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OBJECTIVES AND FIRST RESULTS OF THE CECOFAD PROJECT

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SUMMARY

The continuous implementation of drifting Fish Aggregating Devices (dFAD) by tropical tuna fishermen in the early 1990s has impacted the species and size composition of the tuna catch as well as some components of the epipelagic ecosystem (e.g., sharks, turtles, etc.). In addition, the development of this fishing mode introduced a new uncertainty in stock assessment models as abundance indices derived from FAD-fishing cannot be calculated easily as the conventional unit of fishing effort (i.e., the searching time) traditionally used for free school fishing cannot be applied. For all of these reasons, the objective of the European Research project "Catch, Effort, and eCOsystem impacts of FAD-fishing" (CECOFAD) is to improve our understanding of the use of fish-aggregating devices (FAD) in tropical purse seine tuna fisheries and to provide reliable estimates of abundance indices and accurate indicators on the impact of FAD-fishing on juveniles of bigeye and yellowfin tunas and on by-catch species. We presented here the state of advance of the project in light of its objectives, the progress in recovery for non-conventional data and the first results.

RÉSUMÉ

L'utilisation continue des dispositifs de concentration des poissons dérivants par les pêcheurs de thons tropicaux au début des années 90 a eu un impact sur la composition des espèces et des tailles de la capture de thonidés, ainsi que sur certaines composantes de l'écosystème épipélagique (p. ex., requins, tortues, etc.). En outre, le développement de ce mode de pêche a introduit une nouvelle incertitude dans les modèles d'évaluation des stocks étant donné que les indices d'abondance provenant de la pêche sous DCP ne peuvent pas être facilement calculés du fait que l'unité conventionnelle de l'effort de pêche (c'est-à-dire, le temps de recherche), traditionnellement utilisée pour la pêche en bancs libres, ne peut pas être appliquée. Pour toutes ces raisons, l'objectif du projet de recherche européen « Catch, Effort, and ecosystem impacts of FAD-fishing » (CECOFAD) (Prise, effort et impacts écosystémiques de la pêche sous DCP) consiste à améliorer nos connaissances sur l'utilisation des dispositifs de concentration de poissons (DCP) dans les pêcheries des senneurs tropicaux et à fournir des estimations fiables des indices d'abondance et des indicateurs précis de l'impact de la pêche sous DCP sur les juvéniles de thon obèse et d'albacore et sur les espèces accessoires. Le présent document aborde l'état d'avancement du projet à la lumière de ses objectifs, les progrès accomplis en matière de récupération des données non conventionnelles et les premiers résultats.

RESUMEN

El uso continuo de dispositivos de concentración de peces a la deriva (DCPd) por parte de los pescadores de túnidos tropicales a principios de los noventa, ha tenido un gran impacto en la composición por talla y especies de la captura de túnidos, así como en algunos componentes del ecosistema epipelágico (por ejemplo, tiburones, tortugas, etc.). Además, el desarrollo de este modo de pesca introdujo una nueva incertidumbre en los modelos de evaluación de stock ya que los índices de abundancia derivados de la pesca sobre DCP no pueden calcularse tan fácilmente como la unidad convencional de esfuerzo pesquero (es decir, el tiempo de búsqueda) utilizada tradicionalmente para la pesca sobre banco libre. Por estas razones, el objetivo del proyecto de investigación europeo "Captura, esfuerzo e impacto ecosistémico de la pesca sobre DCP (CECOFAD)" es mejorar los conocimientos sobre el uso de los dispositivos de concentración de peces (DCP) en las pesquerías de cerco de túnidos tropicales y proporcionar estimaciones fiables de los índices de abundancia e indicadores precisos sobre el impacto de la

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pesca con DCP en los juveniles de patudo y rabil y en las especies de captura fortuita. Se presenta en este documento la situación del proyecto con respecto a sus objetivos, los progresos en la recuperación de datos no convencionales y los primeros resultados.

KEYWORDS

FAD-fishing, Tuna CPUE, Acoustic biomass index, By-catch, Non-entangling FADs

Introduction

The continuous massive use of drifting Fish Aggregating Devices (dFAD) by the tropical purse seine fleets in the early 1990s (Ariz *et al*., 1999; Hallier and Parajua, 1999) resulted in many effects 1) on the tuna ressource, 2) on the quality of the scientific studies conducted during stock assessments and consequently on the scientific advices, and 3) on the epipelagic ecosystem.

Impact on the tuna ressource

The major consequence of the development of this new fishing mode was the continuous increase in purse seine catch, mainly for skipjack (*Katsuwonus pelamis*). However the increase in dFAD catch led also to an increase in juvenile catches of the two other species of tropical tunas: yellowfin (*Thunnus albacares*), and bigeye (*Thunnus obesus*), and a direct consequence of this change in size composition of the catch (i.e., a change in selectivity) was the impact on the productivity of some stocks (e.g., a decrease in MSY for Atlantic yellowfin). It should be stressed that FAD-fishing impacts differently the stocks of the tropical tuna species: i.e., impact on juveniles bigeye and yellowfin in a situation of full or overexploitation (in combination with other fishing gears) but in the same time there is no evidence that skipjack be overfished yet.

Impact on the scientific studies and on the scientific advices

The relationship between catch per unit effort (CPUE) and abundance is central to stock assessment models and thus, changes in this relationship will ultimately result in changes in scientific diagnostic and associated management advice. For tropical tuna, since the implementation of dFADs in the early 1990s, progressively equipped with electronic devices, a fishing effort unit is difficult to be defined for purse seiners (Fonteneau *et al*., 1999). In the traditional tuna purse seine fishery (free-swimming schools and natural floating objects), fishing effort was expressed as searching time, i.e., the daylight hours devoted to the detection of tuna schools minus the setting times (i.e., the time spent encircling fish with the purse-seine net and hauling them aboard; Fonteneau, 1978). While this simple definition may be criticized even for free-swimming schools sets (e.g., due to the non-random distribution of fishing effort) dFADs equipped with electronic devices have broken the link between searching time and effective fishing effort for floating object sets. In addition, increasing fishing efficiency through improvements of fishing gears over the years can strongly modify the relationship between CPUE and abundance over time (Fonteneau *et al.*, 1999). Unfortunately, only qualitative information of technological innovation over time is available (Gaertner and Pallares, 1998; Torres-Ireneo *et al*., 2014b; Lopez *et al*., 2014) but quantitative information in terms of number FAD deployed, buoys activated, type of buoys purchased etc is available only for the French purse seine fleet. In addition there is no historic information on the number of supplies vessel (or the ratio supply/ associated purse seiner) which is known to be an essential component of the fishing effort devoted to FAD-fishing. In the absence of suitable standardization of purse-seiner CPUE indices**,** most of the stock assessments of tropical tunas worldwide (yellowfin, bigeye) are based on longline CPUE indices which weakly account for changes in efficiency in the CPUE standardization process and only depict the biomass of the older fraction of tuna stocks. For skipjack, caught significantly only by surface fisheries, the situation may be worst as there is no reliable index to evaluate the trend in abundance over years.

