ON THE MAJOR CONCENTRATION OF LARGE BIGEYE TUNA AND YELLOWFIN TUNA EXPLOITED IN THE ATLANTIC OCEAN BY PURSE SEINERS IN FEBRUARY AND MARCH 2019: ANALYSIS OF THE FISHERY DATA

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SUMMARY

This paper analyzes the major concentration of large bigeye and large yellowfin exploited in free schools by purse seiners in February and March 2019. This tuna concentration was positioned in a small linear area along latitude 2°S and between longitudes 3°W and 10°W. Bigeye catches observed during this event were at the highest level ever observed in the PS fishery and at the level of the best catches observed for longliners by 5° squares quarterly strata. Most caches were taken on mixed species schools, combining variable proportion of large BET and YFT. Several hypotheses can explain the presence of this concentration, but the causes of this fishing event have not been studied by scientists and they remain widely questionable. The abundance of adult bigeye and their large catches could be due to an environmental anomaly producing unexpected spawning or feeding behaviour of these tunas. These high catches may also be in relation with the Lomonossov undercurrent positioned south of the Equator. Further investigations targeting all the skippers' observations and environmental data are recommended to understand this major fishing event.

RÉSUMÉ

Ce document analyse la majeure concentration de grands thons obèses et de grands albacores exploités sur bancs libres par les senneurs en février et mars 2019. Cette concentration de thonidés était positionnée dans une petite zone linéaire le long de la latitude 2°S et entre les longitudes 3°W et 10°W. Les captures de thon obèse observées à cette occasion étaient au plus haut niveau jamais observé dans la pêcherie de senneurs et au niveau des meilleures captures observées pour les palangriers par strates trimestrielles de carrés de 5°. La plupart des captures ont été réalisées sur des bancs d'espèces mixtes, combinant une proportion variable de grands BET et YFT. Plusieurs hypothèses peuvent expliquer la présence de cette concentration, mais les raisons de cet événement de pêche n'ont pas été étudiées par les scientifiques et restent largement discutables. L'abondance de thons obèses adultes et leurs importantes captures pourraient être dues à une anomalie environnementale produisant un comportement reproducteur ou alimentaire inattendu de ces thonidés. Ces captures élevées pourraient également être en lien avec le sous-courant de Lomonosov positionné au sud de l'Équateur. Il est recommandé de procéder à de plus amples études portant sur toutes les observations des capitaines et les données environnementales afin de comprendre cet événement de pêche majeur.

RESUMEN

Este trabajo analiza la mayor concentración de grandes patudos y grandes rabiles explotados en bancos libres por los cerqueros en febrero y marzo de 2019. Esta concentración de atún se situó en una pequeña zona lineal a lo largo de la latitud 2°S y entre las longitudes 3°W y 10°W. Las capturas de patudo observadas durante este evento se situaron en el nivel más alto jamás observado en la pesquería de cerco, y en el nivel de las mejores capturas observadas para los palangreros por estratos trimestrales de cuadriculas de 5º. La mayoría de las capturas se realizaron en bancos de especies mixtas, combinando una proporción variable de patudos y rabiles grandes. Varias hipótesis pueden explicar la presencia de esta concentración, pero las causas de este evento pesquero no han sido estudiadas por los científicos y siguen siendo ampliamente cuestionables. La abundancia de patudos adultos y sus grandes capturas podrían

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deberse a una anomalía ambiental que produzca un inesperado comportamiento de reproducción o alimentación de estos atunes. Estas elevadas capturas también pueden estar relacionadas con la subcorriente de Lomonossov, situada al sur del Ecuador. Se recomiendan nuevas investigaciones centradas en todas las observaciones de los patrones y en los datos medioambientales para comprender este importante acontecimiento pesquero.

KEYWORDS

Bigeye, tuna school, aggregation, feeding behaviour, reproductive behaviour, environmental conditions, purse seining

1. Introduction

During the 1st quarter of 2019, there has been a sharp increase in catches of large bigeye tuna (BET) caught by purse seiners (PS) on free schools. These BET catches have been reaching very high levels that were never observed before in the PS fishery. It is important and interesting to analyze the fishery data in order to identify where, when, how and why these very large catches of large BET were observed. The Task 2 data are showing that these high catches of large BET mainly occurred in a small fishing area positioned between 2°S and 4°S and between 10°W and 3°W and during February and March. These high tuna catches concentrated in a small area and during a short period seems to be typical of the concentrations (i.e., clusters) of free schools that have been analyzed by various authors (Fonteneau 1986, Toihir 1998, Ravier *et al.*, 2000, Fonteneau *et al.*, 2008). These high catches of BET are of special interest in the present context, as the BET stock is still considered as overfished (ICCAT, 2021) and as PS fleets had to limit their yearly BET catches to the levels of the TACs established by ICCAT since 2015. However, and surprisingly, this major concentration of BET has not yet been analyzed by SCRS scientists. The goals of this study are to analyze the characteristics of these BET catches by the various PS fleets, and to compare them with (1) historical 5°-quarters catches of large BET by PS and (2) to the 5°-quarters catches of large BET by longliners (LL). This analysis will be primarily based on the ICCAT TASK2 data and on the detailed logbooks fishing data of the French and Spanish fleets. The paper will discuss the potential causes of this BET concentration and will recommend potential ways to explain this important fishing event.

2. Material & methods

The ICCAT Task 2 data, catch and effort, catch at size of PS and LL and the multispecies sampled catches of the PS and of the sampled catches of LL fisheries are the main data used in this work. The detailed data from the French PS logbooks were also used to analyze the daily catches and their exact location and the fishing mode (i.e., free school or dFAD sets). The species composition of the sets providing these BET catches were based on the multispecies sampling at landing of free schools catches only. The analysis mainly targeted a time and area strata in the south equatorial area during February and March 2019 when a huge concentration of large BET and large YFT was exploited by the PS fleets. These 2019 large catches will be compared with the historical catches of large BET by LL and PS in the Atlantic Ocean, especially for the area fished in 2019.

3. Overview of the equatorial free schools concentration exploited in the equatorial Atlantic in February & March 2019

3.1 PS catches of BET and of YFT & by 1°-month

From ICCAT Task 2 data it can be observed that large catches of BET were caught by PS on free schools in February and March 2019, while the peak of the YFT free schools catches was observed during a wider period between January and May (Figure 1). YFT catches were observed on free schools at quite high levels in January, but mainly in the northern equatorial area and associated with only 9% of BET. These BET catches reached very high levels during the 1st quarter of 2019, BET catches reaching in February and March 40% of the free schools catches, levels that were never observed in the PS fishery since its beginning in the sixties. This peak in the relative free schools catches of large BET (FL > 1m) is even more visible on the time series of the amounts of large BET caught in free schools during the 1st quarters of the 1991-2020 period (**Figure 2**). From the locations of these free schools catches (**Figure 3**), we can conclude that the main fishing area with large BET catches was

mainly positioned between latitudes 1°S and 3°S and between longitudes 10°W and 3°W. This map indicates also that YFT was dominant in these catches, as it is always the case in the free school fishery inside this time and area stratum, but showing an unusual high percentage of 40% of BET. Our study will be mainly targeting the tuna catches in the 1°S-4°S area, as the catches taken north of Equator, that are showing much lower amount of BET, were probably quite independent from the main tuna concentration observed south of the equator. The pattern of the 2019 free schools catches was usual for the PS YFT free school catches, probably because spawning concentrations of YFT are often fished in this area during this season, as shown by figure 4. The typical locations of the YFT catches during the February-March period exhibits symmetrical catches either side of the equator (approximately between 5°N and 5°S and 2°E to 20°W), with reduced catches between the equator and 1°S. During the same years and months, the spatial distribution of BET catches is a little more reduced, but BET catches are always at much lower levels than for YFT (**figure 5**).

