raised. It was noted that similar problems were found in growth analyses of Pacific yellowfin, and that bias in selection can affect estimates of asymptotic length, and that as a result this can bias the estimates of key growth parameters. It was suggested also that a length-based model might be more realistic given some of these issues.

44. The WP noted that the difficulties encountered combining the tagging data and historical age information derived from otoliths. The WP noted that while the otolith data has been excluded from growth analyses by other workers, these data shouldn't be discounted, even if inconsistencies between data sets are apparent, without having substantiated reasons for why the otolith data may be inaccurate. Nevertheless, the WP cautioned against combining the two data sets in a single analysis when such discrepancies exist as this will result in averaging between the two when in fact one or the other is likely to be inaccurate.

45. The WP also noted that while tagging information does not currently provide a reliable estimate of Linf, a value can be derived from long-line (and purse seine for YFT) catch-at-length information (until better information are available). However, it was noted that the use of these length data without confirmation of age could be misleading with respect to estimates of Linf.

46. The WP discussed the potential of tagging induced growth retardation and whether this needs to be accounted for within the assessment model. The WP noted that there is some evidence from Pacific Ocean tagging experiments that growth retardation can occur in all three species.

47. It was mentioned that papers exist that have addressed the issue of integrating selectivity within a growth estimation procedure and that, perhaps, it might be required to estimate growth inside of an assessment framework as opposed to estimating it externally. There was overall support for using simulation investigations to look at the potential selectivity induced bias.

# 5. ESTIMATING TAG SHEDDING RATES AND TAG REPORTING RATES

## *5.1 TAG SHEDDING*

48. Document IOTC-2008-WPTDA-04 described tag shedding and reporting rate estimates for Indian Ocean tuna using double-tagging and tag-seeding experiments undertaken as part of the RTTP-IO. A total of 16% of the fish were double tagged in order to estimate tag shedding rates. Results from two studies based on two different approaches (Bayesian and traditional estimation of Type 1 (immediate), Type 2 (continuous) shedding were presented to estimate the shedding rates for each species using the double tag recovery data.

49. In the first approach, partitions of Time-at-Liberty (TAL) were created and for each partition a probability of retention was estimated. The first partition of the TAL covered in 1-30 days to account for the Type 1 (or immediate) shedding, and then partitions of 100 days (to match the quarterly structure of the data for assessment). This study show evidences of a Type 1 shedding especially for YFT and BET, and that there is a decrease in the retention of tags for YFT and BET between 100 and 200 days. Also, the retention rate is generally higher for BET and SKJ than for the YFT, which was surprising given the behaviour of the fish at tagging.

50. The pooled time-at-liberty approach indicated that the tag retention rates were high – for a time-at-liberty of 6 months (close to the average time-at-liberty for all three species) the median and 95% confidence interval was 0.77 (0.64-0.85) for yellowfin, 0.91 (0.79-0.96) for bigeye and 0.89 (0.81-0.94) for skipjack.

51. Document IOTC-2008-WPTDA-06 described a second approach using a larger subset of the double tag data. Exploratory analyses of the data were undertaken examining the size of the tag (two sizes), the position of the tag (left or right), the cruise and the double tagging itself. The size of the tag did not affect return rate; however, tags placed on the right side of the fish were better retained and double tagged fish had a slightly better return rate than the single tagged fish. The WP noted that these results needed to be confirmed by additional statistical analyses.

52. Further analyses were undertaken during the meeting using a revised dataset. Two alternative models were used to fit the proportion of tags lost over time: a constant type-2 shedding rate model and a time-varying model. Since the fit of the time-varying model could not be distinguished from the constant–rate model, the constant–rate model was preferred. It was noted however that integration of longer-term recovery periods should modify the choice of the best type-2 shedding model. Parameter estimates with bootstrapped confidence intervals (95% B.C.I.) for the constant shedding rate model (i.e., the probability of retention $Q(t) = \alpha \exp(-\lambda t))$ from double tagging experiments for the 3 main species of tuna in the Indian Ocean are presented in the following table.

**Table 1. Parameter estimates with bootstrapped confidence intervals (95% C.I.) for the constant shedding rate model (i.e., the probability of retention $Q(t) = \alpha \exp^{(-\lambda t)}$) from double tagging experiments for the 3 main species of tuna in the Indian Ocean. From IOTC-2008-WPTDA-06.**

| **Species** | **α** | **95 % CI** | **λ (per year)** | **95 % CI** |
|---|---|---|---|---|
| Skipjack | 0.984 | (0.976 - 0.993) | 0.016 | (0.000 – 0.033) |
| Yellowfin | 0.973 | (0.963 - 0.985) | 0.033 | (0.016-0.053) |
| Bigeye | 0.993 | (0.984 - 1.000) | 0.016 | (0.000- 0.027) |

53. Further exploratory work was undertaken to examine the influence of the tagger*cruise interaction effect on tag shedding as the results (for yellowfin tuna only at this stage) suggested that, in addition to the tagger effect, the distance from the area were the tagging cruise took place to the main fishing grounds may also influence the probability of recovering a tagged fish.

54. The estimated tag retention rates were generally similar for both the above approaches, except for yellowfin, where the pooled time at liberty approach predicted that the retention of tags was lower.

55. In general, the low values of the tag shedding parameters found in this study were of a similar order to those previously reported by different authors for tropical tunas in the world oceans. For instance, the largest shedding rate was observed for yellowfin, which reached around 10% only after 2 years after release.

56. **The WP recommended that work comparing the return rates of double tagged fish with those of single tagged fish from the same school or area time strata be conducted**[7]. If no shedding occurs, these return rates should be the same; however, if shedding is relatively common, the double tagged fish should have higher return rates than single tagged fish. Moreover, double tagged fish have more chance to be detected/returned than the single tagged fish (as a single tagged fish that loses its tag will not be identified). Analyses have shown that, in general, the second tag placed into a fish had slightly higher retention than the first tag (this is consistent with observations made by workers in the Pacific Ocean).

57. The WP noted it is important to examine shedding rates attributed to individual taggers. If substantial variation in shedding rates exists among taggers, then pooling the data from all taggers to estimate shedding rates could result in biases in the estimates of mortality rate. Ideally, analyses should use the release and recapture data disaggregated into groups of taggers with similar shedding rates. In the absence of this, it was suggested that the data be examined to identify taggers with high shedding rates and the release and recapture data for these taggers be excluded from analyses as a means to minimise biases.

### *5.2 TAG REPORTING RATES*

58. Document IOTC-2008-WPTDA-04 described the tag seeding operation has been implemented in Seychelles since 2004 whereby dead fish covering the 3 targeted species of different sizes are tagged onboard vessels of the purse-seine fleet based in Seychelles and placed into the ships' wells. In each seeding operation a maximum of 15 fish were tagged. A total of 2539 fish have been 'seeded' of which 2147 (85%) were tagged by voluntary skippers and 392 (15%) by fisheries observers. All seeded recoveries were treated exactly the same as conventional tag recoveries. A Generalized Linear Model (GLM) was used to estimate the reporting rate of the fish unloaded in Seychelles. The effects of year, size and of the tagger (observer or skippers) were examined. Reporting rates have increased since the start of the experiment. Year had a significant effect on the reporting rates of YFT and SKJ, while a tagger effect influenced the reporting rate for BET. When all species were combined, both year and tagger, respectively were significant. The fit of the GLM to the data is poor and it was concluded that a GLM is probably not the best way of analysis that could be done with these data and a binomial Bayesian approach may have better prospects when applied to the raw seeding data.

[7] Refer to Hearn, W. S., J. P. Eveson, T. Polacheck, J. M. Hoenig, K. H. Pollock, and R. Latour. 2007. Estimating tag shedding and tag-induced mortality. Chapter 5 in J.M. Hoenig, K.H. Pollock, R. Latour and W.S. Hearn (eds.), Design and Analysis of Tagging Studies – a Synthesis of Methods for Estimating Mortality Rates. American Fisheries Society, Bethesda, Maryland.

59. The WP noted that the study focused on the reporting rates in Seychelles as information for the other ports where the purse-seine fleet unloads have not yet been analysed. However, it acknowledged that most of the purse seine catch is landed in Port Victoria, Seychelles (95% in 2006 and 91% in 2007) – Table 2.

**Table 2. Landing and Transhipment by Port by purse seiners licensed to Seychelles Fishing Authority.**

| | | Data | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | L_port | YFT | SKJ | BET | ALB | OTH | Total (MT) | % Landing by port |
| 2005 | BANDAR-ABBAS | 1,588 | 63 | 1 | 0 | 172 | 1,823 | 0% |
| | DIEGO SUAREZ | 6,417 | 13,648 | 801 | 1 | 43 | 20,910 | 5% |
| | MAURICE | 1,227 | 2,264 | 169 | 0 | 0 | 3,660 | 1% |
| | MOMBASA | 11,614 | 9,985 | 1,555 | 7 | 55 | 23,216 | 6% |
| | SEYCHELLES | 156,250 | 163,196 | 19,554 | 150 | 602 | 339,752 | 87% |
| **2005 Total** | | **177,094** | **189,156** | **22,080** | **159** | **872** | **389,361** | |
| 2006 | DAR ES SALAAM | 115 | 972 | 33 | 0 | 0 | 1,120 | 0% |
| | DIEGO SUAREZ | 2,148 | 5,795 | 422 | 28 | 51 | 8,445 | 2% |
| | MAURICE | 1,921 | 1,899 | 166 | 13 | 0 | 4,000 | 1% |
| | MOMBASA | 3,039 | 1,791 | 453 | 0 | 0 | 5,283 | 1% |
| | SEYCHELLES | 142,146 | 208,539 | 16,839 | 1,165 | 845 | 369,534 | 95% |
| **2006 Total** | | **149,369** | **218,996** | **17,913** | **1,206** | **896** | **388,381** | |
| 2007 | DIEGO SUAREZ | 2,513 | 11,740 | 782 | 1 | 0 | 15,035 | 6% |
| | MAURICE | 1,298 | 2,601 | 296 | 1 | 0 | 4,196 | 2% |
| | MOMBASA | 2,135 | 1,658 | 332 | 1 | 0 | 4,126 | 2% |
| | SEYCHELLES | 83,743 | 120,162 | 18,440 | 483 | 368 | 223,196 | 91% |
| **2007 Total** | | **89,689** | **136,160** | **19,850** | **486** | **368** | **246,553** | |

60. Concern was expressed that the recovery rate of tuna tags by the longline fishery has been very low (currently information on only 37 yellowfin and 19 bigeye is available from longliners). It is generally believed that this is most likely due to non-reporting of tags. It is important to note, however, that the majority of tagged tuna of all species are smaller than the sizes caught by the longline fishery. In order to investigate this, a simple exponential decay model will be constructed using the tagging length frequency data. The object of this model will be to estimate how many of the tagged fish survive and grow to a size where they can potentially be harvested by the longline fishery. This will be carried out for all three tropical tuna species. The model will take account of the tags already recaptured. In this way it is hoped we can ascertain whether the non-reporting by the longline fishery is also due to the fact that many of the tagged tuna are not available to the fishery. The lack of tag returns from the artisanal fisheries was also noted and information on reporting rates for these fisheries is not available.

61. The WP noted that, based on the catch at size taken by each gear, future recoveries of adult yellowfin can be expected from all three fishing sectors: longline, purse seine and artisanal fisheries (Figure 10) while adult bigeye can only be expected to be recovered from the longline fishery (Figure 10).

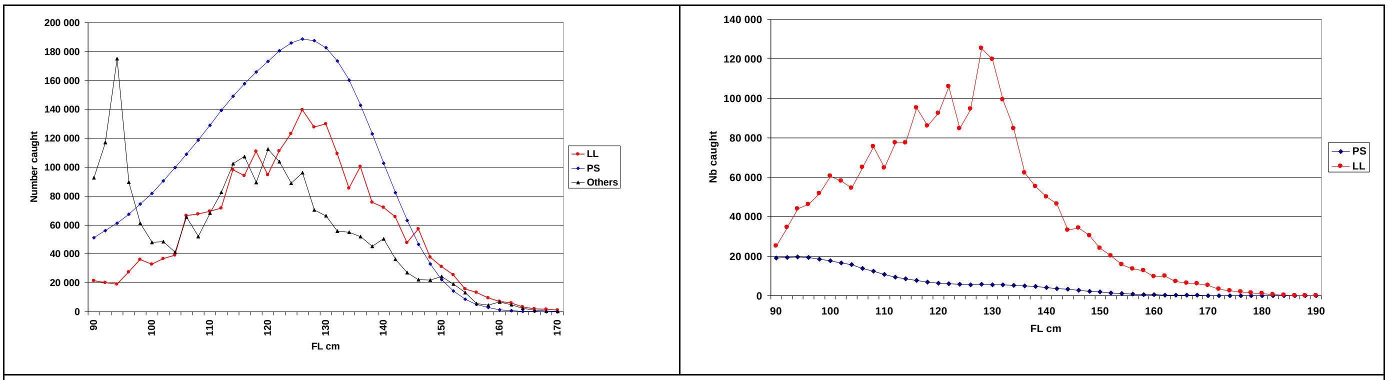



**Figure 10. Average catch at size by gear of yellowfin (left) and bigeye (right) in the Indian Ocean during recent years (2000-2005). From IOTC-2008-WPTDA-05.**

62. **The WP strongly recommended that the tag seeding programme continue for the duration of the RTTP-IO as it is essential that estimates of reporting rates are available across the entire duration of the project.**

63. The WP expressed its great appreciation to all the skippers and crews of the Spanish and French purse seine vessels and to all AZTI, IEO and IRD observers involved in the seeding activities. In particular, the WP paid special mention to Mr. Juan Jose Areso, representative in the Seychelles for the Oficina Espanola de Pesca, who proposed and initiated seeding activities in association with purse seine Captains and without whom the seeding experiment would not have been such a success.

