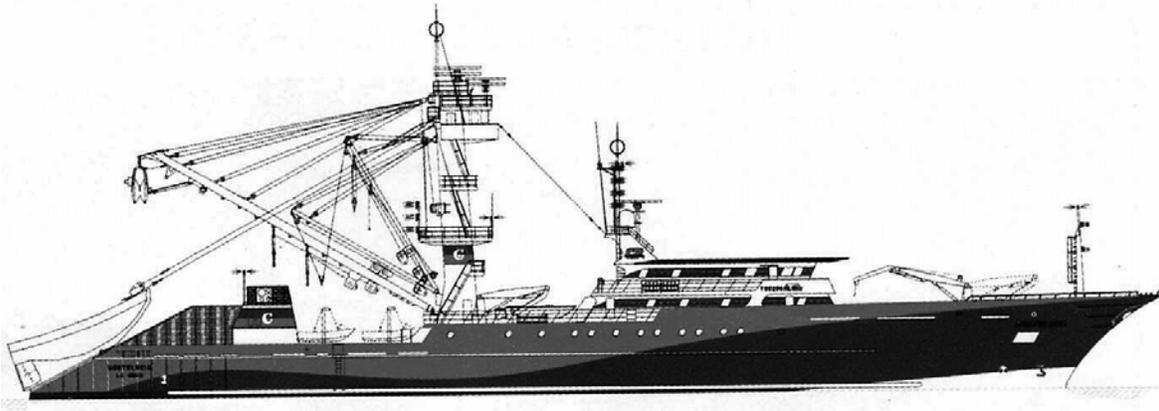




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THE DEVELOPMENT, DESIGN AND RECENT STATUS OF ANCHORED AND DRIFTING FADS IN THE WCPO



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1. INTRODUCTION

The use of anchored Fish Aggregation Devices (FADs) appears to have started in the Philippines where simple bamboo rafts were in use before WWII to aggregate tuna for handliners (de Jesus 1982). Currently, FADs support thousands of fishing vessels in the Philippines and Indonesia. The use of FADS moored, or anchored to the bottom (referred to as **AFADs** in this report) has been promoted throughout the western and central Pacific to assist small scale fisheries from Hawaii to Southeast Asia. Virtually every country and territory in the region has had or now has an AFAD development program (Matsumoto et al. 1981; Preston 1990). In addition, networks of AFADs have been used for decades to promote larger scale domestic pole and line and purse seine fisheries in the Solomon Islands, Papua New Guinea, Indonesia and several Pacific Island countries (Itano 1995).

The use of anchored FADs (payaos) in the Philippines is widespread where thousands are anchored throughout the Moro Gulf, Sulu Sea and around the main islands to support subsistence, artisanal and commercial fisheries (Barut 1999). Dense networks of AFADs also exist throughout Indonesia to support artisanal fisheries, the large domestic pole and line skipjack fishery and joint venture and domestic purse seine fleets. In recent years, thousands of AFADs have been deployed in the waters of Papua New Guinea by purse seine companies working domestically but of Philippine origin (Kumoru 2002).

The use of drifting FADs (**DFADs**) by purse seine fleets has expanded rapidly to the point where many fleets or vessels rely almost exclusively on fishing their own or other vessels' DFADs. It is well known that both AFADs and DFADs tend to aggregate juvenile tuna and an assortment of finfish bycatch species including billfish and oceanic sharks. The incidental take of juvenile bigeye and yellowfin tuna has increased significantly with the expansion of DFAD assisted purse seining and has been a major concern of SCTB in recent years.

This paper has been prepared in response to the following task developed for the Fishing Technology Working Group (FTWG) by the Sixteenth Meeting of the Standing Committee on Tuna and Billfish (SCTB16), held in Mooloolaba, Queensland, Australia, from 9–16 July 2003.

5. Issues related to FADs

- a. Document the development, designs, related gear and utilization of anchored and drifting FADs used by WCPO purse seine fleets (SPC, FFA, regional and national observer programs)*

This paper will present information on the use of anchored and drifting FADs that support large scale industrialized fishing in the WCPO. Artisanal-scale FAD programs and fisheries are well documented and will not be presented here. The primary focus of this paper will to collect what is known of the major anchored FAD networks and information related to drifting FADs that support large purse seine fleets in the WCPO.

2. ANCHORED FADS (AFADs)

2.1 Anchored FADs – for artisanal and small-scale fisheries

2.1.1 The Philippine payao

De Jesus (1982) provides detailed line drawings of Philippine AFADs, or payaos as they are called in the Philippines, and descriptions of the mooring systems. Payaos began as simple bundles of bamboo of the *Bonbon* and *Arong* type, later evolving into well constructed double layer bamboo rafts (Figure 1).

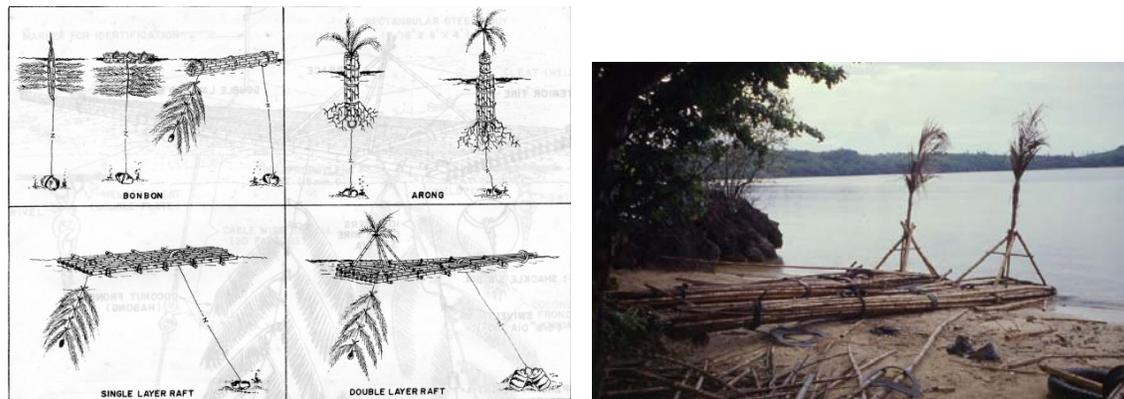


Figure 1. Philippine bamboo payaos (from de Jesus 1982) and two bamboo raft payaos ready for deployment (photo D. Itano)

Bamboo rafts are still commonly used in coastal Philippine waters, but steel rafts are favored for use in exposed, offshore areas subject to rougher sea conditions. Rectangular “sled type” and cylindrical steel rafts are common (Figure 2). Payaos of this type are anchored to the bottom with polypropylene rope, steel cable and cement-filled oil drums in depths up to 5000 m (de Jesus 1982). Note the use of coconut frond aggregators (line drawing) and purse seine webbing aggregators (photo).

