THE CONTRIBUTION OF THE REGIONAL TUNA TAGGING PROJECT - INDIAN OCEAN TO IOTC STOCK ASSESSMENT

Jean-Pierre Hallier[1] and Julien Million[2]

SUMMARY

From May 2005 to August 2007, the Regional Tuna Tagging Project-Indian Ocean (RTTP-IO) released 168,150 YFT, BET and SKJ. So far 27,400 recoveries have been reported or 16.3%. Recoveries per species, month, type of tag, gear, size, tagger, country are explored. For double-tagged tuna 6.8% has lost one tag when recovered. PS recoveries are accounting for 95% of the recoveries with ¼ found at sea and ¾ found ashore. Once date(s) and position(s) are estimated, 80% of PS recoveries have possible recovery dates 7 days apart or less resulting in a good quality level. Time-at-liberty and travelled distance, whatever the species, demonstrate a rapid and extended mixing of the tagged tuna among the rest of the population within 1 or 2 months: a necessity rarely meet by the other tagging projects. SKJ present the highest proportion of long distance recoveries before YFT and BET but all species reached the Eastern Indian Ocean. Movements are spectacular: (1) differences between species are minor; (2) they are not size-dependant; (3) they support the hypothesis of a single stock at the level of the Indian Ocean for the three species. The extremely large number of bigeye tagged by the project is greatly spoiled by the very low reporting rate of the longline fishery.
RTTP-IO targets were fulfilled and even surpassed and the data generated are going to contribute greatly to the stock assessment tasks of IOTC for many years to come.

1. GENERAL CONTEXT

The objective of this document is to give a general idea of the data gathered so far by the Regional Tuna Tagging Project - Indian Ocean (RTTP-IO).

The main objective of the RTTP-IO is to provide the IOTC with the parameters necessary for tuna stock assessments.

The different data and information presented in this document are based on the different RTTP-IO databases up to 19/09/2009. The recovery database contains today 27,706 recoveries (315 were tagged by other tagging projects than the RTTP-IO but recovered by purse seiners) and is completed every day by new recoveries. However as the tagging activity ended in August 2007, the number of new recovery is now very low but made of large fish with long time-at-liberty.

2. THE RTTP-IO PROJECT (Administrative aspects)

The RTTP-IO is an answer of the European Union to the request of the Indian Ocean Tuna Commission (IOTC) scientists who asked for a large-scale tuna tagging programme to address the issue of the state of the

[1] Chief Coordinator of the RTTP-IO, c/o IOTC, P.O. Box 1011, Victoria, Seychelles E-mail : jph@iotc.org
[2] IOTC Tagging Officer, c/o IOTC, P.O. Box 1011, Victoria, Seychelles E-mail : jm@iotc.org

stocks of the three main species of tropical tunas in the Indian Ocean , *ie*. yellowfin tuna (*Thunnus albacares*), bigeye (*T. obesus*) and skipjack (*Katsuwonus pelamis*).

Large-scale tagging is necessary for an efficient assessment of tropical tuna stocks as it brings completementary parameters to the one provided by fisheries data. As the European Community was the only funding agency this large-scale tagging, the area of activity was limited to the area covered by its purse-seine fleet, *ie* the Western Indian Ocean. To cover the Eastern Indian Ocean, Japan made a voluntary contribution to the IOTC which permitted undertaking some small-scale tagging off Maldives, Lakshadweep and Andaman islands (India) and western Indonesia. Few other small-scale tagging operations were implemented in the Western part in Mayotte, Seychelles and South Africa with funds from the EU DG-Fish. The small-scale tagging projects together with the main RTTP-IO are known as the Indian Ocean Tuna Tagging Project (IOTTP). This document is dealing with the activities of the RTTP-IO.

The RTTP-IO was funded under the 9th European Development Fund (EDF) for a total budget of 14 Million Euros. The Financial Convention was signed in December 2003 and the project started in January 2005 with a total period of execution of 5 years.

Tagging vessels and staff were provided via 4 different contracts: one for each of the two vessels, one for the Chief Coordinator (CC) and one for the Technical Assistance (TA). Contracts for the vessels were awarded to AZTI (Arrantzuarekiko Zientzia Eta Teknika Iraskundea - Instituto Tecnologico Pesquero y Alimentario, Spain), the contract for the CC was awarded to Mr. Jean-Pierre Hallier (France) and the contract for the TA was awarded to MEP from (McAllister Elliott & Partners, United Kingdom).

The Regional Authorising Officer (RAO) of the Project is the Indian Ocean Commission (IOC – COI) based in Mauritius which is an intergovernmental organization which members are Comoros, Madagascar, Mauritius, Seychelles and France (La Reunion). The Technical Supervisor of the Project is the Indian Ocean Tuna Commission (IOTC). The project was based in Seychelles because it is the major port of unloading for tuna catches in the Indian Ocean, the main base of the European purse-seine fleet and because of the presence of the IOTC Secretariat.

The European Commission Delegation (DEC) in Mauritius is the funding agency of the Project.

Being funded under the 9th EDF, the RTTP-IO had to follow a set of rules that are not well-suited for this type of activities, especially because projects' activities are not limited to the beneficiary countries of the Inter Regional Coordination Committee (IRCC) which are all ACP countries, but had to be extended to the IOTC members. One of the solutions was the signature of a Contribution Agreement between the FAO/IOTC and the DEC at the end of 2005. This Contribution Agreement is covering all recovery and publicity expenses of the Project as well as some other expenses related to electronic and satellite tagging.

3. STAFF

As the project is due to end on December 31st 2009, the project staff is gradually decreasing, the situation is as follows:

- The Chief Coordinator (CC), Jean-Pierre Hallier, will stay until the end;
- The Publicity and Tag Recovery Officer 2 (PTRO), Teresa Athayde left last June; PTRO 1, Dr. Charles Anderson is still available under MEP contract;
- The Financial and Administrative Officer, Michael Stockwell, will be leaving in October;
- The secretary, Betty Honoré, left in May 2009;
- Two Tag Recovery Officers, left in May 2009, the third one will remain with the project until the end;
- One Tag Recovery Assistant left in May 2009 and two will remain with the project until the end;
- One Accounting Officer, Mrs Peggy Carosin, will stay until the end;
- The IT part-time administrator, Nishan Sugathadasa, will remain until the end;
- Three Cruise leaders, their contracts terminated in September 2007 with the end of the tagging operations;

- Three Tagging Technicians as above for the Cruise Leaders.

Under the MEP contract, short-term expertises are also provided whenever necessary.

The project also benefit during its whole period of execution and especially during the first 2 ½ years of the strong participation of the IOTC Executive Secretary, Alejandro Anganuzzi, of the IOTC Tagging Officer, Julien Million, as well as other IOTC staff. IOTC is still involved in the Project and after December 2009 will take over the collection of the recoveries.

4. RECOVERIES

4.1. The number of recoveries

The last day of tagging of the RTTP-IO was August 29th 2007, more than 2 years ago; consequently the flow of recoveries has slowed down a lot. The number was even more reduced as purse seine fleet, the main contributor to RTTP recoveries, recently experienced low fishing activity, mainly due to piracy acts from Somalia in the Indian Ocean. On October 2nd 2009, 27,391 RTTP recoveries were entered in our database or 16.3% of all tagged tuna.

4.2. Recoveries collected per month

Figure 1 shows the monthly number of recoveries reported. The date taken into consideration is the date of catch or if unknown the closest date to the date of catch. Since the end of the tagging operations, the flow of recoveries is decreasing and it is now quite low: 92 per month on average from January to August 2009. The species composition of the recoveries (Figure 2) shows an overall decrease of the presence of SKJ, up and downs for BET with a decreasing tendency but an overall increase of the YFT. Trends for SKJ are certainly related to the higher natural mortality of this species link to a shorter life compared to YFT and BET, while for BET the decreasing trends is probably due to the low reporting rate of the longline fleets, the main fishing gear for the now large tagged BET.

4.3. Recoveries by type of tag

The overall recovery rates are given in Figure 3 and the recovery rates by type of tag are given in table 1. These data confirm:

- Recovery rates are similar for single (ST) (16.5%) and double tagged (DT) (16.7%) fish;
- Recovery rate of OTC tagged tuna is clearly lower and especially for BET;
- Recovery rate for ET tags is very low.

We mainly used tags of two different colours (yellow and white) and three different sizes (overall length of 9.5, 11.5 and 14.5 cm). The recovery rate of the OTC tagged tuna (white tag) is much lower (10.2%) compare to yellow tags (16.5% for the ST and 16.7% for DT). And this picture remains the same whatever the species (Table 1).

Two main reasons can be put forward to explain the lower recovery rate of OTC tags: (1) a lower reporting rate due to the white colour of the tag less visible than the yellow one of the ST and DT tags; (2) a higher mortality rate induced by the OTC injection. The hypothesis of a lower reporting rate for white OTC tags is supported by two facts: 1) the recovery rate of the smaller white tags (smaller size and smaller diameter of the tag) is only 8.7% while the one of the larger tag by length and diameter is 10.4%. (Figure 4) ; 2) 19.3% of OTC tags are discovered more down the fish processing line (on reefers, or in cold stores or in canneries) while 11.1 % of ST and 4.6% of DT (Figure 5) are recovered during the same processes. ST tags are less detected than DT tags in the early stage of the fish processing.

Colour seems to play a higher role than size in the detection of the tags as seen in (Figure 4) because the BB series of 9.5 cm, the shortest tags, have a higher recovery rate than the two OT series (however the sample size is quite small: 392 tags, 48 recoveries). Among the yellow tags (series BB, CC, EE & KK), the recovery rate increases with the size of the tag with minor differences between 11.5 and 14.5 cm (16.1% and 16.7%). Another evidence of the lower detection of the OT-white tags is given by the percentage of tags discovered Overall, white tags and small tags are less detected than yellow tags and large tags. The lower detection of the white tags is actually tested via the IOTC tag seeding operations as white seeding tags are now used in this experiment.

On top of the colour, OTC tagged tuna might experience a higher induced tagging mortality.

4.4. Recoveries per gear

The recoveries according to the gear used for the recapture are given in table 2. Recoveries by purse seiners are by far the highest and none of the other gear even reaches 1% of all recoveries.

Longline and pole-and-line have been increasing recently accounting for 0.9% with 238 recoveries, and 195 and 0.72 % respectively (Figure 6). Gillnet represents 228 recoveries or 0.85 % but recoveries are now almost nil – most probably an effect of size selectivity as most tagged tuna are now too big to be caught by this gear, or a decreasing reporting by the fisheries using this gear. Then come handline and troll-line. Apart from longline, the other gears are generally used by artisanal fisheries which traditionally have a very low reporting rate. It is very difficult, time and money consuming to improve artisanal reporting and anyway it will never be possible to assess the level of their reporting rate.

Longline recoveries are made of 64% BET, 33% YFT and 3% SKJ. Longline reporting rate is extremely low as illustrated by other documents presented during this meeting. The RTTP-IO with the IOTC is trying to improve the report of tagged tuna caught by longliners but with moderate success (Figure 7). The distribution of the recoveries by LL flag country is not easy to interpret as vessels often have a flag different from their real origin. Our main contributors are Taiwan (China), Japan and China mainland. New publicity boards in English and in 5 different Asian languages will be distributed soon to Observer Projects (IOTC, La Reunion, Madagascar, South Africa, Oman, Iran) as well as to our Recovery Officers in contact with longliners in Mauritius, Kenya, Tanzania, Thailand in order to increase the reporting from those fleets.

Large BET being mainly caught by longline, this species is the most affected by the low participation which is a pity when one considers that no large-scale tagging program has ever tagged and released such a large amount of BET (34,564).

Gillnet recoveries are coming from “artisanal” fleets from Tanzania, Sri Lanka, Iran, Kenya, and Oman.

Handline recoveries are reported by Comoros, Tanzania, Kenya, Oman, Thailand, Mayotte, Seychelles, Sri Lanka and Yemen. A couple of recoveries are coming from sport fisheries (La Réunion, Kenya).

Many different aspects of the recoveries developed below are directly influenced by the overwhelming importance of purse seine recoveries.

4.5. Recoveries by size at tagging and at recapture

As much as possible sizes at recovery are collected (86% of all recoveries have size qualified as “Good”). These data are illustrated in figures 8a, b & c for yellowfin, bigeye and skipjack respectively. We also try to collect weights (70% of all recoveries have weights and 66% have length and weight).

The RTTP-IO is also collecting now some large yellowfin and also large bigeye in fewer numbers which have been at sea for long periods. These recoveries are bringing interesting information on the growth and movements of these large individuals of these two species. Skipjack is also affected at a lesser degree by the same situation. However, we are collecting insufficient number of BET greater than 100 cm as these large

BET are not well represented in the purse seine catch and are a large component of the LL catches which are poorly reported.

