Food and Agriculture Organization of the United Nations

Indian Ocean Tuna Commission
Commission des Thons de l'Ocean Indien
iotc ctoi

[IOTC-2026- WPTT28-24]

TOWARDS THE DEVELOPMENT OF FAD MARKING GUIDELINES IN THE IOTC

Maitane Grande[1], Gala Moreno[2], Mª Lourdes Ramos[3], David M. Kaplan[4], Arnaitz Mugerza[5], Jefferson Murua[5], Hilario Murua[2], Santiago Déniz[3], Taha Imzilen, Esther Mollier[3], José Carlos Báez[3], Iker Zudaire[1]

Discussions (for information and open discussion):

This paper is submitted in response to the requirements established under Resolution 24/02 and the mandate given to the WGFAD to develop DFAD marking guidelines. It reviews existing FAD marking approaches and experiences and aims to facilitate discussion on the development of IOTC FAD marking guidelines and the establishment of a roadmap for their adoption.

Feedback (to collect input and suggestions)

The paper seeks feedback from WPTT28 participants, based on at-sea operational experience and the best available technical and scientific knowledge, on proposed DFAD marking approaches and on the roadmap for the development and adoption of IOTC FAD marking guidelines.

Recommendation (to ask the meeting to endorse a recommendation)

The paper seeks to endorse a recommendation on the road map for the development, consultation, and adoption of IOTC FAD marking guidelines

[1] AZTI, AZTI, Marine Research, Basque Research and Technology Alliance (BRTA). Herrera Kaia, Portualdea z/g, 20110 Pasaia - Gipuzkoa, Spain
[2] International Seafood Sustainability Foundation, Pittsburgh, PA, 15201, United States
[3] Centro Oceanográfico de Canarias (COC-IEO), Instituto Español de Oceanografía (IEO-CSIC), Consejo Superior de Investigaciones Científicas (CSIC), C. Farola del Mar s/n, 38180 Santa Cruz de Tenerife, Spain.
[4] Institut de Recherche pour le Developpement (IRD), UMR MARBEC (Univ Montpellier, IRD, Ifremer, CNRS) 87 av. Jean Monnet, CS 30171, 34203 Sète cédex France
[5] AZTI, Marine Research, Basque Research and Technology Alliance (BRTA). Txatxarramendi ugartea z/g, 48395 Sukarrieta - Bizkaia, Spain

Abstract

In the IOTC area of competence, purse seine fisheries account for approximately 43% of the tropical tuna catch, with most catches taken in association with drifting Fish Aggregating Devices (DFADs). DFADs are deployed by purse seine vessels and associated supply vessels to aggregate tropical tuna species beneath them and are monitored using instrumented buoys equipped with GPS technology, enabling vessels to track their position remotely. However, a significant proportion of DFADs are lost or abandoned during their lifespan.

Resolution 24/02 on Management of DFADs in the IOTC area of competence, defines a Fish Aggregating Device (FAD) as a "*permanent, semi-permanent or temporary object, structure or device of any material, man-made or natural, which is deployed and/or tracked and may aggregate fish*". A DFAD is defined as a "*FAD not tethered to the bottom of the ocean, deployed and tracked for the purpose of aggregating fish*".

Resolution 24/02 requires that, from the 1st of January 2026, CPCs ensure that vessels deploy only DFADs that are permanently marked with an IOTC DFAD unique identifier, which shall be separate physically from the instrumented buoy. It also requests that the standards for individual DFAD marking are to be developed by the IOTC Scientific Committee, following preparatory work by the WGFAD and in close collaboration with the IOTC Secretariat.

The WGFAD should therefore prioritize the development of DFAD marking guidelines, as requested under Resolution 24/02, drawing on operational experience at sea and lessons learned from previous research initiatives. This process should align with, and build upon, ongoing work undertaken by other tuna Regional Fisheries Management Organizations (RFMOs) and expert groups, including the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB). This document aims to review existing DFAD marking guidelines and related practices worldwide, summarize the outcomes of previous DFAD marking initiatives (e.g. BIOFAD projects), assess DFAD characteristics and associated operational challenges in the IOTC area that will need to take into account during DFAD marking, identify potential DFAD marking options and their limitations, and promote discussion on the development and adoption of IOTC DFAD marking guidelines. The adoption of a similar approach for Anchored FADs (AFADs) is also proposed.

Towards the Development of FAD Marking Guidelines in the IOTC

Maitane Grande[6], Gala Moreno[7], Mª Lourdes Ramos[8], David M. Kaplan[9], Arnaitz Mugerza[5], Jefferson Murua[10], Hilario Murua[2], Santiago Déniz[3], Taha Imzilen, Esther Mollier[3], José Carlos Báez[3], Iker Zudaire[1]

In the IOTC area of competence, purse seine fisheries account for approximately 43% of the tropical tuna catch, with most catches taken in association with drifting Fish Aggregating Devices (DFADs). DFADs are deployed by purse seine vessels and associated supply vessels to aggregate tropical tuna species beneath them and are monitored using instrumented buoys equipped with GPS technology, enabling vessels to track their position remotely. However, a significant proportion of DFADs are lost or abandoned during their lifespan.

Resolution 24/02 on Management of DFADs in the IOTC area of competence, defines a Fish Aggregating Device (FAD) as a "*permanent, semi-permanent or temporary object, structure or device of any material, man-made or natural, which is deployed and/or tracked and may aggregate fish"*. A DFAD is defined as a "*FAD not tethered to the bottom of the ocean, deployed and tracked for the purpose of aggregating fish"*.

Resolution 24/02 requires that, from the 1st of January 2026, CPCs ensure that vessels deploy only DFADs that are permanently marked with an IOTC DFAD unique identifier, which shall be separate physically from the instrumented buoy. It also requests that the standards for individual DFAD marking are to be developed by the IOTC Scientific Committee, following preparatory work by the WGFAD and in close collaboration with the IOTC Secretariat.

The WGFAD should therefore prioritize the development of DFAD marking guidelines, as requested under Resolution 24/02, drawing on operational experience at sea and lessons learned from previous research initiatives. This process should align with, and build upon, ongoing work undertaken by other tuna Regional Fisheries Management Organizations (RFMOs) and expert groups, including the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB). This document aims to review existing DFAD marking guidelines and related practices worldwide, summarize the outcomes of previous DFAD marking initiatives (e.g. BIOFAD projects), assess DFAD characteristics and associated operational challenges in the IOTC area that will need to take into account during DFAD marking, identify potential DFAD marking options and their limitations, and promote discussion on the development and adoption of IOTC DFAD marking guidelines. The adoption of a similar approach for Anchored FADs (AFADs) is also proposed.

