Tuna movement patterns presently shown in the Indian Ocean by tag recoveries from the IOTTP tagging program

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Summary

This paper examines the movement patterns shown by the recoveries of yellowfin, skipjack and bigeye tagged by dart tags during the IOTTP large scale tagging. This analysis is based on a large number of 6236 recoveries belonging to the 3 species. These 3 species show similar movement patterns, and these recovered tunas, tagged in a limited number of peculiar areas, are showing very wide and very fast movement patterns, skipjack being the more mobile species. As a result, the recoveries of the 3 species have been widely scattered in the entire fishing zone of purse seiners, a fishery with large catches and with very good reporting of tags recoveries. This rather extreme mobility of the tagged tunas is quite unique world wide and it remains widely unexplained. This study also shows and discusses the strange lack of significant recoveries by the Maldivian skipjack fisheries. It also confirms the insufficient rate of tag reporting by longliners and by various coastal fisheries, that are still presently limiting the knowledge of the real movement patterns at a larger scale of yellowfin and bigeye in their global Indian Ocean habitat.

Résumé

Cet article examine les mouvemens montrés par les recaptures d’albacore, de listao et de patudo qui ont été marques avec des marques classiques Durant le grand programme de marquages de l’IOTC. Cette analyse est basée sur un grand nombre d marques, 6236 recaptures appartenant aux 3 espèces. Ces 3 espèces montrent des schémas de mouvements qui sont voisins, le listao étant l’espèce la plus mobile. Ces thons qui avaient été marques dans un petit nombre de zones très particulières et limitées, montrent des movements très rapides et de grande amplitude géographique. Il en résulte que les recaptures des 3 espèces ont été distribuées dans presque toutes les zones de pêche des senneurs, une pêcherie avec des prises importantes et un très bon taux de retour des marques. Cette extrême mobilité des thons recapturés est remarquable, ceci à l’échelle mondiale, et elle demeure mal expliquée. Cette étude met aussi en évidence et elle discute l’étrange faiblesse des recaptures de listaos par la pêcherie de canneurs des Maldives. L’analyse confirme aussi la faiblesse des recaptures déclarées par les palangriers et par diverses pêcheries côtières, ce qui limite la connaissance des mouvements à plus grande échelle géographique des albacores

et des patudos à l'échelle globale de leur habitat dans l'Océan Indien.

1-Introduction

The large scale tuna tagging program conducted by the IOTTC, the so called IOTTP, was conducted between August 2005 and September 2007 and it allowed to tag with dart tags 168.000 tunas, with a more or less "ideal" proportion of the 3 target species yellowfin (32.5 %), skipjack (46.6 %) and bigeye (20.9%). It was the first time in the history of tuna tagging that such a proportion of tagged species has been reached at such levels. Unfortunately, it can be noticed that there was only a very limited number of archival tags released during the IOTP, and that furthermore these electronic tags were quite unsuccessful. However, this "traditional" large scale multispecies tagging program has been highly successful and unique world wide in the history of past tuna tagging programmes, due to its successful tagging and to its successful recovery programme. The goal of this working paper is to review and to discuss the apparent movement pattern of the tuna recoveries for which the geographical position of the recovered fishes have been well identified (i.e. 2376 yellowfin, 2492 skipjack and 1364 bigeye) , this work being done in parallel on these 3 species.

2- Data and method

The data base used in the analysis was the recovery file available at the IOTC secretariat on June 8th 2008. This data base is still provisional, but it contains 6236 records of recoveries with a valid geographical position and a recovery date. This paper will first show the geographical locations of the tagged tunas and the subsequent recoveries. All the records with a valid date and a valid position were kept for the present analysis, even when there was questionable changes between the species tagged and recovered, in the fishing date, in the growth or/and in the fishing location. It was assumed that this flexible and wide selection of the recovered tags, then possibly incorporating dubious recoveries, would not introduce any major bias in the subsequent analysis of these tuna movements.

The apparent movement of each recovered tag was estimated by the straight line and straight distance between the tagging and the recovery positions, and these estimated distances will be plotted for each species as a function of the time at liberty. These trajectories are also shown on various types of maps. These recoveries are also analysed and visualized as a function of the fishing gears reporting these tags, but mainly for the purse seine fishery as a function of the geographical and seasonal total catches and catch at size taken by this gear in 2006 and 2007, the main period of tag recoveries. An ad hoc mapping software allowing to plot on the same maps the trajectories of quarterly recoveries and the corresponding catch at size of selected species was also developed and used to make exploratory maps.

These results will allow to discuss the geographical movement pattern of the 3 species tagged during the IOTTP.

3- Tuna movements

3-1- Overall: tagging and recovery areas vs fishing zones

Ideal potential tagging zones were studied by the IOTC before the implementation of the IOTTP, based on tagging models doing simulations of perfect tagging. These ideal tagging zones were widely scattered in term of there time and space distributions, basically trying to tag tunas in most of the habitat of each species (at least tagging tunas at all sizes that can be tagged). On the opposite, and due to multiple constraints in the tagging operations (availability of tunas, of bait, distance from fishing purse seiners, access to EEZ, etc..) the IOTTP tagging took place in a very limited number of time and area strata, and primarily off Kenya/Tanzania, were ideal tagging conditions were found during the tagging operations. These “limited” geographical distribution of the IOTTP tagging operation are shown on figure 1 (showing the tagging locations of all recovered tags).

However, maps of tag recoveries show that the subsequent tuna recoveries have been observed for yellowfin, skipjack and bigeye in a wide range of areas (figure 2), and covering *de facto* more or less all the fishing zones in the Western Indian Ocean (for instance the purse seiners fishing zones, see figure 3), showing fast and large scale movements of the tagged tunas in the entire zone fished by purse seiners, and possibly/probably also outside of it?.

The analysis of the available data can be concentrated upon purse seiners, and putting in relation the time and area strata where tags recoveries have been identified, and the catches/CPUE by size in these strata by this fleet. This analysis cannot be done for other fleets (longliners and some coastal artisanal fisheries) because of their statistical weakness and of their unknown (and often probably poor?) reporting rates of recovered tags (for instance various longline fleets).

3-1- Yellowfin

The comparison of sizes of yellowfin tagged during the IOTTP and fished by the entire Indian Ocean fisheries is shown figure 13a. This figure shows that the smallest sizes caught were seldom tagged, sizes between 40 and 100 cm well tagged, when the larger sizes over 1 meter that are dominant in weight in the yellowfin fisheries (71% of recent catches, period 2000-2006), were very seldom tagged. Then, the presently estimated movement patterns have been predominantly observed on medium size yellowfin, but also on large yellowfin over 1 meter for all fishes caught after a significant time at sea (already 25% of the yellowfin recoveries have been taken at sizes over 1 meter). It can then be concluded that the IOTTP results will also be informative on the movement patterns of large yellowfin, at least on fishes caught by purse seiners (unfortunately not well on longliners due to the uncertain reporting rate of tags for this gear?).

The map showing the average catches of yellowfin taken by purse seiners during the recovery period, average 2006-2007, is given figure 4 (for all sizes figure 4a and for small yellowfin, less than 1 m of fork length, figure 4b). The corresponding map showing all the yellowfin apparent linear trajectories of all yellowfin recovered by purse seiners at a known position is shown figure 5. It should also be noticed that the geographical dispersion of the tagged yellowfin tunas has been very fast: distances between tagging and recovery positions of all yellowfin recoveries are shown (figure 5) as a function of time at liberty, a figure showing that the travelled estimated average distances were of 526 nautical miles, a very large average distance compared to most movements observed for yellowfin in other tagging programs (as an example Schaefer et al 2007). They are also much more important that the average distance of 294 miles (and **only 165 miles** excluding the 43 transatlantic recoveries, tagged of USA and recovered off African coasts) covered by yellowfin in the Atlantic between tagging and recovery (ICCAT tagging file, June 2008, figure 23). Furthermore it should also be noted, figure 5, that these large distances travelled in the Indian Ocean have been observed more or less constantly after 2 month at sea, and without seasonality (when such seasonal cycle of distances has been often observed) and without trend over time (no increase of distances covered over time). On the other side, the pattern of tag recoveries also follows the geographical seasonality of fisheries, and showing (figure 16) a seasonal geographical pattern in the tag recoveries, probably also corresponding to movements of tagged tunas. The quarterly maps showing the catches of small yellowfin and the trajectory of the recoveries (given in page 1 annex 1) show a good correspondence between areas of high catches and areas of high recoveries.

These results are strongly indicative that yellowfin tunas fished in the Western IO are highly mobile fishes, and showing a high mixing rate of tagged individuals at least in the area fished by purse seiners. Furthermore the limited numbers of recovered yellowfin already reported from various fishing areas of the Indian Ocean are probably also indicative that these yellowfin have been moving outside the area fished by purse seiners, but unfortunately this result cannot be quantified, being then still purely indicative. These isolated tags recovered at long range distances should be further studied in details, even when their exact fishing location is unknown.

3-2- Skipjack

The comparison of skipjack sizes tagged during the IOTTP and fished by the entire Indian Ocean fisheries is shown figure 13b. This figure shows that:

- the smallest sizes commonly caught by present fisheries under 40cm were seldom tagged,
- sizes between 40 and 60 cm being well tagged,
- larger sizes over 60 cm (that are important in weight in the skipjack fisheries), were very seldom tagged.

However, it should be noticed that the estimated movements from these tagging will correspond to most of the skipjack sizes fished, as the duration at sea for the recovered skipjack are quite significant during long periods of time (already 35 tagged skipjack have been recovered after more than 2 years at sea) and then a significant proportion of recoveries have been already taken at sizes over 60 cm (12 % of the skipjack recoveries over 60 cm).

The map showing the average catches of skipjack taken by purse seiners during the recovery period, average 2006-2007, is given figure 8. The corresponding map showing all the yellowfin apparent linear trajectories of all skipjack recovered by purse seiners at a known position is shown figure 9. It should also be noticed that the geographical dispersion of the tagged skipjack tunas has been very fast: distances travelled between tagging and recovery positions of all skipjack recoveries are shown as a function of numbers of month at liberty, a figure showing that the estimated distances have been equal to 642 nautical miles, then larger than for yellowfin and bigeye. These distances are large ones compared to many limited movement patterns observed for skipjack in other tagging programs (Hilborn and Sibert 1986, Adam 1992). They are also much more important that the average distance of **only 110 miles** covered by skipjack in the Atlantic between tagging and recovery (ICCAT tagging file, June 2008, figure 23). Furthermore, it should also be noted, same figure 9, that these large distances travelled have been observed in the Indian Ocean more or less constantly after 2 month at sea, and without seasonality (when such seasonal cycle of distances has been often observed) and without trend over time (no increase of distances over time). The quarterly maps showing the catches of skipjack and the trajectory of the recoveries (given in page 2 annex 1) show a good correspondence between areas of high catches and areas of high recoveries.

These results are strongly indicating that skipjack tunas fished in the Western IO are highly mobile fishes, and showing a high mixing rate of tagged individuals, at least within the area fished by purse seiners. However, the limited numbers of tags recovered from Maldives and from Sri Lanka will need further study: the present recovery rate of tagged skipjack is very weak :

- A total of nearly 7500 skipjack recoveries for PS, a fishery catching about 175.000 t of skipjack during recent years

- but only 64 recoveries identified for the Maldives/Sri Lanka fisheries, that have been catching approximately the same amount of about 175.000 t of skipjack during the period.

Based on the fishery data, a much higher recovery rate should have been intuitively expected in these Maldivian and Sri Lanka fisheries, taking into account the importance of total catches in the region and the proximity of these fishing zones (if skipjack can travel on distances over 500 miles within a couple of months, they could also easily move to Sri Lanka and Maldives? In the absence of environmental barrier between these rather homogeneous areas of the Indian Ocean monsoon gyre as described by Longhurst 1998, see figure 18). **This weakness of Maldivian recoveries should be further studied by an in depth analysis**. This study should allow to conclude if this weakness of the skipjack recoveries corresponds:

(1) to a real lack of eastward migrations, then to a real segregation between 2 skipjack stocks in the western and central Indian ocean, and then to a lack of potential interaction between the purse seine fisheries and the Maldivian ones) or to

(2) other causes, for instance the lack of reporting the Maldivian recoveries, or other biological/fishery effects, in relation with the sizes of fishes caught in the various areas. As an example, the skipjack caught tend to be bimodal, large number of large skipjack over 60 cm being caught by this fishery (see figure 19). These large fishes have been seldom tagged and recovered but they may soon appear in the Maldivian fishery.

