INTERNATIONAL SEAFOOD SUSTAINABILITY FOUNDATION

ISSF Technical Report 2019-11

RECOMMENDED BEST PRACTICES FOR FAD MANAGEMENT IN TROPICAL TUNA PURSE SEINE FISHERIES

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Suggested citation:
Restrepo, V., H. Koehler, G. Moreno and H. Murua (2019). Recommended Best Practices for FAD management in Tropical Tuna Purse Seine Fisheries. ISSF Technical Report 2019-11. International Seafood Sustainability Foundation, Washington, D.C., USA

Topic Categories: MSC, Purse seine, FADs, FIPs

Abstract

Many industrial purse seiners use drifting Fish Aggregating Devices (FADs) in tropical tuna fisheries. Management of the FAD component of these fisheries has been increasingly the focus of Regional Fishery Management Organizations and stakeholders such as ISSF. ISSF and other NGOs have put together lists of the elements that they consider to be most important for effective management of FADs. This paper expands upon the six elements of management that ISSF considers to be of utmost importance: (i) Complying with flag state and RFMO reporting requirements by set type, (ii) voluntarily reporting additional FAD buoy data for use by RFMO science bodies, (iii) supporting science-based FAD limits, (iv) using non-entangling FADs to reduce ghost fishing, (v) mitigating other environmental impacts due to FAD loss including through the use of biodegradable FADs and FAD recovery policies, and, (vi) implementing further mitigation efforts for silky sharks. We provide practical examples that fleets could adopt as their FAD management policies.

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July 2019

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1. INTRODUCTION

Restrepo and Justel-Rubio (2018) developed a series of recommendations for tropical tuna purse seine fisheries that might be proposed for certification by the Marine Stewardship Council (MSC). Their approach consisted of examining the MSC scoring guidance to obtain an unconditional pass (SG80) in every MSC Principle Indicator and recommending practices that the fleets could implement in order to aim to achieve those scores. A high-level summary of those best practices relating to Fish Aggregating Devices (FADs) was developed by Restrepo and Justel-Rubio (2018) as follows:

- Comply with flag state and RFMO reporting requirements for fisheries statistics by set type;
- Voluntarily report additional FAD use for use by RFMO science bodies;
- Support science-based limits on the overall number of FADs used and/or FAD sets made;
- Use only non-entangling FADs and promote the use of biodegradable FADs;
- Develop a FAD recovery policy, including arrangements to alert coastal countries of derelict FADs that may impact sensitive areas;
- For silky sharks (the main bycatch issue in FAD sets) implement further mitigation efforts.

Similar lists of actions as above have also been identified by a symposium organized in 2017 by PEW with participation by 31 scientists and other experts (Hampton *et al.*, 2017) and by a group of nine NGOs including ISSF (NGO Tuna Forum, 2019).

The objective of this document is to expand on the best practices advice above, based on the latest scientific knowledge, and provide practical examples that fleets could adopt as their FAD management policies. Examples of best practices are summarized in text boxes.

In this document, the six practices identified above have been reorganized as follows in order to more neatly separate ghost fishing (item d) from other environmental impacts (item e):

a) Comply with flag state and RFMO reporting requirements for fisheries statistics by set type;
b) Voluntarily report additional FAD buoy data for use by RFMO science bodies;
c) Support science-based limits on the overall number of FADs used per vessel and/or FAD sets made;
d) Use only non-entangling FADs to reduce ghost fishing;
e) Mitigate other environmental impacts due to FAD loss including through the use of biodegradable FADs and FAD recovery policies;
f) For silky sharks (the main bycatch issue in FAD sets) implement further mitigation efforts.

The recommendations provided here are not to be confused with the FAD Management Plans that RFMOs have adopted and have to be reported by member states that have purse seine fisheries. Rather, this document focuses on best practices that a purse seine vessel-owning company could implement in order to improve its sustainability.

2. BEST PRACTICES FOR FAD MANAGEMENT

2.1. Comply with flag state and RFMO reporting requirements for fisheries statistics by set type

Each tuna RFMO that manages tropical tunas requires the submission of FAD-related data as per the following conservation and management measures:

- IATTC C-17-02 and C-18-05
- ICCAT Rec. 16-01
- IOTC Res. 19/02
- WCPFC CMM 2018-01

The types of data required are summarized in Table 1. In most cases, the data are submitted by the flag state to the RFMO.

