

WORKSHOP FOR THE REDUCTION OF THE IMPACT OF FISH AGGREGATING DEVICES' STRUCTURE ON THE ECOSYSTEM



G. Moreno, J. Murua, L. Dagorn, M. Hall, E. Altamirano, N. Cuevas, M. Grande, I. Moniz, I. Sancristobal, J. Santiago, I. Uriarte, I. Zudaire, V. Restrepo /
September 2018

Suggested citation:

Moreno, G., J. Murua, L. Dagorn, M. Hall, E. Altamirano, N. Cuevas, M. Grande, I. Moniz, I. Sancristobal, J. Santiago, I. Uriarte, I. Zudaire, and V. Restrepo. 2018. Workshop for the reduction of the impact of Fish Aggregating Devices' structure on the ecosystem. ISSF Technical Report 2018-19A. International Seafood Sustainability Foundation, Washington, D.C., USA.

Abstract

This report summarizes the results of a workshop organized by ISSF to reduce the impact of FAD structures on the ecosystem. The workshop gathered fishers and scientists working in the three oceans where tuna is caught with FADs. The main goal of the workshop was to evaluate potential solutions to minimize the impacts and identify the challenges to be faced, including the evaluation of the starting point of the issue regarding the fate of lost and abandoned FADs. Participants in the workshop evaluated, from a technical point of view, the potential of FAD retrieval, the use of FADs that remain in the fishing zone (FADs with navigation capability, FADs that could be sunk, and anchored FADs) and simplifying FAD structures, among others. Likewise, the feasibility of the different measures was assessed in the short and long term.

Author Information

Gala Moreno and Victor Restrepo | **International Seafood Sustainability Foundation**
1440 G Street NW, Washington, D.C. 20005

Jefferson Murua, Maitane Grande, Josu Santiago and Iker Zudaire | **Fundación AZTI, Spain**

Laurent Dagorn | **IRD, France**

Martin Hall and Ernesto Altamirano | **IATTC, USA**

Nagore Cuevas | **Albacora, Spain**

Isadora Moniz | **OPAGAC, Spain**

Igor Sancristobal | **CLS, France**

September 2018

The workshop summarized in the present Technical Report was funded by the FAO-GEF Common Oceans ABNJ Tuna Project and by the International Seafood Sustainability Foundation (ISSF). The report and its results, professional opinions, and conclusions are solely the work of the authors and of the fishers that participated in the workshop. ISSF is grateful to all participants, and especially to skippers for sharing their insightful knowledge.

ISSF is a global coalition of scientists, the tuna industry and World Wildlife Fund (WWF) — the world's leading conservation organization — promoting science-based initiatives for the long-term conservation and sustainable use of tuna stocks, reducing bycatch and promoting ecosystem health. Helping global tuna fisheries meet sustainability criteria to achieve the Marine Stewardship Council certification standard — without conditions — is ISSF's ultimate objective. ISSF receives financial support from charitable foundations and industry sources.

To learn more, visit issf-foundation.org.

Table of Contents

Executive Summary.....	4
Research Questions.....	5
1. Introduction.....	6
2. Objectives.....	8
3.The Fate of FADs.....	9
4. FAD Accumulation Areas.....	13
5. Potential Solutions to the Impact of FAD Structures on the Ecosystem.....	16
6. Feasibility of the Potential Solutions Over Time.....	21
7. Recommendations.....	24
8. Bibliography.....	25
Appendix I: Participants list.....	26
Appendix II: Visual documentation of the workshop.....	27

Executive Summary

One of the impacts related to the use of Fish Aggregating Devices (FAD) is the impact caused by the FAD structure, which is mainly made of plastic, on the ecosystem. Impacts caused by lost and abandoned FADs are damage on coral reefs or other benthic ecosystems, ghost fishing, marine litter, and interference with other economic activities, such as tourism. In order to reduce those impacts, scientists and fishers are working towards the use of biodegradable FADs. Currently there are projects in the three major oceans testing new materials for building FADs that are efficient for fishing purposes but degrade as soon as possible after their useful lifetime.

Although the need is clear for FADs to be made of biodegradable materials to minimize their impact, so that FAD structures do not remain at sea for hundreds of years, there are other options that have not been considered in depth, like the recovery of FADs. Furthermore, until an effective solution is found for FADs made of biodegradable materials, it would be necessary to evaluate other options to reduce the impact of FAD structures, taking action if possible before FADs are lost or abandoned.

In order to move forward, ISSF organized a workshop with scientists and fishers working in three oceans to evaluate the starting point and define the potential solutions to reduce FAD impacts in those oceans. During the workshop, participants assessed, from a technical point of view, different options: FAD recovery, simplifying FAD design, modifying FAD deployment areas, the use of FADs that do not leave the fishing grounds (FADs with navigation capability, FADs that could be sunk and anchored FADs) and limiting FAD numbers. Fishers also identified main FAD beaching areas in the three oceans as well as FAD accumulation areas in the open ocean. Finally, the feasibility of different potential solutions was assessed in the short and long term.

The workshop revealed the lack of global quantitative data on FAD beaching events and the necessity of studying FAD trajectories to have a clear picture of the starting point. Although real FAD trajectories would be desirable for this purpose, models of oceanic drifts could also be used to estimate beaching events. The workshop highlighted a range of solutions that could be used in the short term to minimize the impact of FAD structures. These solutions need to be customized for each ocean. During the workshop, difficulties in implementing each solution were identified, perhaps the most evident being that FAD structures nowadays are very large and bulky, which makes the logistics for the recovery and storage difficult.

Pilot studies were also identified to find other solutions, such as studying FAD trajectories to find efficient FAD deployment sites (for fishing and to minimize the impact), or studies to technically evaluate FADs with navigation capability as well as the strategy to be used for fishing purposes.

Finally, from the workshop discussions, diverse recommendations were proposed.

The options evaluated during the workshop to minimize the impact of FAD structures were the following:

- Limiting the number of FADs
- Simplifying FAD structures
- Avoiding FAD deployment areas that have high risk of stranding
- Building FADs with navigation capability
- Building FADs that could be sunk
- Using anchored FADs
- Recovering FADs at sea
- Recovering FADs from land

Research Questions

- What are the principal FAD stranding areas in each ocean?
- What are the data needs to quantify beaching events and better understand the starting point so that the efficiency of different measures can be evaluated?
- What are the potential recovery areas of FADs at sea? And from land?
- Besides the use of biodegradable FADs, what can be done to minimize the impact of FAD structures that are lost or abandoned?
- What is the feasibility of the potential measures in the short and medium term?

1.Introduction

One impact of Fish Aggregating Devices (FADs) results from their own physical structure. Abandoned or lost FADs can end up stranded in coasts, sometimes in vulnerable ecosystems such as coral reefs. In addition, after beaching, those FADs with netting in their submerged structure can cause ghost fishing, even if tied in bundles to prevent entanglement, because with time the netting becomes unraveled. Another impact associated with FAD structures is their interference with other economic activities, such as tourism, marine transportation, or aquaculture.

Although beaching is the most visible impact, another impact of lost and sinking FAD structures, currently mostly built with plastics (polyethylene nets and ropes), is the accumulation of plastics at sea. This is a problem that affects all fishing gears at a global level, adding to the enormous production of anthropogenic plastic marine debris. Growing concerns over this problem have resulted in projects such as ISSF's work to develop biodegradable FADs, the Global Ghost Gear Initiative (<https://www.ghostgear.org>), and The Ocean Clean Up Project (<https://www.theoceancleanup.com/>), which try to lessen this impact.