3-3- Bigeye

The comparison of sizes of bigeye tagged during the IOTTP and fished by the entire Indian Ocean fisheries is shown figure 13c. This figure shows that the smallest sizes significantly caught <42 cm were seldom tagged, sizes between 40 and 60 cm well tagged, and the sizes over 60 cm, that are widely dominant in weight in the fisheries, were very seldom tagged. Then, the estimated movement patterns are predominantly observed on this limited range of small/medium size bigeye, less than 2% of the bigeye recoveries being caught at large sizes over 1 meter. It can then be concluded that the IOTTP results will not be highly informative on the movement patterns of large bigeye, unless a good reporting rate can be developed on longliners (the gear catching a great majority of large bigeye over 1 meter: 91 % of the bigeye catches during the average period 2000-2005, based on the CAS table estimated in 2007 by the IOTC secretariat.

The map showing the average catches of bigeye taken by purse seiners during the recovery period, average years 2006-2007, is given figure 10. The corresponding map showing all the apparent linear trajectories of all bigeye recovered by purse seiners at a known position is shown figure 11. It should also be noticed that the geographical dispersion of the tagged bigeye has been very fast: distances between tagging and recovery positions of all bigeye recoveries are shown as a function of numbers of month at liberty, a figure showing that the travelled estimated distances have been at 525 nautical miles, a very large average distance compared to most movements observed for bigeye in other tagging programs (Schaefer and Fuller 2006). They are also much more important that the average distance of 177 miles covered by Atlantic bigeye in the Atlantic between tagging and recovery (ICCAT tagging file, June 2008, figure 23). Furthermore it should also be noted, figure 11, that these large distances travelled in the Indian Ocean have been observed more or less constantly after 2 months at sea, and without seasonality (when such seasonal cycle of distances has been often observed) and also without trend over time (no increase of distances covered over time).

These results are strongly indicative that bigeye tunas fished in the Western IO are highly mobile fishes, and showing a high mixing rate of tagged individuals, at least within the area fished by purse seiners and for the juvenile bigeye tagged during the IOTTP. The subsequent movements of adult bigeye caught by longliners in a much wider geographical scale (shown by figure 15b) will soon be estimated, but only if the main longline fleets are well reporting there recoveries of tagged bigeye. However the quarterly maps showing the catches of small bigeye and the trajectory of the recoveries (given in page 3 annex 1) show that large quantities of small bigeye were caught east of the main purse seine fishing zones in the 3rd and 4th quarters of 2007, but in areas where there was no recoveries of tags identified. This point should be further analyzed, but it could indicate that these young bigeye were recruited from an external geographical area (and its untagged fishes).

4- Discussion

The movements of the 3 tuna species tagged during the IOTTP are very impressive and quite unique because of their speed and of the distances covered by these recovered fishes. These results also show that the apparent movement patterns observed for the 3 species are quite/very similar, at least on the presently recovered sizes dominated for bigeye and yellowfin by juvenile tunas. This similarities of the movement patterns of the 3 species is for instance well shown by the apparent distances travelled by the tags on each species as shown by figure 14 or by the maps showing the multispecies recoveries (figure 2, 16 and 17). These data should be further analysed by ad hoc movement models (such as Adam and Sibert 2002, Sibert et al 200X), but there is no doubt that these tunas are perfectly following the law of the sea and its article 64: they do extensive movements across various EEZ in the western Indian Ocean. None of the 3 species tagged in the area could be classified as being “viscous resources” doing limited scale and slow movements. It should be recognized that in the absence of results obtained by archival tags, the exact movements of these tuna tend to remain quite uncertain: it is clear that most tagged tunas have moved quickly from their tagging areas, being quickly scattered in the entire Western Indian Ocean (figure 17). However their real movements within the fished zone and 3 month after their tagging, for instance their seasonal movements or their movement as a function of their age, still remain quite unclear. These tagging results upon the movements of the various tuna species in the Indian Ocean are at least very interesting and very encouraging for the future modelling of these 3 stocks: the wide scale and of the observed fast movements should allow major simplification in the future modelling of these 3 stocks. Further research should also be conducted, comparing the movement scales and patterns estimated from tagging in the other oceans, for instance in relation with the local environment, as the results obtained in the Indian Ocean appear to be really unique world wide.

A potentially serious pending question upon these conclusions may be linked to the potential bias introduced by the main tagging area off Kenya/Tanzania, a quite peculiar coastal area, located in the south-Western range of the main fishing zones. However, this peculiar area cannot be classified as a frontier area, being located at about XXX miles north of the main fishing zones of the purse seine fishery, the northern Mozambic Channel, being a suitable habitat, at least seasonally for all tropical tunas. It can also be noted that sea surface temperatures in the tagging area are suitable for tropical tunas all year round, with SST fluctuating between 25°C and 29°C. This area is special, but not really extreme in the habitat of tropical tunas. Another interesting point to consider in order to better understand the potential peculiarity of Kenyan tagging, is to analyse the trajectory of the limited number of 400 recoveries from the Seychelles tagging cruises. It appears that these recovered tags show average distances of nearly 500 miles (yellowfin: 483 miles, skipjack: 481 miles and bigeye: 403 miles) and also dispersion patterns dispersed towards most potential directions (figure 20), less recoveries being observed in the East and South East, but simply in relation with the lower levels of catches in these areas.

An interesting parameter to keep in mind in the movement patterns observed for the tagged and many recovered tunas is that the sizes of the 3 species tagged were very similar to FAD associated sizes (when these yellowfin sizes are seldom caught in the free schools purse seine fishery). Then (1) taking this fishery fact into account and (2) taking note that many FADs are presently active in the Indian Ocean (about 2100 active FADs were recently estimated by Moreno et al 2008), it can be hypothetized than a large proportion of the recovered tunas have been drifting associated to FADs during part of their lives. This frequent association to FADs may well explain the large distances between many tagging and recovery positions, as it seems that FADs may increase the movement rates and speed of these associated tunas (Hallier and Gaertner 2008). Alternate hypothesis, for instance based on the peculiar environmental characteristics found in the Indian Ocean and of the strong monsoon seasonality, a typical phenomenon in the Indian Ocean, should of course also be envisaged and carefully analyzed in the interpretation of these peculiar and active movement patterns.

Another important point to keep in mind in the discussion and comparison of the tuna movements estimated in each of the tuna stocks that are fished in each ocean is the **size of the geographical area inhabited by each species**, and the size of the area fished. For instance it is clear, when comparing distances travelled by tagged bigeye tunas in the Eastern Pacific (Schaefer and Fuller 2005) or Atlantic, and in the Indian oceans, that the Indian ocean bigeye tunas are much more mobile. But furthermore, it should also be kept in mind that the bigeye areas in the EPO are much wider than in the Indian Ocean: in the EPO, 1358 1° squares have been producing more than 5 t. yearly during the 1995-2004 period, while in the IO such yearly level of catch/square was observed in only 363 squares (see figure 17). In such a context of a much smaller area and of much more active movements, it can easily be concluded that the bigeye stock tend to be a viscous one, at least the geographical scale of the EPO, while the Indian Ocean stocks can be consider as being highly migratory, partly because of the smaller size of the areas fished in the Indian Ocean.

However, it should also be kept in mind that the potential relationship between the main “tagged areas” in the central part of the Western Indian Ocean, and the wider sizes of the geographical distributions of each species (well shown for instance by the much wider areas fished by longliners, see figure 15a yellowfin and 15b bigeye) are still unknown.

Furthermore, it is also clear that many tagged tunas are still presently swimming in the Indian carrying an IOTTP tag: the future recovery of these tags should soon allow to add a lot of scientific information on the tuna movements of adult yellowfin and bigeye, if tagged fishes taken by longliners can be recovered in significant and known proportion. Today only 37 tagged yellowfin and tagged 19 bigeye have been reported by longliners: these recoveries are already very interesting qualitatively, but they are probably widely underestimated at least for some fleets (this potential problem should be better estimated comparing catches and recoveries at size by each gear). This better identification of recoveries on longliners would be of major interest, taking into account the fact that longliners are exploiting yellowfin and bigeye in a much wider fishing zone (figure 15), for instance the bigeye feeding zones at southern latitudes, or in the Arabian Sea (yellowfin), when the movement pattern between adult tunas fished between these various feeding areas and the tagging areas (+ or – the spawning and nurseries areas) remain quite hypothetical.

5- Conclusion

This quick overview of the tagging results is already widely positive and widely informative: even if the location of the tagging operation have been quite limited and poorly scattered when compared to the ideal tagging schemes estimated by tagging models, they have released ideal numbers of dart tags, and these tags have been showing ideal movements: very fast and wide movements that were totally unexpected before the IOTTP. When these movements would of course need further in depth statistical study and ad hoc modelling, but they are clearly very interesting results. These results are well showing intense movements of the 3 tuna species in the entire Western Indian Ocean. Major further research efforts should now be developed by the IOTC and the IOTTP staff in order to improve the recovery of yellowfin and bigeye tags by longliners (and also by artisanal fisheries catching large yellowfin), a difficult but a key stone goal for the future analysis of adult tunas in the Indian Ocean (to estimate well the stock structure, but also to estimate bigeye growth). One of the major pending question will also be the “good” interpretation explaining the lack of recoveries by the Maldivian pole and line fishery, as this question could have major management implications for the Indian Ocean skipjack stock.

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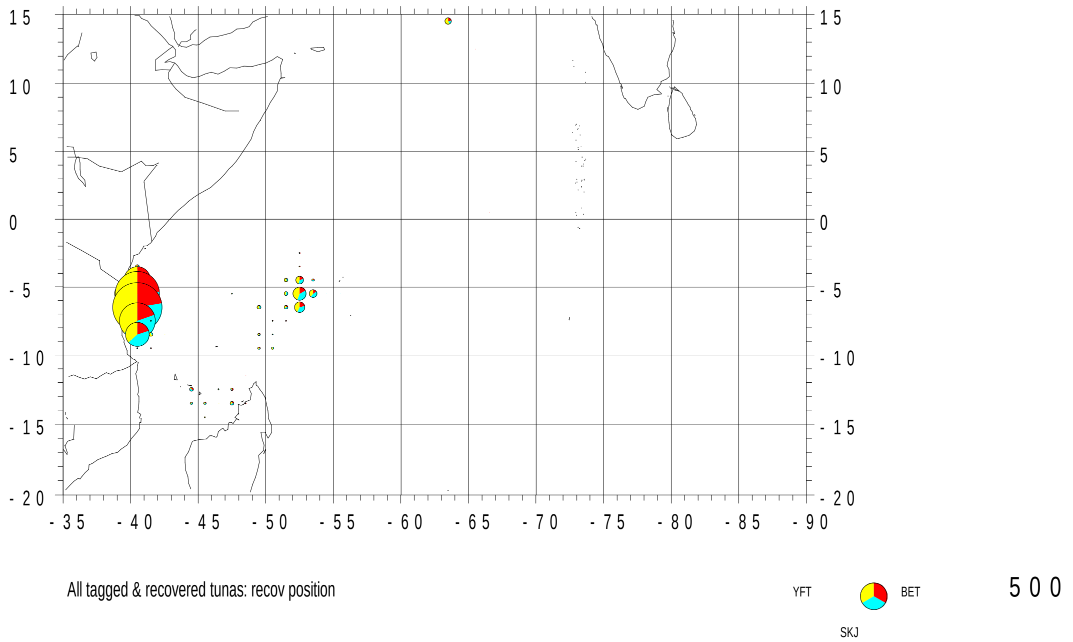


Figure 1: Map showing the tagging location of tunas by species, tagged during the IOTTP, and later recovered (a map probably similap to the map of released tags?)

