Workshop on the Use of Biodegradable Fish Aggregating Devices (FADs)

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1. Background

A workshop on the use of biodegradable FADs, or FADs made with natural materials, was organized by ISSF the 3rd and 4th of November of 2016 in the Aquarium of San Sebastian (Spain). This workshop was organized in order to propose solutions to reduce the amount of plastic and other non-natural materials used in FADs to avoid pollution of the oceans when FADs sink or beach in coastal areas. A recent research conducted in the Indian Ocean, 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)[1]. Nowadays FADs are made using as main components petroleum products as plastic, PVC, nylon nets, etc., that degrade slowly, causing a growing accumulation of these products in coastal areas year on year. The impacts associated to FAD beaching events are damages in coral reefs, marine pollution as well as ghost fishing.

Scientists working on FAD research as well as fishing industry, well aware of the impacts that FAD beaching events can cause in reefs and coastal ecosystems, have been working since 2007 to develop FAD structures that minimize this impact. Among other experiments, trials with FADs made of diverse materials from natural origin were conducted in real fishing conditions. One of the main difficulties detected during the trials at sea was the lack of sufficient observations during the life of experimental biodegradable FADs. Due to the complex fishing strategy with drifting FADs, a high percentage of FADs deployed by a given vessel is usually fished and retrieved by other vessels, which makes difficult to revisit and get information on how the biodegradable structure evolves as well as on its lifetime.

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[1] Maufroy A, Chassot E, Joo R, Kaplan DM (2015) Large-Scale Examination of Spatio-Temporal Patterns of Drifting Fish Aggregating Devices (dFADs) from Tropical Tuna Fisheries of the Indian and Atlantic Oceans. PLoS ONE 10(5): e0128023. doi: 10.1371/journal.pone.0128023

Recently AZTI, ISSF and IATTC have been conducting experiments under controlled conditions to study the behavior of some of the materials from natural origin available in the market, as sisal, cotton and coco fiber configured as ropes, canvas and fabrics of various thicknesses. These experiments which some are still ongoing, measure the breaking strength of the different ropes in time, the amount of biofouling adhered, as well as monitor if fishes are feeding on them. So far, these under-controlled trials have allowed discarding those ropes not suitable due to their low resistance as well as knowing the degradation in time for other materials. 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. ISSF organized the workshop in response to these necessities as well as to involve the fleets from different oceans in the search for solutions. During the workshop, discussions were driven 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 different fleets operating in Indian, Atlantic and Pacific Oceans.

2. Objectives of the workshop

The objective of the workshop was to join efforts, through collaboration of scientists and fishers, to find solutions to reduce the environmental impacts of FADs sinking in the ocean or beaching in coastal areas.

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

1. To determine the structural features needed for a FAD to be productive.
2. To determine the lifetime required for a FAD to be used as an efficient fishing tool in the different oceans.
3. To review the different alternatives available in the market, tested through experiments: from natural origins (biodegradables) and other alternatives from non-natural origin.
4. To design new biodegradable FAD structures for the different oceans.
5. To define the protocol (or strategy) to test biodegradable FADs in real fishing conditions through the cooperation of the fleets in the 3 oceans.

3. Results

3.1 Structural features needed for a FAD to be productive

A review was conducted to determine the structural features needed for future biodegradable FADs to efficiently aggregate tunas.

First of all, fishers agreed to say that any type of floating object can be efficient if it is located in the good place at the good time. Location and time is therefore the key issue for successful tuna attraction. Therefore, the structure of the FAD should be designed so that it will drift to good areas at the good time. The drift of the FAD is the main variable to control in order to aggregate tunas. There are regions where the FAD needs to drift slowly to effectively aggregate tunas. In such regions, a deep FAD structure is needed to anchor it in deep waters. For other regions, the drift needs to be driven by surface currents. In such contexts, the FAD structure should be shallow. Thus, two types of FAD structures need to be addressed, a shallow one and a deep one, basically in relation to the oceanographic conditions of the area and probably to other factors such as the vertical distribution of tuna prey.

The shadow produced by the floating structure of the FAD as well as the strings and flags that are usually added to the shallow part of the submerged structure, were considered necessary to attract those species that occupy the space close to the FAD, named *intranatans*[2] (*Lobotes surinamensis*, *Abudefduf saxatilis*, etc.). Intranatant species in turn, may play the role of attractors of other species that occupy the space at greater distances from the FAD, such as tunas. It may be that once the FAD is colonized by *intranatant* species, the structure of the FAD (color, shadow, etc.) loses importance on the ability to attract tunas, as *intranatant* species once present at FADs, may serve as a more powerful attractor than the FAD structure itself. Although visual and hearing abilities of tunas are not well known yet, it is likely that the noise, odor and movement of *intranatant* and *extranatant* (*Aluterus monoceros*, *Kyphosus cinerascens*, *Caranx sp*., etc.) species at FADs could be detected further away than stimuli produced by the FAD itself, unless there is an element of the structure which produces noise, as it has been mentioned for the case of anchored FADs with the anchoring chain.

Finally, the importance of the depth of the FAD structure was attributed solely to achieve the desired drift.

3.2 Lifetime of a biodegradable FAD to be useful for fishing

Given the complexity of FAD fishing strategy, and the particularities of each ocean on the way FADs are deployed, maturation time and fishing, the required lifetime for a FAD was specified by ocean:

-Eastern Pacific Ocean: From 6 months to 1 year
-Western Pacific Ocean: 1 year
-Indian Ocean: 1 year
- Atlantic Ocean: From 5 months to 1 year

[2] 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

It was considered that a FAD is not usually used beyond the times specified above. Thus, FADs older than these thresholds should be able to degrade as fast as possible.

