Lessons learned from deploying 380 fish aggregation devices

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Background

In October 2020, as an activity of the Food and Agriculture Organization of the United Nations (FAO) FishFAD project, a series of interviews were held with six fish aggregation device (FAD) experts. All of these people had experience deploying FADs in multiple countries spanning several decades. These people were (in alphabetical order of surname) Ian Bertram, Lindsay Chapman, David Itano, Robert U. Lee, Michael Savins and William Sokimi. The six experts were involved in a combined total of about 380 FAD deployments. Most of their FAD experience was in the Pacific Islands region, but their work also included Southeast Asia, Southwest Indian Ocean, East and West Africa and the Caribbean. In short, the six people interviewed know their way around FADs.

These FAD experts were asked about their strong feelings with regards to FADs and any lessons learned in eight FAD-related topics: 1) FAD design, 2) ordering FAD materials, 3) FAD assembly, 4) FAD deployment, 5) post-deployment maintenance of FADs, 6) factors affecting the longevity of FADs, 7) factors affecting the biological productivity of FADs, and 8) a miscellaneous category. The topics covered the "nuts and bolts" aspects of any FAD programme.

Some study details

This short article is not intended to be an instruction handbook. Regional agencies, especially the Pacific Community (SPC), have produced excellent FAD manuals covering the details of FAD design, planning, rigging, deployment and maintenance. This article aims to emphasise specific points that a group of FAD experts feel are especially important based on their past FAD work.

It is recognised that the topics covered in this article do not represent the full range of activities of an effective national FAD programme. Subjects such as cost accounting, interaction with FAD stakeholders, training of fishers, monitoring, and institutional aspects are important, but the present study was tightly focused on materials and procedures associated with FADs. Other important aspects of a national FAD programme are covered in other components of the FAO FishFAD project.

Drawing out the strong feelings and important lessons learned from the six experts involved more than just recording their answers to questions about gear and procedures, as often those responses were simple thoughts, anecdotes or instructions as opposed to more profound insights gained by, for example, analysing multiple observations that span a considerable period. Sometimes a lesson or strong feeling was obtained from an expert in an interview that involved some discussion.

For most of the topics, the discussions with the experts resulted in remarks in several areas. For example, within the topic of FAD assembly, several areas were brought up by the various experts, including splices, supervision and electrolysis. The methodology used by the present study, for each general topic, was to examine the areas that were brought up by at least two of the experts – except for a few points made by a single expert that have special merit. The sections below are organised by the eight topics and much of the information presented is about the common areas within each of those eight topics. It is recognised that this methodology does not capture all the strong opinions for each expert, but rather is more oriented to capturing the consensus of the group of what is important (i.e. giving credibility to areas that are shared).

To avoid confusion, some attention to nomenclature is required:

- The terms "strong feelings" and "lessons learned" are used interchangeably in this article, but there is a tendency for the latter to be somewhat more complex or the result of some analysis.
- Both conventional metal anchors (e.g. Danforth, Hall) and cement blocks are used to moor FADs. For simplicity, when referring to both types of mooring devices together, the term "anchor/block" is used.

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- The term "nearshore" causes some confusion. In the FAD literature of the Pacific Community (e.g. Policy Brief 19/2012[8]), a nearshore FAD is one that is set very close to the reef. The term is also used by SPC to refer to the fishing area between the coastal fisheries zone and the offshore fisheries zone, as seen on the SPC Coastal Fisheries website[9]. In this article, a "nearshore" FAD refers to one deployed close to the reef in water that is generally less than 300 metres in depth.

FAD designs

The experts were asked about FAD designs, and were free to bring up areas related to FAD design that they considered important. The areas that were commonly reported in the responses of several experts were:

- The best reference manual for FAD designs
- The most favoured general FAD design
- Ideas on the spar buoy type FADs
- Appropriate anchors
- Sandbags as anchors
- Reduction in rope diameter
- The use of wire rope
- "Affordable materials"
- Characteristics of pressure floats
- The need for an aggregator

Almost all experts felt strongly that the best reference for FAD designs and associated hardware is the 2020 SPC manual (Sokimi et al. 2020), although there was some mention that this manual makes reference to the 2005 SPC manual (Chapman et al. 2005) so to be complete, the earlier manual is also required. One expert was adamant that the 1984 SPC manual (Boy and Smith 1984) "started it all off" because one of the authors was an experienced buoy engineer. Another comment was that the 1996 SPC manual (Anderson and Gates 1996) was very good for FAD planning.