# 6. MOVEMENT

64. Presentation IOTC-2008-WPTDA-13 described the movements of skipjack (SKJ), yellowfin (YFT), and bigeye (BET) tunas, tagged and released with conventional plastic dart tags in the western Indian Ocean (IO) (Figure 11). These species have been observed to disperse widely and fairly rapidly throughout the western IO. The distances of the movements of BET, YFT and SKJ into the eastern Indian Ocean appear to be similar. However, 96% of the total recoveries have come from purse-seine catches and there are few recoveries from longline vessels. Tag recoveries from longline vessels are very important for understanding the movements of larger YFT and BET, which would not be expected to be recaptured by the surface fisheries over much of eastern the Indian Ocean, especially the high seas areas that are fished mainly by longliners. Dependent on the release locations there are some observed differences in the movements of the three species including directionality, distances, and apparent velocities.

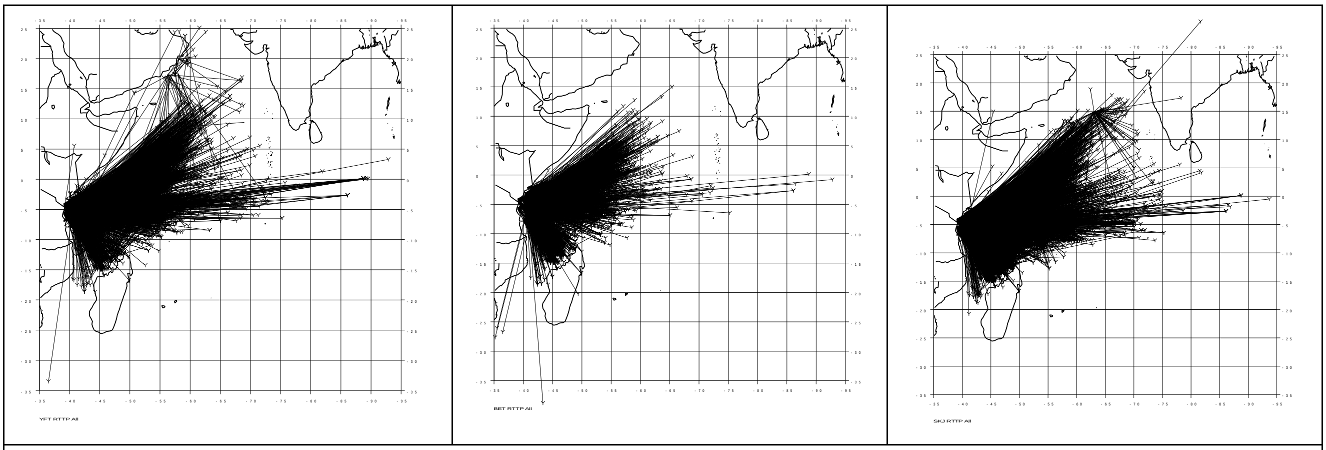
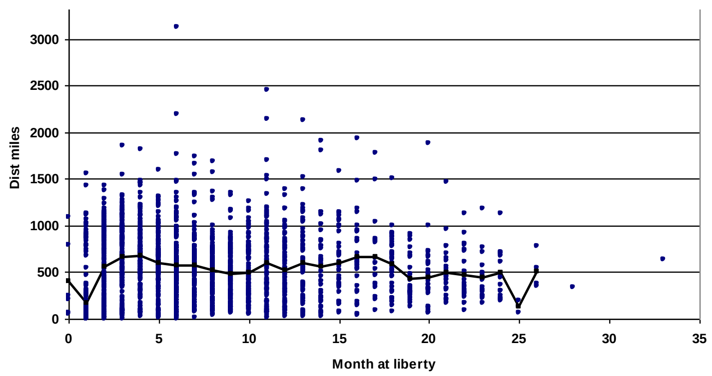
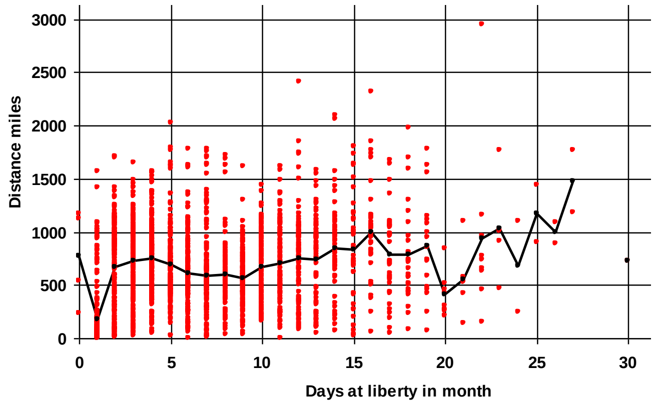


**Figure 11. Movement trajectories of individual tagged fish from the western Indian Ocean area (a) yellowfin (b) bigeye and (c) skipjack. From IOTC-2008-WPTDA-13.**

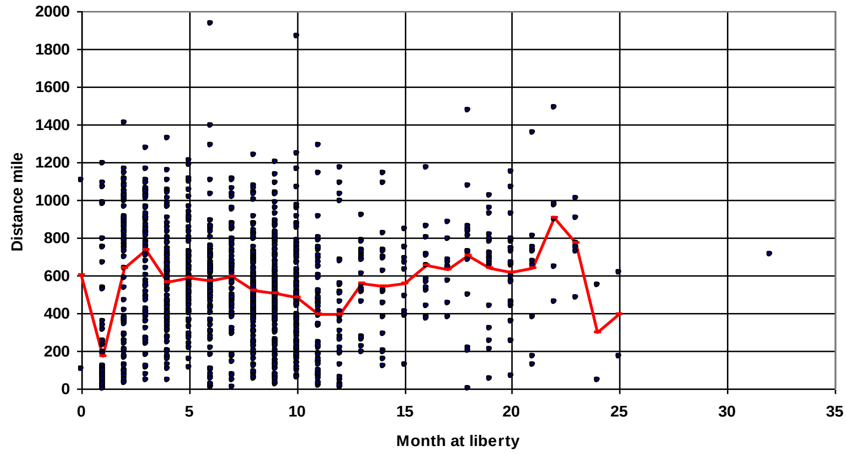
65. Document IOTC-2008-WPTDA-05 argued that understanding the movements of the three tuna species throughout their lives is important — noting that information from mainly smaller sized, younger aged individuals has been obtained from this study to date. While the Indian Ocean tagging has been performed in a relatively small area and involved fish of limited size ranges, the results to-date indicate fairly rapid dispersion as well as spatio-temporal movements throughout the fisheries in the western Indian Ocean. The average linear displacements were 526 nm for YFT, 642 nm for SKJ and 525 nm for BET (Figure 12).




**(a) Yellowfin**



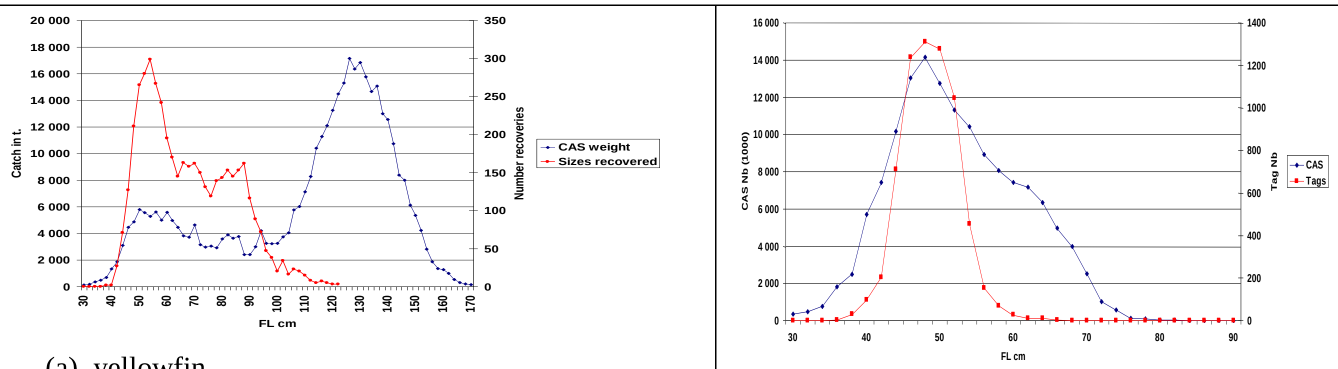

**(b) Skipjack**




**(c) Bigeye**

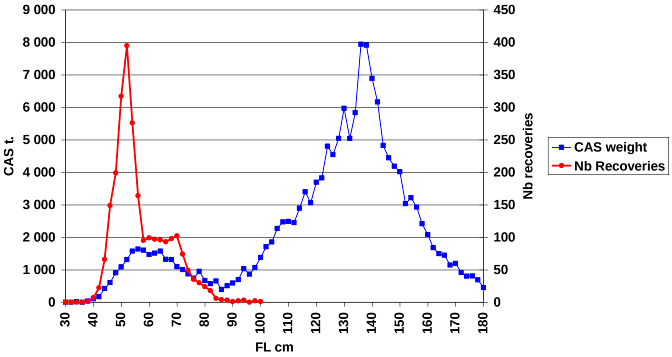
**Figure 12. Linear distances travelled and time at liberty of tagged individual tunas at the time of recapture. Note these distances likely under estimate the actual distances travelled. The line indicates the mean distance travelled for the individuals in each time at liberty class. From IOTC-2008-WPTDA-05.**

66. A comparison of the species specific length frequencies of the catches and the length frequencies of the tagged fish can be useful in an evaluation of tuna movements as this can indicate whether the fish are reaching the fishing grounds of the various fleets involved. For example, Figure 13 compares the catch size frequency distributions for all gears combined with the size frequency distributions of the tagged fish recovered. The modes of the larger sized fish in the catches shown in Figures 13a (yellowfin) and 13c (bigeye) are taken by the longline fisheries thus the absence of large tagged fish could mean they have not moved into the longline fishing grounds, as illustrated in Figure 14; or alternatively, the tags are not being returned by longline fishers. Similarly, it appears that very few skipjack have moved into the Maldives area (the Maldives fisheries typically catch medium and large-sized skipjack) given the sharp drop off in the size of skipjack recovered to-date (Figure 13b).




(a) yellowfin

(b) skipjack




(c) bigeye

**Figure 13. Comparison of the catch size frequency distributions for all gears combined with the size frequency distributions of the fish recovered for (a) yellowfin (b) skipjack and (c) bigeye. From IOTC-2008-WPTDA-05.**

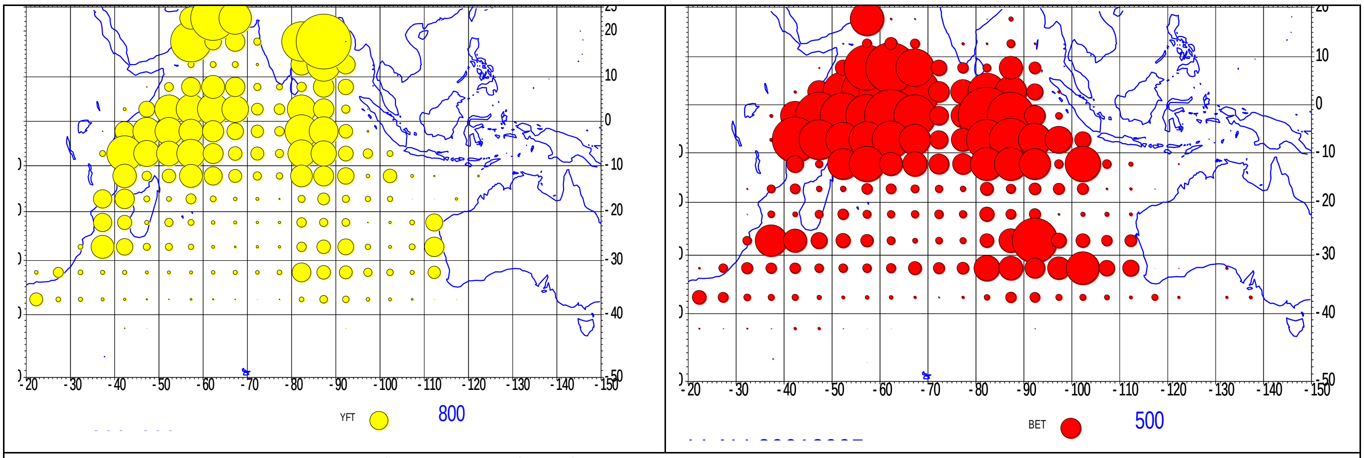



**Figure 14. Location and relative sizes of recent yellowfin (left) and bigeye (right) catches taken by longliners in the Indian Ocean. Circles denote average catches over the period 2001 to 2005. From IOTC-2008-WPTDA-05.**

67. Time series maps of the distribution of tag recaptures such as those in Figure 15 may provide useful information to evaluate movement patterns over time.

68. The WP noted that it is important to keep in mind the size of the Indian Ocean, relative to that of other oceans, in comparisons of movements and dispersion of the three species. For example, the area of Indian Ocean is smaller than the Pacific Ocean therefore movement patterns are likely to be different.

