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Final results of the jelly-FAD performance in the EPO with Ugavi fleet

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Moreno et al.

Final results of the jelly-FAD performance in the EPO with Ugavi fleet

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SUMMARY

In recent years we presented the Jelly-FAD, a new concept on non-entangling and biodegradable FAD (bio-FAD) design that mirroring jellyfish, drifts with quasi-neutral buoyancy, which reduces (i) the structural stress of the FAD at sea, making its lifespan longer 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 presents the final results by Ugavi fleet´s tests with jelly-FADs in the eastern Pacific Ocean (EPO). This study analyses the performance of 95 jelly-FADs that were deployed in pairs together with 95 conventional FADs in the same area. This study demonstrates that the catch performance, aggregation evolution, and drift speed of Jelly-FADs were similar to, or even better than, those of conventional FADs. Jelly-FADs have a proven lifetime of up to 11 months, with several being fished after 9 months at sea and 11% successfully redeployed.

RESUMEN

En los últimos años, presentamos el Jelly-FAD, un nuevo concepto de diseño de FAD (bio-FAD) no enmallante y biodegradable que, imitando a las medusas, deriva con una flotabilidad casi neutra, lo que reduce (i) el estrés estructural del FAD en el mar, prolongando su vida útil, y (ii) la necesidad de flotación adicional de plástico. El Jelly-FAD no es necesariamente un diseño fijo; es más bien un cambio en el concepto de la construcción convencional de dFAD. El presente documento presenta los resultados finales de las pruebas de la flota de Ugavi con Jelly-FADs en el Océano Pacífico Oriental (EPO). Este estudio analiza el rendimiento de 95 Jelly-FADs que se desplegaron en pares junto con 95 FADs convencionales en la misma área. Este estudio demuestra que el rendimiento de captura, la evolución de la agregación y la velocidad de deriva de los Jelly-FADs fueron similares o incluso mejores que los de los FADs convencionales. Los Jelly-FADs tienen una vida útil comprobada de hasta 11 meses, con varios siendo pescados después de 9 meses en el mar y un 11% siendo replantados con éxito.

1 Introduction

The impact caused by the structure of Drifting Fish Aggregating Devices (dFADs) used by tuna fleets in the tropical zones of the Indian, Atlantic and Pacific oceans, 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, the time required by fishers. Currently, projects exist in the three oceans to test dFAD prototypes constructed mostly with biodegradable materials (Moreno et al., 2020; Escalle et al., 2022; Roman et al., 2022; Zudaire 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.

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). It is called the jelly-FAD because it drifts with the least structural stress, and with quasi-neutral buoyancy as jellyfish do. The minimum torsion and shears forces on dFAD structure allow organic materials and thus the bio-FAD last longer. Its main features are (Figure 1):

i. Minimizes 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)

This document presents final results on the performance of 95 jelly-FADs and the 95 conventional FADs deployed together with them. The Jelly-FAD, which is a specific design of a non-entangling and biodegradable FAD, was tested and still is under used by Ugavi fleet, U.S. fleet and Nirsa fleet in the eastern Pacific Ocean (EPO) (see this video and Jelly-FAD construction guide for more information on the Jelly-FAD).

2 Material and methods

2.1 Jelly-FAD design, materials and protocols at sea

The fleet from Ugavi deployed more than 2000 Jelly-FADs, starting in early 2021. This fleet has deployed the highest number of Jelly-FADs so far, that is why the trial allowed to gather the required data to get meaningful results. Each time a jelly-FAD was visited or fished, fishers from Ugavi 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. The fleet tested two categories, Category II and Category IV, of FADs regarding the different bio-FAD categories to be considered in the gradual implementation process of the bio-FADs in CM-23-04 (IATTC CM-23-04):

- *Category II. The FAD is made of 100% biodegradable materials except for plastic-based flotation components (e.g., plastic buoys, foam, purse-seine corks).*

- *Category IV. The subsurface part of the FAD contains non-biodegradable materials, whereas the surface part is made of fully biodegradable materials, except for, possibly, flotation components. (These definitions do not apply to electronic buoys attached to FADs to track them).*

Since the use of 100% bio-FADs is not mandatory, the Ugavi fleet tested both Category II and Category IV FADs. Category II FADs are entirely biodegradable except for the plastic buoys used for flotation. In Category IV FADs, the main rope was made of polyethylene instead of cotton, which was used when cotton rope was unavailable or when fishers needed to construct a Jelly-FAD at sea using materials on hand. Notably, in Category IV, only the main rope is made of plastic; the rest of the cube remains biodegradable.

