# Validation of VMS data and identification of fishing activities of the Spanish tuna purse seine fleet

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## Abstract

Understanding fishing effort and fleet behavior is of primary importance for a proper management of tuna resources, particularly when uncertainties exist in the catch per unit of effort (CPUE) index. Tropical tuna purse seine fisheries are of extremely importance, accounting for about half of the world market tropical tunas. Using Vessel Monitoring System data with a frequency of 1 ping/hour, this study develops a methodological framework that validates and investigates the activity of Spanish tropical tuna purse seine fleet in the tropical Atlantic Ocean by comparing them with observer, fishing logbook and fine-scale vessel tracking data. We present statistics and summary parameters of fishing related activities of Spanish purse seiners, including FAD-oriented activities, as well as examples for potential identification of fishing effort distribution. Results showed that vessels' activity and associated effort are reasonably well identified by the proposed method and highlighted the importance of accessing accurate fisheries-related data for correct validation of activities. This work contributes towards the use of VMS data to increase our knowledge on fleets behavior and strategy and presents a methodology able to provide insight into the potential relationship between significant changes and fleet behavior, which appears to be crucial for a proper definition of the effort to be used in CPUE of this fishery. Results obtained through the methodology developed in this study should be compared to outputs from other validated fleets like, for example, French fleet, which are supposed to less rely on FADs in their fishing strategy.

## Introduction

Effective management of tuna resources need to understand both fleets' fishing effort and behavior, especially when the effort of the fleet is not easy estimated and the relationship between abundance and catchability is not constant. Inadequate effort units or variables used to account for changes in catchability and effort-abundance relationships may lead to uncertainties in the catch per unit of effort (CPUE) index, masking real changes in the dynamics of the stocks (Maunder et al. 2006). Many are the parameters and variables related to the effort and efficiency or increased catchability of a fishing vessel, including technological equipment, vessel characteristics, skippers' skills, environmental conditions and behavioral patterns, among others (Torres-Irineo et al. 2014). This issue is particularly significant in the tropical tuna purse seine fishery, where continuous technological developments are known to occur and fishing strategy is relying more heavily on fish aggregating devices (FADs) (Lopez et al. 2015). In addition to the potential effects of FADs in the ecosystem (e.g. risk of biodiversity loss, deleterious alteration of the movement of fish), these devices have also produced changes in the fishing strategy and efficiency (Dagorn et al. 2012). New technologies and FADs have direct impact on fishing practices and, hence, the time devoted for each fishing activity changes and fluctuates. For example, fleets are known to travel to further fishing grounds now following productive FADs (Lopez et al. 2014), they deploy and retrieve hundreds of FADs to/from the sea throughout the year (Maufroy et al. 2015) and regularly communicate with each other (Scott and Lopez 2014), reducing also search time between fishing operations and making them significantly more efficient than in the past (Anonymous 2012).

In most of the cases, tropical tuna purse seine activity has only been evaluated through fishery-dependent data, although some initiatives have used VMS (Vessel Monitoring System) data for the French fleet (Walker and Bez 2010; Bez et al. 2011). Fishery-dependent data (e.g. catch and effort), if accurately collected and processed, are very useful, but limited in the information by definition. Moreover, fishing logbooks, and a considerable part of observer data, rely exclusively on activities related to fishing operations and in both human will and skills when collected. In addition, human observers are not onboard in all current and past fishing trips and they usually have different objectives rather than collecting activity information, which hinders an accurate assessment of the fleet activity (although the Spanish fleet has recently adopted 100% of coverage; Goñi et al. (2015)). Thus, new fishery-dependent tools and data that assist managers and scientist in the effective assessment of tropical tuna purse seine fleet activity and behavior are of primary importance for a correct management of exploited resources.

The objective of the present study is to develop and validate a methodology to use VMS information to robustly infer fleet activity, behavior as well as estimate units of efforts which will progress towards its inclusion in the stock assessment of tropical tunas. The VMS data will be compared with traditional fisheries-dependent data such as logbooks and observer data, and fine-scale vessel tracking data for its validation.

# Material and methods

## Data collection

Four different data sources were used in this study:

- Spanish fleet VMS data operating in the Atlantic Ocean from 2007 to 2014 (1 ping/hour).
- Fishing logbooks of the Spanish fleet operating in the Atlantic Ocean from 2007 to 2014.

Observer data on vessel activity and fishing operations between 2007 and 2014. This data gathers information on the location, time of day, and instantaneous speed of a given activity. The original 21 activities/categories recorded by the observer were grouped into 6 general activities. Thus, all activities were included in one of the following category: stopped, in route, searching, fishing, drifting, and FAD-related activities (

- Table 1). The activities related to "in route", "searching" and "drifting" were also subcategorized to try to gather and infer fine-scale information of fleet activity.
- Fine-scale vessel track information from a GPS installed onboard a Spanish purse seiner during a fishing trip in the Atlantic Ocean in April-May 2011. The GPS collected information on the course, speed and location of the vessel every 2 minutes.

## Data analysis

Four steps were conducted during the data analysis.

1. Observers' activity data was clustered and analyzed based on the time of the day in which the activity was conducted and their corresponding instantaneous and averaged speeds (i.e. averaged speeds between two consecutive points). This analysis allows gathering information and identifying the main speeds and temporal patterns for each activity considered in the study.
2. Kernel densities (Silverman 1986) were computed for both VMS and fine-scale GPS data.
3. Fishing operations (locations and catch in logarithmic scale) were identified and plotted using logbook and observer data for the fishing trip for which both VMS and fine-scale GPS data are available.
4. Points 2 and 3 were repeated for the fishing trips of a randomly selected fishing vessel for which VMS data, fishing logbooks and observer data are simultaneously available. The analysis was also extended to activities other than fishing.

# Results and discussion

The analysis of the time of the day in which the activity occurred (Figure 1) showed that certain activities can be properly identified based on the variable time. For example, the activity "stopped" (activity 1) or "in route to a FAD" (activity 2.3) are usually happening at 18h, when the fishing day ends.

The examination of the instantaneous speed recorded by the observer onboard also provided interesting information on the speed of different activities of the vessel (Figure 2). When analyzing vessels' activity at finer scale, the general drifting activity (activity 5) can be differentiated between "drifting at night" (activity 5.2) and "drifting close to a school or a floating device" (activity 5.1), being the latter occurring at significantly higher speeds. Similarly, fishing activity (activity 4, speed between 5-10 knots) can be distinguished from "in route" (activity 2) and "searching" activities (activity 3), which occur at slightly higher speeds (median about 11 knots).

