ISSF Technical Report 2026-04

SECOND INTERNATIONAL WORKSHOP on Biodegradable Drifting Fish Aggregating Devices

Photo: Gala Moreno

G. Moreno, L. Escalle, I. Zudaire, M. Roman, J. Murua, G. Morán, M. Grande, E. Chassot, B. Ashigbui, L. Arantzamendi, D. Parreño, L. Recio, V. Restrepo, and H. Murua / **May 2026**

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Abstract

The Second International Workshop on Biodegradable Fish Aggregating Devices (bio-FADs) was organized by the International Seafood Sustainability Foundation (ISSF) in San Sebastián, Spain, in December 2025 as a follow-up to the first workshop in 2024. This report summarizes the main workshop presentations, discussions, and conclusions, with the goal of informing ongoing research, supporting fisheries management processes, and facilitating the transition toward more environmentally sustainable drifting FADs (dFADs) in tropical tuna fisheries.

The event brought together the fishing industry, tuna Regional Fisheries Management Organization (RFMO) representatives, and scientists from the three tropical oceans. Its primary objective was to review progress in biodegradable FAD development and adoption, and to assess fisher and manufacturer practical challenges in implementing these designs. Particular attention was given to lessons learned from recent at-sea trials, advances in biodegradable materials and biodegradable FAD design, and the operational performance of bio-FAD prototypes in different ocean regions.

Participants also aimed to identify remaining technical and operational barriers that may slow the transition toward fully biodegradable FADs, including issues related to material performance, durability, bio-based material certification standards, and large-scale implementation by fishing fleets.

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Table of Contents

Executive Summary

The Second International Workshop on Biodegradable Drifting Fish Aggregating Devices (bio-FADs), organized by the International Seafood Sustainability Foundation (ISSF) in San Sebastián, Spain, in December 2025, brought together fishers, fleet representatives, scientists, FAD manufacturers, and tuna RFMO representatives from the three tropical oceans. Building on the first international bio-FAD workshop held in 2024, the meeting aimed to review progress in the development, testing, and implementation of bio-FADs, with particular attention to lessons learned from recent at-sea trials, material performance, design optimization, and the practical challenges faced by fleets during the transition from conventional dFADs to biodegradable alternatives.

The workshop confirmed that substantial progress has been made. Bio-FAD trials across the Pacific, Indian and Atlantic Oceans show that biodegradable designs can achieve drift behavior, tuna aggregation patterns and fishing performance broadly comparable to conventional dFADs. In the WCPO, jelly-FADs showed similar drift speed and aggregation patterns to conventional dFADs, with some units remaining functional for at least six months. In the EPO, IATTC trials with 780 bio-FADs found no significant difference in mean catch per set between bio-FADs and conventional controls.

Overall, existing trials indicate that bio-FADs can be operationally viable under commercial fishing conditions, although lifespan remains variable among designs and regions. The discussions also highlighted the need for robust trial design. Given that only a small proportion of deployed dFADs are later visited, future trials should include large sample sizes, paired deployments with conventional controls, standardized monitoring protocols, strong fleet participation, quality control during construction, and training for fishers and fleet personnel on bio-FAD construction.

Material selection was identified as one of the most important unresolved issues. Participants broadly agreed that organic, plant-based materials should remain the primary focus for bio-FAD construction, including cotton, abacá/Manila hemp, bamboo, jute, sisal, coconut fiber, balsa wood, and other locally available organic materials. However, their suitability depends on durability, availability, cost, and quality of manufacturing. The workshop also highlighted substantial uncertainty around bioplastics and bio-based materials. A material being bio-based does not necessarily mean that it will biodegrade in the marine environment, and compostability labels should not be interpreted as evidence of marine biodegradability. Reliable certification, transparent technical specifications, chemical safety information, and traceability of materials are therefore essential to ensure that bio-FADs deliver real environmental benefits.

In summary, the workshop showed that the transition toward bio-FADs is already underway and technically feasible, but not yet fully resolved. The main remaining challenges are lifespan for certain designs and biodegradable material availability and cost. Continued international workshops are therefore essential, as they provide a unique forum for exchanging first-hand experience among fishers, scientists, and fleet managers — documenting progress, identifying persistent constraints, and accelerating the practical implementation of bio-FADs. As RFMO timelines for biodegradable FAD adoption approach, maintaining this collaborative, evidence-based process will be critical to ensure that the transition is both operationally realistic for fleets and environmentally meaningful for tropical tuna fisheries.

1. Introduction

Drifting Fish Aggregating Devices (dFADs) are widely used in tropical tuna purse-seine fisheries to enhance fishing efficiency by exploiting the natural tendency of tunas and other pelagic species to aggregate around floating objects. Over the past decades, the number of dFADs deployed globally has increased substantially, due to their efficiency to aggregate and catch tuna, compared to targeting free swimming schools of tuna.

While dFADs have significantly improved fishing efficiency, concerns remain regarding their environmental impacts, particularly those associated with lost, abandoned, or discarded devices. Drifting FADs that are not retrieved may drift for extended periods and eventually strand in coastal ecosystems, including coral reefs, mangroves, and seagrass habitats. These stranding events can damage sensitive habitats and contribute to marine debris accumulation. In addition, the persistence of synthetic materials, primarily plastic components (Fig. 1), used in conventional FAD construction means that these structures may remain in the marine environment for long periods after they cease to be operational.

Figure 1. Subsurface structure ("tail") of a conventional drifting FAD constructed with netting and plastic components. The use of netting materials in dFADs is now prohibited under current conservation measures in the three tropical oceans. Photos: left, G. Moreno; right, M. Taquet.

Recent studies using virtual trajectory modeling and satellite buoy tracking have highlighted the potential scale of these impacts by simulating the drift pathways of dFADs and identifying areas with elevated risks of coastal stranding (Escalle et al. 2019, Imzilen et al., 2022; Scutt Phillips et al., 2025). Such analyses have demonstrated that large numbers of devices may drift from fishing grounds toward coastal ecosystems, emphasizing the need for improved management and mitigation strategies.

In response to these concerns, fisheries management bodies, industry stakeholders, and research institutions have increasingly focused on the development of biodegradable FADs (bio-FADs) as a potential solution to reduce the environmental footprint of dFAD fisheries. The transition toward biodegradable designs, under current management measures in tuna RFMOs, aims to replace synthetic components with organic or bio-based materials that can degrade in marine environments.

Designing biodegradable FADs presents several technical challenges, however. Conventional dFADs often rely on synthetic materials with high mechanical resistance, whereas biodegradable materials such as plant-based ropes and fabrics may have lower durability and different hydrodynamic properties. Consequently, new design approaches are required to ensure that bio-FADs maintain sufficient structural integrity and functionality for the operational lifetime of the FAD (Moreno et al., 2023).

A growing number of experimental trials and pilot projects have been conducted by fishing fleets and research institutions across the three tropical oceans to evaluate the feasibility and performance of bio-FAD designs. These trials aim to assess the behavior, durability, and fishing performance of bio-FADs under real fishing conditions and to identify practical solutions that can facilitate their adoption at larger scales.

To consolidate existing knowledge and accelerate progress toward more sustainable dFAD designs, an international workshop on biodegradable FADs was held in Donostia–San Sebastián in December 2025. Building on the first International Bio-FAD Workshop, held in December 2024, which brought together a diverse range of stakeholders and countries, this second workshop convened fishers from different regions, fleet managers, and scientists involved in bio-FAD research to review existing bio-FAD trials, share lessons learned, and identify best practices for future design and testing efforts (see the list of participants in Appendix I). The workshop also aimed to develop recommendations to support the transition toward bio-FADs in tropical tuna fisheries worldwide.

2. Conventional dFAD Designs

A key objective of the workshop was to improve the understanding of the diversity of dFAD designs currently used in tropical tuna purse-seine fisheries. Although dFADs are commonly discussed as a single type of fishing device, in practice their construction varies across oceans, fleets, and fishing strategies. These differences reflect local operational practices, historical developments in the fishery, availability of materials, and the experience and preferences of fishers.

Understanding these variations is particularly important in the context of the ongoing transition toward bio-FADs. Conventional dFAD designs have evolved over decades through a process of experimentation and adaptation by fishers, who have refined structural characteristics such as raft configuration, depth, materials, and overall size to optimize performance in specific oceanographic, operational, and environmental conditions. As a result, the characteristics that fishers consider important — such as durability, ease of construction, aggregation performance, and handling during deployment or retrieval — must be carefully understood when developing biodegradable alternatives.

Documenting the types of conventional dFAD designs therefore provides a critical baseline for the development of bio-FADs. By identifying the structural features that fishers consider effective or desirable, researchers and managers can better ensure that new biodegradable designs maintain the operational functionality required by the fishery while reducing environmental impacts.

To address this need, participants were divided into working groups and asked to review and classify the main types of dFADs currently used in different oceans. The exercise aimed to identify common structural elements, highlight regional differences in design, and explore the factors influencing fishers' preferences (see Appendix II, for the conventional dFAD types identified by the different groups).

The sketches produced by the working groups show that conventional dFADs can be grouped into a limited number of broad structural categories, despite the considerable variation observed across fleets and ocean basins (Fig. 2, Table 1). In all cases, the devices combine a floating surface component with a submerged appendage, but they differ substantially in the geometry, length, and complexity of the underwater structure.

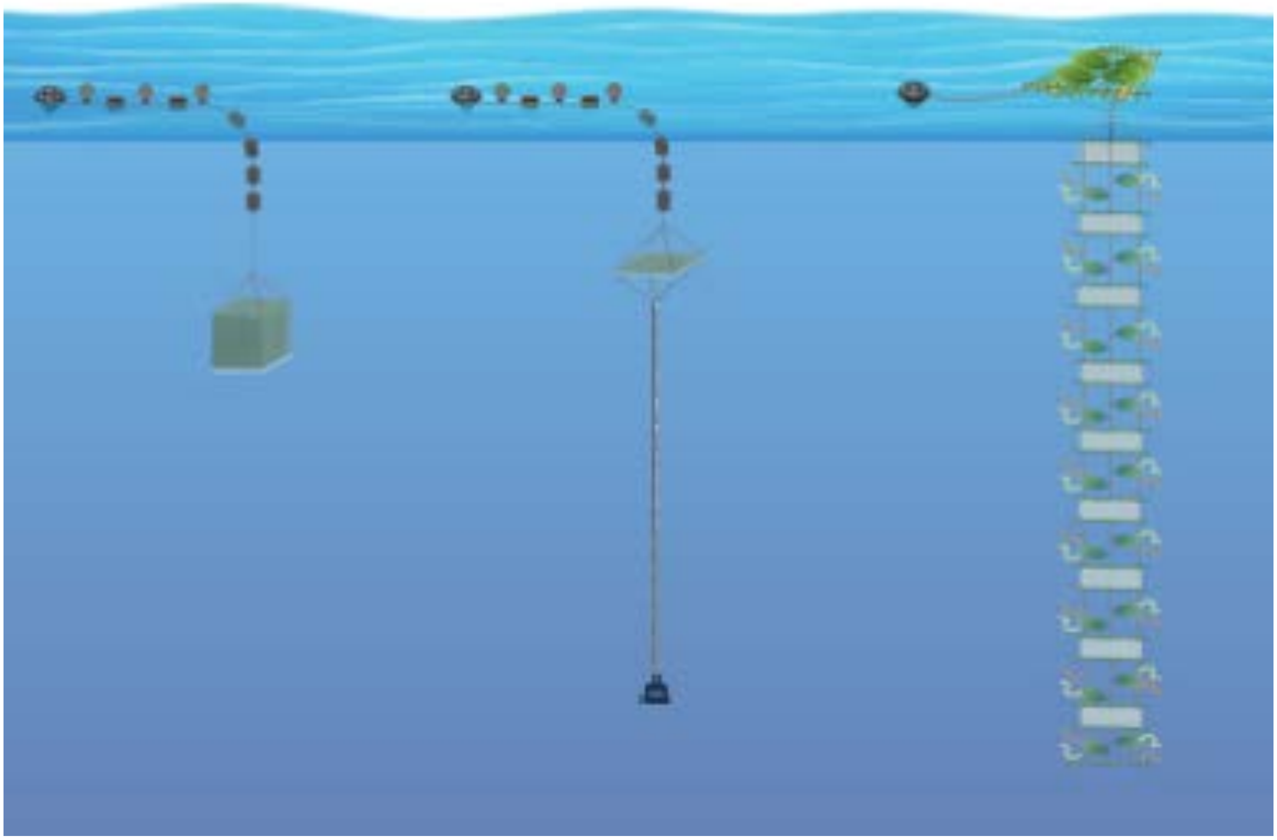

Figure 2. Schematic illustration of three representative conventional dFAD configurations: cage-type (left), tail-type (center), and curtain-type (right). Illustration courtesy of Albacora fishing company.

A first major category includes panel- or curtain-type dFADs (Fig. 2, right), in which the underwater structure consists of a long vertical appendage formed by panels, strips, or successive rectangular sections. This design appear to be especially common in the Pacific and Atlantic Oceans. The drawings suggest that these structures may vary in total length and in the spacing of the panels, resulting in relatively simple but elongated subsurface profiles.

A second category corresponds to tail-type dFADs (Fig. 2, center), in which the submerged structure is based on a central rope or line with hanging strips, cords, or loose appendages. Compared with curtain-type designs, these configurations appear less rigid and structurally simpler, with lower material complexity and a more flexible underwater profile. These designs appear to be specific to the Indian Ocean.

A third important category includes cage-type or jelly-like dFADs (Fig 2. left), in which the subsurface structure has a three-dimensional form, typically cubic. Several variants were identified, including surface cages, submerged cages, and mixed cage-raft configurations. These designs appear to be specific to the Indian Ocean. In some cases, the rafts are partially submerged, while in others it remains clearly at the surface. This indicates that the distinction between categories is not always absolute, and that many conventional dFADs are effectively hybrid designs.

The Pacific Ocean designs emphasize elongated curtain-like structures with relatively standardized dimensions, whereas the Indian Ocean designs show a wider range of forms, including tail-type, cage-type, curtain-like, and other mixed configurations. Other groups also identified designs shared across the Atlantic, Indian, and Pacific Oceans, suggesting that some structural concepts are widespread, even if adapted locally.

The group exercise further indicated that conventional dFADs are constructed from a wide variety of materials, including bamboo, wood, metal frames, ropes, textile panels, plastic floats, and different types of ballast. This diversity suggests that conventional dFAD designs are strongly influenced by operational practices, material availability, cost, and fleet-specific preferences.

The exercise also showed that the Indian Ocean is the basin in which the greatest diversity of conventional dFAD designs is currently used. The discussions suggested that the current distribution of designs is not explained solely by local adaptation, but also by sharing the technical knowledge among fleets operating in multiple oceans. Participants noted that fishers have effectively cross-pollinated dFAD designs across regions, particularly in fleets such as the Spanish and Korean fleets, whose vessels operate in the Atlantic, Indian, and Pacific Oceans.

As a result, design concepts developed or commonly used in one ocean have often been transferred to another, contributing to the spread of some dFAD configurations across basins. However, this process does not appear to apply equally to all designs. According to information shared by fishers during the workshop, the tail-type configuration commonly used in the Indian Ocean seems to perform effectively only in that region and has not been successfully extended to other oceans, suggesting that at least some dFAD types may remain strongly shaped by region-specific oceanographic or operational conditions.

