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# ALTERNATE IMPROVED ESTIMATES OF THE BIGEYE FAD CATCHES BY THE EU AND ASSOCIATED FLAGS PURSE SEINERS AND BY THE GHANAIAN FLEETS IN THE ATLANTIC

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*SUMMARY*

*This paper is describing a new method estimating the species composition of FAD catches and this method is applied to estimate the bigeye FAD catches of the EU et al.[3] PS. Our new estimates of bigeye catches are primarily based on the use of small and mobile 5° areas that are more homogeneous than the large areas used today. Estimates of bigeye catches by the Ghanaian fleet are also done simply correcting an error in the today data processing. These improved methods allow to estimate that until 2011, the FAD bigeye catches were very close to those used by the 2015 bigeye WG, but since 2012, the bigeye catches would have been significantly underestimated, especially for Ghana. Total recent catches of bigeye should be increased by 3% in 2012, 10% in 2013 and 14% in 2014. Such increase in the bigeye FAD catches could have a significant negative impact on the stock status. It is recommended that a fully validated and official revision of the species composition should be conducted on all FAD catches, based on small mobile strata, but based on new calculations done as the today correction on the catches by size categories from the log books.*

*RÉSUMÉ*

*Ce document décrit une nouvelle méthode qui estime la composition par espèce des prises sous DCP; cette méthode est appliquée pour estimer les prises de thon obèse réalisées sous DCP par l'UE et al.[4] PS. Nos nouvelles estimations des captures de thon obèse sont principalement basées sur l'utilisation de zones réduites et mobiles de 5° qui sont plus homogènes que les grandes zones utilisées aujourd'hui. Les estimations des captures de thon obèse par la flottille ghanéenne sont également obtenues en corrigeant simplement une erreur dans le traitement des données d'aujourd'hui. Ces méthodes améliorées permettent d'estimer que, jusqu'en 2011, les captures de thon obèse sous DCP étaient similaires à celles utilisées par le groupe d'espèces sur le thon obèse en 2015 mais que, depuis 2012, les captures de thon obèse auraient été considérablement sous-estimées, en particulier pour le Ghana. Les récentes prises totales de thon obèse devraient être augmentées de 3 % en 2012, de 10 % en 2013 et de 14 % en 2014. Cette augmentation des captures de thon obèse sous DCP pourrait avoir une incidence négative importante sur l'état du stock. Il est recommandé qu'une révision entièrement validée et officielle de la composition par espèce soit réalisée sur toutes les captures sous DCP, sur la base de petites strates mobiles, mais en se fondant sur de nouveaux calculs effectués comme la correction actuelle sur les captures effectuées par catégories de taille qui sont consignées dans les carnets de pêche.*

*RESUMEN*

*Este documento describe un nuevo método para estimar la composición por especies de las capturas de DCP y se aplica para estimar las capturas de patudo de DCP de la UE et al.[5] PS. Nuestras nuevas estimaciones de las capturas de patudo se basan principalmente en el uso de áreas pequeñas y móviles de 5º que son más homogéneas que las áreas grandes que se usan hoy. Se realizan también las estimaciones de las capturas de patudo por parte de la flota ghanesa corrigiendo simplemente un error en el procesamiento de los datos actual. Estos métodos mejorados permiten estimar que, hasta 2011, las capturas de patudo de DCP eran similares a las utilizadas por el Grupo de especies de patudo en 2015 pero que, desde 2012, las capturas de patudo habrían sido considerablemente subestimadas, especialmente para Ghana.*

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[3] EU *et al.* PS: this acronym will be equivalent to the term "European and associated fleets purse seiners".
[4] UE *et al.* PS: cet acronyme sera équivalent au terme " flottilles de senneurs européens et associés".
[5] EU *et al.* PS: este acrónimo es equivalente al término "flotas de cerco europea y asociadas".

*Las capturas totales recientes de patudo deberían aumentarse en un 3% en 2012, un 10% en 2013 y un 14% en 2014. Este aumento en las capturas de patudo sobre DCP podría tener un importante impacto negativo en el estado del stock. Se recomienda llevar a cabo una revisión oficial y totalmente validada de la composición por especies en todas las capturas sobre DCP, basada en pequeños estratos móviles, pero basada también en nuevos cálculos realizados como la corrección actual de las capturas por categorías de talla a partir de los cuadernos de pesca.*

*KEYWORDS*

*Biological sampling, Catch composition, Catch statistics, Multispecies fisheries, Bigeye, Purse seine fisheries, FADs*

## 1. Introduction: Goals of this paper

All statistics of bigeye catches associated to FADs used by the various tuna RFMO (ICCAT, IOTC, IATTC & WCPFC) are entirely based on scientific estimates, and never on the log book data, because the amount of small bigeye have to be sampled by scientists (on board by observers as in the WCPFC area, or during their landing as the ICCAT, IOTC and IATTC areas by field sampling technicians). However, the methods used to estimate bigeye catches are variable and always questionable, because they are facing serious uncertainties, for instance due to inadequate or insufficient multispecies sampling or due to an inadequate data processing of the log books and species sampling data (as it was discussed in the Anon., 2010 document following an ad hoc working group on this subject).

This work will only tackle the second type of problems related to uncertainties in the data processing, being a follow up of Fonteneau, 2015 (*in press*) showing that the areas presently used in the data processing of FAD catches of the EU *et al.* PS in the Atlantic Ocean (following the work by Pianet *et al.*, 2000) are too large and too heterogeneous. This paper was simply proposing the new idea that 5°-quarter strata should preferably be used in the data processing of the species composition, simply because of the large numbers of samples available today in most fished strata.

