Comments on the assessment of catch by species in the tropical purse seine fishery

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Background

In tropical tuna purse seine fishery, catches at sea generally include several target species (*Thunnus albacares*, yellowfin tuna; *Katsuwonus pelamis*, skipjack tuna), not targeted but significatively caught bigeye tuna; *Thunnus obesus*, accompanied in different proportions by other secondary species. These secondary species include both tuna-like species (neritic tunas; *Thunus alalunga*, albacore) and other bycatch species (billfishes, sharks or other bony fishes). Total quantities caught during a fishing operation may vary substantially, up to > 300 tonnes. Two main fishing strategies are used to capture tunas: (1) targeting fish swimming in free schools, (2) targeting fish swimming around drifting objects. In the first approach, called a free-school set (FSC sets), the catches are usually monospecific (large yellowfin tuna mainly), while in the second (FOB sets) the species and commercial size category mixture is larger. When a fishing operation is conducted, onboard set catch-handling is very fast compared to other fisheries. Retained catch is directly stored in freezing tanks (wells) in brine without previous sorting to prevent sanitary and food safety issues. Sometimes, counting all large fish that goes on the well is done by the crew. Sorting is carried out punctually when certain non-marketed species are discarded. Subsequently, during the landing, a sorting of the target species is carried out by the crew according to commercial categories, more linked to the size of the individuals than to their species; for example, the category "skipjack <1.8 kg" is almost always composed of a mixture of small individuals of skipjack, yellowfin and bigeye in variable proportions, even if skipjack is still largely dominant.

The species composition by set is reported in the logbook, but bias in logbooks has been evidenced since the beginning of the tropical tuna purse seine fishery (Fonteneau 1976; Cayré 1984; Fonteneau 2007), mainly for the small individuals. Even if the total weight can be correctly estimated, as catches are weighted at landing, the species composition remains as a tricky issue (Lawson, 2009), which prevent their use as accurate values. Biases in the species composition estimates were already detected in the mid-80s by the ICCAT Tropical Tuna Working Group devoted to juveniles of tropical tunas, when fishing logbooks were compared with the sampling carried out in the port (Anon, 1984). The greater or lesser accuracy in the logbooks may vary but whatever the capacity and experience of the crew member who completes them, it has been proven that some discrepancies exist between the logbook declaration and the real landing. Consequently, to know the specific composition of tropical tuna landed catches, some port sampling can by carried during the landing process. A sampling and data processing strategy for estimating the composition of catches by species and sizes in the European purse seine tropical tuna fisheries (i.e., T3 for “Tropical Tuna Treatment”) was established in 1998 (Pallarés and Petit, 1998), and is routinely used by the EU scientists (France and Spain) based in the main landing ports (i.e. Seychelles, Abidjan and Dakar). This European sampling program for correcting catch and species estimation procedure, which is part of the Data Collection Framework[1], has been recently updated (Duparc, 2019). Currently, this species composition estimate is made once a year (around April of the following year), combining all the data sources (logbooks, landing notes and port sampling data) for the EU French and Spanish purse seine fleets.

Reliable catch information by species is one of the fundamental bases for the stock assessment of tropical tunas conducted in the different Tuna Regional Fisheries Management Organizations (tRFMOs). Without well-grounded commercial catch data, stock assessments can be clearly undermined. Therefore, the purpose of T3 is to provide the best catch composition estimates of the EU tropical tuna purse seiners to support the assessment of these stocks. It is not aimed in any case at determining the catch composition by specific set, as mean species composition values are estimated by strata, understanding as strata a combination of spatial areas, time period and set type – i.e., sets on floating objects (FOB) or on free schools (FSC).

Besides, article 14 of Council Regulation (EC) No 1224/2009[2], the permitted margin of tolerance in estimates recorded in the fishing logbook of the quantities in kilograms of fish retained on board and representing a catch of 50kg at least shall be 10 % per species, when compared with the quantities landed or the result of an inspection. In this context, this document aims to discuss the feasibility of onboard sampling to improve catch composition estimates.

