EXPLOITATION OF LARGE YELLOWFIN TUNA CAUGHT IN FREE SCHOOLS CONCENTRATIONS DURING THE 2013 SPAWNING SEASON (DECEMBER 2012-MAY 2013)

Alain Fonteneau[1], Pedro José Pascual Alayón[2] and Francis Marsac[3]

SUMMARY

An analysis of the EU PS free school fishery during the period December 2012 to May 2013 is showing large quantities of yellowfin caught during the active exploitation of six tuna concentrations, these tunas being caught in small fishing areas and during limited periods. This study analyzes these fishing concentrations: their duration, daily fishing effort (number of vessels, numbers of sets), daily catches and CPUE, sizes of the areas fished and sizes of yellowfin caught during these peculiar fishing events. This analysis is showing that 2 distinct types of fishing efforts targeting free schools were developed during the period: fishing effort targeting isolated free schools and fishing efforts in already localized tuna concentration previously identified by other vessels. An apparent movement pattern of these large yellowfin caught during their spawning season is shown, this movement being consistent with results from gonads status and from tagging and recoveries. Based on these results the existence of 3 types of large yellowfin concentrations has been proposed: pre spawning, spawning and post spawning concentrations, each type of concentration showing peculiar characteristics.

RÉSUMÉ

Une analyse de la pêcherie de senneurs communautaires opérant sur banc libre entre décembre 2012 et mai 2013 montre de grandes quantités d'albacore capturées pendant l'exploitation active de six concentrations de thonidés, ces thonidés étant capturés dans de petites zones de pêche et pendant des périodes limitées. Cette étude analyse ces concentrations de pêche : leur durée, l'effort de pêche journalier (nombre de navires, nombre d'opérations), les prises journalières et la CPUE, les tailles des zones pêchées et les tailles de l'albacore capturé pendant ces opérations de pêche particulières. Cette analyse montre que deux types distincts d'effort de pêche ciblant des bancs libres ont été mis au point pendant la période : effort de pêche ciblant des bancs libres isolés et effort de pêche déployé sur des concentrations de thonidés déjà localisées ayant été antérieurement identifiées par d'autres navires. Un schéma de déplacement apparent de ces grands albacores capturés pendant leur saison de reproduction se dégage, ce déplacement étant conforme aux résultats obtenus de l'état des gonades, du marquage et des récupérations. Sur la base de ces résultats, l'existence de trois types de concentrations de grands albacores a été proposée : concentrations de préponte, de ponte et de postponte, chaque type de concentration montrant des caractéristiques particulières.

RESUMEN

Un análisis de la pesquería de cerco sobre banco libre de la UE durante el periodo de diciembre de 2012 a mayo de 2013 presenta grandes cantidades de rabil capturado durante la explotación activa de seis concentraciones de túnidos, siendo estos túnidos capturados en pequeñas zonas de pesca y durante periodos limitados. Este estudio analiza estas concentraciones de pesca: su duración, el esfuerzo pesquero diario (número de buques, número de lances), las capturas diarias y la CPUE,

[1] Fonteneau Alain, reitred IRD scientist, 9 Bd Porée, 35400 Saint Malo, France. E-Mail: alain.fonteneau@ird.fr
[2] Alayón Pedro José Pascual Alayón: IEO Scientist, C.O. de Canarias, Apartado 1373, 38080 Santa Cruz de Tenerife, Spain. Email: pedro.pascual@ca.ieo.es
[3] Marsac Francis, IRD scientist UMR MARBEC, CRH, CS30171, 34203 Sète, France. Email francis.marsac@ird.fr

los tamaños de las zonas pescadas y las tallas del rabil capturado durante estos peculiares eventos de pesca. Este análisis muestra que durante el periodo se desarrollaron dos tipos diferentes de esfuerzo pesquero dirigido a los bancos libres: el esfuerzo pesquero dirigido a los bancos libres aislados y el esfuerzo pesquero en concentraciones de túnidos ya localizadas previamente identificadas por otros buques. Se muestra un claro patrón de movimiento de estos grandes rabiles capturados durante la temporada de desove, siendo este movimiento coherente con los resultados del estado de las gónadas y del marcado y recaptura. Basándose en estos resultados, se ha propuesto la existencia de tres tipos de concentraciones de rabiles grandes: concentraciones pre desove, desove y post desove, y cada tipo de concentración presenta características peculiares.

KEYWORDS

Yellowfin, spawning migrations, purse seining,
reproductive behaviour, spawning grounds, fishing effort

1. Introduction

Tuna concentrations and their exploitation by PS in the Atlantic have been studied by various authors *(inter alia* by Fonteneau 1986, Ravier et al 2000), but these studies have not been targeting the exploitation of sequential concentrations. The exploitation of various concentrations of large yellowfin that are visible in the PS fishery data during the period December 2012-May 2013 in the Atlantic, offers an interesting field for such study. A major concentration of large yellowfin fished by PS in January 2013 was identified by SCRS in 2014 during the analysis of the FAD moratorium, but it was never studied by scientists. Further examination of the free school fishery during this period is showing that in fact, most of the large yellowfin caught during the period December 2012 to May 2013 were caught during a cascade of 6 tuna concentration: most of these large yellowfin being caught in very small fishing areas and during limited periods. Spatial and temporal distribution of tropical tunas is characterized by fishes congregating in schools and schools gathering into concentrations. These spectacular concentrations are often related to the biology of adult yellowfin and to its spawning behavior concentrated in large surface schools. These concentrations are very important because purse seiners can obtain considerable catches and high CPUEs during short period of time. They also widely condition the fishing effort of PS targeting free schools: the capacity of PS to identify these concentrations, to communicate between cooperating vessels and to efficiency exploit them will widely condition tuna catches on those concentrations. The goal of this work is to analyze several important concentrations of large yellowfin that have been exploited during the period between December 2012 and May 2013 by the fleet of purse seiners fishing under 2 EU flags France and Spain) and under various flags of non EU countries; this fleet will later be call the EU&al PS. This study will analyze each of these fishing concentrations: their duration, the daily fishing effort (number of vessels, numbers of sets), the daily catches and CPUE, the sizes of the areas fished and the sampled sizes of the yellowfin caught during these peculiar fishing events. It will also try to position these fishing concentrations in relation to the seasonal yearly migration of large yellowfin that are assumed to do yearly seasonal spawning migrations in the Guinea Gulf.

2. Data & method

This work is simply based on the basic fishery data, log books and multispecies sampling of the EU & al fleet of purse seiners, namely:

- Log book data of EU&al PS fleets, with the daily catches of all PS, on FADs and on free schools, including their exact locations in ° & minutes. These log books also include information on catch by size category, and our study will primarily focus on large yellowfin at sizes over 10 kg (or 80cm), most of these yellowfin being

potential spawners. These log book data are covering 100% of the EU&al PS fishery during the studied period. Data have been corrected for species composition (ECD file), based on the results of the multispecies samples of the catch per set and using the TT software built by the EU scientists (Pianet *et al.* 2000).

