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Misidentification of free school tunas in the AOTTP database: Issues to identify fish-attractive seamounts

Akia Sosthène [1, 2, 3, *], Perez Ilan [1, 2], Guéry Loreleï [1, 2], Gaertner Daniel [1, 2]

[1] MARBEC, Univ Montpellier, CNRS, Ifremer, IRD, Sète, France
[2] Institut de Recherche pour le Developpement (IRD), UMR MARBEC, 87 Av. Jean Monnet, CS 30171, Sete Cedex 34203, France
[3] Centre de Recherches Océanologiques (CRO), Abidjan, Cote d'Ivoire

* Corresponding author : Sosthène Akia, email adress : sosthene.akia@ird.fr

ilan.perez@ird.fr ; lorelei.guery@cirad.fr ; daniel.gaertner@ird.fr

Abstract :

Several studies have shown that the school type at release can significantly influence the amplitude of the movements of a tagged fish. In particular, it has been shown that seamounts can have a retention effect on tuna, suggesting that their migration patterns may differ significantly depending on the school type at release. However, many tuna releases near well-recognised mid-Atlantic seamounts have not been well coded in the ICCAT-AOTTP database. In addition, the 'Free School' type modality was often assigned to individuals tagged or recaptured near a seamount. This paper explored different criteria for identifying seamounts in the tagging database with the aim to correct the questionable coding of certain school types. To do this, we first investigated how to identify "attractive" seamounts based on their morphology and the distribution of catch data from the European purse seine fleet. This conceptual approach led to several problems discussed in this paper and from which we proposed a simple recoding method using the literature results. The correction criteria made it possible to correct the school type of 4.9% of several records of tagged tuna during the ICCAT AOTTP programme.

Highlights

► The AOTTP data base contains potential misreported free school individuals. ► The height and depth of a seamounts can't explain the catch amount around them. ► A simple correction of the AOTTP database can be done with literature.

Keywords : Seamounts, Tropical tunas, Tagging, Purse seine fisheries, Tuna attractivity

1. Introduction

According to Staudigel et al. (2010), a seamount can be defined as *"any geographically isolated topographic feature on the seafloor taller than 100 m, including ones whose summit regions may temporarily emerge above sea level, but not including features that are located on continental shelves or that are part of other major landmasses"*. Oceanic and Neritic seamounts are major biomes and crucial biodiversity hotspots (Clark et al., 2010; Morato et al., 2010a). The physical features near seamounts, such as Taylor columns, generate an important nutrients input and retention to the water column near seamounts (Brainard, 1986; Chapman and Haidvogel, 1992; Genin and Boehlert, 1985; Morato et al., 2010a). This induces primary production, attracting primary consumers as well as big predatory fishes, making some seamounts important for several fisheries [e.g. Seamount in Hawaïi, (Holland and Grubbs, 2007); Coco de Mer in Seychelles, (Marsac et al., 2014)] and leading some of them to be threatened by overexploitation (Clark and Koslow, 2007).

The attractiveness of seamounts to highly migratory species such as tuna has been described in the past (Dubroca et al., 2014; Fonteneau, 1991; Holland and Grubbs, 2007). Accurate identification of the tuna-seamount association could avoid biases in analysing stock structure based on tuna movements between areas and is therefore crucial for tuna conservation and ecological studies. However, in the Atlantic Ocean Tropical Tuna Tagging Programme (AOTTP) database, the free school modality of the school type variable was often assigned to individuals assumed to be released or recaptured near a seamount. Identifying and correcting this miscoding of AOTTP data is necessary because it can bias the analyses made using these data. Therefore, this study explores a methodology to correct the misidentified school types associated with release and recapture data.

Given the importance of the issue, we developed a 6-step methodology to identify the characteristics of seamounts that would make them productive and essential to aggregate tuna around them. In order to identify the attractive seamounts, we described first the methodology developed, then applied this methodology with the data available on the ICCAT web site. We highlighted the steps that were not explored due to the availability of certain data types and proposed possible issues to deal with this problem.

2. Presentation of the theoretical methodology

The main objective of this study is to present a methodology to identify the characteristics of seamounts that make them attractive for tunas. That involves (1) clustering the seamounts based on their physical characteristics and (2) identifying, from commercial fisheries data or scientific campaigns at-sea, those around which abundant tunas have been observed. For this, six steps have been identified as follows:

2.1 Selection of criteria for sampling the seamounts in the study area.

As the study links the characteristics of the seamounts to fishing activities, this stage consists of selecting all the seamounts identified in the fishing zone. In this study, the fishing area considered is the distribution area of the sets made by French and Spanish purse seiners in the Eastern Atlantic Ocean. According to the literature in the same study area, 1.000 m depth is a threshold for seamounts influence on pelagic communities (Fonteneau, 1991), so we deleted seamounts with depth greater than 1.000 m from the surface. Therefore, from this database, we selected only seamounts for which it was possible to identify at least 100 positive sets (i.e., a successful set that caught the targets species within a radius of 100 km from the summit of the seamount) over the entire study period.