Table 1. Types of FAD related data actually required by tuna RFMOs. Note that most, if not all, FADs are equipped with electronic buoy including an echo-sounder which capture/transmit position and echo-sounder data.

Type of data	Source	Example uses	RFMO requirement
Catch and effort data by set type	Logsheets or observers	Catch and effort indicators by set type	**IATTC** and **WCPFC**: Already required, set-by-set **ICCAT** and **IOTC**: Already required, aggregated
FAD related activities and FAD structure characteristics • deployments • visits • sets (owned vs encountered FADs) • lost • retrieval • FAD structure characteristics (materials, net mesh size, design, etc)	Logsheets or observers	Vessel and FAD interaction indicators (FAD logbook; FAD inventory); FAD related fishing strategy; FAD structure impacts	**IATTC** and **WCPFC**: Already required, set-by-set **ICCAT** and **IOTC**: Already required, aggregated
Processed buoy data on buoy inventory and activity • type of buoy (brand, model) • deployed • operative (active at sea) • deactivated	Fishing companies via buoy provider	Coastal impacts (stranding); effort indicator (operative/active FADs); density of FADs at sea	**IATTC**: Already required, aggregated or disaggregated with one position per day for each buoy (optional) **IOTC**: disaggregated, one position per day for each buoy. **ICCAT**: Already required, aggregated **WCPFC**: Not required, but could potentially receive data

Note that sometimes the same types of data are collected by both observers and in logsheets. This redundancy is often criticized as creating unnecessary work, but it shouldn't. The redundancy is actually desirable because it allows comparison of both data sets for the purpose of verification. Furthermore, observers are not always used (100% coverage is only required in the Pacific Ocean for large scale vessels) or are not always able to determine elements such as set type, which makes it useful for vessel operators to record the data in logsheets.

Catch and effort by set type

The language used to describe set types varies between tRFMOs. The tRFMOs have held joint working group meetings where they have discussed the possible harmonization of set-type terminology (e.g. as recommended by Gaertner *et al.*, 2018), but this has not been achieved to date. In broad terms, observers record the following set types, although not uniformly in all RFMOs (Anon., 2012):

- **School set**: Sets on schools were there are no indications of tuna association with floating objects, marine mammals or whale sharks.
- **Drifting FAD set**: Sets on tuna associated with floating objects constructed and deployed or encountered and modified by the fishers to attract fish to facilitate their aggregation and capture. This may include using the vessel (or its support boats) to act as the FAD.
- **Log set**: Sets on encountered floating objects, including from natural origin (branches, logs, algae) or anthropogenic origin, dead animals, etc., as far as they are not intentionally deployed or modified by human intervention.
- **Payao (anchored FAD) set**: Sets on man-made floating object that are anchored.
- **Whale set**: Sets are made in association with whales, that is, close to or encircling the live whale(s).
- **Whale shark set**: Sets are made in association with whale shark, that is, close to or encircling the live whale shark.
- **Dolphin set**: Common only in the eastern Pacific. There is a clear association, and the set is preceded by a chase of the dolphin herd.
- **Baitboat set**: Sets occur in association with a baitboat (pole and line boat). The baitboat drifts or sails slowly, attracts a tuna school, and may keep it by throwing live baitfish (chumming) into the water. They are left as a separate class because of the potential effect of chumming that makes it different from a regular floating object.

FAD types and FAD related activities

This information is recorded by operators in what are known as "FAD logbooks" and is also complemented by observers records. The aim is to record information on FAD structure and FAD related activities: FAD deployments, FAD visits (with or without a set) and FAD losses. The following, based on ICCAT Rec. 16-01, are the general types of information that should be recorded for each FAD:

- **FAD design characteristics**: material of the floating part and of the underwater hanging structure, dimensions of the FAD, and the entangling or non-entangling nature of the underwater hanging structure;
- **FAD activities:**
  - **FAD deployment**: vessel, position, date, FAD structure type (e.g., drifting artificial FAD, log), FAD identifier (e.g., FAD marking and buoy ID, type of buoy – e.g. only geolocating buoy or equipped with an echo-sounder);
  - **FAD visit**: vessel, position, date, FAD type, FAD identifier, and type of the visit
    - deployment of a buoy: deploying/transferring a buoy on a foreign FAD (which changes the FAD's owner) and changing the buoy on an owned FAD (which does not change the FADs owner).
    - retrieval of FAD and/or buoy,

        - strengthening/consolidation of FAD,
        - intervention on electronic equipment, opportunistic encounter (without fishing) of a FAD belonging to another vessel, visit (without fishing) of a FAD belonging to the vessel;
    - **FAD sets:** owned or encountered FAD and the results of the set in terms of catch and by-catch, whether retained or discarded dead or alive;
    - **FAD loss**: Last registered position, date of the last registered position, FAD identifier.