Plastic-based nets can take centuries to degrade. They accumulate year after year, and when they finally end up breaking down into smaller microparticles, they enter the marine food web. According to United Nations reports, it is estimated that yearly 640,000 tons of fishing gears end up lost at sea. This is a global issue for which it is difficult to predict future consequences. The solution must include finding alternatives to plastics, applying good practices to avoid fishing gear abandonment, and collecting non-utilized fishing gears. Each fishery should search for solutions best suited to their fishing operations.

In the case of FADs used by tuna fleets in the tropical zones of the Indian, Atlantic and Pacific Oceans, the impact caused by their structure has triggered a response by coastal countries affected by this beaching, by scientists and research institutes working on FAD fishing, and by the fishing industry, conscious of potential impacts from this lost or abandoned fishing gear. A direct outcome are some initiatives, both by the fishing sector and research institutes, to develop biodegradable FAD structures that work for fishing during a set time and later degrade. Currently, projects exist in those three oceans to test FAD prototypes constructed mostly with biodegradable materials. (Moreno et al., 2017; Zudaire et al., 2017; Moreno et al., 2018).

While minimizing impacts by switching to biodegradable FAD structures should be considered, other options to minimize these impacts, such as FAD retrieval, have not been examined in depth. However, until biodegradable FADs are successfully implemented, it would be necessary to evaluate other options that reduce these impacts, trying to preferably solve the problem before the loss and beaching of FADs.

Currently, there are several Fisheries Improvement Programs (FIPs) of tuna fleets operating in the tropical regions of the three oceans, and all have identified FAD retrieval as a key task. Although there are some experiences with FAD retrieval in the Indian Ocean by fleets such as OPAGAC (Organización de Productores Asociados de Grandes Atuneros Congeladores, in Spanish), there are still many doubts on its effectiveness, how to approach retrievals, and how to define difficulties and logistical, economic and administrative challenges emerging during FAD retrieval programs.

This report summarizes a workshop organized by ISSF (issf-foundation.org) to tackle possible options to minimize the impact of lost or abandoned FAD structures. Because each ocean has particular characteristics and the

difficulties and solutions can be different in each one, the workshop gathered scientists working in the three Oceans; skippers working in the Pacific, Indian and Atlantic; and FIP coordinators from the three oceanic regions. During the workshop, options to minimize the impacts of FAD structures were assessed in the short and medium term for each ocean.

2.Objectives

The objective of the workshop was to evaluate different options to reduce the impact of lost and abandoned FAD structures on the ecosystem. Fishers and scientists participated to provide expertise on potential measures to minimize the impact in each ocean. Before these options were considered, data on the fate of FADs was discussed in relation to beaching, sinking, and lost or abandoned FADs. Assuming that the use of biodegradable FADs is one of the main solutions to avoid the impacts of FAD structure on the ecosystem, and given workshops and projects to address this specific solution, this workshop did not address the use of biodegradable FADs.

The following options were evaluated during the workshop (in chronological order from the construction of a FAD until they end up lost, abandoned or stranded):

- Limiting number of FADs
- Simplifying FAD structures
- Avoiding FAD deployment areas that have high risk of stranding
- Building FADs with navigation capability
- Building FADs that could be sunk
- Using anchored FADs
- Recovering FADs at sea
- Recovering FADs from land

3.The Fate of FADs

Before assessing potential solutions to minimize the impact of FADs, an exercise was done to understand the fate of FADs in the three major oceans. Currently, data on FAD loss, abandonment, sinking and beaching events are very limited. Maufroy et al. 2015 were able to quantify FAD beaching events from data provided by the French fleet in the Indian and Atlantic Oceans. Following the trajectories of FADs, they estimated that 10% of the FADs deployed by the French fleet ended up in beaching events. The study was possible thanks to the data shared by the French fleet on FAD trajectories; without these data, it is difficult to quantify the issue of lost and abandoned FADs. However, even with data on FAD trajectories, it is not always easy to estimate those events. Once a FAD has drifted away from the fishing zone, fishers deactivate the FAD positioning system (to avoid paying for satellite communications) so that communication is stopped before the FAD beaches and, as result, those FADs remain at sea. Without any owner tracking their trajectories, it is difficult to quantify the potential FAD beaching events and areas.

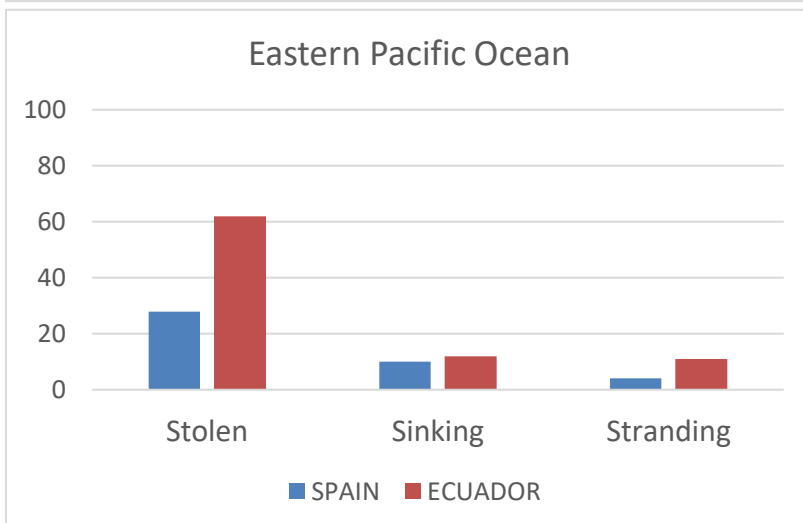
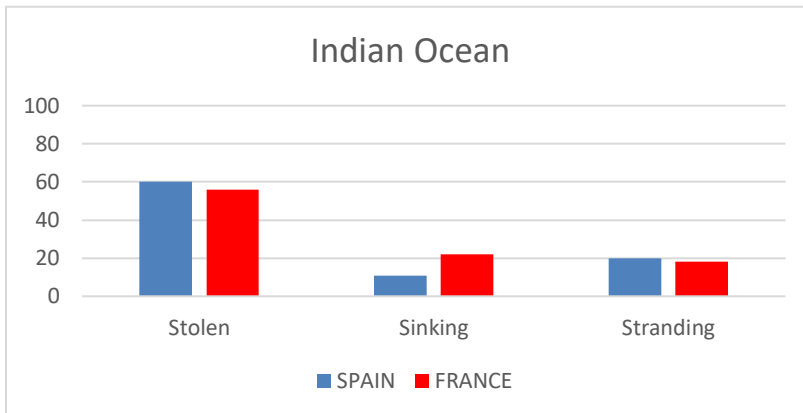
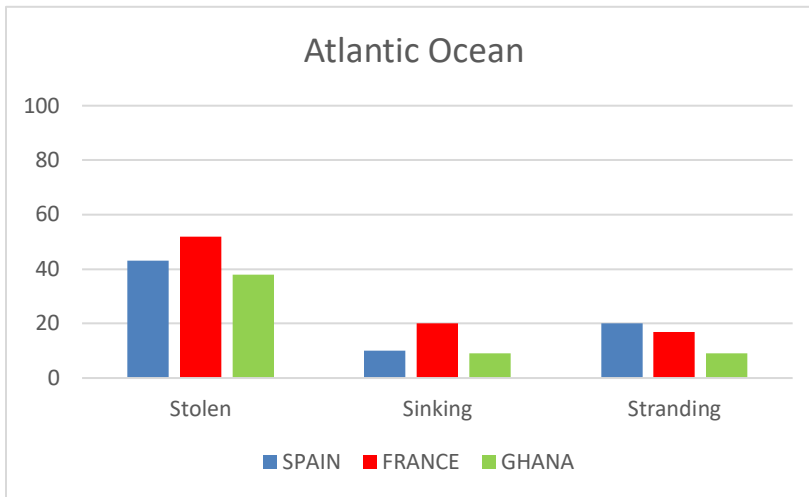
Recently, due to the limits on actively transmitting FADs per vessel set by RFMOs, FAD deactivation has increased. This is because deactivating a FAD that is far from the fishing zone or from the vessel allows for activating a new one within the fishing zone. The cost of a FAD is less than that of the fuel needed to retrieve it, so fishers do not navigate to areas far from where they are fishing in order to recover a FAD. In any case, the last position provided by the FAD could be a good proxy of the beaching area by modeling local currents.

