1. INTRODUCTION

It has long been known that drifting objects such as logs, branches and palm leaves attract and keep fish gathered around them. This phenomenon also occurs around lifeboats and other raft, shipwrecks and oilrigs. The fish behaviour highlighted by this phenomenon is termed "thigmotropism" which means "the desire to be close to a solid object."

Knowledge of this behaviour of fish has been used for a long time by traditional fishermen, particularly in South-East Asia and in Western Pacific. To aggregate and catch fish, palm fronds, logs, branches, old netting, etc., have been anchored in the sea to serve as simple stationary fish aggregating devices (FADs) that have at least for certain periods of the year ensured some catch.

Interest in commercially viable methods to aggregate and catch fish is now growing. Modern tuna fishing vessels get good catches around objects drifting in off-shore waters. This has inspired the production of larger tuna-attracting rafts, sometimes anchored by sophisticated methods. In other places, especially Japan, the tradition of creating artificial bottom environments, attractive to fish, has been developed and refined; and its modern version is artificial reefs.

This paper attempts to review as many fish aggregating devices as possible. The suitability and performance of an FAD depend to a great extent on where it is placed, so the FADs described here are *not* matched against one another in such terms.

The review is selective; it is neither complete nor comprehensive. It culls and compiles all information received through extensive correspondence during February 1981—April 1982. When requesting information from different sources, the FAD has been defined thus: "A Fish Aggregating Device (FAD) is any method, object or construction used for the purpose of facilitating the harvesting of fish by attracting and thus aggregating them."

The author thanks all those who contributed to this review. Their names are included in the reference list. He particularly thanks those who provided exhaustive and detailed replies to his letters: G. L. Preston, Fisheries Officer, Suva, Fiji; R. Balan, Head of Craft & Gear at CIFT, Cochin, India; M. Nomura, Director of Kanagawa International Fisheries Training Centre, Kanagawa, Japan; A. Z. Katekaru, Aquatic Biologist, State of Hawaii DLNR; and R. Shomura, Director, Honolulu Laboratory of the National Marine Fisheries Service.

2. FADs IN GENERAL

A Fish Aggregating Device (FAD) is basically one of three types:

— placed on the bottom

— anchored or drifting and with the attracting structure on or near the water surface

— anchored and with the attracting structure in the water column.

The three types function in different ways: Type (a) FADs (placed on the bottom) serve mainly as shelters and hiding places and also as an improved/expanded habitat for fish larvae (ref. H) and as feeding grounds for larger fish (ref. I); Type (b) surface or near-surface FADs provide shade and shelter and have, in common with Type (c), the function of a complex feeding—"ground". The mechanism is understood to be such that when the FAD is first put in the water, bacteria and micro-algae as well as larger algae start growing on it. These house a large number of smaller animals and together attract smaller species of pelagic fishes that feed on them. The smaller fish will in turn attract individuals of larger species feeding on the smaller ones. In addition, FADs are thought to serve as a navigational aid — reference point — for off-shore pelagic fishes.

Type (a) FADs need only to be materials with negative buoyancy. The Type (b) FAD is a floating object or structure usually anchored with appropriate anchor and anchor line. Type (c), however, is sometimes a more complicated structure. The traditional types are anchored in shallow waters; the attracting device is attached to the line between buoy and anchor, and only sometimes is the device hung on a separate rope from the buoy. (The latter makes harvesting easier and more efficient, as will be seen in section 5.) For modern FADs of the mid-water type, used in deeper waters, a number of more complicated designs have been tested; they are described below. There are several reasons, however, for making them more complicated, and thus more expensive: a larger structure attracts more fish, making a visit by fishermen more profitable. A structure anchored in deep water needs a long anchoring line. These two factors produce higher resistance to currents and such FADs thus need more buoyancy. The buoy used in exposed areas must be long-lasting and be able to withstand strong wind and wave forces. If possible, the FAD should be so designed that the anchoring line can be recovered even if such a buoy is lost; this requires an inoicator-float. For facilitating harvesting with, for example, purse-seine, the structure is sometimes such that the aggregating appendage is easily detached from the buoy and/or anchor line.

Devices for anchoring FADs range from the simplest stone-and-rope arrangement for small near-shore FADs to highly sophisticated systems for large off-shore rafts. A number of detailed descriptions are given below.

