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EFFECTS OF THE ICCAT FAD MORATORIUM ON THE TUNA FISHERIES AND TUNA STOCKSA. Fonteneau¹, D. Gaertner², A. Maufroy³ and M. J. Amandè⁴**SUMMARY**

This paper analyzes the ICCAT FAD moratorium implemented since 2013. Analysis of FAD catches in 2006-2012 showed that 8.7% and 5.3% of bigeye and yellowfin FAD catches respectively were caught in the moratorium strata. For recent years (2013-2014), two major fleets have been operating in the area: the European and associated purse seiners, and Ghanaian vessels. Both fleets have been well following the moratorium during these years. The moratorium implementation has produced a significant decrease in FAD catches during January February for the Ghanaian fleet, but not for the European fleet, as during the moratorium, this fleet was efficiently fishing on FADs in alternate fishing grounds. There was no higher catches in the moratorium area in March 2013-2014 and no visible change in the free school fishing. Total FAD catches have been high during the 2011-2014 period. This moratorium had very little impact in the protection of juvenile tuna; there is no evidence that this regulation may significantly improve stock status. More efficient alternate management of the FAD fishing should be envisaged, larger closed areas and measures targeting to reduce the today overcapacity of the FAD fishery

RÉSUMÉ

Ce document analyse le moratoire de l'ICCAT sur les DCP mis en œuvre depuis 2013. L'analyse des prises réalisées sous DCP entre 2006 et 2012 a montré que 8,7 % et 5,3 % des captures sous DCP de thon obèse et d'albacore, respectivement, ont été réalisées dans les strates du moratoire. Pour ces dernières années (2013-2014), deux grandes flottilles ont opéré dans la zone : les flottilles de senneurs européens et associés et les navires ghanéens. Les deux flottilles ont bien respecté le moratoire au cours de ces années. La mise en œuvre du moratoire a entraîné en janvier et février une diminution significative des captures sous DCP de la flottille ghanéenne, mais pas de la flottille européenne, étant donné que, pendant le moratoire, cette flottille pêchait efficacement sous DCP dans d'autres zones de pêche. Il n'y a pas eu de capture plus élevée dans la zone du moratoire en mars 2013-2014 et aucun changement visible dans la pêche en bancs libres. Les prises totales sous DCP ont été élevées au cours de la période 2011-2014. Ce moratoire a eu très peu d'impact en matière de protection des thons juvéniles ; il n'y a aucune preuve que ce règlement puisse améliorer considérablement l'état des stocks. Il conviendrait d'envisager une gestion alternative plus efficace de la pêche sous DCP, des fermetures de zones plus grandes et des mesures visant à réduire la surcapacité actuelle de la pêche sous DCP.

RESUMEN

Este documento analiza la moratoria de ICCAT a los DCP implementada desde 2013. El análisis de las capturas sobre DCP en 2006-2012 demostró que un 8,7% y un 5,3% de las capturas sobre DCP de patudo y rabil, respectivamente, fueron realizadas en los estratos de la moratoria. Para los años recientes (2013-2014), dos flotas principales han estado operando en la zona: los cerqueros europeos y asociados y los buques ghaneses. Ambas flotas han cumplido bien la moratoria durante estos años. La implementación de la moratoria ha producido un descenso significativo en las capturas de DCP durante enero-febrero para la flota ghanesa, pero no para la flota europea ya que durante la moratoria dicha flota ha pescado de forma eficaz sobre DCP en caladeros alternativos. No se produjeron capturas mayores en la zona de la moratoria en marzo de 2013-2014 y no se produjo ningún cambio visible en la pesca sobre bancos libres. Las capturas totales sobre DCP han sido elevadas durante el periodo 2011-2014. Esta moratoria ha tenido muy poco impacto en la protección de los túnidos juveniles, no

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hay evidencias de que esta reglamentación haya mejorado significativamente el estado del stock. Debería preverse una ordenación alternativa más eficaz de la pesca con DCP, zonas de veda más amplias y medidas destinadas a reducir el exceso de capacidad actual de la pesquería con DCP.

KEYWORDS

*FAD moratorium, Season regulations,
Fishery management, Bigeye, Yellowfin, Purse seine fishery*

1. Goals of the paper

The main goal of this paper is to answer to the paragraph 26 of the Recommendation [14-01] by the ICCAT Commission: “The efficacy of the area/time closure referred to in paragraph 24 for the reduction of catches of juvenile bigeye, yellowfin and skipjack tunas shall be evaluated by the SCRS in 2015”. This work will analyze the potential effects on fisheries and stocks of the present ICCAT moratorium. This work will be based on the catch and effort and catch at size data from the various fisheries active in the moratorium area and it will analyze the changes in the levels of FAD catches of skipjack, bigeye and yellowfin due to the implementation of the ICCAT moratorium since January 2013. The present paper will also examine the potential effects of these changes on the status of these 3 tuna stocks.

2. Materials & methods

This study is based on the most recent ICCAT Task I and Task II, C/E by 1° & 5° squares and CAS, of the two main surface fleets (1) the EU *et al*⁵ PS fleet covering the 1991-2014 period, and (2) the Ghanaian fleet of BB and PS until 2014. Catches by other PS fleets are poorly documented during the period analyzed and consequently were only incorporated in the estimated total FAD catches (based on TASKI). Ghanaian log books and sampling data of the year 2014 have been processed independently, as this data set was not yet available in the ICCAT data base. This ad hoc data processing of the Ghanaian 2014 C/E and CAS data has been done according to the rules proposed by the 2015 ICCAT bigeye WG on the basis of Chassot *et al.* (2015) in order to process the 2006-2013 Ghanaian statistics. This study also compares the current ICCAT Task II and the corrected Bigeye catches proposed by Fonteneau (2015), as it has been recently suggested that the ICCAT total bigeye catches in 2013 and 2014 were underestimated and their geographical distribution likely biased. Because 2015 data were not available yet the analysis of the FAD moratorium effect is based only with the first 2 years of its 3-years implementation period.

3. Ex-ante⁶ analysis of the PS FAD fisheries data: what potential effects could be expected from this Moratorium?

3.1 Catches by species in the moratorium area before the implementation

A fundamental method in a ban of FAD-fishing, targeting a reduction of small bigeye (or small yellowfin) catches, is the choice of a hot spot in terms of FAD catches, and depending of the species to protect, the selection of a spatio-temporal strata with a high percentage of small bigeye or/and small yellowfin.

The implementation of this FAD moratorium was decided in 2011 by the ICCAT Commission, but this management decision did not rely on *ex ante* study of its potential effects on the stocks and fisheries. As a consequence the choice of this time and area measure was primarily made by the ICCAT commissioners on the basis on the advices by their national scientists, and not on a collegial decision-making by the SCRS (this could be interpreted as being in contradiction with ICCAT Res. [11-17] on best available science, which requests *that*

⁵ EU *et al.* : this acronym is used to describe the group of vessels fishing under EU flags (from Spain and France), by also including catches by purse seiners owned and managed by Spanish companies but fishing under various flags of non EU countries (Guatemala, Panama, Cabo Verde, Belize, Netherland Antilla, etc.). All the C/E and CAS statistics of this category of vessels has been always well followed by the IEO Spanish scientists, and these data have been reviewed each year in an EU SCRS document. These data have been routinely submitted to the ICCAT Secretariat.

