# The jelly-FAD: New results on its performance

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## Abstract

Fishers and scientists in the three tropical oceans are investigating different designs of biodegradable FADs (bio-FAD) efficient for fishing. The tactic followed by most fishers is to maintain the same conventional drifting FAD (dFAD) design (submerged netting panels hanging from the raft) but made of organic ropes and canvas (e.g., cotton, yute, abaca, etc.). Results of those experiences show that the lifetime of bio-FADs that maintain the conventional dFAD design but made of organic materials, is shorter than that required by most fishers. The short lifespan of those bio-FADs is due to the structural stress suffered by dFAD designs conventionally used. We present the Jelly-FAD, a new concept on bio-FAD design that mirroring jellyfish, drifts with quasi-neutral buoyancy, which reduces (i) the structural stress of the FAD at sea and (ii) the need for additional plastic flotation. The jelly-FAD is not necessarily a fixed design; it is more of a change in the concept of conventional dFAD construction. The present document aims at summarizing the trials by Ugavi fleet in the eastern Pacific Ocean (EPO), in which Jelly-FADs are being used successfully, aggregating tuna with average catches of 44.1 tons. Jelly-FADs drift with similar speeds as conventional dFADs do or slower. Average and maximum monitored lifespan were 5 and 11 months respectively. Note that the lifespan was inferred from the visits or sets done, some jelly-FADs were redeployed after the set, so those FADs could still be drifting at sea. Finally, recommendations to reduce the impact of dFAD structures on the ecosystem and for bio-FADs construction and use are provided. Although this project was conducted in the eastern Pacific Ocean, the methods, results and recommendations are useful for the fleets in the Indian Ocean.

# Background

This document provides updated information on the use of the Jelly-FAD, which is a specific design of a bio-FAD, by Ugavi fleet in the eastern Pacific Ocean (EPO) (see this video for more information on the Jelly-FAD). This year a larger amount of data and the comparison with the conventional FADs deployed together with the Jelly-FADs are presented. While this project was specifically carried out in the eastern Pacific Ocean, the methods, results, and recommendations derived from this study hold significant relevance for fleets operating in the Indian Ocean as well.

# 1. Introduction

Drifting Fish Aggregating Devices (dFADs), which are comprised by a surface raft and a submerged appendage, are most often made of plastic materials (nylon nets, buoys and polypropylene ropes). The submerged appendages are mostly made of netting material and can reach up to 80 m depth for some fleets in the Pacific Ocean. It is estimated that ~100,000 dFADs are deployed every year by fleets operating in the Indian, Atlantic and Pacific oceans (Gershman *et al*. 2015). Due to the complexity of dFAD fishing strategy, in which dFADs are left drifting with a geo-locating buoy, it is estimated that around 7% - 22% of these dFADs end up stranded (Maufroy et al., 2017; Moreno et al., 2018; Escalle et al., 2020; Imzilen et al. 2021). Impacts caused by lost and abandoned dFADs are ghost fishing (Filmater *et al*. 2013), accumulation of plastic at sea, damage on coral reefs and interference with other economic activities, such as tourism.

In the case of dFADs used by tuna fleets in the tropical zones of the Indian, Atlantic and Pacific oceans, the impact caused by their structure has triggered a response by coastal countries, by scientists and research institutes working on dFAD fishing, and by the fishing industry, conscious of impacts of lost and abandoned dFAD structures. A direct outcome are initiatives, both by the fishing sector and research institutes, to develop biodegradable FAD (bio-FAD) structures efficient for fishing for around one year. Currently, projects exist in the three oceans to test dFAD prototypes constructed mostly with biodegradable materials (Moreno et al., 2017; Zudaire et al., 2017; Moreno et al., 2018; Roman et al. 2020; Murua et al., 2023). But there are also numerous individual initiatives by fishing companies and captains that are trying to find alternatives to the plastic and netting used at dFADs. The present document aims at (i) presenting the results of the performance of Jelly-FADs in the EPO in comparison with the conventional dFADs, (ii) showing other initiatives in the EPO and other regions (iii) providing recommendations to reduce the impact of dFAD structures on the ecosystem.

# 2. The Jelly-FAD: a paradigm shift in bio-FAD design

FAD experts, physical oceanographers and fishers designed together the Jelly-FAD, a bio- FAD for which density is similar to that of seawater (Moreno et al., 2023). The design and neutral buoyancy of the Jelly-FAD allows the minimum torsion and shears forces on dFAD structure so that organic materials and thus the bio-FAD lasts longer. In addition, it decreases the need for floatation. A correct assessment of the weight and flotation is key for the dFAD to suffer the least structural stress and allow the tension of the line to be minimum, which would also avoid the drag created by waves. The flotation and emerged component of the bio-FAD should be the minimum necessary as to avoid surface drags created by wind and waves.

The Jelly-FAD is a dFAD that drifts with the least structural stress, like jellyfish do, its main features are (Figure 1):

i. Reduces dFAD´s structural stress so that the organic materials last longer.
ii. Reduces presently used large dFAD sizes.
iii. Reduces the need for flotation (plastic buoys).
iv. Eliminates netting.
v. Drifts slowly (one of the features fisher´s need for the FAD to be productive)
vi. Provides shade (another feature fisher´s need for the FAD to be productive)

# 3. Performance of the Jelly-FAD tested by Ugavi

## 3.1 Jelly-FAD design and materials tested

The fleet from Ugavi deployed more than 500 Jelly-FADs, starting in early 2021. This fleet has deployed the highest number of Jelly-FADs so far, that is why it allowed to gather more data and learn from the experience. Each time a Jelly-FAD was visited or fished, fishers sent a form on the activity performed (set or only visit, amount of tuna caught, position etc.) and the state of the different components of the Jelly-FAD, (i.e. good, destroyed, repaired etc.). The design of the Jelly-FAD tested is shown in Figure 2. It corresponds to *Category II* regarding the different bio-FAD categories to be considered in the gradual implementation process of the bio-FADs. These categories were defined in the recommendations of previous IATTC´s FAD working group.

*Category II* definition is: The *FAD is made of 100% biodegradable materials except for plastic-based flotation components (e.g., plastic buoys, foam, purse-seine corks). (This definition do not apply to electronic buoys attached to FADs to track them).*

The materials used for the different components were (from the deepest part to the surface):

- *Cube*: bamboo canes and cotton canvas of about 300-400 gr/m2.
- *Weight*: 7 kg recycled chain from the net.
- *Main rope* (connecting the cube with the emerged flotation): Cotton rope or polyethylene rope.
- *Submerged flotation*: plastic buoy of 5 kg.
- *Raft*: bamboo canes and cotton canvas.
- *Emerged flotation*: plastic buoy or recycled cork from the net (about 30 kg).

Because the use of bio-FADs is not mandatory, Ugavi fleet used polyethylene rope to substitute the cotton rope when cotton rope was not available or when fishers wanted to construct a Jelly-FAD at sea. To take into account the two different types of main ropes used (polypropylene and cotton), data analysis for lifespan was conducted separately.

For a proper evaluation of the experimental biodegradable dFADs, whenever possible, each of them was deployed in pairs alongside a conventional dFAD (built according to the model and material decided by the vessel involved at each trial) in a 1:1 ratio. To ensure experimental dFAD (biodegradable and conventional) traceability, both types were “marked” using associated echo sounder buoy unique identification codes.

