SEYCHELLES AUXILIARY VESSELS IN SUPPORT OF PURSE SEINE FISHING IN THE INDIAN OCEAN DURING 2005-2014: SUMMARY OF A DECADE OF MONITORING

Assan C[1], Lucas J[1], Augustin E[1], Delgado de Molina[2], Maufroy A[3], Chassot E[4]

SUMMARY

We used a large database of information collected from logbooks to provide an overview of the activities of the Seychelles auxiliary vessels used in support of the Seychelles purse seiners during 2005-2014. After a decrease in the number of support vessels linked to the piracy threat during 2010-2012, the effort of the fleet has increased in the recent years through the arrival of new vessels and increasing numbers of operations on a daily basis. In particular, the numbers of deployments of Fish Aggregating Devices (FADs), transfers of instrumented buoys and visits of floating objects have been steadily increasing over the recent years. Also, the engine power of the Seychelles support vessels has increased since the mid-2000s while their size has remained constant over the last decade. We argue that the time at sea of support vessels should be accounted for when deriving nominal catch rates from purse seine fisheries data. Information available from support vessels logbooks appears very valuable to describe the dynamics of FAD use and appreciate the component of purse seiner fishing strategy that takes place prior to the capture of tropical tunas.

KEYWORDS: Purse seining, FAD, fishing effort

[1] Seychelles Fishing Authority, Fishing Port, Victoria, SEYCHELLES. Contact: cassan@sfa.sc
[2] Instituto Espanol de Oceanografia, , PO Box 1373, S/C Tenerife, SPAIN
[3] Institut de Recherche pour le Développement, UMR 248 MARBEC, Avenue Jean Monnet, 34203 Sète Cedex, FRANCE
[4] IRD, SFA, Fishing Port, BP570, Victoria, SEYCHELLES

1. Introduction

Support vessels, also called supply or auxiliary vessels, play a major role in tropical tuna purse seine fisheries worldwide, with the exception of the eastern Pacific Ocean where they have been banned to operate as early as 1998 (Anonymous 2012). Support vessels are vessels that are not equipped with any fishing gear but assist one or several purse seiners in the detection of tuna schools and the management of the stock of artificial fish aggregating devices (FADs) and buoys used to locate both natural floating objects (LOGs) and FADs. In addition to GPS, most buoys now include echo-sounder devices that provide information on the biomass of tuna aggregated under the equipped objects (Chassot et al. 2014, Lopez et al. 2014). More specifically, activities of support vessels related to fishing include the building and deployment of FADs, the visit of LOGs and FADs, the transfer of buoys, and the retrieval of FADs and buoys. In addition, support vessels also contribute to increasing the fishing time of the purse seiners they assist through the transport of persons and materials and repairing operations (Arrizabalaga et al. 2001).

In the Indian Ocean, the first support vessels appeared in the late 1980s to act as anchored FADs on the Travin Bank (or seamount ‘Coco de Mer’), enhancing the aggregation of tunas through powerful flashlights. Although some ‘navigating’ support vessels may have become active from the mid-1990s, information on the number and activities of support vessels has only become available with the implementation of a moratorium on FAD-fishing in the Western Indian Ocean during November 1998 – January 1999. Hence, information on the activities of support vessels was first collected through observer data (Mina et al. 2002b, Arrizabalaga & Artetxe 2000, Arrizabalaga et al. 2001). Such data allowed a comprehensive description of the short term operations and tactics of support vessels and of the materials they used in the late 1990s. Following the IOTC Resolution 01/05, logbooks were implemented on support vessels in late 2004 (Delgado de Molina et al. 2004). While they were first found to vary in terms of the quantity and quality of information reported, the reporting rate of logbooks steadily increased throughout the 2000s to reach >90% in 2010 (Ramos et al. 2010). Logbook data collected aboard support vessels then cover a long period of time through the whole year and provide a lot of information on the effort and activities of this component of the purse seine fleet (Sarralde et al. 2007, Ramos et al. 2010).

Here, we describe the main characteristics of the Seychelles support vessel fleet and provide a synthesis of the activities of support vessels during 2005-2014. Our objective is to quantify the contribution of the support vessels to the overall nominal effort of the purse seine fleet and show the main changes that may have occurred in the fleet over the last decade.

2. Materials

The acronym FOB standing for floating object is used thereafter to represent both artificial FADs and natural LOGs.

