MAPPING TUNA OCCURRENCE UNDER DRIFTING FISH AGGREGATING DEVICES FROM FISHER'S ECHOSOUNDER BUOYS IN INDIAN OCEAN

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SUMMARY

Echosounder buoys data obtained from instrumented drifting FADs represent an unprecedented source of information for assessing the spatio-temporal distribution of tropical tuna. Using machine learning algorithms, we transformed acoustic data collected from one of the main echosounder buoys models used by the French purse seine fleet (M3I) into presence/absence of tuna aggregations, enabling the measurement of the amount of inhabited FADs on a given spatio-temporal strata. This paper presents the spatial and temporal distribution of the proportion of drifting fish aggregating devices (DFADs) occupied by tuna aggregations relative to the total number of FADs in the Indian Ocean on a monthly basis, on a 5° grid for year 2016. The perspectives opened up by this new approach in improving estimates of abundance of tropical tuna populations are discussed.

KEYWORDS

Echosounders, drifting fish aggregating devices (FAD), Tropical tunas, Abundance

1. Introduction

Echosounder buoys equipping drifting fish aggregating devices (DFADs) in tropical waters can provide accurate real-time information on the presence/absence of tuna underneath (Baidai et al., 2018). This data can offer an unprecedented opportunity to understand the spatial distribution and behaviour of tropical tuna (Moreno et al., 2016). Indeed, data collected under DFADs are less affected by the typical limitations that characterize fisheries-dependent data. Not only this data allows to study the association dynamics of tuna at the FADs, but also can provide information on the spatial distribution of tuna within regions that are not targeted by the tuna fisheries. Currently, there is an increasing focus on the potential that echosounder buoys data offer in the study of marine pelagic communities (Lopez et al., 2017a, 2017b, 2016; Moreno et al., 2016; Orue et al., 2019a) and the development of fisheries-independent indices of abundance for tuna species (Capello et al., 2016; Santiago et al., 2019). In this study, using a recently-developed algorithm for converting the acoustic signal provided by echosounder buoys into presence/absence of tuna aggregation (Baidai et al., 2018), we propose to examine the distribution of associated tuna populations from data collected on DFADS. We here present spatial maps depicting the proportions of DFADs occupied by tuna aggregations in 2016, at the

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scale of the Indian Ocean. Building these maps constitutes an essential step towards the construction of novel abundance indices for tropical tuna based on the echosounder buoys data.

2. Material and methods

2.1. Data Collection

The study relies on data collected by 10 827 echosounder buoys from the M3I model (Marine Instruments, Nigrán, Spain, www.marineinstruments.es), used by the French purse seine fleet in the Indian Ocean during 2016. M3I buoys are equipped with GPS positioning device and an echosounder powered by solar panels, (frequency 50 KHz, power 500 W, beam angle of 36° – see **Figure 1**), which provides acoustic information processed into discrete indices ranging from 0 to 7, per 3-meter layer over a detection depth of 150 meter (50 layers, the first two corresponding to the transducer blank zone).

2.2. Data cleansing process

Data were first pre-processed according to the procedure described by Baidai et al. (2017) and (Orue et al., 2019b). This process led to removal of aberrant location data (related to failures in satellite communication), unreliable acoustic data recorded under low voltage conditions, and data recorded on land or at shallow positions (depth less than 150 meter, the echosounder detection range). It also allowed the detection and elimination of data from buoys emitting on board ships, using a simple rule algorithm based on the characteristics of buoy trajectories (speed and acceleration), described in detail by Baidai et al. (2017). The total number of buoys that was retained after filtering was 10 386.

2.3. Classification of tuna presence-absence

Acoustic data collected by the M3I buoys was translated into presence or absence of tuna aggregation, using the methodology proposed by Baidai et al. (2018). The approach mainly consists in two stages. Acoustic data from a full day of sampling is standardized into a 6 × 6 matrix referred to as "daily acoustic matrix", with rows corresponding to cluster of layers (resulting from clustering analysis) and columns to a 4-hour time period of samplings. Then, the classification of these matrices into presence/absence of tuna is carried out, using random forest algorithms trained from acoustic data recorded on DFAD deployments and visits without fishing sets (labelled as tuna absence) and positive fishing sets (labelled as tuna presence). A final post-processing step to improve the predictions made by the classification models was also applied. Short-term predictions (single days of presence or absence) were considered unlikely, and attributed rather to misclassification.

2.4. Buoy density

Information on density of buoys used in this work was stratified by month and grid cells of 5°×5°, by summing the total number of operational buoys recorded per day over the entire month in each grid and dividing by the total number of days in the month.