The seasonality of the monthly catches by species of the PS fleets in the selected area (Equator-5°S and 10°W-0°W) are shown in **figure 6**. These catches were caught predominantly on free schools between 1980 and 1990, and only on free schools after 1990. This figure is showing well the seasonal pattern of the PS catches in this selected area: a fishery always dominated by YFT during the first quarter of the year, BET being very seldom fished on free schools in this stratum. The only major anomaly being observed in 2019 with 40% of BET catches. During the period of the studied concentration, 60%, the BET catches identified with a known fishing mode were taken in this fishing stratum by the EU PS fleet, and the remaining 40% by 4 countries, cf **table 1**. Fishing maps by 1° squares of these fleets are showing that each of these non-European fleets have been catching free schools BET in very similar fishing areas (**figure 7**). It must be noted that the total catches of BET on the studied concentration were probably larger because of the various PS fleets potentially fishing in this area without good Task 2 statistics (Belize, Ghana, etc…) and then potentially with unidentified BET catches.

3.2 Sizes of BET caught by PS

The BET caught in free schools are mainly composed by adult individuals (an average weight close to 50 kg) that are typical of free schools catches (**figure 8**). It should be stressed that these sizes of BET caught by PS are similar to the sizes caught by the LL fishery during the same 1st quarter of 2019 in a much wider area (average weight of 50 kg for PS and of 63 kg for LL), but PS catches showing a clear mode of sizes around 150 cm that is less visible in the LL catches.

3.3 Species composition of the sampled catches per set

The De Finetti plot (De Finetti 1937) in the version proposed by Fonteneau *et al.*, (2009) is a powerful way to visualize the species composition sampled in the free schools catches for the time and area stratum of the BET concentration analysed in this study. Our De Finetti plot is showing the frequency (in %) of each species composing a multispecies school caught in free school set, taking into account the 3 species of tropical tunas. Our version of the De Finetti plot is also showing in yellow & in red, for each pie, the relative amount of large YFT or of large BET over 10 kg in the samples (blank areas corresponding to the amount of small tunas under 10 kg), see **figure 9**.

The absence of white areas in all the pies means that all the YFT & BET tunas were sampled at sizes >10 kg). 4 % of the samples showing pure large BET catches and 18% of the samples showing BET sampled catches dominant over YFT. Mixed species samples showing dominant YFT but significant BET catches are also frequent: 46% of the samples. Such pattern of species composition has been seldom observed in previous years, free schools sampled catches in this stratum being always dominated & by far by pure large YFT, BET being seldom observed in the free schools samples, see the following **figure 10**, showing the sampled species composition of free schools catches from the studied area during the period 2000-2018. A great majority of the samples, 86 %, are showing catches of nearly pure large YFT, large BET being mixed with large YFT in only 6 % of the samples.

3.4 LL catches of BET in 2019

From ICCAT Task 2 data it was evidenced that the longline fisheries exerted very low levels of fishing effort in the stratum of the concentration in 2019, which resulted to only 27 t of BET (3 t. in February and 23 t. in March) (see **figure 11**). To help the comparison, the PS stratum is represented by the blue rectangle in the map (5° squares: 300000 and 300005). It should be noted that significant catches of BET were caught by LL at more southern latitudes and at western longitudes showing a total catches south of the Equator close to 3000 t, but in a larger strata than the selected area (fifteen 5°squares and during 3 months). BET was the dominant species in the

LL fishery in this area and was clearly the main species targeted by longliners in the Eastern equatorial Atlantic Ocean during the 1st quarter of 2019. Only 3 flags of LL were active in the area, mainly, and by far, from Chinese Taipei.

3.5 Best quarterly catches of BET observed in the LL and in the PS fisheries

It is also interesting to compare the BET catches caught by PS in this concentration during quarter 1 of 2019 in the square 300005 with the best levels of BET catches by PS & LL observed in these fisheries. This comparison is summarized on **figure 12**. We observe that LL fisheries were commonly catching large BET catches over 2000 t in many 5° squares, while the best catches of BET by the free schools PS fishery by 5° squares were most often at quite low levels, under 1000 t. However, the very large catch of adult BET in the square 300005 by PS during the first quarter of 2019 was similar to the highest levels registered by 5° square in the entire history catch series of the LL fishery during the 1st quarter of the year. The PS BET catches obtained inside this 2019 concentration was really unique in the history of the Atlantic PS fishery. It should be noted that large BET catches of 900 t. were also taken by PS in the neighbouring 5° square: 300000. It should also be kept in mind in the comparison between PS and LL fisheries that the high catches of adult BET in the LL fishery were the result of an active targeting of adult BET by some LL fleets; some 5 degree squares being exploited by 20 vessels, or more, during several months which were catching a majority of BET (see **figure 11**). Finally, it should also be noted that the levels of the LL BET catches in the squares: 300000 and 300005, fished also by PS in 2019, were always low (i.e., their best quarterly BET catches being around 1000 t. during the eighties)

3.6 Detailed analysis of the daily catches and exact fishing locations of French PS by degree – minute

The area of the BET concentration was exploited in February - March 2019 by 10 French PS that caught a total of 3824 t of tunas on free schools (2310 t of large YFT and a record high catch of 1500 t. of large BET. A total of 177 positive sets were done by the French fleet, showing 15 sets with pure large BET, with an average catch per set of 18.2t (max=62 t.) and 25 sets with dominant BET catches, with an average catch per set of 21 t (max=87 t. of BET in a 120 t. set).

It was also exploited in February - March 2019 by 7 Spanish PS that caught a total of 3155 t of tunas on free school (1875t of large YFT and a record high catch of 1280 t. of large BET). A total of 122 positive sets were done by the Spanish fleet, showing:

- 13 sets with pure large BET, with an average catch per set of 20.8 t (max=48t.)
- 14 sets with dominant BET catches with an average catch per set of 20.5 t (max=108 t. of BET in a 113 t. set).
- 6 sets with about 50% BET-YFT catches, with an average catch per set of 11.3 t (max=37t. of BET)

Large catches were also caught in the stratum by other PS fleets (see **figure 7**), but the detailed activities of these PS were not available in our study.

Permanent large daily catches were observed between February 6th and March 26th for both the Spanish and French PS fleets (**figure 13a and b**). The best daily catches of BET were observed between March 6th and 24th. From these 2 figures it can be also observed that YFT catches were dominant until the beginning of March and that BET and YFT catches were at similar levels during the end of the concentration. The exact fishing locations of the BET catches observed in February and in March 2019 for French and Spanish PS are shown by squares of 1 mile on **figure 14a to 14d**. These maps are showing that the fine scale fishing zones of Spanish and French PS were nearly the same. The highest catches of BET are observed in March in a quite small fishing zone from 2°S to 4°S and from 3°W to 10°W. These exact set locations of the BET free schools catches in February and March 2019 are depicting a very unusual linear spatial pattern, most often close and parallel to 2°S, and covering a total distance of about 420 miles. It should also be noticed that the fishing zones of YFT (**figure 15a to 15d**) are nearly identical to the fishing zones of BET and similar for French and Spanish PS. These fishing maps are also showing for both fleets a westward change in the setting locations between February and March. This change may be due to (1) a westward movement of the tunas (YFT and BET) or (2) to local changes in biomass, or (3) in the availability of this biomass to the PS fishery.

3.7 Setting hours

The hour of the free schools sets exerted during the fishing event were analyzed for French and Spanish PS. These setting hours are shown on **figure 16a and 16b**. This figure is showing that the setting times recorded in the logbooks during the studied concentration were similar for the two fleets. They are also showing that the setting times observed on free schools during this concentration were showing a majority of sets in the early

morning, setting times that are similar to the setting times on FADs but quite distinct from the typical setting times observed on free schools that are showing few sets in the early morning before 8 AM and a maximum frequency of sets between 8 AM and 4 PM.

3.8 Potential spawning areas of YFT and BET in the Equatorial Eastern Atlantic Ocean

As the area of the 2019 concentration was located in a stratum known as being a YFT spawning area, but not for BET in this region and season. A simple way to identify the time and area spawning strata is to examine the location of large catches of potential spawners by LL or by PS in warm surface waters, (>25°C, Fonteneau 1998). Based on this criterion, the potential spawning areas of YFT during the 1st quarter are shown by **figure 17**.

