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USING EFFORT CONTROL MEASURES TO IMPLEMENT CATCH CAPACITY LIMITS IN ICCAT PS FISHERIES

Rishi Sharma[1], Miguel Herrera[2]

SUMMARY

Total Allowable Catches (TAC's) have been implemented for numerous stocks by ICCAT. However, in the case of tropical tunas (yellowfin (Thunnus albacares) and bigeye (Thunnus obesus)), catch controls, while intended to ensure that overall fishing mortalities are not exceeded, have failed to maintain catches at the desired level because some ICCAT CPCs have exceed targets on a regular basis or were not covered by the measures. The purpose of this study is to explore how full seasonal closures (over an estimated time-frame), where vessels remain in port, may better assist surface fisheries in achieving the levels of catch reduction sought by the ICCAT. It presents a model based on parameter estimates of individual models to estimate catches by time as a function of available biomass for BET, effort by strata (month), and month-effort interactions to estimate BET catch targets (and associated YFT and SKJ as a result). The implementation of seasonal fishery closures has proved successful at the IATTC, which has been using a control rule based on this principle for over fifteen years with stocks maintained by the target reference level throughout that period. Management systems based on seasonal fishery closures have also proved to be more efficient than those based on TACs, due to the latter leading to underreporting unless extensive monitoring is in place. Some examples of how the control rule may be implemented are provided. A decision support tool is developed based on the data and proposed season closures to implement an overall target catch on Bigeye tuna, one of the stocks managed to a TAC by ICCAT.

KEYWORDS

Catch/effort; Tropical tunas; Season regulations.

[1]: Independent Consultant, Portland, OR (USA)
[2]: OPAGAC C/Ayala 54 2A 28001 Madrid, Spain

1. Introduction

In recent years, all tuna-Regional Fishery Management Organisations (tRFMO) have adopted a range of management measures to ensure that tropical tuna stocks are maintained at the target sustainable biomass levels. To ensure those levels are maintained, tRFMOs have agreed to carry Management Strategy Evaluation (MSE) and move towards the adoption of Harvest Control Rules (HCR) for their stocks (Hillary et. al. 2015). At present, the Indian Ocean Tuna Commission (IOTC) is the only tRFMO to have formally adopted a Harvest Control Rule (HCR) for its skipjack tuna (SKJ) stock, while other stocks are subject to various interim measures, including TACs, FAD closures, limits on active Fish Aggregating Devices (FADs), limits on support vessels, and limits on fishing capacity for partial or complete coverage of a fleet (subset of fleets in CPC's IOTC SC 2017). However, these measures have not been effective at maintaining the catches of the target stocks at the agreed levels, e.g. (yellowfin tuna (YFT) in IOTC and the former and bigeye tuna (BET) in ICCAT).

In the Atlantic Ocean, the ICCAT adopted Total Allowable Catches (TACs) for yellowfin tuna and bigeye tuna since 2001 (ICCAT REC 00-1) for long line fleets and since 2005 (ICCAT REC 04-1) for the rest of the fleets in a multiannual management plan. However, both those TACs have been consistently breached, with recent catches well above the TAC (ICCAT SCRS 2017). FAD closures have also been evaluated as ineffective, mainly due to relocation of effort to areas outside the closure and catch rates in those areas at similar levels than those attained in the past inside the closure area (SCRS, 2017). The multispecies nature of purse seine fisheries also makes it difficult to obtain catch estimates by species in real time. In addition, the quality of catch estimates may be compromised as a consequence of various potential sources of bias associated with the sampling scheme and/or estimation procedures used by some CPCs (Herrera 2018).

In the eastern Pacific Ocean, the Inter-American Tropical Tuna Commission (IATTC) adopted a control rule that contemplates two closures of the purse seine fishery (IATTC RES C-17-02), with the length of those closures adjusted using a formula that relies on the most recent assessments of the stocks of tropical tunas and potential overall levels of capacity of purse seiners estimated for the following year(s). At the start of each year, purse seine companies have to indicate which of their purse seiners will adhere to the first closure and which to the second (Squires et. al. 2016). In addition, IATTC has implemented a ban on support vessels, FAD limits, a FAD closure and input capacity limits for purse seiners, and TACs for longliners (Squires et. al. 2016).

OPAGAC is currently implementing a Fishery Improvement Project (FIP) and adopted an action plan that includes actions to improve stock status and compliance in all oceans, the former through assisting on the implementation of HCR and the latter through assisting improvements in compliance. Considering that the performance reviews of ICCAT (ICCAT , 2016) and IOTC (IOTC, 2016) have recommended that both organisations improve their management framework for tropical tunas, we would like to explore the effectiveness of alternative management measures, along the lines of those adopted by the IATTC, in improving the management framework of those RFMO.

As for the ICCAT area, the goal is to explore if purse seine fisheries would be better managed through a system similar to the one used by the IATTC, rather than through TACs, which have proved to be ineffective in most oceans. This includes the IATTC , which recently shifted from fishery closures to TACs, to realise, in less than one year, that TACs were ineffective, deciding to revert back to fishery closures (IATTC RES C-17-01 amended by C-17-02).

The main objective of this analysis is to explore to which extent the approach taken by the IATTC can be successfully used to manage tropical tunas at the ICCAT (in terms of efficiency of management, including its monitoring and compliance components) and, if so, provide a control rule that would allow converting from a BET TAC into a number of closure days, including a proposal of suitable time-periods for the closure; this is done bearing in mind not only the BET stock but also potential impacts of the measure on other target stocks (YFT and SKJ) . In addition, the report recommends actions that ICCAT would need to undertake to make implementation of the new system possible.

2. Methods

2.1 Approach

Effort is assumed to be proportional to fishing mortality. Hence, effort closures temporally would have the same net effect as allowable TAC. The reason is simply shown below in eq. 1:

$$qE_t = F_t \qquad \text{(eq. 1)}$$

Where *q* is catchability and *E* is the effort in the fishery, and *F*, fishing mortality in the fishery. The assumption essentially is that if we can parse effort by different time periods in a year and close some periods, we would essentially have a net limit of fishing mortality (*F*). Note that, implicitly we assume that q will remain constant through the unit of fishing effort measured (in fishing hours, as reported to ICCAT).

If we have a standardized unit of effort for all fleets, then we could estimate an optimal effort, *Eopt* capacity for the fleet, as a function of optimal fishing mortality, *Fopt* by looking at the following equation

$$E_{opt} = \frac{-ln(1-F_{opt})}{q} \qquad \text{(eq. 2)}$$

Essentially, when we have an over capacity fleet, the yield would be less than optimal (**Figure 0**), as discussed in Squires et. al. (2016)

Once effort exceeds optimal capacity, at some assumed *q*, the ability to get a profitable fishery declines substantially. Hence limiting effort would make sense to some effect on a fishery, especially if it operates at levels over its optimal capacity, as indicated in the SCRS report for BET and YFT (ICCAT SCRS 2017).

We stratified effort data by time and area, and assess its relationship to catch assuming a 1-1 relationship with BET catch by year and area (GLM model developed eq. 3). Essentially, if we can limit effort for a portion of days based on the ICCAT dataset, we would estimate a substantial reduction in catch and thereby achieve the reliable target that is determined pre-season.

So, we will try and estimate the following

$$BET_{PSCatch_t} = \alpha + \beta PS_{Effort_t} + \varepsilon \qquad \text{(eq.3)}$$

Where *BETPSCatch* is a function of the *PSEffort*. We could look at both log response and normal response. Based on slope values by time-period, we can limit overall effort by area to limit catch. This can be related eventually to PS well capacity and number of trips (fishing hours by month and if needed by area) which could be estimated and controlled for.

2.2 Data sources and preparation

The PS data used was downloaded from the ICCAT website in May 2018 or requested through e-mail. The following datasets were used to build the file for the analysis:

- **T1NC_20171013.zip**: Refers to ICCAT's Task I Data, in MS Excel format, which contains nominal catches of Atlantic tunas and tuna-like fish (including sharks), by year (1950-2016), gear, region and flag [MS Excel; version 10/2017[3]];
- **t2ce_20161114.rar**: Refers to ICCAT's Task II Catch & Effort in Access Data Base (various formats, 1950-2015) [MS Access; version 11/2016[4]];

[3] https://www.iccat.int/Data/t1nc_20171013.zip
[4] https://www.iccat.int/Data/t2ce_20161114.rar

- **cdis50_15_all.csv**: Refers to ICCAT's Task II catch data disaggregated and raised to total landings for the main ICCAT market species, including all three tropical tunas (species, 5x5 degree squares, year (1950-2015), quarter, gear) [CSV format; version 7/2016[5]];
- **effdis_ps_1990_2015.csv**: Refers to ICCAT's Task II Spatio-Temporal estimates of overall Atlantic Fishing Effort for Purse seine fleets (5x5 degree squares, year (1990-2015), quarter, gear) [CSV format; version 7/2016[6]];
- **casYFT1960-14_stdFmt_v1.7z.csv**: Refers to ICCAT's Task II Catch-at-Size file for the yellowfin tuna (YFT), as produced for the assessment of the Atlantic Ocean YFT stock by the ICCAT IN 2016 (various formats, 1960-2014) [CSV format; version YFT assessment 2016[7]];
- **casBET7514_details_v2.7z.csv**: Refers to ICCAT's Task II Catch-at-Size file for the bigeye tuna (BET), as produced for the assessment of the Atlantic Ocean BET stock by the ICCAT in 2015 (various formats, 1975-2014) [CSV format; version BET assessment 2015[8]];
- **casSKJ6913_v1.7z.csv**: Refers to ICCAT's Task II Catch-at-Size file for the skipjack tuna (SKJ), as produced for the assessments of the Atlantic Ocean SKJ stocks by the ICCAT in 2014 (various formats, 1969-2013) [CSV format; version SKJ assessment 2014[9]]

The above data were used to produce two files that contained catch and effort of tropical tunas in the Atlantic Ocean, for the period 1991-2015, with one file containing number of specimens and the other weight, in kilograms. For this all purse seine data were extracted and used to produce:

- **VBA_OUTPUTNO.csv**: file containing catches in number, effort, and number of fish measured according to their maturity stage (immature/mature) and by length class bin, by species, 5 degree square grid, year (1991-2015) and month.
- **VBA_OUTPUTKG.csv**: file containing catches in weight, effort, and the weight of fish measured according to their maturity stage (immature/mature) and by length class bin, in kilograms, by species, 5 degree square grid, year (1991-2015) and month.

The number of fish recorded under each length class bin was converted to weight using ICCAT's length-weight equations, as per the ICCAT Manual[10]:

- Yellowfin tuna[11]: $W = 2.153*10^{-5}*FL^{2.976}$ Caverivière (1976)
- Bigeye tuna[12]: $W = 2.396*10^{-5}*FL^{2.9774}$ Parks et al. (1981)
- Skipjack tuna[13]: $W = 7.480*10^{-6}*FL^{3.253}$ Cayré & Laloë (1986)

The amount of fish immature and mature was assigned using ICCAT's length-at-first-maturity for each of ICCAT's tropical tuna stocks, as recorded in the ICCAT Manual:

- Yellowfin tuna[14]: 50% of mature females measuring 108.6 cm (Albaret (1977), Eastern Atlantic);
- Bigeye tuna[15]: 53% mature females measuring 100 cm (Matsumoto and Miyabe (2002), Abidjan). The same authors estimated that 50% mature females measuring 110 cm from samples taken in Dakar. However, data from Abidjan was used as this is the main port of landing of purse seiners in the Atlantic Ocean;

[5] File downloaded at the time of the assessment
[6] https://www.iccat.int/Data/effdis_ps_1990_2015.csv
[7] File downloaded at the time of the assessment
[8] File downloaded at the time of the assessment
[9] File downloaded at the time of the assessment
[10] https://www.iccat.int/en/iccatmanual.html
[11] https://www.iccat.int/Documents/SCRS/Manual/CH2/2_1_1_YFT_ENG.pdf; Table 2, Page 9
[12] https://www.iccat.int/Documents/SCRS/Manual/CH2/2_1_2_BET_ENG.pdf; Table 2, Page 35
[13] https://www.iccat.int/Documents/SCRS/Manual/CH2/2_1_3_SKJ_ENG.pdf; Table 2, Page 59
[14] https://www.iccat.int/Documents/SCRS/Manual/CH2/2_1_1_YFT_ENG.pdf; Table 3, Page 9
[15] https://www.iccat.int/Documents/SCRS/Manual/CH2/2_1_2_BET_ENG.pdf; Table 3, Page 35

- Skipjack tuna[16]: 50% mature females measuring 45 cm (Hazin et al. (2001), Atlantic). Hazin et al. were chosen among the 4 values available for female maturity, with lengths at first maturity ranging from 42 cm to 51 cm, the one chosen being the most recent study.

The data required a fair amount of processing due to the fact that ICCAT produces datafiles at different points in time and data from the different files may differ as ICCAT's databases are under constant review. The data for the different purse seine fleets were aggregated as follows:

- PS-EU: Purse seine fleets operating under EU flags (France & Spain) or other flags that operate as EU purse seiners (e.g. Curaçao, Guatemala, El Salvador, etc.);
- PS-Ghana: Purse seine vessels flagged in Ghana and vessels flying other flags that operate as the former;
- PS-Other: Purse seine vessels flagged to other countries and that do not usually operate in the core area of the purse seine fishery (e.g. Western Central or South Atlantic, Mediterranean Sea, etc.).

Although the final file contained information for 1991-2015, only data from the EU-PS fleet, for the period 2003-2013 were used for the analysis. This is because the EU-PS fleet reports the highest catches and it is the only fleet for which catch, effort, and size data are fully available. The selection of 2003-13 as time-period was made in order to consider recent years of activity of purse seiners and for the recordset to be complete for all three stocks, considering that the last year in which catch-at-size data is available for the skipjack tuna is 2013.

The final file used for the analysis contained total catches of tropical tunas in kilograms taken by EU and assimilated purse seiners, total effort in fishing hours, total catches of immature BET in kg, total catches of mature BET in kg, total catches of immature YFT in kg, total catches of mature YFT in kg, and total catches of immature SKJ in kg and total catches of mature SKJ in kg, by year, month, and 5 degree square grid.

2.3 Generalized linear models examined

Three basic models were examined that looked at response of BET/SKJ/YFT by main effects. We have control on only two of the main effects in terms of management and focus on those (time and/or area), as such models examined only looked at main effects and interactions of these terms with estimated effort (McCullagh and Nelder 1989). The models examined are the following:

$$SPP_{Catch_t} = \alpha + \sum_{i=1}^{n} \beta_i Y_i + \sum_{s=1}^{12} \beta_s M_s + E_t + B_t + \varepsilon_t \qquad \text{(eq.4)}$$

$$SPP_{Catch_{t,a}} = \alpha + \alpha_1 B_t + \sum_{s=1}^{12} \beta_s M_s + \sum_{a=1}^{67} \beta_a A_a + \alpha_2 E_t + \varepsilon_{t,a} \qquad \text{(eq.5)}$$

Where *SPP* is species (BET, YFT or SKJ), *Y* is a year effect, *M* is month effect, and *B* is the Biomass estimated from the assessment (shown in Figures 7 based on the assessment conducted in 2015). Since Year is confounded with assessment biomass, we chose to use on Biomass as a continuous measure (eq. 5 as it would get rid of 11 degrees of freedom).

Finally, since area controls are not a factor to account for, because the consequences of effort relocation are difficult to assess, we analysed the data based on month and effort only, - i.e. full stop of industrial tuna purse seiners for tropical tunas in the core area of the fishery (eastern and central tropical [and subtropical] fishery).

$$SPP_{Catch_{t,a}} = \alpha + \alpha_1 B_t + \sum_{s=1}^{12} \beta_s M_s + \alpha_2 E_t + \varepsilon_{t,a} \qquad \text{(eq.6)}$$

The final model used month:effort interactions so a variation in slopes for each month could be accounted for (eq. 7). This is eventually the resolution with which they could plan for.

$$SPP_{Catch_{t,a}} = \alpha + \alpha_1 B_t + \sum_{s=1}^{12} \beta_s M_s + \sum_{s=1}^{12} \beta_s M_s E_s + \alpha_2 E_t + \varepsilon_{t,a} \qquad \text{(eq.7)}$$

[16] https://www.iccat.int/Documents/SCRS/Manual/CH2/2_1_3_SKJ_ENG.pdf; Table 3, Page 60

3. Results

3.1 Exploratory data analysis

Since we are interested in overall patterns in the fishery over time, we compiled some simple plots looking at overall catch in numbers for BET between 2003-2013 (aggregated, **Figure 1**) some of effort (**Figures 2, 4**), and catch in weight (aggregated by month over the period) for immature and mature fish separately (**Figure 3**). There may be a positive relationship with effort over the series observed (aggregated, **Figure 6**), and monthly variations in landings between 2003-2013 by area (**Figure 5**). In addition, **Figures 8** and **9** show that there are temporal patterns over the years 2003-2013 which could be used to minimize impacts on yellowfin and skipjack if closures were to occur for certain months.

3.2 Results from Generalized linear models examined

The data were conditioned first on BET and then applied to YFT using large fish as the dependent variable. The aim was to assess loss in catch of large YFT and SKJ on each of the time-periods (months) selected for the closure. A log response model as well as a model for non-linear relationships (log catch related to log effort) were also assessed but both models performed poorly with respect to diagnostics. **Table 1** summaries results using ANOVAs on the 3 models described above.

Diagnostic fits to models 1-3 for BET are shown below (**Figures 10-12**). Final Model 3 with parameter values of the coefficients is shown in **Table 1** (**Figure 13**). Similar parameter values for SKJ and large YFT are shown in **Table 2** as well along with diagnostic fits of model 3 on large YFT (**Figure 14**) and SKJ (**Figure 15**).

3.3 Model developed

Based on the data shown in **Table 3** above a general model was developed based on average effort between 2003 and 2013. The models predictive capability of catches for the EUPS fleet is shown in **Figure 16**. The predictive capability of the model with CV's on overall targets is shown in **Table 4** below. For illustrative purposes two other models are developed with differential closure patterns (all at once) or 2 (multiple closures over the year). Effects of these closures are shown in **Figure 17** and **18** and **Tables 5** and **6** (below).

For example if we wanted to estimate a total catch of 13000 tons for BET with one seasonal closure or 2, it could be implemented with **Table 5** or **Table 6** below resulting in catch distribution pattern shown in **Figure 17** and **18**. Note, that the estimated catch is the measure that controls a portion of the fleet (i.e. EUPS fleet that is the EST TOTAL CATCH that can be explained by the model). If we want to expand it to the observed data, we need to expand what this measure would do to the whole fleet based on the ratio of catch that it represents of the whole fleet, i.e. the expanded total catch (EXP Total Catch). So, the estimated (EST) catch is what is explained by the model, has to then be raised to what the total catch of the EUPS fleet is for that period (on average). Similarly raising factors are applied to YFT and SKJ as well. We can see that the model does well for BET (expansion of only 1.08 on average, but for YFT and SKJ the factors are raised by 1.51 and 1.68 respectively.

4. Discussion

IATTC's system currently uses effort in fishing hours to incorporate increases in fishing capacity. This system could easily be adapted to that as Fishing hours estimated across all fleets, could easily be converted to units of fleet/well capacity times the number of trips to overall well capacity for the fleet for that month. Some work would be needed to account for which fleets are fishing at which month and to incorporate an effort measure that is in units of well capacity. We could then limit the overall well capacity instead of hours to estimate the overall impact using this approach. However, it is important to note that the purse seine fleets operating in the Atlantic and Indian oceans are less heterogeneous than the one operating in the Eastern Pacific Ocean.

Squires et. al. (2016) argue for a case where Effort Rights Based Management has received considerably less conceptual or empirical attention in the literature than transferable catch quota approaches. Rather than having open access, olympic type fisheries, where fishers normally don't get optimal price for their catch, Squires et. al. (2016) argue that effort control type fisheries closely align the private behaviour of fishers with society's desired social–economic–ecological objectives of harvests satisfying a sustainable yield or effort target and sustainable social and economic benefits. Squires et. al. (2016) cover 37 different studies where these approaches have worked and also provided a right to the resource using responsible effort based management measures. Squires et. al. (2016) dispel a number of myths about effort-based fisheries, as discussed below.

Effort controls, in contrast to catch controls, create incentives to increase input use and costs in an attempt to maximize individual vessel catches and revenues. This incentive in turn raises, rather than minimizes, input usage and costs, at least collectively for the fleet. As a fleet becomes more efficient it tends to overfish and catch more with the same input (i.e. effort measure). However, controlling that measure can then keep fleets fishing at sustainable levels (e.g. capacity limitation, FAD limits, etc.). In contrast TAC based measures tend to provide stronger incentives to reduce effort and costs and to increase price. Catch rights thereby increase revenue through improved quality or smoothing out seasonality of production (as there is a limited catch). This was the case with halibut ITQ's (Grafton et al. 2000). However, for tuna fisheries this is far from the case and unless a particular fleet catch is in high demand and not effected by supply from other oceans or sectors (longline, pole-and-line and artisanal which is not the case), so this argument would not work for having a TAC based control rather than an effort-based control.

Other issues such as technological creep will provide incentives for the fleet to maximize catch with better efficiency (the case for PS). However, if we update our analysis with the latest information the relationship would be valid for the latest technology and could be updated every 5 years to give a new measure of effort in line with the recommended TAC. Although that is a serious criticism of effort-based measures to control output from the fisheries, especially if the technological creep increase so that more fish is caught every year that planned with a particular opener (Squire et. al. 2016), IATTC has been implementing such a system for over 15 years and has achieved maintaining the tropical tuna stocks to the target reference points over the entire period (never breaching limit reference points for those stocks).

As for the advantages ascribed to effort controls Squires et. al. (2016) mention that those systems are recommended in the case that catches cannot be estimated properly and/or compliance monitoring is poor. This is, to a different degree depending on the fleet, the case of industrial tuna purse seine fisheries because: catches for some ICCAT CPC are very uncertain (e.g. Ghana, Chassot et al. 2014); catches by species cannot be estimated in near real-time or be estimated by vessel to a known precision (e.g. EU fleet, Herrera 2018); the adoption of TACs has led to gross underreporting of catches by some fleets (e.g. Chinese Taipei longline fleet, ICCAT 2015); the ICCAT has not set any mechanism to independently monitor CPC compliance with the TACs of tropical tunas; the costs of such a mechanism will be extremely high.

4.1 Implementation of closures in the context of the ICCAT

The model presented can be used to assess the time-period and number of fishing days of closure required in order to replace the existing or any future Total Allowable BET Catches recommended by the ICCAT for the industrial tuna purse seine component. Other than the recommended TAC, the following information will be required to estimate the number of closure days for a given year:

1. Number of industrial tuna purse seiners to be in operation, by ICCAT CPC, and the expected total number of days that will be fished by those: The number of tuna seiners can be obtained from the latest national report presented by each CPC, and the total number of fishing days from past reports of vessel numbers and catch-and-effort data by each CPC as part of ICCAT's data requirements (Task 2);

2. Trend in the total number of active support vessels / FADs used by purse seiners, or any other new piece of technology that could contribute to an increase in effective fishing effort directed at the BET stock (i.e. effort creep);

3. Any other management measure ICCAT has implemented in complement to the fishery closure that could contribute to a decrease in effective fishing effort directed at the BET stock (e.g. time-area closure on fishing with FADs).

4. BET Biomass value estimate from the latest stock assessment.

While most of the information covered in 1-4 can be obtained from the ICCAT this does not apply to the numbers of active purse seiners and support vessels that will operate in the future in the ICCAT Convention Area as, at present, ICCAT CPCs not covered by the capacity limitation are not obliged to provide this information in advance to the ICCAT. However, ICCAT could contemplate to make it a requirement for CPC to provide this information, including fish carrying capacity, if this measure is implemented in substitution of the TAC.

4.2 Conclusion

This study shows the potential benefits for ICCAT's management to consider replacing the existing TACs of tropical tunas with fishery closures for its purse seine and pole-and-line components.

There are many possible scenarios of developing solutions to achieve a certain BET target with certain monthly closures. However, we may have conflicting objectives as seen that don't allow the catch to exceed 40K tonnes of large YFT while keeping BET targets low. For instance if we wanted 45K t of large YFT, this would not have been possible using scenario 2. If optimizing to one target the other species may not be maximized as seen above. However, considering the multi-species nature of surface fisheries at the ICCAT and the fact that catch limits exist for both bigeye tuna and yellowfin tuna, it would only be reasonable that the closure adopted seeks a reduction in the catches of both stocks. In addition, the TAC adopted by the IOTC for the yellowfin tuna stock has proved to have a adverse effect on fishing behaviour as it has prompted fishermen to avoid catching adult YFT on free-schools towards fishing on FADs, where YFT, mostly juvenile, only represents a fraction of the total catch. Therefore, there is a potential for effort limits to be more effective in addressing catch limits for multi-species fisheries in which catch limits have been adopted for more than one stock (ICCAT) or those fisheries that operate over its optimum capacity and target stocks that have been assessed to be fully exploited or above such levels, as it is the case of purse seine fisheries in the ICCAT and IOTC areas.

Thus, the choice of closures will be dependent on an iterative discussion between the managers and ship operators as shown in situations presented above. In addition, it is evident in certain months (shoulder seasons March April, and September to November) that catch rates of directed species (large YFT) are lower and closures in those months would benefit BET reductions while not compromising the catches of large yellowfin.

Given the large uncertainties in achieving TACs and the failure shown in IOTC, ICCAT and IATTC to do so, effort controls with large industrial fleets like the PS fleet are considered a better alternative. The ability to do so is entirely dependent on the data and management to implement these closures in an effective manner and has already proved effective in the case of the IATTC.

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6. References

Chassot, E. et al. 2014 Analysis of Ghanaian industrial tuna fisheries data: towards tasks i and ii for 2006-2012. Collect. Vol. Sci. Pap. ICCAT, 70(6): 2693-2709 (2014). SCRS/2013/181

Grafton, R., Squires, D. and Fox, K. 2000 Common resources, private rights and economic efficiency. Journal of Law and Economics 43, 679–713.

Herrera, M. 2018 On the potential biases of scientific estimates of catches of tropical tunas the EU and other countries report to the ICCAT and IOTC. (In Press)

Hillary, R., Preece, A.L., Davies, C., Kurota, H. Sakai, O. Itok, T. Parma, A. M., Butterworth, D.S., Ianelli, J., Branch, T.A. 2016. A scientific alternative to moratoria for rebuilding depleted international tuna stocks. Fish and Fisheries Vol 17: 469-482.

ICCAT 2015. Report of the 2015 ICCAT bigeye tuna data preparatory meeting. Madrid, May 2015.

ICCAT 2016. Report of the Independent Performance Review of ICCAT - 2016. Madrid 2016.

ICCAT –SCRS. 2016. Report of the Standing Committee on Research and Statistics. Madrid, October, 2016.

ICCAT –SCRS. 2017. Report of the Standing Committee on Research and Statistics. Madrid, October, 2017.

IOTC 2016. IOTC–PRIOTC02 2016. Report of the 2 Performance Review. Seychelles 2–6 February & 14–18 December 2015. IOTC–2016–PRIOTC02–R[E]: 86 pp

IOTC–SC20 2017. Report of the 20th Session of the IOTC Scientific Committee. Seychelles, 30 November –4 December 2017. IOTC–2017–SC20–R[E]: 232 pp.

McCullagh, P. and Nelder, J. 1989. Generalized Linear Models, Second Edition. Chapman & Hall/CRC 532 pp.

Squires, D., Maunder, M., Allen,, R., et..al. 2016. Effort Rights Based Management. Fish and Fisheries. DOI: 10.1111/faf.12185.

Table 1: ANOVAS on models examined

ANOVA: Model 1

Variables	Df	Deviance	Resid. DF	Resid Dev	F	Pr(>F)	Sign.
NULL	3218	3.41E+13					
factor(dat$Year)	12	3.01E+11	3206	3.38E+13	2.9835	0.000368	<0.001
Biomass	0	0.00E+00	3206	3.38E+13			
factor(Month)	11	2.32E+11	3195	3.36E+13	2.5032	0.00392	0.01
FhoursE	1	6.14E+12	3194	2.75E+13	730.3401	<2.2 E-16	<0.001
factor(Flag)	2	6.07E+11	3192	2.68E+13	36.0588	<2.2 E-16	<0.001

ANOVA: Model 2

Variables	Df	Deviance	Resid. DF	Resid Dev	F	Pr(>F)	Sign.
NULL	3218	3.41E+13					
Biomass	1	3.47E+10	3217	3.41E+13	4.466	0.03465	0.05
factor(Month)	11	2.43E+11	3206	3.39E+13	2.8474	0.00102	0.01
factor(Grid)	67	2.66E+12	3139	3.12E+13	5.1082	<2.2 E-16	<0.001
FhoursE	1	6.66E+12	3138	2.45E+13	856.8687	<2.2 E-16	<0.001
factor(Flag)	2	1.73E+11	3136	2.44E+13	11.1187	1.54E-05	<0.001

ANOVA: Model 3

Variables	Df	Deviance	Resid. DF	Resid Dev	F	Pr(>F)	Sign.
NULL	3218	3.41E+13					
Biomass	1	3.47E+10	3217	3.41E+13	4.1086	0.042747	0.05
factor(Month)	11	2.43E+11	3206	3.39E+13	2.6195	0.002503	0.01
FhoursE	1	6.23E+12	3205	2.76E+13	737.3417	<2.2 E-16	0.001
factor(Flag)	2	5.77E+11	3203	2.70E+13	34.1716	2.07E-15	0.001

ANOVA:Model 4

Variables	Df	Deviance	Resid. DF	Resid Dev	F	Pr(>F)	Sign.
NULL	3218	3.41E+13					
Biomass	1	3.47E+10	3217	3.41E+13	4.4064	0.035882	0.05
factor(Month)	11	2.43E+11	3206	3.39E+13	2.8094	0.001186	0.01
FhoursE	1	6.23E+12	3205	2.76E+13	790.7839	<2.2 E-16	0.001
factor(Flag)	2	5.77E+11	3203	2.70E+13	36.6483	<2.2 E-16	0.001
factor(Month):FhoursE	11	1.91E+12	3192	2.51E+13	22.1047	<2.2 E-16	0.001

Table 2: ANOVA for similar model for YFT and SKJ

ANOVA: YFT_Large

Variables	Df	Deviance	Resid. DF	Resid Dev	F	Pr(>F)	Sign.
NULL	3218	2.85E+14					
Biomass	1	5.76E+10	3217	2.85E+14	0.7901	0.374136	NS
factor(Month)	11	2.15E+12	3206	2.83E+14	2.6803	0.001975	0.01
FhoursE	1	3.16E+13	3205	2.51E+14	433.5564	<2.2 E-16	<0.001
factor(Flag)	2	1.17E+12	3203	2.50E+14	8.0096	0.000339	0.001
factor(Month):FhoursE	11	1.72E+13	3192	2.33E+14	21.4948	<2.2 E-16	<0.001

ANOVA:SKJ

Variables	Df	Deviance	Resid. DF	Resid Dev	F	Pr(>F)	Sign.
NULL	3218	5.63E+14					
Biomass	1	1.67E+12	3217	5.62E+14	11.7947	0.000602	0.001
factor(Month)	11	5.82E+12	3206	5.56E+14	3.7448	2.42E-05	0.001
FhoursE	1	7.84E+13	3205	4.77E+14	554.3754	<2.2 E-16	<0.001
factor(Flag)	2	6.04E+12	3203	4.71E+14	21.3646	6.07E-10	<0.001
factor(Month):FhoursE	11	2.01E+13	3192	4.51E+14	12.9034	<2.2 E-16	<0.001

ANOVA: YFT_Small

Variables	Df	Deviance	Resid. DF	Resid Dev	F	Pr(>F)	Sign.
NULL	3218	2.88E+13					
Biomass	1	1.21E+09	3217	2.88E+13	0.1557	0.69316	NS
factor(Month)	11	3.93E+11	3206	2.84E+13	4.6036	5.50E-07	0.001
FhoursE	1	2.05E+12	3205	2.64E+13	264.7475	<2.2 E-16	<0.001
factor(Flag)	2	5.89E+10	3203	2.63E+13	3.7996	0.02248	0.05
factor(Month):FhoursE	11	1.56E+12	3192	2.48E+13	18.2375	<2.2 E-16	<0.001

Table 3: Parameter values for Model 4 for each species.