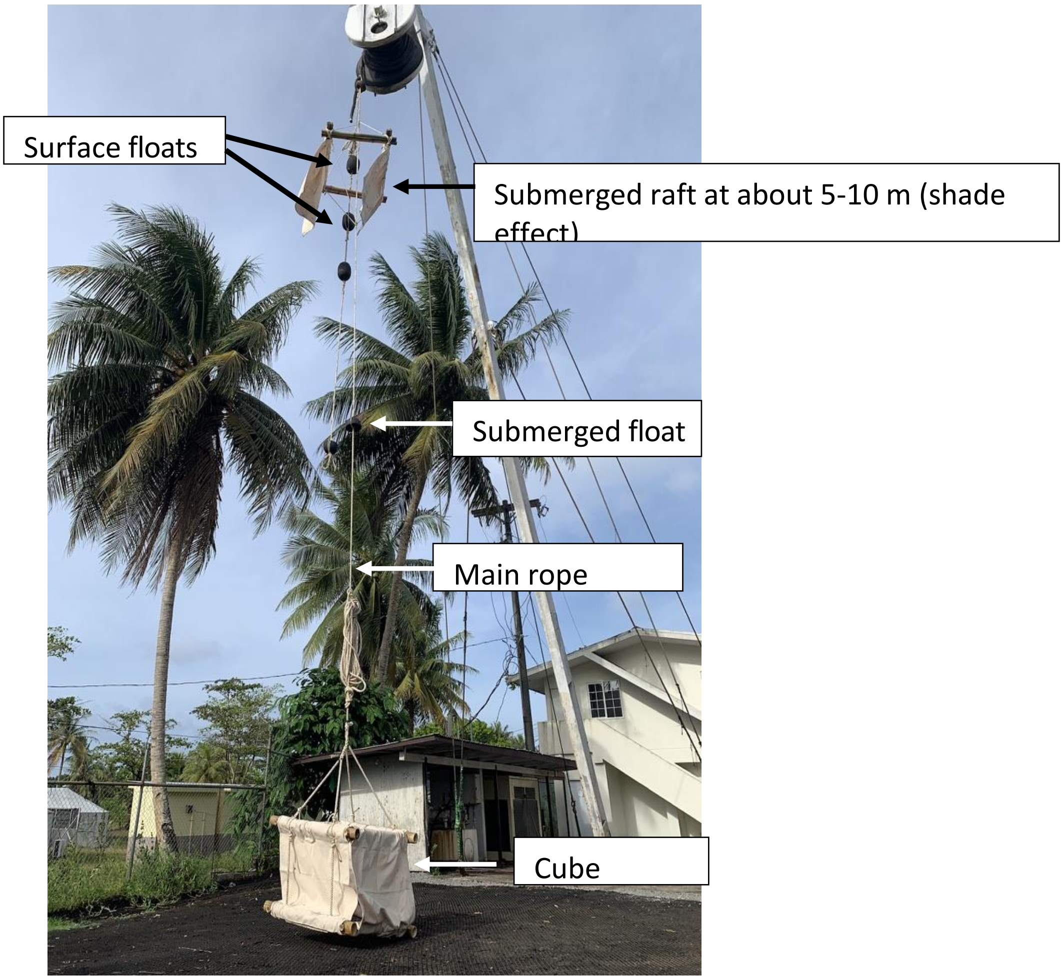

Figure 1. The Jelly-FAD mounted on land (*photo: Gala Moreno*).

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/m^2.
- *Weight*: 7 kg recycled chain from the net.
- *Main rope* (connecting the cube with the emerged flotation): Two type of jelly-FADs were constructed: One with cotton rope (*Category II*) and the other with polyethylene rope (*Category III*). This is the unique difference between the two types of jelly-FADs tested.
- *Submerged flotation*: plastic buoy of 5 kg.
- *Raft*: bamboo canes and cotton canvas.
- *Emerged flotation*: plastic buoy and recycled cork from the net (about 30 kg).

Thus, we conducted all the performance analysis separately in order to account for the performance of category II or IV. For a proper evaluation of the jelly-FAD, each of them was deployed in pair 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 the echosounder buoy unique identification codes used by fishers to track dFADs.

2.2 Data Analysis

For the Jelly-FAD´s performance the following parameters were assessed:

- ***Lifespan.***
  - → *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.
  - → *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.

- ***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 tuna aggregating performance between Jelly-FAD and conventional dFADs.

- ***Biodegradable materials degradation.*** Data relative to the degradation of biodegradable material was collected from the fleets and analysis conducted to assess material performance in real fishing conditions. The degradation rate was measured using a 1 to 4 scale:

→ ***State*** 1: referring to those elements at good state,
→ ***State*** 2: referring to starting to degrade,
→ ***State*** 3: referring to bad state need of reparation
→ ***State*** 4: component was not present
→ ***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 and bycatch biomass aggregated.*** Estimation of tuna biomass was carried out using the echosounder data to compare tuna aggregating performance between Jelly-FAD and conventional dFADs.