3.3 Review of the different biodegradable materials tested by scientists and fishers

During the meeting, a review of the different experiments conducted by both, scientists and fishers was done. 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:

The concept of biodegradable

- Although the definition of biodegradable is "capable of being broken down (decomposed) by the action of microorganisms", the time required for this biodegradation is an important issue here. The challenge for the current objective is to design a biodegradable FAD that aggregates fish and can last up to the above thresholds (from 5 months to 1 year, depending on the ocean) and capable of biodegrading as fast as possible after this time.
- Other alternatives from non-natural origin as plastics, metal, oxo-biodegradable plastics were discarded. Although these materials could have a lesser impact in the manufacturing and transportation stages of their life cycle compared to that of materials from natural origin, their slow degradation and durability and the end of their life cycle can have such an impact on coastal ecosystems that they were not considered as options.

Submerged structure of the FAD

- Some of the materials from natural origin were discarded due to their fragility and short lifetime, as coco fiber and jute in fabric configuration as fish ended up feeding the fabric.
- Nowadays ropes made of cotton are the ones that have shown higher breaking strengths and durability in time. There are 2 types of cotton ropes that have been tested, one with the capability of adhering bio-fouling (similar to those used to grow mussels in ropes) and the ones that do not allow the bio-fouling (Fig 1). The latter would allow the structure of the FAD to be more stable over time while the ones that adhere bio-fouling will aggregate incrusting organisms that will decrease the floatability of the structure with time. However, the latter could be helpful in the first stages of the colonization process of the FAD (this hypothesis has not been tested). Other ropes have not been tested yet as tencel ropes available in the market made of eucalyptus.

Fig. 1. Different rope types from natural origin analyzed during the workshop.

- Canvas made of cotton used for activities that require high resistance, as military activities, were identified as a good alternative to be used as flags attached to the main structure of the FAD, both to create more volume as a "drifting reef" as well as to use them as drift anchors to make the FAD drift slower (Fig 2). First prototypes of FADs using this canvas as drift anchor have recently been deployed at sea. These canvas have different numbering in relation to their thickness, one of the thickest (number 12) was the preferred one for the fleet that is testing them.

Fig. 2. Biodegradable canvas of various thicknesses made of cotton

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 structure. Thus, it is necessary to precisely calculate the buoyancy for the FAD to be active during the required time. Nowadays the biodegradable alternatives for current floating materials used in FADs, as PVC pipes, purse seine net corks, plastic buoys, containers or drums, are scarce. One of the few alternatives presented during the workshop was the balsa wood (*Ochroma pyramidale*) (Fig 3 and 4). This wood that is well known for its great buoyancy could be the biodegradable alternative for the floats of FADs. Tests at sea using this wood together with bamboo canes as floats are in progress. Hopefully results for these first FADs will soon be available (Fig 5).

Fig 3. Fisher evaluating the balsa wood

Fig 4. Detail of the balsa wood

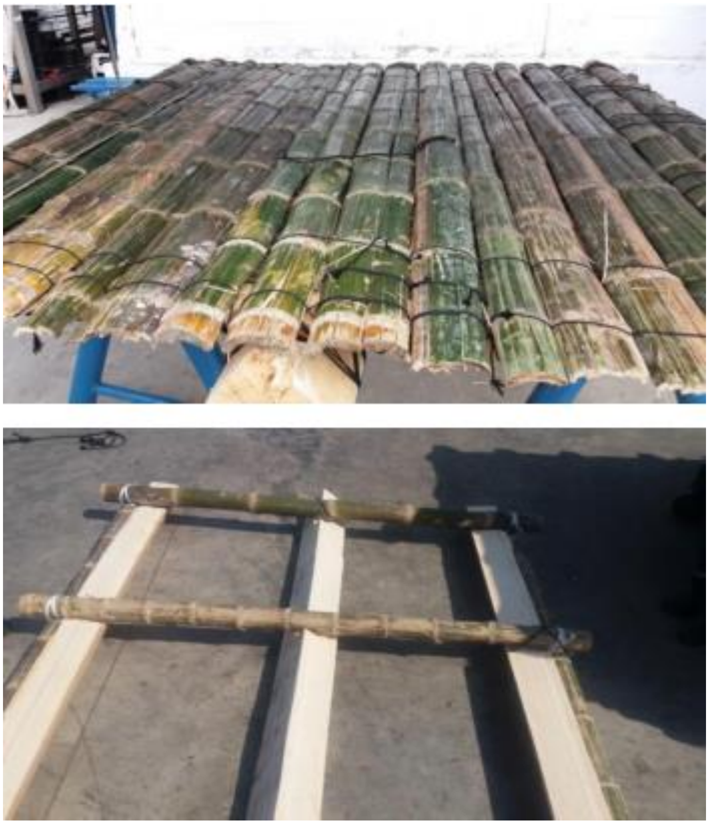

Fig 5. First prototypes deployed at sea using as floats balsa wood and bamboo canes.