These potential spawning areas are mainly located between 3°N and 4°S, and between 2° W and 2° E. Adult BET are never targeted by PS, unlike LL for which the main fishing zones in warm surface waters (>25°C) during the 1st quarter are located in warm surface waters between 10°-5°N and 5°-10°S, see **figure 18**. This distinct geographical pattern could indicate that the main spawning grounds of BET would be located in areas that are quite distinct from the YFT spawning grounds and quite far from the area of the 2019 concentration However, BET spawning grounds would secondarily take place in the main spawning areas observed for YFT caught in the free schools by the PS fishery.

4. Environmental condition in the fished area

4.1 Sea surface temperature

The average geographical pattern of SST observed around the fishing stratum during the 1st quarter and the geographical pattern of the salinity of surface waters are shown by **figure 19a and 19b**. The maps of average sea surface temperature (SST) and salinity indicate that the BET concentration took place in an area of warm surface waters, with an average salinity between 34.8 and 35.8 g/l. The average sea surface temperature of the shallow waters in the fished stratum are at 27.8° C (based on the NOAA Levitu atlas). These SST observed in 2019 are the highest SST recorded for the French fishery since 2000. The average patterns of SST observed during the 2 periods 2000-2018 and in 2019 are shown by **figure 20** from the French and for the Spanish fleet. This figure is showing that large YFT caught in the area during the 1st quarter are always caught in warm waters, and that SST warmer than the average was observed for the 2019 French and Spanish catches of BET in 2019, showing an average SST of 29.0° C vs an average of 28.0°C during the period 2000 to 2018. This apparent anomaly of the SST estimated from the logbooks could be indicative of an environmental anomaly in the region.

4.2 Thermocline and oxycline

The average structure of temperature and oxygen rates of the water are shown by **figure 21 a and b** (based on the NOAA Levitus and Boyer's Atlas). These figures are showing that in this stratum (1) the average vertical distribution of temperature and (2) the rate of oxygen lower than 3ml/l are both observed at 100 meters. This shallow thermocline and shallow oxycline could limit the vertical movements of YFT in the area. On the opposite these temperature-depth and oxygen-depth profiles should not be limiting factors for the vertical distribution of adult BET.

4.3 Lomonossov under current

It was noted that during the studied concentration, the fishing zone was linear and approximately parallel with the Equator positioned at the southern frontier of the 2°S latitude. This Lomonossov undercurrent is a permanent and stable current, described by Gouriou (1988), which originates off the coast of Brazil and ends in the Cape Lopez area. It is centered on the equator, has a width of about 200 km and a thickness of 150 m. Its maximum velocity core in the upper part of the thermocline is between 50 and 125 m deep. The speed of this current is of the order of 60 to 130 cm/s and the maximum velocity core is associated with a salinity maximum; the values of which decrease from west to east. It should then be noted that the tuna concentration was located close to the southern frontier of the Lomonossov under current as it was measured during the PIRATA cruise in March 2019 at 10°W and along the Greenwich meridian (**figure 22**). This figure is showing that maximal speed of this under current (close to 80 cm/s, then close to 3 km/h) was measured at 2°S (10°W) and at 1°50 S (Greenwich). This southern limit of the Lomonossov current corresponds more or less to the linear pattern of the main fishing zones during the fishing event (see **figure 14**). It was also noted by Brandt et al 2021 that the Lomonossov undercurrent has been strengthened by more than 20% from 2008 to 2018. Historical fishery data are most often

showing an area of low catches of large YFT between 1°N and 1°S during the first quarter of the year which corresponds to the main fishing season in the equatorial area. This equatorial area of low catches can easily be viewed on a map representing the average YFT catches by 1°, a map showing 2 peaks of higher catches between 4°N and 1°N and between 1°S and 3°S (see **figure 17**). Depending of its position, depth and speed, and because of the shear effect produced by such undercurrent on the purse seine during the setting, the Lomonossov current may be a factor reducing the catchability of the PS fishery (taking note however that all the PS are equipped with ADCP recorders allowing to measure the speed of such undercurrent and allowing them to avoid setting in such dangerous area). This current may also play a role in the concentration of the tuna schools, simply in relation with its potential barrier effect or its potential source of food. The characteristics and potential peculiarities of the Lomonossov undercurrent during the first quarter of 2019 between 4° and 10°W could probably be evaluated based on the analysis of the data collected by the PIRATA boys described by Bourlès et al 2019 and the ARGO program.

5. Discussion

This concentration of adult BET was really unique in the history of the PS fisheries, surely in the Atlantic and probably also worldwide:

(1) Because of its very large catches of adult BET, at levels never observed for the PS catches in the Atlantic

(2) Because of the peculiar geographical linear & narrow pattern of this concentration, while most or all the tuna concentration that have been analyzed (Fonteneau 1986, Ravier et al 2000) tend to show oval shapes. The quasi linear shape of our concentration of adult BET & YFT, parallel to 2° South and showing a length close to 360 nautical miles, was really spectacular and really unique. This peculiar shape could be linked with a barrier effect of the Lomonossov undercurrent, but this effect would need to be better studied and understood.

(3) Because of the unusual species composition of the schools, showing a mixture of adult YFT & BET in variable proportion, but most often with large amounts of BET.

A serious pending question remains, because this concentration of large BET & large YFT schooling in shallow equatorial waters close to 2° south remains unexplained. One of the pending questions would be to understand if these large catches and large CPUEs of adult BET correspond to an increase of the adult stock biomass , which could call into question the recent results of the stock assessment for this species, or to a change in the size selectivity and in the catchability of adult BET for the PS fishery (due to environmental drivers or to new technology introduced on board purse seiners).

Various explanations could potentially explain this unusual concentration of adult BET mixed with adult YFT in surface schools:

(1) Anomaly in the feeding behaviour of adult BET, these BET feeding on peculiar abundant preys swimming in shallow waters along 2°S, because of an environmental anomaly. It was noted by Brill *et al.,* (2005) that the thermal physiology and feeding behaviour of adult YFT and BET are quite distinct, probably explaining why adult YFT and BET are very seldom swimming and eating together in the same school (see **figure 10**). The species composition of the 2019 concentration was unusual, but it could potentially be explained by a local anomaly in the amount of food available in the stratum. Such a situation was observed in the past in the so called PICOLO area, where large biomass of small tunas associated to dFAD and eating a mesopelagic species, *Vinciguerria nimbaria* (Photichthyidae), which during daylight concentrated in the upper layers in dense schools (Ménard *et al.*, 2000). The concentration of large YFT in the Indian Ocean analyzed by Fonteneau *et al.,* 2008 was also linked with an environmental feeding anomaly and a major phytoplancton bloom, while the very large catches of YFT observed in the Indian ocean during the 2003-2005 period was also mainly due to the unexplained major abundance of Natosquilla, a pelagic stomatopod, swimming in large schools in shallow waters.

(2) An anomaly in the BET spawning behaviour, as many adult BET showing in 2019 the typical behaviour of spawning YFT in this time/area stratum close to the Equator during the first quarter and in warm water conditions. This assumption is based on the presence of a large number of spawning YFT being caught in this concentration mixed with BET. Until now, however such a behaviour of shallow spawning was never observed for BET in the equatorial area or elsewhere.

(3) A change in the schooling behaviour of adult BET due to unknown factors, but likely linked with the local environment.

6. Conclusion and recommendations

We recommend:

(1) that a more in-depth analysis of this fishing event be made based on all the detailed logbooks and all types of potential data collected by all the skippers (PS of France, Spain, Cabo Verde, Salvador, Guatemala and Curaçao) during their exploitation of this concentration. Several skippers have probably made multiple interesting field observations in their private logbooks that could potentially explain this strange fishing concentration of large BET, but unfortunately this event was not noticed and not followed in real time by tuna scientists. However, it should probably be still possible to launch a LEK[5] questionnaire targeting the French and Spanish skippers upon this fishing event.

(2) to recover the environmental information received daily by all the skippers during this event upon the potential anomalies observed from satellite, as in the 2005 YFT concentration observed in the Indian Ocean (Fonteneau *et al.*, 2008), that was fully explained by a small but very active hot spot of primary productivity.