[6] AZTI, AZTI, Marine Research, Basque Research and Technology Alliance (BRTA). Herrera Kaia, Portualdea z/g, 20110 Pasaia - Gipuzkoa, Spain
[7] International Seafood Sustainability Foundation, Pittsburgh, PA, 15201, United States
[8] Centro Oceanográfico de Canarias (COC-IEO), Instituto Español de Oceanografía (IEO-CSIC), Consejo Superior de Investigaciones Científicas (CSIC), C. Farola del Mar s/n, 38180 Santa Cruz de Tenerife, Spain.
[9] Institut de Recherche pour le Developpement (IRD), UMR MARBEC (Univ Montpellier, IRD, Ifremer, CNRS) 87 av. Jean Monnet, CS 30171, 34203 Sète cédex France
[10] AZTI, Marine Research, Basque Research and Technology Alliance (BRTA). Txatxarramendi ugartea z/g, 48395 Sukarrieta - Bizkaia, Spain

1. Introduction

Tropical tuna worldwide catch trends show a continuous increase in global tropical tuna harvests, with a peak of around 5.5 million tonnes in 2024 (ISSF, 2026). The Indian Ocean ranks as the second largest contributor after the western Pacific, accounting for 17% of the total catch (IOTC, 2026). The Indian Ocean tropical tuna annual catch is close to 1.2 million tonnes, and the contribution of industrial and coastal fisheries has averaged approximately 58% and 42% of total tropical tuna catches, respectively (IOTC, 2026). The purse seine fishery is the dominant fishing gear contributing approximately 43% of the total catch, mainly coming from sets on DFADs. The natural aggregative behaviour of tuna around DFADs, combined with the development of echosounder buoy technology for their remote monitoring, has increased fishing efficiency, making DFAD-associated fishing the predominant tuna fishing mode in the Indian Ocean and worldwide. DFADs are deployed at sea by the purse seiner or auxiliary vessels and are typically equipped with geo-location echosounder buoys that provide their position continuously and an estimate of the biomass aggregated beneath them in real time. Fishers track DFAD position and biomass underneath while the device is inside the fishing area. When DFADs drift outside the fishing grounds, fishers commonly deactivate the geolocating buoy, resulting in the loss of DFAD tracking. This practice is common, as it allows the vessel to activate new buoys within fishing areas maintaining the number of active operational DFADs within the limits established by tuna RFMOs while also reducing telecommunication costs associated with tracking out of bound DFADs (Moreno et al. 2023a). As a result, a significant percentage of DFADs end up lost, abandoned, or discarded contributing to marine plastic pollution (Phillips et al., 2025). In the Indian and Atlantic Oceans, Imzilen et al. (2022) estimated that around 15-20% of DFADs deployed by the French fleet eventually become stranded and that more than 40% drift out of the fishing grounds becoming abandoned lost or discarded. In this scenario, tuna RFMOs and other stakeholders are evaluating tools to improve both DFAD tracking, to maintain information on their location and movements, and DFAD marking, to enable identification, traceability and recovery of DFAD structures when they are lost or abandoned, ultimately supporting efforts to mitigate their associated negative environmental impacts.

To reduce the impact of DFAD structures in the marine ecosystems, the IOTC has limited the number of daily operational buoys by vessel from 550 in 2015 to 250 (with higher limits of 270 or 280 for exceptional circumstances) from the 1st of January 2026 and 225 from the 1st of January 2028 (with higher limits of 240 or 255 for exceptional circumstances). The IOTC also adopted the use of non-entangling DFADs in 2020, and established a stepwise transition towards biodegradable DFADs, which will culminate in the exclusive use of fully biodegradable DFADs (category I) from the 1st of January 2029. In addition, to improve the traceability of the DFADs and associated buoys, the IOTC developed a DFAD Register, which became effective on the 1st of January 2026. As established in Resolution 24/02, the IOTC unique DFAD identifier must be recorded in the DFAD Register together with the information associated with the deployment of the instrumented buoy.

From the 1st of January 2026, and with the specific objective of to collect information on how to mitigate DFAD loss and abandonment, CPCs shall ensure that their vessels deploy only DFADs that are permanently marked with a specific IOTC DFAD unique identifier, in addition to the marking of the instrumented buoy referred to in paragraph 39 (Res 24-02). The IOTC Secretariat shall assign the DFAD unique identifier to the CPC, which shall communicate it to the master of the vessel. The DFAD marking shall be separate from the instrumented buoy. This requirement shall apply until the Commission endorses a marking scheme that operationalises the FAO Voluntary Guidelines on the Marking of Fishing Gear (VGMFG), in accordance with the proposed terms of reference for developing such a scheme. The standards for the individual marking of DFADs to be developed by the IOTC Scientific Committee, following preparatory work by the WGFAD, was planned at the latest for its 2025 session, and in close collaboration with the IOTC Secretariat (Res 24-02, p. 40).

Therefore, this document aims to review the available fishing gear and DFAD marking guidelines and promote discussion on the establishment of FAD marking guidelines for the IOTC.

2. Fishing Gear and FADs Marking guidelines

The marking of fishing gear is a management and control measure that facilitates the identification and traceability of fishing gear and, in cases where gear is abandoned, lost or otherwise discarded (ALDFG), can supports its identification, attribution and recovery. The need for a uniform marking scheme across management boundaries and on the high seas resulted in the 1967 Convention on the Conduct of Fishing Operations in the North Atlantic. This convention has acted as the basis for several pieces of fishing gear marking legislation, as well as recommendations for many nations and regions; it is also recommended by FAO in its document *Fishing Operations, Technical Guidelines for Responsible Fisheries, 1* (FAO, 1996).

In addition, Annex V of the International Convention for the Prevention of Pollution from Ships (MARPOL) (IMO, 1973) deals with the prevention of pollution by garbage from ships. As specified in MARPOL "F*ishing gear that is released into the water with the intention of later retrieval, such as DFADs, traps and static nets, should not be considered garbage or accidental loss"* in the context of MARPOL Annex V. The MARPOL Annex V Guidelines call for governments "t*o develop communication frameworks to enable the recording and sharing of information on fishing gear loss where necessary in order to reduce loss and facilitate recovery of fishing gear"* and "*fishing industry, relevant international organizations and Governments are encouraged to undertake such research, technology development, information sharing and management measures as may be needed to minimize the probability of loss, and maximize the probability of retrieval of fishing gear from the sea"* These guidelines make specific reference to FADs[11].