On the most favoured general FAD design, most of the experts specifically indicated that the Indo-Pacific FAD (Box 1) is generally the most appropriate for national FAD programmes. This was qualified, however, by some experts who indicated that this design required additional care to rope chafe caused by the floats, and the use of more robust surface pressure floats (rated to at least 200 metres). One expert felt strongly that more attention be given to electrolysis (i.e. use of dissimilar metals underwater) than given in the Indo-Pacific section of the SPC FAD manuals. Another did not trust the use of purse-seine floats as spacers between the pressure floats due to the possibility of compression when deeply submersed. Some of the experts felt that other FAD designs are more appropriate than the Indo-Pacific model in specialised situations; for example, the lizard FAD and the subsurface FAD when there is the possibility or vandalism or in areas with high boat traffic, and the spar buoy when buoys are strictly regulated by law.

The spar buoy type FAD was the design originally promoted by SPC in the mid-1980s. The FAD experts that spoke of this type of FAD mostly felt that the design has been replaced by more appropriate designs in recent decades. Comments included:

- "The spar buoy has too many things going against it: cost, skills and required experience."
- "Spar buoys can be found easily but they are heavy, cumbersome, and more maintenance is required."
- "Spar buoys have tremendous resistance to waves that stress the system whereas designs like the Indo-Pacific or the lizard FAD slip through swells."

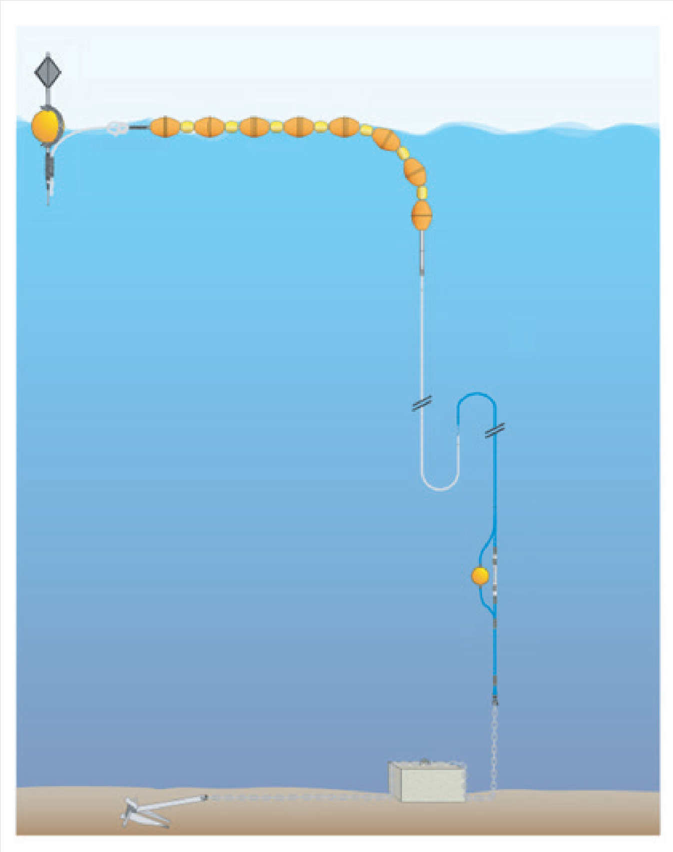
Most of the experts expressed strong feelings on FAD anchors/blocks. The most common ideas expressed concerned the practicality and safety of the anchors, the required weight, and the desirability of sandbag anchors. In terms of practicality and safety, the ideas centred around the idea that, although a large anchor is good for FAD longevity, the size and/or weight must be appropriate for the deploying vessel. Consequently, several of the experts stressed concepts such as more than one relatively small concrete block

