Spatio-temporal dynamic of the species composition in catch of the European purse seine tropical tuna fisheries

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Abstract

The EU purse seine fishery is composed of two major fleets targeting tropical tuna species in the IOTC Convention Area. A common sampling design has been shared and developed by the French and Spanish scientists since the 1980s with the aim to collect data on the fishing activities and the biological parameters of their fishery. Both fleets have evolved simultaneously according to the development of the new technology and fishing practices. Thus, considering their similarities, their catches were historically assumed to be comparable. In the present study, we review the validity of this hypothesis under the evolution of the fishing management in the IOTC area of competence in recent years, focusing on the species composition of the catch and accounting for space and time. We investigated the reporting data and the scientific samples at landing during the period 2010-2021 in 5° squares and quarters commonly exploited by the two fleets. As expected, the French and Spanish catch were highly correlated and homogeneous whatever the fishing mode and the year. Scientific data were more stable than the declaration due to the standardization of the measurement. However, since 2018, the species composition started to slightly differ in catch under floating objects for the two datasets. The frequency of yellowfin tuna remained quite stable in the French fleet whereas it started to be lower in the Spanish reported catch. Opposite dynamic was observed for the skipjack but no pattern regarding the bigeye tuna. This recent trend needs to be confirmed in the following years and further study on the differences in fishing strategies that have possibly led to this change.

Key words

yellowfin, *Thunnus albacore*, bigeye, *Thunnus obesus*, skipjack, *Katsuwonus pelamis*

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Introduction

The EU purse seine fishery is composed of two major fleets targeting tropical tuna species in the IOTC Convention Area since the beginning of the exploitation of these stocks (Marsac et al. 2017, Báez et al. 2020). Both fleets have evolved simultaneously according to the development of the new technology and fishing practices. Thus, considering their similarities, their catches were historically assumed to be comparable. A common sampling design has been shared and developed by the French and Spanish scientists since the 80s with the aim to collect data on the fishing activities and the biological parameters of their fishery (Bach et al. 2018, Guillou et al. 2022).

This last decade, the exponential increase of the fishing aggregating device (FAD) equipped with echosounders allowed fishing captains to devise new fishing strategies and make different fishing decisions.(Dagorn et al. 2013). During these years, Spanish companies went on focusing the effort on school under floating object (FOB) whereas French companies always kept a larger part of the catch on big tuna under free school. More recently the establishment of the quotas on yellowfin tuna disrupted the fishing strategies, forcing companies to report their catch on this species on others and reduce total catch (Resolution 19/01 and 18/01).

Under such major changes in the last decade, the question of the similarity of the European fleets deserves an update. In this paper, we reviewed the validity of this hypothesis, focusing on the species composition of the catch and accounting for space and time. We investigate this issue using two independent sources, the reported catch at sea from the logbook and the scientific sampling dataset performed at landing. We expect that the species composition did not diverge between fleets considering that the fishing management in the IOTC area of competence impacted only their effort but not the quality of the catch once the fishing mode, space and time were accounted for.

Methods

Data

Sample dataset is based on a common sampling plan shared and developed by scientists of France, Spain, Senegal and Seychelles since the 80s. The annual sampling plan is conducted in order to cover the wider geographical area and temporal range, for all vessels and for both free school and associated school sets. To ensure this coverage, the sampling plan is continuously updated according to strata already sampled. As the logbook and the wells plan are communicated in advance, this enables them to determine which wells (i.e., dates, positions and fishing modes) are suitable for sampling. The sampling protocol accounts for the homogeneity of the well's content (e.g., in case of several sets in the same well, it is recommended to select a well containing a single fishing mode, as well as the shortest range in date and locations of the sets).

A sample is composed of 500 fish for FOB set (200 fish for free school) count and identified at the species levels. A variable part of these fish is measured to estimate the length distribution of each tuna species. For this analysis, samples were selected with a minimum of 150 fish measured and counted, and with a maximum of three sets in the well. Length measures are converted in weight using length weight relationship (**Table 1**). The species composition in weight for the major tunas were finally computed accounting for all species, i.e., the other tuna species and bycatch.