- Bamboo canes have been used for many years to build FADs. One of the main difficulties with bamboo is that they lose buoyancy with time due to seeping of water inside cane´s air chambers, eventually making the FAD sink. Fishers prefer green canes or recently-cut canes due to their higher lifetime. However, they still need to add plastic floatation to prevent the FAD from sinking. Another alternative worth exploring are natural oils, waxes or other treatments that are already used in some countries to enhance the lifetime of bamboo canes. Perhaps an appropriate treatment of bamboo canes would extend their lifetime up to the required time (a maximum of one year would be required).
- The potential use of coconuts as an additional floatation to bamboo canes was presented during the workshop.
- Although there have not been tested yet at FADs, current research with new polymers from natural origin (potatoes, algae, etc.) to manufacture containers, open up a series of alternatives to be used as floatation at FADs in the near future.
- Canvas made of cotton described before, were also identified as a good alternative to cover the raft in order to provide consistency to the structure and shadow to attract fish. A range of colors are available for the needs of fishers, as for instance in dark colors to decrease the likelihood of being detected by other vessels that are looking for FADs.
- It was also considered the use of a hydrostatic release unit for the buoy that is used to geo-locate FADs. This unit would allow releasing the buoy before it sinks together with the FAD structure. This way the buoy could be retrieved reducing pollution at sea. Some of the issues to be solved will be

retrieving the buoys as well as making them not being accounted as an active FAD in oceans where there is a limit on FAD numbers per vessel.

3.4 Biodegradable FAD designs to be tested in different oceans

One of the main objectives of the workshop was to design biodegradable FADs that could be tested at sea in the near future, using materials available nowadays in the market. Mixed groups of fishers and scientists were formed to propose FAD designs.

Selected materials for the different FAD designs were:

- Balsa wood (buoyancy)
- Bamboo canes (buoyancy and submerged structure)
- Pinewood (surface structure)
- Cotton canvas (cover of the raft, submerged flags and drift anchor)
- Cotton rope with loops (submerged structure)
- Cotton rope without loops (submerged structure and to assemble canes and balsa wood for the raft)
- Tencel ropes (eucalyptus)
- Stone (weight)
- Sand (weight)
- Hydrostatic release (to release the buoy when the FAD sinks)
- Buoys or purse seine corks[3]

In total, 7 biodegradable FADs were designed (Figs. 6-12). The deepest structures reached 60-80 m, with one design of 40 m and were mainly designed for the Atlantic Ocean. Very shallow FADs were designed for the Indian Ocean, with only 2 m depth. Such shallow FADs could also be effective in the Pacific and in the Atlantic oceans where tunas are feeding in surface, as in Peru and Gabon waters. From the 7 FADs designed, 5 were using biodegradable structures and plastic buoys as floats (to avoid FADs sinking during the first trials) while 2 were 100% biodegradable.

[3] Although buoys or purse seine corks are not biodegradable, they were considered necessary during the trials to get data from the diverse biodegradable materials in test. Some of the experiments at sea 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 the potential sink of experimental FADs during the first trials, plastic buoys could be added to obtain extra buoyancy and assure data is gathered for this experimental FADs.