The goal of this paper is to propose such new data processing of the EU *et al.* PS catches leading to a corrected species composition, simply based on the today Task II corrected by the multispecies sampling file of the EU purse seine fleet by 1° squares (so called NN.T file). In all these calculations, the species composition of FAD catches will be assumed to be identical to the species composition of the sampled catches small 5° areas (fixed or mobile ones) and quarter (sampled tunas being weighted to the sampled catches, in general the sizes of the sets). Strata substitution will be done only if a minimal sampling level has been reached in the strata, and various potential levels of minimal sampling rates will be analyzed. The same problem of using too large areas in the data processing of the species composition has been also faced in the data processing of Ghanaian C/E Task II data, and this problem will also be analyzed, in order to better estimate the Ghanaian species composition.

## 2. Material and methods

This analysis will be using 2 types of data sets:

- The Task II of the EU& al PS and of the Ghanaian fleets submitted to ICCAT by EU (untill 2014) and estimated by Chassot *et al*., 2015 (*in press*) for Ghana until 2103. The 2014 Ghanaian catches will be estimated based on the ad hoc data set handled and described in Fonteneau and Lucas, 2015 on the effects of the FAD moratorium.

- The file of the basic EU multispecies samples and of the observed species composition of the multispecies samples (so called NN.T file). This file contains for each sample, the fishing month and the fishing area by 1° square, and the sampled weight of each species, as well as this sampled weight extrapolated to the weight of the sampled catches. This last parameter will be mainly used in this analysis because it is more representative of the species composition of the catches.

The species composition in each strata is estimated from the sampled catches only if a minimum number of tunas have been sampled in the strata, this calculation being done independently of the total catches in the strata. These calculations have been done for 3 levels of minimal numbers of tunas sampled in the 5°-quarter strata: 500, 1000 and 2000 tunas.

In the very rare cases when a given 5° square has never been significantly sampled during the studied period, is has been assumed that these catches were showing the average species composition of the FAD catches in the 5° strata during the entire studied period 2002-2014 was used. This method has been chosen as a temporary working hypothesis, as it appears that the geographical heterogeneity is the most important factor in the variability of FAD species composition. Future data processing should of course be based on a realistic statistical analysis of time and space heterogeneities, allowing to establish improved well founded rules for strata substitutions.

Two independent methods will be used to estimate this revised species composition and revised bigeye catches at a detailed geographical scale:

- Fixed strata estimates: Doing this calculation by the traditional fixed 5° squares and quarters.
- Mobile strata estimates: Estimating the corrected species composition in each 1° square based (1) on all the samples collected the month before and after the fishing month (including in January and December on samples from the previous or following year) and (2) on all the samples from the 24 surrounding 1 degree squares (i.e. a size of area equivalent to a 5° square.

The basis of these 2 methods are summarized in **Figure 1a and b**.

## 3. New estimates of corrected bigeye catches of the EU& al PS catches

### *3.1 Total bigeye catches*

The fact that the areas used today in the data processing of FAD catches of the EU&al PS are now widely questionable has been shown by Fonteneau, 2015 (*in press*). This conclusion is well summarized by **Figure 2a** showing the average pattern of FAD species composition observed in the EU&al PS samples during the last 15 years. This geographical heterogeneity appears to be widely inconsistent with the large areas used today to estimated the species composition of FAD catches (**Figure 2b**) (as the species composition is assumed to be homogenous in each of these areas).

An easy way to estimate a corrected species composition of the catches is to correct the species composition by 5° & quarters, based on the species composition observed in the sampled catches at the same scale. This simple method has been called the “fixed strata” method. This simple calculations has been done on the 5°-quarter weighted samples, using all strata with a minimum number of tuna sampled: more than 500, 1000 or 2000 individuals sampled.

The second method based on mobile strata is more complex to develop; this method was applied to the same data sets (Task II C/E and samples of the EU&al PS fleet by 1° squares) and following the same rules.

The yearly levels of bigeye catches are very similar at these 3 minimal sampling rates and for the 2 methods used, including during recent years (**Figure 3**). The bigeye catches are not widely distinct from the bigeye catches estimated today. However it should be noted that a significant increase of the bigeye FAD catches is estimated by the new method in 2013 and 2014: an average increase of 1700 t. in the fixed strata method and of 1600 t. in the variable strata method.

This difference is probably due to the quite distinct pattern in the fishing/sampled areas and of the species composition in some area during the 2013-2014 period. This change in the FAD fishing/sampling areas is shown by **Figure 4a and 4b**.

Percentages of strata substitution in the 5°-quarter data processing (**Figure 5**) are showing:

- Low sampling rates and high strata substitution in 2000 & 2001: our method based on 5° square sampling was very difficult to use in 2000 and 2001 because of its too high substitution rate.

– Period 2002-2014: 19% of strata substitutions when a minimum of 2000 individuals is used, and 10 % with a minimum of 1000 tunas sampled in the 5°quarter strata.

Rate of strata substitution would be much lower with a minimal number of 500 tuna sampled by strata, but these results would of course be more uncertain.

Our base case will be based:

1. On a minimal sample of 2000 tunas sampled by 5°-quarter, this minimal level being estimated as being a good compromise between a moderate rate of strata substitution and a probably quite low uncertainty in the sampling of the real species composition of the FAD catches.

2. On the results of the mobile strata method, as this method appears to be more realistic than the fixed strata method, and also because its rate of strata substitution is most often lower than for the first method.

These choices are preliminary ones and they should of course need further statistical study (for instance the analysis based on log book data and on catches by size categories as in the today corrections).

***3.2 Changes in the geographical distribution of bigeye FAD catches***

While during the 2000-2011 period the species composition and the total amount of bigeye catches appear to be quite similar or identical in the official and in our corrected data processing, it should be noted that at a geographical level, there is a constant difference between the official and our corrected catches of bigeye by area.

This geographical pattern is well visible on **Figure 6** showing the average level of total FAD bigeye catches by 5° squares of the EU *et al.* PS in the official ICCAT Task II statistics, with coloured pie showing:

1. In red the average weight of bigeye that should be added to each 5° square bigeye catch, (these red catches being sometimes larger than the today catches shown by the circle, when the average catch in the 5° would need to be multiplied by a factor over 2 ).