4.6. Recovery rates by size at tagging

Figure 9 give a plot of the recovery rates (RR) for each batch of tagged tuna by 4cm interval. One can notice that after an initial low recovery rate for small size classes, the RR reach a maximum between 36 cm (BET) and 48 cm (YFT) and then gradually decreased at a rate fastest for SKJ and slowest for YFT, BET being between these two values. The lower RR for small fish can be related to (1) small sample size, (2) higher natural mortality and/or (3) to the fish immigration outside the Purse Seine area. Then for greater size tuna, the decrease of the RR is a function of the time availability of the fish to the different fishing gears – mainly PS- smaller the fish at tagging longer it remains vulnerable to fishing gears increasing its probability to get caught, and hence to experience a higher RR..

4.7. Recovery rates by tagger

Figures 10 illustrate the recovery rates by tagger; they are in order from the tagger having tagged the largest number of fish on the left to the least number of tags to the right. We have only kept tagger with more than 1,000 tags released; they are accounting for more than 98% of all tagged and recovered tuna. One can notice the low dispersion of the data. This is even more pronounced if we consider taggers who have tagged more than 5,000 tuna (the first 12). This is an expression of the regularity and possibly of the quality of the tagging of the RTTP-IO.

The tagger with the highest RR (23.2 %) has tagged only 2,646 tuna and almost all in October and November 2006; months with RR greater than the average (cf. § 4.8).

The tagger with the lowest RR (12% and 12.3%) released all their tagged fish in 2005 for one and in January & February 2006 and 2007 for the second. Tagged tuna in 2005 have the lowest RR (13.4% against 17.9% in 2006 and 14.3% in 2007). January & February 2006 have an average RR but in 2007 their RR are by far the lowest (cf. § 4.8). Therefore we can conclude that the main taggers of the RTTP-IO maintained a high degree of regularity and quality while doing tagging.

4.8. Recovery rates per tagging month

Recovery rates per tagging month are given in Figure 11. From May 2005 to November 2006, RR shows an overall increasing tendency. One of the explanations is the increasing reporting rate that was hardly 50% in 2005 and reached about 90% at the end of 2006.

December 2006 and January 2007 have by far the highest RR but with very few fish tagged (556 tag released, 183 recovered with a short TL of 139 days). Most of these fish were recaptured quickly: 62% of the recoveries occurred less than 4 months after tagging. The very low RR from February to May 2007 are related to low tagging and to tagging in the Arabian Sea or between the Arabian Sea and Tanzania via Maldives and Seychelles, *i.e.* in areas with no or very little PS fishing activities and with activities of other fisheries having a low reporting rate.

4.9. Double tagging results: Percentage of Tag lost

The objective of double-tagging is to estimate the tag shedding rate (the proportion of tags which fall off the fish before it can be reported – mostly when the fish is still alive at sea). There are different methods to estimate tag shedding rate. In this document only the percentage of tag lost on double-tagged tuna are considered. Double-tagging started in January 2006 and the RR of these tags was given in § 4.3.

Of the 4,650 DT recovered so far 317 were reported with only one tag: 178 have lost the 1st tag (56%) and 139 the 2nd tag (44%). These results are given in Table 3. The overall percentage of DT recovered with only one tag is 6.8%. Considering the low number of recoveries which can be expected in the coming months and years, this percentage should not change much. This percentage is variable according to the taggers and to species. If we take into account only taggers having released at least 1000 DT (12 among the 30 taggers who account for 87% of all DT tags and 78% of all fish tagged), this percentage vary from 0.7% to 9% underlying a tagger effect. We use these percentages or the average (for taggers not having perform DT) to estimate how many tagged tuna got recaptured but were not reported because they shed their tag. So far about 1580 recoveries were not reported because they shed their tag. This should bring the total recoveries to around 29,000, *i.e.*17 % of the tagged fish instead of the 27,390 recorded so far or 16.3%.

The percentage of tag lost according to species is 10.3% for YFT, 4.1% for BET and 4.2% for SKJ. We do not know why this percentage is more than double for YFT than for the two other species. Maybe they possess a stronger rejection power than the other species or their skin is harder, consequently fewer tags are reaching the bones of the 2nd dorsal fin making them more prone to shedding. This situation was also noted for the RTTP of the western tropical Pacific Ocean by J. Hampton (1997).

To estimate the real number of recoveries one should add to this number of tag shed the tags recaptured but not reported. These two biases of the number of recoveries were taken into account in the last YFT stock assessment using MULTIFAN-CL (A. Langley *et al.* IOTC-WPTT 2009).

4.10. Where recoveries were found

The recovery can take place either on a fishing vessel (at sea or in the port), a reefer, cold store, and cannery or at the fish market. The distribution of recoveries between these different locations is given on Figure 12. The discovery on fishing vessel is overwhelming important and has increased at the beginning to reach and remain at around 90% since the 4th quarter of 2006. Recoveries in canneries remained above 10% until the 3rd quarter of 2006. The other locations are anecdotic. As more recoveries show up, especially from purse seine catches, the awareness of stevedores first and fishermen later increased. Consequently fewer recoveries bypass their scrutiny to be discovered later in cold store or canneries.

4.11. Recovery per country

Seychelles is by far the country where most of the recoveries are reported: it always accounts for more than 50% of all recoveries except during the second quarter of the year when purse seiners are fishing in the Mozambique Channel and mainly unloading in Madagascar (Figure 13). At sea recoveries have been increasing since the beginning of the project until Q4 of 2007, and then it was followed by a decreasing trend, Q3 of 2009 being the lowest with 15%. This is certainly due to a lower commitment of purse seine fishermen as the recovery flow is quite low. However the recovery share of canneries is not increasing showing that the stevedore's awareness seems not to be affected (Figure 14).

4.12. Possible Date(s) and Position(s) of PS recoveries

Even if the percentage of recoveries found at sea on board PS is high for this type of project (24.3% - Figure 13), most of these recoveries are found either in port when transhipping or unloading or in canneries (cold store, cannery processing line). For all these recoveries, we collect the well(s) number in which the tagged fish comes from. For the EU or EU related PS we can receive later the logbooks which generally provide the dates and positions of the catch stored in the different wells of a given trip. A software developed by the IT manager of the project, called "DataEditor" permit to do the liaison between the well data from the PS logbooks and the well(s) registered with the recovery. This system works fine but it is time-consuming as recoveries need to be treated one by one. This work has been carried out until the beginning of 2009. We have developed codes to qualify the quality of the liaison. Different types of errors or some missing data can

make the liaison more or less precise or even impossible. The codes “Complete or Minor Discrepancy” (the best link), represent 78% of all PS recoveries not found at sea.

The link will attribute the date(s) and position(s) of the set(s) found in the well(s). We have looked at the difference between the maximum and the minimum dates attributed to these recoveries (Figure 15). Generally, higher the number of sets more chance the different dates will be far apart giving an uncertain date of catch. Recoveries with dates 7 days or less apart are accounting for nearly ¾ of the recoveries and 24% have a single date (only one well with only one set inside). Therefore when PS recoveries at sea are added the general picture is that the vast majority of the PS recoveries have quite accurate date(s) and position(s) (42% have a single date, 80% have dates at the most 7 days apart.

Dispersion of the positions will be accordingly: lower the dates are apart closer are the positions.

The Thailand flag PS (from Russian origin) which are regularly unloading in Seychelles are reporting tags also and we collect the well(s) number. But so far we have not been able to obtain the logbooks in order to run the DataEditor for the attribution of date and position for their 50 recoveries.

4.13. Time-at-liberty

The durations between the date of release and the date of recovery called time-at-liberty (TL) are given in figures 16 for the three species (all recoveries up to August 2009). We have not taken into consideration the 457 recoveries registered by the RTTP chartered vessels while fishing on the AS.

The cumulative percentages of recoveries during the first 12 months after tagging are given for the three species in Figure 17.

These two figures show:

- A very regular collection of the recoveries for all three species;
- The absence of very rapid and important number of recoveries in the first one or two months after tagging, a general feature of most tropical tuna tagging projects (2 months after tagging, only 11.3 % of YFT, 9.5% of BET and 14.5% of SKJ were recaptured);
- After one year at liberty, a bit more than 2/3 of YFT recoveries (69.6%) have been registered compare to 82.8% for BET and 84.5% for SKJ;
- Consequently the average time at liberty is very high in comparison of other tagging projects: 306 days or 10 months for YFT, 258 days or more than 8 months for BET and 220 days or a bit less than 7 months for SKJ; this lower SKJ TL is noticed almost for each tagging area.
- These results demonstrate that (1) mixing of the tagged fish among the untagged fish is rapid; (2) the lowest average TL for SKJ is most certainly link to the shorter life expectancy of the species compared to YFT and BET; (3) despite the fact that BET is the longest living species, it ranks only second for the average TL: this is the combined effect of low abundance of large BET (with long TL) in the PS catch and the low reporting rate of longline fisheries.
- Overall, average TL are greater for fish tagged in the Mozambique Channel (Table 4 – 363 days) and lower for Seychelles (217 days); this is understandable as Mozambique is at the periphery of the PS fishing zone while Seychelles is at the centre.
- Oman tagged tuna is peculiar as all tagged tuna are YFT and they have a very low TL (143 days). The high percentage of local recoveries (33 tags or 46%), all registered in 2007, the tagging year are responsible for this low average TL. We will come back on the case of Oman in § 4.15.

So far, the greatest TL are 1540 days for YFT (4.2 years); 1415 days for BET (3.9 years) and 1343 days for SKJ (3.7 years).

4.14. Distances travelled (DTr)

Distances travelled (DTr) measured as a direct linear distance between tagging and recovery positions are given in figures 18 for the three species. As mentioned previously we have not taken into consideration the recoveries done by the RTTP chartered vessels while fishing on the AS.

Modes are at 800 miles for YFT (average 710), 600 miles for BET (average 657) and SKJ (average 696). DTr are more or less the same for YFY and SKJ and slightly lower for BET. As purse seine recoveries are accounting for most of the recoveries, this means movements of the three species are very similar including movements as far as the Eastern Indian Ocean. The only noticeable difference is for SKJ with a slight peak around 2000-2100 miles. Almost all these recoveries are from SKJ tagged off Tanzania-Kenya and recaptured in Maldives by the local pole-and-line fishery (90% of them) or in the vicinity of Maldives by purse seiners (10%). This aspect will be addressed later in § 4.15 on the geographical distribution of the recoveries.

The slightly lowest average DTr by BET is due to the lowest number of BET recaptures East of 60º E: 2.6% of all BET recoveries compared to 5.5% for YFT and 7.2% for SKJ.

The lack of surface fishing (especially PS) in the Eastern Indian Ocean is mainly responsible for the absence of recoveries in this region. Only 49 recoveries are registered East of 80ºE; 45 are from PS who went to fish there in December 2006 (44 recoveries) and in December 2007 (1 recovery). The 4 others are from artisanal fisheries. Therefore each time the PS went fishing East of 80ºE they caught tuna (the three species) tagged in the West (mainly Tanzania). This result together with the substantial number of recoveries around Maldives (mainly SKJ) can underline an important movement of tuna from West to East of the Indian Ocean – mainly from Seychelles-Tanzania area to the area East of 80ºE.

The more or less similar DTr for the three species again underlie similarity in the movements and mixing of the three species within the PS fishery.

The average DTr according to the main tagging areas are given in Table 5. If overall average DTr between species are more or less similar, they can be quite different between areas. Tuna tagged in Seychelles waters have the lowest average distance travelled (360 miles) most certainly because Seychelles is at the centre of the PS fishing ground where the fishing effort is higher increasing the probability for a tagged fish to be recaptured before it get sufficient time to travel far. The highest DTr are registered for fish tagged in Tanzania/Kenya. These highest DTr confirm the “Tuna hub” aspect of this region. Tuna present in this area are moving out quickly to different places. This makes the Tanzania area a perfect tagging spot well-fit to the objectives of the RTTP-IO.

In Tanzania area, about one month after tagging the average DTr fluctuates between 650 miles for BET and 880 miles for YFT, SKJ lay in between at 710 miles. This means (1) at least part of the tagged tunas moved out quickly and (2) only when they reach the PS fishing grounds off Seychelles or off Somalia they are caught.

The DTr versus the TL is given for the three species tagged off Tanzania in Figure 19. After the initial rapid increase during the month following tagging, the DTr are the same for the three species up to 10 months after tagging. Then after, while YFT and BET show small seasonal fluctuations on a 12-month basis, SKJ DTr follow an increasing trend.

