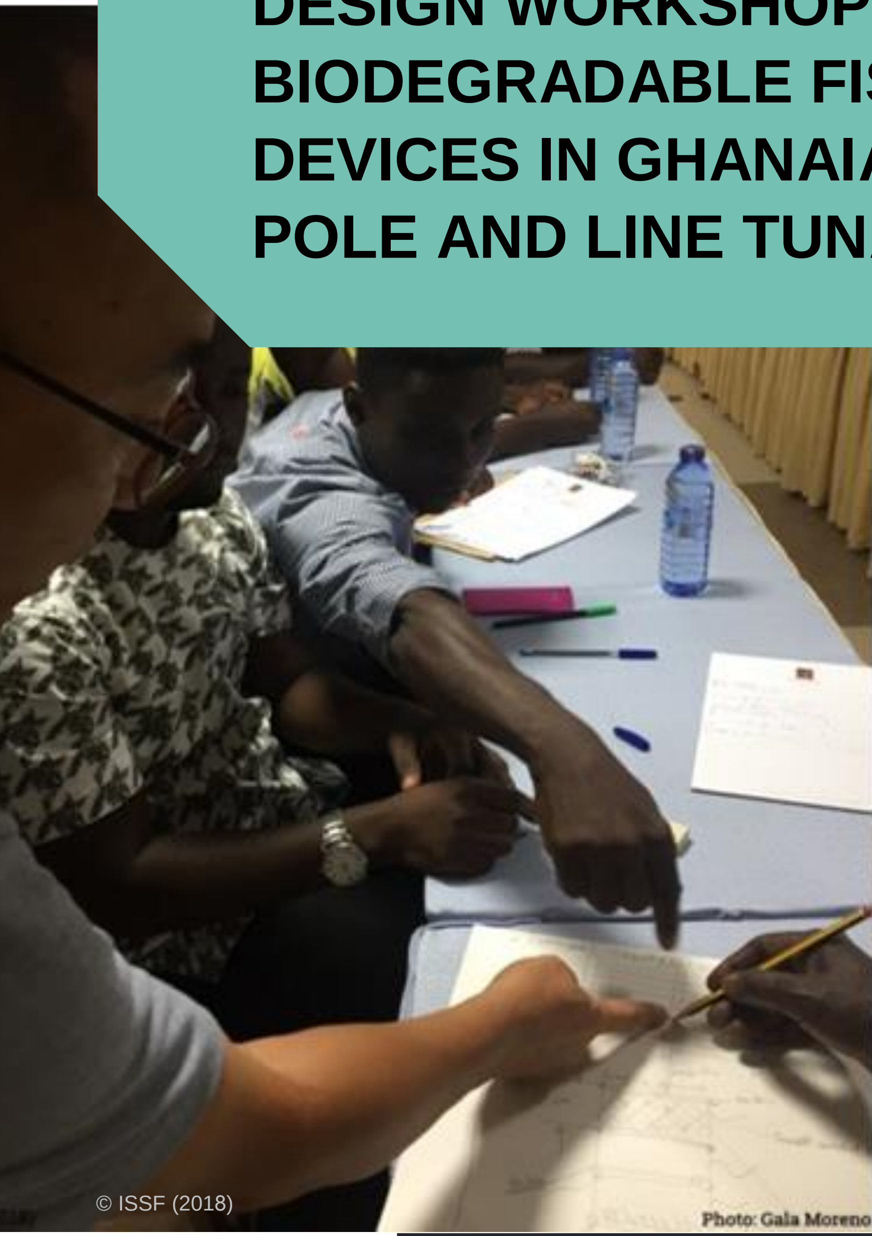
ISSF Technical Report 2018-07

DESIGN WORKSHOP ON THE USE OF BIODEGRADABLE FISH AGGREGATING DEVICES IN GHANAIAN PURSE SEINE AND POLE AND LINE TUNA FLEETS



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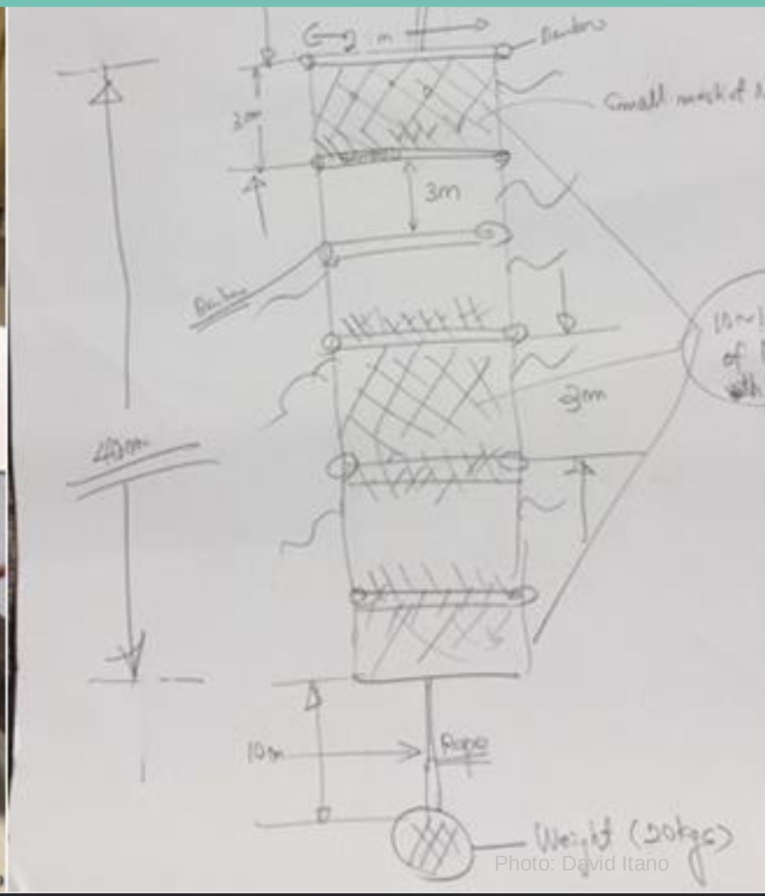

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Abstract

The present report summarizes a workshop conducted by ISSF with the Ghanaian purse seine and pole and line tuna fleets, to design biodegradable Fish Aggregating Devices (FADs). This workshop is one of the first steps of a project funded by FAO-GEF Common Ocean Project that will test biodegradable FADs with one of the most important fleets in the Eastern Atlantic, the Ghanaian fleet, with 26 vessels fishing with FADs. The aim of the workshop was to find an appropriate FAD structure to be tested with biodegradable materials available nowadays, as well as to find the best strategy to test those FADs with the collaboration of the Ghanaian fleets. Fishers worked separately in groups to design 5 biodegradable FADs. The number of experimental FADs to deploy, as well as the protocol to follow them at sea, was also set during the workshop. This year the Ghanaian fleet will deploy 600 biodegradable FADs.

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Executive Summary

Nowadays, most of the FADs used by tuna fleets in the 3 oceans, including the Ghanaian purse seine and pole and line fleets, use as main components petroleum-based nylon nets, which degrade very slowly, causing a growing accumulation of these materials in coastal areas and sea-beds year after year. Scientists at ISSF in collaboration with the fishing industry have been working in diverse projects on the use of biodegradable FADs in the Indian and Eastern Pacific Oceans. In 2018, ISSF — with the help of FAO-GEF Common Oceans ABNJ financed project — launched a project on the use of biodegradable Fish Aggregating Devices (FADs) in Ghanaian fleets, one of the most important fleets in the Atlantic, with 26 vessels fishing with FADs.