2.1 AVDTH database for 2005-2014

All logbook data were first entered in a MS ACCESS database dedicated for the support vessels (Sarralde et al. 2007). Following the extension of the software ‘Acquisition et Validation des Données de Pêche au Thon Tropical’ (AVDTH; Lechauve 1999) to include all activities related to the activities on FADs and buoys added in the logbooks of the French purse seine fleet in 2013, all logbook data from Seychelles support vessels were migrated to a specific AVDTH database. The full dataset covers the period from early November 2004 to nowadays and is restricted here to the period 2005-2014 for consistency reason. Overall, a total of about 36,500 activities were reported in the logbooks for 12 distinct vessels that operated a total of 338 fishing trips during 2005-2014. The trip duration greatly varied between vessels, from a minimum of 3 to a maximum of 135 d, with a median of about 40 days at sea.

2.2 Characteristics of the support vessels

While first support vessels were mostly old pole and liners or trawlers reconverted for conducting the activities required for assisting purse seine fishing, specific designs have been developed in the recent years and brand new support vessels are now built in Spanish shipyards. Based on the initial year of service available for each vessel, we computed the mean age of the Seychelles support vessels to investigate for some changes in the overall strategy of the purse seine fishing companies operating in the Indian Ocean. Also, Seychelles support vessels were characterised by their average length and engine power to look for changes in the fleet over the last decade.

2.3 Supply vessels operations

We focus here on the activities related to fishing although support vessels can also conduct some logistical operations such as transfer of materials and personnel (Arrizabalaga et al. 2001). The referential of activities reported in the logbooks describes the status of the vessel, i.e. route, research, hove, waiting and port, and activities directly related to buoys and FOBs, i.e. addition/retrieval of a buoy on an existing FOB, deployment of a FAD with a buoy, and visit of a FOB with/without a buoy. Information on the buoy type (e.g. with echo sounder) and FOB type (e.g. payao) was also collected from logbooks. Although information on the call of the purse seiner was sometimes available from the logbooks (Ramos et al. 2010), it was not reported in the database. It is noteworthy that the one support vessel started operating under the Seychelles flag in January 2014 as an anchored support vessel on the Travin Bank. Very few operations were therefore recorded for this vessel and its time at sea does not reflect the same effort as navigating support vessels. First, the total number of operations reported in the logbooks was used to describe the overall activities of the support vessels. In a second step, average daily rates of numbers of operations for the support vessel fleet were computed through the ratios between the number of operations and the cumulated time at sea. The anchored support vessel was excluded from these estimates.

3. Results

3.1 Vessels characteristics

The overall capacity and associated nominal effort of the Seychelles support vessel fleet greatly varied over the last decade. The number of Seychelles support vessels decreased from 8-9 in 2006-2009 to 3 in 2011-2012 in relation with the piracy threat and concurrent decrease in the number of Seychelles purse seiners (**Fig. 1a**). The number re-increased to 4 in 2013 and 5 in 2014. It is noteworthy that there were a total of 9 support vessels in operation in 2007 for a total of 10 Seychelles purse seiners active. The annual mean size of the vessels was stable during 2005-2014 and described by a mean value of 36 m length overall (SD = 1.3 m) (**Fig. 1b**). The annual mean engine power of the vessel significantly increased during 2005-2014 from about 1,000 hp in 2004-2005 to about 1,300 hp in 2012-2014 (Adjusted Pearson's $r = 0.75$, p-*value*<0.01) (**Fig. 1c**). The mean age of the vessels was about 20 y old (SD = 2.6 y) and it decreased to 14.6 y in 2014 with the arrival of a new vessel.

3.2 Vessels operations

Support vessels operations mainly consisted of deploying new FADs equipped with buoys at sea and visiting FOBs, i.e. they represented 40% and 38% of all activities reported in the logbooks during 2005-2014, respectively. Overall, more than 13,000 deployments of FADs and 12,000 visits were reported in the logooks over the time period considered. The daily activities greatly varied between vessels and in time and space. Deployments of new FADs at sea equipped with buoys varied from 1 to about 15 (95% quantile value), with a maximum of 50 deployments observed once in 2014 (**Fig. 2a**). Support vessels generally transferred 1-2 buoys, retrieved 1-2 FADs from the water and visited 1-2 FOBs each day (**Fig. 2b-d**).

Excluding the anchored support vessel, the annual cumulated time at sea reported in the Seychelles support vessel logbooks varied from more than 2,500 days in 2007 to a minimum of about 550 days in 2013. The time-at-sea of the Seychelles support vessel fleet strongly decreased from a maximum of about 200 days by month in 2007 to about 50 days by month in 2013, before re-increasing thereafter (**Fig. 3a**). Monthly deployments varied consistently with the time at sea during 2005-2013 before increasing sharply to reach about 400 in June-July 2014 (**Fig. 3b**). Similarly, the buoys transfers showed a very sharp increase recently to reach monthly values around 100 during August-November 2014 (**Fig. 3c**). By contrast, monthly visits of FADs showed a rather consistent pattern during 2005-2014 despite the annual changes in time at sea, with high numbers of visits during September-November every year (**Fig. 3d**).