2. or in green the average weight of bigeye that should be substracted to each 5° square bigeye catch during this average period (these green catches are always smaller than the today catches shown by the circle).

This map is showing a clear geographical pattern: significantly reducing bigeye catches in all coastal areas between 10°N & 5°S, and increasing bigeye catches in most offshore areas.

This pattern is also visible during the 2 last years 2013 and 2014, but showing a more complex pattern, see **Figure 7**.

Large changes in species composition have been estimated in various areas in 2013 and 2014; these changes are following the logical geographical pattern shown by **Figure 2**, but at a wider geographical scale. The same anomalies are estimated by both methods (fixed and mobile strata). The potential causes explaining these differences between the results obtained in 2013 and 2014 by the 2 data processing methods remain unclear, but they are probably due to errors in the today data processing based on too large areas and to the potential heterogeneities in species composition in these wide areas (or to other causes?).

This new pattern of the FAD bigeye geographical catches is an important result: when fishing areas are planned to be closed to FAD fishing in order to reduce the FAD bigeye catches (as the FAD moratorium implemented by ICCAT since 2013), these closures should primarily target the offshore areas because they are showing higher percentage of bigeye, and not the coastal ones (between 10°N & 5°S) where bigeye is most often less abundant in the FAD catches. This point is now clearly visible in the results of our revised data processing, but not in the today ICCAT Task II.

**Figure 8** is showing the average balance between yellowfin & bigeye catches in the average FAD catches of the EU *et al.* PS during the 20012-2014 period. This estimated geographical heterogeneity is probably much more realistic than the heterogeneity estimated today by the EU *et al.* PS Task II statistics.

### *3.3 Species composition of unweighted and weighted samples*

It appears that the species composition of FAD catches are quite distinct if the data processing is done on the basic samples or on the weighted samples. It has been concluded by EU scientists that all data processing of the species composition and sizes caught should be done on the weighted samples (as in the TTT software).

This divergency between these data processing is due to the fact that the observed species composition of the samples is quite dependent of the sampled weights: percentage of bigeye in the samples is showing a decline at increasing weight of sampled catches/sets. This result is well shown by **Figure 9**.

This point should be further analyzed: potentially allowing to reduce bigeye FAD catches: for instance simply reducing the numbers of sets smaller than the today average size of about 30 tons would reduce the bigeye catches.

### *3.4 Species concentration of tuna catches close to statistical frontiers*

When an homogeneous fishing concentration of tunas is exploited on the 2 sides of any of the time and area statistical frontiers used in the today data processing (limits between areas and limits between quarters), the species composition estimated for these catches will be distinct on both side of these statistical frontiers. This artificial difference in the species composition on the 2 sides of this time & space lines will be created by the average quarterly species composition in each of the 2 large strata.

As an example, catches caught on the concentration of FAD associated tunas exploited in October 2002 in a small area of four 1° squares between 4°E and 6°E (then around the 5°E statistical frontier) between 4°N and 2°N is showing today a major heterogeneity in its species composition east and west of the 5°East line: 28% of BET west of the 5°E line, and only 1% of BET east of this line. On the opposite, the species composition based on the local samples used in our method is showing a quite homogeneous species composition of these localized FAD catches: 8% and 5% of BET west and east of the 5°E line. As a result, while the bigeye catches in this strata were estimated today at 124 tons (on a total catch of 800 t.), the real catches of bigeye estimated from the 5300 tunas sampled (18 samples) on these catches are showing a more realistic estimated catch of only 40 tons of bigeye. This case is only shown as an example, but it appears that all the concentrations fished close to any time and area statistical limit will be facing this type of problem in the today data processing: creating artificial heterogeneity of a well sampled homogeneous group of well samples sizes.

## 4. Alternate species composition of the Ghanaian Task II during the 2006-2014 period

It is also of great interest to estimate a potentially revised species composition of the Ghanaian catches based on the 5°quarter EU *et al.* PS samples. This tentative correction was done during the 2006-2014 period keeping all EUPS FAD samples with more than 1000 tunas samples by 5°-quarter. It should be noted that unfortunately these results are obtained each year with a high & stable rate of strata substitution close to 40% between the EU PS and Ghanaian catches by 5°-quarter, even at a quite low minimal rate of 1000 tuna sampled per 5°quarter (**Figure 10**).

This high rate is simply due to the fact that the Ghanaian EU PS fleets are frequently fishing in distinct fishing strata. As a consequence of this spatial heterogeneity, it should be concluded that the EU sampling data cannot be used at the 5° level to estimate the species composition of the Ghanaian catches.

The 3 large areas that have been used by Chassot *et al*., 2015 (*in press*) in their data processing remain a logical way to reduce the amount of strata substitution. However, if the areas are better than the FAD areas used in the today EU&al PS data processing, they may contain spatial heterogeneities that have been introducing some bias in the estimated species composition of Ghanaian catches: as an example the species composition in the so called "Cap Lopez" area between 5°N and 15°S is clearly heterogeneous (cf **Figure 2a**), while the today data processing will assume that the Angolan samples of the EU catches could estimate the species composition of Ghanaian catches in the Cap Lopez area: this is a very unrealistic method, because the FAD species composition off Angola & Gabon is widely distinct!

Furthermore, it appears that the 2006-2013 species composition of the Ghanaian catches was based on all the EU samples in the 3 areas shown by **Figure 11**. This was clearly a wrong hypothesis: the species composition of the large catches and large samples off Angola and Mauritania during recent years (shown by **Figure 4b**) has nothing to do with the Ghanaian catches caught in the 6°N-5°S area. Then the 3 areas used by Chassot *et al.*, 2015 (*in press*) could well be kept in the Ghanaian data processing, but only using the samples caught in the 6°N-5°S area (the fishing zone of the Ghanaian fleet), and eliminating the large number of EU PS FAD samples North of 6°N and south of 5°S. This corrected species composition has been estimated, starting from the species composition estimated by 5°-month by Chassot *et al.,* 2015 (*in press*), and correcting this species composition based on the 6°N-5° EU samples in the 3 areas shown by **Figure 11**. The yearly catches of bigeye estimated by this method are shown by **Figure 12** (including the 2014 results) and compared with the bigeye catches used by the 2015 stock assessment analysis.