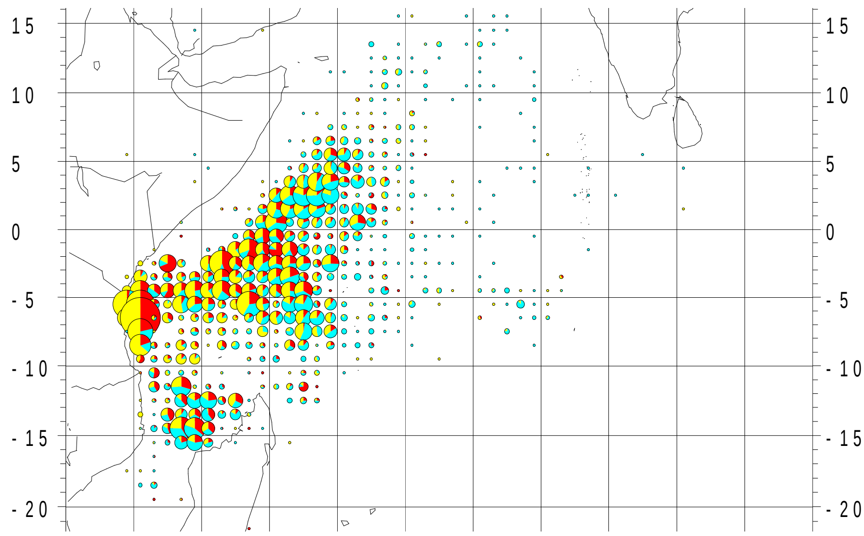


Figure 2: Map showing the reporting locations of tunas by species, tagged during the IOTTP

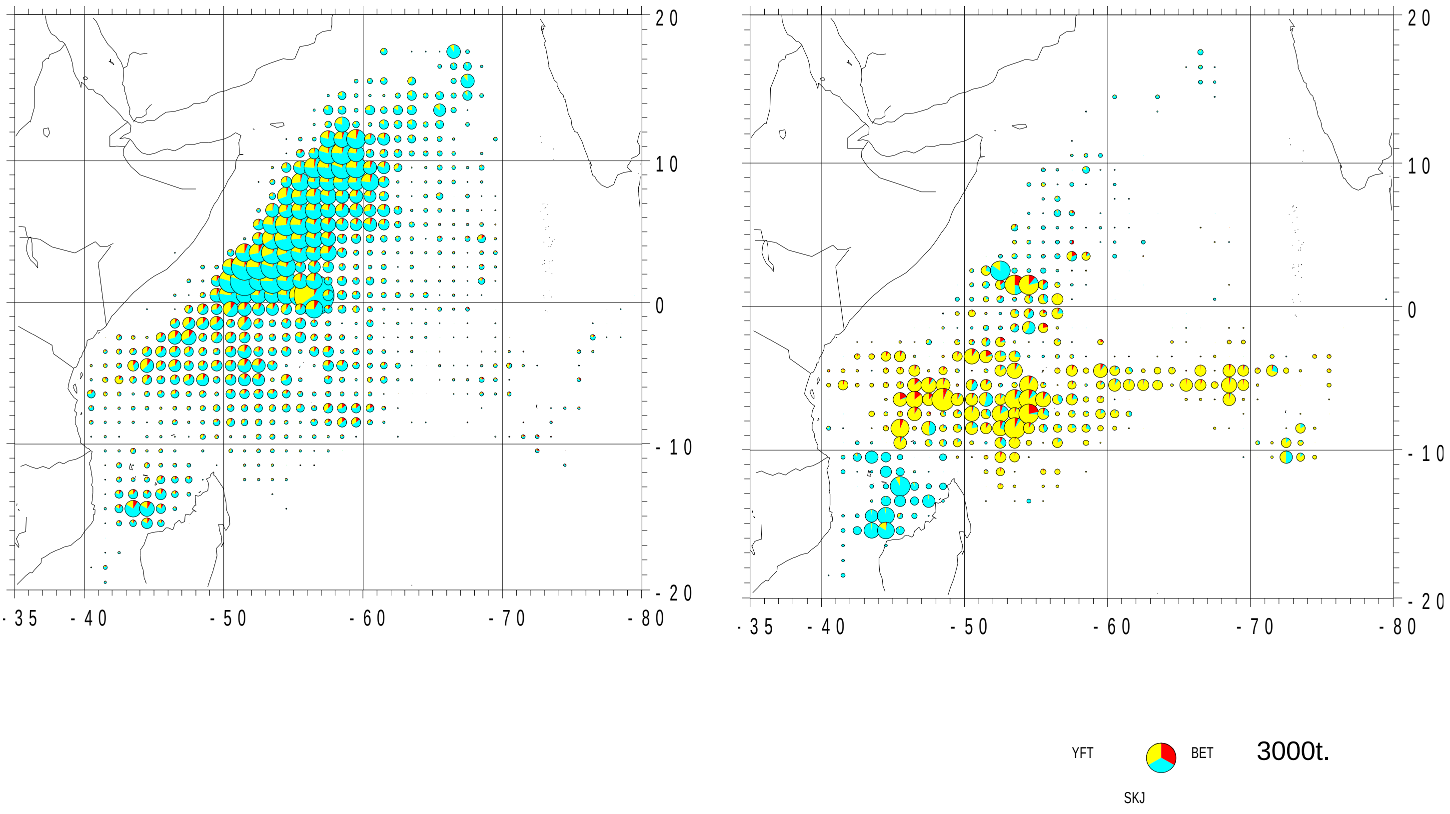


Figure 3: Map showing the average catches of yellowfin, skipjack and bigeye taken by purse seiners during the average perio 2006-2007, on FAD (left) and on free schools (right)

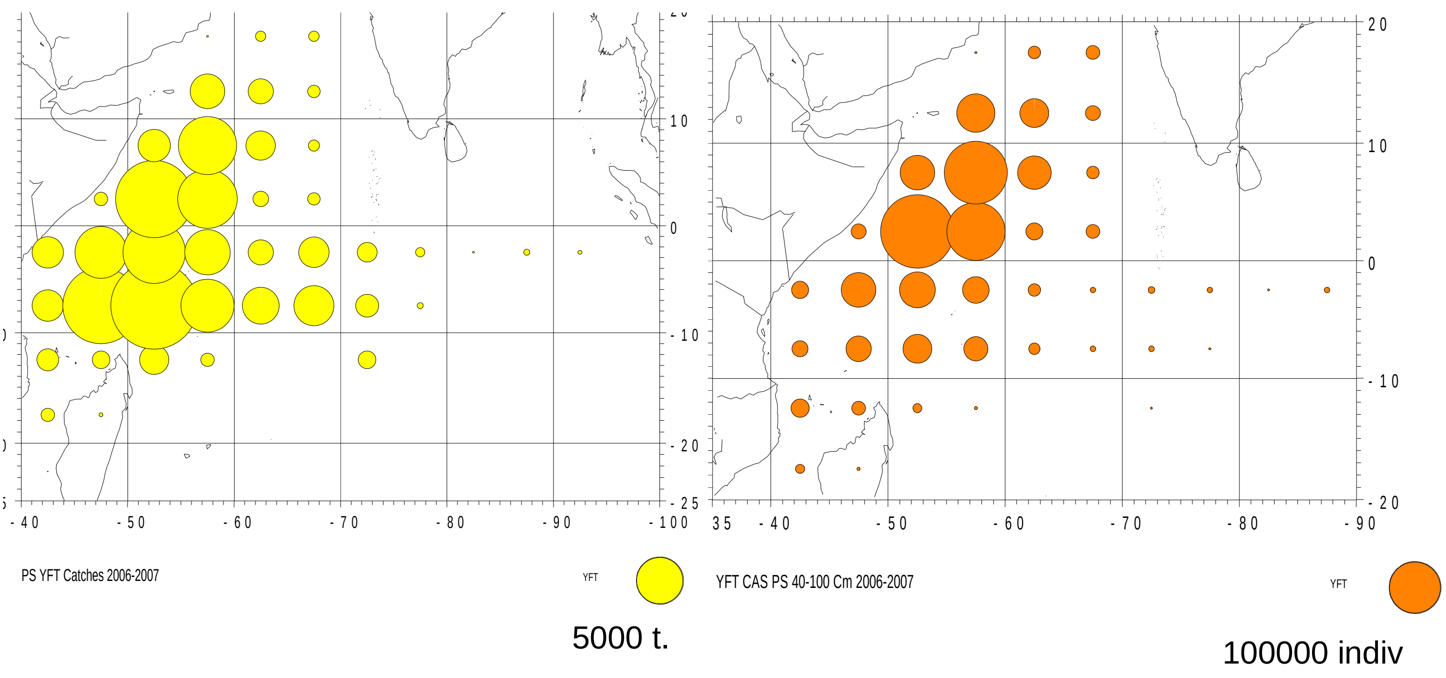


Figure 4: Map showing the average catches of yellowfin by purse seiners during the average period 2006-2007: figure 4a left, total catches, and figure 4 b, right, catch in numbers of juvenile yellowfin smaller than 1 meter (widely dominant in the recovered yellowfin).

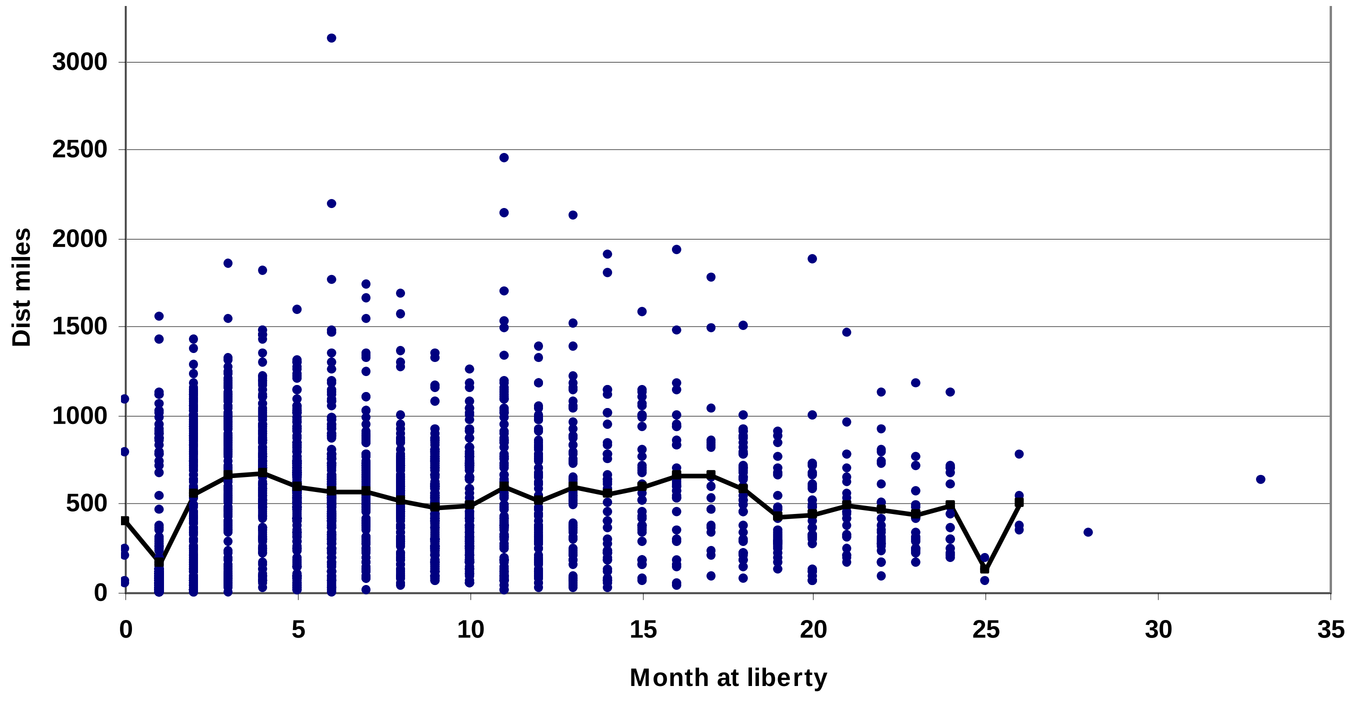


Figure 5: Linear distances estimated between tagging and recovery positions for all yellowfin recovered at a know position (average 526 miles)