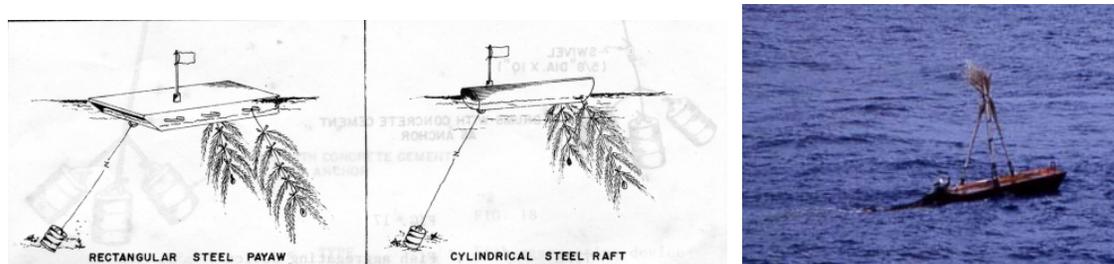


Figure 2. Philippine style rectangular and cylindrical steel payaos (from de Jesus 1982) and a rectangular steel payaw in the waters of the Philippines (photo D. Itano)

Anchored FADs support several small scale fisheries in the Philippines; the most important of which is the artisanal handline fishery for large tunas. Double outrigger *banca*s target large yellowfin and bigeye tuna on payaos using handline gear. Small tunas, squids and scads are usually hooked at the AFAD and used to bait single hook handlines. Fishing formerly took place at night with gas lanterns for bait attraction but shifted to deep daytime fishing for security reasons. Figure 3 show a typical Philippine banca handline boat fishing on a cylindrical steel payao and a typical handline catch of large tuna being unloaded in the southern Philippines.



Figure 3. Philippine banca handline boat tied to a payao in the Moro Gulf and bancas unloading their catch at Lion Beach, General Santos, Mindanao (photos D. Itano)

Anchored payaos also support a fleet of small purse seine and ringnet vessels in the Philippines that take large quantities of very small tunas and tuna-like species. Principal target species are juvenile yellowfin tuna, skipjack tuna, kawakawa (*Euthynnus affinis*) and *Auxis* sp. (Figure 4).



Figure 4. Philippine purse seine, ringnet and handline boats in General Santos, southern Philippines and a typical payao associated catch from a ringnet vessel (photos D. Itano)

2.1.2 Indonesian anchored FADs

The Indonesian pole and line skipjack fishery depends heavily on fishing tuna schools found in association with anchored FAD networks surrounding most of the inhabited islands of the archipelago. **Figure 5** shows a typical Indonesian AFAD of the rectangular steel type with a coconut frond marker and skipjack fishing on the same FAD.



Figure 5. Indonesian domestic pole and line boat on anchored FAD and a similar boat poling skipjack on an anchored FAD (photos D. Itano)

2.2 Anchored FADs – for large scale purse seine fisheries

2.2.1 Background and development in the WCPO

FAD based small-scale purse seine projects have been attempted in several Pacific Island countries and territories; including the Marshall Islands, Western Samoa, Wallis and Futuna, Fiji, Tonga, French Polynesia and the Federated States of Micronesia. However, these projects are poorly documented and for the most part did not persist for long. Two New Zealand flag purse seiners operated on anchored FADs surrounding the island of Viti Levu in Fiji between 1981 and 1985. The operation experienced many startup problems in developing suitable FADs and modifying gear and fishing techniques, but the operations eventually showed some positive results. This project was described in detail by Itano (1989).

The Mar Fishing Company attempted to develop FAD based seining operations in Fiji in 1989 with a medium-sized purse seiner accompanied by a refrigerated carrier. Catch rates were similar with an average of 11.5 and 13.6 mt per set recorded for the entire catch history of the New Zealand purse seine and Philippine (Mar Fishing) ventures respectively (Itano 1995). The Mar Fishing operation was hampered by rough seas and short FAD deployment times. A similar Philippine based purse seine joint venture project was attempted in the Federated States of Micronesia in 1991. Anchored Philippine style payaos were deployed between Pohnpei and Kapingamarangi. This venture also experienced problems due to equipment failures, strong currents, small gear and vessels and rapid loss of FADs due to currents or vandalism by other vessels. **Figure 6** shows one style of raft payao tried in Fiji and a light boat used in the Fiji purse seine operations run by Mar Fishing. The light boat was used to draw more fish to the payao and hold the school while the raft was towed away to permit a set around the school without tangling the FAD mooring line.



Figure 6. Bamboo raft style anchored payao tried in Fiji and a light boat used during pre-dawn sets.

2.2.2 Large-scale Anchored FAD arrays

2.2.2.1 Solomon Islands AFADs

The Solomon Islands has had both group and single domestic purse seine effort on a network of anchored FADs since 1984 through Solomon Taiyo, Ltd. The group seine operation was very successful with one boat landing over 6600 mt in 1987 on FAD associated schools (Oreihaka 2002). In 1988, two 499 GRT single purse seine vessels joined the AFAD fishery for the National Fisheries Development, Ltd. (NFD). The FAD network surrounding the Solomon Islands also has supported several pole and line skipjack vessels that fished for the domestic cannery. Activity of both fleets has declined sharply in recent years due to domestic conflict and instability.

The following observer account describes the type of anchored FADs used and fishing strategy of NFD purse seiners setting on anchored FADs: .. at the time of the observer trip, NFD has somewhere around 335 payaos set around the Solomons Islands. This number was complemented by the Solomon Taiyo Ltd. payaos which were known, plotted and fished by NFD and vice versa. NFD payaos were constructed of a mixture of bamboo and PVC piping (Figure 7). A large float was attached to the raft. None of the payaos I that were deployed



during this particular trip had any extra netting hung from the raft but many do. Nylon rope which needs to be around 4,000 meters long in some cases, connects the raft and the anchor. The anchors consisted of steel oil drums filled with cement. Ten to twenty payaos were deployed each trip by each vessel, in order to maintain a consistent number of payaos on station. Figure 8 shows the deployment of the mooring line and cement anchors.

Figure 7. NFD bamboo payaos in the Solomon Islands (photo D. Brogan)



Figure 8. An NFD anchored FAD being set off the Solomon Islands with rope and anchors being set after the FAD float has been released (photos D. Brogan)

2.2.2.2 Fishing strategy on Solomon Island anchored FADs

The NFD payaos were only set in pre-dawn darkness. A light-boat, equipped with an echo sounder and over-head lights was deployed at the payao around 0400 hrs. The payao and its anchor rope were hooked up and towed away by another speed/light boat. The light boat remained with the aggregation of fish until the net is set around it, at about 0530 hrs. The main concern during the trip was the strength of the current which could have seen the light boat drifting too fast and losing the fish. It was noted that one set was lost with few fish taken when the lights on the light boat failed before the set could be made. Payaos that have been set on are allowed to “rest” for a three week period - the amount of time they believe necessary for sufficient amounts of tuna to return to the FAD.

The purse seine vessels in the NFD fleet target company payaos all year round. Although the Captain has had ample experience fishing free schools - with the US fleet, he said it was rare for the NFD vessels to set on anything but anchored payaos.