Parameters	Estimate BET	Estimate YFT	Estimate SKJ	Estimate YFT Small	Std. Error BET	Std. Error YFT	Std. Error SKJ	Std. Error YFT Small
(Intercept)	39420.00	57840.00	214200.00	2.87E+04	1.62E+04	4.91E+04	6.84E+04	1.60E+04
Biomass	-0.03	-0.10	-0.30	-1.06E-02	3.36E-02	1.02E-01	1.42E-01	3.34E-02
factor(Month)2	-11920.00	-34700.00	10480.00	-3.33E+03	8.95E+03	2.72E+04	3.79E+04	8.88E+03
factor(Month)3	-13810.00	-21320.00	-11500.00	1.08E+04	9.03E+03	2.75E+04	3.82E+04	8.96E+03
factor(Month)4	-10650.00	7479.00	28100.00	9.08E+03	1.04E+04	3.18E+04	4.43E+04	1.04E+04
factor(Month)5	-18500.00	-41030.00	-104300.00	-3.18E+04	1.06E+04	3.22E+04	4.48E+04	1.05E+04
factor(Month)6	-49600.00	-102800.00	-154500.00	-4.33E+04	1.00E+04	3.05E+04	4.25E+04	9.96E+03
factor(Month)7	-18940.00	-38300.00	-143100.00	-4.69E+04	9.39E+03	2.86E+04	3.98E+04	9.32E+03
factor(Month)8	-8887.00	-44660.00	-39630.00	-2.25E+04	9.56E+03	2.91E+04	4.05E+04	9.49E+03
factor(Month)9	3385.00	2788.00	-11230.00	-1.96E+04	9.24E+03	2.81E+04	3.92E+04	9.17E+03
factor(Month)10	15540.00	-4097.00	47290.00	-1.45E+04	8.40E+03	2.56E+04	3.56E+04	8.34E+03
factor(Month)11	15670.00	-2423.00	49440.00	-1.53E+04	8.40E+03	2.56E+04	3.56E+04	8.34E+03
factor(Month)12	-1649.00	-58660.00	62820.00	-2.06E+04	8.47E+03	2.58E+04	3.59E+04	8.41E+03
FhoursE	177.30	416.10	864.30	6.13E+01	2.12E+01	6.46E+01	8.99E+01	2.11E+01
factor(Flag)Ghana	5827.00	3411.00	50650.00	8.49E+03	3.57E+03	1.09E+04	1.51E+04	3.54E+03
factor(Flag)Other	-69720.00	-74380.00	-187900.00	-8.03E+03	1.00E+04	3.05E+04	4.24E+04	9.94E+03
factor(Month)2:FhoursE	-9.73	-30.38	-206.60	5.21E+00	3.07E+01	9.33E+01	1.30E+02	3.04E+01
factor(Month)3:FhoursE	22.47	11.28	-38.94	8.39E+00	3.00E+01	9.14E+01	1.27E+02	2.98E+01
factor(Month)4:FhoursE	-100.80	-334.60	-510.10	-1.59E+01	3.91E+01	1.19E+02	1.66E+02	3.88E+01
factor(Month)5:FhoursE	24.85	19.57	-90.40	8.82E+01	4.24E+01	1.29E+02	1.80E+02	4.21E+01
factor(Month)6:FhoursE	301.70	817.80	420.80	2.11E+02	3.55E+01	1.08E+02	1.51E+02	3.53E+01
factor(Month)7:FhoursE	140.90	299.20	444.80	2.65E+02	2.89E+01	8.79E+01	1.23E+02	2.87E+01
factor(Month)8:FhoursE	23.62	163.60	-377.00	3.49E+01	3.30E+01	1.00E+02	1.40E+02	3.28E+01
factor(Month)9:FhoursE	21.96	-273.60	-369.70	2.80E+01	3.44E+01	1.05E+02	1.46E+02	3.42E+01
factor(Month)10:FhoursE	-107.30	-336.20	-541.80	-8.07E+00	2.74E+01	8.33E+01	1.16E+02	2.72E+01
factor(Month)11:FhoursE	-83.07	-294.20	-445.10	-6.74E+00	2.70E+01	8.22E+01	1.14E+02	2.68E+01
factor(Month)12:FhoursE	47.22	272.80	-363.10	1.19E+01	2.85E+01	8.68E+01	1.21E+02	2.83E+01

Table 4: Catch Estimated with uncertainty based on average effort distribution

Month	Avg Eff	Fishing (on=1)	Biomass (input from BET assessment)	Estimated BET	Estimated Large YFT	Estimated SKJ	Estimated Small YFT	SE (BET)	SE (large YFT)	SE_SKJ	SE (Small YFT)
1	6044	1	400000	1100837	2530905	5317253	395155	157902	480362	668971	156715
2	5947	1	400000	1013870	2275198	4015333	416870	347179	1056162	1470652	344573
3	7045	1	400000	1422843	3005661	5896782	526413	399813	1216247	1694080	396778
4	6275	1	400000	498696	535033	2344480	318908	418433	1273216	1773232	415309
5	6440	1	400000	1312644	2780825	4973333	955783	450083	1369568	1907378	446756
6	5163	1	400000	2452934	6284382	6574606	1385286	332696	1012188	1409387	330184
7	5249	1	400000	1680735	3732778	6822684	1692277	302141	919177	1280391	299856
8	5540	1	400000	1133473	3182927	2753632	535228	339581	1033109	1438631	337017
9	5415	1	400000	1111723	790586	2760851	488892	340252	1034880	1441711	337688
10	5286	1	400000	414861	434389	1845765	291519	294906	897183	1249647	292667
11	4764	1	400000	493882	594445	2140245	269260	267770	814661	1134503	265772
12	5837	1	400000	1338255	3978855	3082212	431241	328590	999721	1392040	326147
			EST TOTAL CATCH (T)	13975	30126	48527	7707				
			EXP TOTAL CATCH (T)	15196	45323	81418	11732				
			cv	0.28	0.40	0.35	0.51				

Table 5: Catch Estimated with uncertainty based on one closure and target of 13000 BET with large YFT near 40000 T.

Month	Avg Eff	Fishing (on=1)	Biomass (input from BET assessment)	Estimated BET	Estimated Large YFT	Estimated SKJ	Estimated Small YFT	SE (BET)	SE (large YFT)	SE_SKJ	SE (Small YFT)
1	6044	1	400000	1100933	2531131	5317722	395188	157913	480397	669019	156726
2	5947	1	400000	1013956	2275396	4015670	416904	347206	1056243	1470765	344599
3	6691	1	400000	1352057	2854224	5604325	501705	381647	1160984	1617104	378749
4	6276	1	400000	498714	535052	2344563	318919	418447	1273259	1773292	415323
5	6441	1	400000	1312769	2781095	4973811	955876	450122	1369688	1907545	446795
6	5312	1	400000	2523983	6467401	6765219	1425622	341115	1037801	1445050	338539
7	5250	1	400000	1681045	3733474	6823958	1692594	302190	919325	1280598	299904
8	5540	1	400000	1133597	3183283	2753932	535287	339614	1033210	1438773	337050
9	0	0	400000	0	0	0	0	0	0	0	0
10	0	0	400000	0	0	0	0	0	0	0	0
11	0	0	400000	0	0	0	0	0	0	0	0
12	5838	1	400000	1338410	3979328	3082556	431291	328624	999825	1392185	326181
			EST TOTAL CATCH (T)	11955	28340	41682	6673				
			EXP TOTAL CATCH (T)	13000	42637	69933	10159				
			cv	0.26	0.33	0.31	0.46				

Table 6: Catch Estimated with uncertainty based on two closures and target of 13000 BET with YFT remaining near 40000 T.

Month	Avg Eff	Fishing (on=1)	Biomass (input from BET assessment)	Estimated BET	Estimated Large YFT	Estimated SKJ	Estimated Small YFT	SE (BET)	SE (large YFT)	SE_SKJ	SE (Small YFT)
1	6532	1	400000	1187402	2734063	5739241	425104	168267	511893	712883	167002
2	0	0	400000	0	0	0	0	0	0	0	0
3	0	0	400000	0	0	0	0	0	0	0	0
4	6798	1	400000	538689	577640	2529649	342684	449956	1369136	1906823	446597
5	6466	1	400000	1317960	2792282	4993684	959716	451757	1374662	1914472	448418
6	5735	1	400000	2726987	6990341	7309858	1540873	365170	1110984	1546951	362412
7	6160	1	400000	1970455	4384057	8014616	1989681	347784	1058028	1473817	345153
8	6470	1	400000	1320271	3721882	3206682	624732	389999	1186493	1652224	387054
9	7000	1	400000	1427493	1016408	3544650	630534	428457	1303140	1815450	425228
10	0	0	400000	0	0	0	0	0	0	0	0
11	0	0	400000	0	0	0	0	0	0	0	0
12	6407	1	400000	1466204	4371442	3367834	472962	356953	1086012	1512193	354299
			EST TOTAL CATCH (T)	11955	26588	38706	6986				
			EXP TOTAL CATCH (T)	13000	40001	64941	10635				
			cv	0.25	0.34	0.32	0.42				

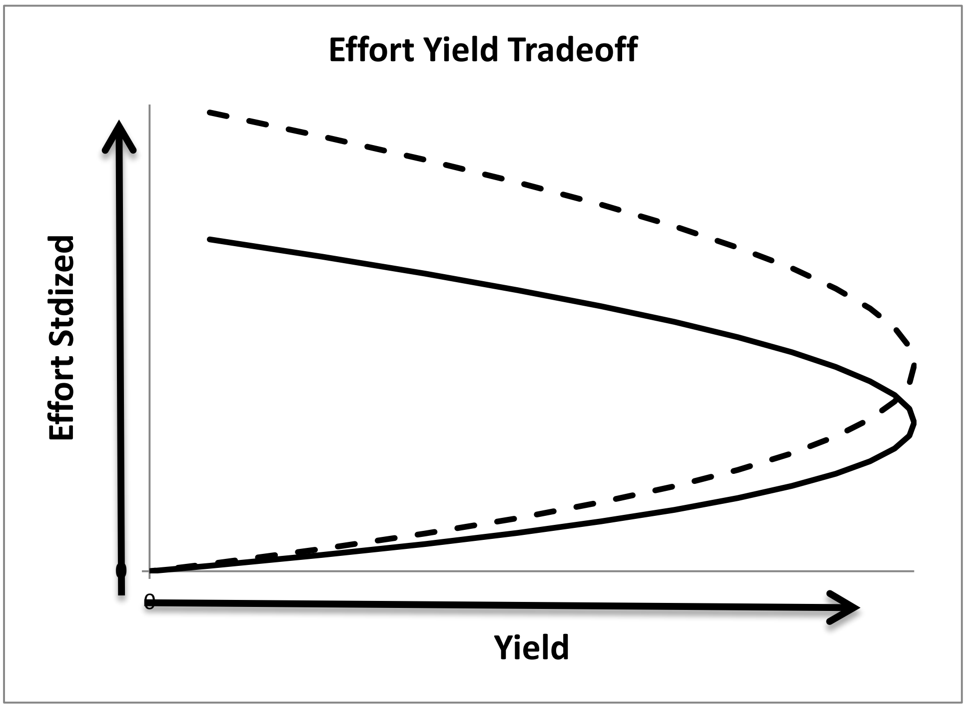


Figure 0: Optimal effort related to yield with different q's.

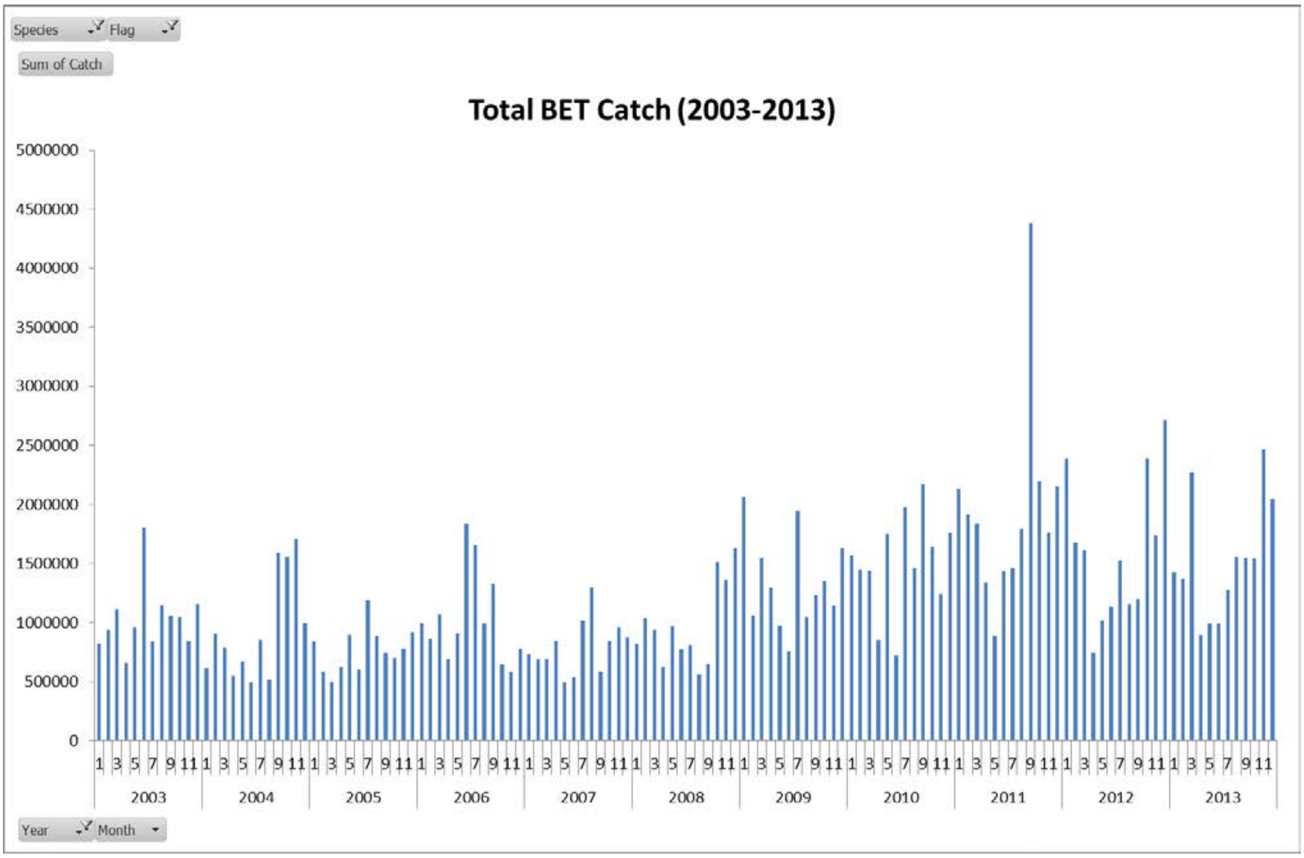


Figure 1: Aggregated Catch in numbers for BET between 2003-2013.

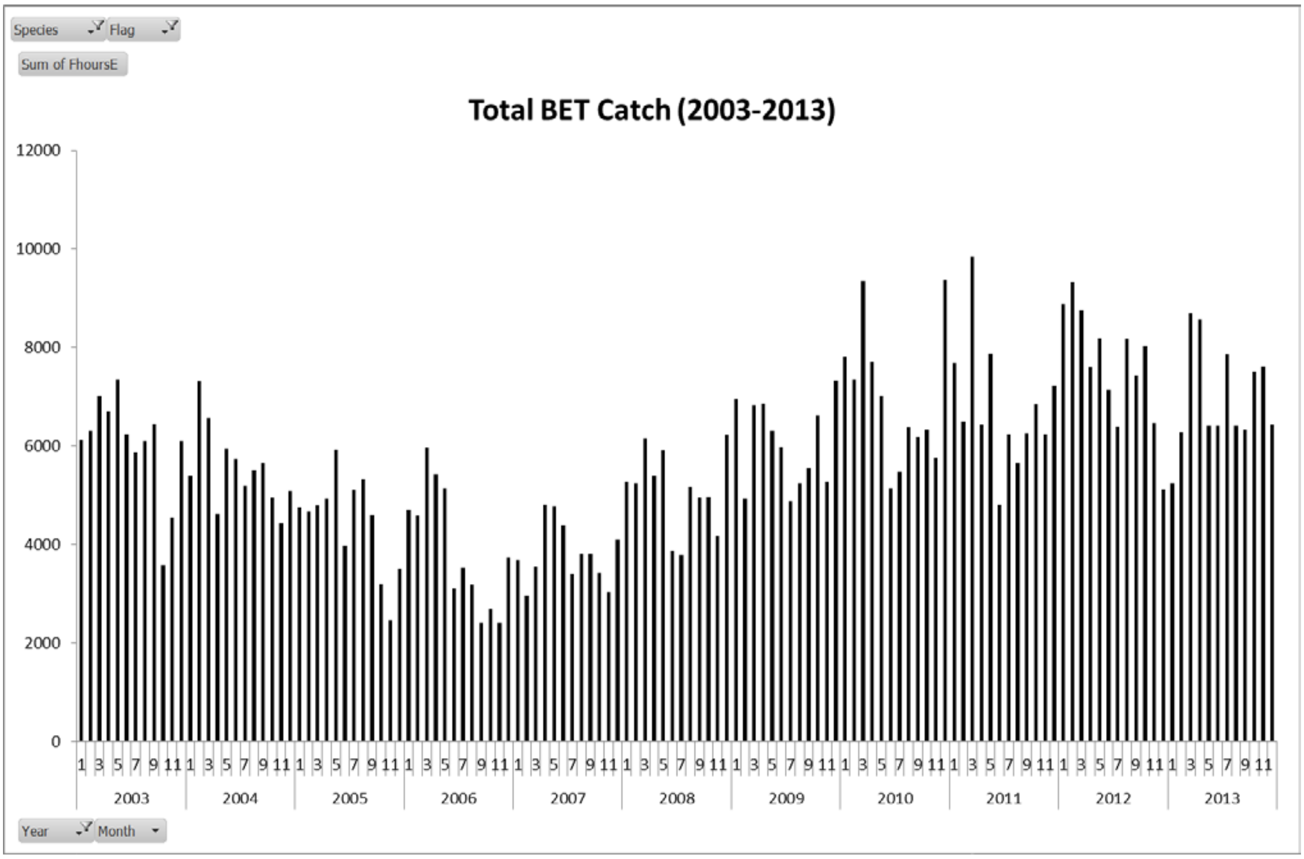


Figure 2: Aggregated effort on BET over the months between 2003 to 2013 (source ICCAT)

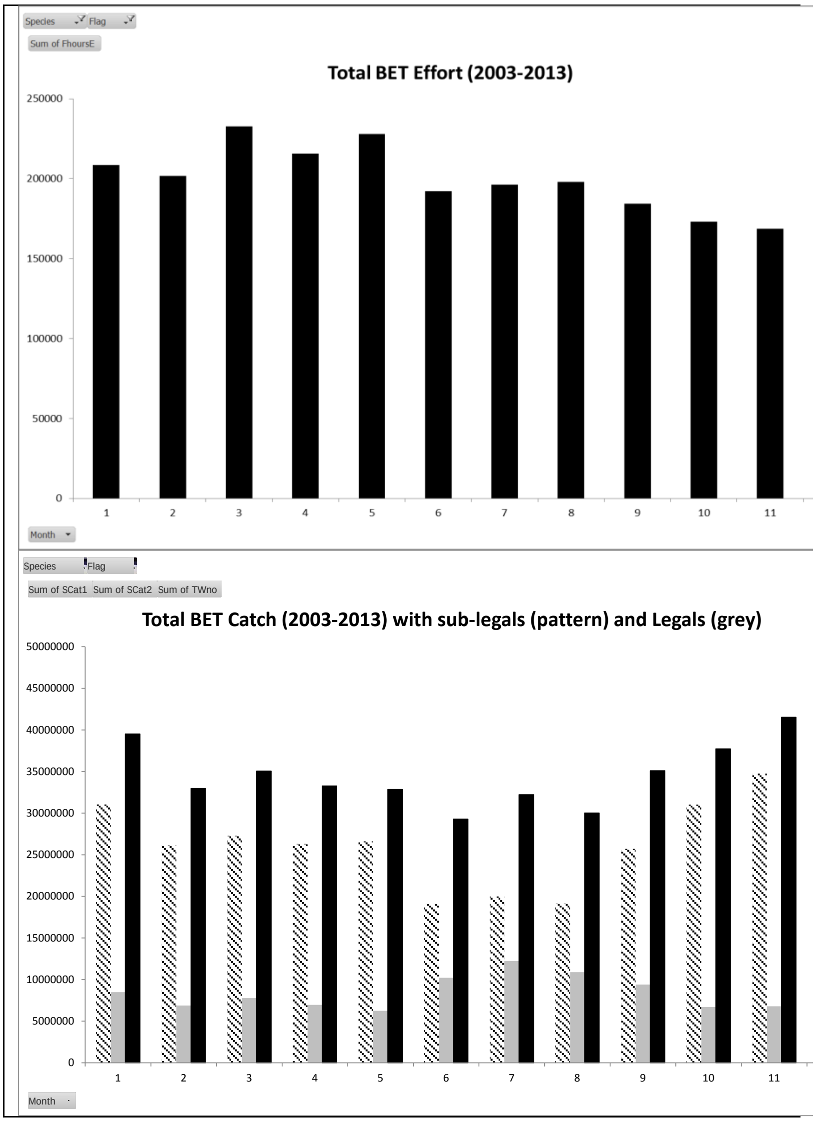


Figure 3: Total BET effort by months (aggregated) and catch by category 1 and 2 (scat 1 are small fish less that l50, and scat2 ae larger fish >l50).

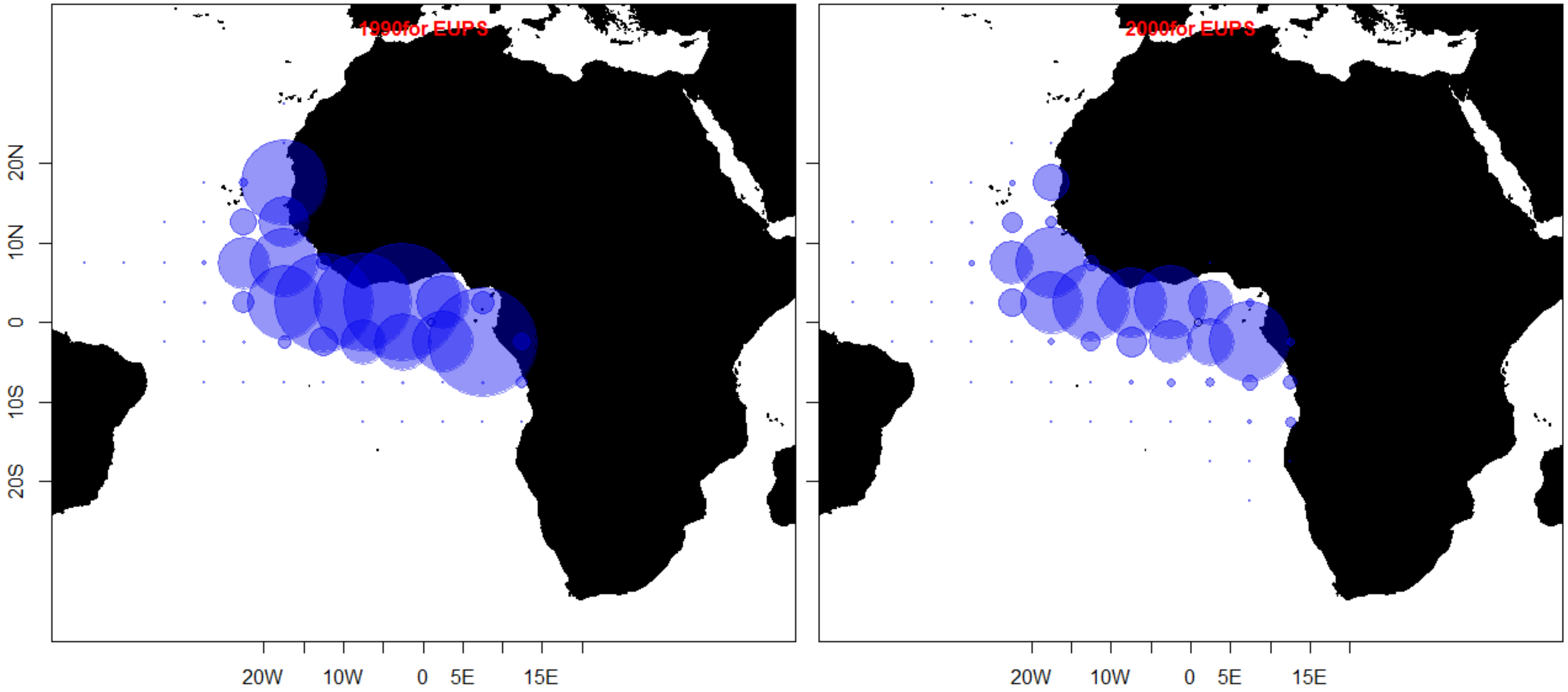


Figure 4: Effort distribution for the PS fleet in the Atlantic by the 1990's and 2000's. Magnitude and spatial extent of the PS fishery has remained the same

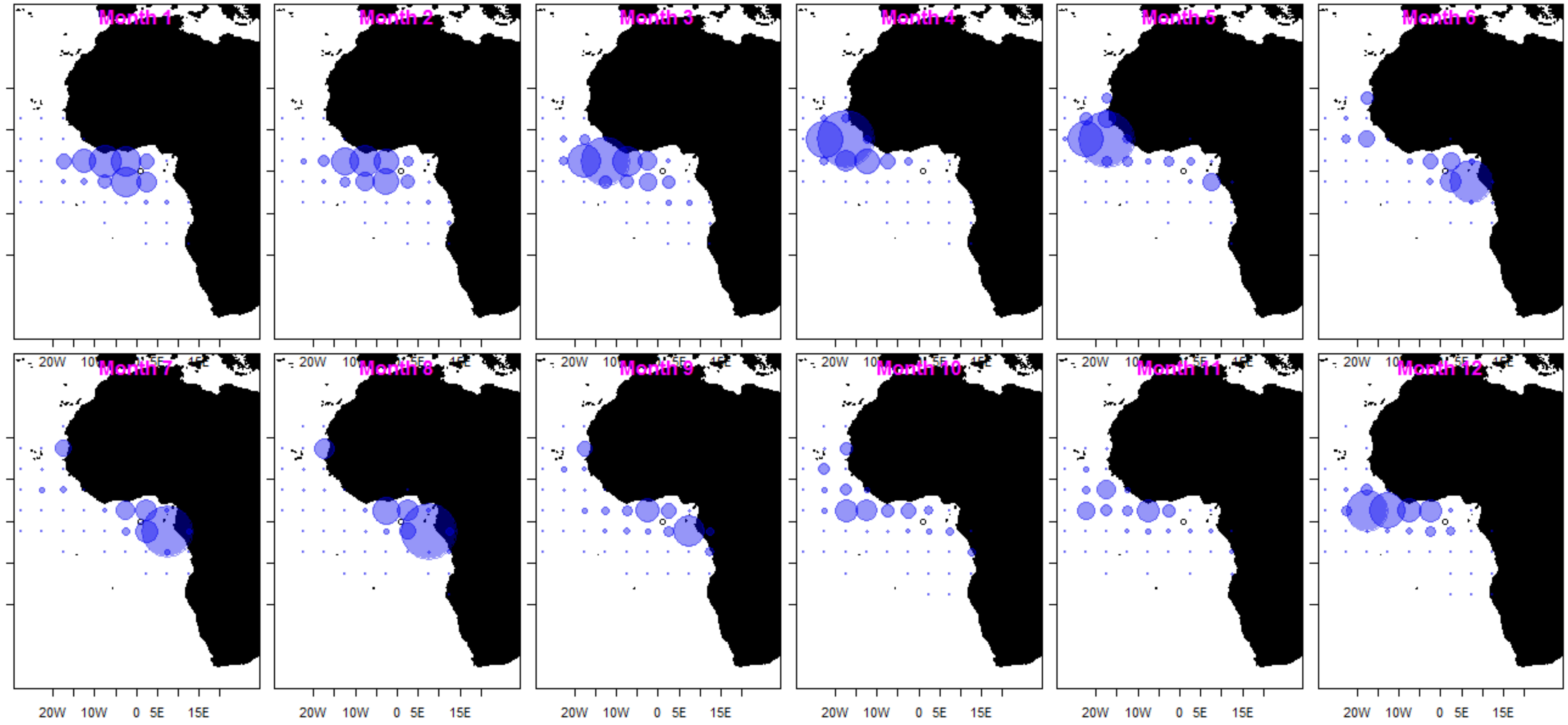


Figure 5: Temporal distribution by month for PS fishery (Month 1=January, Month 12=December on aggregated data over the period 2003-2013)

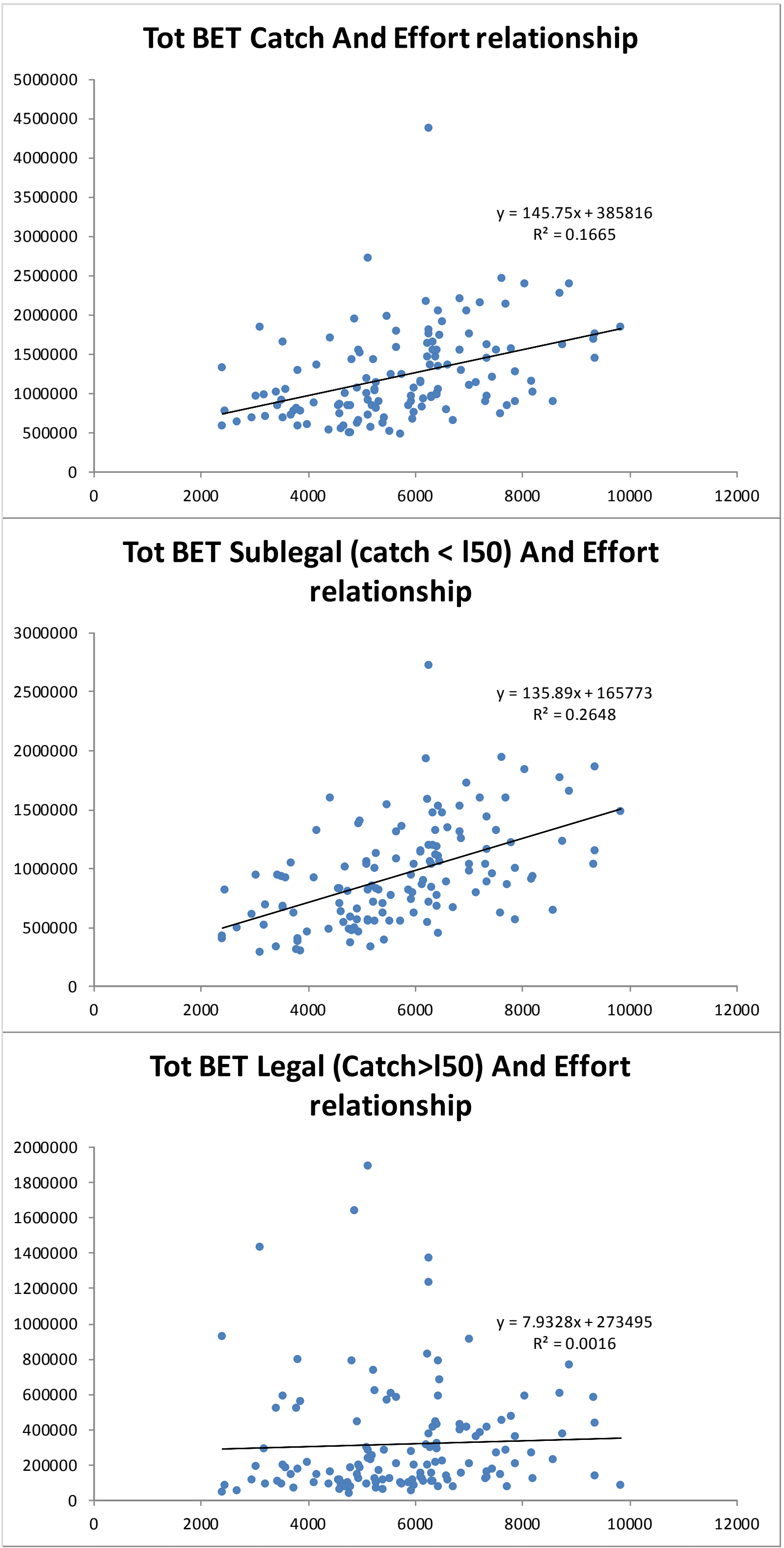


Figure 6: Simple BET relationships (catch in weight in kgs, so divide by 1000 to get catch in weight in tons). Positive significant relationships by size for small and overall fish but not for large fish.

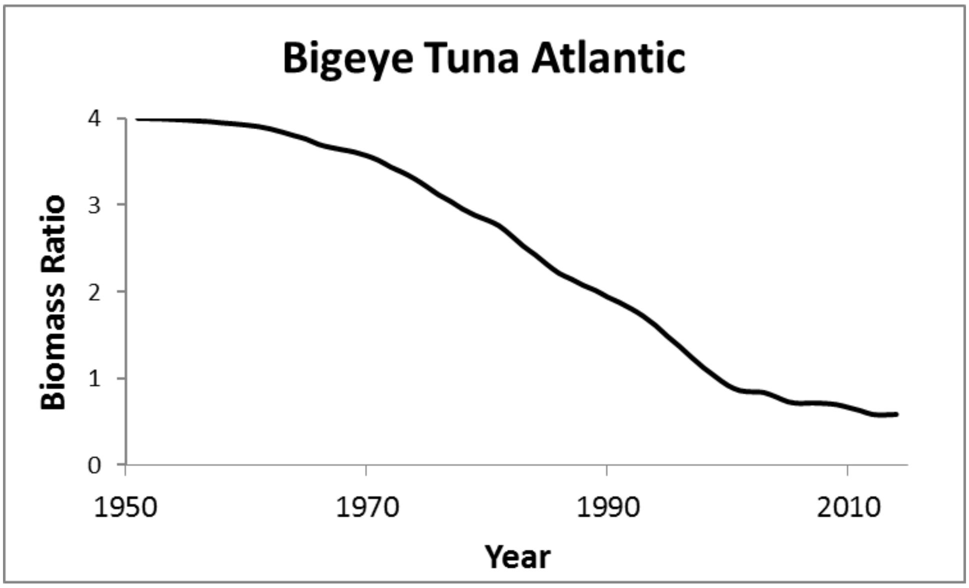


Figure 7: BET scaled abundance trends from last assessment (base run).