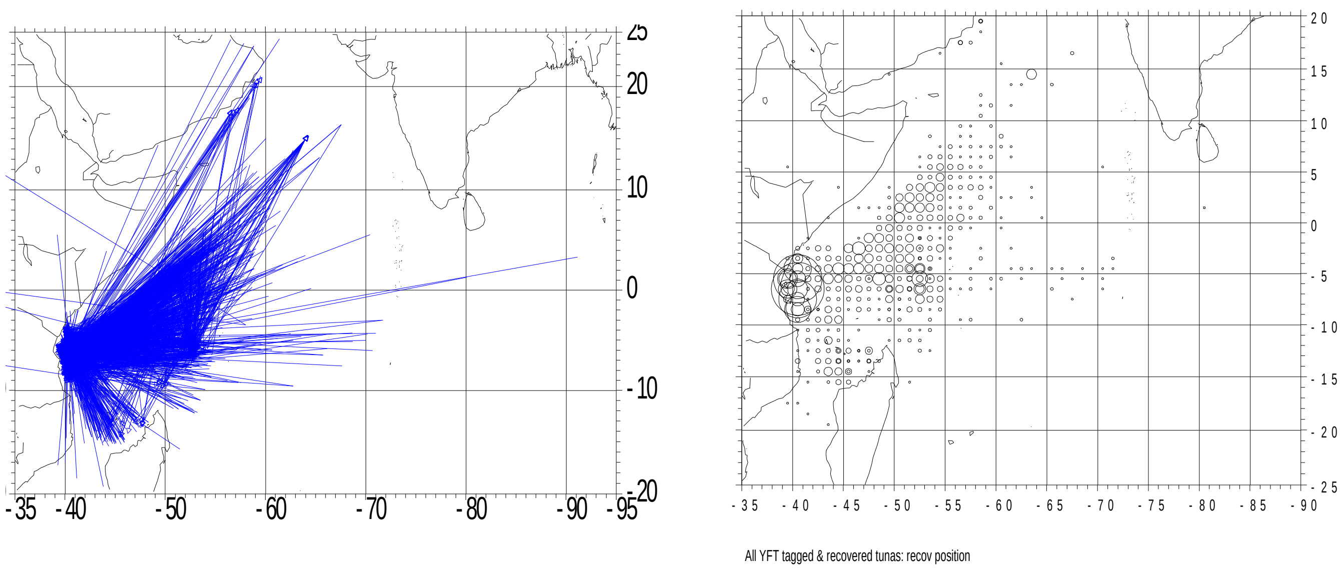


Figure 6: Map showing for all the yellowfin recoveries the linear trajectories betwwen tagging and recovery positions and map of the yellowfin recovery locations..

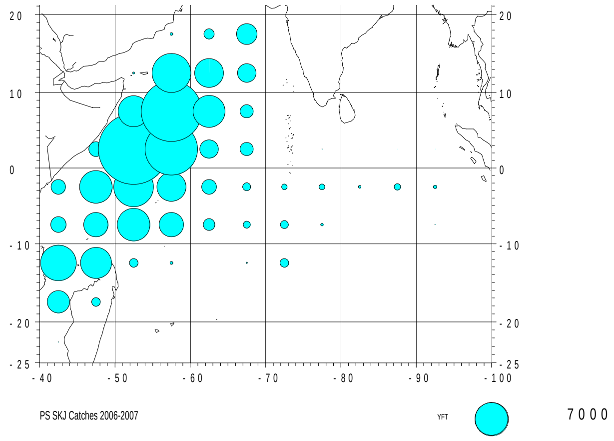


Figure 7: Map showing the average catches of skipjack by purse seiners during the average period 2006-2007

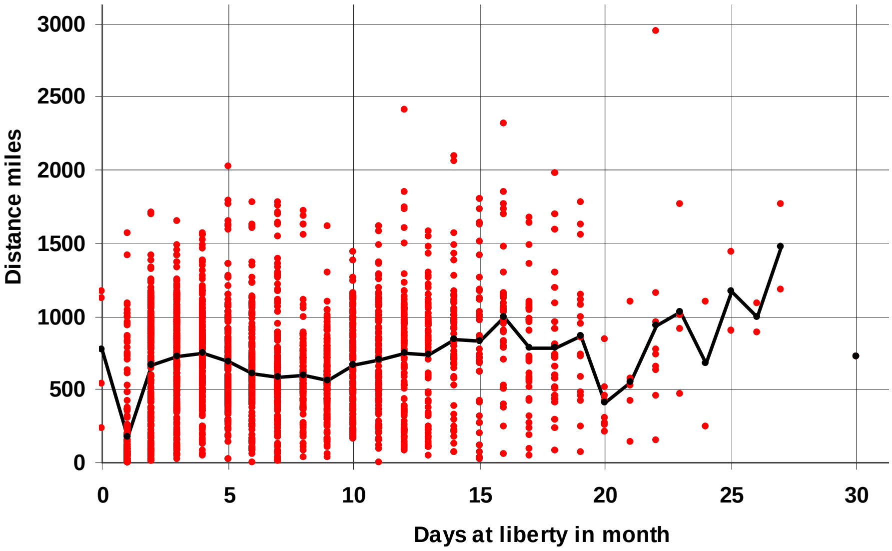


Figure 8: Linear distances estimated between tagging and recovery positions for all skipjack recovered at a known position (average 642 miles)

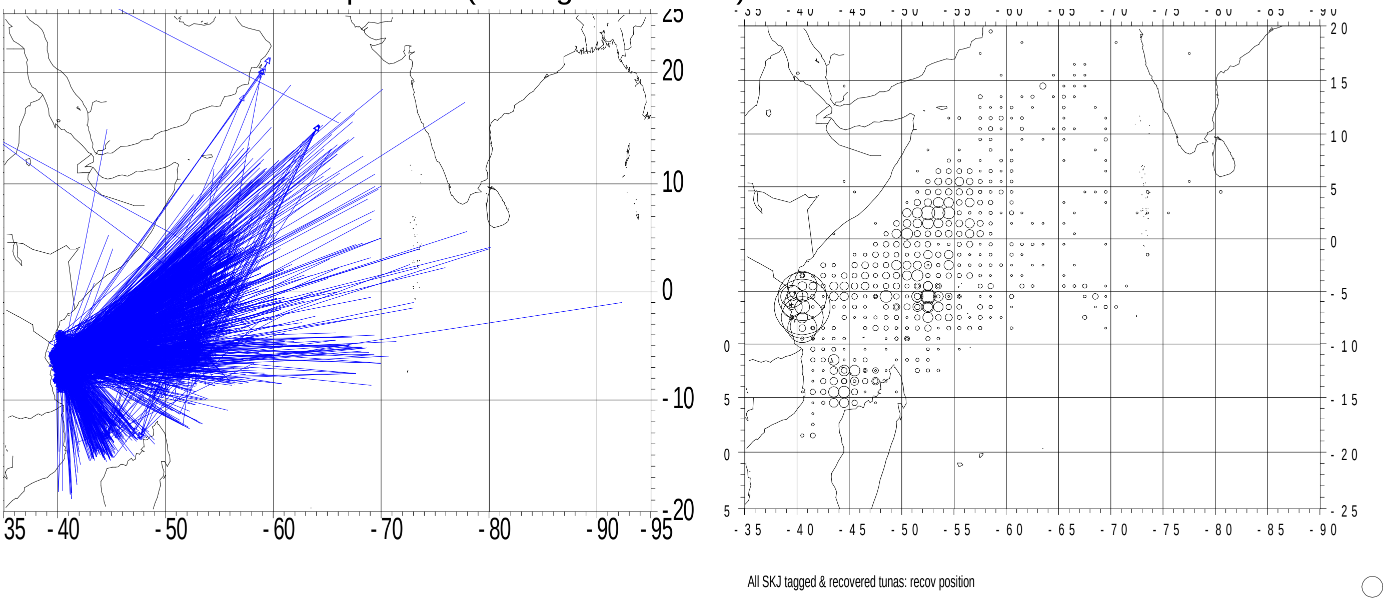


Figure 9: Map showing for all the spikjack recoveries the linear trajectories betwwen tagging and recovery positions.

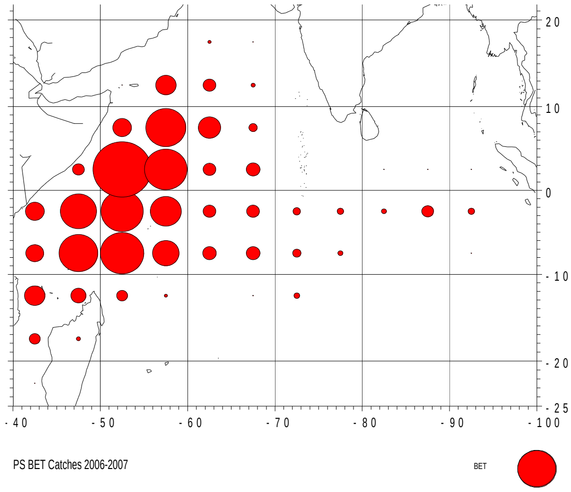


Figure 10: Map showing the average catches of bigeye by purse seiners during the average period 2006-2007

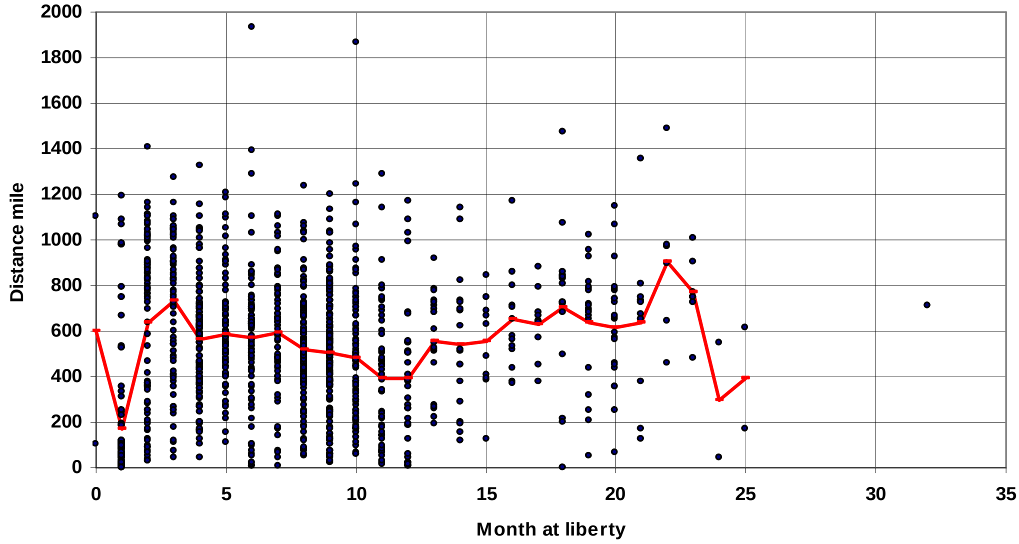


Figure 11: Linear distances estimated between tagging and recovery positions for all bigeye recovered at a known position (average 525 miles)

