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A review of the use of FADs and strengths and weaknesses of the FAD recovery program (FADWATCH)

Initial Report

for:

The food and Agriculture Organization of the United Nations (“FAO”) under [GCP/GLO/983/EC] - IOTC-Support of the IOTC Scientific Committee Program of Work – strengthening the precautionary approach

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1. Introduction

The introduction of the tropical tuna purse seine (PS) industry in early 1980s in the Indian Ocean has contributed considerably to increase the total tuna catch in the region (IOTC, 2019). This increase in their capacity has come together with the use of drifting fish aggregation devices (FADs) and the technology used to locate them, first introduced in the Indian Ocean in the early 90s (Lopez et al., 2014). The technological development of associated monitoring equipment (e.g., radio beacons, satellite-linked GPS buoys or satellite-linked echo-sounder buoys) has led to the purse seine fishery to improve fishing efficiency, in terms of searching time and successful catch rates (Dagorn et al., 2013; Lopez et al., 2014). In parallel to this development, there are concerns about the contribution of FADs to the catch of juveniles of target species, the increase of bycatch and the negative effects on certain marine habitats such as ghost fishing, and FAD loss contributing to marine debris (Dagorn et al., 2012; Filmalter et al., 2013; Davis et al., 2017; Baske and Adam., 2019). Many FADs may eventually end up sinking or reaching coastal ecosystems such as beaches, coral reefs or mangroves (i.e. beaching). According to Maufroy et al. (2015) 10% of the total number of FADs deployed by the French fleet ended up beaching in the coasts of the Indian Ocean. Davies et al. (2017) also detected high potential beaching impact in the Seychelles area, being in specific deployment seasons the estimated beaching rate higher than 30%. Lower values were observed in the FAD-Watch pilot Programme in the Seychelles where from total FAD tracked 0.8 and 0.5% were found to impact the coast during 2016 and 2017, respectively (Zudaire et al., 2018).

FADs are currently built by non-entangling or low entangling-risk materials, but by highly durable synthetic materials (Murua et al., 2018; Grande et al., 2019). Thus, most of these materials can accumulate for long periods in sensitive marine and coastal ecosystems, as observed during the survey on beaching events in Seychelles Islands for the quantification and evaluation of the beaching events and impacts (Balderson and Martin, 2015). Considering all these potential impacts, IOTC has been pioneer in adopting bycatch mitigation measures for the use of non-entangling FADs and promoting the use of more sustainable materials in their construction, such as biodegradable materials (Resolution 19/02). Besides, IOTC established procedures on FAD management plans, including the development of improved FAD designs to reduce the incidence of entanglement of non-target species and the impacts on coastal habitats as well as the reduction of the maximum number of operational buoys followed at any time by PS at 300 and 500 acquired annually from 1st of January of 2020.

Besides the measures proposed by IOTC, there are also further actions carried out by the private sector and NGOs that boost the implementation of sustainable fishing standards by tuna processors and retailers (Lopez et al., 2017; Grande et al., 2019; Zudaire et al., 2019a). And coastal countries like Seychelles are now taking a stronger approach to FAD management in their waters by a Marine Spatial Planning Program and actions for reducing impacts of FAD beaching.

However, the direct and indirect impacts of FADs on marine coastal habitats in Seychelles have been poorly documented (Balderson and Martin, 2015; Davies et al., 2017; Maufroy et al., 2017; Zudaire et al., 2018). In line with this and following the work carried out by ICS over the past 10 years, where was confirmed 'beached' FADs impacting on corals (39% of all FADs found impacting on coral reef habitats) (Balderson and Martin, 2015), the first FAD-Watch Programme was developed in 2016 to prevent and mitigate FAD beaching in the Seychelles (Zudaire et al., 2018). Despite the success of this first multi-sectorial initiative, further efforts need to be done to develop protocols for FAD monitoring and recovery before they beach and thus to be implemented in other countries around. Similarly, further field trials are required to refine the work of the FAD Watch Program and advance in the prevention and mitigation of FAD beaching. As such, the evolution of the FAD use and the strengths and weaknesses of the FADWATCH pilot program are reviewed to propose actions or aspects to be considered for extending the program.

2. Objective

This document is done in support of the IOTC-Support to the IOTC Scientific Committee program of Work- strengthening the precautionary approach (GCP/GLO/953/EC), which seeks to evaluate the feasibility of extending the FAD watch program The Services will contribute to Strategic Objective 2 and Output 20401.

This document give respond to the objective 2 (Task 1) of the project "*Close kin feasibility studies, FAD Beaching prevention and Working Party meeting hosting*", reviewing of the strengths and weaknesses of the FADWATCH pilot program to monitor and mitigate the impacts of FAD beaching on sensitive ecosystems in order to detect needs and define a roadmap for next initiatives.

3.

The use of FADs by the purse seiner fleet in the Indian Ocean

3.1 Evolution on FAD use

Purse Seiner FAD fishery was first introduced in the Indian Ocean in the 80s. Thanks to the development of radio buoys in the 80s and satellite position transmitting buoys with GPS technology and echosounder during 90s and 2000 (Lopez et al., 2014) the fishery expanded rapidly. The echosounder buoys revolutionized tuna fisheries, as fishers could easily monitor at any time the location, buoy dynamic and environmental parameters along the trajectory (e.g. speed, SST) and fish biomass associated underneath the FAD which allowed to optimize the fishing effort. By the late 1990's in most oceans annual FAD sets had superseded free school sets, becoming the principal mode of tuna fishing (especially for skipjack) and increasing the total tuna catch (Fonteneau et al., 2013). Meanwhile, to maximize fishing time of the purse seiners, specialized supply-vessels were increasingly used to cope with FAD-related tasks such as FAD deployments, checks, repairs, and acquiring or removing competitor's floating objects (Arrizabalaga et al., 2001). In the Indian Ocean the purse seiner fishery accounts for 43% of the tropical tuna catches (2014-2018-year period), mainly coming from FAD fishery (IOTC, 2019).