One piece of information from the Filipino officers seemed to ring true during wheelhouse discussions. The Filipinos claim that they saw the same sonar marks in PNG waters while fishing with the Filipino fleet, as the ones they were seeing in the Solomons. The difference being that these marks regularly landed 20-40mt for the Solomon Island fleet while the Filipino fleet was more likely to land 1-2mt a day. The officer suggested to me that this was entirely due to the Filipino practice of setting a light boat to the payao in the early evening. (The NFD vessels set their light boat to the payao only an hour before setting. It was the officer's view that lighting up the payao for an extended period of time caused the fish to

scatter before the early morning's setting. This would fit in with my own experience on Filipino vessels i.e. 1-2 mt a day, but other observer data shows larger landings within the Filipino fleet.

2.2.3 Papua New Guinea anchored FADs

Purse seiner vessels of Philippine origin have been operating in Papua New Guinea and the Solomon Islands since at least the early 1990s. Lawson (1992) estimated that 12 Philippine purse seiners fished in Papua New Guinea and the Solomon Islands in 1991, operating almost exclusively on anchored FADs. Catches have been transhipped to canneries in the Philippines or processed domestically in Papua New Guinea.

Kumoru (2002) stated that over 800 FADs were listed as being in use in PNG waters in 2002 by six purse seine companies of Philippine interest. However, he noted that there may be twice as many FADs actually in use with approximately 4000 FADs set during the previous five years. In order to try and control FAD numbers, the PNG government limited deployments to a maximum of 1000. Most of these AFADs were of the cylindrical steel torpedo shape with coconut palm frond appendages and anchored in place with four to six 200-litre concrete filled steel drums. **Figure 9** indicates the FAD locations during that year, primarily in the Bismark Archipelago. Anchored FAD deployments in the Solomon Sea and outside the archipelagic waters appear to be set in rows in an attempt to intercept and entrain migrating tuna schools. Due to the density of these moorings, significant gear conflict with longline vessels has occurred.

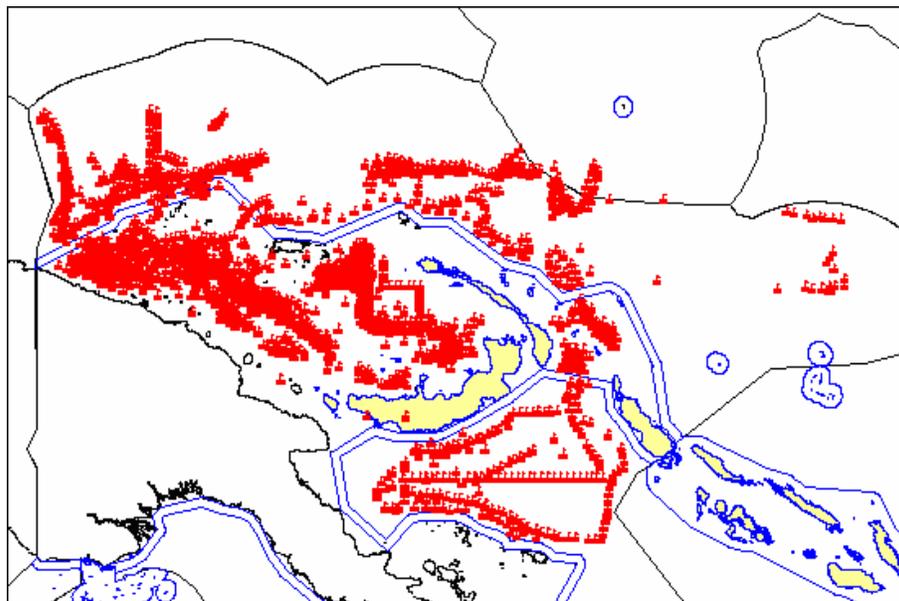


Figure 9. Anchored FAD locations in PNG waters in 2002 (Kumoru 2002)

The following year, Kumoru noted that 17 domestic PNG vessels of Philippine origin operated on AFADs set within the archipelagic waters of the Bismark Sea while 10 Philippine bilateral access vessels worked on AFADs set mainly to the north or the Equator. **Figure 10** indicates the location of anchored FADs set by these companies in PNG waters from Kumoru (2003). The cylindrical steel payao remained the primary anchored FAD type in use.

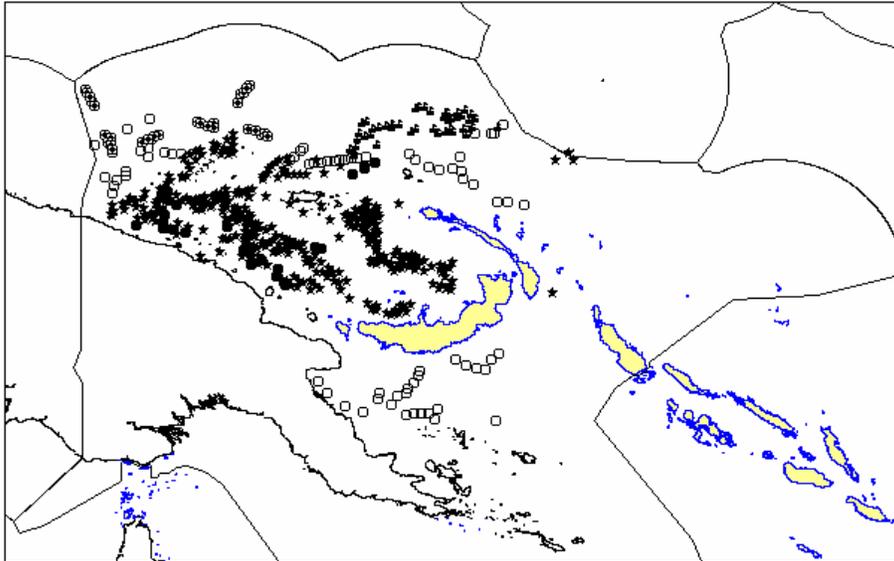


Figure 10. Location of anchored payaos deployed in the PNG zone to support domestic and foreign access purse seine vessels (from Kumoru 2003, source NFA data)

In 2003, six FAD based purse seine companies were licensed in PNG operating 27 catcher vessels, 38 light boats, 22 FAD/supply vessels and 30 refrigerated carriers. Over 610 FADs were registered for use with these companies but the figure is believed to be conservative and the actual number has not been verified.

Information was recently gathered on Philippine purse seine operations in Madang Province by an SPC fishery officer on a scientific observer trip. Payaos were deployed in depths ranging from 500 – 1200 fathoms (914 – 2195 m) as determined from GPS positions and a navigational chart (Fukofuka, pers. comm.). The payaos were set with more than 20% scope on the mooring line to allow for strong currents, adverse sea conditions and allow slack when the payao is towed away by the ranger/light boat before each set. Payaos were anchored 8 to 10 nautical miles from each other by the catcher or carrier vessels.