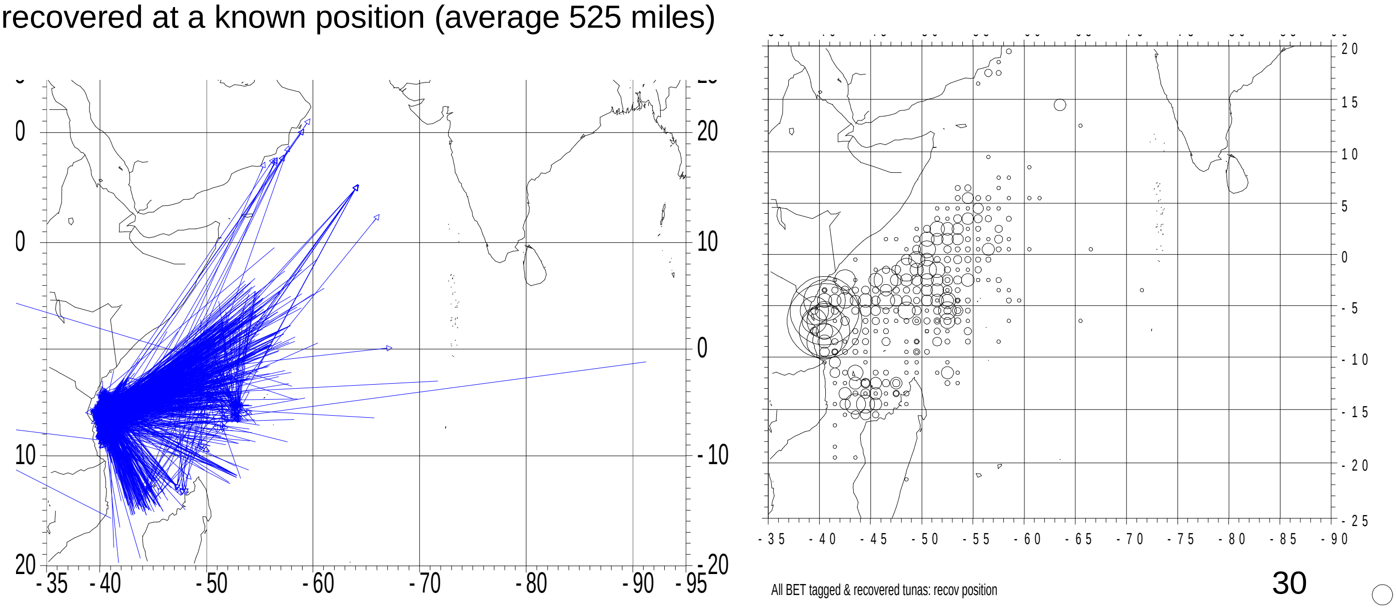
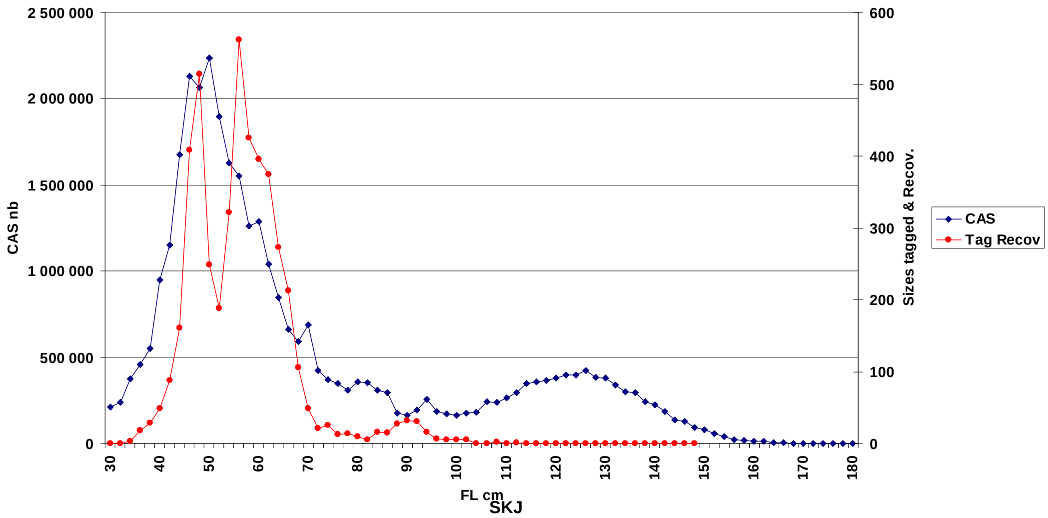


Figure 12: Map showing for all the bigeyerecoveries the linear trajectories betwwen tagging and recovery positions and map of the bigeye recovery locations.



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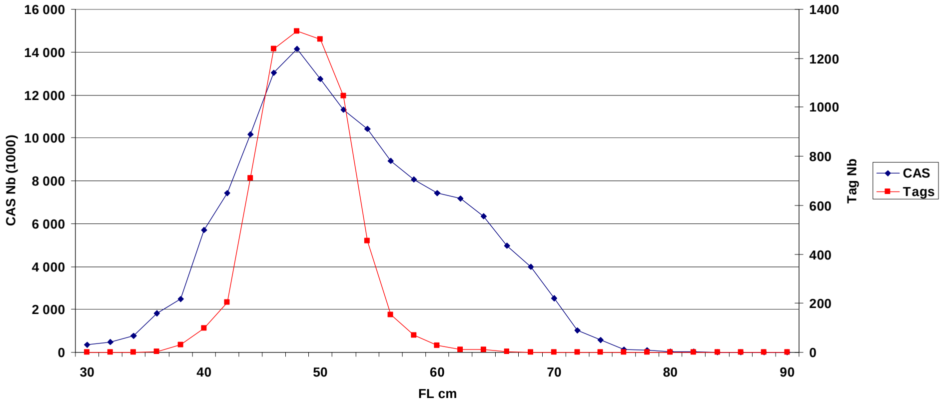

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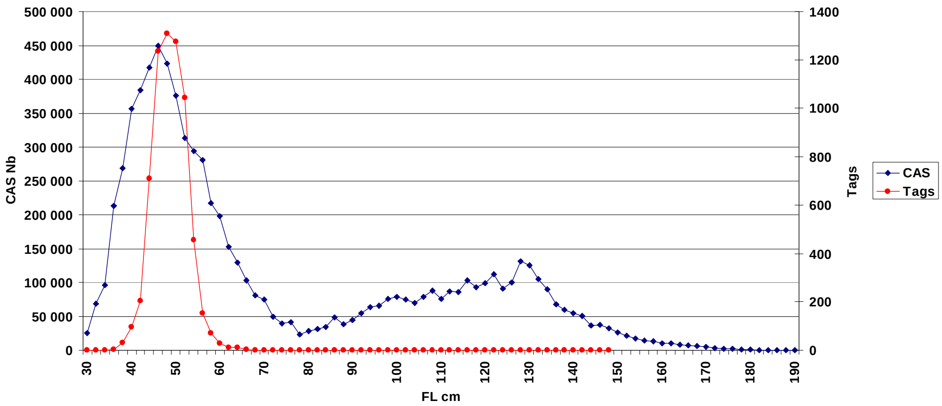


Figure 13: Average catch at size (in numbers of fishes) of yellowfin (12a), skipjqck (12b) and bigeye (12c) and numbers at sizes of the recovered tags for each species (sizes at tagging)

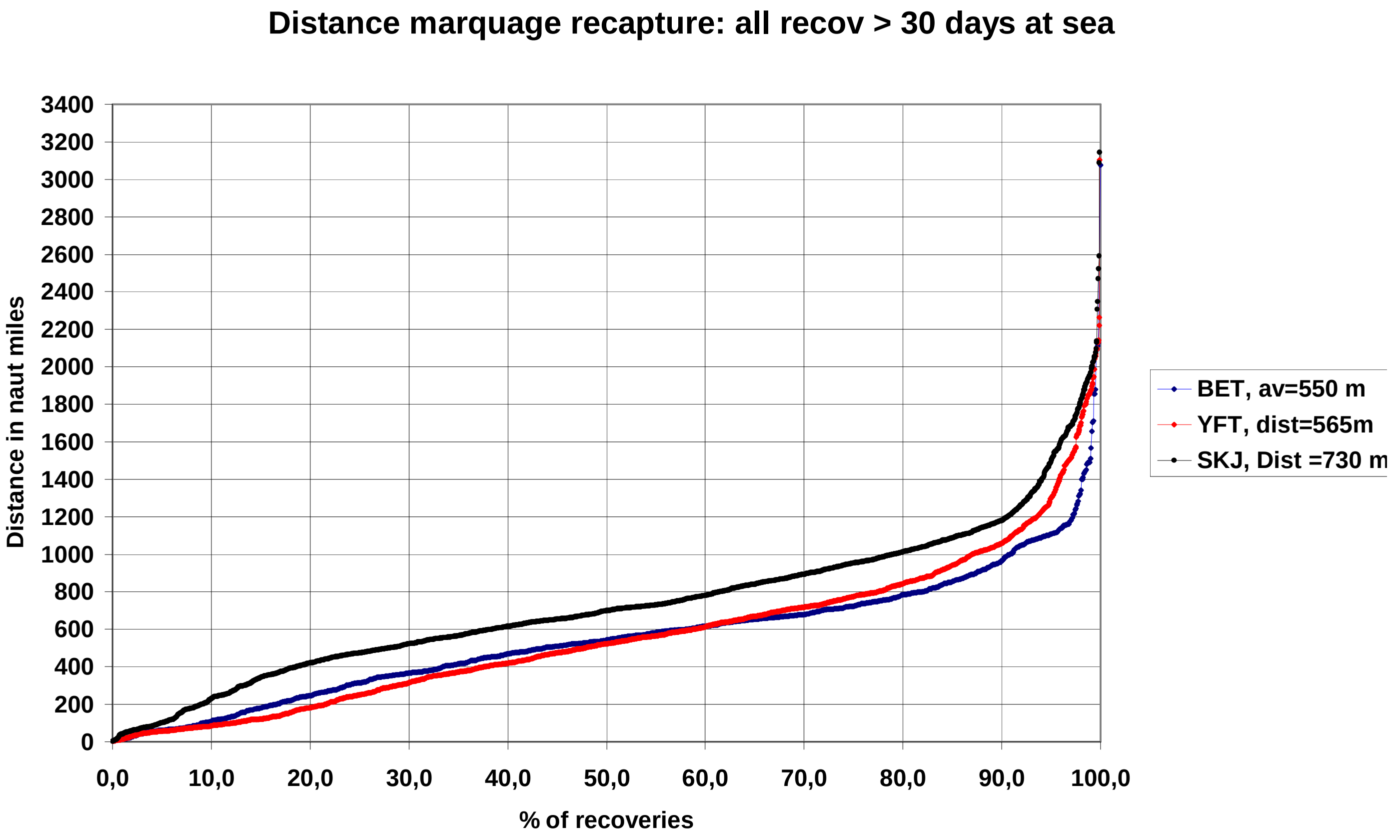


Figure 14: Linear distances between tagging and recovery positions, shown by species and expressed in percentage, these individual distances being sorted by increasing ranges.

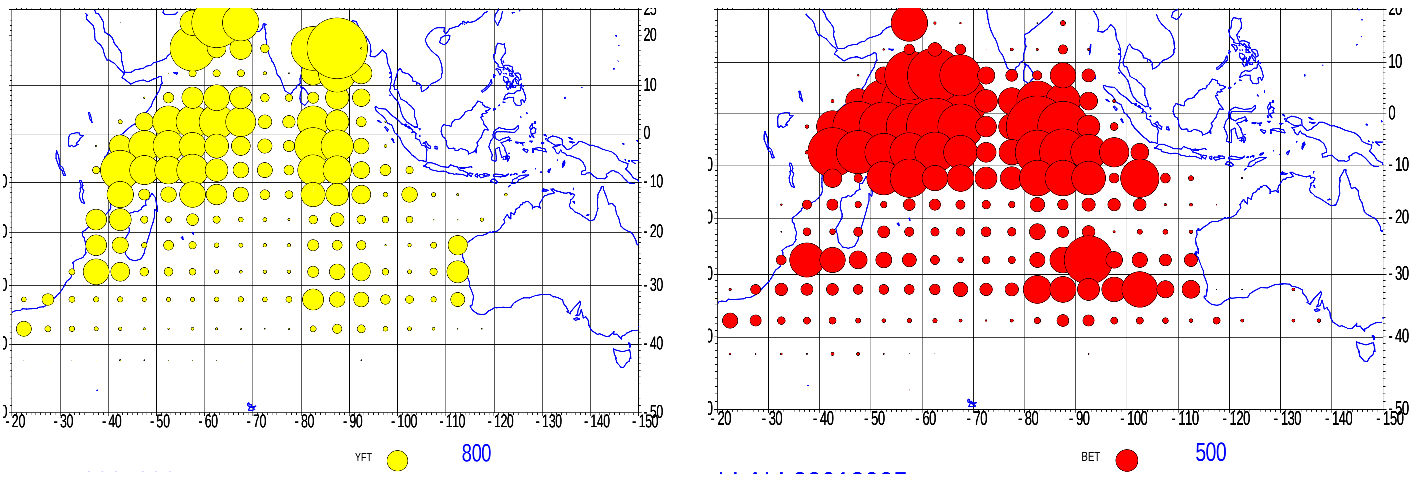


Figure 15: Average catches of yellowfin (14a left) and of bigeye (14 b right) taken by longliners during the 2001-2005 period (note that these 2 fishing zones of adult tunas are much wider than the area with recoveries)