Impact on the epipelagic ecosystem

By-catch in the EU tuna purse seine are low when compared to other fishing gears but FAD-fishing generates more by-catch than Free school-fishing (with some exceptions for some groups or species; Amandé *et al*., 2008; 2010). However, because of the presence of protected species in FADs sets (turtles, silky shark, whitetip shark, etc.), within the framework of the ecosystem approach of fisheries, Tuna RFMOs, international bodies, national administrations and NGOs have raised concern for the status of these species caught incidentally (Dagorn *et al*., 2012, Torres-Ireneo *et al*., 2014a). Another impact of the sudden and massive use of dFADs is their effects on the biology and on the movement of tunas and associated species (concept of ecological trap). Even if it is not demonstrated yet that the entire cycle of life of tuna is altered by massive deployment of dFAD in large areas of the ocean or even if the trapped tunas are systematically attracted towards less productive areas, some effects on growth, plumpness and displacement were evidenced (Hallier and Gaertner, 2008; Wang *et al.*, 2012). Another potential effect of dFADs is the potential stranding of lost dFADs on risky areas such as coral reef areas (Maufroy, comm.. pers.).

For all of these reasons, the objective of the European Research project "Catch, Effort, and eCOsystem impacts of FAD-fishing" (CECOFAD)[5] is to improve our understanding of the use of fish-aggregating devices (FAD) in tropical purse seine tuna fisheries on open-sea ecosystems. The project, co-funded by UE-DG Mare and the partners, began in January 2014 and has a duration of 18 months. Because of some delays in the starting of the project due to administrative constraints and recruitment difficulties, the project has been extended to 31 December 2015.

Further information can be found on the web site: http://www.cecofad.eu/ and at the WIKI pages at http://www.cecofad.eu/w/index.php?title=Main_Page

Objectives

As mentioned in the introduction section, the overall objective of the CECOFAD project is to provide insights into the fishing effort units (for both fishing modes: FADs and free schools) to be used in the calculation of purse-seiner CPUEs in the Atlantic as well as in the Indian and the Pacific Oceans, where European purse-seiners also operate, to ultimately obtain standardized indices of abundance for juveniles and adults of tropical tunas. With regards to the Ecosystem Approach of Fisheries, the CECOFAD project will contribute to improve knowledge on the impact of FAD-fishing on the epipelagic ecosystem.

Bearing in mind the multispecies nature of the tropical tuna purse seine fishery and the regular requests expressed by tuna RFMOs to European tuna scientists to provide reliable estimates of abundance indices and accurate indicators on the impact of FAD-fishing on juveniles of bigeye and yellowfin tunas and on by-catch species, the main objectives of the project are:

1. to define a unit of fishing effort for purse-seiners using FADs that accounts for different factors influencing catchability

2. to standardize catch-per-unit-effort series of the EU purse seine fleet, for juveniles and adults of the three tropical tuna species and

3. to provide information on catch composition around FADs and estimate impacts on other marine organisms (e.g. by-catch of sharks, rays, turtles).

In order to meet these objectives the project is organized into 4 Work Packages (WPs), as follows:

- WP 1 - Definition of a unit of fishing effort for purse-seiners using FADs that accounts for different factors influencing catchability (Objective 1 of the project),

- WP 2 - Standardization of catch-per-unit-effort series of the EU purse seine fleet, for juveniles and adults of the three tropical tuna species and exploration of some FAD-regulations in management strategies (Objective 2),

- WP 3 - Alternatives to catch rates (WP 2 and 3 in conjunction will address (Objective 2),

- WP 4 - Provision of information on catch composition around FADs and estimation of potential impacts on other marine organisms (e.g. by-catch of sharks and criptic mortality; Objective 3).

[5] The research project "Catch, Effort, and eCOsystem impacts of FAD-fishing" (hereatfter termed CECOFAD), is leadered by IRD (France) and included two other Scientific partners: Instituto Español de Oceanografía (IEO, Spain), AZTI Tecnalia (AZTI, Spain), and 3 professional partners: Organisation des producteurs de thon tropical congelé et surgelé (ORTHONGEL (France), Asociación Nacional de Buques Atuneros Congeladores (ANABAC, Spain), Organización de Productores Asociados de Grandes Atuneros Congeladores (OPAGAC, Spain). Tuna RFMOs, such as the International Tuna Commission for the Conservation of Atlantic Tunas (ICCAT), the Indian Ocean Tuna Commission (IOTC), the Inter-American Tropical Tuna Commission (IATTC), as well as the International Seafood Sustainability Foundation (ISSF) are associated to the project as observers.

In addition to these four WPs, transversal activities are conducted to ensure the coordination and technical aspects of the project, the data bases management, the web site development and the administration and management of the project.

Results

1. Fishing effort for FAD-fishing that accounts for different factors influencing catchability

It is widely recognised by the tuna scientific communauty that many data on the fishing technology introduced on board over time should be useful for defining an accurate definition of fishing efftort associated to FAD-fishing. The collection of the dates of quantative and qualitative changes in FAD design and use, as well as in new fishing devices was initiated during the EU research project Esther (Gaertner and Pallares, 1998) for the French fleet and updated recently by Torres-Ireneo *et al*., 2014b (**Figure 1**). Recently, following the study of Moreno *et al.* (2007), new information on technology associated with FAD-fishing has been collected by Lopez *et al.* (2014) for the Spanish fleet (**Figure 2**).

Since the mid 1990s, the use of drifting Fish Aggregating Devices (DFADs) has considerably increased in purse seine tropical fisheries. Besides, since the 2000s, fishers are able to monitor both natural floating objects and DFADs with GPS buoys during their drift. This massive use of DFADs and GPS buoys raises several concerns for tropical tuna stock assessment and management. It is particularly difficult to know how many DFADs and GPS buoys are in use, how fishers decide to deploy new DFADs and GPS buoys as well as the proportion of fishing effort is dedicated on fishing on DFADs and logs or on Free Swimming Schools (FSC).