2.5. Proportion of DFADs inhabited by tuna aggregation

A similar approach was used to assess the proportion of occupied DFADs. In each grid cell, daily proportion of occupied DFADs expressed as the number of DFADs classified as occupied by a tuna aggregation, divided by the total number of DFADs was calculated. Monthly averages were then estimated, excluding days with less than 10 DFADs in the grid cell.

3. Results and Discussion

The spatial distribution of M3I buoys used by French seiners in the Indian Ocean was highly variable, potentially affected by ocean circulation and the seasonality of FAD deployments typical of this ocean. At the ocean-wide scale, there was an average of 24 FADs (standard deviation: 43.34) per day and 5° square (**Figure 3**), with density peaks that could reach more than 200 FADs in the same space-time unit, during the months of December to April, in the Southern Hemisphere, and in July, near the African coasts.

At the ocean scale and on the considered year, the daily average of DFADs occupied by tuna aggregation was 35.4% (standard deviation: 16.82%). This value was about two times lower than those found in the Atlantic Ocean by a recent similar study carried out on the same buoy model (62%) (Baidai et al., 2019). Apparently, the regions having lower DFAD densities appeared to show the highest proportion of occupied FADs. However, some counterexamples could be also observed, e.g., in the central Indian Ocean region (0-10°S, 55°-75°E) during April, where a high proportion of occupied DFADs was observed in the presence of a high DFAD densities. The Arabian Sea, in the northern part of the ocean, having relatively lower FAD densities than in other areas, was characterized by high proportions of DFADs occupied by tuna aggregations during the months of March to May (**Figure 4**). Also, the months of April and May appeared to show a higher homogeneity among the proportion of FADs occupied across the Western Indian Ocean.

Analysing the precise spatial and temporal patterns of the proportion of occupied FADs at the scale of the ocean, as well as understanding how this proportion depends on the environmental features (including the total number of FADs) is key to exploit this data in terms of indicators of tuna abundance. Since the dataset used in this study represents only a limited sample of all FADs observed in the single year 2016, it is important to avoid drawing any conclusions about the patterns observed. The same approach should be applied on other years and larger datasets to understand the observed patterns and confirm their persistence. Also, it will be interesting to compare the observe patterns with the observed seasonality of the tuna fishery, both for the industrial purse-seine fisheries operating offshore and the semi-industrial/artisanal fisheries operating within the EEZ of the coastal countries. Finally, the sensitivity of the proportion of occupied FADs relative to the total number of FADs available in each grid cell should be evaluated. Despite its exploratory nature, this study defines a new pathway towards the derivation of an abundance index for tropical tuna based on the accurate estimation of tuna presence/absence obtained from the echosounder buoys. When related to catch and effort data on DFADs, these maps can provide a new tool for assessing the proportion of associated tuna populations under floating objects.

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Figures

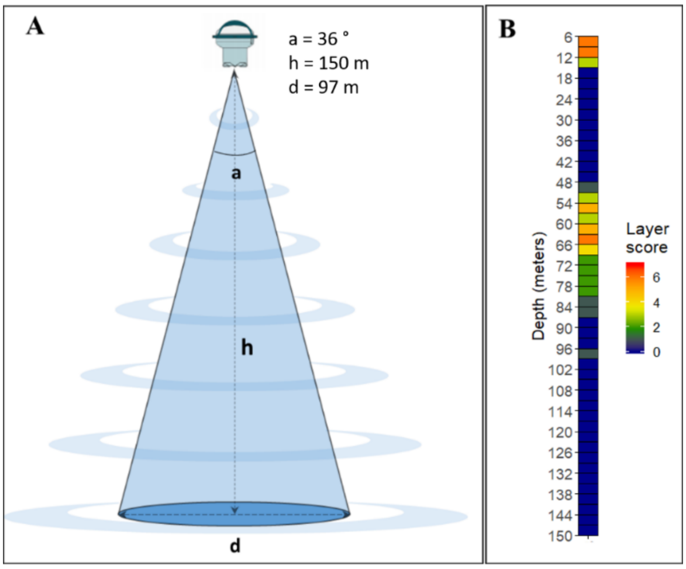

Figure 1. Technical specifications of the Marine Instruments M3I echosounder buoy. (A): beam width or cover angle (a), depth range (h), and diameter (D) at 150 m; (B): example of an acoustic sample.

