TROPICAL TUNA GROWTH AND MIGRATION RATES: AOTTP AND ICCAT'S HISTORICAL TAGGING DATA

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SUMMARY

In this working document we describe the mark-recapture information that AOTTP now has available for estimating the important parameters of growth and migration of tropical tuna in the Atlantic Ocean. The AOTTP data are then compared with the historical tag-recapture data available to ICCAT. We show that growth and migrations of each species of tropical tuna are broadly comparable with those observed in the past. We demonstrate that AOTTP data could already be used to inform growth and migration models/simulations and studies.

RÉSUMÉ

Ce document de travail fait état des informations de marquage-récupération dont dispose actuellement l'AOTTP pour estimer les paramètres importants de la croissance et de la migration des thonidés tropicaux dans l'océan Atlantique. Les données de l'AOTTP ont ensuite été comparées aux données historiques de récupération de marques dont dispose l'ICCAT. Il apparaît que la croissance et les migrations de chaque espèce de thonidé tropical sont largement comparables à celles observées dans le passé. Ce document démontre que les données de l'AOTTP pourraient déjà être utilisées pour étayer les modèles/simulations et les études sur la croissance et la migration.

RESUMEN

En este documento de trabajo se describe la información sobre colocación y recuperación de marcas de la que dispone actualmente el AOTTP para estimar importantes parámetros de crecimiento y migración de túnidos tropicales en el océano Atlántico. Se comparan los datos del AOTTP con los datos históricos de colocación y recuperación de marcas disponibles en ICCAT. Se muestra que los datos de crecimiento y migraciones de cada una de las especies de túnidos tropicales son muy similares a los observados en el pasado. Se demuestra que los datos AOTTP podrían utilizarse ya para aportar información a los estudios y modelos/simulaciones de crecimiento y migración.

KEYWORDS

Growth curves, migrations, tuna fisheries, data collections, tagging.

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1. Introduction

The overall objective of the Atlantic Tuna Tagging Program (AOTTP) is to contribute to food security and economic growth of the Atlantic developing coastal states by ensuring sustainable management of tropical tuna resources in the Atlantic Ocean. The specific objective of this program is to provide evidence based scientific advice to developing coastal states, and other Contracting Parties, to support the adoption of effective Conservation and Management Measures (CMMs) in the framework of the International Commission for the Conservations of Atlantic Tunas (ICCAT). This will be achieved through improving the estimation, derived from tag-recapture data, of key parameters for stock assessment analyses, i.e. growth, natural mortality, movements and stock structure, etc.

Note that AOTTP Coordination is currently focusing its efforts on organizing tagging at sea, the recovery of those tags, the payment of rewards, and the storage of the data. The key objective of the AOTTP, however, is to help reduce the risk of failing to meet ICCAT management objectives for the main tropical tuna stocks, i.e. that B/BMSY is kept above 1 and F/FMSY below 1. To do this requires robust scientific advice; specifically, to reduce the uncertainty in estimates of stock status with respect to reference points and to increase the effectiveness of management measures based on total allowable catches (TACs), harvest control rules (HCRs) and spatial management measures. No confirmed biological parameters from AOTTP data are available as of writing. AOTTP, however, already has a rich dataset which could, even now, be used to estimate growth rates, mortality (including gear selectivity), and migration rates. Once data are approved for circulation by the SCRS analyses to address these key objectives will begin.

AOTTP is a 5-year project that began in June 2015. The overall budget is 15 million euros, funded by the European Union, ICCAT CPCs and Collaborators

2. Material and methods:

2.1 Distribution area and collection of information

In order to summarize migration rates the AOTTP tagging data for the Atlantic were divided into four regions (north and south of 10ºN and east and west of 30º W) based on the schema in Die et al (2014). The tagging operations were implemented on-board bait boats based in the Azores/Madeira, Canary Islands, Senegal, South Africa, Uruguay and Brazil. Tagged tuna have been recovered by all the main tuna gears/vessels used in the Atlantic: specifically purse seiners, bait boats, long liners and gillnetters flagged in Portugal, Spain, Morocco, Senegal, Cape Verde, France, Cote d'Ivoire, Ghana, Korea, Japan and Brazil. Yellow conventional plastic dart tags were used in circa 90% of the tagged tunas, including those double tagged for tag shedding estimates while red ones are used in chemically and/or electronically tagged fish (circa 10 %). One of the most important parameters to evaluate the success of a tagging program is the proportion of well documented data, especially when consider information from the recovered fish. To facilitate this a holistic data collection and upload system, a scheme of database based on Android smartphones developed with templates in the four main languages of the Atlantic (Portuguese, Spanish, French and English) to increase the ease-of-use. Tagging teams at sea and tag-recovery officers, based in the most important tuna landing locations, both introduce data into the templates using smartphones and submit the information to the AOTTP-ICCAT HQ by Telegram. The AOTTP management team thus receive all the data in the same format when they are uploaded to the AOTTP database. Ultimately the data are revised, checked and transferred to the formal ICCAT database. The reduction of time between collection of data and analysis of the information allows the establishment of a more efficient data monitoring and verification system. The first step in the monitoring of data is done at field level by recovery officers consulting the data through an internet portal linked to the main database. The second step involved AOTTP-ICCAT coordination where a set of queries has been designed to identify potentially incorrect information provided by the tag-finders, especially relating to fish size, geographical location and date. The integrated system thus allows to estimate what data are 'well documented'. Tagging and Recovery officers also collect biological data and associated information from selected (red-tagged) tuna. Stretched fork length (to the lowest cm) is used to measure size, while GPS devices on the boats used to get geographical positions. In some cases of tag-recovery digital maps on smartphones used to identify the geographical positions of the recaptures.

2.2 Tagging and recovery data

Between June 2016 and August 2017, a total of 55867 tropical tunas have been tagged and released, and 10307 recaptured under AOTTP. According to the ICCAT historical database, between January 1940 and June 2015 a total of 72200 tropical tunas been tagged and 11289 recovered in the Atlantic as illustrated in **Table 1** and **Table 2**. Up to August 2017, 91% of the AOTTP tagged tunas have been released in the NE and SE quadrants of the Atlantic and only 9% in the SW quadrant. 89 % of the tag-recoveries have been reported from the ports of Dakar and Abidjan. The most commonly tagged species are SKJ with 37 % of the total released tags so far. But the species with most recoveries is, however, YFT with 43 % of the total. During tagging cruises all BET and YFT length classes between 30 and 100 cm of SFL have been sufficiently covered, with minimal of 132 YFT released between 90 and 100 cm as illustrated in **Table 3**. SKJ have been sufficiently covered between 30 and 70 cm of SFL with 570 individuals between 60 and 70 cm SFL released. The mean time at liberty for all species pooled was of 63 days with a maximum of 390 days observed. 40 % of the tag returns were within 30 days of tagging. Preliminary estimates of reporting rates for all gears up to August 2017 are 68%. The highest tag-shedding estimate corresponds to LTA with 5.8%, and the lowest to BET with 2.3 % as illustrated in **Table 4**.