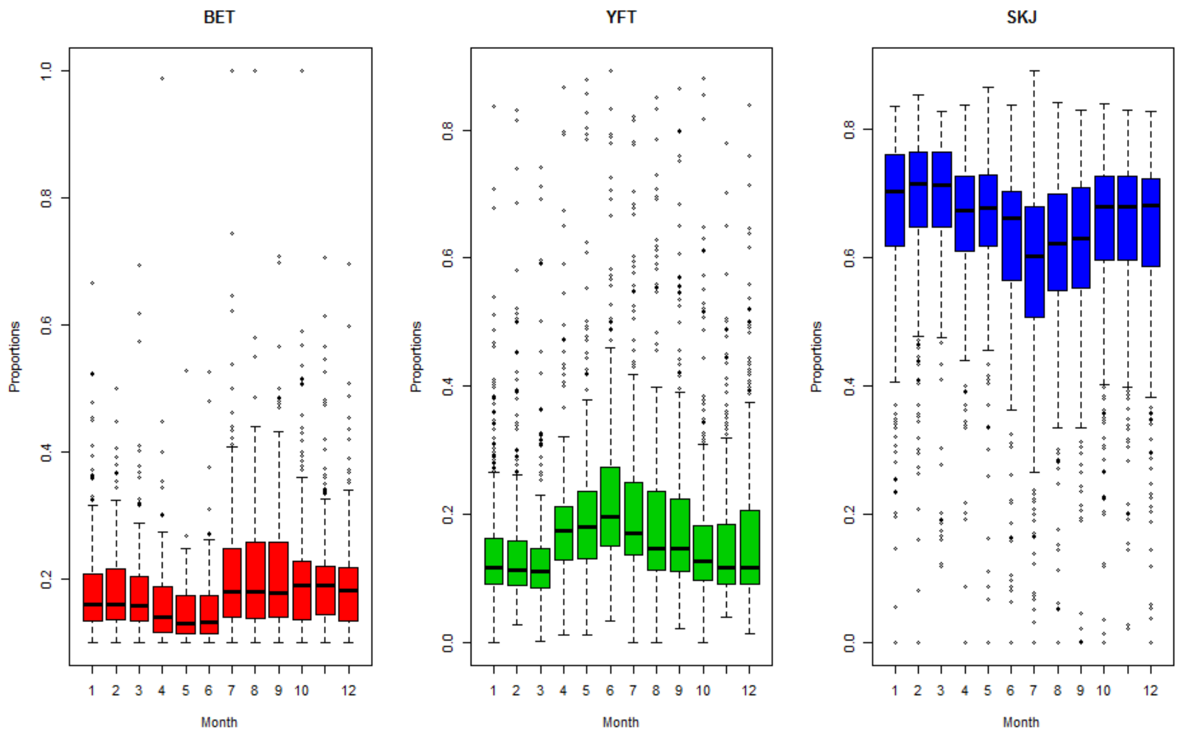


Figure 8: Species proportions by month over 2003-2013 by month.

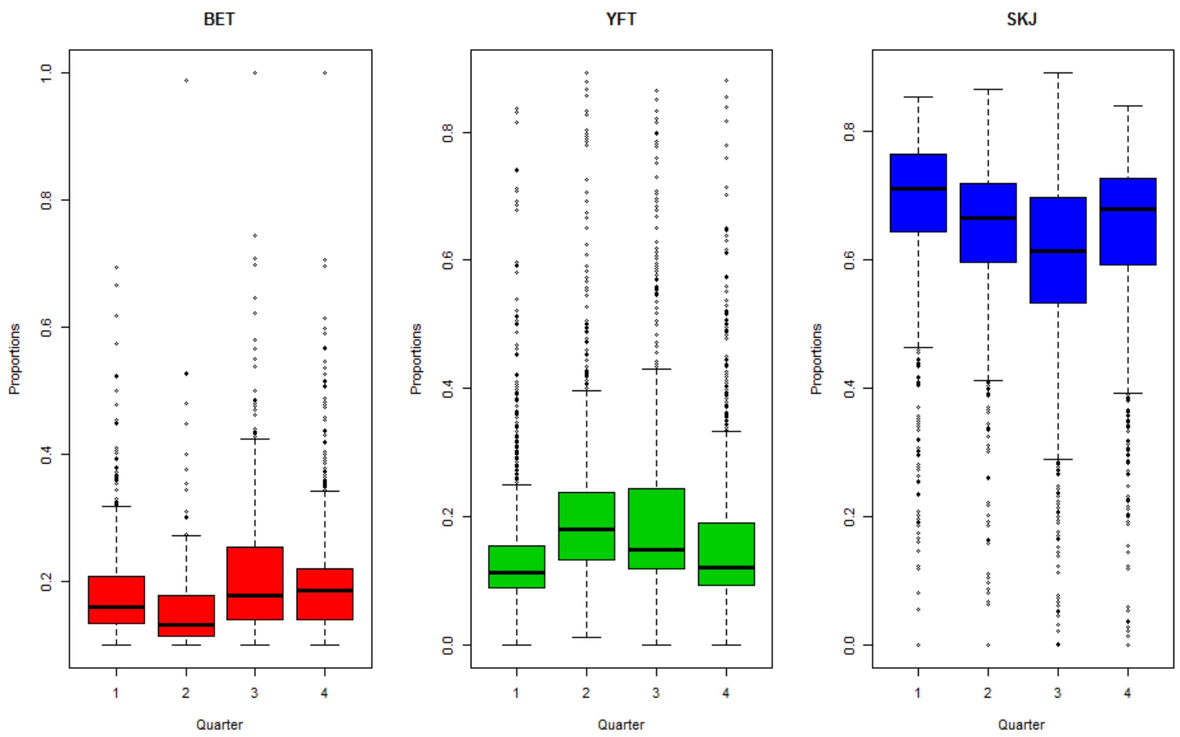


Figure 9: Species proportions by qurter over 2003-2013 by month.

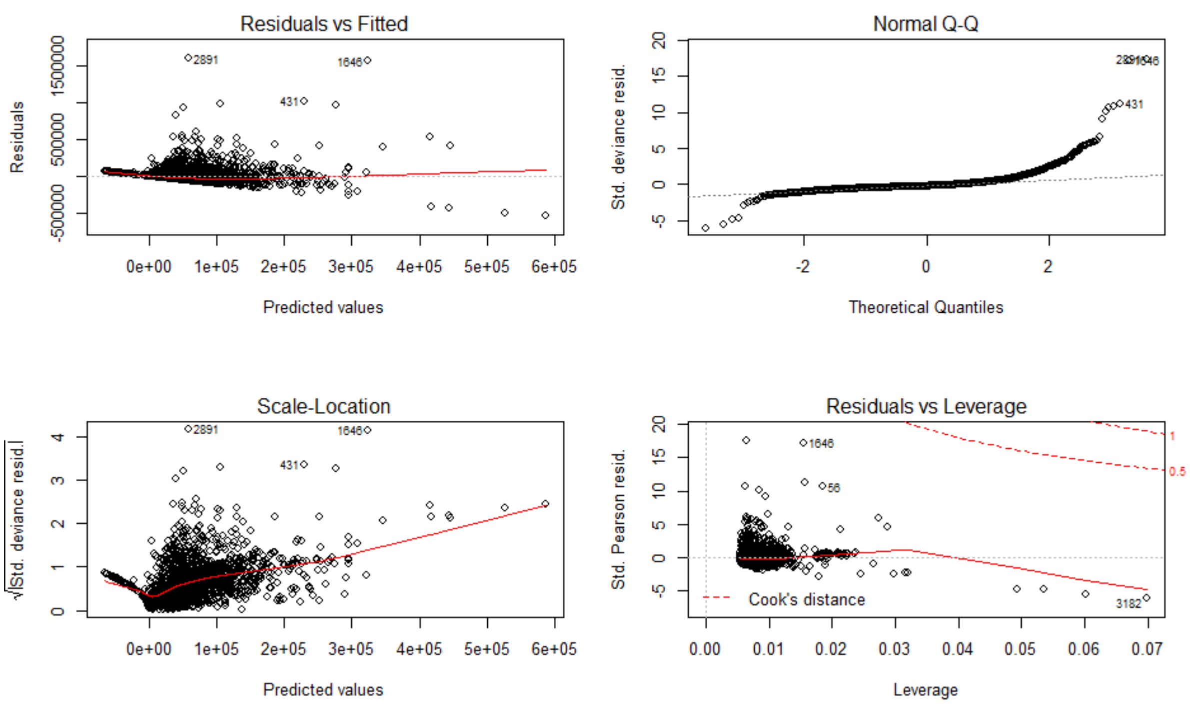


Figure 10: Residual diagnostics for model 1

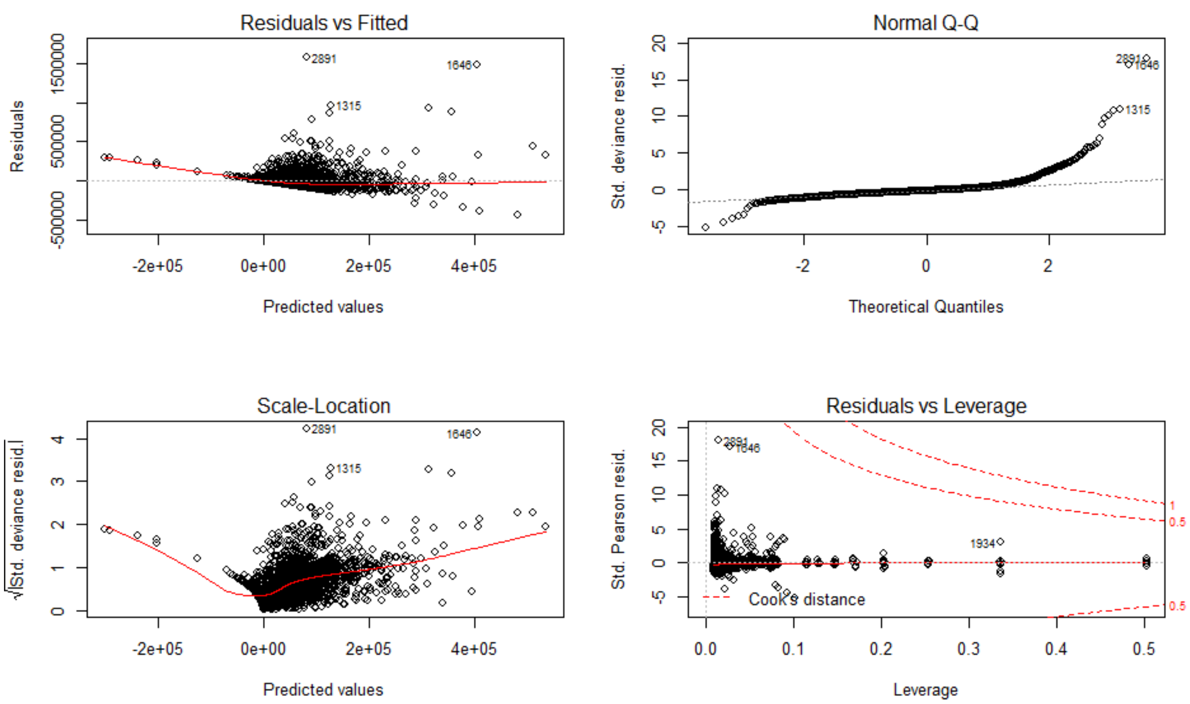


Figure 11: Residual diagnostic for model 2

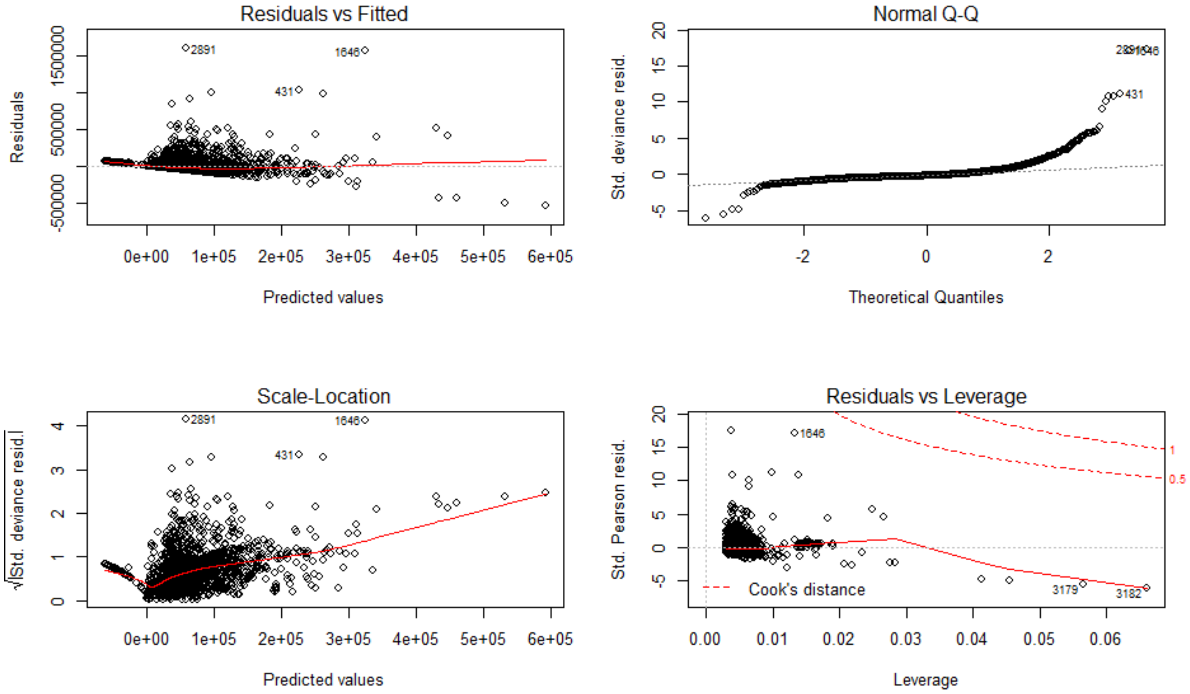


Figure 12: Residual diagnostics for model 3

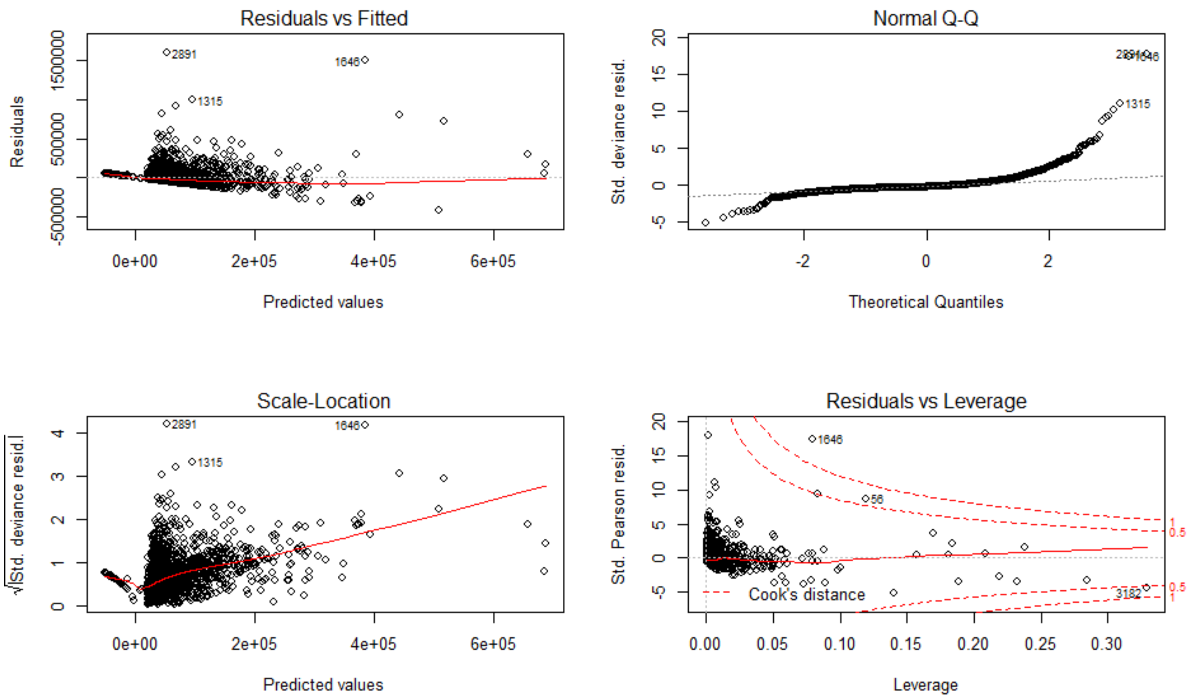


Figure 13: Residual diagnostics for Model on BET- FINAL MODEL.

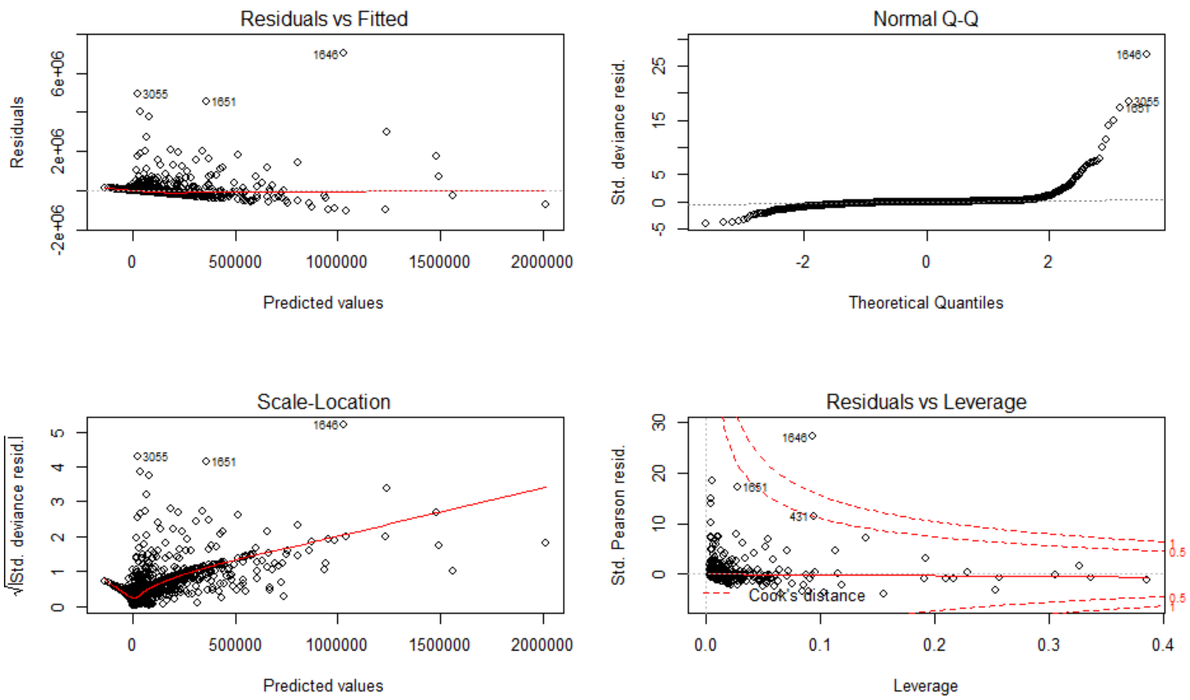


Figure 14: Residual diagnostic for Model on YFT

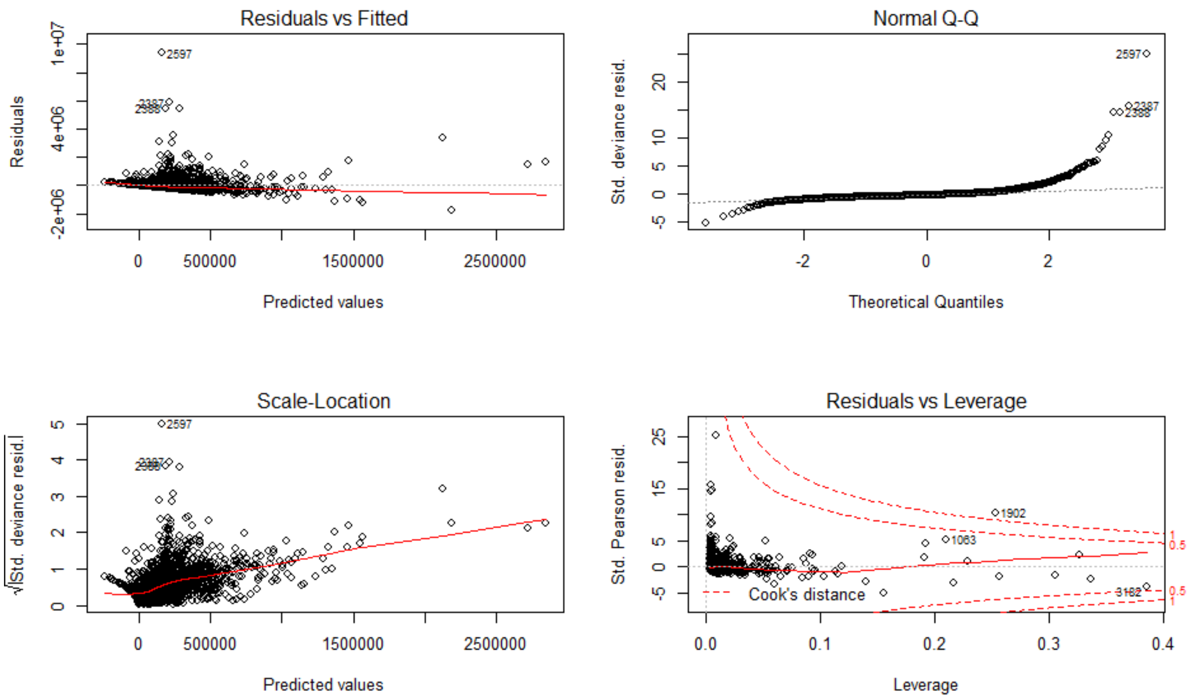


Figure 15: Residual diagnostic for Model on SKJ

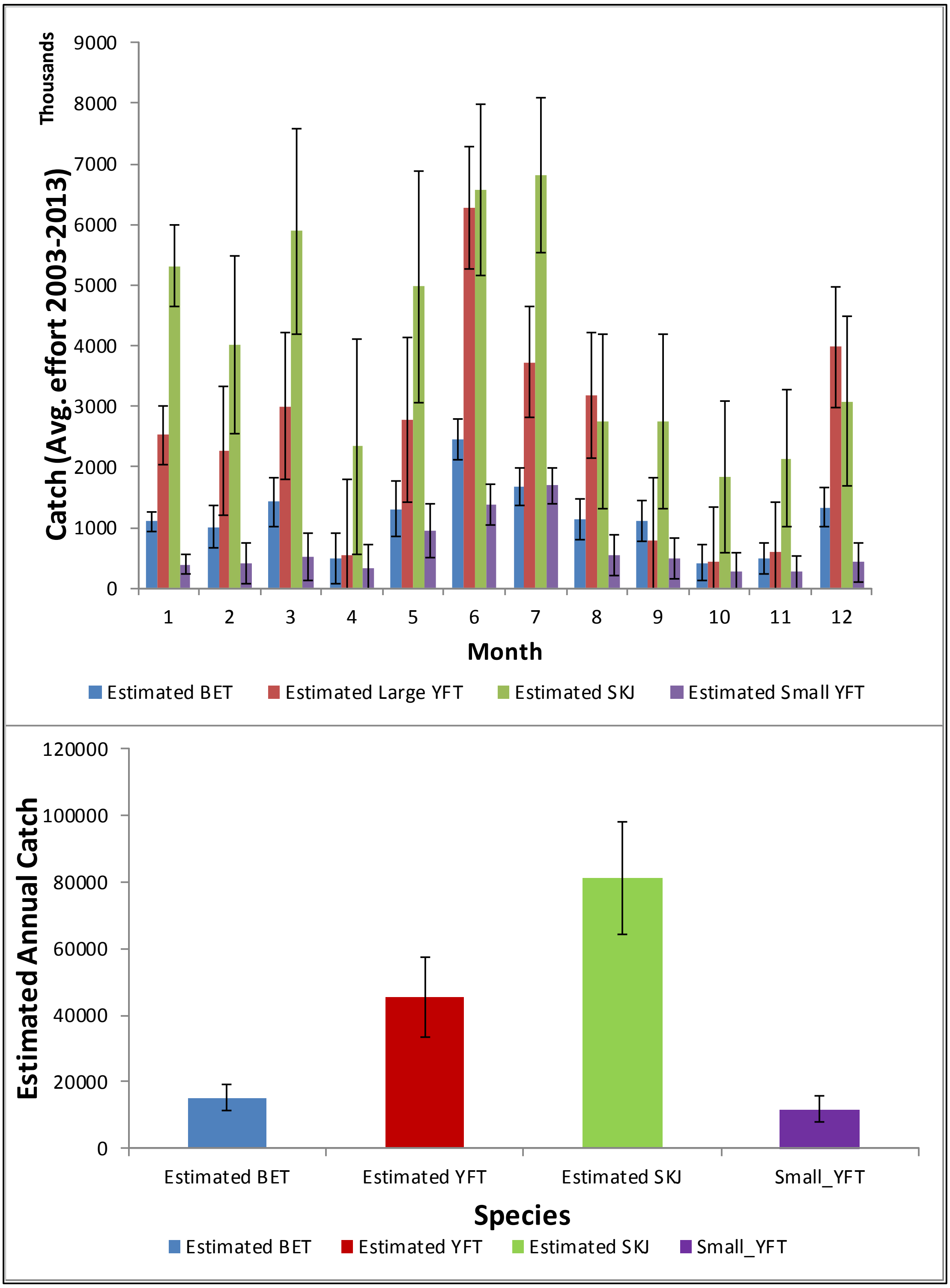


Figure 16: Estimated catch by species and month (above panel) and all year (lower panel) based on average effort distribution and 400000 SPB for BET.

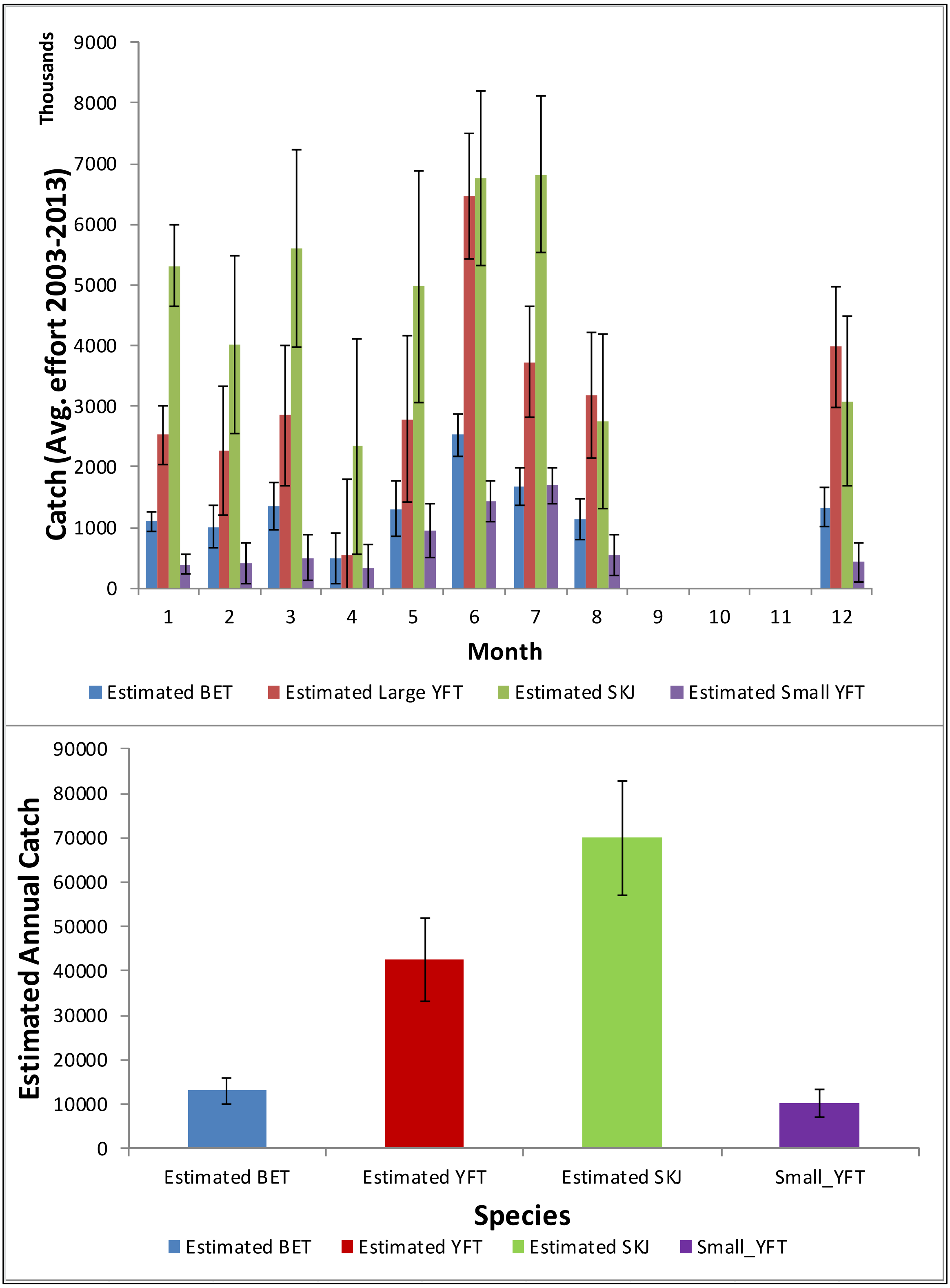


Figure 17: Estimated catch by species and month (above panel) and all year (lower panel) based on one closure of 3 months (Sep, Oct, Nov) and 400000 SPB for BET. The goal is try to limit BET to 10000 T and keep YFT near 40000T

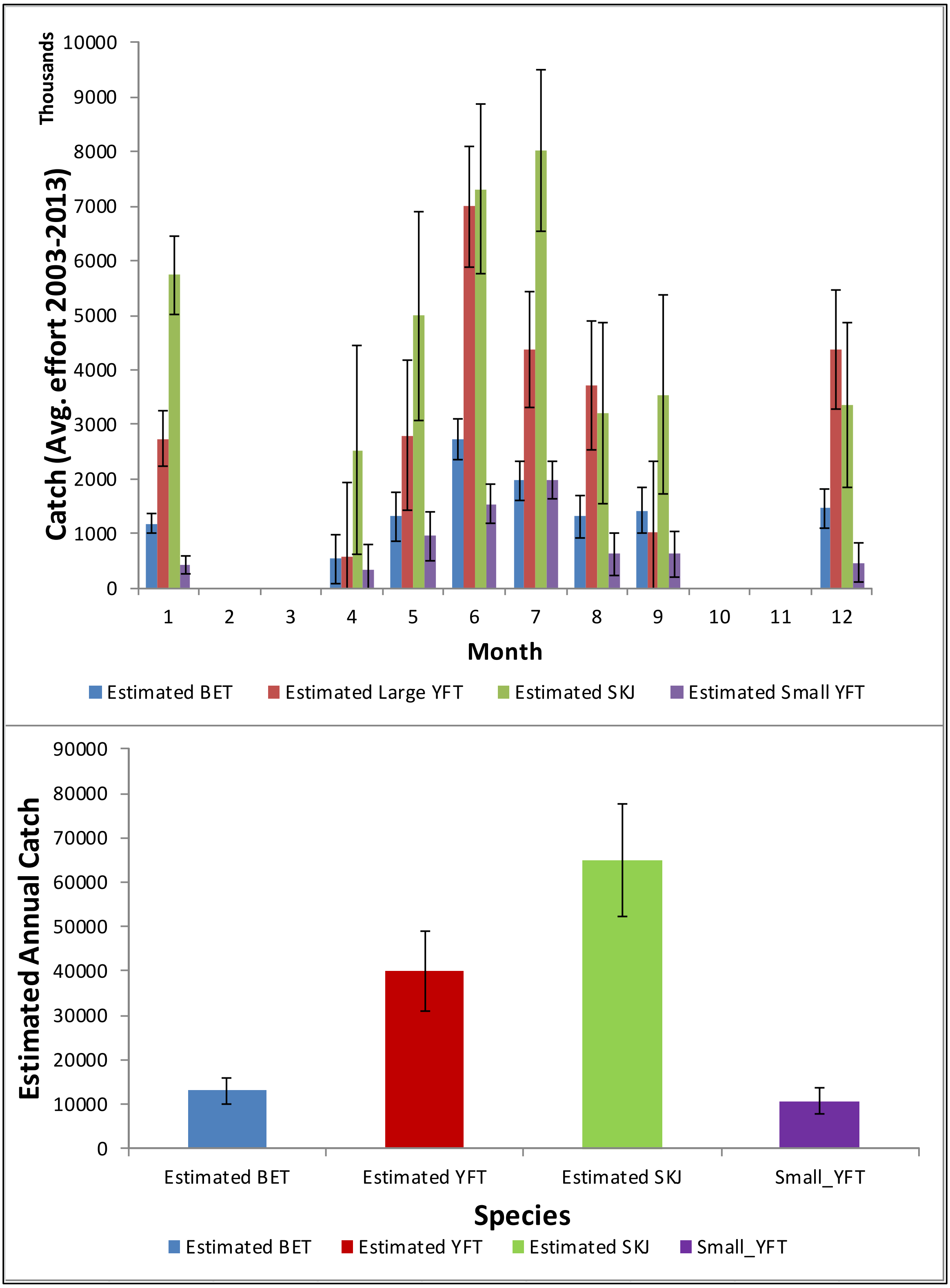


Figure 18: Estimated catch by species and month (above panel) and all year (lower panel) based on two closures of 2 months each (Sep & Oct, Feb & March) and 400000 SPB for BET. The goal is try to limit BET to 13000 T and keep YFT near 40000T.