These findings are highly relevant to the transition from conventional dFADs to bio-FADs. The diversity of existing designs implies that the substitution of conventional synthetic materials with biodegradable alternatives will not pose the same challenges for all structural types or oceans. Some configurations may be comparatively straightforward to adapt (e.g., tail-type dFADs), whereas others may be much more difficult to reproduce with biodegradable materials while maintaining their required buoyancy, structural integrity, and handling characteristics (e.g., curtain-type dFADs). This is particularly important in the case of one of the most common conventional configurations, the curtain-like dFAD, whose long, vertically arranged underwater structure may be especially difficult to replicate using biodegradable materials. In such cases, the transition to bio-FADs may require not only replacing materials but also redesigning key structural elements to ensure that the resulting devices remain operationally feasible.

Table 1. Main conventional dFAD configurations reported by region, the factors likely influencing their use, and implications for bio-FAD development.

Region	Conventional dFAD types	Key characteristics	Required operational dFAD lifetime	Bio-FAD implication
Eastern Pacific Ocean (EPO)	Mainly curtain-like dFADs (Fig. 2 right)	Reaches from 25 to 80 m depth. Raft made of bamboo grid	3–4 months near the continent; up to 6–12 months farther west	Curtain-type designs need longer-lasting biodegradable materials due to the structural stress, or lower structural stress alternative designs such as jelly-FADs
Western and Central Pacific Ocean (WCPO)	Mainly curtain-like dFADs (Fig. 2 right)	Deeper structures than in the EPO: 50 to 80 m depth. Mix of bamboo grid and “burrito” style rafts.	6–12 months (possibly 9–12 months in some fisheries; highly dependent on fleet, basin, and fishing strategy).	Lower-stress designs may be advantageous; complexity and labour of some curtain designs may be a constraint
Indian Ocean (IO)	Multiple designs coexist: tail-type, cage-type/jelly-like, curtain-type. Tail-type and cage-type are especially characteristic of the Indian Ocean (Fig 2. left and center)	Tail-type: central rope/line with hanging strips or cords; simpler, less rigid, more flexible underwater profile. Cage-type/jelly-like: three-dimensional, often cubic; includes surface cages, submerged cages, and mixed forms.	Up to 6 months	Tail-type is the easiest design to convert into biodegradable. Cage-type is also more feasible and cost-effective than the curtain-like design.
Atlantic Ocean (AO)	Very deep (up to 100 m depth). Curtain-like dFADs (Fig. 2, right)	Curtain-like underwater structures; deeper and more complex than in other regions	Up to 1 year	Durability is especially challenging due to the deep and complex structures; may be hardest to convert to biodegradable materials in the AO

Overall, the exercise highlighted that progress toward bio-FAD adoption will need to account for the regional diversity of conventional dFAD designs, the technical constraints associated with reproducing some of the most widely used configurations in biodegradable form, and the manufacturing context in which dFADs are built. This includes whether dFADs are handcrafted locally by fishers or produced by fishing or FAD manufacturers, as these different production pathways may influence access to suitable biodegradable materials, ease of construction, and design standardization.

3. Conventional and Biodegradable FADs' Lifespan

During the workshop, two studies on the lifespans of dFADs, including both conventional and bio-FADs, were presented. Although both analyses were focused on the Pacific Ocean, they provided useful insights into the potential duration of dFADs and the factors influencing their persistence and operational use. Following these presentations, participants discussed several key aspects related to dFAD lifespan, which are developed in this section.

The lifespan of dFADs can be defined in two complementary ways: (1) operational lifespan, corresponding to the period during which the device remains within fishing grounds and is actively used, and (2) physical lifespan, defined by the time at which a dFAD's structure is destroyed or in a condition such that it cannot be used (Fig. 3). The end of a dFAD's structural life may occur either within or outside the fishing grounds. If the dFAD remains within the fishing grounds long enough, its physical lifespan may end there. More commonly, however, the dFAD drifts out of the fishing grounds while still structurally intact. In such cases, its operational lifespan has ended, but its physical lifespan has not, as the dFAD may continue drifting outside the fishing grounds in good condition.

When asked about the physical lifespan of a dFAD, fishers often find it difficult to provide a clear estimate, as they typically lose track of the device once it drifts outside the fishing grounds. In contrast, they more readily identify an operational lifespan, which generally ranges from six months to one year, depending on the fleet, ocean basin, and dFAD fishing strategy. Some fleets operating closer to the continent in the EPO, particularly those using smaller vessels with more limited operational range, consider a lifespan of three months to be sufficient. In practice, this means the dFAD remains available to the owner for about three months, after which it may be lost as it drifts beyond the fleet's operational range or be encountered and reused by other vessels. In the three tropical oceans, dFADs change owner quickly and regularly, reducing the operational lifespan for the original owner but maintaining the overall lifespan of the particular FAD for longer periods, through repairs for instance.

Conventional dFADs, largely constructed from synthetic materials (e.g., plastics, nylon, and metallic components), are characterized by long physical lifespans. Empirical observations and trajectory analyses indicate that dFADs can persist and continue drifting for several years. Royer et al. (2023), in a study conducted in the Hawaiian Islands and Palmyra atoll, on dFADs found stranded ashore, showed that the time elapsed between deployment and found stranded ranged from less than three months to 85 months, indicating that some lost dFADs can remain in the ocean for more than seven years. Most devices reached the Hawaiian Islands from the fishing grounds, within two years of deployment, but those recovered in the Northwestern Hawaiian Islands had drifted for substantially longer periods, with an average persistence at sea of 69 months. These findings show that, even after they cease to be operational, lost dFADs may persist in the marine environment for several years, thereby contributing to long-term marine debris accumulation (Scutt Phillips et al., 2025).

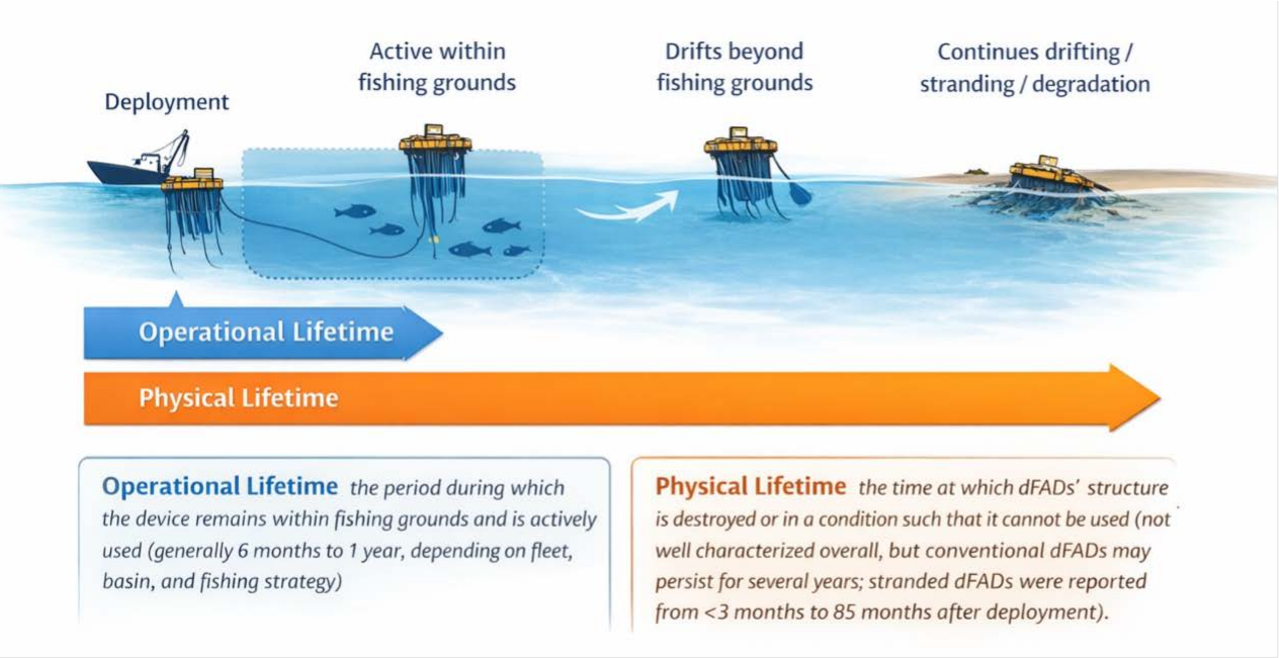

Figure 3. Operational and physical lifetime of dFADs.

Ovando et al. (2005), the first study presented during the workshop, based their analysis on a comprehensive dataset derived primarily from the IATTC onboard observer program, complemented by dFAD tracking data linked through satellite buoy identifiers. Importantly, observer coverage is 100% for large purse seiners, which provides a robust basis for analyzing dFAD dynamics in the EPO. This dataset allowed the reconstruction of dFAD at-sea interactions, including deployments, visits, fishing sets, buoy replacements, and recoveries. In this study, dFAD lifespan was defined operationally as the period between deployment and the last recorded interaction, such as a visit, set, or recovery, rather than as the full physical lifespan of the structure. Consequently, the analysis reflects the observed at-sea lifespan of dFADs.

Results indicated that most dFADs have relatively short operational lifespans. Based on the observer database, approximately 80% of dFADs had observed lifespans of 50 days or less. In addition, around 70% of deployed dFADs were never recorded again after deployment, meaning that no subsequent visit, set, or recovery associated with those devices was documented in the IATTC observer database. Because these dFADs were not re-observed by either the deploying vessel or any other monitored vessel, their subsequent trajectory, condition, and final fate remain unknown. Most recently, analyses using enhanced data resolution have incorporated satellite transmission data from dFAD buoys, as well as records of dFAD deactivation reported to the IATTC Secretariat under Resolution C-25-01, and data on FAD strandings and recoveries from collaborators in the region (Ovando et al. 2026). This novel approach provides more comprehensive information on buoy activity and dFAD trajectories, including cases where dFADs are not physically observed, as long as the buoys remain active (i.e., transmitting). However, when buoys are inactive, this remains a limitation for accurately estimating true dFAD occurrence at sea and adds uncertainty surrounding the fate of a large fraction of deployed dFADs in the EPO.

These findings indicate that most dFADs are either underutilized or lost before being effectively exploited, with only a small fraction contributing directly to catches. In the IATTC Convention Area, dFADs generally drift westward, and a proportion may eventually enter the WCPFC Convention Area. Some of these dFADs may be transferred or sold to fleets operating in the WCPFC region, while others may be encountered opportunistically at sea by those fleets. However, there is currently no systematic tracking of the number of dFADs originating in the IATTC area that are subsequently reused in the WCPFC region, either through formal purchase or chance encounters. This lack of traceability makes it difficult to quantify cross-regional dFAD reuse and to assess its implications for FAD availability, ownership, and management across the Pacific.

In response to the risks associated with lost and abandoned devices, tuna RFMOs have already adopted measures requiring a progressive transition toward bio-FADs as a means of reducing the ecological footprint of dFAD fisheries.

Bio-FADs are intentionally designed to have shorter physical lifespans through the use of natural or certified bio-based materials. Different bio-FAD designs have shown a wide range of durability, from three to four months in designs that largely replicate conventional curtain-like dFAD structures but are constructed with organic materials (G. Moran personal communication, 2024; Murua et al., 2023; Roman et al., 2022), to nine to 12 months in more recent designs such as jelly-FADs,[1] which are more closely aligned with fishers' operational requirements (Moreno et al. 2023).

The second study presented during the workshop, by Scutt Phillips et al. (2025), estimated changes in FAD loss outside fishing areas and the associated reduction in environmental impact and also assessed the potential loss of operational dFADs within fishing grounds due to premature degradation. Because limited data are available on the actual trajectories of dFADs after they are deactivated outside fishing grounds, the study used a modeling approach based on Lagrangian drift simulations to simulate dFAD drift.

Virtual dFADs were seeded across the ocean according to real deployment locations derived from tuna RFMO datasets, including IATTC and WCPFC tracking and observer data, and were then advected using ocean circulation models to simulate their trajectories and fate across the Pacific Ocean. Conventional dFADs were assumed to have a physical lifespan of approximately two years, allowing them to drift widely across different regions of the Pacific. In contrast, bio-FADs were modeled with shorter lifespans, ranging from four to 12 months depending on design. Bio-FADs with lifespans of nine to 12 months broadly matched the natural residence time of conventional dFADs within fishing grounds, whereas shorter-lived designs, such as those lasting around four months, resulted in the premature loss of operational FADs while they were still within fishing areas. This led to a substantial reduction in the number of dFADs available for fishing, with estimated decreases in operational FADs within fishing grounds of approximately 16% for a one-year lifetime, 32% for a nine-month lifetime, and up to 72% for a four-month lifetime.

The use of bio-FADs may reduce the number of dFADs that are ultimately lost outside the equatorial fishing grounds because a greater fraction of devices degrades before drifting beyond the fishing area. At the Pacific scale, the study estimated that reducing dFAD physical lifespan from

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[1] A jelly-FAD is a biodegradable FAD design based on quasi-neutral buoyancy and a low-stress structure. It aims to eliminate plastic and netting from the FAD while maintaining slow drift, adequate durability at sea, and tuna aggregation performance.

about two years to one year would decrease losses outside the fishing grounds by 16.1%, with most of this reduction occurring in the WCPO (13.3%) and a smaller fraction in the EPO (2.8%). The study also showed that this effect becomes stronger as bio-FAD lifespan decreases further: for lifetimes of nine months and especially four months, an increasing proportion of devices no longer escape the fishing grounds, thereby further reducing offshore loss and the potential for long-distance environmental impacts.

Overall, the study highlights a key trade-off in dFAD management: shorter physical lifespans can reduce environmental impacts, but they may also reduce operational efficiency, particularly in regions where fleets rely heavily on drifting devices or on dFADs deployed by other vessels. These effects are also likely to vary regionally, depending on oceanographic conditions and fleet behavior.

When these results are compared with those of Ovando et al. (2025), which were based on observed dFAD activities, an important additional perspective emerges. In that study, the average operational lifespan of conventional dFADs was approximately 50 days. This suggests that even bio-FADs with relatively short physical lifespans, such as four months, could still remain operationally available within fishing grounds while substantially reducing the total time that dFADs persist in the marine environment.

Overall, the transition from conventional dFADs to bio-FADs implies a shift from long-lasting, persistent structures to shorter-lived devices that can reduce environmental impacts. However, this transition will require careful design optimization to extend the useful lifespan of bio-FADs where needed.

4. Current Conservation Measures on dFAD Structures

Tuna Regional Fisheries Management Organizations (RFMOs) are responsible for managing dFADs, which are typically adopted through Conservation and Management Measures (CMMs).

Recent measures adopted by tuna RFMOs, including the Inter-American Tropical Tuna Commission in the eastern Pacific Ocean (IATTC; Resolution C-23-04), the International Commission for the Conservation of Atlantic Tunas (ICCAT; Recommendation 24-01), the Indian Ocean Tuna Commission (IOTC; Resolution 19/02), and the Western and Central Pacific Fisheries Commission (WCPFC; CMM 2023-01) prohibit the use of mesh netting in any part of a dFAD. The first one adopting this measure was the IOTC, with an implementation in 2020, followed by the WCPFC in 2024 and IATTC and ICCAT in 2025. Thus, fishers cannot construct dFADs with any netting material.

However, dFADs deployed prior to the implementation of these binding measures may still be drifting at sea. Given the long persistence of conventional synthetic materials and the extended drifting lifetimes of these devices, some of these legacy FADs can remain in the marine environment for months or even years. During this time, they may continue to pose risks of entanglement, contribute to marine debris, and eventually strand in coastal habitats.