Some ways to *actively attract* and aggregate fish are known:

- light arrangements on rafts
- baiting of traps
- sound vibrations from rattles
- smelling substances.

These are, however, only supplementary to the FAD and can usually be combined with different FADs. Since an FAD is fully operational even without such attractions, only the aggregating devices will be described here.

3. AGGREGATING DEVICES

3.1 FADs placed on the bottom (also known as artificial reefs or as bottom FADs)

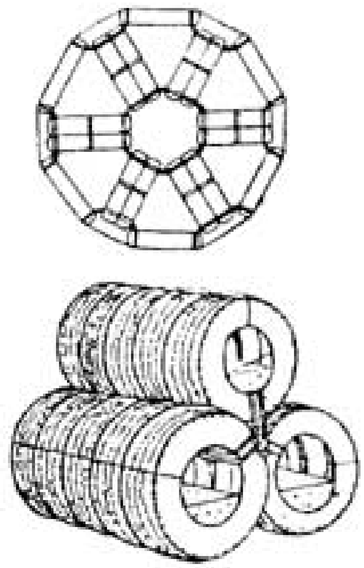
This is the simplest type of FAD, for it does not require any anchoring devices. It is instead kept stationary by its own weight or by additional stones or concrete filling. However, the negative buoyancy must be enough to keep it in place unaffected by wave-and-current forces. It must not be too compact, but provide a lot of hollow space.

This type of FAD is generally called artificial reef.

Old tyres: This material has been used for experiments in the Philippines, Japan and the North American east coast. Off South Carolina, a reef consisting of four shipwrecks and about 15,000 tyres was built in 1968. Surveys showed the fish abundance in the area after the construction to be many times the abundance before (ref. 19). A similar reef built off Florida Keys was found to double the carrying capacity of the area (ref. 19). Fish attracted in these waters include (ref. 24) black sea bass, porgies, grunts—all of which use the construction as shelter. When the tyres are baled or lashed together to achieve a higher reef-profile, sea trout, channel bass, bluefish and spadefish are found, apart from bottom-dwellers.

In Japanese waters, three types of fish shelters made of tyres are used (Figure 1)

Figure 1



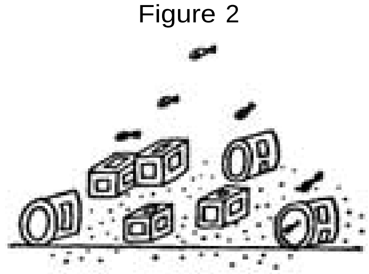
No precise information on performance is available. But these and the so-called "fish apartment" concrete block shelters (see below) have enjoyed a high reputation. It is estimated that nearly one million square metres of sea-bottom in Japanese waters is now covered with such artificial structures for aggregating fish (ref. 19).

The only thorough study of the effectiveness of tyres as fish aggregators in *tropical* waters was carried out in the Philippines in 1978 and 1979 by E. O. Murdy (ref. 13). The reef was built in a shallow lagoon and consisted of 300 tyres lashed together in triads like the one above (second sketch). The study showed that this reef did not accumulate a large standing fish crop, possibly because of factors such as limited feeding opportunities, proximity to natural reefs and the shallow depth of the site. Fish living at the artificial reef were believed to be drawn to the tyres mainly for shelter. Such an artificial environment probably proves to be superior only when no natural shelters are available.

Some fears have been expressed about the use of tyres for artificial reefs. Such reefs could be torn apart by strong wind and heavy seas. The tyres may then spread and possibly damage other gear and property. Hence it has been recommended that tyre reefs should not be anchored in depths of less than 70 ft. unless substantially weighted (ref. 22). This can possibly be done by adding a concrete binding as shown in the figure above. Another fear expressed is that, if misplaced, such artificial reefs could spoil already well established natural spawning grounds for other fish.