The next question is how should fishing gears and FADs be marked? The issue of gear marking has been discussed within FAO since 1989 and was reinforced by the *Code of Conduct for Responsible Fisheries* (1995), which calls for fishing gear to be appropriately marked to identify its owner and to promote internationally recognizable marking systems. As such FAO has worked in developing international guidance on fishing gear marking, including the FAO Voluntary Guidelines on the Marking of Fishing Gear (VGMFG). FAO does not consider FADs to be strictly fishing gears, but a device that may increase fishing efficiency for the main gear they are associated with (Einarsson et al., 2023). However, due to their importance, they have included, both DFADs and AFADs, on the FAO Voluntary Guidelines on the Marking of Fishing Gears. This guideline stipulates that gear and FAD marking systems should facilitate the reporting of gears and FADs lost or abandoned; reporting of fishing gear or FAD found; recovery of ALDFG; and where possible the safe and environmentally sound disposal of end-of-life of the device. The guidelines provide practical guidance on how to mark the most common fishing gears and FADs, drawing on currently available marking techniques and approaches to identify ownership and ascertain the legality of gear or FAD (Einarsson et al., 2023). Regarding to FAO guidelines, the marking of fishing gears and FADs should provide a simple, pragmatic, affordable and verifiable means of identifying the ownership of the fishing device and its link with the vessel(s) and/or operators undertaking the fishing operations. As such, for a ''mark'' refers to "*an identifier that allows the identification of the person/owner or entity responsible for the fishing gear or device. The marks may take the form of tags, labels, printing or inscriptions, or they may be attached to a component of the fishing gear*" or the FAD.

All types of marking should use readable alphanumeric code and provide anyone who recovers or finds the mark with basic information relative to the operator or responsible entity, without the need for special tools or instruments. The guidelines include options ranging from straightforward methods, such as printing on floats or using plastic tags (or tags made of other materials) attached to floats or other parts of the gear, compared

[11] https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/MEPC.295(71).pdf

to other alternatives requiring technological devices, such as radio-frequency identification systems or acoustic transponders (Einarsson et al., 2023). A summary of the alternatives described in FAO guidelines is provided in Table 1, which was also reviewed by Inter-American Tropical Tuna Commission (IATTC) staff (Lopez et al., 2026).

Table 1. Summary of fishing gear and FAD marking options provided by FAO guidelines (Einarsson et al., 2023).

Marking method	Description	Advantages	Disadvantages
Printing & inscription (paint)	To write or print required marking information on a suitable surface of some fishing gear components such as floats.	• Low cost • No reader required • Easy to implement globally • Easily visible and understandable	• Information may fade due to UV exposure and abrasion • Tags can detach or break • Requires periodic maintenance
Welding	Metal plate with pre-cut letters and/or numbers, or welding letters and/or numbers directly onto metal gear parts	• Highly durable and permanent • Difficult to remove or alter • Effective anti-theft measure • Likely lasts the lifetime of the gear	• Restricted to metal components • Requires welding equipment and skills • Limited marking space for small components
Stamped / engraved	Metal stamping for marking metal components of fishing gear with the desired information.	• Robust and long-lasting • Relatively inexpensive • Easy to implement • No electronic reader required • Can be applied to various materials	• May become unreadable if not deeply engraved • Components may break or become detached
Colour coding	Colour code to distinguish between gear categories.	• Inexpensive and straightforward • Easy visual identification • Useful for identifying fisheries, regions or manufacturers • Helps gear recognition and theft prevention	• Colours fade over time • Can be copied by other manufacturers • Not suitable for unique individual identification • Requires standardized colour registry
Knots or marked ropes	Marking system applied in small scale fisheries based in application of special knots or use marked rope at a specific place on the gear.	• Very low cost • No additional materials required • Durable if incorporated into the gear • Simple to implement	• Requires prior knowledge of the coding system • Difficult for inspectors to interpret • Not suitable for large fleets or unique identification
Internal tracer threads	Narrow marker tapes that hold repeated printed information which are integrated into braided and twisted ropes.	• Protected from wear and UV exposure • Likely lasts gear lifetime • Information remains readable over long periods	• Not externally visible • Requires gear inspection to locate • Difficult to provide

		• Cannot easily be removed	unique identifiers for each owner
Barcode / QR code	In place of writing or printing an alphabetic text or numbers, it is possible to use a barcode or QR code (Figure 16), which can be read by a smartphone and can hold much more information than that printed in a small area.	• Large information capacity • Low cost • Can link to online databases • Easily generated and printed • Smartphone readable	• Requires electronic device for reading • Damaged codes may become unreadable • Labels may deteriorate in harsh marine environments
RFID tags	Compact electronic identifiers that can store customizable information, with reading ranges varying from direct contact to over 100 m depending on the technology used.	• High data storage capacity • Small and versatile • Can be embedded inside components • Rapid electronic identification • Potential integration with monitoring systems	• Requires dedicated readers and database systems • Waterproof protection needed • Higher cost than visual markings • Specialized infrastructure required
Acoustic transponders	Enable underwater identification and tracking of fishing gear through acoustic signals, complementing surface marking systems and offering potential integration with RFID technologies.	• Enables underwater identification • Facilitates recovery of lost gear • Can provide location information • Useful for submerged structures	• High cost • Requires hydrophones and specialized equipment • Technology still developing • Not practical for all fisheries

As refers to FAO guidelines, all gears or FADs and electronic marking devices attached should be marked clearly with readable letters or codes that are traceable to their origin or owners. Some components of a fishing devices have a higher risk of loss. So, it is important to mark or attach tags in such a way that others may be able to find the marking or tags quickly, especially in large-scale fishing gears. It is therefore essential to consider where each gear or FAD should be marked or tagged so that lost gear components may be traced to the origin. The suggested locations for marking different fishing gear types will help achieve this objective.

In case of DFADs, most are composed of a surface/sub-surface structure (i.e., raft) and a submerged structure (i.e., appendage, tail). They are deployed with an echosounder buoy equipped with a GPS positioning system, allowing users to track the DFAD in real time for as long as the buoy continues active, transmitting its position. The buoy was considered a marking option in the initial guidelines proposed by FAO (FAO, 2019): "*The structure of a FAD, or the electronic buoy attached to it, should contain a physical unique identification mark*". However, because buoys can be disconnected or become detached from DFADs, the revised FAO recommendation is to mark the DFAD structure itself clearly to identify the owner or vessel responsible for its initial deployment (Einarsson et al., 2023). The four marking positions recommended by FAO for a single structure are:

- on the buoy attached to the DFAD;
- on the raft of the DFAD;
- near the highest part of the DFAD; and
- near the deepest part of the DFAD.