⁶ *Ex-ante* or “before the event”, wording commonly used in commercial world synonymous of WHAT?

independent and objective scientific input, based on the best available and peer-reviewed scientific deliverables, is presented by the SCRS to the Commission. This time-area regulation measure has been targeting a ban of FAD-fishing during two months (January and February) in a wide area of half a million km²; defined as between the African coast to 10°S, and 5°W to 5°E. This regulated area covers a mixture of international waters and of various EEZ, producing in practice for the fleets targeting mainly FADs a total closure of the EEZ from Ghana, Togo, Dahomey, and also large fractions of EEZ from Côte d'Ivoire, Liberia and Equatorial Guinea.

Total yearly catches of FAD associated yellowfin, skipjack and bigeye by the EU *et al.* PS and by Ghanaian fleet in the regulated strata during the 2006-2012 period⁷ were estimated from ICCAT task2. These 2 fisheries are by far widely dominant in the FAD fisheries; catches of minor & poorly documented FAD catches by minor fleets with poor TASK2 statistics have been omitted from the present study, as these small catches would not significantly change the ex ante diagnosis. The selected catches can be compared with the total and FAD catches of tropical tuna for yellowfin and bigeye (**Table 1**).

The same comparison can also be made for skipjack, the main species targeted by the FAD fishery and the dominant species in the Atlantic FAD catches (**Table 2**).

It can be noted from these 2 tables that:

- yellowfin: An average of about 1300 t. (i.e., 5.3%) of the yellowfin was caught in the moratorium strata in association to FADs during the 2006-2012 period. These individuals were caught at a low average weight close to 3.2 kg (2000-2012). However the proportion of catch from the restricted strata represented only 1.2% of the total catch of this species in the Eastern Atlantic.
- skipjack: The amount of skipjack caught under FADs in the moratorium area can be estimated at an average level of 8200 t, (5.7% of the total skipjack catch in the Eastern Atlantic during the 2006-2012 period). skipjack were caught at an average weight of 1.9 kg (similar to the average weight of skipjack in the entire eastern Atlantic = 2.1 kg).
- bigeye: An average of about 1800 t. of bigeye associated to FADs were captured inside the strata. The percentages of bigeye catch under FAD inside the moratorium strata were often significant, reaching an average 9.2% of the FAD catches during the 2006-2012 period. Bigeye were caught at a low average weight of 3.5 kg (period 2000-2012), however, the catch of this species declared from the moratorium strata was only a minor component of the total bigeye catches in the Atlantic Ocean (2.2 %).

However, it should be also kept in mind, that there is a large potential uncertainty in the species composition of the FAD catches inside the restricted area (Fonteneau *et al.*, 2015). This uncertainty concerns mainly the proportion of bigeye and yellowfin in the moratorium strata. This point can be seen by comparison of **Figure 1a**, which represents the average species composition of the EU PS FAD catches from ICCAT Task 2 averaged over the 2002-2014 period (assuming homogeneity in species composition on very large areas) and **Figure 1b** depicting the spatial distribution of the corrected species composition of the FAD catches, but here based on 5° square samples). While the total amount of yellowfin & of bigeye appears to be similar on the 2 maps, the geographical pattern of areas where yellowfin or bigeye are really dominant in the samples are not visible in the ICCAT Task 2. Sizes of tunas caught associated to FADs in the moratorium strata are most often small and consequently typical to tuna FAD sizes. The average sizes for the moratorium area during January and February from 2000-2012, sampled on the EU PS FAD catches and extrapolated to the average FAD catches of the 3 species in the same moratorium strata are displayed by **Figure 2**. From this figure it can be observed that the size distributions of the 3 species are characteristics of FAD associated tunas, most individuals of the 3 species being caught at sizes between 35 and 70 cm. Modal sizes are observed for yellowfin and bigeye in the same range of sizes (class 46.0- 47.9 cm), while skipjack modal sizes are observed in the 44.0-45.9 cm class. For the sake of simplicity, the benefit in terms of percent of reduced catch due to the implementation of the moratorium on FADs is summarized by species and by life-stage (i.e., juveniles and spawners) on **Table 3**. Such simple table highlights that even a full compliance of the closure of the FAD fishery inside this strata could not significantly reduce the total catches of any of the 3 species of tropical tunas, while it could somehow significantly reduce the FAD catches of small yellowfin (5.3%) and more importantly of small bigeye (8.7%). These effects are however highly dependent of 2 additive factors:

⁷ This period 2006-2014 period was selected in order to cover a recent period of at least 7 years before the moratorium, this period being also the period covered by the new statistical revision of Ghanaian TASK2, but the choice of this period is not conditioning the results of our ex-ante analysis.

- (1) a full compliance of the moratorium, as FAD catches by IUU fleets may reduce the potential benefit of the closure, as observed during the historical closure of FAD fishing in the PICOLO area, by fishermen in 1998 and later by ICCAT in 2001 (Torres *et al.* 2011).
- (2) the alternate fishing strategies developed on FADs by PS in response of the ban, for instance discovering and exploiting new FAD fishing zones or heavily exploiting the areas at the border of the closed area, by simply waiting for drifting FADs exiting the area (i.e. “fishing the line”, see Kellner *et al.*, 2007; Torres *et al.*, 2011). This point will be examined in the paragraph 4-4.

3.2 Species primarily targeted by the FAD moratorium?

A key question that remains unclear in the ICCAT Commission management recommendation is: which species are primarily targeted by the FAD-moratorium. While it seems implicitly that juveniles of yellowfin and bigeye were equally targeted by ICCAT Rec. [11-01] creating the moratorium, skipjack was added to the current recommendation 14-01 in the recent tropical management plan Rec. [14-01]. On the opposite the CORALITO seasonal closure implemented by the IATTC since 2010 was primarily targeting to reduce the bigeye fishing mortality. This extension to skipjack was due to the multispecies characteristic of the tropical tuna fisheries and any management plan in such context should account for the 3 species of tropical.