Since 2009, ISSF has been organizing skippers workshops with purse seine fishers using FADs worldwide (Murua et al. 2018). To date, ISSF has conducted more than 80 workshops with 25 different fleets operating purse seiners in main ports all over the world. During these workshops, a questionnaire is distributed to gather fishers' knowledge and opinions. Recently, a new question was included related to the topic of this workshop: Which percentage of your FADs end up beaching, sinking or removed by other vessels?

The results of these questionnaires are shown in Figure 1. In general, for all of the oceans, but specially for the Indian Ocean, which is a relatively small fishing ground with a high density of fishing vessels, the majority of FAD losses for a given owner are due to appropriation by other fishing vessels (around 50% of the FADs). Secondly, FAD losses in the Indian and Atlantic Oceans are due to beaching events. The fishing ground in the Western Indian Ocean is surrounded by islands that stop the drift of the FADs towards the East, and by the continental mass in their trajectory to the West. Finally, sinking events both in the Indian and Atlantic Oceans represent a minor proportion of FAD losses; from fishers' point of view, FADs are taken by other vessels first or stranded. In contrast, in the Eastern Pacific Ocean, it is estimated from questionnaires that sinking events are higher than beaching events. This could be because current drift patterns in the tropical region of the Eastern Pacific Ocean (EPO) are from the East to the West. FADs deployed in the East need to traverse a large mass of water before they end up beaching, so fishers from the EPO believe that FADs sink before they arrive to an island. Likewise, the fleets operating in the Western Pacific Ocean believe that FAD sinking events are greater than beaching events.

As indicated by fishers' questionnaires, the relative importance of sinking and beaching events varies depending on the ocean. In order to better understand the fate of FADs, it is also important to consider the strategy and the type of FAD structure used in each fleet. For instance, in the EPO (Figure 1), the Ecuadorian fleet operates primarily in waters closer to the American continent, where a high density of vessel exits. The Spanish fleet operates in waters closer to the central Pacific where vessel density is low, and thus fishers fish mainly on their FADs and appropriation of others' FADs is less observed. The same result appeared in a study conducted by Lennert-Coddy et al. 2018, in relation to the strategy working with FADs for the different fleet segments operating in the EPO. In the Atlantic Ocean it can be observed that Ghanaian fleets that operate in a relatively small fishing

area visit, repair and retrieve their FADs more often than other fleets. This is probably because the distance to retrieve FADs is shorter, and they need to recover them to maintain a given number of FADs within the fishing area.



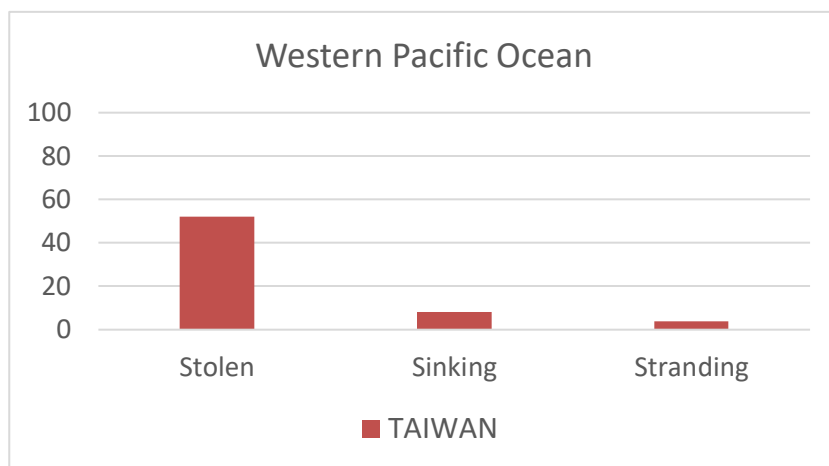


Figure.1 Percentage of FADs stranded, sunk and stolen by ocean and fleet, according to skippers. Data from ISSF skippers workshops.

During the workshop, these figures were discussed along with existing data from the French fleet's FAD trajectories. Fishers participating in the workshop reported that, from their point of view, beaching events were more than 20% of the deployments. The fact that FADs are deactivated before they end up beaching could bias their perception of the real number of FADs stranded, which probably is more than what is assumed. During the workshop fishers said that, even for those who have access to FAD trajectories, the fate of FADs is not always clear. They reported difficulties in distinguishing sinking events from buoys' positioning system failures and from stolen FADs. There are obvious cases, for example, when a FAD with a fish aggregation disappears in an area where other vessels are fishing. However, other cases are less evident, such as when the buoy starts transmitting intermittently, which could be both a sinking event or a failure of the communication system.

The fact that there are vessels (both purse seiners and other fleets) that cut the line that attaches the buoy to the FAD structure makes the fate of FADs more uncertain. Sometimes this practice can be malicious, but other times it could be necessary, such as when a FAD becomes entangled in other fishing gears (e.g., a longline). Although it is not very common, this practice occasionally happens.

Potential actions

The absence of data on the fate of FADs precludes an accurate estimation of the magnitude of the problem. Furthermore, it makes it difficult to evaluate the effectiveness of a given mitigation measure, due to the lack of information at the starting point.

- One of the potential solutions to collect data on lost and abandoned FADs could be the provision of data directly by buoy manufacturers, as important stakeholders of FAD fishing. Although satellite communications are expensive, once the FAD is lost there is no need for high-frequency data reception, but buoy manufacturers could provide a single position per day, with the consent of shipowners. The collaboration among buoy manufacturers, shipowners, and scientists would be crucial to design the most appropriate data collection framework for estimating FAD beaching events as well as informing the strategy to retrieve them.