Table 2. Management measures on biodegradable drifting FADs.

RFMO	Management Measures
IATTC	Stepwise implementation of bio-FADs from 2026 to 2029 (except plastic flotation). In 2030, decide about plastic flotation.
WCPFC	Not required but encouraged
IOTC	Stepwise implementation of bioFADs from 2026 to 2030. Including flotation.
ICCAT	Stepwise implementation of bioFADs from 2025 to 2028. Including flotation.

In addition to non-entangling requirements, recent regulatory developments in the IOTC (Resolution 24/02), ICCAT (Recommendation 24-01) and IATTC (Resolution C-23-04), have introduced specific provisions requiring the stepwise transition to biodegradable[2] FADs (Table 2, Fig. 4). The WCPFC

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[2] *Definition in tuna RFMOs*: Biodegradable means non-synthetic materials* and/or bio-based alternatives that are consistent with international standards** for materials that are biodegradable in marine environments. The components resulting from the degradation of these materials should not be damaging to the marine and coastal ecosystems or include heavy metals or plastics in their composition. *For example, non-synthetic refers to plant-based materials such as cotton, jute, manila hemp (abaca), bamboo, and natural rubber or animal-based such as leather, wool, and lard. **International standards refer to ASTM D6691, D7881, TUV Austria, and European or any such standards approved by the Members of the IATTC.

only encourages the use of biodegradable materials in dFAD construction, but a decision on the stepwise adoption is expected in 2026. In the other tuna RFMOs, the measures classify dFADs according to the degree to which biodegradable materials are used in their construction.

These classifications allow the transition from 100% synthetic dFADs to devices made entirely from biodegradable materials. In between, the conservation measures identify those structures in which only certain components, such as the subsurface structure or the raft, are biodegradable, while other parts may still contain synthetic elements. These classifications are intended to facilitate monitoring of the transition toward biodegradable designs and to support the progressive reduction of synthetic materials used in dFAD construction. The following categories have been established to guide this transition, progressing from Category V to Category I:

- Category I — FADs fully composed of biodegradable materials
- Category II — Fully biodegradable with the exception of plastic flotation devices (foam, buoys, etc.)
- Category III — Contain synthetic, non-biodegradable materials in the raft and flotation components while the submerged components (tail) are composed of fully biodegradable materials
- Category IV — Composed of biodegradable surface components in the raft, excluding floats, and a non-biodegradable tail
- Category V — Composed solely of non-biodegradable materials

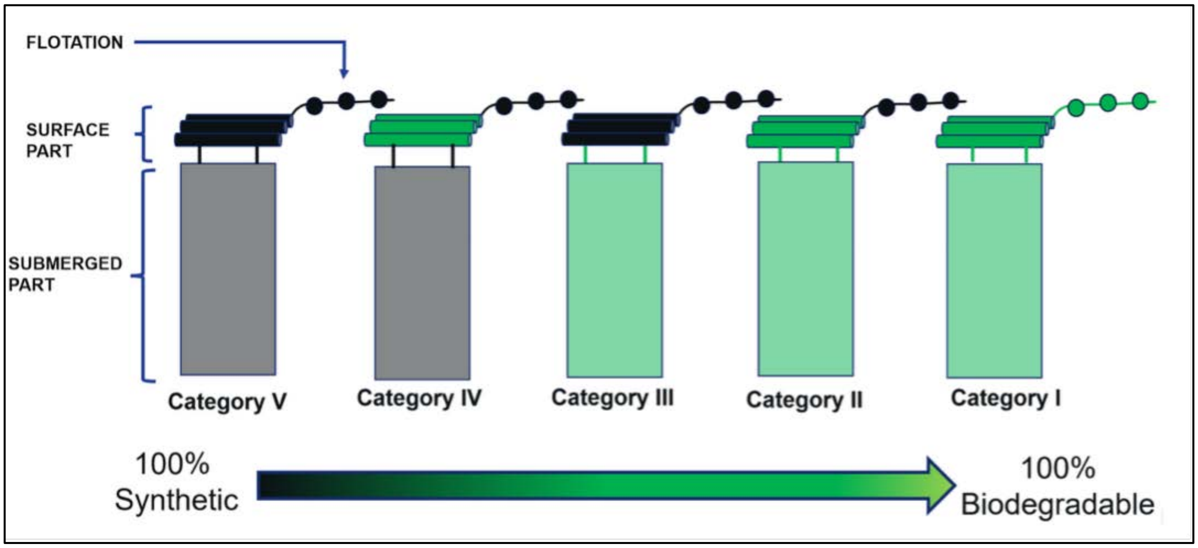

Figure 4. Stepwise transition toward biodegradable FADs adopted by IATTC, IOTC and ICCAT. Biodegradable components are shown in green, while synthetic or fossil-based plastic components are shown in black.

Beyond RFMO regulations, market-based mechanisms are also contributing to the promotion of more environmentally responsible FAD designs. In particular, the Marine Stewardship Council (MSC) has incorporated new requirements related to fishing gear impacts, including lost and abandoned fishing gear, within its evolving fisheries certification standards. Updated MSC standards emphasize the need to minimize gear loss and its ecological consequences, including ghost fishing and habitat damage.

Under these requirements, fisheries seeking certification are expected to demonstrate effective strategies to manage and reduce gear loss. These strategies may include monitoring lost gear, implementing gear marking and dFAD tracking systems, establishing retrieval programs, and adopting gear modifications that reduce environmental impacts. For fisheries using dFADs, this may involve demonstrating that dFAD loss is minimized or effectively managed through mechanisms such as tracking, recovery programs, or the use of low-impact designs such as biodegradable and non-entangling FADs.

Together, these regulatory and market-driven initiatives are accelerating the transition toward more sustainable dFAD designs. By combining tuna RFMO conservation measures, industry innovation, and certification standards, current governance frameworks are increasingly encouraging the adoption of biodegradable and non-entangling FADs (or FAD designs) in tropical tuna fisheries.

5. The Concept of Biodegradable

The transition toward bio-FADs requires a clear understanding of the terminology associated with biodegradable, organic, natural, bio-based, and bioplastic materials. These concepts are often used interchangeably in public discourse, but they refer to distinct material properties that have important implications for the environmental performance of dFAD designs. Appendix III compiles a glossary of terms used and discussed in the workshop.

A wide range of natural, organic materials has been proposed for bio-FAD construction, including plant-based fibers such as cotton (*Gossypium* spp.), abacá (Manila hemp, or *Musa textilis*), and cabuya or fique (*Furcraea* spp.) (Fig. 5). The performance of these materials depends strongly on their physical properties, particularly fiber quality, as well as on rope and canvas construction techniques and the type of attachments and design configurations used in dFAD assembly. The characteristics of ropes (e.g., twisted versus braided structures, number of yarns, presence or absence of a core) are especially critical factors to consider when designing effective bio-FADs.

Figure 5. Abacá (Manila hemp; Musa textilis*) fibers grown locally in Ecuador for the production of ropes and canvas in biodegradable dFAD construction. Photo: G. Moreno.*

Recently, the fishing industry has increasingly explored bioplastics as an alternative to traditional organic materials. Bioplastics are generally defined as plastic materials (polymers) that are either bio-based, biodegradable, or both (European Bioplastics, 2022). A material described as bio-based is derived wholly or partially from biological resources such as plant biomass; however, bio-based materials are not necessarily biodegradable or marine biodegradable. Conversely, materials described as biodegradable are not necessarily bio-based, since some synthetic polymers may also biodegrade under specific environmental conditions (Zimmermann et al., 2020; Cheng et al., 2022; Lavagnolo et al., 2024).

Biodegradation of plastics is generally understood as a two-stage process involving polymer breakdown followed by microbial assimilation (SAPEA, 2020; European Union, 2020). In the first stage, polymer macromolecules are fragmented into smaller organic compounds through abiotic and/or enzymatic reactions. In the second stage, microorganisms assimilate these low-molecular-weight compounds and convert them into carbon dioxide under aerobic conditions, or into carbon dioxide and methane under anaerobic conditions, together with inorganic compounds and microbial biomass (SAPEA, 2020; Lavagnolo et al., 2024). This final microbial assimilation is considered the ultimate endpoint of biodegradation.

Within the broader category of biodegradable plastics, compostable materials represent a distinct subset. These materials are specifically designed to biodegrade under controlled composting conditions and are typically certified for either industrial or home composting systems (European Union, 2020; Ghasemlou et al., 2024). However, certification for compostability does not imply that a material will also biodegrade in natural environments such as the open ocean, where temperature, oxygen availability, light exposure, and microbial communities differ substantially from those used in standardized composting tests (European Union, 2020, 2022; Lavagnolo et al., 2024). Therefore, the presence of a compostability label should not be interpreted as evidence of marine biodegradability.

Some flotation components used in dFAD rafts are made from compostable bioplastics (e.g., PLA). In practice, however, these materials would need to be recovered and transported to an appropriate composting facility in order to degrade as intended (European Union, 2022). This represents a major limitation in the context of dFAD fisheries, where retrieval is logistically difficult, particularly in distant fishing grounds, and where a large proportion of deployed dFADs are ultimately lost, abandoned, or discarded. Even when retrieval programs are in place, access to suitable composting infrastructure is often limited, as many recovery operations occur in remote island locations far from industrial composting facilities. Under such circumstances, the environmental benefit of compostable plastics may be significantly reduced if end-of-life management cannot be guaranteed.

The use of bioplastics in bio-FAD construction also introduces important challenges related to the verification of biodegradability. Unverified claims that a material is “biodegradable” may undermine confidence in the environmental benefits of bio-FAD designs, particularly because current testing frameworks for marine biodegradation still present important limitations (Filiciotto and Rothenberg, 2021; Briassoulis et al., 2024; Lavagnolo et al., 2024). Many existing standards rely on indirect indicators of degradation, such as CO_2 evolution, oxygen demand, or reductions in total or dissolved organic carbon, rather than direct quantification of polymer-derived carbon incorporation into microbial biomass (Cheng et al., 2022; Lavagnolo et al., 2024). In addition, current standards are often designed for small or thin test materials and may not adequately represent the behavior of thicker or more complex plastic components used in practical applications such as FADs (Briassoulis et al., 2024; Lavagnolo et al., 2024).

These limitations are compounded by the strong spatial and temporal variability of marine environments, which can substantially affect degradation rates. As a result, materials certified as biodegradable under one set of conditions may not degrade as expected in other marine compartments, such as deeper waters or the seabed (Benito-Kaesbach et al., 2025). Furthermore, concerns about chemical safety remain relevant, as some bioplastics currently on the market have been shown to contain chemicals with toxicity profiles comparable to those of conventional plastics (Zimmermann et al., 2020). For these reasons, reliable certification schemes, transparent traceability, and testing under environmentally relevant marine conditions are essential to ensure that materials used in dFAD construction are consistent with the environmental objectives of the transition toward bio-FADs. A clear understanding of the distinctions between bio-based, biodegradable, and compostable materials, in marine conditions, is therefore essential for ensuring that the transition toward bio-FADs results in meaningful environmental improvements. Establishing consistent definitions, testing standards, and certification procedures will be critical for supporting both regulatory frameworks, monitoring and compliance, and industry adoption of biodegradable FAD technologies.

6. Stakeholder Views on Biodegradable Materials for Bio-FADs

A group exercise was conducted to examine key questions related to the selection and use of biodegradable materials in bio-FAD construction. Participants were divided into four groups, mixing stakeholders, and asked to discuss six questions addressing: (i) the main sources of confusion in material selection, (ii) the most appropriate materials for use in dFADs, (iii) the adequacy of the current definition of a bio-FAD adopted by tuna RFMOs (see previous section), (iv) the criteria that should guide material selection, (v) the materials tested so far, and (vi) the relative cost of conventional and biodegradable FADs. The exercise was designed to capture practical and technical perspectives from participants with different regional and operational experiences, and to identify areas of agreement, uncertainty, and priority for future work.

1. What are the main sources of confusion when selecting a biodegradable material?

The four groups agreed that there is still substantial uncertainty surrounding the selection of biodegradable materials. *Group 1* highlighted the lack of technical specifications when purchasing materials, noting that key information such as material composition, percentage of components, place of manufacturer, and certification status is often unavailable. This group also pointed out that current regulations do not require technical specification sheets or documentation of certification tests. *Group 2* emphasized the limited knowledge currently available on bioplastics and their potential use in bio-FADs and called for clearer definitions. *Group 3* focused on conceptual confusion, particularly the distinction between degradable and biodegradable, and also noted the need for more information on bio-based materials. *Group 4* raised questions about the meaning of "bio-based," who is responsible for certifying materials, and whether certification should apply to each component individually or to the complete dFAD structure. Overall, the discussion showed that uncertainty arises both from incomplete technical information and from a lack of conceptual clarity.

2. Which biodegradable materials are most appropriate for use in dFADs?

The groups broadly agreed that natural, plant-based materials are the most appropriate candidates for bio-FAD construction, although some groups also recognized a limited role for bioplastics. *Group 1* considered the most suitable materials to be those of plant-based and local origin, sustainably harvested, available in large quantities, competitively priced, and sufficiently durable to allow the dFAD to remain operational. This group accepted a potential use of bioplastics only for attachments and for flotation buoys, provided that their use helps ensure that bio-FADs are not sinking or lost at sea. *Group 2* identified bamboo, cotton, and lyocell[3] as the most proven and

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[3] Lyocell is a regenerated cellulosic fibre produced from dissolved cellulose pulp, typically derived from wood, using a solvent-spinning process.

suitable materials, while considering jute, coconut fiber, natural cork, and albizia[4] as tested but less satisfactory options. *Group 3* simply emphasized organic materials as the preferred option. *Group 4* pointed to the need for materials that are durable, economically viable, organic, and environmentally friendly, while also mentioning both natural materials and bioplastics. In general, the exercise revealed a strong preference for natural plant-based materials, provided they meet operational requirements, especially durability.

3. Is the current definition of a “biodegradable FAD” sufficient and accurate?

The responses to this question revealed some divergence among groups. *Group 1* considered that the current definition is, for the time being, broadly sufficient, but noted that some aspects should be clarified, such as whether ballast materials like iron, sand, rocks, or concrete are allowed, and whether the time required for biodegradation should be explicitly included in the definition. *Group 2* stated that the definition needs clarification. *Group 3* considered the current definition insufficient and argued that it should be more precise. In contrast, *Group 4* considered the current definition adequate. Taken together, these responses suggest that although the current definition may be seen as workable by some participants, there is still a clear demand for greater precision, particularly regarding acceptable materials, certification, and the temporal dimension of biodegradation.

4. List of criteria for selecting a biodegradable material: What should it be like?

All groups identified durability and cost as central criteria for biodegradable material selection, although additional requirements were also mentioned. *Group 1* emphasized the importance of having a technical specification sheet for any candidate material and considered cost a very important factor. *Group 2* identified durability, cost, and tuna aggregation capacity as the main criteria. *Group 3* provided the most detailed list, stating that materials should be durable, cost-effective, efficient, provide appropriate floatability, have a known composition, and be certified. *Group 4* emphasized durability, availability, affordability, and a reasonable target price for the final dFAD. Overall, the exercise showed that the ideal material is expected to combine verified environmental credentials with operational performance, i.e., durability, affordability, and availability.