This **Figure 12** is showing that during the 2006-2011 period, the bigeye catches used by the 2015 bigeye WG are very close to the level of bigeye catches estimated by the proposed method. However, the levels of corrected bigeye catches estimated during recent years 2012-2014, are much higher that the levels of catches estimated and used in the 2015 stock assessment.

Our proposal for a corrected species composition of Ghanaian catches is probably much more realistic that the today species composition because the species composition estimated for a given fishery should never be driven by the samples from fisheries that are active in remote areas and potentially showing widely distinct species composition.

## 5. Discussion and conclusion

It would appear that the bigeye catches during the recent period 2012-2014 could have been widely underestimated for the Ghanaian fleet and to some extent for the EU *et al.* fleet. This potential level of errors of bigeye catches presently estimated for the 2 fleets is summarized by table 1. The revised estimates of bigeye catches of the EU *et al.* PS catches that are solely based on a fine scale 5° scale sampling and with few strata substitutions are probably better than the results based on the very large and potentially heterogeneous fishing zones used today. There is doubt that when a new fishing is developed in a remote distinct area, its species composition should be estimated based solely on the observed species composition of the samples from this new fishing area. In the data processing method used today, these new fishing zones developed by the EU *et al.* PS during recent years and their large number of samples have been facing various types of problems:

1. When the species composition was distinct in the new and remote fishing zone, the samples in the new fishing zones have been introducing an artificial change and bias in the species composition estimated in traditional fishing zones, while its real species composition was stable, the today method producing an erroneous species composition in the newly fishing zone, its estimated species composition being contaminated by samples from the traditional areas.

2. If the large areas used today are showing some variability over the years, this variability of the yearly geographical heterogeneity will disappear because each of the large strata used today is assumed to be permanently valid and homogeneous.

3. The fixed time and area statistical frontiers that have been used today in the data processing have been creating artificial heterogeneity in the estimated species composition in the areas close to these frontiers, even when these catches were showing in their samples an homogeneous species composition, Future data processing should always keep the real species composition of all the well identified catches taken on tuna concentrations when they have been well sampled.

4. In general the today assumption of constant species composition during quarters and in large area tend to mask any potential variability of the species composition (and sizes caught) within these large strata (for instance in the south equatorial area), while on the opposite our proposed method of small mobile strata will keep track of any potential variance spatial and temporal ones, as our calculations are not conditioned by fix strata (or by limits between quarters). These potential problems have been for instance analyzed by Fonteneau and Lucas 2015 in the species composition of FAD catches in the Indian Ocean, the results of our method always showing a much larger variance of monthly species composition by 5° areas that the today method.

In our proposed method based on 5°-quarter scale samples, these types of problems would of course disappear, our method being valid for all configurations of fishing zones (if catches from all the fishing zones have been well sampled) and independently of time or areas statistical frontiers. Furthermore, any potential geographical variability between years will be immediately identified and well visible in the results of this method (without facing potential bias introduced by quarters and large fixed areas).

The same type of problem was indirectly faced in the data processing of the Ghanaian species composition. Our conclusion is that the new species composition proposed in this paper and the corresponding total catches of bigeye are probably much more realistic than the level of declining catches used by the stock assessment WG. These increased bigeye catches are not official ones, but they are probably much more realistic than the data used by the stock assessment WG. In the today context of the increased bigeye catches, revised ASPIC stock assessment model should preferably be conducted before the 2015 SCRS meeting in order to evaluate the impact of these recent increased catches on the today stock status diagnosis obtained by the 2015 stock assessment WG. This revised analysis should ideally be based on an analytical stock assessment analysis (for instance using VPA or SS3) as the recent increase of bigeye catches mainly concerns the catches of class 0 bigeye. It can already be estimated that, based on the proposed correction of FAD catches, the number of bigeye caught at age 0 (i.e. at ages less than 12 months) would be increased at an average rate of approximately 40% during the 2012-2014 period. Consequently this increase of age 0 catches would produce a similar increase in the fishing mortality suffered by class 0 bigeye and then an additional decline in the yield per recruit of the stock. However as the feasibility of this updated analysis is probably low, the ASPIC model would be the only alternative. There is no doubt that these increased catches during the 2012-2014 period will increase the fishing pressure exerted today on the bigeye stock and that it will not improve the today status of the bigeye stock. This logical result is for instance well shown by preliminary ASPIC runs based on these revised 2012-2014 catches that are given in **Annex 1**.

At a general statistical level, it is recommended that a fully validated and official revision of the species composition should be conducted for all FAD catches and especially for the EU *et al.* and for the Ghanaian fleets, during recent years. However, there is no doubt that this future data processing should be stratified in the 3 size categories (<10kg, 10 to 30kg and >30kg) presently used today in the data processing (based on the log book data). Such improved data processing based on the species composition by these 3 size categories was for instance successfully applied by Fonteneau and Lucas 2015 to estimate an improved species composition of the EU *et al.* FAD catches in the Indian Ocean. This future data future data processing should also be based on an optimal scheme of strata substitution based on an in depth statistical analysis of the time and space heterogeneities in species composition and sizes caught.

It should also be kept in mind that these changes in the bigeye catches are also producing some changes in the estimated catches of small yellowfin (and also of skipjack), but at a lower degree. It is also recommended that the future method used in the data processing of the sampling data leading to estimating corrected species composition of the landings should be conducted at the scale of ICCAT and in close cooperation with the IOTC and the IATTC, 2 tuna RFOS that are facing the same types of statistical problems. Great care in this statistical analysis should be given to the choice of the time and area strata used to estimate the species composition of FAD catches, as this choice appears to be of key importance to condition the results. Furthermore, while our data processing method has been solely targeting the species composition of FAD catches, it use should also be envisaged (and recommended) for free schools catches, and also simultaneously targeting species composition and sizes caught, all these calculations being based on small mobile strata.