The mean daily rates of activities computed in each month showed the major shift in the deployments of FADs that took place in 2013 in the fishery. While the daily number of FAD deployments showed a significant but small increase during 2005-2012 (slope = 0.06 y^{-1}, p-*value*<0.01), the deployments increased sharply from May 2015 to vary around a mean value of 2.6 (SD = 0.8) during 2013-2014 (**Fig. 4a**). The mean daily rates of buoy transfers showed a strong seasonal pattern characterized by an underling increasing linear trend during 2005-2014 (slope = 0.07 y^{-1}, p-*value*<0.001) (**Fig. 4b**). The daily number of transfers increased from a monthly average of about 0.1 in 2004 to more than 0.6 in 2014. Similarly, the daily rates of visits of FADs showed some strong seasonal signal and an increasing linear trend over time (slope = 0.08 y^{-1}, p-*value*<0.001) (**Fig. 4c**). Overall, the number of visits increased from about 0.7 in 2004 to more than 1.1 in 2014. No clear pattern was detected in the daily rates of FAD retrievals from the sea and information appeared to be lacking from the database in several months, suggesting the information was not consistently reported in the logbooks (**Fig. 4d**).

3.3 FAD deployments

Areas of FAD deployments are confined to the Western Indian Ocean and vary over the year according to seasons. Quarterly maps of density of FAD deployments show that deployment areas are located along the equator during January-March, with two main zones of operations north of Seychelles (**Fig. 5a**). The support vessels then move southeast to the west of Seychelles during the spring inter-monsoon season (April-June) to deploy FADs that will drift south toward the Mozambique Channel and north off the coast of Somalia (**Fig. 5b**). Most activities of support vessels are located off the coasts of Somalia during July-September and deployments extend north of 10°N (**Fig. 5c**). During the last quarter of the year, the areas of FAD deployments are widespread off the Somalia coast (November) and west and south east of the Seychelles (**Fig. 5d**).

4. Discussion

We used a large database of information collected from logbooks to provide an overview of the activities of the Seychelles auxiliary vessels used in support of the Seychelles purse seiners during 2005-2014. The high reporting rate of the logbooks combined with the consistency in the data (i.e. number of operations, location of activities, patterns, etc.) suggest an overall good quality of the data set to appreciate the dynamics of the fleet and the role it plays in the fishing effort of the Seychelles purse seine fleet. For the first time, we described the main technical characteristics of the support vessel fleet and showed that the engine power of the vessels has steadily increased since the mid-2000s while their size has remained constant over the last decade. The arrival of a new support vessel in the Seychelles fleet in 2014 was concurrent with major investments recently made in the purse seine fishery of the

Indian Ocean where 7 brand new support vessels have joined the fleet during 2013-2015. The major increase in daily activities of the support vessels observed in 2014 seems to reflect some real changes occurring in the fishery as it concerns several vessels of the fleet and no change in IOTC data requirements may explain such a strong increase in the reporting in the logbooks.

4.1 Purse seine fishing effort

The use of purse seiner catch rates (catch per unit effort; CPUE) for deriving indices of abundance to be used in stock assessment models remains a major scientific challenge for several reasons, including the high mobility of purse seiners, multiple technological improvements affecting fishing power and the emergence of FAD-fishing that complexifies the use of time for quantifying fishing effort (Anonymous 2012, IOTC 2013, Fonteneau et al. 2013, Torres-Irineo et al. 2014). Purse seiner nominal CPUEs however provide some useful qualitative information on the overall fishery status and might be useful to detect early-warning signs of major changes occurring in tuna stocks, particularly for skipjack (*Katsuwonus pelamis*) and juveniles of yellowfin (*Thunnus albacares*) and bigeye (*Thunnus obesus*) for which very few information is available from other fisheries. In such context, we argue that the cumulated nominal effort (i.e. time at sea) of support vessels should be accounted for when deriving nominal CPUEs from purse seiner data. While a general mean CPUE can be computed from aggregated data, operational data should be privileged to analyze CPUEs (IOTC 2013). This however requires knowing the association between support vessels and the purse seiners they assist which is not always available in logbooks. Such information is also critical for assessing the effect of support vessels on individual catch rates (Pallarés et al. 2002, Maufroy, Gaertner, et al. 2015) and hence quantifying the impact of support vessels in the overall effort and capacity of the purse seine fleet.