2.3 Data validation

The process of data-validation used here in the growth and migration analysis follows the system proposed by Fonteneau and Hallier (2015). Those data with at least a proper identification of the species, exact release/recovery date and precise geographical release/recovery locations are considered "well documented and thus valid for migration analysis". Those data with at least a proper identification of the species, exact release/recovery date and reliable release/recovery lengths are considered "well documented and thus valid for growth analysis".

2.4 Growth and migration calculations

The method used to estimate growth rate at size was to calculate the difference of SFL (cm) between release and recovery and divide that by the number of months at liberty. That monthly growth value/rate was then assigned to the mean SFL during this period (Schaefer et al. 1961 and Fonteneau and Hallier 2015).

Three methods have been used here to explore the tuna migrations. The first is an estimation of the migration tracks through a visual analysis of the trajectories between tagging and recovery by drawing a straight line between the points of release and recapture. The second is to estimate the distances travelled by each recovered tuna, by calculating the monthly average linear distances between tagging and recovery. The third is a basic estimation of the migration rate by calculating the rates of tagged tunas released in one of the quadrants of the Atlantic Ocean and recovered in a different quadrant as explained in Sculley and Die (2015).

2.5 Area/time closure

In 2017 the conservation and management measure "No fishing with natural or artificial floating objects during January and February of 2017 and 2018 in the area encompassed by the African coast, 20º W, 5ºN and 4ºS" was instigated. Since AOTTP carried on tagging and recovery activities both inside and outside of this closure time/area there is an opportunity to assist the SCRS in the evaluation of the efficiency of that measure.

3. Results:

3.1 Growth

Of the total of 10307 recovered tropical tunas under AOTTP, 8215 are 'well documented' and thus valid for the growth analysis described here. Note that this constitutes an 80 % validation, compared to the 39 % of recovery data validated in the ICCAT historical database.

3.1.1 Bigeye growth rate at size

A minimum time at liberty of 210 days was considered here in order to reduce the impact of measurement error in the calculations of monthly growth rate. A total of 269 BET tagging/recovery observations were thus validated and available for monthly growth analysis. BET between 40 and 55 cm showed a slow growth which increased to reach an average of 2.6 cm/month. Individuals between 55 and 65 cm showed a slight decrease in growth, reaching a minimum of 2.3 cm/month. At 70 cms growth increased to reach 2.8 cm/month and from there growth fell to 1.8

cm/month at 90 cm. Between 90 cm and 100 cm growth increased again to 3 cm/month and then fell to reach a minimum rate of 1.7 cm/month at 110-115 cm. In the other hand the historical ICCAT data showed a decrease in monthly BET growth rate at 85 cm, reaching a minimum of 1.3 cm/month as illustrated in **Figure 1** and **Figure 2**.

3.1.2 Yellowfin growth rate at size

For YFT a minimum time at liberty of 180 days was considered here to reduce the impact of measurement error in the calculations of monthly growth rates. A total of 300 YFT tagging/recovery observations were validated for the YFT monthly growth analysis. Small fish, between 40 and 50 cm, tended to show a monthly growth rate of around 1.6 cm/month. Between 50 and 60 cm there was a steady increase in monthly growth, reaching an average 2.7 cm/month. Between 60 and 70 cm growth rates were relatively stable at around 2.7 cm/month. The growth rates of fish of between 70 and 85 cm increased steadily reaching an average 4.5 cm/month. Data from ICCAT's historical records show similar patterns for YFT as illustrated in **Figure 3** and **Figure 4**.

3.1.3 Skipjack growth rate at size

Times at liberty 90 days or greater were used in the skipjack growth rate analyses. A total of 233 SKJ tagging/recovery data were validated for the monthly growth analysis. SKJ between 35 and 70 cm had relatively stable monthly growth rates of between 1.5 and 2.1 cm/month. The ICCAT historical database, however, shows a relatively slow growth of 0.5 cm/month at 35 cm for SKJ which increases to reach a maximum of 1.7 cm/month at sizes of 65 cm as illustrated in **Figure 5** and **Figure 6**.

3.2 Migration

Of the total of 10307 tropical tunas recovered under AOTTP, 9843 were 'well documented' and thus valid for migration analysis. This constitutes a 95 % validation compared to the 89 % of recovery data validated in the ICCAT historical database. The average linear distances travelled by month between tagging and recovery (with a maximum time at liberty of 390 days) are in general lower under AOTTP than in historical ICCAT database with the exception of SKJ which is of 273 nm/month when in the historical ICCAT database was 191 n.m./month as illustrated in **Table 5**.

Note that AOTTP tagging and recovery activities were only recently initiated in the SW Atlantic; and not yet in the NW. The observations AOTTP has made regarding migrations between the west and eastern sides of the Atlantic are, therefore, rather tentative but the patterns observed do nevertheless indicate at least some pan-Atlantic exchange of individuals.

3.2.1 Bigeye migration

The highest migration rate is 0.1347 between SE and NE Atlantic. Migrations between the SE and SW and between SE and NW were lower. There is a migration rate of 0.0763 from NE to SE and also lower from NE to NW and SW as illustrated in **Table 6**. The data indicate an exchange of fish in both directions, between NE and SE as illustrated in **Figure 7**.

3.2.2 Yellowfin migration

The highest migration rate observed for YFT was 0.0992, between SE and NE. There was also some lesser migration from SE to SW and to the NW. There was a migration rate of 0.0896 from NE to SE but no migration from NE to the west side of the Atlantic as illustrated in **Table 7**. The data indicate again an exchange of individuals in both directions between NE and SE. The trend shows also an exchange of population between Atlantic and Indian Ocean through the coast of South Africa as illustrated in **Figure 8**.

3.2.3 Skipjack migration

The highest migration rate of 0.0942 was observed between SE and NE. There was almost no migration from east to the west side of the Atlantic. There was a migration rate of 0.0573 from NE to SE only anecdotic migration from NE to NW as illustrated in **Table 8**. The data do, however, indicate some movement of individuals in both directions between NE and SE as illustrated in **Figure 9**.