The use of the averaged speed between consecutive points provided additional cues to accurately separate vessels' activities (Figure 3). Results of averaged speeds discern partially from those shown by instantaneous speeds. The activities "in route" (activity 2) and "searching" (activity 3) are more easily discriminated from, and overlapping is almost inexistent with, the rest of the activities when considering averaged speeds. However, when using averaged speeds in the analysis, the activities of fishing (activity 4) and drifting (activity 5) are not distinguished that clearly as they present some similarities, especially in the lowest range of the speed. Therefore, the combined use of these three approaches (i.e. time of day, instantaneous speed, averaged speed) seems to be a useful tool to properly identify vessels' activity. It is important to note, however, that accurate identification of vessel activity requires high quality observer records and that further studies should investigate the precision and robustness of this data by specific scientific analysis.

In order to validate the use of VMS data and its current resolution (1 ping/hour), we compared the kernel density estimates for both VMS data and fine-scale GPS data (1 ping every 2 minutes) (Figure 4 and Figure 5). As it can be observed, no significant differences exist between the spatial distributions provided by both data sources. Also, no evident differences were found in the centroids of each of the day in the fishing trip. The majority of the routes are segments of straight lines occurring between knots produced by the accumulation of neighbor signals. The appropriate resolution of the VMS signals to adequately monitor fleet activity has been discussed broadly (Kelleher 2004; Lee et al. 2010). The data collection and reporting frequency has to be specific and adapted to the particular needs and behavior of each fishery and gear. In some fisheries, certain reporting rates have been considered not to provide adequate estimates of fleet activity (see Lee et al. (2010)). It is worth to mention that comparison between tracks and results obtained through fine-scale GPS data and regular VMS data showed that, for the specific case of the tropical tuna purse seine fishery, the used resolution seems to be suitable to monitor fleet activity effectively and that higher resolution may not be necessary.

When comparing the spatial distribution of the effort and activities perceived by kernel density estimates of VMS data and those recorded in the logbooks (Figure 6 and Figure 7), we observe that all of the fishing sets are on the knots. However, not all the knots shown by the kernel densities correspond to fishing events recorded in the fishing logbook. Reasons behind this may be various. On one hand, day and night data has not been separated for analysis at this exploratory stage. On the other hand, the called "Fishing" activity (4) also considers the "arrival to a detected system" activity, which does not necessarily represent a fishing operation but reflects part of the effort. Thus, the "arrival to a detected system" activity could indicate approaching to a FAD/Free school without an associated fishing set or a null fishing set, instead of real fishing event with positive catch, as showed in the figures. This issue could indirectly be seen in figure 1, where the median time of "arrival at detected system" activity is after the "start of fishing operation" activity, reflecting that not all arrivals are necessarily followed by fishing events. The consideration of "arrival to a detected system" as part of the fishing effort is important to better estimate realistic effort indices of the fleet in the CPUE standardization process. However, for proper comparison of logbooks with VMS data it would be desirable to include only clearly identified fishing events in the analysis, including only start and end of fishing activities in observers' data and a comprehensive fishing records from fishing logbooks with null sets. Moreover, further analysis should investigate and measure the accuracy of predictions using, for example, confusion matrix or sensitivity analysis. Knowing the reliability provided by VMS data seems crucial for future assumptions of fleet dynamics, effort distribution and activity monitoring purposes.

Figure 8, based on simultaneous VMS data, fishing logbooks and observer data of a randomly selected vessel showed significant differences depending on the information used for comparison. Whereas only some knots of VMS kernel densities are associated with fishing events in the logbooks, the vast majority of knots seem to be related to fishing related activities in the observers' records; however, there are also several fishing activities by observers that are not related neither to logbook sets nor to VMS knots of kernel densities (figure 8 trip 3, 7 and 17) and several knots without either fishing sets in logbooks and observer data (figure 8 trip 5). This could be related again to the issue of "arrival to a detected system" included as fishing and because non-positive sets have been not showed in the figures. The frequency and reliability of these discrepancy patterns should be confirmed analyzing data from other vessels, which would certainly assist in the understanding of the real magnitude of this issue.

The grouped activities recorded by observers were plotted on the randomly selected fishing trips of VMS data and showed convergence with both track and the knots, depending on the type of activity (Figure 9 and Figure 10). The majority of fishing activities are properly linked to knots in the VMS data. FAD-related activities were unabundant during some of the selected fishing trips but all of them were associated to a fishing event and a given VMS knot. The minor activity on FADs observed in trip 3 (Figure 9) may also suggest that the "arrival at a detected system" could also include activities on FADs, such as visit, deployment, recovery, etc., and not only fishing sets. It is also worth mentioning that many of the fishing activities of trip 3 in Figure 9 are very similar to those shown by the "stopped" activity. This behavior may suggest that many night stops are associated with FAD-related activities, including fishing sets but also FAD visits. Frequently, fleets arrive to or visit FADs during the afternoon and wait until the next morning to conduct the set or check the aggregation. The approach used in this study allows inferring this kind of behaviors if the datasets are studied with no constrains. The activities "drifting" and "stopped" are usually linked to knots and do not present overlapping between them. It is important to note that most of these activities occur after or during a fishing event or at night/close to the sunset periods, so that they can easily be discerned from other type of activities. Both in route and searching activities are associated to the segments between knots and converge spatially with the VMS track (Figure 9 and 10). At this moment, searching time is of primary importance for this fishery, where it has historically been used as a proxy for effort. Although it has been widely accepted that this index is inappropriate to reflect nominal effort (Fonteneau et al. 2013), identifying search time areas and associated activities would assist in the better understanding of the fleet behavior and activity, key needs for a better and more accurate management of tuna resources.

The methodology presented in the current study can be considered as a first step towards the simple and effective use of VMS data to better monitor and manage fleet activity. Once validated, the trends and patterns found in this work for each activity, especially those related to fishing effort, should be extended to the whole fleet and compared to current results as well as to independent outputs coming from other data sources to see their consistency and robustness. The large scale application of this methodology, traduced as an expert system that allow the identification of different activities occurring during a fishing trip, would assist in the identification and monitoring of more realistic areas and seasons of effective effort, providing interesting insights into the fleet dynamics and exploited resources.