4.2 Dynamics in FADs deployments and buoys transfers

The number of satellite-tracked buoys available to fishermen for equipping FOBs has steadily increased over the last decades while their technology has improved and costs decreased (Chassot et al. 2014, Lopez et al. 2014, Maufroy et al. 2014). Although information on an operational basis remains not available for some components of the purse seine fleet, reporting has recently improved in the Indian Ocean through new IOTC resolutions and good cooperation with fishing companies (Delgado de Molina et al. 2013, Chassot et al. 2014, this study). While up to 8-10 FADs were found to be deployed every 10 nm along linear transects in the late 1990s (Arrizabalaga et al. 2001) and a maximum number of objects of 14 could be deployed daily in the mid-2000s (Sarralde et al. 2007), recent data available from Seychelles support vessels indicate that more than 15 FADs can now be often deployed in a given day. Indeed, the increase in the number of FADs at sea has resulted in a high turn-over of the buoy deployments and transfers and more and more deployments are required to maintain a constant stock of instrumented FOBs at sea (Chassot et al. 2014). Such dynamics have resulted in a strong competitive race among fishing companies so as to increase the numbers of buoys available to each purse seiner in the recent years. The implementation of a limit of 550 active buoys operated by a purse seine vessel at any one time and a cap of 1100 instrumented buoys acquired annually under IOTC resolution 15/08 is expected to limit the increasing trends recently observed in the fishery. The monitoring of the compliance with Resolution 15/08 remains however fuzzy and clear rules based on data independent declarations (e.g. through satellite transmission providers) should be established in collaboration with purse seine fishing companies and research institutes or administrations of the CPCs concerned. It is noteworthy that the information available on the numbers of buoys and FADs deployments appears not well appropriate for deriving a nominal effort on FADs as the information on buoys retrievals and end of transmission (e.g. when a FOB beaches or sinks) seems to be poorly reported in vessel logbooks. Indeed, the increased rates of buoys activation/deactivation might not be a good indicator of the standing stock of instrumented FOBs at sea that depends on the time spent by each FOB within the purse seine fishing grounds. Information on buoys retrievals is available through purse seine observer programs but they currently only cover part of the purse seine fleet due to piracy threat and lack of space onboard some vessels in the Indian Ocean. The availability of FOBs GPS locations then represents the only means of determining the magnitude and spatio-temporal patterns in the component of purse seine effort. Such data have recently become available for some components of the purse seine fleet (Maufroy, Chassot, et al. 2015) and been shown not to pose any issue to the fishing industry when confidentiality aspects are properly managed and a reasonable delay (e.g. 6 months) is considered before they become available to the scientific Community.

Acknowledgments. We are grateful to Javier Ariz, Pilar Pallarés, Roberto Sarralde, and all past and current personnel involved in the collection and management of logbook data on support vessels. We are particularly grateful to the skippers and captains involved in data reporting as well as ANABAC and OPAGAC for fruitful collaboration for the monitoring of the purse seine fleet in the Indian Ocean. We thank the MCS section of SFA for the collection of logbooks and the staff of the Observatoire Thonier (IRD) for maintaining the AVDTH database used for data management. This paper is a contribution of the European project CECOFAD (MARE/2012/24).

5. References

Anonymous (2012) Report of the 2012 ISSF stock assessment workshop: Understanding purse seine CPUE. ISSF, Rome, Italy

Arrizabalaga H, Ariz J, Mina X, Delgado de Molina A, Artetxe I, Pallarés P, Iriondo A (2001) Analysis of the activities of supply vessels in the Indian Ocean from observers data. In: IOTC Proceedings. IOTC, Victoria, Seychelles, 19-27 June 2001, p 390–401

Arrizabalaga H, Artetxe I (2000) Preliminary analysis of observers data available from the 1998-1999 moratorium in the Indian Ocean. In: IOTC Proceedings. IOTC, Victoria, Seychelles, 23-27 September 2000, p 260–265

Chassot E, Goujon M, Maufroy A, Cauquil P, Fonteneau A, Gaertner D (2014) The use of artificial fish aggregating devices by the French tropical tuna purse seine fleet: historical perspective and current practice in the Indian Ocean. In: 16ème groupe de travail sur les thons tropicaux. CTOI, Victoria, 17p

Delgado de Molina A, Ariz J, Carlos Santana J, Rodriguez S, Soto M, Fernandez F, Murua H (2013) The Spanish Fish Aggregating Device Management Plan from 2010-2013. In: IOTC, Busan, Rep. of Korea, 2-6 December 2013, p 8

Delgado de Molina A, Ariz J, Pallarés P (2004) Logbooks of the support boats for the European purse seine fleet. In: IOTC Proceedings. IOTC, Victoria, Seychelles, 13-21 July 2004, 3p

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. Aquat Living Resour 26:37–48

IOTC (2013) Report of the IOTC CPUE Workshop. In: IOTC Proceedings. IOTC, San Sebastian, Spain, 21-22 October 2013, p 38p