Despite increasing FAD use and concerns, little information is available regarding FAD use worldwide (such as number of FADs deploy and lost yearly), which is necessary for an appropriate impact monitoring and management. Some estimate FADs deployed per year globally at 90,000-120,000 FADs (Scott and Lopez, 2014; Gersham et al., 2015). In the Indian, 3,299 deployments of FADs were estimated for French fleet (12 purse seiners vessels) during

2018 which could be indicative of other fleets (Floch et al., 2019). Monitoring of buoy tracking data indicate that since year 2,000 FADs and buoys attached drifting at sea has increased, while since 2016-2017 the number seems to be stabilized or either decrease (Maufroy et al., 2017; Zudaire et al., 2018; Imzilen et al., 2019; Floch et al., 2019), mainly due to the buoy limitations in force (Fig 1).

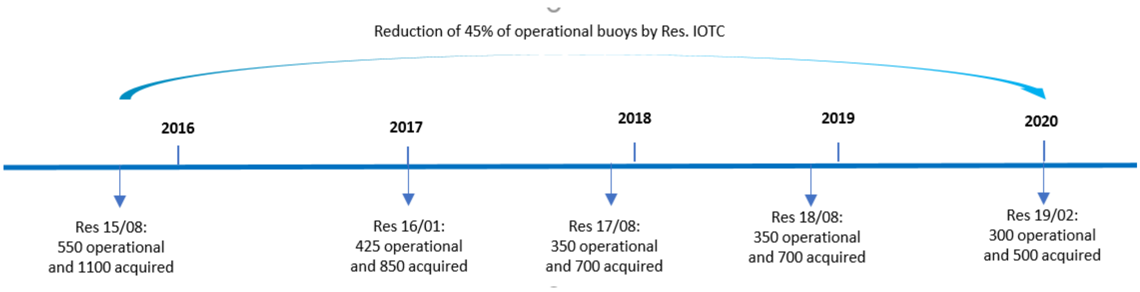

Figure 1. Timeline of the resolutions on buoy limitations in the IOTC area

In the Indian Ocean 4 distinguished deployment seasons were identified for the French fleet which were yearly repeated and were in accordance with the monsoon pattern in the area (i.e. from march to May in Mozambique Channel, from June to July around west Seychelles, from August to October around Somalia and from November to February at south east Seychelles) (Maufroy et al., 2017). According to Maufroy et al., (2015) around 10% of the buoys used end up beached and in the Indian Ocean beaching events mainly occur over Somalia, the Seychelles, the Maldives, and Sri Lanka. The same areas were also identified by skippers operating in the area, except for Sri Lanka (Moreno et al., 2018a). This percentage could be higher as only buoys transmitting GPS position and beaching events occurring in coastal areas were accounted, while the non-geolocated FADs and those beached in offshore shallow waters were not considered in the analysis (Maufroy et al., 2015). In addition, given the ocean circulation, each of the deployment area and season has different associated beaching risk (Davies et al., 2017; Imzilen et al., 2019). It was detected that a significant proportion of the buoys deployed around Seychelles during winter monsoon drift out of the fishing ground travelling eastward thought Maldives drove by the eastward South Eastern Counter Current (Schott et al., 2009; Maufroy et al., 2015; Davis et al., 2017). However, FADs seem to cross the ZEE (Davies et al., 2017). This area seems to be more affected during August October deployment season (Davies et al., 2017). The coast of Tanzania, Kenia and Mozambique seems to be more exposed during June and July

(Davies et al., 2017). Somalia has been identified as one of the coastlines with highest beaching rates (Imzilen et al., 2019).

3.2 FAD construction

Traditionally, the FADs used by industrial purse seiners consisted of bamboo rafts with extra floats (platform) and nets hanging below (submerged appendage), typically constructed using reused purse seine nets with large mesh size (>12 cm) which were the most common type since the start of FADs in the 1980's. These kinds of FADs have been categorized by scientists as high entanglement risk FADs (HERFADs), as they are the ones with the greatest potential to ghost fish bycatch species (ISSF, 2015; 2019). As this kind of FAD with large mesh size is supposed to entail higher risk of entanglement for sensitive species like sharks or turtles (Filmanter et al., 2013), their designs have been evolving to favor desirable characteristics that increase fish aggregation potential and reduce entanglement risk (Murua et al., 2018). At present, fleets in the Indian, Atlantic, and Eastern Pacific Ocean following the RFMOs requirements and by adoption of voluntary commitments have totally replaced or are in the process of phasing-out HERFADs.