2.3 Comparison between jelly-FADs and their conventional pairs

In this study, we measured the performance of the catch, tuna aggregation, and drift speed using only FAD pairs (jelly-FAD and conventional) that drifted together through the same water masses. This approach is crucial for accurately comparing biomass aggregated and drift speeds, as local conditions or the presence of tuna in the areas where the FADs drifted and local currents can influence the results. Figure 2 illustrates the trajectories observed in our data base among dFAD pairs, which exhibited similar (top image), partially similar (middle image), and divergent patterns (botton image). For our analysis, on catch, tuna biomass and drift speed we included only the pairs that drifted in similar patterns (image on the top). However, for the lifespan we took into account all monitored FADs.

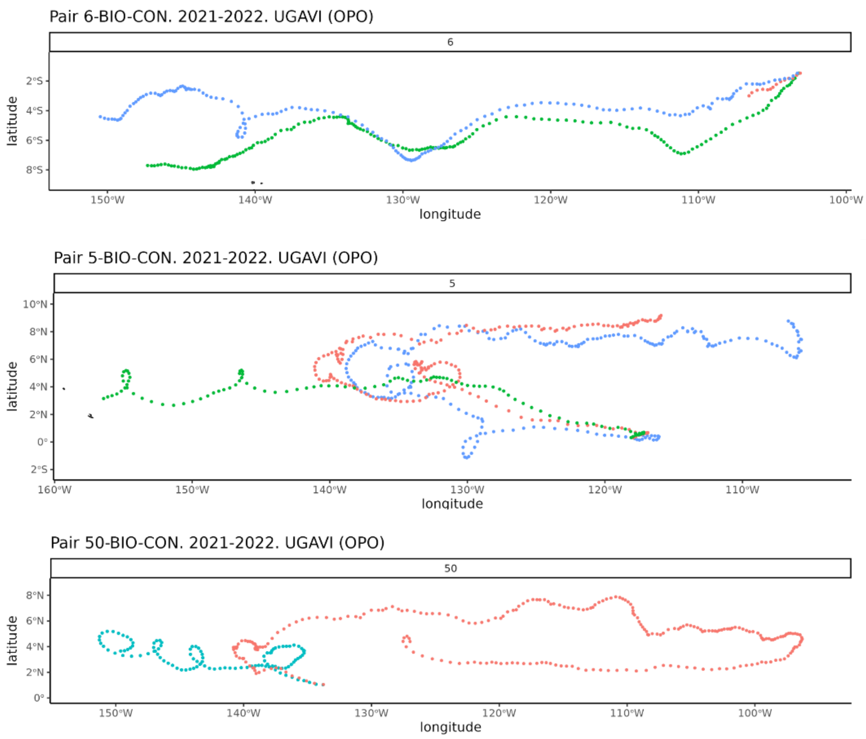

Figure 2. Jelly-FAD and Conventional dFAD pairs drift comparison, classified in 3 types of drift patterns, similar, partially similar and divergent.

3 Results of the Ugavi tests in the EPO

From June 2021 to February 2023, 107 Jelly-FADs (both Category II and IV) were reported by Ugavi fleet, those reports corresponded to fished and visited Jelly-FADs (Table 1). Each Jelly-FAD was deployed paired with a conventional dFAD (Figure 2). However, we only took into account dFADs that followed same trajectories, thus 95 pairs were analysed. The conventional dFADs´ design was a typical dFAD using low risk entanglement netting “windows or sails” and bamboo canes, we call that design “Free design”.

Table 1. Number of Jelly-FAD and conventional FADs, monitored.

FAD Type	Deployments	Sets
JellyFAD_hybrid (Cat IV)	60	36
JellyFAD_organic (Cat II)	47	34
Total JellyFAD	**107**	**70**
Conventional FAD	**137**	**45**