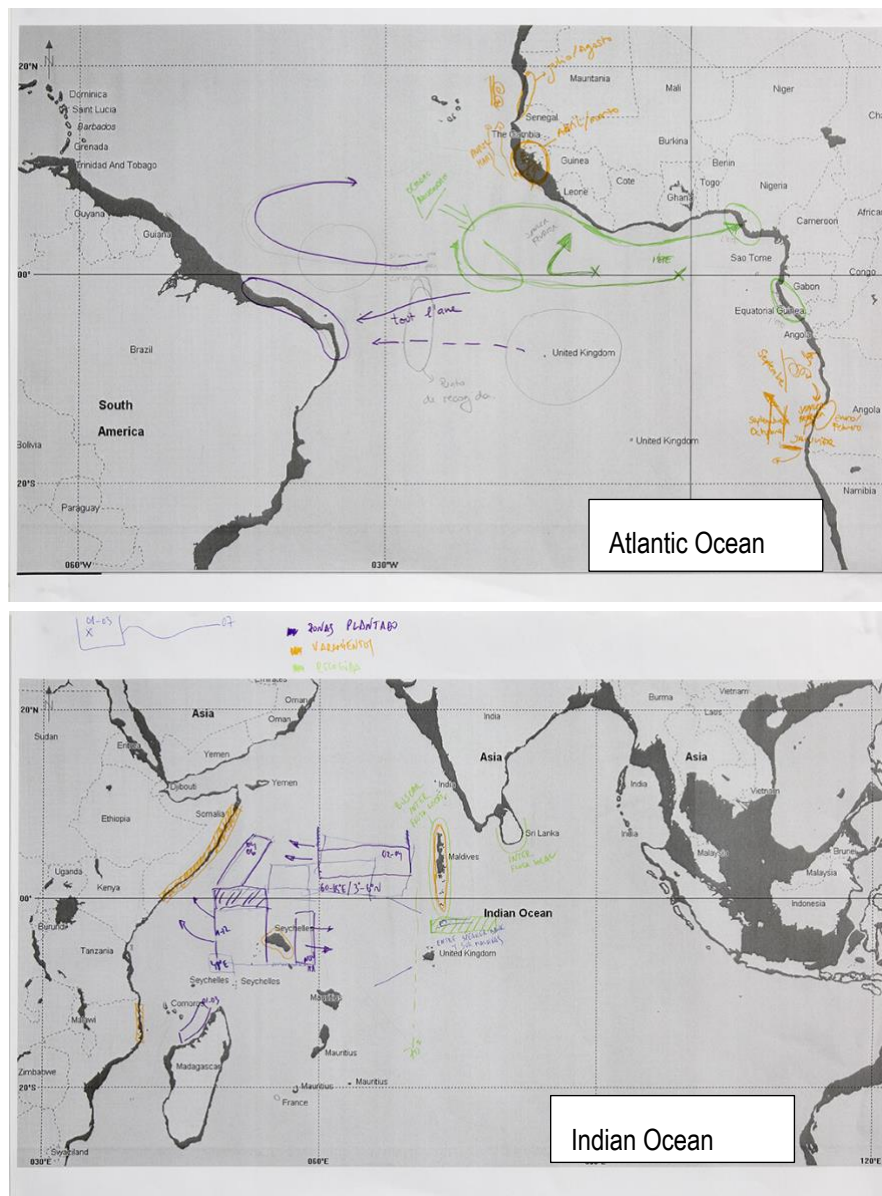
- Modeling oceanic currents to simulate FAD drifts could help to quantify and identify the most important FAD beaching areas. For that, using the last positions of the FAD before deactivation would be the most appropriate approach. One of the issues with drift models is that they are suitable for oceanic waters but less accurate close to the coast, as they are influenced by local tidal currents, which are more difficult to predict.

4. FAD Accumulation Areas

Data on beaching areas and FAD accumulation in open ocean

During the workshop, scientists presented a sample of real FAD trajectories from French and Spanish FADs in the Atlantic and Indian Oceans as well as models simulating FAD trajectories in the EPO from their deployment position.

Without real data to identify FAD beaching and accumulation areas in open ocean, workshop participants worked in mixed groups of scientists and fishers to identify those areas with a likely high incidence of beaching events as well as areas of FAD accumulation in open ocean. Figure 2 shows the result of this group exercise.



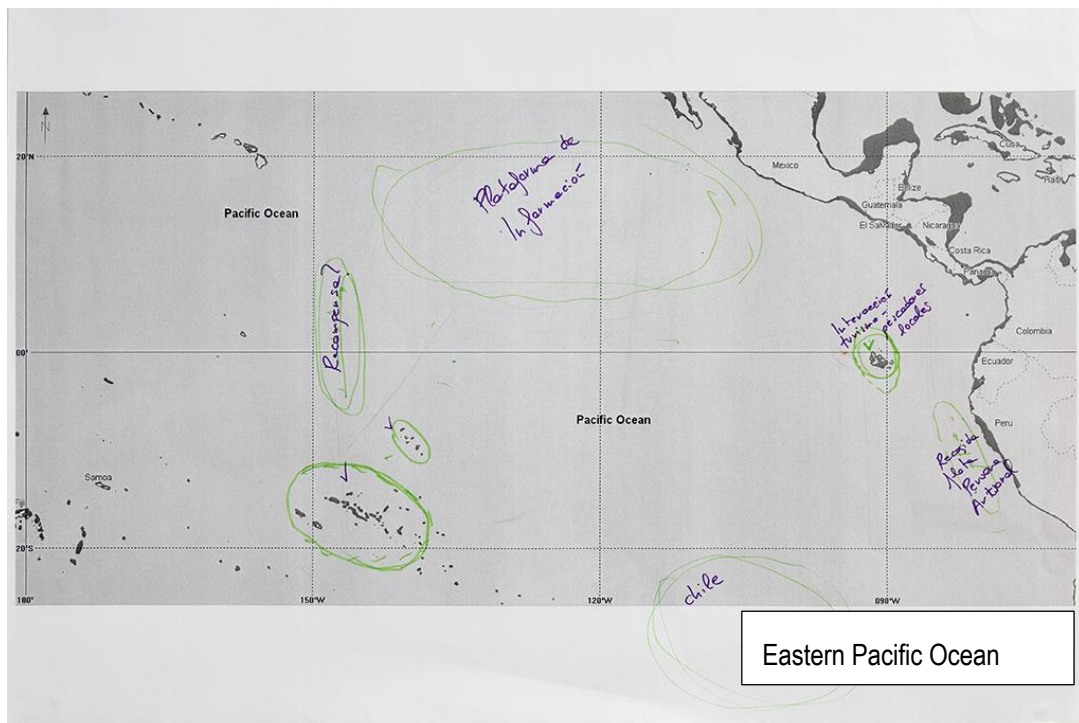


Figure 2. Maps by ocean identifying main FAD beaching areas and accumulation in open ocean.

The following areas were identified as potential areas of FAD retrieval:

West Indian Ocean:

Main likely beaching areas:

- Somalia
- Maldives
- Chagos
- Seychelles

Areas of potential retrieval at sea:

- Between the south of Laquedivas (India) and Chagos islands, there is a stream of FADs crossing those waters towards the Eastern Indian Ocean.
- Maldives before FADs arrive to the coast (coral reefs)
- South of Sri Lanka
- Some areas in Seychelles

Atlantic Ocean:

Main likely beaching areas:

- Brazil
- Nigeria
- Mauritania
- Equatorial Guinea

Areas of potential retrieval at sea:

- Around Longitude 25° West, before arriving to Brazilian waters
- From the coast in those areas with greater estimated stranding, and where it interferes with other economic activities or vulnerable ecosystems.

Eastern Pacific Ocean:

Main likely beaching areas:

- Galapagos
- French Polynesia
- Peru
- Marquesas Islands

Areas of potential retrieval at sea:

- Before arriving at Galápagos, French Polynesia and Marquesas islands.
- Latitude 10-15 N of Central Pacific Ocean, those FADs that drift north out of the fishing zone tend to accumulate in that latitude.

FAD accumulation areas identified in this workshop have been determined through the empirical knowledge of fishers that participated in the workshop. It is necessary to better study, by ocean, those beaching and FAD accumulation areas at sea, by following real FAD trajectories if possible. Although FADs are deactivated when drifting out of the fishing zone, the last position provided by the positioning system together with oceanic currents could be a good proxy for the beaching zones.

