Testing differences in the associated and non-associated tropical tuna schools fisheries strategy of Spanish purse seine fleet

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Abstract

The main aim of present paper is to test the differences in the associated and non-associated tropical tuna schools fisheries strategy of Spanish purse seine fleet operating from Atlantic, Indian and Pacific Ocean. We hypothesize that the purse seine effort of the Spanish fleet revolves mainly around their own dFADs, and if among them the fishermen observe a YFT-free school, opportunistically, the fishermen will fish in it, and not as part of a directed fishing strategy. Our results indicate that the opportunistic fishing strategy for non-associated schools has only occurred in the Indian Ocean before the implementation of the YFT stock rebuilding plan.

1. INTRODUCTION

Spanish tropical tuna purse seiner fleet operate globally from Atlantic, Indian and Pacific Oceans. This fleet targeting mainly yellowfin tuna, *Thunnus albacares* (YFT), skipjack, *Katsuwonus pelamis* (SKJ), and bigeye, *Thunnus obesus* (BET) from tropical areas around of the world. Traditionally, Spanish tropical tuna purse seine fleet performed three different types of fishing modes: a) setting on free-swimming or non-associated schools (where mature yellowfin tuna YFT or skipjack SKJ specimens catch predominates); b) setting on schools associated with floating objects (where SKJ catch predominates, but with a significant presence of juveniles of YFT and BET); and c) setting on dolphin associated tuna schools (only in the eastern Pacific Ocean, where large YFT are caught).

The number of associated school sets (dFADs and logs) has been consistently increasing from the early period (1984–1990), with 31.9% of the sets directed at associated schools from Indian Ocean, to around of 76% of the sets in recent years (2008–2017 period). A maximum peak was recorded in 2018 (96%), and an 83% in 2019 (Báez et al., 2020a). Not only the number of sets has increased in recent years, but also the space-time frame between sets performed is rapidly approaching. Searching time between sets seems to be shorter than in previous years (Báez et al., 2020a,b).

Fishing non-associated schools imply active detection of schools, by direct observation (i.e. tuna breaking the ocean surface) and/or by tracking the activity of other animals (notably birds and marine mammals- particularly dolphins in the eastern Pacific Ocean), using technology devices such as marine telescopic binoculars, sonar or bird radars. Traditionally, this fishery was actively developed during certain periods of the year. However, Baez et al. (2020b) found that the probability of perform at sets on free-swimming increased in function to the density of FADs deployments by 5x5 grid in the Spanish purse seine fleet from Indian Ocean,. In this context, we wonder: What determines the non-associated school active fishing strategy? Do these findings imply a change in fishing strategy for the Spanish fleet? Is it a unique strategy from the Indian Ocean or is it widely used? Paraphrasing Shakespeare: Fishing on free-swimming school or not to fish, that is the question.

The main aim of present paper is to test the differences in the associated and non-associated tropical tuna schools fisheries strategy of Spanish purse seine fleet operating from Atlantic, Indian and Pacific Ocean. We hypothesize that the purse seine effort of the Spanish fleet revolves mainly around their own dFADs, and if among them the fishermen observe a YFT-free school, opportunistically, the fishermen will fish on this, and not as part of a directed fishing strategy.

2. MATERIAL AND METHODS

Fisheries data origin

The Spanish Ministry of Agriculture, Food and Environment, in close collaboration with the IEO (the Spanish Institution of Oceanography) and the Spanish tropical tuna purse seine fleet organizations ANABAC (National Association of Shipowners Tuna Freezers) and OPAGAC (Organization Associated Producers Large Tuna Freezers) implemented a FAD Management Plan (FADMP) in 2010 in the Spanish fleet. Indeed, the FAD logbook developed in the framework of the Spanish FADMP has been useful as a template for various t-RFMOs and member countries (Delgado de Molina et al., 2014, 2015). The FADs data have been obtained from the Spanish FAD logbook (Ramos et al., 2017 for a review of the FADs). We use the data from this program between the years 2015 and 2020 for the three oceans.

The YFT catches data are the values of catches corrected using T3 (Báez et al., 2020a; for a review of the Spanish case).

Statistical analysis

The possible causal effect of the dFADs deployment (used here as a abundance dFADs proxy) per 5x5 grid, quarter and year (dFADs_Abun) on the number of total sets per 5x5 grid, quarter and year, on YFT non-associated (i.e. TS_YFTSF), was analysed by using the dFADs_Abun (independent variable) versus a binary variable performed from TS_YFTSF. Thus, we assigned 0 when the number of sets observed a specific 5x5 grid, quarter and year, was leas to the mean of observed set per 5x5 grids, quarter and year (this mean varied by oceans, being 5 for the Indian, 4 for the Atlantic and 1 for the Pacific Ocean), in contrast, we assigned 1, when we observed a number of sets higher to the mean by Ocean. In a second analysis, we assigned 0 when the non-associated set was not observed in a specific 5x5 grid, quarter and year, in contrast, we assigned 1, when we observed at least one set non-associated in a specific 5x5 grid, quarter and year.

Logistic binary stepwise regression were performed to test whether the probability of obtaining a number of sets on free-swimming higher to the mean in a particular 5x5 grids, quarter and year increased in function to the number of dFADs deployments.