5. Inventory of materials tested so far

The inventory compiled by the groups confirms that a wide range of organic and bio-based materials has already been tested in different components of bio-FADs. *Group 1* listed plant-based materials such as manila hemp (abacá), jute, cotton, and natural rubber, together with bamboo canes, balsa wood, paulownia wood, and the bio-based compostable, PBS (polybutylene succinate) flotation product Zunfloat. *Group 2* distinguished between materials that were considered proven and good — bamboo, cotton, and lyocell — and others that had been tested but gave poorer

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[4] Albizia is a genus of tropical and subtropical trees and shrubs belonging to the family Fabaceae. Several species are fast-growing and are used for timber, fuelwood, shade, fodder, or ornamental purpose.

results, including jute, coconut fiber, natural cork, and albizia. *Group 3* organized materials according to FAD component: for flotation, paulownia, bamboo, balsa and bio-based buoys; for the raft and submerged component of the dFAD, cotton canvas, cotton ropes, manila hemp, jute, and lyocell; and for ballast, stones, sand, clay, and bricks. *Group 4* provided the broadest inventory, including paulownia, pine, balsa, bamboo, rattan, cotton, raffia, palm fronds, hemp, coir, jute, sisal, and coconut leaves. Altogether, the exercise highlighted the extensive experimentation already conducted and underway.

6. Cost of conventional FADs and bio-FADs

All groups recognized cost as a major issue in the transition to bio-FADs, although their assessments differed somewhat depending on region and assumptions. *Group 1* considered that conventional and bio-FADs have a similar cost; however, they mentioned that factors such as productivity, durability, and reusability should be taken into account in the overall cost. *Group 2* provided specific estimates, indicating that conventional dFADs cost around USD 150–180 in France and about USD 350 in the Pacific Ocean, whereas bio-FADs in Europe cost around USD 600. They also emphasized the importance of purchasing materials in large quantities, potentially through joint procurement by several fleet companies, in order to obtain more competitive prices. *Group 3* estimated the cost of conventional FADs at around USD 200 for materials only, excluding construction, while bio-FADs, including both materials and construction, were estimated at around USD 450. *Group 4* stated more generally that, for the same design, bio-FADs are always more expensive than traditional plastic-based dFADs, suggesting a preferred cost range of around USD 200–300, while also noting that conventional FADs in Korea can exceed USD 500. Overall, the exercise confirmed that bio-FADs are generally perceived as more expensive than conventional dFADs, except for one group. Taken together, the costs mentioned during the workshop suggest an approximate range of USD 200-600 for bio-FADs and USD150 to more than USD500 for conventional dFADs, depending on the fleet, region and design.

Overall, the group exercise showed broad agreement that material selection remains one of the main challenges in the transition toward bio-FADs. Across all questions, participants repeatedly emphasized the need for better technical documentation, and more robust certification systems for biodegradable and bio-based materials. Organic, plant-based materials were generally considered the most appropriate option, although their suitability depends strongly on durability and availability.

While some participants viewed the current definition of a bio-FAD as broadly acceptable, most groups identified important areas requiring clarification, particularly with regard to some ballast materials such as iron, and certification requirements. Durability and cost emerged as the most important criteria for selecting materials, and the inventory of tested materials demonstrated substantial experimentation. Finally, the exercise confirmed that bio-FADs are generally considered more expensive than conventional ones, which remains a significant barrier to wider implementation. Overall, the discussion highlighted that further progress would depend not only on material innovation, but also on greater conceptual clarity, better documentation regarding material´s specifications, and a more consistent framework for evaluating material suitability in bio-FAD construction.

7. Sea Trials of Biodegradable Drifting Fish Aggregating Devices

In recent years, several experimental programs have been conducted across the Indian, Atlantic, and Pacific oceans to evaluate the operational performance of bio-FADs under commercial fishing conditions. These initiatives involve collaborations between research institutions, fishing companies, and non-governmental organizations, with the objective of assessing whether biodegradable designs can maintain the functionality of conventional dFADs while reducing their environmental impact.

In this workshop, only the most recent and ongoing bio-FAD projects are presented (see Appendix IV for the summary table of the trials), since earlier initiatives, including the large-scale bio-FAD trial in the Indian Ocean, were already covered during the first International Bio-FAD Workshop. Other ongoing trials are not included here because deployments had not yet started at the time of the workshop. These initiatives will be considered in future bio-FAD workshops once results become available.

Trials in the Western and Central Pacific Ocean

In the WCPO, ongoing trials led by the Pacific Community (SPC) in collaboration with ISSF are being conducted involving five fleets and more than 56 vessels, with paired deployments of conventional and biodegradable designs to compare performance under real fishing conditions. A total of 665 jelly-FADs (Fig. 6) were planned, of which 444 had already been deployed at the time of the workshop.

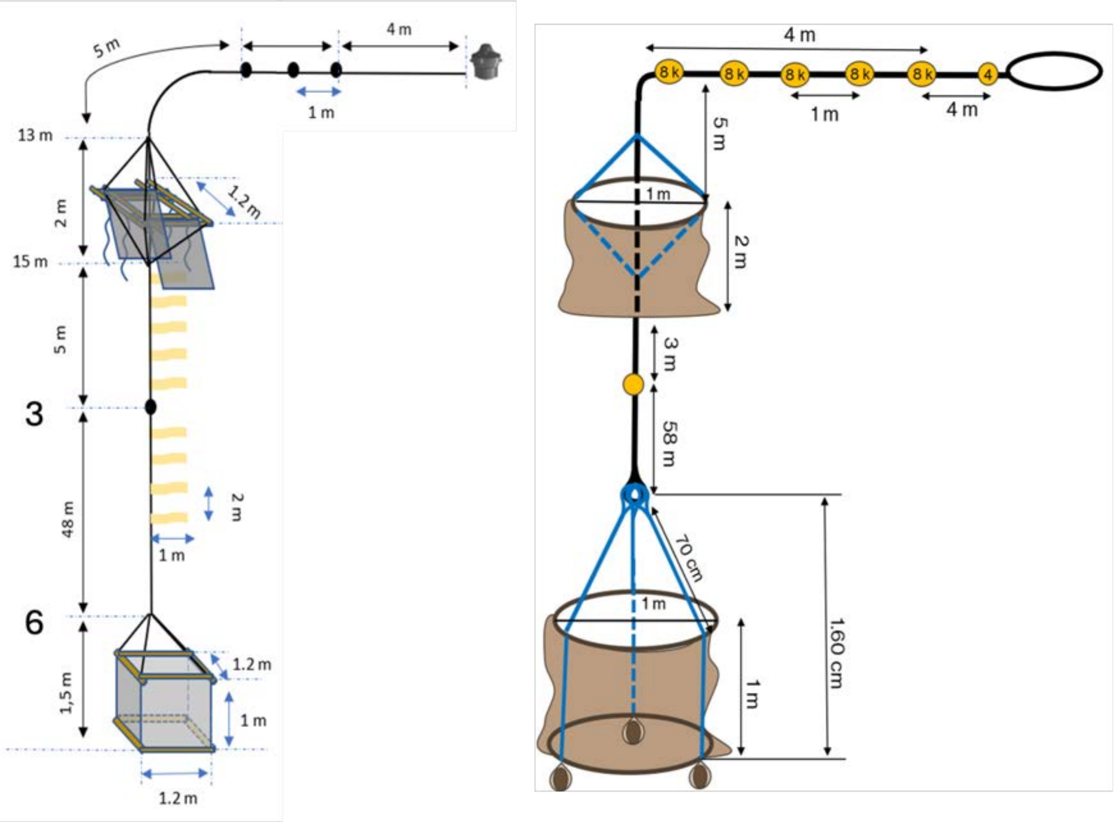


Figure 6. Schematic representation of two jelly-FAD designs: the cubic version on the left and the cylindrical version on the right. The cylindrical design is the most recent prototype and was developed to be lighter, less expensive, and easier to retrieve, as well as to further reduce the environmental impact of the dFAD.

The jelly-FAD is intended to reduce the structural stress experienced by conventional dFADs and thereby improve the performance of biodegradable materials at sea. The concept is based on quasi-neutral buoyancy, a symmetrical three-dimensional drogue to reduce the drift speed, and a flexible structure designed to maintain slow drift and the shading effect considered important for tuna aggregation. These trials showed that drift speed was similar between conventional and jelly-FADs, suggesting that the biodegradable design can behave comparably to conventional devices in the water. Tuna aggregation patterns were also broadly similar, with a peak in aggregation about one month after deployment (Fig. 7).

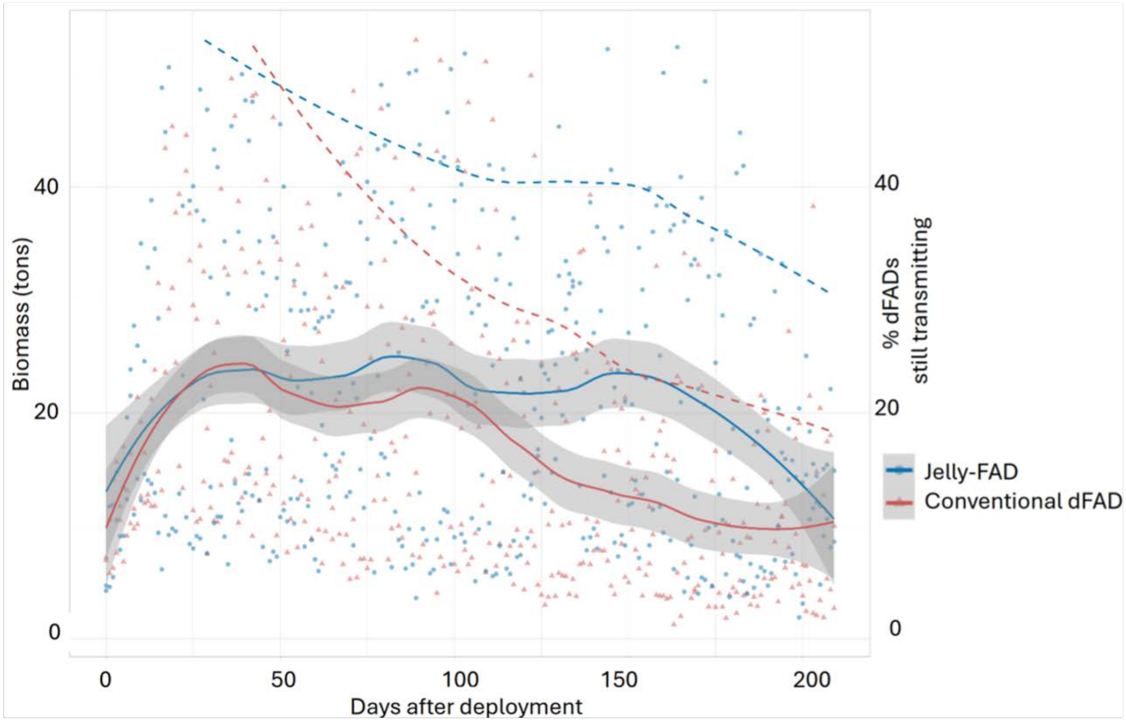


Figure 7. Tuna biomass aggregation patterns from deployment to 200 days at sea, based on data from the echosounder buoys used to track both dFAD types. Dotted lines indicate the number of dFADs transmitting information, while continuous lines represent the estimated biomass aggregated beneath the dFADs. Conventional dFADs are shown in red and jelly-FADs in blue.

Although conventional dFADs recorded a higher median catch per set (42.5 mt, n=58) than jelly-FADs (35 mt, n=20) in this trial, the median catch on jelly-FADs was still above the 2023 fleet-wide average median (30 mt, n=13322). This indicates that jelly-FAD catch performance was broadly comparable to that of the overall fleet in the WCPFC. In addition, no differences were found between jelly-FADs and the paired conventional dFADs in either catch performance or drift speed. In terms of durability, monitored bio-FADs appeared to remain functional and in usable condition for at least six months, although data beyond that point were limited.

Korean fleets in the WCPO are currently testing several bio-FAD designs. Although no specific trial was presented during the workshop with associated results, detailed information was provided on the two types of bio-FADs being tested, as summarized below (Fig. 8; Fig. 9).

Figure 8. Bio-FAD used by Korean fleets, curtain-type dFAD made of bamboo, cotton rope, coir rope, and coir canvas, with chain as weight.

Figure 9. Bio-FAD used by Korean fleets, curtain-type dFAD made of bamboo, cotton rope, coir rope, and cotton canvas, with chain as weight.

The main differences between the two models presented by the Korean FAD manufacturers at the workshop were the type of canvas used, and the greater number of attractors distributed along the line in the second design. In Figure 6, the canvas is made of coir (coconut fiber), whereas in Figure 7 it is made of cotton. Both designs are relatively sophisticated, with a curtain-type underwater structure incorporating multiple details and attractor elements made of coir. This level of complexity suggests that their construction may require considerable time, effort, and manual labor and would *need to be done on shore.*

Trials in the Eastern Pacific Ocean

In the EPO, the IATTC presented results from trials evaluating three prototype bio-FAD designs (Fig. 10). In total, 780 biodegradable dFADs were deployed alongside 764 conventional dFADs used as controls.

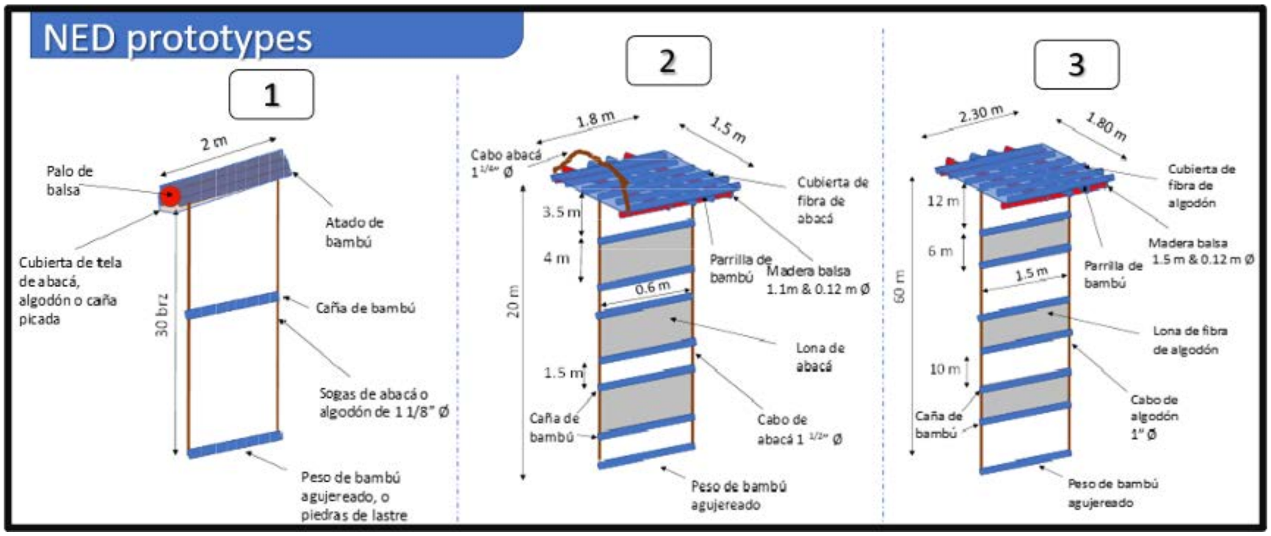


Figure 10. Three different bio-FAD designs used in IATTC-EPO trials — the curtain-type dFADs, conventional dFAD designs made with organic materials.