However, even with these considerations in mind, a specific regulation measure is likely not applicable for all the species and consequently important scientific comments could be made concerning the species that should be primarily targeted by a specific measure such as a FAD moratorium. Current knowledge on life history traits of the 3 species and of the exploitation rates of the 3 stocks, allows to identify which species should be primarily targeted by the moratorium. On the basis of our current knowledge of the FAD catches, and especially on the fact that similar numbers of yellowfin and of bigeye are caught yearly under FADs in the Atlantic, and of the biology and stock status of the 3 species we propose that in the context of the today Atlantic fisheries, FAD-moratorium should target the 3 tropical tuna species in a decreasing order of priority, as follows:

- 1) Bigeye: It should be stressed that bigeye is a long lived species (over 15 years?) because of its low natural mortality and showing quite low numbers of yearly recruits. It was evidenced that an average 6.5 million/year of juvenile bigeye were caught under FADs during the 2006-2012 period. These large catches in numbers correspond to a high fishing mortality of juveniles (0 and 1 year-classes), and consequently have a strong negative impact on the yield per recruit of the bigeye Atlantic stock. Most bigeye stocks in the World Ocean, including in the Atlantic are now heavily fished or overfished and showing a low yield per recruit because of these excessive FAD catches.
- 2) Yellowfin: The exploited life of yellowfin is much shorter than for bigeye (less than 10 years?) in relation to its much higher natural mortality; subsequently the numbers of yellowfin that are recruited each year are much higher than for the bigeye stock. As an average of 7.4 million/year of yellowfin (mostly juvenile classes 0 and 1 year) have been caught under FADs during the period 2006-2012, these catches correspond to a much lower average fishing mortality than for bigeye. In addition, these FAD catches also have a negative impact on the yield per recruit of the yellowfin stock, but to a much lesser extent than for bigeye.
- 3) Skipjack is a species showing very high natural mortality, an early spawning and a short exploited life (less than 4 or 5 years); very large numbers of individuals skipjack are recruited each year. Today the Eastern Atlantic skipjack stock is heavily fished by purse seiners and are currently mainly caught under FADs. Skipjack sizes caught under FADs tend to be small (about 1.9 kg for the 2000-2013 period), but most of these skipjack are already mature. It was not evidenced yet that skipjack stocks, including in the Atlantic Ocean, have been overfished, likely due to these biological characteristics, even if it was shown that the massive use of drifting FADs may modify some aspects of its biology and ecology (Fonteneau *et al.*, 2000; Hallier and Gaertner, 2008, Wang *et al.* 2014). At least the today skipjack FAD catches are not producing serious decline of the stock yield per recruit as for the yellowfin and the bigeye stocks. As a consequence, using a spatio-temporal ban of FAD-fishing for skipjack seems less a priority than for yellowfin and bigeye.

As a conclusion, in a scientific attempt to prioritize the 3 species of tropical tunas, bigeye should probably be the logical 1st target of the moratorium, followed by yellowfin, and by skipjack with a much lower priority. This proposed ranking of the species priority in the management recommendation should be clarified, first by SCRS scientists and later by the ICCAT Commission. This priority is an important factor as it widely conditions the choice of the appropriate time and area closure.

4. Ex post-analysis: fishery data inside and outside the moratorium area in January & February 2013 & 2014: EU *et al.* PS & Ghana

4.1 Overview of the FAD-fishing during the 2005-2014 period

To perform the analysis of the trends in total catches of tropical tunas associated to FADs yearly catches were estimated since 2005 (**Table 2**) in the following way:

- Knowing the most recent yearly catches by flag, gear and species (TASKI file, September 2015)
- Knowing the catches associated to FADs for the EU *et al.* PS, as declared to ICCAT
- Assuming that all the declared catches of the Ghanaian fleets were caught in association to FADs during recent years
- Estimating the total catches and FAD associated catches for other PS fleets, classified in the category “fisheries without good Task 2”. The total catches of this category of purse seiners was calculated by subtracting the total catches of non EU vessels in the log book data collected and managed by EU scientists from the total ICCAT Task 1 of non EU and non Ghanaian vessels. Based on surveys at landing it was assumed that 90% of these yearly catches were caught under FADs.

This simple reconstitution of the yearly FAD catches indicates that during recent years, the catches of major tunas associated to FADs have been reaching their maximum level estimated between 220.000 and 230.000 tons/year. The estimated FAD catches are showing a plateau during this period. There is no obvious effect of the FAD moratorium regarding a decline of FAD catches in 2013 and 2014.

4.2 FAD catches in the moratorium strata

Fishery data submitted to ICCAT (or available to us on a com pers basis: e.g., Ghana 2014) indicate that there was no FAD fishing declared in the moratorium area in January & February 2013 and 2014 for the EU *et al.* and for the Ghanaian fleets. Minor catches by the Ghanaian fleet have been identified in the Task 2 inside the restricted area (786 t in 2013 and 82 tons in 2014), but in the absence of observer data the associated fishing modes (free schools or/and FADs) were not reported, as fishing mode is not well identified in the Ghanaian log books. The average yearly FAD catches by 5° squares, by species, of the EU *et al.* PS and of Ghana (mostly on FADs) before and during the 2 first years of the moratoria implementation in 2013 & 2014 are showed in **Figure 3 and 4**; The observed changes in the fishing zones of the 2 fleets will be discussed in paragraph 4-5. **Figure 5** depicts the changes over the 2006-2014 period in total catches on FADs of the EU *et al.* PS fleet and the total Ghanaian catches, during the 2 months of the ban. Such figure may be useful to examine if the moratorium produced the expected decline in FAD catches, at least during the period of the closure. These observed changes in the yearly catches of the 2 fleets in the closed strata will be discussed in paragraph 4-5.

4.3 Free schools catches in the moratorium strata

In the same way of idea the changes over time in catches on free schools by the EU *et al.* PS fleet during the months of the moratorium may indicate that the closure of the FAD fishing may have produced an increase of the effort targeting free schools, and then a subsequent increase of the free schools catches (**Figure 6**). This figure indicates that 2013 and 2014 free schools catches by the EU *et al.* PS fleet were similar to the average level of free school catches over 2006-2012 period, close to 10.000 tons. This result would indicate that the moratorium did not produced major changes in the targeting of the fleet favouring free schools sets.

4.4 “Fishing the line effect” during the moratorium

As FADs are highly mobile and drifting over large distances (Maufroy *et al.* 2015), it should be envisaged that FADs seeded before the regulated season inside or close to the moratorium area will move during the months of the moratorium outside the restricted area where they may be caught legally during the moratorium close to its frontiers. Oceanographical data from the Eastern Atlantic region are showing that surface and subsurface

currents in the area are of relatively low intensity in January and February, predominantly moving westward but also eastward in the northern and southern sub areas of the moratorium, see **Figure 7** from Gyory *et al.* 2006. This “frontier effect” may tend to reduce the efficiency of the moratorium, if large numbers of FADs are simply extracting the tuna biomass outside the closed area (as in the ecological trap hypothesis by Marsac *et al.* 2000). Fishing maps by 1° square during the moratorium period have been done to explore this potential phenomenon by a simple comparison before and during the ban for the EU *et al.* PS FAD catches, comparing the 2000-2012 average period (**Figure 8a and 8b**) and for the Ghanaian fleet (**Figure 9a and 9b**), comparing the total average catches by 1° during the 2002-2010 period (as the 2011-2013 Ghanaian data are not available by 1° squares) and in 2014. It can be seen that higher FAD catches have been observed during the moratorium close to the limits of the restricted area. This suggests a potential “frontier effect” or as previously mentioned a “fishing the line effect” as observed during the first moratorium on FAD (Torres *et al.*, 2011): FADs moving outside the moratorium area followed by their associated tuna schools. This phenomenon would need to be studied in more details, for instance:

- 1) Based on a detailed study of the real surface currents in the area during the closure,
- 2) Based on observer data
- 3) Analyzing trajectories of FADs and echo sounder records of FADs in the moratorium area (these data being permanently collected daily by every purse seiners and sometimes analyzed by scientists, as by Maufroy *et al.* 2015)
- 4) Understanding FAD and GPS buoy deployment and retrieval strategies, to anticipate potential changes in these strategies that would reduce the benefits of the moratoria (For instance replacing GPS buoys of stolen FADs within the closed area.