Processed FAD buoy data

Assuming that each FAD is equipped with a satellite buoy, processed buoy data complement the information recorded in FAD logbooks in terms of FAD activity (e.g. deployment location, number of FADs deployed, etc.). A differential characteristic of the processed buoy data is that are obtained directly from the satellite buoy providers (with permission from the buoy owner) without the intervention of the vessel operator or the observer.

Recommended best practices for complying with flag state and RFMO reporting requirements by set type:

- **Logsheets**: Commit to filling out completely and accurately the logsheets required by the flag state, licensing authority, and/or RFMO for each set on a trip. The data should include catch and bycatch by set type.
- **FAD activity:** Provide data on FAD activity (deployments, visits, sets and loss) through "FAD logbooks" and data on number of active FADs through the analysis of satellite buoy daily position data provided by satellite buoy provider.
- **Observer coverage**: Commit to 100% observer coverage (either human or electronic). If electronic monitoring is used, follow best-practice minimum standards (Restrepo *et al.*, 2018).

2.2. Voluntarily report additional FAD buoy data for use by RFMO science bodies

There are numerous potential scientific uses of data provided by the buoy used to track FADs that can help improve stock assessments and evaluation of the ecosystem impacts of FAD related fishing activities (Moreno *et al.*, 2016). The types of data that could be provided to science bodies voluntarily are positional data and acoustic data from the echo-sounder buoys used to track FADs.

Buoy positional raw data

Buoy positional data can be used to develop indicators of fishing effort spatially over time as well as to characterize the “floating object” environment of tunas, which can be useful to assess various impacts of the fishery on the ecosystems. This is important especially in the context of understanding FAD densities in a given area at a given time, and how that may influence catch per unit of effort (CPUE) as well as other possible impacts. Also importantly, FAD tracks can help identify impacts on vulnerable marine ecosystems such as coral reefs where FADs may end up beaching. FAD tracks are currently only required by IOTC (Resolution 19/02) where CPCs shall report daily information on all active FADs to the Secretariat to support the monitoring of compliance with the FAD limitation starting 1 January 2020. Similarly, FAD tracking data are required by the Parties to the Nauru Agreement (PNA) where much of the purse seine fishing activity in the western Pacific Ocean takes place (see Escalle *et al.*, 2019). Provision of FAD track information to science bodies require a certain capacity by the science body to receive and assimilate large amounts of data. Thus, in cases where the

RFMO Secretariat or Science Provider are not ready to receive such data, arrangements can be made with other scientific institutions such as national research institutes.

Raw acoustic data from echo-sounder buoys

Most buoys used by many fleets to track FADs are equipped with echo-sounders that estimate the biomass of fish aggregated under a FAD and transmit this information to the vessel and ship-owners via satellite. Skippers use this information remotely to help inform their fishing strategy, e.g. what area to visit and what FADs to set on. But this information can also be very valuable to address several scientific questions as well as to construct indices of tuna abundance which are used in stock assessments. For the latter, typically, the acoustic signal at specific depth ranges, time of the day and period of the FAD drift are required (Santiago *et al.*, 2019). Recent research on tuna species acoustic discrimination would allow in the near future obtaining indices of abundance by tuna species, as well as improving current biomass estimates provided by the echo-sounder buoys (Moreno *et al.*, 2019). This information can be reported directly by the satellite provider to the tunaRFMO Secretariat, tunaRFMO science providers or any science institution in charge of monitoring the fisheries, with consent from the buoy owner. In the case of the tunaRFMO Secretariat, they must be able to assimilate large volumes of data. Alternatively, arrangements can be made with other science institutions where necessary.