In Seychelles area, average DTr versus TL are available for YFT and SKJ (Figure 20). We notice a gradual increase of the DTr from tagging until 8-9 months after tagging similar for both species underling a regular diffusion of the fish from the tagging area. There is a slight decrease around 12-14 months that could be related to a seasonal signal of some fish coming back towards their tagging point. But 16 months after tagging the two species are diverging as SKJ DTr show a clear increasing tendency. The same trend is noticed for YFT but starting only 21 months after tagging.

In the Mozambique Channel, average DT are high for SKJ (736 nm) and BET (653 nm) but low for YFT (352 nm) (Table 5). However, of the 91 YFT recoveries of YFT tagged in the Mozambique Channel, 46

(50%) are recoveries made only 1, 2 or 3 days after tagging. This is one of the rare cases where the tagging vessels tagged among PS at the end of the Mozambique PS fishing season in 2005. If we don't count these very short time recoveries, the average YFT DT is 646 nm similar to the two other species. Therefore, for all three species the Mozambique Channel is like Tanzania a place where tuna are moving out far.

The DTr versus the TL for SKJ (Figure 21 - there is not enough data for YFT) show a seasonal pattern even better marked than for the Tanzania and Seychelles areas which is expected as the region is at the southern edge of PS fishing grounds. Here too we notice an increasing tendency of the DTr.

4.15. Recoveries by geographical area

These distributions of recoveries by geographical areas are represented by a straight line between tagging and recovery positions. We did not present the overall movements maps for each species as they are too many (several thousand for each species).
Different maps according to species, tagging area, size at tagging, size at recovery, recovery gear are presented and briefly discussed.

1. Short TL (30 days or less– Figures 22a, b, c for YFT, BET & YFT respectively). For tuna tagged in Tanzania, movements for all 3 species are very similar: the main direction is North-East with some BET and SKJ going East, and even SE for BET (Mozambique Channel). The movements are fast: average DTr are 524 nm for YFT, 548 for BET and 730 nm for SKJ for a TL <= 30 days.
   For SKJ and YFT tagged off Seychelles, they are moving in all directions but on shorter distances: average DT of 241 nm for YFT and 206 nm for SKJ (very few BET).
   SKJ & YFT tagged in the Mozambique Channel are moving North and North-East with some at very short distance.
2. Long DTr (>=1500 nm - Figures 23a, b, c for YFT, BET & YFT respectively). So far nearly 800 recoveries have DTr >=1500 nm – the species composition of these long-distance recoveries is 62% SKJ, 30% YFT and 8% BET. Therefore SKJ is showing more long-distance recoveries than YFT and even more than BET comforting the position of SKJ as moving farther. Overall the percentages of long-distance recoveries are 2.7%, 1.3% and 4.2% for YFT, BET and SKJ respectively. Furthermore occurrence of long-distance recoveries are tagging area dependant: 3.6% of recoveries from Tanzania or from Mozambique made more than 1500 nm while only 0.4% of Seychelles do it. But the highest % of DT >=1500 nm are recoveries from Oman tagged fish – 9.2%. Globally Oman tagged tuna are either caught locally, and if not they are caught far from their tagging spot.
   Movements East of 80ºE concern the three species. One YFT cross the all ocean from Tanzanian coasts to Indonesian coasts.
3. Tuna tagged in Oman (Figure 24) – all are YFT. Apart from the movements along the coast to the North (Persian Gulf) or to the South (Yemen) – they represent 46% of all recoveries-, the YFT moved to the South even south of the equator into the PS fishery down to the Mozambique Channel (1 YFT). 49% of the recoveries are from the PS (32). Scientists believe that YFT from the Arabian Sea belong to the same stock as the small and large YFT fished further South by the PS and the movements shown in this map comfort this hypothesis. However all these PS recoveries were registered the latest in January 2008 while tagging took place between February and April 2007. Considering the tagging sizes of the Oman YFT and their potential growth, we were expecting more recoveries during the PS fishing season on spawning YFT between December 2008 and March 2009. But none of these recoveries were registered. Maybe some recoveries might show up during the next fishing season from December 2009 to March 2010.
4. Tuna tagged in the North-West of Lakshadweep Islands are shown in Figure 25 (1834 tagged including 93% SKJ, 7% YFT). As for Seychelles, recoveries are found in all directions but those going to the North are not going very far; only was recovered towards the Arabian Sea. Of the 95 recoveries registered so far (5.2% of all tagged tuna) 72 or 76% were registered in 2007 from August to December, 22 in 2008 and 1 in 2009. Their average TL is low (214 days) and their average DTr is moderate (426 nm). Small-scale tagging implemented by the Indian Fisheries and IOTC in the Lakshadweep Islands show even shorter DTr.
5. Movements according to size at tagging (Figure 26a, b, c) or size at recovery (Figures 27a, b, c, d) for YFT release off Tanzania. Differences between maps are minor. We can notice the absence of

recoveries of YFT<=50 cm at recovery in the Mozambique Channel. However, in 2007, tagging stopped in August, a 40-42 cm YFT tagged in August 2007 can be caught by PS in the Mozambique Channel not before March or April 2008, by this time it will be closer or greater than 50 cm. In 2006, only 219 YFT of 45 cm or less were released off Tanzania between August and November, again very few of these fish will still be 50 cm or lower by March or April 2007. Therefore there are no real differences in the YFT movements according to size.

6. The same exercise is illustrated for BET in Figures 28 (sizes at tagging) and SKJ 29 (size at recovery). For BET the main difference with YFT are (1) no BET moved to the Arabian Sea and (2) one BET moved into area 4. For SKJ, there are numerous movements from Tanzania, Seychelles and even the Mozambique Channel to Maldives.
7. We follow month by month (from October 2006 to June 2007) the recoveries of all fish tagged in Tanzania between September and November 2006 (Figure 30a to i). In October 2006, fish were caught in the "Somalia" area, and still in November but some fish are already caught in Seychelles waters and between Seychelles and Chagos. In December, many fish are still coming from Somalia and more from Seychelles; a few fish show up in Comoros (artisanal fishery). From January to March 2007, most recoveries are recorded West, NW & SW of Seychelles and gradually more fish are recovered in the North of the Mozambique Channel. April present a majority of recoveries in the Mozambique Channel while in May they are equally divided between the Mozambique Channel and West of Seychelles; this last region become the main recovery ground in June while few recoveries are registered in the Mozambique Channel. This general pattern reproduces the seasonality of the PS fishery in the Western Indian Ocean.
8. Recoveries by longliners are given in Figure 31a. Large numbers of recoveries are coming from areas along the African coasts from Kenya to North of Mozambique. Most of them were reported by our Kenyan partners (33 recoveries or 14% of all LL recoveries). Another good source of LL reporting is Mr. Wu in Mauritius who is visiting the LL vessels calling into Mauritius (47 recoveries or 20%). LL recoveries are also coming from South Africa and the IOTC observers. However we have not received any recoveries from Tanzania, Pukhet in Thailand or Oman. It is worth noting that we have no recovery East of 80ºE even if LL are active in the Eastern part of the Indian Ocean.
9. Recoveries by gears other than PS or LL are given in Figure 31b & c; recoveries in artisanal fisheries of fish tagged off Tanzania in Figure 31b and fish tagged elsewhere and recovered by artisanal fisheries in Figure 31c. Both these figures show the important number of recoveries in Maldives of tuna tagged in every region where the RTTP-IO has done tagging but Oman: Maldives appear as the meeting point of tuna moving in the region (mostly SKJ). However this is the result of (1) the importance of the Maldives fishery, (2) the high reporting rate, (3) the efficient work of the Marine Fishery Centre. Altogether we have 190 RTTP tags recovered in Maldives (0.7% of all recoveries) including 96% SKJ.

   As seen in § 4.4, gillnet recoveries are 228 and distributed in a very wide area between 10ºS-25ºN and 39ºE-80ºE. This is due to the existence of many different fisheries (Iran, Oman, Kenya, Tanzania and Sri Lanka). Reporting is considered as very low.

   On Figure 31b, many recoveries are registered in the artisanal fisheries (Handline & Troll line) of Comoros (147). They must be more as the reporting rate is suspected to be high. Even if most recoveries are from of Tanzania tagged tuna there are few recoveries coming from Seychelles and Mozambique Channel.
10. Movements of BET are illustrated in Figures 32a, b, c, d, e & f. There are no important differences with the other species. We can notice the recovery of BET nearly in the ICCAT Region: 3 BET caught off the South coast of South-Africa by 22ºE and 21ºE.
11. Movements between MFCL fishing areas. For stock assessment models fishing areas were defined that divided the Indian Ocean in 5 different regions. Figure 33a, b, c are recovery density for YFT, BET and SKJ respectively. They show that tagged tuna moved back and forth between areas 1, 2 and 3. There are also movements from areas 2 and 3 towards area 5. These movements are underestimated as (1) EU PS has a very low fishing effort in area 5 (but every time they went there they caught tagged tuna of the three species); (2) LL and Artisanal gear and other PS who fished in the Eastern Indian Ocean either are not reporting their tags or report only a small fraction. Movement between area 2 and area 4 is materialized only by 3 BET only.

The general picture is as follows:

- A large and fast dispersion of the RTTP tagged tuna including recoveries in the Eastern Indian Ocean globally similar for the three species but still with some differences associated to where the tuna were tagged.
- Tuna tagged in Seychelles are moving less before being captured as PS fishing effort in Seychelles waters is high and Seychelles is at the centre of the PS fishing grounds.
- SKJ overall is moving farther that the two others species whatever the tagging ground.
- Tuna tagged in Tanzania move far and fast for all three species, confirming the quality of this area as tagging zone (the concept of the "Tuna Hub") which is fortunate as 79% of tagged tuna were released there.
- Movements in general are driven by the PS fishery as 96% of the recoveries were provided by this gear.
- Size at tagging or at recovery did not change movements for all three species.
- No SKJ and BET recovered in the Arabian Sea.
- Apart from very rare recoveries from longliners, there are no recoveries in the area south of 15ºS and East of Madagascar (except 3 BET).
- There are no recoveries by longliners East of 80ºE and recoveries by other gears East of 80ºE are only 95 or 0.35%, 91 are from PS. It is worth noting that the very limited effort of PS East of 80ºE have always resulted in recoveries.

5. CONCLUSIONS

The RTTP-IO has more than fulfilled its targets in term of number and species of tuna tagged but it has also registered a very large number of recoveries characterized by genuine long time-at-liberty and large distances travelled. It demonstrates movements from West to East all across the Indian Ocean, from North to South and for YFT from the Arabian Sea to the equatorial regions confirming the existence of only one stock for each tropical tuna species. It also shed new lights on the growths of yellowfin and bigeye.

The different data and analysis presented here are showing only a small part of the richness of the data collected; a lot more analysis should be done.

Other documents presented during this WP and other WPs to come will certainly prove the very valuable contribution of the RTTP-IO to the stock assessment objectives of the IOTC.

All the team of the RTTP-IO and IOTC as well as all the different participants and partners to this tagging program are very proud to deliver these data to the scientific community.