The lack of information on the numbers of FADs is probably due to a combination of different factors such as the confidential nature of this sensitive information that was not legally requested until very recently by tuna RFMOs (and rather for compliance than for scientific purpose), as well as the complexity of collecting and using an index representing the “number of FADs”. With regards to this last aspect, the term of number of FADs can express: (1) the total numbers of new buoys and FADs (of all types) released during a time unit by each fleet and by their associated support vessels (e.g., the number of new buoys bought during the year) or (2) the average of active buoys in the fishing zone that have been followed daily by each purse seiner on its computer screen.

To address the question on how many DFADs and GPS buoy tracked objects are currently drifting in the Atlantic and the Indian Ocean two complementary sources of information derived from declarations and observations at-sea were used.

The first approach was based on based on historical purchase orders buoys and declarations of activities related to dFAD activities. In the case of the Atlantic Ocean, the information collected for the French fleet only showed the changes over time of the different types of buoys purchased every year (**Table 1**). The transition toward most modern buoys (i.e., from HF-buoys to GPS-buoys equipped with echo-sounders) is clearly evidenced. From the number of buoys purchased and from the quarterly information on the activation/deactivation communicated by the providers of satellite communication, it was estimated that on average 156 buoys by vessel were purchased in 2013, from which 90 were active. It should be noted that the number of buoys purchased by year and by purse seiner and the number of active buoys by vessel have been limited to 200 and 150 units, respectively, by the French tuna owner association.

Since the full use on board of the new logbook system which account for the different activities related to FAD-fishing it was showed that 63% of the activities of the vessel are related to FADs monitored by the same vessel against 36% for FADs equipped by other vessels and only 1% for FADs without any radio range beacon (see Goujon *et al*., 2015 for more detailed information).

For the Spanish fleet operating in the Atlantic Ocean an average of 429 active FADs per year is followed by each purse seiner (Delgado *et al*., 2015). However, as for the French purse seiners, this estimate could be overestimated as some active FADs are followed by more than one vessel and, thus, could be double counted. As for the French purse seine fleet, some information was also collected on the different activities conducted by the purse seiners with regard to FAD-fishing as well on the implementation of non-entangling FADs. The use of non-entangling FADs which reduces the “ghost” mortality of sensitive species such as turtles and sharks is taken into consideration in the paragraph related to WP4.

Based on the yearly average number of buoys deployed by French purse seiner (Goujon *et al*., 2015), and the corresponding yearly FAD catch, the average yearly catch per buoy deployed has been estimated (**Table 2**).

In the absence of data for the Spanish fleet at the time of the analysis, it has been assumed that yearly FAD catches per vessel for the 2004-2013 periods were proportional to their number of FADs. The numbers of FADs seeded per each Spanish purse seiner was estimated at an average level of being 2.5 times more important than for the average French purse seiner (against three times in previous studies). From this method, the average number of FADs released by each Spanish purse seiner in 2013 has been estimated at about 385 FADs, which is close to the number of 426 active FADs seeded per Spanish purse seiner given by Delgado *et al*. (2015).

There is no data submitted to the ICCAT on the numbers of FADs or buoys used by other non-European fleets of purse seiners (Ghana, Cote d'Ivoire, and Guinea). However, assuming that the yearly average catch per seeded FAD was identical to the average yearly FAD catches per buoy of the French and Spanish fleets, the numbers of FADs seeded by these fleets has been estimated from their total catches on FADs. Based on these data and assumptions, the estimated total numbers of FADs released yearly in the Atlantic Ocean by all purse seine fleets has dramatically increased from less than 7,000 FADs before 2008, to 17,300 FADs in 2013 (**Figure 3**). This corresponds to a 2.6 fold increase between the 2004-2007 and 2010-2013 periods.

For the Indian Ocean, Chassot *et al.*, (2014) combined 3 three data sources with the aim to describe the use of DFADs and buoys by the French purse seiners over the last decade. First, archives of buoy purchase orders during 2002-2014 were provided by fishing companies so as to give insight into the historical use of DFADs. Second, information derived from satellite transmission data was made available for the period 2010-2013 based on quarterly reports that are produced by buoy supplier companies on a vessel basis. Third, activities related to DFAD and buoys have been included into purse seiner logbooks since 2013. With the aim to have some elements of comparison with the Atlantic Ocean only the purchase orders information was considered. The number of buoys available by French purse seiner increased by an average rate of about 10 units per year over the last decade (i.e., the median number of buoys per vessel increased from 60 in 2002 to 200 in 2014; **Figure 4**).

With regards to technological changes, as mentioned for the Atlantic Ocean for the French fleet (no information on this aspect has been provided yet for the Spanish fleet) there was a quick change from a combination of HF radio and GPS to a single GPS system in 2007-2008 (**Figure 5**). In addition to this evolution towards modern buoys, due to the lack of potential independent control the use of HF buoys was definitively prohibited by the French tuna association Orthongel in 2012. Echo-sounder buoys have started to be used by the French fleet in the Indian Ocean since 2011.

The numbers of buoys active per vessel (and having emitted) appeared rather stable over years during 2010-2014 (between a minimum of 62 in January 2013 to a maximum of 118 in April 2012).

From data collected since 2013, it was showed than on average 401 active FADs were followed by each Spanish purse seiner operating in the Indian Ocean (Delgado *et al*., 2014). The average yearly number of FADs deployed by Spanish flag vessels was around 854, if only purse seiners are considered. As for the Atlantic document, the different activities carried out in 2013 on FADs/floating objects by the Spanish fleets were described. By order of importance, the activities covered were: deployment, visit a FAD, set on FADs, FAD retrieval, FAD buoy change and setting a buoy to a natural object. In addition, the geographic distribution of all activities done with FADs, the location of FAD deployments and FAD sets reported in the FAD management plan (purse seiner and support vessels), were also described respectively.