5. Potential Solutions to the Impact of FAD Structures on the Ecosystem

The potential solutions to reduce the impact of FAD structure on the ecosystem were discussed and evaluated. The workshop only considered technological solutions in relation to the fishing operation, fishing strategy and tactics. Here, those options are summarized in chronological order in relation to the lifetime of a FAD — from the construction of the FAD until it ends up lost, abandoned or stranded. Following a precautionary approach viewpoint, the sooner those measures are taken in a FAD's lifetime, the lower the consequences of FADs on the ecosystem.

Limiting FAD deployments

FAD use has increased worldwide — not only because fleets already using them have increased the number of FADs used, but also because fleets that were not relying on FAD fishing have moved towards the use of FADs (Lennert-Cody et al 2018). Recently, three tuna RFMOs have adopted a limit of active FADs per vessel, and in the Indian Ocean, the Indian Ocean Tuna Commission (IOTC) has limited the number of instrumented buoys acquired annually for each purse seine vessel.

It is clear that limiting the number of FADs used limits the various impacts that FADs can have on the ecosystem, including those derived from the loss and abandonment of FAD structures. It is worth mentioning that the limits for the three oceans are on active FADs at sea and not on the actual numbers of FADs at sea. When FAD transmissions are deactivated, they do not count as active FADs at sea, but those structures remain at sea with impacts on the ecosystem. Nonetheless, further limiting the numbers of active FADs at sea would limit the overall impact of FADs, and this measure could be equally implemented in the three oceans.

One of the challenges that researchers face is determining a sustainable number of FADs at sea based on science. The ideal sustainable number of FADs at sea would allow efficient fishing and minimize the non-effective fishing effort that thousands of FADs drifting out of the fishing zone may be causing.

In relation to the non-effective, unobserved fishing effort caused by lost and abandoned FADs, during the workshop, maps on FAD sets were compared to the spatial distribution of FADs in the three oceans. Those maps clearly revealed that the spatial distribution of FADs is wider compared to the fishing zone. One of the few studies that estimated the time spent by FADs out of the fishing zone is by Maufroy et al. 2015, where non-effective time out of the fishing zone was calculated using FAD trajectories from the French fleet. Without such information it would be very hard to estimate non-effective effort caused by lost and abandoned FADs. A greater understanding of FAD trajectories would allow estimating not only an effective and sustainable number of active FADs at sea, but also identifying the most suitable FAD deployment areas as well as those areas with high risk of FAD loss.

Today, there are limits on active FADs per vessel. However, the effectiveness of these measures is unknown at present. Further limiting the number of FADs would limit all of the impacts that FADs can cause, including those impacts derived from lost and abandoned FADs.

Simplifying FAD structure

In the last decade, an increase in the depth reached by FAD structures has been observed worldwide (Murua et al. 2016). Large, deep-reaching FADs were originally used in the Atlantic Ocean by Korean and Ghanaian fleets, so the FADs would drift slowly. This practice has extended to other regions. The submerged appendages of FADs have increased significantly, reaching sometimes 100 m depth and occasionally exceeding this depth (Hall and

Roman, 2013). Apart from the increase in depth, FADs have evolved to be more sophisticated and complex, with net panels acting as anchor drifts to decrease FAD speed.

Logically, a longer and more voluminous FAD structure made with synthetic materials has a greater impact on the ecosystem when it strands on the coast or sinks. While a limit on the number of FADs used could limit the impact, the fact that the structures have increased in size reduces the expected positive effect of the decrease in the number of FADs.

From a fisher's point of view, in general, FADs with deeper structures are more likely to aggregate tuna, and their success is that deep FADs cause slow drift. This is with the exception of areas where tunas are feeding on the surface, in which case FADs without any submerged structure would be more effective. There is little scientific evidence on the effect of different FAD depths on the ability to aggregate tuna. A study by Lennert-Cody et al (2007) showed that FAD depth could be a significant factor in explaining the catch of bigeye tuna (*Thunnus obesus*) in the EPO, but factors such as the area and time of fishing also were significant. It is difficult to know the depth at which a FAD's structure actually works. On the one hand, it is possible that over time the structure changes its configuration and breaks, or loses or gains weight, changing the depth reached. On the other hand, the drift would change depending on the structure of the water column. The depth of the mixed layer and the currents in the water column could cause two FADs of different depths to drift the same — or they could, in areas where internal waves are generated, drift differently. ISSF conducted an experiment in the EPO with 300 FADs to compare the ability to aggregate bigeye of the traditional FADs used in the EPO of 36 and 47 meters deep with FADs of 5-meter-deep appendages (Restrepo et al., 2016). This experiment resulted in no significant differences in drift velocity between the two types of FADs, and there were no significant differences in the ability to aggregate tuna, nor in the species composition found at each FAD type. The area of this experiment is a region where the thermocline is shallow, so it is not known if these results could be extrapolated to other regions. At least for the study area of this experiment, it seems that a much simpler structure could provide the same result as a deep FAD structure. Deep and more complex FAD structures are more expensive and, from the logistical point of view, more difficult to handle, retrieve and store.

Therefore, one of the potential solutions to the impact of the FAD structure is to simplify it by reducing both the volume (m³) and weight (kg) of materials used in its construction. Studies that prove simpler FAD structures' ability to aggregate tuna would be desirable. During the workshop, participating fishers indicated that although they are accustomed to using deep FADs, especially in the Atlantic, they agreed that any type of structure could aggregate tuna, provided that this structure drifted slowly. From the point of view of oceanographers working with drifting buoys to study oceanic currents at different depths, for a FAD to drift slowly it is not strictly necessary that it be a very sophisticated structure from the surface to 100 m depth. According to them, a sufficient structure would be a rope from the surface of the FAD to below the mixed layer (up to 60 m depending on the region of the ocean) where a sail or structure similar to a floating anchor would have to be added. Possibly, a FAD of this type would drift equally slowly, and, without large net panels, its impact would be much lower.

Finally, a simpler FAD structure would allow a more efficient FAD retrieval and storage process. Currently the main problem when retrieving FADs, both from coast and offshore, is the large volume and weight of the structures used. In order to retrieve FADs, first to hoist a structure of 50 - 100 m long, a mechanical crane is necessary. And for its subsequent storage onboard, a vessel large enough to carry multiple FADs is necessary. Therefore, simplifying the structure of FADs would allow not only less impact when FADs are lost, but also simplify the process of their collection and storage. It would be desirable to conduct studies to test the effectiveness of simpler FADs.

Avoiding FAD deployment areas that imply high risk of stranding

There are some areas that are more susceptible to stranding because the predominant currents cause the FADs to drift towards them, as in the case of the Maldives. But there are also deployment sites that make FADs more susceptible to beaching, for example in areas where the continental slope is closer to the coast, or where there is high productivity near the coast due to upwellings, productive estuaries, etc. FADs that are deployed in these areas that also have currents with variable directions or that mainly drift to the coast have a high probability of ending up stranded. This is the case, for example, with Mauritania or Angola, where FADs are deployed closer to the coast.

It would be desirable to identify, by ocean, which fishing areas associated with the continental slope (or more coastal) exist, study these cases in particular, and look for solutions that minimize strandings. Some of the short-term and long-term solutions could be: (i) setting deployment limits according to proximity to the coast, (ii) searching for, based on current models, another deployment strategy in the area that minimizes stranding, or (iii) in the long term, to use anchored FADs in these specific areas, as is done in many other places. In the latter case, it would also be necessary to consider how the FADs anchored in those areas would be managed.