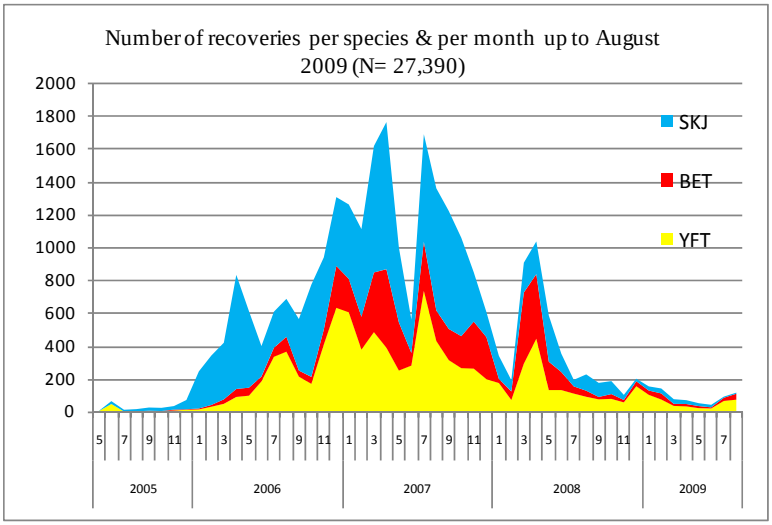

Figure 1: RTTP-IO monthly recovery by species from May 2005 to August 2009

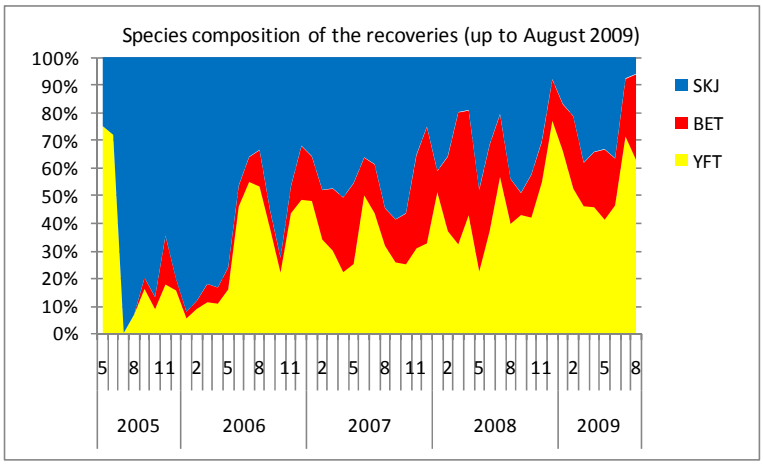

Figure 2: Species composition of the recoveries from May 2005 to August 2009

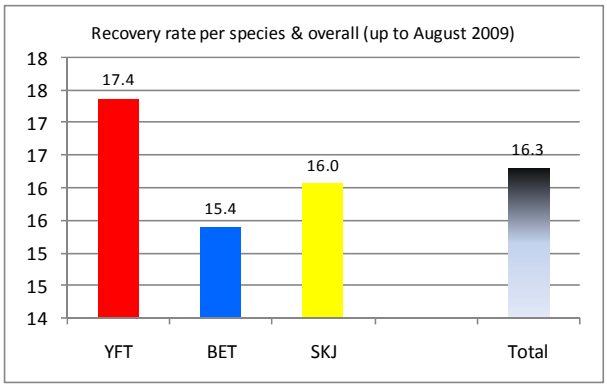

Figure 3: Overall recovery rates per species

Table 1: Recovery rates per type of tag and per species

Recovery Rates	YFT	BET	SKJ	UNK	Total
ST (Single Tag)	17.4	16.3	16.2	0.5	16.5
DT (Double Tag)	18.6	15.3	15.8	3.3	16.7
OT (OTC Tag)	12.2	7.5	12.3	0.0	10.2
OTS (OTC + Sonic Tag)	0.0	0.0	0.0		0.0
ET (Archive Tag)	2.3	3.0			2.4
Total	17.4	15.4	16.0	0.5	16.3

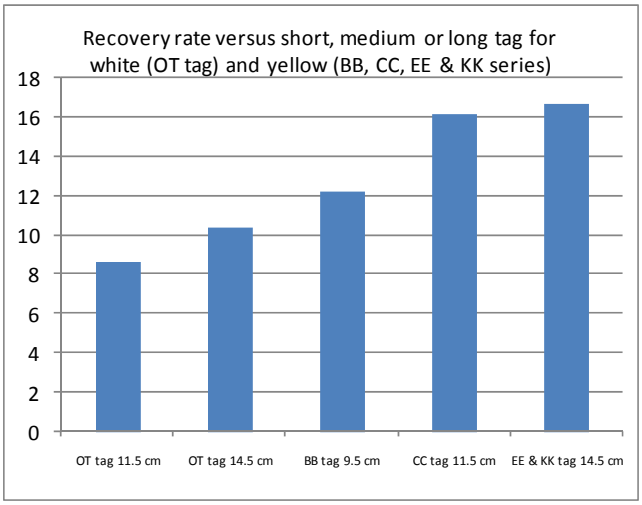

Figure 4: Recovery rate by color (white OT tags & yellow BB, CC, EE & KK series) and by size

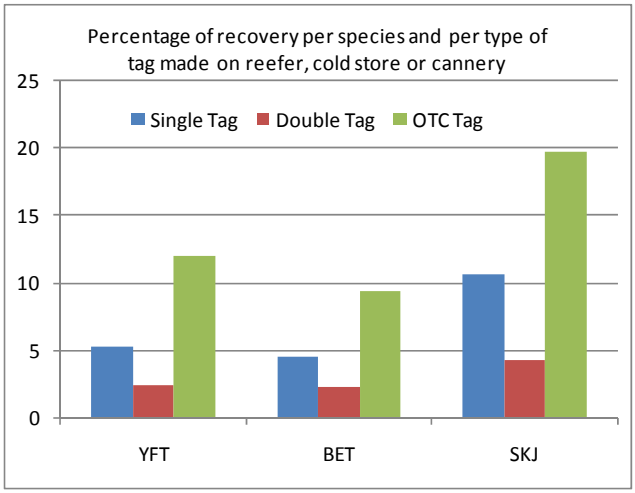

Figure 5: Percentage of recovery by type of tag registered on reefers, in cold store or in cannery

Table 2: Recovery per gear and species in number and in percentage

	YFT	BET	SKJ	UNK	Total	*YFT*	*BET*	*SKJ*	*Total*
Gil net	157	4	67		228	*1.7*	*0.1*	*0.5*	*0.8*
Hand line	83	18	39		140	*0.9*	*0.3*	*0.3*	*0.5*
Longline	79	152	6		237	*0.8*	*2.9*	*0.0*	*0.9*
Pole line	4	1	190		195	*0.0*	*0.0*	*1.5*	*0.7*
Purseseine	8856	5048	12095	3	26002	*93.2*	*94.9*	*96.2*	*94.9*
Troll line	48	6	48		102	*0.5*	*0.1*	*0.4*	*0.4*
unk	23	2	10		35	*0.2*	*0.0*	*0.1*	*0.1*
Total	9250	5231	12455	3	26939				

N.B. Recoveries made by the tagging vessels (all by pole-and-line gear) are excluded

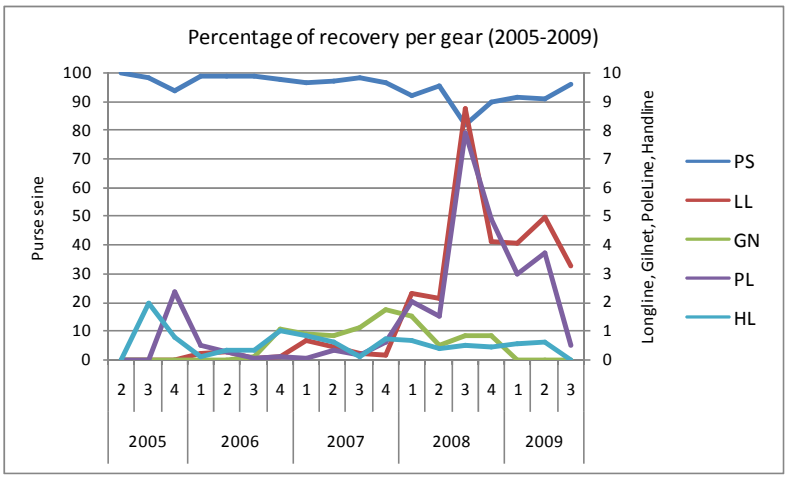

Figure 6: Percentage of recoveries per gear (all species combined)