During the trip, the catcher vessel deployed 10 anchored payaos. All rigging of payaos and preparation for deployment were conducted onboard the purse seine vessel. Materials for each payao included 3 coils of 3 strand polypropylene (660 meter each coil), three 200-litre steel drums filled with cement to serve as an anchor and 30 to 40 meters of wire cable to be attached to each floating devices. The floating devices were made of steel with a bullet shape, 4 meters long with an approximate diameter of 80 centimeters, similar to those pictured in **Figure 11**. The last two payaos were deployed to the west of Manus Island at

greater depths of 1780 fathoms (3255 m) with 8 coils of rope used for each payao. Aggregators such as coconut and pandanus leaves were also attached to the payao. **Figure 12** shows a FAD deployment vessel loaded with FAD mooring lines and new cylindrical FAD floats. Note the pandanus leaf on the vessel to be used to mark the FADs and for use as aggregators.



Figure 11. Philippine style cylindrical payao on station and a FAD tender vessel loaded with cement anchors and new FAD floats (photos S. Fukofuka)



Figure 12. FAD mooring lines, floats and aggregators (photos S. Fukofuka)

3. DRIFTING FADs (DFADs)

3.1 Development of drifting FADs in the WCPO

The use of drifting FADs in the WCPO developed directly from the tendency of tuna to aggregate to natural drifting objects like logs or man-made flotsam or jetsam such as cable spools, crates, wooden pallets or discarded cargo nets. The Japanese first developed successful year around purse seining in the equatorial WCPO by developing techniques to capture tuna schools found in association with natural drift objects, similar to the logs pictured in **Figure 13** (Watanabe 1983). Hampton and Bailey (1999) provide a detailed report on the fisheries associated with drifting objects in the WCPO.



Figure 13. Natural drift log marked with a radio buoy and a log being towed out of the net during a purse seine set (photos D. Itano)

Some vessels experimented with retrieving natural drift logs and re-deploying them at different locations where better signs of tuna were present, or tying several natural drift logs together to form a larger floating mass (**Figure 14**). Another common strategy that is still used today was to use derelict Philippine payaos that had broken their moorings and drifted east into the WCPO purse seine grounds. **Figure 15** shows a cylindrical Philippine payao with a natural drift log tied to it to form a DFAD.



Figure 14. Recovering a natural drift log to use as a FAD and roping several natural drift logs together to form one large raft to aggregate tuna for purse seining (photos D. Itano)



Figure 15. Drifting payao tied to a natural lot to form a drifting FAD (photo D. Itano)

3.2 Experimental U.S. drifting FADs

It was a short step from enhancing natural drift logs or using recovered anchored FADs that had broken their moorings to the construction of purpose built drifting FADs. The development and use of drifting FADs was also actively promoted by the U.S. National Marine Fisheries Service as an alternative fishing method to setting on tuna associated with dolphins in the Eastern Tropical Pacific (ETP) purse seine fishery. As part of the NMFS Dolphin-Safe Program, research projects were developed with potential to furthering the understanding of the tuna-dolphin association and toward the development of fishing methods to locate and capture tuna not associated with dolphins or marine mammals. Several different drifting FAD designs were tested in the ETP from 1990 – 1994 similar to those pictured in **Figure 16** (Armstrong and Oliver 1995).

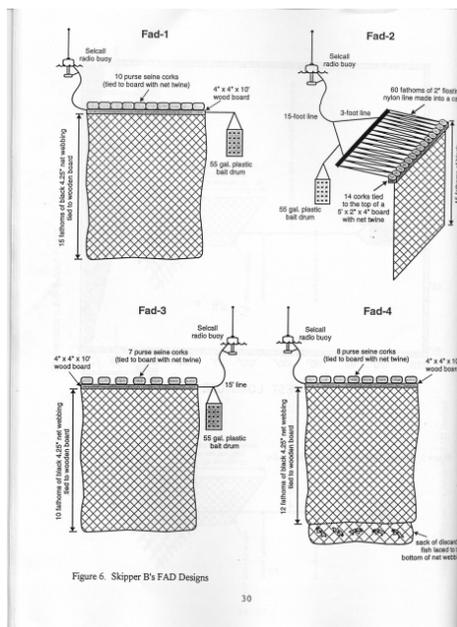


Figure 6. Skipper B's FAD Designs

Most of the DFADs tested were constructed of a three meter wooden board or wooden pallets and spare purse seine webbing. Other DFADs added a floating carpet of rope to add surface area. Additional purse seine corks were tied to the board for additional flotation with chains weighting down the nylon webbing that hung 11 – 18 meters below the surface. On some FADs, the net webbing was soaked in a heavy fish oil “solubles” (a by-product of fish oil production from fish meal) or chum was added to a 55 gallon plastic drum attached to the DFAD float. The DFADs were marked with a radio buoy and set in areas where the fishermen felt “good signs” of fish were present; such as jumping tuna, tuna schools forming ‘breezers’ on the surface, baitfish concentrations, or the presence of dolphinfish and sharks.

Figure 16. Drifting FAD designs tested by U.S. fishermen (Armstrong and Oliver 1995)

Two purse seine captains tested the drifting FADs and reported some very high catch rates averaging close to 200 mt per set. The captains felt that the area fished was more important to FAD productivity than structural design. However, there was agreement that net hanging down from the FAD was important to productivity. They felt that location of the FAD, ease of storage, deployment and recovery was more important than expending a great deal of effort on designing special features into the FAD structure.

3.3 Different drifting FAD types

3.3.1 U.S. drifting FADs

The following information was taken from observer reports and direct observations by the authors on fishing and research vessels operating in the WCPO. One style of DFAD was made of bamboo, purse seine net and chain, similar to the raft pictured in **Figure 17**. Actually, the DFAD pictured here was believed to belong to a Japanese vessel and was an example of a natural log enhanced with additional floatation and aggregators. It consisted of three or four bamboo poles laced and tied around the log and attached to 25 – 30 fathoms of purse seine webbing. At the bottom of the net a length of chain was attached to keep the net in a vertical position. The bamboo also acted as a float, which supported the length of the net. All rafts were attached with a radio buoy (sel call type). Sub-surface aggregators such as coconut fronds and other materials were attached to the lower part of the raft.

The enhancement of a natural log by man-made material blurs the definition of what is a “log” and what is a “DFAD”, which can become a problem with reporting of catch and effort between the two. However, this is clearly a DFAD and not a log.



Figure 17. Example of a natural log enhanced with bamboo floatation and net webbing to form a drifting FAD (photo D. Itano).

Another style of raft used by U.S. vessels is constructed from purse seine net, bamboo, chain, coconut leaves, PVC pipe and purse seine floats (Fukofuka pers. comm.). The main floatation is PVC pipe covered with thick plastic to avoid leakage. Eight to nine PS floats were also attached to the PVC pipe to support the weight of the net, bamboo etc. A 25 fathom net (double layer) was attached to the floatation. A ½ inch chain was laced to the bottom of the net to keep the net in a vertical position. Bamboo was also tied to the net in a horizontal position to the net. Other appendages like salt sacks and coconut leaves were added to the net. Bait was also attached to the net in the form of salt sacks filled with discarded skipjack and rainbow runner. A radio buoy was attached to the raft before deployment. According to the Deck Boss, the depth of the netting was reduced from 50 to 25 fathoms in an effort to keep the tuna closer to the surface during pursing. **Figure 18** shows this style of drifting FAD marked with a GPS positioning radio buoy.

