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BUOY DERIVED ABUNDANCE INDICES OF TROPICAL TUNAS IN THE INDIAN OCEAN

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One of the most important technological developments that have been recently introduced by the purse seine fleet fishing with FADs are the satellite linked echo-sounder buoys. Their generalized use is causing rapid changes in the fishing strategy and fleet behavior (Lopez *et al.,* 2015), as they continuously provide fishers with near real-time information about the accurate geolocation of the FADs and the presence and abundance of tuna aggregations underneath. Consequently, search time (i.e., the time devoted to the searching of tuna concentrations), the metric traditionally used to reflect nominal effort, is no longer useful. Those changes in fishing strategies and technology make it difficult to evaluate the effective effort of the purse seine fisheries and have therefore hindered the reliable estimation of standardized purse seine CPUE indices (Gaertner *et al*., 2016). However, echo-sounder buoys have also the potential of being a privileged observation platform to estimate abundances of tunas and accompanying species using fishery-independent data (Dagorn *et al*., 2006; Moreno *et al*., 2015, Lopez *et al*., 2013). In a recent work Santiago *et al*. (2016) discussed methodologies to use the acoustic records of the echo-sounder buoys of the FADs as a potential source of fishery independent indices of abundance of tropical tunas. Following their approach, this document presents some preliminary results of an overall index of abundance of tropical tunas in the Indian Ocean from 2013 to 2015. This potential source of information may be used by scientist in future stock assessments.

Methods

The database used in this preliminary analysis has been provided by the purse seine vessel company Echebastar. It comprises information from January 2013 to July 2015 and corresponds to records collected by one of the echo-sounder buoy brands Echebastar's fleet uses. The total number of records reached around 3.4 million including 720,111 acoustic valid records used in the analysis (**Table 1**).

During the data cleaning process, records without acoustic information (records with only position, speed and velocity), outliers (invalid, impossible or extreme values of acoustic information), erroneous positions, time, or other awkward general variables were removed. Apart from the regular exclusions due to data inconsistencies, the following criteria were also considered to select data for further analysis:

- Vertical range of the buoy: acoustic information from the shallower layers, <25m were excluded. According to Lopez (2016), Robert *et al.* (2013), the potential vertical boundary between non-tuna species and tunas can be considered at about 25 m. Excluding the information of the first layers (i.e. up to 25m) from the analysis the noise potentially corresponding to the non-tuna species biomass associated to the DFAD was unconsidered.
- Bottom depth: Using high resolution bathymetry data (British Oceanographic Data Centre, UK, www.gebco.net), acoustic records from buoys located in areas shallower than 200 m were excluded, as FADs that have drifted to shallow coastal areas may provide false positives.
- Speed of the buoy: Satellite linked buoys automatically records information on their trajectory values (speed and bearing). As buoys are usually turned on minutes or hours prior to their deployments and are turned off after an uncertain period when retrieved from the sea, some of their acoustic measurements could be compromised and correspond to false positives as well. In our dataset, values bigger than 6 knots were excluded.

The model used assumes that the signal from the echo-sounder is proportional to the abundance of fish: $BAI_t = \varphi \, . B_t$, where BAI_t is the Buoy-derived Abundance Index , φ is the coefficient of proportionality and B_t is the abundance in time t.

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To ensure that φ can be assumed to be constant (i.e. to control the effects other than those caused by changes in the abundance of the population), the nominal measurements of the echo-sounders were standardized using a Generalized Linear Mixed Modelling approach. Because of the significant proportion of records with zero abundance (54.5%) a Delta method was used. The Delta model estimates the predicted abundances as the result of two processes: i) the probability of encounter tropical tuna in the acoustic observations (proportion of positives) and, ii) the mean relative abundance given that a positive observation has been realized. Then the estimated Buoy-derived Abundance Indices (BAI) are the product of these two processes.

The following factors were considered in the analyses: year-quarter[2013Q1 to 2015Q2], area ["north" (LAT >= 10), "east"(LAT < 10 & LAT >-15 & LON<=65), "west" (LAT < 10 & LAT >-15 & LON>65), "Channel" (LAT < -15 & LON<50) and "South" (LAT < -15 & LON>50)], time of the day [UTC, <=06:00 and >06:00], days since deployment[3] [<=30, 30<days<=90, >90], buoy speed [<=1, 1<vel<=2, >2] and SST[4] [<=28, 28<SST<=29, 29<SST<=30, >30]. Some of these factors should be corrected in further analysis: UTC to time zone correction, days since deployment/visit to the FAD and try to incorporate new layers of information, i.e. catch and catch composition.