69. The WP discussed the issues of the restricted time and area, as well as the associative school type in which most of the tagging occurred. The seasonality of tagging in specific locations should be examined as it may influence the results of the movements. The WP also noted that it was not possible to compare movement rate quantitatively from different tagging experiments without taking into account the distribution of releases, the spatial/temporal distribution of the fisheries and reporting rates for different fisheries components.

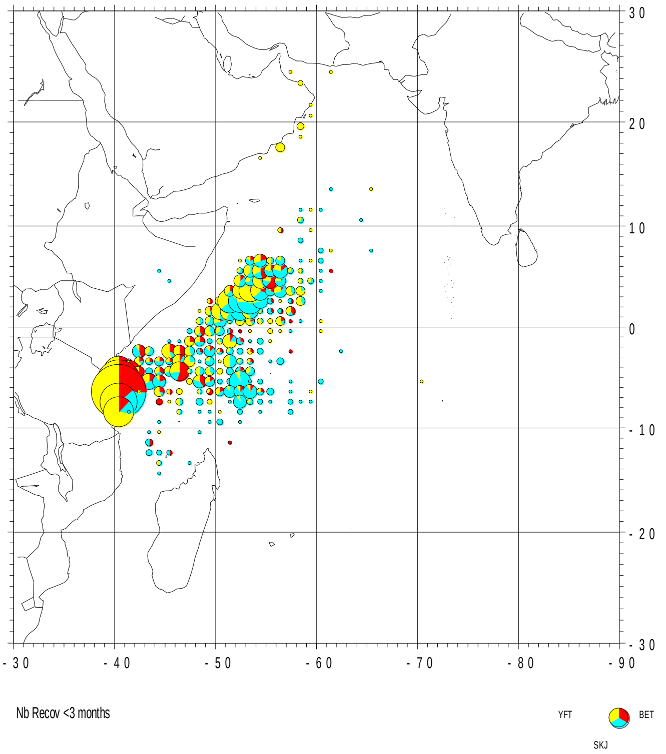
70. **The WP recommended that the CPUE data be integrated with the tagging data to better understand the movements of the tagged tunas.** The WP also suggested that the movements derived from tagging data should be evaluated within a model that includes both fishing mortality and natural mortality along with relatively fine scale fishing effort data.

71. The WP suggested that the linear displacements based on tag and recapture data should also be illustrated as one-degree density maps (as in Figure 15), in addition to ‘traditional’ straight lines (Figure 11), as it provides a much better graphical display for such data.

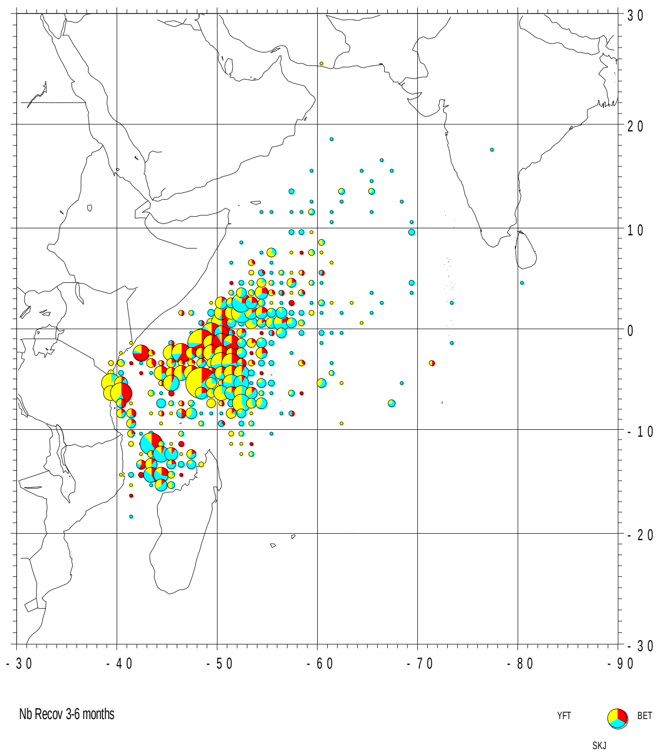
72. There was some discussion regarding the lack of SKJ recoveries from the Maldivian fishery, but some participants indicated that this may not be unexpected considering mortality rates and the distance of the Maldives fisheries from the tagging locations. Further quantitative analyses will be necessary to evaluate the interaction.

73. The WP noted that there is an opportunity to obtain tags from foreign longliners operating in Maldives waters and encouraged the Maldives tagging team to work with the people involved with these vessels in order to obtain any tags they find.

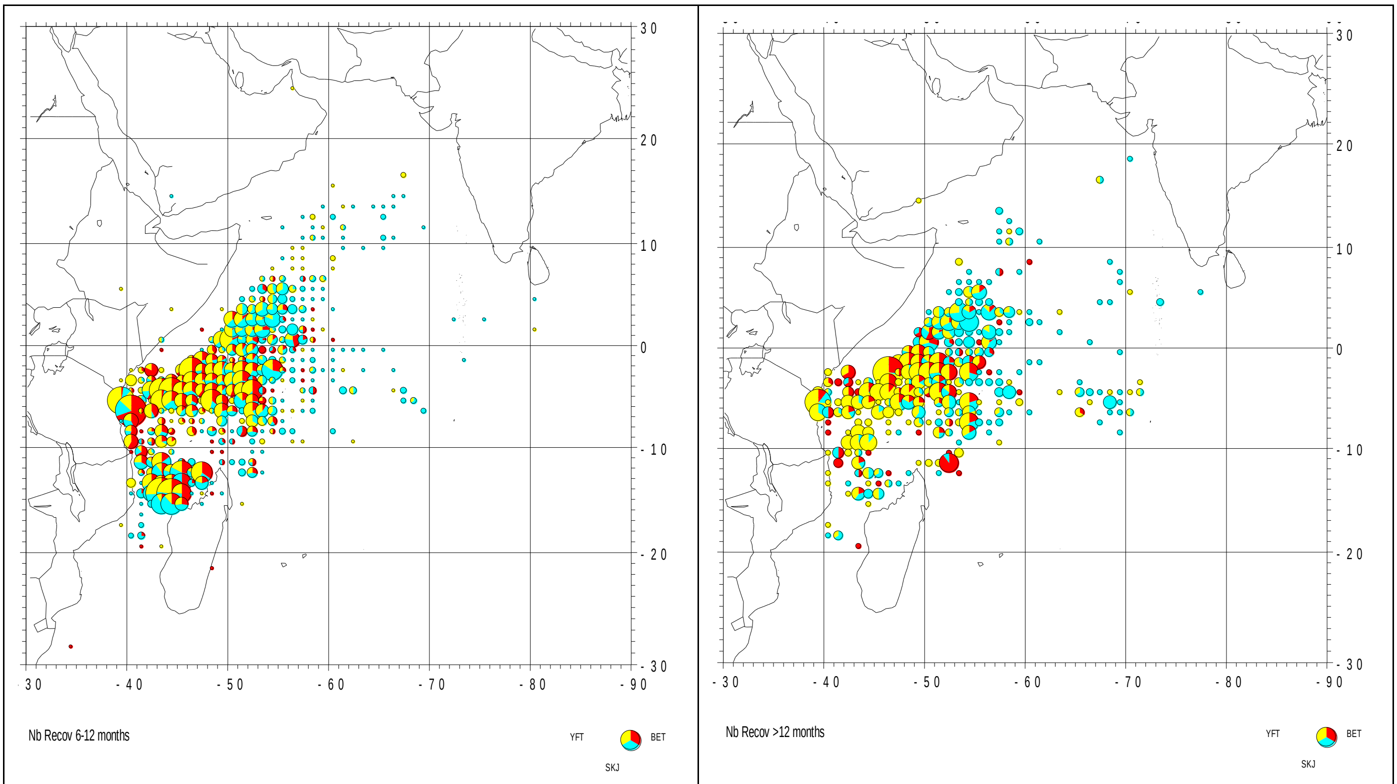
74. **The WP recommended that analyses examining tuna movements and environmental factors be undertaken in the future.** It was noted that the tagging/recovery data should also be incorporated in environmental models. It is expected that these models should allow a much better understanding of the movement patterns of tagged/recovered tunas, as a function of tuna species and sizes recovered.




**less than 3 months**




**3-6 months**




**6 – 12 months** | **over 12 months**

**Figure 15. Location of recoveries, by species, as a function of time at liberty, and classified in 4 time categories: a) short term recoveries taken within the 3 months after tagging, (b): after a period between 3 and 6 months, (c): after a period between 6 and 12 months (d): after a long period over 12 months. From Document IOTC-2008-WPTDA-05**

## 7. CRITICAL EXAMINATION OF POTENTIAL EXTERNAL ANALYSES

75. The following external analyses of the tagging data were viewed as potentially highly informative and should be undertaken as an adjunct to comprehensive integrated stock assessments as they can often provide more robust inputs to the range of alternative stock assessment based on conventional methods.

- Brownie-type analysis[8] of release and recapture cohorts to estimate natural mortality and fishing mortality for the tagged population
- Models with regional spatial structure, in which movement among a restricted number of model regions is explicitly recognized and estimated, along with fishing and natural mortality
- High-resolution (e.g. 1x1 degree) spatial analysis with movement modelled as an advection-diffusion process.
- Tag attrition models to estimate exploitation rates

76. It was noted that for each of these model types, it is necessary to have (i) supporting catch and/or effort data for the main fisheries recapturing the tagged fish; and (ii) estimates of tag-reporting and tag-shedding rates.

77. The issue of natural mortality estimation was specifically discussed. Whether this is done in external analyses or in an integrated assessment model, it is critical to preserve the cohort structure of the tagged population over the period in which most tag recaptures occur.

78. The possibility of conducting external analyses on all three species in the same model was discussed. This approach was proposed so that the hypothesis of similar levels of natural mortality rates for YFT and BET during

[8] Brownie tagging experiments involve multiple releases on the same cohorts in at least three distinct time periods. The approach allows for the estimation of both age-specific natural and fishing mortality rates if reporting and shedding rates are available. The primary information for the estimation of the mortality rates comes primarily from comparison of the return rates over time from the multiple release events combined with the overall decline in the number of tags over time. See Brownie, C., Anderson, D.R., Burnham, K.P., and Robson, D.S. 1985. Statistical inference from band recovery data: a handbook. U.S. Fish and Wildlife Resource Publication 156.

the period of their vulnerability to the purse seine fishery could be evaluated. However, there were differing views among some participants regarding the likelihood that the two species would share such characteristics, given differences in their basic physiology and behaviour at all life history stages. Notwithstanding these differences in opinion, given that data now exist for large numbers of small bigeye and small yellowfin simultaneously tagged and recovered in the Indian Ocean, it may be possible to examine this question further.

# 8. EXAMINATION OF THE PERFORMANCE OF INTEGRATED STOCK ASSESSMENT MODELS USING RTTP-IO TAGGING DATA

79. Document IOTC-2008-WPTDA-PRES15 provided an overview of integrated stock assessment models and how they differ from traditional stock assessment approaches (this was a summary of a paper prepared for the IATTC Tagging Workshop in October 2007). Traditional stock assessment analyses have relied mainly on a two-step analytical procedure. First, a summarized version of some type of raw data is produced in a first analysis. The summarized data are then provided as input for a second analysis. One example is the use of raw tagging data to obtain a Petersen estimate of stock size (first step), which is then used in the fitting procedure of a population dynamics model (second step). The traditional approach has some disadvantages, including loss of information in the summarization process, inconsistencies between the assumptions for the two analyses, difficulties in determining the error structure, inclusion of uncertainty from the first analyses, and reduced diagnostic ability.

80. The development of modelling and statistical approaches to assimilate large and diverse data sets is a very active research field at the present. This is strongly motivated by recent developments in computer technology, allowing analyses that were prohibitive until very recently. Within this context, the “integrated analysis” approach for stock assessments has recently emerged. Basically, it consists of combining the first analysis (e.g., estimating stock size from tagging data) and the population dynamics modelling into a single analysis, instead of the traditional two-step process. Data and parameters are thus shared in this one-step process. All the information contained in the raw data is now entirely available to the stock assessment, and conflicting assumptions are avoided within this framework. Uncertainty is propagated throughout the analysis, and correlation among parameters is automatically considered. Diagnostics ability is greatly enhanced within the integrated approach. The presentation reviewed the different types of integrated analysis with emphasis on models which integrate tagging and population dynamics models in fisheries stock assessment. It also identified the challenges involved in applying the integrated approach in stock assessment context.

81. IOTC-2008-WPTDA-PRES16 provided an overview of the integrated stock assessment model MULTIFAN-CL. (MFCL). MFCL was designed to integrate data typically available from tuna fisheries in the western and central Pacific Ocean – catch (in weight or numbers), effort, length frequency, weight frequency and tagging data. The model is age structured and is fit to the data using appropriate error structures. The parameterization is constrained by a variety of prior information, e.g. tag-reporting rates. The parameters estimated may include selectivity, catchability, growth, natural mortality, recruitment deviates, random effects in the effort-fishing mortality relationship (effort deviations) and catchability trends. Catch may be assumed to have error or be exact. Either the Baranov catch equation or Pope-type approximations may be specified. The model incorporates the estimation of MSY-based reference points and procedures to obtain probability distributions of Fcurrent/FMSY, Bcurrent/BMSY and SBcurrent/SBMSY by likelihood profile. Tagging data are incorporated into the model through the modelling of tagged cohorts over time, allowing for initial mixing. The tagged and untagged populations are allowed to share population parameters, with the tagging data being informative regarding natural mortality at age and movement. At this stage, MFCL does not utilize length-increment data from tagging to assist with the estimation of growth. This may be incorporated into future versions. MFCL executables, documentation and example data sets may be downloaded from www.multifan-cl.org, and the source code is available on request.