SCRS/ 2018/119

USING FADs TO DEVELOP BETTER ABUNDANCE INDICES FOR TROPICAL TUNA

Isadora Moniz[1], Julio Morón[2], Miguel Herrera[2]

SUMMARY

Through its Fishery Improvement Project (FIP), OPAGAC launched a research project with AZTI to support stock assessments for the Atlantic Ocean. OPAGAC is contributing to abundance indices development, both fishery dependent and independent, by providing its FAD data, which is necessary to support and improve the sustainable management of tropical tuna nowadays. For fishery dependent indices this includes catch and effort, sizes, and FAD density; and for fishery independent indices the acoustic records of beacons' echo sounders is provided. Additionally, to contribute to a more comprehensive study, a temporal data series was made available.

KEYWORDS

Catch/effort; Biomass; Fishing technology; Purse seining; Tuna fisheries; Data collections.

[1] Independent consultant, Madrid, Spain
[2] OPAGAC C/Ayala 54 2A 28001 Madrid, Spain

Modern technology is ensuring fishing fleets around the world are as efficient and effective as possible. Particularly regarding the purse seine fishery, several technological improvements resulted in increased efficiency (Torres-Irineo et al. 2014), including the use of GPS buoys to more accurately locate drifting Fish Aggregating Devices (dFADs) and other floating objects, and the introduction of echo sounder buoys to monitor the amount of biomass aggregated under FADs (Lopez et al. 2014). Nowadays, the generalized use of FADs equipped with satellite buoys coupled with echo sounders is causing rapid changes in the fishing strategy and fleet, as they continuously provide fishers with near real-time information about the accurate location of the FADs and an estimate of the biomass aggregated underneath each FAD. Moreover, the echo sounder buoys have also the potential of being an observation platform to evaluate relative abundances of FAD-associated fish using fishery independent data. This potential source of information, independent from catching efficiency and fleets dynamics, may be used by scientist in future stock assessments.
The introduction of man-made FADs in the early 1990s has been considered by many as the most significant technological innovation that has occurred in tropical tuna fishing in the last decades (Ariz et al. 1999; Miyake 2005). However, since its introduction, it has proven difficult to define a fishing effort unit for purse seiners (Fonteneau et al. 1999; Fonteneau et al. 2013).
The relationship between catch per unit effort (CPUE) and abundance is key to stock assessment models. The provision of fine scale buoy and echo sounder data from the OPAGAC fleet aims at assisting attempts to develop indices of abundance from purse seine fisheries, something that has proved difficult since the beginning of these fisheries. For this reason, most of the stock assessments of tropical tunas worldwide (yellowfin, bigeye) are based on longline, and to a lesser extent pole-and-line, CPUE indices.

The information needed to improve fishery-dependent abundance indices is:

a) Buoy density per 1º x 1º grid;
b) Characteristics and technical evolution of the beacons utilized;
c) Historical evolution of the number of supply vessels and their association with the purse seiners.

It is important to note that this complements other information reported, which includes vessel details, logbooks from purse seiners and supply vessels, as well as maps from purse seiners and landing statistics, apart from the sampling conducted in port and observer data, which assist in the estimates of catch by purse seiners. Moreover, it adds to what is already reported by the Spanish FAD Logbook (please check Ramos et al. 2017 and references therein for further details), such as:

- Vessel name
- Number of trip
- Registration
- Position
- Date
- Hour
- FAD identification
- FAD type
- FAD design characteristics
- Type of buoy
- Type of activity
- Type of activity with the buoy
- If the activity is a set, the results of the set in terms of catch and bycatch
- Characteristics of any attached buoy or positioning equipment
- Observations

The information needed to try to develop new fishery-independent indices consists of the acoustic records of the beacons' echo sounders. Data of 20 buoys per purse seiner and day throughout each year will be made available, replacing deactivated buoys by new buoys to maintain that number throughout the series for which there is information. Nevertheless, it should be taken into account that echo sounders provide an estimate of the biomass found underneath each FAD in an aggregated status and not discriminated by species, thus despite being fishery independent, this information might need to be cross checked with logbook records to perceive species richness and its relative abundance. Hence, the main objective of this project is to support in providing estimates of tuna abundance at FADs by species, suitable for selective fishing and fisheries independent estimates of tropical tuna abundance.

Considering that it is necessary to have an historical series to be able to incorporate indices of abundance in the evaluations of fish populations, the data available covers the longest possible period of time, from 2010 (or earlier if it existed) to December 2017. This is one of the voluntary initiatives being implemented by the OPAGAC fleet, in the framework of its FIP (Herrera and Morón 2017).

Annex 1 - Format of the information to be requested from buoy suppliers' companies

The information will have the below described components, which are the usual formats reported for AZTI to verify the number of active buoys in each tRFMO.

a. Information about buoys' daily positions

To determine the densities of satellite buoys per grid of 1º x 1º and month, and the evolution of the characteristics of the buoys used by the OPAGAC fleet in the Atlantic Ocean, it is necessary to have the daily position of each buoy (identified with its unique code) according to the format described below. A single csv. file will be prepared independently for each company and year.
The information collected in the csv. files is:

- date [dd-mm-aa]
- hour [hh: mm]
- unique identification code of the buoy [the format varies depending on the manufacturer, although it is always alphanumeric]
- latitude [expressed in degrees and minutes in decimal values],
- latitude [expressed in degrees and minutes in decimal values], and
- speed [knots].

b. Information on acoustic records

The data of 20 buoys per purse seiner and day will be sent throughout the year, replacing buoys deactivated by new buoys to maintain that number throughout the series for which there is information.

Components provided per buoy manufacturer:

- ZUNIBAL: Company, Buoy Code, date (day, hour), Type (position or echo sounder), Latitude, Longitude, Speed, Drift, Total;
- SATLINK: Company, Buoy Code, md, date (day, time), Latitude, Longitude, bat, temp, speed, drift, layer1, layer2, layer3, layer4, layer5, layer6, layer7, layer8, layer9, layer10, total , maximum, mag1, mag2, mag3, mag4, mag5, mag6, mag7, mag8;
- MARINE INSTRUMENTS: Company, Buoy code, date (day, time), lat, mode, lon, light, poll, temperature, vcc, date2, gain, layers, layerbits, maxdepth, sd1, sd2, sd3, sd4, sd5, SD6, SD7, SD8, SD9, SD10, SD11, SD12, SD13, SD14, SD15, SD16, SD17, SD18, SD19, SD20, SD21, SD22, SD23, SD24, SD25, SD26, SD27, SD28, SD29, SD30, sd31, sd32, sd33, sd34, sd35, sd36, sd37, sd38, sd39, sd40.

Annex 2 - Format of the information requested from the companies

To determine the historical evolution of the number of supply vessels and their association with the purse seiner(s), each company will prepare tables with the following fields:

- Year: year of activity
- Company name
- Name of the purse seiner(s)
- Name of the supply, in case the purse seiner has worked totally or partially supported by the supply
- Percentage of dedication of the supply vessel to the purse seiner (0.50 if the supply has been shared by two purse seiners, 1.00 if the supply has been exclusive to one purse seiner)

References

Ariz, J., Delgado de Molina, A., Fonteneau, A., Gonzales Costas, F., Pallarés, P., 1999. Logs and tunas in the eastern tropical Atlantic: a review of present knowledge and uncertainties. In: Scott, M.D., Bayliff, W.H., Lennert-Cody, C.E., Schaefer, K.M. (Eds.), Proceedings of the International Workshop on the Ecology and Fisheries for Tunas Associated with Floating Objects. Presented at the Inter-American Tropical Tuna Commission Special Report 11. La Jolla, CA, pp. 21–65.

Fonteneau, A., Chassot, E., Bodin, N. 2013. Global spatio-temporal patterns in tropical tuna purse seine fisheries on drifting fish aggregating devices (DFADs): Taking a historical perspective to inform current challenges. Aquatic Living Resources 26(1): 37-48.

Fonteneau, A., Gaertner, D., Nordström, V. 1999. An overview of problems in the CPUE-abundance relationship for the tropical purse seine fisheries. Collect. Vol. Sci. Pap. ICCAT 49, 259–276.

Herrera, M., Morón, J. 2017. Implementing management plans and voluntary initiatives regarding FADs: the OPAGAC experience. Joint t-RFMO FAD Working Group meeting. Doc. No. j-FAD_15/2017.

Lopez, J., Moreno, G., Sancristobal, I., Murua, J. 2014. Evolution and current state of the technology of echo-sounder buoys used by Spanish tropical tuna purse seiners in the Atlantic, Indian and Pacific Oceans. Fisheries Research 155: 127–137.

Miyake, P.M., 2005. A brief history of the tuna fisheries of the world. In: Second Meeting of the Technical Advisory Committee of the FAO Project Management of Tuna Fishing Capacity: Conservation and Socio-economics. FAO Fish. Proc., Madrid, Spain, pp. 23–50.

Ramos, M.L, Baez, J.C., Grande, M., Herrera, M.A., Lopez, J., Justel, A., Pascual, P.J., Soto, M., Murua, H., Muniategi, A. and Abascal, F.J. 2017. Spanish FADs logbook: solving past issues, responding to new global requirements. Joint t-RFMO FAD Working Group meeting. Doc. No. j-FAD_11/2017

Torres-Irineo, E., Gaertner, D., Chassot, E., Dreyfus-Leon, M. 2014. Changes in fishing power and fishing strategies driven by new technologies: the case of tropical tuna purse seiners in the eastern Atlantic Ocean. Fisheries Research 155: 10–19.

ON THE POTENTIAL BIASES OF SCIENTIFIC ESTIMATES OF CATCHES OF TROPICAL TUNAS OF PURSE SEINERS THE EU AND OTHER COUNTRIES REPORT TO THE ICCAT AND IOTC

Miguel Herrera[1], José Carlos Báez[2]

SUMMARY

This document represents a first attempt to explore potential differences between the catches of tropical tunas estimated using the EU software T3 and those recorded on sale slips completed by the canning factories purchasing fish from 48 vessels registered with OPAGAC in the Atlantic and Indian oceans, over the period 2011-16. The analysis identified potential sources of bias estimates of catch of tropical tunas that the EU and other countries have been reporting to the ICCAT and the IOTC during the study period, although probably longer, may be subject to. The magnitude of the biases identified varied depending on the ocean, fleet, and size category, with the largest bias recorded in the Indian Ocean, where EU estimates of catch of yellowfin tuna and bigeye tuna, especially of large size, appeared to be well below those recorded on sale slips. Although to a lesser extent, in the Atlantic Ocean the catches of yellowfin and bigeye tunas seem to be also underestimated, although in this case underestimation of both large and small fish seem to be responsible for this. Although the study is preliminary and the available datasets need to be further explored and cross-verified with actual monitoring of fish in processing plants, the results obtained indicate that the system the EU is using to sample purse seine landings and estimate catches may be subject to large bias which, if confirmed, could have consequences on the statistics, stock assessments, management advice, and management measures adopted by ICCAT and IOTC.

KEYWORDS

Catch composition; Size composition; Tropical tunas; Purse seining

[1] Producers' Organisation of Large Tuna Freezers (OPAGAC), C/Ayala 54 2A 28001 Madrid, Spain (miguel.herrera@opagac.org)

[2] Instituto Español de Oceanografía (IEO), Centro oceanográfico de Canarias, Vía Espaldón, Dársena Pesquera, Parcela 8 38180 Santa Cruz de Tenerife, Spain

1. Introduction

The European purse seine fleet operates in tropical and subtropical waters of the Atlantic, Indian and Pacific oceans (Clermont et al., 2012; Escalle et al., 2017a), in areas under the competence of the four tuna-RFMO that manage stocks of tropical tunas (IATTC, ICCAT, IOTC and WCPFC), which are the target of EU purse seiners . At present all EU purse seiners for tropical tunas are flagged in either France, Italy, or Spain.

The "Institut de recherche pour le développement" (IRD) in France and the "Instituto Español de Oceanografía" (IEO) in Spain are the institutions responsible to produce scientific estimates of catch, effort, and other biological data (e.g. size frequency distribution of the catches) for their respective countries. However, while ICCAT and IOTC fully rely on the data reported by the EU, the IATTC and WCPFC have implemented different arrangements and are not covered here (IATTC 2016; Lawson 2013).

The multi-species nature of tropical tuna surface fisheries gives rise to a series of difficulties at the time of estimating basic catch by species and catch by size statistics. Fonteneau (1976) discussed about the difficulty of some patterns to correctly identify the composition of the retained catch. In the Atlantic and Indian oceans, the IRD and the IEO agreed to harmonize data collection and catch estimation procedures in 1998, with the same sampling and catch estimation procedure adopted for both oceans since that year and catch estimates for previous years adjusted to account for the new procedures (Pallares & Petit, 1998). The new system used the same sampling protocols and estimating procedures (known as T3) for both oceans, unlike the two systems existing between 1980 and 1997. All systems were based on the correction of catches reported on vessel logbooks using data collected from port sampling.

In addition, EU scientists have assisted non-EU countries having purse seiners to implement the EU sampling and estimation procedures. This includes Seychelles and Mauritius in the Indian Ocean and Belize, Cape Verde, Curaçao, El Salvador, Guatemala, Panama and Senegal in the Atlantic Ocean.

This document presents some preliminary exploratory analysis that compare estimates of landings of tropical tunas obtained using the EU sampling and catch estimation procedures with data obtained from sale slips produced by the canning factories that acquired those fish, in the Areas of Competence of ICCAT and IOTC and for the period 2011-2016. The study is limited to the fleet ascribed to OPAGAC its main purpose being to assess the concordance of estimates of total catch and catch by species and size category produced by EU institutions with the data recorded on the sale slips collected for that period.

The objective is to assess the reliability of scientific estimates of catch produced using EU procedures as compared to sale slips from canning factories and the consequences that any potential bias identified could have on estimates of total catch and catch by species and size category for EU and other fleets; and the potential consequences of any discrepancy over the status of stocks of tropical tunas, and their management.

2. Methods

2.1 European sampling and catch estimation procedures

EU scientists collect the following information from purse seiners in order to produce the statistics required by the flag state/RFMO concerned:

- Logbooks and well plans completed by skippers/chief engineers of tuna purse seiners and handed over at the end of each fishing trip to enumerators and compliance officers;
- Total catches unloaded/transhipped in port reported by the skippers/fishing companies at the end of each unloading operation;
- Data from port sampling, conducted by staff of research institutions in coastal countries with which EU scientists have established cooperative arrangements (mainly "Centre de Recherches Océanologiques" in Abidjan, "Centre de Recherches Océanographiques Dakar Thiaroye" in Dakar, Seychelles Fishing Authority in Victoria, "Unité Statistique Thonière d'Antsiranana" in Diego Suarez, Madagascar);
- Biological samples, collected on an opportunistic manner, intended to provide the information required to convert length samples into weight.

The sampling procedure is summarized in the following paragraphs. Sampling are stratified by:

- fishing mode, with sets to free-swimming and associated tuna schools treated separately;
- fishing area, with 6 areas in the Atlantic Ocean and 8 in the Indian Ocean;
- time-period, with each year broken by quarter (January-March, April-June, July-September, October-December).

Thus, a fish tank is selected for sampling only when all the catches stored in it come from sets recorded for the same fishing mode, fishing area, and time-period;

Collection of samples: where large (≥10kg) and small (<10kg) fish are present in a selected tank fish are randomly selected for each category and measured independently. The objective is to take a minimum number of samples per stratum, with each sample consisting of two sub-samples, taken at different times during the unloading of the selected fish tank.

- If a fish tank contains only large specimens (≥10kg) the sample consists of two sub-samples of 150 specimens each with the pre-dorsal length (length from the tip of the snout to the base of the first dorsal fin) and species of each individual recorded (YFT or BET).

- If a fish tank contains only small fish (<10kg) or a mix of large (≥10kg) and small fish the objective is to monitor 500 small fish (two sub-samples of around 250 specimens each or 300+200), attempting to measure as many large fish (YFT, BET) as possible from those fish unloaded at the time each sub-sample of small fish is taking place.

    - Small fish: the sampling consists on the random selection of small fish as it is unloaded from the tank until the target sampled number is attained with a different approach used for SKJ specimens as compared to YFT and BET:

        - Skipjack tuna: the first 30 SKJ identified from the fish taken for sampling are measured in fork length while all SKJ specimens monitored beyond that number are simply counted (with just the total number recorded in the sampling form);
        - Small yellowfin and bigeye tunas: the fork length and species of all individuals appearing on the sample is recorded until the target sample number is attained;

    - Large fish: All individuals unloaded as small fish are being sampled are classified by species and measured in pre-dorsal length, regardless of their numbers.

The methodology used by EU and other scientists to produce catch, effort and size frequency distributions for purse seiners is known as TTT, or T3. The estimation procedure is summarized in Figure 1.

Thus, the samples from all vessels/fish tanks for a given fishing mode, quarter and T3 statistical area are used to correct the species composition of each and every individual set recorded under the same stratum, regardless of the vessel from which samples come from (i.e. the estimation procedure is not specific to the boat). This procedure involves the following steps:

- Conversion of the numbers of fish sampled for length into weight, for which length (fork or pre-dorsal)-weight relationships are used, as adopted by EU scientists;
- Estimation of total weight of skipjack tuna using the weight and number of specimens sampled for length and the total number of SKJ monitored;
- Estimation of total weight sampled for other species by summing up the weights of all fish sampled;
- Raising the weights sampled by T3 size class (total ≥10kg & <10kg) to the total reported for each sampling unit (fish tank) and breaking the catches of each size class according to the proportions obtained from the sample;

- Adding the total amounts estimated from all sampling units to obtain the final proportions of YFT, BET (≥10kg & <10kg) and SKJ (<10kg), for each T3 size category.

Once that the final proportions for species composition and size category are obtained for each stratum, those proportions are used to adjust the catches from each individual set following scaling of the catches in logbooks to the totals unloaded, as shown in Figure 1.

Therefore, it is important to bear in mind the following points:

- The EU system relies on the total amounts unloaded reported by vessel skippers or fleet representatives; however, landing data is only used in bulk (i.e. each catch entry in a logbook is scaled by the factor obtained by dividing the total catch of tropical tunas unloaded by the total catch of tropical tunas recorded in the logbook of the trip concerned);
- The EU system relies on the total amounts of tropical tunas in the category ≥10kg and <10kg recorded in vessel logbooks and well maps;
- The EU system relies on multi-vessel port sampling data to break the catches reported under each of the above size categories by species (i.e. it ignores the catches by species reported in logbooks);

The outcome of this process is that the catches of all EU and associated fleets made inside the same stratum (Size category, Fishing mode, Area, Quarter) end up having exactly the same species and size composition. This is a strong assumption as it smooths away any individual vessel effects, unlike what has been described in other regions, like the Pacific Ocean (Lennert-Cody et al. 2008; Escalle et al. 2017b).

Pallares & Petit (1998) provide more details about the sampling and catch estimation procedures used by the EU and other countries for their purse seine fleets.

2.2 Data sources and preparation

This study covers the activities of 48 purse seiners registered with OPAGAC over the period 2011-2016, which unloaded around 100,000 tons of tropical tunas per ocean per year over that period.

The following data were compiled for each boat:

T3 Output tables: Output tables from the T3 process for the period of reference were provided by the IEO (OPAGAC purse seiners flagged in Spain, Indian and Atlantic oceans), SFA (OPAGAC purse seiners flagged in Seychelles, Indian Ocean), and Vanessa Rojo (staff from OPAGAC responsible for the statistics of OPAGAC's purse seiners not flagged in Spain). The format of the tables is reproduced in Annex 1. Data are presented in logbook format (i.e. one line per day/fishing activity with effort and catches by time, location species/size category). The table also contains information about the date(s) of unloading of the catches that were taken during each fishing trip. The following information was used from this record (fields recorded in bold red font in Annex 1):

ocean: Ocean of activity;
flag: Flag state of the vessel;
vescode: Vessel code as per FIBATO's classification (IEO/IRD Vessel Registry);
year_dbq: Year of unloading;
v_poids_capt_skj : Catch of skipjack tuna in metric tons;
v_poids_capt_yft_cat1: Catch of yellowfin tuna size category 1 (<10kg);
v_poids_capt_yft_cat2: Catch of yellowfin tuna size category 2 (10kg-30kg);
v_poids_capt_yft_cat3: Catch of yellowfin tuna size category 3 (≥30kg);
v_poids_capt_bet_cat1: Catch of bigeye tuna size category 1 (<10kg);
v_poids_capt_bet_cat2: Catch of bigeye tuna size category 2 (10kg-30kg);
v_poids_capt_bet_cat3: Catch of bigeye tuna size category 3 (≥30kg).

Sale slips from canning factories: Sale slips are documents produced by the canning factories of destination of the tuna caught by purse seiners. They reflect the amounts purchased, in weight for each species and commercial category from each landing. They usually include several size categories for each species, depending on the canning factory. The format of the tables provided by the companies of OPAGAC is provided in Annex 2. The following information was used from the records sent (fields recorded in bold red font in Annex 2):

Nombre del buque: Name of the purse seiner;
Fecha de desembarco: Date of unloading;
Descarga completa? (Si/No): All catches unloaded? (Yes/No);
YFT>10kg: Catch yellowfin tuna ≥10kg;
YFT<10kg: Catch yellowfin tuna <10kg;
BET>10kg: Catch bigeye tuna ≥10kg;
BET<10kg: Catch bigeye tuna <10kg;
SKJ: Catch skipjack tuna.

The landing data collected from the above two sources was aggregated by ocean, boat, flag country (Spain, Seychelles, Other flags), year, and the following species and size categories:

Yellowfin and bigeye tuna weighting 10kg or more (AT≥10);
Yellowfin and bigeye tuna weighting less than 10kg (AT<10);
Skipjack tuna (SKJ).

2.2 Methods

Data were prepared as indicated in the previous section to be able to compare T3 estimates with sale slips for those species groups and size categories for which the weights recorded on sale slips are considered reliable. This is because each of the three groups used fetches a different price in the market, with the highest price paid for specimens AT≥10 and the lowest paid for skipjack tuna. The categories also match those T3 uses, as presented in Figure 1.

Once all data was compiled and aggregated as per the above categories, the two records were compared using simple tables and plots and several statistical tests, including:

- Concordance Correlation Coefficient (CCC): Measures the level of agreement between two continuous variables. A value equal to +1 corresponds to perfect agreement between two measurement methods. A value equal to 0 indicates that the two methods are independent to one another. A value of -1 points to a total mismatch between the two methods (Carrasco & Jover, 2004).
- Intraclass Correlation Coefficient (ICC): The intraclass correlation is commonly used to assess the consistency or reproducibility of quantitative measurements made by different observers measuring the same quantity. Quantifies the concordance between different measurements of a numerical variable. This coefficient estimates the average of the correlations between all possible ordinations of pairs of available observations. The value of ICC ranges from 0 to 1. Therefore, the maximum possible match corresponds to a value of ICC = 1. In this case, all observed variability would be explained by the differences between subjects and not by the differences between the measurement methods. On the other hand, the value ICC = 0 is obtained when the observed concordance is equal to the one that would be expected to occur only by chance (Pita Fernández & Pértegas Díaz, 2004). According to Pita Fernández & Pértegas Díaz (2004), concordance is very strong for values over 0.9, strong for values between 0.71-0. 9, moderately strong for values between 0.51-0.7, weak for values between 0.31-0.5 and poor or inexistent for values <0.31.
- Wilcoxon signed-rank test: A Wilcoxon signed-rank test is a nonparametric test that can be used to determine whether two dependent samples were selected from populations having the same distribution. It assumes that the scale of measurement for x and y has the properties of an equal-interval scale; that the differences between the paired values of x and y have been randomly drawn from the source population; and that the source population from which these differences have been drawn can be reasonably supposed to have a normal distribution. Two data samples are matched if they come from repeated observations of the same subject. Using the Wilcoxon Signed-Rank Test, we can decide whether the corresponding data population distributions are identical without assuming them to follow the normal distribution. The null hypothesis is that the unloadings obtained from sale slips and T3 are from identical populations. The null hypothesis is rejected for p-values less than the .05 significance level.

- Paired t-test: A paired t-test is used to compare two population means where there are two samples in which observations in one sample can be paired with observations in the other sample. As above, the null hypothesis is rejected for p-values less than the .05 significance level.
- Bland and Altman method (B&A): The Bland and Altman method is a graphical procedure to evaluate the concordance between two measurement systems (Pita Fernández & Pértegas Díaz, 2004) and quantifies agreement between two quantitative measurements by constructing limits of agreement. These statistical limits are calculated by using the mean and the standard deviation (s) of the differences between two measurements. Bland-Altman plots are extensively used to evaluate two measurements techniques. Bland-Altman plots allow identification of any systematic difference between the measurements (i.e., fixed bias) or possible outliers. The mean difference is the estimated bias, and the SD of the differences measures the random fluctuations around this mean. If the mean value of the difference differs significantly from 0 on the basis of a 1-sample t-test, this indicates the presence of fixed bias. If there is a consistent bias, it can be adjusted for by subtracting the mean difference from the new method (Bland & Altman, 1986).

3. Results

3.1 Landings by flag group

Table 1 shows the species composition obtained from T3 estimates and sale slips by ocean (Top: Atlantic Ocean; Bottom: Indian Ocean), flag category (Right: Spain; Top left; various flags other than Spain; Bottom left: Seychelles), year (2011-2016, and all combined), and species group (AT≥10: YFT+BET ≥10kg; AT<10: YFT+BET <10kg; SKJ).

Spanish fleet: In the Atlantic Ocean, T3 seems to underestimate catches of tunas in the categories AT≥10kg and AT<10kg, while overestimating catches of skipjack tuna, with results that are consistent over the time-period in study. The same applies to the Indian Ocean, although in this case T3 appears to largely underestimate the catches of tunas AT≥10kg (T3: 24%; SSLIP: 31%) and overestimate the catches of skipjack tuna (T3: 50%; SSLIP: 40%), throughout the time series.

Other fleets: The same applies to the Atlantic Ocean although the differences between T3 and SSLIP tend the be lower. For the Seychelles fleet in the Indian Ocean estimates are similar than those for Spain, although differences are somewhat higher.

Figure 2 shows the percentage that each species group category made over the total landings recorded for the OPAGAC fleet during 2011-16, by ocean (RFMO area) and flag (Spain, Seychelles, Other flags), as obtained from sale slips (SS) and T3 output tables (T3). The corresponding values are recorded in Table 1 (Line Total).
As noted before (Table 1), the differences between T3 estimates and amounts on sale slips seem to be quite large.

In addition, the box plot charts shown in Figure 3a-d present median values (black horizontal line), 25th and 75th percentiles (box lower and upper margins), whiskers and outliers (as per R default definition) from the landings of tropical tunas available for the OPAGAC fleet, by boat and year (covering 2011-16), with data presented separately for sale slips (SS: orange bars) and T3 estimates (T3: green bars), broken by ocean (AO: Atlantic Ocean; IO: Indian Ocean) and flag group (ESP: Spain; SYC: Seychelles; OTH: Other flags).

Figure 3a shows that total catches of tropical tunas estimated using T3 and from sale slips are very similar across both oceans and groups of fleets, with only some slight differences recorded in the Indian Ocean. Overall, the difference is 1% or lower and therefore the landing reports that T3 uses seem to be accurate. As for the size categories presented in figures 3b-d they confirm the differences expressed before for each fleet and ocean.

3.2 Landings by year

Box plots in Figure 4 show total catches of tropical tunas and catches for each species and size group, by ocean and year. In general, there appears to be consistency in the magnitude of the bias recorded for each species group and size class over the time period. However, those differences seem to have been higher since 2014 in the Indian Ocean and 2015 in the Atlantic Ocean, especially regarding the category AT<10 kg.

3.3 Landings by ownership

Figure 5 presents box plots by ocean and ownership group. In the same way, the magnitude of the bias seems to be consistent for all ownership groups and categories under consideration.

3.4 Statistical tests

Table 2 shows the results of the concordance (CCC and CCI), Wilcoxon signed-rank, paired t- and Bland and Altman tests performed for the above data, with Bland and Altman dispersion and difference plots presented in Figure 6a-d (by species group, ocean and for all flags combined).

Both concordance analysis show a high level of correlation between T3 results and Sale Slips, with moderate-low levels of correlation only obtained for the Seychelles fleet in the Indian Ocean, in particular for the category AT≥10kg. Considering that correlation methods tend to be highly sensitive to sample heterogeneity (Giavarina 2015), as it is the case for purse seine landings, these results are only useful to prove that both sampling methods (T3 and sale slips) are measuring the same population rather than proving full concordance between pairs of values. Apart from vessel size, such heterogeneity may be also due to vessels having different targeting practices or fishing grounds (e.g. number of access agreements each vessel has secured to operate the ZEE of coastal states).

On the contrary, the results from paired t-test, Wilcoxon signed-rank test and Bland and Altman method presented in table 2 and plots (Figure 6a-d; Annex 3) are useful to appreciate how catches estimated using T3 may be biased. Thus, the ρ-values obtained from the two former are only significant (ρ-values higher than 0.05) when the total unloadings for all three tropical tunas combined are compared, being well below significance levels in all other cases. This proves that catches from sale slips and T3 estimates are not identical and that difference cannot be attributed to chance. This is also shown through the deviation from average landing values presented in Table 4 (B&Ad), and Bland and Altman plots (Figures 6 & 7), where that difference is expressed in absolute terms (mid panel) and as the percentage deviation (right panel) that amounts on sale slips represent when compared to average values from the two records (Bland and Altman method). Thus, the distance between the continuous horizontal black line and the broken horizontal black line shows the absolute systematic error (in % and absolute).

Both dispersion and Bland and Altman plots for total catches of tropical tunas tend to indicate that estimates of total catches by both systems are very similar and not likely to be subject to error.

On the contrary, the analysis run for each commercial category appears to indicate that T3 estimates may be subject to bias of various magnitudes, depending on the size category, fleet, and ocean under consideration. The largest potential biases relate to the category AT≥10 kg in the Indian Ocean (≈35%, Figure 6b, bottom) and, to a lesser extent, Atlantic Ocean (≈15%, Figure 6b, top), with T3 grossly underestimating catches under this category. On the contrary, estimates for the category AT<10 kg seem to be subject to higher bias in the Atlantic Ocean (≈25%, Figure 6c, top) than in the Indian Ocean (≈10%, Figure 6c, bottom), with large unloadings prone to bias of higher magnitude than small unloadings (dispersion plot Figure 6c). As for skipjack tuna, it is also subject to a potentially high bias, higher in the Indian Ocean (>20%) than in the Atlantic Ocean (<10%).

It is important to note that Figure 6 shows results by ocean and all flags combined while Table 2 and Figure 7 present results by flag, and the magnitude of the bias may vary depending on the flag group. However, there does not seem to be a large deviation between the results presented below and those for each individual fleet (see figures in Annex 3).