Indeed, tuna RFMOs, processors and retailers have implemented the obligation of the use of non-entangling FADs. IOTC in the Res 18/08 states that the FAD must be constructed of non-mesh material which will be gradually incorporated from 2014 and should be fully implemented in 1st of January of 2020 when the Res. 19/02 enters in force. In addition, ISSF (International Seafood Sustainability Foundation) recently adopted a conservation measure for the use of lower entanglement risk or non-entangling FADs (i.e. measure 3.5: Transactions with Vessels that Use Only Non-entangling FADs). (ISSF, 2015 updated in 2019). Other standards such as the UNE 195006:2016 for Tuna from Responsible Fishing also include the use of non-entangling FADs as a must, which defined the non-entangling FADs as having non-meshed materials, or if this is present in open panels the mesh size should be <7 cm or if >7cm it should be rolled in coils.

The big push in alternative FAD with lower entangling potential designs came when European tropical tuna purse seine fishers and scientists cooperated in larger scale anti-entanglement FAD trials between 2010 and 2013 with the involvement of the whole European fleets. For example, the French fleet in the Indian Ocean tested over 800 alternative FADs, providing solid results and making skippers more used to working with this kind of floating objects in the water (Goujon et al., 2012). In this line, the EU tuna purse seiners associations adopted in 2012 a voluntary agreement for the application of a code of good practices for responsible tuna fishing activities for reducing potential impacts associated with FAD use (i.e. The Spanish Code of Good Practices (SCGP)[1] , and ORTHONGEL[2] commitment for the use of non-entangling FADs. This included the construction and deployment of non-entangling FADs, where non-entangling FADs refers to FADs constructed with non-meshed material or if present, the mesh size should be < 7 cm or rolled and well tied in coils (this classifications includes as non-entangling, lower entanglement risk FADs referring to ISSF categories, ISSF 2019). Nowadays, the FADs are mainly construct in at port facilities and the fleet has gradually replaced traditional FADs by non-entangling FADs (Lopez et al., 2017; Grande et al., 2019a). Results show that the voluntarily adopted commitment by the EU fleets and the effort made since the implementation of the Good Practices is gradually replacing the traditional FADs in the water by non-entangling FADs, as shown by the characteristics of the FADs evaluated at arrival (i.e., tracked FADs or randomly encountered non-tracked FADs), and at departure (i.e., FADs left at sea as a result of a deployment or after a visit). The percentage of totally non-entangling FADs evaluated at departure and at arrival has increased since 2015, being close to 80% of the visible FADs classified as totally non-entangling in 2017 (Grande et al., 2019a)

However, moving to non-entangling FADs constructed entirely without any net material will help to avoid the potential entangling risk, detected when netting material is deteriorated over time and when beached increasing their entangling potential (Balderson and Martin, 2015; Zudaire et al., 2018). In addition, FADs themselves, due to materials used in their construction, are a concern due to the increasing use of synthetic materials such as nylon netting and plastic floats (Moreno et al 2017; Murua et al., 2018; Moreno et al 2018a, 2018b; Zudaire et al., 2019a). These long-lasting synthetic materials may eventually end up sinking or reaching coastal ecosystems such as beaches, coral reefs or mangroves (i.e. beaching); damaging coastal habitats and contributing to marine debris. Eliminating all synthetic materials used in the construction of FADs will reduce their residence time at sea, and consequently their associated impacts in marine ecosystem (e.g. beaching), which will suppose a significant progress to the fishery (Davis et al., 2017; Moreno et al., 2018a). Since 2009, PS fleet worldwide, is working in parallel in

[1] https://www.azti.es/atuneroscongeladores/wp-content/uploads/2017/05/Buenas-Prácticas-OPAGAC-ANABAC-feb-2017-FIRMADO_English.pdf

[2] http://orthongel.fr/docs/reglt/orthongel/Dec11-DCPeco.pdf

different projects in the Indian, Atlantic and Eastern and Central Pacific Ocean to test new FAD prototypes built with biodegradable and non-entangling material (Franco et al., 2009, 2012; Moreno et al., 2017; Moreno et al., 2018b; Lopez et al., 2019; Zudaire et al., 2019a). Result of the last large scale trial in the Indian Ocean were presented in the WPTT21 at IOTC (Zudaire et al., 2019a) The findings of the has already contribute to identify effective FAD designs and materials, which will make possible at a short-medium term to stablish the basis for the gradual replacement of traditional FAD by biodegradable NEFAD in line with Res. 19/02.

3.3 FAD tracking and monitoring

FADs are nowadays deployed with GPS geolocated buoys which make possible the continuous tracking of the FAD. Indeed in the Indian Ocean Res 19/02 set the obligation of the deployments of FADs with operational buoys attached (i.e. any instrumented buoy, previously activated, switched on and deployed at sea on a drifting FAD or log, which transmit position and any other available information such as eco-sounder estimates). The transmission rate and type of information received by skippers depends on the buoy brand, model and user. The skippers or fleet owners choose the best fishing option, and so, during the last decades geolocated echosounder buoys have replaced gradually the radio and non-echosounder devices (Lopez et al., 2014; Grande et al., 2019b). Thus, nowadays buoy position and information of the biomass aggregated underneath the FADs is daily available for skippers. These devices represent one of the mayor technological improvements for this fishery and have become essential for determining the fishing strategy (Baske et al. 2012; Lopez et al., 2014), but also are valuable tools for management bodies which have integrated them in the FAD use control and management systems. Indeed, in the Indian Ocean, radio buoys are forbidden, and all buoys used should be instrumented buoys (i.e. a buoy with a clearly marked with a unique reference number allowing identification of its owner and equipped with a satellite tracking system to monitor its position). All buoys should be made operational on board, prohibiting the remote activation. In addition, since 2015 the number of buoys followed at any one time by PS vessel in the IOTC area has been gradually reduced from 550 to 300 and the yearly acquired buoys from 1100 to 500 (Res 19/02) (Fig 1).