2.2 Analysis of fishing activity and tuna abundance around seamounts.

We used the effort and catch data for analysing the abundance around each seamount. At this stage, it is assumed that all seamounts around which there has been fishing activity are a priori attractive. The distances between the catch observation and the seamount summit has been divided into 20 classes of 5 km intervals, from 0 to 100 km. Each cell with data was then assigned to one of the distance classes, and catches were averaged for each class. The variability of the abundance, as a function of the distance between the observation cell and the seamount summit, allows analysing the tuna abundance around each seamount [as proposed by Morato et al. in (Morato et al., 2010b)]. Furthermore, it allows extracting information on its attractiveness and possibly the range of action in case of attractiveness. This analysis is coupled with a study of the distribution of fishing effort around the seamount to assess whether it is recognised by fishermen as a hotspot of abundance and consequently visited frequently. The results of the study of the evolution of catches and fishing effort make it possible to identify some characteristics of attractive and/or active seamounts and those that are not.

2.3 Creation of clusters of seamounts according to their height and depth

Having selected the height and depth of the seamounts as the physical structures most likely to explain their attractive behaviour, we split all the sampled seamounts into clusters. The clustering is done by using a hierarchical classification (with function hclust of the R package "stats" implementing the Ward2 methods). Applying the results of the previous step to this one allows to discriminate the clusters with the least attractive physical characteristics from those with the most attractive ones.

2.4 Analysis of the attractiveness of seamounts by cluster

After having separated the seamounts in two groups, this step allows us to define the physical characteristics of non-attractive seamounts definitively. For this purpose, we considered that a set of characteristics defining a seamount cluster can confirm the attractiveness of seamounts if there is at least one attractive seamount in the cluster. On the other hand, we considered that a set of features defining a seamount cluster cannot confirm the non-attractiveness of non-attractive seamounts in the absence of no attractive seamount in the cluster.

2.5 Exploration of other discriminant factors on the attractiveness of seamounts

As the methodology aims to define the characteristics of the attractive seamounts to correct the AOTTP database, it is essential to know why the attractiveness of seamounts belonging to the same cluster may vary. Furthermore, this phase aims to explore the integration of other explanatory factors to the analysis and test their contribution to this heterogeneity. Morato et al. (2016) summarised that the incorporation of oceanographic data could be of paramount importance to unveil many paradigms of seamount ecology. This phase addresses the issue of integrating all of these potential factors with previous analyses to refine the results.

2.6 Synthesis of the characteristics of an attractive seamount.

The last phase of this methodology aims to synthesise all the characteristics of an attractive seamount and test their level of attractiveness through a sampling of scientific fishing survey data.

3. Application of the methodology

The application of this methodology requires three sources of data: (1) catch and effort data, (2) data from the AOTTP tagging programme and (3) environmental data. In the following, we will present the data used, the application of the six steps of this methodology, the difficulties encountered, and possible ways to overcome them in future analyses.

3.1 Data

3.1.1 Atlantic Ocean Tropical Tuna Tagging Programme (AOTTP) data

The AOTTP conducted a series of tagging campaigns in several regions of the tropical Atlantic Ocean from July 2016-2020. The tagging operations were led by bait boats or small vessels dedicated to recreational activity, while the recapture was done mainly through commercial surface fisheries. A school type code was assigned to each release and recapture event, depending on whether the tuna were released/recaptured near a drifting Fish Aggregating Device (DRF), an anchored FAD (ANF), a seamount (SMO), associated with a boat (BAS) or in a free school (FSC) **(Fig. 1).**

3.1.2 French and Spanish purse seine fisheries data

The French and Spanish purse seine operational catch and effort data were supplied by the French Tuna Observatory (Ob7) and the Spanish Oceanographic Institute (IEO). These data contain the geographical location and associated catch composition for each purse seine set of the EU tuna fleets between 2007 and 2019. Some of these are summaries of a few sets where the fishing position is not as precise. We removed this kind of data for ease of interpretation, and only the data for ‘a single set’ have been retained. The catch's location and composition are declared by fishing set in the EU purse seine fisheries data. However, sometimes the fishers aggregate many sets in one line in the database. When several purse seine sets are aggregated in the database, the information on catches and localization of the result set is the average of all the sets, leading to inaccurate positions. However, we need precise locations for this study, so we only used non-aggregated sets called "single set data". After filtering the data, the resulting dataset contained 108 014 sets, mainly concentrated in the Gulf of Guinea and off Mauritania (**Fig. 2**).

3.1.3 Seamounts data

Yesson et al. (2011) made a list of knolls and seamounts (available on the PANGEA website) based on the topological features computed from a global 30 s (~1 km) bathymetry grid. From this list, we used the criteria suggested by Staudigel et al. (2010) to filter out all the knolls that are not considered to have the physical particularity of a seamount. In the selected area (-30° E to 25° E Longitude; -30° N to 25° N Latitude), 1151 seamounts were identified **(Fig. 3).** The median height from sea bottom to the peak was 1476 m, and the median peak depth was -2384 m (**Fig. 4; Fig. 5**, respectively).

3.1.4 Other factors of seamounts attractiveness

This study requires data on possible factors that could explain the attractiveness of seamounts. Therefore, we are interested in data related to environmental conditions (e.g. biotic and abiotic variables, currents) and other natural or artificial tools (FADs) that can affect tuna aggregation behaviour.

3.2 Application

Our initial intention was to apply this methodology to correct the coding of the misidentified school types, but the quality of the data did not allow us to comply with all the six steps proposed. We, therefore, drew on the results of work in the literature on the subject to correct the data using a more straightforward method. This method is presented and applied in section 4; however, we present the steps of our methodology that we were able to process and the few difficulties encountered here.