82. Document IOTC-2008-WPTDA-14 described preliminary results from an initial application of the CASAL integrated stock assessment model to the yellowfin data for the Indian Ocean including incorporation of RTTP-IO tagging data. The assessment was set up using the CASAL integrated stock assessment tool and allows for the integration of catch-at-age/length, relative abundance, ageing and tagging data. The model structure was single stock and area, with a quarterly time-step and with 7 fishing fleets, to cover the range of gear types seen in the fishery. Raised catch-at-length proportions were used for all fleets, with Japanese long-line CPUE being the relative abundance index used within the model. The tagging release and recapture data from 2006 were employed on a quarterly time-scale, with the releases from quarter one and two and the recaptures in quarters three and four, respectively, coming through the Stevedore-processed catches in the Seychelles, for which there is reporting rate information.

83. The model parameters in this initial CASAL application were selectivity parameters, unfished spawning biomass, yearly recruitment parameters and observation-related process error terms. Weightings to the relevant data sets were assigned using statistical methods where information on data variance structure was available and pragmatically when it was not, in the sense that high weight was not given to data sets for which there is little or no information on their representativeness or precision. The model results were not considered to be sensible and there are suspected to be both serious problems with how the CASAL package models recruitment (as a single yearly pulse) and the biology of tropical tunas, and also that when integrating the tagging data the mutual selection of tagged fish at different spatial/temporal areas/times by different gear types makes the correct treatment of the dynamics of the tagged fish non-trivial and perhaps beyond the capabilities of generic stock assessment packages.

84. There was extensive discussion on the general use of integrated statistical stock assessment models; their applicability to the skipjack, yellowfin and bigeye fisheries of the Indian Ocean; and the preliminary results from the initial application of the CASAL model. The general discussion of integrated statistical models included:

- The integrated statistical modelling framework provided the most appropriate approach for the direct incorporation of the RTTP-IO tagging data into the stock assessments for the three tuna species. Such approaches would provide for the information gained from the tagging program to be fully utilized directly in the assessments.
- Experience has shown that the development and application of integrated statistical modelling to a particular fishery situation is non-trivial and not something that can be accomplished within the scope of a short working meeting. In fact, initially, the development and application may take several iterations before stable and robust results are obtainable. In this regard, it is important that sufficient time and resources are provided not only during working group meetings but in the inter-sessional meeting periods.
- In the application of statistical modelling, it is not necessary to have complete time series of inputs for all of the primary inputs (e.g. size-frequency data). When these are missing or highly unreliable, substituted or "best guess" estimates should not be used. This ensures that the model will fit to those data that have actually been observed and allows for the uncertainty created by such missing data to be addressed.
- Statistical integrated models are not a substitute for the need for reliable fishery data. In fact their application actually highlights the need for collecting data based on well designed sampling procedures so that the statistical properties of the input data (i.e. their accuracy and precision) can be assessed and directly utilized for providing an objective basis for determining the relative weight to give to different data used in the model and for the calculation of uncertainty associated with the model results.
- When contradictions exist in data from different sources, integrated modelling approaches are not a panacea for resolving them. In some cases the additional complexity in which these models allow for reality to be represented may result in plausible explanations for apparent inconsistencies. Nevertheless, when unresolved inconsistencies exist it is important to examine the implications of one or the other being in fact correct. Otherwise, the result will reflect some form of "average" compromise between the two (i.e. "split the difference" ) which will in many cases be the most unlikely situation.

85. In considering the application of the integrated models to the Indian Ocean tagging fishery, a number of issues were discussed. The question of how best to estimate growth received considerable attention given the large amount of information on growth contained in the increment data from the RTTP-IO data set. It was noted that ideally the estimation of growth should be done within the estimation process of the integrated model as there are additional sources of information that are used in the model that contained information on growth (e.g. the size frequency data). Moreover, selectivity parameters estimated by the models may influence the estimation of growth from the tag increment data. However, the estimation of growth parameters within integrated models which incorporate tag increment data is computationally complex and intensive – particularly if there is a large amount of such data. Currently, none of the generally available integrated models utilize tag increment data for the estimation of growth. Two approaches have been used (1) to estimate growth parameters external to the model (this may involve an integrated approach using various sources of information) and (2) to estimate growth parameters internally within the model but without the use of the tag increment data and to check as part of the diagnostic the consistency of the growth information in the tagging data with the model predicted growth rates. The working party did not resolve which approach was preferable in the case of IO tunas and agreed that it would be worthwhile initially to explore both approaches using different existing modelling frameworks. In the longer term, attempting to develop an integrate model that could use the tagging increment data or to incorporate the tagging increment into current integrated models would be the preferable.

86. In discussion of the application of the integrated models to the IO tuna fishery and the initial application of the CASAL model, a number of issues were discussed. These included:

- It is important that the information in the tagging data on M and fishery specific selectivities are maintained in how the tag release and return data are inputted into the model. In particular, it is important that the cohort, year/quarter and fishery strata/area of the releases and recapture data are preserved in order to maximize the potential information in the tagging data with respect to M and F (movement rates if the models have spatial structure).
- It is essential that tag shedding rates are available as well as reporting rates for at least one component of the fishery and preferably more. In the absence of reporting rates, the models will implicitly estimate a reporting rate for those fishery components based on ratio of tags recaptures to catch numbers for components where such data are available.
- It was noted that information from tagging data are the only potential source of fishery independent data for "tuning" the models. Also, the information from tagging is fundamentally different than that from CPUE – as the latter provides only information on relative abundance while the former provides information related to absolute abundance or fishing mortality rates. It is for this reason why results from a single tagging experiment can be highly informative in contrast to the long time series required for CPUE data.
- Limitations in the CASAL software with respect to how tagging data were treated and yearly time periods were noted. The present use of the latter could possibly be overcome by treating quarters as years and adjusting any input mortality rates appropriately. It was less clear that some of the limitations with respect to the tagging could be overcome within the current version of the model (particularly those related to incomplete mixing with artisanal fisheries). In the longer term, it was not clear whether the currently existing integrated modelling software would be able to provide the most appropriate framework for dealing with the particularities of the Indian Ocean tuna fisheries, without some modifications / further development (particular issues were incorporation of the tag increment data, handling of artisanal fleets, changes in selectivity overtime).
- The determination of appropriate "sample sizes" for size frequency distribution is an important matter to resolve in the use of integrated models. The input sample sizes determine the relative weight given to each length frequency data set in fitting the model. It is important to consider that the number of fish measured is not an appropriate measure because the measurements never represent a random sample but are derived from a complex, multi-stage sampling scheme and often with no design for ensuring the representativeness of the samples. In addition, there is process as well as measurement error embed in the observed size frequency data.

# 9. OTHER ANALYSES

## *9.1 ARCHIVAL TAGS*

87. Archival tagging is now an important component of many tagging programs, as archival tags provide information on the daily (horizontal and vertical) movements of tunas (dart tags only provide information at the points of capture and recapture). While the price of archival tags is considerably higher than that of dart tags, they can be highly informative when interpreting the results obtained from dart tags.

88. The RTTP-IO had at its disposal 282 archival tags, 40 Wildlife popup and 60 sonic tags (IOTC-2008-WPTDA-15).

89. All the archival tags have been used, with tagging taking place mainly in Tanzania and the Arabian Sea, with 216 YFT (60-114 cm) and 66 BET (60-87 cm). Of them, only 5 YFT and 2 BET were recovered in Oman and the centre of the fishing area, with time at liberty ranging from 18 to 344 days. Unfortunately, only one tag had a reasonable amount of data, that was 18 days of data, while the others were apparently lost or did not record. It was also noticed that the recovery rate of archival tags was much lower than for the spaghetti tags (only 2.4% vs 14%) and furthermore some of the recovered tags had technical failures.

90. The group examined the tagging procedures (and specially the tagging duration) which were considered as good and cannot directly explain these poor recoveries. It was noticed that an examination of the movies taken during these tagging operation can help to identify some potential deficiencies. Other possible explanation could be linked to the OTC application, the colour of the tag, a tagger effect or a high tag shedding for those fishes. The tagging area and low reward value were not considered as a cause. Another potential problem causing this failure

could also be linked to a lack of fully sterile equipment during the tagging operations: ideally, archival tags should be inserted under sterile conditions, but this is seldom the case in at sea tagging. Steps should be taken to maximize the highest possible sterility in future archival tagging operation.

91. Due the failure of archival tagging, it is now quite difficult to obtain new funding to conduct these operations. The use of dummy archival tags was suggested to evaluate the recovery rates under different recovery schemes and tagging procedures, as it should provide an indication whether future recovery rates of these dummy tags could be expected to be at normal levels.

92. Only 6 YFT (114-125 cm) were tagged with pop-up off Tanzania; short transmissions were obtained from two of them, 3 died rapidly and the last disappeared. Two were also released in Maldives, one is lost and the second is expected to report at the end of July.

93. Forty sonic tags were used (14 YFT, 14 SKJ, 12 BET) in order to check the residence time of fishes in the school tagged. Results are in accordance with observations coming from the immediate recaptures by the tagging boats.

### *9.2 COMPARISON OF TAGGING PROGRAMS*

94. The interest of the comparison of some basic parameters (such as juvenile and adult growth rates, mean time at liberty, mean distance covered within one month) obtained from the different tagging projects worldwide (IATTC, CPS, Maldives, ICCAT) was suggested. This was considered as an interesting study, but not achievable during this working party. It was also noted that such comparisons needed to take account of the different objectives and designs of the different tagging projects worldwide.

95. **All participants agreed on the value of such a comparison, and the WP recommended that an in depth comparative analysis of tagging results between oceans, primarily based on analytical models, be undertaken in the future.**

## 10. RECOMMENDATIONS RELATING TO NEW INFORMATION FOR THE ASSESSMENTS OF TROPICAL TUNAS

96. It is most likely that a mature and fully explored integrated stock assessment will not be available for the Working Party in 2008. As has been seen in many other fora, this approach more often than not takes more time than is available before the meeting. While external analyses can perhaps give us an informative view of the exploitation pressure over the range of the current recaptured fish, and also be informative as to estimates of key parameters such as growth and natural mortality, the Working Party stated the importance of having potential alternatives, with respect to stock assessment. **In the past more traditional methods such as VPA, ASPM and production and delay-difference models have been used on yellowfin and bigeye and the continued exploration of the data using these methods is to be recommended for the Working Party meeting in October.**

97. The WP noted the following commitments from participants in preparation for the tropical tunas assessments planned for the WP on Tropical Tunas 23-31 October 2008.

98. In accordance with the agreed timeline for the provision of data and other information in advance of the IOTC Working Party of Tropical Tunas. The following dates are important:

1. **8 August** Data will be frozen by the Secretariat and no additional data will be included in the proposed analyses
2. **7 September** All input data for stock assessments are to be available e.g. CAA, CPUE
3. **9 October** Assessment results to be posted
4. **23 October** WPTT meets

### For yellowfin tuna

| Task | Specifics | Timing | Who |
|---|---|---|---|
| Fisheries data 2007 | | | |
| Provide latest Purse seine | | Available now | na |
| Provide latest Longline | Japan 2007<br>Taiwan,China 2007 | By 8 August | Secretariat to contact Japan and Taiwan,China |
| Provide latest Gillnet/BB? | In particular<br>Iran?<br>Maldives | By 8 August | Secretariat to contact Iran and Maldives |
| Data processing | | 7 September | Secretariat |
| Derive indices of abundance | PS index<br>LL | 7 September<br>Japan / Taiwan,China | Pianet<br>Secretariat to contact Japan and Taiwan,China |
| | | | |
| External analyses | | | |
| Estimate M | Requires LL data | 7 September | Secretariat |
| Exploitation rate | | 7 September | Secretariat |
| | | | |
| Growth (required for CAA) | Revised LEP analysis using clean dataset | 8 August | Secretariat |
| Reporting rates | | 8 August | Secretariat |
| CAA | | 7 September | Secretariat |
| Other Stock assessment requirements | | | |
| **Stock assessment work** | | | |
| ASPM | Requires M, CAA | Results due 9 October | Japan (Nishida) |
| SS3 – proposed work only | Special data formatting required - geo stratification | PrelimResults 9 October | Secretariat to assist with special formatting of the data.<br>Assessment by Shono (Japan) / Aires-Da-Silva (IATTC) |
| MFCL – proposed work only | Special data formatting required - geo stratification | prelimResults 9 October | Hampton (SPC) |
| CASAL | | Results due 9 October | Secretariat |

### For bigeye tuna

| Task | Specifics | Timing | Who |
|---|---|---|---|
| Fisheries data 2007 | | | |
| Provide latest Purse seine | | Available | na |
| Provide latest Longline | Japan 2007<br>Taiwan,China 2007 | By 8 August | Secretariat to contact Japan and Taiwan,China |
| Other? | | | |
| Data processing | | 7 September | Secretariat |
| Derive indices of abundance | LL | 7 September<br>Japan / Taiwan,China | Secretariat to contact Japan and Taiwan,China |
| | | | |
| External analyses | | | |
| Estimate M | Req LL data | 7 September | Secretariat |
| Exploitation rate | | 7 September | Secretariat |
| | | | |
| Growth (required for CAA) | Revised LEP analysis using clean dataset | 8 August | Secretariat |
| Reporting rates | | 8 August | Secretariat |
| CAA | | 7 September | Secretariat |
| Other Stock assessment requirements | | | |
| **Stock assessment work** | | | |
| CASAL | | Results due 9 October | Secretariat |

**For skipjack tuna**

| Task | Specifics | Timing | Who |
|---|---|---|---|
| Fisheries data 2007 | | | |
| Provide latest Purse seine | | Available | |
| Provide latest Longline | | By 8 August | |
| Other? BB, Gillnet | Maldives<br>Sri Lanka/Indonesia | By 8 August | Secretariat to contact |
| Data processing | | 7 September | Secretariat |
| Derive indices of abundance ? | Maldives | | Secretariat to contact |
| | | | |
| External analyses | | | |
| Estimate M | Req LL | 7 September | Secretariat |
| Exploitation rate | | 7 September | Secretariat |
| | | | |
| Growth (required for CAA) | Revised LEP analysis using clean dataset | 8 August | Secretariat |
| Reporting rates | | 8 August | Secretariat |
| CAA | | 7 September | Secretariat |
| Other Stock assessment requirements | | | |
| **Stock assessment work** | | | |
| CASAL | | Results due 9 October | Secretariat |

## 11. OTHER BUSINESS

### *11.1 Activities to be maintained at the end of the current RTTP-IO*

99. There is a fundamental need to maintain a full scale, permanent effort to maximise the recovery of tagged tunas over the next 10 years, as these recoveries will be essential for the analysis of tuna movements and of tuna growth.