3. Tuna RFMO requirements

Regarding tuna RFMO requirements, they do differ in their implementation of marking guidelines. ICCAT incorporates DFAD marking provisions within its DFAD management framework and has adopted broader requirements on fishing gear marking (not DFADs in this context) through Recommendation 03-12, consistent with the FAO Voluntary Guidelines on the Marking of Fishing Gear (VGMFG). However, ICCAT DFAD marking is operationalized using the instrumented buoys attached to DFADs. Therefore, ICCAT currently does not require a marking system for the DFAD structure itself, nor is there a marking system independent of the satellite buoy used by fishers to track the DFAD (Fig 1).

The IATTC requires DFADs to be identified so that any interaction with a DFAD can be recorded using its unique DFAD ID. Under the IATTC guidelines, CPCs may obtain unique alphanumeric codes from the IATTC staff and distribute them to vessels for DFADs that may be deployed or modified. Alternatively, when a unique identifier is already associated with the DFAD, such as the manufacturer's identification code of the attached buoy, this identifier may be used as the unique DFAD code. In practice, the buoy ID is commonly used for this purpose (Fig 1).

The guidelines also specify how the identifier should be displayed. "*The alphanumeric code must be clearly painted in characters at least 5 cm high on the upper portion of the attached radio or satellite buoy, without covering its solar cells. For FADs without an attached radio or satellite buoy, the identifier must instead be painted on the uppermost or emergent portion of the FAD. The marking must be durable and visible during daylight.*"

In summary, while DFADs must be uniquely identified, this does not imply a marking system independent of the tracking buoy or a requirement to mark different parts of the DFAD structure.

IATTC staff recently reviewed the pros and cons of alternative marking system in the eastern Pacific DFAD use and monitoring scenario. The work concluded that the current buoy-based system is robust and operationally well-established, supported by total observer coverage in class 6 vessels and buoy derived data reporting system (Lopez et al., 2026). Therefore, the IATTC staff does not recommend a specific marking method at this stage, other than the current buoy-based identification/marking system. However, the IATTC FAD working group recommended first clarifying the objectives and scientific requirements for FAD marking, exchanging knowledge with the ICES-FAO Working group on Fishing Technology and Fish Behaviour (WGFTFB) Topic Group on fishing gear marking, and exploring a pilot physical marking system for different categories of biodegradable FADs under C-23-04. Ultimately, the IATTC does not recommend a specific DFAD marking system at this stage, as further preparatory work is needed before such a system can be developed and recommended.

In 2015 the WCPFC FAD Management Options Intersessional Working Group noted that a lack of unique identifiers made it difficult to track the fate of individual FADs and recommended the development of a unique identification system. However, the WCPFC has not yet adopted a formal DFAD marking or unique DFAD identification scheme. Consequently, DFADs are commonly identified through the satellite buoy identification number used in FAD tracking datasets (Fig. 1).

Within the IOTC, Resolution 24/02 establishes the most comprehensive framework for FAD identification among t-RFMOs (Fig. 1). It explicitly links future requirements to the development of a scheme to operationalise the FAO Voluntary Guidelines on the Marking of Fishing Gear. Until such a scheme is endorsed by the Commission, CPCs are required to ensure that all deployed DFADs carry an instrumented buoy that is permanently marked with both the manufacturer-provided buoy identification number and the IOTC unique vessel identifier. In addition, from 1st January 2026, CPCs must ensure that all deployed DFADs are permanently marked with a specific IOTC DFAD unique identifier, separate from the instrumented buoy marking. This identifier is assigned by the IOTC Secretariat to the CPC, which is responsible for

communicating it to the vessel master. Resolution 24/02 further mandates the development of technical standards for the individual marking of DFADs by the Scientific Committee, following preparatory work by the WGFAD and in close collaboration with the Secretariat. Consequently, while IOTC has already established the requirement for both buoy and DFAD-specific identifiers, the practical specifications for the DFAD physical marking system remain under development, providing an opportunity to design a harmonised, durable and operationally feasible marking scheme aligned with FAO guidelines and the objectives of reducing DFAD loss and abandonment.

	IATTC	WCPFC	IOTC	ICCAT
FAD structure marking requirement	*	**	✓	**
FAD marking guidelines	✓	✗	***	✗
FAD deactivation rules	†	‡	✗	✗

* Buoy ID allowed and used
** Buoy ID used
*** FAO guidelines recommended
† Deactivation prohibited in specific geographic areas only; deactivated FAD trajectories cannot be tracked.
‡ PNA only / limited scope within WCPFC.

Figure 1. Summary of the FAD marking and deactivation requirement at RFMOs

4. FAD marking initiatives

The first large scale biodegradable DFAD (BIOFAD) project in the Indian Ocean was one of the first initiatives of DFAD marking, dedicated to only tested experimental DFADs (Murua et al., 2023). The marking scheme was co-developed with the EU purse seiner companies in dedicated workshops. Participants agreed on a standardized identification and traceability system to ensure that each BIOFAD could be uniquely tracked throughout its entire lifecycle. Under this system, every BIOFAD was assigned a permanent unique identifier (e.g. BIO-0001 to BIO-1000), displayed on two identical ID plates, one attached to the raft and the other to the associated echo-sounder buoy (Fig 2). The identifier remained linked to the same BIOFAD throughout the project, even when structural components or buoys were replaced, with the corresponding ID plate transferred accordingly if buoy exchanges occurred. In addition, a colour system was applied for differentiate the biodegradables experimental DFADs from their conventional relatives which were deployed together (in pairs) in 2 nautical mile distance for comparing BIOFAD performance (Fig. 2). Maintaining matching identification numbers on both the raft and buoy was considered essential to ensure traceability.

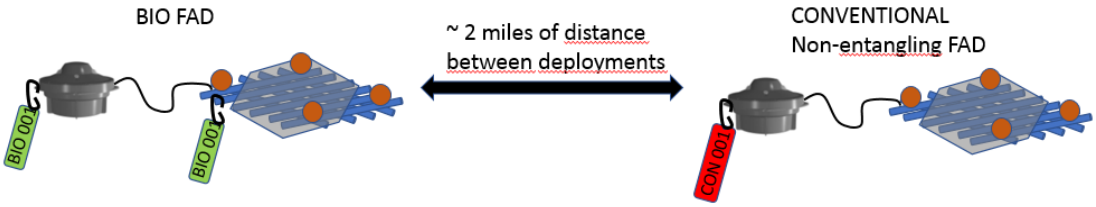

Figure 2. DFAD marking scheme in the Indian Ocean BIOFAD project.