- Sampled sizes of yellowfin caught, associated with 1° locations and day of the catches, based on multispecies random sampling (NN.T & species files). Large number of samples have been collected during these fishing events, 387 samples (with an average of 70 yellowfin measured in each sample) corresponding to a total of 11.6 tons of tunas sampled. Results from this active sampling allows to estimate precisely estimate the sizes and the species composition of tunas caught in each of these concentrations.

This work analyzes the time and space distribution of catches, fishing efforts and size of large yellowfin caught during these dense concentrations of free schools, with emphasis on large yellowfin caught in free schools during the period December 2012-May 2013, within and outside concentrations. It also examines the types of fishing efforts developed on free schools and on FADs by the EU&al PS and the apparent movement of large yellowfin based on their daily catches by area.

3. Yellowfin concentration: characteristics of their exploitation

3.1 Overview

The analysis of daily catches of large yellowfin during the period December 2012 to May 2013 is showing that a great majority of free schools catches during the period were observed on only 6 fishing events or concentrations. Table 1 gives a summarized overview of the fishing activities and of the main characteristics of each of these events.

3.2 Fished areas during concentrations

The map of total catches on free schools in the concentration strata observed during the December 2012-May2013 period by the EU&al PS fleet is shown by **Figure 1**, while **Figure 2** is showing the nominal fishing effort and the free schools catches by species during the same period. This map is clearly showing that during the studied period the PS fleet was active in a wide area, but catching few free schools outside the concentration strata. The exact location of these events (position of each set in mile) are shown by **Figure 3**, a Figure showing the very small sizes of the 4 concentrations exploited during the January to March period, and the larger but quite limited sizes of the 2 concentrations in December 2012 and April-May 2013. The monthly surface of the areas fished in the concentration strata and outside of them is shown by **Figure 4**, with the monthly numbers of 1° squares explored by the EU&al PS. This Figure is showing that areas explored monthly outside the concentration areas were always much larger than the areas fished inside concentrations.

3.3 Catches

Daily catches by PS fleets and flag, inside and outside concentrations, are shown in **Figure 5**. Concentrations in December and April-May were characterized by sustained high catches over 4 weeks, whilst concentrations in January-March were exploited during shorter durations (*ca.* 2 weeks). During the whole studied period, concentrations were exploited by the 3 fleets (France, Spain and associated flags). **Figure 6** is showing the monthly catches of large yellowfin by the EU&al PS inside and outside the concentration areas. Catches made in the concentrations were much higher during the whole studied period, except February 2013 when yellowfin catches were low and at a similar level inside and outside concentrations. The monthly species composition (in percentage) in concentration areas fished by the EU&al PS is shown by **Figure 7**. yellowfin was always the dominant species (an average of 90% of the catch) while the species composition of free school catches in the Guinea Gulf was more heterogeneous and variable (**Figure 8**): still showing dominant catches of yellowfin, however with lower proportion, and increasing ratio of SKJ at the end of the studied period (April and May 2013). The species composition by size categories of the 387 samples of tuna catches collected on the studied concentrations (representing 11.6 tons of tunas) is shown on a Definetti plot in **Figure 9.** Samples were highly dominated by large yellowfin catches, while few large BET was also observed in a significant number of samples. It should be noted that free schools catches were widely dominant in all the studied concentrations (**Figure 10**), while the amount of FAD catches was significant only in May 2013. It can also be noted (**Figure 11**) that the amount of FAD catches appears to be related

to the size of the area fished in each concentration: the larger the area fished (represented in number of 1° squares), the higher the FAD catches. Unlike free school catches, FAD catches are not dense at a fine spatial scale.

The numbers of free schools sets, inside and outside the concentration strata and the average catch per set of large yellowfin on free schools, inside and outside the concentration strata are shown by **Figure 12 and 13**. These 2 Figures are showing that the average catch per set of large yellowfin was always much higher in the concentration strata, while the numbers of sets were dominant in the concentrations fished in December 2012 and in April-May 2013.

3.4 Fishing efforts

Monthly total fishing efforts of the EU&al PS inside and outside concentration areas are shown in **Figure 14**. In December 2012 and April-May 2013, the nominal fishing efforts developed by the EU&al PS fleet was at a similar level inside and outside concentrations, while the fishing effort in the concentration strata were lower or much lower in January, February and March.

3.5 CPUEs

Monthly nominal CPUEs (t/day) of the EU&al PS inside and outside concentration areas are shown in **Figure 15**. Yellowfin CPUEs were high inside concentrations (average= 22 t/day) and very low outside (average= 1.7 t/day).

3.6 Average fishing zones and situation observed in 2013

It is interesting to compare the fishing zones and the monthly levels of large yellowfin catches for the studied period to the average Figures recorded over a longer period (1991-2015). The average catch pattern of large yellowfin is represented for different months: December (**Figure 16a**), 1st quarter (**Figure 16b**) and April-May (**Figure 16c**). Comparing these maps with the location of monthly concentrations (see **Figure 1**), the dense fishing zones observed in December 2012 are unusual as catches tend to be geographically scattered in December. However, concentrations formed in Jan-May 2014 were found in the same areas as usual. The anomalies occurred mostly in terms of production (**Figure 17**). Yellowfin Catches in December 2012 were 4 times higher than average and slightly above average in January 2013. By contrast, yellowfin catches in Feb-April 2013 were lower than average (twice less). Finally, catches in April-May 2013 were at normal levels. The fishing locations observed during the studied period may also usefully be compared to the average catches by 1° squares during the average period 1991-2015: in 2 average periods, January to May and June to December (**Figure 18a and 18b**). These maps are showing that the average catches of large yellowfin during the second half of the year are lower, more scattered than during the January-May period, and in quite distinct fishing zones, for instance showing much larger catches east of 5°W in an axis between Cote d'Ivoire and Cape Lopez.

3.7 Sizes of the large yellowfin

Sizes caught during the studied fishing events have been well sampled (table 1), allowing valid comparison of sizes caught during each of the concentration. This analysis is showing that sizes of the large yellowfin caught during the period December 2012 to May 2013 were nearly identical, and always dominated by a unimodal size distribution and a peak of catches at 152-154 cm (or 65-70 kg) (**Figure 19**), all these yellowfin being well above the size at first maturity at about 1 meter (Albaret 1975). It can also be noticed that sizes of yellowfin caught in the concentration were widely distinct and much larger, compared to the yellowfin sizes caught between June and December 2013, this difference being especially important in the major fishing ground of Cap Lopez where yellowfin caught during summer in free schools are always caught at much smaller sizes. It should also be noticed that the small quantities of yellowfin caught outside the concentrations were showing the same sizes (**Figure 20**).