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**Table 1.** Total bigeye catches used by the WG and tentatively corrected.

| *Year* | *BET catches: BET WG* | *Ghanaian missing BET* | *EU PS missing BET* | *Corrected BET catches* | *% of catch increase* |
|---|---|---|---|---|---|
| 2012 | 73386 | 2581 | 0 | 75967 | 3.5 |
| 2013 | 67986 | 5066 | 1440 | 74492 | 9.6 |
| 2014 | 68390 | 7550 | 1699 | 77639 | 13.5 |

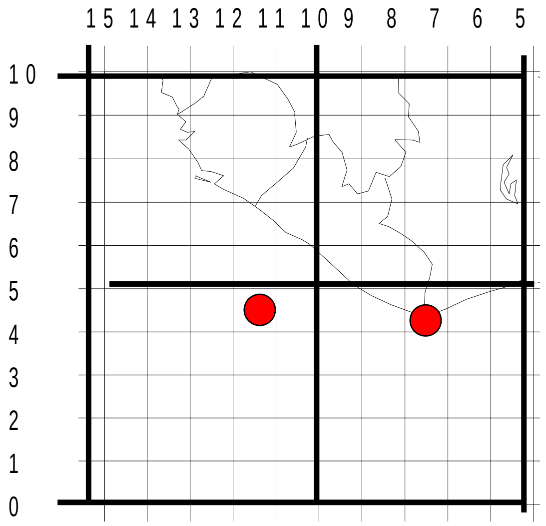


**Figure 1a.** Fixed strata method. January catches in the two 1° areas: their species composition is estimated based on the species composition of the sampled catches in each 5° and quarter

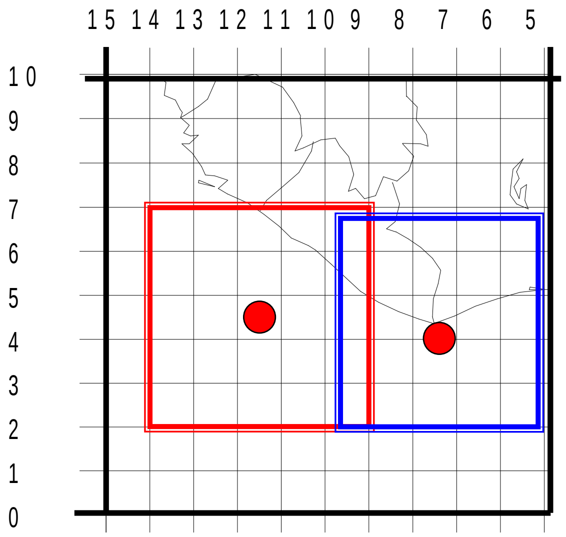


**Figure 1b.** Mobile strata method: January catches in the two 1° areas: their species composition is estimated based on the species composition of the sampled catches in the 5° area centred at the fished 1°-quarter, during the fishing month of December, January and February

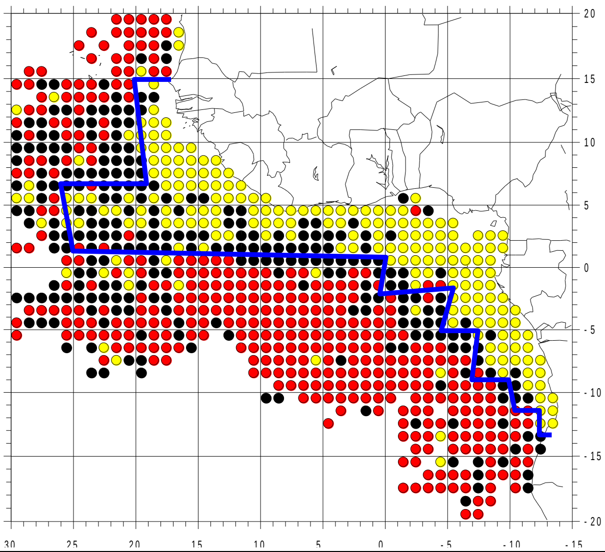

**Figure 2a.** Map showing the average species composition of yellowfin and bigeye proportion in the EU PS FAD samples, period 2000-2014: in yellow yellowfin dominant (+60% yellowfin), in red bigeye dominant in the non skipjack catches(+60% of bigeye).(all 1° squares sampled with at least an average of 2 tons of FAD catches sampled in each 1°).

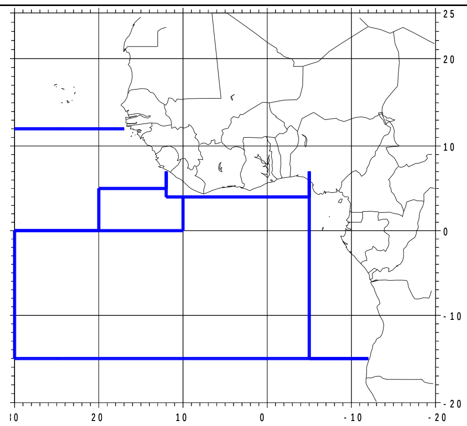

**Figure 2b.** Areas used today to estimate the species composition of FAD catches. The species composition is assumed to be homogeneous in each area during each calendar quarter and permanently since 1991.