Lechauve J-J (1999) AVDTH98. Acquisition et validation des données de pêche au thon tropical. Institut de Recherche pour le Développement

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. Fish Res 155:127–137

Maufroy A, Bez N, Kaplan DM, Delgado de Molina A, Murua H, Chassot E (2014) How many Fish Aggregating Devices are currently drifting in the Indian Ocean? Combining sources of information to provide a reliable estimate. In: 16ème groupe de travail sur les thons tropicaux. CTOI, Victoria, p 27p

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

Maufroy A, Gaertner D, Kaplan DM, Bez N, Lucas J, Soto M, Assan C, Chassot E (2015) Evaluating the efficiency of UE tropical tuna purse seiners in the Indian Ocean: first steps towards a measure of fishing effort. In: 17ème groupe de travail sur les thons tropicaux. CTOI, Victoria

Mina X, Artetxe I, Arrizabalaga H (2002b) Updated analysis of observers data available from the 1998-1999 moratorium in the Indian Ocean. In: IOTC Proceedings. IOTC, Shanghai, China, 03-11 June 2002, p 340–345

Pallarés P, Mina X, Delgado de Molina A, Artetxe I, Ariz J, Arrizabalaga H (2002) Analisis de la actividad de los buques auxiliares en el oceano Atlantico y su effecto sobre el rendimiento de atuneros. In: Tropical tunas = Thonidés tropicaux = Tunidos tropicales. ICCAT, Madrid, Spain, p 139–156

Ramos ML, Delgado de Molina A, Ariz J (2010) Analysis of activity data obtained from supply vessel's logbooks implemented by the Spanish fleet and associated in Indian Ocean. In: IOTC Proceedings. IOTC, Victoria, Seychelles, 18-25 October 2010, 13p

Sarralde R, Delgado de Molina A, Ariz J, Santana JC (2007) Preliminary data obtained from supply logbooks implemented by the Spanish fleet since 2004. In: IOTC Proceedings. IOTC, Victoria, Seychelles, 10-20 July 2007, 10p

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. Fish Res 155:10–19

Figures

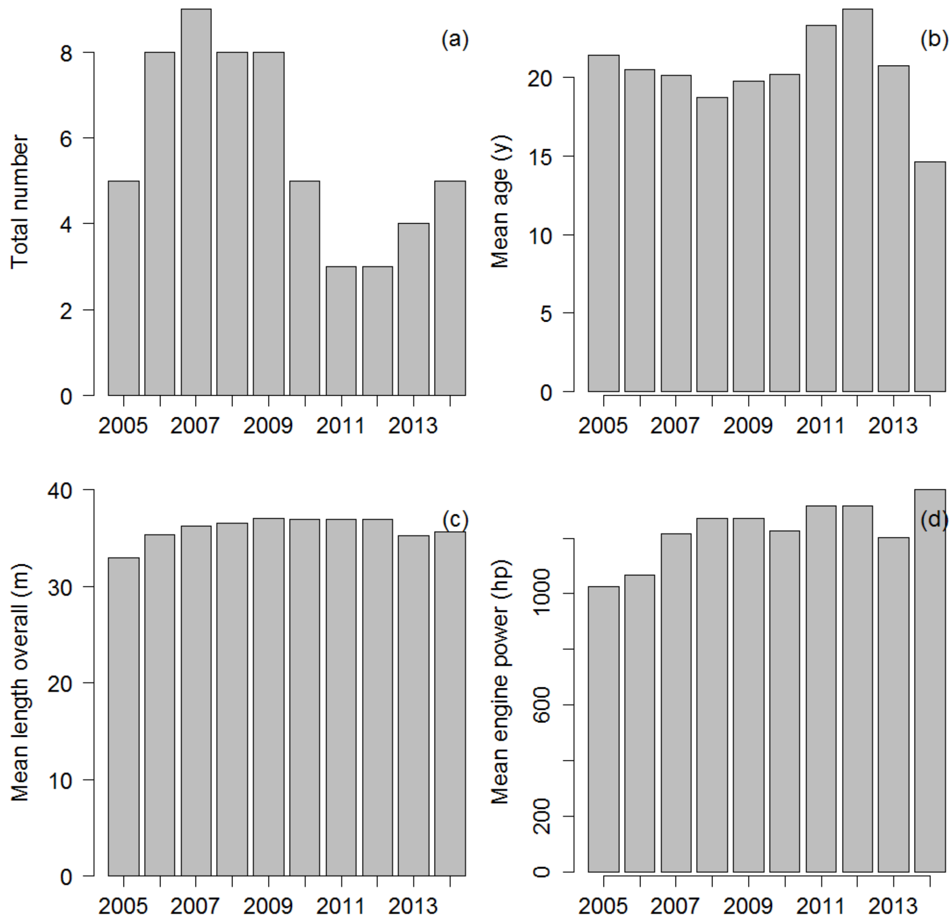

Fig. 1. Yearly main characteristics of the Seychelles support vessel fleet during 2005-2014: (a) Total number of vessels in operation, (b) Mean age of the vessels, (c) Mean length overall, (d) Mean engine power