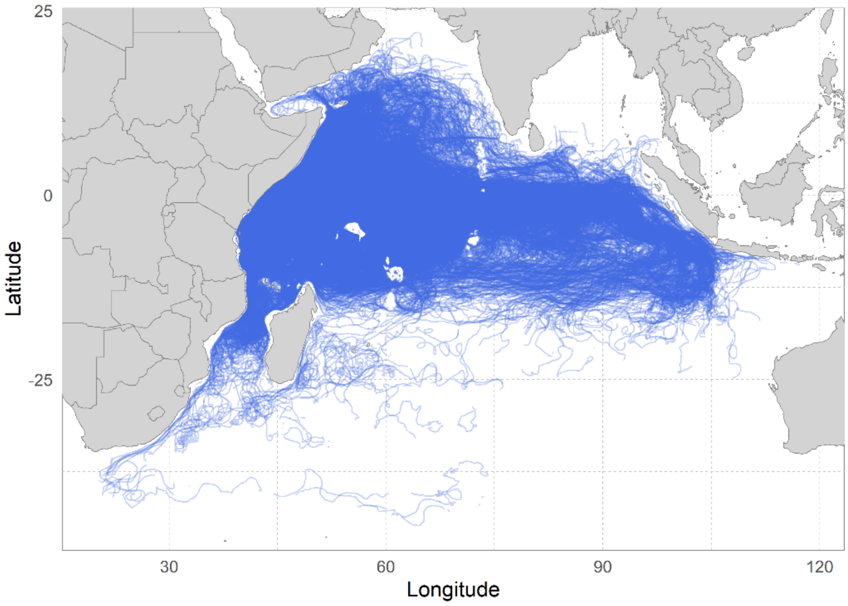

Figure 2. Trajectories of M3I buoys used by the French fleet of purse-seiners during 2016 in the Indian Ocean.

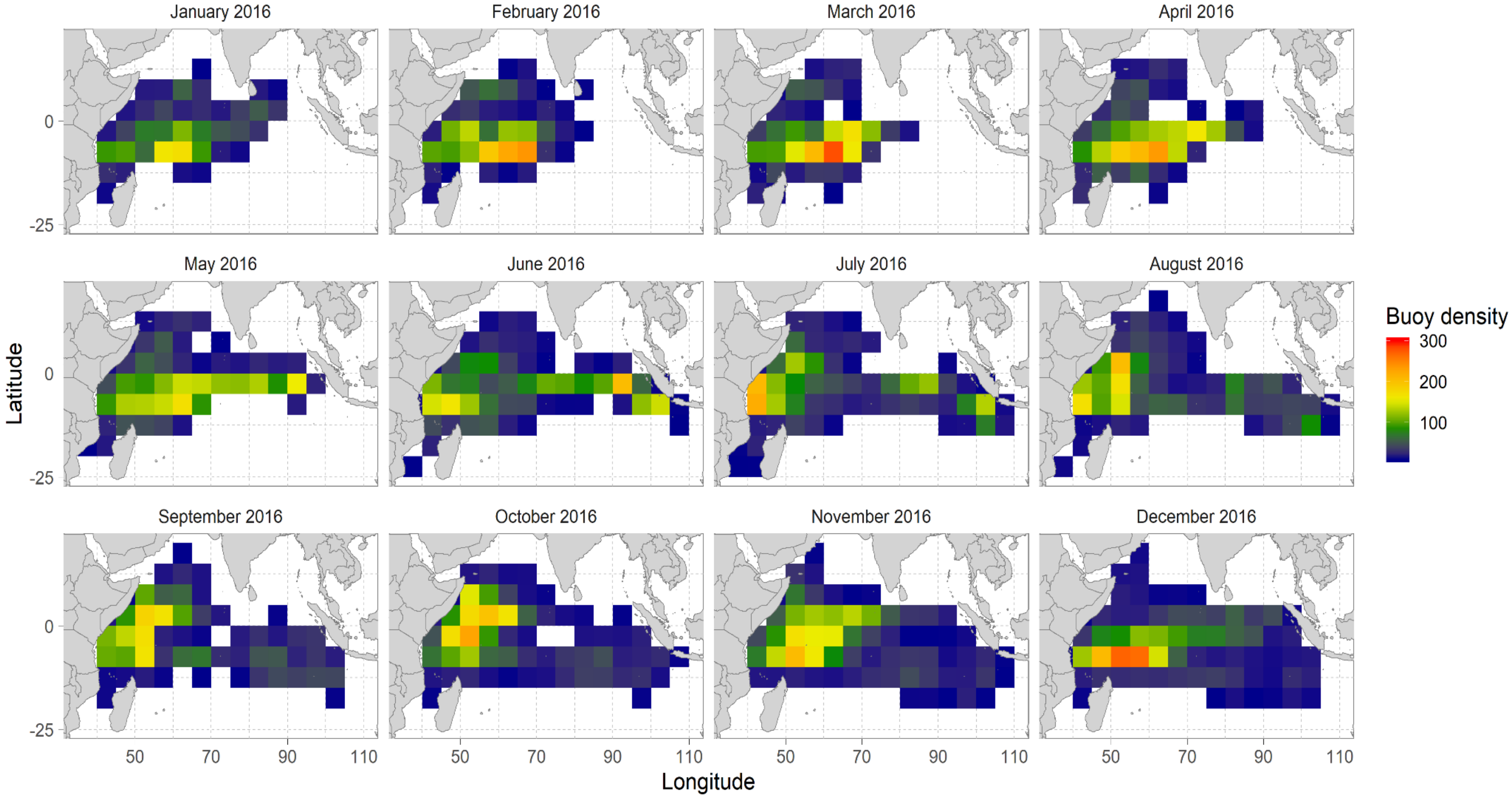

Figure 3. Monthly average number of M3I echosounder buoys available in the database during 2016 in the Indian Ocean per 5° square.