3.3 Area/time closure

During January and February 2017, a total of 3436 topical tunas were tagged and released inside of the Closure area and 5324 outside. YFT was the most tagged species in both cases with 1797 and 2746 respectively as illustrated in **Table 9**. From those tunas tagged during January and February 2017 inside the Closure area, the overall recovery percentage, up to August 2017, is 13.9 % but only 27.1% outside. The species with lowest recovery percentage is SKJ tagged inside of the Closure area and the highest is YFT tagged outside of the Closure area as illustrated in **Table 10**. The migration rate of the tropical tunas tagged during January and February 2017 inside of the Closure area to outside of the area is 0.55. Most of the trajectories to outside of the Closure area point to the NW as illustrated in **Figure 10**.

4. Discussion

Although AOTTP will continue tagging and recovery activities during next three years, there are actually data available now that could already be used to estimate key parameters like growth and/or movements which could support stock assessments. Especially for YFT and BET there are already more tagging and recovery data available the AOTTP database than in the historical ICCAT records as illustrated in **Table 1** and **Table 2**. In reference to the collection of information, there are also higher percentages of well documented data validated for growth and migration analyses available from the AOTTP than in the historical ICCAT database. Nevertheless, there remain some substantial areas that have not been sufficiently covered, e.g. both tagging and recovery activities in the NW Atlantic, the only recently initiated tagging and recovery activities in the SW and/or the otolith age-readings which will be reinforced in the next months.

Preliminary analyses of monthly growth rates per length classes are described in this paper. Some differences have been detected between the data from AOTTP and the data from ICCAT historical database, especially for BET, but in general the growth rate patterns are similar. Further analyses of the growth patterns are necessary and recommended. Similarly, some exploratory investigations into the migrations of Atlantic tuna during AOTTP are showcased herein. In all three species (BET, YFT and SKJ) migrations between SE and NE and vice versa have been detected with a minimum rate of 0.06 and a maximum of 0.13. The exchange between populations in the East Atlantic is also confirmed by the trajectories maps. There are not yet enough information from AOTTP about the West side but there are already some indications of BET migration from both the East to NW and SW. There are also already indications of YFT migration from SE to NW and SW. There are not yet any indications of SKJ migrations between the East and West. Further analyses are necessary and recommended.

The results from those 3436 tropical tunas tagged during January and February 2017 in the Closure area, compared with those 5324 tagged during same period but outside of the Closure area show a much lower recovery percentage up to August 2017 than those tagged within the time/area closure. Further analyses are necessary but these preliminary results do suggest some positive effects. The data show that most of the fish tagged inside of the area/time Closure and recovered outside went to the NW.

References

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Table 1. Number of tropical tunas tagged in the Atlantic Ocean: comparison between AOTTP and historical ICCAT database.

Campaigns	BET	YFT	SKJ	LTA	WAH	BLF	FRI	Total
AOTTP	14943	19143	20980	762	23	9	1	55867
Historical ICCAT	11225	18228	42747	- - -	-			72200

Table 2. Number of tropical tunas recovered in the Atlantic Ocean: comparison between AOTTP and historical ICCAT database.

Campaigns	BET	YFT	SKJ	LTA	WAH	BLF	FRI	Total
AOTTP	3403	4496	2249	158	0	0	1	10307
Historical ICCAT	2878	1562	6849	- - -	-			11289

Table 3. Number of tropical tunas tagged per Stretched Fork Length class (cm) under AOTTP.

20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100-110	110<
BET	12	1355	5038	4079	3273	682	215	196	40	39
BLF	0	3	5	1	0	0	0	0	0	0
FRI	0	0	1	0	0	0	0	0	0	0
LTA	2	47	563	148	1	1	0	0	0	0
SKJ	11	4834	10855	4661	570	25	0	0	0	0
WAH	0	0	0	1	0	0	0	1	1	20
YFT	4	5517	7972	3059	1564	502	232	132	30	93

Table 4. Summary of times at liberty (number of days), reporting rates and tag-shedding rates (percentages) per species under AOTTP.

Parameters	BET	YFT	SKJ	LTA	WAH	BLF	FRI	Total
Mean time at liberty	71	69	41	68	-	-	103	63
Maximum time at liberty	390	390	325	262	-	-	103	390
Reporting rate	100	70.2	63.6	-	-	-	-	68.1
Tag shedding	2.3	3.4	3.8	5.8	-	-	0	2.9

Table 5. Estimation of average linear distance travelled by month (nautical miles/month) between tagging and recovery: comparison between AOTTP and historical ICCAT database with minimal time at liberty of 390 days.

Campaigns	BET	YFT	SKJ	LTA	WAH	BLF	FRI	Total
AOTTP	133	133	273	207	-	-	-	165
Historical ICCAT	221	174	191	- - -	-			197

Table 6. BET estimation of the basic migration rate between quadrants of Atlantic under AOTTP.

Quadrants Releases	NE	SE	NW	SW
Recoveries				
NE	0.9203	0.1347	-	0
SE	0.0763	0.8633	-	0
NW	0.0019	0.0006	-	0
SW	0.0013	0.0012	-	1

Table 7. YFT estimation of the basic migration rate between quadrants of Atlantic under AOTTP.

Quadrants Releases	NE	SE	NW	SW
Recoveries				
NE	0.9103	0.0992	-	0
SE	0.0896	0.8991	-	0
NW	0	0.0009	-	0
SW	0	0.0006	-	1

Table 8. SKJ estimation of the basic migration rate between quadrants of Atlantic under AOTTP.

Quadrants Releases	NE	SE	NW	SW
Recoveries				
NE	0.9420	0.0942	-	0
SE	0.0573	0.9057	-	0
NW	0.0006	0	-	0
SW	0	0	-	1

Table 9. Number of tropical tunas tagged in January and February 2017 inside and outside of the Closure area under AOTTP.

Tagging location	BET	YFT	SKJ	LTA	BLF	FRI	Total
Inside of the Closure area	920	1797	703	12	4	-	3436
Outside of the Closure area	1497	2746	811	269	-	1	5324

Table 10. Recovery percentage (%) up to August 2017 of those tropical tunas tagged during January and February 2017 inside and outside of the Closure area under AOTTP.