3.2.1 Selection of criteria for sampling the seamounts in the study area.

We were able to sample the seamounts in the study area by cross-referencing all the seamounts identified in the Atlantic Ocean (**Fig. 3**) with the catch data (**Fig. 2**), taking into account the seamounts for which it was possible to identify at least 100 positive sets over the entire study period within a radius of 100 km around their summit. Of the 1151 seamounts identified, only 15 were sampled based on the above criteria.

3.2.2 Analysis of fishing activity and tuna abundance around the seamounts

In this analysis, we planned to measure the abundance of tuna from the biomass caught. Indeed, we are more interested in the presence of tuna aggregated on seamounts than in fishermen's yields. However, one major difficulty that impacted the full implementation of this step was the lack of sufficient data to analyse the abundance of tuna around seamounts. Indeed, some seamounts were rarely visited during the entire study period, which considerably reduced the number of seamounts selected from 1151 to 15. To remedy this problem in future studies and to better analyse the abundance of tunas in the vicinity of seamounts, we propose the implementation of scientific acoustic cruises targeting seamount ecosystems with well-structured and appropriate protocols or integrating various data sources concerning other tuna fisheries in the area.

3.2.3 Clustering of seamounts according to their height and depth

Hierarchical ascendant classification (with function hclust of the R package “stats” implementing the Ward2 method) was applied to create clusters of seamounts by height and depth classes. Following this step, we split the identified seamounts into two groups: the seamounts retained after the filters on fishing effort and the seamounts abandoned because of the scarcity of catches made within a radius of 100 km. However, the small amount of data did not allow us to exploit the results of this stage.

3.2.4 Analysis of the attractiveness of seamounts by cluster

The analysis of the attractiveness of the seamounts by cluster corresponds to a synthesis of the analyses of stages 2 and 3 on the selected seamounts. This step, which aims to identify clusters in which some seamounts have physical characteristics that make them attractive compared to others with unattractive characteristics (by considering the relationship between tuna catches and seamounts characteristics such as Depth or Height as shown in **Fig. 6** and **Fig. 7**), could not be carried out thoroughly. The significant difficulty encountered in this step was related to the dificulty to evaluate the own attractiveness of a specific seamount belonging to a cluster. We identified some regions with numerous seamounts very closed (less than 50 km) to each other (e.g. Machucambo Seamount on the Sierra Leone Rise, **Fig. 8-A and Fig. 8-B**). Such situations distort the attribution of the effect of one seamount cluster to another. To avoid this problem, we propose identifying the seamount networks and eliminating them from the analysis. As our data is insufficient, this further elimination has reduced the data available for further analysis again. The identification of these networks was made by creating a 100 km buffer around each seamount. Seamounts whose buffers intersect are considered members of the same network, and those that do not intersect any other seamounts are considered isolated seamounts. The remainder of the study would be carried out on the isolated seamounts, and the results could be confirmed by extending the results to seamount networks to confirm the conclusions obtained on the isolated seamounts. This step would make it possible to highlight the disparity in the attractiveness of seamounts within the same cluster and to justify the need to explore other attractiveness factors.

3.2.5 Exploration of other factors of discrimination between attractive and unattractive seamounts

For this fifth step, we selected environmental data such as sea surface temperature (SST), currents and data relating to the bathymetry around seamounts and the presence of other school types with tuna aggregation capacity such as FADs in order to analyse the existence of possible factors that could explain the disparity in the attractiveness of seamounts within the same cluster. However, we could not deploy the various analyses planned for this step due to not applying the previous steps.

4. Proposal to correct the AOTTP database

Due to problems encountered in applying our methodology, we proposed correcting the coding of FSC tuna whenever release or recapture was carried out in the vicinity of a seamount. We drew on the results of work in the literature to do this, even if they remain results that need improvement. Several authors have studied the relationship between tuna and seamounts, including work on the maximum radius of influence of an attractive seamount and its physical characteristics, such as the depth limit of the peak. For the radius of influence, Fonteneau (1991) showed an average radius of influence of 11.6 km, Morato et al. (2008) experiments on Hawaiian seamounts showed maximum biodiversity within 10-30 km of the seamount summit, and Dubroca et al. (2014) showed a significant effect of seamounts on catches in the eastern Atlantic within 15 km. However, the literature is less precise for the depth limit. For example, Morato et al. (2010a) stated no significant association between tuna and seamounts at depths greater than 400 m absolute, while Dubroca et al. (2014) stated that a seamount could be attractive to tuna down to -1000 m depth. Due to these uncertainties, we decided to use a 15 km radius buffer zone around a seamount peaking at -500 m or shallower and recode all tagged and/or recaptured individuals as FSC or "Unknown" within this buffer zone associated to a seamount. This method led to a minor correction of the whole dataset (4.9%) but accounted for 10.9% and 28.6% of fish released and recaptured and originally coded as a FSC, respectively.

5. Conclusion and perspectives

We have seen that commercial catch data are not sufficient to estimate the radius of a seamount's attractiveness. We, therefore, suggest the use of scientific survey data that would target fish associations with seamounts. As the literature has shown that two seamounts with the same size and depth characteristics will not systematically attract tropical tunas in the same way, several other factors, such as the environmental conditions around the seamount, the distance of the seamount's peak from the coast or the strength of the currents, should be taken into account for a more thorough analysis. In a Bayesian framework, information from these various data could provide answers to the poorly understood relationship between tropical tunas and seamounts, thus allowing traditional studies of tuna movement behaviour to be reconsidered.