4. Discussion: dynamics and exploitation of these large yellowfin concentrations

4.1 Fishing effort & concentrations

Monthly fishing efforts of PS were distributed in wide areas during the period December 2012- May 2013, but very few free schools and large yellowfin were caught outside the concentration time and area strata. Consequently, the fishing efforts that were really & efficiently targeting free schools of large yellowfin were mainly concentrated in very small time & space strata where many surface free schools of large yellowfin have been spotted by purse seiners. It would appear based on our knowledge of the fishery, that most often each concentration was first identified by a single vessel and that its skipper has been communicating this information to other PS. As a result, the efficiency of the PS fleet to harvest these concentrations appears to be widely dependent of the communications between vessels. Fishing efforts were mainly targeting free schools and large yellowfin in the studied strata where FADs were seldom fished. The exploitation pattern of these concentrations is a typical case illustrating a free school fishing tactic. As a result, the total yearly catches & CPUEs of large yellowfin are driven by the number & sizes of concentrations that have been identified & fished by PS, and the capacity of PS to locate the small strata where large concentrations of large yellowfin are located is a fundamental component in the free school fishing effort. A major component of the PS fishing effort targeting free schools is linked to the fishing efficiency of each PS to catch free schools when a fleet of PS is already exploiting a given small concentration of large yellowfin free schools. This basic question would need a peculiar statistical analysis of the fishing effort at a very small scale (hours and mile) based on the detailed catch & effort data in each concentration stratum. Its data should necessarily be obtained from observers and from fine scale VMS positioning, not only from log books (however such study has never been done).
The identification of tuna concentrations by the PS fleet is also essential to allow their full exploitation: there is no doubt that the 4 very small concentrations fished during the January to March period, could have been missed by the PS fleet. Then it should be noted that extensive searching trajectories in offshore areas and fast communication between vessels is essential to allow the identification and the full & fast exploitation of these concentrations by the PS fleet: this real time communication between skippers is quite complex as it may be working between skippers from the same flag and company, but also among friends fishing on PS with distinct flags. Furthermore, the beginning of the exploitation of a tuna concentration may also be identified by electronic spying, and some concentrations may also be identified by supply vessels, and not by PS. This complex point would need further studies, for instance based on observers' data and on ad hoc interviews with skippers.

4.2 Biology & behaviour of large yellowfin during the period: feeding, spawning and migration

This analysis has underlined the importance of concentrations in the PS fishing tactic. Based on our observations and on past studies on the ecology and life cycle of tunas in the East Atlantic, it may be hypothesized that this observed pattern in the seasonal distribution of large yellowfin catches PS corresponds to a typical spawning migration, a migration showing a cascade of 3 types of concentrations:

1) **Pre spawning concentrations**: in western equatorial area, in a quite wide area & during 1 month, probably a feeding zone.

2) **Spawning concentrations**: in the western central Guinea Gulf, close to the Equator, in very small areas & during very short durations.

3) **Post spawning concentrations**: in a north western fishing area off the « Guinea dome », a productive area, and in a quite wide fishing zone area, during 2 months: probably a feeding zone? The higher relative abundance of FAD catches in this strata would also indicates that the area was probably a feeding zone for the small tunas associated to FADs.

This potential biological heterogeneity in the yellowfin concentrations would be similar to the heterogeneity observed for southern bluefin tunas, a species typically showing these 3 types of concentrations in relation with spawning (**Figure 21**). It may also be hypothesized based on the present analysis that the feeding and spawning behaviour of these large yellowfin and their schooling in large surface schools, that are easily identified and caught by PS, was widely distinct in these 3 types of concentrations. This point would need to be clarified, based on other more detailed types of information, for instance from observers on the biological feeding and/or spawning conditions of these tunas and from VMS showing the daily trajectories of all the PS and the exact positions of every sets. It can further be noticed that the December 2012 fishing zone was positioned in the South west of the areas where large yellowfin are mainly distributed during summer time, between 5° & 15°N, west of 20°W, as shown by the average yellowfin catches by LL since 1955 (**Figure 22**). This hypothetical migration pattern synthesized by **Figure 22** would be in agreement with most scientific studies on this matter (*inter alia* by Albaret 1975, Fonteneau 1981,

Foucher 1994, Fonteneau and Pallares 1996), this migration pattern being also in agreement with the multiple transatlantic recoveries of large yellowfin, a great majority of these tunas being caught during the spawning seasons & in our potential spawning zones. It can also be hypothesized based on the catch at size data that these large yellowfin were belonging to the same group of tunas showing a typical seasonal spawning migration in the Guinea Gulf. It should also be noticed that the spawning concentrations are observed during the January to March period in very small time and area strata, probably in relation with a peculiar spawning behaviour that is typical of many tunas (for instance for Mediterranean and showing a peculiar hourly pattern of vertical movements in relation with their spawning, Medina & al 2013).

4.3 What are the real spawning sizes of Atlantic yellowfin?

This study of the spawning concentrations observed during the 1st quarter of 2013 may also be indicative of the sizes of adult yellowfin that are actively spawning in the Guinea Gulf. Most assessment models have been assuming that all adult yellowfin are doing yearly spawning after their size/age at maturity, for instance following the fecundity at size estimated by Diaha 2016 and used in the 2016 yellowfin stock assessment, shown by **Figure 23** in comparison with yellowfin sizes caught in the 2013 concentrations. However our analysis of the 2013 concentrations are providing a confirmation that sizes of yellowfin caught in spawning concentrations during the 1st quarter are showing a clear mode at 150 cm, at much larger sizes than the estimated sizes at first maturity, and with very few yellowfin caught in a size range between 1m and 1,4m. On the opposite, it can be noted that sizes of adult yellowfin caught by longliners in deep waters and by PS outside spawning strata are showing a widely distinct size structure: a high proportion of yellowfin smaller than 140 cm, and very seldom the modal sizes of spawning concentrations above 150 cm. In such context, it could be hypothesized that the small/young adult yellowfin at sizes lower than 140 cm are playing a minor role in the yearly spawning of the yellowfin stock, because they are seldom visible in the spawning concentrations. On the opposite, the yellowfin sizes caught in such spawning concentrations would be indicative of the sizes and ages of yellowfin that are mostly contributing to the spawning of the stock. This point would need further investigation.