Recommended best practices for voluntary report of additional FAD buoy data for use by RFMO science bodies:

- **Buoy positional and acoustic raw data**: Participate in scientific programs that require the recovery of historical data and use of FAD position data and acoustic records from the echo-sounder buoys (with a time lag, as needed for time-sensitive confidentiality) either at the RFMO level or with specialized research institutions. The recovery of historical information should receive high priority. Ideally, information on position and acoustic record for the whole track should be provided; alternatively, one position and echosounder record per day as a minimum.

2.3. Support science-based limits on the overall number of FADs used per vessel and/or FAD sets made

The four tRFMOs have adopted limits to the number of active or operational instrumented FADs at sea, at any one time, allowed per vessel. Currently these are 70-450 in IATTC (depending on vessel size), 500 in ICCAT, and 350 in WCPFC and 300 in IOTC. There was no scientific basis for any of these limits and it is believed that they would result in a reduction in the number of FADs per vessel only in some fleets. For example, Escalle *et al.* (2019) estimated that few or no vessels operated as many as 350 FADs in the WCPO. And, if all large scale purse seine vessels fishing for tropical tunas in the world (~686 according to Justel-Rubio and Recio, 2019) used 350 FADs each, the number of FADs in the oceans would be about twice as many as the most recent estimation (80,000 to 121,000 FADs) by Scott and Lopez (2014) and Gershman *et al.* (2015). Clearly, the current FAD number limits are not very limiting to most fleets depending on the region (e.g. they could be limiting in the Indian Ocean and not in the Atlantic or Pacific Ocean). Only one tRFMO (IOTC) has adopted a limit on the number of FADs that can be acquired annually and have in stock at any time, for each purse seine vessel operating in its region, this limit is set at no more than 500 FADs purchased per year and having in stock at any time.

The following practices may reduce the number of FADs:

- **Limit number of active FADs/buoys**: Set company limits of number of FADs per vessel that are lower than those adopted by the RFMO. This could be done, for example, by using the same number of FADs used at some previous time (eg. average of last 5 years).
- **Limit the purchase of buoys or buoys in stock**: reducing not only the number of FADs that are active at sea but the number of purchases or number of buoys in stock would allow reducing the number of FADs that are at sea.
- **Manage active and inactive FADs**: The RFMO FAD limits are based on "active" buoys, i.e. buoys that are making satellite transmissions. When a FAD drifts out of the fishing zone or connection is lost, the owner can deactivate that buoy and deploy a new FAD with another buoy. Thus, the number of FADs in the water could be greater than the limit. Fishing companies could maintain buoys active to allow buoys to report at least once per day while they are in the water.
- **Promote FAD marking schemes and FAD ownership rules**. Many of the FADs deployed by one vessel are found opportunistically or by active search by other vessels that appropriate them by attaching their own buoy and bringing the retrieved buoy to the port for reutilization. In some cases, the majority of sets are made on other vessels' FADs (Lennert-Coddy *et al.*, 2018; Snouck-Hurgronje *et al.*, 2018). Companies should work collectively to develop FAD marking schemes and adoption rules of FAD ownership which will allow to foster strategies that will rely less on appropriated FADs.
- **Reduce lost or abandonment of FADs.** Promoting good practices that reduce and manage the abandonment and loss of FADs, including their retrieval, would reduce the number of FADs at sea. This could be done following a code of good practices and also working in cooperation with other vessels and stakeholder to reduce loss and retrieve FADs. Only IATTC has currently a measure to retrieve FADs that have been fished 15 days before the time-area closure takes place.

In terms of FAD sets, RFMOs have used either direct or indirect limits with varying degrees of effectiveness. The WCPFC has a 3 and 5 months (in the Convention Area and in the high seas, respectively) prohibition on deploying and setting on FADs. IATTC has a 72-day closure for all large-scale purse seine vessels (all set types). ICCAT has a 2-month FAD moratorium in the Gulf of Guinea. These measures appear to be effective in the Pacific Ocean in terms of reducing the impact of FAD fishing on small bigeye catches from what it would be otherwise. In the Atlantic, the FAD moratorium appears to be ineffective because it covers a relatively small area/time.

In terms of FAD sets, companies could voluntarily:

- **Promote effective closed time/areas in the RFMOs**. Especially in the Atlantic and Indian Oceans, companies could support the adoption of meaningful FAD closures that will mitigate impacts of FAD fishing on target tuna stocks. By 'meaningful' it is understood that the FAD closures should be large enough and long enough to be effective.