(3) to recover any potential observation concerning this 2019 fishing event, targeting inter alia their observation on the feeding and spawning behaviour of these large BET and the local fine scale environment,

(4) To analyze the various scientific environmental information collected during this fishing event in the area of the fished stratum, obtained from merchant ship, by satellite imagery data (SST, surface current, altimetry, chlorophyll and others), and by the ARGO and PIRATA programs (using drifting and anchored buoys close to the studied area).

All this information should allow to understand better the causes of this surprising fishing event, allowing to improve the relationship between the standardized CPUE and the tuna biomass, and subsequently to improve the stock assessment analysis of the Atlantic BET stock.

Aknowledgments

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[5] LEK : Local Ecological Knowledge, as it was used by Silvano *et al.*, 2008.

Table 1. Free school catches by flag and by species in the area of the BET concentration (2°S-4°S and 10°W-3°W) in February and March 2019 and percentage of BET (based on the ICCAT Task 2 data).

Flag	Month	YFT	BET	Total	%BET
France	February	824	371	1 195	31,1
Spain	February	1 054	392	1 445	27,1
Others	February	442	585	1 027	57,0
Total	February	2 319	1 348	3 667	36,8
France	March	1 486	1 131	2 616	43,2
Spain	March	822	850	1 672	50,8
Others	March	2 378	1 240	3 618	34,3
Total	March	4 685	3 221	7 906	40,7
France	**Months 2+3**	**2 309**	**1 502**	**3 811**	**39,4**
Spain	**Months 2+3**	**1 875**	**1 242**	**3 117**	**39,8**
Others	**Months 2+3**	**2 820**	**1 825**	**4 645**	**39,3**
Total	**Months 2+3**	**7 004**	**4 569**	**11 572**	**39,5**

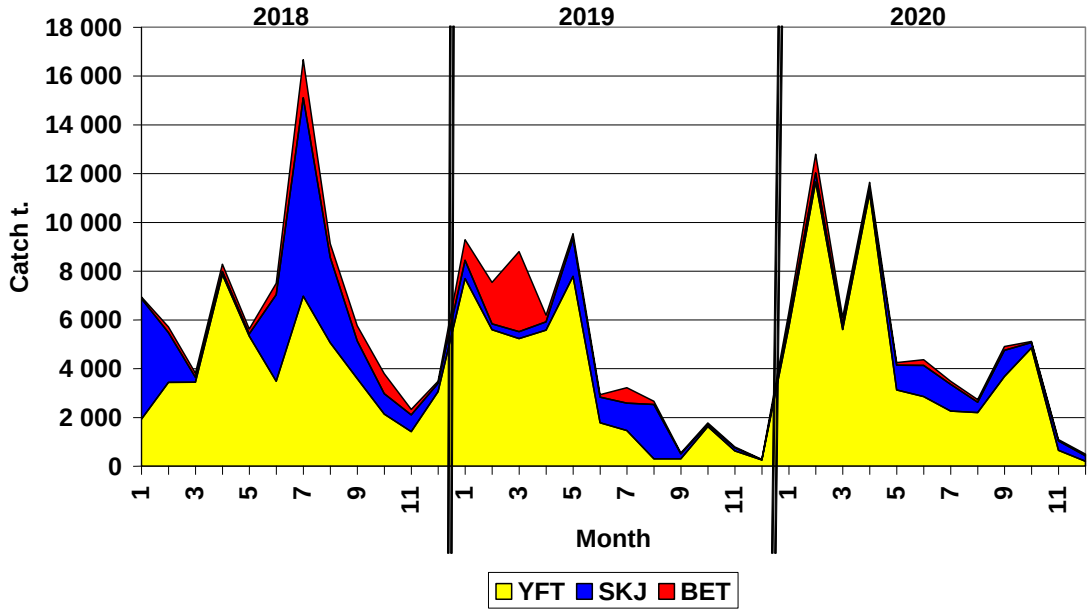

Figure 1. Monthly catches by species on free schools during the 2018-2020 period (ICCAT Task 2).

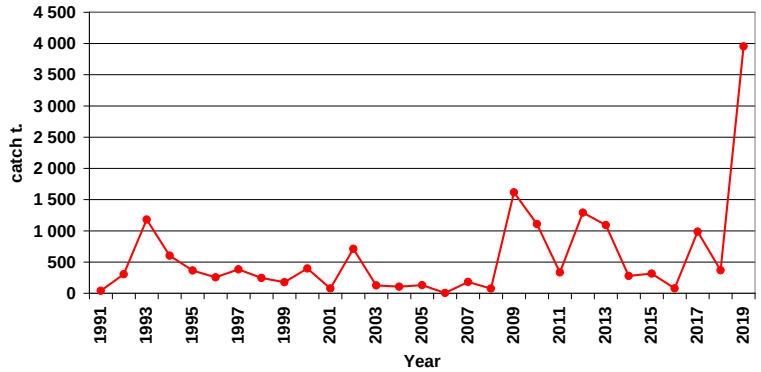

Figure 2. Yearly catches of large BET (FL > 1m) caught on free schools by PS during the 1st quarter between 1991 and 2020 (ICCAT BET catch at size).

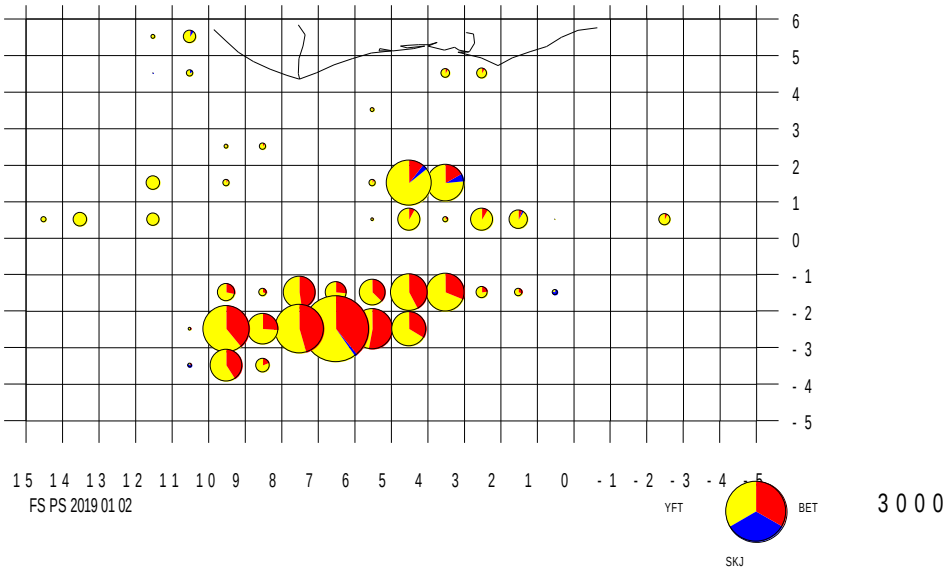

Figure 3. PS free schools catches by species in February and March 2019.

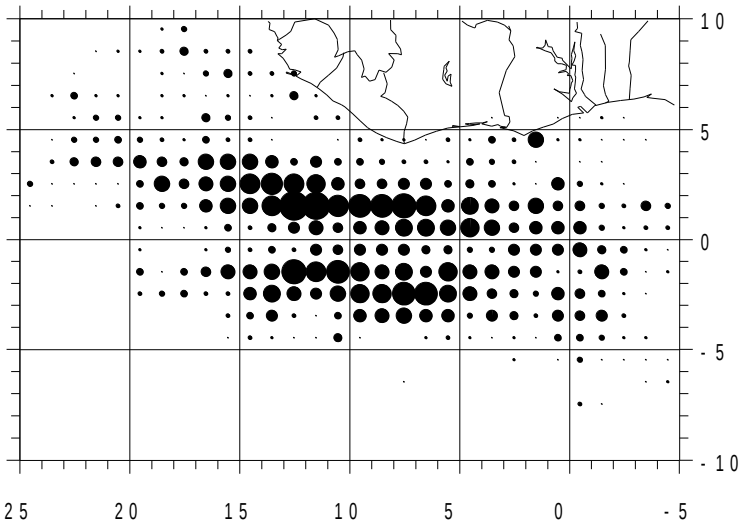

Figure 4. Average catches by 1° square of large YFT caught in free schools from February to March during the 1991-2020 period (all PS)

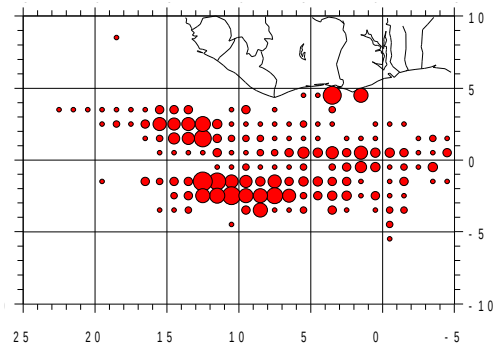

Figure 5. Average catches by 1° square of large BET caught in free schools from February to March during the 1991-2020 period.