Biodegradable and conventional FAD pairs in the Pacific Ocean. 2021-2023

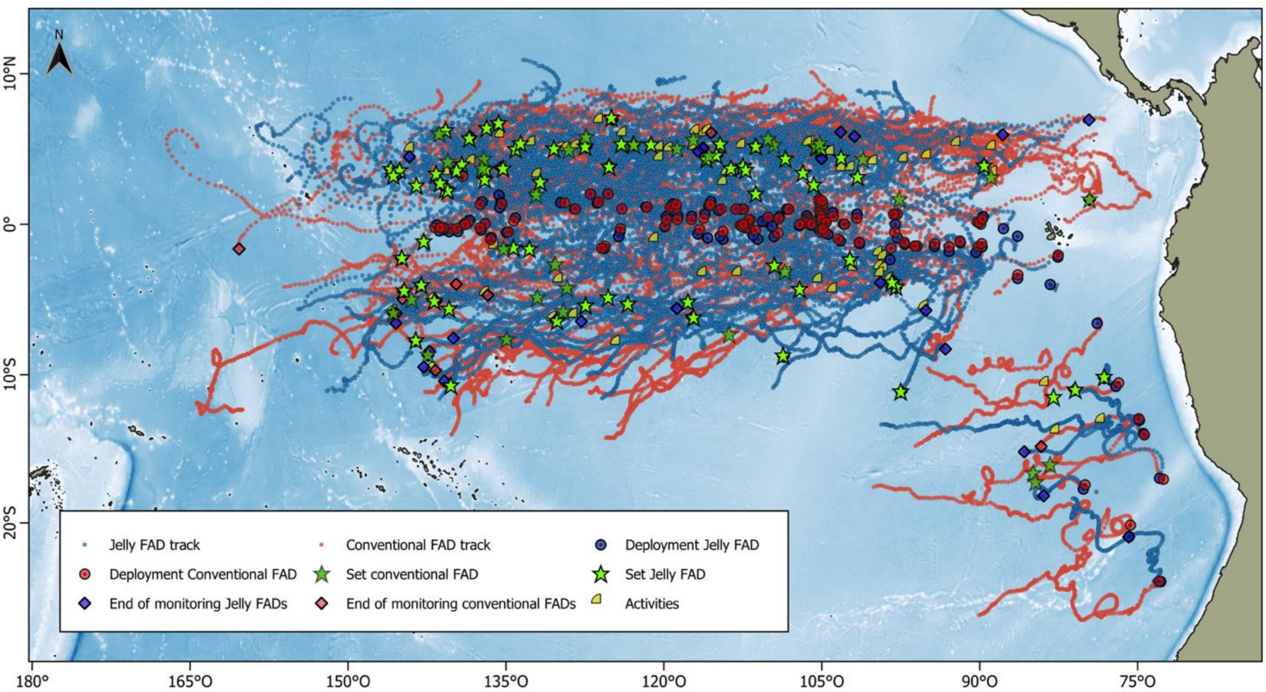

Figure 3. Deployment and tracks of jelly-FADs (blue) and conventional dFADs (red). Sets on jelly-FADs (light green); Set on con-FADs (dark green).

Figure 3 illustrates the extensive spatial coverage of the trial, with a total of 244 FADs tracked and studied. The deployment patterns for both conventional and jelly-FADs are shown to be consistent, predominantly around latitude 0º. Similarly, both types of FADs were fished either north or south of the equator, reaching up to 10ºS and 10ºN. From this map and the tracks, we can clearly conclude that fishers used the two types of FADs in the same manner and that both types followed the same drift behavior.

3.1 Drift performance

For fishes, one of the key characteristics of FADs to be productive is their slow drift. This ensures that the FADs do not quickly drift out of the fishing zone, reducing the likelihood of losing them. Therefore, studying the drift speed of FADs is important not only because it is a requirement for fishers but also because it decreases the risk of abandoning FADs, and thus its impact on the habitat, if they drift out of the fishing zone too quickly. Both dFAD types (Jelly-FAD and conventional) showed similar average and maximum speed values, 0.8 and around 3.7 knots, respectively (Table 2).

Table 2. Drif speed of Jelly-FAD and conventional FADs that drifted together.

FAD type	N	Records	min (knots)	mean (knots)	max (Knots)
Jelly-FAD	48	178,9	0	0,8	3,7
Conventional	48	173,9	0	0,8	3,6