In addition, the provision of required and voluntary FAD data (sections 2.1 and 2.2) will ultimately enable scientists to correctly assess fishing effort, fishery-independent tuna abundance and impacts on marine ecosystems, and make management recommendations for science-based limits.

Recommended best practices for science-based limits on the overall number of FADs and/or FAD sets made:

- **Limit number of FADs**: Commit to not increase the number of FADs per vessel even if the RFMO would allow for an increase. Commit to other practices that limit the number of FADs such as:
  - ⇒ Deploying only FADs with satellite tracking buoys,
  - ⇒ Not activating remotely the buoys of dormant FADs, and
  - ⇒ Allowing buoys to report at least once per day while they are in the water.
- **Time/area closures**: Support the adoption of meaningful FAD closures that will mitigate impacts of FAD fishing on target tuna stocks. From a point of view of monitoring and compliance, a complete closure would be preferred.

2.4. Use only non-entangling FADs to reduce ghost fishing

Ghost fishing is an impact caused by FADs that have received considerable attention in recent years.

Ghost fishing due to entanglement in FADs

A study in the Indian Ocean (Filmalter *et al.*, 2013) showed that, in the early 2010s, the magnitude of sharks that died entangled in the FAD structure, i.e. from ghost fishing by FADs, was much higher than the number of sharks that were actively caught by the purse seine net. Observers reports also showed that turtles can get entangled on the raft and sub-surface structure of FADs that have netting. Since then, ISSF, other NGOs, CPCs and several fishing associations have advocated for the adoption of non-entangling FAD requirements by the tuna RFMOs. Today, all tropical tuna RFMOs have adopted some type of non-entanglement requirement that is consistent with the guidelines published by ISSF (ISSF, 2019) and fleets have progressed on the use of non-entangling FADs (Murua *et al.*, 2016). However, the time by which a full transition has to be made from traditional to non-entangling FADs is not clear in some RFMOs.

Non-entangling FADs have the following characteristics:

- **Raft**: The surface structure should not be covered with any netting or meshed materials. Covering the raft with netting and putting cloth or tarpaulin on top is not a lasting solution because, when those fabrics degrade, the underlying netting becomes exposed.
- **Tail**: Only FADs constructed without netting can completely eliminate the unintentional entanglement of turtles, sharks and finfish species and be considered totally non-entangling FAD.

If a net with large mesh size is used as submerged tail of the FAD, it should be tightly tied into bundles (sausages). And If an open panel netting is used, only small mesh size (e.g. < 2.5 inch (7 cm) stretched mesh) should be used and the panel must be weighted to keep it taut. The solutions above using netting material make the FAD with low entanglement risk but must be seen as transitional towards the elimination of any netting material in the construction of FADs. The construction of FADs in land-based facilities is preferred as it will allow for greater quality control.

Recommended best practices for using non-entangling FADs:

- **Non-entangling FADs**: Commit to using non-entangling FADs (without any netting) only. Commit to removing entangling FADs that are found in the water.

2.5. Mitigate other environmental impacts due to FAD loss including through the use of biodegradable FADs and FAD recovery policies

Marine debris produced by FADs and impacts on sensitive areas due to stranded FADs are two impacts caused by FADs that are receiving considerable attention in recent years.

Marine debris due to FAD degradation

Petroleum-derived plastic products such as PVC and nylon nets are commonly used to construct FADs. Eventually, petroleum-derived materials break up and end up contributing to ocean pollution as macro- and micro-plastics. ISSF is working on several projects to find new materials of natural origin for FAD construction to reduce the marine debris production (Moreno *et al.*, 2018a; Zudaire *et al.*, 2019).

Biodegradable FADs have the following characteristics:

- **Raft:** Rafts should be constructed using bamboo, balsa wood or other natural materials that degrade without producing pollution on the marine environment. For FAD flotation, the use of plastic buoys and containers should be reduced as much as possible (e.g., reducing the weight and volume of the FAD structure would require less flotation).
- **Tail:** Only natural and/or biodegradable materials (cotton ropes and canvas, manila hemp, sisal, coconut fiber, etc.) should be used, so that they degrade without causing impact on the ecosystem.

Some fleets are testing biodegradable FADs on their own by deploying a limited number of FADs. It is difficult to learn from those small-scale trials because most of them end up lost or appropriated by other fleets. Companies should participate in coordinated research projects that would allow tracking the lifetime of FADs and catches around those FADs, for example by joining larger coordinated experiments (e.g. Moreno *et al.*, 2017, 2018a; Zudaire *et al.*, 2019).

