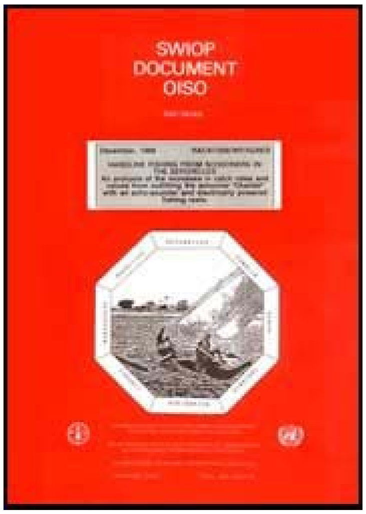
SWIOP/SW/49 - Introduction of Fish Aggregating Devices in the Southwest Indian Ocean (A Case Study)



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IPFC SYMPOSIUM ON ARTIFICIAL REEFS AND FISH AGGREGATING DEVICES (FADS) AS RESOURCE ENHANCEMENT AND FISHERIES MANAGEMENT TOOLS (COLOMBO, SRI LANKA, MAY 1990)

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1. Introduction

During the past decades, several countries of the Southwest Indian Ocean region have attempted setting Fish Aggregating Devices (FADs) with varying success.

Initially, FADs were rapidly lost without being able to produce any results. The gradual improvement in design through the work carried out mainly by SWIOP1 in the region, lead to the development of long lived FADs in Mauritius. The transfer of that technology to other islands such as Reunion, Madagascar, Comores and Rodrigues (Mauritius) gave a new impulse to the activity.

1. Project for the Development and Management of fisheries in the Southwest Indian Ocean (RAF/79/065 - RAF/87/008).

2. Objectives of FAD Fisheries

It is known that drifting objects such as logs, branches, rafts, ropes or dead whales, etc., aggregate fish around them. Fishermen have since long used this knowledge of the behaviour of fish to associate themselves with floating objects. In the South East Asian area and in the Western Pacific, important quantities of fish are caught during well known seasons of drift of flotsam (Mohan, 1985).

Locating such objects has an element of chance and extending their use over long periods is almost impossible. Consequently, fishermen have been driven to construct their own rafts and have anchored them so that they remain accessible. These rafts are commonly known as Fish Aggregating Devices (FADs), or Payaos (Philippines). Some ocean going purse seiners also fish with artificially built drifting FADs.

The use of FADs to attract and hold schools of pelagic fish like tunas and dolfinfish is one of the significant recent developments in the tuna fisheries of many insular states. In the Philippines - a major tuna fishing nation (approximately 260 000 tonnes of tuna landed in 1985), there could be well over 5 000 Payaos presently in use (Stequert, 1989).

Aware of the existence of scattered pelagic fish in their coastal waters, the countries of this region have made considerable efforts during the last years to tap these resources by use of FADs.

Where the continental shelf is quite narrow and demersal stocks are fully exploited such as in Mauritius, Reunion, the Grande Comore and Anjouan (Comores) (Sanders, 1988), the access to new resources could play a major role in the supply of more fish to markets. From the management point of view, the relocation of fishing effort from over-fished traditional grounds to FAD-associated fisheries would be quite a significant policy.

In FAD-associated fisheries for migratory species, fishermen spend less time scouting for fish. Consequently, there is substantial economy on fuel and a net reduction in the number of nil catch days; the safety factor for small boat operations is also improved.

3. Experience with Fish Aggregating Devices in the Southwest Indian Ocean

3.1. Comores

FADs could have been in use as far back as in 1956 in Anjouan. They were made of trunks of banana trees on which a flag was posted. Their lifespan was about six months. During 1959-1960, semi-immersed bamboo cages were used in the bay of Mutsamudu and these lasted about nine months before the disaggregation of the bamboo. Lastly, in 1969, 200 litre steel drums were anchored about one mile offshore, where depths attained 70 to 80 m; the mooring line was made of braided coconut fibre. Built and set by the artisanal fishermen, they were meant at the outset to capture sharks, but soon dolfinfish and tunas became the main target of the fishery (Marsac and Stequert, 1987).

More recently, in 1982 (de San, 1982), two foam filled tyre-type FADs were set with support from SWIOP. The first was set off Grande Comoro at a depth of 350 m, but was destroyed by fishermen a few days later, due to ownership rights. The second, set at a depth of 1 350 m towards the North of Anjouan, disappeared after about twenty days due to loss of buoyancy after successive immersions (de San, 1983). The raft consisted of five lorry tyres filled with pieces of polystyrene foam, cemented with polyurethane foam, linked to each by a light chain, fixed at one end to the mast and at the other to an 18 mm polypropylene mooring. The anchoring device, except for slight modifications, is still in use in the new generation FAD designs described later.