In order to conduct the verification of the limits on buoy used stablished by RFMOs (i.e. Res. 19/02 in IOTC) or to give response to RFMO data collection requirements, EU purse seiner associations have made the decision to provide buoy data to national scientists under specific data use agreements for the monitoring of operational buoys at sea (Santiago et al., 2017; Maufroy and Goujon, 2019; Floch et al., 2019). In addition, this information is used for specific research actions as is the case of CPUE standardization or the development of alternative indices of abundances based on echosounder records (Baidai et al., 2018; Katara et al., 2018; Grande et al., 2019b; Santiago et al., 2019) or estimating deployment patterns and beaching events (Maufroy et al., 2017; Davies et al., 2017; Zudaire et al., 2018; Imzilen et al., 2019).

In addition, skippers collect detailed data in each interaction with FADs following specific guidelines (Res 18/08 superseded by 19/02) and member states provide FAD related data to IOTC secretariat in relation to: (i) total number (by type) of FADs deployed by purse seiners and support vessels by month/quarter and fleet, (ii) effort data expressed as the total number of FAD visits per type of FAD, type of visit, 1ºx1º grid area and month; and (iii) total catches of target IOTC species and bycatch species taken on FADs

While RFMOs have stablish clear rules for the control of the number of operational buoys at sea and activities with FADs for effort assessment, these bodies still did not address the marine litter issue derived from fishing activities, while development of mechanisms and best practices could be stabilized to comply with MARPOL's Annex V (Huntington , 2016). New MARPOL guidelines require members to take action to minimize the probability of loss, to record and report losses, and to maximize recovery of lost gear. In addition, according to Hanick et al. (2019) the FAD is fishing from deployment to recovery, so the obligations during the FAD life cycle should be strength to minimize the impacts related to lost FADs.

3.4 Impacts of FADs

To date the assessment of the environmental impacts of FADs has been concentrated in the impact on target and sensitive species populations (Dagorn et al., 2012), while, those related with beaching events and contribution to marine litter have been poorly investigated.

Floating objects sets, both natural logs and FADs, are characterized by having not only target tuna species but a mixture of other bycatch species, which can make on average 2.24% of the catch (Justel-Rubio and Restrepo, 2015). Most FAD-associated bycatch comes from small pelagic tuna species of the *Auxis* group (e.g. frigate and bullet tuna) or the *Euthynnus* group (e.g. Pacific black skipjack, little tunny), making 80 % of the bycatch, but other bony fish species such as dolphinfish (*Choryphaena hippurus*), triggerfish (*Balistes spp*.), or rainbow runner (*Elagatis bipinnulata*) commonly appear too. These small pelagic tunas and pelagic bony fishes are highly productive species and their bycatch is not considered to be a threat to their oceanic stocks (Dagorn et al. 2012). Also, in smaller numbers, megafauna such as marlins, turtles or sharks can be found, i.e. less than 1% of the catch (Taquet et al., 2000; Lezama-Ochoa et al., 2015; Ruiz et al., 2018). These species are of greater concern due to their vulnerable population status in many oceans (Myers et al., 2007; Lewison et al., 2014). An important impact related to FADs identified by scientists and fishery managers is the high-level of small sized (e.g. 2-5 kg) juvenile bigeye and yellowfin tunas caught in FADs. Some of the stocks of these larger tuna species, which take longer to mature and reproduce (e.g. 2-3 years), are under increasing pressure and have reached an overfished status as is the case of yellowfin tuna in the Indian Ocean. On the other hand, some scientists hypothesize that the massive deployment of FADs, may keep or “trap” tunas in FAD abundant zones, altering their normal migratory patterns (Marsac et al., 2000; Hallier and Gaertner, 2008; Wang et al., 2016). In theory, because at present FADs are present in large numbers in most oceanic areas (Dagorn et al., 2013) including both plankton-rich and -poor ones, some tunas may stay longer than normal in low-quality habitats (e.g. low productive areas) due to their attraction to FADs. While some studies have found tunas in higher FADs density areas to have lower body condition factor (Hallier and Gaertner, 2008; Wang et al., 2017), which is used as an indicator measure of health status related to body energy storage, other studies have not found this relationship (Restrepo et al., 2016).

Regarding to FAD lost and associated impacts, thanks to the instrumented buoys attached to FADs and daily GPS position received and gathered in the last years for scientific purposes (Maufroy et al., 2015; Davis et al., 2017; ; Imzilen et al., 2019), simulation models have been developed to account and understand the spatial distribution of beaching events identifying hot-spots and deployments areas and seasons linked to high beaching probability by simulation and retrospective analysis (Maufroy et al., 2015; Zudaire et al., 2018; Davis et al., 2017: Imzilen et al., 2019), however there are not still approximate estimates of FAD lost and beaching event, potential area affected or the potential contribution to marine litter (Zudaire et al., 2019b). Regarding to beaching events, it has been detected that coral reefs are one of the most impacted habitats. In FAD recovery programs in Seychelles area FADs mainly were found stuck in coral reefs or with corals entangled (Balderson and Martin, 2015; Zudaire et al., 2018). Using nets in the submerged structure gets the FADs more suitable to getting trapped on these sensitive habitats (Balderson and Martin, 2015), even if open panels with small mesh size or sausages are used. The nets get broken when entangled in corals or rocky seabed increasing their entangling potential and being a thread for sensitive fauna which were found entangled (Balderson and Martin, 2015; Zudaire et al., 2018), or other coral reef species. FADs constructed with ropes on the submerged structure seem less likely to be entangled (Balderson and Martin, 2015). On the other hand, the FADs entangled, and the ballast weight attached, can exert a mechanical force thought the sea floor breaking the coral reef which could take long periods to recover and the reef could become permanently altered (Davies et al., 2017). Mechanical impacts could also affect to seagrass communities. This damage could occur relatively quickly.