Concrete: Concrete has the same function as old tyres, but concrete can produce a wide variety of three-dimensional structures (adapted to the artificial reef structure preferred). Though costly, a concrete reef will last longer than tyres. (See Figure 2)

Figure 2



Concrete block fish shelters

The fish apartment mentioned earlier is a fish shelter made of hollow concrete cubes, either a single block or a combination of blocks (ref. 25). The concrete is sometimes reinforced with iron. Each side of the cube is 1.3 to 1.5 metres long and has a window of about 30 x 30 cm, the window size differing with depth of water and other conditions. In Japan the main species thus aggregated are red sea bream, black sea bream, common sea bass, rock-cod, shad, mackerel, yellowtail.

In 1960, an artificial reef of 800 concrete blocks (40 x 45 x 20 cm) was constructed on sea-grass bottom in about 9 m water in Lesser Lameshur Bay, St John, Virgin Islands. Two to three years later, sampling on the artificial reef yielded '10 times more catch per unit area than two natural reference areas nearby (ref. 4).

A few illustrations of concrete constructions set outin Japanesewatersfollow. (Figures3&4)

Fibreglass reinforced plastic (FRP): This material can be used in a variety of shapes and sizes. In Japan, more than 25 reefs have been built using units of different sizes up to 10.5 m high and 720 m^3. These units have a large surface area which is rapidly colonised. The weight per unit area of FRP units is less than half that of concrete and they can be used in areas unsuitable for more massive reef types. The reefs are generally weighted with concrete according to the local bottom type, wave and current conditions. Such reefs are not expensive to install for they can be towed to the site using air bags (D.J. Sheehy in ref. 22).

Sand bags: Attractive shelters for yellow tail have been produced in Japan (ref. 25) ; around 20 sand bags, each weighing around 75 kg, are sunk with anchors and buoys. The buoys are made of bundled bamboos, each containing 10 to 15 pieces, and are connected to other similar buoys, each with four or five pieces, used for mooring of boats. The bamboos are usually some 2 m in length and 10 cm across the butt. (See Figure 5.)

The bags are submerged to the bottom where the depth is between 35 and 60 m. The bottom is a reef area, preferably with a steep slope on one side and a slow slope on the other. The current should be slow enough to allow the submerging.

On the reef, fishermen scatter fish food daily in quantities large enough to lure the fish. The fish thus gathered are caught with handlines or poles: mainly yellow tail but also sea bream, sea bass, tuna, sharks, common dolphinfish, This fisheryiscarriedout mainlyin baysalongthe Japanese coast.

Mangrove wood.- In Sri Lanka, the fishermen in the western estuaries and lagoons have developed a method to create an artificial mangrove habitat. A so-called Athu Kotu consisting of a pile of mangrove brushwood is placed in shallow waters and fixed so that wind and waves cannot carry it away. As and when the wood rots, new branches are added. Harvesting starts after a few weeks and is done at 4—6 weeks' intervals for fish, but almost daily for shrimp. The gear used is an encircling net fixed with 12 or 14 poles. Catch is seasonal, best when the waters are clear (ref. 23).