The extrapolation process from the French FAD data base (**Table 3**) to the total number of FADS active in the Indian Ocean (Fonteneau and Chassot, 2014) used the same method described previously for the Atlantic Ocean (Fonteneau *et al*., 2015). Various converging sources of observations, at-sea and in the landing ports indicate that the numbers of DFADs active at-sea and deployed by the Spanish and Seychelles fleets, including by their support vessels, are much higher than for French purse seiners. However the numbers of DFADs seeded, or monitored, yearly by these fleets are not yet available. Consequently the numbers of Spanish and Seychelles DFADs were tentatively estimated on the basis of the 2 following assumptions:

1. Hyp. RF1: assuming that larger DFAD catches reported by the Spanish-Seychelles fleet is due to a larger number of DFADs seeded yearly. On the basis on the average ratio of DFAD yearly catches per vessel during the 2009-2013 periods, each Spanish purse seiner could seed 1.7 more DFADs than French purse seiner.

2. Hyp. RF2: from previous studies, it can be assumed that each Spanish-Seychelles purse seiner has been seeding each year (including the DFADs seeded by supply vessels) 3 times more DFADs than an average French purse seiner.

Based on these 2 assumptions, the numbers of Spanish and Seychelles DFADs deployed by vessel and total has tentatively been estimated (**Figure 6**Figure).
Another extrapolation process used to estimate the total DFADs and floating objects in the Indian Ocean (Maufroy *et al*., 2014) combined different types of information, such as:

1. GPS buoy tracks of the DFADs and logs monitored by the French fleet,
2. quarterly French fishing companies orders of buoys,
3. interviews with purse seine skippers and
4. observations of DFADs and logs by observers aboard French and Spanish purse seiners (**Figure 7**).

All this complementary information was used to (i) provide an estimate of the daily number of DFADs drifting at sea and active tracking GPS buoys in the Indian Ocean over the period 2007-2013, and (ii) describe the strategies of the French fleet regarding DFAD and tracking GPS buoy deployment. This analysis suggested that between 2007 and 2013 the estimated number of dFADs at sea increased from 900 to 4,300 while the number of buoys increased from 1,400 to 5,800 (**Figure 8**). As expected, for the same period there are significant differences in terms of the estimates of GPS buoys used between the French fleet (from 250 to 1,100) and the Spanish fleet (1,000 to 4,600), as showed in **Figure 9**.

It must be stressed that GPS buoy data available for this study only consisted on at sea positions of GPS buoys used, or on orders, by the French fleet, with no distinction between DFAD and natural logs that these buoys are equipping. Evaluating the total number of DFADs and total floating objects at sea requires the combination of data giving information on the proportions of buoys used on DFADs or logs as well as the proportions of French and foreign GPS buoys.

With the aim of a better understanding of the strategies developed by fishers regarding DFAD and tracking GPS buoy deployments. 4 DFAD and log seasons were identified (**Figure 10**).

2. Standardization of catch-per-unit-effort series

In support to CPUE analyses, the spatio-temporal patterns of the FAD-fishing effort of French purse seiners were analyzed in the Indian Ocean during 2000-2012 using a geostatistical approach (Saulnier, 2014). FAD-fishing effort was defined as the local density of FAD-fishing sets on a quarterly time period by combining logbook and VMS data. Over time the main changes occurred during the 1rst quarter of the year where the prospected area and the successful fishing area (i.e., with FAD sets) increased very much (4 and 3 fold respectively).

To better understanding the specific impact of the new technologies on the different parts of the fishing operation, the CPUE can be decomposed into several sub-indices (Gaertner and Pallares, 1998; Chassot *et al*., 2012).

1. the total number of sets per fishing day to depict the ability to detect a concentration of tuna schools,
2. the proportion of successful sets to describe the ability of catching a school,
3. the amount of catch per positive set, an index that combines a proxy of the size of the school with the ability to maximize a catch during the setting.

Katara and Gaertner (2014) have followed this approach to modeling the different catch rates built from skipjack free schools in the Indian Ocean with the aim to provide an insight on the changes in fishing efficiency of the purse seine fleet. To account for the changes in the spatial distribution of the fishing effort over time, the spatial explanatory variables are treated as random effects in GLMMs. By treating space as a random effect it is assumed to make inference for the potentially fished area rather than the realized fished area, thus improving the comparability of annual standardized CPUE estimates. This study must be considered as preliminary but showed that GLM estimates may be biased because annual CPUE predictions are restricted to the sites that were fished on the specific year. Areas historically fished or with the potential of being fished are overlooked. Therefore GLMMs, with "site" as a random effect, allow for CPUE predictions outside the fished areas, in sites that are not sampled. The flexibility of GLMMs is offset by the higher uncertainty of predictions. If the sampling sites are fixed, the estimated error equals the error per site; by randomizing the sites the estimated error incorporates variability stemming from two sources: within each sampled site and the between sites.

An ongoing study on the standardization of the bigeye CPUE on FADs by the French purse seine fishery, not published yet, depict the usefulness a variable selection using Lasso penalization in GLM and GLMM frameworks. Several variables, not traditionally included in tuna CPUE standardization models, were retained by the Lasso model selection process, such as: the skipper, the vessel, the price of targeted tuna species, the number and spatial distribution of FADs and the number/type of deployed buoys among other. Additional non-conventional information is needed to describe and quantify fishing effort due to advances in fishing technology and because vessels differentiate in the types of technologies they are using.

3. Alternatives to catch rates

Alternatives to catch rates, such as direct estimate of the aggregated biomass around buoys from echo-sounder information.are also one of the objective of CECOFAD. The information acquired by drifting FADs have been collected and loaded into a database for further processing. This database includes data of the most important buoy manufacturers (Zunibal, Marine Instruments and Satlink) from the Spanish tuna fleet operating in the Atlantic, Pacific and Indian Ocean. In the Atlantic and Pacific Ocean, the database includes the information registered during March 2011, whereas in the Indian Ocean data were collected in October 2011. Apart from the geographic position, direction and time, each of the buoy records an acoustic signal related to the aggregated biomass around the buoy. Since buoy manufacturers use different format and system to measure the strength of the acoustic signal, the database has been designed to include the information from different sources. The database contains the trajectory and acoustic biomass index registered by 8,811 drifting buoys from 49 vessels throughout the Atlantic, Pacific and Indian Ocean. The number of messages registered by buoy depends considerably on the transmission frequency in which it was programmed, as well as on the useful life of the buoy. Overall, a drifting buoy can register about 60,000 position and 12,000 acoustic messages over 3 months. The database created with the information registered during one month by 8,811 buoys contains more than 630.000 messages, which gives an idea of the dimension and complexity of the task we are undertaking (**Figure 11**).