4. Discussion

The following points can be drawn from the results presented on Tables 1-2 and Figures 2-4:

- **The total combined landings of tropical tunas T3 uses for the OPAGAC fleet** (Table 2 & Figure 3a), **are similar to those obtained from sale slips**, with no large deviations detected; the deviations recorded are likely to originate from weighing of the fish at unloading, which T3 uses, and weights recorded in the canning factories of destination; however, the fact that total landings for both T3 and sale slips come from the same source (fishing industry) warrant for the reason of the existing discrepancies to be further investigated and selection of data from the best source used for future estimates;

- **T3 appears to underestimate, to a much larger degree in the Indian Ocean, the amount of yellowfin tuna and bigeye tuna of over 10kg unloaded** (Tables 1-2, Figures 3b, 5b, 6b); considering that T3 relies on the amounts of large tuna (AT≥10 kg) reported in vessel logbooks/well maps rather than landing statistics, this points to a potential bias due to a **likely underreporting of large fish on logbooks**; the fact that the difference is larger in the Indian Ocean, where there seems to be a larger amount of fish of intermediate sizes (between 10-20kg) tends to confirm that skipper logbooks/well maps do not record accurately the amount of large fish, leading to T3 underestimating this component; this has also consequences on the amounts that are estimated for other species, and the catch-at-size estimated for both yellowfin tuna and bigeye tuna (i.e. potential significant bias when the selectivity of the purse seine gear is assessed from catch-at-size estimated from T3 samples and catch estimates);
- **T3 appears to overestimate the catches of skipjack tuna and underestimate the catches of small yellowfin and bigeye tuna** (Tables 1-2, Figures 3c-d, 5c-d, 6c-d); as indicated previously, skipjack tuna tends to fetch a lower market price than small yellowfin and bigeye tunas and therefore the amounts of SKJ on sale slips are considered reliable, or at least a good approximation to the highest possible amount unloaded for this species, as some canning factories may record some juvenile YFT and BET as part of the SKJ component in order to purchase the fish at a lower price (never the contrary); thus, the differences between sale slips and T3 estimates point to **issues related with sampling protocols and/or poor implementation of sampling in port**. However, the accuracy of T3 estimates relies highly on the relationships that are used to convert length measurements into weight for each species and size category (Marsac et al., 2017) and, for this reason, it is necessary to **verify that the length-weight equations used for small sizes are appropriate**.

Tables 3a-b illustrate the potential consequences that the confirmation of the biases identified in this document would have on the catches recorded by ICCAT (3a) and IOTC (3b) for purse seine fleets covered by the EU sampling scheme. For this comparison, nominal catch data from the ICCAT and IOTC databases was downloaded and catches extracted for all purse seine fleets that are covered through the EU sampling scheme and catch estimation procedures (T3), assuming that all fleets are subject to the same bias than the OPAGAC fleet.

As presented in Table 3a, **the ICCAT database may record catches of yellowfin tuna and bigeye tuna well below the values that would be expected if the biases identified in this analysis are confirmed**. Thus, YFT catches for the period 2011-2016 may have been between 7,000 and 10,000 tons, with recent years showing a higher difference. The difference between reported and corrected catches is also high for the BET, with corrected catches around 3,000 tons higher than recorded catches, over the time-period. As for SKJ, the difference between recorded and corrected catches ranges between 10,000-15,000 tons, with the highest difference recorded in 2016.

Table 3b shows that **recorded and corrected catches differ by a greater order of magnitude in the Indian Ocean**, including differences between 20,000-30,000 tons for YFT (higher corrected catches); 1,000-4,000 tons for the BET (higher corrected catches): and 20,000-30,000 for the SKJ (lower corrected catches).

In addition to the above, the potential bias identified in the catches and size categories of yellowfin and bigeye tuna would translate into catch-at-size tables showing very different size distributions than the ones currently existing, with a higher amount of specimens of sizes equivalent to weights 10kg or over, and proportionally less specimens of less than 10kg. This could have **marked consequences on estimates of selectivity for the purse seine gear and stock assessments and advice for these species**.

5. Conclusion

This document represents a first attempt to explore potential differences between the catches of tropical tunas estimated using the EU software T3 and those recorded on sale slips completed by the canning factories purchasing fish from 48 vessels registered with OPAGAC in the Atlantic and Indian oceans, over the period 2011-16.

Although the study is preliminary and the available datasets need to be further explored and cross-verified with actual monitoring of fish in processing plants, the results obtained indicate that the system the EU is using to sample purse seine landings and estimate catches may be subject to bias which, if confirmed, could have consequences on the statistics, stock assessments, management advice, and management measures adopted by both organizations.

As the discrepancies are further investigated through the use of sale slip data of higher resolution (by individual trip, destination market, etc.), plant sampling and details from vessel logbooks and T3 output (catches by trip by fishing mode by species and size), it is advisable that the ICCAT and the IOTC consider contemplating alternative scenarios of catch and size frequency distributions in assessing the status of the stocks of tropical tunas, through the incorporation of catch series and catch-at-size matrices adjusted for the biases identified in this study. Considering that the EU adopted the existing sampling scheme in 1998, it is recommended that alternative scenarios contemplate extending the time-series for as long as required.

The results of this study, while preliminary, stress the need for an urgent revision of the sampling and catch estimation protocols the EU has been using since 1998. In conducting this review, the EU should contemplate verifying the validity of T3 to estimate the catches of individual vessels, in particular in cases where those estimates are used for purposes as quota monitoring. The results of this study and previous work seem to invalidate its use for that purpose.

6. Acknowledgments

The authors thank the IEO (Pedro Pascual, Francisco Abascal), Vanessa Rojo (OPAGAC IEO Tenerife) and SFA (Vincent Lucas) for providing T3 output tables for the OPAGAC fleet and representatives of the fishing companies ascribed to OPAGAC for providing all data available on sale slips used for this study. We are also thankful to Aitor Forcada (University of Alicante) for providing insight on Concordance Correlation and Bland & Altman Methods to assess concordance between two measurement methods.

7. References

Bland, J.M., D.G. Altman, 1986. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet, 327 (8476): 307–10.

Carrasco, J-L., L. Jover, 2004. Métodos estadísticos para evaluar la concordancia. Med. Clin (Barc) 2004; 122(Supp 1):28-34.

Clermont, S., P. Chavance, A. Delgado, H. Murua, J. Ruiz, S. Ciccione, J. Bourjea, 2012. EU purse seine fishery interaction with marine turtles in the Atlantic and Indian Oceans: A 15 years analyses. 8th session of the working party on environment and bycatch, IOTC. 17-19 September 2012, South Africa.

Escalle, L., D. Gaertner, P. Chavance, A. Delgado de Molina, J. Ariz, B. Mérigot, 2017a. Forecasted consequences of simulated FAD moratoria in the Atlantic and Indian Oceans on catches and bycatches. ICES Journal of Marine Science, Volume 74, Issue 3, 1 March 2017, Pages 780–792.

Escalle, L., S. Brouwer, G. Pilling, 2017b. Report from Project 77: Development of potential measures to reduce interactions with bigeye tuna in the purse seine fishery in the western and central Pacific Ocean ('bigeye hotspots analysis'). Submitted at the 13th Regular Session of the Scientific Committee of the Western and Central Pacific Fisheries Commission. WCPFC-SC13-2017/MI-WP-07. https://www.wcpfc.int/file/157226/download?token=bhU_Y4-L

Fonteneau, A., 1976. Note sur les problèmes d'identification du bigeye dans les statistiques de pêche. Col. Doc. Cient. ICCAT, Vol. V(1): 168-171.

Giavarina, D., 2015. Understanding Bland Altman analysis. Biochemia Medica 2015;25(2):141-51.

IATTC, 2018. Tunas, billfishes and other pelagic species in the eastern Pacific Ocean in 2017. Submitted at the 93rd Regular Session of the Inter-American Tropical Tuna Commission. IATTC-93-01. https://www.wcpfc.int/file/215712/download?token=Rq2wuo-A

Lawson, T., 2013. Update on the estimation of the species composition of the catch by purse seiners in the Western and Central Pacific Ocean, with responses to recent independent reviews. Submitted at the 9th Regular Session of the Scientific Committee of the Western and Central Pacific Fisheries Commission. WCPFC-SC9-2013/ ST-WP-03. https://www.wcpfc.int/system/files/ST-WP-03-Spp-Comp-PS-WCPO.pdf

Lennert-Cody, C. E., Roberts, J. J., Stephenson, R. J. 2008. Effects of gear characteristics on the presence of bigeye tuna (Thunnus obesus) in the catches of the purse-seine fishery of the eastern Pacific Ocean. – ICES Journal of Marine Science, 65: 970–978.

Marsac, F., J.C. Báez, L. Floch, A. Fonteneau, 2017. Potential changes affecting species composition and tuna catch at size for purse seine fleets by using the new length-weight relationships for tropical tunas in the Indian Ocean. Submitted to 13th Working Party on Data Collection and Statistics. IOTC-2017-WPDCS13-20.

Pallarés P., Ch. Petit, 1998. Tropical tunas : new sampling and data processing strategy for estimating the composition of catches by species and sizes. Col. Doc. Cient. ICCAT, Vol. XLVIII (2): 230- 246 (SCRS/97/28).

Pianet R., Pallarés P., Petit C., 2000, New sampling and data processing strategy for estimating the composition of catches by species and sizes in the European purse seine tropical tuna fisheries. IOTC-WPDCS/2000/10.

Pita Fernández, S., S. Pértegas Díaz, 2004. La fiabilidad de las mediciones clínicas: el análisis de concordancia para variables numéricas. http://www.fisterra.com/mbe/investiga/conc_numerica/conc_numerica2.pdf

R Core Team, 2013. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/

Table 1: Species composition (percentage) estimated using T3 and obtained from sale slips, for vessel unloadings of the OPAGAC fleet during 2011-2016, by flag group, year and species group, and totals estimated from all unloadings.

	Spain	T3			SSLIP			Other	T3			SSLIP		
		AT>10	SKJ	AT<10	AT>10	SKJ	AT<10		AT>10	SKJ	AT<10	AT>10	SKJ	AT<10
ATLANTIC OCEAN	2011	25	61	15	31	52	18	2011	23	60	17	23	55	22
	2012	21	67	12	24	62	14	2012	26	62	12	27	57	17
	2013	17	74	9	20	69	11	2013	20	69	11	21	63	16
	2014	19	67	13	25	58	18	2014	22	67	11	23	66	11
	2015	20	62	17	23	51	26	2015	19	66	14	21	60	20
	2016	22	63	15	28	53	18	2016	19	66	15	22	56	22
	Total	21	66	14	25	58	18	Total	21	65	13	23	60	18
INDIAN OCEAN	Spain	T3			SSLIP			Seychelles	T3			SSLIP		
		AT>10	SKJ	AT<10	AT>10	SKJ	AT<10		AT>10	SKJ	AT<10	AT>10	SKJ	AT<10
	2011	20	53	27	29	44	28	2011	21	51	28	30	41	29
	2012	36	40	25	46	29	25	2012	36	40	24	44	30	26
	2013	*na*	*na*	*na*	*na*	*na*	*na*	2013	15	46	39	28	40	32
	2014	21	51	28	28	41	30	2014	16	55	28	27	45	29
	2015	29	47	24	35	35	30	2015	24	48	27	34	33	33
	2016	18	55	27	24	46	31	2016	12	59	29	20	50	30
	Total	24	50	26	31	40	29	Total	21	51	29	30	40	30

Table 2: Results from the Concordance Correlation Coefficient (CCC) of Lind and Intraclass Correlation Coefficient (ICC) analysis; and deviation from the mean (MT) estimated using Bland and Altman (B&A) analysis; results include point (ρ_c; ρ_i) and lower bound (LB) and upper bound (UB) estimates for each test. Data are presented by Ocean, Flag group (Spain/Other), and for all flags combined (All).

Top left: Total unloadings for the three tropical tuna species combined

Top right: Unloadings of Yellowfin tuna and Bigeye tuna of 10kg and above

Bottom left: Unloadings of Yellowfin tuna and Bigeye tuna of under 10kg

Bottom right: Unloadings of skipjack tuna (of under 10kg)

Com. Cat.	Total Unloaded Tropical Tunas						Yellowfin/Bigeye tuna ≥10kg (AT≥10)					
Ocean	Atlantic Ocean			Indian Ocean			Atlantic Ocean			Indian Ocean		
Flag	Spain	Other	All	Spain	Other	All	Spain	Other	All	Spain	Other	All
CCCρ_c	**0.99**	**0.97**	**0.98**	**0.96**	**0.94**	**0.95**	**0.92**	**0.93**	**0.93**	**0.83**	**0.62**	**0.74**
CCC$_{LB}$	*0.97*	*0.95*	*0.97*	*0.82*	*0.86*	*0.90*	*0.81*	*0.90*	*0.88*	*0.74*	*0.44*	*0.64*
CCC$_{UB}$	*0.99*	*0.98*	*0.99*	*0.99*	*0.98*	*0.98*	*0.97*	*0.95*	*0.95*	*0.89*	*0.75*	*0.82*
ICCρ_i	**0.99**	**0.97**	**0.98**	**0.96**	**0.94**	**0.95**	**0.93**	**0.93**	**0.93**	**0.82**	**0.56**	**0.72**
ICC$_{LB}$	*0.97*	*0.95*	*0.97*	*0.93*	*0.88*	*0.92*	*0.85*	*0.89*	*0.89*	*0.67*	*0.24*	*0.57*
ICC$_{UB}$	*0.99*	*0.98*	*0.99*	*0.98*	*0.97*	*0.97*	*0.97*	*0.96*	*0.95*	*0.91*	*0.77*	*0.82*
WSRTρ	**0.24**	**0.27**	**0.15**	**0.15**	**0.17**	**0.95**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
t	*-0.7*	*-1.1*	*-1.3*	*0.5*	*-1.6*	*-0.8*	*-4.5*	*-3.5*	*-5.3*	*-8.5*	*-7.1*	*-10.7*
df	*25*	*67*	*93*	*33*	*26*	*60*	*25*	*67*	*93*	*33*	*26*	*60*
ρ	**0.52**	**0.27**	**0.20**	**0.65**	**0.12**	**0.40**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
CI$_L$	*-339*	*-208*	*-194*	*-236*	*-734*	*-351*	*-418*	*-156*	*-207*	*-852*	*-1219*	*-953*
CI$_U$	*176*	*60*	*42*	*374*	*87*	*142*	*-156*	*-42*	*-95*	*-524*	*-674*	*-652*
B&A$_d$	**82**	**74**	**76**	**-69**	**323**	**105**	**287**	**99**	**151**	**688**	**946**	**802**
B&A$_{LB}$	*-1193*	*-1033*	*-1073*	*-1819*	*-1754*	*-1821*	*-363*	*-373*	*-399*	*-251*	*-432*	*-370*
B&A$_{UB}$	*1357*	*1180*	*1225*	*1682*	*2400*	*2031*	*936*	*572*	*701*	*1628*	*2324*	*1975*
Com. Cat.	Yellowfin/Bigeye tuna <10kg (AT<10)						Skipjack tuna (SKJ)					
Ocean	Atlantic Ocean			Indian Ocean			Atlantic Ocean			Indian Ocean		
Flag	Spain	Other	All	Spain	Other	All	Spain	Other	All	Spain	Other	All
CCCρ_c	**0.76**	**0.63**	**0.67**	**0.85**	**0.88**	**0.87**	**0.97**	**0.94**	**0.95**	**0.79**	**0.81**	**0.79**
CCC$_{LB}$	*0.61*	*0.52*	*0.59*	*0.69*	*0.75*	*0.78*	*0.94*	*0.91*	*0.93*	*0.67*	*0.64*	*0.71*
CCC$_{UB}$	*0.86*	*0.72*	*0.74*	*0.93*	*0.94*	*0.92*	*0.98*	*0.97*	*0.97*	*0.87*	*0.90*	*0.86*
ICCρ_i	**0.75**	**0.59**	**0.64**	**0.85**	**0.88**	**0.86**	**0.97**	**0.94**	**0.95**	**0.77**	**0.79**	**0.78**
ICC$_{LB}$	*0.52*	*0.42*	*0.51*	*0.73*	*0.76*	*0.78*	*0.93*	*0.91*	*0.93*	*0.59*	*0.60*	*0.65*
ICC$_{UB}$	*0.88*	*0.73*	*0.75*	*0.92*	*0.94*	*0.92*	*0.99*	*0.96*	*0.97*	*0.88*	*0.90*	*0.86*
WSRTρ	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
t	*-4.7*	*-8.4*	*-9.7*	*-3.1*	*-2.7*	*-4.2*	*4.9*	*5.6*	*7.4*	*10.4*	*6.4*	*11.7*
df	*25*	*67*	*93*	*33*	*26*	*60*	*25*	*67*	*93*	*33*	*26*	*60*
ρ	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
CI$_L$	*-388*	*-390*	*-365*	*-402*	*-406*	*-352*	*277*	*220*	*276*	*805*	*579*	*776*
CI$_U$	*-152*	*-241*	*-241*	*-86*	*-55*	*-124*	*673*	*462*	*480*	*1198*	*1128*	*1096*
B&A$_d$	**270**	**315**	**303**	**244**	**230**	**238**	**-475**	**-341**	**-378**	**-1002**	**-853**	**-936**
B&A$_{LB}$	*-315*	*-301*	*-303*	*-662*	*-656*	*-652*	*-1456*	*-1340*	*-1374*	*-2128*	*-2241*	*-2183*
B&A$_{UB}$	*856*	*932*	*909*	*1151*	*1116*	*1128*	*506*	*659*	*619*	*125*	*535*	*311*

Table 3a: Catches of tropical tunas recorded in the ICCAT database for purse seine fleets under the European sampling and catch estimation scheme (YFTr, BETr, SKJr); and catches corrected using the results obtained from the present analysis (YFTr, BETr, SKJr). Catches (metric tons) are presented by ocean, species and year.

ICCAT	PS EU+OTHER REPORTED			PS EU+OTHER CORRECTED		
	YFTr	BETr	SKJr	YFTc	BETc	SKJc
2011	54,935	19,724	96,581	61,948	23,073	86,218
2012	57,302	17,463	105,580	64,995	20,548	94,802
2013	48,932	16,395	119,282	56,328	19,579	108,702
2014	55,061	17,059	110,210	62,743	20,166	99,421
2015	65,172	15,382	116,639	74,087	18,139	104,966
2016	79,213	21,351	140,132	89,809	25,112	125,774

Table 3b: Catches of tropical tunas recorded in the IOTC database for purse seine fleets under the European sampling and catch estimation scheme (YFTr, BETr, SKJr); and catches corrected using the results obtained from the present analysis (YFTr, BETr, SKJr). Catches (metric tons) are presented by ocean, species and year.

IOTC	PS EU+SYC REPORTED			PS EU+SYC CORRECTED		
	YFTr	BETr	SKJr	YFTc	BETc	SKJc
2011	98,630	19,302	118,098	121,195	22,875	91,961
2012	108,697	14,132	72,885	126,242	15,830	53,643
2013	116,255	23,159	104,357	138,429	26,597	78,745
2014	114,868	18,264	118,645	139,266	21,356	91,155
2015	122,750	21,729	119,107	147,615	25,203	90,768
2016	125,222	20,100	166,886	156,154	24,175	131,880

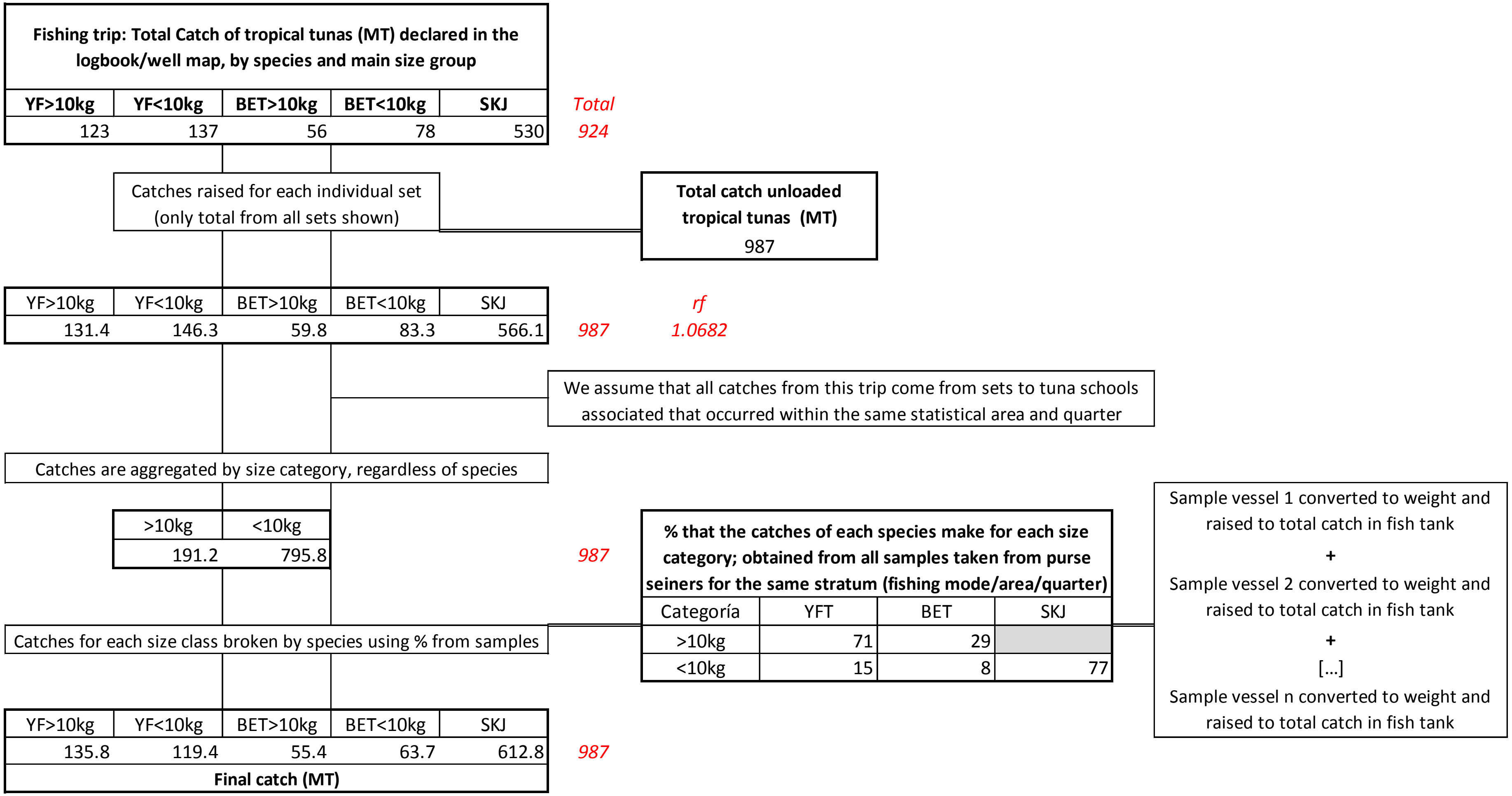


Figure 1: Flow chart summarising the procedure used by EU and Seychelles scientists to estimate catches by species and size for the tuna purse seine fishery in the Atlantic and Indian oceans.

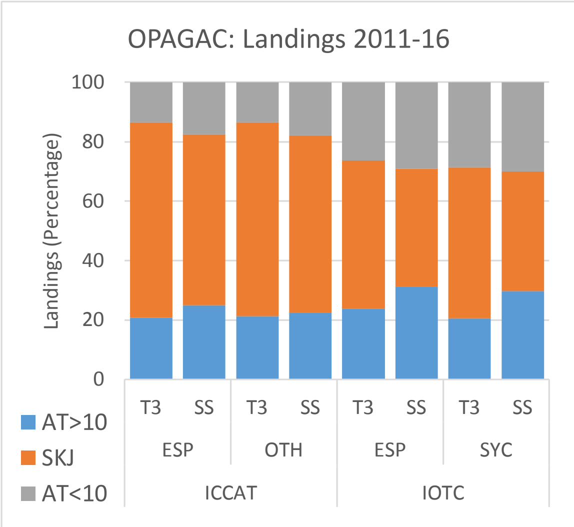
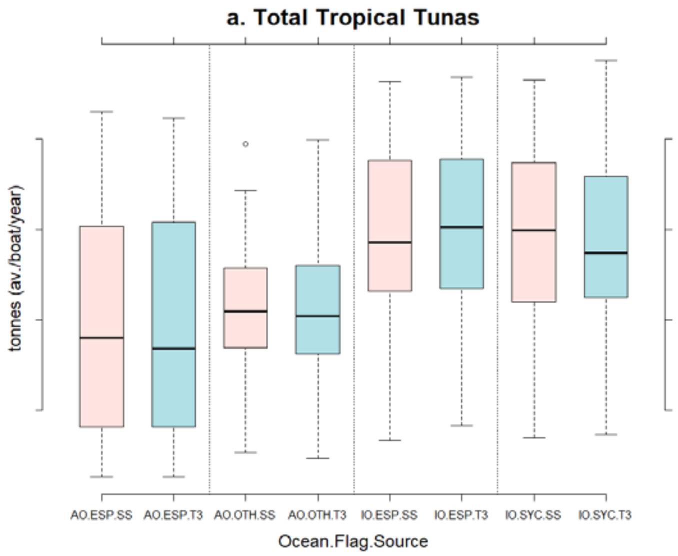
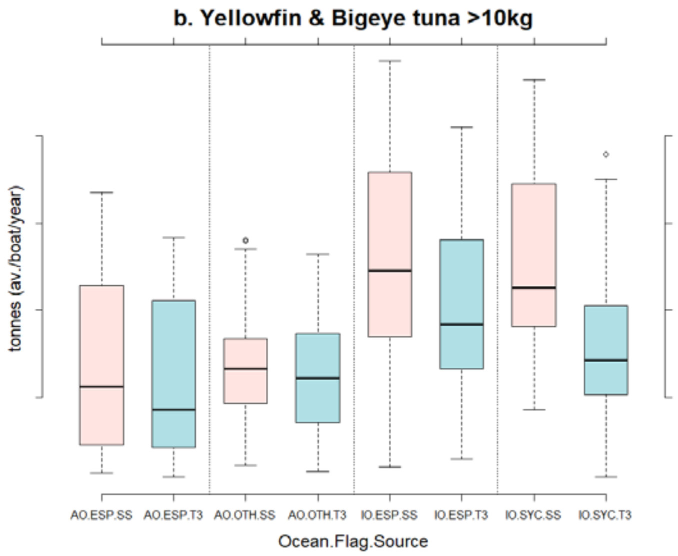
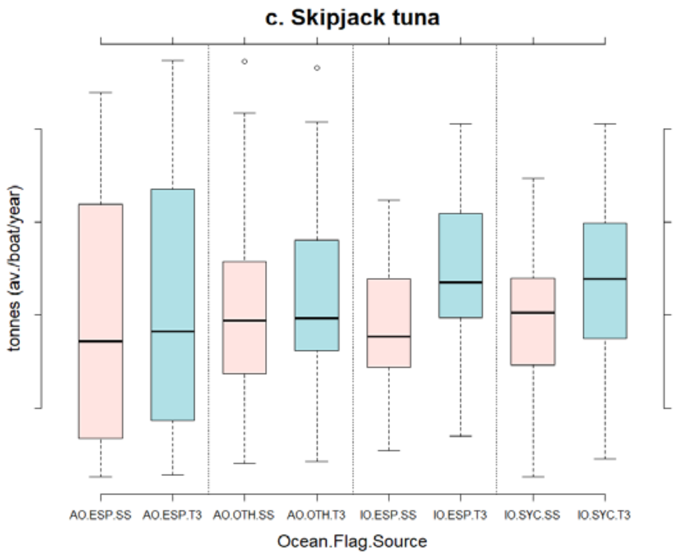


Figure 2: Contribution (percentage) that each species group category made over the total catches unloaded by the OPAGAC fleet during 2011-16, by type of document (Sale Slips (SS) or T3 estimates), RFMO Area and Flag group.


a. Total Tropical Tunas
tonnes (av./boat/year)
AO.ESP.SS
AO.ESP.T3
AO.OTH.SS
AO.OTH.T3
IO.ESP.SS
IO.ESP.T3
IO.SYC.SS
IO.SYC.T3
Ocean.Flag.Source


b. Yellowfin & Bigeye tuna >10kg
tonnes (av./boat/year)
AO.ESP.SS
AO.ESP.T3
AO.OTH.SS
AO.OTH.T3
IO.ESP.SS
IO.ESP.T3
IO.SYC.SS
IO.SYC.T3
Ocean.Flag.Source



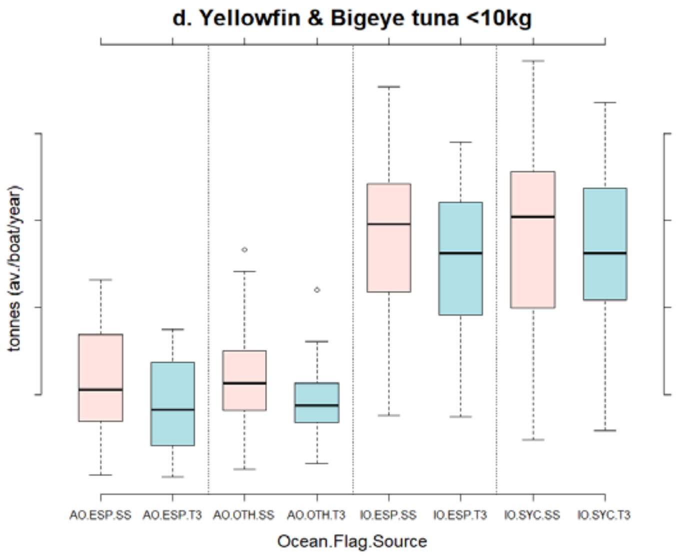


Figure 3: Box plots showing catches unloaded (in metric tons) per boat, ocean (AO: Atlantic Ocean; IO: Indian Ocean) and flag group for the OPAGAC fleet, over the period 2011-16.

a. Total catches of tropical tunas unloaded: shows box plots for total catches of tropical tunas unloaded per boat per year, with box plots presented in pairs including Sale Slips (SS: orange boxes) and T3 estimates (T3: green boxes);

b. Catches of specimens of yellowfin tuna and bigeye tuna weighing 10 kg or more: as above but only for large specimens of YFT & BET (AT≥10 kg);

c. Catches of specimens of skipjack tuna: as above but only for specimens of SKJ, with all specimens assumed to belong to the category <10kg;

d. Catches of specimens of yellowfin tuna and bigeye tuna weighing less than 10 kg: as above but only for small specimens of YFT & BET (AT<10 kg).

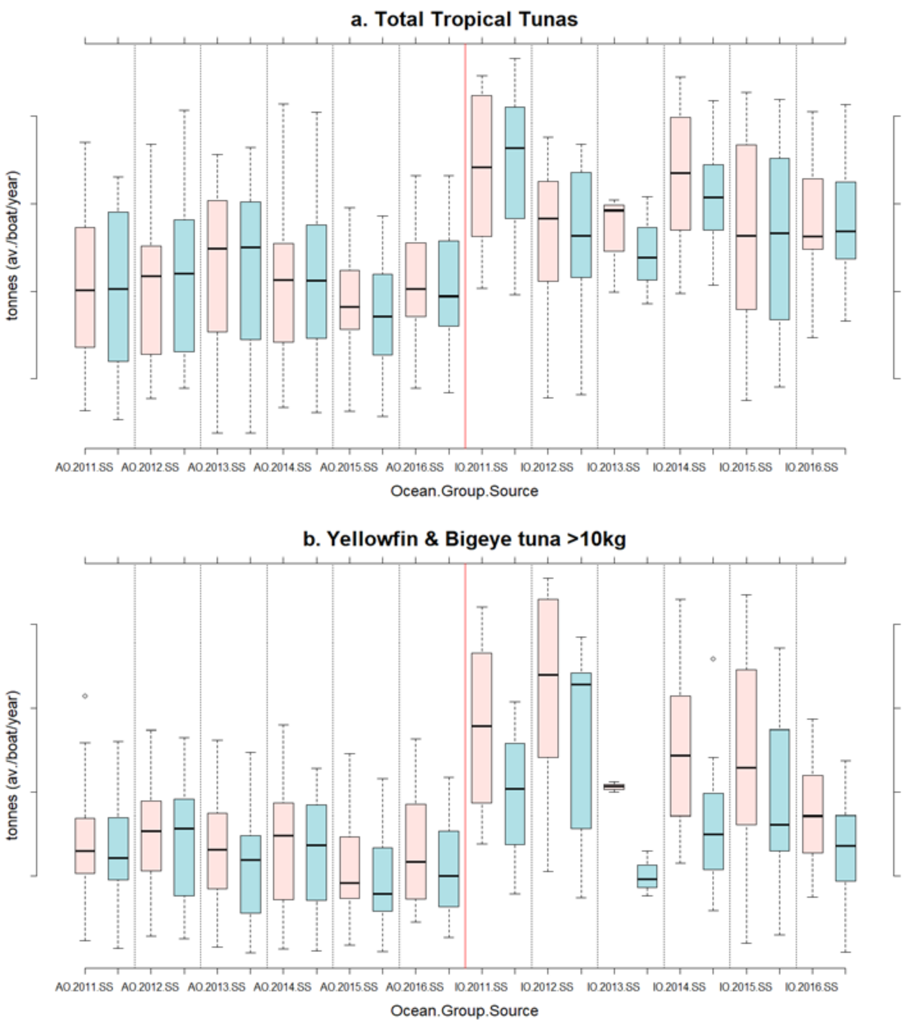
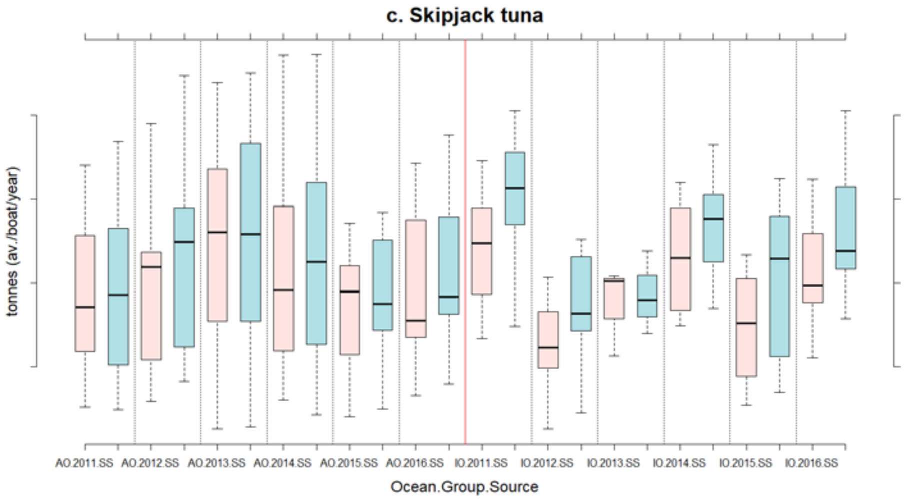


Figure 4: Box plots showing catches unloaded (in metric tons) per boat, ocean (AO: Atlantic Ocean; IO: Indian Ocean) and year for the OPAGAC fleet, over the period 2011-16.

a. Total catches of tropical tunas unloaded: shows box plots for total catches of tropical tunas unloaded per ocean per year, with box plots presented in pairs including Sale Slips (SS: orange boxes) and T3 estimates (T3: green boxes);

b. Catches of specimens of yellowfin tuna and bigeye tuna weighing 10 kg or more: as above but only for large specimens of YFT & BET (AT≥10 kg);



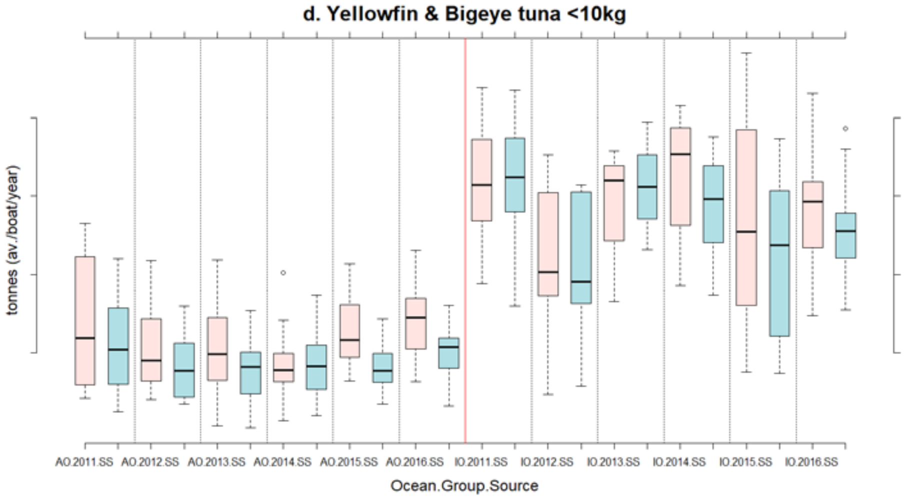


Figure 4(cont.)**:** Box plots showing catches unloaded (in metric tons) per boat, ocean (AO: Atlantic Ocean; IO: Indian Ocean) and year for the OPAGAC fleet, over the period 2011-16.

c. Catches of specimens of skipjack tuna: as above but only for specimens of SKJ, with all specimens assumed to belong to the category <10kg;

d. Catches of specimens of yellowfin tuna and bigeye tuna weighing less than 10 kg: as above but only for small specimens of YFT & BET (AT<10 kg).