# Tables

Table 1. Fishing Activity Codification

| Codification_1 (C1) | Original Activity | Codification_2 (C2) | Activity | Codification_3 (C3) | Activity_2 |
|---|---|---|---|---|---|
| 0 | In port | 1 | Stop | 1 | Stop |
| 1 | Transit (route without search) | 2 | Route | 2.1 | Route |
| 2 | Search (in general) | 3 | Search | 3.1 | Search |
| 3 | Exclusive search for floating devices | 3 | Search | 3.2 | Search_FAD |
| 4 | Route towards an observed system | 2 | Route | 2.2 | Route_FREE |
| 5 | Arrival at a detected system | 4 | Fishing | 4 | Fishing |
| 6 | Commencement of a fishing set (lowering of Tug boat) | 4 | Fishing | 4 | Fishing |
| 7 | End of fishing ( Tug boat on board) | 4 | Fishing | 4 | Fishing |
| 8 | Drifting close to a school or a foating device, observation of a system after arriving there | 5 | Drifting | 5.1 | Drifting_TUN |
| 9 | Drifting at night (engine stopped) | 5 | Drifting | 5.2 | Drifting |
| 10 | Heaving (bad weather) | 1 | Stop | 1 | Stop |
| 11 | Failure at sea | 1 | Stop | 1 | Stop |
| 12 | Transfer at sea (fuel, supplies, etc.) | 1 | Stop | 1 | Stop |
| 13 | FAD (visit, lay, modification, recovery, fishing set) | 6 | FAD | 6 | FAD |
| 14 | Recovering a proper FAD | 6 | FAD | 6 | FAD |
| 15 | Recovering an FAD From another boat | 6 | FAD | 6 | FAD |
| 16 | End of watch (binoculars down at the end of the day) | 1 | Stop | 1 | Stop |
| 18 | Night time route towards device | 2 | Route | 2.3 | Route_FAD |
| 19 | Continua hacia sistema observado | 2 | Route | 2.2 | Route_FREE |
| 60 | Anchoring on seamount | 1 | Stop | 1 | Stop |
| 99 | Others (to be detailed in notes) | 1 | Stop | 1 | Stop |