100. At the end of the project, the IOTC will still have funds to pay for the rewards. However the IOTC may lack the staff and budget to maintain and develop an efficient system to recover the tags, for instance on artisanal fisheries and more importantly on longliners. The longline fishery will soon become the principal source of tag returns, and the only one for large bigeye, as fishes become older (Figure 12). It was suggested to get ad hoc funding (especially from the concerned countries) to maintain and improve the collection system, and possibly to use observers to collect tags onboard and run small scale tagging operations on longliners. It was also stressed that Mauritius, Phuket and Indonesia were the major harbours to monitor as great quantities of yellowfin and bigeye are commonly landed by longliners in these ports.

101. Given its location and major fisheries for tropical tunas, the WP considered Maldives to be an important hub for tagging tuna, in particular YFT.

### *11.2 The tagging data users policy*

102. The WP reviewed the Tuna Tagging Data Users policy (Appendix VIII) and concluded that while the tagging data is in the public domain, collaborative work involving those people that have been involved in the programme is preferable to the data being analysed by disconnected individuals. One of the main reasons for this being the valuable insight into the data that those associated with the programme have.

103. It was also suggested to enhance the project output through a special issue in a recognized publication (as planned by ICCAT for example), and by the organization of a symposium. **The WP recommended that such final symposium would be very important, in term of communication as well that in term of full use of its scientific results, and that funding be sought for the symposium, its organization and the publication, probably in 2010.**

### *11.3 Other matters*

104. The WP reiterated the importance of the tagging data but stressed that it will take several years and considerable intellectual resources to fully analyse the data and integrate it into the stock assessments of the

tropical tuna species. For these reasons the WP stressed the need for the Scientific Committee to make it clear to the Commission that the benefits of the tagging programme to assessments and, ultimately, the advice on the status of the stocks will be realised over the next 3 to 5 years (and possibly longer) rather than being instant.

105. The WP participants unanimously agreed that regular tagging projects are absolutely necessary tools for tuna assessment, as they are the only source of fishery independent data. They should then be planned regularly, if not recurrent on a 5 years basis.

106. Maldives scientists noted that the new large and efficient Maldivian pole and line vessels currently in operation would make ideal tagging platforms as they offer efficient tuna tagging at a wide geographical scale. It was noted that the because the vessels fly a Maldives flag they may not be eligible for EU DG DEV funding, but that this problem could be solved by finding alternative funding sources (for example DG MARE funds)

107. The need of training scientists (not only from developing countries) to the understanding and use of the new complex assessment models was also mentioned; it was stated that the new assessment expert to be recruited by IOTC will also be in charge of training; SPC noted that they already do this type of training and was open to collaborate on this subject;

108. **The WP strongly recommended that the tagging data be used in ecosystem models.** In particular, in conjunction with ecosystem models developed at a global scale (e.g. SEPODYM by SPC/CLS and APECOSM by IRD) in the GLOBEC/CLIOTOP framework. It is expected that these models would improve the understanding of the movement patterns of tagged/recovered tunas, as a function of species and size.

109. The need to promote the importance of fisheries data collection, often not well understood and accepted by some concerned countries authorities was also noted; such training should help all developing countries to better understand why the fishery data that are requested yearly by the IOTC are essential to do a consistent tuna stock assessment.

110. The WP noted the new EU data collection regulation (DCR, which will be mandatory for all EU countries on 1st January 2009) recognizing the role of RFB's as one of the major component of its policy (cf. Article 7 : "The Commission shall assess the implementation of the national programmes on the basis of …, the consultation of appropriate regional fisheries management organisations to which the Community is contracting party or observer and relevant international scientific bodies, …"). **The WP recommended that the IOTC Scientific Committee should make a firm recommendation that tagging programs should be undertaken on a routine basis as being an essential component in stock assessment and then in stock conservation.** It is intended that such a clear recommendation on the need for routine tagging should greatly assist to obtain the funds that are needed to conduct these expensive operations and to ensure the tags recovery operations are ongoing.

111. It was noted that the future analysis of the tagging/recovery data will be a complex task, but that scientific staff from developing countries should be fully involved in this very interesting and important work. **The WP recommended that ad hoc funding and facilities should be sought and obtained by the IOTC in order to allow their full participation in this work.**

## 12. SUMMARY OF THE RECOMMENDATIONS MADE BY THE WPTDA

*Status of the Indian Ocean Tagging Programme – small-scale tagging operations in the Indian Ocean*

1. The WP noted that funds from the Japanese Government are still available, and recommended that further pop-up tagging continue in the Maldives (2 popup tags have already been deployed) – paragraph 8.

*Status of the RTTP-IO and small-scale tagging project data*

2. The WP recommended that lengths not be calculated when weight data only are available – paragraph 18.
3. The WP acknowledged the improvements in the quality of the databases and recommended that work continue in order to obtain the best possible databases before the meeting of the WP on Tropical Tunas in October 2008 – paragraph 21.

*Estimating growth*

4. The WP recommended that the current and historical methods used to examine the otoliths be compared; and if possible, some of the historical otoliths be re-read by the workers currently examining the RTTP-IO otoliths – paragraph 36.
5. The WP also recommended that it was important that the validation of otoliths be carried out across the full size range of fish being aged. Furthermore, the variance of age estimates should be evaluated to determine whether statistically significant differences exist between readers and for individual readers – paragraph 37.
6. The WP recommended investigations to quantify post-mortem shrinkage in tuna length caused by freezing – paragraph 41.

*Estimating tag shedding rates and tag reporting rates*

7. The WP recommended that work comparing the return rates of double tagged fish with those of single tagged fish from the same school or area time strata be conducted – paragraph 56
8. The WP strongly recommended that the tag seeding programme continue for the duration of the RTTP-IO as it is essential that estimates of reporting rates are available across the entire duration of the project – paragraph 62.

*Movement*

9. The WP recommended that the CPUE data be integrated with the tagging data to better understand the movements of the tagged tunas – paragraph 70.
10. The WP recommended that analyses examining tuna movement and environmental factors be undertaken in the future – paragraph 74.

*Other analyses: comparison of tagging programmes*

11. WP recommended that an in-depth comparative analysis of tagging results between oceans, primarily based on analytical models, be undertaken in the future – paragraph 95.

*Recommendations relating to new information for the assessments of tropical tunas*

12. In the past more traditional methods such as VPA, ASPM and production and delay-difference models have been used on yellowfin and bigeye and the continued exploration of the data using these methods is to be recommended for the Tropical tunas Working Party meeting in October – paragraph 96.

*Other business: the tagging data users policy*

13. The WP recommended that such final symposium would be very important, in term of communication as well that in term of full use of its scientific results, and that funding be sought for the symposium, its organization and the publication, probably in 2010 – paragraph 103.

*Other business: other matters*

14. The WP strongly recommended that the tagging data be used in ecosystem models – paragraph 108.
15. The WP recommended that the IOTC Scientific Committee should make a firm recommendation that tagging programs should be undertaken on a routine basis as being an essential component in stock assessment and then in stock conservation – paragraph 110.
16. The WP recommended that ad hoc funding and facilities should be sought and obtained by the IOTC in order to allow their full participation to this incoming work – paragraph 111.

## 13. ADOPTION OF THE REPORT

112. The Report of the First Session of the WPTDA was adopted on Friday 4 July 2008.

# APPENDIX I:
# LIST OF PARTICIPANTS

## IOTC WORKING PARTY ON TAGGING DATA ANALYSIS

**Mr. Mohamed Abdouchakoua**
Responsable Recherche Appliquée
Direction Nationale Ressources Halieutique
Ministere de la Pêche
B.P 41 Moroni
**COMORES**
Tel: + 269 7735630/3330723
Fax: + 269 7750013
Email: abdouchame@yahoo.fr / dg.peche@comorestelecom.km

**Dr. Mohamed Shiham Adam**
Executive Director
Marine Research Centre
Ministry of Fisheries
Agriculture and Marine Resources
H.White waves
Malé
**MALDIVES**
Tel:+ 960 3313681
Fax: +960 3322509
Email: msadam@gov.mv

**Dr. Alexandre Aires-Da-Silva**
Senior Scientist
Inter-American
Tropical Tuna Commission
8604 La Jolla Sholes Drive
La Jolla 92037-l508 CA
**USA**
Tel:+858 5467022
Fax:+ 858 546 7133
Email:alexdasilva@iattc.org

**Dr Juma Al-Mamry**
Fisheries Management Researcher
Marine Science and Fisheries Center
Ministry of Fisheries Wealth
227 code 100 Muscat
**SULTANATE OF OMAN**
Tel: + 968 24740061
Fax:+ 968 24740159
Email: jumammry@hotmail.com

**Dr. Charles Anderson**
Marine Biologist
P.O.B 2074
Malé
**MALDIVES**
Tel: + 960 3327024
Email: Anderson@dhivehinet.net.mv

**Ms. Nanet Bristol**
Research Technician
Seychelles Fishing Authority
P.O. Box 449
Fishing Port
Victoria
Mahé
**SEYCHELLES**
Tel: 248 670376
Fax: +248 224508
Email: nbristol@sfa.sc

**Dr. Emmanuel Chassot**
Scientist
IRD - Centre de Recherche Halieutique Méditerrannéenne et Tropicale
US OSIRIS- CRH
B.P. 171
Av. Jean Monnet
34203 Sète Cedex
**FRANCE**
Tel: +33 4 99 57 3224
Fax: +33 4 99 57 3595
Email:emmanuel.chassot@ird.fr

**Dr. Paul de Bruyn**
Researcher
Marine Research Unit
AZTI Tecnalia
Herrera Kaia Portnaldea zlg
Pasaia Z0110
Basque
**SPAIN**
Tel:+ 3494 300 48 00
Fax: + 3494 300 4801
Email: pdebruyn@pas.azti.es

**Ms. Juliette Dorizo**
Senior Fisheries Statistician
Seychelles Fishing Authority
P.O. Box 449
Fishing Port
Victoria
Mahé
**SEYCHELLES**
Tel: +248 670327
Fax: +248 224508
Email: jdorizo@sfa.sc

**Dr. Alain Fonteneau**
Scientist
IRD - Centre de Recherche Halieutique Méditerrannéenne et Tropicale
UR 109 THETIS
B.P. 171
Av. Jean Monnet
34203 Sète Cedex
**FRANCE**
Tel: +33 4 99 57 3255
Fax: +33 4 99 57 3295
Email:alain.fonteneau@ird.fr / fonteneau@ird.fr

**Dr. Daniel Gaertner**
IRD - Centre de Recherche Halieutique Méditerrannéenne et Tropicale
UR 109 THETIS
B.P. 171
Av Jean Monnet
34203 Sète Cedex
**FRANCE**
Tel: +33 499573231
Email: gaertner@ird.fr

**Dr. John Hampton**
Oceanic Fisheries Program Manager
Secretariat of the Pacific Community
P.O.B D5
Nouméa 98868
**NEW CALEDONIA**
Tel:+ 687 260 147
Fax: + 687 263 818
Email:JohnH@spc.int

**Dr. Richard Hillary**
Lecturer Imperial College
Biology Dpt
Exhibition Road
London SW7 2BP
**UK**
Tel:+ 440207 589 9310
Fax:+ 440207 589 9493
Email:rhillary@imperial.ac.uk

**Mr. Seyed Abbas Hossein**
Head of Biology and Stock Assessment Dpt
Offshore Fisheries Research Center
Daneshgah Avenue
Chabahar
**IRAN**
Tel:+ 98 5452220452
Fax: + 98 545 2220537

**Mr. Ahmed Riyaz Jauhree**
Fishery Biologist
Marine Research Centre
Ministry Of Fisheries and Agriculture
Malé
**MALDIVES**
Tel:+ 960 3313681
Fax: +960 3322509
Email: arjauharee@yahoo.com

**Dr. Francis Marsac**
Scientific Coordinator THETIS Research Group
IRD - Centre de Recherche Halieutique Méditerrannéenne et Tropicale
B.P. 171
Av Jean Monnet
34203 Sète Cedex
**FRANCE**
Tel: +33 499573226
Fax: +33 499573295
Email: marsac@ird.fr

**Ms. Elizabeth Mueni**
Senior Fisheries Officer
Fisheries Department
Ministry of Fisheries Development
P.O.B 90423 Liwatoni area Mombassa 80100
**KENYA**
Tel: +254 412315904
Fax: +254 412315904
Email: emuenibf@yahoo.com