4. Estimation of potential impacts on other marine organisms

With the aim of reducing the impact of FADs on incidental catches, specifically on turtles and sharks, French and Spanish tuna owner companies have promoted the use of a non-entangling net under the FAD. In the case of the French fleet, first design of non-entangling FADs began in 2010 in the Indian Ocean and in 2011 in the Atlantic. Since 2012 French purse seiners can use only non-entangling FADs when they have to deploy a new FAD at sea. For the component of this fleet operating in the Atlantic Ocean, a total of 48 non-entangling FAD per vessel was ordered and deployed in 2013 (Goujon *et al*., 2015). At the beginning of 2012 the Spanish fleet started to substitute the traditional FAD by non-entangling FAD. The definition of non-entangled FAD agreed by the fleet refers to FADs (i) with the surface structure of the FAD not covered, only covered with non-meshed material or with a maximum mesh size of 3 cm-s; and (ii) with the sub-surface component made from non-meshed materials such as ropes or canvas sheets or using netting rolled up and securely tied in to “sausages” with nets of maximum 3 cm-s. The percentages of non-entangling FADs deployed by the Spanish fleet in 2013 in the Atlantic and in the Indian oceans were estimated around 55% and 28%, respectively (Delgado *et al*., 2015, Delgado *et al*., 2014).

5. Transerval activities

One of the challenges identified in the research project CECOFAD has been to provide links between different data sets (i.e., logbooks, observers data, VMS, echo-sounder data, etc.) representing heterogeneous sources of information collected from the different working packages. This part of the project is the core of the transversal activity termed the transversal WP5, focused on the relationships between these data sets and the future requirement for the different WPs of the project.

To achieve the objectives defined during the kick-off meeting of CECOFAD, we worked to retrieve useful datasets for the project in a common and understandable format. To accomplish this task, we decided to use the SDEF (Standard Data Exchange Format) to export format[6] and in combination to use the R software[7] and the related R COST library[8] as an export tool.

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[6] ICES Cooperative Research Report No. 296
http://www.ices.dk/sites/pub/Publication%20Reports/Cooperative%20Research%20Report%20(CRR)/crr296/CRR%20296.pdf

In addition of these technical aspects which will be applied on the French and the Spanish data sets, as IRD is in charge only of exporting all French tropical tuna data, at the time of writing this report and regarding the expected data[9], the Observatoire Thonier (OT) of IRD has already made the following tasks:

- the export of the French log-book dataset from the BALBAYA database to the SDEF format, according to the CECOFAD requirement
- the export of the French on-board observer dataset from the OBSTUNA database to the SDEF format
- the provision of those two datasets to the CECOFAD project
- the development of an extension of the R COST library to improve the SDEF format manipulation. It is assumed that the Spanish data will be processed in the same way with the same tools by the Spanish scientists.

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Table 1. Number of buoys by main types and by years purchased by the French purse seiner fleet operating in the Atlantic Ocean (from Goujon *et al*., 2015).

Années	*Nb navires*	*HF*	*BS*	*BSE*	*Total*
2004	9	285	20	0	305
2005	9	275	90	0	365
2006	6	117	157	0	274
2007	5	50	162	0	212
2008	5	15	246	0	261
2009	8	0	614	0	614
2010	10	0	668	50	718
2011	9	0	335	544	879
2012	9	0	280	780	1060
2013	9	0	120	1286	1406
2014	9	0	0	1510*	1510*

Table 2. Numbers of FADs used by French purse seiners: seeded yearly and active ones on a quarterly basis, number of purse seiners and total catches on FADs from Fonteneau *et al*., 2015.

	Nb of Active buoys/PS	Nb buoys seeded yearly/PS	Ratio Nbs FAD Seeded & active	Nb French PS	Average Nb of active FADs	Total Nb of seeded buoys yearly	Yearly FAD catches France	Average Catches on FAD by each PS	Average catch per buoy seeded yearly
2004		41		13		533	20 246	1557	38,0
2005		41		9		369	13 531	1503	36,7
2006		47		7		329	5 178	740	15,7
2007		42		5		210	4 453	891	21,2
2008		54		7		378	3 044	435	8,1
2009		60		10		600	7 552	755	12,6
2010	68	72	1,05	10	683	720	16 125	1613	22,4
2011	71	82	1,16	9	635	738	13 195	1466	17,9
2012	96	118	1,23	9	861	1062	16 956	1884	16,0
2013	90	156	1,74	9	808	1404	16 749	1861	11,9
2014		200		9		1800			
Average 2004-2013		71		9	747	634	11703	1270	20,0
Average 2010-2013	81	107	1,30	9	747	981	15756	1706	17,0

Table 3. Numbers of DFADs used by French purse seiners: seeded yearly and active ones on a quarterly basis, number of purse seiners and total catches on DFADs.

	Nb of Active buoys/PS	Nb buoys seeded yearly by each PS	Ratio Nbs FAD Seeded & active	Nb French PS	Total Average Nb of active FADs	Total Nb of seeded buoys yearly	Yearly FAD catches France	Average FAD Catches by each PS	Average catch per buoy seeded yearly
2003	20	100	5,00	14,8		1481	54 017	3 650	36,5
2004	20	94	4,69	15,4		1445	50 311	3 267	34,8
2005	20	106	5,28	14,8		1564	50 337	3 401	32,2
2006		83		18,0		1487	56 911	3 162	38,3
2007		100		19,5		1940	44 617	2 288	23,0
2008		118		18,5		2182	46 713	2 525	21,4
2009		114		13,5		1539	50 463	3 738	32,8
2010	88	181	2,07	11,6		2102	46 674	4 024	22,2
2011	106	198	1,86	12,7	1348	2510	50 374	3 966	20,1
2012	87	180	2,07	11,6	1008	2088	34 246	2 952	16,4
2013	80	190	2,37	13,0	1042	2470	46 663	3 589	18,9
Average 2003-2013		133		14,9		1 892	48 302	3 324	27,0
Average 2009-2013		173	2,09	12,5	1133	2142	45684	3654	22,1