# Figures

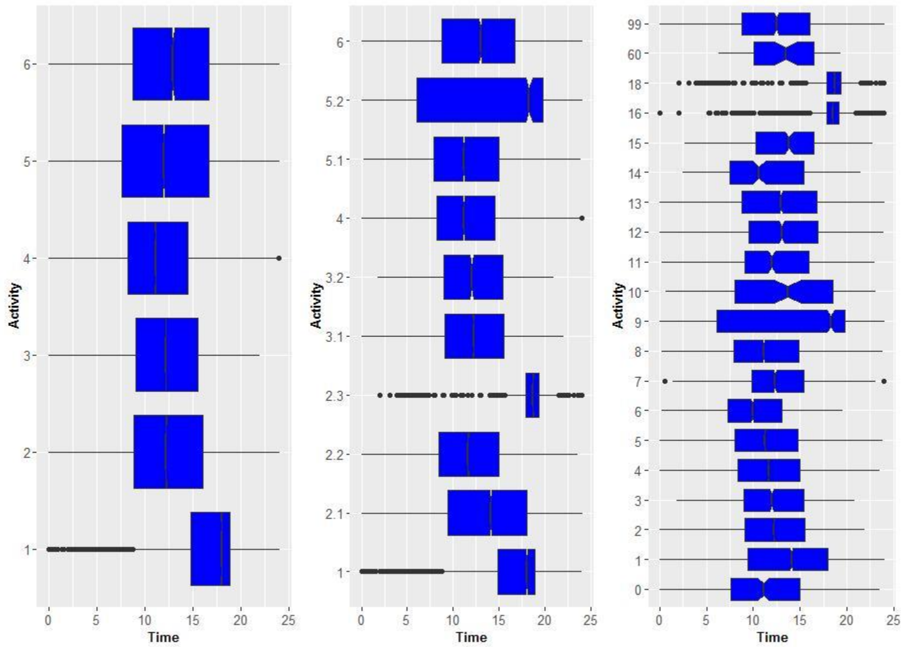


Figure 1. Time of the day by different levels of activity classification

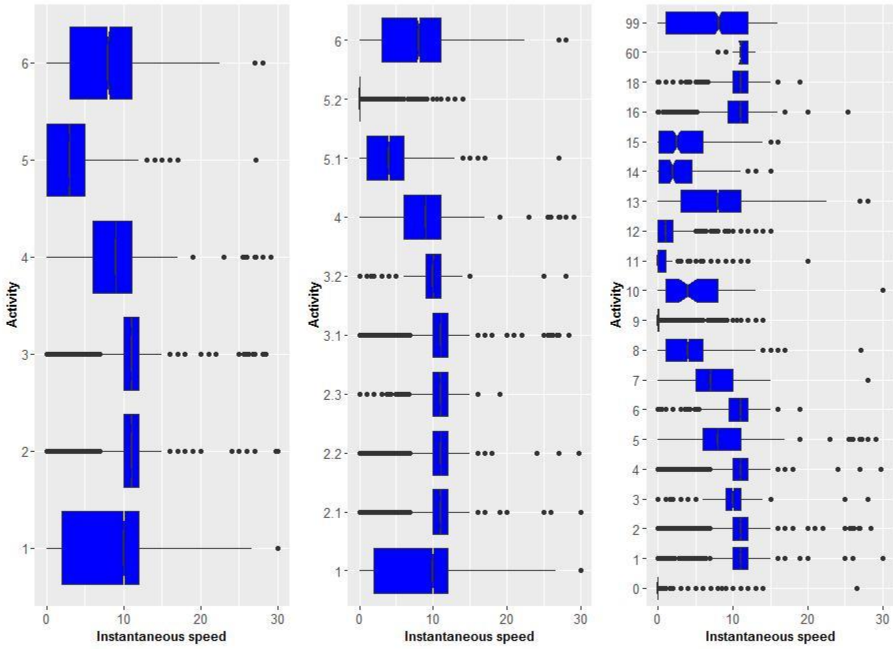


Figure 2. Instantaneous speed by different levels of activity classification

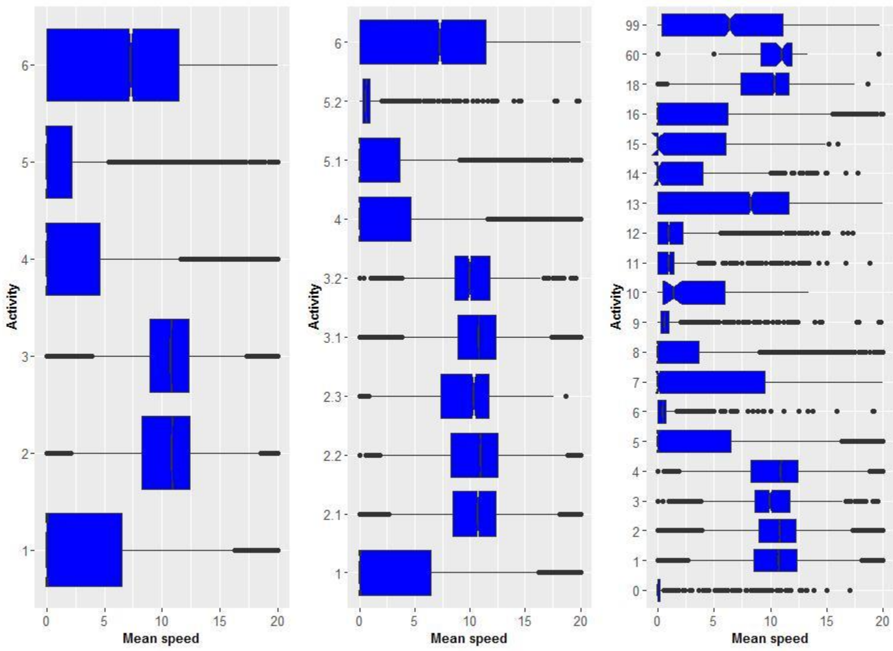


Figure 3. Mean speed by different levels of activity classification

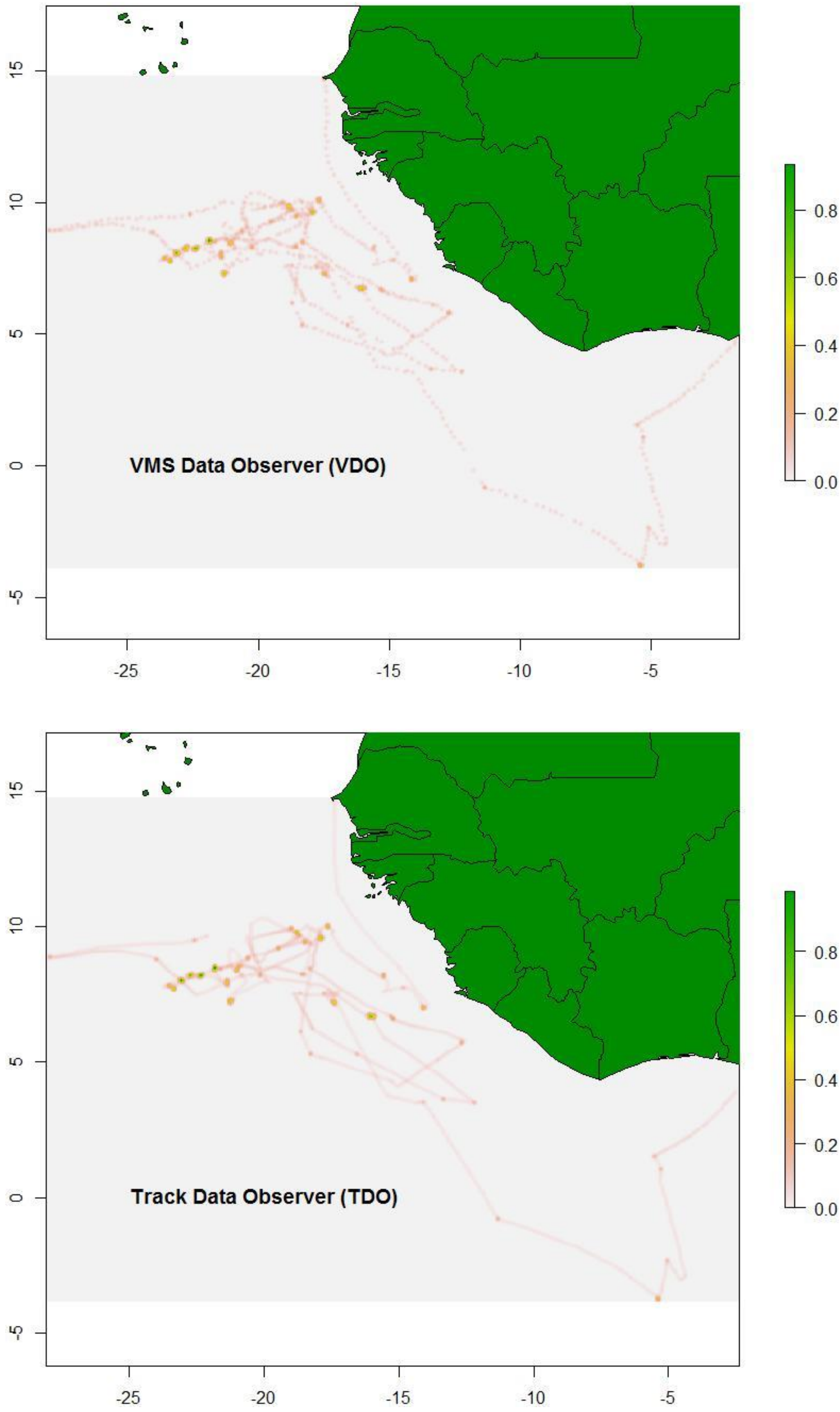


Figure 4. Spatial distribution (kernel density) of vms data (up) and GPS fine-scale track data (down) from observer on board