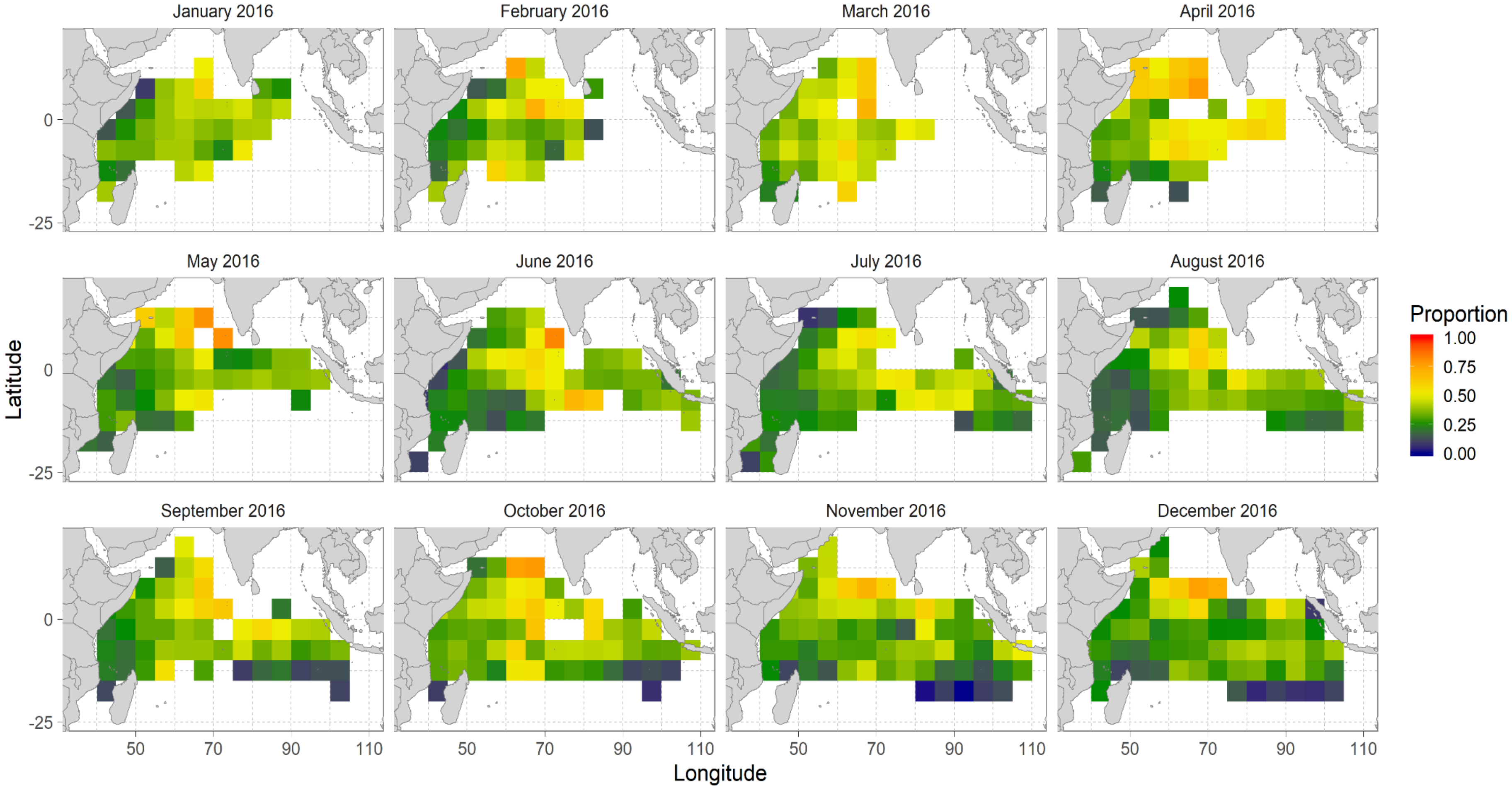

Figure 4. Monthly average proportion of drifting FADs occupied by tuna per 5° square in 2016 in the Indian Ocean.