During the meeting, it became clear that it would be very useful to be able to study the FAD trajectories to determine the FAD deployment zones that reduce strandings and the ineffective, unobserved effort made by FADs that drift outside the fishing area.

Use FADs that remain in the fishing area

At the workshop, the possibility of using FADs that do not leave the fishing zone was discussed — that is, to reduce those FADs that drift far from the fishing area so that they would not have an impact on the coast or produce non-effective fishing effort. The different options that were contemplated were the following:

✓ *Use FADs with navigation capability*

Today, there are autonomous vehicles with navigation capacity that could be one of the solutions to FAD loss and abandonment. These autonomous vehicles that could resemble a FAD could be deployed as is done with conventional FADs and leave them adrift. The difference is that these, given their navigational capacity, could be redirected before they left the fishing area or before they strand on an island. From the fisher point of view, the navigation capacity's advantage is not clear in times when the sea conditions are adverse. One of the solutions that the fishers proposed was the possibility of not redirecting the FAD back to the starting point or traveling a long way to where the fisher might be interested, but rather to leave them "waiting" in an area where they can go to with an auxiliary boat or another tuna boat from the company to pick them up. That is to say, it would be a question of not navigating but of remaining "stationary" in an area, or at least slowing down its drift.

Another limitation could be the price. At the moment, a FAD is cheaper than an autonomous platform with navigation capability. It was also discussed that in the case of FADs with navigation capability, the number of FADs needed would be lower since they would be reused. Also, it would not be necessary to deploy FADs in many areas but rather to move them from one area to another.

The technology exists, and these FADs could be tested in pilot projects to learn their real navigation capacity and how to fish with them and retrieve them in the different oceans. The results of these pilot projects would help to improve the technology.

✓ *Use FADs that could be sunk*

Another alternative, to reduce FADs' impact on the coasts, could be FADs that could be sunk at will. The largest volume of the structure includes the submerged part, so the idea would be sinking the structure of the FAD (its submerged part) before it reaches shore. A mechanism similar to that used in pop-up tags for the tracking of marine animals could be added to FADs, so that the submerged part of the FAD is freed from the superficial part when the FAD is going to leave the fishing zone. Thus, the FAD tail (the submerged structure) would never arrive at the coast.

Although technically this solution would be possible, it did not have much acceptance among the workshop participants, basically because it is not a solution to marine pollution. It would amount to depositing all FADs on the seabed, where degradation is very slow due to lack of light and reduced oxygen. There would still be an impact, even in the case of biodegradable FADs, since they would also be modifying the habitat of the seabed.

✓ *Use of anchored FADs*

Anchored FADs are successfully used to fish for tuna in the three oceans, although the vast majority of these are found in the Western Pacific Ocean. Some anchored FADs, such as those used in Southeast Asia, have proven to be very effective in tuna aggregation and have been exploited before drifting FADs existed.

Using anchored FADs is a potential solution to FAD loss and abandonment. Currently, as in the case of Hawaii, a FAD can be anchored at depths of 3000 m or more. The cost of an anchored FAD is a function of the depth to which it is anchored; in Hawaii, it can be around USD 7,500 (Holland et al., 2000). This would be similar to the cost of six drifting FADs, including the buoy, but the anchored FADs would have an additional maintenance cost.

During the meeting, this alternative was not well received because the way anchored FADs would be managed (ownership, maintenance, monitoring) among the fleets fishing with FADs, leaves too many unknowns nowadays.

Although this is not a short-term solution, a socioeconomic study could elucidate the potential cost in terms of structures, anchoring, fuel and fishing surveillance systems with anchored FADs compared to the costs of using hundreds of drifting FADs per vessel. An important part of the study would be to determine how an anchored FAD could be managed between the various fleets and even within the companies that exploit them. Today there is technology that could be used for the surveillance and exploitation of anchored FADs. On a much smaller scale, there are companies that exploit seamounts and use auxiliary vessels that act as anchored FADs.

The use of anchored FADs, although not feasible for the total replacement of drifting FADs, could be an option for areas where fishing is more associated with the coast and where there is a high risk of stranding. These zones should be studied for each ocean.

Recover FADs at sea

It is inevitable that FADs will drift out of the fishing zone using today's technology. If the FAD owner vessel is not nearby to retrieve a FAD, it is most likely that it will be deactivated, and the vessel will stop receiving the transmission of the satellite buoy position. One of the potential solutions to FAD loss would be their retrieval at sea. During the workshop, the following different possibilities were discussed:

- Carry out good practices, once the FAD is fished, including collecting the entire structure if it is not going to be productive anymore in that area or if it is at risk of drifting out of the fishing zone.
- Share the location information with other fishers, either from the same company or create a "stock exchange" of the FADs that are beyond the reach of the owner. This option does not guarantee that the FAD will be retrieved if good practices are not followed and another vessel could fish on it but not pick it up.
- The capacity of a ship to collect FADs is limited, given the large volume that FADs have today. Therefore, a simpler structure would make FAD retrieval more efficient.
- The logistics necessary to store and recycle these structures should exist on land.
- There are convergence zones where FADs accumulate in open ocean. The FADs could be collected in those areas on the high seas cooperatively, using an auxiliary vessel for that purpose.
- The collection at sea should be studied for each ocean. In the case of the Pacific, which is very large, the cost of fuel can be an important limitation.

Recover FADs from the coast

Even following good practices, some FAD beaching will continue. Today there are projects to retrieve FADs, such as the one from OPAGAC in the Indian Ocean. During the workshop, the following points were discussed in relation to collecting FADs from the coast:

- First of all, it would be necessary to have quantitative data to determine the priority zones for the collection of FADs from land, taking into account the vulnerability of the area, as well as the number of FADs that end up stranding. For this, the use of real trajectories (not necessarily in real time), or collaboration with companies supplying satellite buoys to obtain positions once they have been deactivated, would be the best options. If obtaining this information is not possible, modeling FAD trajectories from the last position provided by the FAD would be an alternative to calculate the stranding area.
- FADs could be picked up by artisanal fleets, which could fish on them and collect them, for which FAD position should be shared. This option does not guarantee the collection of the FAD. There are small fleets that fish on the FADs they find near their coasts, but do not pick them up. The collection of FADs, given their weight and volume, requires a vessel that is not available to many of the artisanal fleets. In addition, the vessel that would act as a collector needs to have the technology to know the position of the FAD in real time, something that is not available to many artisanal fleets.
- Projects in which NGOs or community-based cleanup efforts collaborate on FAD collection could be another option, but it also requires boats with communications, space and sufficient autonomy to be effective in FAD retrieval. FADs are not easy to find even when their position is known; the sea and weather conditions and the experience of the seeker are crucial. Also, it appears that the distance between FADs, in many occasions, is too long for a single vessel to collect a significant number of them.
- For the two previous options, there should be a plan for the management of FADs on land, since there are many islands that could not process or recycle the volume of FADs that could be arriving to their coasts.