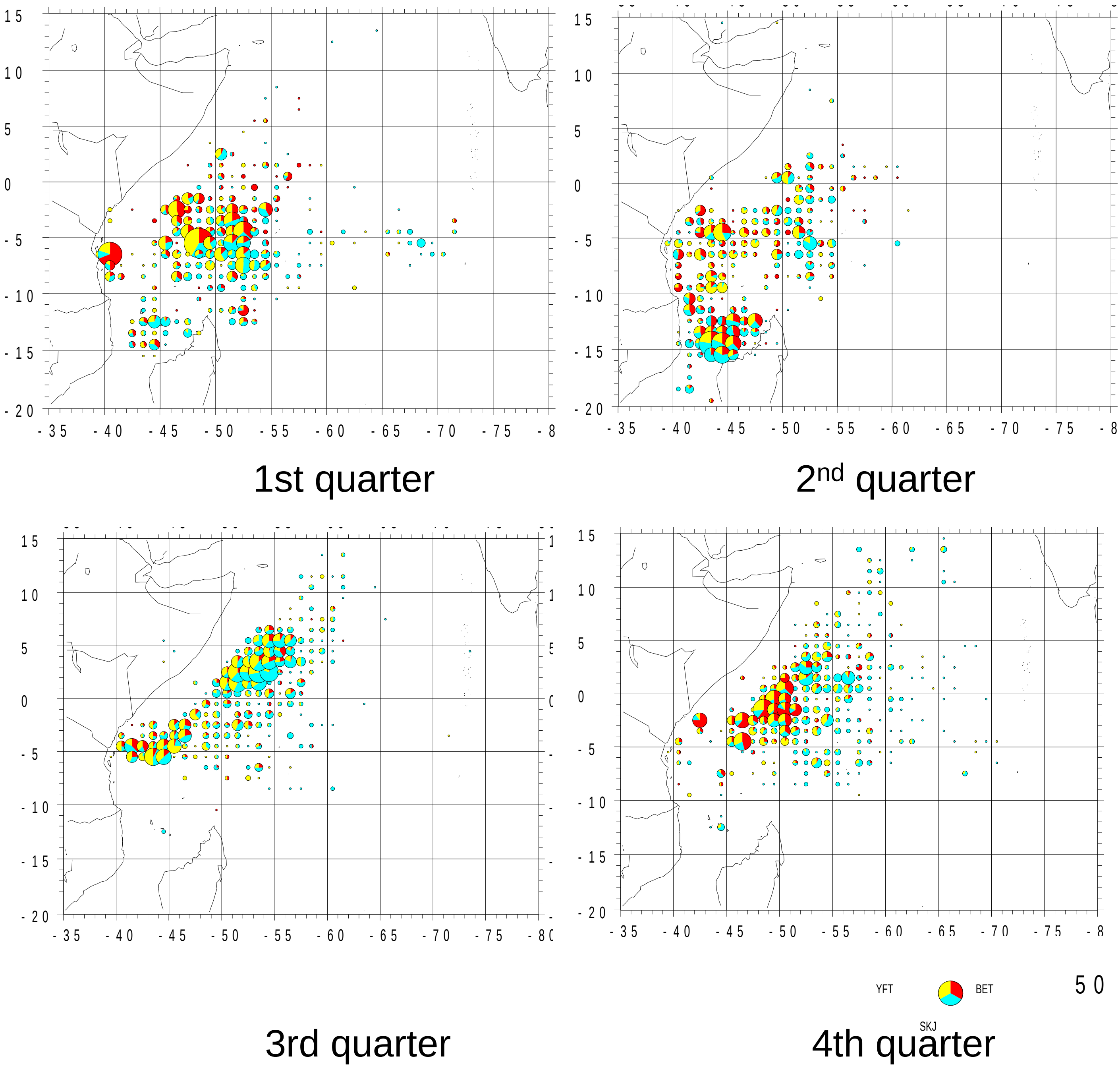
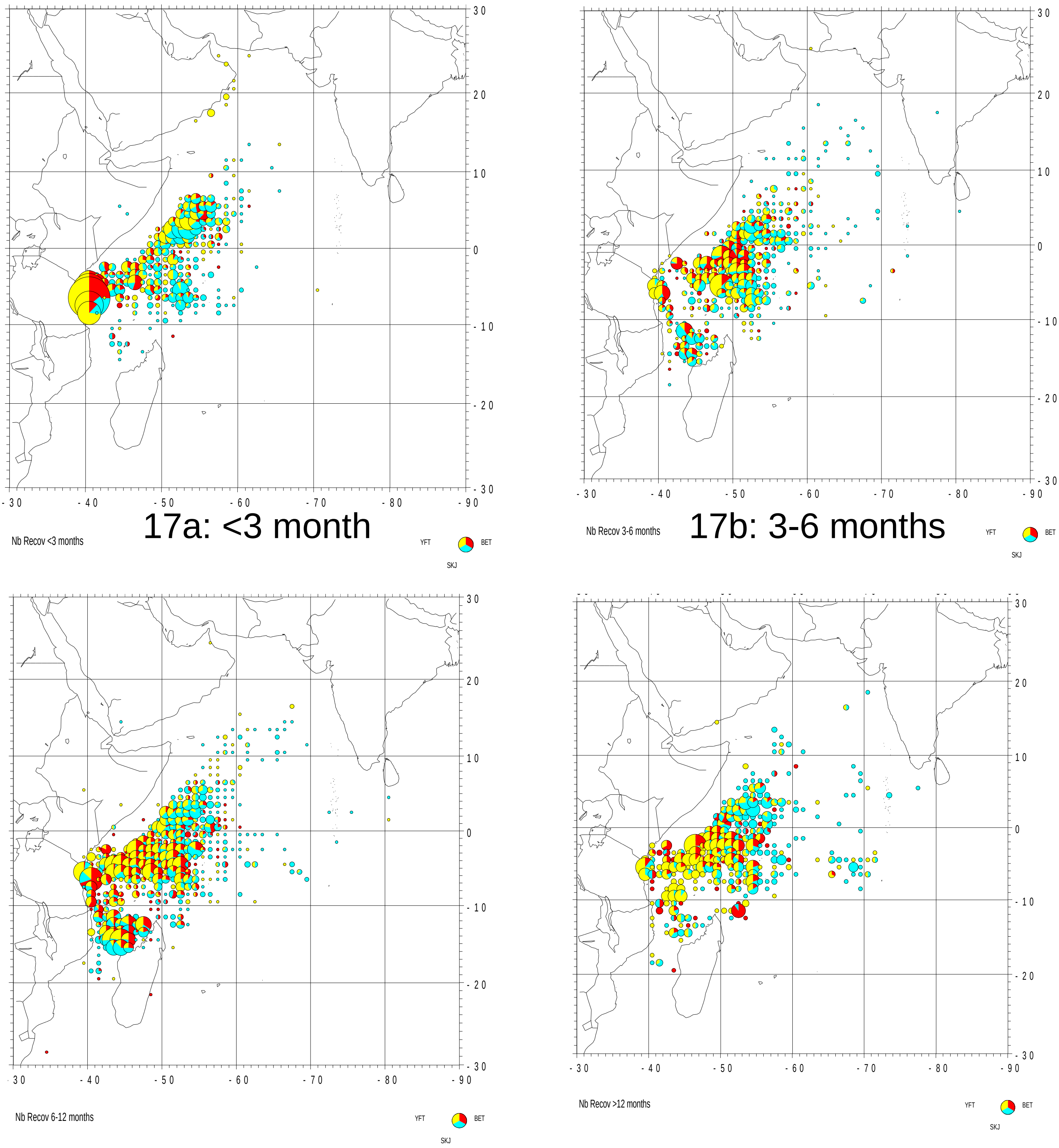


Figure 16: Quarterly geographical distribution of the observed recoveries, by species, during the period 4th quarter 2005-1st quarter 2008.



17c: 6-12 months

17d: Over 12 months

Figure 17: Geographical distribution of the observed recoveries, by species, as a function of time at liberty, and classified in 4 categories:

17-a) short term recoveries taken within the 3 months after tagging,

17-b: after a period between 3 and 6 month,

17-c: after a period between 6 and 12 month

17-d: after a long period over 12 months.

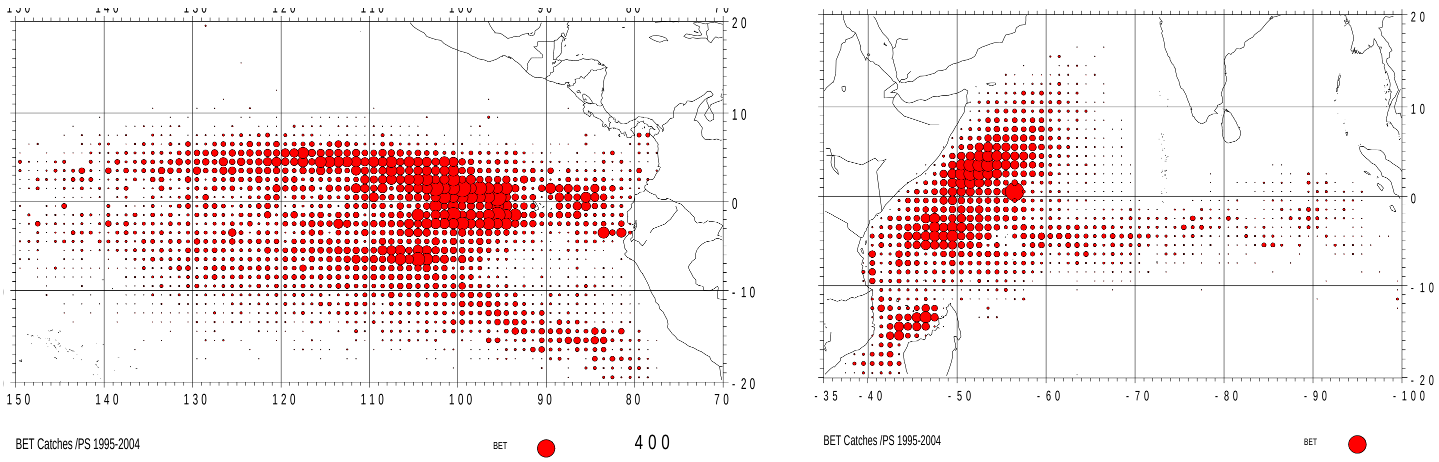


Figure 17: Map showing the recent average catches of bigeye by purse seine fisheries (period 1995-2004) in the Indian Ocean (right figure) and in the Eastern Pacific (left figure). In the IO 636 1°squares have been fished with an average bigeye catch >5t, when 1358 1°squares have been producing this level of BET catches in the EPO.