[8] http://purl.org/spc/digilib/doc/89tm5
[9] https://coastfish.spc.int

Box 1: The Indo-Pacific FAD

The Indo-Pacific FAD is a renaming of the previously known SPC Indian Ocean FAD. The new name accounts for the design's origin (Indian Ocean) as well as the modifications to the design by Pacific Island FAD technicians. The Indo-Pacific FAD is a robust FAD design that can be deployed in strong currents, and was developed primarily as a tool to support small-scale commercial fishing. There have been a number of refinements and modifications to the Indo-Pacific FAD since the 2005 SPC FAD manual was produced. The increased availability of multistrand rope in the region has largely replaced the use of three-strand rope and related hardware (shackles and swivels). Cost being previously one of a FAD's most vulnerable points, a reduction in hardware also means a reduction in cost. In recent years the Indo-Pacific FAD has been successfully deployed in nearshore environments, using fewer floats in the upper flotation section.

Source: Sokimi et al. (2020)



(modular concept), or the use of a less weighty conventional anchor (e.g. Danforth or Hall). The experts were less enthusiastic about sandbag anchors. As expressed by one expert: "Sandbags are now heavily promoted but have limited applicability. Good in some places but bad when there is abrasion – which is often the case."

Some of the experts expressed feelings on the evolution of the diameter of rope. The original SPC FAD manual (Boy and Smith 1984) was based on a rope diameter of 20 mm. Expert opinions included: "Reduction of line from 18 and 20 mm to 16 mm has reduced cost without sacrificing quality", "16 mm rope is now judged to be as good as 18 mm or 20 mm, but less cost and less drag", and "Heavy rope is expensive and has more drag". The lesson learned is that the progression to smaller rope diameter has been positive.

Although the use of wire rope (i.e. steel cable) in the FAD design was only mentioned by two experts, one of those experts (perhaps the one with most FAD experience) indicated that his view on wire rope was one of the strongest feelings he had on FADs – hence the inclusion of the subject here. Quite simply, wire rope should not be used in a FAD. This is because the metal in the wire is most often different from the other metal FAD components, which causes electrolysis, and the wire becomes brittle after months in the marine environment.

In discussions of FAD designs in the region, the term "affordable materials" is often heard. For those experts that brought up this subject, they appeared to mean using locally available materials whenever possible. Only one expert was in favour of this concept, with the others expressing almost opposite opinions: "Affordable materials is nonsense: chain, rope, swivels, shackles and floats are required and are not available locally", and "not in favour of going cheap".

In retrospect, the difference in opinions could be due to the experts referring to different FAD models, such as community or private ownership versus FADs for a national government programme. A wise comment from one of the experts was:

> "When doing FAD work, we need 'durable materials'. If it's affordable but not durable, then there's no point in using it for FADs. It will be a waste of time. On the other hand, if it's affordable and durable, then by all means that should be the way to go. This is the whole process that a FAD technician should be looking at: reduce the cost of putting FADs in place without compromising its durability. So, in this context, I would support using locally available materials, such as coconut fronds for aggregators and bamboo for flag poles. "

Several of the experts voiced opinions on pressure floats, probably because their favoured design, the Indo-Pacific FAD, is highly dependent on them. There was little consistency in the views of four experts who had strong feelings on pressure floats:

- "Hard to find reliable pressure floats"
- "There is a need for vendors to accurately describe each float in detail; it is difficult to order floats due to inconsistent way in which they are described"
- "Need to use 200-metre working depth for surface floats"
- "Not a fan of big floats"
- "The pressure floats that keep the rope off the bottom should be ABS [acrylonitrile butadiene styrene] high pressure trawl floats (with centre hole or lug ears) rated for about twice their working depth".

Aggregators are various types of attachments to the upper part of a FAD that are thought to have a positive effect on the attraction of fish. Coconut leaves, purse-seine netting, plastic strips, and other materials have been used as aggregators. Of the four experts that included aggregators among the subjects where they had strong feelings, their opinions ranged from a mild requirement ("On the need for an aggregator, the jury is still out but something is necessary") to being adamant ("Aggregators are very important. Fishers complain when a FAD has no aggregator").