Rafts were set on more than once during the observer trip and two rafts were set on twice, one after the other. Live rainbow runner that were accidentally brailed aboard were returned to the water as soon as possible as they believed that the “bait” would return to the raft and help attract more tuna. More than 30 rafts were deployed during the end of the trip where 16 had disappeared or had been stolen according to the navigator. A total of 27 rafts were deployed, 6 during fishing period and 21 after the vessel had filled up. During this trip a new floatation device for the rafts (PVC pipe) was used and filled with foam to keep from flooding. The fishermen stated that purse seine floats were preferred, but more expensive.



Figure 18. Drifting FAD made of PVC, purse seine floats and netting, marked with a GPS positioning radio buoy in PNG waters (photos S. Fukofuka)

3.3.2 Japanese drifting FADs

The Japanese have been deploying drifting FADs made of bamboo in the WCPO for decades. Gillett (1986) documented their use on Japanese purse seiners operating in the Federated States of Micronesia on an observer trip in 1982. Gillett states:

“The Takuryu Maru No. 1 made extensive use of free-floating bamboo rafts. These rafts were constructed aboard the vessel, and were set adrift on the fishing ground after being marked with a radio beacon and flashing light. The fishing techniques used in association with these “artificial” logs were identical to those used with those logs encountered by searching”

More recent observer trips on Japanese purse seiners noted drifting FADs made of bamboo and tied together with a net that hung down 20 to 30 meters, weighted by chain. A sack of tuna was also attached to each FAD as it was deployed. These FADs would be similar to those pictured in **Figure 19**.

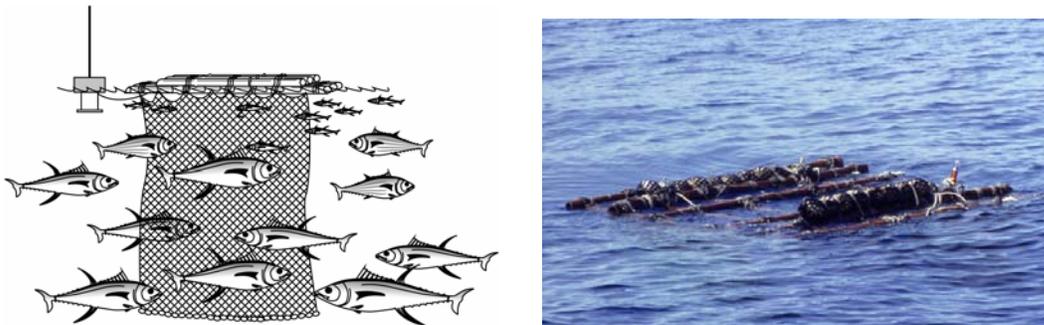


Figure 19. Graphic representation of a bamboo raft type drifting FAD an (SPC drawing for training sheets), and a Japanese drifting FAD in the WCPO (photo S. Fukofuka)

3.3.3 Taiwanese drifting FADs

Taiwanese purse seiners also used drifting FADs made of bamboo and net twine. **Figure 20** shows the construction of a drifting FAD on a Taiwanese purse seine vessel using purse seine webbing that is used as the sub-surface aggregator. A bundle of bamboo used for flotation is visible in the second picture. The red and green plastic strap material is tied to the webbing to form additional aggregators for fish attraction.



Figure 20. The construction of a bamboo and net drifting FAD on a Taiwanese seiner (photos S. Fukofuka)

3.3.4 Korean drifting FADs

Little information was available on Korean drifting FADs. This fleet is somewhat unique in the WCPO fishery by concentrating on unassociated sets of large tuna instead of log or drifting FAD sets that take mostly juvenile tuna. **Figure 21** shows one example of a steel DFAD used by a Korean purse seine vessel. However, it may actually be a derelict Philippine anchored FAD that has broken loose and was retrieved by the vessel.

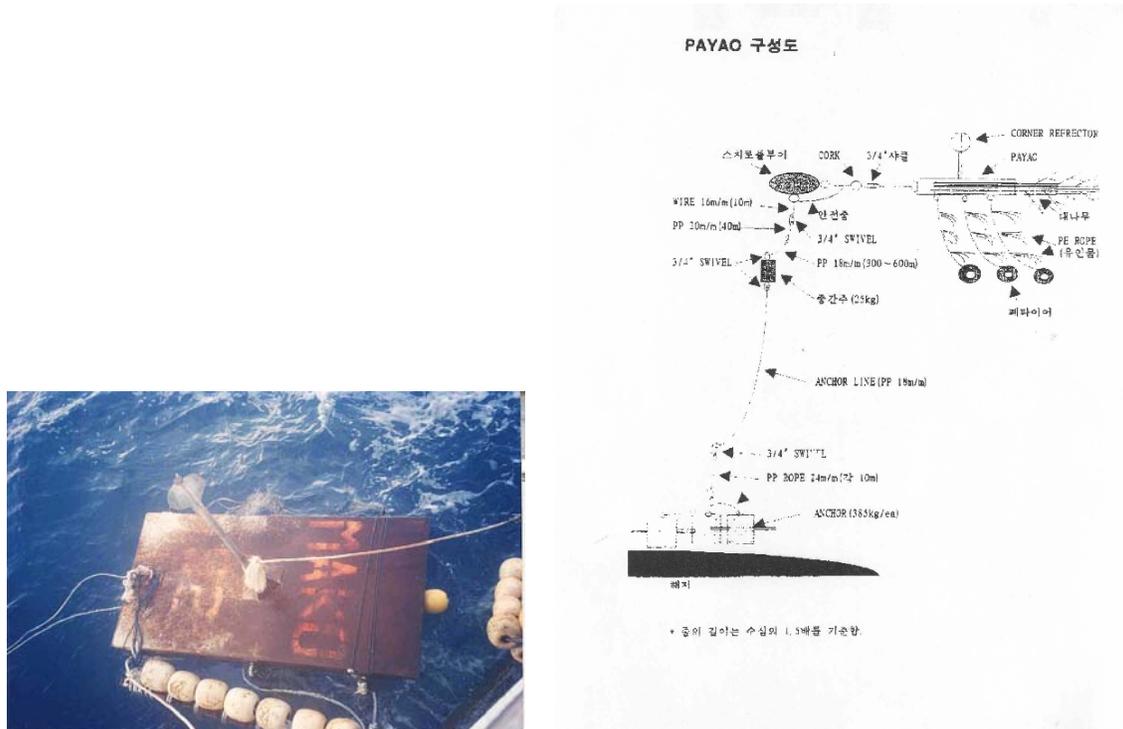


Figure 21. Rectangular steel drifting FAD used by a Korean vessel and a Korean schematic for an anchored FAD (photos D. Brogan)

3.3.5 European Union drifting FADs

The European Union (EU) purse seine fleets, primarily Spanish and French, were possibly the first major purse seine fleets to widely adopt drifting FADs as a primary fishing strategy. These developments took place mainly in the Gulf of Guinea in the eastern Atlantic followed by intensive DFAD fishing in the western and central Indian Ocean basin. The Spanish fleet in particular has adopted DFAD fishing as a primary fishing mode interspersed with free school fishing on large fish when available.