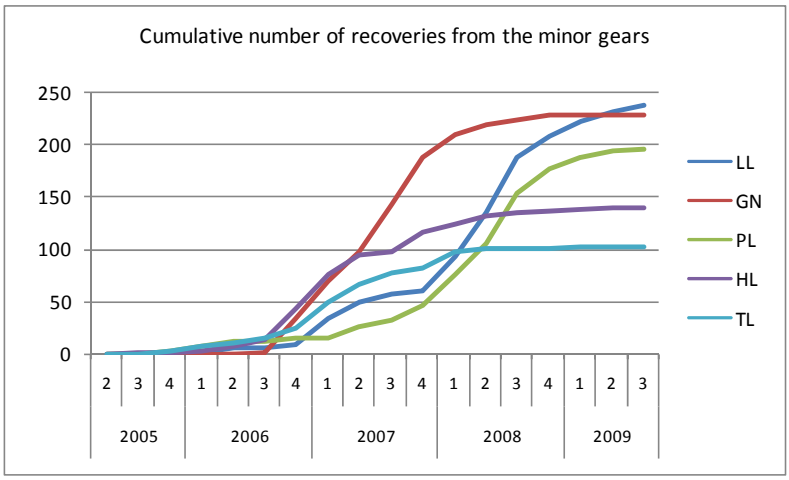

Figure 7: Cumulative number of recoveries by gears other than PS

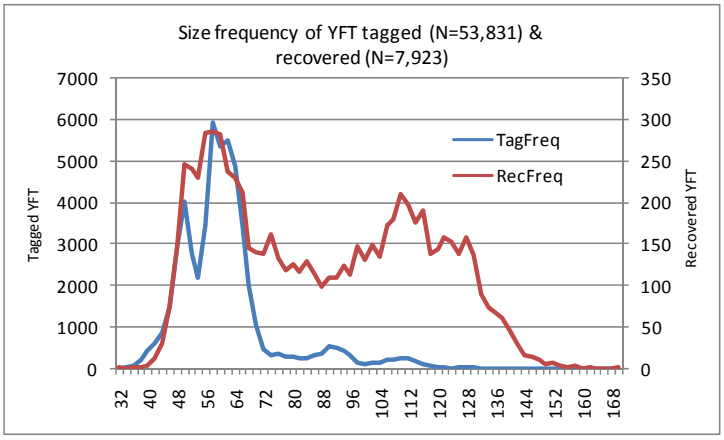

Figure 8a: Size distribution of YFT at tagging and at recovery

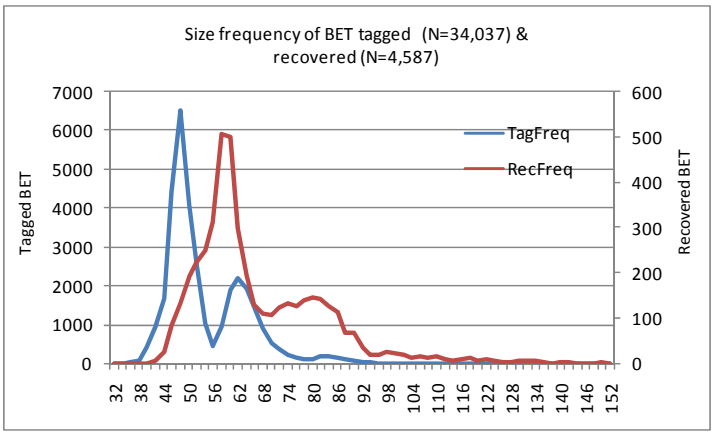

Figure 8b: Size distribution of BET at tagging and at recovery

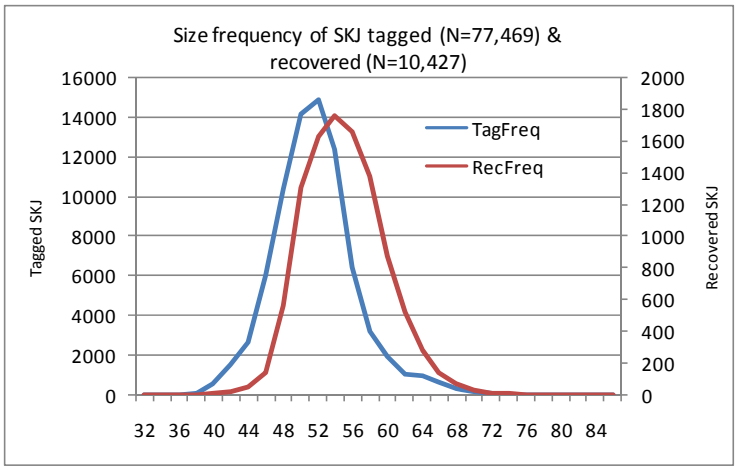

Figure 8c: Size distribution of SKJ at tagging and at recovery

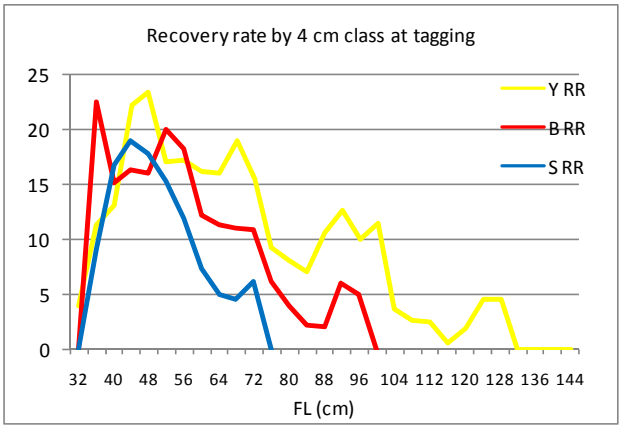

Figure 9: Recovery rate for tagged tuna grouped by 4 cm interval

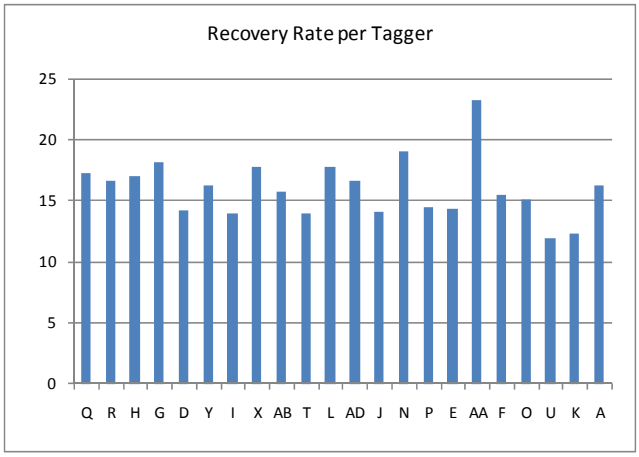

Figure 10: Recovery rate by taggers having tagged at least 1000 tuna

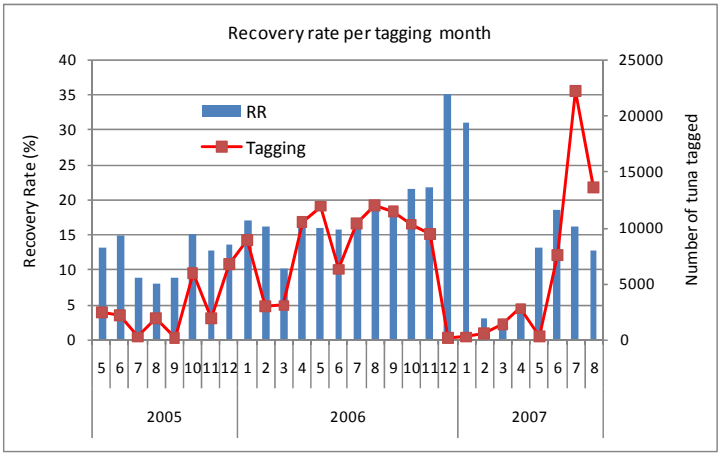

Figure 11: Number of fish tagged per month and their corresponding RR

Table 3: Percentage of tag lost from Double-Tagged tuna according to tagger (for taggers that did not perform double tagging the average tag lost percentage was used for the estimation of the number of recoveries not detected because their tag was shed)

Tagger	1st tag shed	2nd tag shed	Tag shed	% 1st shed	% 2nd shed	% shedding	Rank	ST+OT shed	Adjusted Rec	Adjusted RR
A	0	1	1	0.0	0.7	0.7	1	3	653	14.1
B	0	1	1	0.0	2.5	2.5	2	4	214	16.6
C	1	1	2	1.9	1.9	3.7	3	30	899	19.7
D	4	10	14	1.2	3.1	4.3	4	59	1756	16.8
E	28	15	43	3.5	1.9	5.4	5	171	4105	18.1
F	7	9	16	2.3	3.0	5.4	6	151	3270	17.4
G	5	4	9	3.0	2.4	5.4	7	50	1157	18.6
H	8	7	15	3.0	2.7	5.7	8	51	1209	16.4
I	12	8	20	3.5	2.3	5.8	9	83	1847	14.8
J	9	4	13	4.9	2.2	7.1	10	85	1458	14.8
K	9	7	16	4.3	3.3	7.6	11	56	1001	14.8
L	18	15	33	4.2	3.5	7.7	12	156	2604	18.1
M	8	3	11	6.0	2.2	8.2	13	121	1724	19.1
N	18	2	20	7.6	0.8	8.4	14	66	1092	17.6
O	24	29	53	3.9	4.7	8.6	15	155	2579	19.2
P	7	5	12	5.3	3.8	9.0	16	37	577	15.5
Q	5	7	12	4.8	6.7	11.4	17	58	673	25.4
R	9	4	13	8.3	3.7	11.9	18	33	415	16.7
S	4	2	6	11.8	5.9	17.6	19	16	139	19.5
T	0	1	1	0.0	25.0	25.0	20	62	313	14.9
U	2	4	6	8.7	17.4	26.1	21	77	396	18.8
V			0					1	10	13.0
W			0					0	0	0.0
X			0					27	418	15.3
Y			0					14	226	13.2
Z			0					6	91	12.3
AA			0					9	134	13.6
AB			0					0	0	0.0
AC			0					1	11	11.5
AD			0					0	1	2.8
Total	178	139	317	3.8	3.0	6.8		1580	28970	17.2

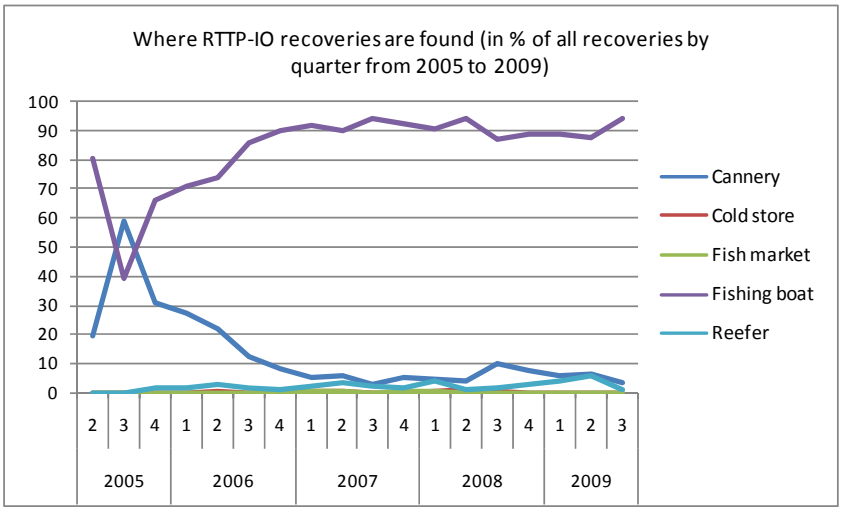

Figure 12: Where tagged tuna recaptured are found

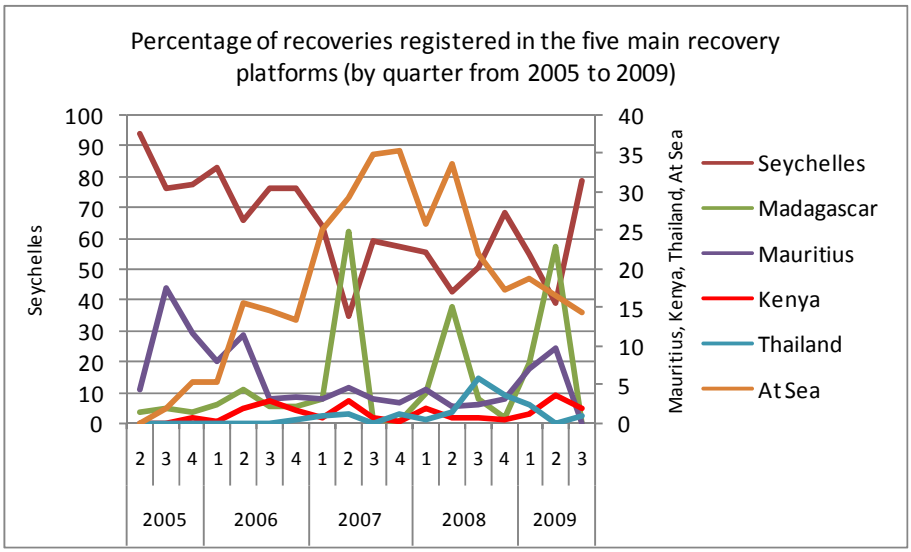

Figure 13: Importance ot the main recovery platforms of the RTTP-IO

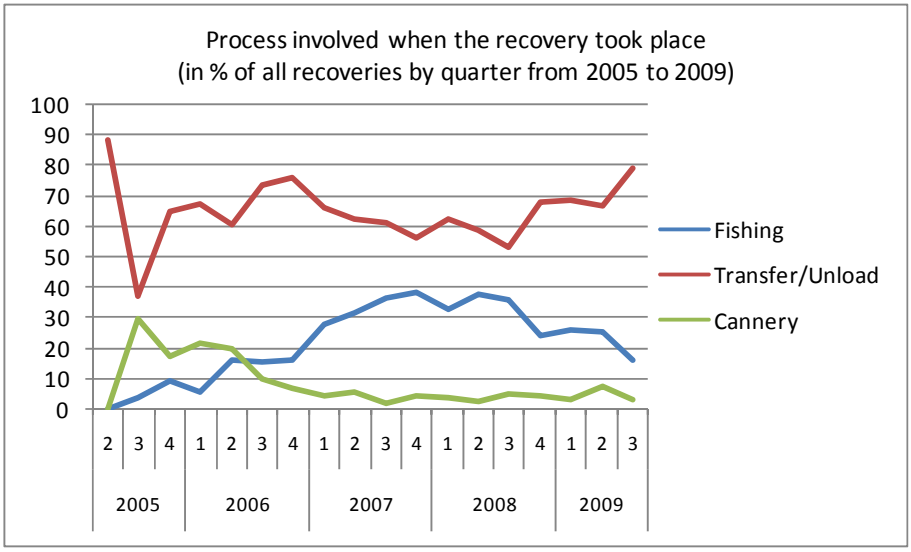

Figure 14: Process involved when the recoveries are taking place

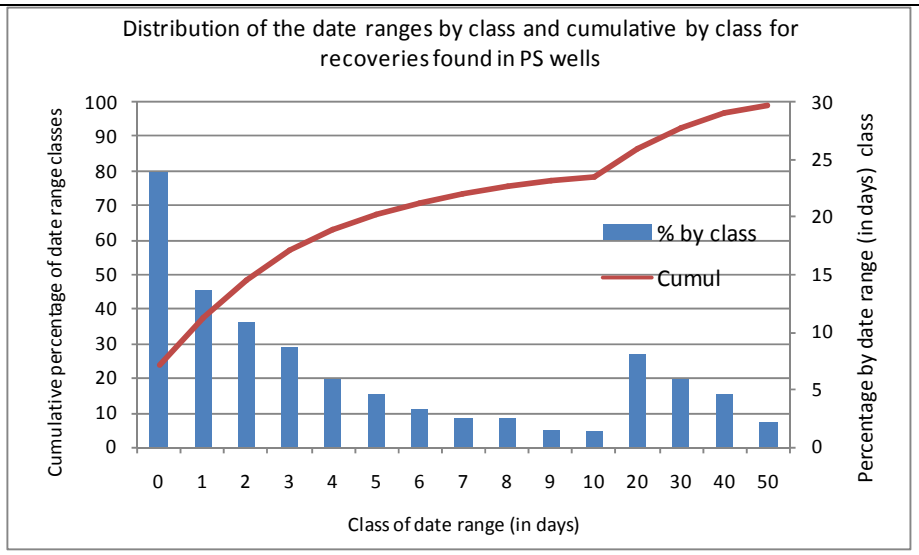

Figure 15: Date range for recoveries found in PS wells. The date range is the number of days between the oldest date and the newest date of the different sets attributed to the recovery. Classes goes from 0 (Minimum date and maximum date are equal) to 10 by one day interval and then from 10 to 50 by 10 days interval

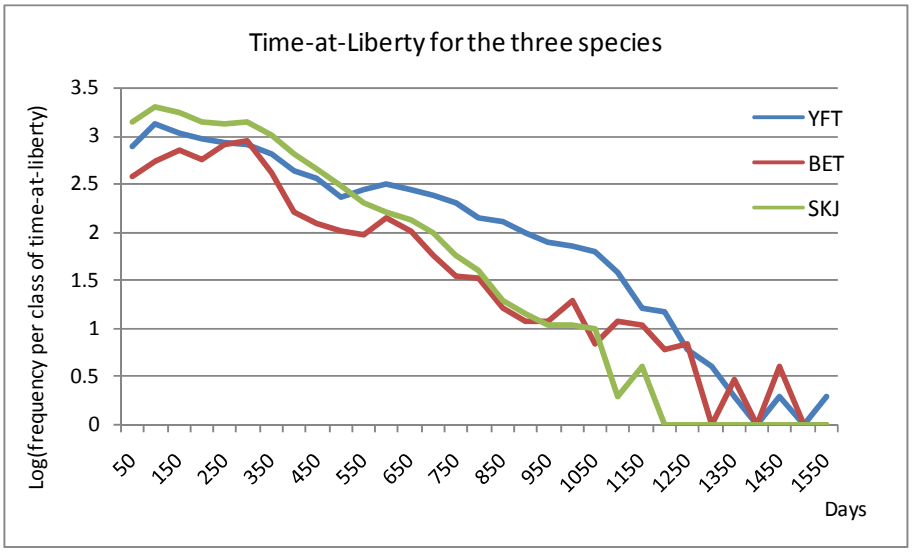

Figure 16: Distribution of the Frequency of the Time-at-Liberty (TL) for the three species