5. Conclusion & recommendations

During the studied period, the free school fishery was totally dominated by large catches of large yellowfin caught in small & peculiar areas: these fished areas corresponding to very small proportion of the area searched by PS fleets in the East Tropical Atlantic and the Guinea Gulf. Sizes of the many yellowfin sampled in each of these concentrations are strongly showing that the same group of large yellowfin, same size classes has been exploited during these 6 concentrations. Following this work, the following research recommendations could be done:

- The analysis of the large yellowfin concentrations fished by the EU PS should be generalized to the yellowfin concentrations that have been fished during other years, for instance targeting the wider period 1980 to 2015.
- Further research on satellite imagery data should also be developed in relation with these observed concentrations in order to identify if they were related to localized peaks of primary productivity (such as the 2005 yellowfin concentration in the Indian Ocean analyzed by Fonteneau & al 2008 that was clearly in relation with such environmental localized anomaly).
- The analysis of fishery data should be associated to the analysis of gonad status of when these data have been collected, in order to validate the potential spawning migration of these large yellowfin. Biological data of gonad status and stomach content from large yellowfin caught in these various types of concentrations should be routinely collected in the future (preferably by observers) and analyzed by scientists.
- Detailed analysis of fishery data should be conducted on highly detailed observer data, for instance on the schooling behaviour of tunas and on the depth of the schools (that are well followed by skippers) and from SMS data collected during these intense fishing events. Observers should for instance make behavioural observations on the yellowfin schools, in order to determine if these schools of large yellowfin were showing a typical feeding behaviour or the courtship behaviour that is typical of spawning (Schaefer 2001).
- The results of archival tagging done on large yellowfin would provide very useful information on the vertical behaviour of spawning yellowfin if these results can be obtained during the incoming AOTTP: then the tagging of large yellowfin in pre-spawning condition (November or December) is recommended targeting observations on the behaviour of yellowfin in January and February.

- The concept of fishing efforts targeting individual free schools and/or fishing efforts exploiting these peculiar & localized concentrations of spawners should also be fully investigated (again based on observer and on VMS data) and well handled in the standardization of large yellowfin free schools GLM CPUEs.

Bibliography

Albaret J.J. 1975. La reproduction de l'albacore (*Thunnus.albacares*, Bonnaterre 1778) dans le Golfe de Guinée. Thèse de 3ième cycle, Université de Paris 7, 163 pages.

Aranda G., Abascal F.J., Varela J.L., Medina A. 2013. Spawning Behaviour and Post-Spawning Migration Patterns of Atlantic Bluefin Tuna (*Thunnus thynnus*) ascertained from Satellite Archival Tags. PLoS ONE 8(10), 14p.

Fonteneau A. 1986. Analyse de l'exploitation de quelques concentrations d'albacore par les senneurs durant la période 1980-1983 dans l'Atlantique Est. Rec. Doc. Sci. ICCAT 25 : 81-98.

Fonteneau A. 1991. La concentration plurispécifique exploitée par 3° Sud et 15° ouest en décembre 1983 et janvier 1984 : Caractéristiques biologiques et de l'exploitation. Rec. Doc. Scient. ICCAT. Vol. 36, pp. 326-347.

Fonteneau A. and Pallares P. 1996. Interactions between tuna fisheries: A global review with specific examples from the Atlantic Ocean. In proceedings of the second FAO consultation on interaction of Pacific tuna fisheries. Shomura R.S., Majkowski J., Harman R.F.-eds. FAO Fisheries Technical Paper No. 365 pp. 84-123.

Fonteneau A., Lucas V., Tewkai E., Delgado A., Demarcq H. 2008 Mesoscale exploitation of a major tuna concentration in the Indian Ocean. Aquatic Living Resources, 21 (2), p. 109-121.

Foucher E. 1994. Dynamique saisonnière et spatiale de la ressource dans les pêcheries thonières de l'Atlantique tropical est. Thèse de doctorat. ENSAR. ORSTOM ed., TDM 131, 127 p. +annexes.

Schaefer K.M. 2001. Reproductive biology of tunas. *Fish Physiology, 19*, 225-270.

Ménard F., A. Hervé et A. Fonteneau. 1998. An area of high seasonal concentrations of tunas, 2°-4°N, 10°-20°W, the site of the PICOLO program. J. Beckett Ed. Actes du symposium ICCAT de Punta Delgada. Rec. Doc. Scient. ICCAT Vol. L (1): 405-420.

Pianet R., P. Pallares and C. Petit. 2000. New sampling and data processing strategy for estimating the composition of catches by species and sizes in the European purse seine tropical tuna fisheries. IOTC Proceedings no. 3 (2000), pp 104-139.

Ravier-C., Marsac F., Fonteneau A and Pallares P. 2000. Contribution to the study of tuna concentrations in the eastern tropical Atlantic. Coll. Vol. Sci. Pap. ICCAT; Vol. 51(1): 699-713.

Toihir I.M. 2009. Ecologie et dynamique d'exploitation des concentrations de thons tropicaux dans l'océan Indien. Rapport de stage Université de la Méditerranée, Centre d'océanologie de Marseille, Master professionnel "Environnement Marin", 52 p.

Table 1. Summary of the fishing activities and of the main characteristics of each concentration identified in the EU&al PS fishery during the December 2012-May 2013 period.

Month	catches of large YFT inside concentration t.	catch of Large YFT outside concentrations	Fishing duration number of days	Monthly surface fished inside concentration (1°)	Number of 1° squares explored with >2FD	Numbers of free schools sets inside concentrations	Numbers of free schools sets outside concentrations area	Number of YFT tunas sampled
December 2012	**9 000**	**1 204**	**31**	**5,5**	**53**	**392**	**139**	**8 742**
January 2013	**4 800**	**1 147**	**16**	**0,2**	**68**	**421**	**135**	**3 630**
February 2013	**1 160**	**2 187**	**6**	**0,2**	**110**	**195**	**192**	**2 000**
March 2013	**3 700**	**1 446**	**13 & 17**	**1.0 & 0.1**	**30**	**39**	**264**	**2 410**
April-May 2013	**8 100**	**1 378**	**46**	**10,0**	**99**	**418**	**475**	**10 424**
Total	**26 760**	**7 361**		**15,9**		**1 465**	**1 205**	**27 206**

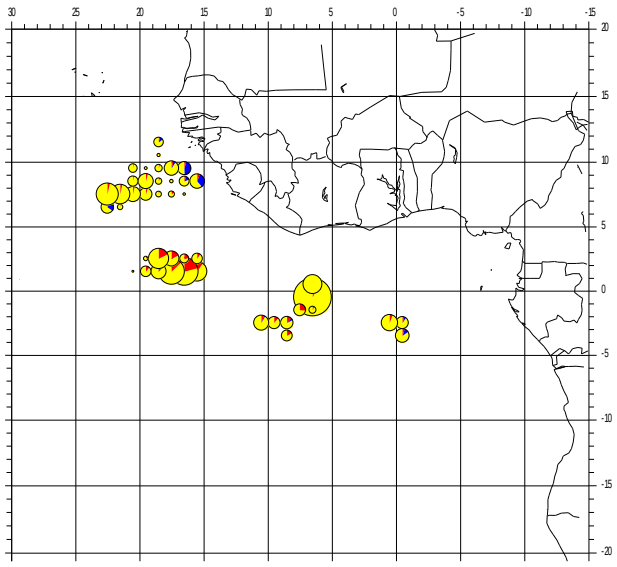

Figure 1. Map showing the 1° free schools catches, by species, in the concentration strata during the December 2012-May2013 period by the EU&al PS fleet.