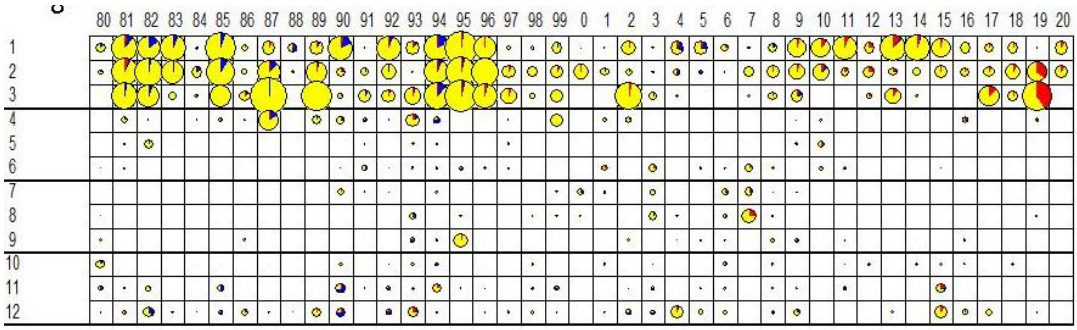

Figure 6. Monthly catches by species of the PS fisheries in the selected area (Equator-5°S and 10°W-0°W) during the 1980-2020 period. The surface of each pie is proportional to the total catch during each month (vertical axe) and year (horizontal axe).

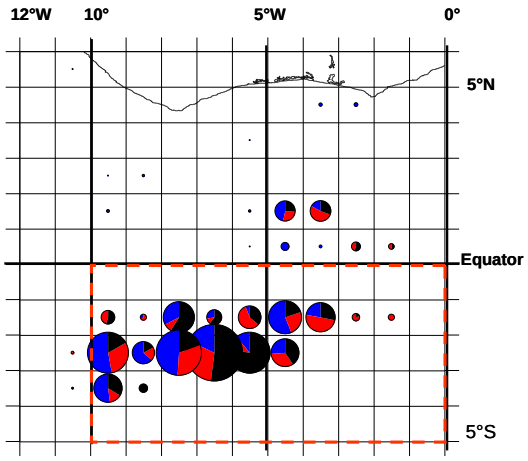

Figure 7. BET catches of PS in February and March 2019 by flag (blue: France, red: Spain, black: other flags) and area selected for the study of the concentration.

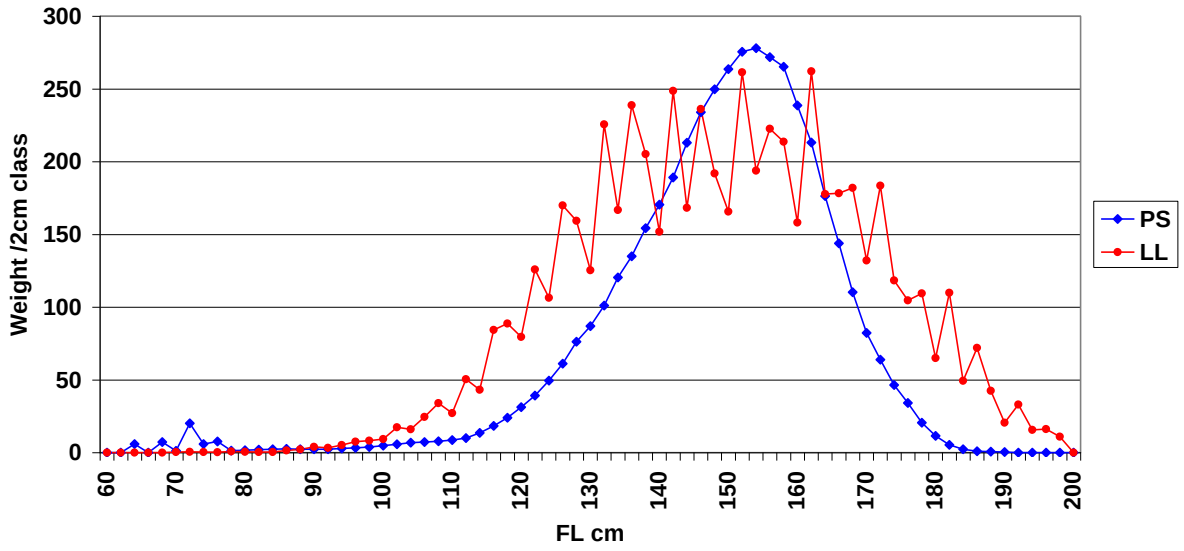

Figure 8. Catch at size of BET (in weight) caught by PS in the studied concentration and of BET caught by LL during the 1st quarter of 2019 in the area between 10°N and 15°S, east of 30°W.

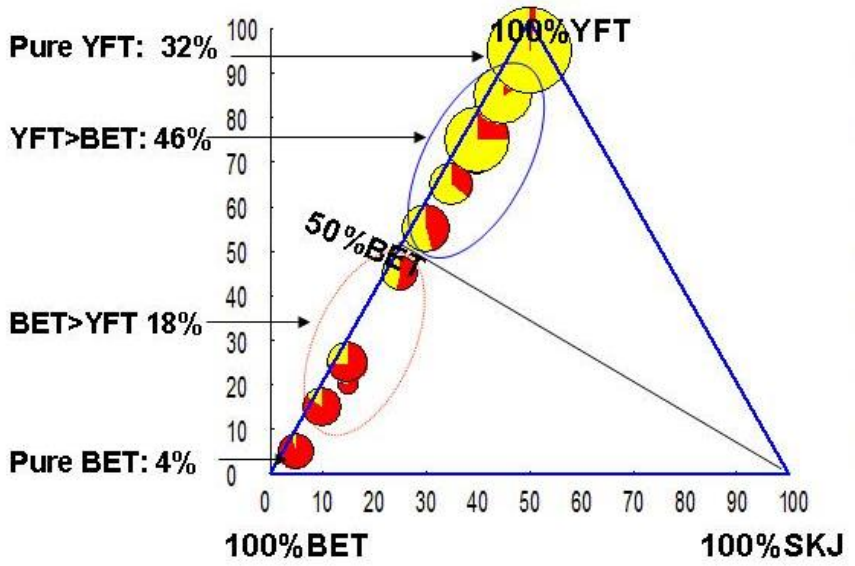

Figure 9. De Finetti plot showing the species composition of the 136 multispecies samples done on free schools catches from tunas caught in 2019 on the studied concentration (BET over 10kg in red, YFT over 10kg in yellow). Percentages on the left are showing the frequency of the samples classified in 4 categories.