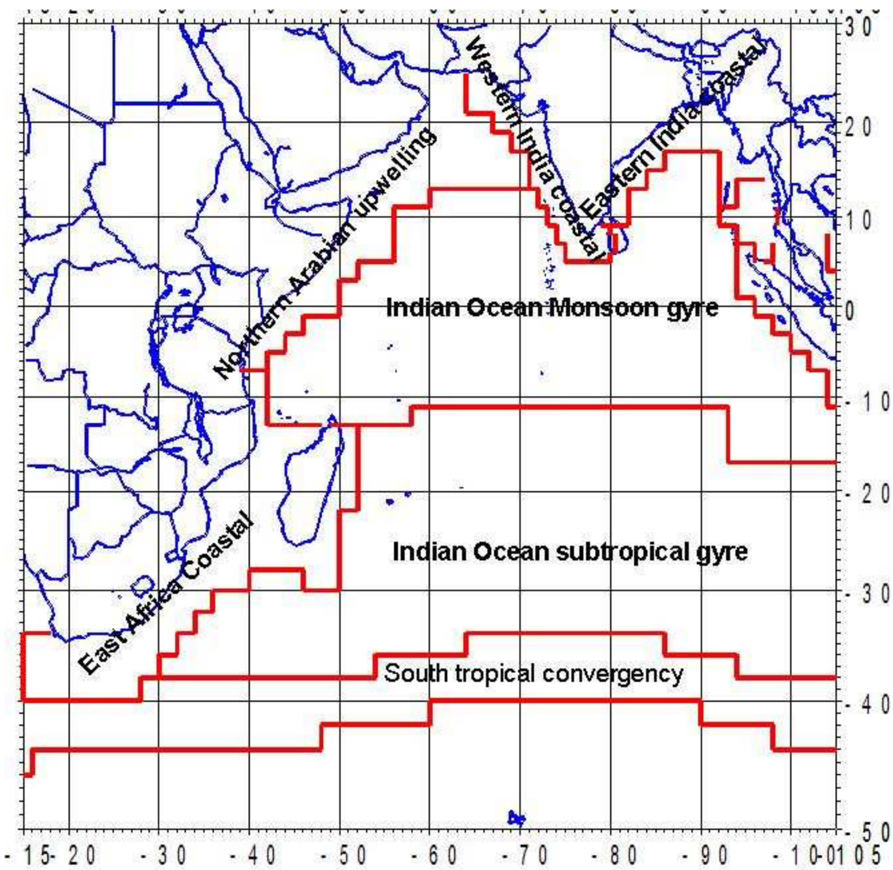


Figure 18: Longhurst areas in the Indian Ocean

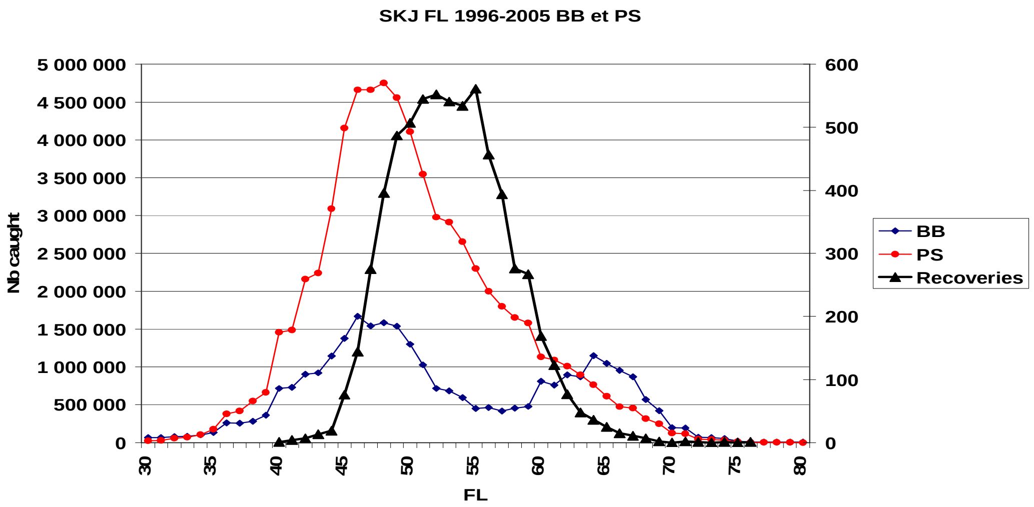
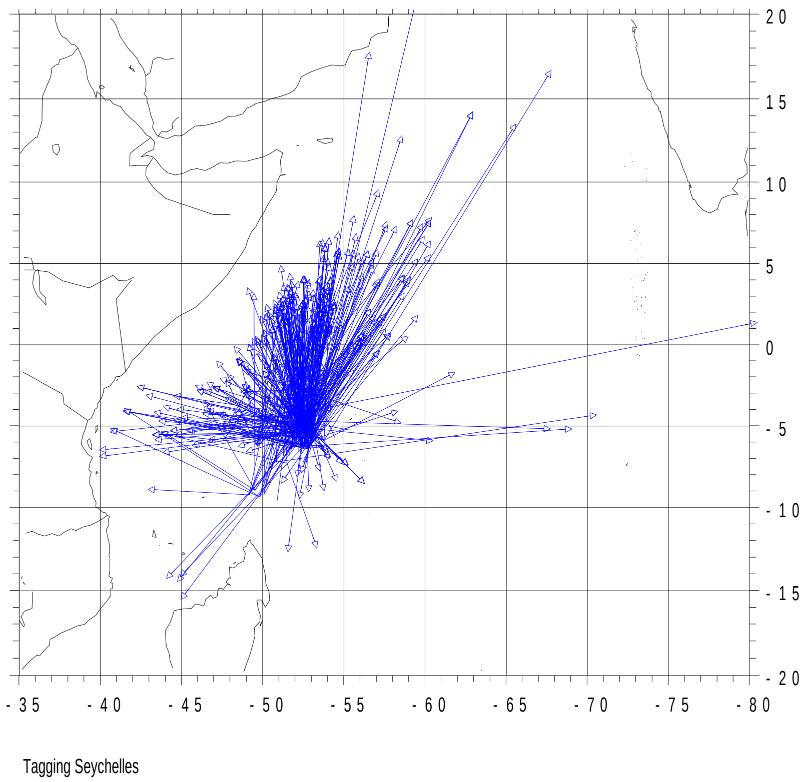
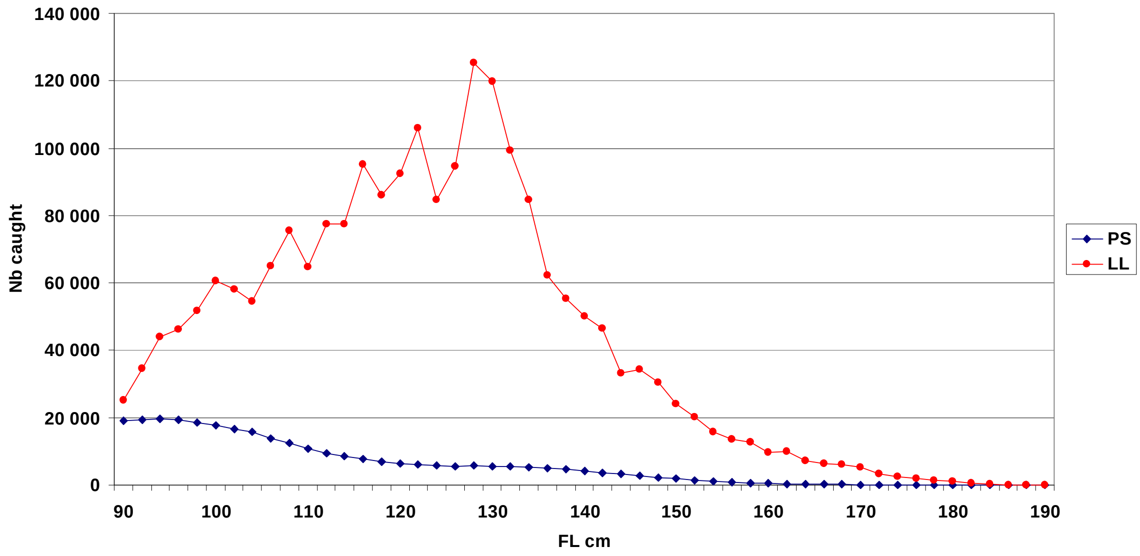


Figure 19: Total sizes of skipjack caught by purse seiners and by baitboats during recent years, period 1996-2005, and sizes of skipjack presently recovered and declared to the IOTC.



	YFT	SKJ	BET	Total/Average
Number Recov	160	164	74	398
Average Distanc	483	481	403	467

Figure 20: Linear trajectories of all the tuna recoveries of tunas tagged in Seychelles waters



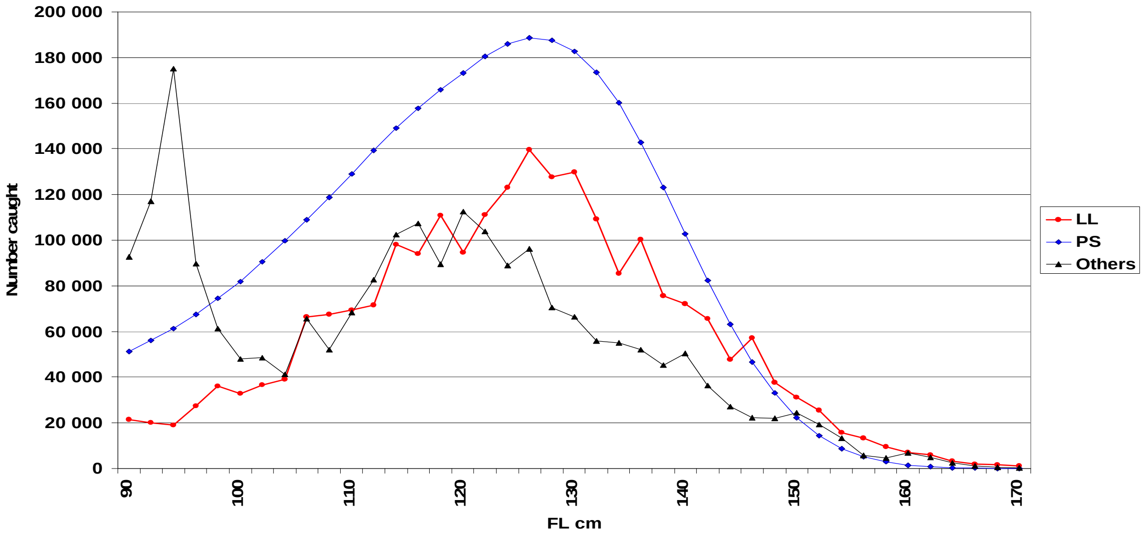


Figure 21: Average catch at size of large bigeye (upper figure) and for large yellowfin (lower figure) taken during recent years by the main Indian Ocean fisheries,

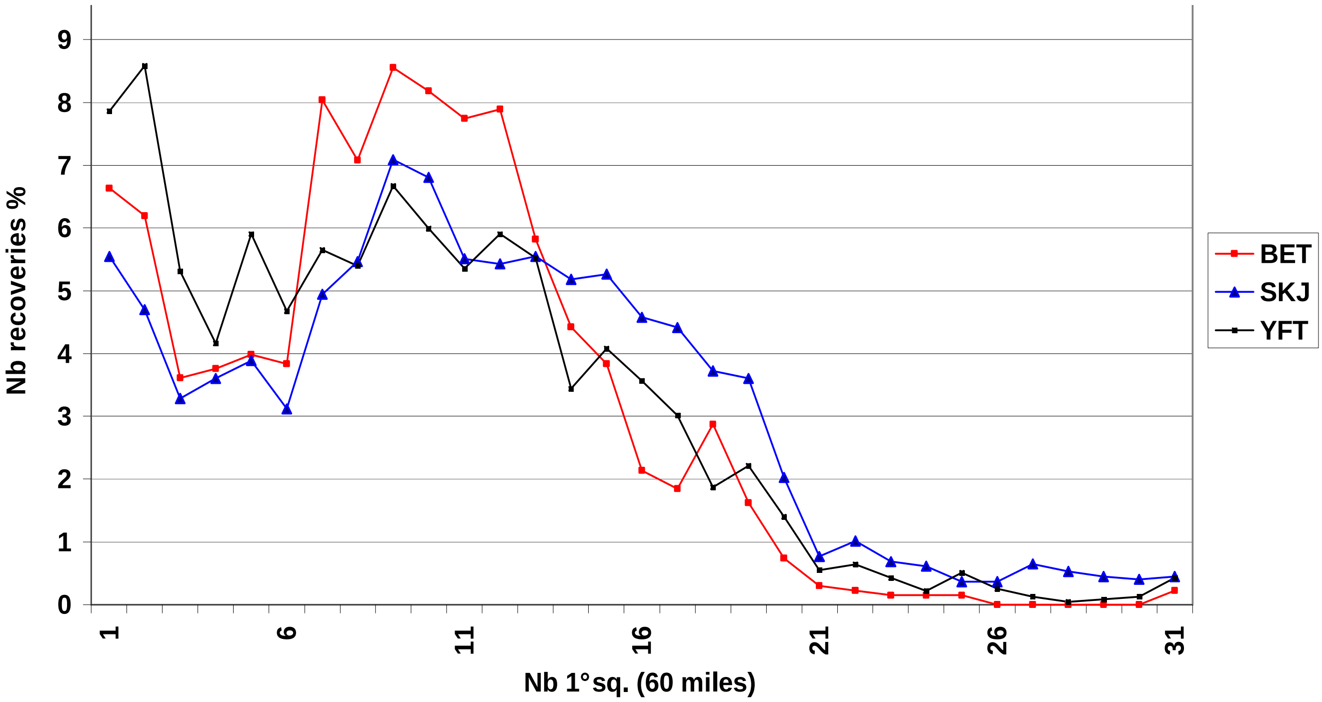


Figure 22: Frequency of the distances between tagging and recoveries, in the present IOTTP Indian Ocean recoveries of yellowfin, bigeye and skipjack (expressed in numbers of 1° squares, i.e. by intervals of 60 miles)