One of the first steps of this project was designing, together with Ghanaian fleets, a biodegradable FAD that could be useful for their fishing strategy with FADs. For that, a workshop was conducted with 69 participants, mainly Ghanaian fishers but also representatives from the fishing companies, Ghanaian Tuna Association and Fisheries commission.

During the workshop, fishers worked with ISSF scientists in groups to design biodegradable FADs made of materials from natural origin that are available in the market today. Experimental FADs were designed that took into account required lifetime for a FAD to be successful in Ghanaian fleets, biodegradability, logistics to build them and costs. It was also discussed in plenary the best way to test those biodegradable FADs in a collaborative way, so that results on the performance of the experimental FADs were obtained. The number of FADs to be tested per vessel as well as the strategy to build, deploy and collect data were determined during the workshop.

Five biodegradable FAD structures were designed by fishers in five groups separately, but all the designs converged towards a similar structure for pole and line and purse seine fleets. Materials used were bamboo canes (buoyancy and submerged structure), cotton ropes (submerged structure), cotton canvas (submerged flags and drift anchor), palm leaves (submerged structure) and finally plastic buoys or purse seine corks.

One of the most critical parts of constructing a FAD is the buoyancy of the structure. Their lifetime depends in many cases on the adequate assessment of the buoyancy needed for a given FAD structure and weight. Currently, biodegradable alternatives to substitute artificial floating materials used in FADs, such as purse seine corks, are scarce. In order to obtain results on the performance of biodegradable FADs, it was decided to allow the use of plastic buoys to prevent experimental FADs from sinking.

Ghanaian fleets will build and deploy 600 biodegradable FADs throughout the year 2018 and will collect the data on the performance of biodegradable FADs in real fishing conditions.

Key Findings:

1. **69 participants in the workshop, from 12 Ghanaian fishing companies, designed biodegradable FADs made of materials from natural origin.**
2. **FAD structures in Ghanaian fleets are deeper compared to those of other fleets in the Atlantic, and their required lifetime is a maximum of one year.**
3. **In 2018, Ghanaian fleets will deploy 600 biodegradable FADs to be tested in real fishing conditions.**
4. **The sum of knowledge by fishers about FAD designs specific for the Atlantic, and that acquired by ISSF scientists in previous projects on biodegradable FADs, was of great value.**

Fishers will also share with ISSF scientists the data from the echo-sounder buoys attached to experimental FADs.

Once again, the workshop showed the importance of involving the different stakeholders of the fishery, e.g., fishers and scientists, to find practical solutions to reduce FAD ecosystem-associated impacts.

Research Questions

The workshop was designed to answer the following questions**:**

- Which **FAD structure** is used nowadays by Ghanaian tuna fleets?
- What makes those **FAD designs** successful for fishing?
- What is the **desired life-time for a FAD** to be successful for fishing in Ghanaian fleets?
- Which **biodegradable FAD design** could be successful for fishing in Ghanaian fleets, taking into account lifetime, costs and logistics to build?
- How many **biodegradable FADs should be tested** by vessels in real fishing conditions?
- What is the best **strategy to test biodegradable FADs** in real fishing conditions?

1. **Introduction**

Subsequent to the November 2017 official launch of a Common Oceans ABNJ financed project on the use of biodegradable Fish Aggregating Devices (FADs), or FADs made with natural materials (Ghana BioFAD Launch), a design workshop was organized by ISSF February 26, 2018, in Tema (Ghana). This workshop is the second step of a FAO-GEF Common Oceans Project on the use of biodegradable FADs in the Eastern Atlantic Ocean. It was organized to propose FAD designs and tests at sea in Ghanaian tropical tuna fleets to reduce the amount of plastic and other non-natural materials used in FADs.

Recent research conducted in the Atlantic and Indian Oceans, using information from the trajectories of the buoys utilized to geo-locate FADs, showed that 10% of the deployed FADs ended up in stranding events (Maufroy et al 2015). This phenomenon of FADs ending up stranded in coastal zones, like beaches or coral reefs, is generally referred to as "beaching." Nowadays, most of the FADs used by tuna fleets in the three oceans, including the Ghanaian purse seine and pole and line fleets, use as main components petroleum-based nylon nets that degrade very slowly, causing a growing accumulation of these materials in coastal areas and sea-beds year after year.

26 vessels from Ghanaian purse seine and pole and line fleets participate in the biodegradable FADs project.

Scientists at ISSF in collaboration with the fishing industry have been working in diverse projects on the use of biodegradable FADs in the Indian and Pacific Oceans. Among other experiments, trials in controlled conditions with biodegradable ropes to be used at FADs were conducted together with the IPNLF foundation in Maldivian waters (Restrepo et al. 2016; Moreno et al. 2017a). These experiments measured the breaking strength of the different natural material ropes in time, the amount of bio-fouling adhered, as well as monitoring if fishes were feeding on them. These controlled trials allowed the selection of best materials for biodegradable ropes in terms of degradation time and high resistance for use in FADs.

However, trials in real fishing conditions are necessary to obtain conclusive results on the capacity of biodegradable FADs to aggregate tunas, as well as to discern the most appropriate biodegradable materials to be used. As FAD designs are fleet/ocean specific, ISSF organized a workshop in 2016 with scientists and fleets from the three tropical oceanic regions to take another step towards the search for solutions (Moreno et al. 2016). One of the results of that workshop was identifying the importance of testing biodegradable FADs in large quantities and in a collaborative way with the fleets fishing in the same region, as FADs are usually stolen, sink or drift away from the fishing zone. Thus, in order to get results on the performance of experimental FADs, a large-scale experiment with a large deployment of biodegradable FADs was identified as the best strategy. Following this strategy, a UE project in collaboration with ISSF (BIOFAD project) will test 1000 biodegradable FADs in the Indian Ocean.

This time, ISSF has worked specifically with the Ghanaian purse seine and pole and line fleet (represented under the Ghanaian Tuna Association [GTA]), one of the most important fleets with 26 vessels fishing with FADs in the Eastern Atlantic Ocean. The aim of the workshop was to find an appropriate FAD structure to be tested with biodegradable materials available today, as well as to find the best strategy to test those FADs with the collaboration of the Ghanaian fleets in the Eastern Atlantic Ocean. This report summarizes the results from the workshop.

Figure 1. Participants in the workshop on biodegradable FADs design. Ghanaian purse seine and pole and line tuna fleets. Members from Ghanaian Tuna Association and Ghanaian government. Jefferson Murua (AZTI) and Gala Moreno (ISSF).

2. Objectives

Specific objectives, in accordance with the development of biodegradable FADs, were to:

- Determine the structural features needed for a FAD to be productive in Ghanaian tuna fleets.
- Determine the minimum lifetime required for a FAD to be used in Ghanaian tuna fleets.
- Review the different biodegradable materials tested by scientists and fishers in previous science-industry projects.
- Design new biodegradable FAD structures appropriate to the fishing needs of the Ghanaian fleets.
- Define the protocol (or strategy) to test biodegradable FADs in real fishing conditions through the cooperation of the fleets in Ghana, with a timetable on the gradual implementation of these FADs by vessel.
- Define the data collection procedure to gather information that compares biodegradable and artificial material FADs results.