4. Initiatives for FAD retrieval

FADs during its lifetime can be reutilized by other fleets, encounter and recovered at sea or sinked due to the deterioration of materials and loss of floatability. However, a percentage of FADs deploy by the purse seiner fleet or associated supply vessels are lost as they drift toward remote areas and/or end up beached (Grande et al., 2018). This FADs that interact with the coast can be a threat for sensitive habitats as coral reefs and are a source of marine litter. The quantification of this impact is limited worldwide and in the Indian Ocean. Seychelles was one of the first country implementing a FAD monitoring a recovery program over along its coastline.

4.1 ICS Coastal Monitoring Program

Land based monitoring programs in the IOTC area and worldwide are scarce. The Island Conservation Society (ICS) conducted the first baseline survey around Desroches, Poivre, St. Joseph, Alphonse, St. Francois, Farquhar and Cosmoledo islands in 2015 to quantify the beaching events, describing their environmental impact, identifying which vessels/companies were responsible for the FADs and offering advice on mitigation measures to be implemented by the relevant authorities and administrators (Balderson and Martin, 2015).

ICS began collecting information on FAD beaching in Seychelles in early 2,000. The data were first recorded opportunistically, and photographs were taken which has allowed to go back and recover new details in beaching events. In 2015 a data base was created, and planned surveys were conducted in the area of St. Francois and Farquhar atolls where information on the habitat in which the FAD was found, ID of the buoy and vessel, design of the FAD, dimension and materials, condition or degradation stage, species entanglement and status (i.e. alive or death) and affected area (m^2) were recorded (Balderson and Martin, 2015). In the 2012-2015 period 214 FAD were intercepted were the 98% were stuck. At the time, FADs were constructed with synthetic materials and the submerged structure of the FAD was net rolled in sausages (low entanglement risk material as classified by ISSF, 2019) and the raft covered with netting (mesh size not described). The results were presented at the 11th session of IOTC Working Party on Ecosystems and Bycatch and confirmed that entanglement of wildlife is a concern with the use of FADs with netting. 39% of all FADs were found on coral reef habitats (Balderson and Martin, 2015). It also highlighted; another significant problem attributed to FADs being marine pollution. More than 70% of FADs encountered were made of synthetic material. This was the first initiative in the region collecting data on FAD beaching event which created the basis for stablishing a FAD recovery pilot program in the area to mitigate beaching events.

4.2 FAD Watch Program

The FAD Watch Program was the first pilot FAD retrieval program in the world with the participation of different stakeholder (including the fishing industry) to preventing and mitigating FAD beaching events. It was a multi-stakeholder program promoted by OPAGAC which run with the participation of OPAGAC fleet, Island Conservation Society (ICS), Seychelles Fishing Authority (SFA) and Islands Development Company (IDC). It was conducted in Seychelles Archipelago where ICS was active.

4.2.1 Desing of the project

In order to reduce and avoid the impact of beaching events in Seychelles Islands the Spanish Tuna PS fishing representative OPAGAC, ICS, IDC and SFA signed a Memorandum of understanding (MOU) in 2016. The study was conducted in the Alphonse, Farquhar, Desroches, Poivre, Aride and Silhouette islands (Fig. 2), where ICS was responsible to intercept and remove the FAD upon receiving an alert. For FAD tracking, all FADs of the OPAGAC fleet are deployed with an activated and switched on instrumented buoy which is transmitting a GPS position. With the collaboration of buoy providers (i.e. Satlink and Marine Instruments), a software was developed in which an alarm system alerted ICS whenever a buoy attached to the FAD arrived within 5 nautical miles or 3 nautical miles of any of these islands under the study. Therefore, sharing buoy position information within buffer areas was indispensable for the program. ICS checked the alert system once a week and if a FAD was detected in the buffer areas the Science Coordinator contact island teams to organize FAD recovery with the support of IDC (Fig. 3). For FAD recovering and material management sea and land-based resources were available (e.g fiberglass boat and tractors to recover the FADs, waste disposal and management places, barges for waste transport to Mahe).