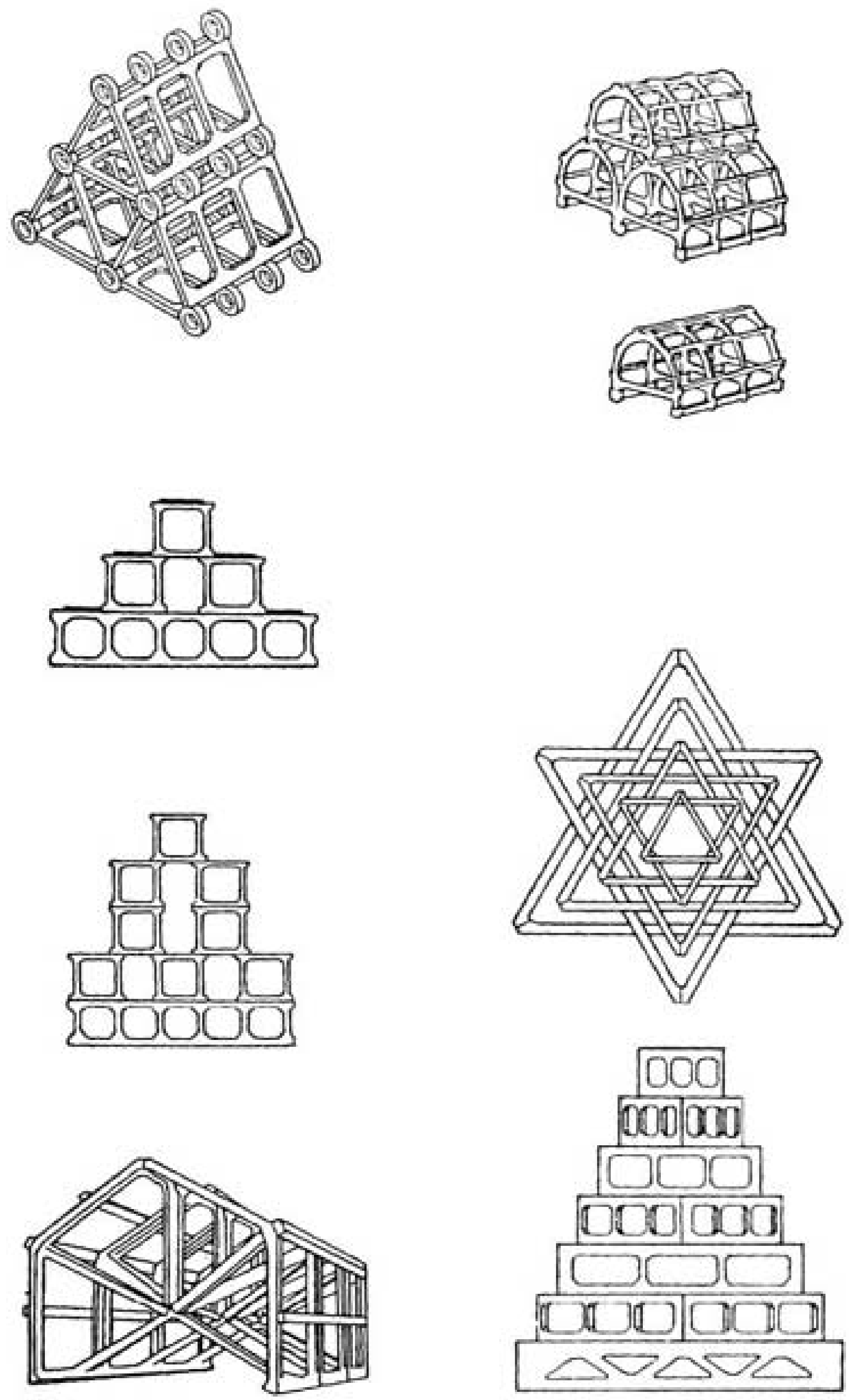
Mangrove/coconut tree.- In Sabah, East Malaysia, fishermen have practised the use of FADs by sinking bundled mangrove and/or coconut trees weighted with stones. After one or two weeks, fishing with handlines starts (ref. 30).

Trees or branches: Anchored to the bottom with weights, trees or branches have been used also in South India to aggregate fish.

Bundled twigs: Made preferably of box-tree, bundled twigs are used — again in Japan — together with a boat seine for catching squid (ref. 25). Though various types of gear are employed in such fishing, the one shown here is a lengthy but low gillnet, measurir.g some 30 m in length and 4 m in depth. (See Figure 6.)

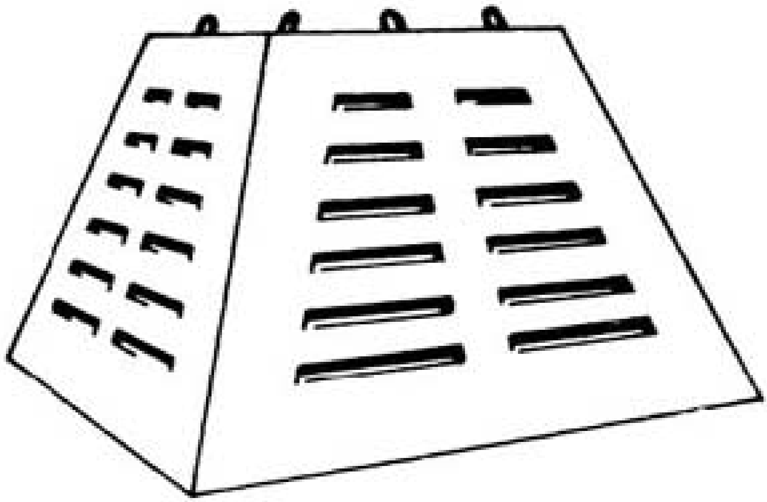
The spawning nests for squids are made of bundled twigs, each nest with some 10 pieces, a twig being 60—90 cm long. As a first step, fishermen sink 30 or 40 nests with stone sinkers at