CRediT author statement:

Sosthène Akia: Investigation, Formal analysis, Visualization

Ilan Perez: Investigation, Formal analysis, Visualization.

Loreleï Guéry: Supervision, Methodology, Project administration, Funding Acquisition.

Daniel Gaertner: Conceptualization, Supervision, Methodology, Project administration, Funding Acquisition. All authors contributed to writing, reviewing and editing.

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Figures

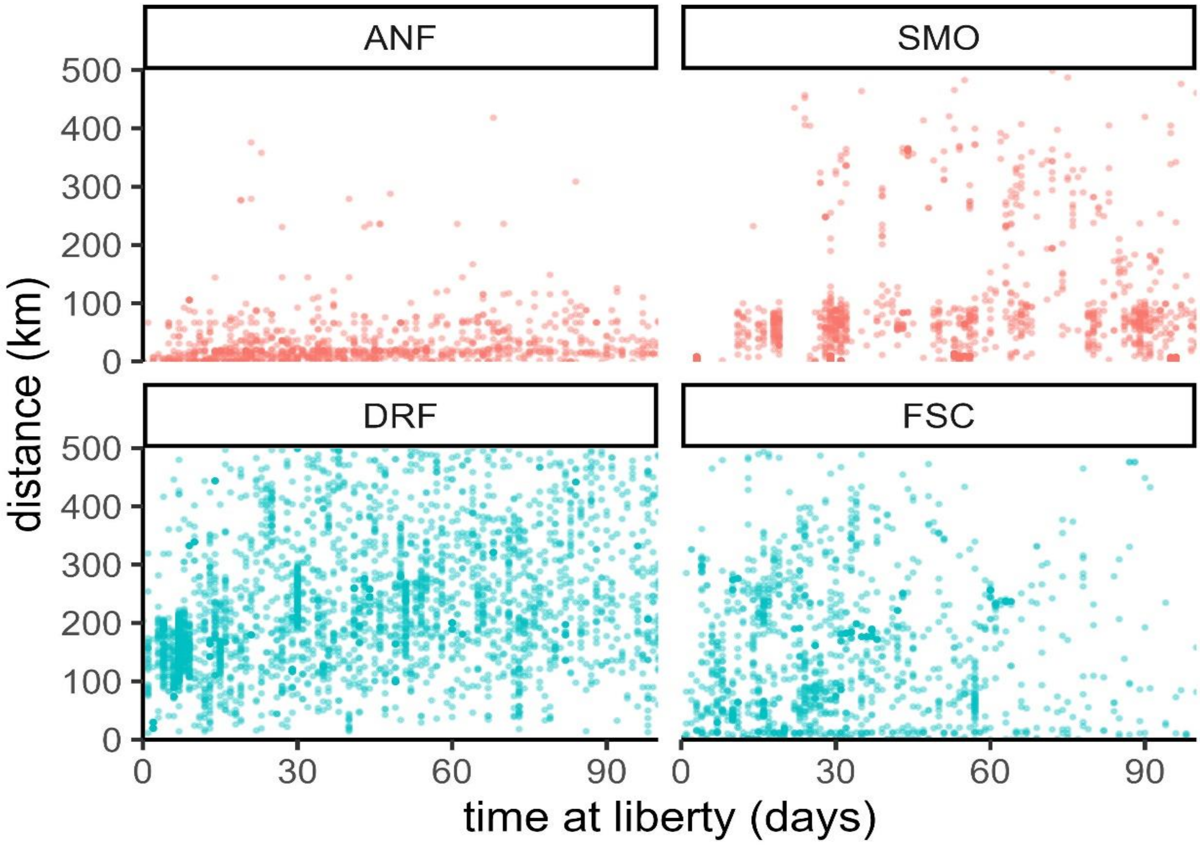

Fig. 1. Relation between time at liberty and distance travelled by tunas tagged under fixed structures (anchored FADs -ANF- and seamounts -SMO-) and under drifting FADs (DRF) or free schools (FSC).