Impacts on sensitive areas due to beaching

FADs are deployed in specific areas according to each skipper's fishing strategy, which includes an understanding of how FADs will drift towards productive fishing zones. However, oceanic currents are difficult to predict and therefore the resulting FAD trajectories are not always well controlled. As a result, FADs can drift away from the fishing zone and end up being lost or abandoned by the vessel. In many cases, FADs end up beaching in vulnerable areas such as coral reefs (recent studies estimated that 7% in West Pacific, 10% in the Indian/Atlantic Ocean, and 2 % in a limited area of Seychelles of the deployed FADs ended up stranded -Maufroy *et al.*, 2015; Escalle *et al.*, 2019; Zudaire *et al.*, 2018). In addition, FAD structures have evolved towards more complex and deeper structures 60-80 meters deep. Naturally, the impacts of these deep FADs are greater compared to those 5-20 meters deep used in the past (Moreno *et al.*, 2018b).

Discussions at a recent international workshop (Restrepo *et al.*, 2019) indicated that there is no unique solution to reduce the impacts of FAD material and structure on marine ecosystems. A combination of solutions adapted to each ocean and region may be necessary (e.g. reducing the length of the submerged part of FAD may be suitable in the EPO but not in the AO).

The following are practices that can mitigate the impact of FAD loss on the environment:

- **Reduce the number of FADs**: Limiting the number of FADs (see section 2.3) will also mitigate impacts from beaching or sinking.

- **Simplify FAD structure**: Deep FAD structures may not be necessary in every area/season. Fleets should investigate using shallower, simpler FADs.
- **Provide FAD track data**: Data on the position of FADs should be accessible to scientists or RFMOs in order to quantify their impacts on coastal environments, to develop models of risk seeding areas, and to measure the efficiency of the initiatives taken to mitigate the loss and abandonment of FADs. If the fishing company decides to deactivate FADs when they drift out of the fishing zone, these buoys can still communicate position to buoy providers, which can report these data in a cost-effective manner, e.g. by providing less detailed and frequent data such as one position for every x days.
- **Recover FADs from the water**: Fleets could adopt a policy to recover a percentage of the FADs that are deployed before they are lost or drift out of the fishing zone. Initiatives could include (i) removing from the water every FAD encountered that is an entangling FAD or (ii) removing a given number of FADs towards the end of a trip or the end of the fishing season. Provision of positional satellite buoy data on beached FADs would facilitate recovery.
- **Recover stranded FADs from vulnerable habitats**: Various NGOs undertake activities to clean up beaches or protect reefs. Fishing companies should explore collaborating with such NGOs in order to alert them of FADs that are drifting in the direction of the area where they work.
- **Avoid high-risk deployment areas**: If there are known deployment areas that are identified having a high risk that the FADs will end up beaching, these should be avoided.

Recommended best practices for mitigating environmental impacts due to FAD loss including through the use of biodegradable FADs and FAD recovery policies:

- **Biodegradable FADs**: Test biodegradable FADs, using local materials if possible. Participation in research collaborative projects to test biodegradable FADs is encouraged.
- **Limit number of FADs**: Commit to not increase the number of FADs per vessel even if the RFMO would allow for an increase. Commit to other practices that limit the number of FADs such as:
  - ⇒ Deploying only FADs with satellite tracking buoys,
  - ⇒ Not activating remotely the buoys of dormant FADs, and
  - ⇒ Allowing buoys to report at least once per day while they are in the water.
- **FAD construction and deployment:** Test whether simpler, smaller FADs effectively aggregate tunas and use them if so. Participate in research programs to determine deployment areas that are highly likely to result in stranding.
- **FAD abandonment and loss**: Promote good practices to reduce the loss and abandonment of FADs, such as:
  - ⇒ Increase storing capacity onboard purse seiners for FADs that are retrieved,
  - ⇒ Develop a program to remove a percentage of FADs from the water, relative to the number deployed,
  - ⇒ Provide FAD track data to identify areas of high incidence of stranding events and positional data on beached FADs to enable targeted recovery, and
  - ⇒ Participate in cooperative efforts to remove stranded FADs.