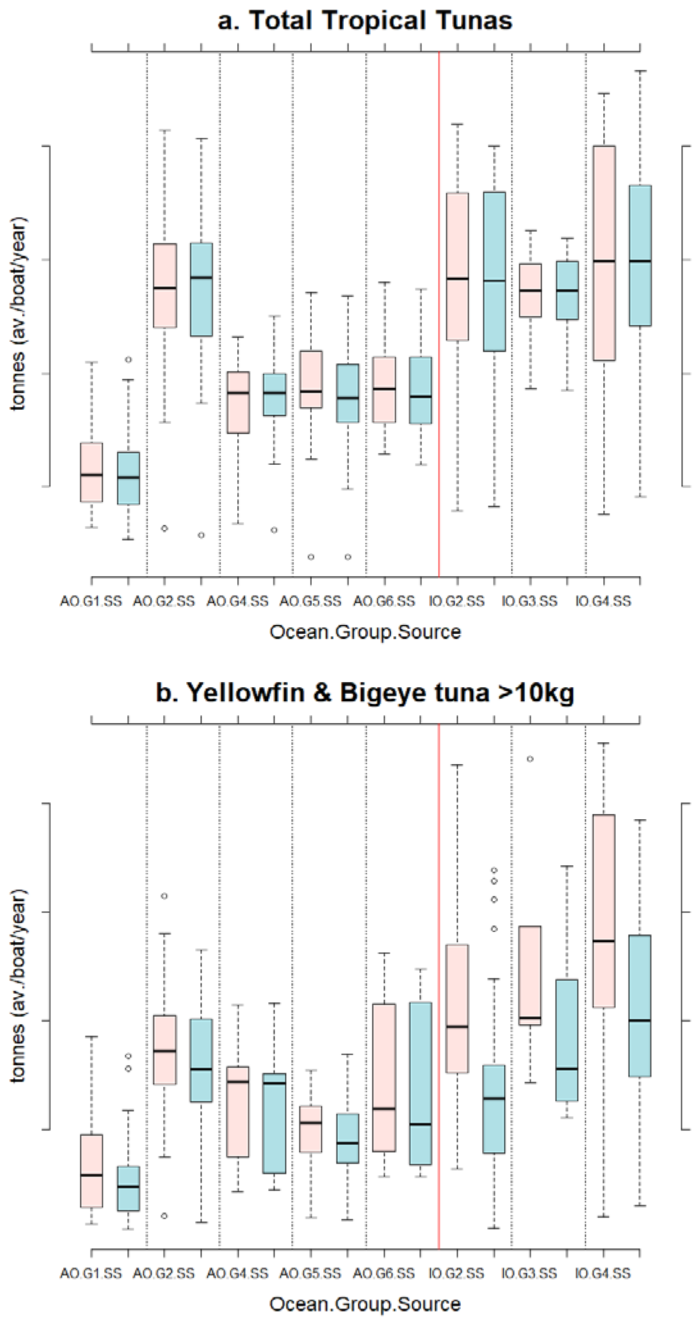
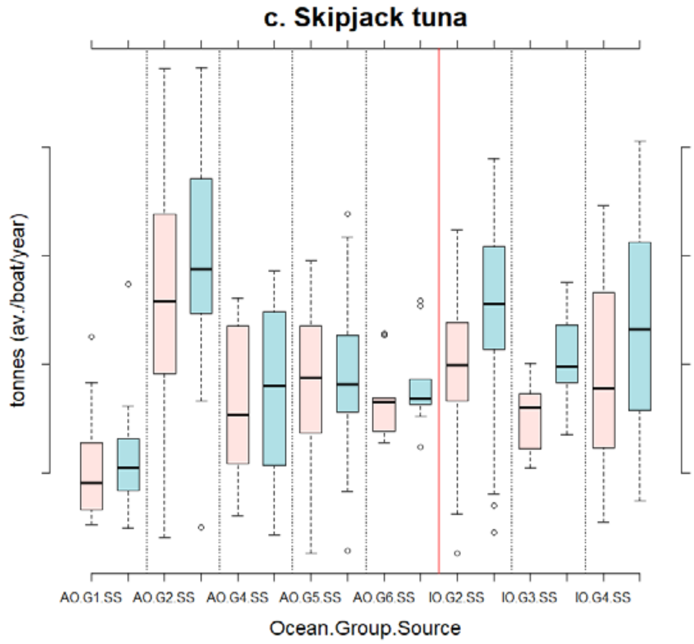


Figure 5: Box plots showing catches unloaded (in metric tons) per boat, ocean (AO: Atlantic Ocean; IO: Indian Ocean) and ownership for the OPAGAC fleet, over the period 2011-16.

a. Total catches of tropical tunas unloaded: shows box plots for total catches of tropical tunas unloaded per ownership per year, with box plots presented in pairs including Sale Slips (SS: orange boxes) and T3 estimates (T3: green boxes);

b. Catches of specimens of yellowfin tuna and bigeye tuna weighing 10 kg or more: as above but only for large specimens of YFT & BET (AT≥10 kg);



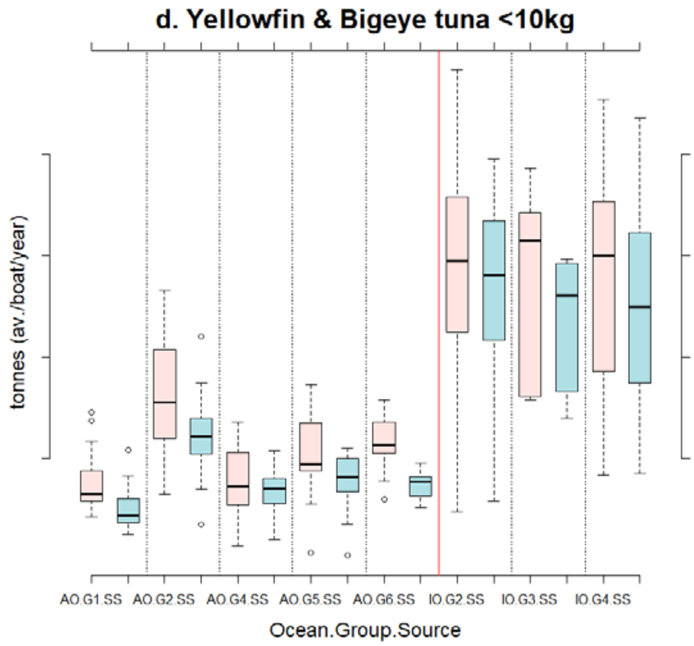


Figure 5(cont.)**:** Box plots showing catches unloaded (in metric tons) per boat, ocean (AO: Atlantic Ocean; IO: Indian Ocean) and ownership for the OPAGAC fleet, over the period 2011-16.

c. Catches of specimens of skipjack tuna: as above but only for specimens of SKJ, with all specimens assumed to belong to the category <10kg;

d. Catches of specimens of yellowfin tuna and bigeye tuna weighing less than 10 kg: as above but only for small specimens of YFT & BET (AT<10 kg).

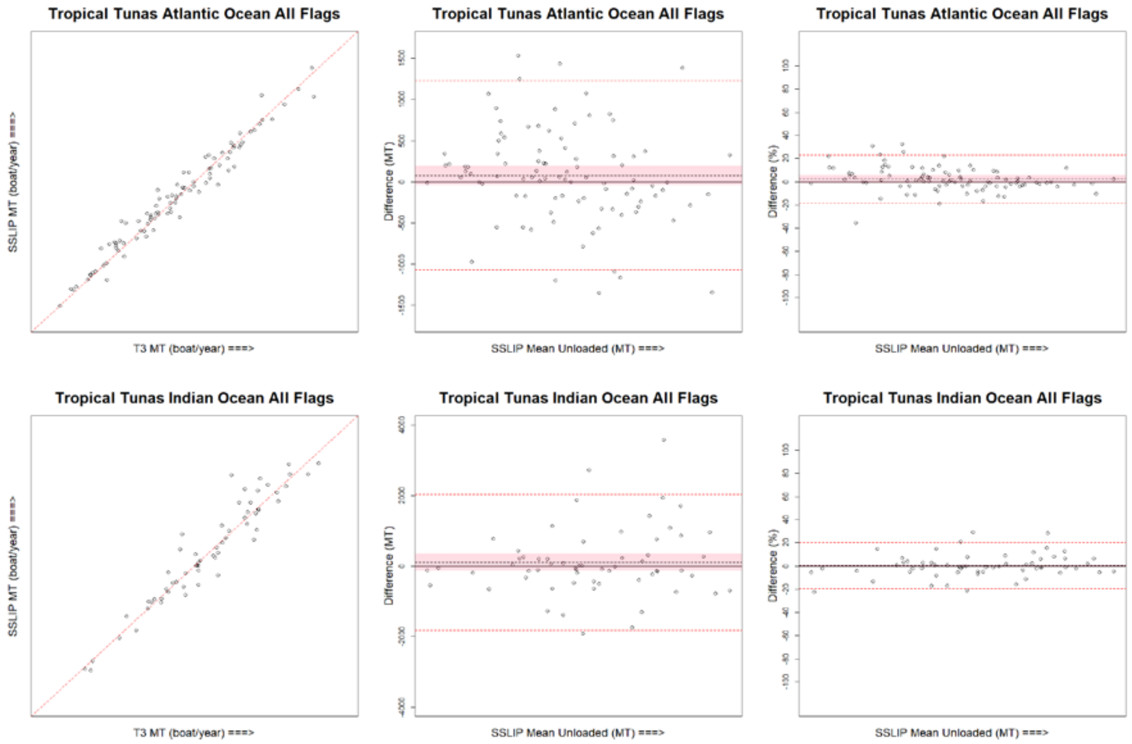


Figure 6a: Dispersion and difference Bland and Altman plots used to compare T3 estimates and unloadings of tropical tunas obtained from sale slips provided by the OPAGAC fleet for the period 2011-16, by RFMO Area.

Left panel: Unloadings estimated using T3 (x axis) versus those obtained from sale slips (y axis), with line of equality.

Mid panel: Plot of differences (metric tons per vessel per year) between T3 estimates and sale slip data versus the mean of the two measurements. The bias is represented by the gap between the x axis corresponding to a zero differences, and the parallel broken black line to the x axis. Confidence intervals (metric tons) are represented through the pink-shaded area and 1.96*se (metric tons) through the broken red lines.

Right panel: Plot of differences (%) between T3 estimates and sale slip data versus the mean of the two measurements. The bias is represented by the gap between the x axis corresponding to a zero differences, and the parallel broken black line to the x axis. Confidence intervals (%) are represented through the pink-shaded area and 1.96*se (%) through the broken red lines.

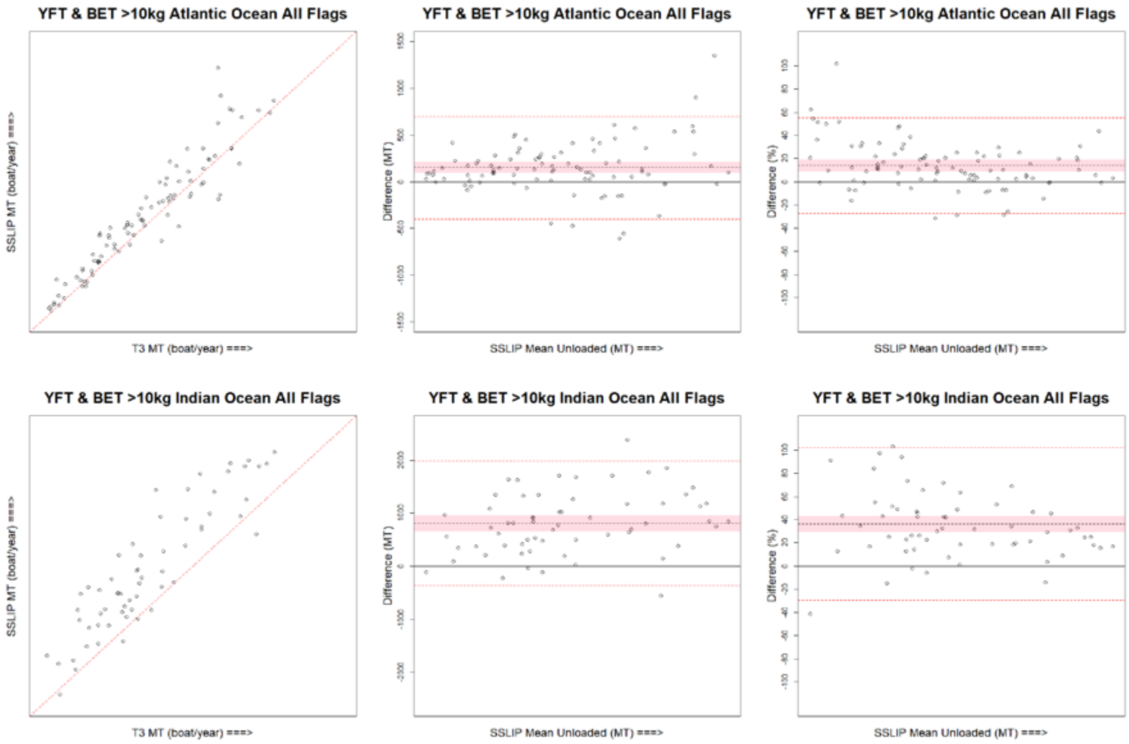


Figure 6b: Dispersion and difference Bland and Altman plots used to compare T3 estimates and unloadings of yellowfin tuna and bigeye tuna ≥10kg (AT≥10 kg) obtained from sale slips provided by the OPAGAC fleet for the period 2011-16, by RFMO Area.

Left panel: Unloadings estimated using T3 (x axis) versus those obtained from sale slips (y axis), with line of equality.

Mid panel: Plot of differences (metric tons per vessel per year) between T3 estimates and sale slip data versus the mean of the two measurements. The bias is represented by the gap between the x axis corresponding to a zero differences, and the parallel broken black line to the x axis. Confidence intervals (metric tons) are represented through the pink-shaded area and 1.96*se (metric tons) through the broken red lines.

Right panel: Plot of differences (%) between T3 estimates and sale slip data versus the mean of the two measurements. The bias is represented by the gap between the x axis corresponding to a zero differences, and the parallel broken black line to the x axis. Confidence intervals (%) are represented through the pink-shaded area and 1.96*se (%) through the broken red lines.

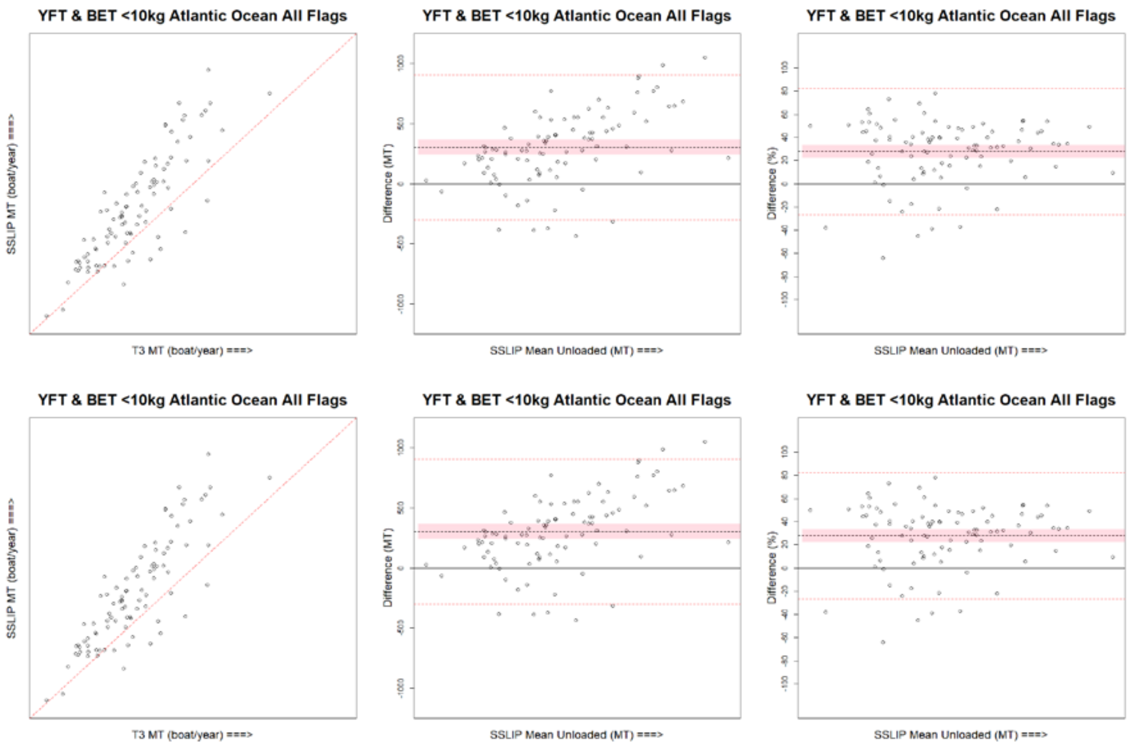


Figure 6c: Dispersion and difference Bland and Altman plots used to compare T3 estimates and unloadings of yellowfin tuna and bigeye tuna <10kg (AT<10 kg) obtained from sale slips provided by the OPAGAC fleet for the period 2011-16, by RFMO Area.

Left panel: Unloadings estimated using T3 (x axis) versus those obtained from sale slips (y axis), with line of equality.

Mid panel: Plot of differences (metric tons per vessel per year) between T3 estimates and sale slip data versus the mean of the two measurements. The bias is represented by the gap between the x axis corresponding to a zero differences, and the parallel broken black line to the x axis. Confidence intervals (metric tons) are represented through the pink-shaded area and 1.96*se (metric tons) through the broken red lines.

Right panel: Plot of differences (%) between T3 estimates and sale slip data versus the mean of the two measurements. The bias is represented by the gap between the x axis corresponding to a zero differences, and the parallel broken black line to the x axis. Confidence intervals (%) are represented through the pink-shaded area and 1.96*se (%) through the broken red lines.

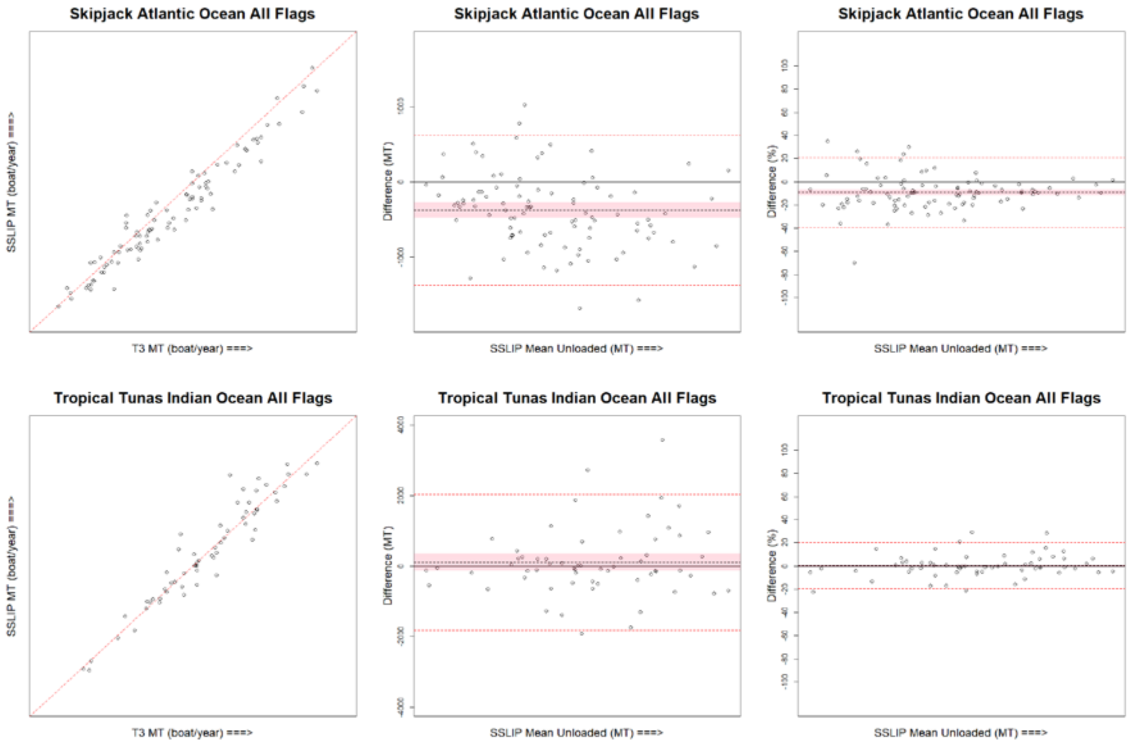


Figure 6d: Dispersion and difference Bland and Altman plots used to compare T3 estimates and unloadings of skipjack tuna obtained from sale slips provided by the OPAGAC fleet for the period 2011-16, by RFMO Area.

Left panel: Unloadings estimated using T3 (x axis) versus those obtained from sale slips (y axis), with line of equality.

Mid panel: Plot of differences (metric tons per vessel per year) between T3 estimates and sale slip data versus the mean of the two measurements. The bias is represented by the gap between the x axis corresponding to a zero differences, and the parallel broken black line to the x axis. Confidence intervals (metric tons) are represented through the pink-shaded area and 1.96*se (metric tons) through the broken red lines.

Right panel: Plot of differences (%) between T3 estimates and sale slip data versus the mean of the two measurements. The bias is represented by the gap between the x axis corresponding to a zero differences, and the parallel broken black line to the x axis. Confidence intervals (%) are represented through the pink-shaded area and 1.96*se (%) through the broken red lines.

ANNEX 1. Output Table from the T3 Process

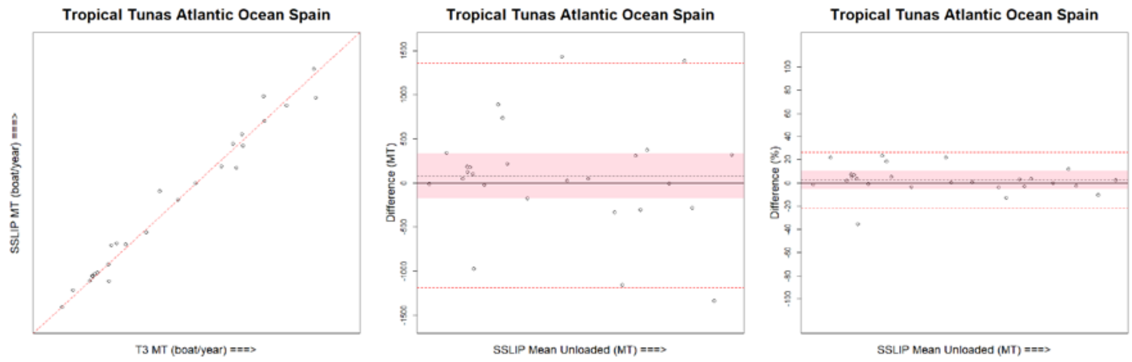
ID	Primary key
ocean	**ocean of activity**
port	port of activity
flag	**Flag state of the vessel**
engine	Type of engine as per FIBATO's classification
vescode	**Vessel code as per FIBATO's classification**
vestype	Type of vessel as per FIBATO's classification (all purse seiners)
vescat	Vessel category as per FIBATO's classification
year_dbq	**Year of unloading**
month_dbq	Month of unloading
day_dbq	Day of unloading
year_d_act	Year of activity
month_d_act	Month of activity
day_d_act	Day of activity
hour_d_act	Hour of activity
fortnight	Fortnight of activity
quarter	Quarter of activity
quadrant	Quadrant of activity as per ICCAT's standards
latdeg	Degrees of latitude of activity
latmin	Minutes of latitude of activity
londeg	Degrees of longitude of activity
lonmin	Minutes of longitude of activity
cwp1x1	One degree square grid as per CWP's standards
cwp5x5	Five degrees square grid as per CWP's standards
c_zet	*Unknown (?)*
c_zee	Exclusive Economic Zone of activity as per AVDTH's classification
v_tmer	Number of hours at sea
v_tpec	Number of fishing hours
v_tpec_std	Number of fishing hours standardized as per AVDTH'S STANDARDS
v_nb_calees	Total number of fishing sets
v_nb_calee_pos	Number of sets with catch (positive set)
v_nb_calee_nulles	Number of sets with no catches (null or blank)
n_act	Serial number assigned to each individual activity recorded for the day (1, 2, etc.)
c_opera	Code of type of operation as per AVDTH's standards
flag_expert	*Unknown (?)*
c_assoc1	Code type of association category 1 as per AVDTH's standards
c_assoc2	Code type of association category 2 as per AVDTH's standards
c_assoc3	Code type of association category 3 as per AVDTH's standards
c_assoc4	Code type of association category 4 as per AVDTH's standards
c_assoc5	Code type of association category 5 as per AVDTH's standards
c_assoc_reduced	Code type of association aggregate as per AVDTH's standards
codeassocg	Code type of association aggregate as per AVDTH's standards
v_temp_s	Sea surface temperature in degrees C
v_cour_dir	Direction of the current in degrees
v_cour_vit	Speed of the current in knots
v_rf3	*Unknown (?)*
v_dur_cal	Length of the fishing set in hours, where applicable
v_poids_capt_yft	Catch of yellowfin tuna in metric tons
v_poids_capt_skj	**Catch of skipjack tuna in metric tons**
v_poids_capt_bet	Catch of yellowfin tuna in metric tons
v_poids_capt_alb	Catch of albacore in metric tons
v_poids_capt_lta	Catch of little tunny (Atlantic black skipjack) in metric tons
v_poids_capt_fri	Catch of frigate tuna in metric tons
v_poids_capt_shx	Catch of sharks in metric tons
v_poids_capt_dsc	*Unknown (?)*
v_poids_capt_you	*Unknown (?)*
v_poids_capt_kaw	Catch of kawakawa in metric tons
v_poids_capt_lot	Catch of longtail tuna in metric tons
v_poids_capt_blf	Catch of bluefin tuna in metric tons
v_poids_capt_yft_cat1	**Catch of yellowfin tuna size category 1 (<10kg)**
v_poids_capt_yft_cat2	**Catch of yellowfin tuna size category 2 (10kg-30kg)**
v_poids_capt_yft_cat3	**Catch of yellowfin tuna size category 3 (≥30kg)**
v_poids_capt_bet_cat1	**Catch of bigeye tuna size category 1 (<10kg)**
v_poids_capt_bet_cat2	**Catch of bigeye tuna size category 2 (10kg-30kg)**
v_poids_capt_bet_cat3	**Catch of bigeye tuna size category 3 (≥30kg)**

ANNEX 2. Output Table Sale Slips

Nombre del buque	**Name of the purse seiner**
Fecha de desembarco	**Date of unloading**
Fecha inicio Marea	Date start of the trip
Fecha Fin Marea	Date end of the trip
Descarga completa? (Si/No)	**All catches unloaded? (Yes/No)**
Total no descargado (kg)	Total catch not unloaded (kg)
Total descargado (kg)	Total catch unloaded (kg)
YFT>10kg	**Catch yellowfin tuna ≥10kg**
YFT<10kg	**Catch yellowfin tuna <10kg**
BET>10kg	**Catch bigeye tuna ≥10kg**
BET<10kg	**Catch bigeye tuna <10kg**
SKJ	**Catch skipjack tuna**
ALB	Catch albacore
Melva/Bacoreta	Catch frigate tuna/Atlantic black skipjack
Otros	Catch other species

ANNEX 3. Bland & Altman Plots

a



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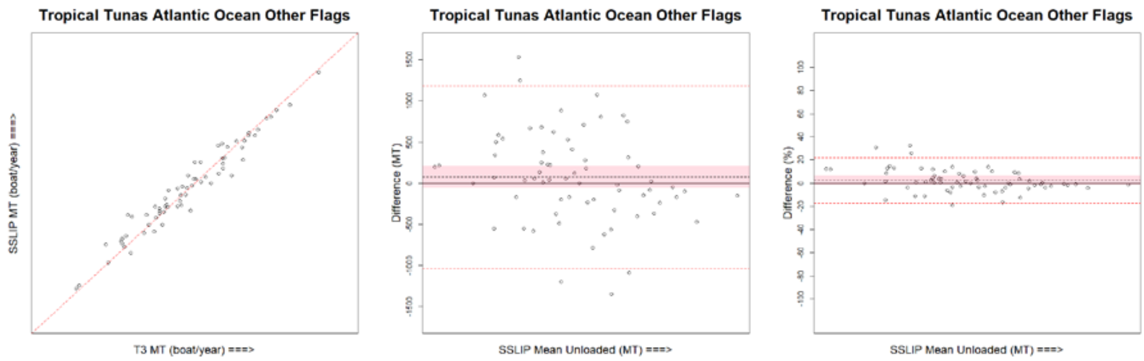

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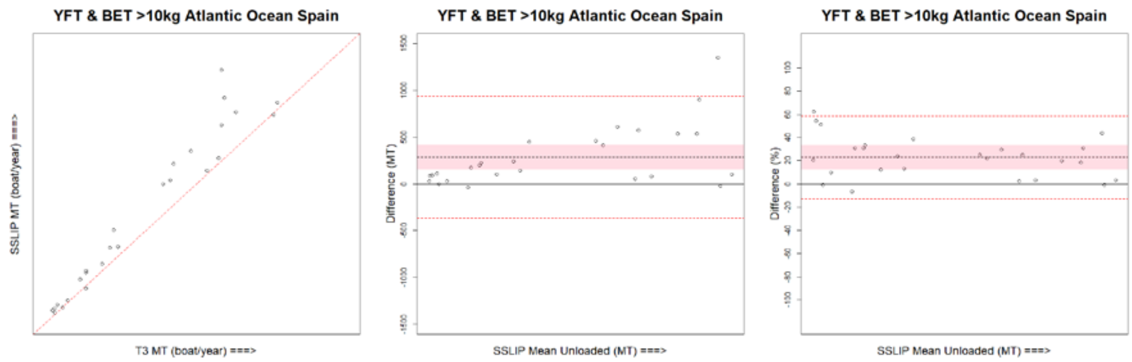