Interactions among factors were also evaluated. If an interaction was statically significant, and included the year-quarter factor in particular, it was then considered as a random interaction(s) within the final model

Preliminary results

The results of the model deviance are shown in **Table 2**. The most significant explanatory factors for the binomial model on the proportion of positives included area, time of the day, days since deployment, speed and the interactions year-quarter*area and year-quarter*vel. The most significant explanatory factors for the lognormal model on the positive records were year-quarter, area, days since deployment, speed and the interaction year-quarter*SST. Interactions were considered as random.

The estimates of the final Delta model are provided in **Figure 1**. The Buoy-derived Abundance Index (BAI) shows no clear trend. The CVs remain relatively stable (between 13-49%) during the whole time series.

With this document, we present some very preliminary results to remotely estimate a BAI for Indian Ocean tropical tunas. We will continue developing this index including data from more years and the information coming from other brands not already integrated in the current analysis, as well as refining the analysis and including other potentially significant variables. We greatly appreciate the collaboration of the Echebastar fleet who kindly provided the data recorded by their own buoys and we hope that other companies will join the project soon. Acoustic data from the echo-sounder buoys of the FADs can provide significant information to further complement current stock assessments of tropical tuna fisheries, assisting scientist and improving the knowledge between the biomass-CPUE relationship while providing indices less dependent on catch data or less affected by changes in the fishing technology or the fishing effort.

[3] "Deployment" does not correspond to a real deployment; it refers to the first appearance of the buoy in the data set.
[4] Weekly 1ºx1º NOAA_OI_SST_V2 data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA, from their web site at http://www.esrl.noaa.gov/psd/

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Table 1. Number of vessels operated by the Echebastar fleet, total number of records and acoustic records used in the analysis

	2013	2014	2015	TOTAL
VESSELS	6	6	6	6
NUMBER OF RECORDS	980,332	1,555,738	818,491	3,354,561
ACOUSTIC RECORDS	186,716	338,803	194,592	720,111

Table 2. Deviance tables for the binomial (top) and the lognormal (bottom) components of the Delta-lognormal model. Significant (p<0.05) factors and interactions of total deviance are highlighted.

a) **Model: binomial, link: logit** [Response: posit]

	Df	Deviance	Resid. Df	Resid. Dev	Pr(>Chi)		
NULL			635066	877751			
YEAR_QUARTER	9	678.8	635057	877072	< 2.2e-16	***	2%
AREA	4	2044.3	635053	875028	< 2.2e-16	***	5%
HOUR	1	6501.7	635052	868526	< 2.2e-16	***	15%
DAYS	2	5176.2	635050	863350	< 2.2e-16	***	12%
VEL	2	18072.7	635048	845277	< 2.2e-16	***	42%
YEAR_QUARTER:AREA	36	2765.2	635012	842512	< 2.2e-16	***	6%
YEAR_QUARTER:HOUR	9	367.7	635003	842144	< 2.2e-16	***	1%
YEAR_QUARTER:DAYS	18	1277.8	634985	840866	< 2.2e-16	***	3%
YEAR_QUARTER:VEL	18	2788.1	634967	838078	< 2.2e-16	***	6%
AREA:HOUR	4	399.2	634963	837679	< 2.2e-16	***	1%
AREA:DAYS	8	134.9	634955	837544	< 2.2e-16	***	0%
AREA:VEL	8	1359.6	634947	836184	< 2.2e-16	***	3%
HOUR:DAYS	2	435.3	634945	835749	< 2.2e-16	***	1%
HOUR:VEL	2	49.7	634943	835699	1.615E-11	***	0%
DAYS:VEL	4	1254.2	634939	834445	< 2.2e-16	***	3%

b) **Model: gaussian, link: identity** [Response: log(ECHO)]