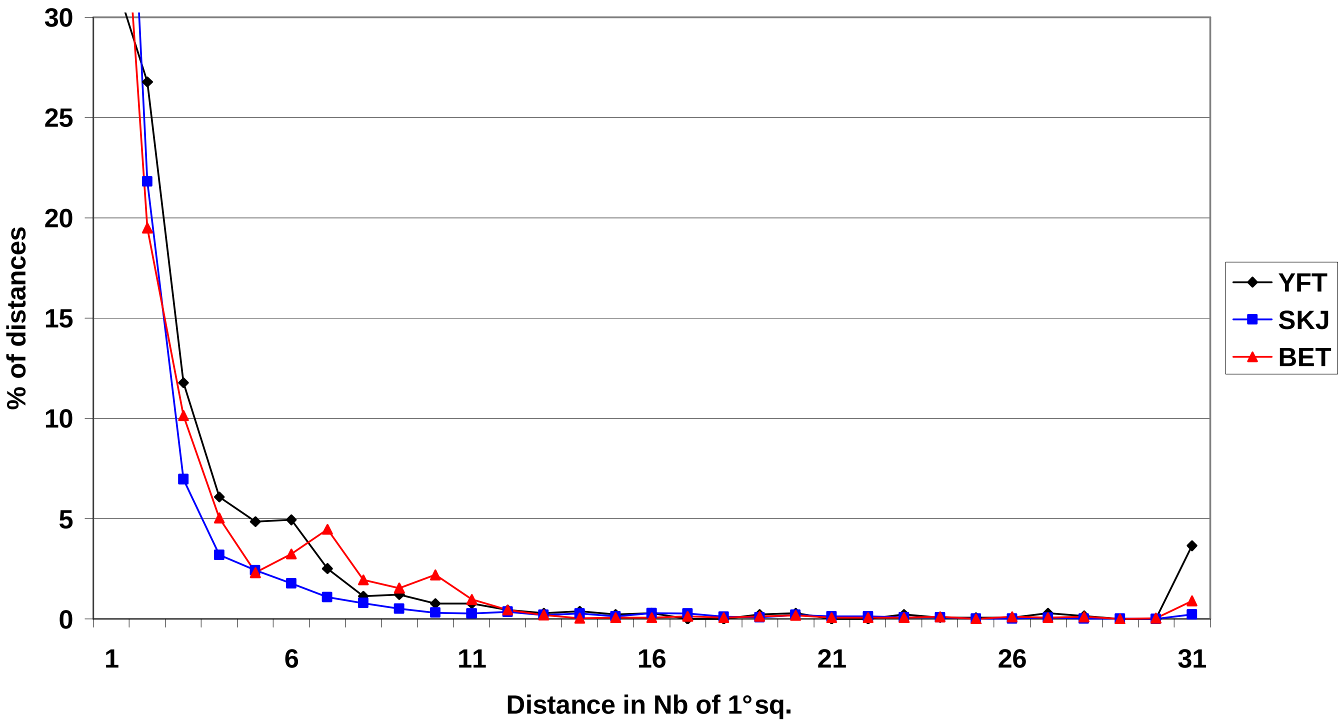


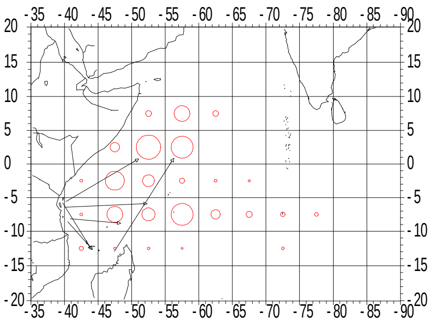
Figure 23: Frequency of the distances between tagging and recoveries, for the ICCAT/Atlantic recoveries of yellowfin, bigeye and skipjack (expressed in numbers of 1°squares, i.e. by intervals of 60 miles)

Annex 1
Map of quarterly catch at size and quarterly recoveries by species

An ad hoc software allows to do quarterly maps combining any subset of tag recoveries, and of catch at size by purse seiners. These maps are real ones, but alternative maps could easily be done by the WG using this automated fast software.

Trajectories of recoveries and catch at size of small & medium yellowfin by PS

Quarter 1 | 2 | 3 | 4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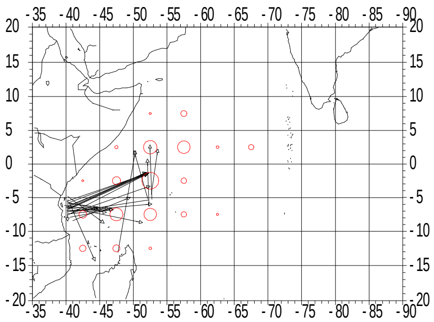
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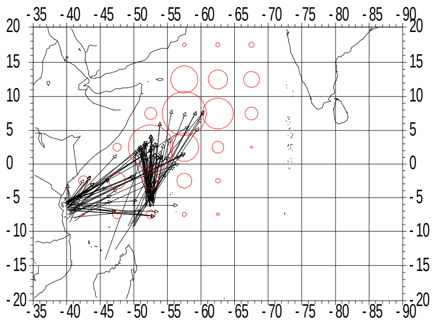
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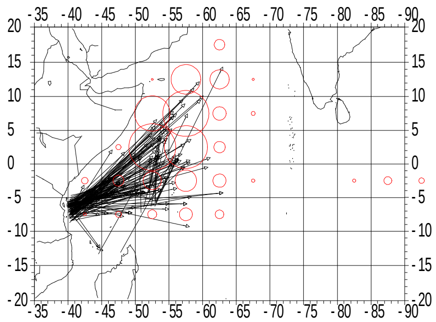
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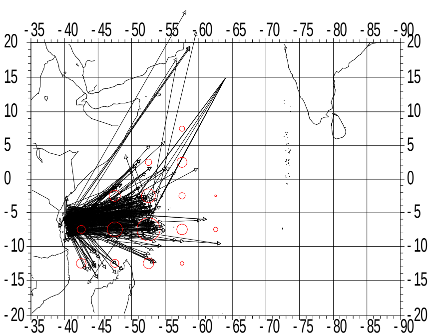
2006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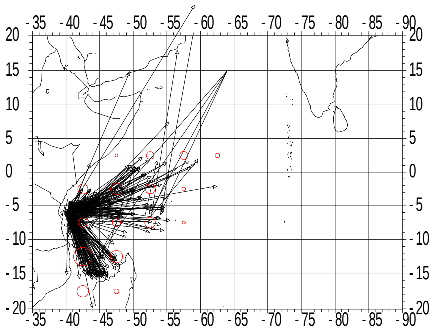
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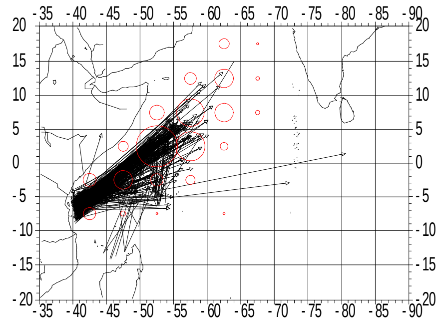
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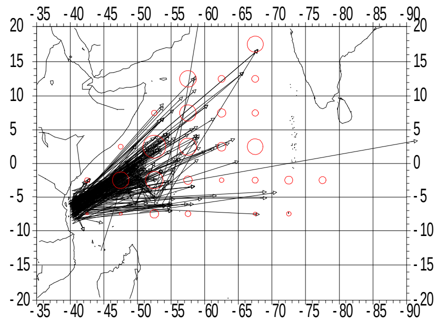
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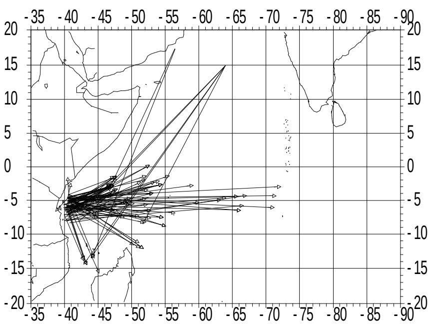
2007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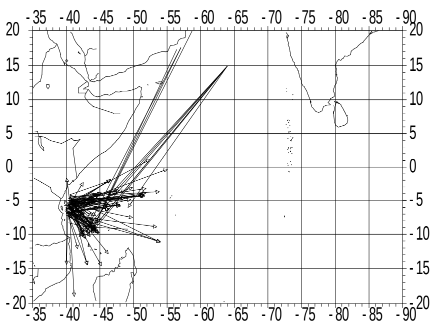
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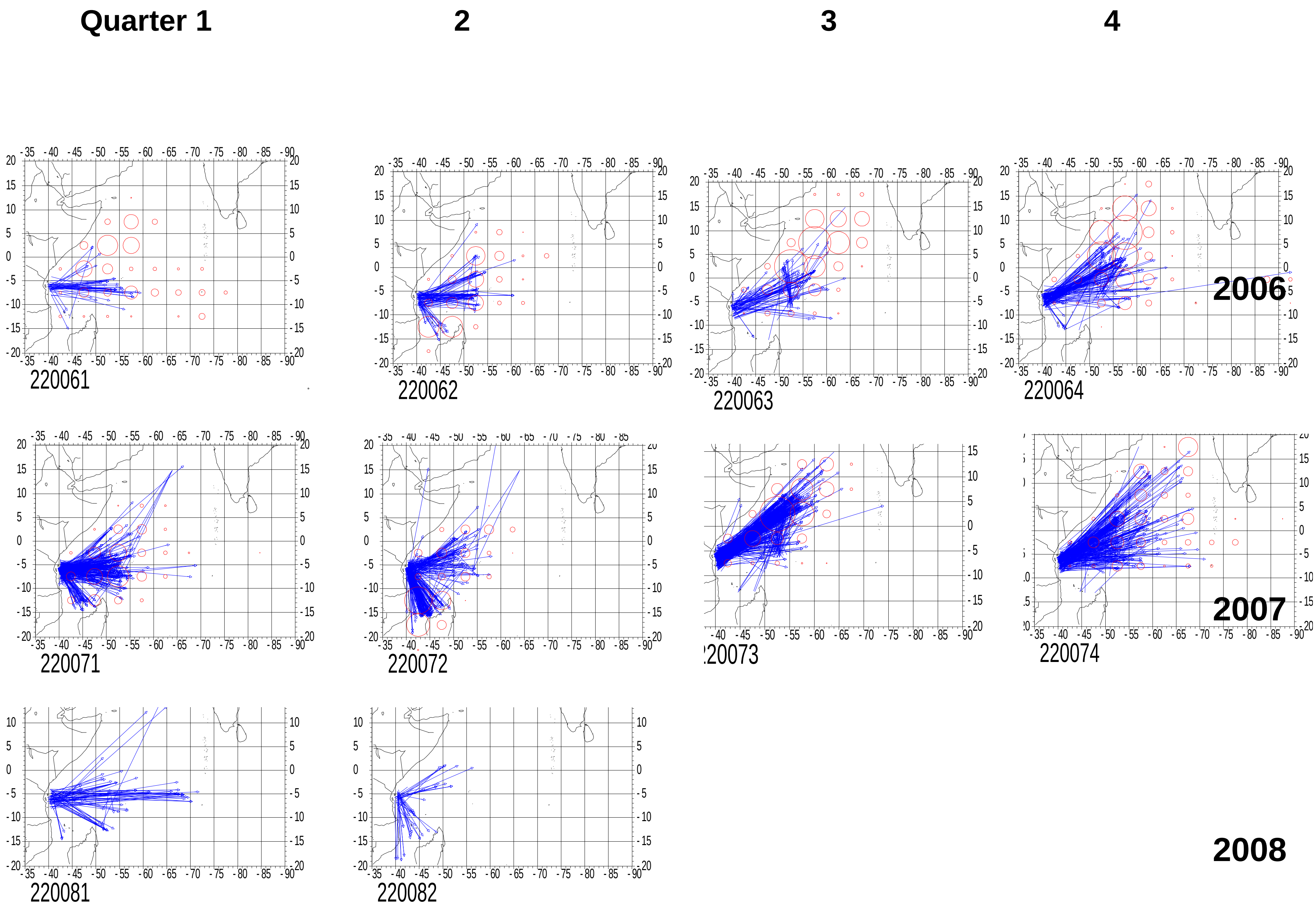
2008

Skipjack recoveries and catch by PS



Trajectories of recoveries and catch at size of small & medium bigeye by PS

Quarter 1 2 3 4