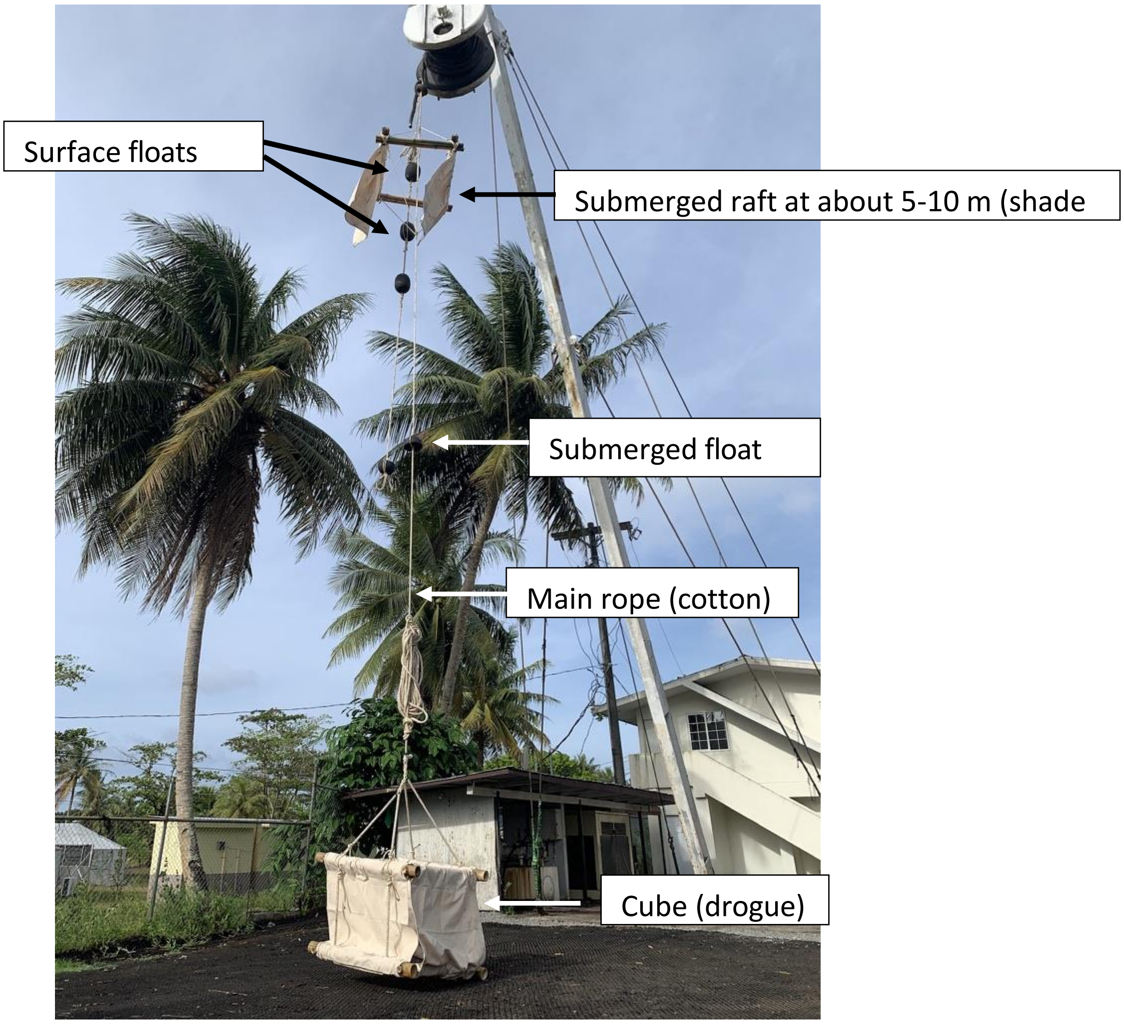

**Figure 1.** The Jelly-FAD mounted on land.

## 3.2 Data Analysis

### *3.2.1 Databases*

Two databases were prepared and linked for the data analysis:

*Fleet data base:* Data from Ugavi fleet was collected to create a general database including the information relative to fishing activity (deployment, visit, transfer, recovery, deactivation, etc.), activity date and position, dFAD type (biodegradable and Conventional), unique buoy identification code (model and serial number), catch data and material used for dFAD construction degradation status and repairs done.

*Acoustic database:* Data from buoy providers included data relating dFAD´s tracking buoy information, i.e. date of transmission, buoy position, buoy speed, biomass estimation, etc. This database contains data of the echosounder buoy tracking the Jelly-FAD and echosounder buoy tracking the conventional dFAD deployed close to the Jelly-FAD.