The mean catch per set was 33.6 mt for bio-FADs and 31.7 mt for conventional dFADs (Table 3), with no statistically significant difference between the two. These findings are consistent with those of Ovando et al. (2025), who found that, on average, bio-FADs did not yield statistically significant lower lifetime catches for any tuna species or for total catch. The biodegradable components of prototypes 1 and 2 remained in good condition for more than two months adrift, while prototype 3 remained in acceptable condition for at least two months. Importantly, the prototypes did not perform worse than the control dFADs during the monitored period; if anything, the non-entangling biodegradable prototypes showed a slightly higher mean catch per set than the paired controls. However, the observed lifespans of these prototypes are still insufficient for most fishers in the EPO. Fishers operating closer to the American continent generally require FADs to remain operational for at least three to four months, whereas those fishing farther west, toward the western Pacific, typically require even longer-lasting dFADs with a six-to-12-month lifespan.

Table 3. Interactions with bio-FAD prototypes and control, conventional dFADs

Experimental FAD	Deployed	Visits	Sets	Catch (mt)	Catch per set (mt)
Prot. 1	114	5	8	488	61
Prot. 2	395	74	46	1342	29.2
Prot. 3	271	7	3	88	29.3
Total bio-FADs	**780**	**86**	**57**	**1918**	**33.6**
Control pair	764	112	145	4599	31.7

In the EPO, jelly-FAD trials led by ISSF in collaboration with the Ugavi fleet were also developed in response to the limited lifespan of earlier bio-FAD designs. The jelly-FAD (Fig. 11) was conceived to reduce the structural stress typically experienced by conventional dFADs, thereby improving the performance of biodegradable materials at sea and extending device lifespan. In these trials, the Ugavi fleet tested two jelly-FAD configurations: a fully biodegradable design, except for the flotation component, and a hybrid design in which the central main rope was made of plastic while the remainder of the structure was biodegradable, excluding the flotation buoys.

Figure 11. Jelly-FAD design with a cubic drogue. Photo: G. Moreno

Sea trials in the EPO showed that jelly-FADs achieved soaking times broadly comparable to those of conventional dFADs (Table 4), with mean values of 122–132 days for the jelly-FAD designs and

106 days for conventional dFADs. Mean catch per set was slightly higher for jelly-FADs (38.5–40.2 t) than for conventional dFADs (35.9 t).

Overall, these results suggest that both the fully biodegradable and hybrid jelly-FAD designs performed at least as well as conventional dFADs in terms of soaking time and catch. According to the trial results, jelly-FADs showed drift behavior similar to that of conventional dFADs. Observations on component condition indicated that the main cotton rope was not subject to major stress: It was found in good condition in FADs at sea after 12 months, supporting the underlying design concept, by which the lack of stress increases the lifespan. The cotton canvas was found in bad condition in the beginning of the trials for most of the dFADs; however, fleet managers found a more resistant canvas that performed well later on. At the same time, the trials highlighted that the correct adjustment of weights and added components is critical to prevent sinking and ensure proper performance. It is also worth noting that shipowners and fishers made a lot of effort to improve and control the jelly-FAD construction. Overall, the results suggest that the jelly-FAD is a promising design for the transition to bio-FADs.

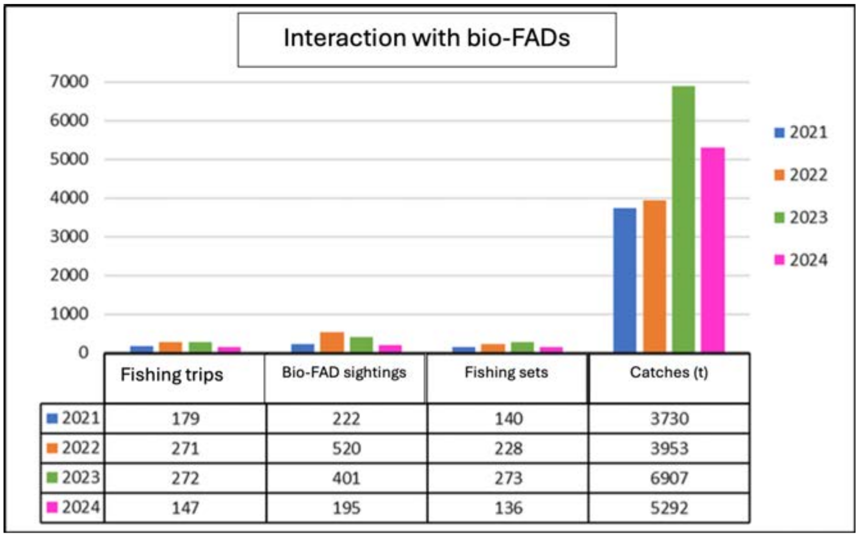
Table 4. Soaking time and catch of the jelly-FADs and control, conventional pairs

		Soaking Time (days)			Catch (tons)		
FAD Prototype	**N**	**min**	**mean**	**max**	**min**	**mean**	**max**
JellyFAD organic (CAT II)	34	37	132	335	0	38,5	125
JellyFAD hybrid (Cat IV)	36	33	113	238	0	40,2	120
JellyFAD total	**70**	**33**	**122**	**335**	**0**	**39,4**	**125**
Conventional	**46**	**28**	**106**	**267**	**0**	**35,9**	**265**

Another important trial in the EPO is that of Tunacons. The Tunacons fleet has made a substantial commitment to the testing of “eco-FADs” (the term used by the Tunacons fleet to refer to bio-FADs), with the companies aiming to construct 20% of its deployed dFADs using biodegradable materials. Tunacons uses curtain-type dFADs, made primarily with Manila hemp ropes and canvas, and bamboo for the raft. As shown in Figure 12, the number of eco-FAD visits has increased markedly in recent years, together with the number of sets made on bio-FADs. Unlike other experimental programs, this trial did not include a parallel monitoring scheme for conventional dFADs deployed by the fleet. Data for 2024 were still incomplete at the time of the workshop; therefore, the lower number of recorded interactions reflects incomplete reporting rather than an actual decline in activity.

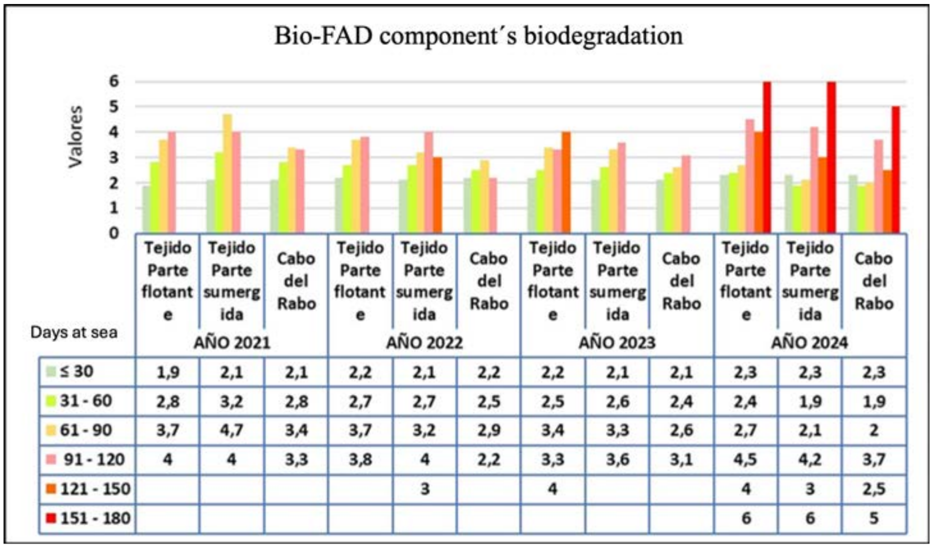
Figure 13 shows the progressive deterioration of the different components of the FAD structure as a function of time at sea (in days). The condition scale ranges from 1 = excellent to 6 = very poor, so higher values indicate greater degradation.

Overall, a clear pattern is observed across all years during the first 30–60 days; most values ranged from 1.9 to 3.2, indicating conditions from very good to good. Between 61 and 90 days, degradation became more evident, with several components reaching values between 3 and 4.7, particularly the submerged fabric panel. After 91–120 days, many components shifted into the fair to poor condition categories.



	Fishing trips	Bio-FAD sightings	Fishing sets	Catches (t)
2021	179	222	140	3730
2022	271	520	228	3953
2023	272	401	273	6907
2024	147	195	136	5292

Figure 12. Interaction with bio-FADs deployed by Tunacons fleets.



	AÑO 2021			AÑO 2022			AÑO 2023			AÑO 2024		
Days at sea	Tejido Parte flotante	Tejido Parte sumergida	Cabo del Rabo	Tejido Parte flotante	Tejido Parte sumergida	Cabo del Rabo	Tejido Parte flotante	Tejido Parte sumergida	Cabo del Rabo	Tejido Parte flotante	Tejido Parte sumergida	Cabo del Rabo
≤ 30	1,9	2,1	2,1	2,2	2,1	2,2	2,2	2,1	2,1	2,3	2,3	2,3
31 - 60	2,8	3,2	2,8	2,7	2,7	2,5	2,5	2,6	2,4	2,4	1,9	1,9
61 - 90	3,7	4,7	3,4	3,7	3,2	2,9	3,4	3,3	2,6	2,7	2,1	2
91 - 120	4	4	3,3	3,8	4	2,2	3,3	3,6	3,1	4,5	4,2	3,7
121 - 150					3		4			4	3	2,5
151 - 180										6	6	5

Figure 13. Condition of the main biodegradable components of Tunacons eco-FADs as a function of time at sea (days since deployment). Material condition was assessed using an ordinal scale from 1 (excellent) to 6 (very poor), showing progressive deterioration of the floating panel ("tejido parte flotante"), submerged panel ("tejido parte sumergida"), and tail rope ("cabo del rabo") with increasing soaking time.

The most severe deterioration was recorded in 2024, when the highest scores of the entire series were observed. In that year, both the fabric used for the raft and the submerged fabric panel reached a value of six between 151 and 180 days, corresponding to a very poor condition, while the tail rope reached a value of five. In contrast, during 2021–2023, most materials generally remained in good or fair condition up to around 90–120 days, although clear signs of degradation were already apparent beyond that period.

Overall, the Tunacons results indicate a progressive loss of structural integrity, particularly in the textile elements of the floating and submerged sections. Although the materials generally remained in acceptable condition during the first months after deployment, deterioration became much more pronounced thereafter. Taken together, these observations suggest that the bio-FADs begin to lose their operational effectiveness after approximately three to four months at sea.

Trials in the Indian Ocean

The large-scale Indian Ocean bio-FAD trial by French, Spanish and Korean fleets was not presented in this workshop, as it had already been discussed at the previous international bio-FAD workshop (Moreno et al., 2025; Murua et al., 2023). That trial, which involved the deployment of 771 bio-FADs under commercial fishing conditions, showed that bio-FADs performed similarly to conventional dFADs in terms of tuna presence, biomass aggregated beneath the FAD, and catch per set. Overall, prototypes in both bio-FAD and conventional dFAD treatments remained at sea for more than one year, although their degradation status was not assessed beyond six months. The cotton ropes used in the tail appeared to be a promising biodegradable alternative for the Indian Ocean. Conventional dFADs showed slightly faster initial colonization and higher biomass during the first month, but these differences were not statistically significant. Likewise, no significant differences in tuna catch were detected between dFAD types.

In 2026, the Echebastar and Albacora fleets will test three bio-FAD designs in the Indian Ocean. One of them is based on the conventional hanging-rope dFAD design commonly used in the Indian Ocean (see the central design in Figure 2), while the other two incorporate the jelly-FAD concept, but with a cylindrical drogue instead of a cubic one. The results of these trials will be available and presented at subsequent workshops.

Trials in the Atlantic Ocean

French, Spanish, and Ghanaian fleets are currently testing biodegradable dFADs in the Atlantic Ocean. Most of these devices retain the conventional curtain-type design but are constructed with organic materials. The Atlantic is considered one of the most challenging regions for the transition to bio-FADs, as fishers generally require deeper and more complex underwater structures to reduce drift speed and prevent dFADs from rapidly leaving the fishing grounds toward the western Atlantic. This greater structural complexity increases both the cost of bio-FAD construction and the mechanical stress experienced by the device at sea, which may in turn compromise the lifespan of biodegradable materials. Nevertheless, the fishing industry is making substantial efforts to identify materials and manufacturers capable of providing more durable biodegradable components.

Previous bio-FAD trials in the Atlantic have yielded limited results. Both the Ghanaian fleets (Figure 14) and the Spanish Opagac fleet deployed relatively small numbers of bio-FADs, around 150 units per fleet, including both jelly-FADs and curtain-type designs made of organic materials. In both cases, the proportion of in situ observations was very low, at approximately 4%, largely as a consequence of the limited number of experimental devices deployed. This low observation rate prevented scientists from drawing robust conclusions from the trials. The scarcity of observations reflects both the nature of dFAD fishing strategies — in which a proportion of deployed devices are lost, abandoned, or taken over by other fleets — and the tendency of vessels to prioritize visits to conventional dFADs over newly tested prototypes.

Figure 14. Curtain-type bio-FAD designs deployed by Ghanaian purse-seine fleets. Top left: design incorporating palm fronds; top right: design using recycled cocoa bean sacks; bottom: design using cotton canvas. Photo: Ben Ashigbui.

Overall, the trials presented during the workshop suggest that bio-FADs can achieve drift behavior and tuna aggregation patterns similar to those of conventional dFADs, while reducing long-term persistence and impact at sea. The main results indicate that the technology is already feasible at operational scale, but that design optimization is still needed, particularly to improve durability.

Designs based on new concepts, such as the jelly-FAD, are intended to reduce the mechanical stress experienced by the dFAD structure, thereby allowing biodegradable materials to remain functional for longer periods at sea. This design has proven to be as effective as conventional dFADs in terms of catch performance. Its main drawback is that it differs substantially from the designs traditionally used by fishing fleets, which may slow its adoption relative to biodegradable designs that more closely resemble conventional dFAD configurations.

The discussions during the workshop underscored the importance of rigorous construction protocols, quality control during manufacturing, and adequate training of fishers and fleet personnel to ensure that trial results are reliable and comparable across fleets and regions. They also emphasized that robust evaluation requires large sample sizes, given that only a small proportion of deployed dFADs, typically around 4–10%, whether conventional or biodegradable, are subsequently visited by vessels. In this context, the use of paired deployments with conventional control dFADs is especially valuable, as it allows a more rigorous comparison of performance under similar deployment areas, oceanographic conditions, and tuna presence. Taken together, these lessons provide a clear framework for improving future trials and for accelerating the refinement and implementation of effective bio-FAD designs.

8. Discussion

The discussion presented here places particular emphasis on material-related aspects, as these emerged as one of the most novel and technically unresolved themes of the workshop. In contrast, other topics, such as experimental design, trial implementation, and performance evaluation under fishing conditions, have already been examined in greater depth in previous bio-FAD workshops.

In particular, one of the most relevant issues addressed during this meeting was the evaluation of the term “biodegradable” itself, together with the emerging use of bioplastics as potential materials for bio-FAD construction. The discussions made clear that this topic still requires substantial clarification, particularly with regard to definitions, certification standards, environmental safety, and the actual behavior of these materials under marine conditions. Nevertheless, the workshop allowed several preliminary conclusions to be identified, including the following:

- *Organic materials should remain the primary focus for bio-FAD construction*. Priority should be given to organic materials, particularly plant-based fibers. These include materials such as cotton, abacá/Manila hemp, jute, sisal, coconut fiber, bamboo, balsa wood, and other locally available plant-based materials.