In reviewing the above ideas on FAD designs, the main lessons appear to be that there is considerable confidence in the SPC FAD manuals and there is general satisfaction with the Indo-Pacific FAD design. Because there is considerable ongoing activity in refining several FAD components (especially anchors and floats and the use of lighter materials), this suggests that there is still considerable room for innovation in FAD design.

Ordering FAD materials

Because the ordering of FAD materials can be challenging for staff of national FAD programmes, the six experts were requested to offer any lessons they have learned in purchasing FAD hardware. Their responses covered a variety of subjects within this general area, with subjects being common to the responses of several experts:

- Favoured supply countries
- Favoured supply companies
- Ideas regarding the trade-offs between cost and quality of FAD materials.

Most of the FAD experts identified New Zealand and Taiwan as their favoured supply countries. New Zealand has the advantage of easy shipping to Pacific Island countries south of the equator and being the home to some of the historically reliable companies. Taiwan has cost advantages, a wide selection of materials, and easy shipping to Pacific Island countries north of the equator. One expert cited the United States as his least favoured country because of the high prices. An interesting observation made by one of the FAD experts was that "preferences by FAD technicians for specific countries or companies are irrelevant as all national governments and donors require a tender process in which it is not possible to select one's preferred supplier".

Two companies were named by two or more of the FAD experts as being good suppliers of FAD materials:[10] Bridon Cookes in East Tamaki, Auckland, New Zealand (www.bridon-bekaert.com) and Sea Master Enterprise Company in Kaohsiung, Taiwan (www.seamaster.com.tw).

Two interesting observations were made regarding the trade-offs between cost and quality of FAD materials: "There is a tendency for FAD technicians to blame poor materials when a FAD breaks loose", and "If going cheap, go all cheap; a FAD is only as strong as the weakest component so it is a waste of money to buy a few top-quality components". Half of the experts expressed an idea that can be summarised as "Top-dollar FAD equipment is not worthwhile, therefore go for the B or B+ quality", and "In the balance of cost and quality, go for the middle quality". Another expert did not disagree with that idea but advised that FAD technicians who are unsure of the quality of materials should "err on the side of quality".

The major lessons learned in ordering FAD materials appear to be that FAD technicians need to be very quality conscious, but nobody seems to be in favour of paying "top dollar" for FAD components.

Assembly of FADs

Because the two recent SPC FAD manuals give detailed instructions on assembly, the FAD experts were instructed to give their assembly-related comments on points that deserve extra attention. Therefore, this section is not intended to be a recipe for assembling a FAD.

Each FAD expert had his own list of areas related to assembling a FAD where he had strong feelings or learned lessons. The subjects stressed by more than one expert were:

- Someone needs to be in total control of the FAD assembly operation. The boss needs to focus on quality control and should closely scrutinise every single connection to verify that it has been done properly. A concept mentioned in the material ordering section above is also relevant here: a FAD is only as strong as the weakest component.

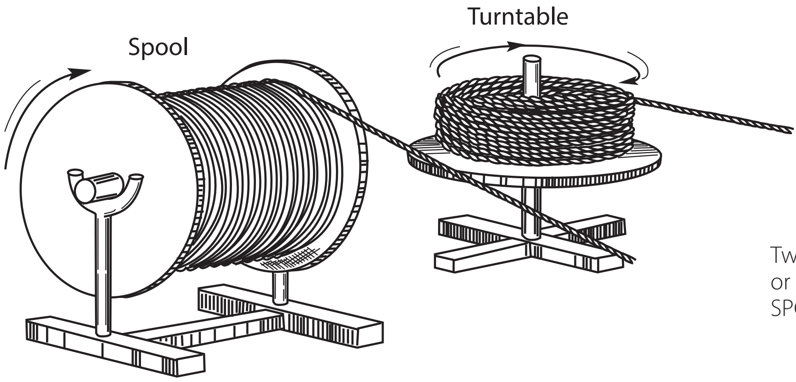
[10] The citing of suppliers here does not imply that the Pacific Community endorses these companies or their products.