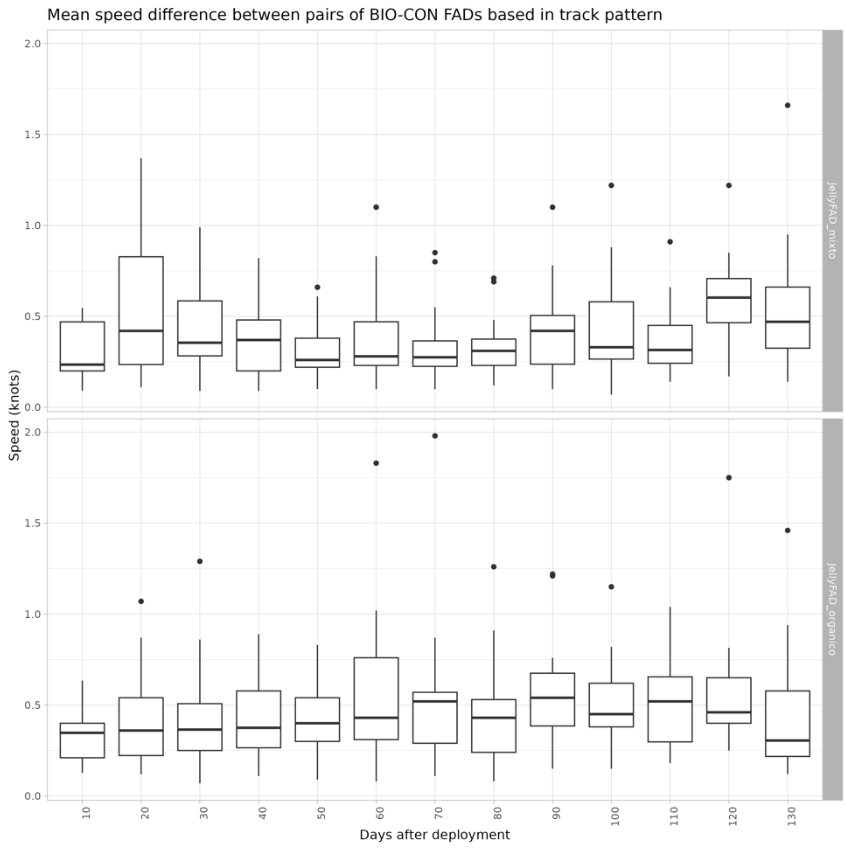

Figure 4. Observed mean speed difference among tested dFAD pairs. Hybrid jelly-FAD vs conventional (top). Organic jelly-FAD vs. conventional (botton).

It is important to highlight that these pairs (jelly-FADs and conventional FADs) drifting in the same waters exhibited similar drift speed patterns. Notably, the jelly-FAD achieves the same slow drift with a much lighter and less bulky structure.

3.2 Catch performance

Out of the 95 FAD pairs examined, 70 sets were done using jelly-FADs, with some FADs being fished multiple times (Table 4), while 46 sets were made using conventional dFADs (see Table 3 for summary data). On average, 39.4 tons of tuna were caught in jelly-FAD sets, totaling 2,756 tons, and an average of 35.9 tons were caught in conventional dFAD sets, totaling 1,653 tons. The highest catch recorded on a jelly-FAD was 125 tons, while on a conventional FAD, it was 265 tons.

The average time between deployment and setting was 122 days for jelly-FADs and 106 days for conventional dFADs. The shortest time at sea before setting was 33 days for Jelly-FADs and 28 days for conventional dFADs. Notably, a Category II Jelly-FAD (100% biodegradable except for the flotation) was retrieved after nearly a year at sea (335 days), having been previously fished and redeployed after three months (94 days) and nine months (275 days). This jelly-FAD was redeployed twice and proved effective after a year but it was not the only jelly-FAD category II, redeployed and fished after a second long period at sea (Table 4).

Table 3. Catch performance and soaking time of the 95 FAD pairs studied.

		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**

Table 4. Redeployments of jelly-FADs and their catch performance.

Prototype	FAD ID	eploymen	# of fishing set	Fishing set date	Soaking time (days/month)	Total catch (tons)
JellyFAD_organic	14	25/1/22	1	12/3/22	46 days (1.5 months)	125
JellyFAD_organic	14	25/1/22	2	14/3/22	48 (1,6 months)	0
JellyFAD_organic	35	28/1/22	1	2/5/22	94 (3 months)	70
JellyFAD_organic	35	28/1/22	2	30/10/22	275 (9 months)	40
JellyFAD_organic	35	28/1/22	3	29/12/22	335 (11 months)	65
JellyFAD_hybrid	36	20/6/22	1	3/10/22	105 (3 months)	75
JellyFAD_hybrid	36	20/6/22	2	10/10/22	112 (4 months)	20
JellyFAD_organic	50	14/4/22	1	17/6/22	64 (2 months)	15
JellyFAD_organic	50	14/4/22	2	5/8/22	113 (4 months)	15
JellyFAD_organic	51	25/1/22	1	21/6/22	147 (5months)	10
JellyFAD_organic	51	25/1/22	2	13/8/22	200 (7 months)	15
JellyFAD_organic	52	24/1/22	1	26/6/22	153 (5 months)	35
JellyFAD_organic	52	24/1/22	2	7/10/22	256 (9 months)	30
JellyFAD_organic	77	27/1/22	1	17/4/22	80 (2,7 months)	115
JellyFAD_organic	77	27/1/22	2	10/5/22	103 (3,4)	23
JellyFAD_organic	2	29/10/21	1	1/3/22	123 (4 months)	120
JellyFAD_organic	2	29/10/21	2	13/7/22	257 (9 months)	10

Table 4 highlights the effectiveness of jelly-FADs even after their first fishing set. Specifically, 11% of the jelly-FADs fished, were redeployed and successfully fished a second time, with the exception of one (ID 14). While we lack comparable data for conventional FADs, the table indicates that jelly-FADs, particularly those in category II, can be reused for a second and third fishing event. This reuse occurs even after the FADs have spent an additional four months at sea between the first and second fishing sets.

Table 5 presents a comparison of catch events conducted on pairs of FADs. It details the number of bioFADs that were fished when their conventional pair was not, the number of conventional FADs that were fished when their bioFAD pair was not, and the instances where both or neither FADs in a pair were fished.