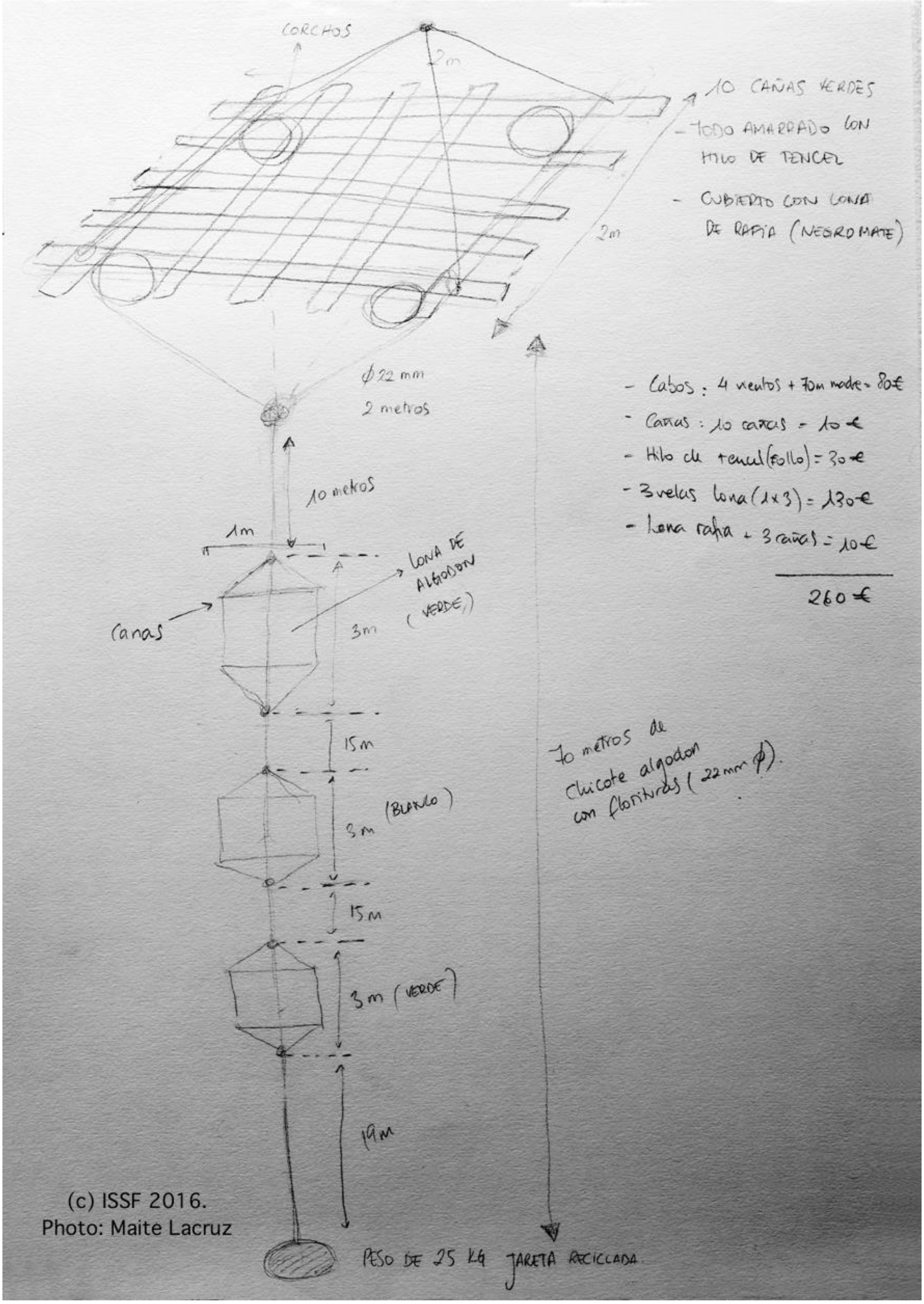

Fig. 6. Biodegradable FAD designed during the workshop for the Atlantic Ocean.

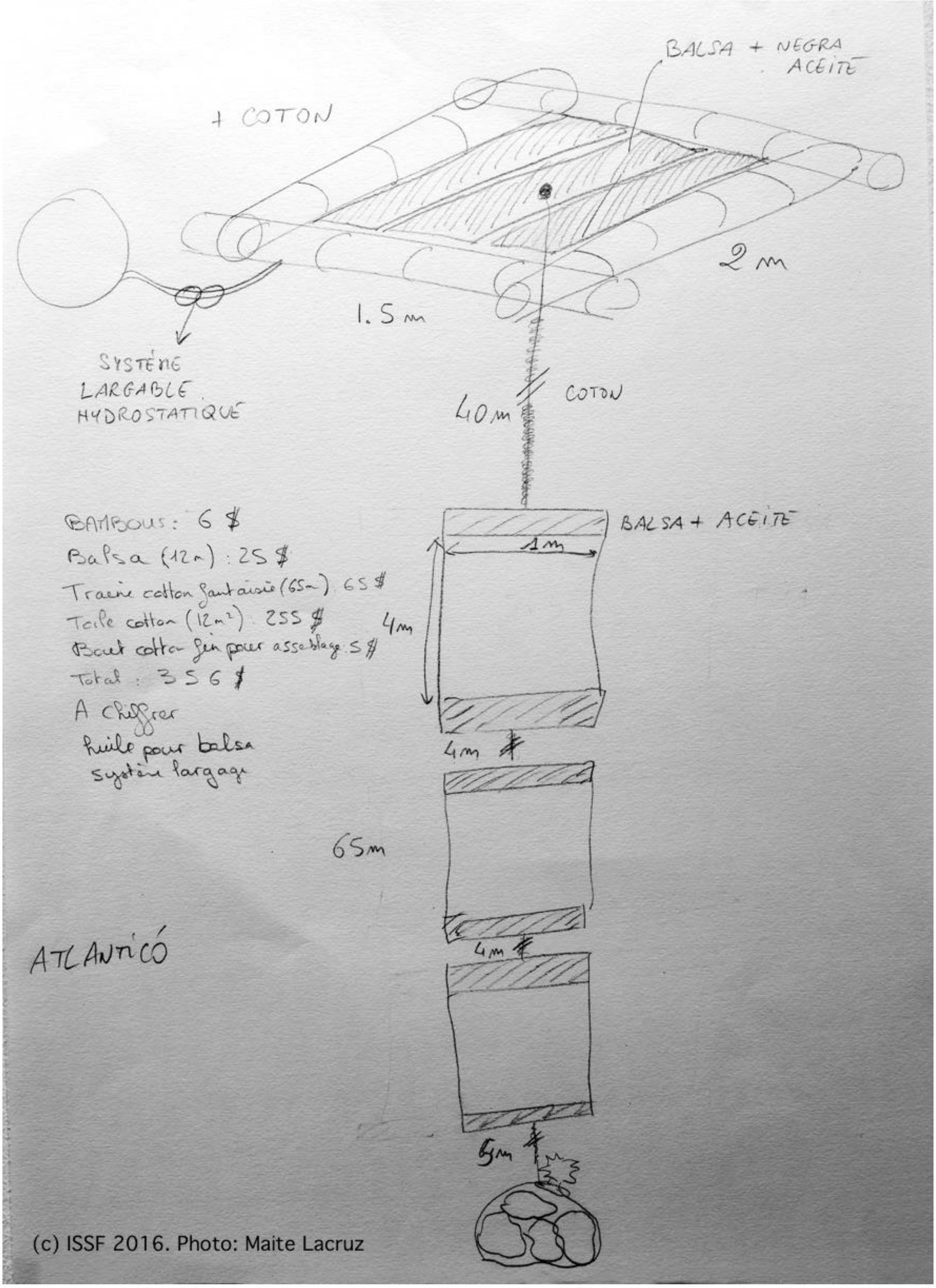

Fig. 7. Biodegradable FAD designed during the workshop for the Atlantic Ocean.