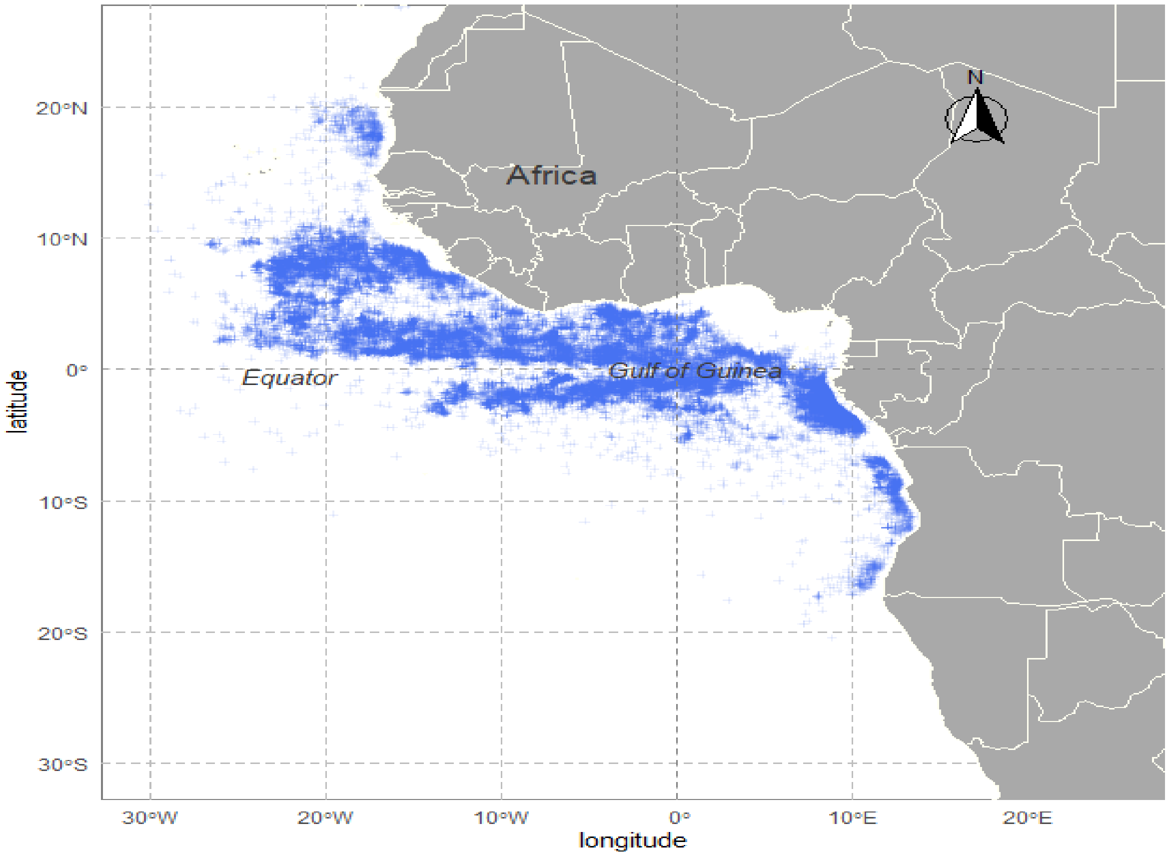

Fig. 2. Distribution of all sets from French and Spanish purse seiners in the 2007-2019 period.

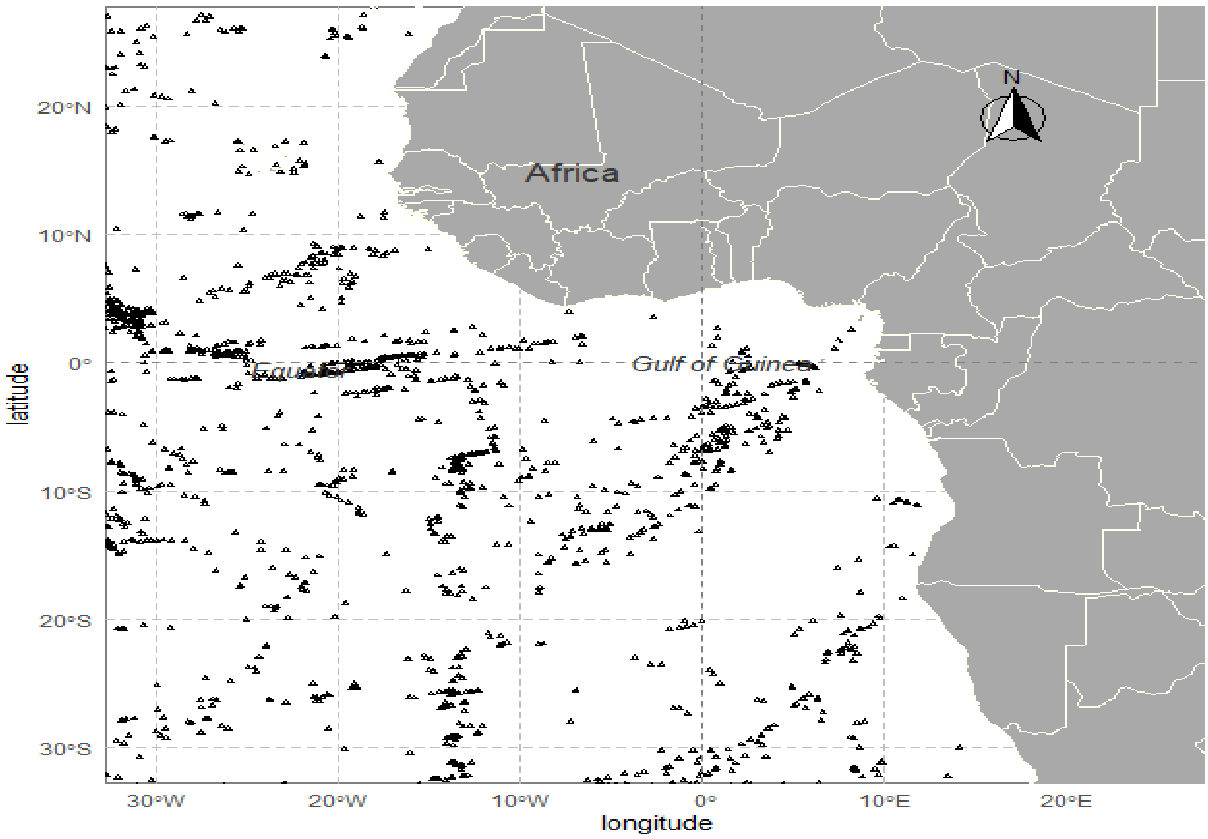

Fig. 3. Positions of the seamounts from the Yesson et al. (2011) database.