Tagging location	BET	YFT	SKJ	LTA	BLF	FRI	Total
Inside of the Closure area	17.1	14.5	8.9	0	0	-	13.9
Outside of the Closure area	24.8	32.9	16.2	19.3	-	100	27.4

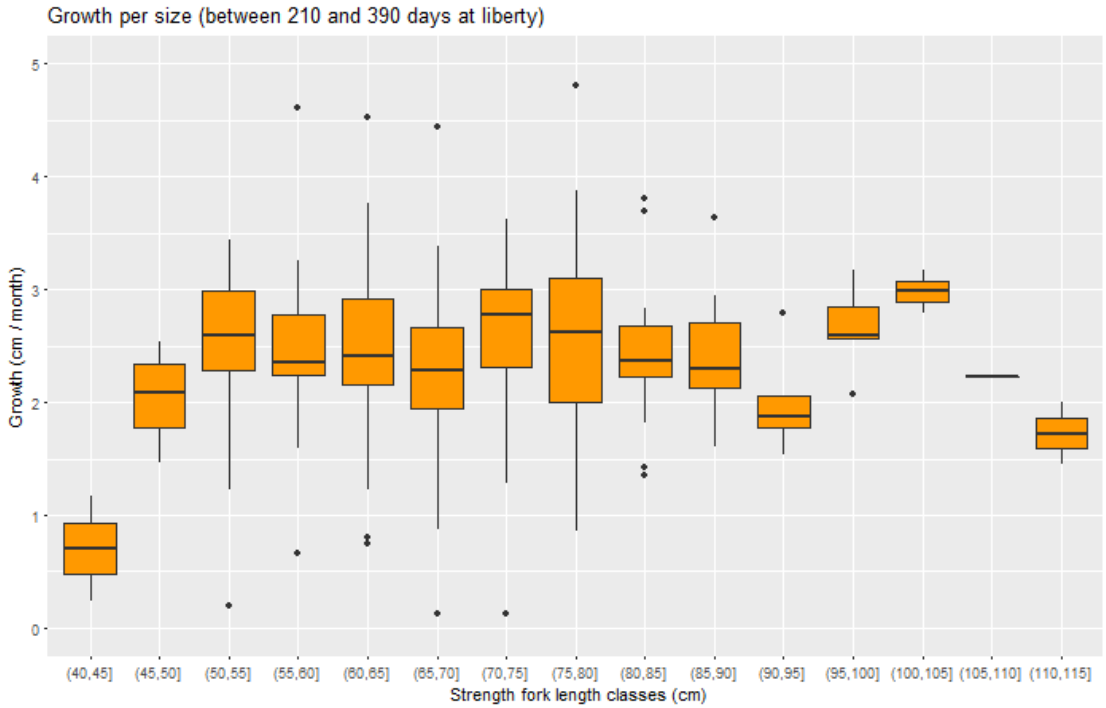

Figure 1. BET monthly growth rate (cm/month) by stretched fork length classes (cm) between tagging and recovery with a time at liberty between 210 and 390 days from AOTTP data.

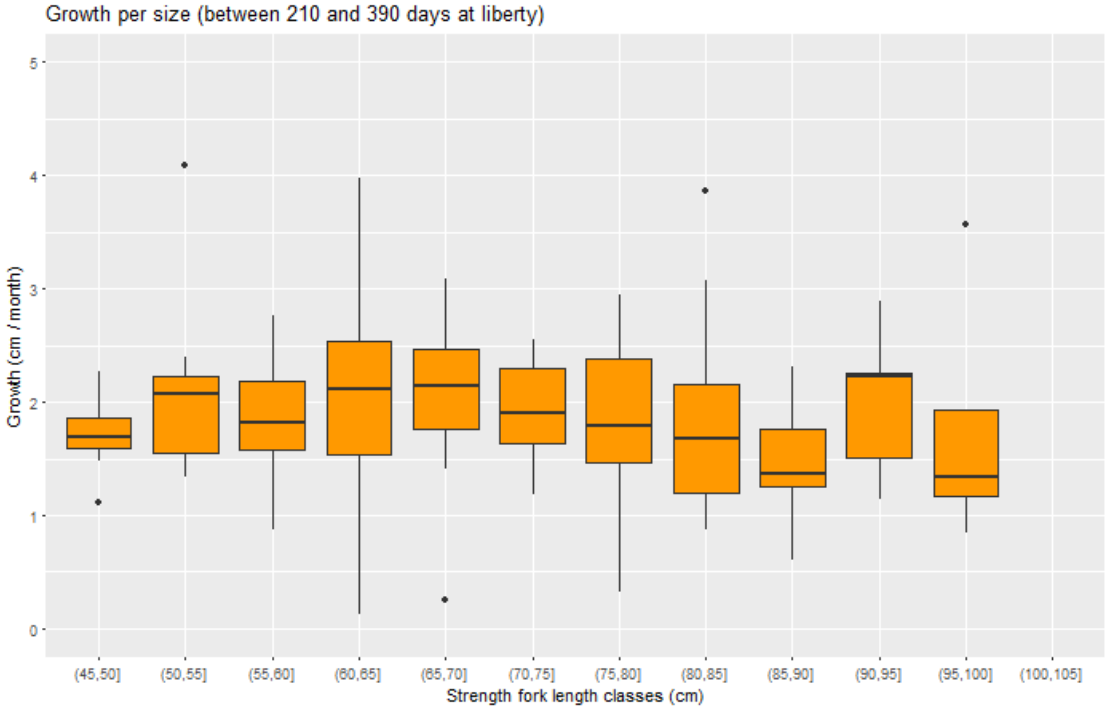

Figure 2. BET monthly growth rate (cm/month) by stretched fork length classes (cm) between tagging and recovery with a time at liberty between 210 and 390 days from the ICCAT historical database.