3. Results

3.1. Participation

A total of 69 participants attended the workshop (**Figure 1**, see **Annex I** for attendance list). Ghanaian fleets fish for tuna on FADs using two types of fishing gears, purse seine gear and pole and line. We had fishers (captains, officers and deck bosses) from the two types of fishing gears from 12 different fishing companies representing the vast majority of these fleets: D-H Fisheries, Laif Fisheries, G-L Fisheries, Trust Allied Fisheries, Rico Fisheries, BSK Marine, Africa Star Fisheries, Agnespark Fisheries, Dong Sheng Co. Ltd, World Marine Co., Panofi Co. Ltd, Asante Fisheries Co. Ltd. We also had representatives from the Ghanaian Fisheries Commission, Ghana Tuna Association (GTA), Pioneer Food Cannery, Signotrade Ltd and three ISSF scientists conducting the workshop.

There was high participation of fishers during plenary discussions, working in groups and presenting their ideas on biodegradable FAD. Once again, the workshop showed the importance of involving the different stakeholders of the fishery, e.g. fishers and scientists, to find practical solutions to reduce FAD ecosystem-associated impacts. The sum of knowledge by fishers in FAD designs specific for the Atlantic, and that acquired by ISSF scientists in previous projects on biodegradable FADs, was of great value.

69 participants from Ghanaian purse seine and pole and line fleets designed biodegradable FADs during the workshop.

3.2. Structural features needed for a FAD to be productive in the Ghanaian fleet

Firstly, a discussion was conducted to determine the structural features needed for FADs to be efficient in aggregating tuna for the purse seine and pole and line Ghanaian fleets. As it had been identified in other workshops (e.g. ISSF Skippers Workshops, Biodegradable FAD Workshop in San Sebastian), FAD drift speed and trajectory was the main variable to control to be an efficient fishing tool (Moreno et al. 2016). In particular for Ghanaian fleets, a slow drift of the FAD is especially important not only to aggregate tunas but also to maintain FADs within Ghanaian waters for a longer time (as many Ghanaian pole and line vessels only operate within their EEZ). A shallow FAD would cause FADs drifting out from Ghanaian fishing area very fast, precluding most of Ghanaian fleets from fishing on them.

Thus, Ghanaian fleets use especially deep FAD structures (e.g. 60-150 m) compared to other fleets to slow down the FAD and achieve the slow drift needed (**Figure 2**). These deep FAD designs (sometimes referred to as “Korean-style FADs” because Korean skippers navigate Ghanaian fleet vessels) were copied by other fleets like the Spanish and French in the Atlantic, and later derived to other oceans in the belief that deep FAD designs are more successful at aggregating tuna than shallower ones.

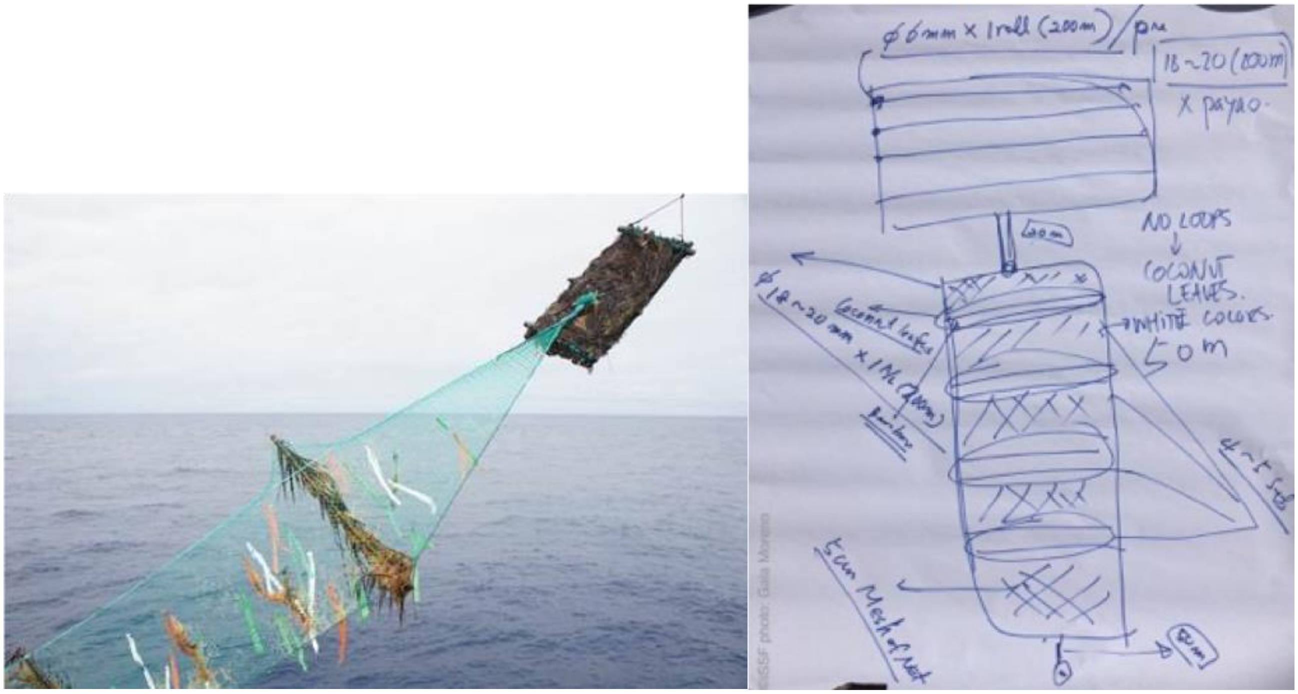

Figure 2. Left: Photo of the traditional "Korean Style" FAD design used in Ghanaian fleets. Right: Same FAD with technical details designed by fishers during the workshop.

The traditional Ghanaian FAD is constructed with bamboo canes in the raft and plastic cork-line buoys to achieve the flotation needed. The shadow produced by the floating and submerged structure is also considered important for Ghanaian fleets in order to aggregate species that occupy the space close to the FAD, named intranatans[1] (*Lobotes surinamensis*, *Abudefduf saxatilis*, etc.), as they may play the role of attractors of tuna species.

In general, fishers in Ghana use palm leaves to cover the raft, and strings and flags with colors that are usually added to the shallow part of the submerged structure. In general, Ghanaian fleets use in the submerged part of the FAD open net panels (average size of the mesh used is 4 inches [approx. 100 mm]) as it is shown in **Figure 2**, to create drag and extra-surface area. Fishers said they do not use different kinds of FADs in different areas of the Atlantic. They use the same design for all of their traditional FADs, the only difference being the depth of the tail appendage, which can range between 50 to over a 100 m in depth. After adoption by the International Commission for the Conservation of Atlantic Tunas (ICCAT) of regulation 16/01, establishing obligatory use of non-entangling FADs by January 2017, fishers have substituted wide open net with smaller mesh sized net (e.g. small pelagic net with < 2.5 inches mesh), but the structure remains the same.