- Special attention needs to be paid to splices. As different types of ropes (e.g. three-strand, multi-strand) require different types of splices, the appropriate splice must be used. One expert went so far as to state that lots of people damage the mainline when they splice, so "unless they can make the appropriate splice properly, knots should be used as connectors instead: a double sheet bend or blood knot, both secured with whipping".
- There is a need for secure storage of FAD materials: "a big expensive lesson is that people love to steal FAD materials". FAD materials need to be stored in a locked dry container. There should be an inventory of FAD materials after each fabrication and the materials used for each FAD should be documented.
- If practical, fishers need to be part of the assembly process. There is a feeling that this could contribute to greater understanding of the FAD components, identification with the goals of the FAD programme, and a reduction of vandalism.
- The mainline of the FAD must be protected at all times, so to avoid kinks in it, a turntable or spool arrangement should be used for uncoiling the rope.

The subject of electrolysis (where two different metals are in contact in seawater) is treated differently by the various FAD experts in this study. Some did not acknowledge its importance, some made casual mention (e.g. the need to swap out the stainless steel pins of galvanised shackles), one thought it was quite important, while another expert referred to electrolysis as a "black box". It is interesting to note that the first SPC FAD manual (Boy and Smooth 1984) has a section on electrolysis, while there is no mention of electrolysis in the two most recent SPC FAD manuals (Chapman et al. 2005; Sokimi et al. 2020). The lesson here appears to be that there is considerable inconsistency in the perceived importance of electrolysis among the experts.

Several experts commented on the practice of national FAD technicians departing from materials specified in the FAD manuals. The comments of the experts on this practice included "minor departures can result in major failures", "If you do not know much, always follow the manual", and "this is OK if the technicians are very familiar with why the recommended materials are used".

From the information presented above and the enthusiasm of the experts during the interviews, the major lesson learned in the assembly of a FAD appears to be that careful attention must be given to doing each connection properly, and there should be close supervision of the process and meticulous inspection of the finished connections.



Two ways of properly uncoiling a rope spool or bundle, as shown on page 28 of the 2005 SPC FAD manual (Chapman et al. 2005).

The base of an office chair can be used as a turntable. (image: © William Sokimi, SPC)

FAD deployment

The strongest feelings expressed on FAD deployment by the experts were in the areas of surveys of bottom topography, safety, anchor/block handling, and logistics.

There was consensus that a pre-deployment survey of the bottom topography is absolutely necessary. Charts should not be trusted for either depth or contour as there have been problems in the past. The survey must be done before a FAD is assembled so that the length of the rope can be calculated. The strongest feeling from one of the experts was: "Assuring the system's rope length is correct in relation to deployment depth".

Both a survey prior to the day of deployment (days or even years before the date) and "a few runs on the day of deployment" are needed. The deploying vessel must have an echo-sounder with suitable depth range and a GPS (global positioning system) chart plotter.

Deploying a FAD can be very dangerous, and the most risky aspects are: 1) the damage that an anchor/block can do during loading onto the deploying vessel and transporting it on the vessel to the deployment site; and 2) during the actual deployment, the rope catching on a crewmember or fixtures of the deploying vessel. The mitigation measures offered by the experts included: 1) having somebody in firm control of the whole deployment operation, with close coordination and good communication between the helmsman and the person in control; 2) having the anchor/block very secure on the trip out to the site; 3) having a clean layout of rope (e.g. flaking-out the rope in a box if possible); and 4) doing only float-first deployments, with the possible exception of subsurface FADs, and then only for a very experienced crew. One expert had another sensible suggestion: "take only a small number of crew on the deployment vessel; if there is excess crew, there is a greater chance that somebody will get snagged by the rope, so any observers should be on a separate boat".

With respect to anchor/block handling, it is critically important that the deploying crew are knowledgeable about the procedures for loading and storing heavy anchors/blocks. The position on the deployment vessel is critical: the device can slip into the water or back into the boat, and both situations are hazardous. The anchor/block should not be connected until the deployment vessel arrives at the deployment site. The deployment vessel should be appropriate for the size of the anchor/block, with an important lesson being that the small boats used by small-scale fishers often cannot deploy heavy anchors/blocks with the necessary degree of safety.