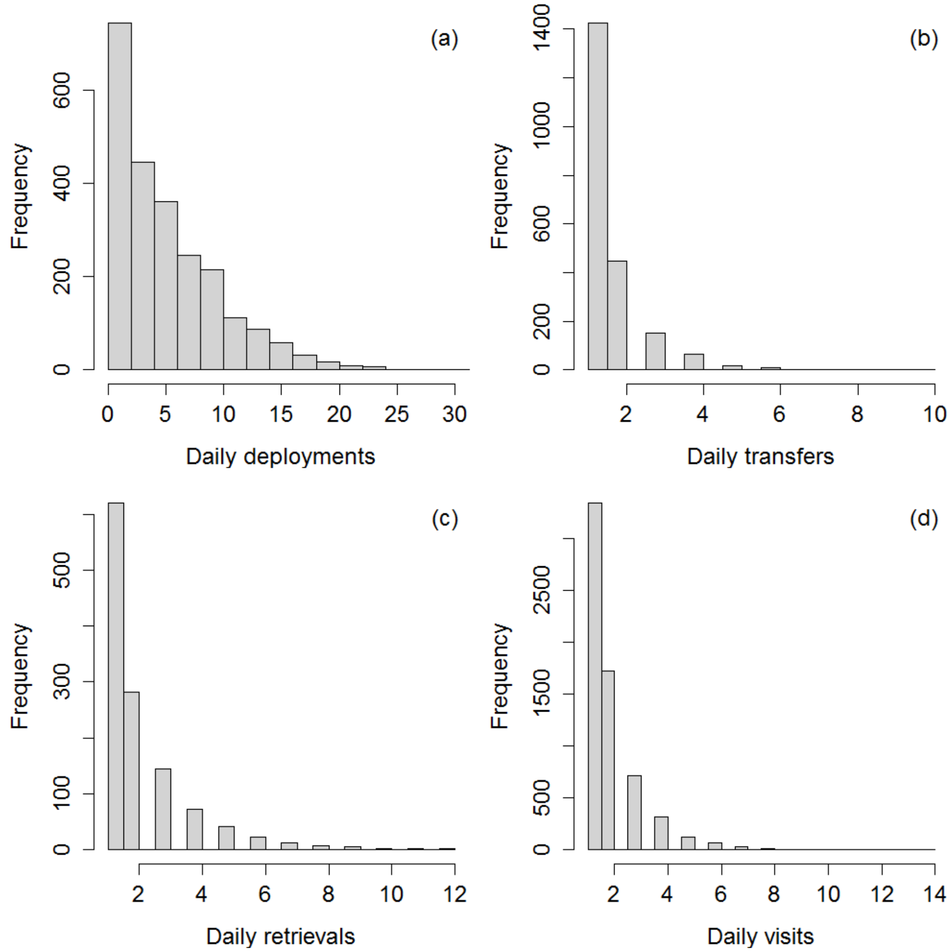

Fig. 2. Histograms of the principal operations related to fishing performed by Seychelles support vessels during 2005-2014: (a) Daily deployments of FADs at sea, (b) Daily transfers of buoys on FOBs, (c) Daily retrievals of FADs from the water and (d) Daily visits of FOBs.