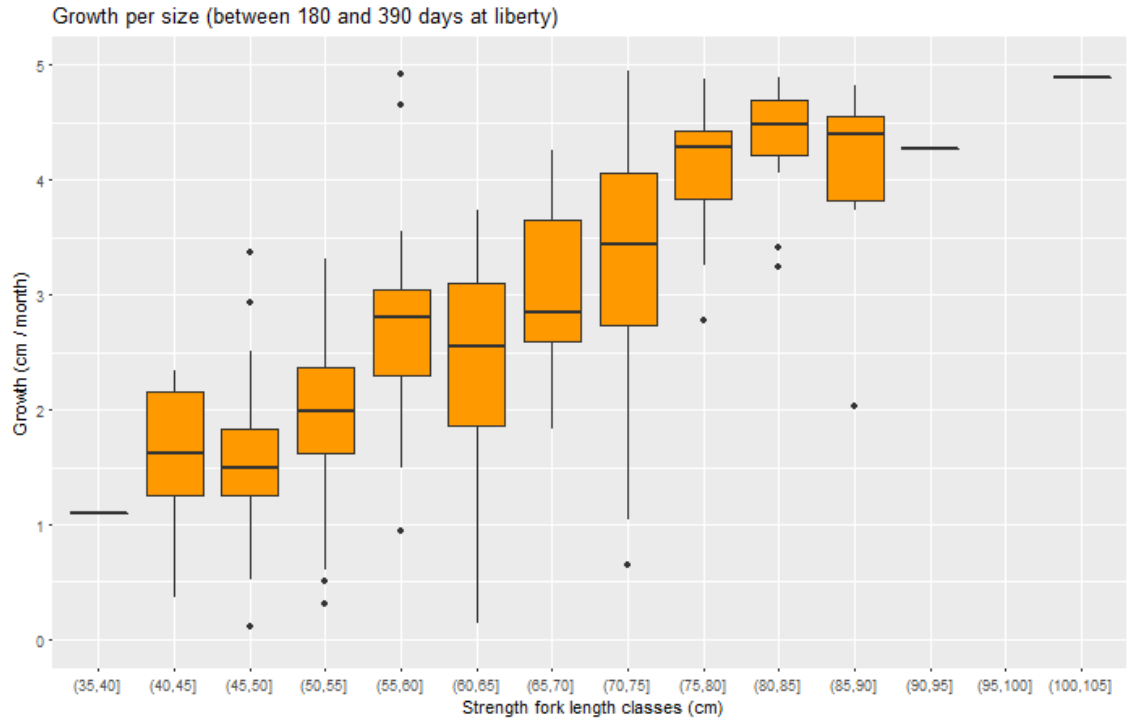

Figure 3. YFT monthly growth rate (cm/month) by stretched fork length classes (cm) between tagging and recovery with a time at liberty between 180 and 390 days from AOTTP data.

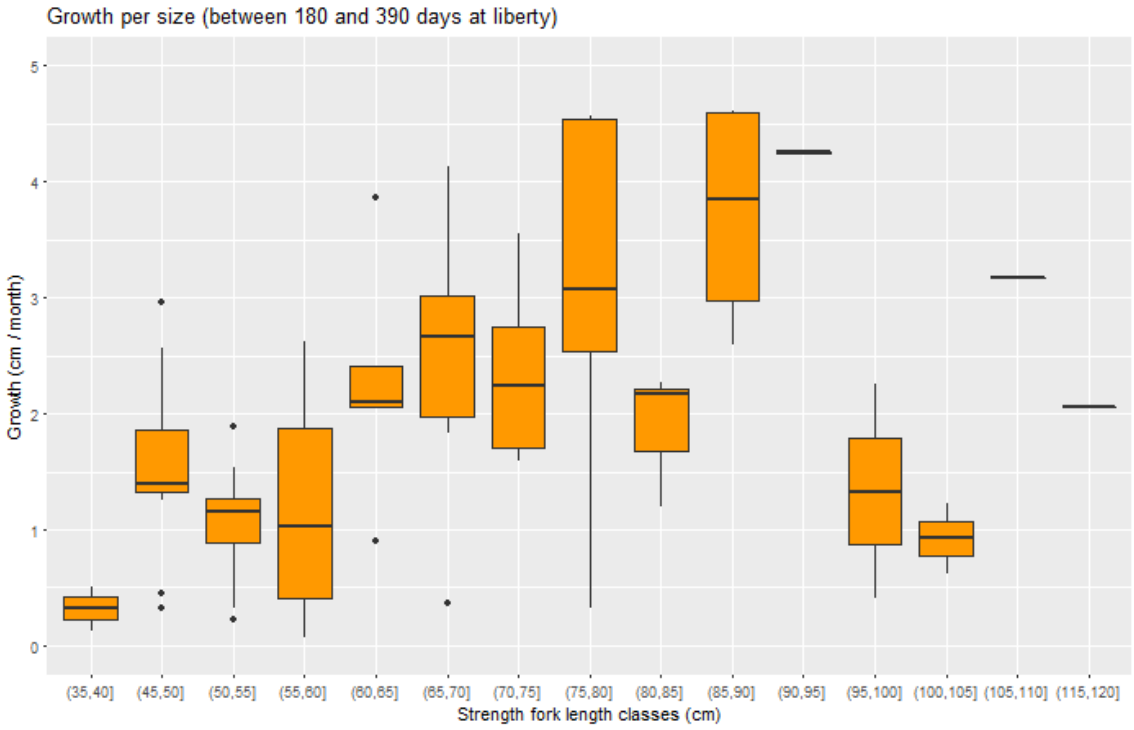

Figure 4. YFT monthly growth rate (cm/month) by strength fork length classes (cm) between tagging and recovery with a time at liberty between 180 and 390 days from the ICCAT historical database.

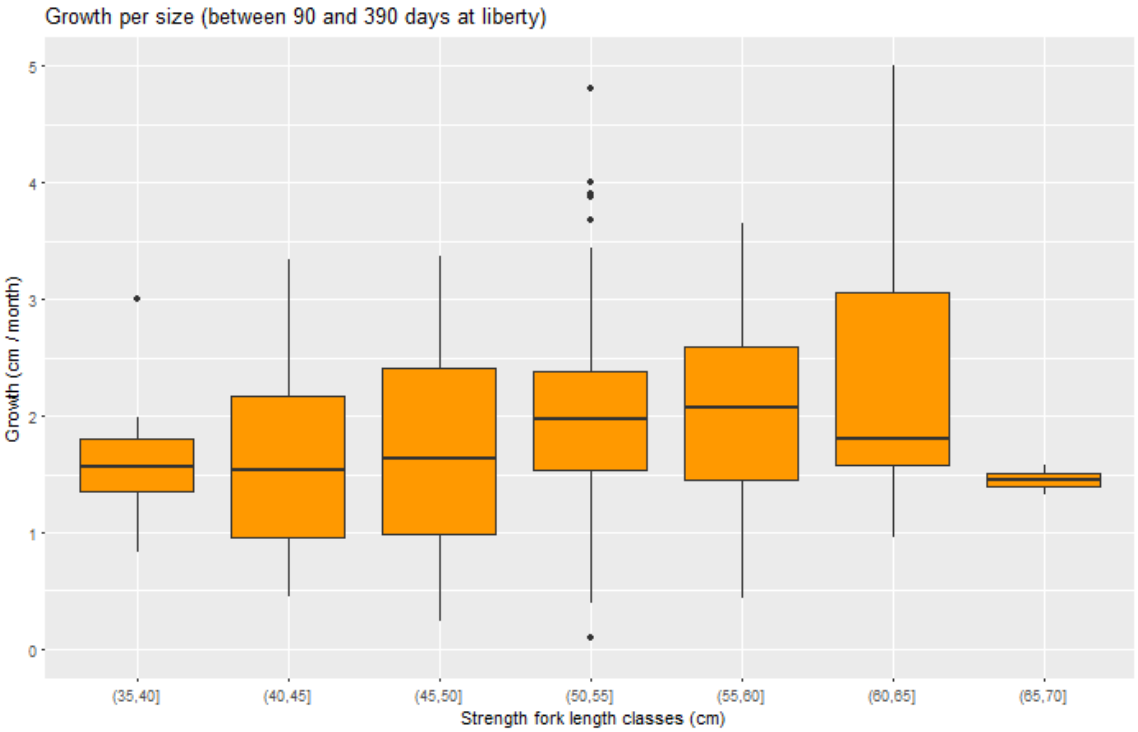

Figure 5. SKJ monthly growth rate (cm/month) by stretched fork length classes (cm) between tagging and recovery with a time at liberty between 90 and 390 days from AOTTP data.