Table 5. Comparison of the catch event conducted on FAD pairs.

Sets	N	%
Only on BIO pair	38	40%
Only on CON pair	15	16%
Both	17	18%
None	25	26%

Our detailed monitoring of both jelly-FADs and conventional FAD pairs shows no difference in capture performance between the two types, in terms of soaking time and tons of catch. Similarly, performance was similar for category II and IV. The authors of this study believe that tunas cannot differentiate between category II and IV jelly-FADs, and that both types performed equally well in terms of captures. The only difference between these categories was the main rope, made of either plastic or cotton. Notably, the longest soaking time resulting in a successful catch, 11.2 months at sea, was achieved with an organic category II jelly-FAD (Table 3). Additionally, Table 4 shows that other category II jelly-FADs were successfully fished after 9 months at sea following redeployment.

3.3 Lifespan of Jelly-FADs and Conventional FADs

From the catch performance and visits we can infer the lifetime of FADs. Table 3 shows that the maximum lifespan in working condition and with a successful set on a jelly-FAD was 335 days (11 months), while for jelly-FADs of category II was 238 days. However the maximum days at which a set was conducted in a conventional FAD, was 267 days. Some of those FADs, both conventionald and jelly-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.

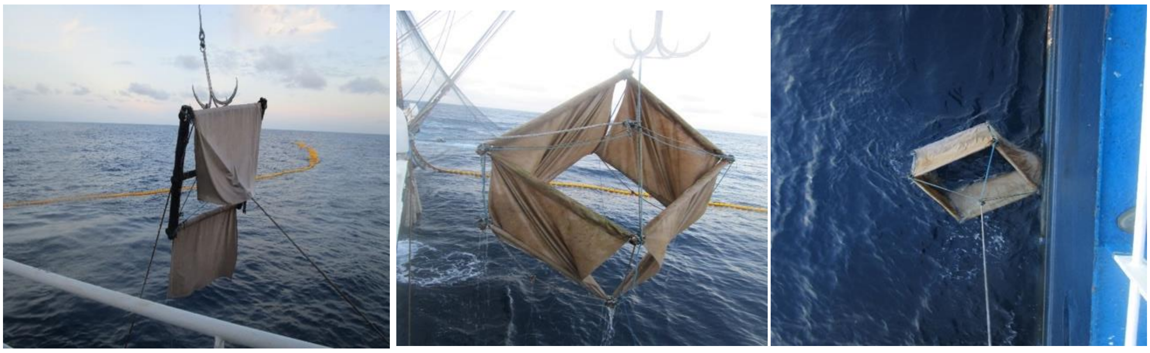

Figure 5. A Jelly-FAD fished after 5 months at sea (45 tons) and re-deployed in the EPO.

Echosounder buoy tracks were also used as an indicator of the lifespan of jelly-FADs compared to Conventional dFADs. Fishers deactivate buoys once the FAD leaves the fishing zone, is lost, or is abandoned. Therefore, if a buoy remains active and its monitoring fee is being paid, it indicates the vessel's continued interest in that FAD. We use this as an indicator of the lifespan of different FADs.Table 6 shows the maximum, mean and minimum (in days) of monitored period of the three dFAD types. The jelly-FADs and conventional FADs showed similar average monitored lifespan. The Jelly-FAD containing organic rope (N=46) showed the highest mean values (179 days of monitorization) in comparison to Jelly-FAD with polyethylene rope, 157 days (N=60) and conventional dFAD, 150 days (N=131) (Table 6, Figure 6).