Deployment logistics were also an area for which the FAD experts had strong feelings. The FAD should be loaded on the vessel the day before deployment as there is too much going on during the deployment day. Deployment should be rescheduled if weather or sea conditions are not good. If there is doubt about conditions, the deployment should be rescheduled. If possible, deployment should take place in the early morning when sea and wind conditions are often the calmest.

Two experts had strong feelings about shallow-water deployments, and those views were quite similar. The idea is that the farther offshore a FAD is deployed, the better the water quality is for tuna, which are characteristically repelled by low salinity or warm water that is often found close to islands. Typically, shallow-water FADs are more appropriate

Deploying FAD anchors made of cement blocks can be very dangerous, especially from a small craft. (image: © William Sokimi, SPC)

for small atolls and reef islands (typically with oceanic water quality close to shore) than for big atolls and high islands with freshwater runoff. Often, the sites for shallow-water FADs have more forces at work (waves, current) and consequently additional attention must be paid to anchoring and bottom topography.

The main lessons learned regarding FAD deployments include: 1) they can be very dangerous, and a number of measures need to be taken to lower the risk; and 2) pre-deployment surveys of the bottom topography are absolutely necessary.

Post-deployment maintenance

All experts were in favour of some form of maintenance of FADs after they are deployed, but not many strong feelings were expressed on the details of that maintenance. The main point was the importance of periodically checking the FAD components that can be safely changed with the available gear and expertise. One expert was adamant that FAD components should only be lifted into a vessel if there is slack (most often at the lowest tide), and the removal of any coral from the rope should be carried out only if it can be done without damaging the rope. One expert emphasised the idea of repetitive motion (i.e. shifts in the gear with each swell) and the need to inspect those components that are subjected to the associated stresses. Another expert indicated that one of the lessons he learned about deployment maintenance is that there is always some fun involved: spearing fish and retrieving snagged fishing lures.

Factors affecting FAD longevity

The experts were presented with a list of factors that could conceivably affect how long a FAD would remain in position. The list consisted of materials, electrolysis, skills and experience of the FAD technicians, vandalism, FAD design, bottom topography, and others. The experts were asked to identify which of those factors were the most important in determining FAD longevity.

As expected, there was diversity in the responses. Several indicated that most, or all, of the factors were important, or something similar to the idea that "a chain is only as strong as its weakest link". It is quite significant that this concept also emerged in the above discussion of FAD materials.

Of the specific longevity factors thought to be important, the ones cited most often were materials, bottom topography, and skills. It was pointed out that the latter is crucially important because the skill of a FAD technician is cross-cutting as it can affect most of the other longevity factors.

Besides the longevity factors listed above, some additional items were mentioned by the experts. These included: 1) the quality of the supervising technician; 2) the correct length of rope for the depth of water; 3) the prevalence of cyclones; 4) the amount of vessel traffic in the area; 5) pressure to respond to political directives; and 6) "less about the materials but more about the way the materials are put together". It is interesting to note that, although the list of longevity factors is largely about technical issues, several of the experts commented on institutional issues being important in FAD longevity.

- "The lack of accountability of lost FADs by FAD fisheries departments; if FADs are lost on deployment or soon after, it is just considered "unfortunate", and at no point is any analysis undertaken or person held accountable."
- "Lying to cover up failure, and no action being taken to rectify the real cause of FAD loss."
- "If anyone is tasked to install FADs, it is their duty to make every effort to install a system that lasts; not just throw in something that looks like a FAD then tick a box for 'FAD deployed' ".

The impact of cyclones on FAD longevity deserves special attention. The one expert who mentioned this longevity factor offered some mitigation measures. There is more chance of a FAD surviving a cyclone if there is a large amount of rope scope. On steep slopes, however, that increased scope can lead to chafing on the bottom, so the lesson is that in areas of high incidence of cyclones, deployment on a flat bottom is important. In addition, the pressure floats used must be stronger than the normal ones. Prior to a cyclone's arrival, beacons, floats and aggregators should be removed from a FAD.