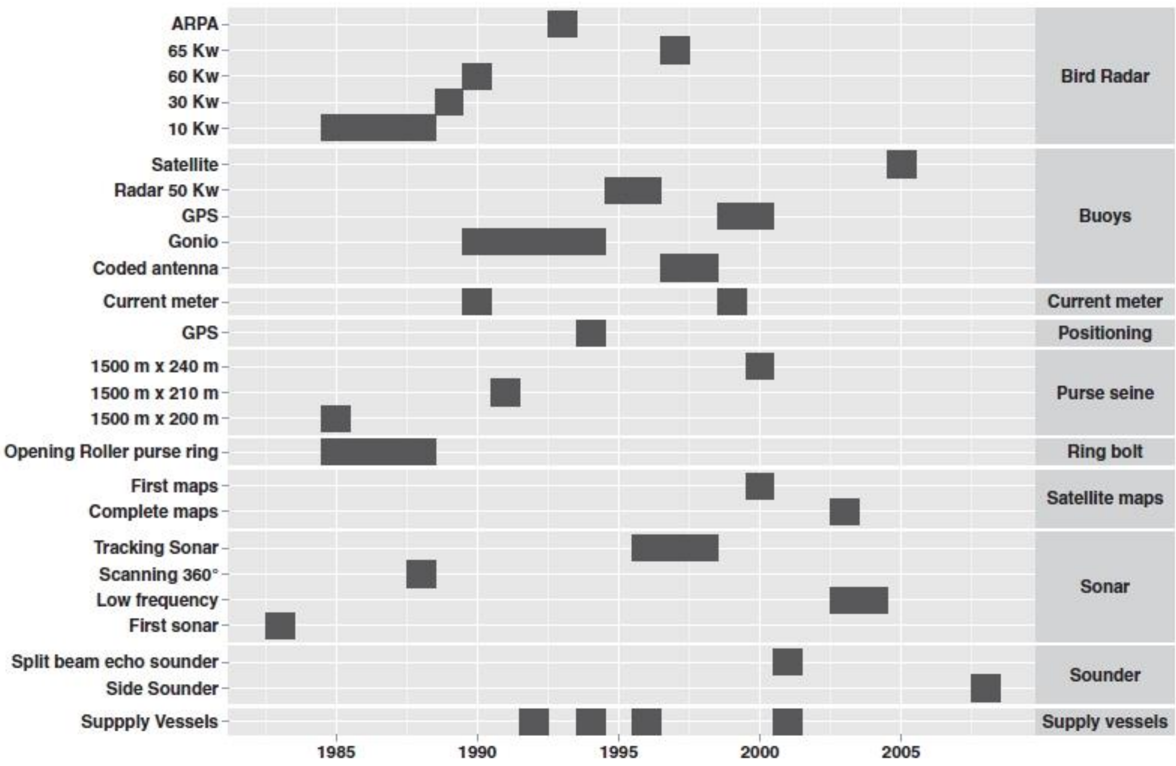

Figure 1. Dates of introduction of new fishing technology on board French purse seiners (from Torres-Ireneo *et al.*, 2014)

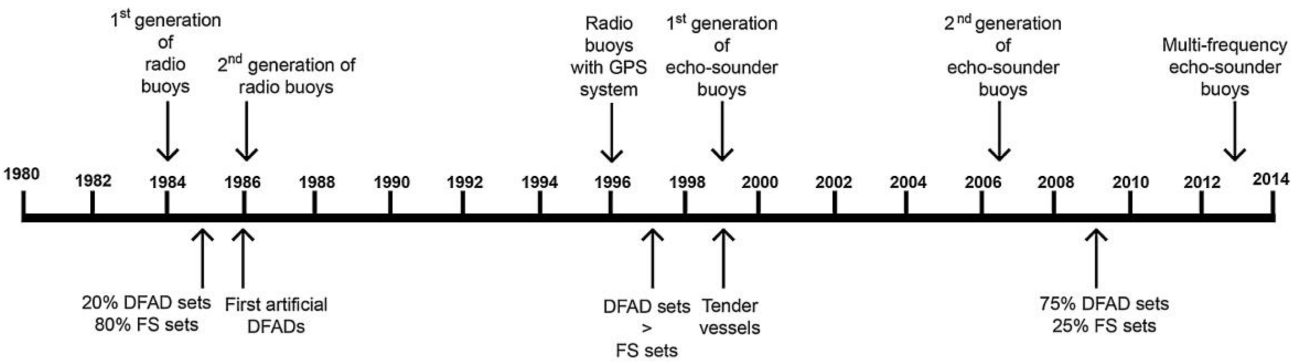

Figure 2. Evolution over the years of the equipment associated with FAD-fishing in the Spanish purse seiners (Lopez *et al.*, 2014).

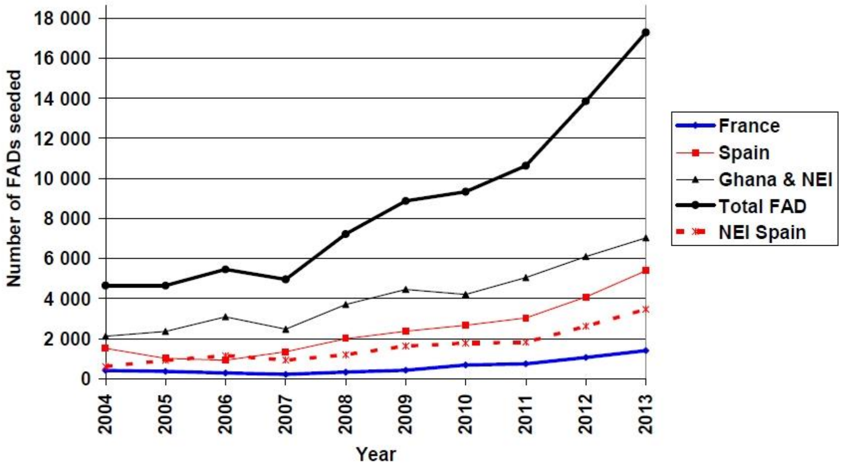

Figure 3. Estimated yearly numbers of FADs seeded, by flags and total in the Atlantic Ocean (from Fonteneau *et al*., 2015).