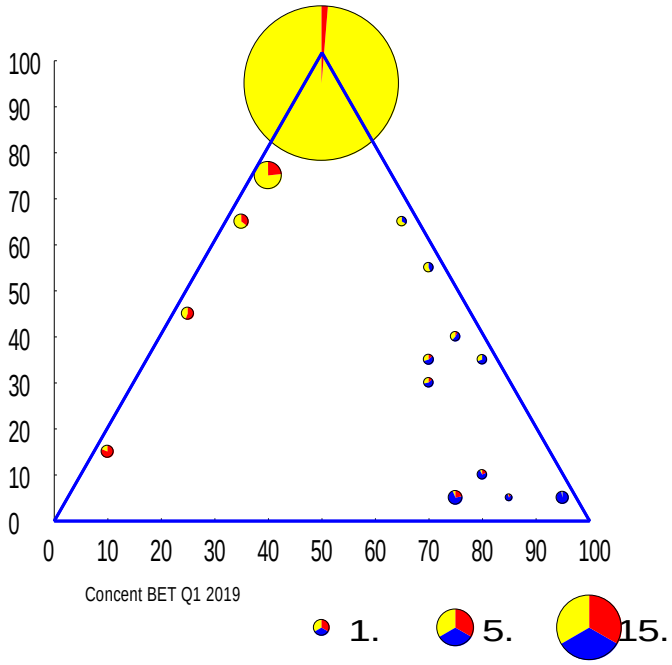

Figure 10. De Finetti plot showing the species composition of 746 samples done on tunas caught in free schools (area of the studied concentration between Equator and 5°S and between 10°W -0°W) during the period 2000-2018 (BET > 10kg in red, YFT > 10kg in yellow).

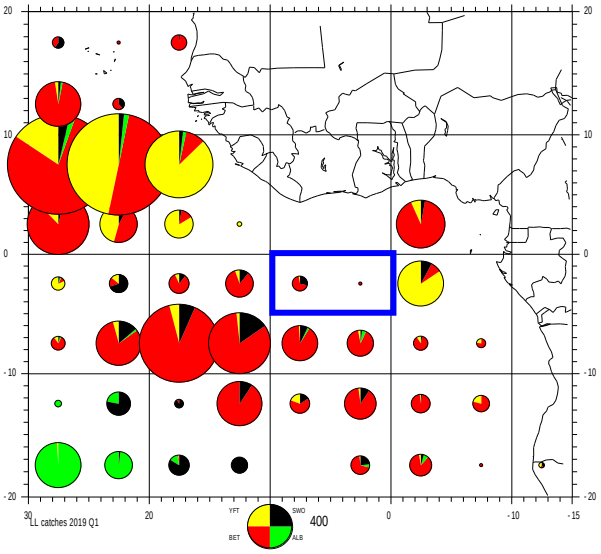

Figure 11. Tuna and swordfish catches by longline fleets (CATDIS file) during the 1st quarter of 2019, BET catches in red and YFT in yellow, the area of the tuna concentration exploited by PS in represented by the rectangle in blue.

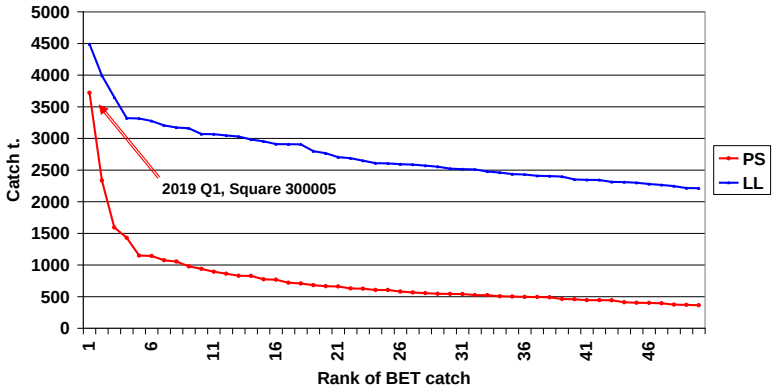

Figure 12. Levels of the 50 best quarterly catches of BET caught by 5° squares, observed for PS on free schools (in red) and for LL (in blue), during the period 1990-2020.

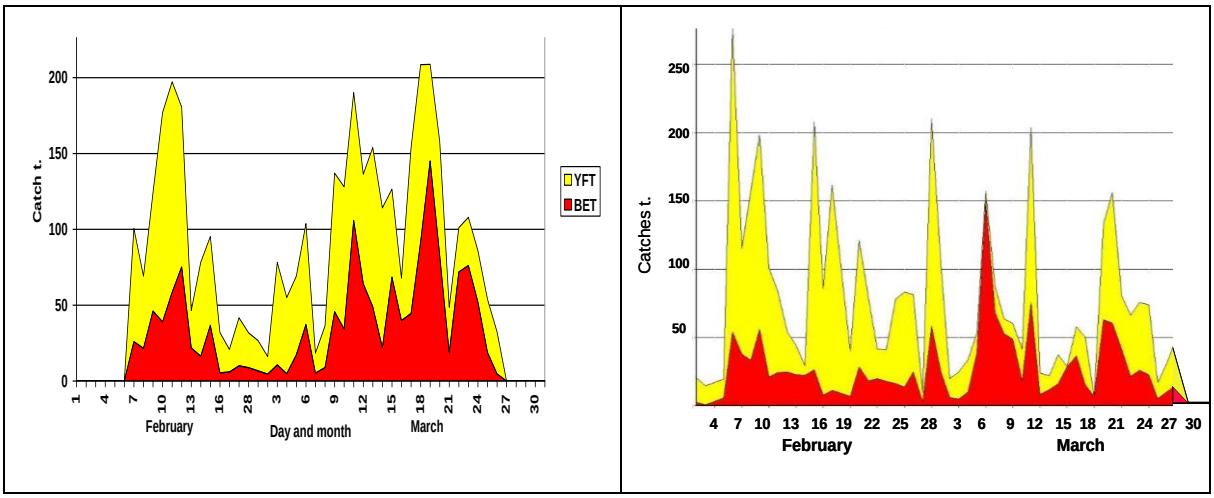

Figure 13. Daily catches on free schools by species of PS inside the studied concentration area: 13 a, left, French PS and 13 b, right, Spanish PS.

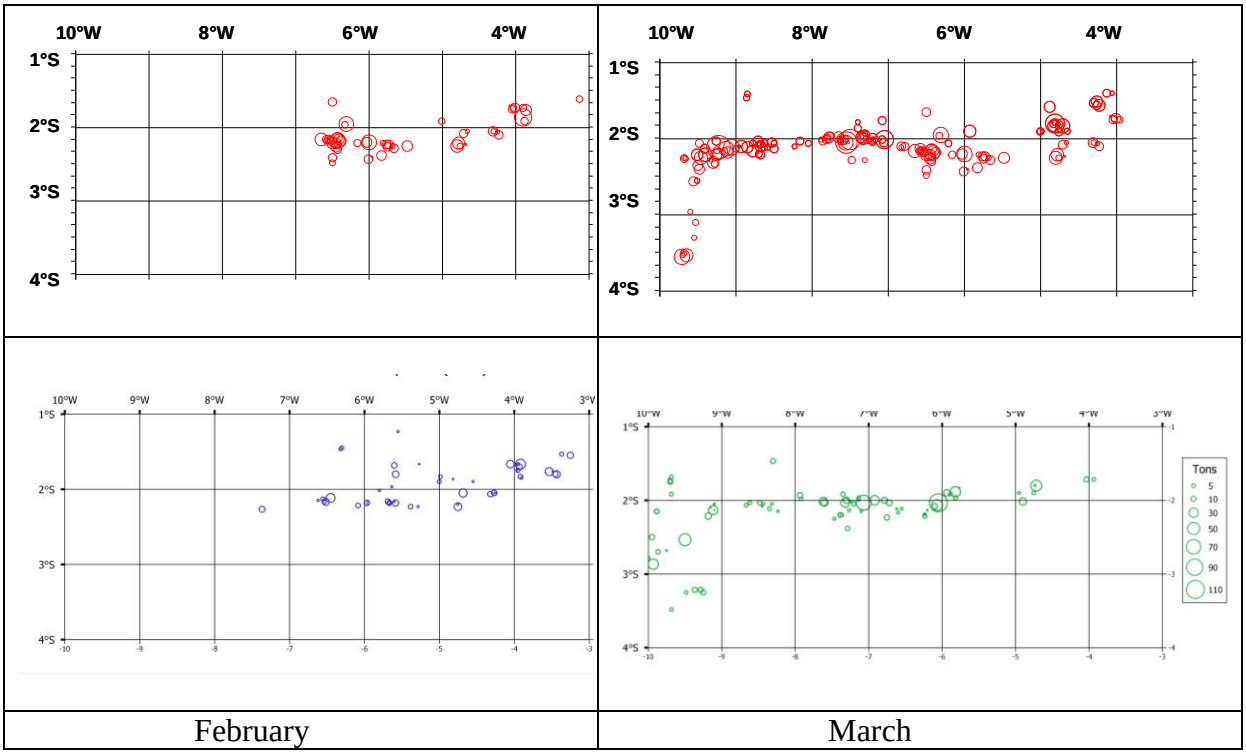

Figure 14. Catches on free schools of BET by 1 mile squares of French (upper maps) and Spanish PS (lower maps) in February and March 2019 (distinct scale for French and Spanish PS).