The purse seine company African Star is the only one using the other type of FAD structure, made using a "sausage" tied net in the subsurface, making the FAD a lower entanglement risk (LER) FAD (**Figure 3**). The use of this LER FAD is not a fishers' choice, but rather a company policy. FADs are made on land and then distributed to the boats. Fishers do not like the "sausage" FADs because they think that the drift is too fast, and it attracts less tuna than open panel traditional

[1] Those species that move within 2 m range from the FAD. Parin, N.V., and Fedoryako, B.I 1999.Pelagic fish communities around floating objects in the open ocean. Fishing for Tunas associated with floating Objects, International workshop. Inter-American Tropical Tuna Commission (11): 447-458

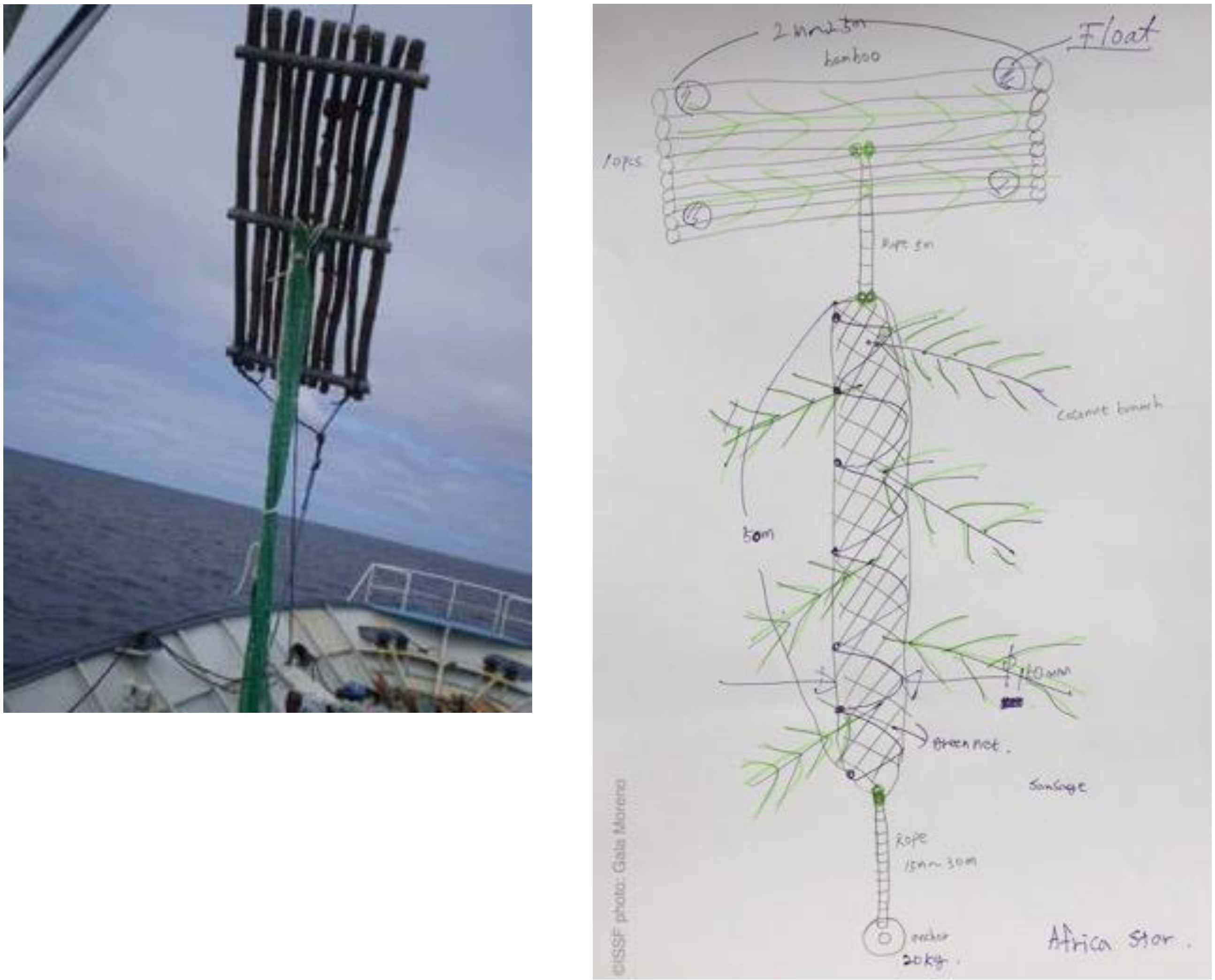

Figure 3. Left: Net tied in "sausage" Low Entanglement Risk FAD used in Ghana (©F. Iriarte). Right: Same FAD with technical details designed by fishers during the workshop.

"Korean style FADs." For the raft they have decided to not use any kind of netting or cover, just the bamboo and corks. This makes the raft a non-entangling (NE) one. When asked if they have more FADs stolen due to greater visibility of rafts without a dark cover, the answer was no. Fishers are not satisfied with the tied-netting model as they think the performance of this type of FAD is poorer compared to the open-net panel traditional ones.

3.3. Lifetime of a biodegradable FAD to be useful for fishing by Ghanaian fleets

The required lifetime of a FAD (i.e., the time the FAD remains working adequately at sea before deteriorating) for a given fleet/ocean heavily relies on FAD fishing strategy of the fleet. The life duration of the Ghanaian FADs is between nine months and one year, and this is what fishers expect the working life of a biodegradable FAD should be. The longer duration of FADs for this fleet compared to others (e.g., EU fleets say FADs last 3-9 months) is probably associated with the regular maintenance work Ghanaian fishers do on each FAD at least every 3-4 months. Pole and line fishers explained that they retrieve their FADs before they drift out of Ghanaian waters (approximately every 2 months), so that they can refurbish them to use them again. It was considered that a FAD is no longer in a good working state beyond the times specified above. Thus, after a working period of a year, FADs should degrade as fast as possible.

Figure 4. Left: 20 mm cotton rope; Right: Cotton rope with loops to allow bio-fouling.

3.4. Review of the different biodegradable materials tested by scientists and fishers in previous projects and their adequacy to the tuna Ghanaian fleets

During the meeting, a review of the different experiments conducted by both scientists and fishers was done (Franco et al., 2009, 2012; Goujon et al., 2012; Moreno et al., 2017a,b; Murua et al., 2018). The behavior, resistance, bio-fouling, price and other issues were discussed for materials from natural origin, as well as for other alternatives that come from non-natural origin. The following items were discussed and agreed from the results of this review:

SUBMERGED STRUCTURE OF THE FAD

- Nowadays biodegradable ropes made with cotton are the ones that have shown higher breaking strengths and durability in time. Fishers participating in large-scale biodegradable FAD experiments in the Indian Ocean are using them, as well as some of the experimental biodegradable FADs tested in the Eastern Pacific Ocean. There are two types of cotton ropes that have been tested so far, one with the capability of adhering bio-fouling (similar to ropes used to grow mussels in aquaculture) and others that do not enhance bio-fouling (**Figure 4**). The latter would allow the structure of the FAD to be more stable over time, while the bio-fouling adhering type will aggregate incrusting organisms, which some fishers believe is good for fish attraction during the FAD colonization phase.