It should also be recommended that when an “*ex ante*” analysis of a potential moratorium is conducted, this study should also cover an analysis of the surface currents in the area.

4.5 Moratorium effects on the EU *et al.* PS and on the Ghanaian fleets

The effects of the moratorium appear to be quite distinct for the EU *et al.* PS and for the Ghanaian fleets:

- ↯ **Figure 5a** shows that the total FAD catches in 2013 and 2014 by the EU *et al.* PS fleet were 30 % lower than in the 2010-2012 period, but at an average level of 13300 tons, i.e. similar to the level of FAD catches during the period 2006-2009 (12,150 t.). It can be concluded from these figures that the moratorium had little or no effect on a significant reduction of FAD catches by the EU *et al.* PS fleet. This lack of significant effects was simply due to changes in the areas fished by this fleet: FAD catches being quite high in various southern areas off Angola where low levels of catches but high levels of CPUEs were observed during previous years. It can also be noticed that the species composition and sizes caught in this southern area off Angola was typical of FADs in terms of its species composition and average size caught. This change in the fishing pattern produced by the moratorium is a typical phenomenon for large scale oceanic PS fleets that are highly mobile and flexible in their fishing behaviour.
- ↯ **Figure 5b** shows that during the January & February closure, the total catches in 2013 and 2014 by the Ghanaian fleet was 33 % lower than during the 2006-2012 period, but still at an average level of 6,300 tons. It can be concluded, from these figures that the moratorium significantly reduced the Ghanaian catches (predominantly on FADs).

This larger impact was probably due:

- (1) to the location of the closed area, with a closure of the Ghanaian and Ivorian EEZ, the 2 main fishing zones of many Ghanaian vessels, and
- (2) to the fact that many Ghanaian vessels are much less mobile than the EU *et al.* PS, and never fishing south of 5°S or in remote areas. Consequently the fishing zones of the Ghanaian fleet during the closure were similar to its traditional fishing zones, but reducing its fishing grounds as well as its fishing effort (many vessels remaining in their home port of Tema during the closure, Bannerman personal communication).

As a consequence, it can be concluded that the moratorium had minor impact to reduce the FAD catches of the EU *et al.* PS fleet, while it did produced a significant decline of the Ghanaian fleet catches. It is also interesting to examine the fishing zone and catch per area in March 2013 and 2014 after the closure. **Figure 10a and 10b** are showing maps of the average FAD catches by the EU *et al.* and the Ghanaian fleets during the month of March 2013-2014 (average) following the ICCAT closure in 2013-2014. These figures are interesting, because in various cases, major catches may be observed in the closed area during the month following its opening. These maps are showing that there was no major fishing activities on FAD in the closed area after its reopening in March 2013 - 2014: most of the EU *et al.* PS fleet has been remaining in the southern offshore waters off Angola, having good FAD catches and also in the southern part of the moratorium area after its opening (but not very good ones). On the opposite, the Ghanaian fleet came back in March to its traditional FAD fishing zone but without showing large catches in the moratorium area.

The validity of these results remains open to discussion: these data are the official ones submitted to ICCAT, but they remain somehow questionable because of various additive reasons such as:

1. Some illegal FAD fishing may have occurred in the moratorium strata without being recorded in the log books used in the analysis. As none of the observer data of the various PS fleets is available in the ICCAT data base, there is no way to estimate these potential unreported catches.
2. Knowing that various minor fleets of purse seiners were also active in the area in 2012 and 2014, for instance from Belize, Cote d'Ivoire/Korea or Guinea, and that they may have been fishing on FADs in the moratorium strata. These catches are difficult to estimate because most of the C/E statistics available for these fleets remain limited and questionable. However, as the major fleets from the EU *et al.* PS and from Ghana have been relatively well monitored during the period, corresponding to about 95% of the total PS catches during the 2013-2014 period, it can be hypothesized that there were no major FAD catches in the closed strata by IUU fleets.
3. Because of the serious uncertainties in the current species composition of FAD catches during the years 2013 and 2014: following the work by Fonteneau 2015, the levels of the estimated current FAD catches of bigeye and yellowfin in the today ICCAT statistics would appear to be widely underestimated, being underestimated of 25% for yellowfin and of 33% for bigeye in 2013-2014 (because of problems in the today data processing leading to the estimates of species composition FAD catches).

Another important point, shown by the same Fonteneau 2015 paper, is the possibility that present C/E statistics of the FAD fisheries are possibly overestimating bigeye catches in the northern coastal part of the moratorium area (north of the equator) and underestimating the FAD bigeye catches in its southern offshore component. This potential statistical uncertainty probably remains of minor importance to evaluate the consequences of the moratorium. However there is no doubt that the choice of closed fishing zone and seasons should be based on fully valid species composition of the FAD catches by time and area, allowing to identify well the areas with higher percentages and higher catches of bigeye of yellowfin (depending of the species primarily targeted by the closure). In the Atlantic, based on the analysis of species composition of the EU *et al.* PS FAD catches by Fonteneau 2015 it would appear that:

1. Coastal areas of the Guinea Gulf between 15°N and 15°S are most often showing a relatively a lower percentage of bigeye associated to FADs.
2. Percentages of bigeye are most often higher in the offshore areas.

As an example, based on the corrected species composition of the FAD catches proposed by Fonteneau 2015, there was an average 9 % of bigeye in the bigeye FAD catches in the coastal areas north of equator, between 10°W and 5°E), while the average percentage of bigeye was reaching 17 % in the symmetrical three 5° squares positioned south of the equator. This basic statistical information should be fully analyzed and well taken into account in the choice of the closed area, probably leading to target the offshore FAD areas when planning FAD moratorium that are aiming to reduce the bigeye FAD catches. On the opposite, coastal areas should be primarily closed if the main management target is to reduce catches of small yellowfin.

5. Potential effects of the moratorium on the bigeye, skipjack & yellowfin stocks?

The closed strata chosen by the ICCAT commission was clearly of significant duration and size, especially for Ghanaian fleet because of the location of its main fishing zone, but it appears that the impact of this closure for the conservation of any of the 3 stocks of yellowfin, skipjack and bigeye cannot be highly significant:

1. because of the quite limited amount of FAD catches in the closed strata in comparison with total catches of tropical tunas (easily shown in the *ex ante* analysis).
2. because of the great flexibility of most modern tuna fleets. As a consequence, while there was temporarily a significant decline in the Ghanaian FAD catches due to the moratorium, there was very little or do decline of FAD fishing for the dominant fleet of EU *et al.* PS, but simply a change in their fishing strategy, keeping FAD fishing as their main fishing strategy.