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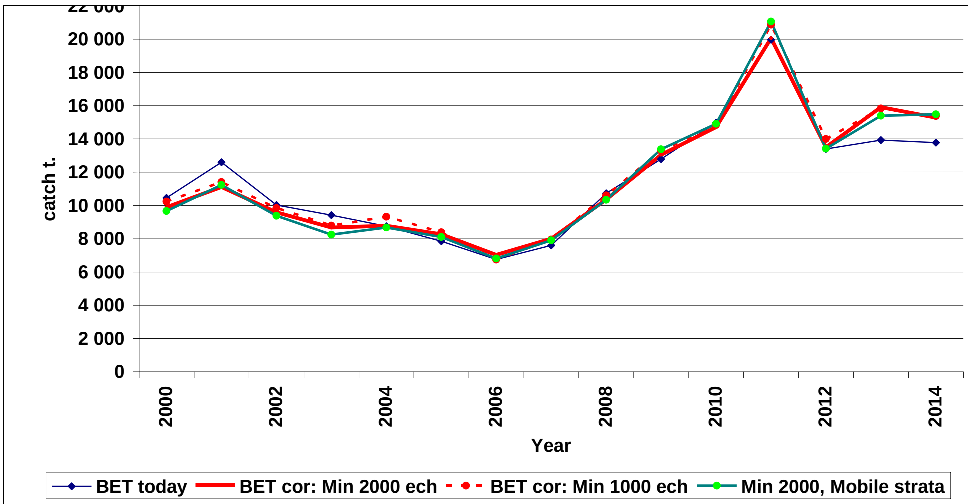


**Figure 3.** Total yearly FAD catches of bigeye by the EU *et al.* PS.

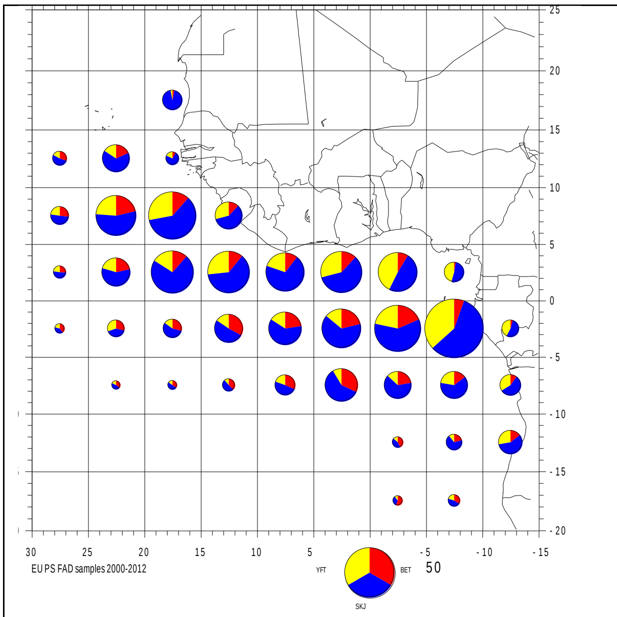


**Figure 4a.** Average catch by species sampled by 5°areas on the EU *et al.* PS fleet during the period 2000-2012.

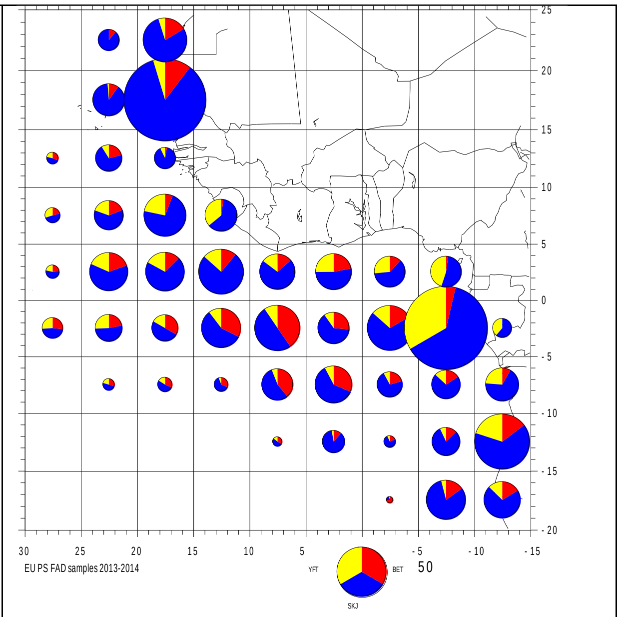


**Figure 4b.** Average catch by species sampled by 5°areas on the EU *et al.* PS fleet during the period 2013-2014.

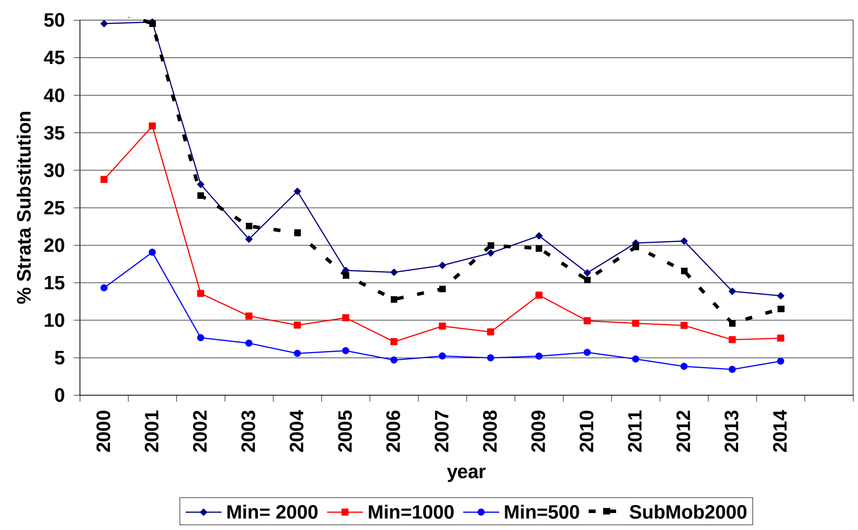


**Figure 5.** Yearly rates of strata substitution under 3 levels of minimal numbers of tuna sampled in each 5°quarter strata for the fixed strata method 1 & of a minimum of 2000 tunas samples in the variable strata method 2.