  Ghanaian fleet fishers at the workshop liked the cotton rope without loops (e.g., no-biofouling) to support the main submerged structure of the FAD. However, they did not consider necessary the rope with the loops, as they use other “attractors” as palm leaves submerged and attached to the main structure (Fig 1). Thus, for Ghanaian fleets biodegradable FADs only made of cotton rope without loops would be required.

- Biodegradable canvas made of cotton was identified as a good alternative to be used as underwater flags or “sails” attached to the submerged structure of the FAD, both to create more volume and shadow as well as to function as drift anchors that slow down FAD movement (**Figure 5**).

SURFACE STRUCTURE OF THE FAD

One of the most critical parts of constructing a FAD is the buoyancy of the structure. Their lifetime depends in many cases on the adequate assessment of the buoyancy needed for a given FAD structure and weight. Thus, it is necessary to precisely calculate FAD buoyancy requirements (including the weight it will gain over time through water absorption and bio-fouling) for it to be actively working during the desired time period. Currently, biodegradable alternatives to substitute artificial floating materials used in FADs such as PVC pipes, purse seine net corks, plastic buoys, containers or drums are scarce. These are the main components that were discussed for the Ghanaian case:

- Bamboo canes have been used for many years to build FADs. One of the principal difficulties with using only bamboo is that the FADs lose buoyancy over time due to water absorption into the cane´s air chambers, eventually making the FADs sink. Fishers in Ghanaian fleets use bamboo canes; however, they still need to add plastic flotation to prevent the FAD from sinking. Perhaps an appropriate treatment of bamboo canes with natural varnishes or other methods would extend their lifetime up to the required time (e.g., one year) — this possibility has not been tested yet.
- One of the few alternatives presented during the workshop was balsa wood (*Ochroma pyramidale*). This wood that is well known for its great buoyancy could be the best biodegradable alternative identified at present for the floats of FADs. Fishers at the workshop were surprised about the characteristics of this wood; however, it is not clear if this wood is available in sufficient quantities in Ghana or neighboring countries.
- In previous workshops with other fleets (e.g., Spanish, French), dark-colored cotton canvas was also identified as a good biodegradable alternative to cover the raft in order to provide consistency to the structure and shadow to attract fish. Fishers from Ghana did not consider necessary covering the FAD´s raft, so this possibility was discarded.

Figure 5. Cotton canvas of various thicknesses

3.5. Biodegradable FAD designs to be tested in Ghanaian fleets

One of the main objectives of the workshop was to design biodegradable FADs that could be tested at sea in the near future, using biodegradable materials available in the market. As a workshop activity, fishers were divided into five working groups to propose best biodegradable FAD designs (**Figure 6**). Selected materials for the different FAD designs were:

- Bamboo canes (buoyancy and submerged structure)
- Cotton rope without loops (submerged structure)
- Cotton canvas (submerged flags and drift anchor)
- Palm leaves (submerged structure)
- Plastic buoys or purse seine corks[2]

[2] Although buoys or purse seine corks are not biodegradable, they were considered necessary during the trials to get data from the diverse biodegradable materials being tested. Some of the experiments at sea conducted in the Atlantic failed because all the FADs sank, and no data was retrieved. The buoyancy needed for a given structure needs to be tested by monitoring the bio-fouling adhered to the different parts of the FAD. To avoid potential

In total, five biodegradable FAD prototypes were designed (**Figures 7-11**). Most of the FADs reached more than 100 m depth. The shallower FAD was 60 m depth and the deepest FAD structure reached 120-170 m depth. All FADs were designed using biodegradable structures for the tail and rafts, except for the plastic buoys as floats (to avoid experimental FADs sinking during the first trials to test biodegradable structures and thus not receiving results on their performance). Although fishers worked in five different groups separately to design biodegradable FAD structures, the designs converged towards a similar structure for pole and line and purse seine fleets, a non-entangling Korean Style FAD with biodegradable materials.

sinking of experimental FADs during these initial trials, plastic buoys could be used to provide extra buoyancy and ensure data is gathered for these experimental FADs.

Figure 6. Ghanaian fishers designing biodegradable FADs.

The following biodegradable FAD designs are the result of the work in groups:

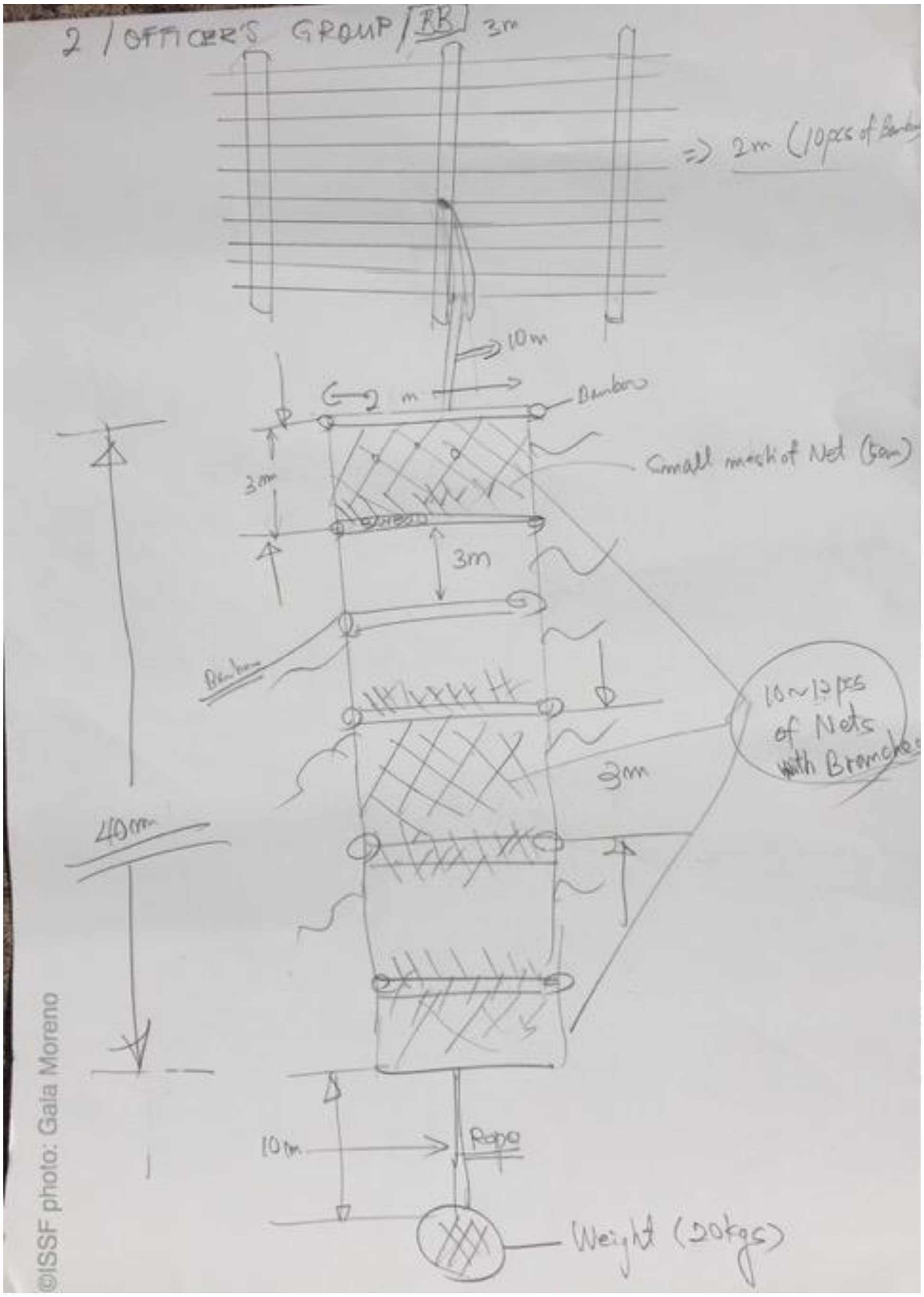

Figure 7. Biodegradable FAD designed by group 1.