In September 1986, following the development of long lived FADs in Mauritius, SWIOP envisaged the transfer of the technology to the Comores. Two heavy and two light FADs were built, three of which were set in the bay of Mutsamudu (Anon., 1986). The depths ranged from 1 700 to 1 800 m, approximately three miles offshore.

The light FADs were constituted of six 280 mm diameter floats mounted on wire cable. The mooring line was of 10 mm diameter polyethylene. The light FADs were essentially meant to ascertain the depth for the mooring of the heavier FADs, as no echo-sounder was available. The light FADs on the other hand, could have been used as an alternative to the heavier and more expensive ones if their lifespan had been long enough (Roullot and Venkatasami, 1986 a).

The heavier FADS were constituted of twenty-six 280 mm diameter and five 200 mm diameter high resistance floats strung on an 11 mm diameter steel wire rope. The mooring was 16'mm "diameter polypropylene.

The FADs, however, did not stay long due to lack of maintenance. In fact, the steel wire ropes, which corroded after some time, should have been replaced. Fishing started 17 days after setting and results obtained were quite satisfactory, 1 020 kg of tuna and 340 kg of sharks having been caught over a period of twelve days. The number of canoes involved is, unfortunately not known. The boat of the Anjouan Fishermen's Training School, on the other hand, obtained low catch rates during trolling, averaging only 4.5 kg per hour. The species caught consisted of skipjack and yellowfin tunas and a few dolfinfish (JICA Experts, pers. comm.).

This trial introduced the design and mooring techniques of long-lived FADs and also demonstrated the interest of fishermen in the FAD fishery.

Starting from 1987, the EDF [2] /COI [3] Regional Tuna Project set FADs for the three main islands. As at April 1989, twelve had already been moored, with an expected six more to be set later. The depth and distance characteristics are not available, but Figure 2 shows their location.

[2] European Development Fund.
[3] Commission de l'Océan Indien (Indian Ocean Commission)

3.2. Madagascar

Two technicians from Madagascar followed a short training on FAD construction in Mauritius in 1987.

The CNRO (Centre National de Recherche Oceanographique), in association with the IOC/Regional Tuna Project, have since January 1989, set seven deep sea and two shallow water FADs of the Mauritius design off Nosy Be (Table 1). One deep sea and two shallow water FADs were lost two months after setting for unknown reasons.

Table 1: Summary of Information on FADs presently in use in Madagascar (Source: CNRO; Muyard, pers. comm.).

S.N.	Depth (m)	Distance Offshore (n.m.)	Date Set	Longevity at 24.05.89 (days)	Remarks	Reasons for Loss
1	1 100	20	18.01.89	126	Active	
2	1 230	16	18.01.89	126	Active	
3	1 400	24	31.01.89	28	Lost	Unknown
4	1 900	27	08.03.89	77	Active	
5	1 100	22	08.03.89	77	Active	

6	1 400	32	09.03.89	76	Active	
7	720	-	17.05.89	7	Active	
8	45	-	03.02.89	70(?)	Lost	Unknown
9	30	-	03.02.89	70(?)	Lost	Unknown

N.B.: Distances from shore extrapolated from available coordinates.

Fishing results have not been very positive during the few visits made to the FADs. It should be noted that offshore fishing is practically non-existent off Nosy Be and the deep water FADs are found more than 20 miles offshore where they are not accessible to artisanal fishermen. However, the FADs were here meant to develop a small scale industrial fishery and the outcome has to be followed up.

3.3. Mauritius

3.3.1. Mauritius Island

It seems that in 1974, two bamboo FADs were set from the 26 vessel *Investigator* one was anchored at a depth of about 200 m off Round Island and the other at a depth of 300 to 400 m off Flat Island, they were rapidly lost during a cyclone, producing no results, though engineering was lacking, explaining the short lifespan, it is doubted whether they could have aggregated fish, being found on the shelf itself.

Two other FADs were set in February 1983 with SWIOP assistance (de San, 1982). These FADs, set off the West of Port Louis at about 2 000 m depth, did not have time to produce any results; the first was lost during mooring and the second was destroyed by sports fishermen within three days. The construction was the same as the foam filled tyre type described in 3.1.

Several other models of FADs were built and tried between 1985 and 1988 under a UNDP/FAO Project. Twenty-three light FADs made of 50 litre plastic drums and a piece of polystyrene foam, moored with 6 mm polypropylene rope, were set during 1985. The average lifespan was only 19 days, but the few that lasted for about two months aggregated fish successfully and good catch rates were obtained (Roullot and Venkatasami, 1986 b).

One heavy FAD made of an 8 mm thick steel cylinder 3.6 m long and 0.9 m in diameter, was set off the Northwest Coast using a 16.5mm steel wire rope as mooring line. It lasted only about three months, the high buoyancy having probably floated the 1 300 kg anchor towards deeper water. Sports fishermen reported good catches of tuna, dolfinfish and wahoo while it was present (Roullot and Venkatasami, 1986 b).