- *The bio-based origin of a material does not ensure environmental safety*. The fact that a material (plastic) is derived from biological resources does not necessarily imply that it will degrade in the marine environment. Many bio-based polymers have chemical structures similar to those of conventional plastics and may persist for long periods at sea, potentially contributing to marine debris and microplastic formation if dFADs are lost or abandoned.

- *Material transparency and chemical safety are critical considerations*. Some materials marketed as bioplastics may contain additives or chemical compounds with environmental or toxicological implications comparable to those found in conventional plastics. Clear identification of polymer composition, additives, test standards, and certification status is therefore essential to ensure credibility and environmental safety.

- *Marine biodegradability should be the primary criterion for material selection*. For dFAD applications, the relevant question is whether a material can biodegrade under realistic oceanic conditions. Materials that are considered biodegradable under industrial composting or terrestrial conditions may not break down effectively in marine environments, where temperature, oxygen levels, light availability, and microbial communities differ substantially. Certification for marine biodegradability should further develop in the framework of fisheries and FAD use.

- *Existing biodegradability standards present methodological limitations*. Current certification procedures generally infer biodegradation through indirect indicators such as carbon dioxide production, oxygen demand, or changes in organic carbon concentrations. These approaches do not directly measure the transformation of polymer carbon into microbial biomass, and many protocols are designed for small or thin samples rather than the thicker or composite materials commonly used in FAD structures.

- *A balance must be found between operational lifespan and environmental objectives*. Fishers require FADs to remain functional for a sufficient period to support fishing operations. As a result, industry has explored coatings and polymer-based materials that increase durability. However, increased resistance to degradation may conflict with the goal of minimizing environmental impacts when dFADs are lost at sea.

- *Improved traceability of materials used in dFAD construction is needed*. Establishing a structured inventory linking dFAD components with their material composition, manufacturers, and certification standards would enhance transparency and facilitate monitoring. Such a system would support fisheries management and help verify compliance with tuna RFMO bio-FAD requirements.

Given the current uncertainty surrounding the use of bioplastics and other emerging materials, organic materials should remain the priority for bio-FAD construction. One of the issues discussed during the workshop was the limited availability and relatively high cost of suitable organic materials. This concern is likely to become even more important as other land-based industries, as well as other fishing fleets, increasingly shift toward biodegradable alternatives to replace conventional plastics, thereby increasing competition for the same raw materials.

Several potential solutions were proposed during the workshop. One suggestion from the fleets was to coordinate purchases among several companies in order to obtain better prices through larger-volume procurement. Another, put forward by scientists and supported by some fishers, was to develop simpler and less voluminous dFAD designs, which would require smaller amounts of material and therefore help reduce costs further.

The workshop also highlighted that dFAD lifespan must be understood in terms of both operational and physical lifespan. While conventional dFADs can remain in the marine environment for years after they cease to be operational — i.e., drift out of the fishing grounds — bio-FADs offer clear potential to reduce long-term environmental impacts by shortening physical lifespan. However, this benefit must be balanced against the need to maintain sufficient operational lifespan for fishing activities, emphasizing the importance of continued design optimization. Increased dFAD repairs and collaboration among fleets may also promote extended lifespan of bio-FADs. Given IATTC' presentation at the workshop, it is also possible that the operational lifetime of bio-FADs may not differ substantially from that of conventional dFADs, at least in regions such as the EPO, where the observed operational life of conventional dFADs is already relatively short. At present, there are still insufficient data to accurately characterize either the operational or the physical lifespan of conventional dFADs as a robust reference against which to assess the potential effects of shorter lifespan of bio-FADs, on fishing operations. Nevertheless, the evidence currently available suggests that the operational availability of bio-FADs and conventional dFADs may, in practice, be more similar than previously assumed.

9. Conclusion

This report synthesizes the main outcomes of the workshop and highlights the substantial progress made in the transition toward bio-FADs across the tropical tuna purse-seine fisheries. The discussions and presentations showed that important advances have already been achieved in testing biodegradable materials, the refinement of dFAD designs, and the evaluation of their fishing performance under commercial conditions. At the same time, the workshop made clear that challenges remain, particularly with respect to bio-FAD durability, material availability, and cost.

The workshop also confirmed that no single design or material solution is likely to be universally applicable across all oceans and fleets. Bio-FAD development must consider regional differences in fishing strategies, oceanographic conditions, and fleet requirements. Nevertheless, some common lessons emerged clearly.

Bio-FADs can achieve fishing performance broadly comparable to that of conventional dFADs, but robust evaluation requires well-designed trials, large sample sizes (deployments), quality control during bio-FAD construction, and strong fleet involvement. In parallel, future progress will depend on improving the availability and performance of suitable biodegradable materials, simplifying designs where possible, and ensuring that the concept of biodegradability is supported by scientifically sound definitions and certification frameworks relevant to marine conditions.

A major strength of this workshop was that it provided a unique forum for fishers, fleet managers, scientists, and tuna RFMO representatives to assess the current state of progress directly from the fleets involved in these trials. This exchange of first-hand experience was particularly valuable because it allowed participants not only to review results, but also to understand the practical lessons behind them: which designs have shown promise, which approaches have failed, what operational constraints remain, and how fishers themselves perceive the feasibility of adoption.

In this sense, the workshop demonstrated that the transition toward bio-FADs is already underway, but that its success will depend on continued collaboration among fleets, scientists, manufacturers, and managers. Regular international workshops of this type are therefore essential, as they provide a structured mechanism to document progress, compare regional experiences, identify persistent barriers, reduce the risk of repeating unsuccessful approaches, and accelerate the transfer of practical knowledge across fleets and oceans.

As regulatory timelines for the adoption of bio-FADs approach, maintaining this collaborative and evidence-based process will be critical to ensure that the transition is both operationally feasible for fisheries and environmentally meaningful.

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Appendix I: List of Participants

Participant	Company	Country
Aitor Lekanda	Albacora	Spain
Ben Ashigbui	Fisheries Ghana / Thai Union	Ghana
Borja Rodriguez	Albacora	Spain
Bruce Han	Korea FAD Co LTD.	Korea
Damien Dugay	Sapmer	France
David Parreño	SFP	Spain
Emmanuel Chassot	IOTC	Seychelles
Gabriel Martinez de Pisson	Inpesca	Spain
Gala Moreno	ISSF	Spain / U.S.
Guillermo Morán	Tunacons	Ecuador
Hilario Murua	ISSF	Spain / U.S.
Iker Zudaire	AZTI	Spain
Illia Zaitsev	Inpesca	Spain
Iñigo San Millán	Echebastar	Spain
Jefferson Murua	AZTI	Spain
Jon Lartitegue	Inpesca	Spain
Jose Félix Intxausti	Inpesca	Spain
Josebe Echaide	Inpesca	Spain
Julien Mercier	CFTO	France
Kauko Ndyene	Inpesca	Spain
Lander Fano	Echebastar	Spain
Lauriane Escalle	The Pacific Community (SPC)	New Caledonia
Leire Arantzamendi	AZTI	Spain
Maitane Grande	AZTI	Spain
Marlon Roman	IATTC	U.S.
Mikel Monasterio	Echebastar	Spain
Pascal Landrein	Sapmer	France
Rosalie Crespin	Orthongel	France
Txabi Izokaitz San Pedro	Inpesca	Spain

Appendix II: Group Exercise Results on Conventional dFAD Types

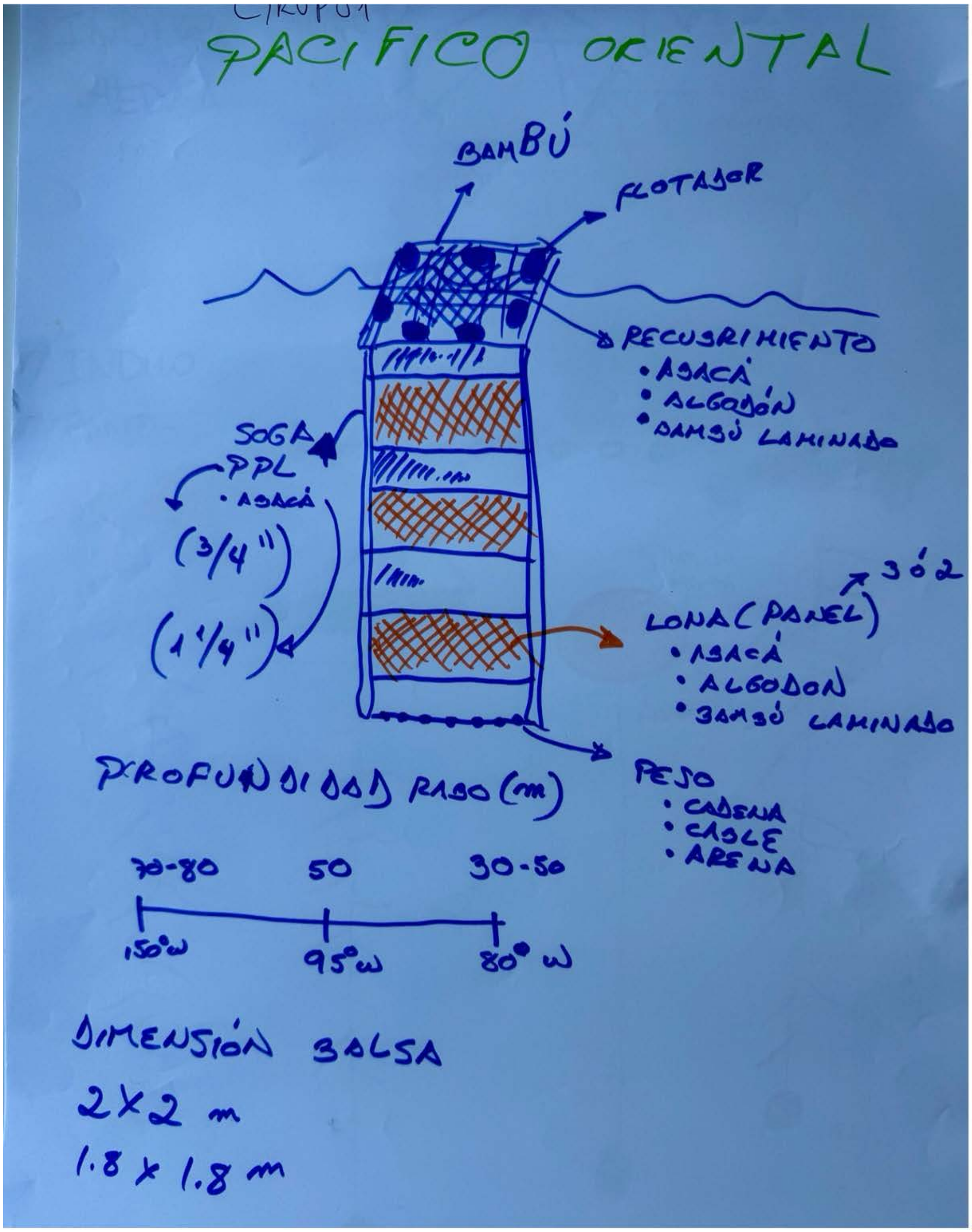


Figure A1. Curtain-like conventional dFAD used in the eastern Pacific Ocean (Group 1)

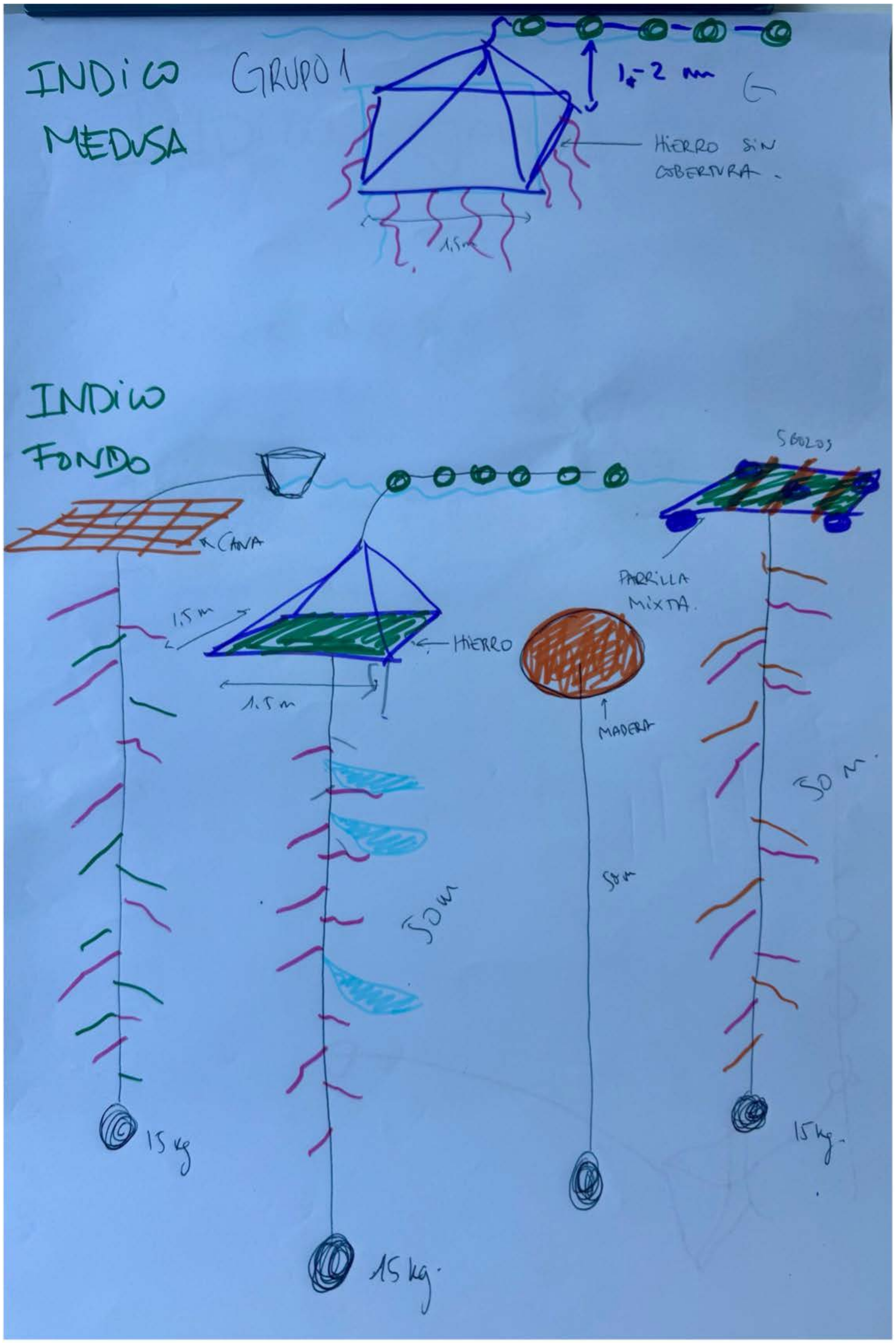


Figure A2. Conventional dFAD types used in the Indian Ocean, jelly-like (on top) and deeper dFADs with ropes (Group 1)