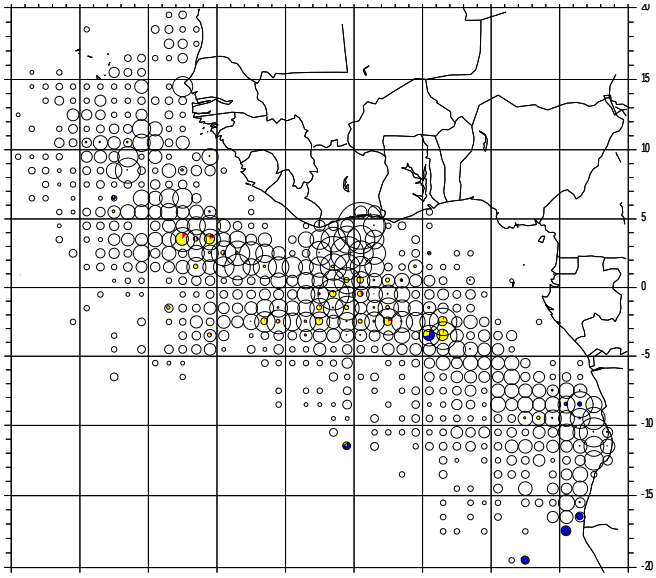

Figure 2. Map of the average fishing efforts of PS by 1° (circles) and of the reduced free schools catches (coloured circles), by species, caught outside the concentration strata (December 2012-May2013, coloured pies), EU&al PS fleet.

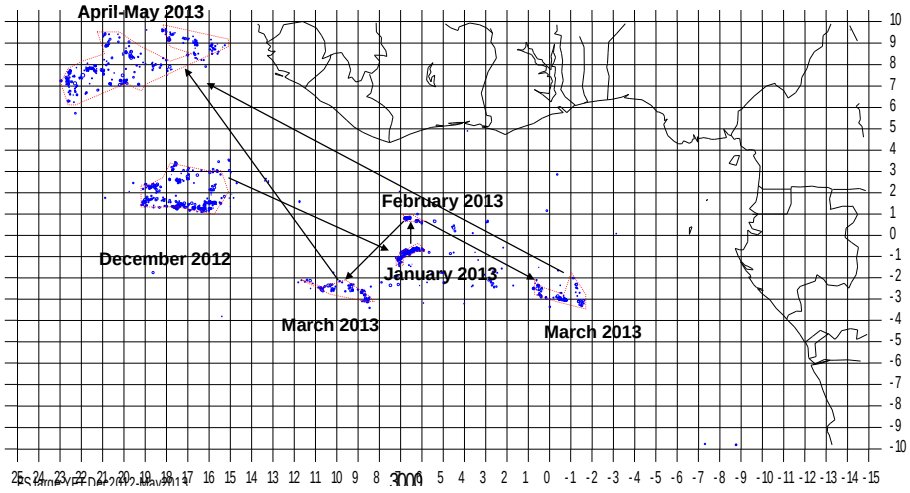

Figure 3. Fishing locations of large yellowfin (in ° & mn) and dates of each of the 6 fishing events identified in the log book data between December 2012 and May 2013 and potential linear trajectories between these local events.

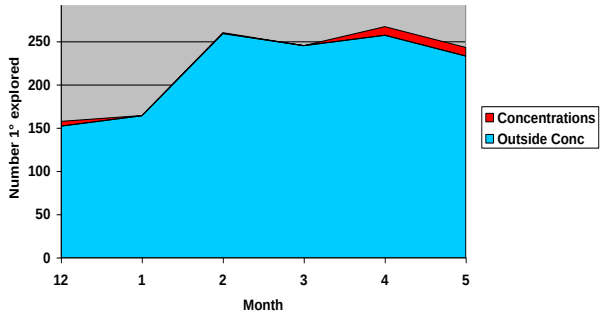

Figure 4. Monthly numbers of 1° squares explored by the EU&al PS in the concentration strata and outside of them.

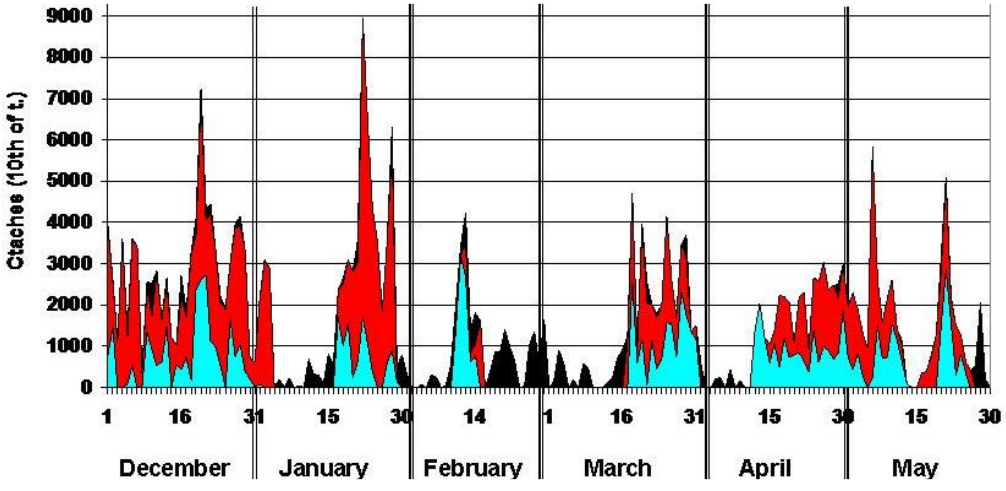

Figure 5. Daily catches of large yellowfin in each of the 6 concentrations, by country (France in blue & Spain&al in red) and outside of these concentrations (black) during the period December 2012-May 2013.

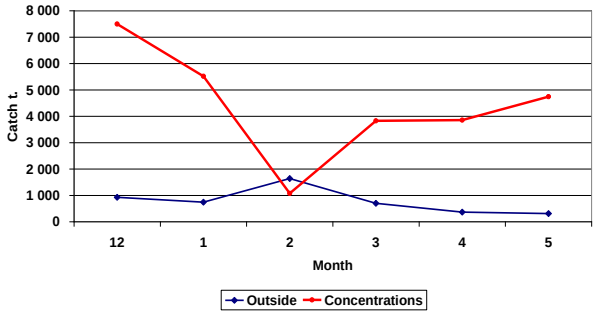

Figure 6. Monthly total catches of large yellowfin by the EU&al PS in the concentration strata and outside of them.