As a result, while the maximum targeted effect of the moratorium (a cryptic target, in the absence of an *ex ante* analysis of this moratorium) was moderately ambitious, as shown by **Table 3**, its ideal goal has not been reached and by far, since the moratorium did not significantly reduced yellowfin, skipjack and bigeye FAD catches. As a result FAD catches have been maintained since 2013 at their highest level (**Table 4**). There is still a possibility that the bigeye FAD catches would have been higher without the implementation of the ICCAT moratorium, but this possibility remains difficult to evaluate. It should also be noted and kept in mind that:

1. This potential reduction in the yellowfin, skipjack and bigeye catches due to the moratorium would be very limited, for instance compared to the current statistical uncertainties in total FAD catches,
2. This potential reduction of catch is so limited that none of the stock assessment analytical models currently used by SCRS that are most often quite uncertain in their results, could quantitatively evaluate this small impact on the stock status of the three tropical tunas.

Conclusion

Our conclusion is that while this ICCAT FAD moratorium was quite ambitious, its results appear to be limited and quite disappointing. The analysis of fishery data strongly demonstrates that this moratorium was well applied by the main fisheries, but that there was no visible decline in the estimated FAD catches during and after the closure, and then probably very little or no hope to expect significant improvement in the yellowfin, skipjack or bigeye stock status. This lack of visible results would tend to cast serious doubts on the efficiency of such moratorium: even a 2 months closure of a large and active fishing zone did not produced visible positive effects to reduce FAD fishing catches and FAD fishing mortality, and to improve the current stock status of tropical tunas. As a lesson, this is a confirmation that modern fleets of PS are so flexible today in their fishing behaviour and strategy that they can most often compensate for the seasonal closure of a given fishing zone, being able to efficiently fish on FADs in alternate new fishing zones. The main cases where/when the moratorium could be of great interest remain the closure of a given hot spot identified in the fishery data: for instance a given time & area strata showing very high catches of juvenile bigeye/yellowfin, or a high biodiversity of species associated to FADs. These potential biological hotspot should of course be identified by scientific studies.

On the other side, this moratorium on FAD fishing that has been well followed by most fishermen offers a wide range of scientific studies based on the detailed analysis of fishery data, on the movements of FADs and on the biomass of tunas associated to them, of fine scale activities of purse seiners and their supply vessels should urgently be developed by ICCAT scientists. This work could provide new scientific information on tunas, FAD and fisheries in relation with such closed time and area strata. This work should necessarily be based on close cooperation between EU and Ghanaian scientists and a full sharing of their data bases, especially in relation with FAD fishing. In most cases, the main target of an efficient management of FAD fishing should primarily target to reduce the today overcapacity of the FAD fishing: too many purse seiners fishing on FADs, too many supply vessels and too many FADs permanently deployed and monitored as it was analyzed by Fonteneau *et al* 2015 (even if the level of fishing effort targeting FADs cannot be measured). This question has been recently tackled by the ICCAT scientists and by the FAD working group created in 2014 by the ICCAT commission FAD (An. ICCAT 2015), but these management prospects of FADs fisheries remain totally hypothetical ones. However and based on this analysis it could be concluded that unless some efficient management actions are taken by tuna RFOs and by ICCAT to reduce the overcapacity of the FAD fishing, there is probably very little of no hope to efficiently manage the FAD fisheries solely implementing seasonal closures of selected time and area strata.

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Table 1. Bigeye and yellowfin FAD catches in the moratorium strata, total catches (free schools and FADs) from ICCAT Task I and FAD catches from the 2 main fleets selected (EU *et al.* and Ghana).

Year	BET Moratorium strata	YFT moratorium strata	Total BET	Total YFT	% of BET catches	% of YFT catches	BET FAD catches	YFT FAD catches	% BET FAD catches	% YFT FAD catches
2006	1446	1164	65 011	105 393	2,2	1,1	14 827	23 628	9,8	4,9
2007	1290	1138	73 482	95 905	1,8	1,2	13 362	21 409	9,7	5,3
2008	1117	1048	67 955	109 284	1,6	1,0	17 161	28 513	6,5	3,7
2009	2053	1653	85 040	120 445	2,4	1,4	21 622	26 040	9,5	6,3
2010	1926	1536	85 189	114 047	2,3	1,3	24 924	28 617	7,7	5,4
2011	3070	1865	88 861	106 266	3,5	1,8	29 686	23 120	10,3	8,1
2012	1423	864	75 332	103 611	1,9	0,8	19 252	22 094	7,4	3,9
Average 2006-2012	1761	1324	77267	107850	2,2	1,2	20 119	24775	8,7	5,3

Table 2. Skipjack FAD catches in the moratorium strata, total catches (free schools and FADs) from ICCAT Task I and FAD catches of the 2 main fleets selected (EU *et al.* and Ghana).