The next FADs tried were the first generation of the improved FADs now in use in Mauritius and elsewhere in the region. Ten were set in early 1986. High resistance trawl floats were strung on a single steel wire rope. The mast was supported by four lorry tyres stacked on each other and packed with similar floats. A galvanized tube crossed through the tyres and served as mast.

The mast was too heavy and served no great purpose, and caused a high drag on the mooring rope; the steel wire ropes corroded very quickly. These setbacks led to the gradual improvement of the engineering and to the FADs now in use and described later. Presently, FADs are found in thirteen selected locations around Mauritius (Table 2).

Table 2: Summary of Information of FADs Presently in use in Mauritius

S.N.	Location	Depth (m)	Distance Offshore (n.m.)	Date set	Longevity at 31.7.89 (days)	Remarks	Reasons for loss
1		1 130	2.4	07.11.85	1 390	Active	
2	1	1 250	2.5	07.11.86	674	Lost	Shipping
3		1 250	2.5	07.11.88	257	Active	
4	2	950	3.0	04.12.85	102	Lost	Shipping
5		950	3.0	02.06.86	1 153	Active	
6	3	2 500	5.5	18.03.86	1 119	Lost	Shipping?
7		2 600	6.3	10.02.87	745	Lost	Shipping?
8		1 800	3.0	27.05.86	214	Lost	Cable Corrosion
9	4	1 800	3.0	04.02.87	124	Lost	Cable Corrosion

10		1 800	3.0	28.08.87	690	Active	
11	5	2 300	5.0	17.07.86	1 102	Active	
12	6	1 125	3.2	13.03.87	262	Lost	Chafed on sea ledge
13		2 000	5.5	13.04.88	474	Active	
14	7	1 050	2.5	05.11.86	958	Active	
15		800	5.0	14.11.86	483	Lost	Shipping
16	8	850	3.0	26.11.86	967	Active	
17	9	1 000	2.2	08.12.86	954	Active	
18	10	920	2.8	12.12.86	950	Active	
19	11	980	5.5	17.12.86	475	Lost	Not known
20	12	3 000	12.0	16.09.87	671	Active	
21	13	3 000	9.4	07.09.88	261	Lost	Not known

3.3.2. Rodrigues

Rodrigues, situated at 350 nm to the East North East of mainland Mauritius, had its first FAD in May 1987 and six have been set to-date at depths ranging from 390 to 800 m and at distances of 6 to 11.5 miles offshore (Table 3).

Table 3: Summary of Information on FADs presently in use in Rodrigues. (Source: Lozac'hmeur, 1989).

S.N.	Depth (m)	Distance Offshore (n.m.)	Date Set	Longevity at 30.06.89 (days)	Remarks	Reasons for Loss
1	400	6.5	30.05.87	566	Lost	By shark caught on longline
2	390	6.0	09.02.89	161	Active	
3	850	6.0	06.04.88	468	Active	
4	800	11.5	27.07.88	356	Active	
5	820	6.8	12.10.88	281	Active	
6	810	6.0	19.04.88	146	Lost	Chafe on sea ledge

These FADs were of the same design as the new generation FADs in use in Mauritius and were set partly under an FAO/TCP and partly under a UNDP/FAO Project (Lozac'hmeur, 1988, 1989).

Rodrigues having a relatively small population (around 35 000 in 1987) and a rather vast lagoon area does not have fishermen going constantly offshore. The FADs have, therefore, been visited only occasionally. The catch rates, which are relatively good, could be a fair -complement to demersal catches and serve as a basis for the development of an offshore pelagic/demersal fishery in the future.

3.4. Mozambique

Two FADs were set in the northern part of the country during September and October 1983. They were lost too soon to be able to produce any useful information. In March 1984, a FAD was set on the Almirante Leite Bank, off Maputo; it disappeared in April. Once more, no lesson could be drawn (Moreira Rato, 1985; Marsac and Stequert, 1987).

3.5. Reunion

Following a study mission in Mauritius in early 1987, where FAD technology had been considerably improved and fishing rates were good. IFREMER 4 in collaboration with local authorities set FADs in the coastal waters of the island. The FADs, with a few minor modifications (floats strung on steel ropes), were identical in design to the new generation FAD used in Mauritius. Of the eleven set during 1988, seven were moored by the *La Rieuse of* the "Marine Nationale" and four by the *Mascaroi* of the COI/Regional Tuna Project (Biais and Taquet, 1988) Table 4.

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Table 4: Summary of Information on FADs presently in use in Reunion (Source: IFREMER, Reunion).