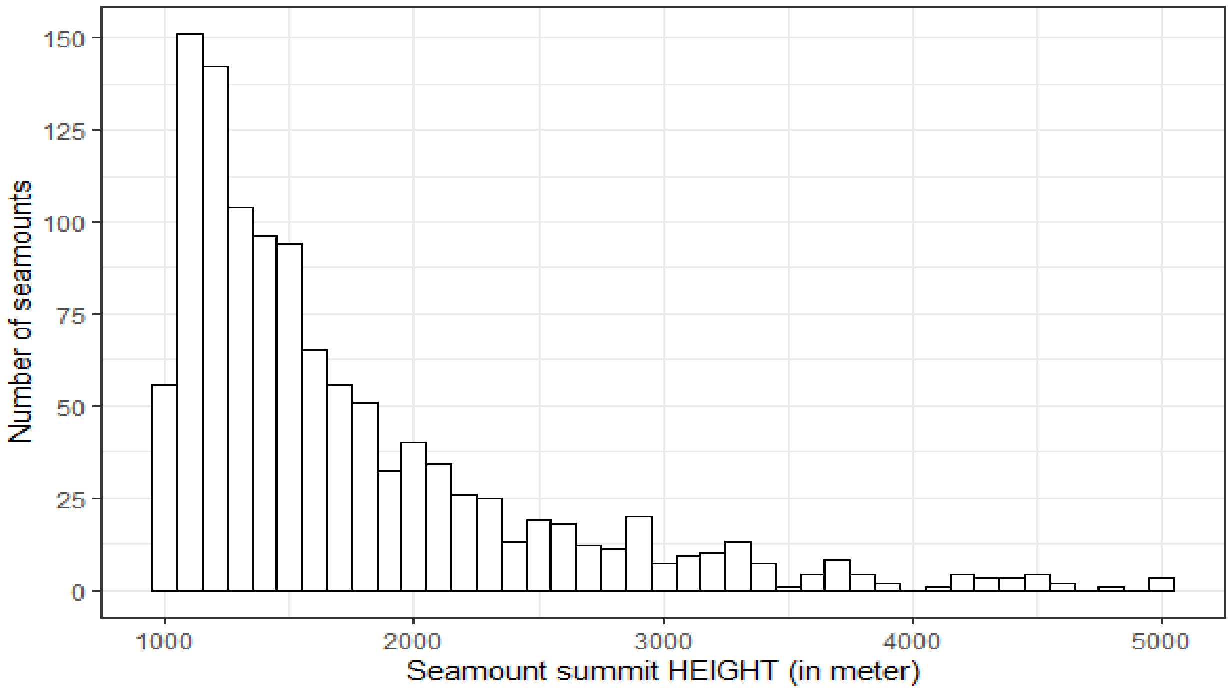

Fig. 4. Histogram of summit depths of seamounts from Yesson et al. (2011) seamounts within selected area (-30° E to 25° E Longitude; -30° N to 25° N Latitude).