**Mr. Stephen Ndegwa**
Senior Fisheries Officer
Fisheries Department
Ministry of Livestock & Fisheries Development
P.O.B 90423 Liwatoni
Mombassa 80100
**KENYA**
Tel: +254 412315904
Fax: +254 412315904
Email: ndegwafish@yahoo.com

**Dr. Tsutomu (Tom) Nishida**
Scientist
National Research Institute of Far Seas Fisheries
Fisheries Research Agency of Japan
5-7-1, Shimizu - Orido
Shizuoka 424-8633
**JAPAN**
Tel: +054 336 6052
Fax: +054 3366052
Email: tnishida@affrc.go.jp

**Ms. Praulai Nootmorn**
Director
Andaman Sea Fisheries Research and Development Centre
77 Tumbon Vichit
Maung District,
Phuket 83000
**THAILAND**
Tel: +66 76 391138
Fax:+ 66 76 391139
Email:nootmorn@yahoo.com

**Mr. Juan Antonio Pereira Rodriguez**
Technical Assisstant
OPAGAC
Ayala 59-2A
Madrid 28001
**SPAIN**
Tel: +34 914317857
Fax: + 34 915761222
Email: opagac@arrakis.es

**Mr. Renaud Pianet**
Scientist
B.P. 570
Victoria
**SEYCHELLES**
Tel: +248 224742
Fax: +248 224742
Email:renaud.pianet@ird.fr

**Dr. Thomas W Polacheck**
CSIRO
G.P.O Box 1538
Cestray Esplanade
Hobart 7000
**AUSTRALIA**
Tel: + 61 362325132
Fax: + 61 362325000
Email: tom.polacheck@csiro.au

**Mr. Tiana Randriambola**
Chef De Service Suivi Des Ressources
Centre de Surveillance Des Peches
Ministere de L'agriculture de elevage et de la Pêche
B.P 60114 Antananarivo
**MADAGASCAR**
Tel: + 261 202240065
Fax: + 261 202249014
Email: csp-soc@blueline.mg

**Mr. Jan Robinson**
Manager
Fisheries Research
Seychelles Fishing Authority
P.O. Box 449
Fishing Port
Victoria
Mahé
**SEYCHELLES**
Tel: 248 670338
Fax: 284 224508
Email: jrobinson@sfa.sc

**Ms. Maria Soto Ruiz**
Instituto Espaniol De Oceanografia
Tropical Tuna Dpt
C/Corazon de Maria 8
Madrid 28002
**SPAIN**
Tel: + 349 13473620
Fax: + 349 14135597
Email:maria.soto@md.ieo.es

**Dr. Kurt Schaefer**
Senior Scientist
Inter-American Tropical Tuna Commission
8604 La Jolla Shores Drive
La Jolla CA 92037
**USA**
Tel: + 858 546 7159
Fax: + 858 546 7133
Email: kschaefer@iattc.org

**Mr. Saeed Shaher**
Tuna Fishery Biologist
MSBRA
Marine Fishery Research
Ministry of Fish Wealth
Labour Island
Korlmaksar Street
Aden 96702
**YEMEN**
Tel:+ 967 (02) 383295
Email: saeed_saher@yahoo.com

**Mr. Kusno Susanto**
Fisheries Scientist
Research Center forCapture Fisheries
Ministry Of Marine Affairs and Fisheries
Jalan Pasir Putih I, Ancol Timur
Jakarta
**INDONESIA**
Tel:+ 021 64711940
Fax: + 021 6402640
Email: kusno_prpt@indo.ned.id

**Mr.Sihaba Haji Vuai**
Chief Fisheries Officer
Dept of Fisheries and
Marine Resources,
Ministry of Agriculture
Livestock & Environment,
P.O.B 774 Livingstone House
ZANZIBAR
Tel: + 255 242239623
Fax:+ 255 242237285
Email: mcsznz@zanlink.com

**IOTC SECRETARIAT/SECRETARIAT CTOI**
Indian Ocean Tuna Commission
P.O.Box 1011 Fishing Port
Victoria
**SEYCHELLES**
Tel: (+248) 225591
Fax: (+248) 224364

**Mr. Alejandro Anganuzzi**
Executive Secretary
Email: aa@iotc.org

**Dr. Chris O'Brien**
Deputy Secretary
Email: cob@iotc.org

**M. Julien Million**
Tagging Assistant
Email: julien.million@iotc.org

**Ms. Carmen Gonzalez- Valles**
Project Cooperation Tandem
Email: cgv@iotc.org

**Ms. Aurélie Duhec**
Project Cooperation Tandem
Email: ad@iotc.org

**IOTC-OFCF Project/ Projet OFCF-CTOI**

**Mr. Shunji Fujiwara**
IOTC-OFCF Fishery Expert
Email: sf@iotc.org

**REGIONAL TUNA TAGGING PROJECT – INDIAN OCEAN / PROJET REGIONAL DE MARQUAGE DE THONS – OCEAN INDIEN**

**Dr. Jean-Pierre. Hallier**
Chief Coordinator RTTP
Regional Tuna Tagging Project - Indian Ocean
Room 35-37 Kingsgate House
**SEYCHELLES**
Tel: +248 610846
Fax: +248 610841
Email: Jean-pierre.hallier@iotc.org

**Mr Michael Stockwell**
Administration/Financial officer
Email: ms@iotc.org

**Ms. Theresa Athayde**
Publicity Tag recovery officer
Email: ta@iotc.org

***Thanks to the support team from the IOTC Secretariat***
Jemy Mathiot
Claudia Marie
Nishan Sugathadasa

# APPENDIX II:
# AGENDA

1. **OPENING OF THE MEETING**
2. **ADOPTION OF THE AGENDA**
3. **STATUS OF THE INDIAN OCEAN TAGGING PROGRAMME RTTP-IO**
    - Overview and current status of the of the RTTP-IO and small-scale projects, including data analysis and storage, and an examination of the recoveries from the different tagging projects, by recovery platform, with reference catch and associated reporting rate (RTTP-IO with data prepared by RTTP-IO)
4. **STATUS OF THE RTTP-IO data**
    - Overview and current status of the of the RTTP-IO data including indications of its state of readiness and limitations.
5. **ESTIMATING GROWTH**
    - Results of growth analyses for BET, YFT and SKJ incorporating tagging data (Secretariat)
    - Other analyses
6. **ESTIMATING TAG SHEDDING RATES and TAG REPORTING RATES**
    - Examination of data from the double tag work (RTTP-IO) and estimation of tag shedding rates (provisional estimates provided by RTTP-IO)
    - Examination of data from the RTTP-IO tag seeding experiments (data prepared by RTTP-IO)
    - Estimation of tag reporting rates (provisional estimates provided by RTTP-IO)
7. **CRITICAL EXAMINATION OF POTENTIAL EXTERNAL ANALYSES**
    - Review of the potential of estimating natural mortality, exploitation rates, and other factors using methods other than integrated stock assessment models (WP discussion)
8. **MOVEMENT**
    - Examination of the movement of the yellowfin skipjack and bigeye and its implications for the stock assessments of these species (preliminary analyses provided by the RTTP-IO).
9. **EXAMINATION OF THE PERFORMANCE OF INTERGRATED STOCK ASSESSMENT MODELS USING RTTP-IO TAGGING DATA**
    - An examination of the of the performance of integrated models relating to the stock assessments of for bigeye, yellowfin and skipjack tunas in the Indian Ocean
        - CASAL (Secretariat)
        - SS2 (Aires-Da-Silva and Nishida et al, respectively)
        - other models
10. **OTHER ANALYSES:**
    - Archival tag status: review of the current status of the tagging programme using Archival Tags and the corresponding recoveries (preliminary analyses provided by the RTTP-IO)
    - Comparison of tagging programmes: the results from the Indian Ocean compared to the results of the large-scale tuna tagging projects implemented in other oceans.
11. **RECOMMENDATION RELATING TO NEW INFORMATION FOR THE ASSESSMENTS OF TROPICAL TUNAS**
12. **OTHER BUSINESS**
    - The tagging data users policy

# APPENDIX III:
# LIST OF DOCUMENTS

| Document | Title |
|---|---|
| IOTC-2008-WPTDA-01 | Draft agenda of the Working Party on Tagging Data Analysis |
| IOTC-2008-WPTDA -02 | WPTDA List of documents |
| IOTC-2008-WPTDA -03 | Exploratory modeling of Indian Ocean tuna growth incorporating both mark recapture data and otlolith data. *Hillary, Million and Anganuzzi* (presented using IOTC-2008-WPTDA-PRES07) |
| IOTC-2008-WPTDA -04 | Tag shedding and reporting rate estimates for the Indian Ocean tuna using double tagging and tag-seeding experiments. *Hillary, Million and Anganuzzi* (presented using IOTC-2008-WPTDA-PRES13) |
| IOTC-2008-WPTDA -05 | Tuna movement patterns presently shown in the Indian Ocean by tag recoveries from the IOTTP tagging program. *Alain Fonteneau* (presented using IOTC-2008-WPTDA-PRES12) |
| IOTC-2008-WPTDA -06 | Tag Shedding by Tropical Tunas: First results and explanatory analyses (Power Point presentation). *Daniel Gaertner and Jean Pierre Hallier* (presented using IOTC-2008-WPTDA-PRES14). |
| IOTC-2008-WPTDA -07<br>IOTC-2008-WPTDA-07-add1 | Estimation of growth parameters for yellowfin, bigeye and skipjack tuna using tag-recapture data. *J. Paige Eveson and Julien Million*. (presented using IOTC-2008-WPTDA-PRES08) |
| IOTC-2008-WPTDA -08 | Growth rates and apparent growth curves, for yellowfin, skipjack and bigeye tagged and recovered in the Indian Ocean during the IOTTP. *Fonteneau, Alain and Didier Gascuel.* (presented using IOTC-2008-WPTDA-PRES09) |
| IOTC-2008-WPTDA -09 | Two simple alternative growth models for skipjack tuna (*Katsuwonus pelamis*) in the Indian Ocean, as estimated from tagging data. *P. A. de Bruyn and H. Murua* |
| IOTC-2008-WPTDA -10 | Status of the Indian Ocean tuna tagging programme – RTTP-IO. *Jean-Pierre Hallier* (presented using IOTC-2008-WPTDA-PRES01) |
| IOTC-2008-WPTDA -11 | Overview and current status of the RTTP-IO data including indications of its state of readiness and limitations. *Jean-Pierre Hallier* (presented using IOTC-2008-WPTDA-PRES06) |
| IOTC-2008-WPTDA -12 | Skipjack growth analysis with tagging data. *D. Gaertner*. |
| IOTC-2008- WPTDA -13 | Examination of the movement of the yellowfin, skipjack and bigeye and its implications for the stock assessments of these species. *Jean-Pierre Hallier* (presented using IOTC-2008-WPTDA-PRES11). |
| IOTC-2008-WPTDA -14 | Preliminary CASAL YFT Assessment. *Hillary et al* (presented using IOTC-2008-WPTDA-PRES17) |
| IOTC-2008-WPTDA -15 | Electronic tags (archival, popup & sonic): review of the current status of rttp-io using these electronic tags. *Jean-Pierre Hallier* (presented using IOTC-2008-WPTDA-PRES18) |
| IOTC-2008-WPTDA-PRES01 | RTTP-IO overview. *Jean-Pierre Hallier.* |
| IOTC-2008-WPTDA-PRES02 | Small-scale tagging projects. *Julien Million.* |
| IOTC-2008-WPTDA-PRES03 | Tuna tagging in WCPO. *John Hampton.* |
| IOTC-2008-WPTDA-PRES04 | Excerpts from: Horizontal Movements of Bigeye Tuna (*Thunnus obesus*) in the Eastern Pacific Ocean, as Determined from Conventional and Archival Tagging Experiments Initiated During 2000-2006. *Kurt M. Schaefer and Daniel W. Fuller* |
| IOTC-2008-WPTDA-PRES05 | SBT tagging. *Tom Polachek.* |
| IOTC-2008-WPTDA-PRES06 | Status of the RTTP-IO data. *JP Hallier, T. Athayde* |
| IOTC-2008-WPTDA-PRES07 | Exploratory growth analyses for Indian Ocean tuna spp. *R. Hillary, J. Million & A. Anganuzzi* |
| IOTC-2008-WPTDA-PRES08 | Estimation of growth parameters for yellowfin, bigeye and skipjack tuna using tag-recapture data. *J. Paige Eveson Julien Million* |
| IOTC-2008-WPTDA-PRES09 | Growth rates and apparent growth curves, for yellowfin, skipjack and bigeye tagged and recovered in the Indian Ocean during the IOTTP. *Alain Fonteneau and Didier Gascuel* |
| IOTC-2008-WPTDA-PRES10 | Growth – preliminary results from otoliths. *J. Million*. |
| IOTC-2008-WPTDA-PRES11 | Movements between tagging and recovery positions. *Jean-Pierre Hallier*. |
| IOTC-2008-WPTDA-PRES12 | Tagging & movement: the ultimate goal is to estimate at least ½ quantitatively, the movement flow of tunas in the entire Indian Ocean, and during the entire lives of tunas. *Alain Fonteneau* |
| IOTC-2008-WPTDA-PRES13 | Shedding & reporting rate analyses for Indian Ocean tuna spp. *R. Hillary; J. Million, A. Anganuzzi; J.J. Areso* |
| IOTC-2008-WPTDA-PRES14 | Tag Shedding by Tropical Tunas in the Indian Ocean: First results and explanatory analyses. *Daniel Gaertner and Jean Pierre Hallier* |
| IOTC-2008-WPTDA-PRES15 | Integrated analysis - a brief introduction. *Alexandre Aires-da-Silva and Mark Maunder* |
| IOTC-2008-WPTDA-PRES16a & b | Integrated tagging in MFCL. *A Langley et al. presented by John Hampton* |
| IOTC-2008-WPTDA-PRES17 | Preliminary CASAL YFT Assessment. Hillary et al |

| Document | Title |
|---|---|
| IOTC-2008-WPTDA-PRES18 | RTTP-IO Archival tags status. *Jean Pierre Hallier* |
| IOTC-2008-WPTDA-PRES19 | Preliminary growth analyses. *Alain Fonteneau* |
| IOTC-2008-WPTDA –INF01 | Determination of Fish Movement Patterns from Tag Recoveries - using Maximum Likelihood Estimators. R. Hilborn |
| IOTC-2008-WPTDA –INF02 | Inter-American Tropical Tuna Commission Workshop On Stock Assessment Methods. La Jolla, California (USA). 7-11 November 2005. Report Compiled by Mark N. Maunder |
| IOTC-2008-WPTDA –INF03 | Inter-American Tropical Tuna Commission Workshop On Using Tagging Data For Fisheries Stock Assessment And Management Strategies. La Jolla, California (USA), 16-19 October 2007. Report Compiled by Mark N. Maunder |