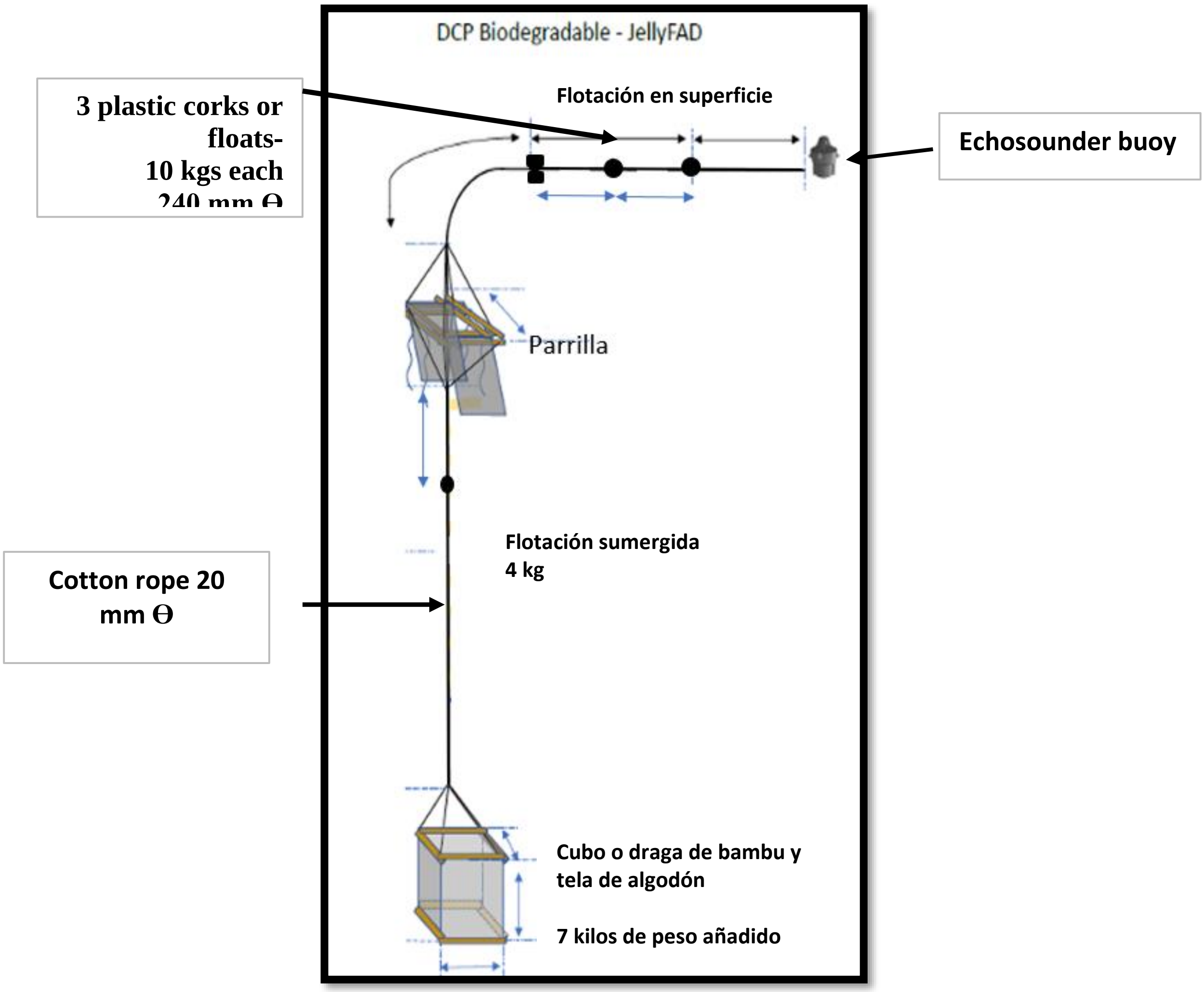

**Figure 2**. Jelly-FAD design of about 50 m / 28 fathoms depth used in Ugavi fleet.

### *3.2.2 Data filtering*

The first step of filtering involved the combination of the two databases as it implied data cleaning and correction to create the final database for the analysis:

- *First*, dFAD track segments were identified and selected for the analysis. Only those dFAD and associated buoys records consistent with the activation date and position data were considered for the analysis. Only the trajectory segments and acoustic records related to the test period were selected, removing all segments before the deployment day. Non-connection period of more than 7 days were identified throughout all dFAD trajectory and these were removed.
- *Second*, the filtering process also applied to the buoy data provided by the suppliers. Records corresponding to at-sea and operational dFADs were selected. Buoys or buoy records identified as on board, on shore or with anomalous data records at the time of analysis were eliminated. The original data was filtered to remove onboard positions for which all buoys which overcome a speed of 4 knots was eliminated (Orue et al., 2019).
- *Third*, the filtering process applied to acoustic data from those buoys and buoy records also implied acoustic layer filtering for tuna and bycatch biomass aggregation estimation. Acoustic record from the shallow layers (<25m) were excluded because they are considered to potentially reflect non-tuna species (Orue et al. 2019; Uranga et al., 2021).

### *3.2.3 Jelly-FAD´s performance assessment*

The following parameters were assessed:

- ***Lifespan.***
  *From echosounder buoys*: The duration of the experimental dFADs, both conventional and Jelly-FADs, was assessed from the day of deployment until the day when the connection with the buoy was stopped. The reasons for the end of the monitoring were: buoy deactivation, dFAD recovery without redeployment, or last data recorded before the analysis.

  *From visits and sets:* Assessed trough the visits and sets conducted on Jelly-FADs. Lifespan analysis also considered the type of material used in the main rope (polyethylene or cotton) in the construction of the Jelly-FAD.
- ***Drifting performance.*** Trajectory, speed and distance between pairs (Jelly-FAD and conventional dFAD) were assessed to compare drifting performance of those dFADs that drifted close, in the same water masses.
- ***Catch.*** Catch data was collected and analysed to compare aggregating performance between Jelly-FAD and conventional dFADs.
- ***Biodegradable material degradation.*** Data relative to the degradation of biodegradable material was collected from the fleets and analysis conducted to assess material performance in real conditions. The degradation rate was measured using a 1 to 4 scale: 1 referring to those elements at good state, 2 referring to starting to degrade, 3 referring to bad state need of reparation or were not functional. State 4 was assigned when the element was not present and state 5 when the data was unknown. The degradation information was analysed, whenever available, considering the deployment date and each of the observations date to assign a degradation state according to the time at sea (in months).
- ***Tuna biomass.*** Estimation of tuna biomass was carried out using the echosounder data to compare tuna aggregating performance between Jelly-FAD and conventional dFADs. The biomass estimates considered for the analysis was defined as the first period between the date of deployment until any of these activities recorded for each dFAD: first set, dFAD recovery, buoy transfer (in case dFAD is lifted up), deactivation, last data recorded of the dFAD before the analysis. The 90th percentile of the biomass estimated by the echo sounder buoys was used for this analysis.

## 3.3 Results of the Ugavi tests in the EPO

From June 2021 to February 2023, 71 Jelly-FADs were reported by Ugavi fleet, those reports corresponded to visited or fished Jelly-FADs (Table 1). Each Jelly-FAD was deployed paired with a conventional dFAD (Figure 3). Information from 63 conventional dFAD was available for the analysis. Conventional dFADs´ design was a typical dFAD using low risk entanglement netting “windows or sails” and bamboo canes.

**Table 1 .** Number of tested Jelly-FADs and conventional dFADs. Jelly-FADs for which all the structure was organic were called Jelly-FADs; those that used the main rope made of Polyethylene rope were called JellyFAD_mix_and ; Jelly-FAD _unknown were those for which there was no information on the type of main rope used. The conventional dFAD was called 2D with sails.

| FAD type | Prototype | N |
|---|---|---|
| BIO | JellyFAD_unknown | 7 |
| BIO | JellyFAD_mix | 29 |
| BIO | JellyFAD | 35 |
| CON | 2D with sails | 63 |

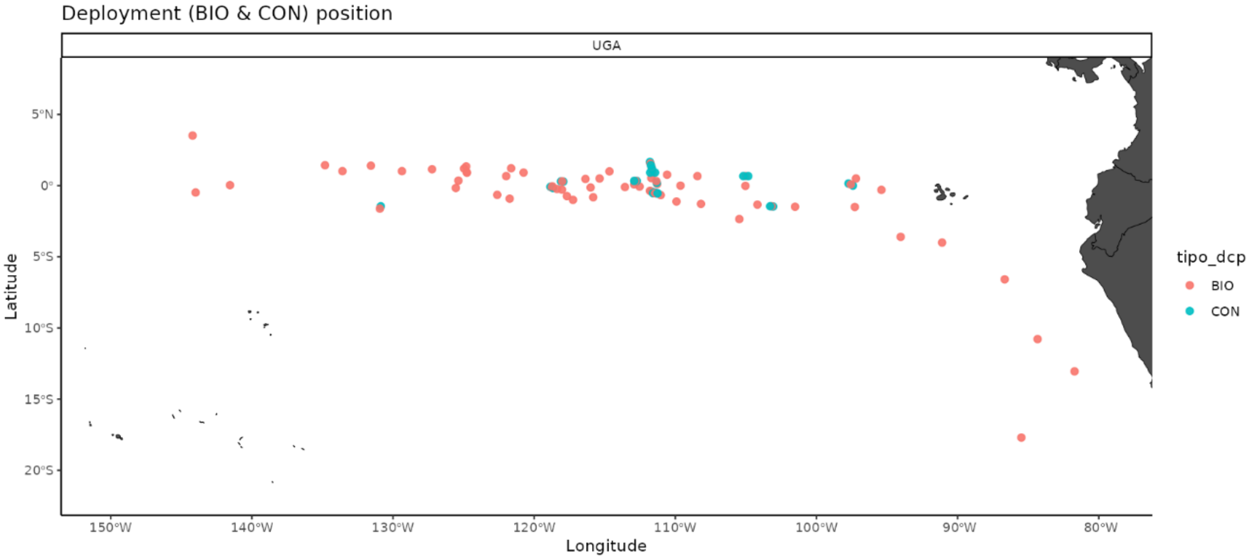

**Figure 3.** Deployment of Jelly-FADs (BIO) and conventional dFADs (CON) during the eastern Pacific Ocean program by UGAVI fleet