S.N.	Aprox. Depth (m)	Distance Offshore (n.m.)	Date Set at 30.4.89	Longevity (days)	Remarks	Reasons for Loss
1	550	4.9	06.05.88	274	Lost	Corrosion of twin steel ropes
2	590	6.2	06.05.88	170	Lost	Shark hunting on entangled fish.
3	1 400	12.2	07.09.88	235	Active	
4	1 000	3.6	07.09.88	235	Active	

5	950	6.8	07.09.88	71	Lost	Shipping
6	750	3.2	07.09.88	235	Active	One steel rope broken - 134 days.
7	590	6.2	08.09.88	234	Active	
8	900	3.1	18.10.88	129	Lost	Shipping
9	950	5.7	19.10.88	193	Active	
10	850	2.9	19.10.88	193	Active	
11	1 450	4.0	19:10.88	179	Lost	Not specified

N.B.: Depths estimated from chart

The FADs are regularly visited by artisanal and sports fishermen, the fishing technique and results are discussed later.

3.6. Seychelles

During February and March 1982, five FADs were set by ORSTOM 5 at 1 500 m depths on the drop-off of the Mahé. Plateau. They were made of a metallic frame packed with bamboo and surmounted by a pyramidal structure to hold a flashing light and a radar reflector. Pieces of nets and coconut fronds were suspended as appendages.

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Three of them were lost at the beginning of the monsoon in May and the other two also disappeared before the end of the monsoon. No systematic follow-up of the FADs were carried out, either by the local fishermen or by the one purse seiner present in the area. It is reported that concentrations of skipjack tuna of the order of 20 tonnes were observed occasionally, but it appeared that due to strong currents, fish did not remain in the vicinity over long periods (Marsac and Stequert, 1987).

In 1982, in order to experiment on cheap FADs using as far as possible locally available materials, others were set on the Mahé Plateau at depths of 60 to 70 m. The first two were set by SWIOP/FAO using foam filled tyres as previously described (de San, 1982). Due to rough sea conditions and strong currents prevailing in this region, the rafts lost their buoyancy quite rapidly and sank to the bottom. This was confirmed by de San (1983) some time later, after having observed that after each successive immersion of the first tyres, they gradually lost their buoyancy as the foam got compressed. These tyres when sinking immersed the next tyre in the row and subsequently the raft as a whole lost buoyancy and sank.

The SFAS 6 attempted another design as from 1984. Bundles of long bamboo were, assembled by squeezing the extremities into tyres, giving the whole structure a roughly cylindrical form. Fifteen were set around Mahé, Praslin and La Digue, but their sea keeping ability was poor. Moreover, they have frequently been destroyed by fishermen. A few surviving FADs yielded catches which were judged complementary to the production of the artisanal fishermen from demersal sources (Marsac and Stequert, 1987).

6 Seychelles Fishing Authority

The experiments carried out on the Mahé Plateau led to the setting of five FADs at depths ranging from 500 to 1 500 m. The rafts were made of foam filled 200 litre drums mounted on metallic frames, and were set near Denis and Bird Islands on the drop-off of the Mahé Plateau and near Coetivy Island. Local fishermen having visited these FADs obtained excellent catch rates. Fish were observed within ten days after setting (Marsac and Stequert, 1987). The loss of these FADs was due to the persistent strong currents prevailing in the zone and to human interference.

In 1986, two more FADs made of trawl floats were anchored off Denis and Bird Islands on the slope at depths of 500 m. One lasted two months, before breaking off its wire rope mooring, the other was lost five months later after a strong storm which could have caused the anchor to be dragged down the slope. This time, no appreciable concentration of fish was observed (Marsac and Stequert. 1987).

Although FAD outputs remained generally below expectations, the SFA continued setting low cost FADs at depths of 50 to 70 m on the Mahé Plateau. They were not as productive as in deeper waters, but were regularly visited by artisanal and sports fishermen. Artisanal fishermen also used the devices as "landmarks" to locate demersal fishing grounds; the catch obtained was considered as a complement to demersal catches.

Six other FADs were set during 1988. The mooring was of 11.5 m steel wire rope and the raft consisted of foam filled drums covered with fibreglass and epoxy resin and three rigid buoys of 300 mm diameter. Details of their location and longevity are presented in Table 5.

Table 5: Details of FADs recently set in Seychelles. (Source: SFA, Seychelles).

S.N. for	Location	Depth (m)	Coordinates	Date Set	Longevity at 30.05.89 (days)	Remarks	Reasons Loss
1	Bane Malgache	67	04°41'S 55°19'Å	06.09.88	266		
2	Bar Michaud	67	04°39'S 55°12'E	06.09.88	266		
3	Bane Requin	60	04°33'S 55°22'Å	06.09.88	266		
4	Stork Patch	65	04°46'S 55°32'E	15.09.88	257		
5	Pointe Sud	67	04°55'S 55°33'E	15.09.88	180	Lost	Unspecified
6	West Mahé	64	04°36'S 55°09'E	19.09.88	176	Lost	Unspecified

3.7. Tanzania

3.7.1 Zanzibar

The SWIO/FAO Project set two FADs in 1984, one South of Zanzibar and the other South of Pemba Island, at depths of around 450 m. The construction of the floating section had a completely new design from what had previously been used in the region or elsewhere and constituted the basis for the development of the new generation long lived FADs. That section was built with trawl floats- of a total buoyancy of 250 litres strung on a single wire cable, closely wrapped with line.