Method

In order to understand the implications in a tuna purse seine vessel of the provisions of the rule or regulation (i.e. estimate during every set the total catch in weight by species with an error less than 10%), (1) we first estimated the number of fish that the crew should sample in each set, (2) we explored the possible challenges that may exist to perform a robust sampling. On this regard, we focused on the following aspects: species composition by set type (i.e. FSC and FOB sets), difficulties in species identification, random selection of the sample and time availability.

The estimation of the sample size n was based on the conventional formula used to estimate the sample size in sampling for proportions (Cochran, 1977):

$$n_0 = \frac{t^2 pq}{d^2 p^2}$$

Where d is the margin of tolerance or maximum error permitted (0.1), p is the proportion of a specific species in a set, and t is the abscissa of the normal curve that cuts and area of α=0.05 in the tails (1.96) and q is 1-p. Simple random sampling is assumed, and p is taken as normally distributed. It must be noted that the selection of an α value of 0.05 implies this sample size will

[1] REGULATION (EU) 2017/1004 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 May 2017 on the establishment of a Union framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the common fisheries policy and repealing Council Regulation (EC) No 199/2008 (recast)

[2] COUNCIL REGULATION (EC) No 1224/2009 of 20 November 2009 establishing a Community control system for ensuring compliance with the rules of the common fisheries policy, amending Regulations (EC) No 847/96, (EC) No 2371/2002, (EC) No 811/2004, (EC) No 768/2005, (EC) No 2115/2005, (EC) No 2166/2005, (EC) No 388/2006, (EC) No 509/2007, (EC) No 676/2007, (EC) No 1098/2007, (EC) No 1300/2008, (EC) No 1342/2008 and repealing Regulations (EEC) No 2847/93, (EC) No 1627/94 and (EC) No 1966/2006.

result in the correct estimation of species composition, within the 10% tolerance level, in 95% of the cases.

Then, sample size (n) for fishing sets of different size (N) (i.e. catches of 1,000/ 5,000/ 10,000 /30,000 individuals) was calculated as

$$n = \frac{n_0}{1 + (\frac{n_0}{N})}$$

Results

Table 1 shows the number of fishes that should be sampled (sample size) in order to have a maximum error of 10% when estimating the proportion of one species within a fishing set (with a 95% level of confidence). As it is shown, these sample size vary based on the (1) real proportion of that species in the catch, and (2) the total catch in the set. As expected, the smaller the proportion of a species in the catch, the greater the number of individuals that we should randomly sample so as not to have a deviation greater than 10%. Similarly, sets with higher catches demand a bigger sample size. Thus, in sets with catches greater than 5,000 fishes, the minimum sample should be greater than 1,000 individuals in order to correctly estimate the weight of all those species that are represented less than 25% of the total catch. In the set with 30,000 fishes caught, the minimum sample would reach 5,871 individuals to correctly estimate the proportion of a species that represents 5% of the total catch.

Figure 1 represents the relationship between the sample size and the proportion of a given species in a fishing operation assuming an 10% error. Same relation is presented for fishing sets of different sizes: 5,000/ 10,000/ 30,000 individuals. For species with a proportion below 25%, the number of fish needed in the sample increases greatly.

Table1. Estimated sample size, as number of fishes to be measured, based on the proportion that one species represents on the total catch and total size of the catch (1,000/ 5,000/ 10,000/ 30,000 individuals).

Proportion	n1000	n5000	n10000	n30000
0.05	**880**	**2967**	**4219**	**5871**
0.1	**776**	**2044**	**2569**	**3100**
0.15	**685**	**1517**	**1788**	**2030**
0.2	**606**	**1175**	**1332**	**1462**
0.25	**535**	**937**	**1033**	**1110**
0.3	473	760	823	870
0.35	416	624	666	697
0.4	366	517	545	565
0.45	320	429	448	462
0.5	278	357	370	379
0.55	239	296	305	311
0.6	204	244	250	254
0.65	171	199	203	205
0.7	141	159	162	164
0.75	114	125	126	128
0.8	88	94	95	96