The Spanish distant water purse seine fishery entered the Indian Ocean in 1984 when fishing was mainly based on free schools. Over time, the strategy of both the Spanish and French DW fleets in the Indian Ocean has shifted to a fishery based on drifting FADs. Initially, DFADs used by the Spanish fleet were made of wood but shifted mainly to bamboo rafts after 1992 (Morón 2001).

Figures 22 and 23 show bamboo construction rafts commonly used by EU purse seiners in the Indian Ocean. The rafts are simple and light in construction but held together with net twine and additional purse seine corks to increase strength and flotation. Netting is hung down from the rafts as is common for all fleets. Hand in hand with the development of EU drifting FAD use has been a stepwise advancement in radio buoy technology (Morón 2001). Another significant development utilized by the Spanish fleet was the incorporation of FAD tender or supply vessels in their fishing strategy. These vessels work in conjunction with one or a group of large purse seine vessels to improve overall efficiency. The FAD tender vessels deploy DFADs, monitor aggregations, retrieve DFADs that drift off too far, search out and assess other vessels DFADs and guard aggregations of tuna on their own DFADs from poaching by other vessels (Arrizabalanga, et al. 2001). **Figure 24** is an example of a FAD tender and supply vessel that works with an EU purse seiner(s). The improved efficiency of EU purse seiners as a result of drifting FADs and associated electronic advancements was a primary concern of the ESTHER Project (Efficiency of Tuna Purse Seiners and Effective Effort) that looked at advances in vessel efficiency in the EU fleets.



Figure 22. Bamboo frames for construction of drifting FADs and a drifting FAD constructed of bamboo (photos D. Itano and L. Dagorn)

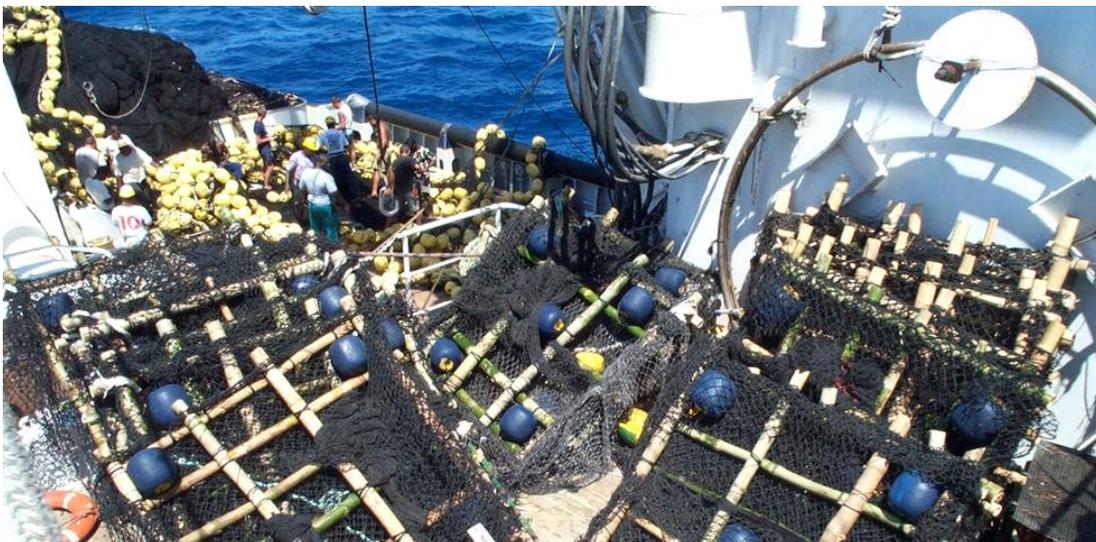


Figure 23. Drifting FADs constructed of bamboo, net and floats on an EU purse seiner (photo A. Fonteneau)



Figure 24. A tender or supply vessel that supports the activities of a purse seine vessel, especially in regard to the maintenance of drifting FADs (photo D. Itano)

4. RADIO BUOY TECHNOLOGY AND DRIFTING FADS

The development of highly efficient purse seining on drifting FADs would not be possible without the rapid improvement in marine electronics and radio buoy technology that has occurred over the past fifteen years. Morón (2001) details these developments for the Spanish, Indian Ocean fishery. These developments were described in detail by Itano (2003) and the text of that section of the report is inserted below:

“7.6.1 Historical development

Early model radio buoys that are still used in many fisheries are always activated, transmitting an undisguised signal every few minutes detectable by an onboard radio detection finder (RDF). These devices were commonly used in the development phase of the WCPO purse seine fishery to mark logs and natural drifting objects. The range of detection is limited to less than 100 nmi, and generally less than 75 nmi with limited battery duration. These devices provide the vessel with only a crude bearing and their distance can only be estimated by signal strength. As the fishery developed, vessels began to capitalize on the open nature of the transmissions and actively scanned common RDF frequencies to locate and set upon logs belonging to other vessels. The transmitting frequency of these buoys could be easily changed, so theft of radio buoys was also a problem. However, it was the loss of logs and associated schools that drove the industry to demand more sophisticated technology. Constant transmit radio buoys were commonly used by WCPO purse seine fleets from the beginning of the fishery to around the mid 1980s¹

Select call radio buoys were quickly adopted in the 80s to reduce theft of gear and productive logs and FADs. A single drifting object can (over some time) fill up a purse seine vessel, so this is no small consideration. Select call, or ‘sel call’ buoys

¹ All dates of gear adoption are general estimates and need to be better defined by systematic interviews and research.

remain in a low power ‘sleep’ mode until a coded signal from the vessel activates the buoy for a short series of transmissions. The vessel can lock in on the direction of the buoy during the brief ‘wake up’ period and obtain a general range and bearing. Further developments raised the transmit frequency to improve detection of bearing to approximately 200 nmi (Morón, et al. 2001). **Figure 57** depicts the general characteristics and gear involved with constant transmit, select call and GPS positioning radio buoys.

Drifting FAD fishing increased significantly for the EU Indian Ocean fleets, and radar detection of radio buoys was becoming problematic. As noted in the previous section on navigational radar, the loading coils of RDF buoys can be detected by high grade radar units, thus allowing vessels to actively scan for the logs and FADs belonging to other vessels. In 1995, EU vessels began to incline their radio buoy antennas to reduce the detection range by other vessels (Morón, et al. 2001). **Figure 58** shows radio buoys with inclined antennae that are a standard feature of Indian Ocean purse seiners. However, it is not believed that this development has been widely adopted in the WCPO fishery.

In the late 1990s, GPS technology was incorporated into drifting radio buoys. GPS positioning buoys have revolutionized purse seine fishing and were quickly adopted by all modern fleets. These buoys combine a sel call feature with the ability to transmit the exact GPS position, allowing vessels to carefully plan their fishing campaigns. Interestingly, Morón (2001) notes that GPS buoys contributed to an expansion of the Indian Ocean fishing grounds as vessels ventured further a field to retrieve lost radio buoys that had drifted out of traditional areas.