Though there was no follow-up on the activities around these rafts, they seem to have existed for over a year. Apparently, fishermen had caught dolfinfish around them, but FADs were not visited regularly due to their remoteness from the shore (Ardill, pers. comm.).

3.7.2 Mainland

SWIOP, in association a British Assistance Programme 7, set four FADs off Lindi, three of which were light ones made of bamboo and moored on 9 to 10 mm polypropylene line and one heavy with trawl floats. There was no follow-up and all were rapidly lost possibly due to theft of materials, producing no conclusive results (Ardill, pers. comm.).

7. RIDEP (Rural Integrated Development Programme)

3.8. Other FADs

To complete this chapter, mention should be made of artificially built drifting FADs used on an industrial scale by certain purse seiners in the region.

The industrial purse seine fleet operating since the early eighties, mainly from the Seychelles, exercises quite an important effort on log-associated schools. Between 1982 and 1987, about 55% of the catch of French and Ivorian purse seiners were obtained on drifting objects (Hallier, 1989). He found that a positive set on drifting objects was 32 tonnes on an average, compared to 26 tonnes on free-swimming schools.

The two Mauritian purse seiners *Lady Sushil I* and *Lady Sushil II* fish practically all the time with artificially built drifting FADs. The rafts used by these vessels are made of bamboo and old purse seine floats mounted on a galvanized steel tube frame, from which old nets are hung as appendages. The rafts, up to fifteen in number per vessel, are fitted with radio beacons to avoid loss when they go astray.

In 1985-86 and 1986-87, the *Nippon Ìîãè* (two vessels), JAMARC 8 operated vessels, experimented on moored FADs whose rafts were detached from the mooring prior to setting the seine. Sixteen FADs were thus moored in a zone between the Seychelles and the Chagos and off the southeast of the Maldives. Analyzing the results of the surveys, Watanabe *et at.* (1988), found that the average catch per set on FADS was around 22 tonnes, consisting mainly of skipjack and yellowfin tuna. They found little variation in catch rates from FADS of different construction and from driftwood. Schooling occurred in less than one week after setting. It was noted that one raft provided 175 tonnes of fish in three successive sets and that one raft was able to be operated for up to five successive times.

8. Japan Marine Fishery Resource end Research Centre

4. The Design of Long-lived FADs Developed in the Region.

4.1. Design Considerations

One important factor in planning a FAD deployment programme is to obtain a satisfactory longevity of the device at least cost. In this region where cyclones are frequent and currents are strong during certain periods of the year, construction should be sturdy. The surface floats have frequently been seen to immerse due to the current drag on the mooring line, and the constant movement from wave action causes considerable wear.

The use for the raft section of high resistance floats strung on a rope is an important design element. The flexible structure permits this section to act as a whip under constraint of big waves or strong currents. The sea keeping abilities of this structure, compared to the classical bamboo, catamaran, foam filled drums or tyres, steel discs, etc., need not be emphasized.

The other important element is the anchor system which has a mass of around 1 000 kg. Instead of the usual concrete blocks or oil drums filled with concrete which are voluminous and heavy to handle, several pieces of scrap iron (Figure 1) which can each individually be man-handled, have been used. These blocks, weighing around 70 to 80 kg each, are linked to one another, and to the mooring line by a chain. Prior to setting they are put over the side and lashed to the boat. When ready for release, the lashing ropes are cut. This FAD setting operation can easily be carried out by a single boat not exceeding 10 m LOA. In Mauritius, FADs were set from 10 m GRP boats (Roullot and Venkatasami, 1976 b).

4.2. Construction Details of the FADs (Figure 1).

The raft section is made of two rows of 30 floats of 200 mm diameter, each strung on a 35 m nylon rope of 18 mm diameter. Rubber discs are placed between the floats to decrease abrasion. One end of the float is attached through a swivel to a mast which carries a flag and radar reflector; no flashing light is placed, since it will get spoilt when the raft immerses during strong currents. The mast is held upright by twenty-four similar floats strung on a rope and tightly lashed to its central part. A chain at its lower end acts as counterweight. Old nets are hung along the chain as appendages. The total volume of the floats used is 376 litres. Floats are strung in two rows to avoid the loss of the FAD in the event that one row breaks. This section of the device is most subjected to wave action and currents which cause, abrasion, wear and tear.

The other end of the float is attached to between 100 and 200 m of polyamide (nylon) rope which has a negative buoyancy and prevents the mooring line from floating at the surface when the current slackens. Polyethylene strapping material is added onto this section to increase the appendage effect. The mooring line attached to this rope is of buoyant polypropylene of 18 mm diameter. The other end is attached through a swivel with a 20 m long, 16 mm chain linked to the anchor.