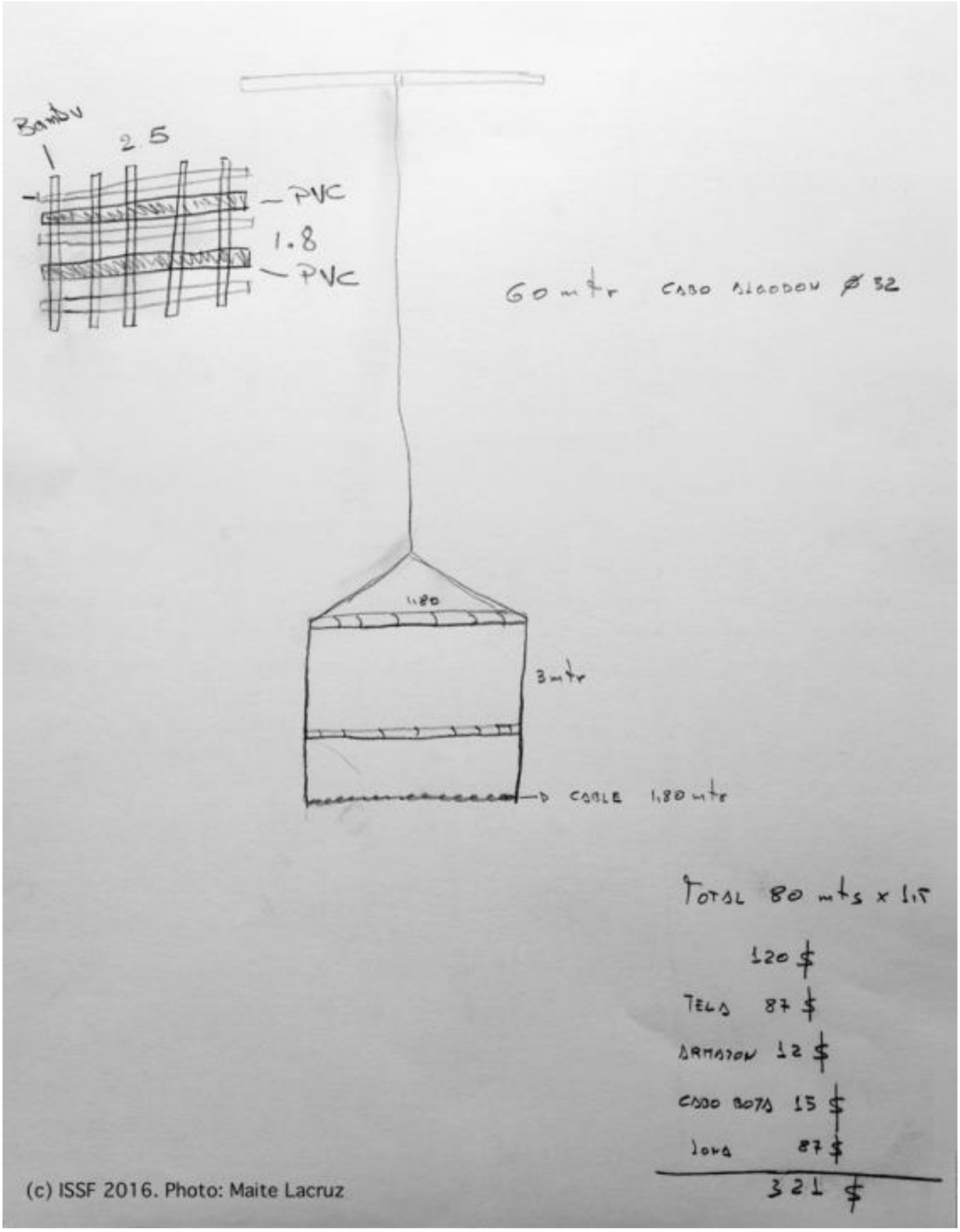

Fig. 8. Biodegradable FAD designed during the workshop for the Pacific Ocean.