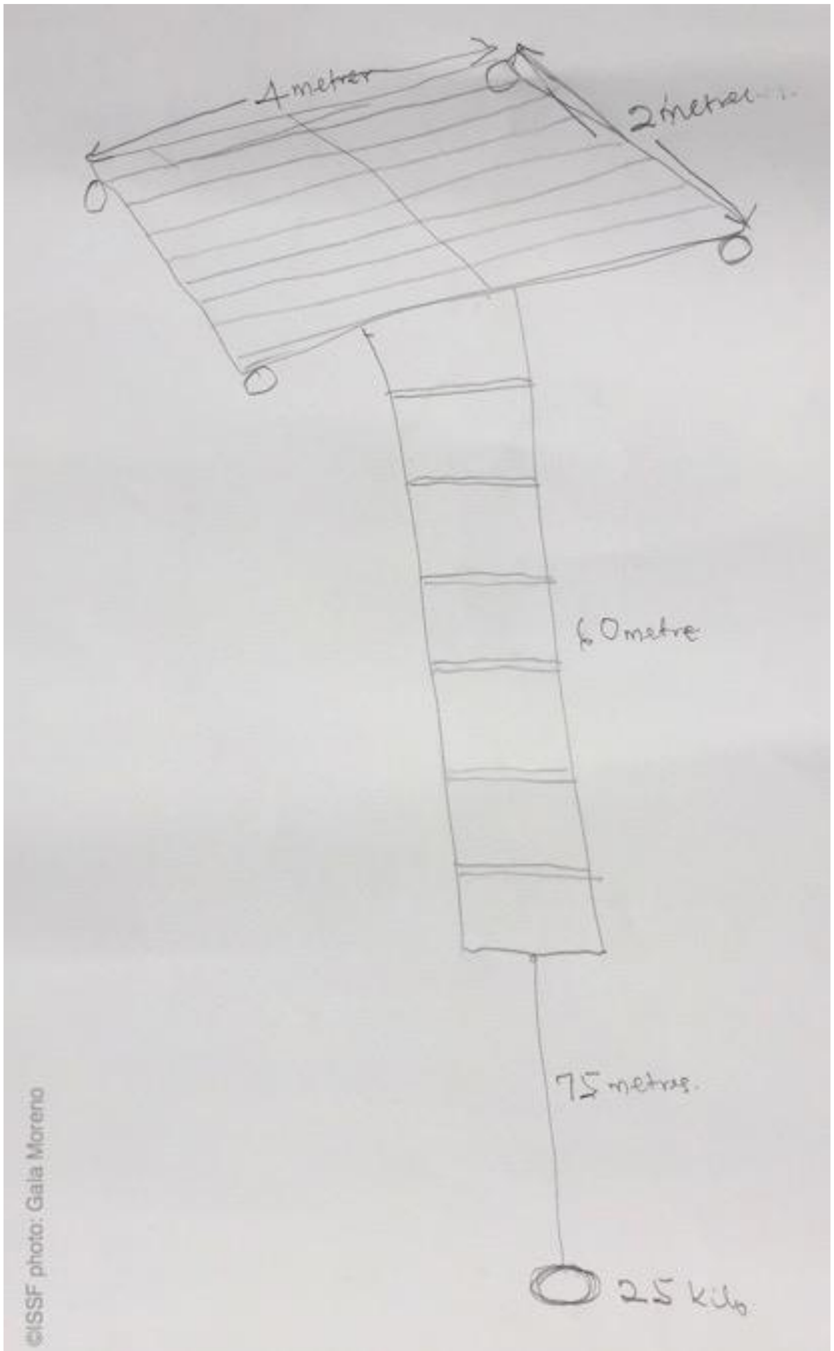

Figure 8. Biodegradable FAD designed by group 2.