The species composition from the crew declarations were directly calculated from the weight categories registered in the logbook. Only sets representing more than 5 t (about 98% of the sets) were included in the analysis to avoid particular species composition due to specific cases (for instance, negative catch or net overturning).

Species frequency was averaged by 5° squares and quarter based on location and fishing date reported in the logbooks. Common square-quarter of the two fleets were selected with at least 5 sets (by fleet) to ensure a better representativity of the mean species composition. At the end, 35 square-quarters were selected for the free school mode and 163 for catch under floating objects.

The year 2020 was not included in the analyses due to a lack of data.

Analyses

First, we investigated the species frequency along the time series using simple gam models on the mean frequency of each species and fleet by square-quarter.

Second, we tested whether the species frequency was homogenous between the french and the spanish fleet. We performed a simple linear model with an intercept at 0 and an effect of the species on the slope. Mean frequency of the square-quarter of the french fleet was the response variable and spain fleet the explanatory variable.

We estimated the slope coefficient and 95% CI by species and calculated the R^2 to assess the strength of relationship. A slope of 1 is expected to reach a perfect similarity in species frequency between the two fleets.

We repeated the same process for the logbook declaration and sample data.

Results and discussion

The two European fleets clearly showed a similar pattern of species composition whatever the fishing mode during the period 2010-2021 (**Figure 1a and 1b**). The mean proportion of Yellowfin tuna and Skipjack in both fleets are correlated to 0.90 in the common square-quarter with a slope of 1 (always for the yellowfin) or close (**Table 2**) in logbook declaration and samples. As expected, the time series are more homogenous with the sampling data as the methodology is standardized and less subject to human bias. The general dynamic is not interpretable because the squares exploited by the EU fleet can change along quarter and years. However, the squares of the same quarter are common to the two fleets and let appear a significant differentiation from 2018 - 2019 to 2021. The mean frequency of yellowfin tuna in catch under FOB started to be lower in the Spanish catch than in the French one and an opposite dynamic was observed for the skipjack. This trend is confirmed when mean proportions were directly compared. Indeed, the slope of the relationship between the frequencies of the two fleets was almost higher than 1 for the yellowfin and lower than 1 for the skipjack in 2019-2021 (**Table 3**). The result for 2018 was not that clear, as sample and declaration are contradictory.

No such trend was observed regarding the frequency of bigeye tuna in the catch. It seems that this species is more frequent in the catch under FOB of Spain than France but with a lower correlation (R^2 =0.46 in logbooks and 0.63 in samples). This result can be explained by the low proportion of this bigeye in the catch and the small range of value. This made its estimation difficult by the crew members in the declaration and also increased uncertainty in estimation by sampling.

Finally, this new trend of the last few years remained surprising, considering the similarity of the two fleets in the last decade. The increase of FAD in the purse seiner fisheries did not differently impact the species composition of the catch of the EU fleets. But, the arrival of the quota on yellowfin tuna in 2018 could have changed the perception of the crew members in their declaration at sea. However, the observed pattern was also found at landing in an independent scientific sampling. This change in species composition could be due to evolution of the fishing practice in Spanish fleet compared to French fleet, as, for instance, an avoidance of schools with a high proportion of yellowfin. Another possibility is that the Spanish ministry of agriculture, fisheries and food, regulated more strictly, since 2019 for its own fleet, the yellowfin catch and total tuna limitation at vessel levels (Order APA/22/2019), independently from the French fleet. Maybe, the scale of 5° is too large for some parts of the fishing area and heterogeneity at small scales can explain these differences, such as near the coast or a ZEE. Thus, further analyses and investigation are needed to rule on these short-term results.