### *3.1.1 Lifespan of Jelly-FADs and Conventional dFADs*

The time after deployment at which sets and visits were conducted was recorded for lifespan analysis (Figure 5). Data shows that the maximum lifespan in working condition and with a successful set on a jelly-FAD was 335 days (11 months) with an average of 125 days (4 months). Some of those FADs were redeployed and their track lost, so their lifespan in working conditions, could probably be longer. Note that this lifespan indicator means that fishers visited or fished a Jelly-FAD and the Jelly-FAD was in good condition, which does not mean that it was the end of its lifespan.

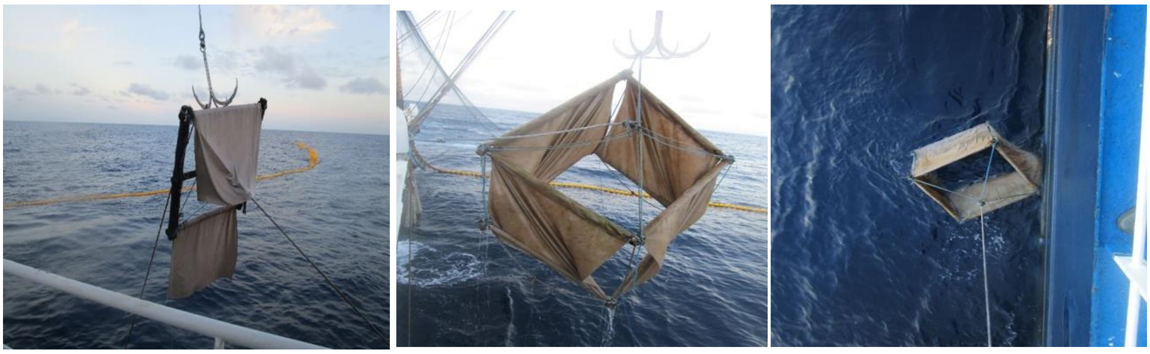

**Figure 5.** A Jelly-FAD fished after 5 months at sea (45 tons) and re-deployed in the EPO.

Echosounder buoy tracks were also used as an indicator of the lifespan of Jelly-FADs compared to Conventional dFADs. Table 2 shows the maximum, mean and minimum (in days) of monitored period of the dFAD types (Jelly-FAD and conventional). Both types showed similar average and maximum lifespan values around 125 and 330 days at sea, respectively. The Jelly-FAD containing organic rope showed the highest mean (130 days) and maximum (338 days) lifespan values in comparison to Jelly-FAD with polyethylene rope and conventional dFAD (Figure 4). Jelly-FAD with unknown rope material information (n=4) showed differences with the other two types of Jelly-FAD (organic and mix) and conventional dFAD. However, the low sample size for this type makes it difficult a clear interpretation of the data.

**Table 2**. General information on the monitored period by dFAD type.

| FAD type | Prototype | N | Records | min (days) | mean (days) | max (days) |
|---|---|---|---|---|---|---|
| BIO | JellyFAD_unknown | 4 | 437 | 194 | 251 | 290 |
| BIO | JellyFAD_mix | 25 | 292 | 9 | 120 | 256 |
| BIO | JellyFAD | 23 | 354 | 9 | 130 | 338 |
| CON | 2D with sails | 59 | 225 | 8 | 125 | 328 |

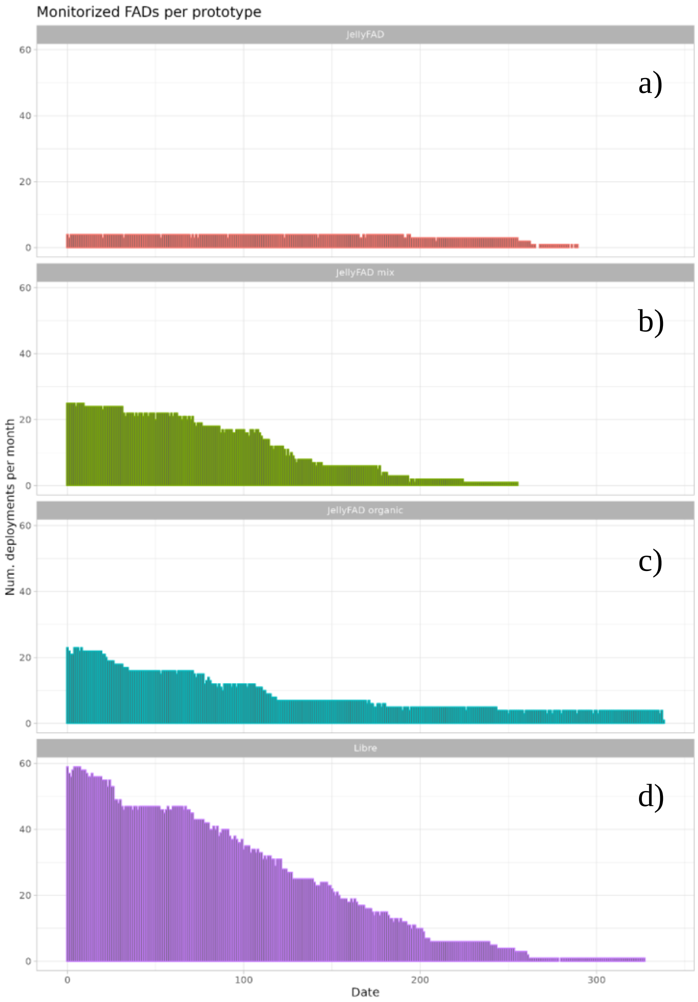

**Figure 4**. Monitored period in terms of days after deployment and number of observations by dFAD type. a) Jelly-FAD of unknown type; b) Jelly-FAD_mix c) Jelly-FAD; d) Conventional dFADdFAD drifting performance.

The trajectories observed among dFAD pairs (Jelly-FAD and conventional dFADs) followed similar, partially similar and divergent patterns (Figure 5). In this document, observed trajectories were assessed together and only the dFAD type (biodegradable vs conventional) was considered for the analysis. Further data analysis will compare conventional dFAD with the Jelly-FAD trajectories by drift type (i.e., similar, partically similar, divergent) so that we compare drift performace for dFADs that drifted in similar water masses.