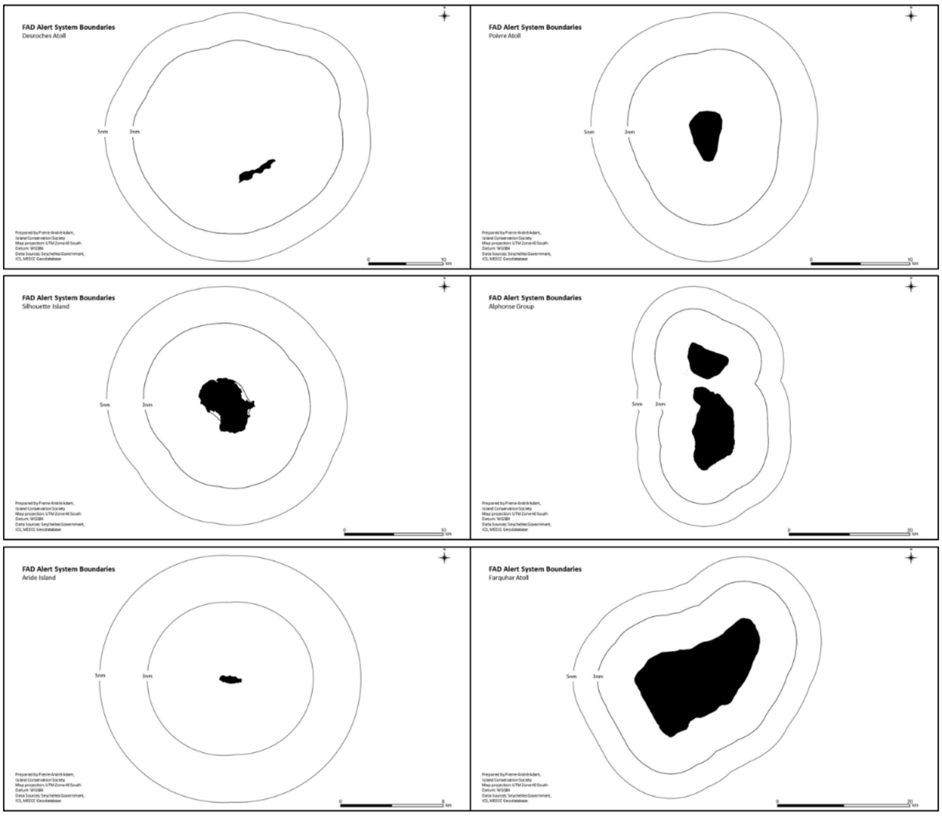

Figure 2. Defined buffer areas (Alphonse, Farquhar, Desroches, Poivre, Aride and Silhouette islands) set for alerts: 5 and 3 nautical miles (*Source: Zudaire et al., 2018*).

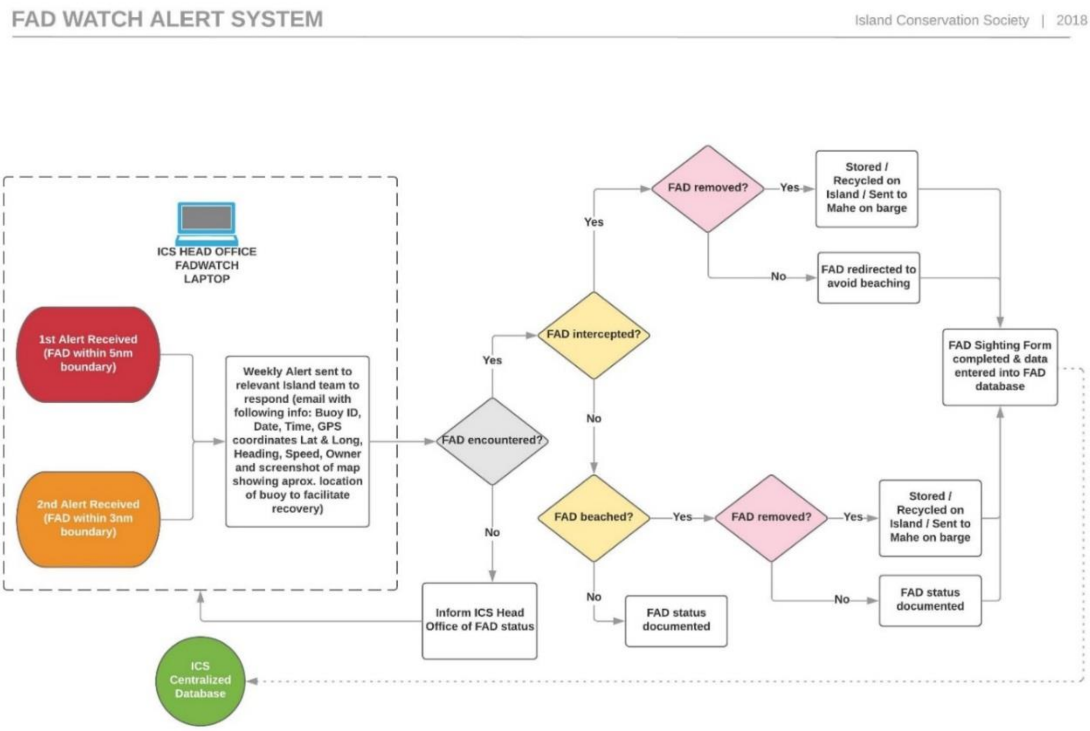

Figure. 3. Working scheme for FAD detection and recovery (*Source: Zudaire et al., 2018*).

In order to estimate the proportion of FAD beached, all buoy tracks of OPAGAC were available for scientist, which accounted for buoys drifting thought EEZ of Seychelles and buffer areas (Zudaire et al., 2018).