The main lesson on FAD longevity appears to be that for a FAD to remain in place for a long period, a FAD technician must diligently carry out a large number of tasks, especially choosing appropriate materials, assembling them correctly, and choosing a site with suitable bottom topography.

Factors affecting biological productivity

"Biological productivity" refers to the amount of fish and other organisms that a FAD is able to aggregate. In this study, the experts were presented with a list of factors that could conceivably affect biological productivity. The list includes the distance offshore, FAD placement in naturally productive areas, and the use of aggregators. The experts were asked to identify which of those, or other factors, are important in determining the biological productivity of a FAD.

Most of the experts mentioned the importance of all three factors: distance offshore (or the closely related water quality), naturally productive areas (or the closely related areas where local fishers often see birds and surface schools of tuna), and to a lesser degree, aggregators.

As mentioned in the section on FAD deployment, the farther offshore, the better the water quality is for tuna, which are characteristically repelled by turbid, low salinity or warm water that is often found close to islands. Although other species can be attracted by FADs in low-quality water, their biomass is typically far less than that of tuna schools around FADs. As explained by one of the experts, the distance offshore can be a proxy for water quality. Other experts commented: "a FAD needs to be at least three miles offshore except when there are canoes fishing for pelagics" and "FADs in less than 500 m of water and within 1 mile of land are often unproductive: the dead zone".

Most of the experts felt quite strongly about using both local knowledge ("where they go to catch tuna") and visual sightings of birds to determine naturally productive areas. In places where a FAD is unproductive, local fishers often grumble "why didn't they ask us where the FAD should go?"

The experts' opinions on the impacts of aggregators are covered in the section on FAD designs above. In summary, of the four experts who had opinions that ranged from a mild requirement ("On the need for an aggregator, the jury is still out but something is necessary") to being adamant ("Aggregators are *very* important"). One expert had an interesting observation: "Aggregators are needed in the period just after deployment, but once a tuna school has arrived, they are not needed".

The main lesson with respect to the biological productivity of FADs is that a small number of factors (distance offshore, proximity to productive areas, and perhaps aggregators) seem to account for much of the variation between FADs in amounts of fish aggregated.

Conclusions

To summarise, the main lessons learned and the strong feelings expressed from the six experts regarding the FAD-related categories are as follows.

- **FAD designs:** There is considerable confidence in the SPC FAD manuals and general satisfaction with the Indo-Pacific FAD design. There is much ongoing activity in refining several FAD components, especially the anchors and floats and in the use of lighter materials.
- **Ordering FAD materials:** FAD technicians need to be very quality conscious but none of the experts seem to be in favour of paying "top dollar" for FAD components.
- **FAD assembly:** Careful attention must be given to doing each connection properly and there should be close supervision of the process and meticulous inspection of the finished connections.
- **FAD deployment:** 1) Pre-deployment surveys of the bottom topography are absolutely necessary, and 2) deployments can be very dangerous and a number of measures need to be taken to lower the risk of an accident.
- **Post deployment maintenance:** It is important to periodically check FAD components that can be safely changed with the available gear and expertise.
- **FAD longevity:** For a FAD to remain in place for a long period, a FAD technician must diligently carry out a large number of tasks, especially choosing appropriate materials, assembling them correctly, and choosing a site with suitable bottom topography.
- **Biological productivity of FADs:** A small number of factors (distance offshore, proximity to productive areas, and aggregators) seem to account for much of the variation between FADs in terms of the amount of fish that aggregate around them.

The idea of "a chain is only as strong as its weakest link" has been mentioned in earlier sections of this article. The concept is applicable to several aspects of FADs, including FAD design, materials, assembly and deployment. This emphasises that a small deficiency in any one of a large number of areas can be disastrous, hence the importance of attention to detail and constant diligence by FAD technicians.

This article shows the evolution in preferred FAD designs (e.g. ropes, anchors), and highlights the differences in what FAD experts feel strongly about. Taken together, these two concepts suggest there is much room for future FAD improvements and innovations.

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