Figure 3



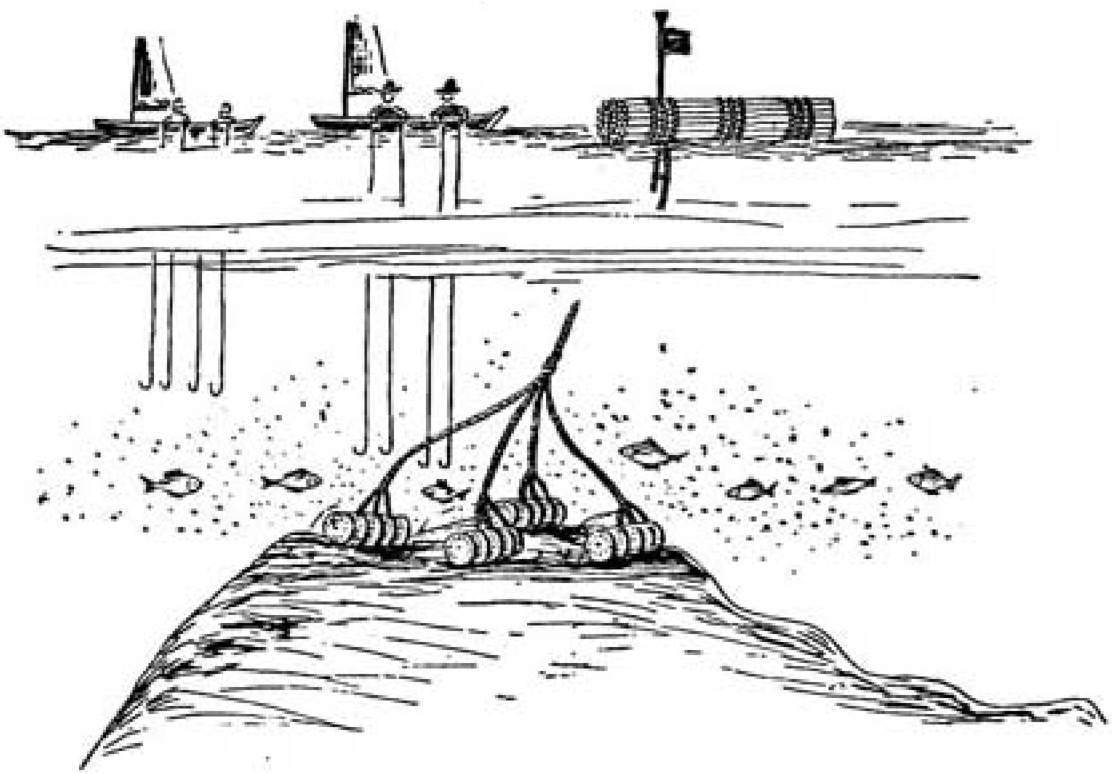
Various designs of concrete fish shelters

Figure 4



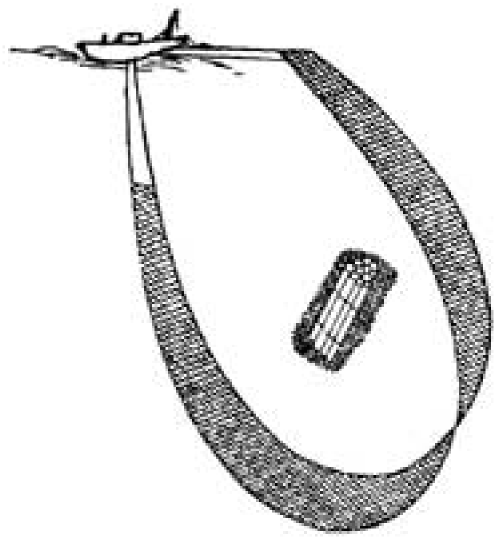
Shelter unit for spiny lobster used in Nagasaki, Japan