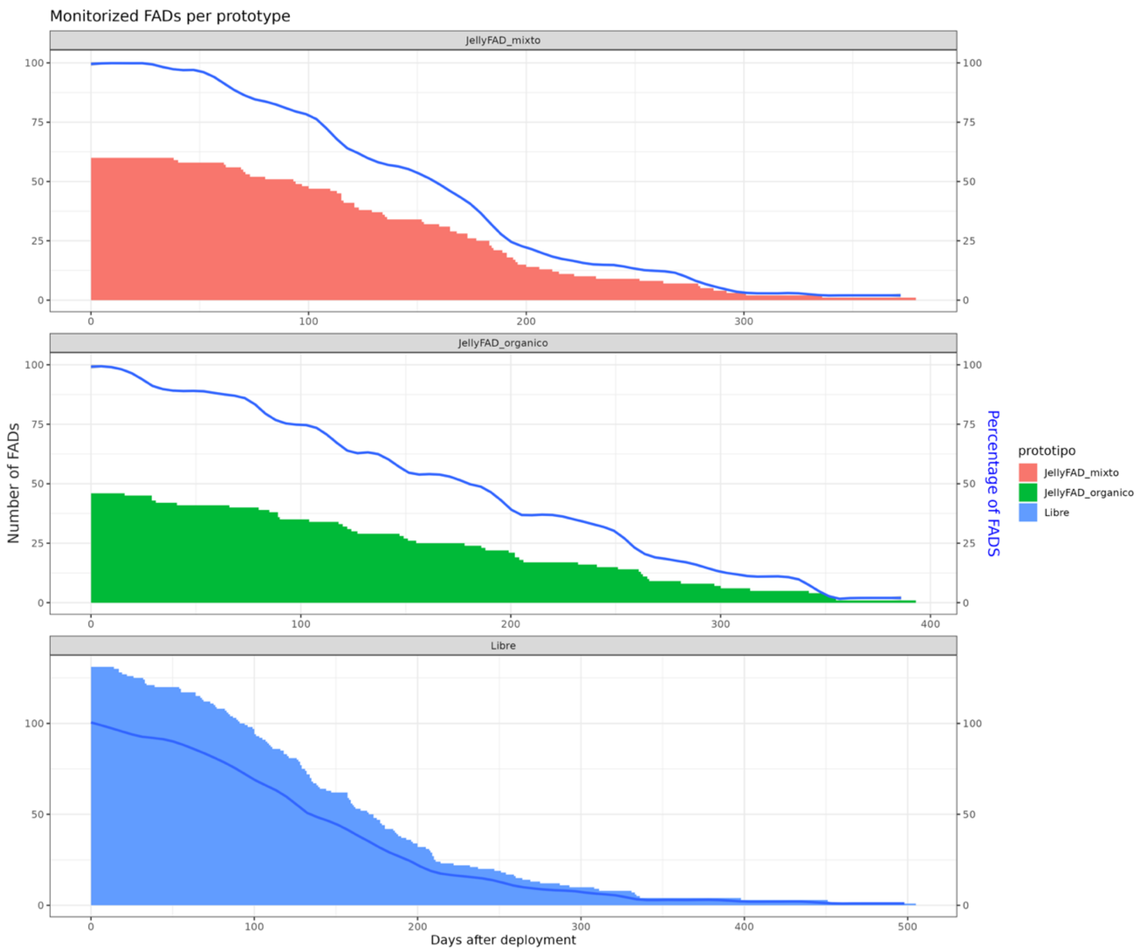

Figure 6. Monitored period in terms of days after deployment and number of observations by dFAD type. Top: Hybrid Jelly-FAD of category IV; Middle: Organic Jelly-FAD, category II Botton: Conventional FAD

Table 6. Monitored period by dFAD type.

FAD Type	N	Records	min (days)	mean (days)	max (days)
JellyFAD_hybrid	60	158,0	31,0	157,7	372,0
JellyFAD_organic	46	179,8	9,0	178,9	386,0
Conventional	131	151,3	8,0	150,6	498,0

An interesting conclusion drawn from figure 4 is the fact that fishers do not monitor FADs longer than about a year, for any of the types. After about 200 days at sea, monitored conventional FADs dropped to 25% of the deployed FADs and very few lasted a year. This same pattern has also been observed in other trials with bio-FADs.

3.4 Biomass estimation from echosounder buoys

Biomass estimates were directly extracted from the echosounder buoys associated to experimental dFADs. These data allowed following the evolution of the biomass beneath the different type of FADs. The 90th percentile of the biomass estimated by the echosounder buoys was used for this analysis. Figure 7 shows the evolution in the tuna biomass aggregation estimates during monitored period for each dFAD type. Both types of dFADs (Jelly-FAD and conventional dFAD) exhibited similar aggregation patterns for up to 100 days after deployment, with a peak in tuna aggregation around three months post-deployment. After 100 days, the variability increases significantly, likely due to fishing operations on these mature FADs and the initiation of a new colonization process.