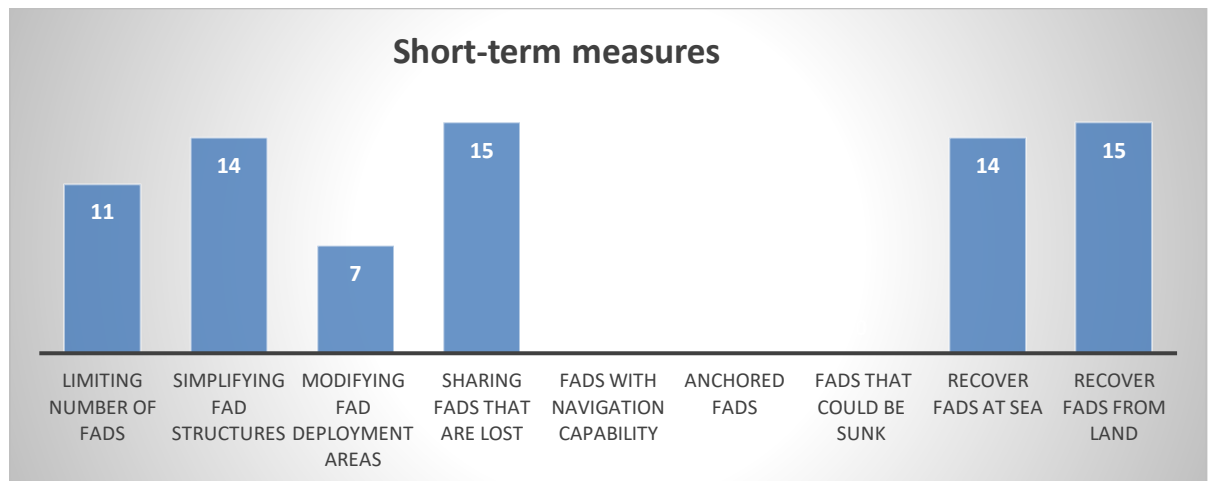
6. Feasibility of the Potential Solutions Over Time

To conclude the workshop, a survey was conducted with the 16 participants, both fishers and scientists, on the feasibility of the different options that had been discussed. To this end, each participant was asked to identify those measures that could be implemented in the short term or within a period of 10 years (once more studies have been done or the technology is available). Finally, they were asked to identify those options that were completely discarded, that is, options that they thought would never be effective or viable.

The different options that were offered were:

1. Limiting number of FADs
2. Simplifying FAD structures
3. Avoiding FAD deployment areas that have high risk of stranding
4. Sharing FADs that are lost or out of the range of the owner
5. FADs with navigation capability
6. FADs that could be sunk
7. Anchored FADs
8. Recover FADs at sea
9. Recover FADs from land

Figure 3 shows the results of the options chosen by the 16 participants based on the time necessary for their implementation, measures that could be used in the short term, medium-term measures and measures that were completely discarded:



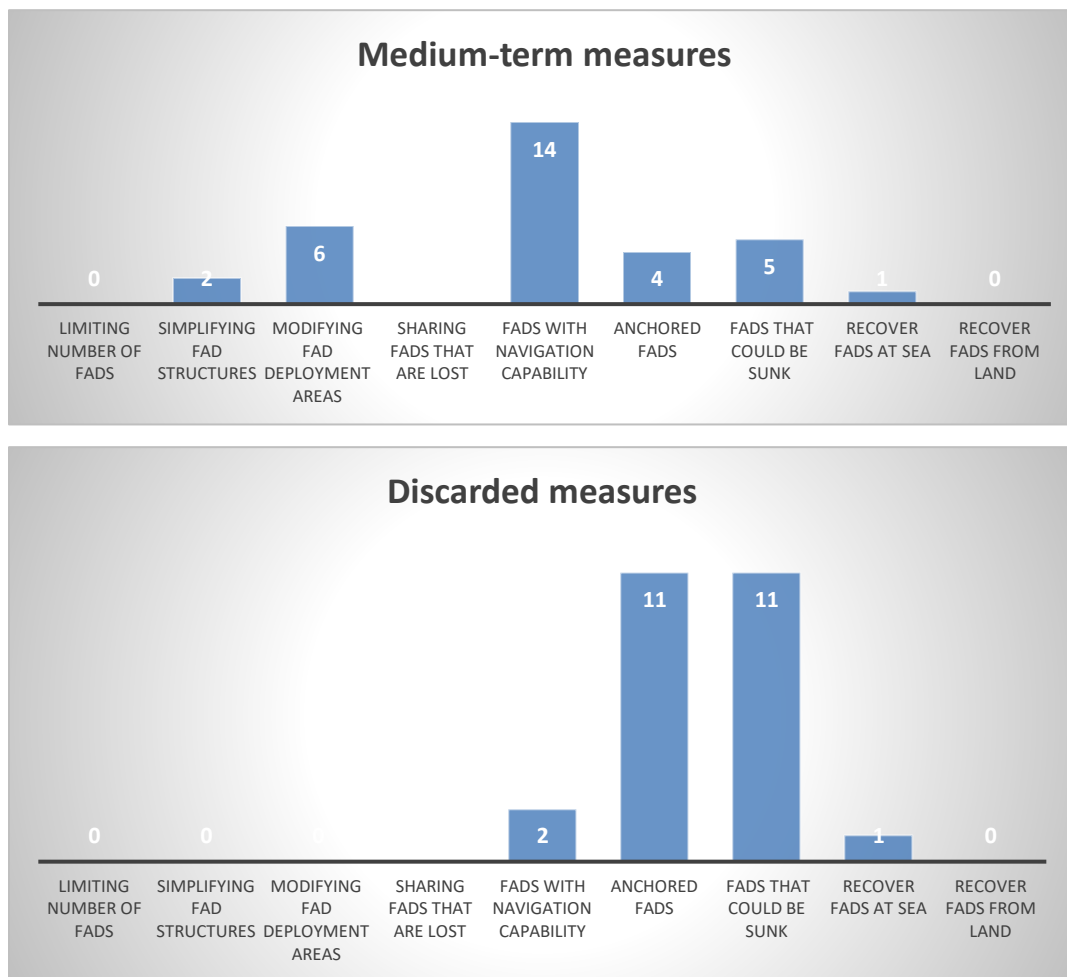


Figure 3. Options selected by the workshop participants to reduce the impact of FADs, based on the time of implementation of the measures

The survey results clearly show that most of the measures could be implemented in the short term, except the use of anchored FADs, FADs with navigation capability, and FADs that could be sunk. The majority of the participants believed that FADs with navigability could be used in the medium term once tests have been carried out and the technology is evaluated. In the case of anchored FADs, most of the participants discarded that option because of the difficulty of managing fishing access to them and assigning them to the different fleets and vessels within each company. The few participants that opted for the implementation of the anchored FADs in the medium term did so based on their use in specific zones, to avoid high stranding, rather than in the complete replacement of drifting FADs by the anchored ones. In the case of the FADs that could be sunk, most of the participants eliminated that option because they believed it did not solve the problem of marine litter. The few participants who believed FADs that could be sunk were an alternative in the medium term thought that biodegradable FADs did not have an impact on the ecosystem. One participant completely dismissed the idea of FAD collection in open ocean; in this case, it was a fisher fishing in the Pacific Ocean whose opinion was that the travel distances are too long to make that option viable. The modification of the deployment areas to avoid stranding and make the life of the FAD more effective was selected by some participants as a short-term measure and by other participants as a longer-term measure; the latter thought that studying real FAD trajectories was necessary to develop this idea properly.

Finally, Figure 4 provides a synoptic view, from the surveys to the workshop participants, of the different measures that could be used to reduce the impact of the FADs that are lost or abandoned, taking into account the implementation time, as well as those that are discarded completely.