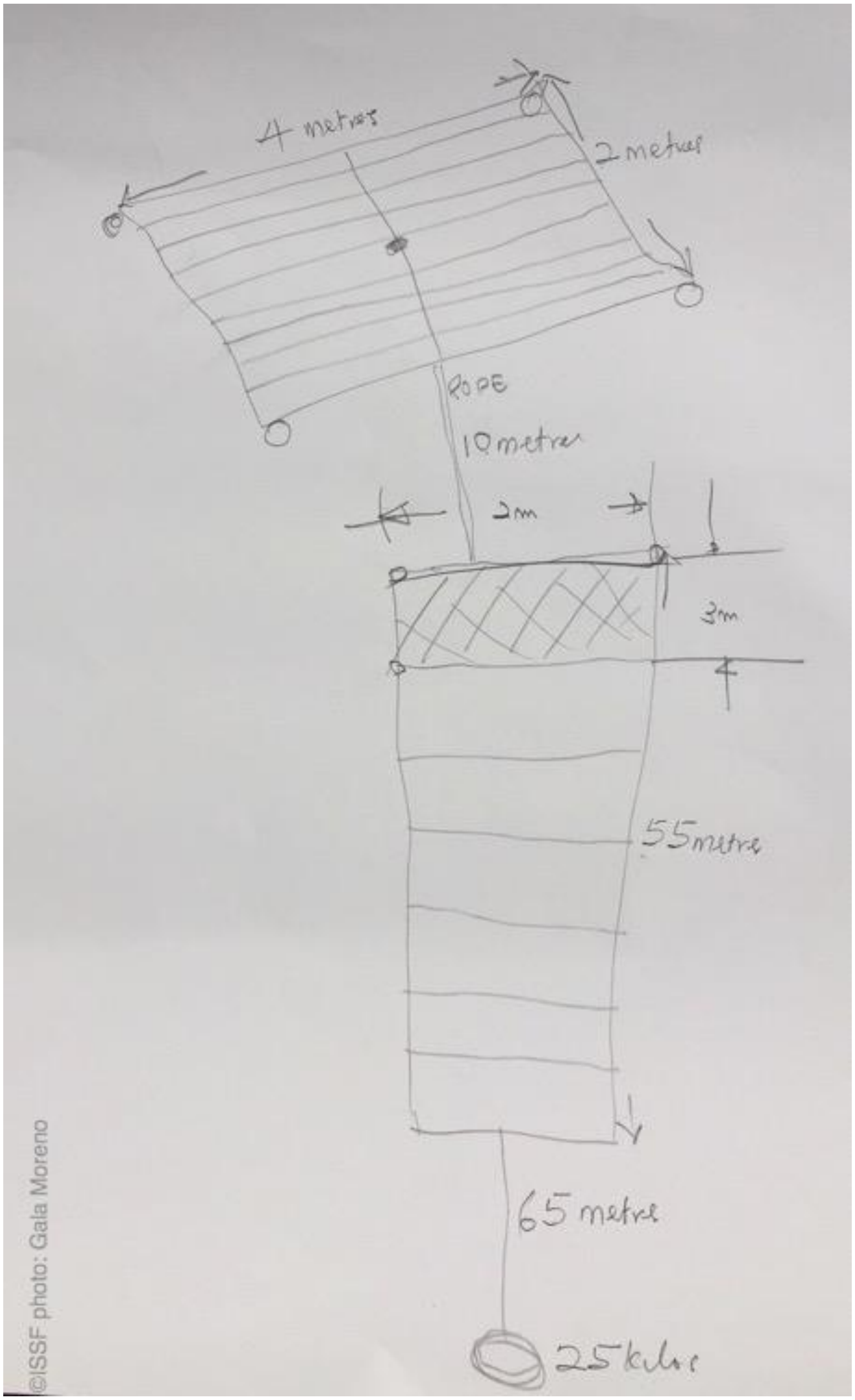

Figure 9. Biodegradable FAD designed by group 3.

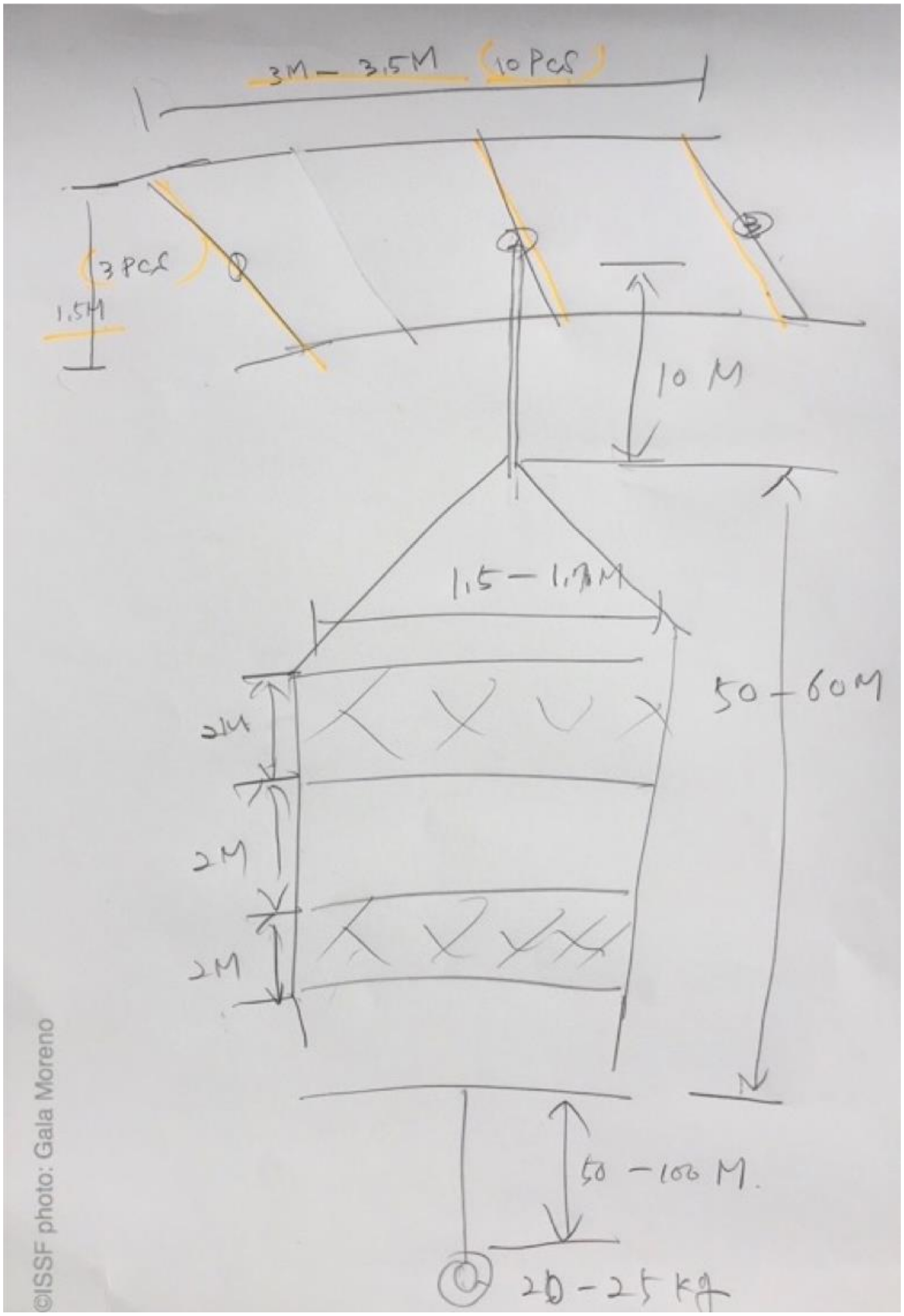

Figure 10. Biodegradable FAD designed by group 4.