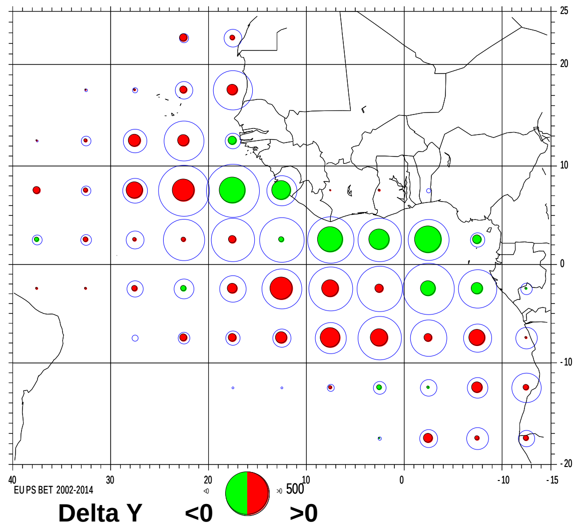


**Figure 6.** Average catches of bigeye associated to FADs by the EU *et al.* PS, today ICCAT data period 2002-2014, and changes in the estimated bigeye catches by 5° squares following the mobile strata method.

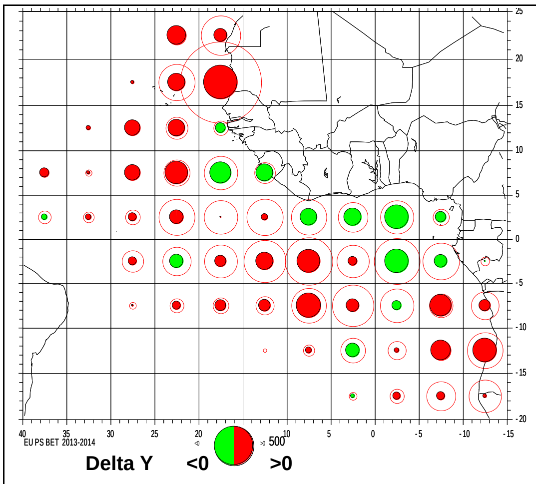


**Figure 7.** Average catches of bigeye associated to FADs by the EU *et al.* PS, today ICCAT data period 2013-2014, and changes in the estimated bigeye catches by 5° squares produced by the mobile strata method.

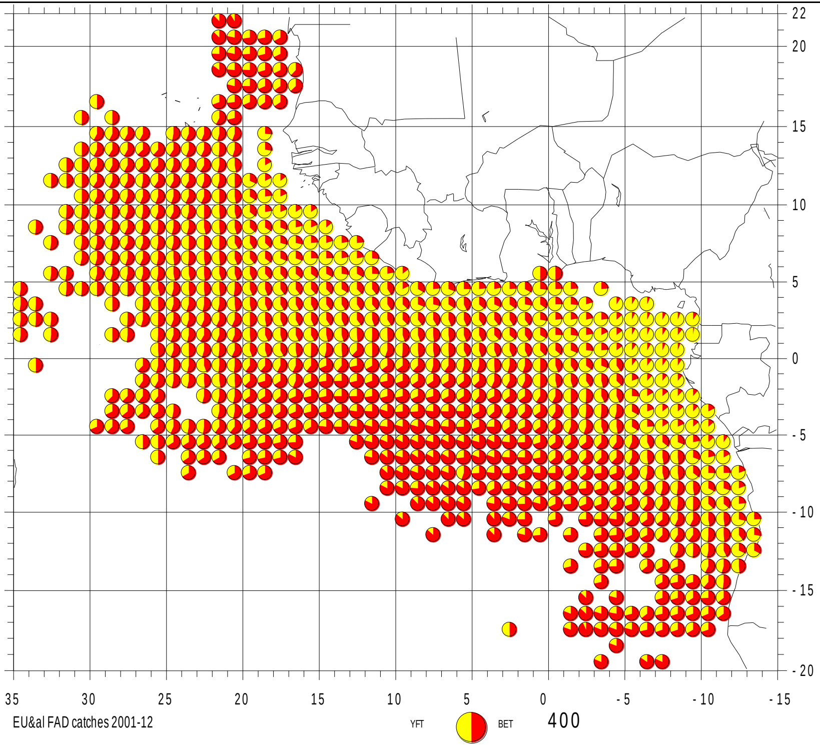


**Figure 8.** Average balance between yellowfin and bigeye (in %) of the FAD catches of the EU *et al.* PS catches, period 2002-2014, as estimated by the mobile 5°-quarter strata method.