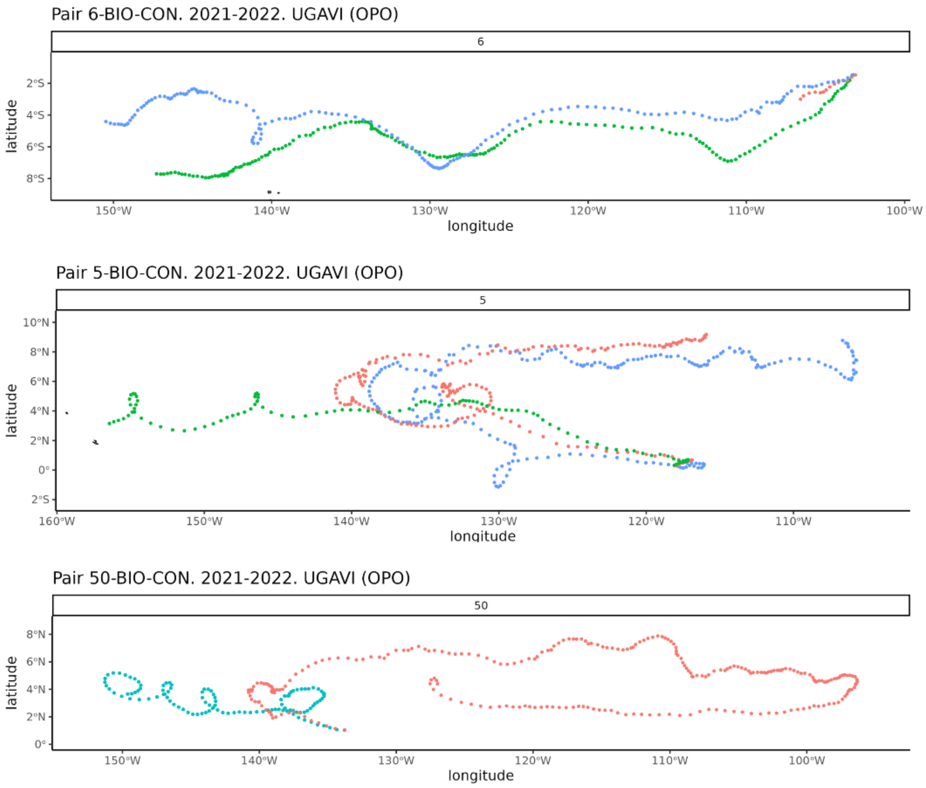

**Figure 5.** Jelly-FAD and Conventional dFAD pairs drift comparison, classified in 3 types of driftpatterns, similar, partially similar and divergent.

Figure 6 shows the distance between Jelly-FADs and their paired conventional dFAD from the date of deployment. Data shows low values at the beginning of the monitored period and with an increasing trend as the days after deployment increased. This increasing pattern was to be expected, as all pairs, regardless of the drift pattern (similar, partially similar and divergent), were analysed together. Same patterns were observed in other BIOFADs tests (Murua et al. 2023).

Both dFAD types (Jelly-FAD and conventional) showed similar average and maximum speed values, 0.9 and around 3.7 knots, respectively (Table 3). The lowest maximum speed value (3.7 knots) was observed in Jelly-FAD with organic ropes. Figure 7 shows small differences between pairs throughout the monitored period. Despite the slightly similar speed differences among pairs throughout the monitored period, speed difference values were higher as dFAD were closer to the end of their lifespan. This can be partly due to those dFAD pairs showing partially similar and divergent tracks, where pairs could be drifting in different areas with different oceanographic and environmental conditions.

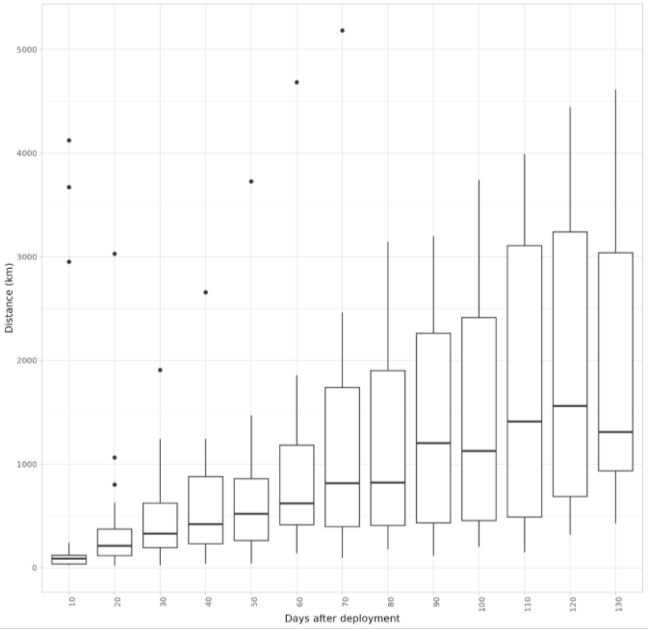

**Figure 6.** Observed distance difference among tested dFAD pairs (jelly-FAD Vs conventional)

**Table 3**. Maximum, mean and minimum speed values observed in the deployed dFADs.

| FAD type | Prototype | N | Records | min (knots) | mean (knots) | max (Knots) |
|---|---|---|---|---|---|---|
| BIO | JellyFAD | 4 | 437 | 0.1 | 1.0 | 3.1 |
| BIO | JellyFAD_mix | 25 | 292 | 0.0 | 0.9 | 3.9 |
| BIO | JellyFAD_organic | 23 | 354 | 0.0 | 0.9 | 3.7 |
| CON | Free | 59 | 225 | 0.0 | 0.9 | 4.0 |

### *3.3.3 Biomass estimation from echosounder buoys.*

#### ***a) Tuna biomass estimation***

Biomass estimates were directly extracted from the echosounder buoys associated to experimental dFADs. The 90th percentile of the biomass estimated by the echosounder buoys was used for this analysis. Figure 8 shows the evolution in the tuna biomass aggregation estimates during monitored period considering dFAD type. Both dFAD types (Jelly-FAD and conventional dFAD) showed similar aggregation patterns until 150 days after deployment, with a peak of tuna aggregation around 3 months after deployment day. Differences in tuna estimates were only observed between dFAD types around 200 days since the beginning of the monitored period, conventional dFADs showing a second peak in tuna aggregation while Jelly-FAD followed a decreasing pattern.