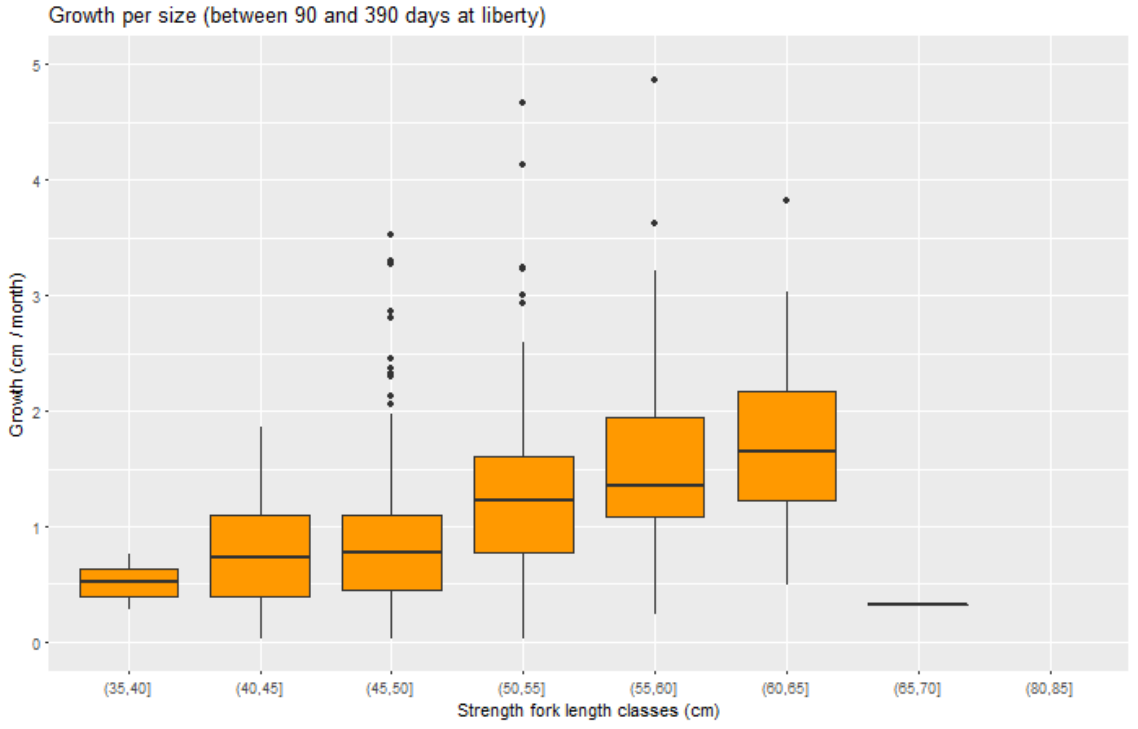

Figure 6. SKJ monthly growth rate (cm/month) by stretched fork length classes (cm) between tagging and recovery with a time at liberty between 90 and 390 days from the ICCAT historical database.