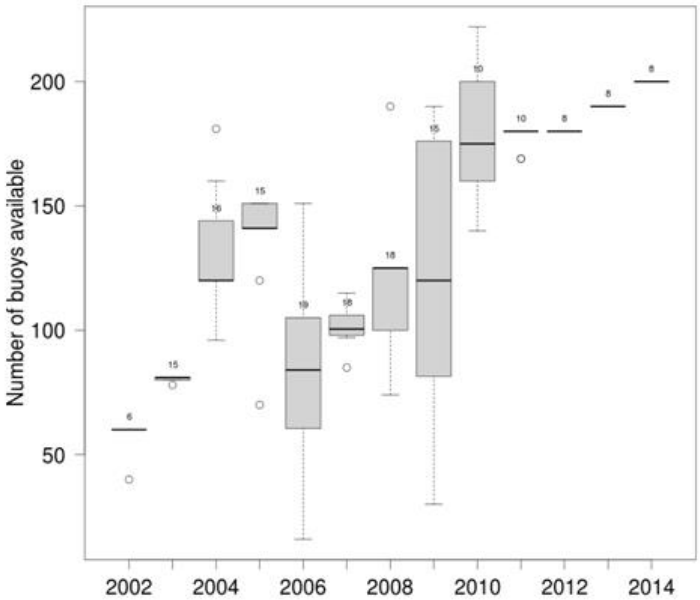

Figure 4. Annual number of buoys available by French purse seiner during 2002-2014. Numbers indicate the number of vessels for which data were available (from Chassot *et al.*, 2014).

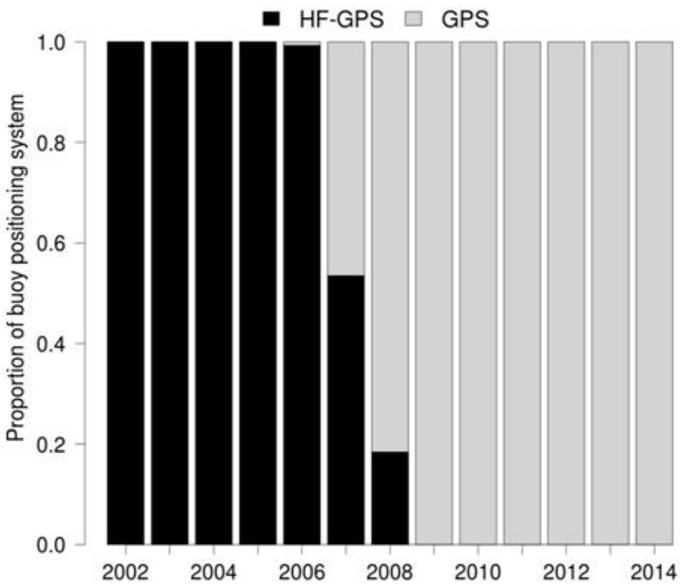

Figure 5. Change in proportion of buoys by type of positioning system for the French purse seiners during the 2002-2014 period (from Chassot *et al.*, 2014).

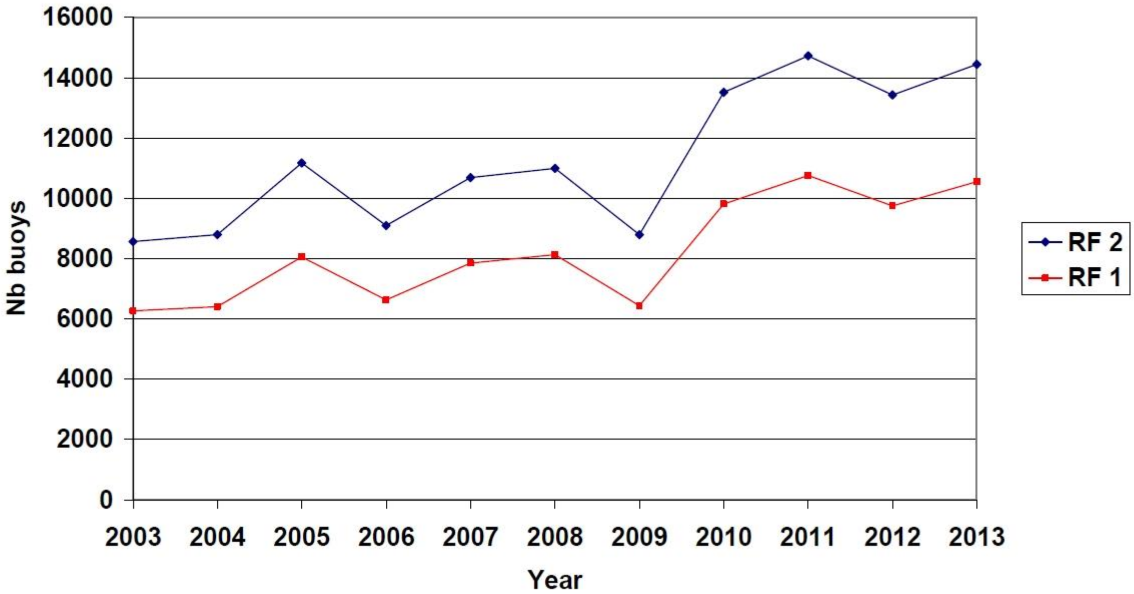

Figure 6. Average yearly catch per deployed buoy observed for French purse seiners and estimated for combined Spanish and Seychelles purse seiners (based on 2 assumptions RF1 and RF2) in the Indian Ocean.

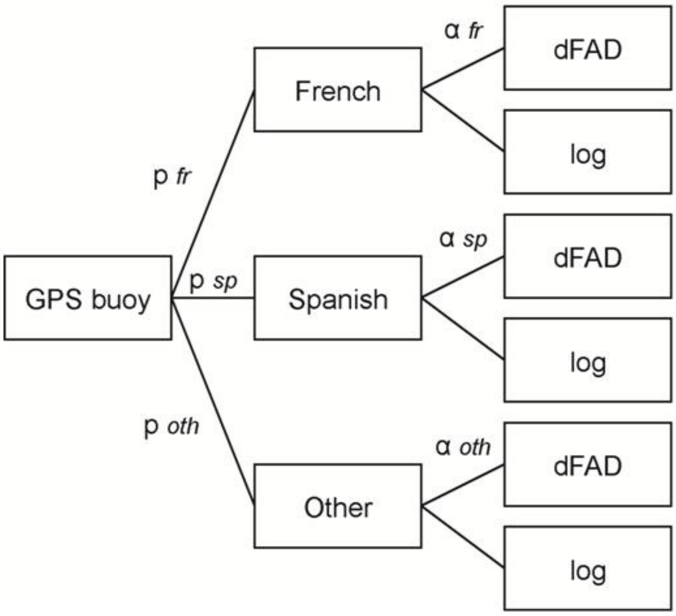

Figure 7. Extrapolation process used to estimate the total DFADs and floating objects (Maufroy *et al*., 2014).