Model coefficients were assessed by means of an Omnibus test. The Omnibus test examines whether there are significant differences between the -2LL (less than twice the natural logarithm of the likelihood) of the initial step, and the -2LL of the model, using a Chi-squared test with one degree of freedom. In addition, the discrimination capacity of the model (trade-off between sensitivity and specificity) was evaluated with the receiving operating characteristic (ROC) curve. Furthermore, the area under the ROC curve (AUC) provides a scalar value representing the expected discrimination capacity of the model. The relative importance of each variable within the model was assessed using the Wald test (Hosmer & Lemeshow, 2000).

3. RESULTS

During the study period (years 2015-2020), the Spanish purse-seine tuna fleet in the three oceans has deployed a total of 121,333 FADs (62% correspond to the Indian Ocean, 33% correspond to the Atlantic Ocean and 5% correspond to the Pacific). The total number of sets performed by this fleet was 44,748 (61% correspond to the Indian Ocean, 35% correspond to the Atlantic and 4% to the Pacific Ocean). Table 1 shows the number of sets to free-swimming tuna schools and associated schools by year.

Table 1. Number of sets performed per Ocean, year and fishing mode. Key: FS, free-swimming school sets; FOB, associated school sets.

	Atlantic		Indian		Pacific	
Year	FS	FOB	FS	FOB	FS	FOB
2015	925	1796	1126	3109	114	367
2016	898	1847	818	3991	4	267
2017	413	2381	892	3354	1	254
2018	667	1863	171	4387	11	300
2019	631	1814	848	4190	7	227
2020	638	1705	447	4143	0	142

When we analyzed the probability of performed a number of non-associated sets higher to the mean by ocean per 5x5 grid, quarter and year in function to dFADs_Abun, we only found significant models in two consecutive years from the Indian Ocean (Table 2). However, when we analyze the probability of performed at least one non-associated set per5x5 grid, quarter and year in function to dFADs_Abun, we only found significant models in three consecutive years from the Indian Ocean (Table 3).

Table 2. Logistic regression results, after estimated the probability of setting a number of non-associated sets higher to the mean by ocean per 5x5 grid, quarter and year in function to dFADs_Abun. Key: NS, Not significant; NA, Not applicable.

	Atlantic		**Indian**		**Pacific**	
Year	**P**	**AUC**	**P**	**AUC**	**P**	**AUC**
2015	NS	NA	NS	NA	NS	NA
2016	NS	NA	**0.033**	**0.6**	NS	NA
2017	NS	NA	**0.006**	**0.53**	NS	NA
2018	NS	NA	NS	NA	NS	NA
2019	NS	NA	NS	NA	NS	NA
2020	NS	NA	NS	NA	NS	NA

Table 3. Logistic regression results, after estimated the probability of setting at least one non-associated set by ocean per 5x5 grid, quarter and year in function to dFADs_Abun. Key: NS, Not significant; NA, Not applicable.

	Atlantic		**Indian**		**Pacific**	
Year	**P**	**AUC**	**P**	**AUC**	**P**	**AUC**
2015	NS	NA	NS	NA	NS	NA
2016	NS	NA	**<0.001**	**0.53**	NS	NA
2017	NS	NA	**<0.001**	**0.53**	NS	NA
2018	NS	NA	**<0.001**	**0.52**	NS	NA
2019	NS	NA	NS	NA	NS	NA
2020	NS	NA	NS	NA	NS	NA

Indian Ocean is the only ocean where we found a relationship between the probability of setting on free-swimming schools and the number of FADs deployed. Table 4 shows the total caught by YFT (the main species caught in free-swimming schools) in tons, according to its commercial category (<10, 10-30,> 30 kg).

Table 4. Total YFT landing in t per year and commercial category from Indian Ocean. We indicate (gray) the values above the average. Key: category 1, <10 kg; category 2, 10-30 kg; category 3, >30kg. * Value close to the mean.

Year	Category 1	Category 2	Category 3
2015	24055,565	2970,538	25604,166
2016	28291,351*	1732,35	21465,084
2017	30496,121	1447,587	22569,144
2018	41277,606	115,488	17451,034
2019	25740,839	695,916	19104,515
2020	25735,263	641,589	15094,148
Mean per year	29266,1242	1267,24467	20214,6818

If we compare the mean by category for the years 2016-2017-2018 versus the years 2015-2019-2020 obtained for category 1 (<10 kg), significant differences (Man-Whitney U, P = 0.05).

4. DISCUSSION

The present study shows that the fishing strategy in the Indian Ocean is different from that of the other oceans, also in previous years the purse seine effort of the Spanish fleet revolves mainly around their own dFADs. Thus, the fisheries on free-swimming schools were opportunistic. However, during 2018, coinciding with the YFT catch restrictions in the framework of YFT Rebuilding Plan (IOTC Resolution 19/01 at present), this strategy changed. In fact the trend in the proportion of sets to free-swimming schools has declined throughout the study period. Currently, the Spanish fleet avoids setting on free-swimming schools, but in years prior to the restrictions, free-swimming schools might not be.

There are multiple attempts to estimate a standardized YFT CPUE (for example, Guéry et al., 2019). However, the relationship found here implies a change in fishing behaviour in recent years, at least for the Spanish fleet. Future attempts to estimate standardized CPUE should take into account current results.

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