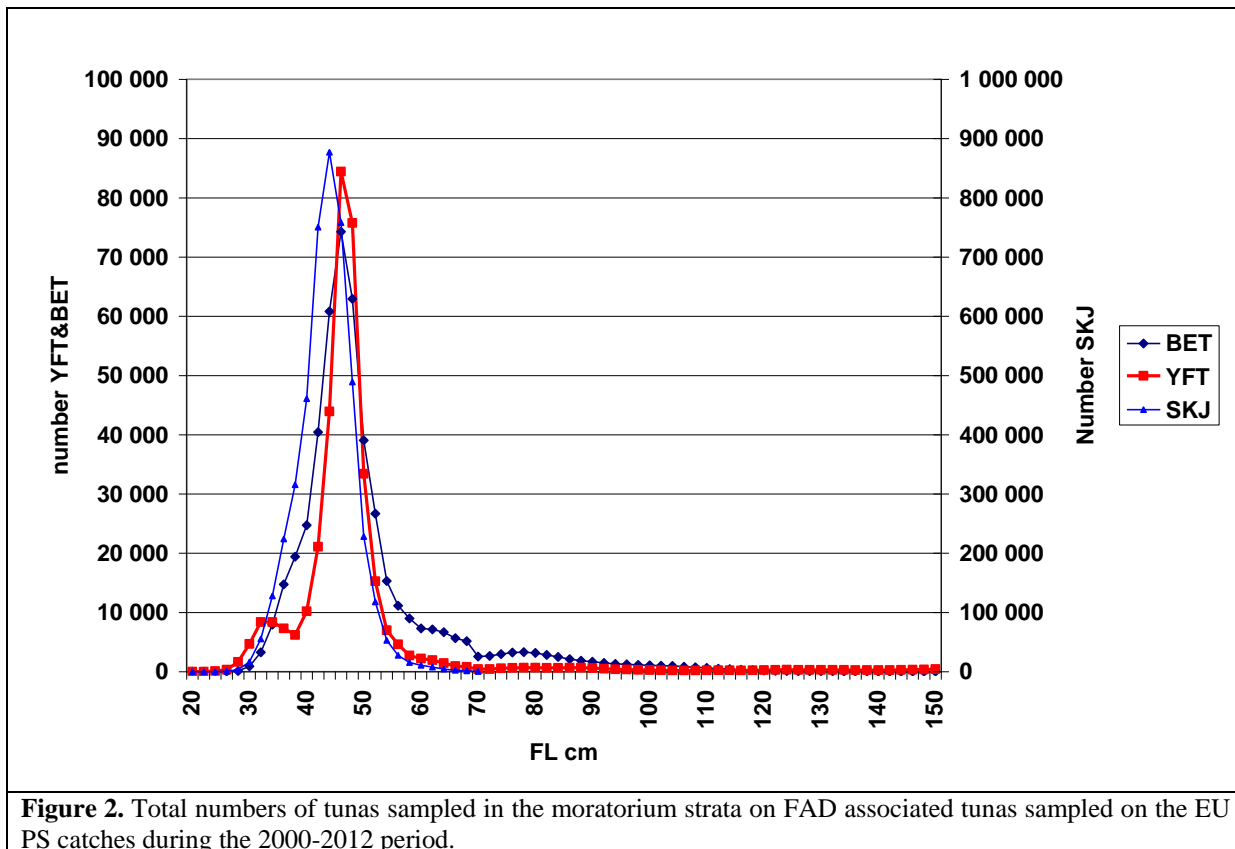
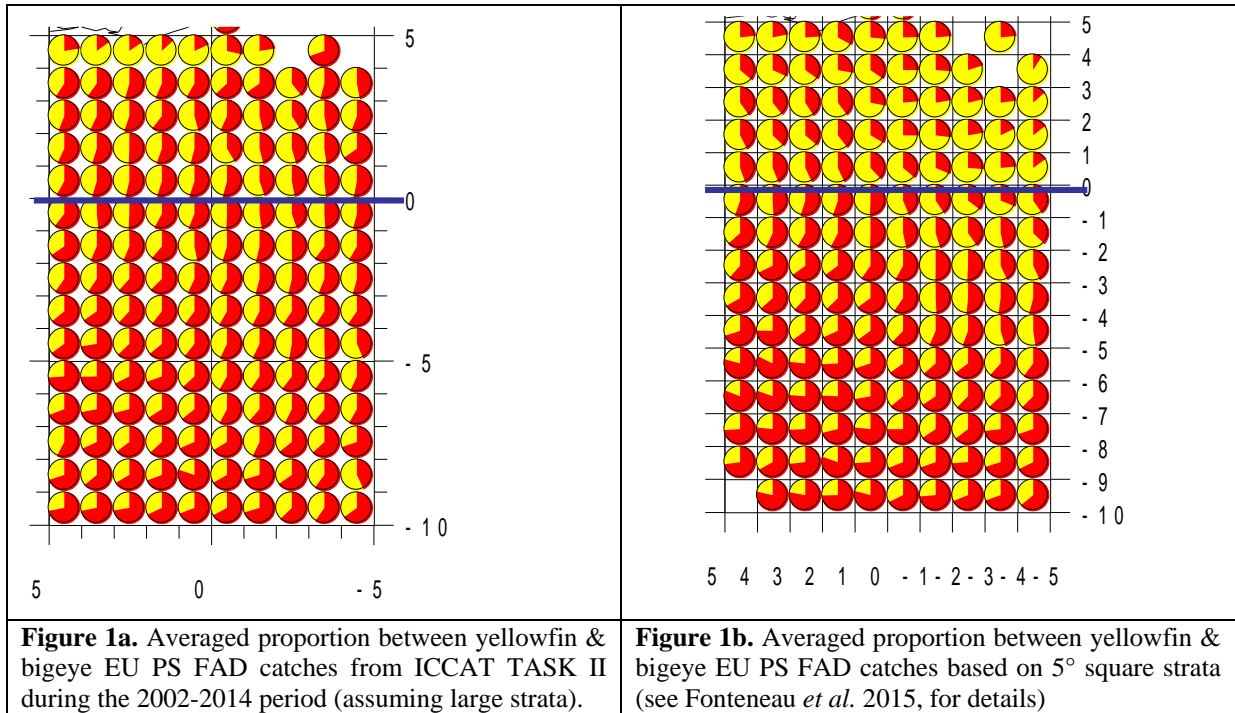
Year	SKJ moratorium strata	Total Eastern Atlantic SKJ	% of SKJ catches
2006	7 333	112 570	6,5
2007	6 131	113 331	5,4
2008	7 031	120 053	5,9
2009	7 671	125 093	6,1
2010	9 405	166 261	5,7
2011	12 565	187 449	6,7
2012	7 236	207 545	3,5
Average 2006-2012	8 196	147 472	5,7

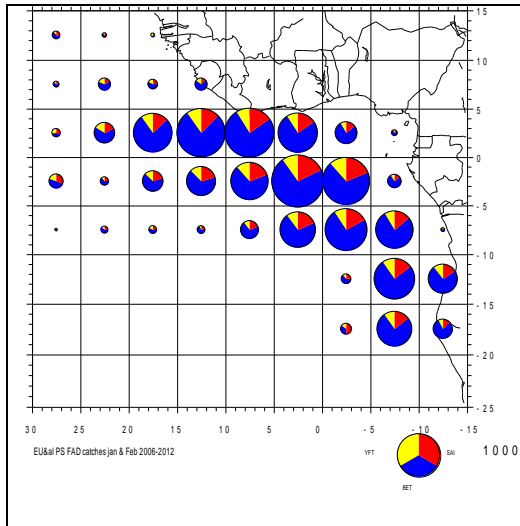
Table 3. Maximum average benefit in terms of percent of reduced catches that could be expected from the ban (decline of catches & of fishing mortality) based on Task 2 data (the impact of juvenile catches was estimated based on the average catch at size of these 2 species and assuming first spawning at 1 m).

	Juvenile	spawners	whole stock
yellowfin	5.3%	ε	1.2%
skipjack	ε	4.3%	4.3%
bigeye	8.7%	ε	2.2%

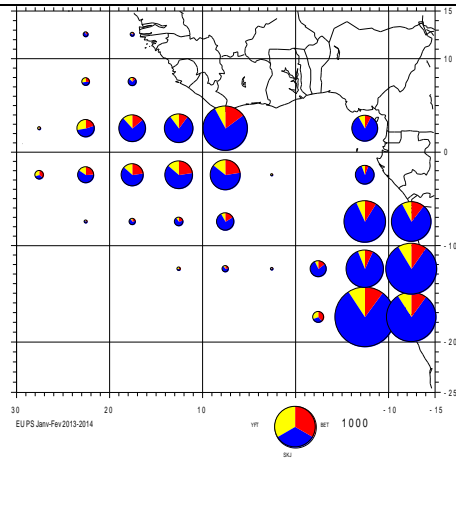
Table 4. Estimates of total catches of tropical tunas associated to FADs.