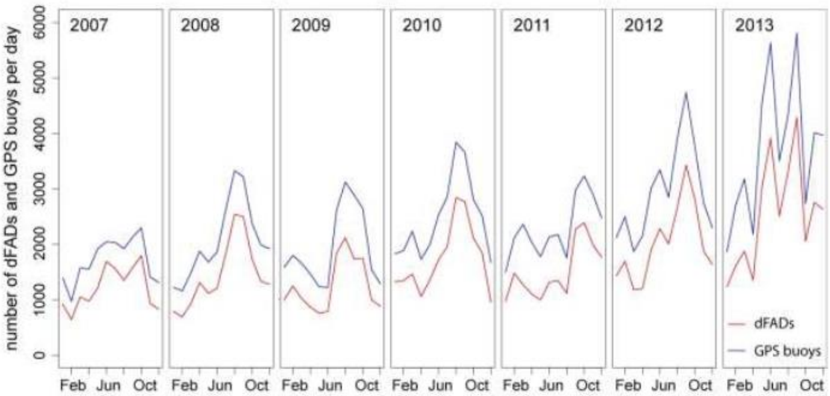

Figure 8. Total number of dFADs and GPS buoy-equipped FOBs per day (Maufroy *et al*., 2014).

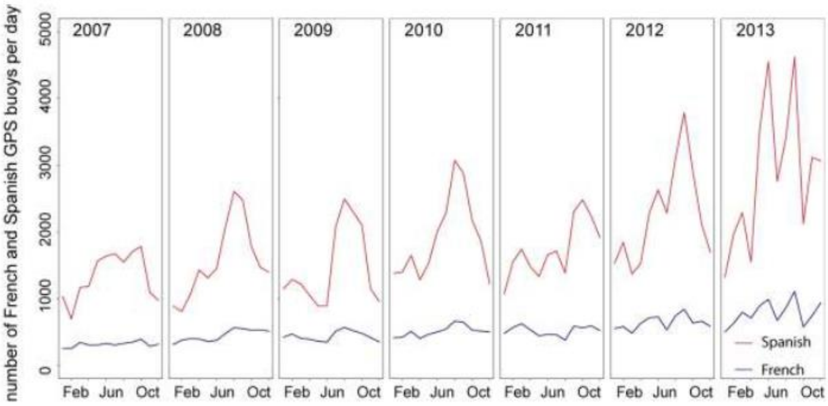

Figure 9. Total number of French and Spanish GPS buoys active day.

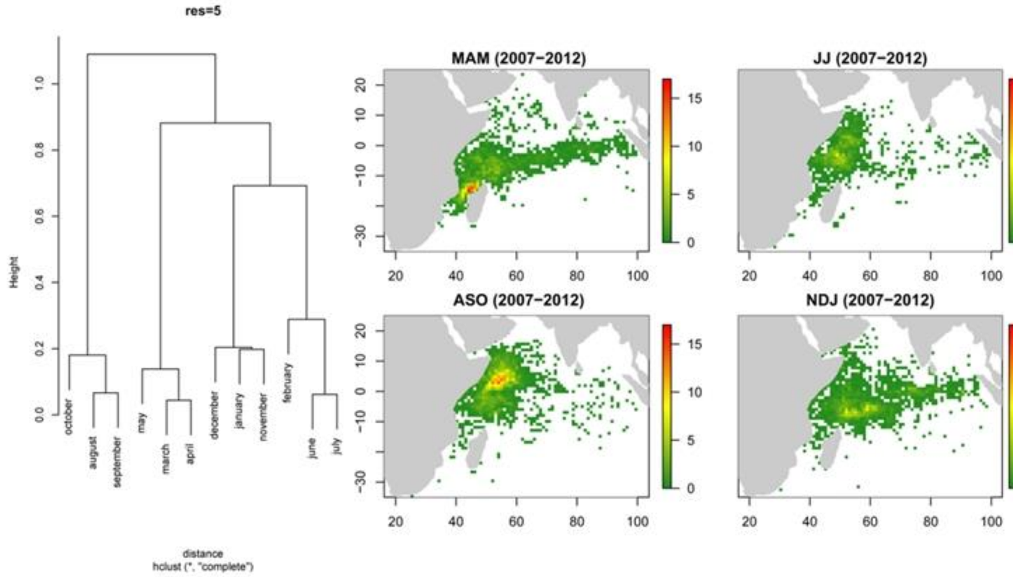

Figure 10. Seasonal patterns in GPS buoy-equipped floating-object drifts (Maufroy *et al*., 2014).

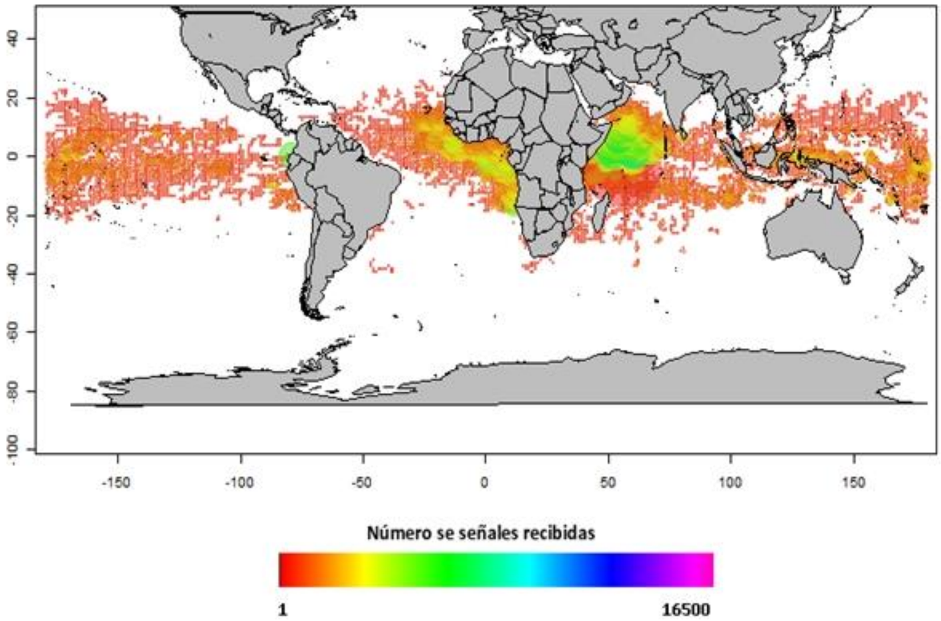

Figure 11. Spatial distribution of the 630.000 acoustic messages registered during one month by 8811 buoys (Spanish fleet only, G. Moreno, comm.. pers.).