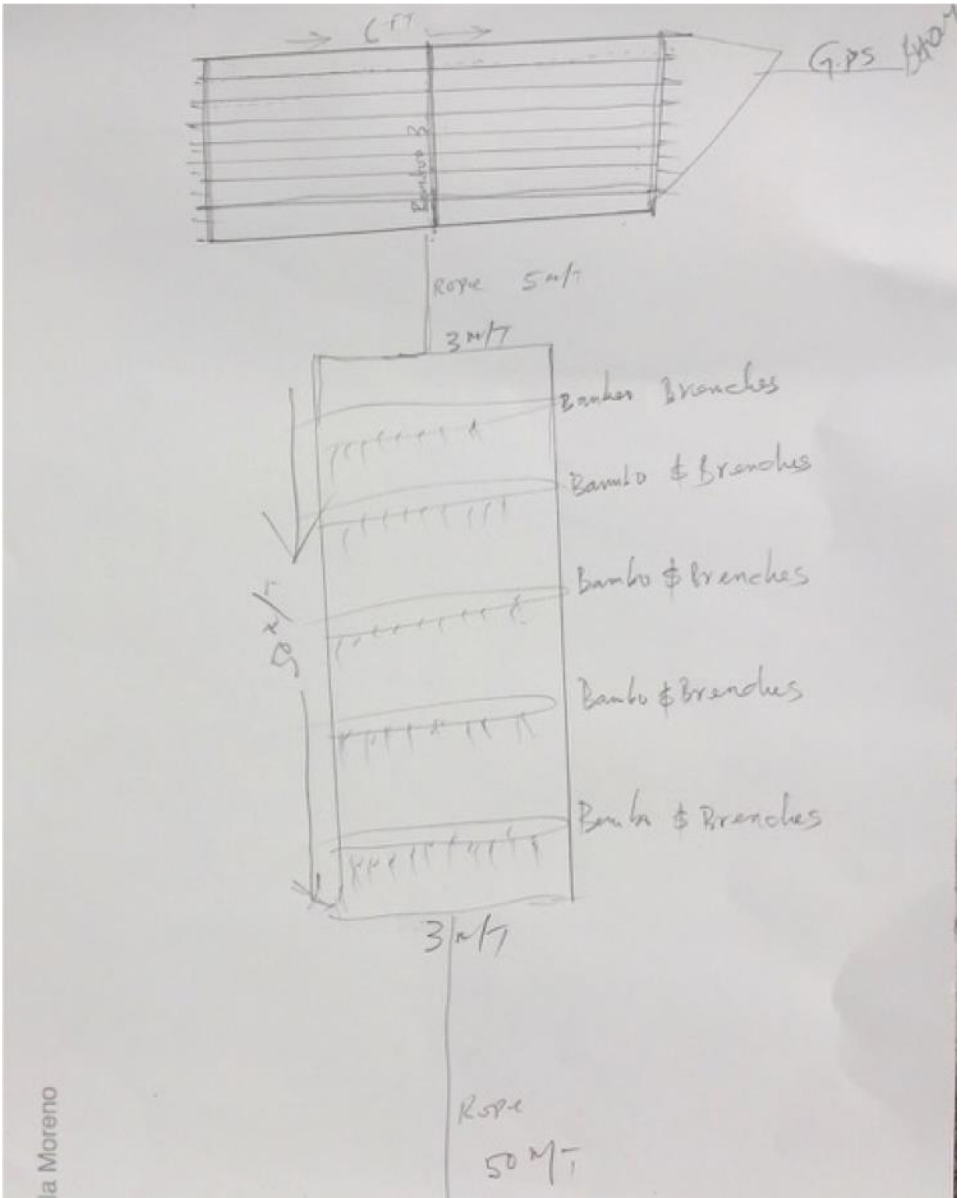

Figure 11. Biodegradable FAD designed by group 5.

3.6. Strategy to test biodegradable FADs during fishing operations

Once the different biodegradable FADs were designed and presented in front of the rest of participants, discussions were driven to define an effective strategy to test them in real fishing conditions.

Until now, the strategy of deploying a reduced number of experimental FADs has consistently been unsuccessful as stated earlier in this document, due to the difficulty of revisiting and getting information on few experimental FADs when FAD loss rates are substantial (e.g., loss to other vessels, through sinking, beaching, etc.).

Thus, for all participants, it was clear that a large enough FAD number should be deployed, and that the collaboration of the different fleets was necessary to achieve an efficient monitoring of the evolution of the FAD structure over time. Hence, for the success of the trials with biodegradable FADs the following protocol was proposed:

- Every vessel from the Ghanaian Fleet should build and deploy five biodegradable FADs every trip (approximate trip length estimated at 45 days), during four consecutive trips. Thus, a total of 20 FADs would be deployed per vessel over six months for the project (**Table 1**).
- ISSF will provide the material to build the submerged part of the biodegradable FADs, i.e., rope and canvas. ISSF will also provide extra biodegradable material to allow experimental FAD repairs when needed.
- Bamboo canes and palm leaves for the raft would be provided by fishing companies as well as the buoy to track the FAD. These are materials they are already buying for traditional FADs.
- Fishers will repair biodegradable FADs, if needed, using the extra biodegradable material provided by ISSF or biodegradable materials of their own (e.g., bamboo).
- Since the objective is to monitor the time evolution of biodegradable materials and assess the buoyancy of the FAD, non-biodegradable flotation could be added at the beginning to guarantee that the FAD does not sink and that data will be collected.
- Experimental FADs should be deployed in the same area and time as traditional FADs, so their effectiveness could be compared with that of the traditional FADs for the same spatial and temporal strata.
- Provide information on the time evolution of biodegradable FADs encountered at sea, both through a template filled by the officer and by the observer. The project aims at following the state and tuna attraction ability of biodegradable FADs over one year, if possible.
- Deployment site, type of biodegradable design and the code of the geo-locating buoy should be registered. Every FAD should be well identified so that data can be retrieved and followed by the different owners.
- If a biodegradable FAD is encountered at sea, the following data should be registered: the catch (if any), the condition of the FAD and the new code for the buoy if the original has been replaced.
- Ghanaian fishers agreed to provide the trajectories and biomass of echo-sounder buoys attached to biodegradable FADs. This data would allow assessing the capability of biodegradable FADs to aggregate tunas, even if they are not visited or fished, as well as following their lifetime if they are not retrieved by the owner vessel.
- A Ghanaian consultant hired by ISSF through ABNJ funding would be in charge of gathering experimental biodegradable FAD results from the boats, monitoring whether the correct information is being collected by fishers and observers, creating a database and analyzing the data.

Table 1. Time table of biodegradable FADs implementation per vessel

ACTIVITY PER VESSEL	TRIP 1*	TRIP 2	TRIP 3	TRIP 4	TRIP 5	TRIP 6	TRIP 7	TRIP 8
Construction and deployment	5 bio FADs	5 bio FADs	5 bio FADs	5 bio FADs				
Visits & Repairs								
Sharing echo-sounder data								
Data reporting**								

**Trips were estimated to be around 45 days. **End of each trip*

The deployment to test Biodegradable FADs will start as soon as the biodegradable materials arrive in Ghana. Meanwhile, a database will be created and meetings with Ghanaian fleets will be conducted to assess the progress of the project and data collection protocols.

3.7. Retrieving FADs

Even if biodegradable FADs will considerably reduce the ghost fishing and pollution impacts on marine ecosystems, they will not completely remove all impacts.

Retrieving FADs that beach in critical areas of particular vulnerability, such as coral reefs, was discussed in a separate workshop (ISSF Skippers Workshop) the following day. Several alternatives, such as having specialized clean-up groups on land or vessels at sea, or each boat collecting their derelict FADs before they sink, were mentioned.

4. Conclusion

Participants at the workshop, primarily fishers and ship-owners, were very collaborative in explaining their types of FADs and fishing strategies and trying to find new designs for biodegradable FADs to be tested in Ghana. Fishers worked in five different groups to design five biodegradable FADs. However, those designs converged in a very similar biodegradable FAD design.

Biodegradable materials will be sent to Ghana so that fishers in collaboration with ISSF can test them during fishing conditions in large quantities (e.g., $\approx$ 600 biodegradable FADs). The main challenge for now is to find a successful biodegradable alternative to the artificial floats (purse seine corks, buoys, etc.). However, having 90% of the structure of the FAD made of biodegradable materials such as cotton would be a huge step towards minimizing FAD impacts on the ecosystem.

Fishers clearly understood the benefits of using biodegradable FADs and were keen to collaborate at sea to collectively test new biodegradable materials and designs for non-entangling FADs.

Acknowledgments

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Recommendations

The workshop resulted in the following recommendations:

Recommendation 1:

- Required lifetime of Ghanaian FADs to be useful for fishing purposes is a maximum of one year.

Recommendation 2:

- Experimental, biodegradable FADs need to be tested in great quantities in order to obtain meaningful results, thus Ghanaian fleets should deploy a large quantity, around 600 biodegradable FADs.

Recommendation 3:

- Fishers should share data from echo-sounder buoys attached to experimental FADs with scientists to follow remotely the evolution of the experimental FADs that are not visited by fishers.

Recommendation 4:

- Research to find alternatives to provide biodegradable buoyancy to FADs is needed.

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Annex I

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