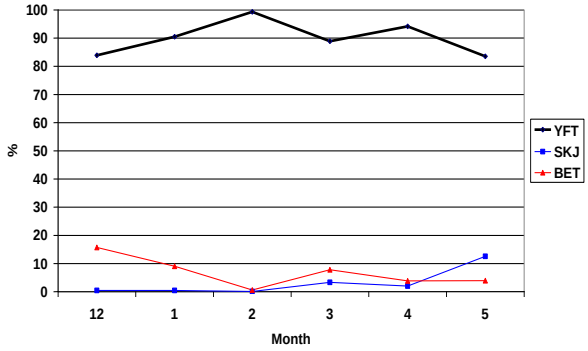

Figure 7. Monthly species composition (in %) in the 6 concentrations fished by the EU&al PS fleet (Dec 2012-May 2013).

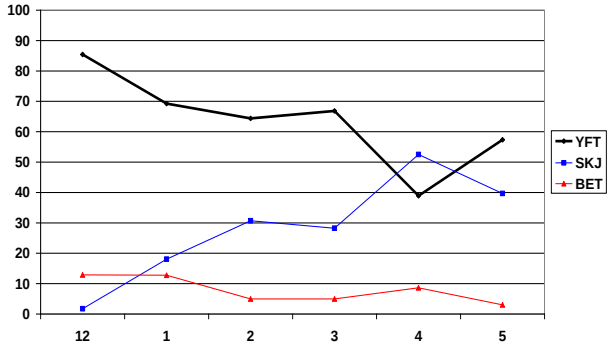

Figure 8. Monthly species composition (in %) of free schools catches in the Guinea Gulf (EU&al fleet, Dec 2012-May 2013).

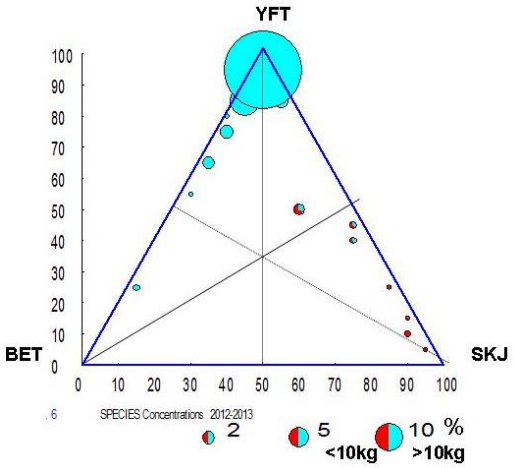

Figure 9. Definetti ternary plot showing the species composition by size categories of the 387 samples of tuna catches collected on the studied concentrations: 11.6 tons of tunas sampled.

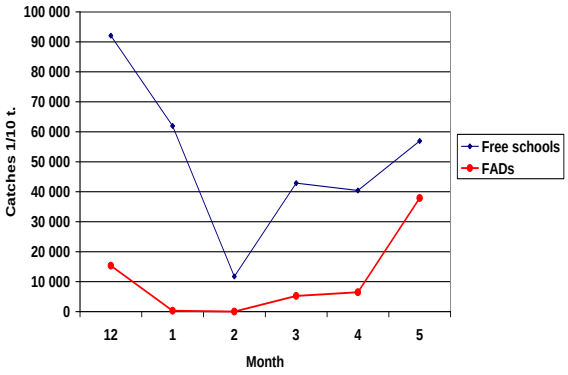

Figure 10. Monthly catches by the EU&al PS on free schools and on FADs in the concentration strata (period Dec. 2012-May2013).

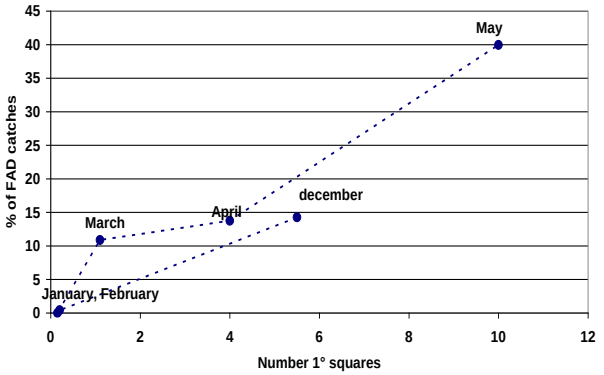

Figure 11. Monthly % of FAD catches by the EU&al PS in relation with the number of 1°squares fished in each of the concentration.

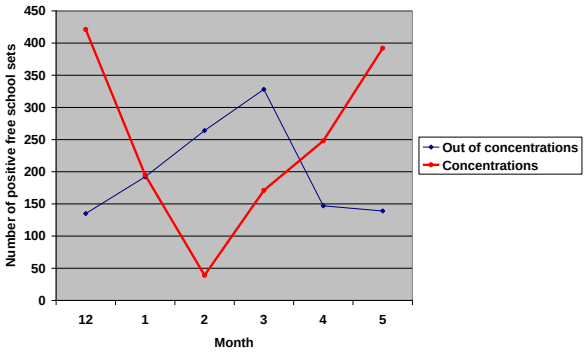

Figure 12. Numbers of free schools sets, inside and outside the concentration areas.

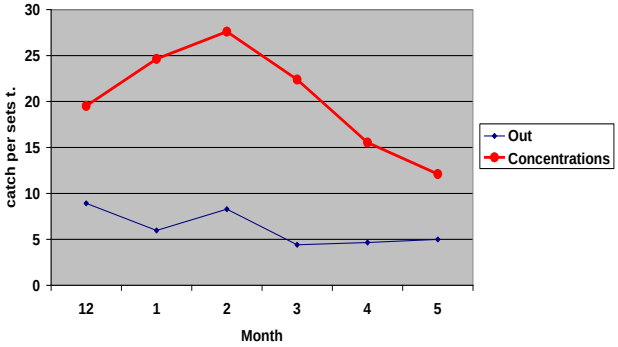

Figure 13. Average catch per set of large yellowfin on free schools, inside and outside the concentration areas.

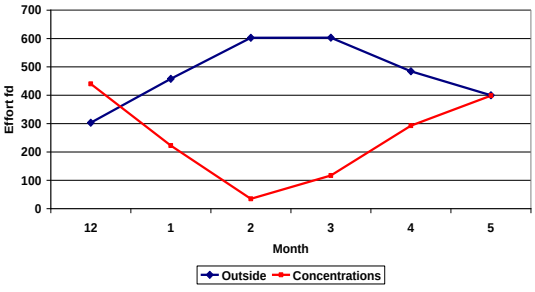

Figure 14. Monthly total fishing efforts of the EU&al PS in the concentration strata and outside of them.

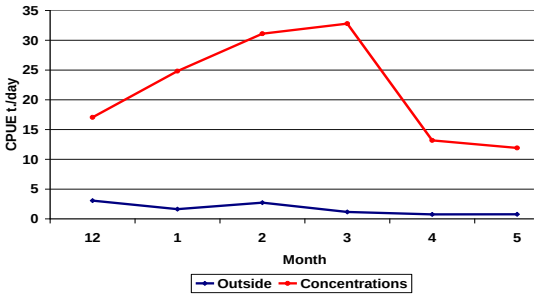

Figure 15. Monthly nominal CPUEs (t/ady) of the EU&al PS in the concentration strata and outside of them.