0.85	63	67	67	68
0.9	41	42	43	43
0.95	20	20	20	20
1	0	0	0	0

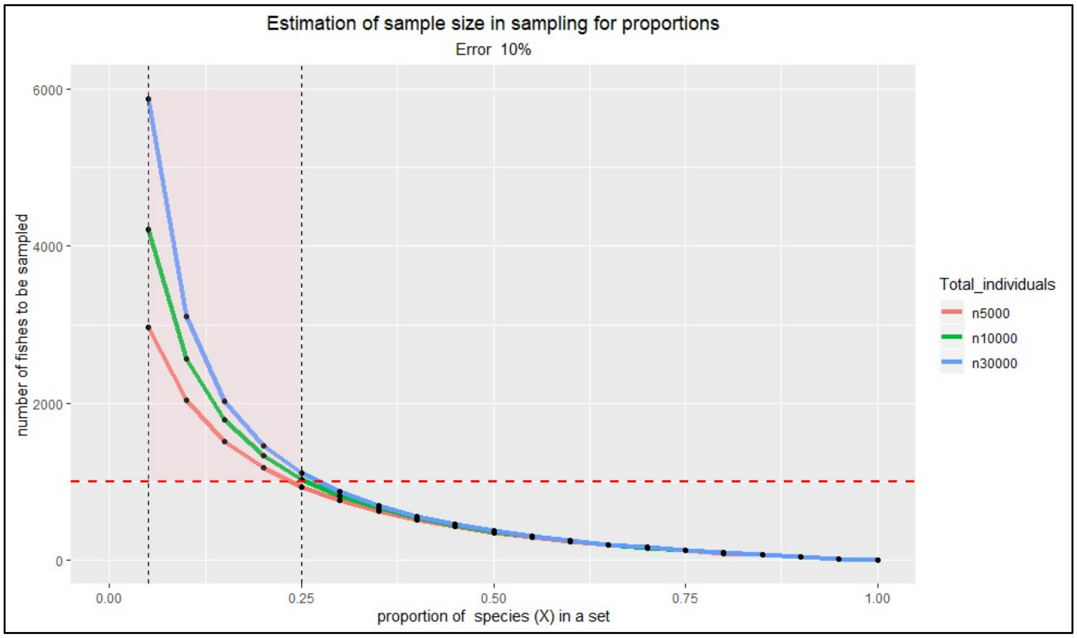

Figure 1. Relationship between the sample size and the proportion of a given species in a fishing operation. A 10% error is assumed, and the data is represented for operations with a total capture of 5,000/ 10,000/ 30,000 individuals. Red horizontal dashed line represents a threshold for the sample size of 1,000 individuals.

Discussion

Results show that the number of fish that the crew should sample on board to comply with the permissible margin of tolerance, for each species, varies depending on the total catch of the set and the proportion between species.

While in monospecific or very small sets the sample size would be low, the sample size increases exponentially according to the set size and the low proportion of the species in a set. Considering the FOB sets with a mean fish weight of 4.1 kg [4.0; 4.2] (median = 3.8 kg) and a mean set size of 26.4 [25.8; 26.9] t (median = 19.3 t, see figure 2 for distributions), the estimated mean number of fish is about 6500. In such case, to reach a 10% error, more than 2200 fish should be sampled for species representing less than 10% of the set, threshold which is quite frequent for many species (bigeye tuna, albacore, neritic tunas and many other bycatches).