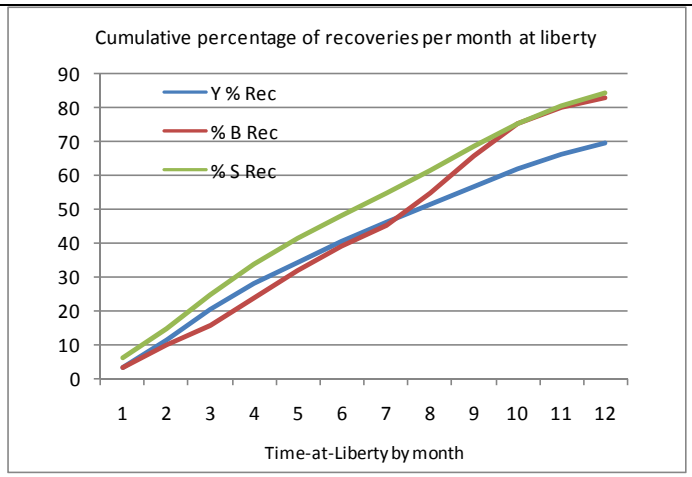

Figure 17: Cumulative percentage of recoveries during the first 12 months after tagging

Table 4: Average Time-at-Liberty per species and per main tagging areas

	MOZ	SEY	TAN/KEN	OMAN	ALL IO
YFT	300*	396	301	143	710
BET	546	284	257		657
SKJ	370	175	224		696
ALL	363	217	261		694

* In MOZ area 44 of the 102 recoveries were registered 1, 2 or 3 days after their tagging. If they are excluded, the average TL = 516 days, similar to BET TL

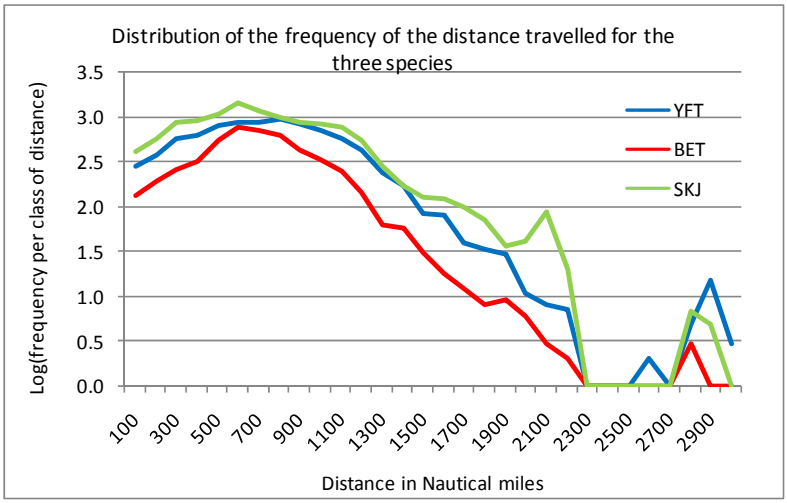

Figure 18: Distribution of the Frequency of the Distance Travelled (DTr) for the three species

Table 5: Average DTr according to species and main tagging areas

[redacted]

* In MOZ area 44 of the 91 recoveries were registered 1, 2 or 3 days after their tagging. If they are excluded, the average DTr = 646 nm, similar to SKJ and BET

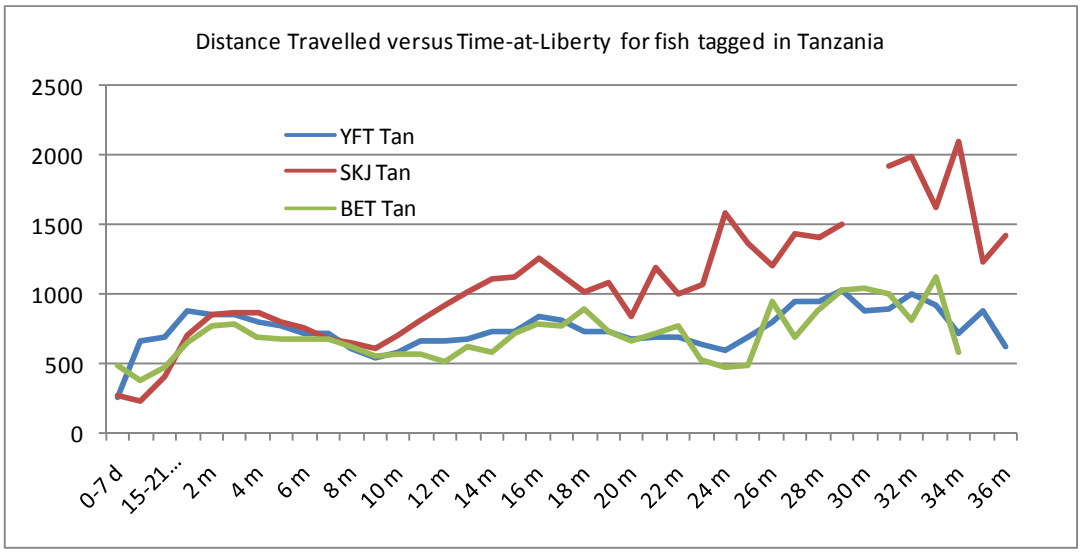

Figure 19: Distance versus Time-at-liberty for fish tagged off Tanzania (in weeks during the 1st month, then in months).

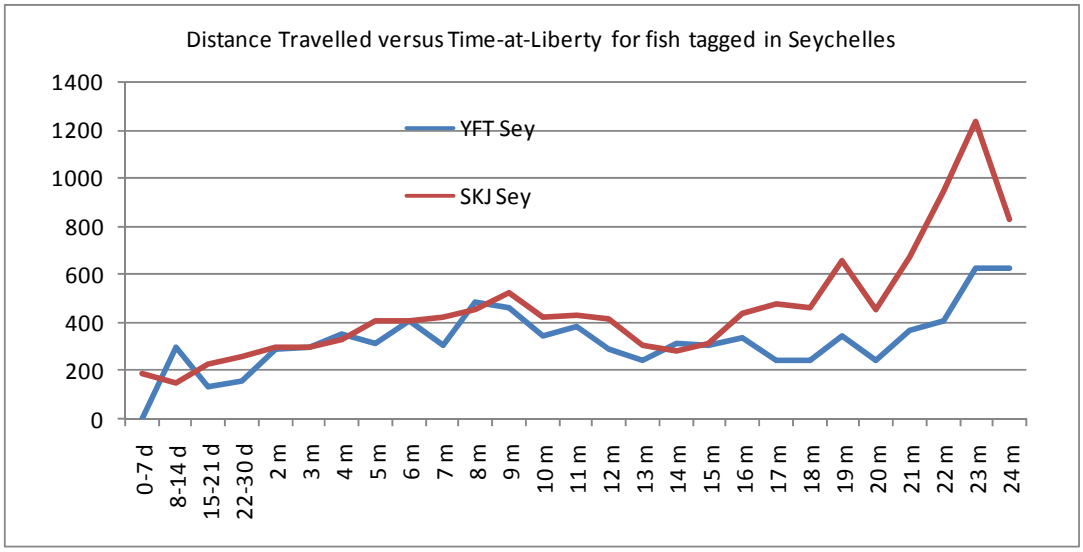

Figure 20: Distance versus Time-at-liberty for YFT & SKJ tagged off Seychelles (in weeks during the 1st month, then in months).

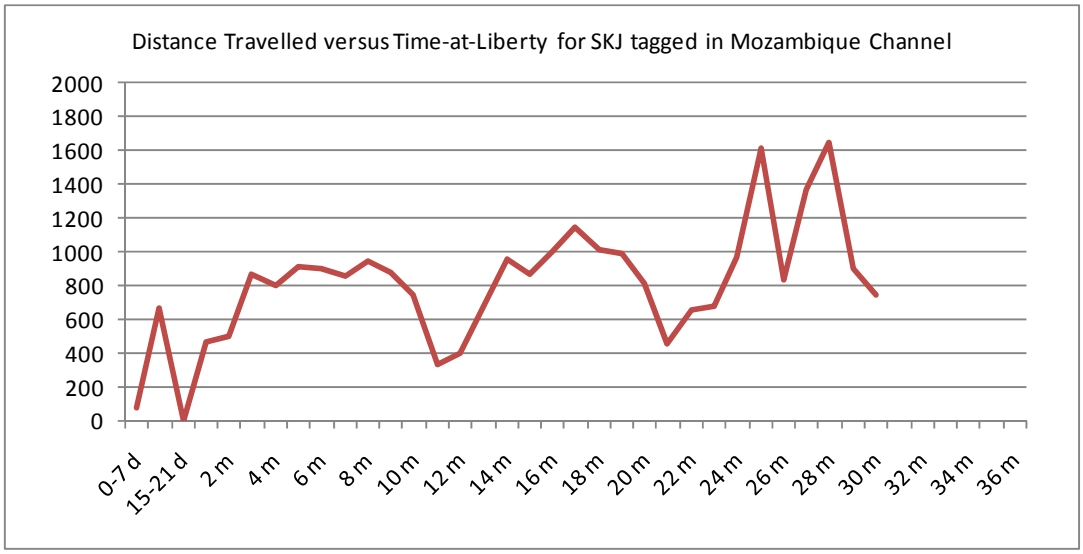

Figure 21: Distance versus Time-at-liberty for SKJ tagged in the Mozambique Channel (in weeks during the 1st month, then in months).

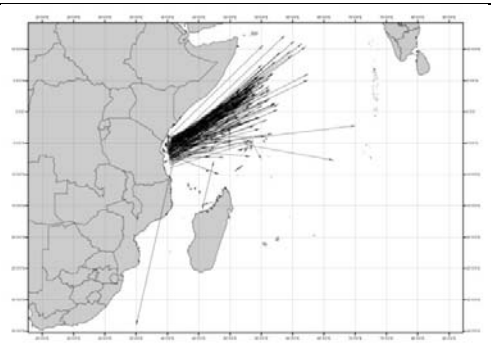

Figure 22a: YFT tagged and recovered with TL <= 30days

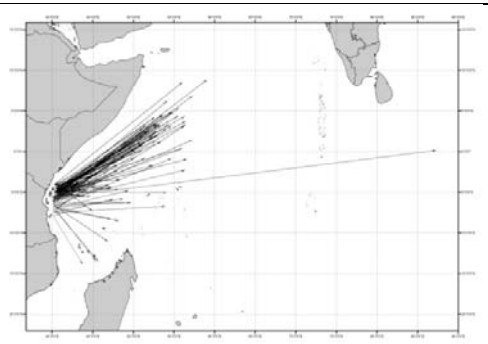

Figure 22b: BET tagged and recovered with TL <= 30days

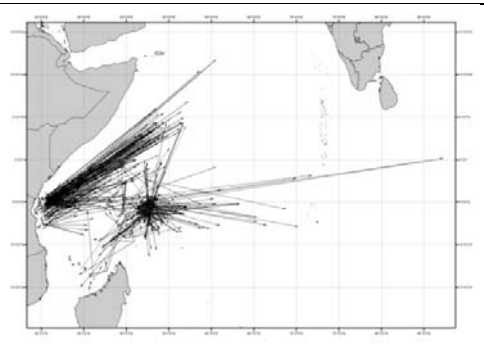

Figure 22c: SKJ tagged and recovered with TL <= 30days

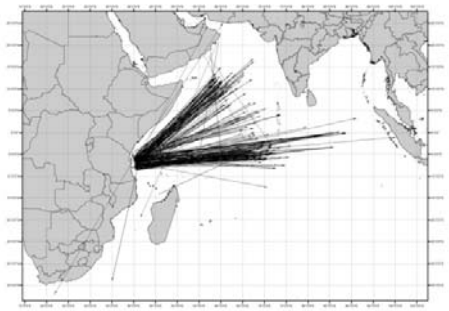

Figure 23a: YFT tagged and recovered with DTr >= 1500 nautical miles

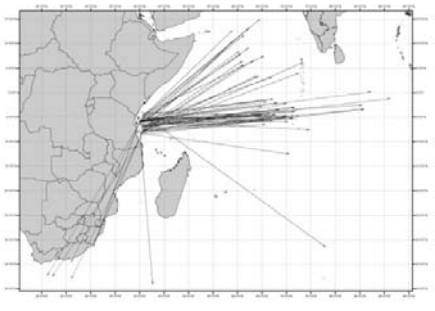

Figure 23b: BET tagged and recovered with DTr >= 1500 nautical miles

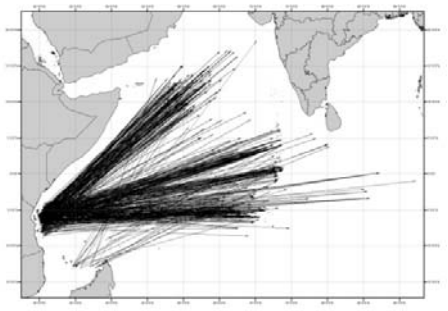

Figure 23c: SKJ tagged and recovered with DTr >= 1500 nautical miles

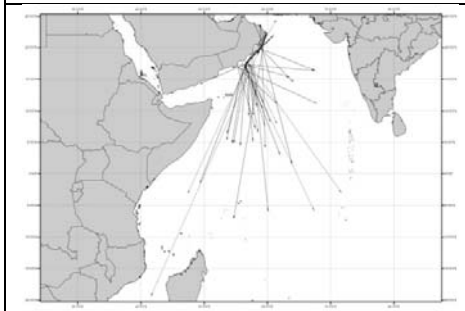

Figure 24: Tuna tagged in Oman and recovered (they are all YFT)