	Df	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)		
NULL			297070	710708				
YEAR_QUARTER	9	12509	297061	698199	841.497	< 2.2e-16	***	6%
AREA	4	10159	297057	688040	1537.699	< 2.2e-16	***	5%
HOUR	1	502	297056	687538	304.086	< 2.2e-16	***	0%
DAYS	2	44868	297054	642670	13582.867	< 2.2e-16	***	20%
VEL	2	109874	297052	532795	33262.05	< 2.2e-16	***	50%
SST	3	1717	297049	531079	346.44	< 2.2e-16	***	1%
YEAR_QUARTER:AREA	36	6282	297013	524797	105.65	< 2.2e-16	***	3%
YEAR_QUARTER:HOUR	9	1872	297004	522925	125.924	< 2.2e-16	***	1%
YEAR_QUARTER:DAYS	18	1988	296986	520937	66.877	< 2.2e-16	***	1%
YEAR_QUARTER:VEL	18	6047	296968	514890	203.401	< 2.2e-16	***	3%
YEAR_QUARTER:SST	27	18959	296941	495930	425.153	< 2.2e-16	***	9%
AREA:HOUR	4	526	296937	495405	79.558	< 2.2e-16	***	0%
AREA:DAYS	7	269	296930	495136	23.245	< 2.2e-16	***	0%
AREA:VEL	8	1484	296922	493652	112.297	< 2.2e-16	***	1%
AREA:SST	5	198	296917	493455	23.92	< 2.2e-16	***	0%
HOUR:DAYS	2	443	296915	493011	134.207	< 2.2e-16	***	0%
HOUR:VEL	2	547	296913	492465	165.48	< 2.2e-16	***	0%
HOUR:SST	3	98	296910	492367	19.807	7.839E-13	***	0%
DAYS:VEL	4	727	296906	491639	110.096	< 2.2e-16	***	0%
DAYS:SST	6	423	296900	491216	42.723	< 2.2e-16	***	0%
VEL:SST	6	853	296894	490363	86.038	< 2.2e-16	***	0%

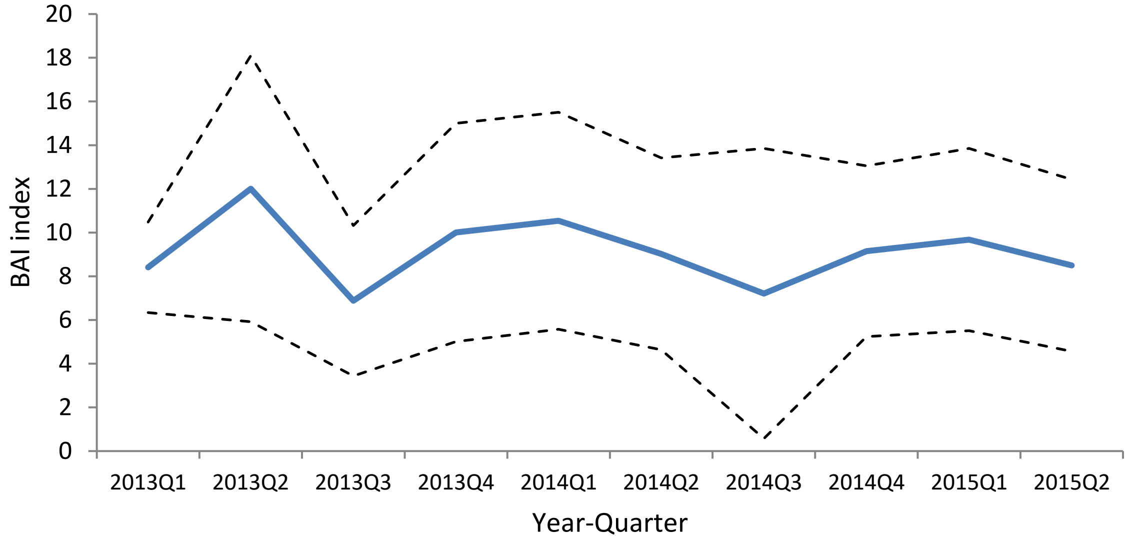

Figure 1. Time series of the quarterly values of the Tropical Tuna Buoy-derived Abundance Index (BAI) for the period 2013Q1-2015Q2. The upper and lower confidence intervals are also shown.