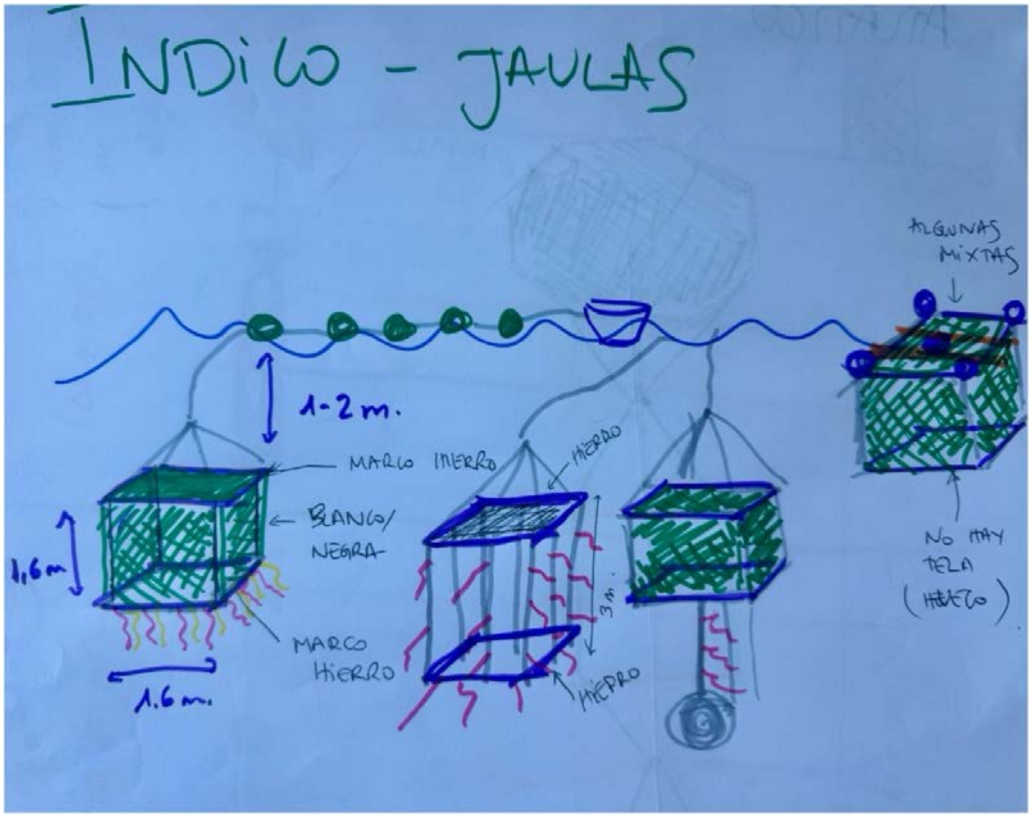


Figure A3. Cage-like conventional dFAD types used in the Indian Ocean (Group 1)

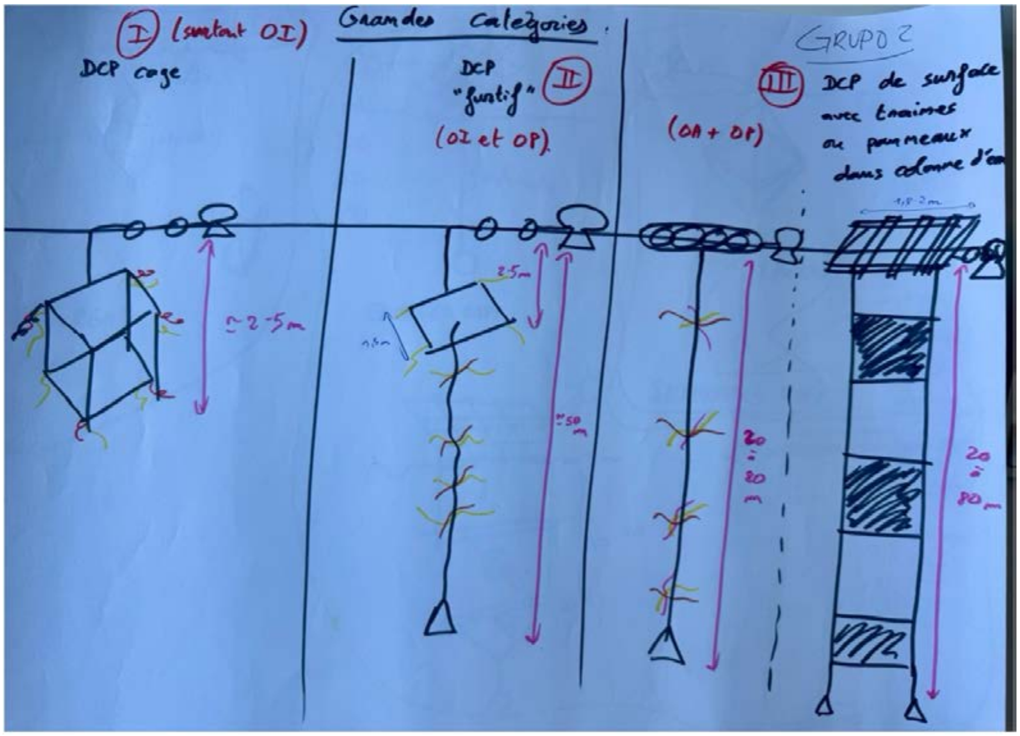


Figure A4. Conventional dFAD designs used in the Indian Ocean (left), in the Indian and Pacific Oceans (center), and in the Atlantic and Pacific Oceans (right) (Group 2).

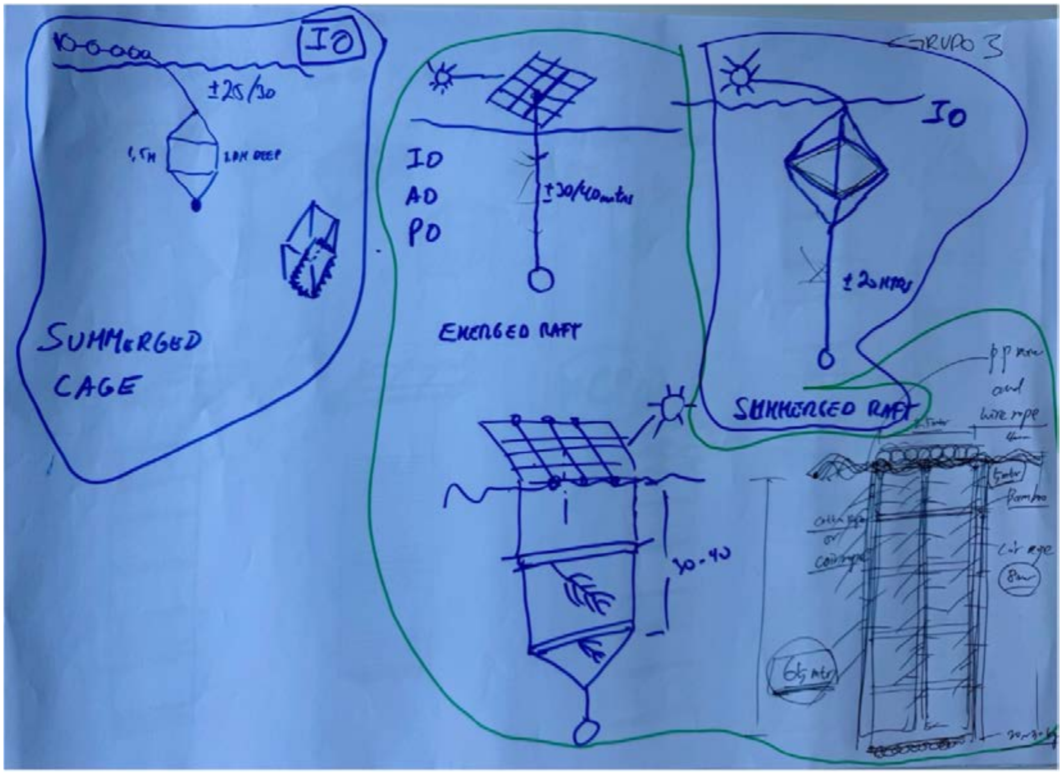


Figure A5. Conventional dFAD designs used in the Indian Ocean (left), in the Indian Atlantic and Pacific Oceans (center), and in Indian Ocean (top right) (Group 3).

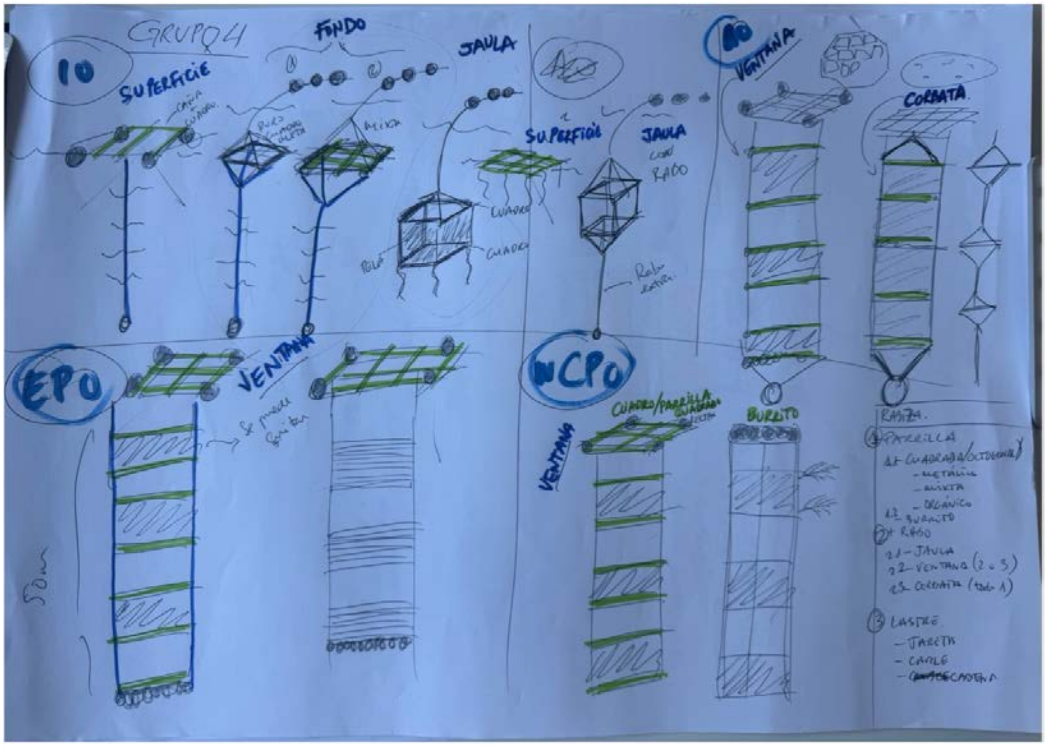


Figure A6. Conventional dFAD designs used in the Indian Ocean (top left), in the Atlantic Ocean (top right), eastern Pacific Ocean (bottom left), and in the western and central Pacific Ocean (bottom right) (Group 4).

Appendix III: Glossary of Key Terms

Polymer: A polymer is a material made of very large molecules (macromolecules) built from repeating smaller units called monomers. Polymers can be natural (e.g., cellulose, starch, natural rubber) or synthetic (e.g., polyethylene, polypropylene). Plastics — including bioplastics — are a class of polymeric materials engineered to deliver specific properties such as strength, flexibility, and durability.

Biodegradable: A material is biodegradable if naturally occurring microorganisms can break it down and convert its carbon into CO_2 (under aerobic conditions) or CO_2 and CH_4 (under anaerobic conditions), plus inorganic compounds and new microbial biomass. In practice, biodegradability must always be defined for a specific environment (marine, soil, compost, etc.) and a specified timeframe, because the same material can behave very differently under different conditions.

Bio-based (biobased): A bio-based material is produced wholly or partly from renewable biological resources (plants, algae, microorganisms, agricultural residues, etc.). The term refers to the origin of the feedstock (where the carbon comes from), not to what happens to the material in the environment. Importantly, bio-based does not necessarily mean biodegradable. Thus there are non-biodegradable bio-based materials.

Bioplastic: “Bioplastic” is an umbrella term for plastics that are bio-based (from biological sources), biodegradable, or both. This broad definition can be misleading because it includes materials with very different environmental fates: some are bio-based but not biodegradable, others are biodegradable but fossil-based, and some have both properties. For that reason, “bioplastic” should ideally be accompanied by clear information on polymer type, additives, and relevant biodegradability standards/certifications.

Biodeterioration: Biodeterioration refers to biological damage that changes a material’s properties (e.g., loss of strength, surface erosion, fragmentation) due to microbial activity, without necessarily achieving full mineralization (conversion of polymer carbon into CO_2/CH_4 and biomass). A plastic may show biodeterioration yet still persist as fragments if true biodegradation is incomplete.

Compostable: A compostable material is a subset of biodegradable materials designed to biodegrade under composting conditions, and to produce compost that is suitable for soil application. Compostability typically requires collection and treatment in appropriate composting systems and does not imply that the material will biodegrade effectively in the ocean.

Oxo-biodegradable plastic: A conventional plastic (typically polyethylene, polypropylene, or polystyrene) that contains pro-oxidant additives designed to promote abiotic oxidative degradation when exposed to heat, oxygen, and ultraviolet radiation. This process results primarily in fragmentation of the plastic into smaller pieces, including microplastics and potentially nanoplastics, rather than complete microbial mineralization. As a result, the final degradation products are persistent plastic fragments, not carbon dioxide, methane, water, or microbial biomass, and therefore oxo-biodegradable plastics do not meet true biodegradability.

Tuna RFMOs’ Biodegradable FAD definition: A biodegradable dFAD would be composed of non-netting form renewable lignocellulosic materials (i.e., plant dry matter — here described as natural material) and/or bio-based compounds that comply with international relevant standards or certification labels for plastic biodegradability in marine environments. In addition, the substances resulting from the degradation of these materials should not be toxic for the marine and coastal ecosystems or include heavy metals in their composition. This definition does not apply to electronic buoys attached to dFADs to track them.