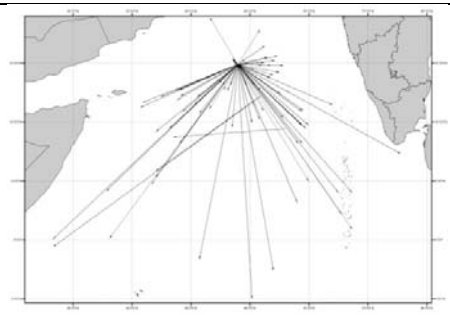

Figure 25: Tuna tagged North of Lakshadweep Island and West of Maldives and recovered (mainly SKJ)

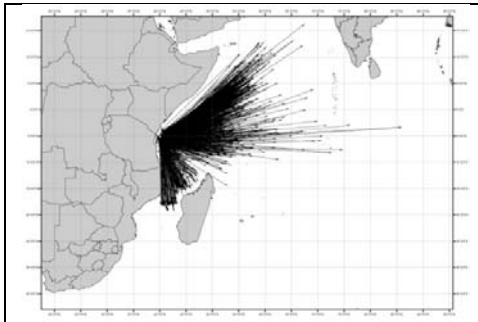

Figure 26a: Recoveries of YFT<=50 cm at tagging

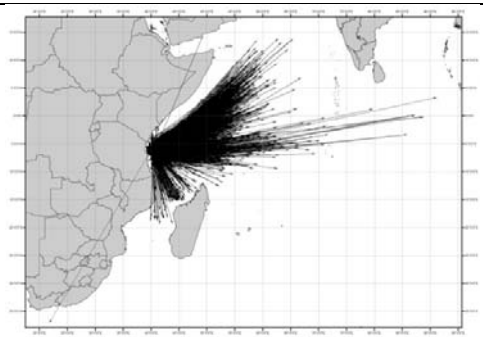

Figure 26b: Recoveries of 50<YFT<=60 cm at tagging

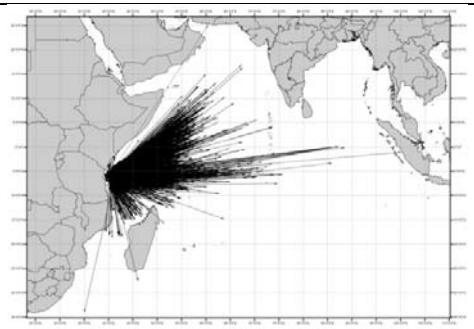

Figure 26c: Recoveries of YFT>60 cm at tagging

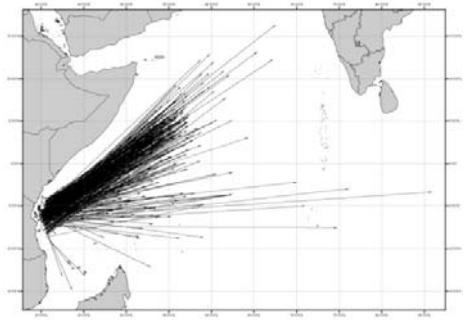

Figure 27a: Recoveries of YFT<=50 cm at recovery

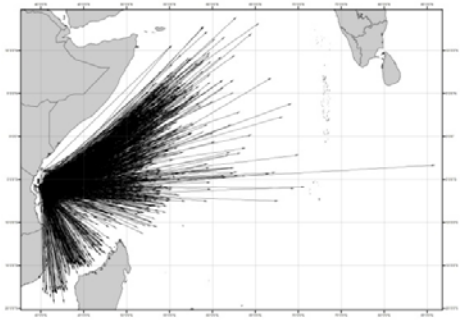

Figure 27b: Recoveries of YFT 50<YFT<=60 cm at recovery

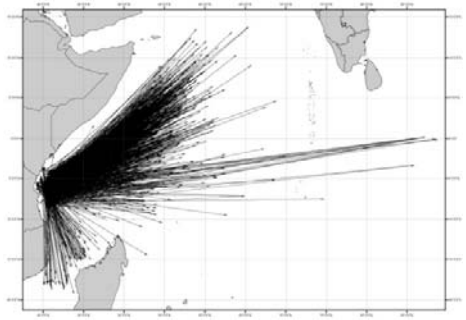

Figure 27c: Recoveries of YFT 60<YFT<=80 cm at recovery

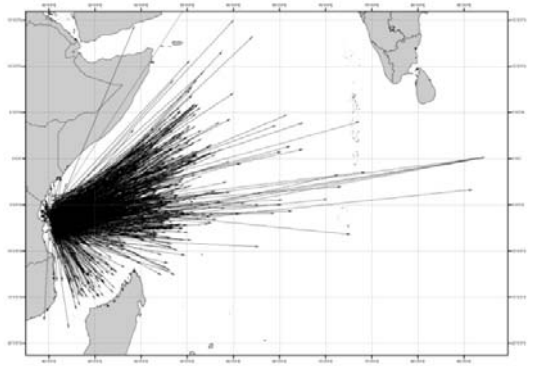

Figure 27d: Recoveries of YFT 80<YFT<=100 cm at recovery

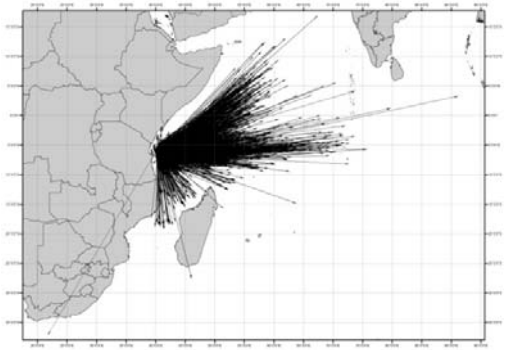

Figure 27e: Recoveries of YFT>100 cm at recovery

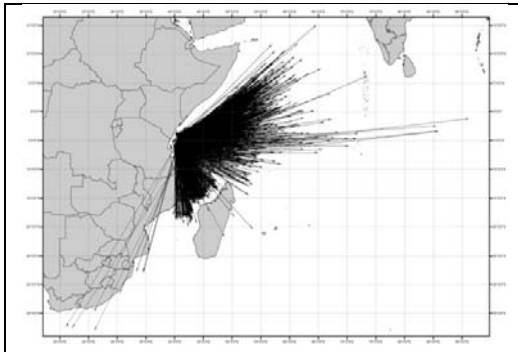

Figure 28a: Recoveries of BET <=50 cm at tagging

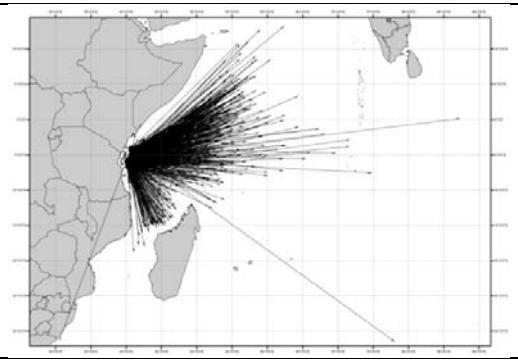

Figure 28b: Recoveries of 50 <BET <=60 cm at tagging

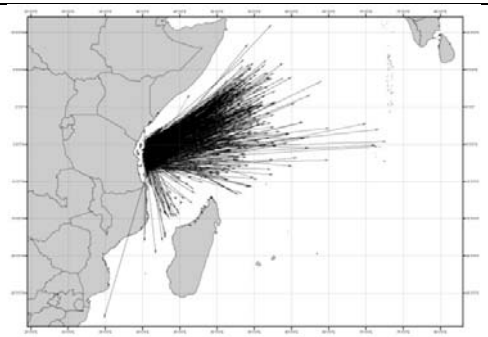

Figure 28c: Recoveries of BET >60 cm at tagging

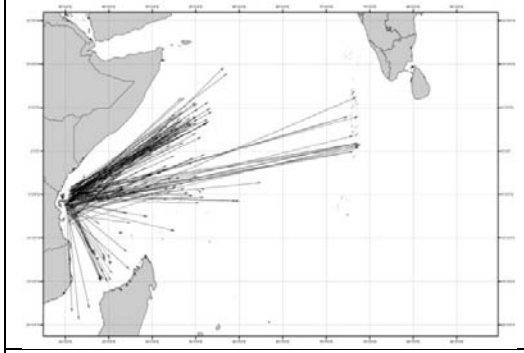

Figure 29a: Recoveries of SKJ <=45 cm at recovery

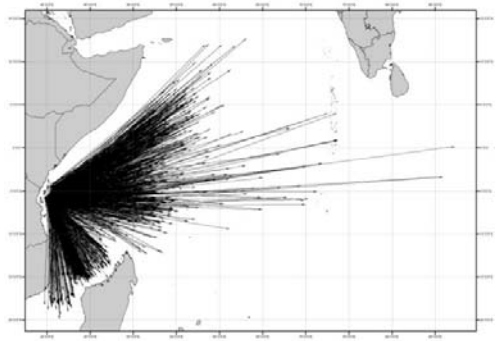

Figure 29b: Recoveries of 45<SKJ <=50 cm at recovery

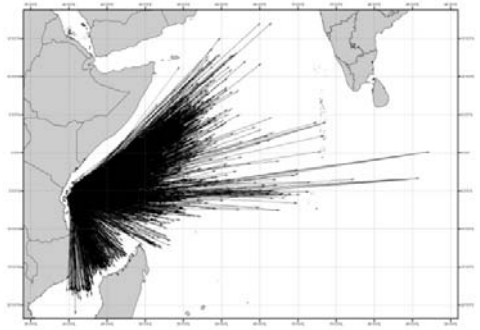

Figure 29c: Recoveries of 50<SKJ <=55 cm at recovery

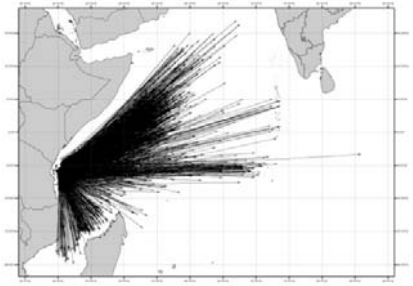

Figure 29d: Recoveries of 55<SKJ <=60 cm at recovery

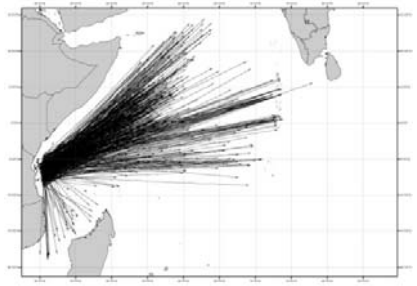

Figure 29e: Recoveries of SKJ > 60 cm at recovery

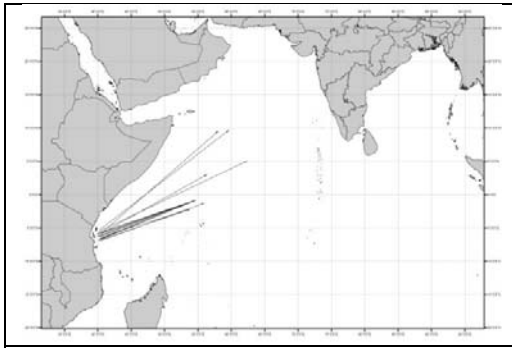

Figure 30a: Recoveries in October 2006 of tuna tagged in Sept-Oct-Nov 2006 off Tanzania