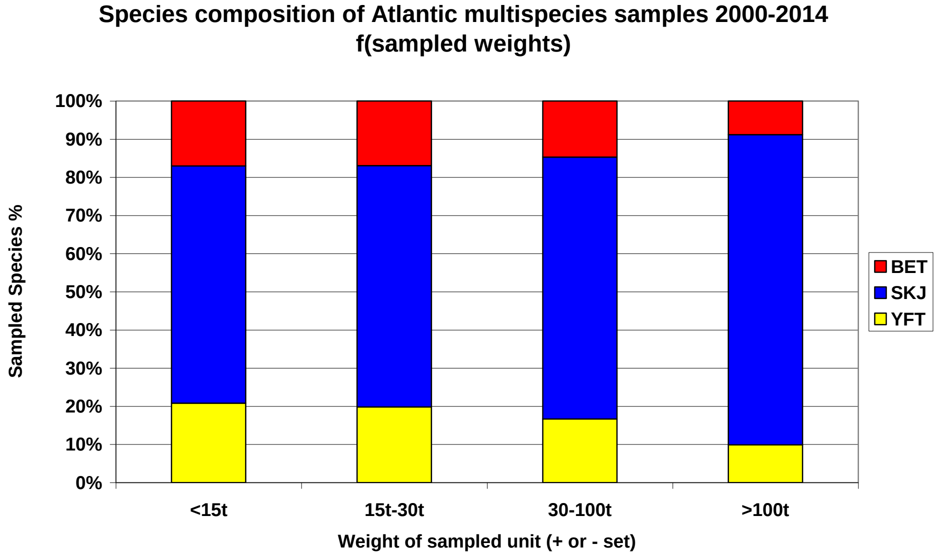


**Figure 9.** Average species composition of the sampled FAD catches as a function of sampled weights categories.

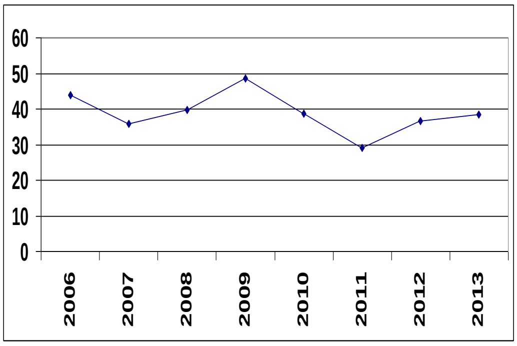


**Figure 10.** Rate of strata substitution in the Ghanaian data processing with a minimum number of 1000 tuna samples by 5°-quarter strata.

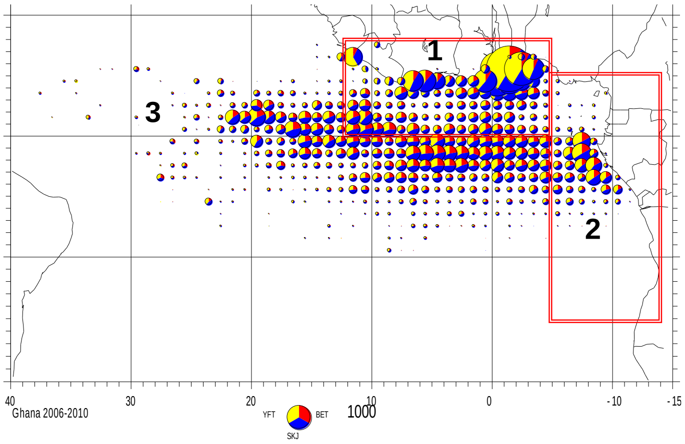


**Figure 11.** Average catches by 1° squares of the Ghanaian fleet during the 2006-2010 period and areas presently used to estimate species composition of the catches.

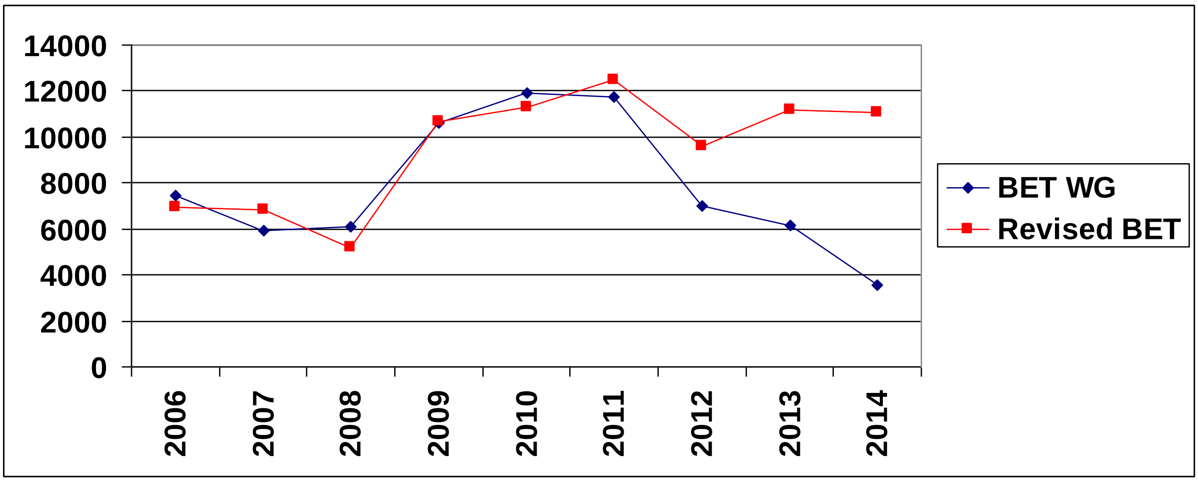


**Figure 12.** Yearly revised bigeye catches by the Ghanaian fleet estimated in the 3 sampling areas shown by **Figure 10** and bigeye Ghanaian catches used by the 2015 stock assessment analysis (bigeye WG).

**Annex 1**

**Preliminary ASPIC runs estimating the present bigeye stock status based on the revised catches during the 2012-2014 period.**

New runs of the ASPIC model were ran: (1) on the data used by the WG and (2) on revised/increased bigeye catches during the 2012-2014 period proposed by **Table 1**. Two runs based on the CPUEs of USA and of Taiwanese longliners were conducted, both assuming an exponential Fox model.

- In the ICCAT WG run based on CPUE of USA longliners: MSY was estimated at 65.000 tons, while F/FMSY was estimated at 1.42 and the ratio B/B MSY at 0.74. The same model was applied on the 2012-2014 revised catches, leading to the same estimated MSY, a slightly lower ratio of B/B MSY of 0.72 and a much higher ratio of F/F MSY estimated in 2014 at 1.63, then an increase of 15 % of the last year fishing mortality relative to F MSY.

- In the ICCAT WG run based on CPUE of Taiwanese longliners: MSY was estimated at 84.000 tons, while F/FMSY was estimated in 2014 at 1.10 and the ratio B/B MSY at 0.75. The same model was applied on the 2012-2014 revised catches, leading to the same estimated MSY, a slightly lower ratio of B/B MSY of 0.72 and a much higher ratio of F/F MSY estimated at 1.29, then an increase of 19 % of the last year fishing mortality relative to F MSY.

These results are quite logical ones in their trend and levels: the increased catches during the last 3 years do not modify the MSY of the stock, but they are simply producing a significant increase of the recent fishing mortality suffered by the bigeye stock and a moderate decline in its biomass.