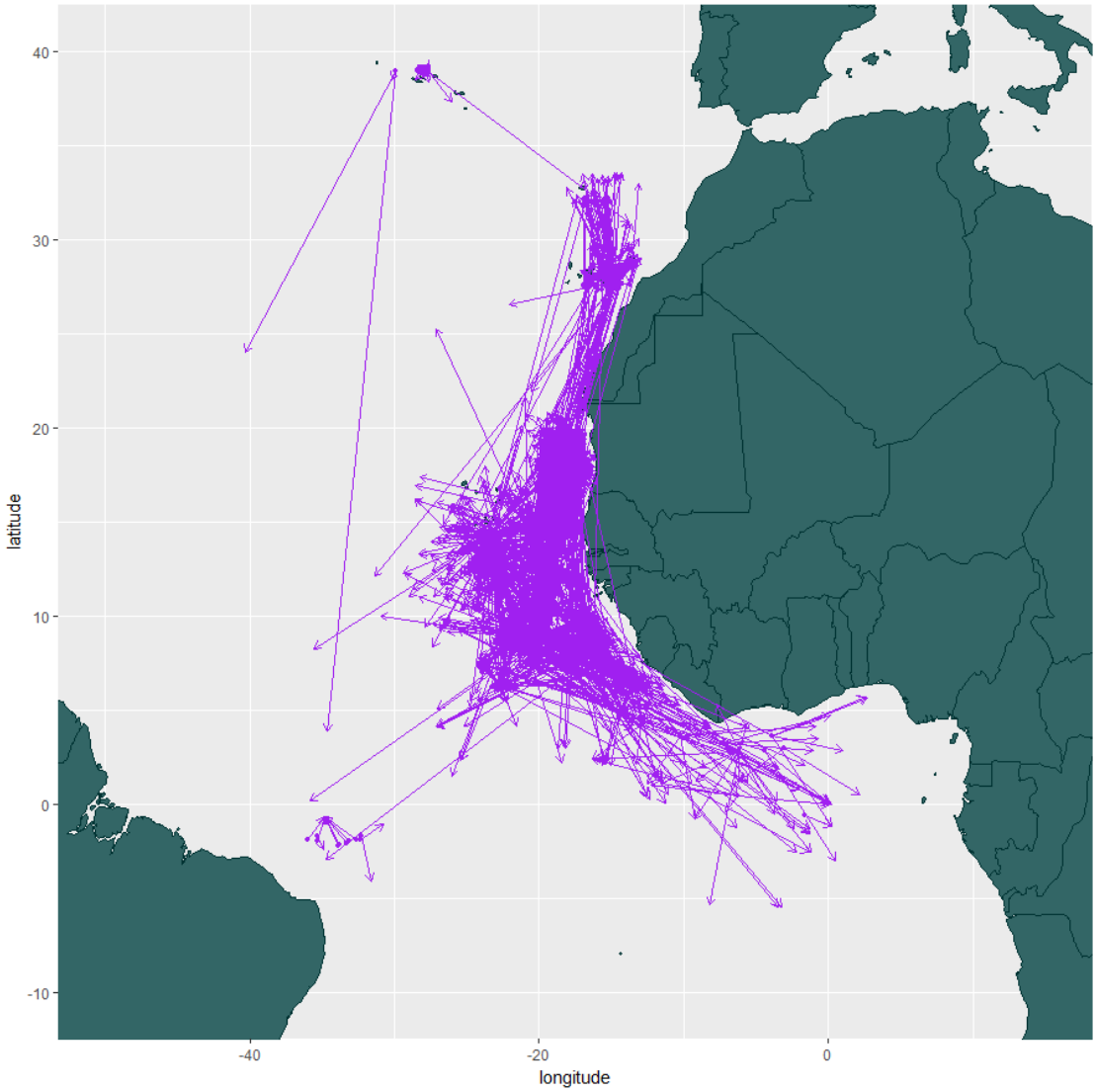

Figure 7. BET trajectories between tagging and recovery estimated by drawing a straight line between the points of release and recapture from AOTTP data.

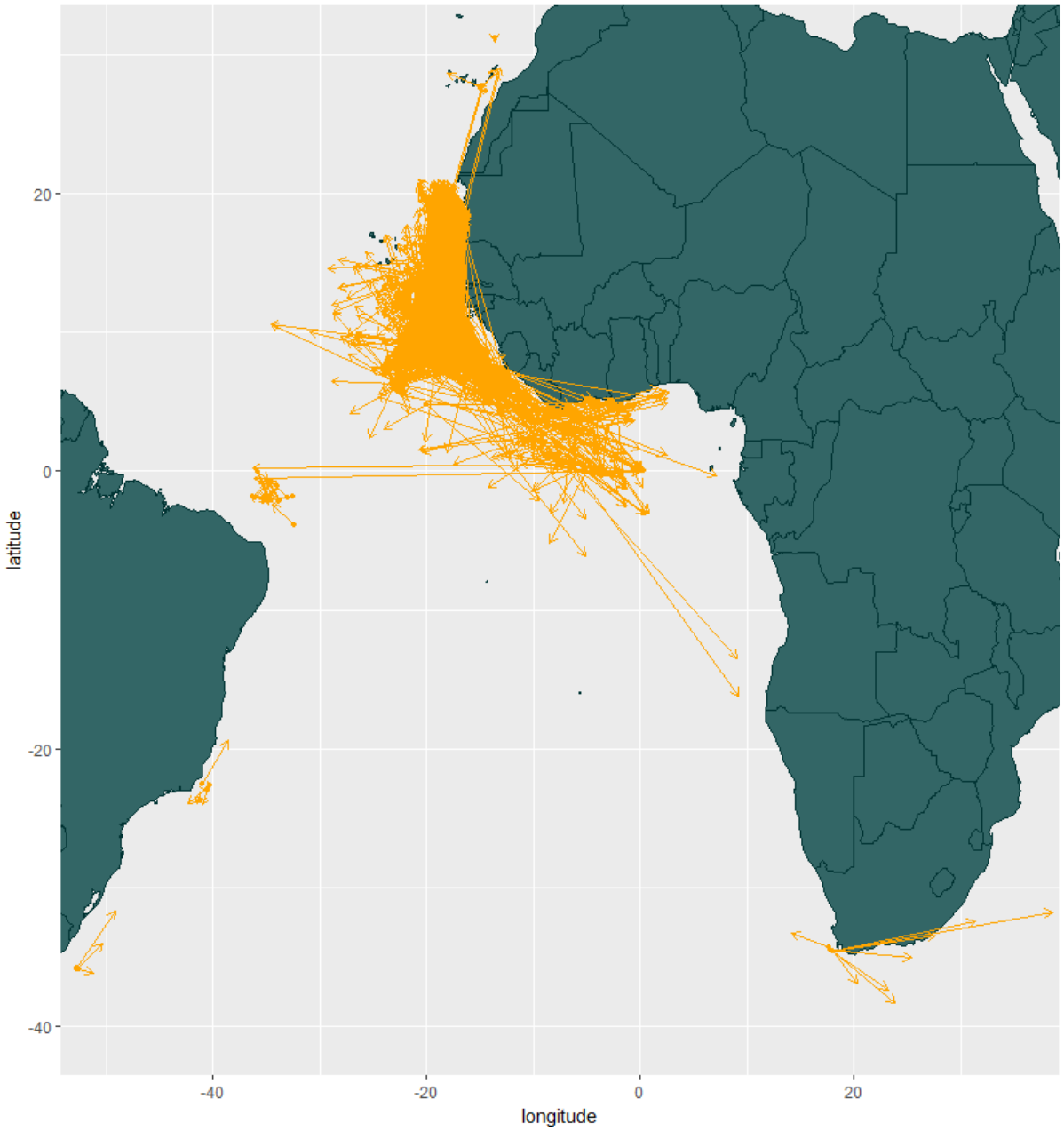

Figure 8. YFT trajectories between tagging and recovery estimated by drawing a straight line between the points of release and recapture from AOTTP data.