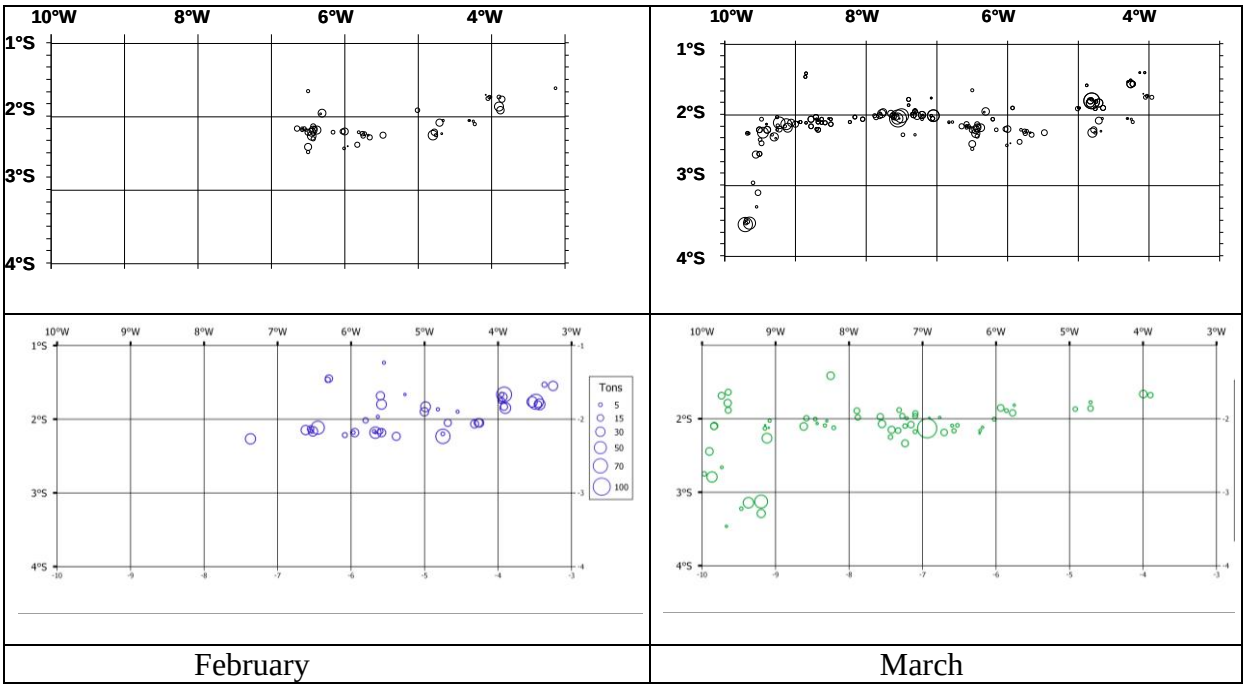

Figure 15. Catches on free schools of YFT by 1 mile squares of French (upper maps) and Spanish PS (lower maps) in February and March 2019.

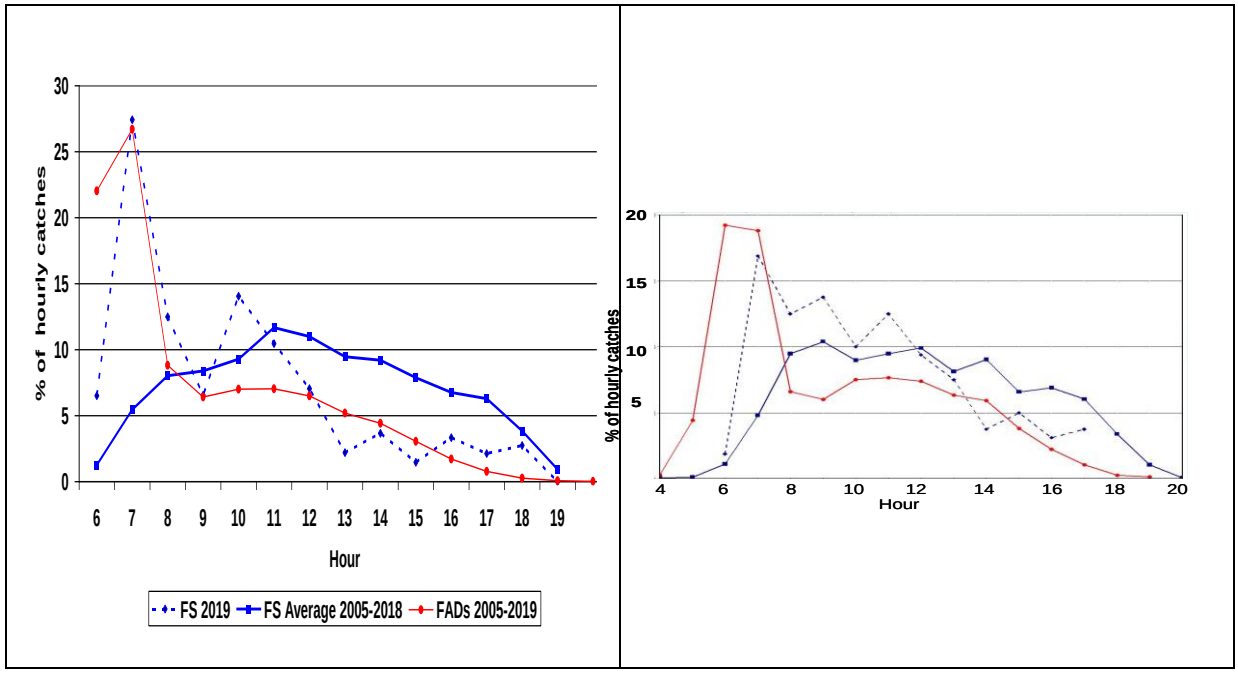

Figure 16. Setting hours of French PS and Spanish (1) on free schools (in blue) in February and March 2019 in the area of the BET concentration, and in all the areas during the period 2004-2018 and (2) for FAD sets, in red, all areas, during the 2005-2019 period (**Figure 16 a**, left, for French PS and 16b, right, for Spanish PS).

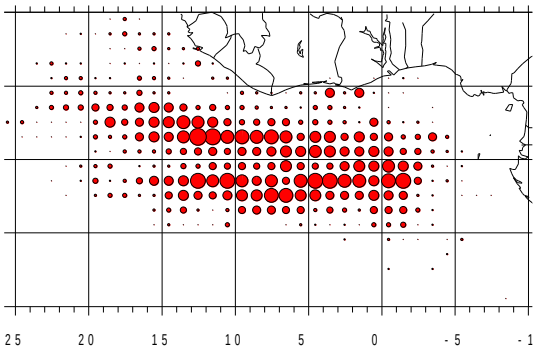

Figure 17. Average catches of large YFT caught in free schools with SST >25°C (potential spawning grounds) during the 1st quarter of the year, period 1991-2020.

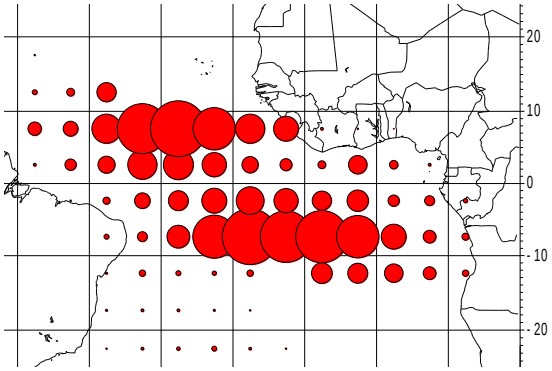

Figure 18. Average quarterly catches of BET by LL for areas with SST >25°C (potential spawning grounds) during the first quarter of the year, period 1960-2020.