To ensure the proper implementation and continuity of the tracking system, information and awareness materials were distributed among participating vessels (Fig 3)

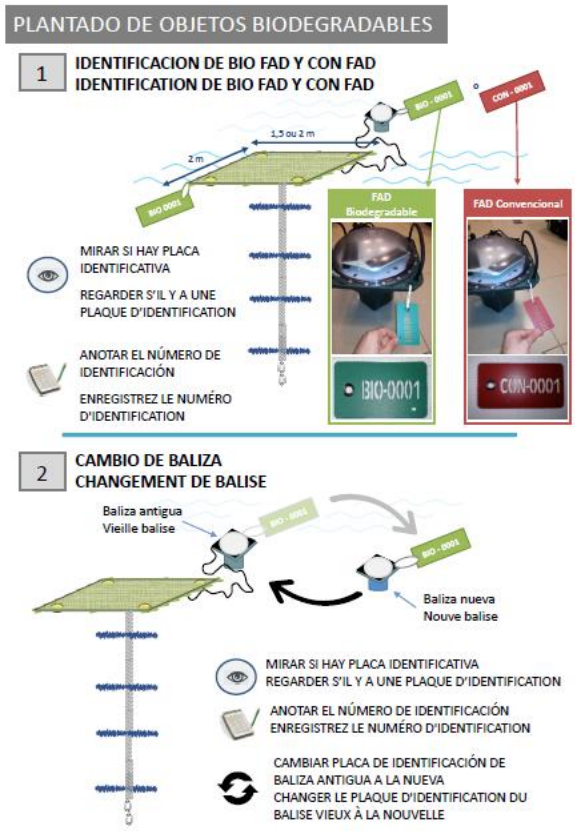

Figure 3. Guidelines for managing DFADs tags in the BIOFAD projects

This marking approach was also implemented in other BIOFADs projects in the Pacific Ocean (Roman et al., 2022), demonstrating its feasibility for experimental DFAD programmes in which identification tags need to be transferred between replacement buoys for only a small proportion of DFADs deployed at sea. However, its applicability at the scale of a commercial fishery has not yet been evaluated and could prove challenging to implement, particularly in regions or seasons characterized by high buoy replacement rates. Frequent buoy exchanges may increase the risk of identification errors and impose additional operational burdens on vessel crews.

In addition, the IATTC supported the development and testing of technologies aimed at improving DFAD monitoring through the remote identification of satellite buoys (Lopez et al., 2024). Trials of LoRaWAN-based communication systems conducted under controlled conditions in Panama demonstrated reliable detection of buoy signals at distances of up to 500-750 m. The results indicate that this technology may offer a practical mechanism for the automatic remote identification of DFAD buoys by vessels, thereby enhancing DFAD traceability and facilitating the collection of information on DFAD interactions.

Another marking alternative that has been tested is the NAOS FAD tracking device developed by CLS (NAOS device) (Fig. 4). This system consists of a low-cost buoy equipped with satellite connectivity. Tests have been conducted in both the Pacific and Indian Oceans (Moreno et al., 2020; Moreno et al., 2023b). Results showed that the trajectories recorded by the NAOS beacons were highly consistent with those provided by fishers' echo-sounder buoys. However, unlike conventional buoy systems, NAOS beacons can continue tracking a DFAD after the associated fishing buoy has been deactivated. This enables DFAD traceability beyond the operational life of the fishing buoy and allows remote monitoring, thereby improving the detection of abandoned, lost, or discarded fishing gear (ALDFG) and supporting mitigation strategies. Nevertheless, the system requires communication costs to be covered throughout the entire lifetime of the DFAD. In addition, monitoring should be conducted by an entity independent of fishing operations, including fishing companies and echo-sounder buoy manufacturers, as DFAD ownership may change during its operational lifetime. It could also add more non-biodegradable materials to the DFAD, contributing to marine pollution if not retrieved.



Figure 4 - NAOS beacons being prepared on a purse seiner's deck (from Moreno et al., 2023b)

5. DFAD use in the Indian Ocean and marking challenges

The diversity of the DFADs used worldwide requires adaptable systems for marking, therefore, it is essential to evaluate the DFAD types in the region before proposing specific guidelines.

In the Indian Ocean, most DFADs are designed with subsurface or fully submerged structures, with only the echosounder buoy, flotation elements and the connecting rope remaining visible at the surface (Fig. 5 and 6). The DFADs might be of few meters below the sea surface to 50 m deep.

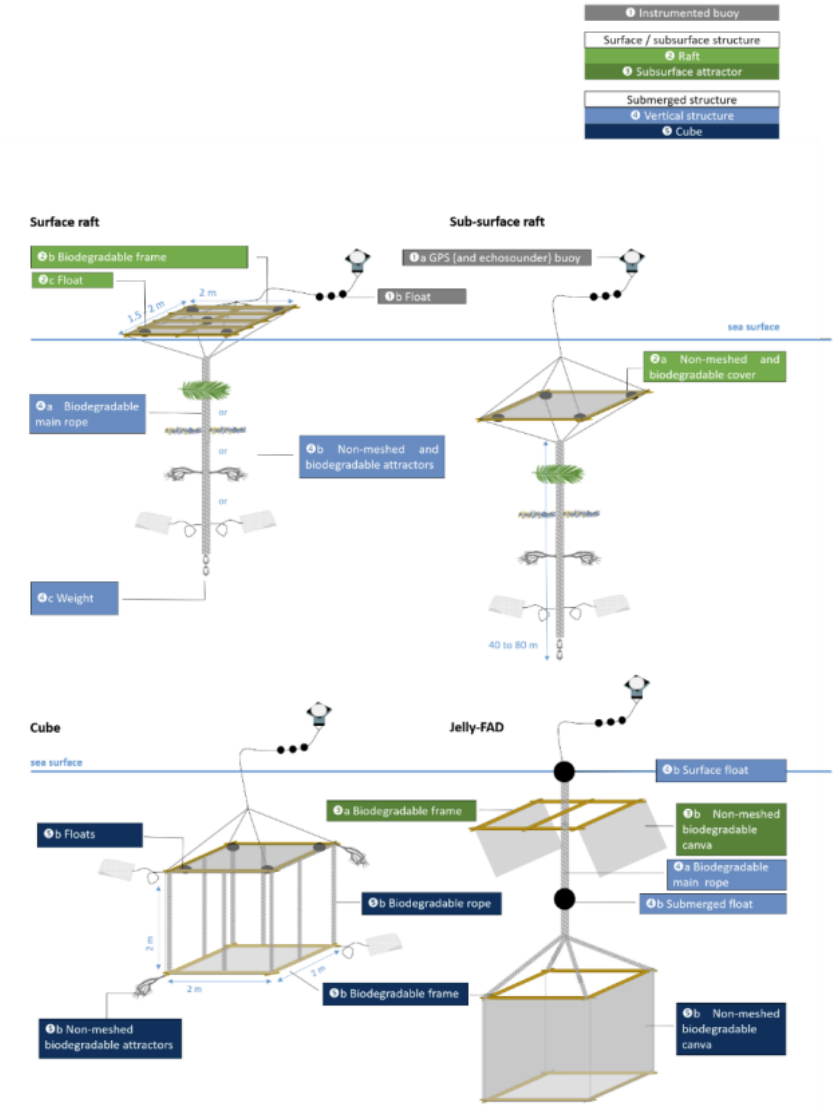

Figure 5. FAD structures commonly used in the Indian Ocean (*Source:* *Resolution 24/02 on management of drifting fish aggregating devices (FADs) in the iotc area of competence | IOTC*)