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Tables

Table 1: Coefficient of the length weight relationship

Species	a	b
Bigeye tuna	0.000027	2.951
Skipjack	0.00000532	3.34958
Yellowfin tuna	0.000015849	3.046

Table 2: Slope fitted values and 95% CI of the linear models on the mean species frequency in 5° square and quarter between the french and spanish purse seine fleet during the period 2010-2021

Dataset	Species	Number of square-quarter	Slope value	R^2
Logbook	Bigeye tuna	198	0.51 [0.43; 0.59]	0.46
	Skipjack	198	1.01 [0.97; 1.04]	0.93
	Yellowfin tuna	198	0.95 [0.90; 1.00]	0.88
Sample	Bigeye tuna	198	0.73 [0.66; 0.82]	0.63
	Skipjack	198	0.90 [0.85; 0.94]	0.89
	Yellowfin tuna	198	0.99 [0.96; 1.03]	0.93

Table 3: Yearly slope fitted values and 95% CI of the linear models on the mean species frequency in 5° square and quarter between the french and spanish purse seine fleet during the period 2018-2021

Dataset	Species	Year	Number of square-quarter	Slope value
Logbook	Bigeye tuna	2018	19	0.44 [0.24; 0.64]
	Bigeye tuna	2019	21	0.42 [0.28; 0.56]
	Bigeye tuna	2021	13	0.69 [0.39; 0.98]
Sample	Bigeye tuna	2018	19	0.63 [0.26; 0.99]
	Bigeye tuna	2019	21	0.54 [0.33; 0.75]
	Bigeye tuna	2021	13	0.48 [0.17; 0.78]
Logbook	Skipjack	2018	19	0.88 [0.79; 0.97]
	Skipjack	2019	21	0.85 [0.76; 0.94]
	Skipjack	2021	13	0.94 [0.83; 1.06]
Sample	Skipjack	2018	19	1.05 [0.92; 1.18]
	Skipjack	2019	21	0.75 [0.65; 0.84]
	Skipjack	2021	13	0.83 [0.72; 0.94]
Logbook	Yellowfin tuna	2018	19	1.58 [1.26; 1.90]
	Yellowfin tuna	2019	21	1.56 [1.30; 1.82]
	Yellowfin tuna	2021	13	1.26 [1.03; 1.50]
Sample	Yellowfin tuna	2018	19	0.84 [0.70; 0.97]
	Yellowfin tuna	2019	21	1.35 [1.19; 1.51]
	Yellowfin tuna	2021	13	1.17 [0.99; 1.35]