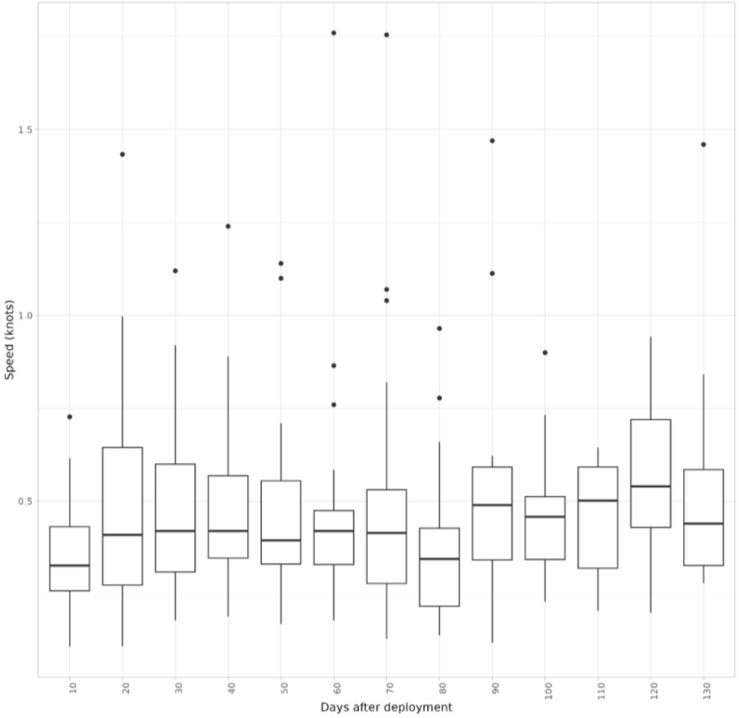

**Figure 7.** Observed mean speed difference among tested dFAD pairs.

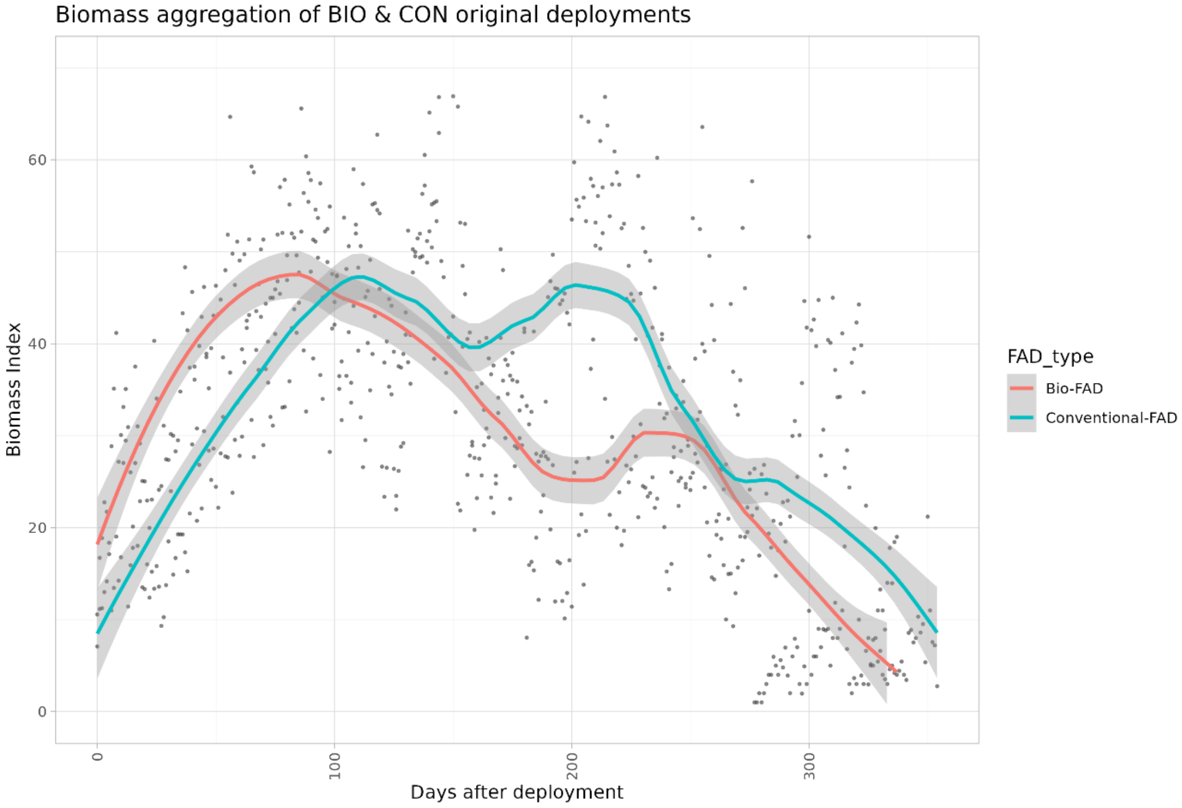

**Figure 8.** Tuna biomass estimation in tons (y-axis) and days after deployment (x-axis) by dFAD type, Jelly-FAD (red) and conventional (green).

### 3.3.4. *Catch data.*

In total 50 sets were made to Jelly-FADs and 5 sets to conventional dFADs (Figure 9). Most of the dFADs (both Jelly-FAD and conventional dFAD) with positive sets were deployed on the equator, while sets were mostly made at latitudes close to 5° north and to a lesser extent at 5° south. In total 2205 tonnes of tuna were caught in the 50 Jelly-FADs sets and 130 tonnes in conventional dFADs. On average 44.1 tons of tuna were caught in Jelly-FADs sets and 26 tons in conventional dFADs (Table 4) with a maximum of 125 tons at one Jelly-FAD set. The time elapsed between the day of deployment and the day of the set averaged 125 days in the case of Jelly-FAD and 110 days in conventional dFADs; the minimum days at sea until the day of the set was 33 days in the case of the Jelly-FAD and 93 days for conventional dFAD. This comparison of the Jelly-FAD and conventional dFADs ´catch performance should be taken with caution as the data from fishers came for those Jelly-FADs that were visited or fished and we compared those jelly-Fads with the conventional dFADs deployed with them. This strategy directs the sampling towards the Jelly-FADs that were visited and fished.

**Table 4.** Information on catches by dFAD type

| FAD type | Prototype | N of sets | min (tons) | mean (tons) | max (tons) |
|---|---|---|---|---|---|
| BIO | JellyFAD | 50 | 2 | 44.1 | 125 |
| CON | 2D with sails | 5 | 15 | 26.0 | 55 |