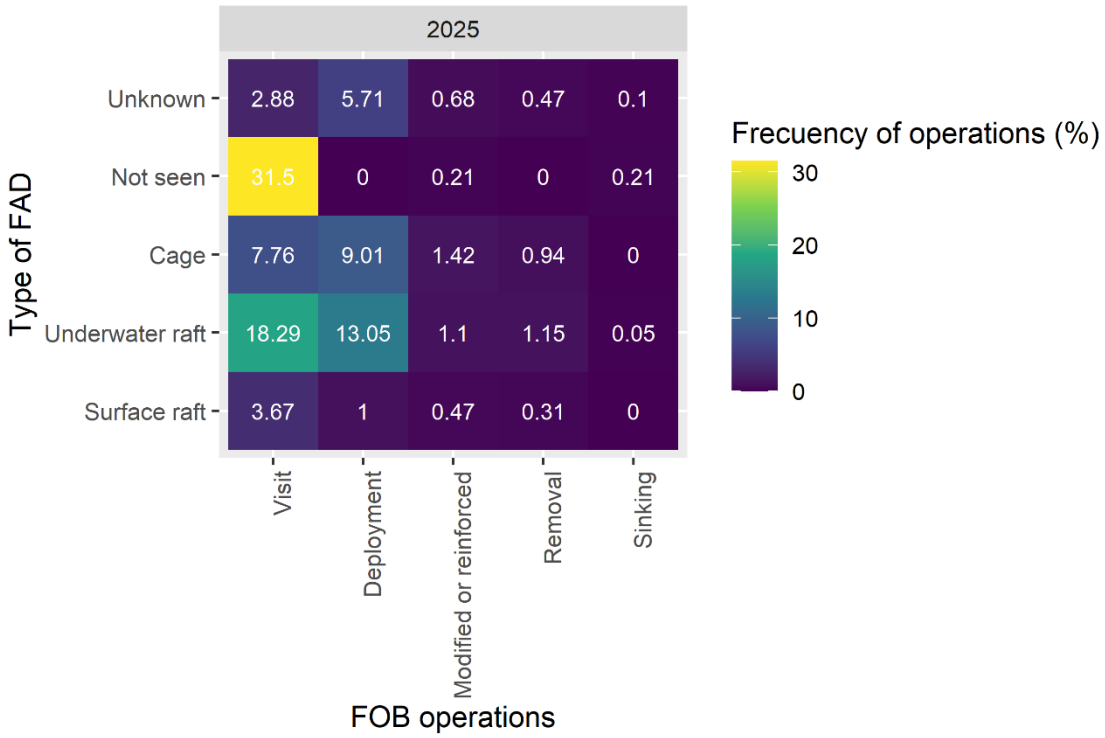

Figure 6. Type of FAD structures involved in FAD-related operations in the Indian Ocean (frequency in percentage), based on European observer data, collected under the Data Collection Framework (DCF) in purse seiners.

During routine DFAD visits and buoy replacement operations, skippers generally seek to minimize their interaction with the DFAD to prevent altering fish aggregation behaviour around the device. As a result, any marking system requiring frequent handling of the structure may present operational challenges and could reduce acceptance by fishers. Particularly in the Indian Ocean where DFAD visits and buoy exchanges are frequent activities and a significant percentage of the structure remain underwater (Fig. 6 and 7) (IOTC, 2026).

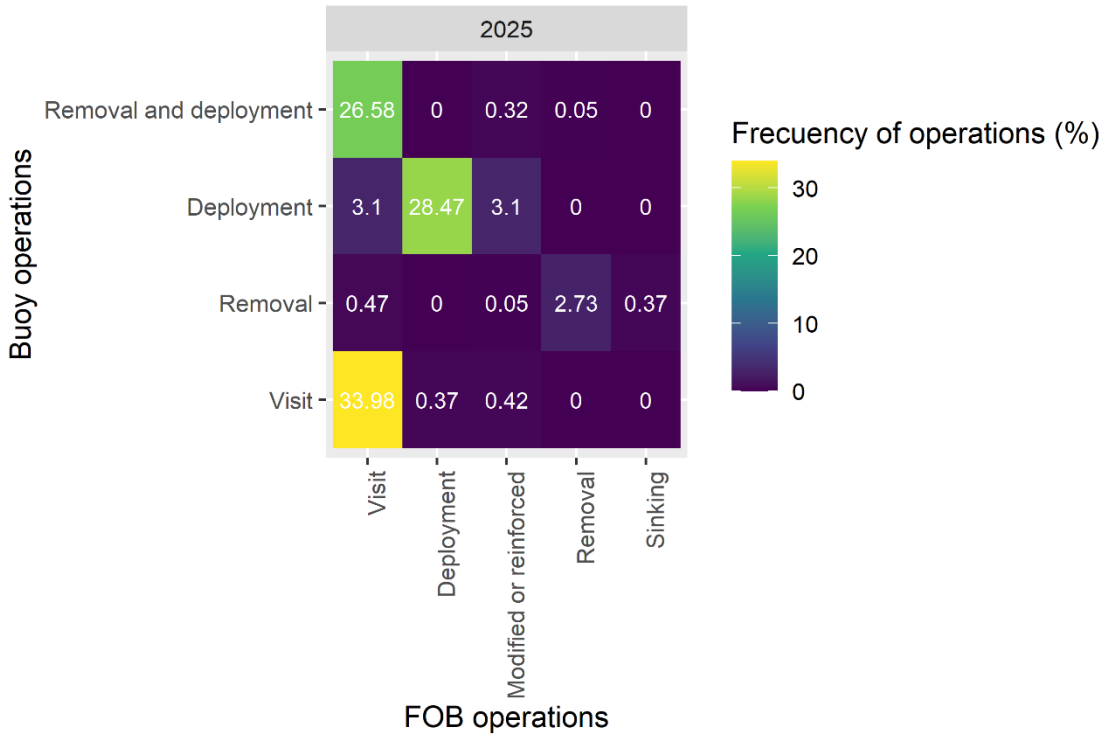

Figure 7. Buoy operations associated with different FOB operation types in the Indian Ocean (frequency in percentage), based on European observer data collected under the Data Collection Framework (DCF) in purse seiners.

.