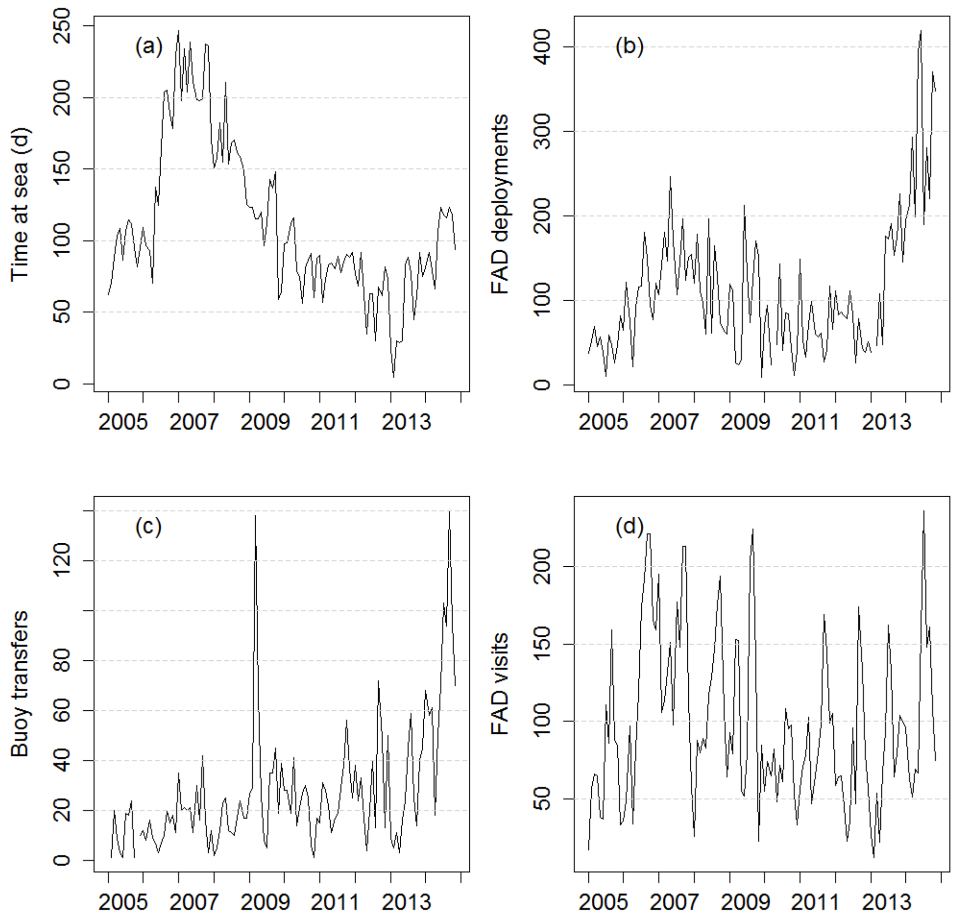

Fig. 3. Monthly time series of the principal operations related to fishing performed by Seychelles support vessels during 2005-2014: (a) Total time at sea in days (b) Total monthly deployments of FADs at sea, (c) Total transfers of buoys on FOBs, (d) Daily visits of FOBs. The data exclude the support vessel anchored on the Travin Bank

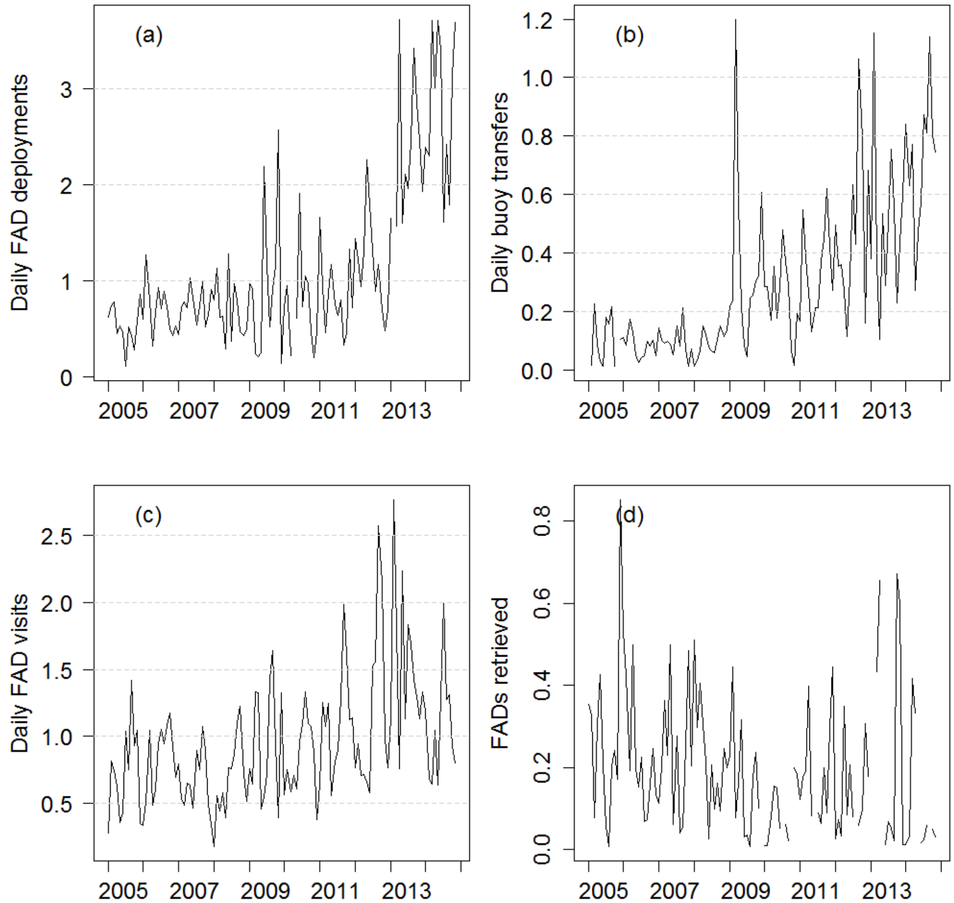

Fig. 4. Monthly standardised time series of the principal operations related to fishing performed by Seychelles support vessels during 2005-2014: (a) Daily rates of deployments of FADs at sea, (b) Daily rates of transfers of buoys on FOBs, (c) Daily rates of visits of FOBs, (d) Daily retrievals of buoys. The data exclude the support vessel anchored on the Travin Bank