# APPENDIX IV:
# Growth simulation on tagging to investigate potential bias in the results of the Fonteneau and Gascuel estimated growth rates at size

## Materials and Methods

The Fonteneau-Gascuel (IOTC 2008-WPTDA-8) method was tested through simulations to investigate the effects on the results of integrating growth increments over different time periods. 2 standard growth models for yellowfin tuna (*Thunnus albacares*) were considered: the von Bertalanffy growth (von Bertalanffy, 1938) and the 2-stanza growth used for the Atlantic Ocean stock (Gascuel et al., 1992). Considering an initial length set equal to the observed length-at-tagging and the time spent at sea, length-at-recovery was estimated following each growth model. The F-G method was then applied to the simulated growth rates and results were compared with the 'theoretical' growth rates based on each model derivative.

## Results

The F-G method poorly affects the results in the case of a von Bertalanffy growth curve for the mark-recapture dataset considered (Fig. 1). The growth rates estimated match well for small fish but the F-G method appears to underestimate growth rates for older fish. For the 2-stanza model, the shape of the growth curve is consistent with the 'theoretical' curve but the pattern of increasing discrepancy with length is more pronounced, leading to a bias of about 0.3 cm.month-1 for large fish (Fig. 2). This bias is logical and probably linked with the fact that the recoveries of large yellowfin tend to be observed at larger sizes. Then it can be assumed that this bias will increase with the expected addition of future recoveries.

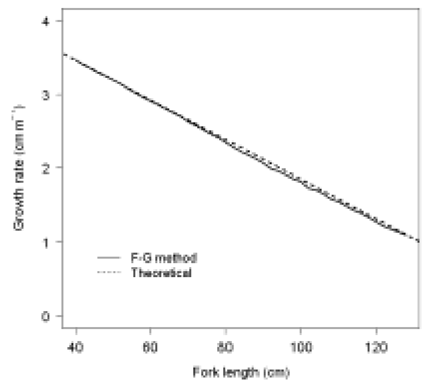



**Fig. 1. Comparison of growth rates between the Fonteneau-Gascuel (F-G) method (solid line) and based on the derivative of the von Bertalanffy growth curve (dashed line).**

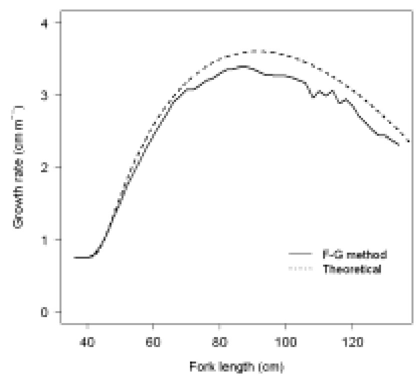



**Fig. 2. Comparison of growth rates between the Fonteneau-Gascuel (F-G) method (solid line) and based on the derivative of the 2-stanza growth curve (dashed line).**

## References

Gascuel D, Fonteneau, A. & Capisano, C. (1992) Modélisation d'une croissance en deux stances chez l'albacore (*Thunnus albacares*) de l'Atlantique Est. Aquatic Living Resources 5, 155-172.

von Bertalanffy, 1938, A quantitative theory of organic growth (Inquiries on growth Laws II). H. Biol. 10, 181-213.

# APPENDIX V:
# Criteria used to groom the tag dataset to produce a revised dataset for growth analyses.

***As agreed by the WPTDA during the meeting***

During the meeting, a sub-group of participants derived a set of data grooming criteria intended to would remove uncertain and likely erroneous data from the existing tag dataset for growth. The groomed dataset would be used for estimating growth in preparation for the stock assessments of tropical tunas scheduled for October 2008.

It was decided to remove records when:

- length at tagging and at recovery were not of the best quality (records were retained only when code = 1 for FL reliability at tagging or code = good at recovery);
- recovery length code = CL, SL, or UNK;
- recovery measurement tool = eye, string or unknown;
- there was a discrepancy in species recorded between tagging and recovery, including when this had been corrected at a later stage;
- species at tagging had a reliability code of 2 (uncertain);
- recoveries had a time at liberty was ≤ 30 days;
- they were recoveries from purse seiners found in port for which the dates of the possible different sets are more than 7 days apart;
- the date of recovery was before 01 April 2007;
- they were from recoveries made in canneries after the fish was cooked.

Application of these criteria reduced the dataset to from 25,528 to 8,673 records (3,758 SKJ; 2,707 YFT and 2,208 BET).

# APPENDIX VI:
# Estimates of growth parameters

Estimates of growth parameters from isolated studies for skipjack in the world's oceans used for modelling the bioenergetic function expressing $L_\infty$ as a function of $K$ used into the integrated approach.

| Area | $L_\infty$ | $K$ | Method | Reference |
|---|---|---|---|---|
| E. Atlantic G. of Guinea | | 80 | 0.32 | Tagging Bard and Antoine, 1986 |
| E. Atlantic N. trop | 80 | 0.60 | Tagging | Bard and Antoine, 1986 |
| E. Atlantic G. of Guinea | | 86.7 | 0.31 | Spines Chur and Zharov, 1983 |
| E. Atlantic Senegal | 62 | 2.08 | Tagging | Cayré et al, 1986 |
| E. Atlantic Cap Vert | 60 | 1.54 | Tagging | Cayré et al, 1986 |
| E. Atlantic Senegal | 97.26 | 0.25 | Tagging | Hallier and Gaertner, 2006 |
| W. Atlantic Caribbean sea | | 94.9 | 0.34 | Length-freq Pagavino and Gaertner, 1995 |
| W. Atlantic Brasil | 87.12 | 0.22 | Spines | Vilela and Costello, 1991 |
| Indian Ocean | 60.6 | 0.93 | Length-freq | Marcille and Stequert, 1976 |
| Indian Ocean Maldives | | 64.3 | 0.55 | Tagging Adams, 1999 |
| Indian Ocean Maldives | | 82 | 0.45 | Length-freq Hafiz, 1987, in Adams 1999 |
| Indian Ocean Sri Lanka | | 85 | 0.62 | Length-freq Amarasiri and Joseph, 1987 |
| Indian Ocean Sri Lanka | | 77 | 0.52 | Length-freq Sivasubramanium, 1985; in Adams, 1999 |
| Indian Ocean Minicoy | 90 | 0.49 | Length-freq | Mohan and Kunhikoya, 1985; in Adams, 1999 |
| E. Pacific | 75.5 | 0.77 | Tagging | Sibert et al, 1979 |
| E. Pacific | 79 | 0.64 | Tagging | Josse et al, 1979 |
| E. Pacific N | 96.3 | 0.52 | Tagging | Bayliff, 1988 |
| E. Pacific S | 66.5 | 1.81 | Tagging | Bayliff, 1988 |
| E. Pacific | 73 | 0.82 | Tagging | Joseph and Calkins, 1969 |
| E. Pacific | 107 | 0.42 | Length-freq | Joseph and Calkins, 1969 |
| W. Pacific | 61.3 | 1.25 | Tagging | Sibert et al, 1979 |
| W. Pacific | 65.5 | 0.95 | Tagging | Josse et al, 1979 |
| W. Pacific Vanuatu | 60 | 0.75 | Length-freq | Brouard et al, 1984 |
| W. Pacific Trop. & Jap. | | 93.6 | 0.43 | Otolith Tanabe et al, 2003 |
| W. Pacific Japan | 76.6 | 0.60 | Length-freq | Yao, 1981; in Wild and Hampton, 1994 |
| W. Pacific Taiwan | 103.6 | 0.30 | Vertebrae | Chi and Yang, 1973; in Wild and Hampton, 1994 |
| Central Pacific | 102.2 | 0.55 | Otolith | Uchiyama and Struhsaker, 1981 |
| Central Pacific | 80 | 0.95 | Grouped L-freq | Brock, 1954; in Adams, 1999 |
| Central Pacific West | 74.8 | 0.52 | Length-freq | Wankowski, 1981 |

Summary of results from IOTC-2008-WPTDA-06, bootstrapped statistics for the von Bertalanffy-Fabens model and for the integrated likelihood approaches (unweighted and size sample weighted) combining the Indian Ocean tagging data (1512 observations).

| Method | | Estimate | $K$ | $L_\infty$ | $C$ | $h$ |
|---|---|---|---|---|---|---|
| | | mean | 0.26 | 77.84 | NA | NA |
| Fabens | | median | 0.26 | 77.48 | NA | NA |
| | | C.I. | 0.18-0.31 | 73.70-90.00 | NA | NA |
| | Unweighted | mean | 0.22 | 81.96* | 68.33 0.12 | |
| | combined | median | 0.22 | 81.82* | 68.42 | 0.12 |
| Likelihood | C.I. | 0.19-0.26 | 77.21-87.55 | 62.19-73.86 | 0.05-0.19 | |
| Weighted | mean | 0.26 | 77.66* | 64.64 | 0.14 | |
| combined | median | 0.26 | 77.44* | 64.84 | 0.13 | |
| Likelihood | C.I. | 0.22-0.30 | 73.91-82.84 | 57.99-70.69 | 0.05-0.22 | |

# APPENDIX VII: Estimation of Length Measurement Error for Tagged Fish at the Time of Release

Tom Polacheck

## Introduction

During the RTMP-IO tagging program, 7,421 tagged fish were recaptured by the tagging vessel during tagging operations. All of these were re-measured for length and almost all of them were released by the tagging vessel. The data on these recapture fish can provide valuable information on length measurement error at the time of release and potentially information on short term growth, the effects of tagging on growth and residence time. In the current appendices, preliminary analyses are present on the measurement error at the time of tagging.

## Material and Methods

The data used in this appendix were tagged fish that were recaptured by the tagging vessel within five days of their release. In addition, the data were screen to remove any fish for which the recorded time at re-capture was prior to the time of release, fish for which the reliability code for either of the length measurements were not 1 (i.e. judged to be good) and fish for which the species code at the time of release differed. In addition, the small number of fish that were recaptured more then a single time within five days of release (85) were also excluded to simplify the calculations. This provided a sample size of 1,970 for the estimation of measurement error.

To estimate the level of length measurement error at the time of tagging, the variance for the length measure for each recapture fish was calculated using the standard approach (i.e. $\text{var}(L_i) = \sum_{j=1}^{2}(L_{i,j} - \overline{L_i})^2$ where $L_{i,j}$ equals the j$^{th}$ measurement for the i$^{th}$ fish and $\overline{L_i}$ equals the mean for the two estimates). An estimate of variance in length measure for any group of fish (i.e. all fish of given species) is simply the mean of the individual variance estimates.

## Results and Discussion

Figure 1 shows the distribution of the difference between the first and second measurement lengths for all re-released fish that were released within five days of tagging. What is evident in this figure is that there are a small number of fish with excessive differences in their measurement lengths (i.e. differences in excess of 10cm). These large differences are most likely due to key-punch/transcription error, miss placement of a fish on the cradle or mis-reading of correct the 10 cm increment on the cradle.

Figure 2 shows the relationship between the difference between the first and second measurement lengths and the initial length measurement for all re-released fish five days of tagging. The differences appear to be independent of the actual release length (e.g. estimate of the slope is 0.0014 for the regression with the intercept fixed at the origin). Similarly, Figure 3 which shows the relationship between the initial and re-released measurements indicates that there is no bias exists between the two (i.e. estimated slope is 1.0001 with the intercept fixed at the origin).

Finally, Figure 4 shows the relationship between the initial and subsequent measurement of fish that were re-captured by the tagging vessels within five days of tagging but were not re-released. In this case, these fish were put aside while the tagging was being done and then measured either with a caliber or measuring board. As such these latter measurements provide the most accurate estimates of the length of a fish. Comparison of the two length measurement suggests that there is a slight bias in the measurements made at the time of tagging relative to the caliper/measurement board estimates, with the latter being slightly larger (e.g. the estimates for the regression coefficients for caliper/measurement board lengths versus initial lengths are 1.563 for the intercept and 0.966 for the slope). This is most likely due to the curvature that occurs when a fish is measured in the tagging cradle and/or muscle relaxation.