Therefore, in the IOTC area, where DFADs are required to carry an identifier independent from the buoy, the marking should remain visible from the surface to facilitate identification during routine vessel operations. As an interim solution, pending the adoption of specific DFAD marking guidelines, a common practice has been to use the buoy as the means of identifying the DFAD by displaying the DFAD identifier on the buoy itself. However, this approach does not provide independent identification of the floating structure and may become ineffective when buoys are replaced, and the DFAD ID is not transferred from buoy to buoy. Consequently, alternative marking schemes should be explored to enable the permanent and independent marking of the DFAD structure while remaining visible and practical under operational fishing conditions.

6. DFAD Marking Guidelines: Proposal and Roadmap for Implementation

In the IOTC DFAD use scenario, instrumented buoys provide several advantages as a DFAD marking system. Each buoy is assigned a unique identifier that is registered within RFMO buoy management systems and linked through the DFAD Register to the buoy owner, the vessel, company and flag responsible for its use. As a result, the buoy identification code enables buoy ownership attribution while also providing real-time tracking and remote localization of the DFAD when the buoy is actively transmitting. These capabilities facilitate the monitoring of DFAD movements, the reporting of lost devices, and the implementation of retrieval efforts when FAD recovery programs are in place. However, instrumented buoys alone in the actual buoy use scenario do not fully track the DFAD during their lifetime and nor meet the DFAD marking requirements established under Resolution 24/02, nor the recommendations contained in the FAO Voluntary Guidelines on the Marking of Fishing Gear, which call for an independent and durable marking system attached directly to the DFAD.

An independent alphanumeric code attached directly to the DFAD provides a complementary means of identification, particularly when a DFAD is recovered or encountered by third parties. They may be considered a useful complementary marking method, particularly for maintaining DFAD identification when the buoy is lost, removed, exchanged, or deactivated. Such systems, complemented by buoy tracking, have successfully supported maintaining DFAD traceability during BIOFAD experiments. The suitability on DFADs of other options proposed in FAO guidelines is reviewed in the Table 2.

Unlike instrumented buoys or other remote tracking systems, physical identification tags do not allow remote localization or real-time monitoring. The identifier can only be recorded through direct interaction with the DFAD, which may not always be possible for devices drifting offshore, submerged structures, or DFAD stranded in remote coastal areas. In addition, introducing an independent identification system for DFADs, other than the ID of the buoy attached, and manual recording may increase the risk of transcription errors and, consequently, result in the loss of DFAD traceability. Therefore, future developments should focus on technological solutions that simplify data collection, improve traceability, and reduce the need for manual data entry.

Considering the current state of technology and its rapid evolution, IOTC guidelines should propose, as a minimum requirement, a simple marking system based on physical identification tags, while avoiding restrictions that could limit future technological developments (Table 2).

Table 2. Suitability of different marking options for FADs

Method	Suitability for DFADs	Comments
Printing & inscription	High	Simple and already widely used on echosounder buoys. This could be applied to floats or other parts of the DFADs.
Welding	Low	The progression for biodegradable FADs will reduce the metal components present in biodegradable FAD designs.
Stamped / engraved plates	High	Simple and durable solution that could be attached to floats other parts of the DFADs.
Colour coding	Medium	This could serve as a useful supplementary identifier to distinguish biodegradable DFAD categories. However, because DFAD designs may evolve throughout their lifetime due to repairs, modifications, or component replacement, relying on design-based classifications could complicate traceability.
Knots / marked ropes	Low	As DFADs are constructed many time on-board by different users it will difficult maintaining the criteria for tracking of the DFAD. It cannot be used for individual DFAD ID.
Internal tracer threads	Low	Material traceability at the FAD level would require modifications to existing supply chain logistics, which currently operate at a different level of aggregation. Difficult to provide unique identifiers for each DFAD.
QR codes	High	This is a strong candidate for linking physical markings to a digital DFAD registry. It could also help address some of the challenges associated with manual data recording.
RFID tags	Medium	Suitable for automated identification and traceability but requires associated technology development.
Acoustic transponders	Medium	This option is particularly relevant for FAD recovery and underwater detection. However, it would require the development of associated detection technologies. It could also be complemented by RFID tags or other identification systems to enable the detection of tags that remain above the water surface.
Tags equipped with satellite connectivity	High	Echosounder buoys are the FAD tracking system most widely used worldwide. However, interruptions in communications limit their ability to provide continuous traceability under current buoy management practices. Alternative GPS tracking systems, such as NAOS, can ensure full traceability throughout the FAD's lifetime

In order to respond to IOTC requirements, as prompt implementation, and align with FAO recommendations, the following marking guidelines are proposed:

- Physical identification tags should be attached to all DFADs in a visible location. The preferred location is to attach the mark to the first float located immediately after the echosounder buoy (Fig. 8), as this component remains permanently attached to the DFAD, stays at the surface, and is generally not replaced during buoy exchanges. In accordance with the FAO Voluntary Guidelines, an additional mark should be attached near the deepest section of the DFAD structure to enable identification and tracking if it becomes detached from the surface rope (Fig. 8). While these locations are proposed as suitable options for DFAD marking in the short term, further evaluation would be beneficial to identify

the most appropriate marking system and placement. This should include consultation with fishers through dedicated workshops, complemented by further research to assess the feasibility, durability, visibility, and operational suitability of alternative marking systems under actual fishing conditions.