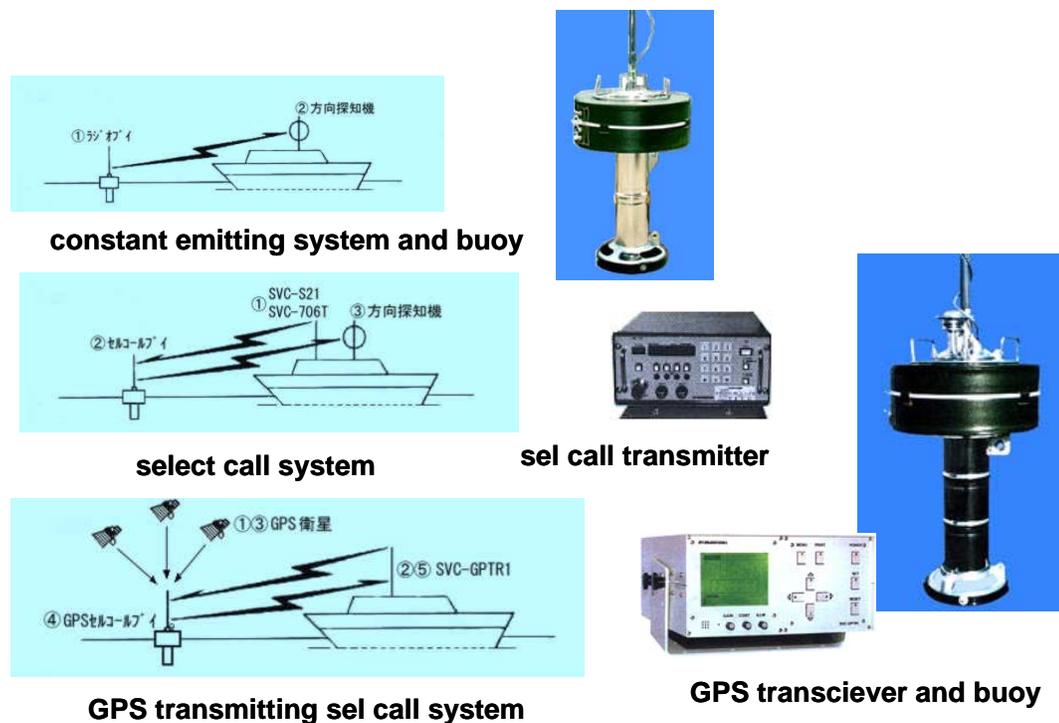


Figure 57. Early evolution of radio buoy technology (Ryokuseisha Corp.)



Figure 58. Inclined antennae on RDF buoys (photo D. Itano)

7.6.2 Recent developments in radio buoy technology

In the late 1990s, more sophisticated radio buoys became available, again revolutionizing modern purse seining. These GPS tracking buoys transmit continuous position data to a computer interface at ranges close to 1000 nmi. A continuous “worm trail” of the buoy is represented on the computer screen at all times. These buoys also transmit SST and battery condition with slim antennae without loading coil making them very difficult to detect by radar (**Figure 59**).



Figure 59. Serpe type GPS tracking radio buoys and computer interface (Martec).

The next development in transmitting buoys utilized Inmarsat technology to link the vessel to a low profile sonar buoy with no visible antennae (**Figure 60**). These buoys transmit GPS position, SST, battery life and sonar readings directly to

computer displays on the vessel via satellite. With no antennae, the units are extremely difficult to detect by other vessels and have unlimited range. Also, a bright light can be triggered to flash and signal the vessel when it approaches the unit for FAD detection and retrieval.

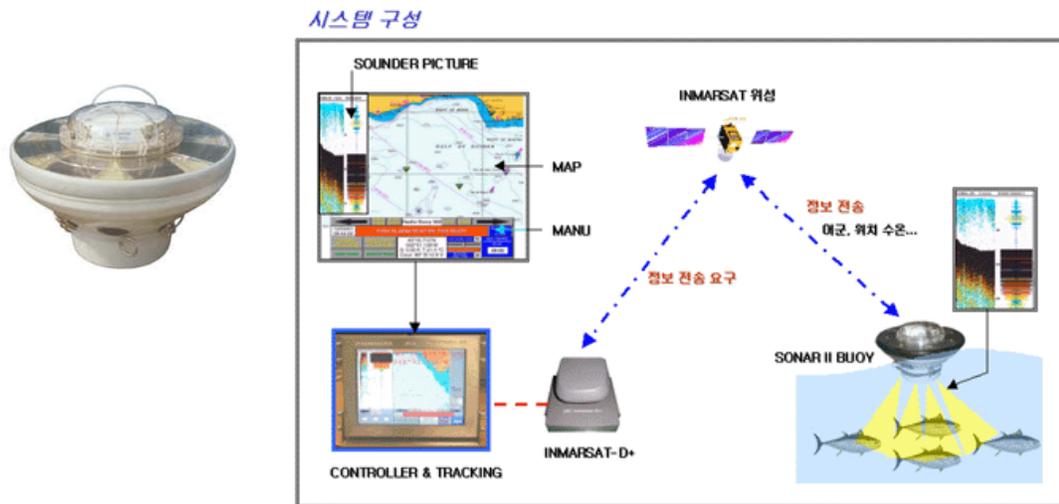


Figure 60. Satellite linked sonar transmitting GPS buoy (Zunibal).

The latest generation radio buoys (2003) continue to improve in response to the needs and concerns of industry. GPS transmitting buoys have eliminated the need for antennae and taken a low profile shape, making them extremely difficult to detect visually or by radar. Computer transceivers and display units are now marketed in laptop computers to conserve space (**Figure 61**). Another significant improvement to sonar buoys has been the addition of solar panels, providing them with virtually unlimited autonomy and eliminating the battery concerns of earlier models. The solar powered unit pictured in **Figure 61** transmits via satellite a GPS position, battery state, as well as current speed and direction. Current velocity threshold alarms can be set that can notify the owner of unusual conditions. Excessively high speeds may indicate to the owner that his buoy is no longer in use but traveling at high speed onboard another vessel !



Figure 61. New generation GPS and sonar transmitting buoys (Martec, Zunibal).

The use of sonar transmitting buoys by purse seiners is a significant development for the industry. Earlier models often represented false hopes to the fishermen and were limited in scope of coverage below the buoy. However, with better technology and experience, sonar transmitting buoys have become very beneficial in maximizing “search” time, or the time spent traveling to and assessing FADs. Aretxe and Mosqueira (2003) examined catch composition and catch parameters for FADs marked by different types of radio buoys. While noting no difference in species compositions, the success rate and percent of larger sets appeared to be significantly higher on FADs equipped with sonar transmitting satellite buoys. This may indicate simply that these devices are efficient in predicting when good concentrations of tuna are present, thus avoiding unnecessary visits that unnecessarily occupy a vessels schedule. The primary manufacturer of satellite linked sonar buoys concluded a business arrangement in 2001 that permitted worldwide, and Pacific-wide coverage for these devices, thus opening up their full use to the WCPO.”