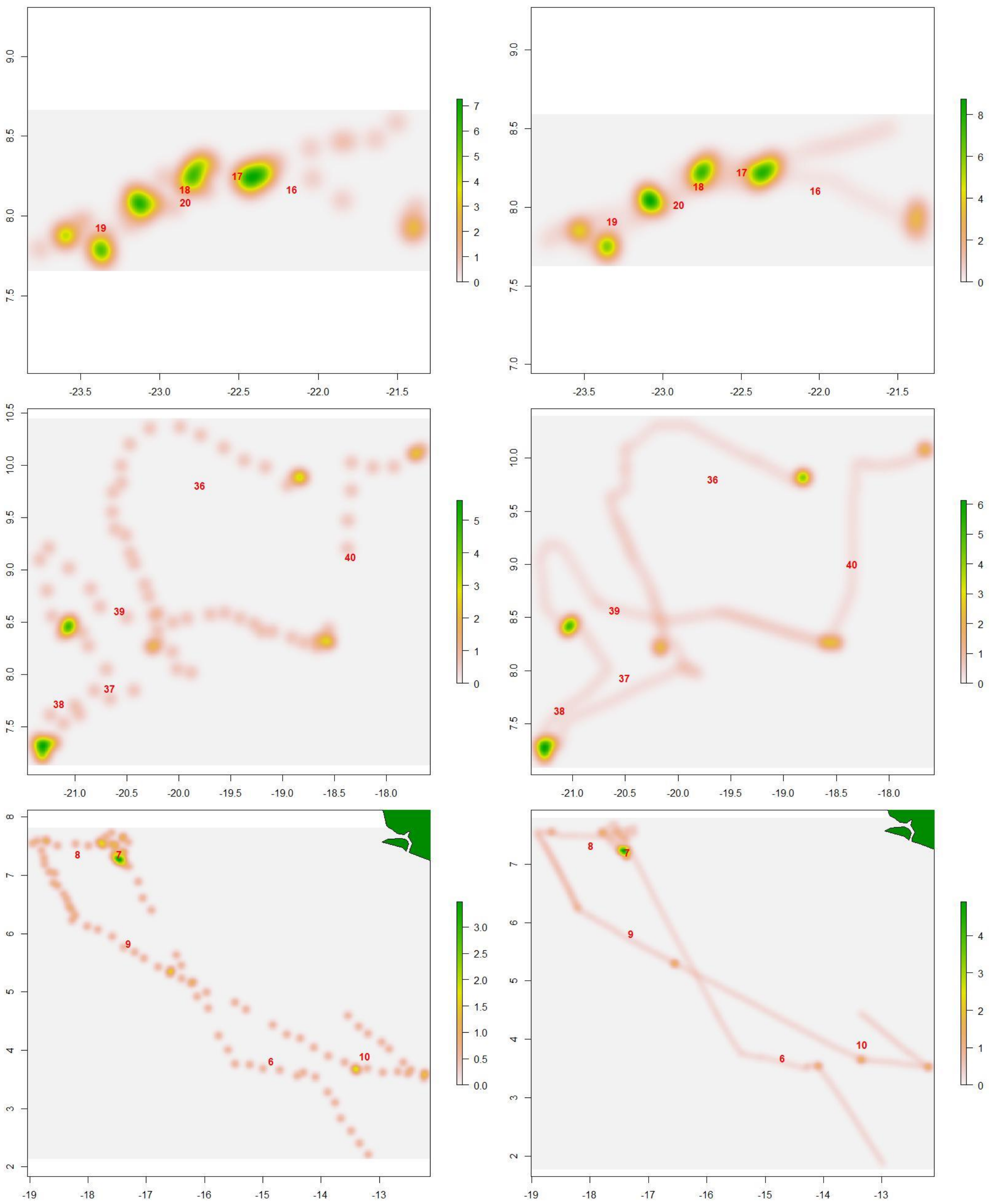


Figure 5. Zoom over some of the fishing days from vms data (left) and fine-scale GPS track data (right). Numbers show the day number of the trip and their position is the center of the spatial distribution of the fishing day.

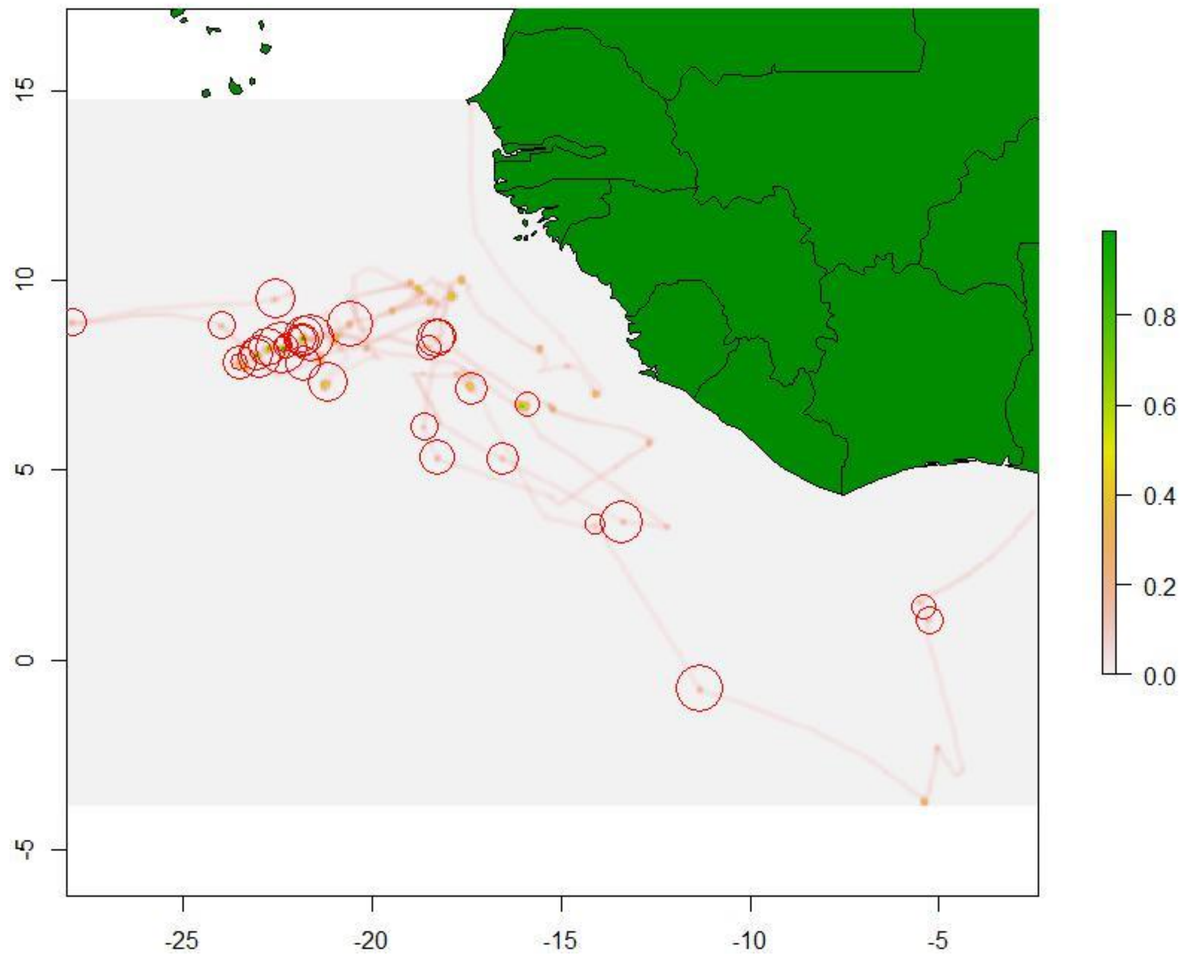


Figure 6. Spatial distribution of the vms data with observer on board with landings from logbooks (red circle: the radius is the log of the landings in tons)