The scope ratio of the mooring, that is the relation of the depth to the length should be between 1: 1.1 and 1.2. A higher ratio might cause excess rope to float and get entangled in boat propellers when current slackens; it might also induce fishermen to plunder the visible rope, causing the loss of the FAD. A conservative scope ratio diminishes the watch circle of the raft, making it easier for fishermen to locate.

A list of materials necessary for the construction of a FAD and their cost are presented in Annex 1.

4.3. Longevity and reasons of loss of FADs

4.3.1. Longevity

With the present design of the raft and the mooring system, several of the long-lived FADs in operation in Mauritius have lifespans having exceeded 900 days.

The upper section of nylon rope suffers wear and tear due to the permanent movement and friction near the surface. The life of the raft is prolonged by lashing a lazy rope along it every four to six months. To further extend the life of the FAD, the top section should be completely changed after 15 to 18 months.

In places where FADs are set for the first time and there is the possibility that fishermen, unaware of the benefits of the devices might destroy them to profit from the material, the floats can be strung on 16 to 18 mm steel wire cables. Steel cables, however, corrode very quickly and they should be verified regularly and changed within five months after setting (Roullot and Venkatasami, 1976b). The weight of the cable also needs to be compensated by additional floats.

4.3.2. Reasons for loss

During the trial and error period when FAD construction technology was being improved, FAD loss or partial damage was quite frequent. This was mostly due to corrosion of the steel wire ropes on which floats were strung.

Except for damage to the masts, no loss occurred after the passage of two recent cyclones in Mauritius and Reunion. One loss occurred in Mauritius and one in Rodrigues when the mooring rope chafed against sea ledges not detected at the time of setting. Several losses in Mauritius and Reunion (Taquet, 1989), occurred due to shipping. One FAD was lost in Rodrigues due to a shark caught on a line attached to the FAD float; the thin steel leader cut through the mooring (Lozac'hmeur, 1989). Sharks bit through the mooring of a FAD in Reunion when they were hunting on an entangled whale (Taquet, 1989).

A few cases of loss remain unknown, but there is no indication of loss due to vandalism. There is no report either of loss due to breaking off of the anchor, rupture of mooring line, slipping of splices, loosening of shackles, or thimbles and swivels giving way.

For observation purposes, 400 m of the mooring of a FAD anchored at a depth of 1 300 m for over two years was recently pulled up in Mauritius. The rope and hardware found below 40 m were as good as new. In Reunion, hardware examined after one year of immersion showed no visible signs of fatigue (Taquet, 1989).

4.4. Location of FADs

FADs are located so as to remain accessible to the fishermen. In Madagascar, FADs are found at about 20 miles off Nosy Be and are mainly aimed at developing a semi-industrial fishery. In Mauritius (including Rodrigues), Reunion, Comores and the Seychelles, the devices are geared to improve the landings of artisanal fisheries.

Artisanal fishermen could not, at the outset, be asked to make use of FADs found too far from their traditional fishing grounds. On the other hand, for FADs to be fully effective, they should be far enough from shallow banks, the shore or islets which themselves may act as fish aggregaters. Marcille (pers. comm.), recommends that FADs should be found at least 10 miles away from the 200 m isobaths and 12 to 15 miles from each other in order to avoid interaction.

As a compromise in the first instance, FADs in Mauritius, Rodrigues, Comores and Reunion were placed at such distances from fishing villages so as to remain within reach of the local fishermen. In Mauritius, other FADs were gradually moored further out, and fishermen, who were already accustomed to nearshore FADs, did not hesitate to venture to the far ones, considering that catch rates were higher there.

Location of FADs are given in Tables 1 to 5, and in Figure 2.

5. Fish Production from FADs

5.1. Fishing Techniques

In Madagascar, the use of semi-industrial techniques is to be demonstrated. Elsewhere, in the region, fish is captured mostly by low-output artisanal methods. Industrial capture techniques like purse seining are not likely to be tried soon, the major limitations being the relatively small number of FADs and irregular occurrence of high concentrations of fish.

The fishing techniques in use are mostly trolling, handlining or drifting lines set with one or several hooks. Handlining is done either with the boat moored to the raft or drifting around it, with live or dead bait, live bait producing better results. In trolling, towing live or dead bait at low speed is more efficient than artificial lures. Gill nets tried on an experimental basis in Mauritius were abandoned due to low catch rates and the frequent entangling of the nets with the rafts (Roullot *et al.,* 1989). The most effective hours for trolling were at dawn or late afternoon (Figure 5).

Following a positive demonstration made by the *Mascaroi* in Reunion, about ten boats have started using pole and line. Live bait is captured during the night and kept in artisanally built bait tanks; water circulation is maintained by the deck wash pump (Taquet, 1989).

5.2. Species Caught

Fish landed from FADS consists mainly of the dolfinfish, yellowfin tuna, skipjack tuna, dogtooth tuna, rainbow runners, sharks and wahoo. Marlins, sailfish, bigeye and albacore tuna are other species captured.