5. NEW DEVELOPMENTS IN DRIFTING FAD TECHNOLOGY

Undoubtedly, the technology involved with radio buoys will continue to improve and thus increase efficiency of vessels. The primary advantage of this technology is to reduce search time and maximize directed fishing effort on productive FADs.

The enhancement of the aggregative ability of the FAD itself is another matter and needs to be investigated and better documented. One significant aspect of this may be the use of artificial light and its role in the aggregation process. Kumoru (2002) noted that new styles of FADs were being experimented with in the PNG fishery that had onboard lighting systems. **Figure 25** is a diagram showing the layout of this experimental FAD with integrated batteries and underwater lights.

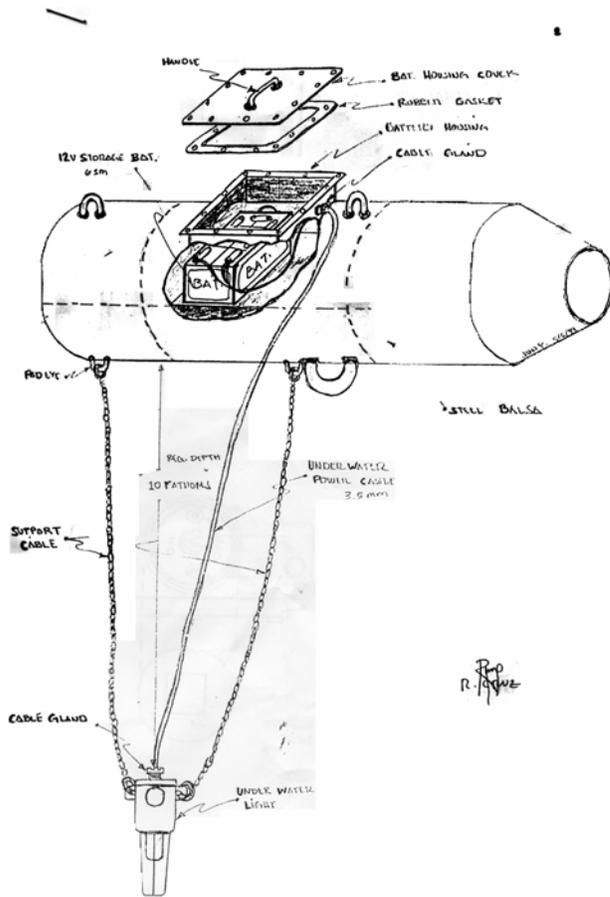


Figure 25. Experimental FAD with batteries and underwater bait/fish attraction light (Kumoru 2002)

6. SUMMARY

This review of available information on anchored and drifting FADs has highlighted the scarcity of documented information on technical parameters of FADs that are used in the WCPO fishery. Another conclusion may be that specific technical information on FADs that may influence their efficacy and aggregative characteristics needs to be defined to facilitate coordinated data collection efforts. Before this is done, it seems counterproductive to conduct analyses on the possible differences or similarities between “log” and “FAD” catches. First of all, it will be necessary to define useful parameters to collect in a standardized manner and more basically, to define the difference between the two. Currently, the characteristics of main interest to SCTB and the WCPO Commission will likely be related to the aggregative characteristics of FADs in relation to juvenile bigeye tuna, undersize market tuna in general and bycatch species.

Even though we can not say what makes one FAD more “effective” than another at this stage, the experience of fishermen and their comments should be noted and investigated. For anchored FADs, the use of sub-surface aggregators is a fundamental part of the Philippine

payao design. However, the most important aspect of their anchored FAD fisheries seems to favor FAD density and large numbers of FADs over other considerations.

The drifting FAD designs appear to have converged to a common type, which is not surprising considering the degree of poaching that occurs between different vessels and fleets. The most common feature is that all drifting FADs seem to use a long panel of weighted netting that hangs down below the FAD. The importance of sub-surface mass to a drifting FAD was discussed by Itano (1998) as follows:

“This generalized design varies from vessel to vessel, but there is a consensus among fishermen that a significant amount of subsurface area is important to a successful FAD. It is common knowledge in the fleet that the most successful natural drifting object besides a dead whale is a large log that has become waterlogged and floats vertically with only a small portion above the surface (Hampton and Bailey, 1993). Several theories have been put forth to explain the importance of sub-surface structure to drifting and anchored FADs, including:

- , vertical logs are vertical because they have become waterlogged with time and have been in the water longer and have had more time to aggregate tuna;*
- , sub-surface mass holds or tracks better in the water column, positioning the FAD in productive current gyres or current boundaries, rather than drifting with surface winds;*
- , sub-surface structure offers greater surface area for shelter and habitat for baitfish and associated drift communities, including juvenile tuna;*
- , tuna can discern, locate and aggregate to logs or FADs with large a sub-surface area at greater distances either through auditory, visual or other means.*

The reason for the apparent success of FADs with large sub-surface structure is not clear but the fishermen believe this to be true and fashion their drifting FADs accordingly. The predictable drift of FADs that hold well in the prevailing current is an additional benefit as one vessel may be tracking and monitoring more than 10 FADs at the same time.”

Another common belief of fishermen that appears in observer reports is that a large mass of associated finfish on a FAD helps to aggregate more tuna and enhances the repopulation of tuna to a FAD that has been set upon repeatedly. Fishermen often try to save the “bait” by returning it to the water near the FAD and by slowly towing the FAD out of the net between the vessel and the suspended stern end of the seine after pursing is complete (Hampton and Bailey 1993). Feeding and predator/prey relationships do not seem important here considering that many of the non-tuna fish species (oceanic triggerfish, rainbow runner) are large and not normally eaten by tuna, and especially by the juvenile tuna that are often found on FADs. Other mechanisms of aggregation may be involved that should be investigated.

Other aspects of drifting FADs that fishermen believe may enhance their attraction to tuna include the use of artificial light, attachment of a chum container, and use of heavy fish oils that disperse slowly from the FAD. However, fishermen seem to agree that the most important aspect of tuna aggregation to drifting FADs has to do with location.

7. RECOMMENDATIONS

It is recommended that the experience and knowledge of fishermen be taken into consideration, but examined as objectively as possible to look at the effect of FAD design, presence of baitfish, artificial light, chumming, and other factors that may influence species specific aggregation.

A great deal of this information may already be available in the narrative sections from years of observer reports on different fleets. The problem is that observer coverage is low for many of the fleets and there has been sensitivity over disclosing detailed technical data on drifting FADs and innovative fishing techniques. However, any potential source of FAD data should be compiled that may be important to defining the design and efficiency of FADs (particularly drifting FADs) used by WCPO purse seine fleets. Comparisons with catch data, particularly for bigeye tuna and undersize tuna could then be examined where the reporting of these catches is considered accurate.

Finally, research on species specific aggregation of pelagic species to both anchored and drifting FADs should continue but with direction from the research and management community.

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