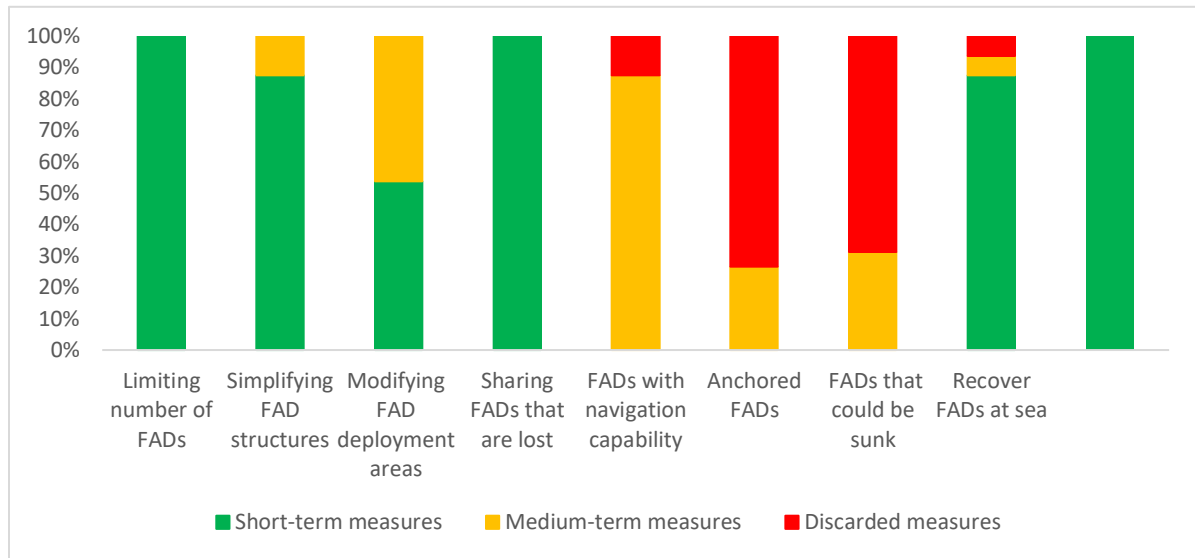


Figure 4. Workshop participant views of measures, based on implementation time, for reducing the impact of lost or abandoned FADs.

7. Recommendations

The discussions during the workshop resulted in the following recommendations:

Recommendation 1:

- Develop a guide of good practices for tuna purse seiners and auxiliary vessels with the aim to reduce the loss and abandonment of FADs, as well as to facilitate their collection.

Recommendation 2:

- Quantify strandings: Identify main beaching zones by establishing priority areas based on the vulnerability of the ecosystem and the degree of stranding. If possible, based on real FAD trajectories, collaborate with shipowners and buoy manufacturers or, failing that, use FAD drift models.

Recommendation 3:

- Simplify the structure of the FAD as much as possible. Conduct studies to find simple structures that meet the needs of the fleets.

Recommendation 4:

- Study the trajectories of FADs based on the position and time of deployment to determine the deployment areas with the highest risk of FAD loss of FADs and causing ineffective fishing effort.

Recommendation 5:

- Study the dynamics of deployment and stranding events in fishing areas close to shore, in order to better manage those areas (change deployment zone, limit deployment according to distance to coast, or season of the year — with reference to currents — use anchored FADs, etc.).

Recommendation 6:

- Conduct pilot studies at sea of FADs with navigation capacity to better understand the behavior of these FAD "drones" and the possible strategy for their use.

Recommendation 7:

- In projects on FAD retrieval from the coast, to ensure the efficiency of the collection system, determine the minimum requirements for the vessels that would recover FADs, as well as ensure the management of the waste on land.

Recommendation 8:

- Carry out workshops in each ocean with the participation of scientists and fishers to define the potential solutions and recommendations of this document, based on the characteristics of each ocean.

8. Bibliography

Franco, J., Moreno, G., Lopez, J., Sancristobal, I., (2012). Testing new designs of drifting fish aggregating devices (dFAD) in the eastern Atlantic to reduce turtle and shark mortality. Collect. Vol. Sci. Pap. ICCAT 68, 1754-1762.

Hall and Roman Hall, M.; Roman, M. 2013. Bycatch and non-tuna catch in the tropical tuna purse seine fisheries of the world. FAO Fisheries and Aquaculture Technical Paper No. 568. Rome, FAO. 249 pp.

Holland, K.N., Jaffe, A., Cortez, W., 2000. The fish aggregating device (FAD) system of Hawaii. In: Le Gall J.-Y., Cayre P. and Taquet M. (eds), *Peche thoniere et dispositifs de concentration de poissons*. Ed. Ifremer, Actes Colloq. 28, 55-62.

Maufroy, A., Chassot, E., Joo, R., Kaplan, D.M., (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.

Moreno, G., Restrepo, V., Dagorn, L., Hall, M., Murua, J., Sancristobal, I., Grande, M., Le Couls, S. and Santiago, J. (2016). Workshop on the use of biodegradable fish aggregating devices (FADs). ISSF Technical Report 2016-18A, International Seafood Sustainability Foundation, Washington, D.C., USA.

Moreno, G., Jauhary, R., Shiham, M.A. and Restrepo, V. 2017a. Moving away from synthetic materials used at FADs: evaluating biodegradable ropes' degradation. IOTC-2017-WPEB13-INF12.

Moreno, G., Orue, B. and Restrepo, V. 2017b. Pilot project to test biodegradable ropes at FADs in real fishing conditions in Western Indian Ocean. IOTC-2017-WPTT19-51.

Moreno, G., Murua, J., Kebe, P., Scott, J. and Restrepo, V. (2018). Design workshop on the use of biodegradable fish aggregating devices in Ghanaian purse seine and pole and line tuna fleets. ISSF Technical Report 2018-07. International Seafood Sustainability Foundation, Washington, D.C., USA

Murua, J., G. Moreno, D. Itano, M. Hall, L. Dagorn, and V. Restrepo (2018). ISSF skippers' workshops round 7. ISSF Technical Report 2018-01. International Seafood Sustainability Foundation, Washington, D.C., USA.

Restrepo, V., L. Dagorn, G. Moreno, F. Forget, K. Schaefer, I. Sancristobal, J. Muir and D. Itano. (2016). Compendium of ISSF At-Sea Bycatch Mitigation Research Activities as of 12/2016. ISSF Technical Report 2016-13A. International Seafood Sustainability Foundation, USA.

Zudaire et al. 2017. Testing designs and identify options to mitigate impacts of drifting FADs on the ecosystem. Indian Ocean tuna commission, IOTC-2017-SC20-INF07.

Appendix I. Participants list

1. Ernesto Altamirano (IATTC, USA)
2. Nagore Cuevas (Albacora)
3. Laurent Dagorn (IRD, France)
4. Maitane Grande (Azti, Spain)
5. Martin Hall (IATTC, USA)
6. Thibault Kergourlay (Patrón de pesca, Atlántico)
7. Isadora Moniz (FIP OPAGAC)
8. Gala Moreno (ISSF, Chair of the workshop)
9. Eukén Mujika (Patrón de pesca, Pacífico)
10. Jefferson Murua (Azti, Spain)
11. Borja Rodríguez (Patrón de pesca, Atlántico)
12. Igor Sancristobal (CLS, France)
13. Aitor Santiago (Patrón de pesca, Indico)
14. Josu Santiago (Azti, Spain)
15. Iñaki Uriarte (Pevasa, Spain)
16. Iker Zudaire (Azti, Spain)



Appendix II. Visual documentation of the workshop





www.iss-foundation.org

1440 G Street NW
Washington D.C. 20005
United States

Phone: + 1 703 226 8101
E-mail: info@iss-foundation.org