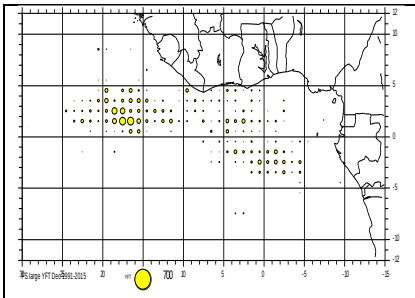

Figure 16a. Average catches of large yellowfin by PS, during the December 1991-2015.

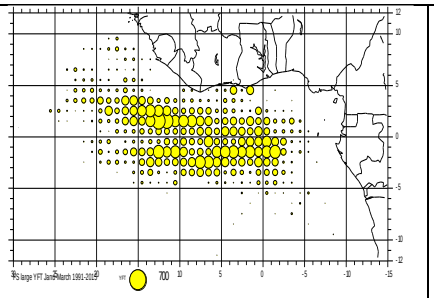

Figure 16b. Average catches of large yellowfin by PS, during the 1st quarter 1991-2015.

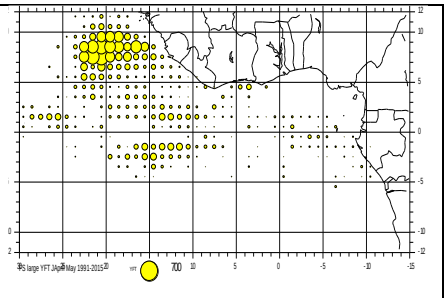

Figure 16c. Average catches of large yellowfin by PS, during the average period April-May 1991-2015.

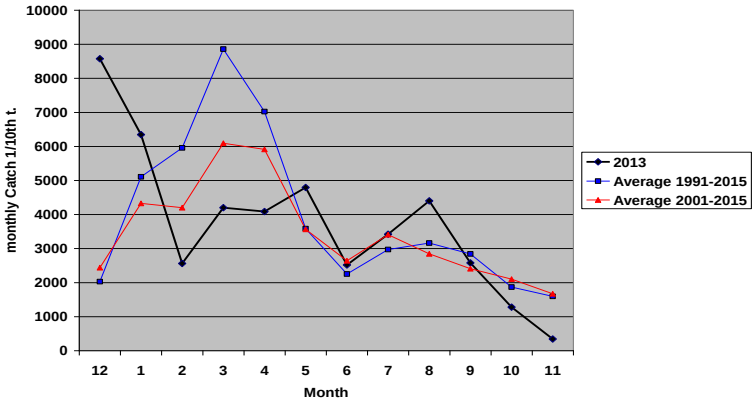

Figure 17. Total catches of large yellowfin by the EU&al PS during the studied December 2012-May 2013 period, compared to average monthly catches in previous years.

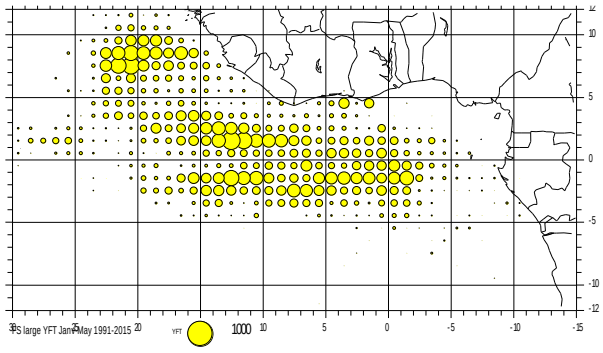

Figure 18a. Average catches of large yellowfin by the EU&al PS, 1991-2015 period, during the period January to May.

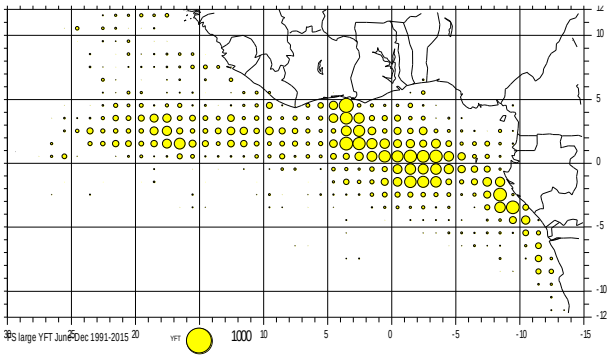

Figure 18b. Average catches of large yellowfin by the EU&al PS, 1991-2015 period, during the period June to December.

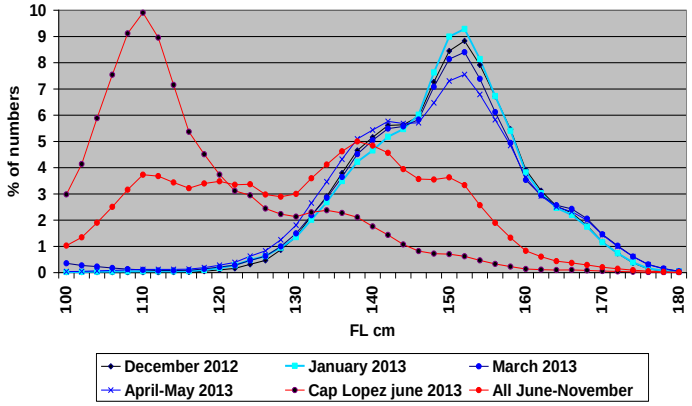

Figure 19. Number and sizes of large yellowfin caught in the concentrations by the EU&al PS and sampled for size, compared to sizes of yellowfin caught in 2013 outside of these concentrations.

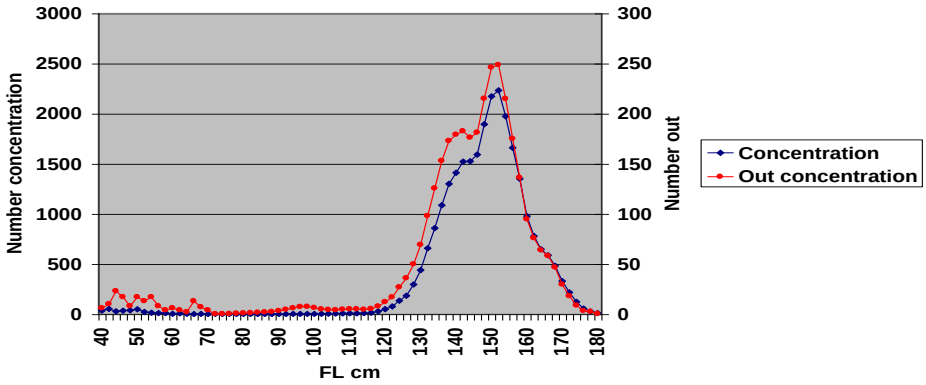

Figure 20. Number & sizes of yellowfin caught in the concentrations & outside of them in the period December 2012-May 2013.