Year	EU&al PS	Ghana	Fisheries without good TASK2	Total FAD catches
2005	67 811	76 085	1 596	145 492
2006	59 756	69 186	0	128 942
2007	67 862	64 259	4 457	136 577
2008	80 187	58 224	2 057	140 468
2009	83 366	77 308	5 492	166 165
2010	99 056	86 485	9 035	194 576
2011	120 430	81 471	27 149	229 049
2012	115 686	77 954	37 311	230 951
2013	132 715	60 736	33 009	226 460
2014	129 735	71 011	31 086	231 832

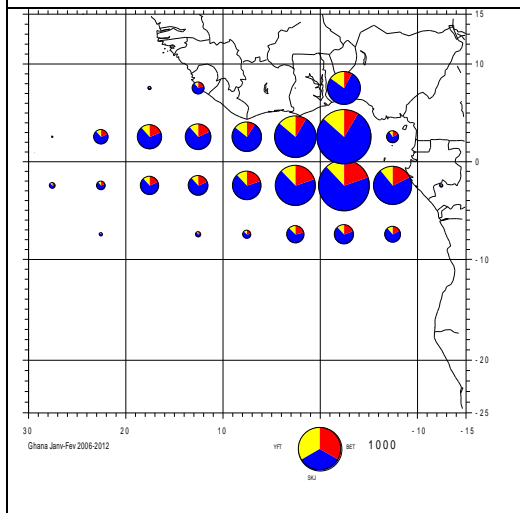




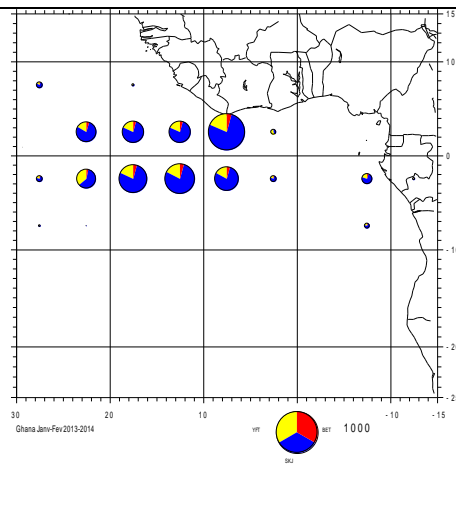
EU et al. PS FAD catches Jan & Feb 2006-2012



EU PS Jan+Feb 2013-2014



Ghana Jan+Feb 2006-2012



Ghana Jan+Feb 2013-2014

Figure 3a (upper fig.). Average FAD catches by the EU *et al.* PS fleet during January-February 2006-2012, and 3b (lower figure) total Ghanaian catches same period.

Figure 4a (upper fig.): Average FAD catches by the EU *et al.* PS fleet during January-February 2013-2014, and 4b (lower figure) total Ghanaian catches same period.

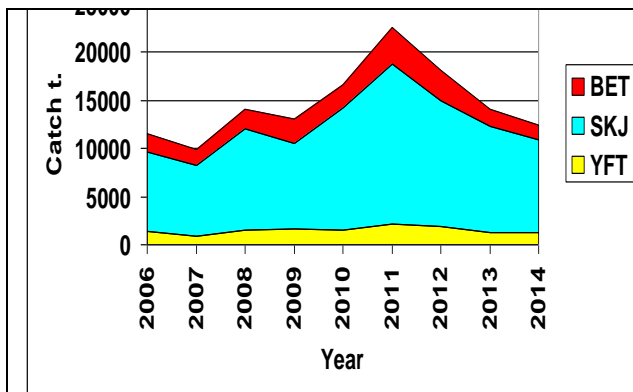


Figure 5a. Total catches on FADs of the EU *et al.* PS fleet during the 2 months closure

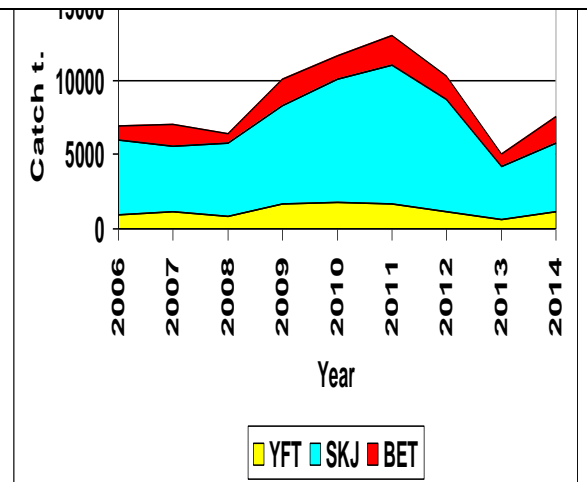


Figure 5b. Total catches of the Ghana fleet during the 2 months closure

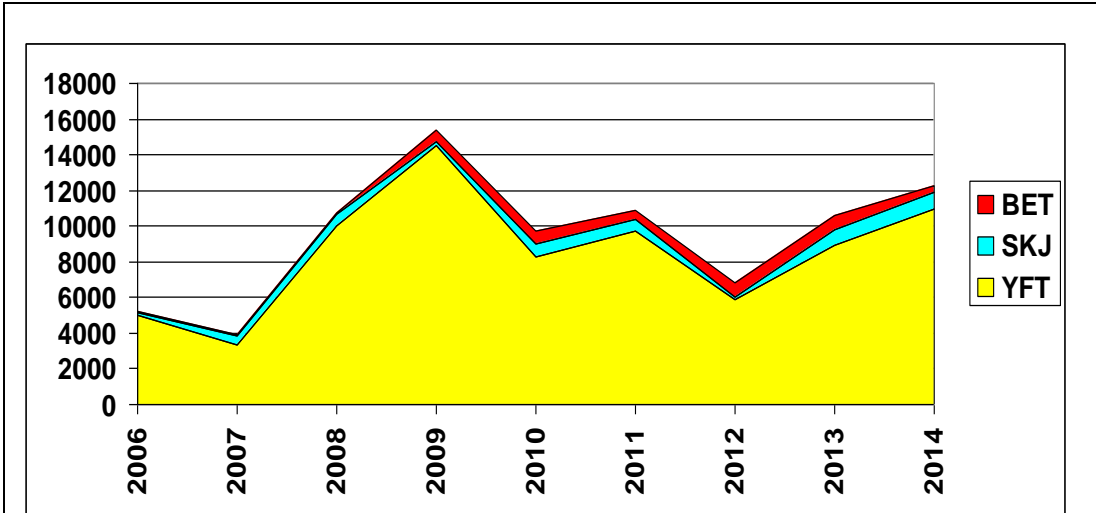


Figure 6. Yearly catches on free schools by the EU & al PS fleet during January and February.

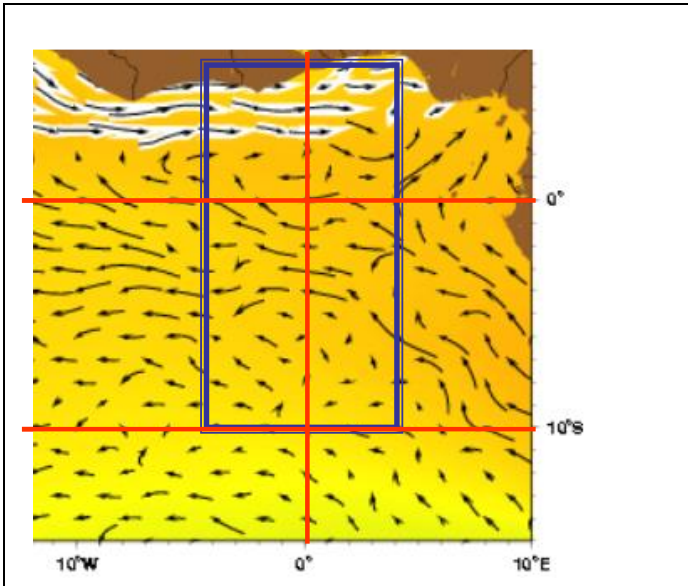


Figure 7. Average direction and speed of surface currents in the moratorium area during the 1st quarter (taken from Gyory *et al.* 2006).