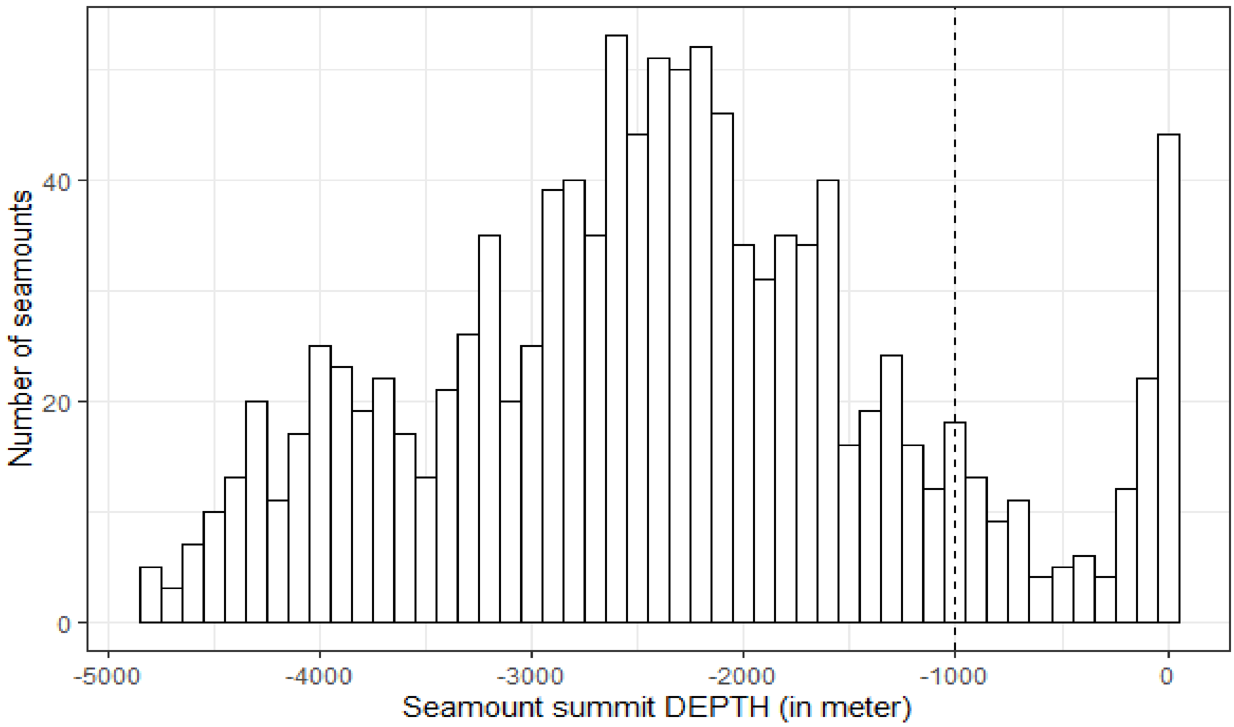

Fig. 5. Heights distribution among the Yesson et al. (2011) seamounts within selected area (-30° E to 25° E Longitude; -30° N to 25° N Latitude). The vertical dashe line separates seamounts shallower than 1.000 m from other seamounts.

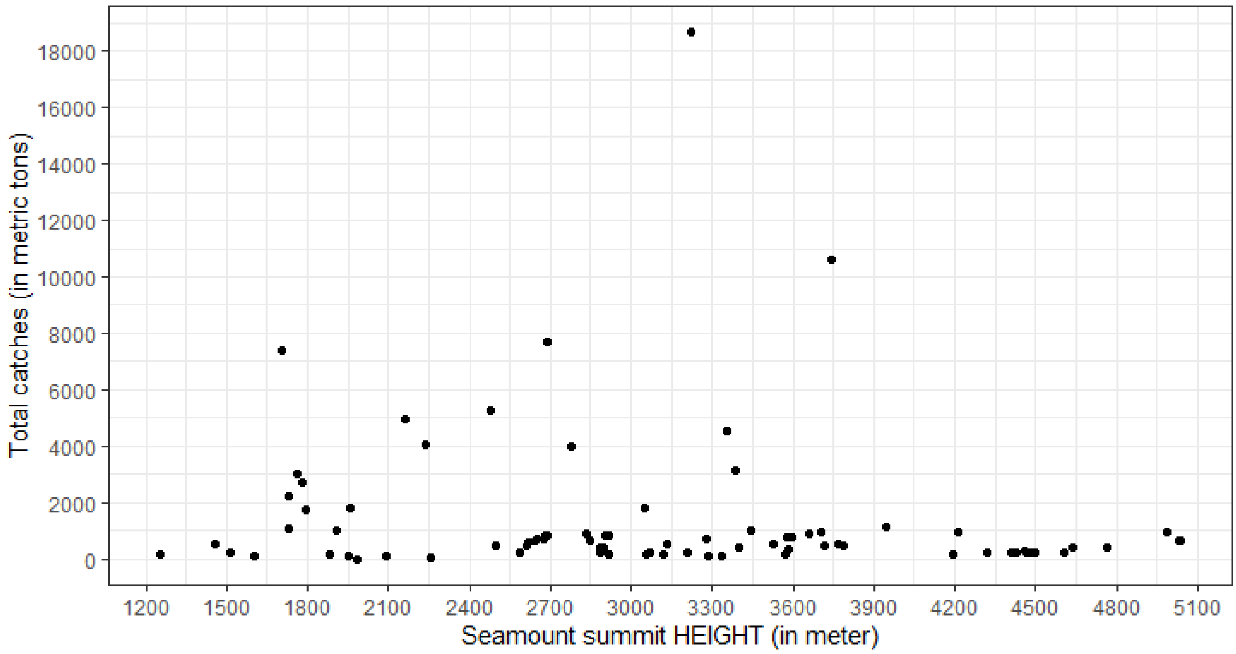

Fig. 6. Relation between height of the seamounts and catches whithin a 50 km radius from the peak of the seamount.