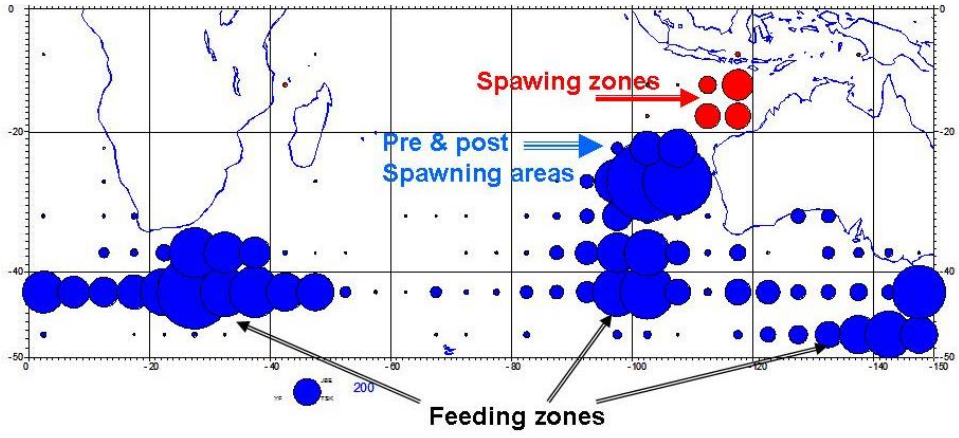

Figure 21. Overview of hypothetical spawning & feeding strata & of migration of Southern bluefin, based on fishery and on biological data.

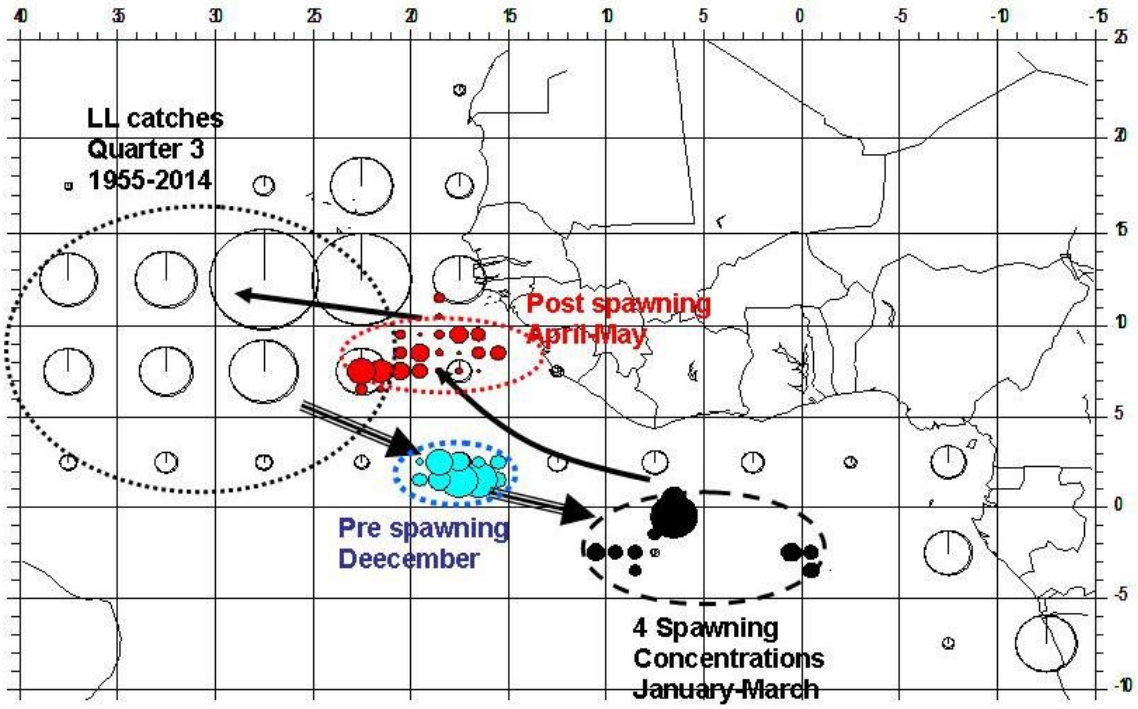

Figure 22. Overview of a hypothetical spawning migration pattern of adult yellowfin, from the north central Atlantic ocean in summer, to the Guinea Gulf before, during and after each 1st quarter.

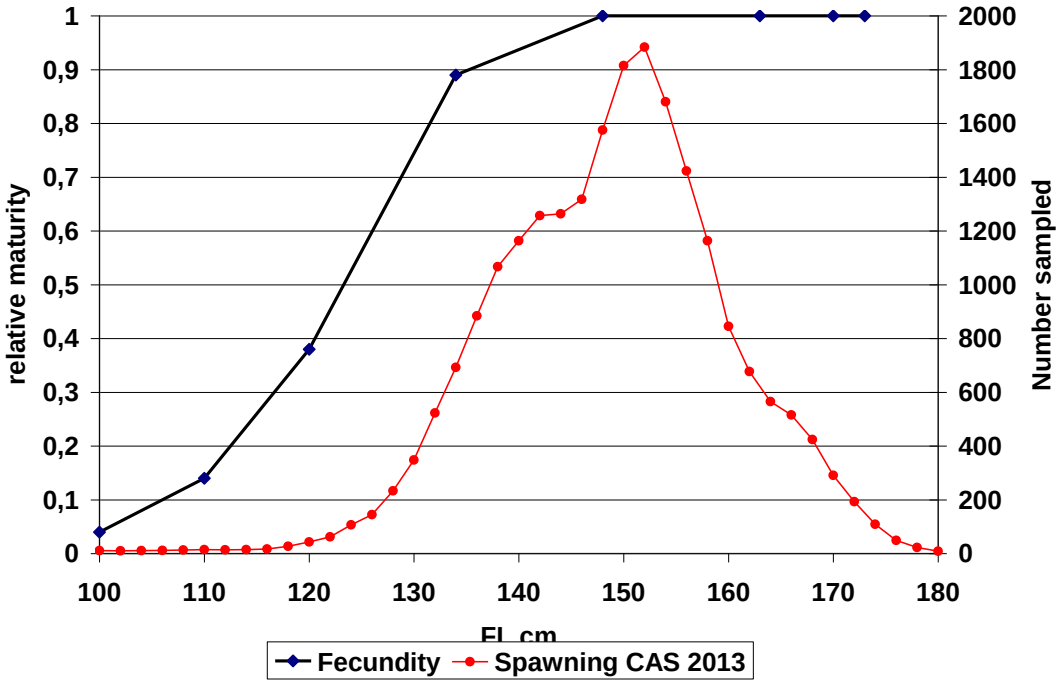

Figure 23. Average sampled catch at size of Atlantic yellowfin during quarter 1 of 2013 and assumed fecundity at size of yellowfin (ICCAT yellowfin WG 2016).