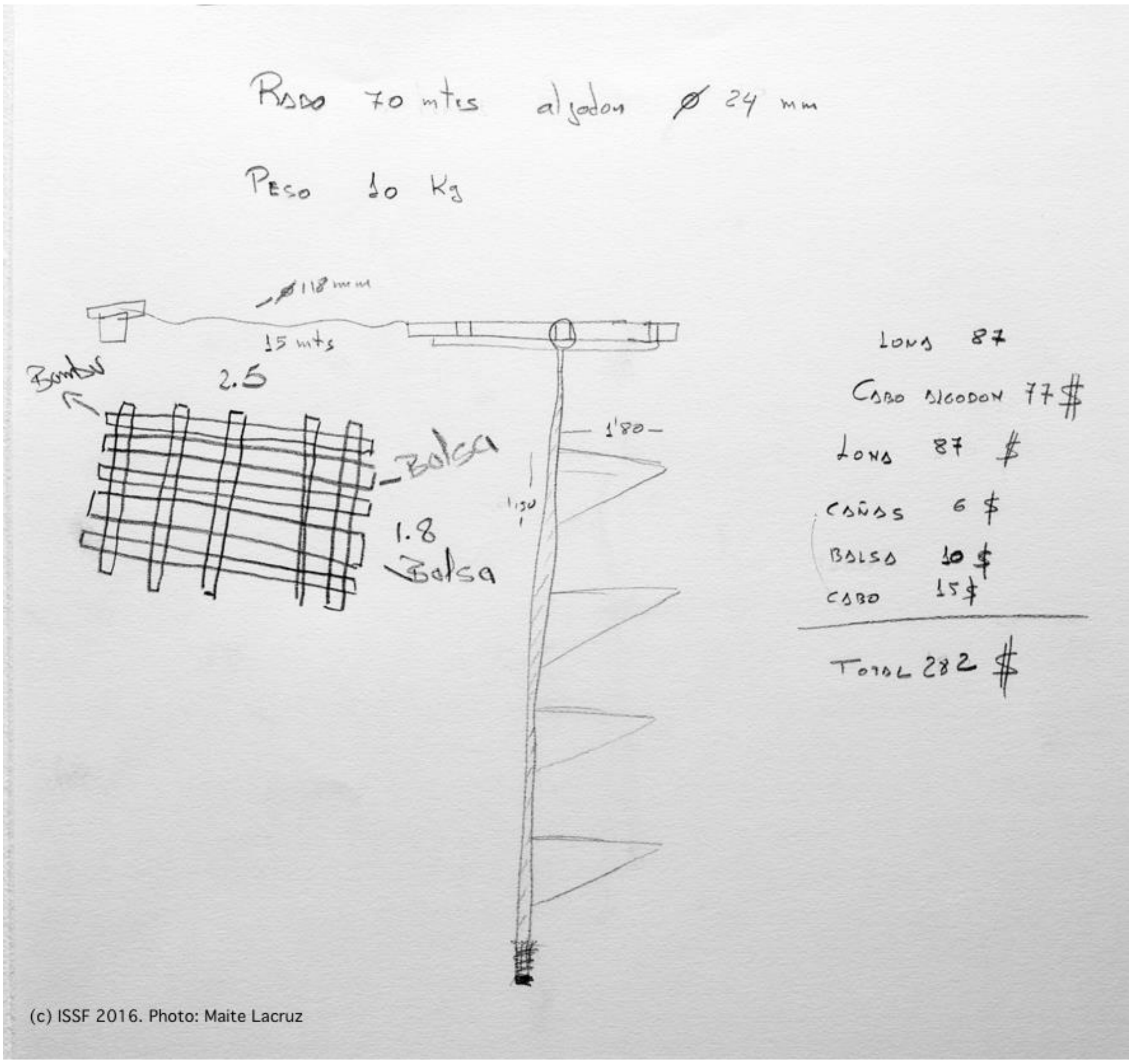

Fig. 9. Biodegradable FADs designed during the workshop for the Pacific Ocean.

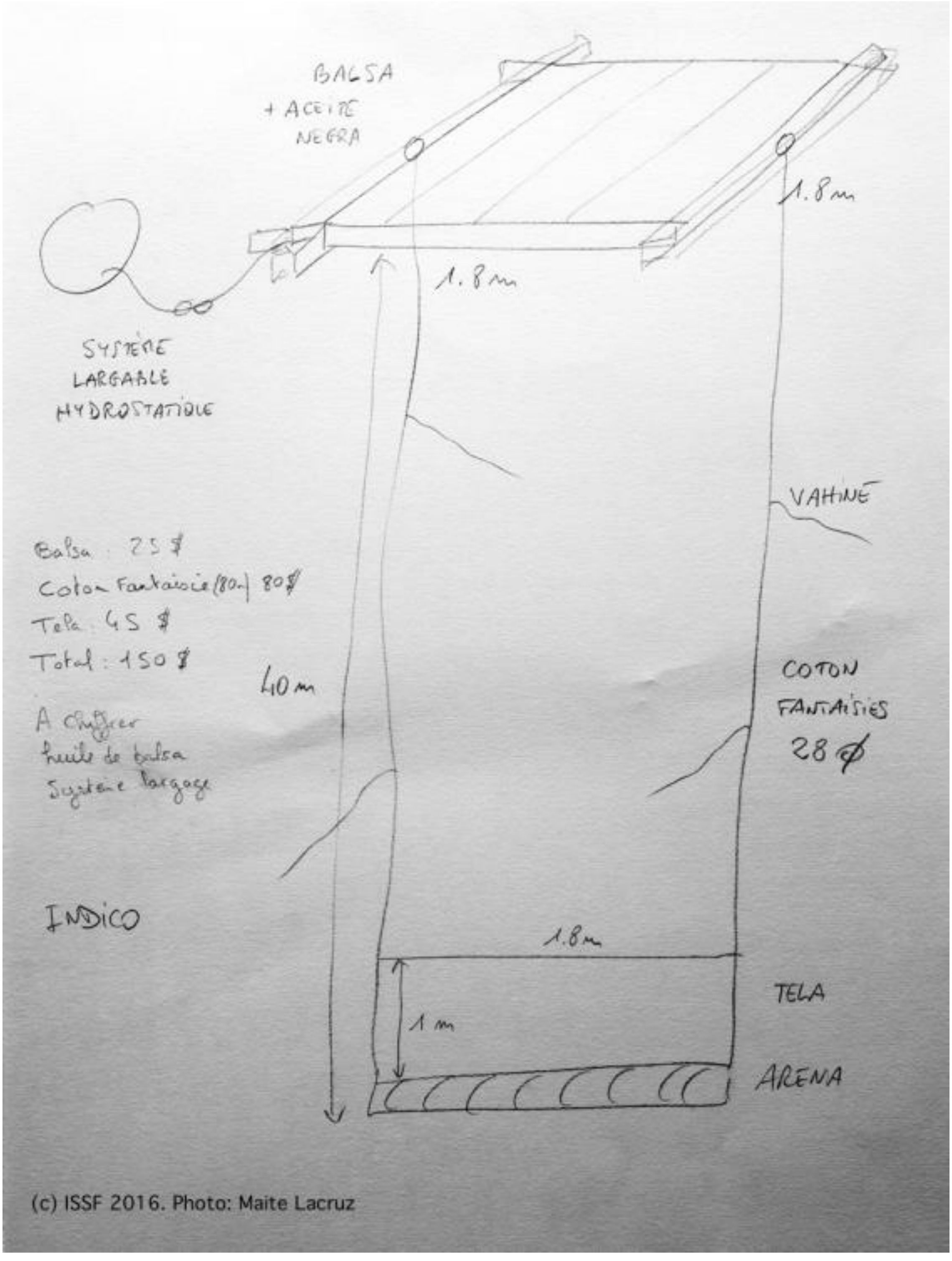

Fig. 10. Biodegradable FAD designed during the workshop for the Indian Ocean.