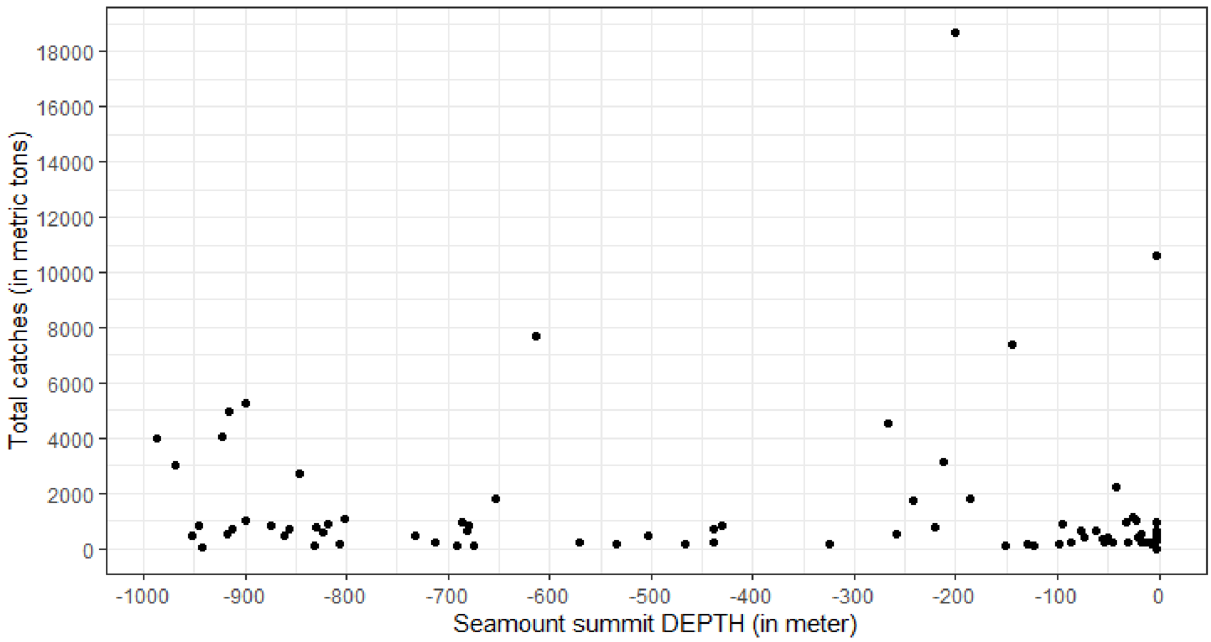

Fig. 7. Relation Relation between depth of the seamounts and catches whithin a 50 km radius from the peak of the seamount.

A) B)

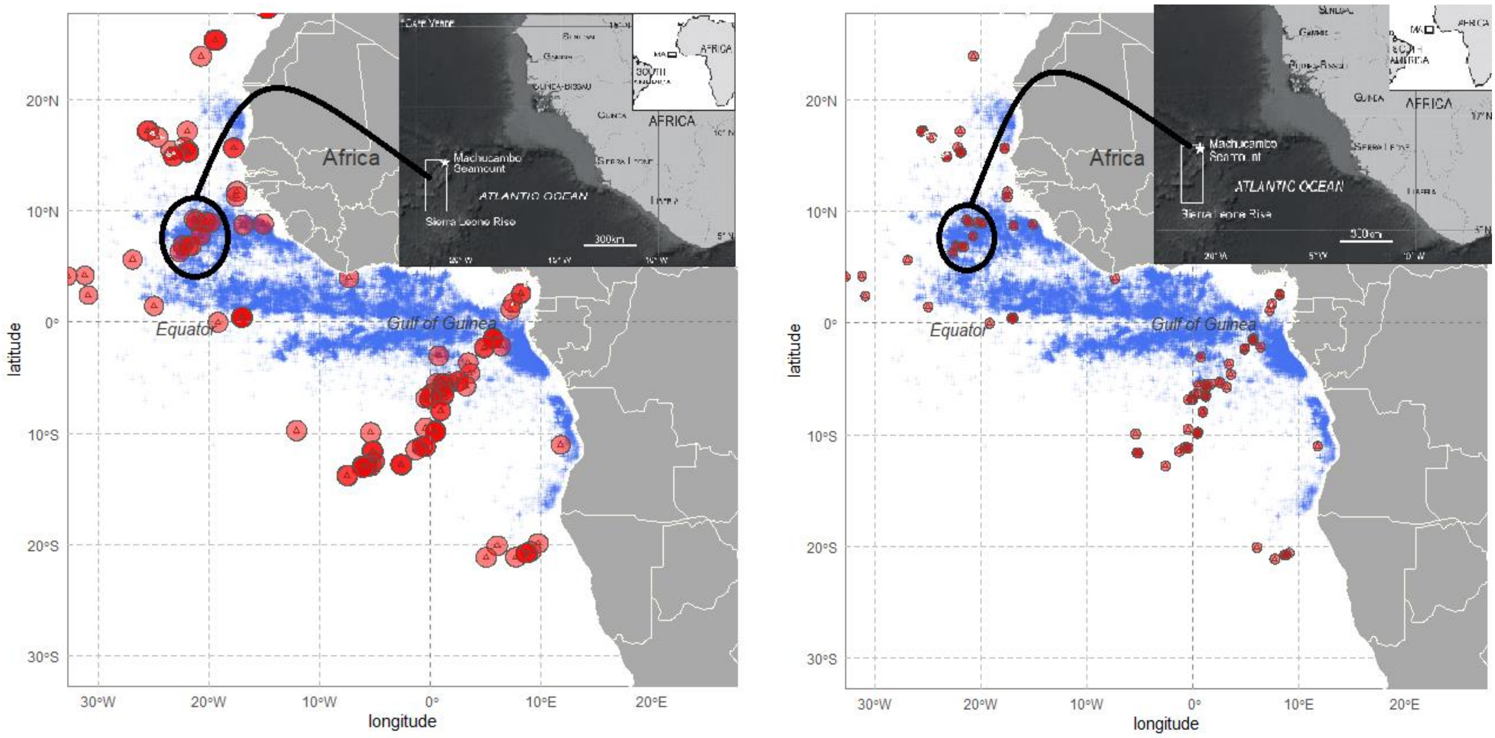

Fig. 8. The plot of identified seamounts with a depth shallow than 1.000 m with at least 100 fishing sets made within 100km - A (50km radius in Fig. 8-B). The circled seamounts are part of Machucambo Seamount on the Sierra Leone Rise. The circle in color red represent the seamount's position and buffer of 100 km (in Fig 8-A) or 50 km (in Fig. 8-B) around them. The area in blue represents the distribution of all sets from French and Spanish purse seiners in the 2007-2019 period.

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