Table 1 provides estimates of the variance and standard deviation for the measurement error at the time of tagging. Estimates are provided by species and for all species pooled. The estimated error is largest for skipjack, and smallest for bigeye, although the differences in the latter case are small. The differences in the measurement error are accordance with the expectation of those who have undertaken tagging of the three different species based on differences in the behavioral characteristics of the three species in the tagging cradle. Table 2 provides similar estimates of the measurement error as Table 1 except that fish for which the difference between the first and second measurement was 10cm or greater have been excluded. When these small number of "outliers" are excluded, there is a large reduction in the estimated variances and standard deviations (e.g. for skipjack the standard deviation is reduced from 1.185 to 0.751). In most case, large errors in excess of ~10cm would result in obvious outliers in the increment for recapture fish and would most likely be excluded in analyses of growth using the increment. The possible exception may be in the case of longer term recaptures. As such, the most appropriate estimate to use for release measurement error to use the estimation of growth would be those which exclude these outliers.

**Table 1: Estimates of the variance and SD for the length measurements made at the time of tagging based on length measurements taken at the time of initial release and at the time of release for recaptured tagged fish within 5 days of releases.**

| Species | Variance | SD | N |
|---|---|---|---|
| Skipjack | 1.405 | 1.185 | 805 |
| Yellowfin | 0.860 | 0.927 | 572 |
| Bigeye | 0.554 | 0.744 | 593 |
| All species | 1.407 | 1.186 | 1970 |

**Table 2: Estimates of the variance and SD for the length measurements made at the time of tagging based on length measurements taken at the time of initial release and at the time of release for recaptured tagged fish within 5 days of releases and where fish for which the difference in the initial and second length measurements was equal to or exceed 10 cm.**

| Species | Variance | SD | N |
|---|---|---|---|
| Skipjack | 0.564 | 0.751 | 799 |
| Yellowfin | 0.256 | 0.506 | 566 |
| Bigeye | 0.224 | 0.473 | 587 |
| All species | 0.514 | 0.717 | 1952 |

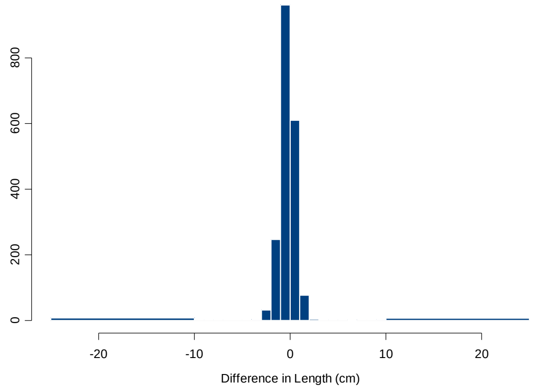



**Figure 1: Histogram of the difference between the initial and second length measurement for fish recaptured and released by the tagging vessel within 5 days of tagging. Note that the bars centered at -20 and 20 are pooled for all values below or in excess of -10 and 10 respectively, while the interval for the other bars is zero. Note that the bar just below zero includes the zero values and is the reason why the figure suggests an apparent bias.**

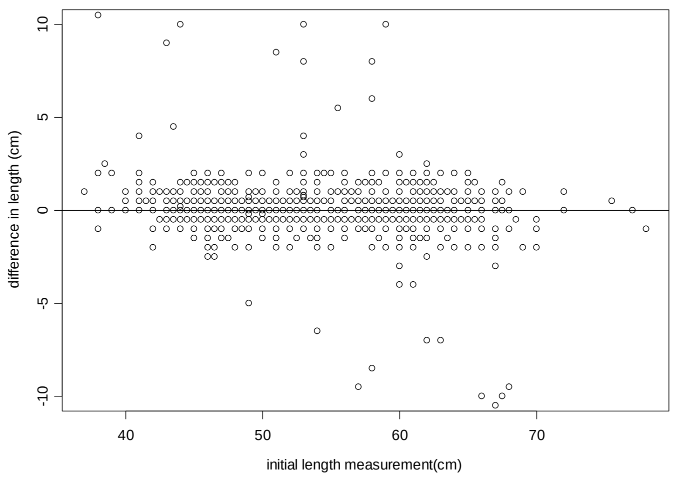



**Figure 2: The relationship the initial length of a tagged fish and the difference between the initial and second length measurement for fish recaptured and released by the tagging vessel within 5 days of tagging. Note cases in which the difference in length exceed 10cm have been excluded.**

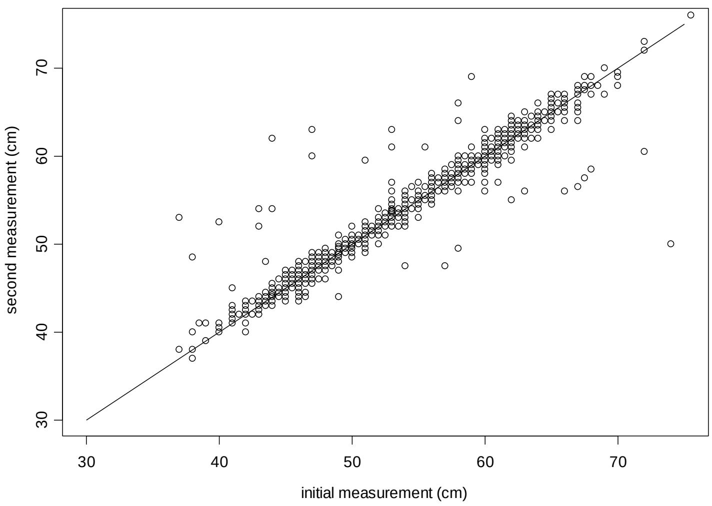



**Figure 3: The relationship between the initial and second length measurement for fish recaptured and released by the tagging vessel within 5 days of tagging.**

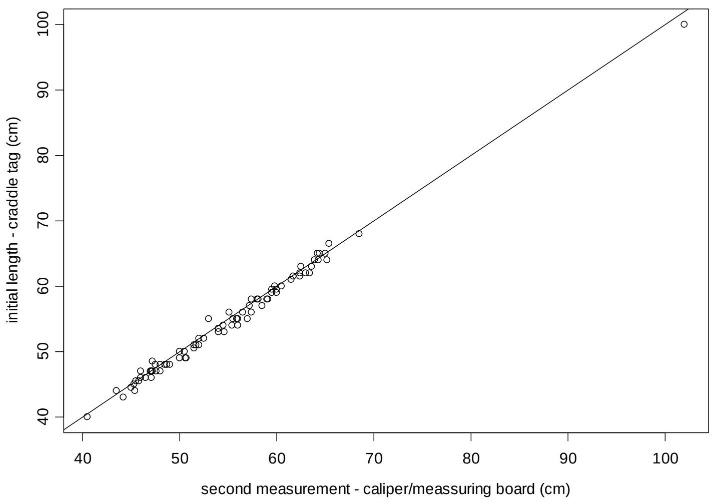



**Figure 4: The relationship between caliper/measurement board length measurements for recaptured tagged fish and initial length measurements made at the time of tagging. Only fish that were recaptured within 5 days of tagging are included. Note that the fish measured with calipers or measurement boards were dead at the time of measurement.**

# APPENDIX VIII:
## Indian Ocean Tuna Tagging Programme- Data Users Policy and Application Form

The Secretariat of the Indian Ocean Tuna Commission (IOTC) is the central repository for the master conventional and archival tagging release, recapture and sampling data obtained from the Indian Ocean Tuna Tagging Programme (IOTTP).

The IOTTP comprises the large-scale Regional Tuna Tagging Project of the Indian Ocean which was funded under the 9th European Development Fund (9.ACP.RSA.005/006) of the European Union and several small scale projects implemented in Maldives, India, Mayotte, Indonesia and South Africa and funded by the DG-Fish European Commission and the Government of Japan.

Data from these projects are available to bona fide researchers or institutions in accordance with this Data Users Policy, IOTC Data Confidentiality Policy and Procedures (see IOTC Resolution 98/02 below) and upon a formal request to the IOTC Secretariat (see the application form below). The Executive Secretary IOTC, in consultation with the Chair of the IOTC Scientific Committee, is responsible for the approval process.

Organisations or individuals requesting tagging data are required to provide a description of the research they intend to undertake, including the objectives, methods and intentions for publication. A list of the individuals having access to the data is also to be provided. Furthermore, the Secretariat expects to be informed of any changes to the data users list.

In acknowledgement of the funding bodies, the organisations that managed the administrative and technical aspects of the programme, the numerous National and Recovery Officers and Fisheries Administrations based in the different countries involved with the project, the tagging teams, and the collaboration of all fishermen reporting recoveries, one of the following acknowledgement is expected to be included any publication arising from the use of the tagging data.

*For use of the RTTP-IO data only*

The tuna tagging data analysed in this publication were collected by the Regional Tuna Tagging Project of the Indian Ocean (RTTP-IO) funded under the 9th European Development Fund (9.ACP.RSA.005/006) of the European Union. The RTTP-IO was implemented by the Indian Ocean Commission under the technical supervision of the Indian Ocean Tuna Commission. We wish to acknowledge the contributions of the project staff and all the technicians, recovery officers and fishers that have been involved in the RTTP-IO.

*For use of the RTTP-IO data and data from one or more of the small-scale tuna tagging projects*

The tuna tagging data analysed in this publication were collected under the Indian Ocean Tuna Tagging Programme comprising the Regional Tuna Tagging Project of the Indian Ocean funded under the 9th European Development Fund (9.ACP.RSA.005/006) of the European Union, and several small-scale tagging projects funded by the European Union and the Government of Japan. We wish to acknowledge the contributions of all the people that have been involved in the Indian Ocean Tuna Tagging Programme.

*For use of data from one or more of the small-scale tuna tagging projects*

The tuna tagging data analysed in this publication were collected under the Indian Ocean Tuna Tagging Programme. The tagging work was funded by the European Union and the Government of Japan. We wish to acknowledge the contributions of project staff and all the people that have been involved in the Indian Ocean Tuna Tagging Programme.

While the tagging data are typically only released for use in the specified research project and must not be used for other purposes without the permission of the Executive Secretary IOTC.

All inquiries regarding the Indian Ocean Tagging Data, including applications to use the data should be made to the:

Executive Secretary IOTC

secretariat@iotc.org

## TAGGING DATA USERS APPLICATION FORM

**To the Executive Secretary of the Indian Ocean Tuna Commission**

I wish to submit the following request to receive and analyse data from the Indian Ocean Tuna Tagging Programme. I have read the above Data Users Policy, noting in particular, the matters relating to data confidentiality and providing an appropriate acknowledgement in the case of any publications arising from the use of these data, and agree to all the conditions listed.

| |
|---|
| Name of the institution/s requesting the data and contact details for the head researcher |
| Project outline |
| Specifications of the data required |
| Names and positions of the staff accessing the data (*Note, the Secretariat expects to be informed of any changes to the data users list*) |
| Intentions with respect to publication of the results of the proposed work |

Signature and date:

Name.....................................................................................................

Position...............................................................................................

Organisation.........................................................................................

Approved / Not Approved

Signature and date:

Executive Secretary IOTC

## IOTC Resolution 98/02:
## Data Confidentiality Policy And Procedures

**The Indian Ocean Tuna Commission (IOTC),**

RECOGNIZING the need for confidentiality at the commercial and organisational levels for data submitted to IOTC, the following policy and procedures on confidentiality of data will apply:

### DATA SUBMITTED TO THE SECRETARIAT

1. The policy for releasing catch-and-effort and length-frequency data will be as follows:
2. Catch-and-effort and length-frequency data grouped by 5° longitude by 5° latitude by month for longline and 1° longitude by 1° latitude by month for surface fisheries stratified by fishing nation are considered to be in the public domain, provided that the catch of no individual vessel can be identified within a time/area stratum. In cases when an individual vessel can be identified, the data will be aggregated by time, area or flag to preclude such identification, and will then be in the public domain.
3. Catch-and-effort and length-frequency data grouped at a finer level of time-area stratification will only be released with written authorisation from the sources of the data. Each data release will require the specific permission of the Secretary.
4. A Working Party will specify the reasons for which the data are required.
5. Individuals requesting the data are required to provide a description of the research project, including the objectives, methodology and intentions for publication. Prior to publication, the manuscript should be cleared by the Secretary. The data are released only for use in the specified research project and the data must be destroyed upon completion of the project. However, with authorisation from the sources of the data, catch-and-effort and length-frequency data may be released for long-term usage for research purposes, and in such cases the data need not be destroyed.
6. The identity of individual vessels will be hidden in fine-level data unless the individual requesting this information can justify its necessity.
7. Both Working Parties and individuals requesting data shall provide a report of the results of the research project to IOTC for subsequent forwarding to the sources of the data.

### PROCEDURES FOR THE SAFEGUARD OF RECORDS

Procedures for safeguarding records and databases will be as follows:

1. Access to logbook-level information will be restricted to IOTC staff requiring these records for their official duties. Each staff member having access to these records will be required to sign an attestation recognising the restrictions on the use and disclosure of the information.
2. Logbook records will be kept locked, under the specific responsibility of the Data Manager. These sheets will only be released to authorised IOTC personnel for the purpose of data input, editing or verification. Copies of these records will be authorised only for legitimate purposes and will be subjected to the same restrictions on access and storage as the originals.
3. Databases will be encrypted to preclude access by unauthorised persons. Full access to the database will be restricted to the Data Manager and to senior IOTC staff requiring access to these data for official purposes, under the authority of the Secretary. Staff entrusted with data input, editing and verification will be provided with access to those functions and data sets required for their work.

### DATA SUBMITTED TO WORKING PARTIES

1. Data submitted to Working Parties will be retained by the Secretariat or made available for other analyses only with the permission of the source.

2. The above rules of confidentiality will apply to all members of Working Parties.