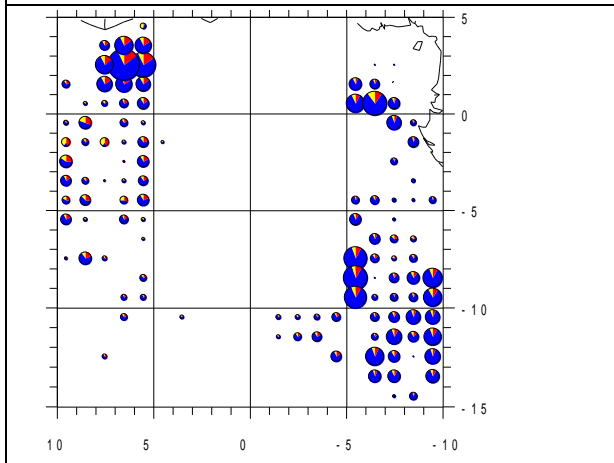
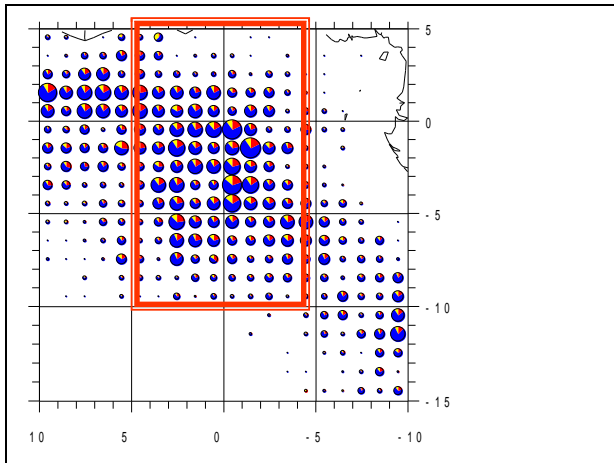


Figure 8. Average fishing map of the EU *et al.* PS fleet in January and February: 8a upper figure 2000-2012 period, and 8b lower figure 2013-2014.

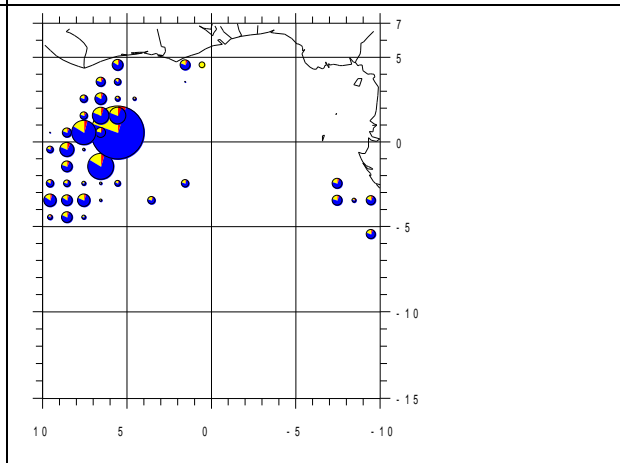
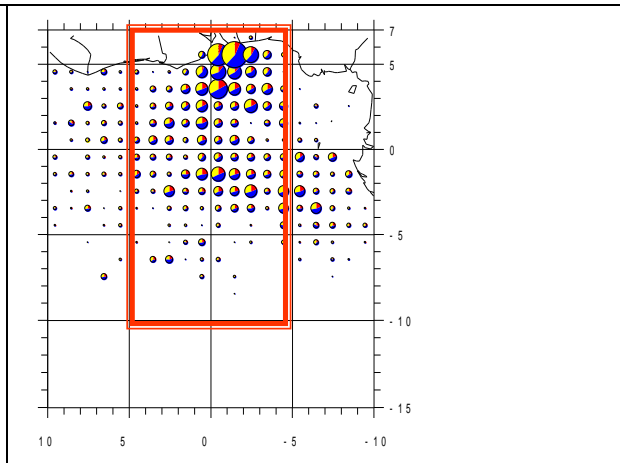


Figure 9. Average fishing map of the Ghanaian fleet in January and February: 9a upper figure 2002-2010 period, and 9b lower figure 2014.

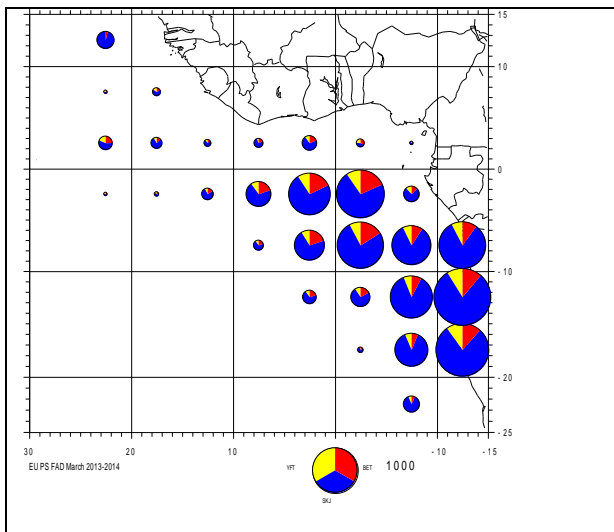


Figure 10a. Average FAD catches by the EU *et al.* PS fleet in March 2013-2014.

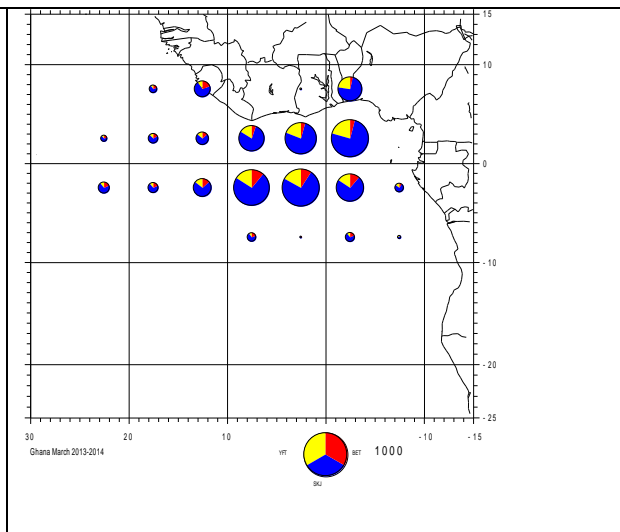


Figure 10b. Average catches by the Ghanaian fleet in March 2013-2014.