The species composition of the catch differs according to the techniques employed. In Mauritius, for example, project vessels which used mostly trolling and long lines caught more dolfinfish than tuna, while the reverse is true for artisanal fishermen who mostly use handlines. Similarly, sports fishermen using thin trolling lines obtained more skipjack tuna, which they aimed at, since these are used as bait to capture martins. Table 6 shows the species composition of the catch of Project vessels, artisanal and sports fishermen.

Table 6: Species Catch Composition (%) of Project Vessels, Artisanal and Sports Fishermen in Mauritius.

Vessel Type	Tuna	Dolfinfish	Skipjack	Sharks	Others	Total
Project Boats	11.3	46.2	11.1	5.4	26	100
Artisanal	57.3	28.5	4.8	3.1	6.3	100
Sports	14.0	35.5	34.0	2.4	14.1	100

After Roullot et al. (1989).

The same tendency is observed in Reunion; larger vessels which troll most of the time catch more dolfinfish and the smaller canoes most handlining obtain larger quantities of tuna (Table 7).

Table 7: Species Catch Composition (%) of one Larger Vessel and a Canoe in Reunion

Vessel Type	Tuna	Dolfinfish	Skipjack	Sharks	Others	Total
Large	13.4	61.4	10.1	13.3	1.8	100
Canoe	59.1	22.8	8.4	6.8	9.7	100

After Biais and Taquet (1988).

5.3. Catch Data Analysis

5.3.1. Fishing Data Limitations

Only a few fishermen in Mauritius and Reunion agreed to fill in log books and it is believed that they provide underestimated figures. In Seychelles, fish landings are not systematically monitored and the follow-up in Madagascar is irregular. The fish capture data from Comores could, unfortunately, not be made available, de San (pers. comm.), reported catches of 52 kg/boat/day in Shimoni, Grande Comore.

5.3.2. Seasonal Fluctuation of Catch

Analyzing the catch data of Mauritian project vessels, Roullot *et al.* (1989a) found two peak seasons for fishing around FADs. These were generally from October to December and April to May (Figure 3). However, artisanal fishermen in Mauritius seem to be obtaining rather uniform catch rates year round, except during winter months from June to September when the number of fishing days are considerably reduced due to rough sea conditions during that period (Figure 4).

Looking at the data from Reunion, the figures available from May to October 1988 indicate no appreciable variation of catch rates over the months for the larger vessels, while the decrease is significant for the canoes for the winter months (Table 8).

Table 8: Monthly Catch Rates of Reunion Vessels (kg).

Vessel Type	May	June	July	August	September	October
Large	892	304.5	198.5	981	281	1 149.5
Canoe	347.5	1 136.5	101	-	-	78

After Biais and Taquet, 1988.

5.3.3. Landings

The average daily catch per boat of the artisanal fishery in Mauritius is estimated at 56 kg (Roullot *et al.,* 1989). These boats are generally manned by two to three fishermen. Catch per man day from the FAD fishery is therefore much higher than that from the traditional fishery which is estimated at only 5 to 6 kg (Source: AFRC 9). The catch rate of the sports fishery obtained by Roullot *et al.* (1989) was 49 kg per day and the same figure was attained by project boats.

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The average daily catch obtained in Reunion (Biais and Taquet, 1988) by a canoe and a large boat for the period May to October, 1988 is shown in Table 9.

Table 9: Average Daily Catch Rates (kg) in Reunion.

Vessel	May	June	July	August	September	October	Average
Large	44.6	23.4	40.0	44.6	23.4	47.9	37.3
Canoe	43.4	22.8	12.6		0	11.1	18.0

After Bids and Taquet (*1988*).

Roullot *et al* (1989), estimated the annual landings from one FAD to be 47.5 tonnes. The seven FADs situated off the Mauritian West coast produced 333 tonnes of fish, comparing favourably with the total landings of the artisanal fishery, estimated at 1 600 tonnes (Source: AFRC).

Table 10 summarizes average daily catch rates of fishing boat obtained around FADs in certain countries.

Table 10: Daily Catch Rates (kg) per FAD visit.

Country	Reference		Catch (kg)
Comores	Marsac *et al*	(1987)	50
Hawaii	Marcille	(1979)	140
Maldives	Stequert *et al*	(1986)	200
Martinique	Sacchi	(1986)	50
Mauritius	RouIlot *et al*	(1988)	56
Philippines	Stequert	(1989)	55
Seychelles	Stequert *et al*	(1986)	50
Sri Lanka	Weerassoriya	(1987)	50
Tahiti	Depoutot	(1987)	150
Thailand	Stequert *et al*	(1986)	0
Vanuatu	Cillauren	(1987)	80

6. Socio-Economic and Other Aspects of FAD Fisheries

6.1. Users

Primary users of Fish Aggregating Devices in this region are artisanal fishermen who, without major improvements of their tools of production (fishing gear, boats) are capable of obtaining better catches than from traditional grounds or to complement their normal landings from fish caught adjacent to FADs.