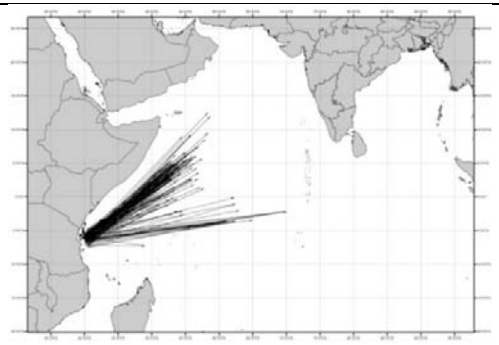

Figure 30b: Recoveries in November 2006

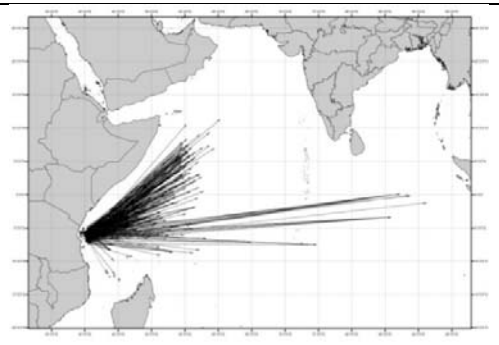

Figure 30c: Recoveries in December 2006

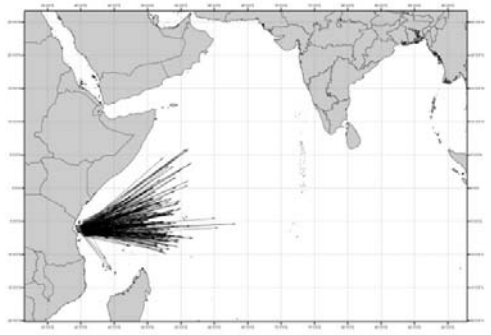

Figure 30d: Recoveries in January 2007

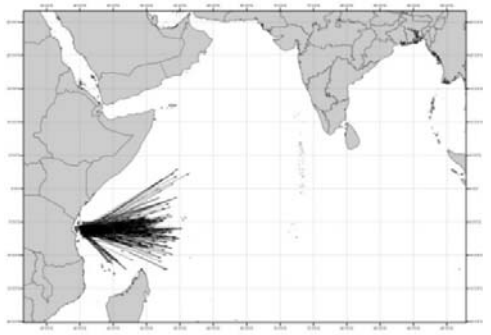

Figure 30e: Recoveries in February 2007

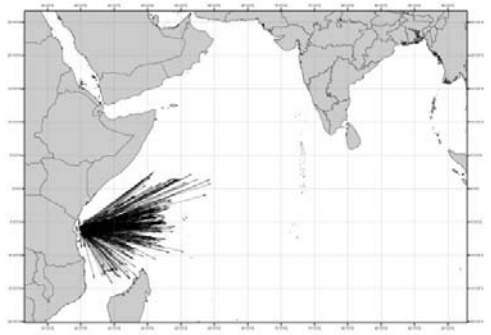

Figure 30f: Recoveries in March 2007

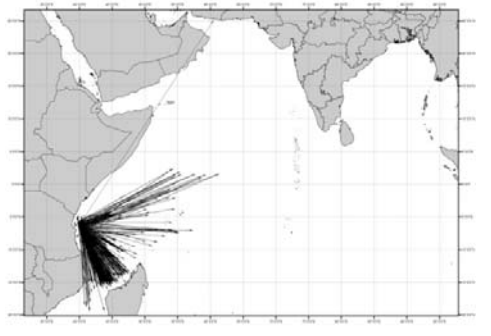

Figure 30g: Recoveries in April 2007

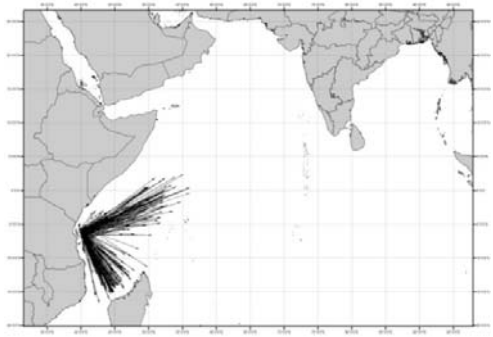

Figure 30h: Recoveries in May 2007

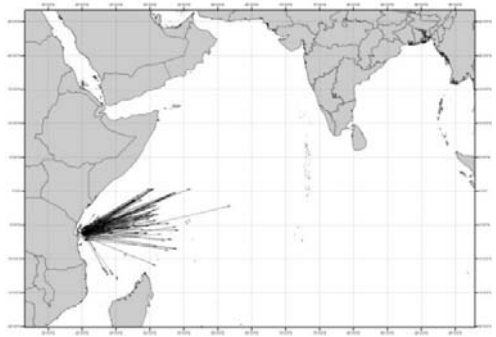

Figure 30i: Recoveries in June 2007

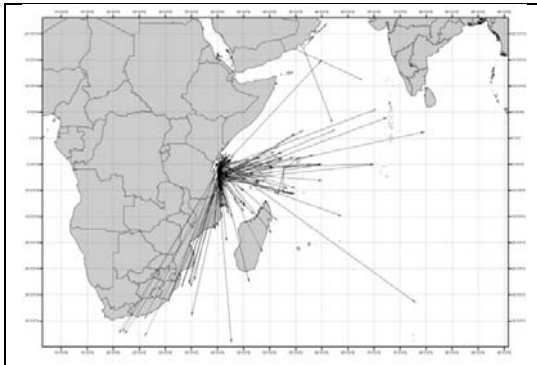

Figure 31a: Recoveries by Longliners

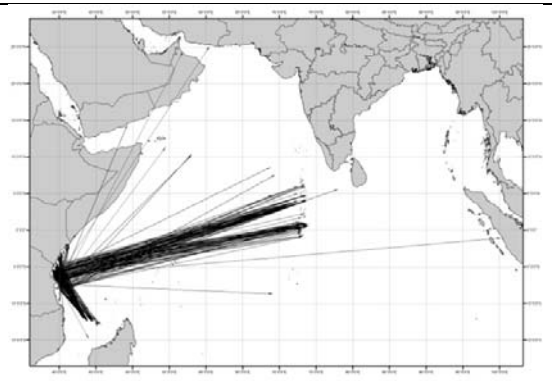

Figure 31b: Recoveries by artisanal fisheries of fish tagged in Tanzania

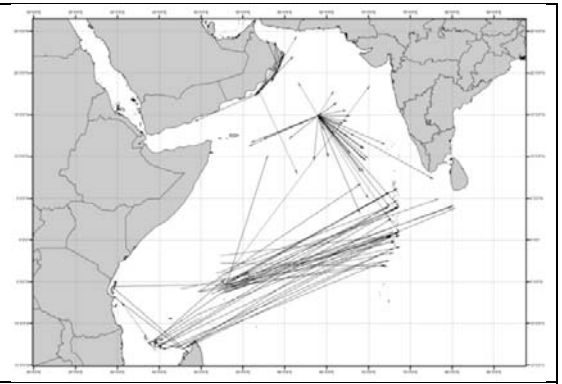

Figure 31c: Recoveries by artisanal fisheries of fish tagged elsewhere than in Tanzania

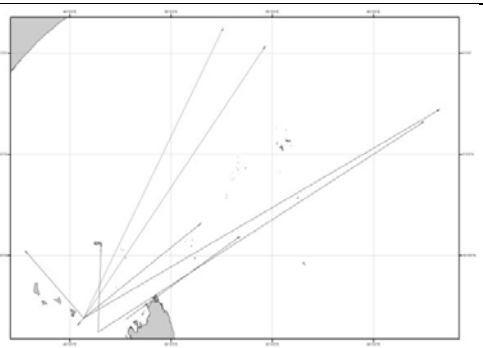

Figure 32a: Recoveries of BET tagged in Mozambique Channel in 2005

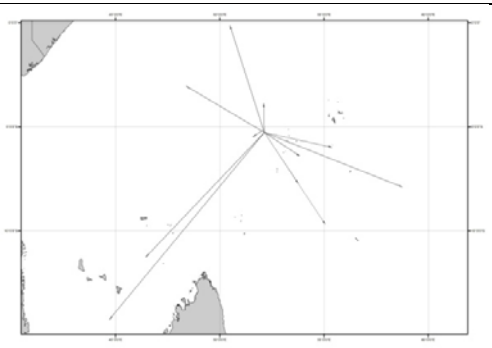

Figure 32b: Recoveries of BET tagged off Seychelles in 2005

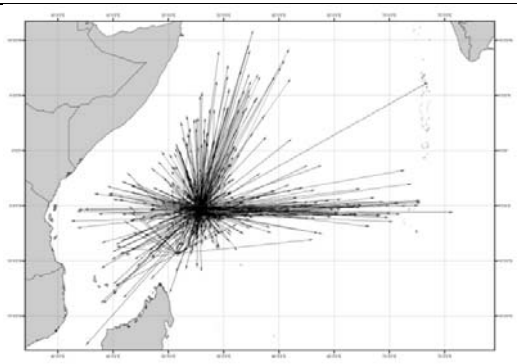

Figure 32c: Recoveries of YFT tagged off Seychelles in 2006

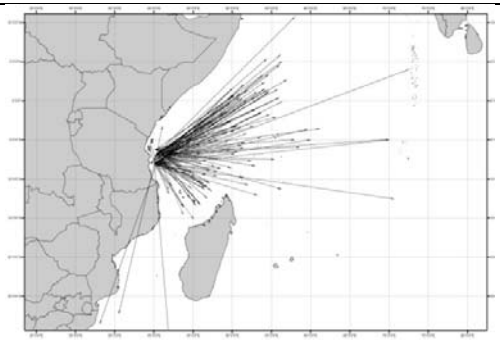

Figure 32d: Recoveries of BET tagged off Tanzania in 2005

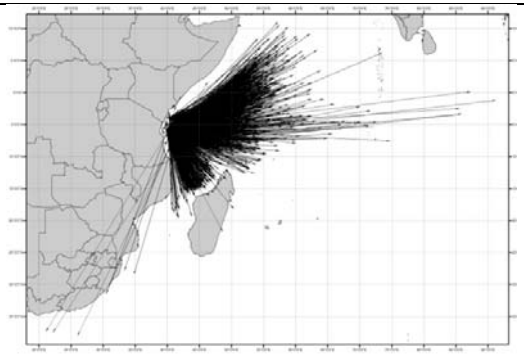

Figure 32e: Recoveries of BET tagged off Tanzania in 2006

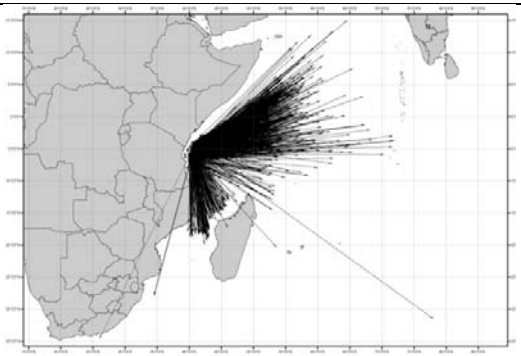

Figure 32f: Recoveries of BET tagged off Tanzania in 2007

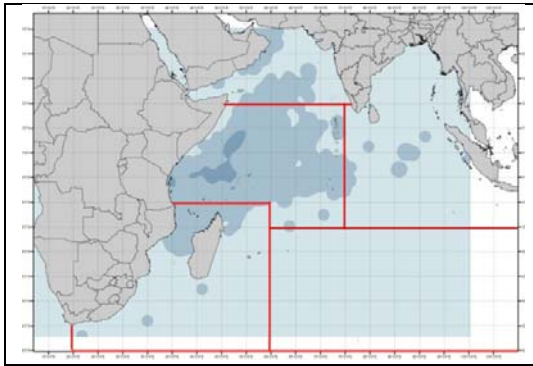

Figure 33a: Recovery density of YFT tagged in the Western Indian Ocean by the RTTP-IO and MFCL fishing areas

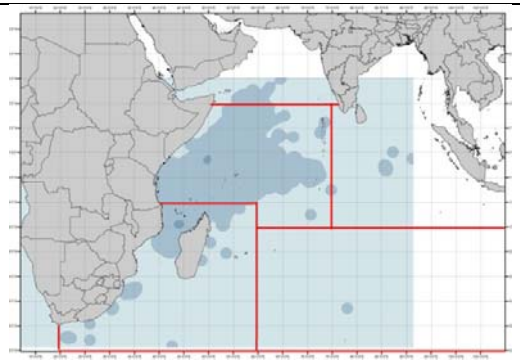

Figure 33b: Recovery density of BET tagged in the Western Indian Ocean by the RTTP-IO and MFCL fishing areas

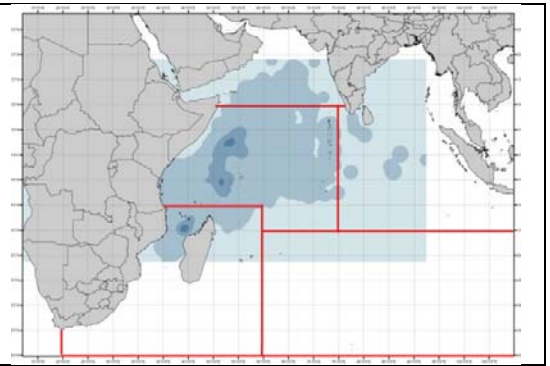

Figure 33c: Recovery density of SKJ tagged in the Western Indian Ocean by the RTTP-IO and MFCL fishing areas