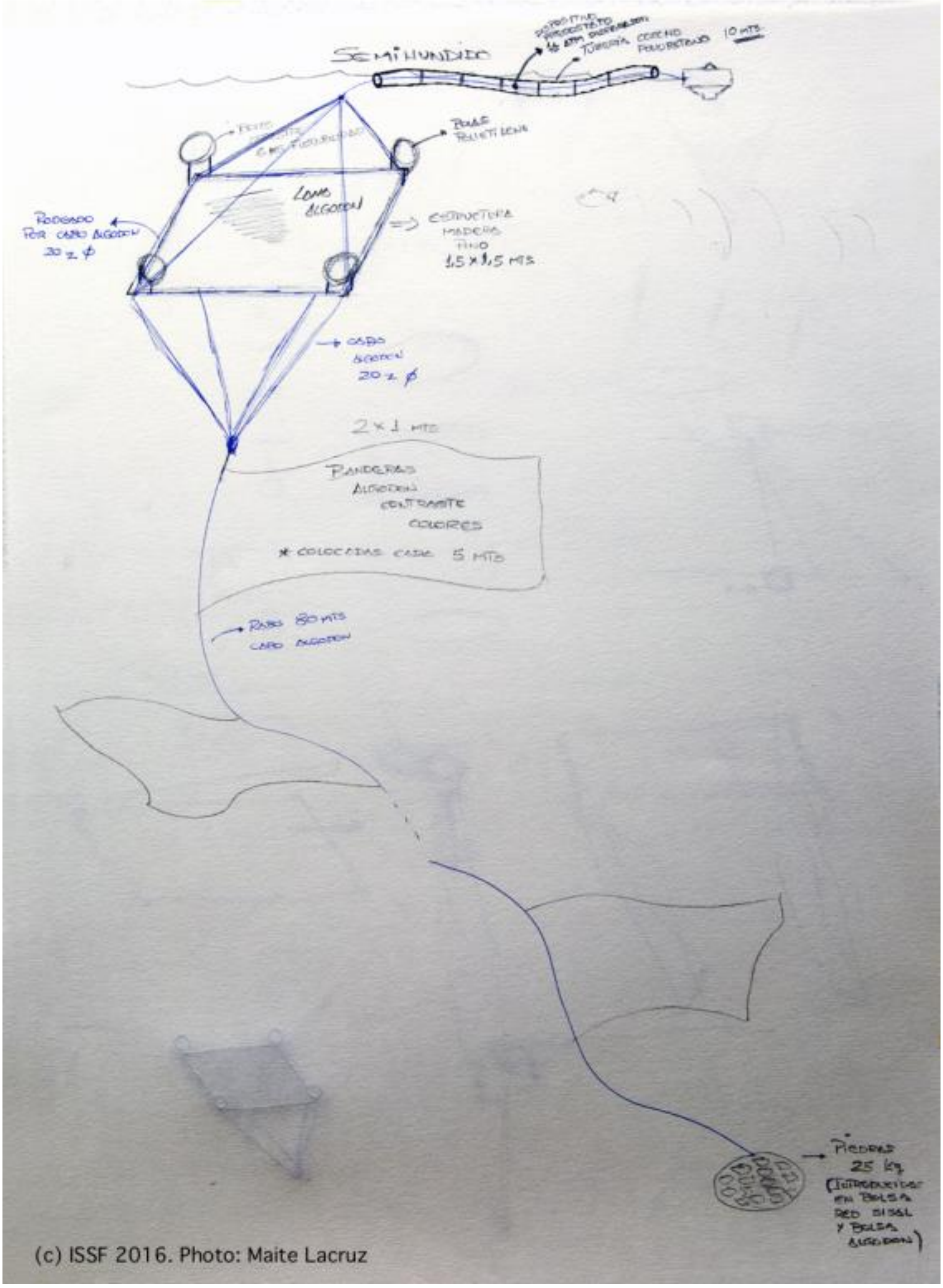

Fig. 11. Biodegradable FAD designed during the workshop for the Indian Ocean.