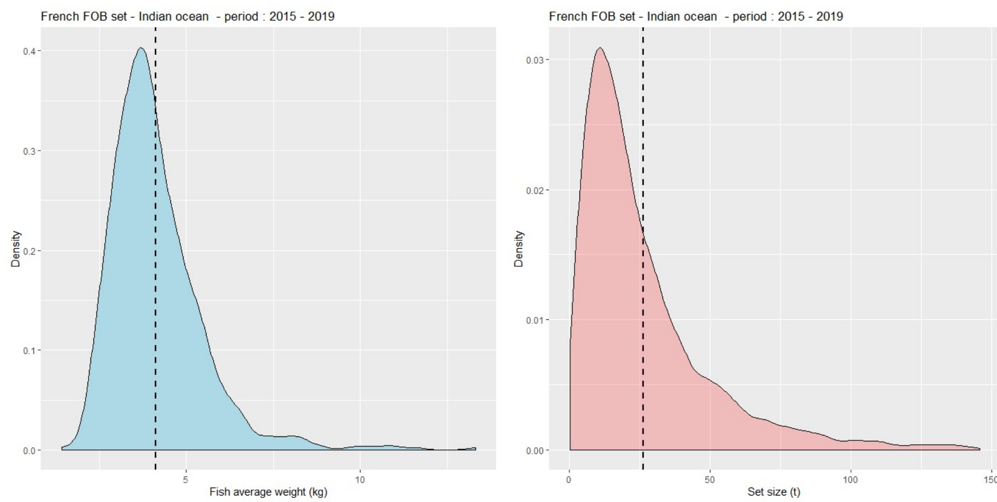

Figure 2. Left panel - Distribution of the fish weight in samples at landing on FOB sets for the French fleet in Indian ocean during the 2015-2019 period. Right panel - Distribution of the set size on FOB sets for the 2015-2019 period. Dashed lines represent the means.

Fishing sets above 10,000 fish (about 40t on FOB sets) , and even more, are not sporadic. Multi-species sets either, especially when considering sets on FOBs where several species of target (yellowfin tuna, bigeye and skipjack) and non-target tunas (albacore, bullet tuna, frigate tuna, little tunny, etc.) are captured at the same time (Tolotti *et al*., 2020). The number of FADs (Fish Aggregating Devices; man-made FOBs) being used by purse seine vessels has increased steadily in the last two decades and represent around 70 % of the total fishing sets of the EU fleet (Pascual Alayon *et al.,* 2019).

In this context, there would be many sets where the sample size that the crew should manage would exceed 1,000 fish. But, is this feasible? What could be the limiting factors?

1) *Onboard random sampling during the set*: It is known that in the net, before the brailing, the catch can be stratified in layers, by species and sizes (Sancristobal *et al*., 2014). This stratification challenges the necessity of randomness in the sampling. Thus, the sample should be done distributed with a regular step during the complete catch handling period from almost the first brail to the last one. Previous studies on board purse seiners carried out by the Pacific Community (which works as scientific services provider for the Western and Central Pacific Fisheries Commission) have evidenced that fish are not randomly selected for sampling either due to physical constraints, such as layering in the set, brail or well, or to behaviour, such that samplers have a tendency to select certain species and/or sizes of fish more than others (Lawson, 2009). This implies that the accurate determination of species proportion does not only require a high, in many instances unfeasible, sample size, but also a well-defined methodology (e.g., spilling part of each brail in a bin to avoid selection bias by samplers). On the other hand, the method used in this document for estimating sample size assumes simple random sampling as the sample selection method onboard, when it might not be the always the case. Large fish could be counted (total enumeration when possible), this way the part of the capture compose of large specimens would be estimated separately, reducing to a certain extent the population (N) to be sampled. Thus, reducing the required sample size.

2) *Species Id:* Most tuna species captured by the purse seine fleet are easily distinguishable, since they have characteristic physical features. However, distinguishing between small yellowfin and bigeye, can be challenging. The three tuna species most likely to be encountered during tropical tuna purse seine fishing are skipjack, yellowfin, and bigeye. The skipjack is easy to distinguish by the horizontal stripes that run down its body. Large adult bigeye and yellowfin are characterized by dissimilar body and fin shapes. However, these differences are less noticeable when they are young, even if they do exhibit somewhat different external features: length and shape of pectoral fins, markings and colours (on fresh fish only). It is important to point out that these characteristics that can help distinguishing small specimens vary during the growth (<30cm, 30-50cm, 50-100 cm). Thus, juvenile bigeye and yellowfin are easy to confuse (Figure 3 up, Báez et al 2019). While it is true that some internal characteristics (shape and scarification of the lobules of the liver) could be used for the identification of these two species (figure 3 bottom), this type of characteristics would not be valid for intensive sampling on board. More details available in *Handbook for the Identification of Yellowfin and Bigeye Tunas in Fresh Condition (v2)* (Itano, 2005).