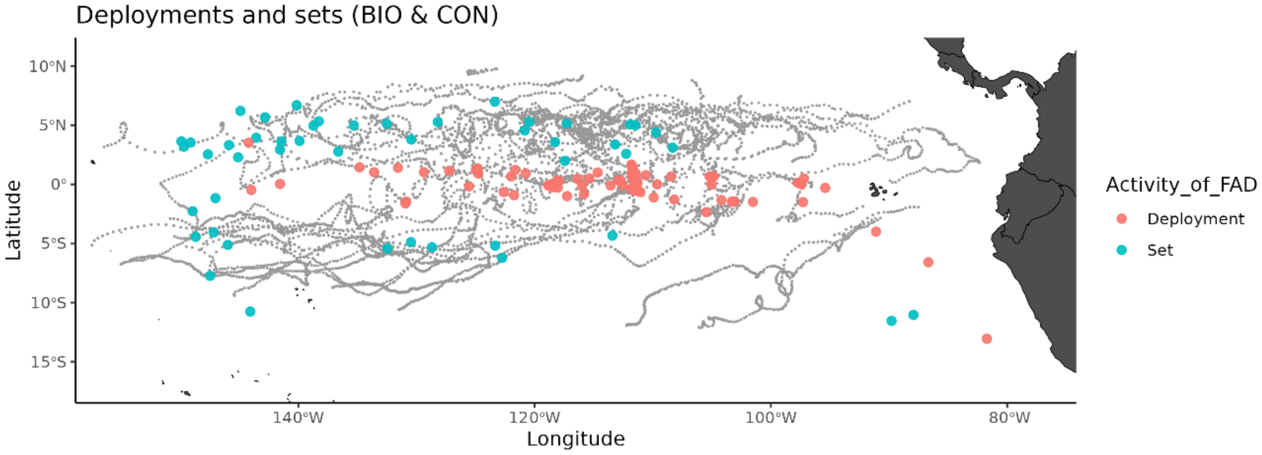

**Figure 9**. Map of the deployments (red dots) and sets (green dots)

### 3.3.5. *Biodegradable material degradation*

The data on the state of degradation of the Jelly-FAD materials provided by vessels allowed the evaluation of some of its elements, e.g. the raft (i.e. bamboo structure and cotton canvas), the main rope (i.e. cotton and polyethylene ropes), and the cube (i.e. bamboo structure and cotton canvas). However, the low number of observations for these elements during the monitored period makes robust analysis difficult. In the case of the bamboo structure of both the raft and the cube, the condition was good in a high percentage of the observations during the 7 months after deployment. There were observations of the absence of the cube from the third month onwards, although the absence of the studied element was more significant in the case of the cotton canvas. This absence of the cotton canvas was observed in both the raft and the cube. The data showed a high percentage of observations in state 4 (absence of the element) from the third month onwards in both cases. Both cotton and polyethylene ropes showed high percentages of observations in state 1 (good condition) until the sixth month after deployment. From this month onwards, observations were scarce, which did not allow us to analyse the degradation of these elements. There was not evident differences between cotton and polyethylene ropes based on the observations made by the vessels (Figure 10).

## 3.4 Summary of key results of Ugavi trials

### *3.4.1 Performance of the Jelly-FAD*

- **Lifespan**:

*From visits and sets*:
The maximum monitored lifespan in working condition and with a successful set on a Jelly-FAD was 335 days (11 months). An average of 125 days was obtained for activities i.e visits and sets, conducted with Jelly-FADs. Some of those Jelly-FADs were redeployed and were not visited anymore, so their lifespan in working conditions will likely be longer. Note that this lifespan indicator means that fishers visited or fished a Jelly-FAD, which does not mean that it was the end of its lifespan.

*From echosounder buoys biomass estimates*:
Conventional dFADs and Jelly-FADs showed similar average and maximum lifespan values, 125 and 330 monitored days at sea, respectively. The Jelly-FAD containing organic rope showed the highest mean (130 days) and maximum (338 days) lifespan values in comparison to Jelly-FAD with polyethylene rope and conventional dFAD. Note that this lifespan indicator, relays on monitored days at sea with the echosounder buoy, but there was no data on the state of the dFAD. However, the fact that the dFAD was active for fishers is an indicator of their lifespan.

- **Drifting performance:**

Both dFAD types (Jelly-FAD and conventional) showed similar average and maximum speed values, 0.9 and around 3.7 knots, respectively. The lowest maximum speed value (3.7 knots) was observed in Jelly-FAD with organic ropes.

- **Tuna Catch:**

In total 2205 tonnes of tuna were caught in the 50 Jelly-FADs sets and 130 tonnes in the paired conventional dFADs. On average 44.1 tons of tuna were caught in Jelly-FADs sets and 26 tons in conventional dFADs (Table 4) with a maximum of 125 tons at one Jelly-FAD set. The time elapsed between the day of deployment and the day of the set averaged 125 days in the case of Jelly-FAD and 110 days in conventional dFADs; the minimum days at sea until the day of the set was 33 days in the case of the Jelly-FAD and 93 days for conventional dFAD. This comparison of the Jelly-FAD and conventional dFADs ´catch performance should be taken with caution as the reports from fishers came from those Jelly-FADs that were visited or fished and we compared those jelly-FADs with the conventional dFADs deployed with them. This strategy directs the sampling towards the Jelly-FADs that *a priori* were selected by fishers for their potential to have fish.

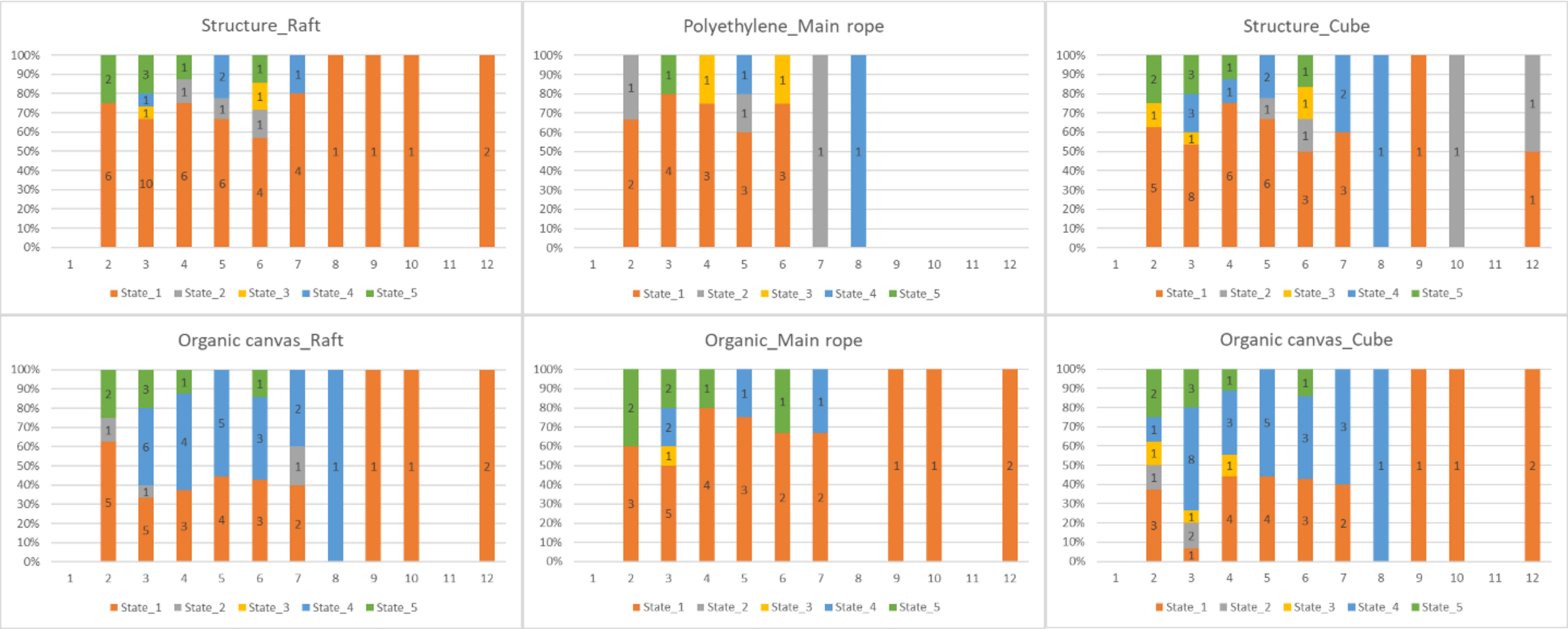

**Figure 10.** Degradation of the different components over time in months (X-axis). State 1 = good condition, State 2 = starting to degrade, 3 = bad state need of repair. State 4 = component not present and State 5 = unknown. Number of observations are written in the columns.