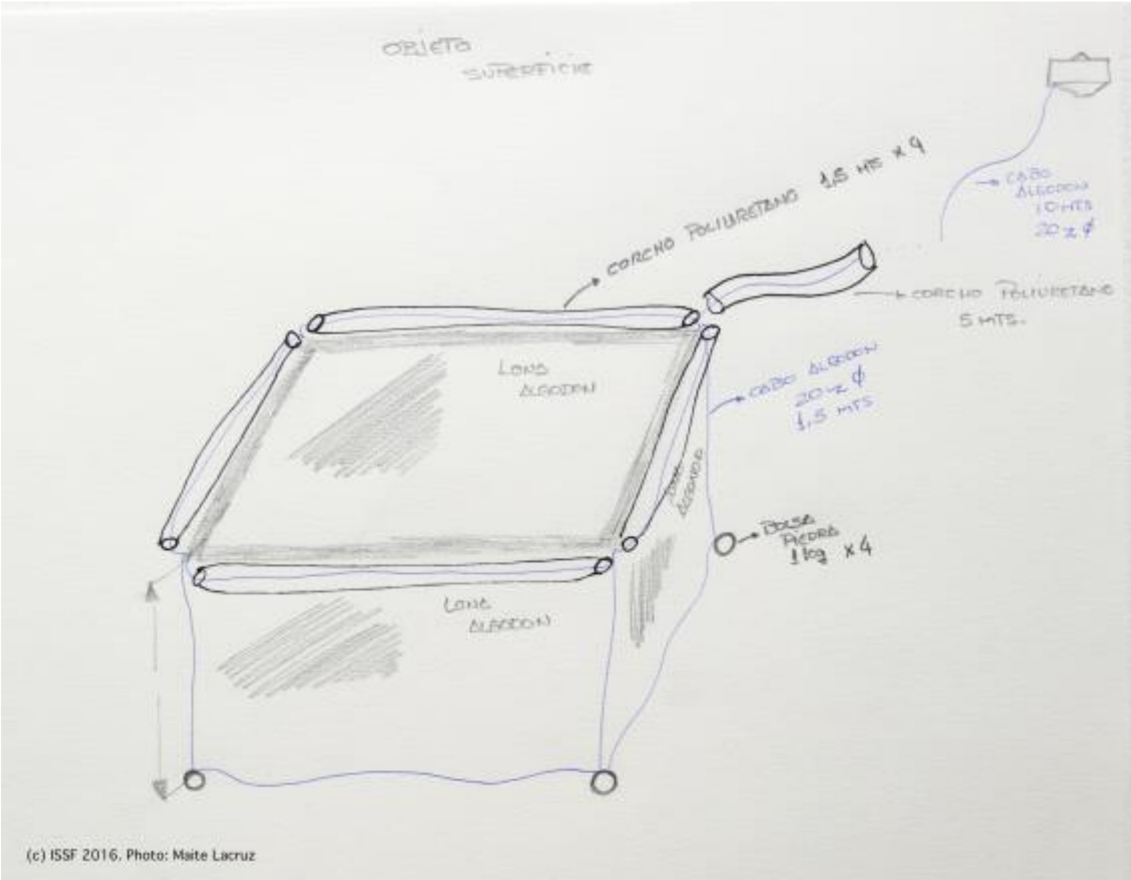

Fig. 12. Biodegradable FAD designed during the workshop for the Indian Ocean (shallow structure).

3.5 Strategy to test biodegradable FADs during fishing operations

Once the different biodegradable FADs were designed, discussions were driven to define an effective strategy to test them in real fishing conditions. Until now the experiments to test new designs at sea have been conducted by individual companies deploying a reduced number of FADs. This strategy was not successful as stated earlier in this document, due basically to the difficulty of revisiting and getting information on the experimental FADs. Frequently, a single FAD has different owners in its lifetime which makes difficult to monitor the FAD structure over time. It is thus necessary to be able to monitor a FAD in a coordinated way. Moreover, the different owners add or repair some elements of the structure that have degraded so that the FAD can be different from the first deployment to future visits. Thus, it was clear that the collaboration of the different fleets and purse seine companies 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:

- Fleets should collaborate by deploying FADs and providing information on the time evolution of biodegradable FADs encountered at sea.
- Fleets deploy a given number of biodegradable FADs per vessel (e.g. 10-20 FADs per vessel to reach a significant large number of FADs). These numbers should be determined during the meetings with the different fleets (fleet-owners and fishers).
- In order to get a meaningful result, 3 to 4 standardized designs maximum per ocean should be tested, so that enough data is retrieved per design type. Ideally experimental FADs should be built in port and deployed in the same area as traditional FADs, so their effectiveness could be compared with that of the traditional FADs for the same spatial and temporal strata.
- Since the objective is to monitor the time evolution of biodegradable materials and assess the buoyancy of the FAD, non-biodegradable floatation could be added at the beginning to guarantee that the FAD does not sink and that data will be collected.
- 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.
- Having access to the trajectories and sounder of the buoys attached to biodegradable FADs, would allow assessing the capability of biodegradable FADs to aggregate tunas even if they are not visited or fished by purse seiners, as well as following their lifetime if they are not retrieved.
- Data should not be collected in real time but with a given time delay and should be subject to a confidentiality agreement.
- An entity should be in charge of collecting and analyzing the data. It was suggested that ISSF could fulfill this role.

3.6 Retrieving FADs

Even if biodegradable FADs will considerably reduce the impacts on the ecosystems, it will not completely eliminate all impacts. Retrieving FADs that beached in critical areas of particular vulnerability, as coral reefs, was discussed.

4. Conclusion

First of all, the workshop showed the importance of involving the different stakeholders of the fishery, e.g. fishers and scientists, to find practical solutions to reduce impacts that FADs have on the ecosystem. The combination of empirical knowledge of fishers and scientific knowledge by scientists was of great value.

The participants in the workshop agreed that biodegradable FADs would be as productive as traditional FADs, as long as they drift to the good places at the good time, which also means that they must last long enough. Different designs of FADs have been proposed, depending on the oceanic regions. The main challenge is to find a successful biodegradable alternative to the floats (purse seine corks, buoys, etc.). Fishers were keen to collaborate at sea to collectively test new materials and new designs of FADs.

Annex I. Participants

Fishing industry

Abel Pinaud (Fishing master of CFTO, Atlantic Ocean)
Alfredo Eres (Fishing master of Nirsa, Eastern Pacific Ocean)
George Cañarte (Fishing master, Eastern Pacific Ocean)
Gotzon Goikoetxea (Fishing master of Albacora, Indian Ocean)
Jagoba Codina (Fishing master of Garavilla, Pacific Ocean)
Javi Alarcia (Fishing master of Albacora, Atlantic Ocean)
Maitane Grande (Marine biologist from Albacora company)
Patrick Helies (Fishing master of CFTO, Indian Ocean)
Sarah Le Couls (Responsible of Fleet strategy in CFTO)

Scientists

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Josu Santiago (AZTI, Spain)
Laurent Dagorn (IRD , France)
Martin Hall (IATTC, USA)
Víctor Restrepo (ISSF, USA)

Annex II. Graphical material