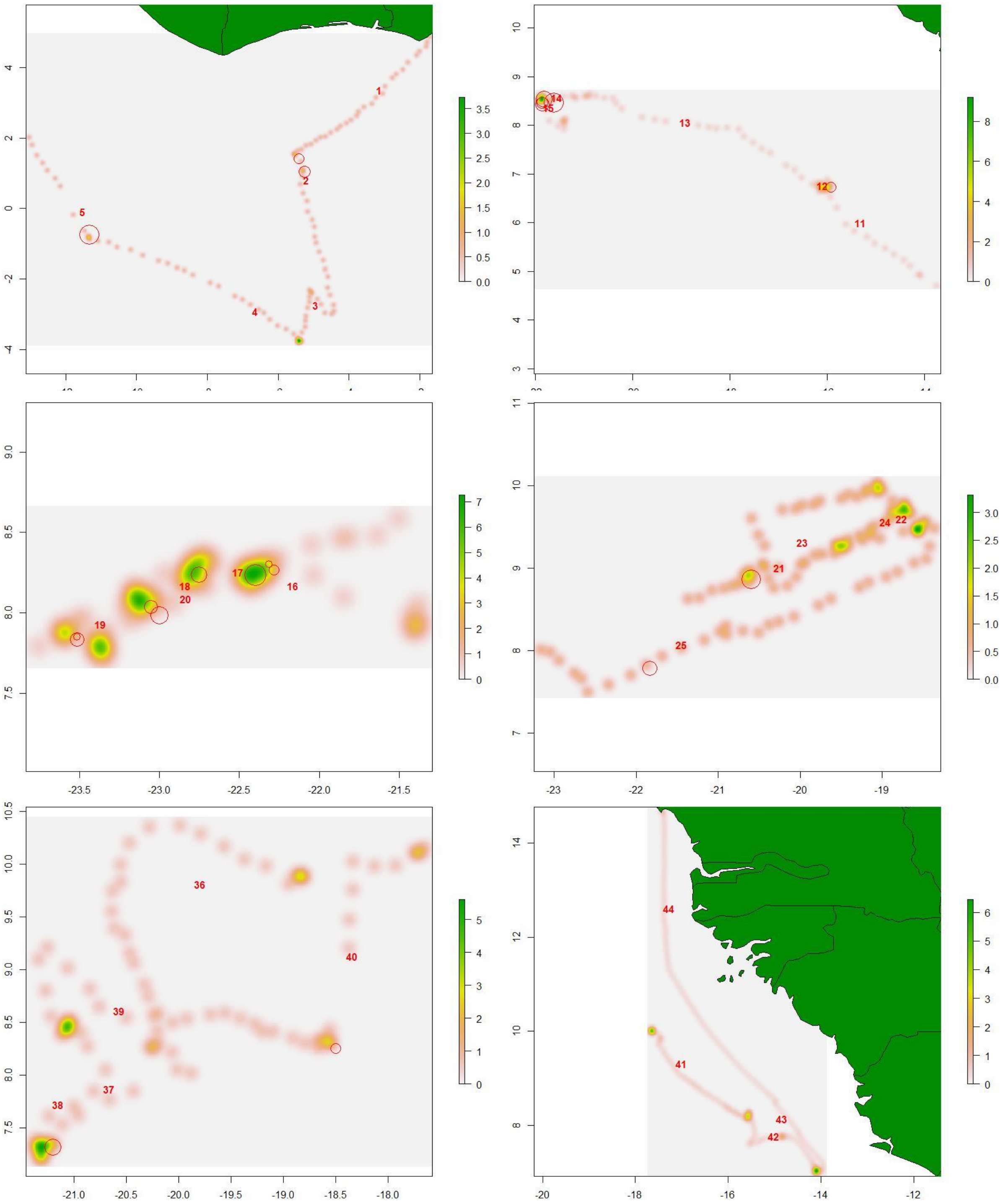

Figure 7. Zoom over some of the fishing days from vms data with observer on board with landings from logbooks (red circle: the radius is the log of the landings in tons). Numbers show the day number of the trip and their position is the center of the spatial distribution of the fishing day.