Figures

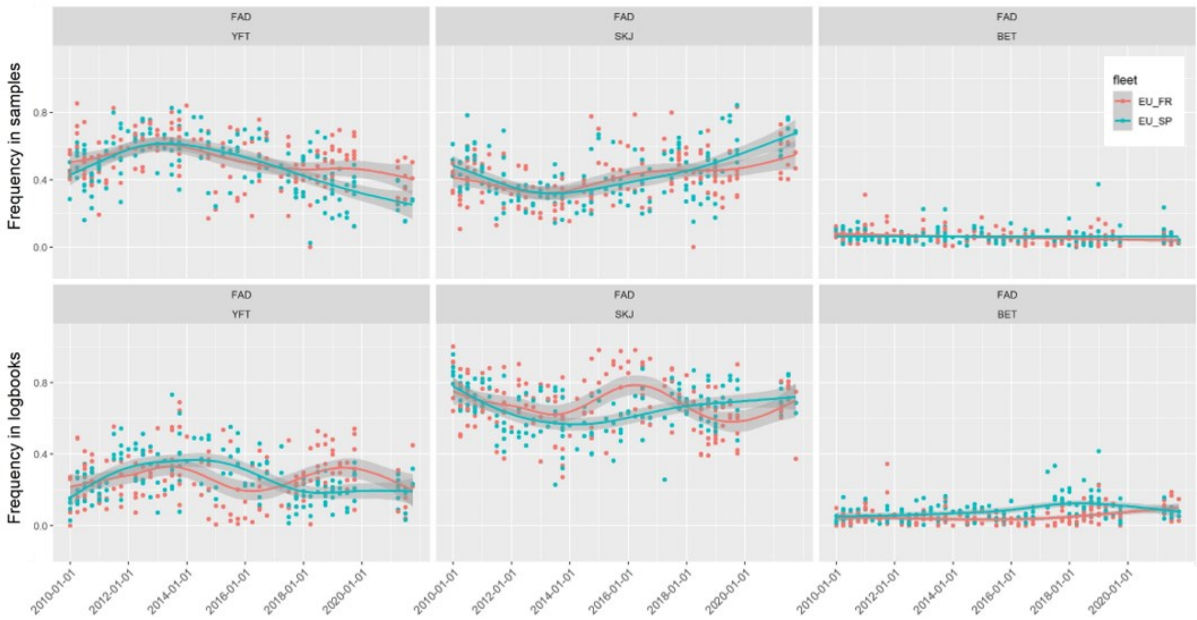

Figure 1a: Mean frequency of species by quarter and 5° squares in catch under floating object, in samples at landing and in logbook declaration by species and fleet. Lines and shades represent the fitted value and 95%CI of a gam model.

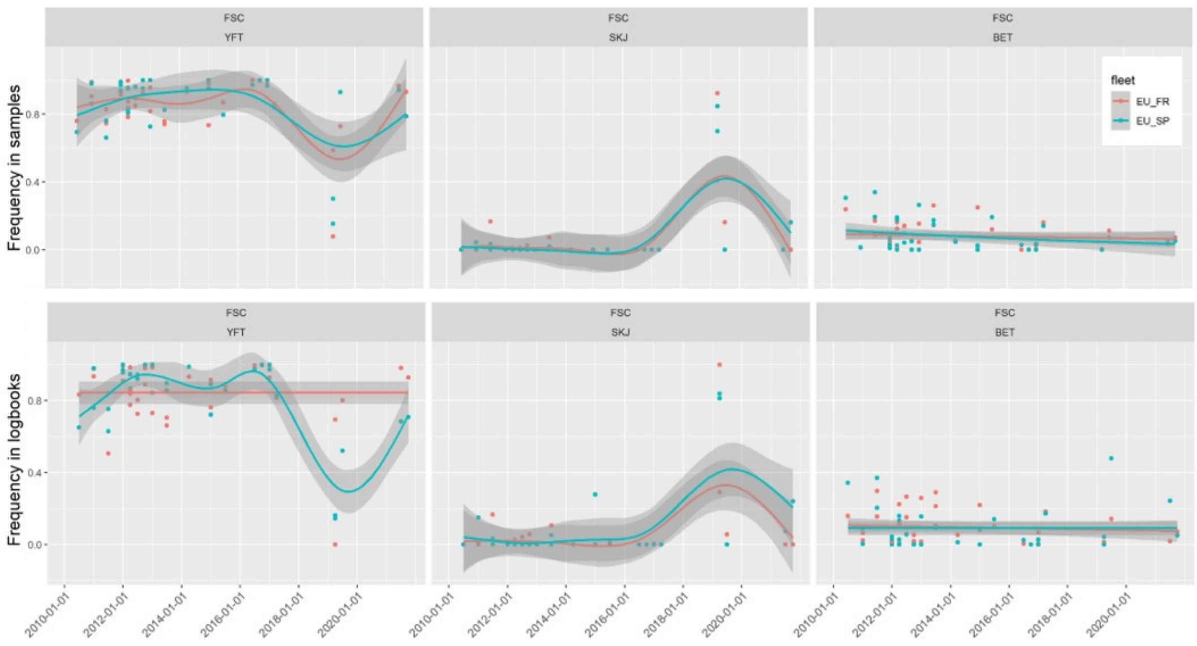

Figure 1b: Mean frequency of species by quarter and 5° squares in catch on free school, in samples at landing and in logbook declaration by species and fleet. Lines and shades represent the fitted value and 95%CI of a gam model.