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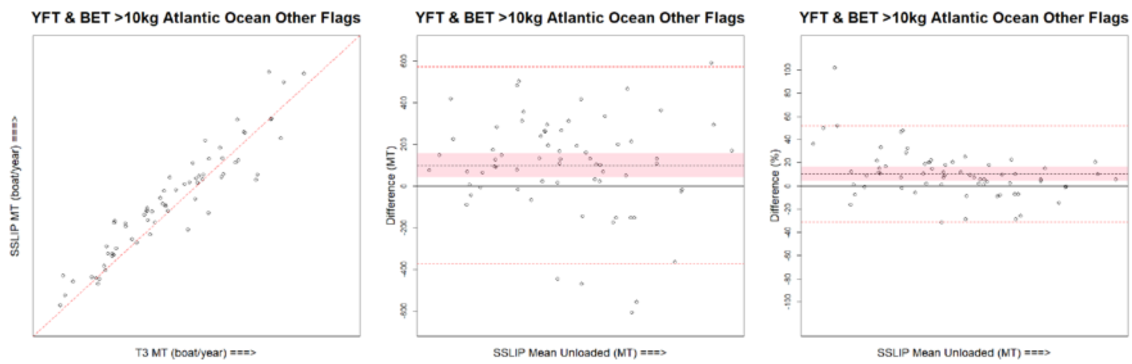

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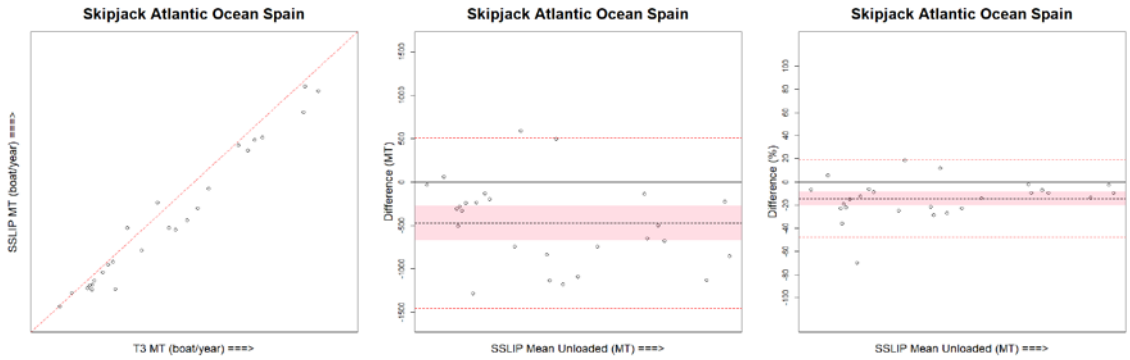
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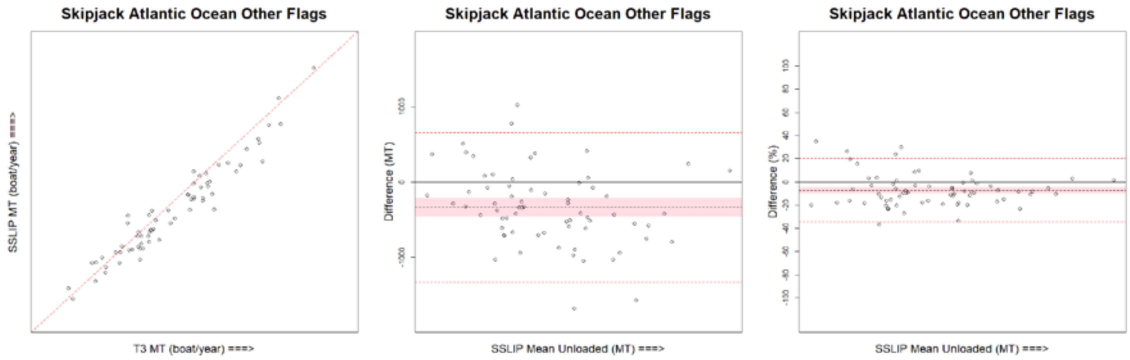
T3 MT (boat/year) ===>
Skipjack Atlantic Ocean Spain
Difference (MT)
SSLIP Mean Unloaded (MT) ===>
Skipjack Atlantic Ocean Spain
Difference (%)
SSLIP Mean Unloaded (MT) ===>

f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SSLIP MT (boat/year) ===>
T3 MT (boat/year) ===>
Skipjack Atlantic Ocean Other Flags
Difference (MT)
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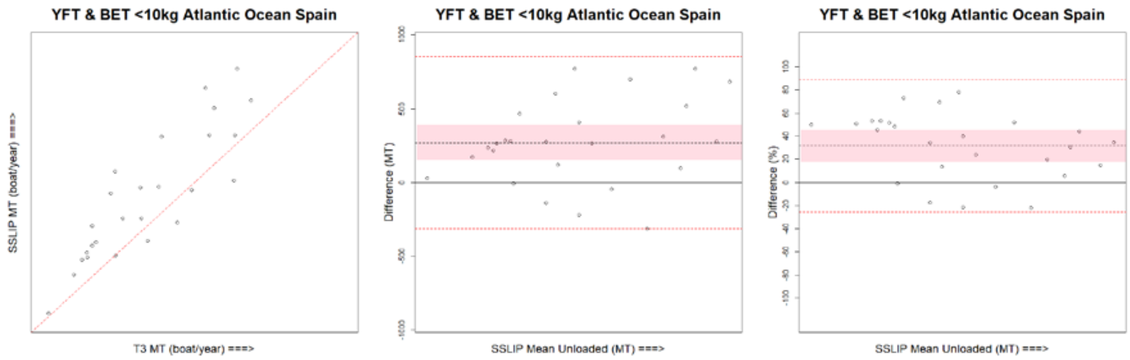
Skipjack Atlantic Ocean Other Flags
Difference (%)
SSLIP Mean Unloaded (MT) ===>

g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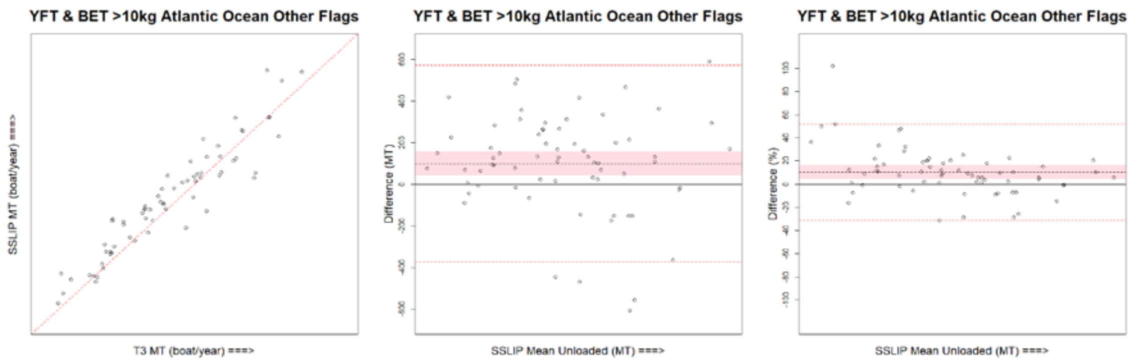
T3 MT (boat/year) ===>
YFT & BET <10kg Atlantic Ocean Spain
Difference (MT)
SSLIP Mean Unloaded (MT) ===>
YFT & BET <10kg Atlantic Ocean Spain
Difference (%)
SSLIP Mean Unloaded (MT) ===>

h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Difference (%)
SSLIP Mean Unloaded (MT) ===>

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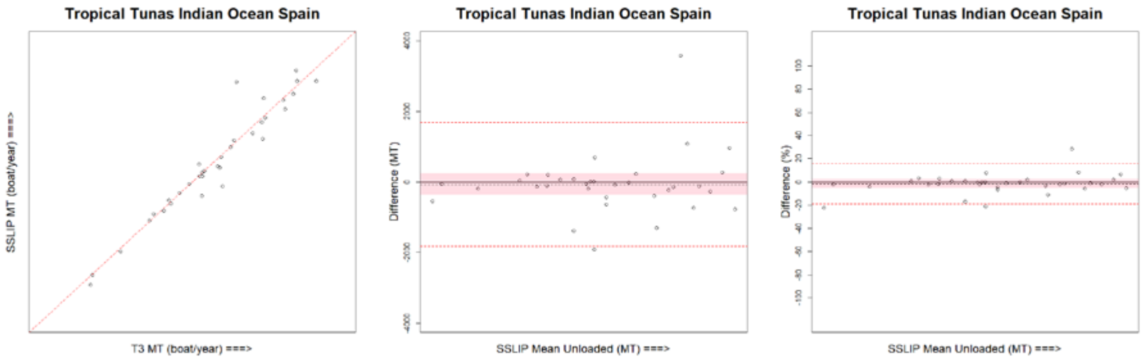
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T3 MT (boat/year) ===>
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Difference (MT)
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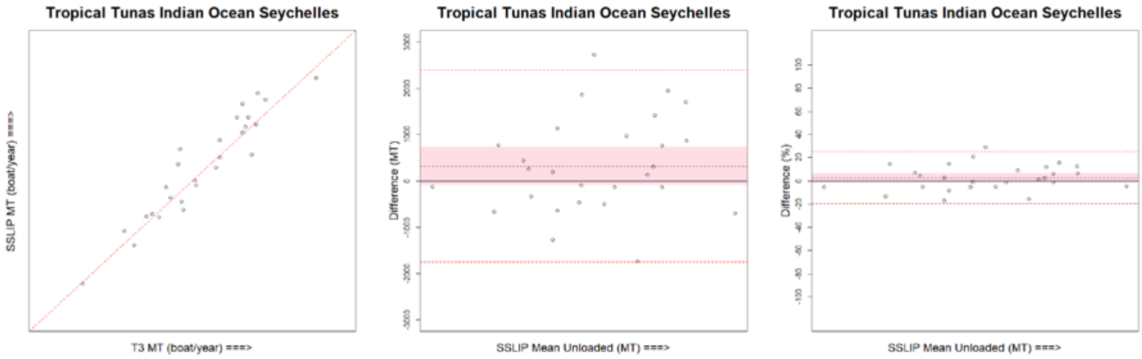
Tropical Tunas Indian Ocean Spain
Difference (%)
SSLIP Mean Unloaded (MT) ===>

j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Difference (MT)
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Tropical Tunas Indian Ocean Seychelles
Difference (%)
SSLIP Mean Unloaded (MT) ===>

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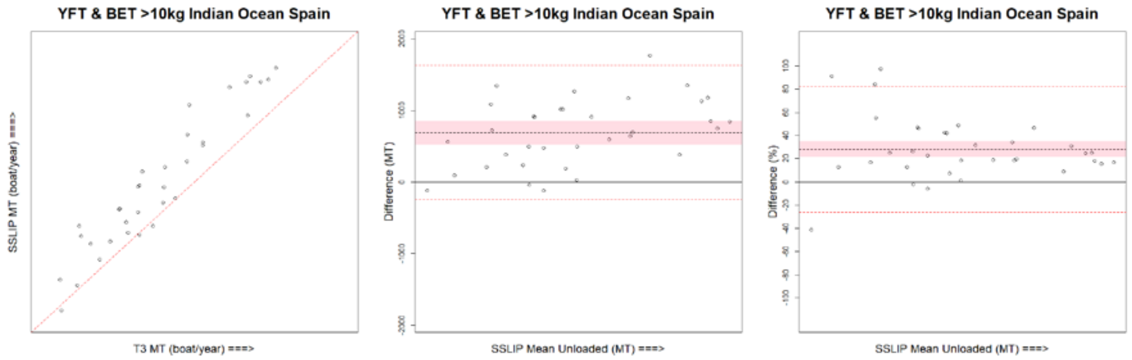
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YFT & BET >10kg Indian Ocean Spain
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YFT & BET >10kg Indian Ocean Spain
Difference (%)
SSLIP Mean Unloaded (MT) ===>

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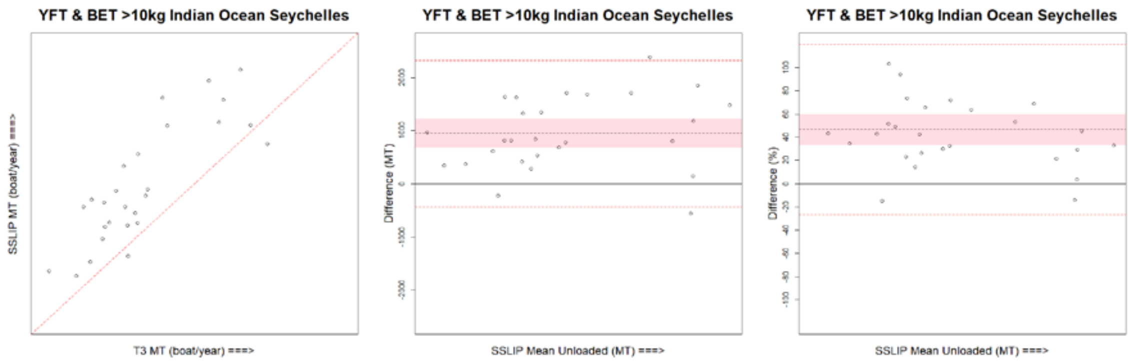
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YFT & BET >10kg Indian Ocean Seychelles
Difference (%)
SSLIP Mean Unloaded (MT) ===>

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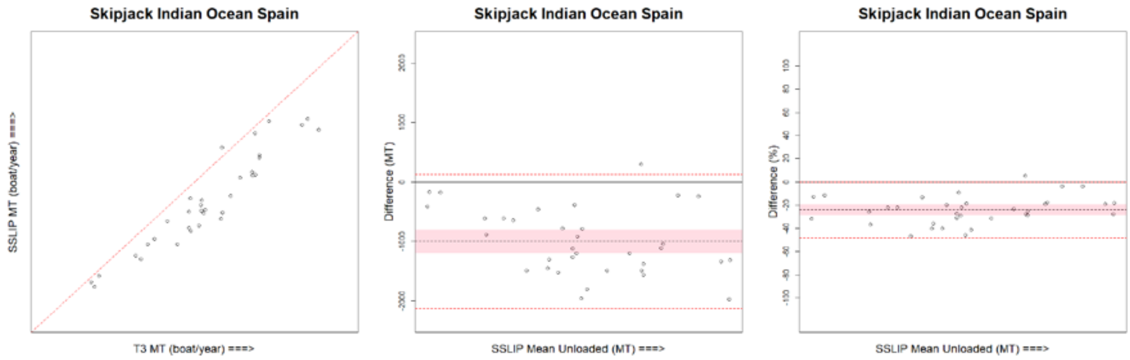

Skipjack Indian Ocean Spain
Skipjack Indian Ocean Spain
Skipjack Indian Ocean Spain
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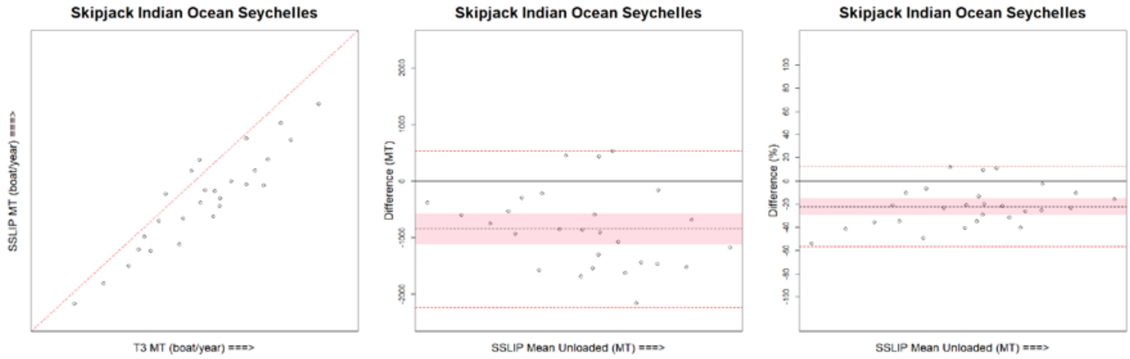
T3 MT (boat/year) ===>
Difference (MT)
SSLIP Mean Unloaded (MT) ===>
Difference (%)
SSLIP Mean Unloaded (MT) ===>

n



Skipjack Indian Ocean Seychelles
Skipjack Indian Ocean Seychelles
Skipjack Indian Ocean Seychelles
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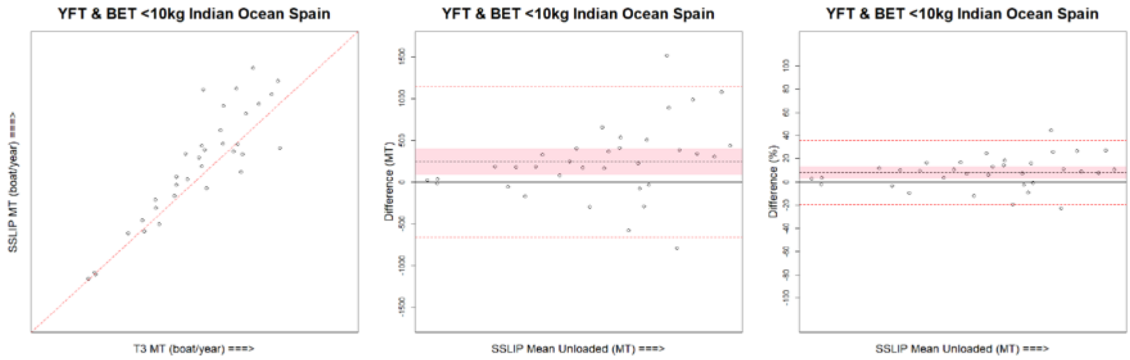
o



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YFT & BET <10kg Indian Ocean Spain
YFT & BET <10kg Indian Ocean Spain
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Difference (MT)
SSLIP Mean Unloaded (MT) ===>
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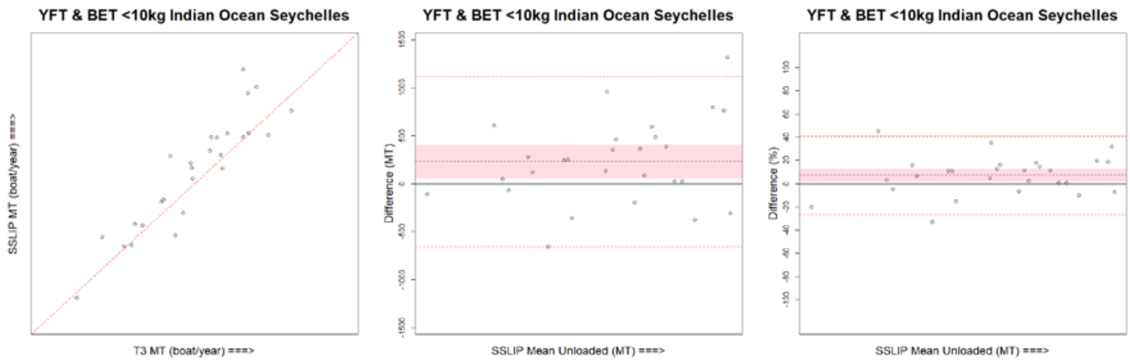
p



YFT & BET <10kg Indian Ocean Seychelles
YFT & BET <10kg Indian Ocean Seychelles
YFT & BET <10kg Indian Ocean Seychelles
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T3 MT (boat/year) ===>
Difference (MT)
SSLIP Mean Unloaded (MT) ===>
Difference (%)
SSLIP Mean Unloaded (MT) ===>

Figure 7 (previous pages)**:** Dispersion and difference Bland and Altman plots used to compare T3 estimates and unloadings obtained from sale slips provided by the OPAGAC fleet for the period 2011-16, by species and commercial category group, flag group and RFMO Area.

Left panel: Unloadings estimated using T3 (x axis) versus those obtained from sale slips (y axis), with line of equality.

Mid panel: Plot of differences (metric tons per vessel per year) between T3 estimates and sale slip data versus the mean of the two measurements. The bias is represented by the gap between the x axis corresponding to a zero differences, and the parallel broken black line to the x axis. Confidence intervals (metric tons) are represented through the pink-shaded area and 1.96*se (metric tons) through the broken red lines.

Right panel: Plot of differences (%) between T3 estimates and sale slip data versus the mean of the two measurements. The bias is represented by the gap between the x axis corresponding to a zero differences, and the parallel broken black line to the x axis. Confidence intervals (%) are represented through the pink-shaded area and 1.96*se (%) through the broken red lines.

ATLANTIC OCEAN:

a. OPAGAC Spain: Total unloadings of tropical tunas
b. OPAGAC Other Flags: Total unloadings of tropical tunas
c. OPAGAC Spain: Unloadings of yellowfin & bigeye tunas ≥10 kg
d. OPAGAC Other Flags: Unloadings of yellowfin & bigeye tunas ≥10 kg
e. OPAGAC Spain: Unloadings of skipjack tuna
f. OPAGAC Other Flags: Unloadings of skipjack tuna
g. OPAGAC Spain: Unloadings of yellowfin & bigeye tunas <10 kg
h. OPAGAC Other Flags: Unloadings of yellowfin & bigeye tunas <10 kg

INDIAN OCEAN:

i. OPAGAC Spain: Total unloadings of tropical tunas
j. OPAGAC Other Flags: Total unloadings of tropical tunas
k. OPAGAC Spain: Unloadings of yellowfin & bigeye tunas ≥10 kg
l. OPAGAC Other Flags: Unloadings of yellowfin & bigeye tunas ≥10 kg
m. OPAGAC Spain: Unloadings of skipjack tuna
n. OPAGAC Other Flags: Unloadings of skipjack tuna
o. OPAGAC Spain: Unloadings of yellowfin & bigeye tunas <10 kg
p. OPAGAC Other Flags: Unloadings of yellowfin & bigeye tunas <10 kg

BEST STANDARDS FOR DATA COLLECTION AND REPORTING REQUIREMENTS ON FOBS: TOWARDS A SCIENCE-BASED FOB FISHERY MANAGEMENT

Maitane Grande[1*], *José Carlos Baez*[2], *Mº Lourdes Ramos*[2], *Jon Ruiz*[3], *Iker Zudaire*[1], *Hilario Murua*[1], *Josu Santiago*[3], Pedro Pascual[2], Francisco Abascal[2], Daniel Gaertner[4], Pascal Cauquil[4], Laurent Floch[4], *Alexandra Maufroy*[5], *Anertz Muniategi*[6], *Miguel Herrera*[7]

SUMMARY

A major concern for tropical tunas, on these last years, has been the worldwide increasing use of drifting FOBs by purse seiners, which are equipped with satellite buoys and echo-sounders. The use of these floating objects has contributed to increase the catch of skipjack tuna, but also of juveniles of yellowfin and bigeye tunas. Moreover, it has increased the amount of by-catch (including some species classified as vulnerable or endangered) and has likely resulted in adverse effects on the ecology of fish and on vulnerable areas (e.g. beaching events on coral reef areas). Despite the increasing FOB use and concerns, little information is available on FOB use worldwide for an appropriate monitoring and management. Thus, FOB monitoring has become a priority in all tuna t-RFMOs. However, the data collection and reporting requirements around FOBs are not standardized and there are significant data gaps. The aim of this document is to review current requirements and procedures in place and propose standards for data collection and submission on FOBs to t-RFMOs. The proposals included in this document are the result of a collaborative work between scientists and the fishing industry.

KEYWORDS: floating object, FOB, fish aggregating device, FAD, tropical tuna, purse-seine, data collection, data reporting

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[1] AZTI-Tecnalia. Herrera Kaia, Portualdea z/g, 20110 Pasaia, Gipuzkoa (Spain).
[2] Instituto Español de Oceanografía (IEO), Centro Oceanográfico de Canarias. Vía Espaldón, dársena pesquera, Parcela 8 38180 Santa Cruz de Tenerife (Spain).
[3] AZTI-Tecnalia. Txatxarramendi Ugartea z/g, 48395 Sukarrieta, Bizkaia (Spain).

[4] Institut de Recherche pour le Développement (IRD), UMR MARBEC, Avenue Jean Monnet, CAS 30171, 34203 Sète (France).
[5] ORTHONGEL, 5 rue des sardiniers, 29900 Concarneau (France).
[6] Asociación Nacional de Armadores de Buques Atuneros Congeladores (ANABAC), Txibitxiaga, 24 – Entreplanta 48370 Bermeo, Bizkaia (Spain)
[7] Organización de Productores Asociados de Grandes Atuneros Congeladores (OPAGAC), Calle de Ayala, 54, 28001 Madrid (Spain)
[*] Author to whom correspondence should be addressed. E-mail: mgrande@azti.es

1. Introduction

Tropical tuna purse seiners operate globally fishing on free schools and on Floating Objects (FOBs), including man-made Fish Aggregating Devices (FADs) and other floating objects. Since the late 90s with the development of satellite-linked echo-sounder buoys for tracking FOBs (Lopez et al. 2014), the use of FOBs has continuously increased (Fonteneau et al. 2013), with FAD-associated catches now exceeding those on free schools in the case of the European Fleet. For example, the European tropical tuna purse seine fishery operating in the Indian Ocean has increased the percentage of FOB sets from 40% in 1990-1994 to 73% in 2010-2014 (Chassot et al., 2015, Ramos et al., 2017), following similar trend in the Atlantic Ocean. Along the document the term Floating Objects (FOBs), includes the man-made Fish Aggregating Devices (FADs) and other floating objects (Gaertner et al., 2016).

The increasing use of FOBs has introduced worldwide major changes in the tropical tuna purse seiners fishing patterns which could have affected the marine environment. In this sense, potential effects associated with the increased number of FOB deployments at sea has been described: alteration of normal movements of tuna (Marsac et al., 2001; Hallier and Gaertner, 2008), increased skipjack catches (the principal target species), reduction in yield per recruit of yellowfin and bigeye (from which small specimens co-occur in the catches with skipjack), increase in bycatch, potential impacts on coastal habitats and source of pollution (Dagorn et al. 2013, Maufroy et al., 2015, Davies et al., 2017). Despite these concerns, little information is available on FOB use worldwide while it is crucial for the understanding, monitoring and management of the impacts of FOBs on pelagic ecosystems. As a result, Tuna Regional Fisheries Management Organizations (t-RFMOs) have called for FAD management plans, including data collection on deployment and use of FOBs by purse seiners and supply vessels and data reporting requirements on FOBs to CPCs/t-RFMOs (ICCAT, 2016a, 2016b).

Although efforts are being made to record and report information on FOBs, including man-made FADs and other natural floating objects, due to the complexity of this fishing strategy and the lack of unified data collection and reporting requirements (an absence of harmonized definitions for relevant terms or ambiguity among t-RFMOs), there are significant data gaps (Ramos et al., 2017; Lopez et al., 2018) and the information collected so far by the skippers and available for analysis has been of limited utility. Several works have been conducted recently to analyze data collection and submission related problems and have proposed potential solutions, such as interpretations on the data collection and submission requirements or new FAD logbook templates to improve the quality of the data recorded (Baez et al., 2017a; Baez et al., 2017b; Ramos et al., 2017; Lopez et al., 2018). Some of these proposals have been implemented regionally or by some users. However, standardization among CPCs and t-RFMOs would be highly desirable. Therefore, efforts from all stakeholders are required to improve data collection and submission on FOBs. In this sense, the RECOLAPE project (MARE/2016/22, "Strengthening Regional cooperation in large pelagic fisheries data collection"), which seeks to improve the coordination among EU Member States in the fisheries data collection field in support of stock assessment and fisheries advice, aims to develop protocols for FOB data collection and data storage tools to meet the requirements of the tuna t-RFMOs. The aim of the present document is to summarize the results of the workshop which took place in the frame of RECOLAPE project during 24th and 25th of May in AZTI (Sukarrieta) in which t-RFMO requirements and other procedures in place were reviewed and standards for the collection and submission of FOB-related data were proposed. The proposals included in this document are the result of a collaborative work between scientists and the fishing industry.

2. t-RFMOs requirements

t-RFMOs have called for FAD management plans, including data collection on deployment and use of FOBs by purse seiner and supply vessels, and data reporting requirements on FADs to CPCs/t-RFMOs (Table 1). Recent works reviewed these t-RFMOs requirements including a detailed analysis of the data gaps, data requested on FAD-logbooks and other data submission specific forms (Ramos et al., 2017; Baez et al., 2017a; Baez et al., 2017b; Lopez et al., 2018), which are not repeated here. We briefly summarize and discuss the issues detected in each t-RFMO.

Table 1. t-RFMO data collection and reporting requirements on FOBs

t-RFMOS	Data Collection Requirements	Data Reporting Requirements
IOTC	Resolution 17/08 (para. 10) [Annex I and Annex 2]. No form provided	Resolution 17/08 (para. 9); Resolution 15/02 (para. 6); Guidelines for the reporting of fisheries statistics to the IOTC - Form 3FA
ICCAT	Rec. 16-01 (para. 21) Annex 2 form [activities with FADs] Annex 3 minimum standards; Rec. 16-01 (para. 22) - Annex 4 form [list of deployed FADs and buoys]	Rec. 16-01 (para. 23); Rec. 13-01 Form: ST08-FadsDep form
IATTC	C-16-01 (para. 2) Annex I FAD Form 9/2016 C-17-02	C-16-01 (para. 3); C-17-02 (para. 11, 12); Guidance in reporting on FADs in accordance with IATTC Resolution C-17-02: INF1; INF2
WCPFC	Not specified in the Resolutions Report - tenth meeting of the Tuna fishery Data Collection Committee	Not specified in the Resolutions

2.1. ICCAT

The International Commission for the Conservation of Atlantic Tunas (ICCAT) through Recommendation 16-01: Rec 16-01 (21) Annex 2 form [FAD logbook]; Annex 3 on the nomenclature of FADs and activities; and RES 16-01 (22) Annex 4 form [list of deployed FADs and buoys], proposed specific forms for data collection on FOBs including CECOFAD codes for type of floating objects and activities. In these forms an identification code is proposed for marking the FOBs in addition to the buoy ID. This marking scheme was previously applied with not promising results, and therefore the 2nd FAD Working Group of ICCAT concluded that the FADs should be marked/tracked by the buoy unique ID attached to the FAD (given by the buoy manufacturer), recording in the logbook details of all changes (ICCAT 2016a, Ramos et al., 2017). In addition, two templates are provided for recording activities with FOBs, instead of one, as proposed by Ramos et al. (2017). In this sense the forms included in the Annex 2 and 4 (Rec. 16-01) are not in line with the recommendations made from previous experience and reviews on data collection (ICCAT 2016a, Ramos et al., 2017). ICCAT recommendations also establishes the obligation by CPCs to provide data on FOBs. According to the management recommendations: Rec. 16-01, Rec. 13-01(paragraph 2), ICCAT developed ST08-FadsDep form for data submission to the t-RFMO. Paragraph 23 of Rec 16/01 requested that the CPCs should provide to the t-RFMO (i) the number of deployed FADs with and without beacon, (ii) the average number of active beacons, (iii) the average number of deactivated beacons followed per vessel, (iv) the average number of active lost and (v) the number of FADs deployed by support vessel by month, 1 x 1 square (only specified for some data), FAD and beacon type.

During the 2nd FAD Working Group of ICCAT, the ICCAT Secretariat provided the data received so far from Form ST08 regarding FAD deployments. The Secretariat highlighted that very few CPCs provided data using the recently modified ST08 forms. In addition, several problems with the received submissions were noted. In one case information was provided by 5º x 5º rather than 1º x 1º degree squares, which may be due to a misinterpretation, as the spatial stratification is not specified for all data required (i.e. number of buoys activated and deactivated) (Baez et al., 2017a). This provides an idea of the problems in FAD data submission and underlines the need for standardization and homogenization of the criteria for filling the forms.

In relation to this, Báez et al. (2017a) summarizes the interpretation of EU-Spain with regards to the ICCAT's data reporting requirements for activities on FADs from the Spanish tropical tuna purse seine with the aim to describe the difficulties, posing questions and providing interpretations on the FAD data collection requirements under ST08-Rec 16/01 to allow standardizing the data collection and reporting of FAD information for the fleets that use them.

The main observations and recommendations from Báez et al. (2017a) were:

- Harmonization of the request made in the Recommendation 16-1 under paragraph 23 and the file ST08 FAD Form provided to CPCs to report the data, taking into account the data collection mechanism available.
- Definition of terms and detailed description of each field (i.e. deployed FAD, active beacon, deactivated beacon, lost beacon)
- Harmonization between required information and codes between different Regional fisheries management organizations (t-RFMOs) (e.g. FAD and beacon types)

2.2. IOTC

The Indian Ocean Tuna Commission (IOTC) through IOTC´s Resolution 13/08[8] includes standards for the collection and reporting of data on fishing activities around FOBs, both drifting and anchored, undertaken by purse seine and pole-and-line fisheries. This resolution has been reviewed and updated by 15/08 and, most recently, 17/08. Resolution 17/08 stablish guidelines for FOBs management plans including more strict limitations on the numbers of FOBs, more detailed specifications of data collection from visits to FOBs (Annex I) including date, position, FOB type, identifier and catch and type of visits. In addition, Resolution 15/01 (which superseded Res. 13/03) on the recording of catch and effort data for fishing vessels aims to harmonize data collection and to further monitor FOBs use. It also defines minimum requirements on data collection on FOBs deployments and sets on FOBs (Annex I and II). Although minimum requirements on data collection are provided, none of the resolutions presents specific forms for data collection on FOBs onboard.