4.2.2 Outcomes

The beaching events can be predicted and are easily detected by buoy trajectories attached which send daily GPS position. This made it possible to stablish an alarm system to alert the Islands team involved in the FAD recovery program to intercept and remove the FADs detected in buffer areas. Based on the buoy GPS position data, the number of buoys drifting in Seychelles EEZ decreased a 20% from 2016 (n=12,051) to 2017 (n=9,638) which could be an effect of the buoy limitation in force, in which the operational buoys at any time were reduced from 550 in 2016 to 350 in 2017 (Res. 17/08). A decreasing pattern was also observer for beaching events estimated from buoy transmission data in Seychelles area archipelago (i.e. 98 in 2016 and 57 in 2017) and specific islands selected for the study (i.e. 22 in 2016 and 12 in 2017) (for more details see Zudaire et al., 2018).

The FADs intercepted by the ICS during 2016-2017 period, belonged to the target fleet (monitored FADs under the program) (i.e. n=19, 17% of the total number of FADs intercepted) and other fleets operating in the area (not monitored FADs under the program) (i.e. n=90, 83% of the total number of FADs intercepted) (Zudaire et al., 2018). The fleet collaborating in the program mainly use Lower Entanglement Risk FADs or Non entangling FAD designs (Grande et al., 2019a; ISSF, 2019). However, some intercepted FADs were found to have open panels netting and incidences of fauna entanglement was detected (i.e. turtles and corals). The FADs were principally found beached or at coral reefs (Zudaire et al., 2018). Incineration on islands was the most used method for FAD disposal. The location in which the FAD was intercepted (coral reefs with difficult access), the weather or FAD structure (deep submerged structure) affected on the FAD recovery operative, sometimes making difficult the FAD retrieval (Zudaire et al., 2018).

4.3 Strength and weakness of the FAD recovery Program

4.3.1 Study area

Since 2012 a FAD beaching monitoring program was undertaken in Seychelles archipelago. Aware of the adverse impacts that FADs deployed by tuna purse seine fleets were having over coastal marine ecosystems in the Seychelles islands, the stakeholder in the region stablished the basis for implementing the FAD Watch program in the area. Following this line and owing to the interest of the country to conduct a FAD recovery pilot program the FAD Watch Program was promoted by OPAGAC. This allowed to base the program in the resources and the working-net already on-going in the archipelago, which permitted a rapid implementation of the activities along the islands under the program.

However, the study area was not selected following a specific evaluation of risk assessment (e.g. pre-evaluation of beaching rates or FAD beaching density in the area), assessment of the damaged in sensitive habitats or feasibility of the project in the area as proposed by Herrera et al. (2019). Indeed, based on the study of buoy tracks in the area (Zudaire et al., 2018), high percentage of FADs seem to cross the EEZ of Seychelles without interacting with the coastline.

Though the buoy track analysis, results show that from FADs drifting in EEZ of Seychelles less than 1% impacted the coast of the archipelago. In this sense, in order to justify the implementation of the program, do a proper selection of the country and coastline area, and do an efficient planning of resource investment, a detailed analysis of the buoy tracks of vessels operating in the area should be counted prior to any implementation. As it has been described by simulations models and buoy track analysis, beaching events have a spatio-temporal pattern, connectivity with deployment areas/seasons and ocean circulation patterns which should be assessed before any implementation of a FAD recovery program (Davis et al., 2017; Maufroy et al., 2017; Escalle et al., 2019; Imzilen et al., 2019). For example, for some areas of the western Pacific Ocean deployment limits could be more effective mitigation option than shoreline cleaning programs (Escalle et al., 2019). In this line a development of a framework including the stakeholders involved should be conducted for buoy track analysis and the detection of sensitive areas in the IOTC area. In addition, short-term surveys should be conducted in other to evaluate the geographical area and identify the resources needed. Other factors that could be considered for evaluating the need and feasibility of the program in a given area are the interaction with other activities as tourism, existence of fishing agreements, biodiversity, cost, governance or country status and presence of organizations for conducting the fieldwork (Herrera et al., 2019).

4.3.2 FAD tracking

The FAD watch program was conducted with the participation of the OPAGAC fleet. While it accounts for a significant part of the fishing fleet operating in the area (i.e. 15 purse seiners fishing vessels), the implication of other fleets working in the area would help to improve the results. Indeed, over 65% of the FAD beaching events registered by ICS through the duration of the Pilot referred to FADs not owned by the OPAGAC fleet, or FADs of unknown ownership. While the ICS staff removed also those FADs, the fact that ICS did not receive information about their location prior to beaching led to increased adverse environmental impacts, as interception of those FADs prior to beaching was not possible. Therefore, for a full and effective mitigation of FAD beaching, the participation of all companies working with FADs in the area should be considered, sharing the daily position of buoys when entering on the buffer areas selected. Following the success of the pilot, other members of Sustainable Indian Ocean Tuna Initiative (SIOTI) composed by 42 vessels with French, Italian, Mauritius, Seychelles and Spanish flag, also showed their interest in the participation of the FAD Watch in Seychelles. Other examples for

FAD tracking data sharing is the FAD tracking program implemented in the EEZ of the parties of the Nauru Agreement in the western Pacific Ocean could be an example of the integral FAD tracking in specific areas (Escalle et al., 2019). This would allow following all buoys transmitting a signal. However, the intentional and unintentional deactivation of buoys is part of the FAD use strategy (Grande et al., 2018) which would prevent for tracking part of the FADs still drifting but without a GPS position. In order to account for them, with the engagement of buoy providers, such information could be made available to the RFMO secretariat or responsible independent body within the project so that the overall potential FAD beaching could be assessed (Huntington, 2016; Moreno et al., 2018a; Zudaire et al., 2018; Baske and Adam 2019).