Improved fish landings, besides having a direct impact on the availability of fish on the market, improve the socio-economic status of artisanal fishermen in the community through increased income.

Other users are leisure and big game fisheries which are quite well developed in Mauritius, Reunion and Seychelles. FADs are mainly visited to capture skipjack tuna,, used for live bait to fish martins. These fishermen also visit FADs to increase the chances to obtain a fish strike and to avoid the tourist clients from coming back empty handed. Big game fishing vessels in Mauritius have frequently been observed fishing dolfinfish and tunas with handlines.

6.2. FAD Ownership

All the Fish Aggregating Devices in the region have been set by governmental institutions. As such, FADs are considered as common property of the fishermen of these countries. There is no indication so far of the wish of fishermen to set their own FADs. It seems that governments consider the FAD setting programme as a needed indirect subsidy to the artisanal fishery, in order to relocate fishing effort from traditional grounds and provide more fresh fish to local markets.

6.3. Management Issues

Fish Aggregating Devices are meant to retain migratory species of fish temporarily or to aggregate scattered schools, rendering their capture easier. This type of activity can lead to long-term overfishing of a stock. In the Philippines FAD associated purse-seine fishery, this type of overfishing occurs. The intensive use of FADs has led to catches consisting of individual tuna fishes of relatively small size (less than 40 cm in length). (Stequert. 1989).

However, at this stage, this type of problem does not arise in the region under study. The exploitation of probably not more than sixty FADs at a time in such a vast area and the relatively low output fishing techniques employed are not likely to produce either temporary or long-term over-fishing. The number of FADS will surely increase with time, but little improvement is to be foreseen in capture techniques.

Nonetheless, the evolution of the fishery should continuously be monitored by the collection and analysis of fish data.

6.4. Financial Feasibility

The level of investment required to set and maintain FADs is quite low when compared to the returns obtained from them. Lens *et al* (1987), making a first evaluation of the FAD fishery in Mauritius in July 1987, found the operation to be economically viable. The calculation was based on FAD lifespan of 275 days, the average attained at the time. However, the average longevity today has exceeded 668 days and the viability is further improved.

Roullot *et al* (1989), found that the total investment in a FAD represented only 3.98% of the value of the fish landed from it in a year. The calculation was based on an average lifespan of 506 days and the annual cost involved in the setting and maintenance of a FAD was Mauritian Rupees (MR) 28 347. This figure is not to be confused with the cost of a FAD, which is around MR 35 000.

7. Conclusion

The introduction of fish aggregating devices in certain countries of the region is positively perceived by fishermen communities. The investment required for the programme is relatively low compared to the benefits derived by the fishermen and the country.

Although the FAD design in use in the region has in general a good lifespan, further improvements should still be possible.

Support to FAD programmes from governmental institutions is considered necessary for setting and servicing of FADs. More fishermen should be encouraged to fish around these, devices and, where the need exists, they should be provided with some basic knowledge in navigation, improved fishing techniques and safety.

Landings from fish aggregating devices are expected to increase gradually, as more and more fishermen, motivated by higher catch rates, join in the fishery.

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Annex 1: List of Materials for Construction a FAD and Costs. (1 US $ = 14 MR November 1988).

ITEM	SPECIFICATIONS	QUANTITY	MR	USD
Float-high resistant	200 mm	105 m	8 967	640
Rope PP	18 mm	1 600 m	9 264	662
Rope PA	18 mm	200 m	1 850	132
Shackle safety type	13 mm	5	200	14
Shackle safety type	16 mm	5	300	22
Shackle ordinary	12 mm	10	90	6
Thimble	18 mm	10	115	8
Swivel	16 mm	4	330	24
Chain	12 mm	50 m	3 860	276
Chain	16 mm	20 m	2 744	196
Strap bands	12 × 14 mm	100 m	124	9
Twine PA	280 m/kg	1 kg	155	11
Pipe-galvanized	34 mm	16 m	125	9
Radar reflector	-	1	200	14
Chain (second hand)	14 mm	20 m	600	43
Steel blocks	-	1 000 kg	1 000	72
Sundries	-	-	530	37
Labour	-	-	2 500	180
Transport & Fuel	-	-	1 550	111
		Total	35 074	2 466

Fig. 1 - FISH AGGREGATING DEVICES IN USE IN MAURITIUS. (after ROUILOT et al.1989)

Fig. 2 - Location of FADs - COMORES (at 24.4.1989)

Fig. 3 - Seasonal fluctuation îf catch project boats after ROULLOT et al. (1989)

Fig. 4 - Seasonal fluctuation of catch - artisanal boats (after ROULLOT et al. 1989)

Fig. 5 - Fluctuation of catch according to time of the day trolling after ROULLOT et al. (1989)