Figure 3. Small size (40-60 cm) yellowfin tuna (up) and bigeye (bottom) (Photos: AZTI).

3) *Time available for sampling:* When the fish die, their defence mechanisms stop acting allowing bacterial growth and, therefore, the production of the enzyme and the subsequent generation of histamine. This process occurs in a wide range of temperatures, and the higher the temperature, the faster the process. Thus, catch should be stored in well as soon as possible. As mentioned by FAO in the technical paper 334 -" *Assurance of seafood quality",* all studies seem to agree that storage of fish products at 0° C, or very close to 0° C, limits the formation of histamine in fish to negligible levels, therefore, the key factor in this aspect of food safety is the time since the fish death until it reaches 0ºC (Huss, 1997). It is clear and it is known that the formation of histamine derives mainly from the time it takes for the fish to begin to cool after death, that is, the time that passes until the moment it enters the well, and not that much from what happens then inside of the well during the freezing process. The recommendations in this regard emphasize that in the worst conditions of air Tª (> 28ºC) and seawater Tª (> 18ºC), the Tª of the fish must have dropped to 4.4ºC or less, 6 hours after death (Anon, 2011). Based on the Regulation (EC) No 853/2004[3] of the European Parliament – *Chapter V – Requirements for processed fishery products*, food business operators must ensure that the limits with regard to histamine are not exceeded.

It should be also noted that in the Western Pacific scientists have more than a decade of experience in relation to the onboard sampling to determine the specific composition of the purse seiners. This sampling is done by observers (not by the crew members), but in any case, the conclusion by the authors for the sample size and its associated error is clarifying, where (Lawson, 2009) concluded that; "*The coefficients of variation for skipjack are relatively low (most less than 10%), while those for yellowfin are moderate (most less than 30%) and those for bigeye are high (greater than 30%). There is a clear relationship between the "coefficient of variation" and the*

[3] REGULATION (EC) No 853/2004 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 29 April 2004 laying down specific hygiene rules for on the hygiene of foodstuffs.

sample size for skipjack and yellowfin, which suggests that spill sample sizes of about 300 to 400 fish are a reasonable compromise between sampling effort and reliability. There are so few bigeye individuals in most of the spill samples examined in this study that much larger sample sizes would have been required in order to reduce the "coefficients of variation".

Finally, it is important to mention that logbooks account only for main tuna species. The remainder of catches not discarded at sea is sold in the local market (also known as "*Faux poisson*") and its detailed species composition is not available. Therefore, IRD and IEO collect, in parallel of the sampling for the target species at landing, data on associated-tuna species composition and catch of the local market, a market which is more developed in the Atlantic (Abidjan) that in the Indian Ocean. Many of these species in the local market represent a lower proportion of catches than major tuna species and are not well reported in logbooks because of the difficulties of their detection among the dominant species. The estimation of their precise catches onboard would require a very intensive effort in sample (often more than 3000 individuals in each set).

Conclusion

In view of what is stated in this document, performing sampling at the set level for estimating the tuna species composition with a 10% error margin for all sets is not plausible. For sets with more than 5,000 individuals and a mixture of several species, the sampling would be exaggeratedly large (at least to estimate accurately any species with a proportion < 25%). Technically, this on-board sampling is further complicated, if we consider; (1) the difficulty to identify correctly small size bigeye and yellowfin, (2) the onboard constraint to put the catch in the wells as soon as possible (3) and the requirement of qualified human resources needed. Previous experiences also evidenced such a sampling would still be subject to several sources of sampling bias. This implies that the accurate determination of species composition onboard does not only require a high, in many instances unfeasible, sample size, but a well-defined methodology.

Thus, the fishing operations carried out by tropical tuna purse-seiners allow reliable estimates of total catch by set but do not allow to accurately estimate the quantities in kilograms by species of the fish retained on board without an intensive and time-consuming sampling effort.

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