- ***Material´s degradation:***

In the case of the bamboo structure of both the raft and the cube, the condition was good in a high percentage of the observations during 7 months after deployment. The absence of the cotton canvas was observed in both the raft and the cube. The data showed a high percentage of observations in state 4 (absence of the element) from the third month onwards for the canvas. Both cotton and polyethylene ropes showed high percentages of observations in state 1 (good condition) until the sixth month after deployment. From this month onwards, observations were scarce, which did not allow us to analyse the degradation of these elements. There was not evident differences between cotton and polyethylene ropes based on the observations made by the vessels.

Some of the observation by fishers showed that even when the canvas was broken or absent, they fished on the Jelly-FADs. This could suggest that once tuna is aggregated in a given dFAD, the structure itself loses importance as tuna may have other motivations to remain aggregated to that dFAD.

Fishers shared with us that conventional dFADs sometimes end up broken or have a component that is damaged. In the same way conventional dFADs are repaired by fishers, the diverse components of the Jelly-FAD, if damaged after the set, could be replaced by another cube that fishers could have ready onboard for the Jelly-FAD to be re-deployed, as fishers do with the tail and raft of conventional structures.

Finally, it is noteworthy that Jelly-FADs lasted up to 335 days, 11 months at sea. The lifespan of Jelly-FAD, as for conventional dFADs, will be highly dependent on the dFAD being well constructed, including an accurate assessment of weight and flotation needs, and the oceanographic conditions of the water that drifted.

As experiments progress, the jelly-FAD structure will probably evolve in the hands of fishers maintaining the key physical oceanography concepts on flotation and drag but changing the shape of the drogue or raft used for fish attraction. The Jelly-FAD concept represents a significant step forward in the use of smaller and more efficient bio-FADs with a much reduced impact on the ecosystem.

### *3.4.2 Learning curve on the use of the Jelly-FAD*

- The first 150 deployments provided few results due to the lack of data:

  (i) Mistakes in the construction and deployment operation, made Jelly-FADs sink or the structure work incorrectly.
  (ii) Fishers rarely visited them due to lack of confidence about their performance.
  (iii) Finally, as it is common in FAD fishery many of them were stolen or drifted out of the fishing zone.

- The shipowners facilitated a continued deployment of Jelly-FADs throughout 2021 and 2023 This continued effort, resulted in:

  (i) Fishers learning how to properly construct and use Jelly-FAD structure, including the deployment operation from the vessel.
  (ii) Jelly-FADs started working properly and aggregating tuna
  (iii) More visits due to the presence of tuna and as result of the increased visits, the acceleration of the learning process.
  (iv) A growing confidence of fishers in Jelly-FAD performance

## 4. Ongoing trials at sea with the Jelly-FAD

1. *The Mediterranean Sea (ISSF-ICM)*: the Mediterranean Sea was selected for our controlled experiments with Jelly-FADs at sea due to the lack of fleets fishing with dFADs. In 2023 a new generation of Jelly-FADs will be tested. These Jelly-FADs will be lighter, and with organic components for flotation, wood and balsa wood.
2. *Eastern Pacific Ocean with Ugavi fleet (ISSF)*: this fleet started testing Jelly-FADs in 2021. They have deployed more than 500 Jelly-FADs, deployments continue in 2023 in a regular bases. Results are presented in section 3 above.
3. *Eastern Pacific Ocean with NIRSA fleet (ISSF-IATTC):* Nirsa is deploying bio-FADs of conventional design in a regular bases as a percentage of the total FADs deployed and also started testing Jelly-FADs. The lifespan of both types seems to be very short, around 50-55 days. Scientists have recommended a review of the construction process to check if flotation, weight and the different steps required are appropiate, as other fleets´ results show a longer average lifespan of around 4 months (see section 3 above).
4. *Western Pacific Ocean with Caroline Fisheries corporation (ISSF-SPC-FAO-AZTI)*: this fleet deployed a total of 100 Bio-FADs, 50% of the experimental dFADs tested were a design that copied the conventional dFAD but made of biodegradable materials (manila hemp rope and jute canvas). The other 50% deployed were Jelly-FADs. First results showed that the Jelly-FAD lasted more than the conventional bio-FAD made of organic materials and that the Jelly-FAD drifted slower than the bio-FAD with the conventional design. CFC will continue testing only Jelly-FADs with a new project lead by SPC.
5. *Western and eastern Pacific Ocean with the U.S. tuna purse seine fleet (ISSF-NOAA-SPC):* a total of 216 Jelly-FADs will be deployed by the U.S. fleet in 2022-2023. Results are not available yet.
6. *Western Pacific Ocean with Silla, FCF and CFC fleets (U.S.-EU-SPC-ISSF):* a total of 250 Jelly-FADs, will be tested by fleets starting in 2023. Results are not available yet.
7. *Atlantic Ocean with Ghanaian purse seine and pole and line fleets (ISSF-FAO-AZTI):* From the total of 133 deployed bio-FADs deployed, few visits were made due to the loss of bio-FADs (i.e being stolen or sunk) or because they drifted out of the fishing zone. To get results on their performance more deployments are required.
8. *Atlantic Ocean with Pevasa fleet (ISSF-FAO):* This fleet will trial around 200 Jelly-FADs made of cotton rope and cotton canvas during 2022-2023. First results show a good performance of the Jelly-FAD.
9. *Atlantic Ocean with the fleet from Opagac (AZTI- ISSF):* 214 Jelly-FADs made of cotton rope and cotton canvas were tested. Results did not show significant differences between Jelly-FAD and conventional dFAD. Only 9 sets and 10 visits were done so more deployments would be needed to obtain meaningful results.
10. *Atlantic Ocean, via ocean fleet (Via Ocean*-ISSF): This French fleet has deployed 60 Jelly-FADs and will continue deployments in 2023. Results are not available yet.

## 5. Recommendations

1. Only dFADs constructed without netting can completely eliminate the entanglement of turtles, sharks and finfish species. New biodegradable materials should not be configured in a net format; instead, they should use other forms such as ropes or canvas.
2. To reduce the dFAD structural stress so as to enlarge the lifespan of biodegradable materials for the construction of dFADs, an innovative bio-FAD concept named Jelly-FAD is recommended (see Moreno et al 2023).
3. The degradation suffered by biodegradable materials on the sea surface and immediate subsurface (i.e., 0 to 10 m depth) is higher compared to that suffered below, deeper in the water column. Thus, the poor performance of some materials on the sea surface or subsurface layers of the water column should not prevent new experiments from testing the same materials in the tail components of dFADs situated deeper in the water column.
4. For dFADs to drift slowly, the cube should be three-dimensional and symmetric and should be "anchored" below the mixed layer. The design of the dFAD is crucial to reduce stress on the structure and increase their lifespan.
5. The correct assessment of the flotation and weight distribution in the design of the dFAD is a crucial factor to extend its working lifespan. This is especially important for biodegradable dFADs, as materials might be more susceptible to physical stress. If those parameters are not well calculated, the tension and torsion suffered by the structure will result in substantial damages, and the submerged appendage is more likely to detach from the raft — reducing dFAD's lifespan and aggregation effectiveness.
6. Fishers supported by shipowners should start trialing bio-FAD designs in a continued effort, deploying systematically a percentage of their dFADs made of biodegradable materials.

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