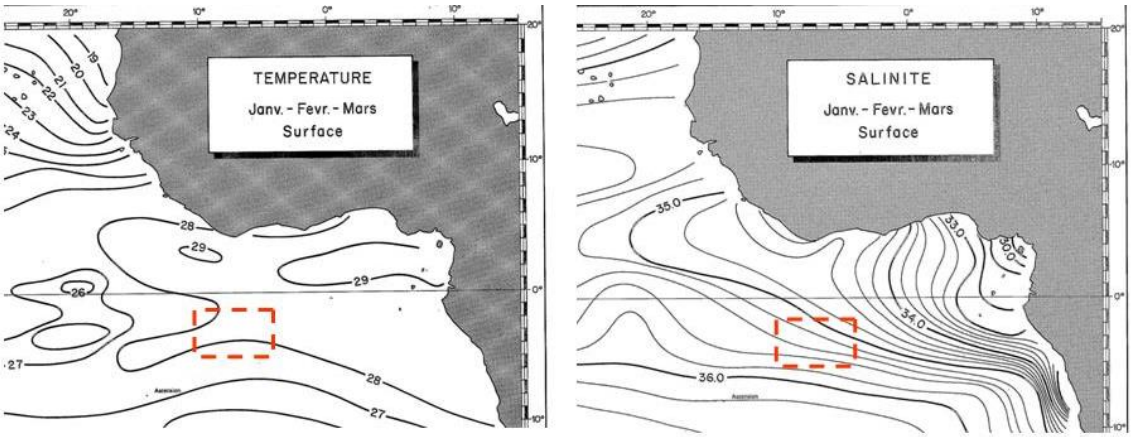

Figure 19. a) Average sea surface temperature (in the left); b) average salinity observed in the Eastern Atlantic during the 1st quarter (in the right); from the Merle 1978 Atlas). The area of the 2019 concentration is shown in red.

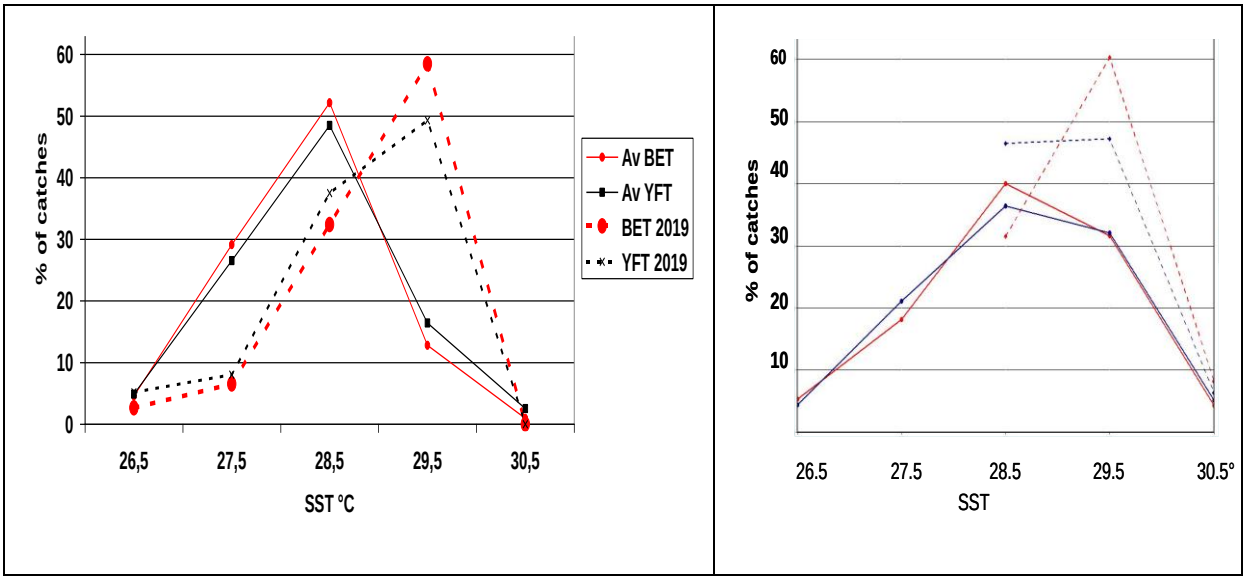

Figure 20. Average catches of YFT and of BET, in percentage of the total catches and in the studied stratum, as a function of the sea surface temperature of each set recorded in the French (**Figure 20a**, left) and Spanish logbooks (**Figure 20b**, right), during the 1st quarters of 2 periods: average period 2000-2018 and 2019.

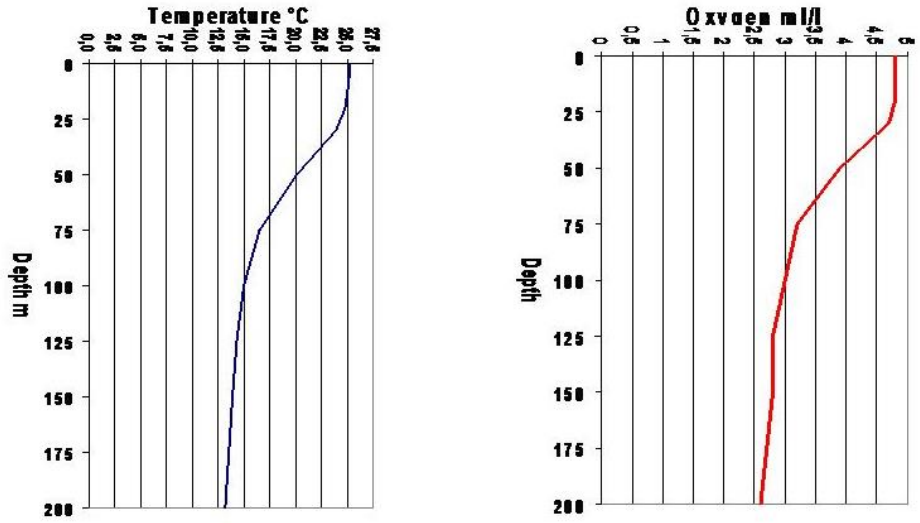

Figure 21. a) Average temperature (left) and b) oxygen rates (right), as a function of depth during the first quarter of the year in the 5° square: 300005 (from the NOAA Levitus & Boyer's atlas).

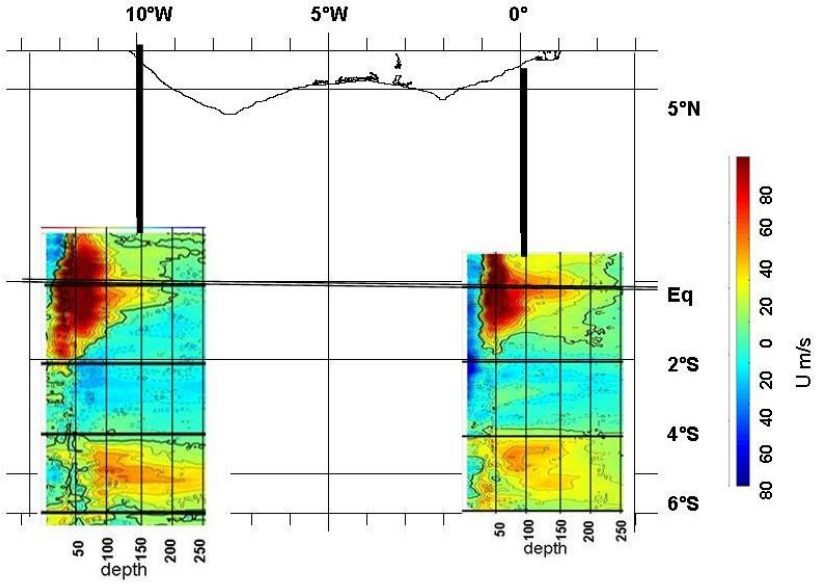

Figure 22. Vertical section of the zonal components of the currents between 10 and 250 meters measured in March 2019 by the PIRATA research vessel Antea using ADCP, at 10°W and along the Greenwich meridian (from Bourlès *et al.*, 2019).

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