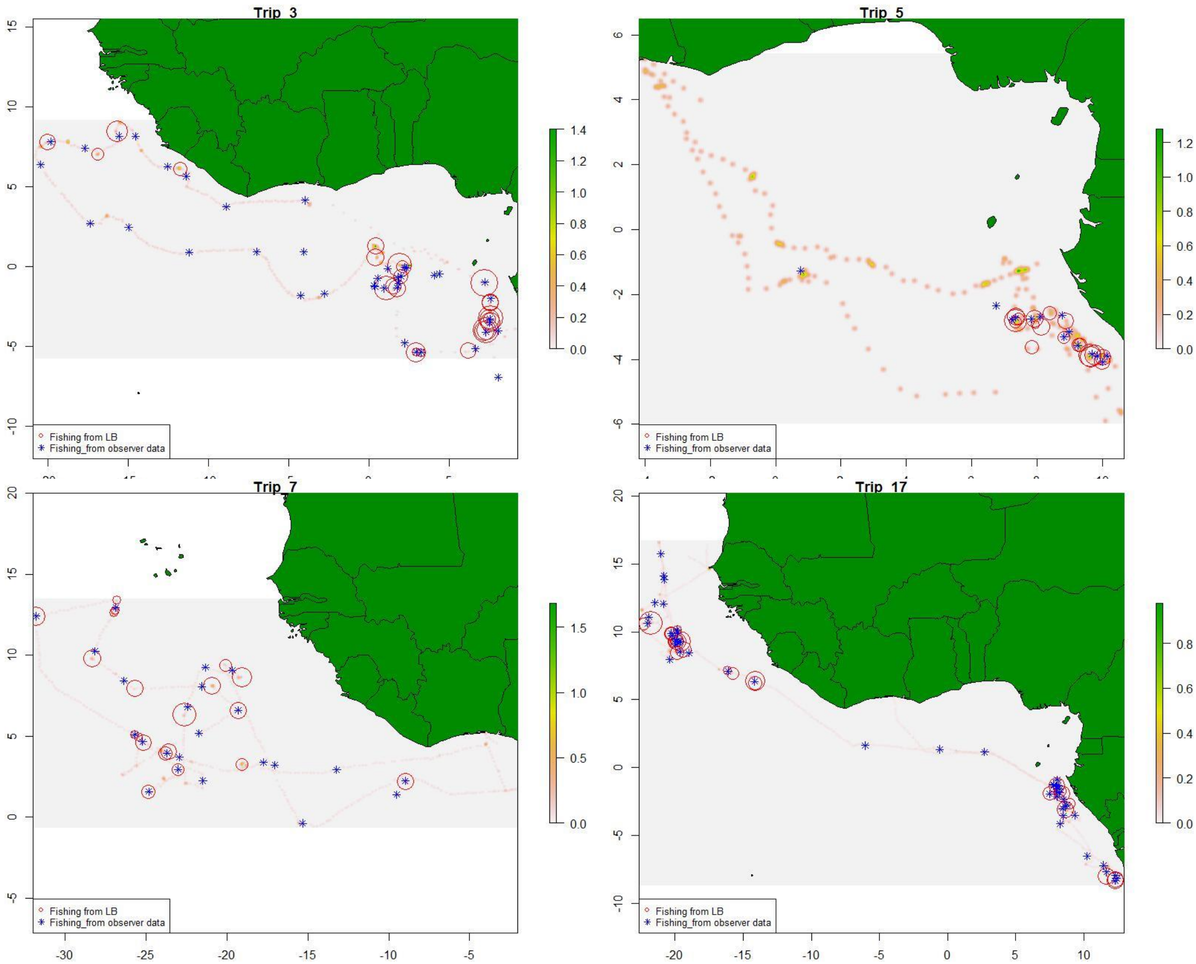


Figure 8. Comparison between VMS data and the locations of fishing-related activities from fishing logbooks and observer data from randomly selected fishing trips.

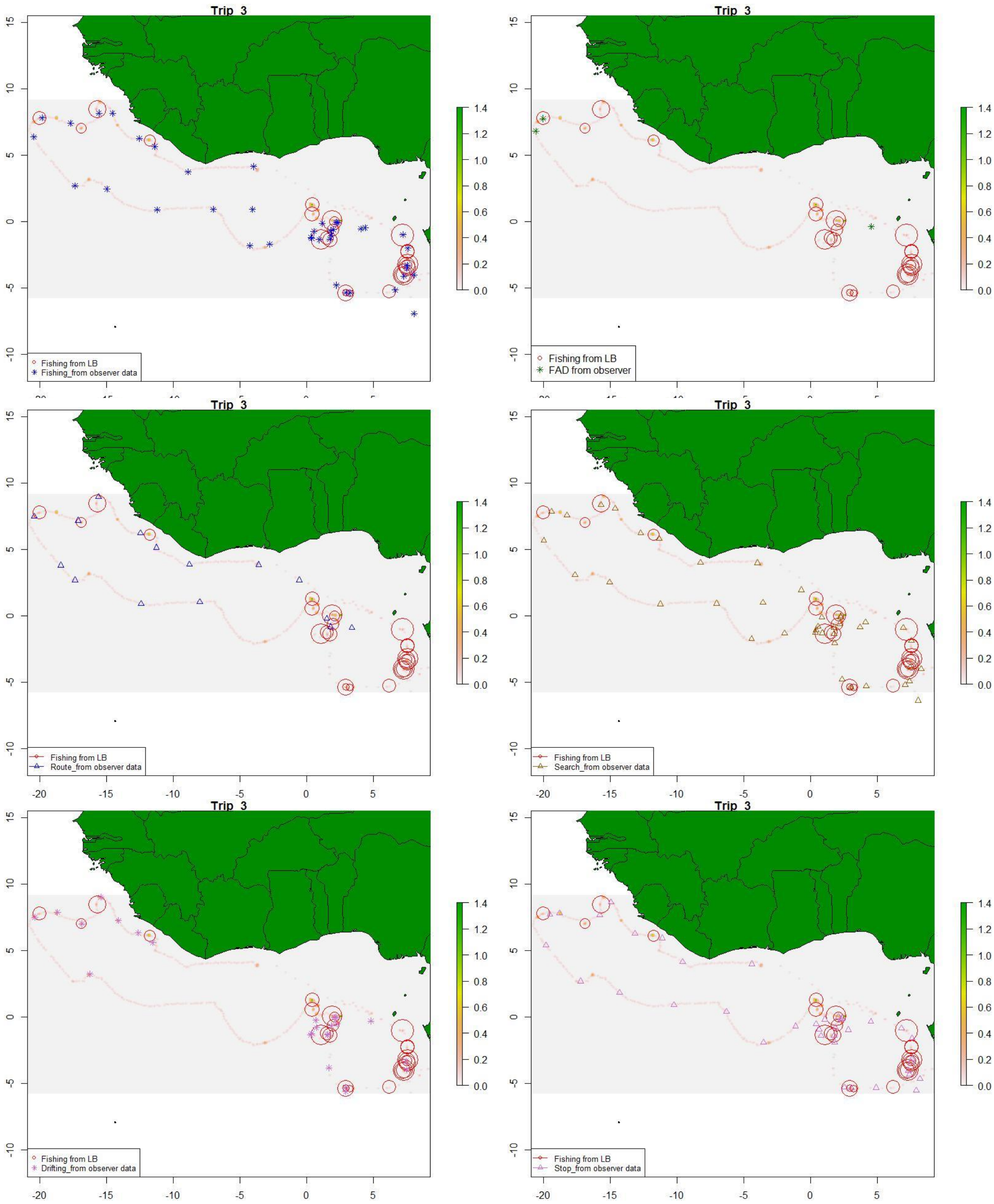


Figure 9. Detailed spatial distribution of the main activities of a vessel during an example fishing trip, including fishing logbook information and grouped observer activities (fishing, FAD, in route, searching, drifting and stopped activities).