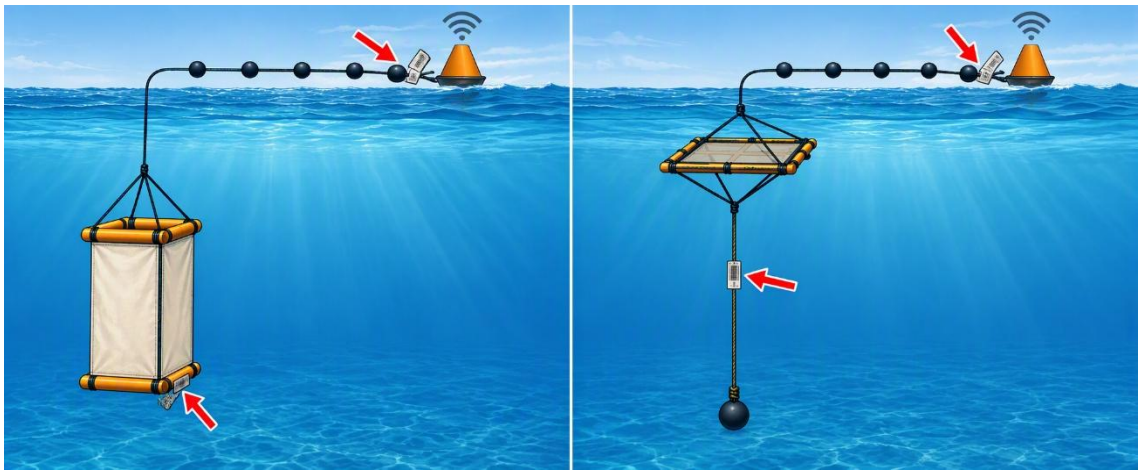

Figure 8. Suggested DFAD marking points for physical marking

- Permanent, waterproof ink should be used to ensure that the marking remains legible throughout the lifetime of the device.
- The alphanumeric ID assigned to the DFAD should be complemented with a QR code if users prefer to record or access the information using this method.
- Introducing an additional independent identification code may increase data-entry complexity and transcription errors. Consequently, efforts should be directed towards the development of technological solutions that facilitate identification, reporting, and traceability for users and management bodies.
    - To partially resolve the data entry and reporting questions of DFAD ID, DFAD register should be adapted to automatically transfer DFAD IDs from buoy to buoy, when interactions occur with a given DFAD. As such the user should only need to register one ID.
    - An ideal long-term solution would build upon existing tracking technologies. For example, future instrumented buoy systems could automatically recognize and transmit the DFAD identification code, regardless of buoy model, or ownership. In such a system, the DFAD identification number would remain associated with the buoy throughout its lifetime or until a buoy deactivation or exchange is register, while the physical tag would provide a permanent backup identifier in the DFAD. Alternatively, traceability and remote tracking throughout the DFAD's lifetime could be achieved by maintaining fishing buoy transmissions beyond the active fishing phase of the DFAD, "non-operational buoys" as defined by IATTC, without these buoys counting towards active buoy limits. Future revisions of the regulatory framework could consider a separate tracking status under which satellite transmission is maintained after the buoy stops to be operationally available to the fishing vessel, without counting towards the vessel's active buoy limit. Such a system would require a distinction from "deactivation" as currently defined in Resolution 24/02. The continued tracking of deactivated buoys should be overseen by an independent entity to ensure transparency.

- Additional independent tracking technologies, such as the NAOS system or other emerging solutions, should continue to be evaluated and developed. At present, however, these technologies should be considered complementary to, rather than replacements for, a physical marking system. Therefore, any DFAD equipped with these technologies should also carry the physical identification tags proposed in these guidelines.
- The guidelines proposed in this document should be revised intersessional in consultation with relevant stakeholders, with the aim of submitting them for adoption by the WGFAD in 2027.
- Marking options and the associated guidelines should be regularly reviewed and discussed with DFAD users and other stakeholders to evaluate their practical implementation while DFAD designs evolve and identify opportunities for improvement arising from emerging technological developments.
- Finally, Resolution 23/01 of the IOTC on management of anchored fish aggregating devices (AFADs) stipulates that, until a scheme to operationalize the FAO Voluntary Guidelines on the Marking of Fishing Gear (VGMFG) is developed, CPCs shall ensure that their vessels deploy only AFADs that are permanently marked with a Unique National Identification (UNI) number identifying either the CPC or the vessel(s) to which the AFAD belongs, as applicable. The UNI number must be clearly visible and permanently marked on the AFAD buoy. Therefore, the WGFAD should also undertake the development and operationalization of marking guidelines for AFADs, in alignment with the requirements of Resolution 23/01.

References:

Einarsson, H., He, P. & Lansley, J. 2023. Voluntary Guidelines on the Marking of Fishing Gear – Manual for the marking of fishing gear. Suppl. 2. Rome, FAO. https://doi.org/10.4060/cc4251en

FAO. 1995. Code of Conduct for Responsible Fisheries. FAO, Rome (also available at http://www.fao.org/fishery/code/en)

FAO, 1996. Technical Guidelines for Responsible Fisheries. No. 1. Rome, FAO. 1996. 26p. 6 annexes.

Imzilen, Taha; Lett, Christophe; Chassot, Emmanuel; Maufroy, Alexandra; Goujon, Michel; Kaplan, David M. (2022): Recovery at sea of abandoned, lost or discarded drifting fish aggregating devices. In *Nature Sustainability* 5 (7), pp. 593–602. DOI: 10.1038/s41893-022-00883-y.

IOTC, 2026. Review of the statistics for Indian ocean tropical tuna fisheries, 1950-2024 IOTC-2026-WPTT28-07a_Rev1

ISSF. 2026. Status of the world fisheries for tuna. Jan. 2026. ISSF Technical Report 2026-01. International Seafood Sustainability Foundation, Pittsburgh, PA, USA

Lopez J., Marlon Román, Jose Luis Beloso , Tomás Galán, Gonzalo Legorburu, 2024. Exploring technologies for remote identification of FADS. DOCUMENT FAD-08-03

Lopez, J., Dan Ovando, Marlon Roman, 2026. Options for FAD marking in the IATTC. DOCUMENT FAD-10-04 (https://www.iattc.org/GetAttachment/dd07eaaa-082a-4975-8f32-f3be96ce43ee/FAD-10-04_Options_for_FAD_marking-EN.pdf)

Moreno, G., Murua, J., Jauharee, A., Zudaire, I., Murua, H., and Restrepo, V. (2020). Compendium of ISSF research activities to reduce FAD structure impacts on the ecosystem. ISSF Technical Report 2020-13. International Seafood Sustainability Foundation, Washington, D.C., USA https://iss-foundation.org/download-monitor-demo/download-info/issf-2020-13-compendium-of-issf-research-activities-to-reduce-fad-structure-impacts-on-the-ecosystem/

Moreno, G., Salvador, J., Zudaire, I., Murua, J., Uranga, J., and Murua, H. 2023a. The JellyFAD: a paradigm shift in Bio-FAD designs. Marine Policy 147 (2023) 105352. https://doi.org/10.1016/j.marpol.2022.105352

Moreno, G., Crochet, T., Murua, H., & Restrepo, V. 2023b. A novel FAD tracking device tested in the Pacific Ocean. Inter-American Tropical Tuna Commission, 7th Meeting of the Ad Hoc Working Group on FADs, La Jolla, California, US

Phillips, J. S., Escalle, L., Murua, H., Lopez, J., & Moreno, G. (2025). A short-lived FAD in the Pacific: Implications and adaptations in the move to biodegradable fish aggregating devices. *Marine Pollution Bulletin*, *218*, 118130.

Román, M., Jon Lopez, Martín Hall, Francisco Robayo, Nick Vogel, José Luis García, Miguel Herrera and Alexandre Aires-da-Silva, 2022. Testing biodegradable materials and prototypes for the tropical tuna fad fishery: progress report and staff's recommendations. DOCUMENT FAD-06-02