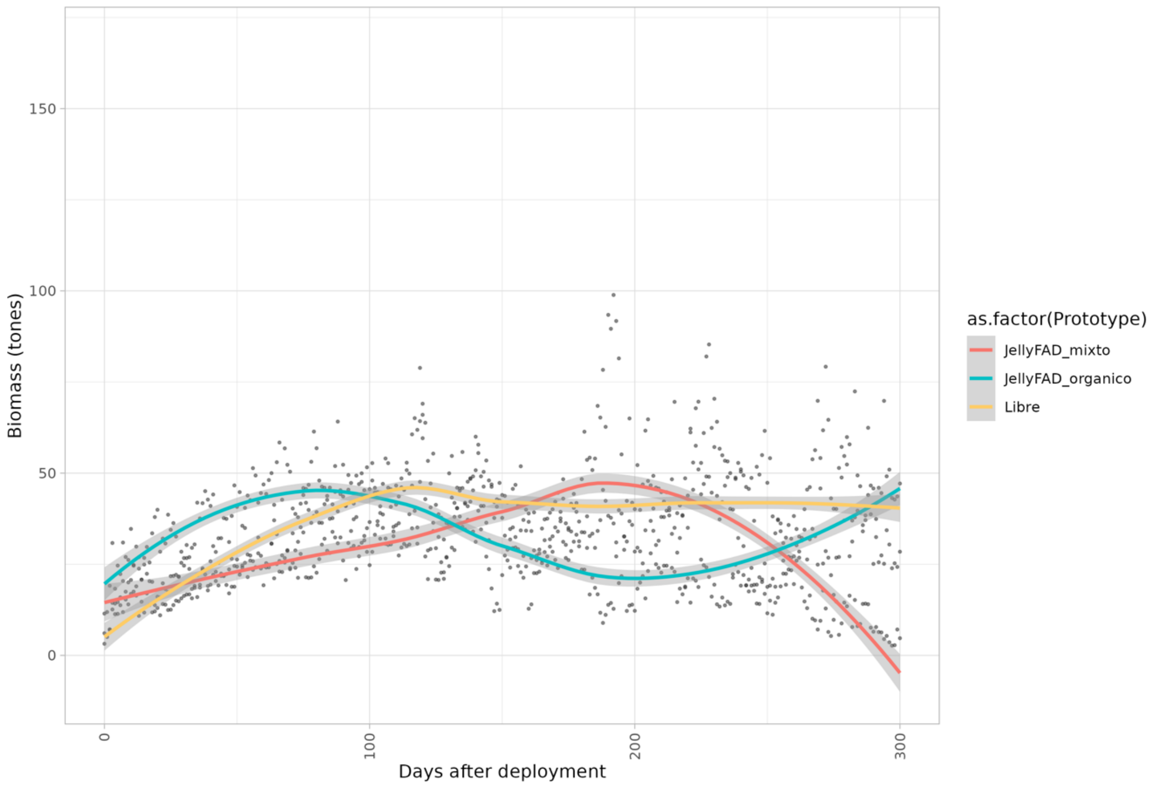

Figure 7. Tuna biomass estimation in tons (y-axis) and days after deployment (x-axis) by dFAD type, Jelly-FAD_hybrid (red); Jelly-FAD_organic (blue) and conventional (yellow).

3.5 Biodegradable material degradation

The data on the state of degradation of the Jelly-FAD materials provided by captains allowed the evaluation of its elements as shown in Figure 8. The bamboo raft structure was found to be in good condition in nearly all observations until month 12. The organic canvas for the raft was identified as the most vulnerable part of the FAD due to degradation from sun exposure and wave action. In 2022, the shipowner changed the canvas used, resulting in improved performance over time. A similar pattern was observed with the canvas used for the cube. The performance of the cube structure was generally good until month 6, after which it needed repair or was absent. The cube has been shown to break when lifted, but fishers noted that this may be due to the strong stress experienced during lifting. Despite this, fishers were still able to catch effectively even when the cube was broken (it could be that the cube was in good condition until it was lifted). The main rope made of cotton performed better than the polyethylene rope.

4 Conclusion

This study demonstrates that the catch performance, aggregation evolution, and drift speed of jelly-FADs were similar to, or even better than, those of conventional FADs:

→ **Lifetime**: Proven to last up to a maximum of 11 months (observed fishing set) but with various FADs being fished after 9 months at sea and being redeployed.
→ **Drift Speed**: Similar to that of conventional FADs.
→ **Catch Performance**: Better on Jelly-FADs than on their conventional counterparts.
→ **Redeployment**: Jelly-FADs were successfully redeployed and fished more than once.
→ **Jeely-FAD Category Comparison**: No significant difference between category II and category IV Jelly-FADs; however, organic Jelly-FADs showed better catch performance and longer monitored time (which is an indicator of the lifespan).

The lifespan of Jelly-FADs, like conventional dFADs, depends heavily on proper construction, including accurate assessment of weight and flotation needs, as well as the oceanographic conditions they encounter. Repairs may be necessary to extend their lifespan, similar to conventional FADs.

The success of this trial was largely due to the shipowner’s effort to deploy jelly-FADs systematically throughout 2021 and 2023 and the captains commitment to learn and improve throughout the process. This sustained effort led to:

→ **Learning Curve**: Fishers learned how to properly construct and deploy Jelly-FADs.
→ **Functionality**: Jelly-FADs began to function effectively and aggregate tuna.
→ **Increased Visits**: More frequent visits due to tuna presence and accelerated the learning process.
→ **Growing Confidence**: Fishers developed increasing confidence in the performance of Jelly-FADs.

Figure 8. Degradation of the different components over time in months (X-axis). State 1 = good condition (green), State 2 = needs repair (blue), State 3 = bad (yellow), State 4 = component not present (red) State 5 = unknown (purple). Number of observations are written in the columns.

Acknowledgements

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