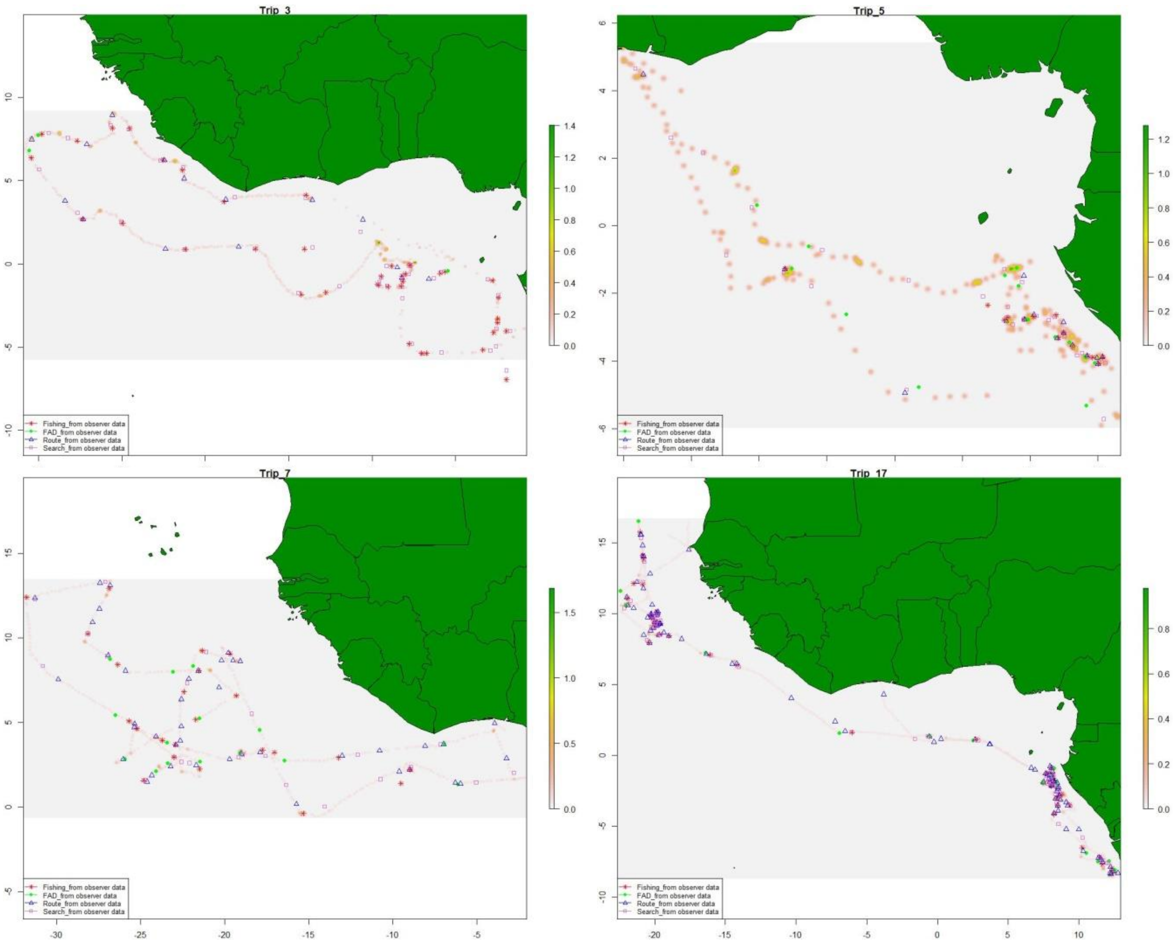


Figure 10 Detailed spatial distribution of the main activities of a vessel during an different fishing trips, including information on observer activities related to effort (fishing, FAD, in route, and searching).

# REFERENCES

Anonymous (2012) Report of the 2012 ISSF Stock Assessment Workshop: Understanding Purse Seine CPUE. ISSF Technical Report 2012-10 International Seafood Sustainability Foundation, Washington, DC, USA

Bez N, Walker E, Gaertner D, Rivoirard J, Gaspar P (2011) Fishing activity of tuna purse seiners estimated from vessel monitoring system (VMS) data. Canadian Journal of Fisheries and Aquatic Sciences 68: 1998-2010 doi 10.1139/f2011-114

Dagorn L, Holland KN, Restrepo V, Moreno G (2012) Is it good or bad to fish with FADs? What are the real impacts of the use of drifting FADs on pelagic marine ecosystems? Fish and Fisheries: n/a-n/a doi 10.1111/j.1467-2979.2012.00478.x

Fonteneau A, Chassot E, Bodin N (2013) Global spatio-temporal patterns in tropical tuna purse seine fisheries on drifting fish aggregating devices (DFADs): Taking a historical perspective to inform current challenges. Aquatic Living Resources 26: 37-48 doi doi:10.1051/alr/2013046

Goñi N, Ruiz J, Murua H, Santiago J, Krug I, Sotillo de Olano B, Gonzalez de Zarate A, Moreno G, Murua J (2015) System of verification of the code of good practices on board ANABAC and OPAGAC tuna purse seiners and preliminary results for the Atlantic Ocean. IOTC–2015–WPEB11–INF09

Kelleher K (2004) Institutional options for VMS cooperation among the Parties to the Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean. WCPFC/PrepCon/WP23

Lee J, South AB, Jennings S (2010) Developing reliable, repeatable, and accessible methods to provide high-resolution estimates of fishing-effort distributions from vessel monitoring system (VMS) data. ICES Journal of Marine Science: Journal du Conseil 67: 1260-1271 doi 10.1093/icesjms/fsq010

Lopez J, Fraile I, Murua J, Santiago J, Merino G, Murua H (2015) Technological and fisher's evolution on fishing tactics and strategies on FADs vs. non-associated fisheries. IOTC–2015–WPTT17–32

Lopez J, Moreno G, Sancristobal I, Murua J (2014) Evolution and current state of the technology of echo-sounder buoys used by Spanish tropical tuna purse seiners in the Atlantic, Indian and Pacific Oceans. Fisheries Research 155: 127-137 doi http://dx.doi.org/10.1016/j.fishres.2014.02.033

Maufroy A, Chassot E, Joo R, Kaplan DM (2015) Large-Scale Examination of Spatio-Temporal Patterns of Drifting Fish Aggregating Devices (dFADs) from Tropical Tuna Fisheries of the Indian and Atlantic Oceans. PLoS ONE 10: e0128023 doi 10.1371/journal.pone.0128023

Maunder MN, Sibert JR, Fonteneau A, Hampton J, Kleiber P, Harley SJ (2006) Interpreting catch per unit effort data to assess the status of individual stocks and communities. ICES Journal of Marine Science: Journal du Conseil 63: 1373-1385 doi 10.1016/j.icesjms.2006.05.008

Scott GP, Lopez J (2014) The use of FADs in tuna fisheries. European Parliament Policy Department B: Structural and Cohesion Policies: Fisheries IP/B/PECH/IC/2013-123: 70p

Silverman BW (1986) Density estimation for statistics and data analysis. CRC press

Torres-Irineo E, Gaertner D, Chassot E, Dreyfus-León M (2014) Changes in fishing power and fishing strategies driven by new technologies: The case of tropical tuna purse seiners in the eastern Atlantic Ocean. Fisheries Research 155: 10-19 doi http://dx.doi.org/10.1016/j.fishres.2014.02.017

Walker E, Bez N (2010) A pioneer validation of a state-space model of vessel trajectories (VMS) with observers' data. Ecological Modelling 221: 2008-2017 doi http://dx.doi.org/10.1016/j.ecolmodel.2010.05.007