On the other hand, within the project the FAD beaching alarm system was checked once a week by the ICS officers and Science Coordinator who transferred the information to the respective island teams to plan and intercept the FADs. In addition, the poor quality of the internet connection in some of the islands, prevented the direct monitoring of buoys by ICS staff in those locations, as the software did not work in those areas. In those cases, information on drifting buoys was transmitted via e-mail or mobile phone from headquarters. This working procedure could suppose a significant time elapse between the occurrence of the FAD detection on the buffer areas and the recovery action, which hampered the work of ICS staff, as it took more time to locate the FADs, which in some cases were only detected after beaching and the damage already occurred. Therefore, in other to avoid any damage and to ensure a quick response in remote spots, technical glitches such providing each team with tools to receive real-time information and setting up an automated alert system at any buffer area cross should reduce any time delay caused by relaying information from switchboard to each work team. In addition, extending the surface of buffer areas could give more time to the working teams to react and reach the FAD while drifting at sea facilitating the recovery maneuver.

4.3.3 FAD handling and waste management

The program has benefitted from the collaboration of the IDC, which supported in the removal of FADs with boats and tractors to move the FADs. However, sea and land-based resources were not enough as FADs were usually heavy, especially its hanging part, which indeed gains weight through colonisation from barnacles and other sessile species. This made some FADs unmanageable, as they could not be brought onboard the boats. In those cases, the ICS staff either dived to break the FAD apart and bring its component onboard, one at a time, or towed the FAD into open water and released it, for it to continue drifting. In addition, weather conditions were also detected as being one of the main difficulties as the work equipment available or provided (e.g. boats) was not adapted to navigation in rough sea. In this situation suitable equipment should be made available for future actions, for example with the participation of supply vessels or local fishermen on the FAD interception and retrieval works. For supply vessels a special license should be conceded in order to be allowed to participate in operations near the coastline.

The waste management procedure at the project stablished that FADs materials and buoys should be stored for further collection and transport to Port Victoria. However, when FADs were removed from the sea or coast, the main FAD disposal method was the incineration on islands (Zudaire et al., 2018). In these remote islands the waste management is limited and thus, within the project, effective waste management plans should be defined including ways to transport it for its reutilization or to proper disposal and/or recycling facilities in accordance with MARPOL (Annex 5). In addition, simplifying the FAD design (e.g. reduce the FAD submerged structure depth), minimizing the amount of material used to construct the FAD and the use of biodegradable materials in the construction of FADs would contribute to mitigate the impacts, facilitate the FAD recovery and waste management (Huntington, 2016; Moreno et al., 2018; Zudaire et al., 2018; Escalle et al., 2019).

4.3.4 Evaluation of the costs and benefits

The cost of a FAD retrieval program might be significant. In order to justify the project, the magnitude of the wide range of socio-economic costs derived for the loss and beaching of FADs in a given area should be evaluated. In some cases, preventative measures may be more cost-effective in reducing the impacts derived from FAD beaching (Macfadyen et al.,2009). Depending on the coastline, the identification of alternative funding mechanisms may be required, especially in the case that running costs are very high.

5. Conclusions and Recommendations

Although FADs are widely used in the PS tuna fishery and the data collection mechanism on FADs has been improved for fishing effort assessment, still there is a significant lack on the quantification of the number of FADs beached and the evaluation of potential damage in the coastlines of each specific country in the Indian Ocean, due to the confidential character and restricted use of GPS positions of instrumented buoys attached to FADs.

In order to evaluate and mitigate impacts of FAD beaching in the Seychelles Archipelago and based on the coastline monitoring program running in the area, OPAGAC promoted the FAD Watch pilot program in which a Memorandum of understanding (MOU) was signed in 2016 among OPAGAC, ICS, IDC and SFA. During two-years period, thanks to the monitoring of GPS positions of instrumented buoys the number of beaching events were accounted in Seychelles coastline, which showed to be lower than the predictions made by previous simulation analysis. ICS managed the detection and recovery of FADs (n=109) by following the instrumented buoy tracks when entering in defined buffer areas. The FAD-Watch pilot project demonstrated that successful recovery programs can be implemented with a multi-stakeholder cooperation and the commitment of purse seiner vessel operators. This also allowed to detect improvement needs for extending the project. Based on the results obtained within the FAD Watch pilot project the following considerations are proposed for extending the project:

- For an integral evaluation of FAD beaching risk and development of an effective mitigation action, the participation of all fishing companies working with FADs in the area should be considered, sharing the daily position of instrumented buoys. The development of a framework including the stakeholders involved should be conducted for buoy track analysis and also for the detection of other sensitive areas in the IOTC area of competence. This would allow identifying suitable areas for extending the FAD Watch Program.

- Short-term surveys should be conducted in other to evaluate the geographical area and identify the resources needed. Other factors that could be considered for evaluating the need and feasibility of the program in a given area are the interaction with other activities such as tourism and fisheries; It is also fundamental to assess the local biodiversity and the country status, and to identify an organism able to conduct FAD recovery tasks.
- Within the project effective waste management plans should be defined including ways to transport it for its reutilization or to proper disposal and/or recycling facilities in accordance with MARPOL (Annex 5).
- An assessment if the cost and benefits, including the magnitude of the wide range of socio-economic costs derived for the lost and beaching of FADs in a given area could help for decision making.
- It is extremely important to secure the participation of as many vessels' operators as possible.

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