Currently, as specified in Resolutions 15/02 and 17/08, and according to the guidelines for the reporting of fishery statistics to the IOTC (Form 3FA, IOTC Secretariat, 2014), CPCs must provide catch-and-effort data in relation to: (i) total number (by type) of FOBs deployed by purse seiners and support vessels by month/quarter and fleet, (ii) effort data expressed as the total number of FOB visits per type of FOB, type of visit, 1° grid area and month; and (iii) total catches of target IOTC species and bycatch species taken on FOBs, at the same level of resolution. However, some of the information requested is unclear and the requirements are not harmonized in Resolution 17/08 and Form 3FA (e.g., spatial stratification, or interpretation of the types of visits) (Báez et al., 2017b). The ambiguity in the interpretation of FOB data requirements may result in the development of FAD logbooks not adjusted to the requirements. A clarification of ambiguous details can make possible harmonize data collection.

Báez et al. (2017b) described the difficulties, raised questions and provided interpretations on the FOB collection requirements under Form 3FA to allow standardization among the data submission. Finally, this paper proposes a reorganization of Form 3FA, using CECOFAD conclusions for FOB types and activities.

2.3. IATTC

The Inter-American Tropical Tuna Commission (IATTC) through resolutions C-16-01 (Article 2 and Annex I) and C-17-02 established data collection and reporting requirements for purse seiner vessels operating with FADs on the IATTC Convention area. From 1st of January 2017 the skippers shall collect, and report information contained in the Annex I which referred to activities with FADs, including position, date, hour, FAD identification, FAD design characteristics, type of the activity, the result of the catch when resulting in a set, and buoy

[8] "Procedures on a fish aggregating devices (FADs) management plan, including more detailed specifications of catch reporting from FAD sets, and the development of improved FAD designs to reduce the incidence of entanglement of non-target species". For the purposes of this Resolution, the term "Fish-Aggregating Device" (FAD) means anchored, drifting, floating or submerged objects deployed and/or tracked by vessels, including through the use of radio and/or satellite buoys, for the purpose of aggregating target tuna species for purse-seine fishing operations.

characteristics if any attached to the FAD. To record this information, the working group on FADs designed and proposed a FAD form to be used on board (i.e. IATTC Form. FAD Form 9/2016). This new form is composed by two files, one dedicated to record activities on FADs (following the requirements stablished in C-16-01, Annex I) and a second one which should be used as an inventory of active FADs including specifications of the raft and hanging structure. In these IATTC forms, a unique identification is given to FADs, being allowed to use the buoy ID attached or to follow the FAD identification scheme proposed by the IATTC which assigns an independent ID for each FAD. This form structure (activity and inventory in separate forms) and using and independent ID for FADs is not in line with the recommendations made from previous experience and reviews which aim to simplify and adapt to the use on board (ICCAT, 2016c; Ramos et al., 2017).

During 2017, with the establishment of new measures for FADs including limits on the number of active FADs (as refer in the resolution), new reporting requirements were designated (C-17-02). From 1st of January of 2018 CPCs shall report monthly to the Secretariat, with a delay between 60 to 90 days, daily information of all active FADs following the guidelines established by the *Ad Hoc* Permanent Working Group on FADs.. In this sense, two files should be reported, which are still under discussion (Lopez et al., 2018), including information about the number of active buoys per vessel and day, and a monthly summary of the activated, deactivated and average number of active FADs followed by vessel and 1º square grid (INF1 and INF2, respectively).. The information used to monitor the number of active FADs should be provided by the FAD tracking services directly to the designated verification body of each CPC (and/or to the IATTC staff if so requested by the CPC).

Lopez et al., (2018) recently reviewed the data collection and reporting requirements identifying data gaps regarding FAD logbooks and active FAD information. The IATTC proposed modifications in the CIAT Form 9/2016 aiming to collect detailed data on FOB (as information about buoys-swapping, re-deployment, including activities with natural objects). However, the form maintains two files (activity and inventory form) and an independent marking scheme for FADs and buoys. To standardize and improve the data collection on FOBs as described in the C-16-01 (Article 2 and Annex 1) and reporting to IATTC, this t-RFMO proposes a web application as data collection tool (Lopez et al., 2018). Finally, aiming to assess the compliance with the C-17-02, the provision of fine scale buoy transmission data from buoy manufactures and VMS data are recommended.

2.4. WCPFC

In the case of the Western and Central Pacific Commission (WCPFC), new FAD/buoy control measures are in force limiting the number of activated instrumented buoys attached to FADs at any given moment to 350 (CMM 2017-01). There are not specified formats for data collection on FOBs for skippers and for data submission to the t-RFMO. The fishing logbook (SPC / FFA Regional Purse-Seine Logsheet) give the possibility to collect some activities with FOBs (i.e. Investigate floating object; Deploy - raft, FAD or payao; Retrieve - raft, FAD or payao) and have the option to characterize the FOB (drifting log, debris or dead animal"; "drifting raft, FAD or payao"; "anchored raft, FAD or payao"; "live whale"; and "live whale shark"). Since 2010, purse seine vessels operating in the Convention Area of this t-RFMO have a 100% observer coverage (as established by CMM2008-01 and following Conservation and Management Measures). The Regional Observer Program includes data collection on FOB activities (WCPFC 2017).

3. Best standards on Data Collection

The lack of unified criteria among t-RFMOs on FOBs data collection, specific guidelines and a standard and easy template for the fleet has resulted in a non-harmonized data collection; which hampers its use for scientific purposes (Ramos et al., 2017). During 2016 and 2017 various works were conducted and presented in t-RFMOs´ working groups to address the problem (Gaertner et al., 2016; Baez et al., 2017a; Baez et al., 2017b; Ramos et al., 2017). Specific details requested by the t-RFMOs are reviewed and discussed, and best standards for data collection are proposed for each requirement.

3.1. Template format:

The forms propose among t-RFMOs (i.e. ICCAT 16/01 – Annex 2 and Annex 3; and IATTC FAD Form 9/2016) are not harmonized and not in line with the recommendations made from previous experience and reviews (ICCAT 2016a, Ramos et al., 2017), which proposed to simplify the marking scheme and structure of the form. We recommend using a unique form to record all activities on FOB, merging the inventory and activity form as proposed by Ramos et al., 2017; and eliminating the second form or inventory which was previously used in the Spanish FAD Management Plan with limited used and is now proposed by the IATTC (FAD Form 2016/09). This inventory was designed to record the relation and design, or type of the FOBs used. However, it is not a suitable tool to be used on board as it requires a daily update of the list, and hardly provided good quality data (Ramos et al., 2017). Moreover, the information of the dynamics of FOB use can be deduced from the FOB activity form (if information on the structure and material is also given in each record) and information on buoy transmissions if they are made available for scientific purposes to the research institutions or bodies responsible for the verification of compliance with buoy limitations in force. In this situation, the inventory does not provide additional relevant information and, thus, it could be removed to facilitate data collection on board.

On the other hand, in case of purse seiners with Electronic Reporting System (ERS) the FOB logbook and fishing logbook should be linked somehow to minimize the errors due to double recording.

3.2 Data to be recorded:

All interaction with FOBs (FADs or other floating objects) and buoys if present, should be recorded in the FAD logbook while only sets should be recorded on the fishing logbook.

The record of each activity should provide information on buoy attached if present (including the ID of the manufacturer and ownership), specifications on the FOB type and structure allowing the assessment of the entangling and nature of the material, as well as the occurrence and catch of fishing sets, when applicable. Overall, the information provided should also allow the scientists classifying the activities and FOBs in CECOFAD categories (Gaertner et al., 2016).

Some purse-seine vessels work in collaboration with other purse seiners and/or with supply vessels. In these cases, every vessel should register its own activities, even when they are supporting other vessels (e.g., deployment of buoys for another vessel) (Ramos et al., 2017). If vessels working in collaboration are of different flag states, the information on activities should be shared with the corresponding CPC for effort assessment.

Details of each specific information to be collected are included in the tables below. The tables include details of the information required by the t-RFMOs (IATTC, ICCAT, IOTC, and WCPFC) regarding the marking scheme, spatial and seasonal dynamics, FOB type, FOB structure, activity with FOB and buoys, and information on the fishing set/catch. In each case, best standards for data collection and minimum details to be recorded are proposed for a standardize data collection in each case.

3.2.1. Identification

The identification of each activity should be linked with the name of the vessel and IMO number, and starting and end date of the trip. As activities with FOBs could be given between fishing trips (e.g. lost), records between the trips will belong to the next starting trip. Each FOB should be identified by the buoy ID if present. The identification of the buoy in the FOB should be noted (model and identification number) and the ownership of the buoy if known (name of the vessel owing the buoy). The date, time and position of each specific activity (included in the next table) are also crucial for the identification of each record.

General Data	t-RFMOs Data collection Requirements	IATTC	ICCAT	IOTC	WCPFC	Standards for data collection	Minimum Details
Identification	**Vessel**	Required	Not required	Required	-	Required	Name of the vessel fulfilling the form and conducting the activity
	nº of trip/ Identification of the trip	Calendar year of the start of the trip and the consecutive number of the trip for that calendar year in the spaces provided. For example:' 2015-001', denotes the first trip in 2015.	Not required	Not required	-	Required	(*) Start of the trip and its end [= when arriving at port], same as in the logbook
	Register number	Required	Not required	Required	-	Required	IMO number
	Identification (of the locating buoy):	Unique identification number of the locating buoy. If this is a satellite buoy, it must be the unique serial number. If it is another type of locating buoy, use a unique identification code self-provided to the FAD or the locating buoy and that could be used as reference for future encounters.	Required	Required	-	ID Buoy required	Model and identification number
	FAD ID	CPCs shall obtain unique alphanumeric codes from the IATTC staff, or in the alternative, if there is already a unique FAD identifier associated with the FAD (e.g., the manufacturer identification code for the attached buoy), the vessel owner or operator may instead use that identifier as the unique code for each FAD that may be deployed or modified.	FAD Marking and buoy ID or any information allowing to identify the owner. If ID are absent or unreadable, the FAD shall not be deployed	D FAD Marking or beacon ID or any information allowing to identify the owner	-	Not required	Given by the buoy identifier
	Other information not requested				-	Ownership	Name of the vessel owning the buoy if present

(*) *As indicated for the DEA, the fishing activity is considered to be finished with the arrival at port, the unloading document or the end of the trip (http://www.mapama.gob.es/es/pesca/temas/control-e-inspeccion-pesquera/informacion-sobre-actividad-pesquera/preguntas_diario_electronico_pesca.aspx). For scientific issues, the arrival date should coincide with the unloading date and the date registered in the DEA/ERS.*

3.2.2. Seasonal and Spatial Dynamics

The details on the position, time and date allows exploring the seasonal and spatial dynamics, but also it is indispensable information for the identification of each record.

General Data	t-RFMOs Data collection Requirements	IATTC	ICCAT	IOTC	WCPFC	Standards for data collection	Minimum Details
Seasonal and Spatial dynamics	**Time**	The local time of the event in a 24 hour format (13:00 = 1 pm).	hh:mm.	24-hour format, GMT or local time	-	Required	Time* of the activity in UTC (HHMM) If a loss of the buoy, information of the last transmission should be provided
	Position	Write the geographic location of the event (Latitude and Longitude) in degrees and minutes. Note the corresponding hemisphere (N=North, S=South, E=East, W=West).	N/S/mm/dd or °E/W/mm/dd In case of loss, last registered position	Not specified format	-	Required	Position* of the activity.
	Date	The date of the event in the format DD/MM/YY (day/month/year)	dd/mm/yy	YYYY/MM/DD	-	Date	Date* of the activity.

***** *If a loss of the buoy, information of the last transmission should be provided*

3.2.3. Floating Object (FOB) type

The FOB type should include all types of floating objects and not only FADs. The group recommends recording enough information on the FOB logbook to allow researchers to classify on CECOFAD categories or giving as choice to the fleet the CECOFAD categories (Gaertner et al., 2016):

DFAD: Drifting FAD
AFAD: Anchored FAD
FALOG: Artisanal log resulting from human activity (related to fishing activities)
HALOG: Artificial log resulting from human activity (not related to fishing activities)
ANLOG: Natural log of animal origin
VMLOG: Natural log of plan origin

General Data	t-RFMOs Data collection Requirements	IATTC	ICCAT	IOTC	WCPFC	Standards for data collection	Minimum Details
FOB TYPE	**FAD Type**	1. Natural (log, ropes, pallets/racks, fronds, dead animal); 2. FAD owned by your vessel; 3. FAD owned by another vessel; 4. Anchored object	anchored FAD, drifting natural FAD, drifting artificial FAD: DFAD; AFAD; FALOG; HALOG; ANLOG; VNLOG	drifting natural FAD, drifting artificial FAD),	Not specific fad logbook provided. Given in the fishing logbook drifting log, debris or dead animal"; "drifting raft, FAD or payao"; "anchored raft, FAD or payao"; "live whale"; and "live whale shark".	The information collected should allow to classify in CECOFAD codes	CECOFAD codes could be provided by skippers or could be obtained by posterior analysis of detailed characteristics on FOB

3.2.4. Floating Object (FOB) structure

The information given should allow evaluating the potential of entanglement of the FOB and the nature of the integral material (synthetic or natural and/or biodegradable).

General Data	t-RFMOs Data collection Requiments	IATTC	ICCAT	IOTC	WCPFC	Standards for data collection	Minimum Details
FOB Structure	**FOB Dimension**	Dimensions and material of the floating part (in meters); W –Width -, L –Length–, D –Depth Dimensions of the underwater hanging structure (Not specified format)	Required	Required. Not specified format	-	Dimensions for the floating and hanging structure	Floating structure [aaxbb] (width and length) Hanging structure: depth in m
	Components of the surface structure	Raft: 1. Bamboo Rack; 2. Bamboo in a sausage form; 3. Metallic; 4. PVC or plastic; 5. No raft; 6. Other Wrapping/covering: 1. Entangling net; 2. Non-entangling net; 3. Cloth; 4. Palm fronds; 5. No wrapping; 6. Other Floating devices: 1. Net corks; 2. Plastic buoys; 3. Plastic containers; 4. No floats; 5. Other	Material of the floating part and the entangling or non-entangling feature of the underwater hanging structure	Material of the floating part and of the underwater hanging structure	-	non-entangling character based in ISSF classification scheme and biodegradable character	- Type of material: Natural and biodegradable; or other synthetic materials in the FOB. - Entangling potential of the external mesh size (if present)
	FOB Hanging structure (tail)	Components 1 and 2: 1. Nylon; 2. Palm fronds; 3. Bamboo; 4. No tail; 5. Other Config. (Configuration): 1. Sausage; 2. Ropes; 3. Cloth; 4. Other Mesh size: If the tail is made of net, indicate the mesh size. Otherwise, leave blank.	Material of the underwater hanging structure and the entangling or non-entangling feature of the underwater hanging structure	Material of the floating part and of the underwater hanging structure	-	non-entangling character based in ISSF classification scheme and biodegradable character	-Type of material: Natural and biodegradable or synthetic - Entangling potential of the hanging structure (reference to the mesh size and configuration, i.e. open or coiled)

3.2.5. *Type of activity*

The group recommends recording enough information on the logbook to allow researchers to classify on CECOFAD categories or giving as choice to the fleet the CECOFAD categories (Gaertner et al., 2016). When any part of the FOB is modified, or the buoy or ownership are changed, the specification prior and after the change should be recorded.

General Data	t-RFMOs Data collection Requiments	IATTC	ICCAT	IOTC	WCPFC	Standards for data collection	Minimum Details
FOB Activity	**Type of the activity on FOB**	Set, deployment, hauling, retrieving, loss, other	Recommends using the terms in CECOFAD: FOB: Enconter, visit, deployment, strenghening, remove FAD, fishing.	deployment, hauling, retrieving, loss	Not specific fad logbook. Given in the fishing logbook as: Set; Searching; Transit; No fishing - Breakdown; No fishing - Bad weather; In port; Net cleaning set; Investigate free school; Investigate floating object; Deploy - raft, FAD or payao; Retrieve - raft, FAD or payao"	CECOFAD activities with FOBs	Recommend using the CECOFAD activities on FOB: Encounter, visit, deployment, strengthening, remove FAD, fishing.
BUOY Activity	**Type of the activity on BUOY**	intervention on electronic equipment,	Buoy: Tagging, remove buoy, loss	intervention on electronic equipment	-	CECOFAD activities with buoys	Recommend using the CECOFAD activities on Buoy: Tagging, remove buoy, loss.

3.2.6. Catch

The FAD logbook should be preferably linked with the fishing logbook when using ERS or dedicated software for standardize data collection and catch obtained from fishing logbook. The destiny of the catch should be included (i.e. retained, discarded or released in case of sensitive species). If the FAD logbook is not linked with the fishing logbook specific fields for the catch should be included in the FAD form

General Data	**t-RFMOs Data collection Requiments**	**IATTC**	**ICCAT**	**IOTC**	**WCPFC**	**Standards for data collection**	**Minimum Details**
Catch	**Target species**	If the event is a set, the catch in metric tons of each of the tuna species denoted. When the catch includes other tunas (OTH), record the quantities and species under Comments.	If the visit is followed by a set, the results of the set in terms of catch. If the visit is not followed by a set, note the reason (e.g. not enough fish, fish too small, etc.). Estimated catches expressed in metric tons.	If the visit is followed by a set, the results of the set in terms of catch	-	Required. Preferably linked to fishing logbook in ERS and obtained from fishing logbook	Target species (tn). Destiny should be included [retained, discarded]. When the catch includes other tunas (OTH), record the quantities and species as bycatch
	Bycatch	For the groups noted (Sharks – SHRK –, Turtles – TURT –, Billfishes – BILL –, Manta rays – MANT – and Other vertebrates – OTR –), present in the set, indicate either the number of individuals (N) or metric tonnage (t) caught. Use the line below to record the quantity of these, released alive.	If the visit is followed by a set, the results of the set in terms of by-catch whether retained or discarded dead or alive (in case of release expressed as number of specimen.). Estimated catches expressed in weight or in number.	If the visit is followed by a set, the results of the set in terms of bycatch.	-	Required. Preferably linked to fishing logbook in ERS and obtained from fishing logbook	little tuna; other bony fishes; billfishes; sensible species; (n or tones). Destiny should be included [retained, discarded or released in case of sensitive species].

3.2.7. Other Requirements

Some t-RFMOs refer to the specification of the buoy attached to the FOB. This is given by the buoy model and therefore it is not necessary to include another field different from the one provided to the buoy identification.

General Data	t-RFMOs Data collection Requirements	IATTC	ICCAT	IOTC	WCPFC	Standards for data collection	Minimum Details
Others	**Characteristics of any attached buoy or positioning equipment**	1. GPS, SHERPE type; 2. Satellite with eco-sounder; 3. Satellite with no eco-sunder; 4. Other	E.g. GPS, sounder, etc. If no electronic device is associated to the FAD, note this absence of equipment	Serial number required		Given by the buoy model	

4. Best Standards on Reporting Requirements

The t-RFMOs aiming to assess the effort on FOBs have strength the data reporting requirements and specific templates has been provided to CPCs for data submission on FOBs. However, some data gaps have been identified for the different RFMOs (Ramos et al., 2017; Baez et al., 2017a; Baez et al., 2017b; Lopez et al., 2018), indicating a generalized problem in data collection and reporting schemes stablished. Some of the potential sources of un-reporting are identified as un-harmonized spatial and temporal stratification of the data required, misinterpretation of the request due to un-specific guidelines, lack of definitions of the terms and variables to be recorded, inadequate templates where information extracted from different sources cannot be integrated in a single template (i.e., information from FOB or FAD logbooks vs. information from buoy transmissions), etc...

In order to provide the t-RFMOs with good quality information on FOBs and facilitate CPCs the collection and submission of data, we reviewed the t-RFMO data reporting requirements and identified best standards.

4.1 Format of the templates:

Regarding to the previous experiences we recommend using two specific templates adjusted to the data collections sources (FOB logbook vs. buoy tracks~~)~~: one dedicated form to report activities on FOB (based in CECOFAD categories) which are extracted from the FOB or FAD logbooks; and another template dedicated to report information on density of followed and/or owned buoys or FADs, which is extracted from buoys transmission information.

4.2 Definition of terms:

The activities with buoys and FOBs, as well as FOB types should be in line with CECOFAD categories.

4.3. Data to be requested:

The information on buoy density should be requested stratified by month and 1ºx1º. This information should be extracted from buoy transmissions provided by buoy manufactures and not from FAD or FOB logbooks. It should be requested by all t-RFMOs.

The data on FOB and buoy activities should be extracted from FOB logbooks. This information should be requested in an independent template. The group aware of the difficulties of logbook analysis and recommends reducing the request to certain activities: deployment, tagging and loss (CECOFAD categories), until the development and implementation of a standardized data collection tool is available and implemented.

4.3.1. Seasonal and Spatial Distribution

The guidelines to CPCs for data reporting in terms of spatial and temporal resolution are not specified for all data required and not harmonized among t-RFMOs, as it refers to 1º or 5º grid square size and to the monthly or quarterly basis. This has resulted in a misinterpretation of the request and inadequate submissions of data (Baez et al., 2017a, 2017b). The group recommends the harmonization to 1º grid square and monthly basis.

General Data	**t-RFMOs Data collection Requiments**	**IATTC**	**ICCAT**	**IOTC**	**Information extracted from FAD Logbook**	**Information extracted from Buoys transmissions**	**Standards for data reporting**
Seasonal and spatial distribution	Grid size	1x1	1x1 (but not specified for all data required)	1x1	X	X	Harmonize grid size:1x1
	Time scale	Monthly	Monthly	Is not harmonized. [Monthly and Quarterly]	X	X	Harmonize time scale to a monthly basis

4.3.2. Floating Object (FOB) Type

The information on FOB types described in each t-RFMO are various, and the group recommend using a single classification based in CECOFAD categories:

DFAD: Drifting FAD
AFAD: Anchored FAD
FALOG: Artisanal log resulting from human activity (related to fishing activities)
HALOG: Artificial log resulting from human activity (not related to fishing activities)
ANLOG: Natural log of animal origin
VMLOG: Natural log of plan origin

The information on FOB type comes from the FAD logbooks and those it should be request in independent template different from the one provided for buoy density (information coming from buoy transmission).

General Data	t-RFMOs Data collection Requiments	IATTC	ICCAT	IOTC	Information extracted from FAD Logbook	Information extracted from Buoys transmissions	Standards for data reporting
FOB TYPE	FAD TYPE	Not required	FAA Anchored FAD FADN Drifting Natural FAD FADA Drifting artifical FAD	IOTC FADs codes: LOG, LGT, NFD, NFT, FAD, FDT, ANF, DFR, DRT	X		CECOFAD categories for information coming from FAD logbooks

4.3.3. Activities with FOBs

The activities should refer to activities described in CECOFAD. The activities are extracted from FOB logbooks and should be requested by t-RFMOs in a separated template, different from the one designated to record information from buoy transmissions.

General Data	t-RFMOs Data collection Requirements	ICCAT	IATTC	IOTC	Information extracted from FAD Logbook	Information extracted from Buoys transmissions	Standards for data reporting
Activities with FOBs	Number of FAD visits per type of FAD	Not required	Not required	Total number of FAD visits (deployment, retrieval/encounter, hauling, revisiting or loss**)** by purse seiners, support vessels	X		Given by CECOFAD activities with FOB
	Number of FADs deployed	The number of FADs deployed on a monthly basis per 1°x1° statistical rectangles, by FAD type (Type: FAA - Anchored FAD; FADN - Drifting Natural FAD; FADA Drifting artifical FAD) indicating the presence or absence of a beacon/buoy or of an echo-sounder associated to the FAD and specifying the number of FADs deployed by associated support vessels, irrespective of their flag;	INF2: No. Deployed belonging to the vessel over the month in 1º degree square	Required (1°x1° statistical and month)	X		Given by CECOFAD activities with FOB
	Numbers of lost FADs	Average numbers of lost FADs with active buoys on a monthly basis	Not required	Required (1°x1° statistical and month)	X		- Given by CECOFAD activities with buoys -The term '*lost*' should refer to the end of the transmission of the buoy, in line with CECOFAD
	Number of sets			Required (1°x1° statistical and month)			Should not be included in FOB related templates as it is provided by other means.

4.3.4. Activities with buoys

The activities should refer to activities described in CECOFAD:

Tagging - Deployment of a buoy on FOB (Deploying a buoy on a FOB includes three aspects : deploying a buoy on a foreign FOB, transferring a buoy (which changes the FOB owner) and changing the buoy on the same FOB (which does not change the FOB owner).
Remove BUOY - Retrieval of the buoy equipping the FOB.
Loss - Loss of the buoy/End of transmission of the buoy.

Specific terms used in t-RFMOs as “activated” or “deactivated” which are poorly defined should be harmonized, by adopting common terms of “deploying” or “Tagging” or “Loss” in CECOFAD. The activities should be extracted from FOB logbooks and should be requested by t-RFMOs in a separated template different from the one designated to record information on buoy density which is derived from buoy transmissions.

General Data	t-RFMOs Data collection Requiments	IATTC	ICCAT	IOTC	Information extracted from FAD Logbook	Information extracted from Buoys trasmisions	Standards for data reporting
Activities with buoys	Number and type of beacons/buoys deployed	Not required	Examples for the type of beacon: e.g. radio, sonar only, sonar with echo-sounder; deployed on a monthly basis per 1°x1° statistical rectangles;	The number of deployments refer to FADs	X		- Given by CECOFAD activities with buoys
	Numbers of beacons/buoys activated and deactivated	No of deactivated belonging to the vessel over the month in 1º degree square	The average numbers of beacons/buoys activated and deactivated on a monthly basis that have been followed by each vessel; the spatial resolution is not specified.	The number of instrumented buoys activated, deactivated on each quarter during 2016 its purse seine vessel under the confidentiality rules set by Resolution 12/02. Required by quarter			- Given by CECOFAD activities with buoys -When referring to the submission of activities with buoys the activated buoy should refer to tagging - The deactivated buoy should reflect the loss

4.3.5. FOB density

The FOB density is estimated by the analysis of daily buoy transmissions which are provided by the buoy manufacturer to the organism responsible of the verification of the compliance with buoy limitation. This information should be provided in a separate template different from the one designated to report data on FOB and buoy activities.

The information provided by the CPCs to t-RFMOs should include at least the average number of buoys owned and followed by vessel in each 1ºx1º square and month

- Year [Year of activity],
- Month [Month of activity],
- CPC
- Number of vessels,
- Latitude [decimal degree],
- Longitude [decimal degree],
- Average number of active FADs or buoys [Average number of active buoys belonging to the total number of vessels of the CPC over the month]

General Data	t-RFMOs Data collection Requiments	IATTC	ICCAT	IOTC	Information extracted from FAD Logbook	Information extracted from Buoys trasmisions	Standards for data reporting
FOB number	Active FADs / buoys	Daily information on all active FADs to the Secretariat, in accordance with guidance developed under Paragraph 12, with reports at monthly intervals submitted with a time delay of at least 60 days, but no longer than 90 days: INF1: Number of active FADs/date INF2: Average number of active FADs belonging to the vessel over the month (by summing up the total number of active beacons recorded per day over the entire month and dividing by the total number of days) in 1 degree square	Average No. Active beacons followed per vessel.	Res 17-08 (9) - the number of instrumented buoys active on each quarter during 2016 its purse seine vessel under the confidentiality rules set by Resolution 12/02		X	Average number of active buoys owned by vessels in 1ºx1º and month Should be reported in a separated form

4.3.6. Catch

The catch data are generally obtained by other sources and in order to avoid data duplication and facilitate the data reporting to CPCs this information shouldn´t be provided in templates designated to report activities on FOBs or data on buoy densities.

General Data	**t-RFMOs Data collection Requiments**	**ICCAT**	**IATTC**	**IOTC**	**Information extracted from FAD Logbook**	**Information extracted from Buoys transmissions**	**Standards for data reporting**
Catch	Catches and effort	when the activities of purse seine are carried out in association with baitboat, report catches and effort in line Task I and Task II requirements as "purse seine associated to baitboats" (PS+BB).	Not required	Total catches of target IOTC species and bycatch species taken on FOBs, at the same level of resolution (1ºx1º and month) Retained catches: catches for each species retained on board in live weight and/or number. Discard levels: discard levels for each species in live weight or number.			Shouldn´t be required related to information on FOB activities or buoy densities as it is provided in other Tasks

References

Báez, J.C., Ramos, M.L., López, J., Santiago, J., Grande, M., Herrera, M.A., Rojo, V., Moniz, I., Muniategi, A., Pascual, P.J., Murua, H. & Abascal, F.J. (2017a). Interpreting ICCAT's data reporting requirements for activities on FADs: An overview from EU-Spain. Documento de trabajo presentado en el Standing Committee on Research and Statistics (SCRS) de ICCAT, número SCRS/2017/217. Madrid 25-29 de septiembre 2017.

Báez, J.C., Bach, P., Capello, M., Floch, L, Gaertner, D., Goujon, M., Grande, M., Herrera, M.A., López, J., Marsac, F., Maufroy, A., Moniz, I., Muniategi, A., Murua, H., Pascual, P.J., Ramos, Mª.L., Rojo, V., Sabarros, P.S., Santiago, J. & Abascal, F.J. (2017b). Interpreting IOTC`s data reporting requirements for activities on floating objects: an outlook from EU scientist and fishing operators. Submitted to 13th Working Party on Data Collection and Statistics. IOTC-2017-WPDCS13-27.

Chassot, E., Assan, C., Soto, M., Damiano, A., Delgado de Molina, A., Statistics of the European Union and associated flags purse seine fishing fleet targeting tropical tunas in the Indian Ocean 1981-2014. IOTC-2015-WPTT17-12. 17th session of the IOTC Working Party on Tropical Tunas, Montpellier, France.

Dagorn, L., Holland, K. N., Restrepo, V. and Moreno, G. 2013. Is it good or bad to fish with FADs? What are the real impacts of the use of drifting FADs on pelagic marine ecosystems? Fish and Fisheries, 14: 391–415.

Davies, T. K., Curnick, D., Barde, J. and Chassot, E. 2017. Potential environmental impacts caused by beaching of drifting Fish Aggregating Devices and identification of management solutions and uncertainties. 1st joint t-RFMO FAD WG.

Fonteneau, A., Chassot, E. and Bodin, N. 2013. Global spatio-temporal patterns in tropical tuna purse seine fisheries on drifting fish aggregating devices (DFADs): Taking a historical perspective to inform current challenges. Aquatic Living Resources, 26: 37–48.

Gaertner, D., Ariz, J., Bez, N., Clermidy, S., Moreno, G., Murua, H., Soto, M., Marsac, F., 2016. Results achieved within the framework of the EU research project: Catch, Effort, and eCOsystem impacts of FAD-fishing (CECOFAD). IOTC-2016-WPTT18-35. 18th Session of the IOTC Working Party on Tropical Tunas, Mahé, Seychelles.

Hallier, J.P., Gaertner, D., 2008. Drifting fish aggregation devices could act as an ecological trap for tropical tuna species. Marine Ecology Progress Series 353: 255-264.

ICCAT, 2016a. Second meeting of the ad hoc Working Group on FADs (Bilbao, Spain, 14-16 march 2016).

ICCAT, 2016b. Recommendation by ICCAT on a Multi-Annual Conservation and Management Program for Tropical Tunas. Rec. 16-01.

Lopez, J., Moreno, G., Sancristobal, I., and Murua, J. 2014. Evolution and current state of the technology of echo-sounder buoys used by Spanish tropical tuna purse seiners in the Atlantic, Indian and Pacific Oceans. Fisheries Research, 155: 127–137.

Lopez, J., Altamirano, E., Lennert-Cody, C., Maunder, M., Hall, M. (2018). Review of IATTC resolutions C-16-01 and C-17-02: available information, data gaps, and potential improvements for monitoring the fad fishery. 3rd Meeting of the Ad Hoc Working Group on FADs La Jolla, California USA, 11-12 May 2018

Marsac F, Fonteneau A, Ménard F (2000) Drifting FADs used in tuna fisheries: an ecological trap? In: Le Gall JY, Cayré P, Taquet M (eds) Pêche thonière et dispositifs de concentration de poisons. Actes Colloques-IFREMER 28:537–552

Maufroy A, Chassot E, Joo R, Kaplan DM (2015) Large-Scale Examination of Spatio-Temporal Patterns of Drifting Fish Aggregating Devices (dFADs) from Tropical Tuna Fisheries of the Indian and Atlantic Oceans. PLoS ONE 10(5): e0128023. doi: 10.1371/journal.pone.0128023

Ramos, Mª.L., Báez, J.C., Grande, M., Herrera, M.A., López, J., Justel, A., Pascual, P.J., Soto, M., Murua, H., Muniategi, A., Abascal, F.J. (2017). Spanish FADs logbook: solving past issues, responding to new global requirements. Joint t-RFMO FAD Working Group meeting Doc. No. j-FAD_11/2017. April 19-21, 2017 Madrid, Spain.