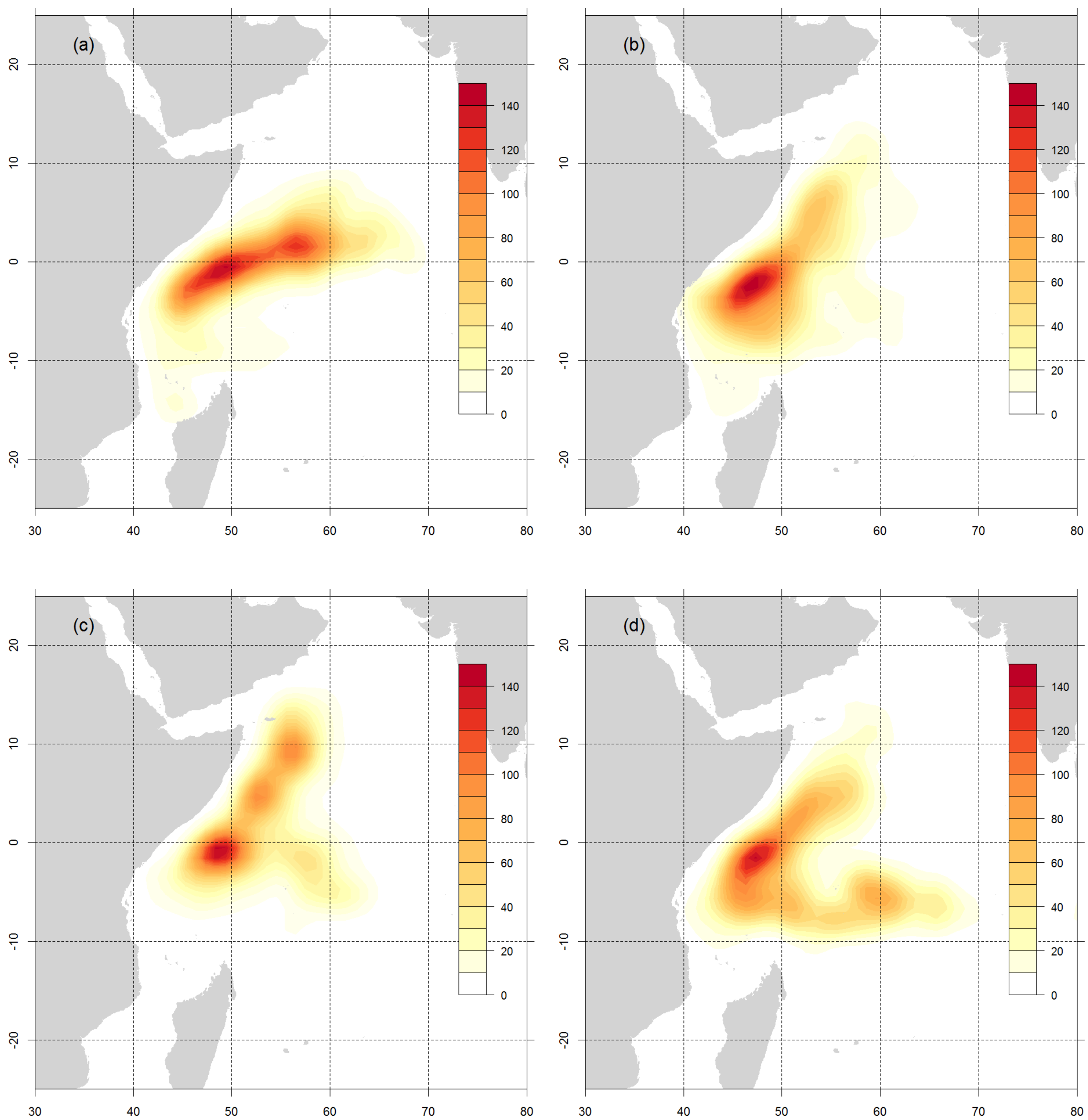

Fig. 5. Quarterly maps of density of deployments of FADs at sea by Seychelles support vessels during 2005-2014: (a) January-March, (b) April-June, (c) July-September, (d) October-December