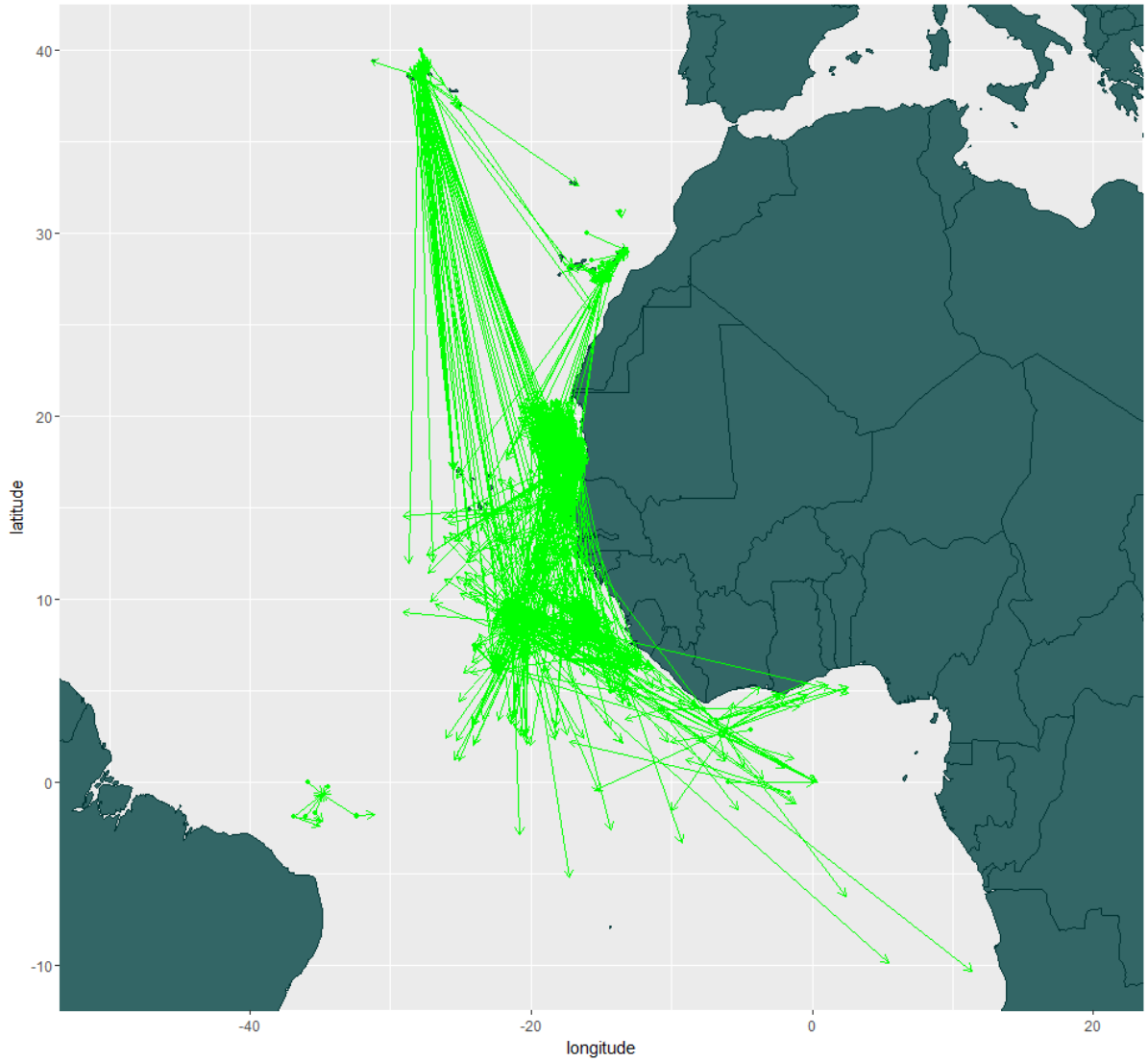

Figure 9. SKJ trajectories between tagging and recovery estimated a drawing a straight line between the points of release and recapture from AOTTP data.

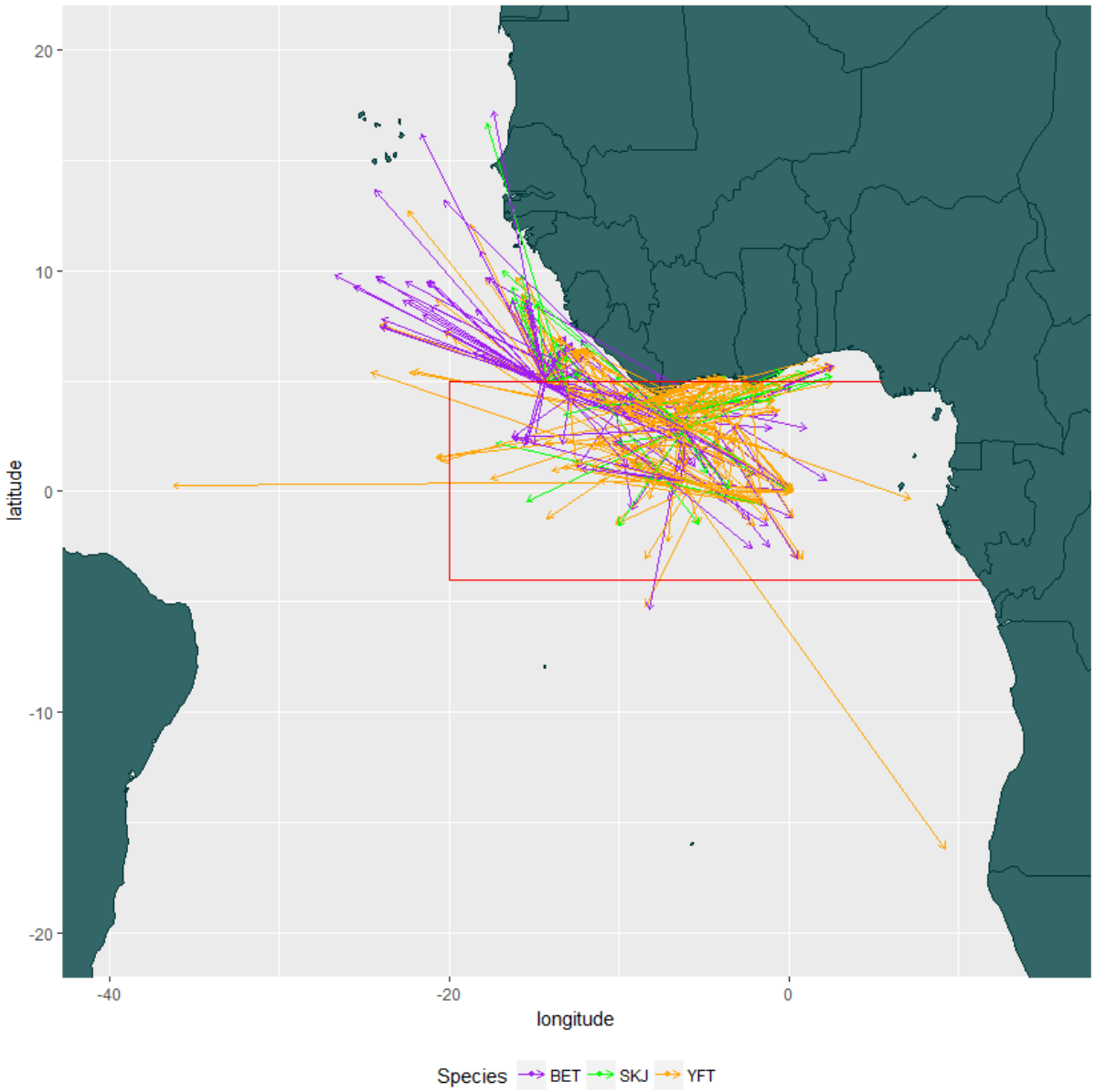

Figure 10. Tropical tuna trajectories between tagging and recovery drawing a straight line between the points of release and recapture from those tagged during January and February 2017 inside of the Closure area (closure area limit in red color).