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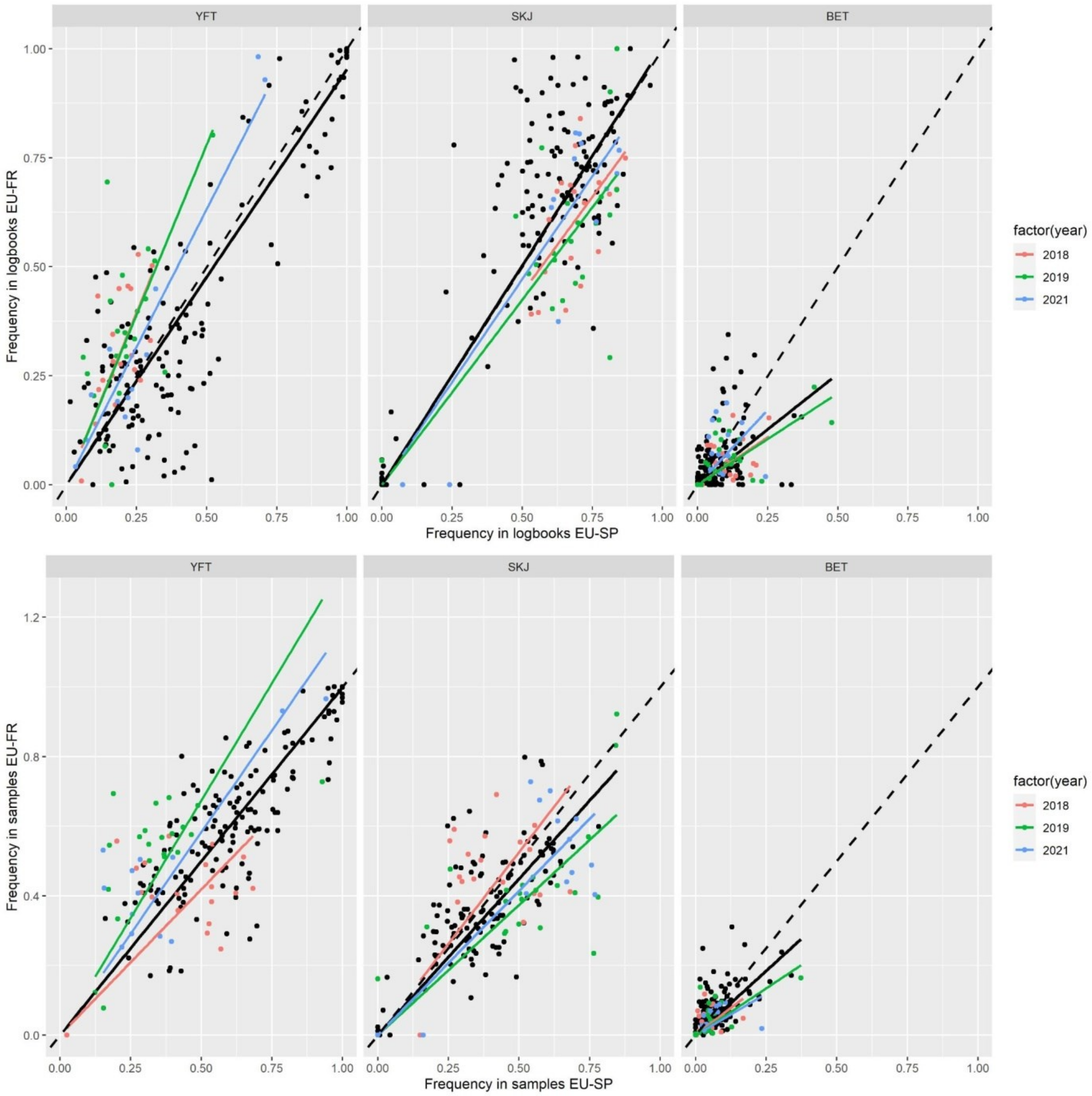

Figure 2: Mean frequencies of major tuna species in EU-FR in function of EU-SP by 5°squares on the 2010-2021. lines are simple linear models with a 0 intercept (all data in bold black). dashed lines are the line with a slope = 1 and intercept 0.