2.6. For silky sharks (the main bycatch issue in FAD sets), implement further mitigation efforts

Pelagic sharks are not targeted by tropical tuna purse seine fisheries, but they are caught incidentally, especially around floating objects like FADs. Over 90% of the shark bycatch is composed of silky sharks, *Carcharhinus falciformis*. Because of their low reproductive rates and other life history characteristics, silky sharks are a vulnerable species. Other gear types such as longlines or gillnets have a larger impact on silky sharks than purse seine fisheries do. The contribution of purse seining to the total catch of this species varies by Ocean: from 4% in the Indian and eastern Pacific Oceans, to about 25% in the western and Central Pacific Ocean. Nevertheless, the global magnitude of catch of the purse seine fishery is quite large, so reducing the mortality caused by these fisheries can contribute towards global conservation efforts of silky shark. Restrepo *et al.* (2016) have identified this as the main bycatch issue in tropical tuna purse seine fisheries.

Restrepo *et al.* (2016) have identified actions that can reduce shark mortality in purse seine fisheries:

- **Non-entangling FADs**: Use non-entangling FADs only (see section 2.4)
- **Switch some effort to free school**: In areas where shark bycatch is higher on FAD sets, switching some effort to free swimming school sets would reduce shark mortality.
- **Avoid setting on small tuna aggregations**: Because the number of sharks around FADs is independent of the size of the tuna aggregations, targeting larger tuna aggregations will result in a lower shark:tuna catch ratio (Dagorn *et al.*, 2012).
- **Release from the net**: ISSF research cruises have shown that small sharks, the most common sizes found at FADs, can easily be caught by handline during FAD sets and released out of the net. This procedure requires good weather, training for safety and large commitment from the fishermen; but can save 15-35% of the encircled sharks.
- **Release from the deck**: Using safe handling and release practices to release live sharks from the deck can increase shark survival (ISSF, 2016). Crew safety is of utmost importance, especially with larger sharks. Using a hopper will facilitate life release. This practice can save up to 20% of encircled sharks.
- **Avoid shark hotspots**: commit to avoid areas/periods of high concentration of sharks.

Recommended best practices mitigating bycatch of silky sharks:

- **Adopt best practices to reduce shark bycatch and increase survival**: Commit to using non-entangling FADs only. Adopt a combination of practices that can reduce mortality and increase shark survival amongst the following:
  - ⇒ Making fewer FAD sets,
  - ⇒ Avoiding small sets (e.g. under 10 tons),
  - ⇒ Releasing sharks from the net, when safe and practical, and
  - ⇒ Practicing live and safe release of sharks (and rays) from the deck.

3. CONCLUDING REMARKS

The recommended best practices are intended to be comprehensive, although it is understood that not all of them will be practical for every purse seine fleet to implement. In some cases, the practices are already mandated by RFMOs (e.g. non-entangling FADs) and the aim here is to ensure that fleets implement them correctly. However, while other recommended best practices are not yet required by tRFMOs, voluntary implementation by fleets, including through fishery improvement projects (FIPs), will have positive impacts on reducing pollution in the marine ecosystem, supporting efforts to rebuild overfish stocks, strengthening monitoring and stock assessment and reducing impacts on habitats and sensitive non-target species.

Some of these practices can help mitigate several impacts at once. For instance, limiting the number of FADs can be beneficial for overfished stocks and also mitigate impacts on habitats and on vulnerable bycatch species like sharks. Also, some practices can help mitigate a given type of impact across all set types (e.g., following best practices for safe live release of sharks and rays).

It should also be noted some of the practices would be most impactful if they are implemented collectively by most or all fleets in a region. An example, again, is limiting the number of FADs. In the context of MSC certification, fishing companies should be mindful that some elements of the MSC standards (version 2.0) require the consideration of the cumulative impacts of all overlapping fisheries that are certified. This is the case for PIs 2.1.1 on Primary Species, 2.2.1 on Secondary Species, 2.3.1 on Endangered, Threatened or Protected Species, and 2.4.2 on Habitats. Therefore, fisheries should have a better basis to be certified if best practices for FAD management are implemented collectively.

4. ACKNOWLEDGMENTS

We are grateful to Alexandre Aires-da-Silva, Laurent Dagorn, John Hampton, Susan Jackson, Josu Santiago, Jerry Scott and Meryl Williams, who provided useful comments on an earlier draft of this document.

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