Appendix IV: Summary of Bio-FAD Trials Discussed in Section 7

Ocean – Lead	Design(s) tested	Trial status / scale	Main findings	Limitations / next steps
WCPO – SPC + ISSF	Jelly-FADs (cubic and cylindrical) paired with conventional dFADs	Ongoing paired trial; 5 fleets, >56 vessels; 665 planned, 444 deployed at the time of the workshop	• Drift speed and tuna aggregation patterns were broadly similar to conventional dFADs. • No significant differences were found in catch performance or drift speed. • Median catch per set on jelly-FADs was 35 mt, lower than on paired conventional dFADs (42.5 mt), but still above the 2023 WCPFC fleet-wide median (30 mt). • Monitored bio-FADs appeared to remain functional for at least 6 months.	Observations beyond 6 months were limited. Greater effort needed to test more bio-FADs per fleet.
WCPO – Korean fleets	Two curtain-type bio-FADs using bamboo, cotton rope, coir rope, and either coir or cotton canvas	In development; no comparative dataset presented	• The two models differed mainly in the type of canvas used and the number of attractors. • Both designs were described as relatively sophisticated and labor-intensive to construct.	No performance results were presented during the workshop, so these designs should be described as currently being tested rather than evaluated.
EPO – IATTC	Three curtain-type bio-FAD prototypes made with organic materials, paired	Comparative trial; 780 biodegradable dFADs and 764	• Mean catch per set was 33.6 mt for bio-FADs and 31.7 mt for conventional dFADs,	Observed lifespans were still insufficient for most EPO fishers, who generally

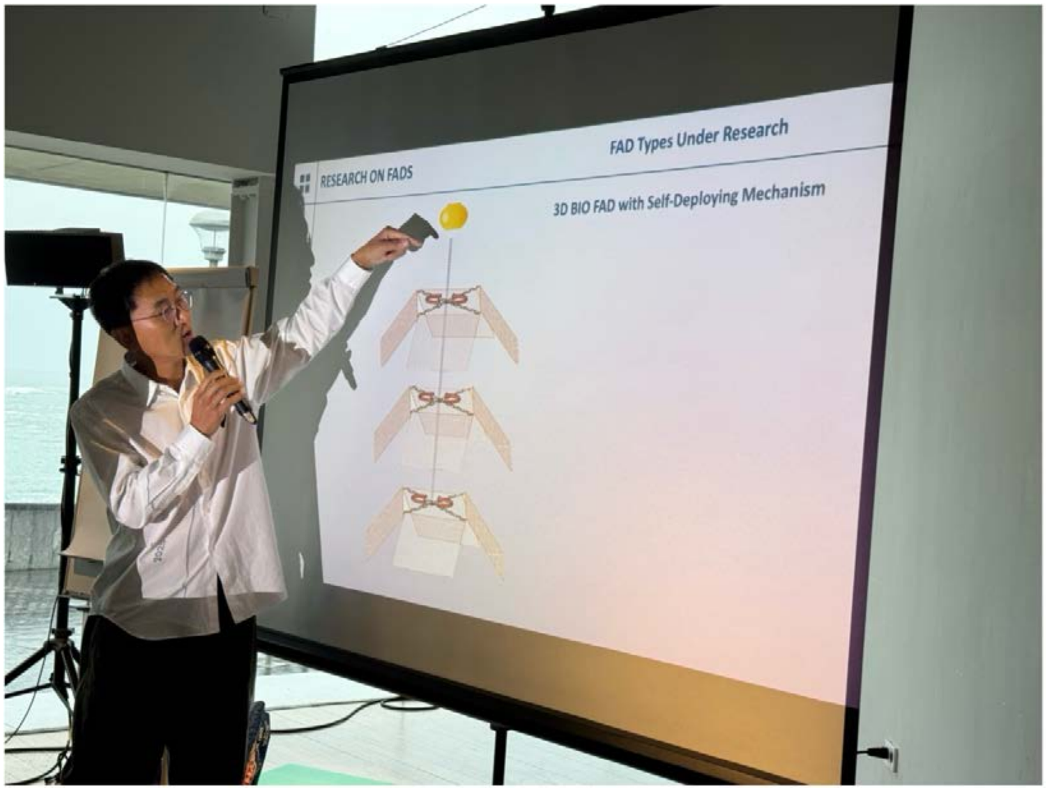
	with conventional controls	conventional controls	with no significant difference. • Prototypes 1 and 2 remained in good condition for more than 2 months drifting. • Prototype 3 remained in acceptable condition for at least 2 months.	need at least 3–4 months near the continent and longer farther west.
EPO – ISSF + Ugavi	Jelly-FADs: fully biodegradable except flotation, and a hybrid design with plastic main rope	Comparative paired trial	• Mean soaking times were 122–132 days for jelly-FADs vs 106 days for conventional dFADs. • Mean catch per set was slightly higher for jelly-FADs (38.5–40.2 t) than for conventional dFADs (35.9 t). • Drift behavior was similar for both conventional and bio-FADs. • The main cotton rope remained in good condition after 12 months in observed FADs. • Early cotton-canvas problems were later reduced by using a more resistant canvas.	Correct adjustment of weights and flotation was critical to avoid sinking and ensure good performance. The design appears promising; construction and quality control are key.
EPO – Tunacons	Eco-FADs: curtain-type bio-FADs made mainly with Manila hemp ropes and canvas and bamboo raft	Operational trial with Tunacons fleets deploying 20% of their FADs made of biodegradable materials; no parallel conventional control	• The number of visits and sets on bio-FADs increased over time. • Material condition data showed progressive deterioration, especially in textile components. • Materials generally remained acceptable	No conventional control dFADs were monitored in parallel. Deterioration became more pronounced after 90–120 days, suggesting loss of operational

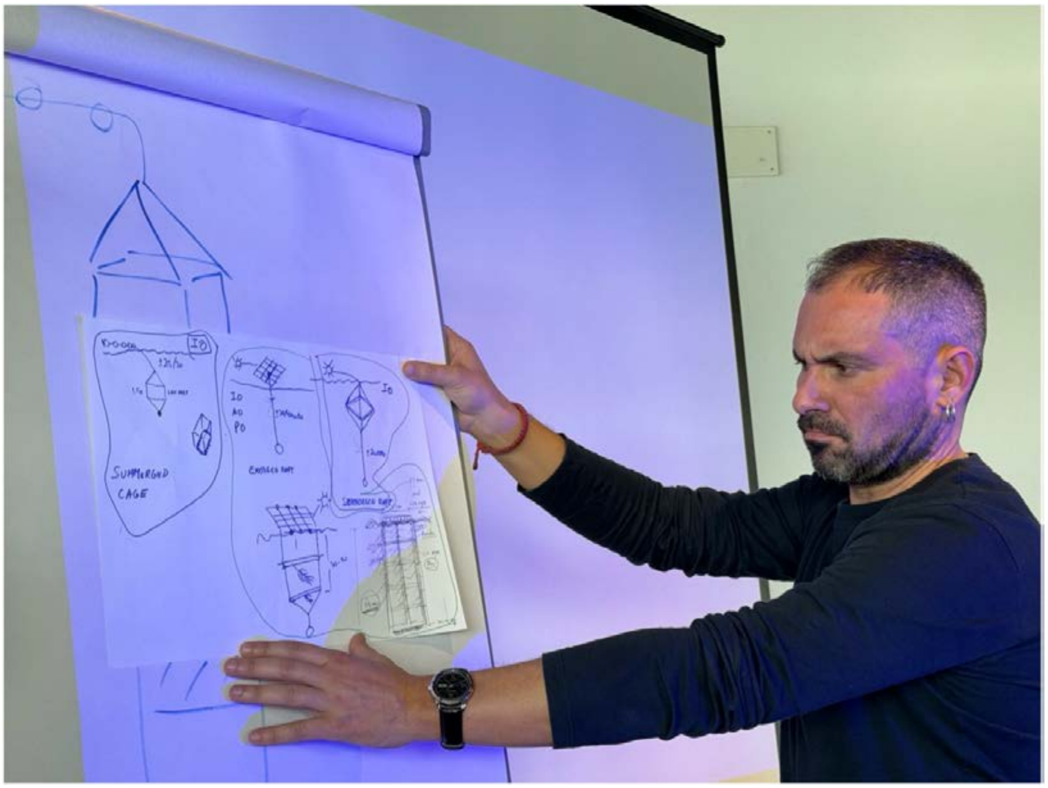
			during the first 3 months.	effectiveness after about 3–4 months.
Indian Ocean – earlier large-scale trial	Large-scale bio-FAD vs conventional dFAD comparison; cotton rope in tail highlighted as promising	Completed earlier trial, summarized here; 771 bio-FADs deployed	• Bio-FADs performed similarly to conventional dFADs in tuna presence, biomass beneath the FAD, and catch per set. • Cotton ropes in the tail appeared promising.	Degradation status was not assessed beyond 6 months, so long-term component durability remained insufficiently characterized.
Indian Ocean – Echebastar + Albacora	One bio-FAD based on the conventional hanging-rope Indian Ocean design, plus two cylindrical jelly-FAD variants	Future trial; 3 designs to be tested in 2026	The planned designs combine adaptation of a conventional Indian Ocean structure with lower-stress jelly-FAD concepts.	Results were not yet available at the time of the workshop and should therefore be presented only as upcoming work.
Atlantic – Ghanaian and Opagac fleets	Mainly curtain-type bio-FADs made with organic materials; some jelly-FADs also deployed	Early-stage / limited-evidence trials; around 150 bio-FADs in total; low *in situ* observation rate around 4%	Atlantic trials require deeper and more complex structures to reduce drift speed and prevent rapid loss from fishing grounds.	Observation rates were very low, preventing strong inference. More deployments and more in situ observations will be needed before performance can be assessed robustly.

Appendix V: Visual Documentation of the Workshop

(Photo credit: Gala Moreno and David Parreño)


MSC requirements on biodegradable FADs
SHARKS OF THE GALAPAGOS


RESEARCH ON FADS
FAD Types Under Research
3D BIO FAD with Self-Deploying Mechanism


IO
SUMMERGED
CAGE
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AO
PO
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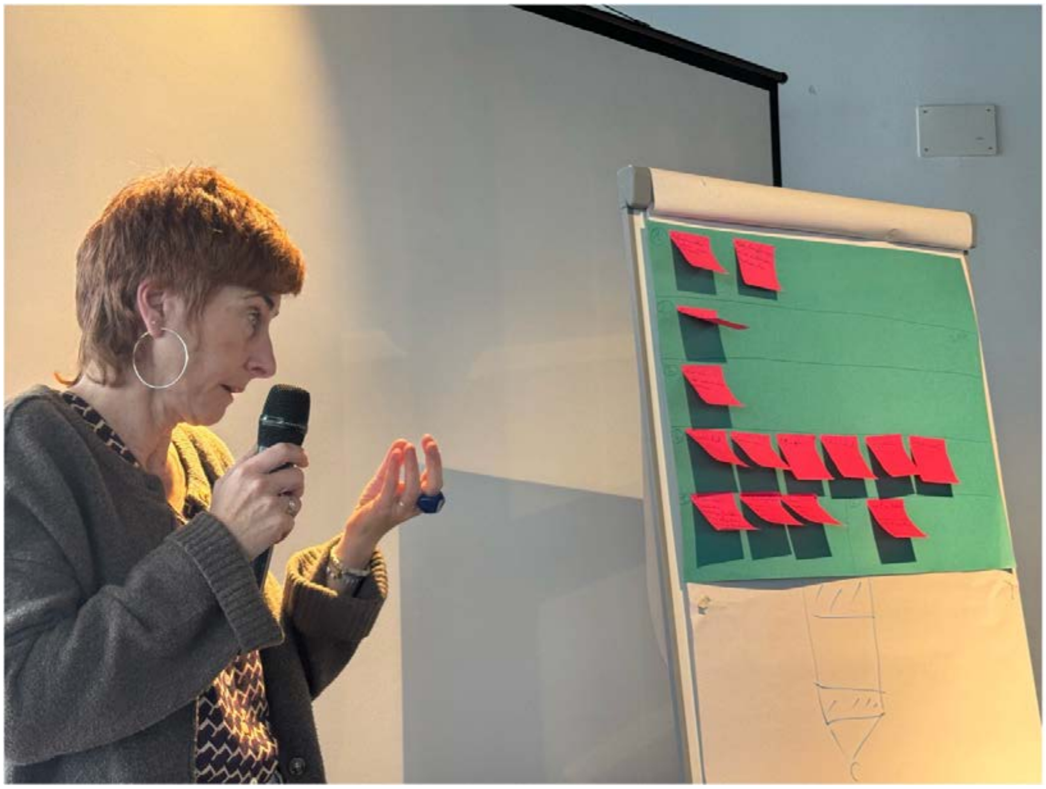
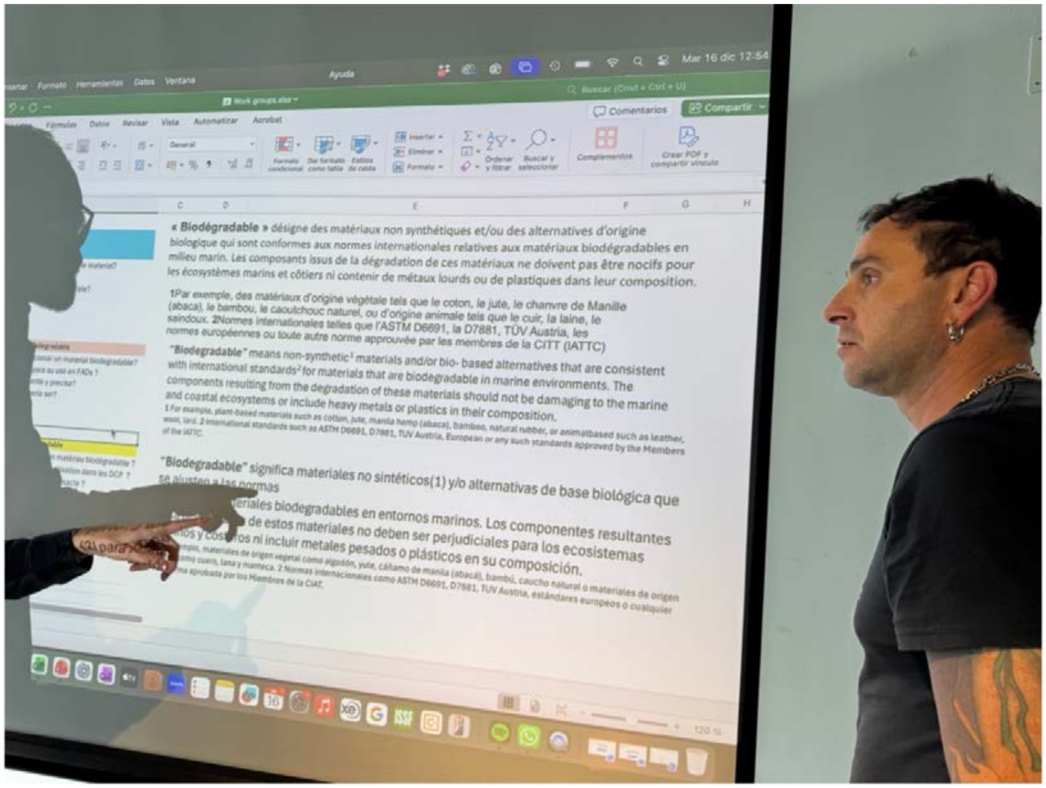
HEMP
COTTON
BAMBOO
CORK
JUTE


i ♥ paella




PESCA
SOSTENIBLE
PEZ ESPADA
ECUADOR
FIP



« **Biodégradable** » désigne des matériaux non synthétiques et/ou des alternatives d'origine biologique qui sont conformes aux normes internationales relatives aux matériaux biodégradables en milieu marin. Les composants issus de la dégradation de ces matériaux ne doivent pas être nocifs pour les écosystèmes marins et côtiers ni contenir de métaux lourds ou de plastiques dans leur composition.

1Par exemple, des matériaux d'origine végétale tels que le coton, le jute, le chanvre de Manille (abaca), le bambou, le caoutchouc naturel, ou d'origine animale tels que le cuir, la laine, le saindoux. 2Normes internationales telles que l'ASTM D6691, la D7881, TÜV Austria, les normes européennes ou toute autre norme approuvée par les membres de la CITT (IATTC)

"**Biodegradable**" means non-synthetic[1] materials and/or bio- based alternatives that are consistent with international standards[2] for materials that are biodegradable in marine environments. The components resulting from the degradation of these materials should not be damaging to the marine and coastal ecosystems or include heavy metals or plastics in their composition.

1 For example, plant-based materials such as cotton, jute, manila hemp (abaca), bamboo, natural rubber, or animalbased such as leather, wool, lard. 2 International standards such as ASTM D6691, D7881, TUV Austria, European or any such standards approved by the Members of the IATTC.

"**Biodegradable**" significa materiales no sintéticos(1) y/o alternativas de base biológica que se ajustan a las normas

eriales biodegradables en entornos marinos. Los componentes resultantes de estos materiales no deben ser perjudiciales para los ecosistemas nos y cos ros ni incluir metales pesados o plásticos en su composición.

mplo, materiales de origen vegetal como algodón, yute, cáñamo de manila (abacá), bambú, caucho natural o materiales de origen omo cuero, lana y manteca. 2 Normas internacionales como ASTM D6691, D7881, TUV Austria, estándares europeos o cualquier ma aprobada por los Miembros de la CIAT.

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