Figure 5



Sandbags are used to attract ye/low-tail in Japanese waters

Figure 6

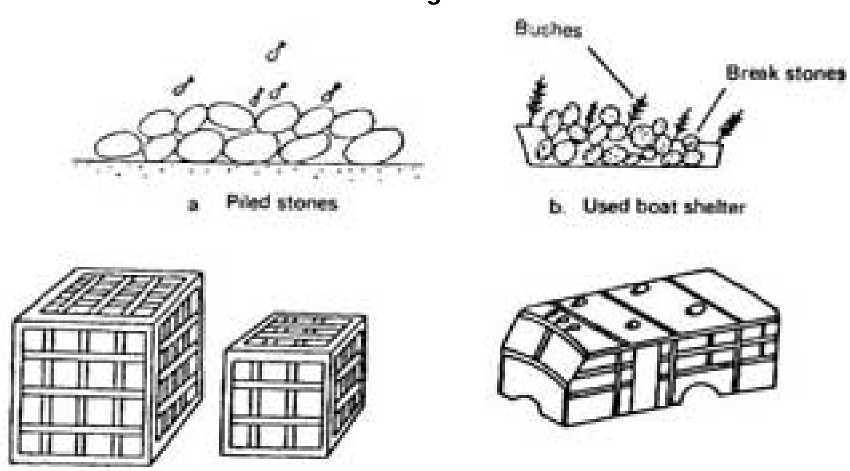


Bundled twigs

intervals of 50 m. The presence of squid eggs adhering to the twigs shows that plenty of squids are lured to the nests. The men then start fishing by surrounding the nests with the gear, and throwing stones at the nests. This attack frightens the squids hiding there and they dart to the gillnet. The net is then hauled into the boat.

Shipwrecks: Shipwrecks have been known for a long time to attract fish, and fishermen often search for them. As early as in 1935 four ships were deliberately sunk off the United States coast together with other materials, to produce an artificial fish habitat. A more recent example was mentioned earlier. In 1968, four vessels ranging from 26 ft. to 140 ft. in length were sunk off South Carolina together with about 15,000 tyres. This wreckage was found to have significantly increased fish abundance in the area (ref. 19). Finally, shipwrecks 250—300 years old were recently discovered in Sri Lankan waters. They housed huge colonies of food fishes (ref. 35). *Other examples* of artificial reef material are illustrated in Figure 7 (ref. 25).

Figure 7



c. **steel fish shelter** d. **Bus shell**

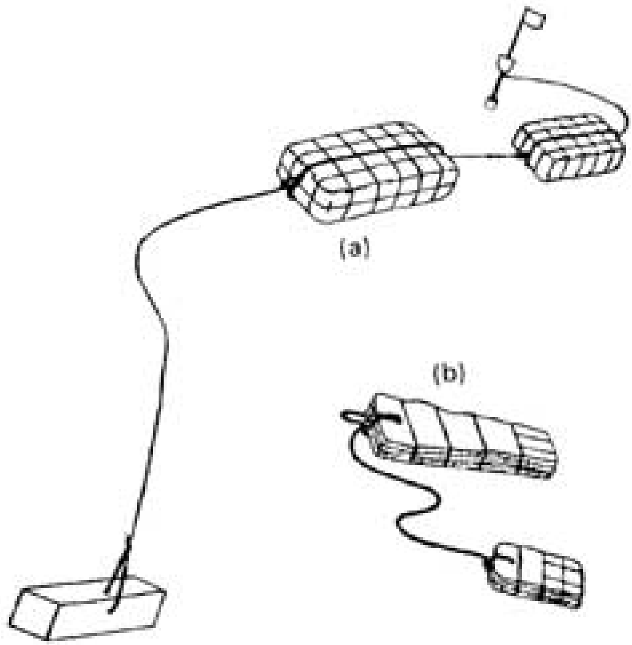
3.2 FADs anchored or drifting on or near the water surface (surface FADs)

Lures for flying fish: The best known traditional FAD of this type is used by traditional craft to capture flying fish. For example, along the east coast of South India (ref. 1), bundles of branches and leaves of screwpine (Pandanus) and of a small Iegurnincus shrub called kavalai are tied to the ends of three ropes of unequal length. These are then cast overboard on the wind side of the kattumaram or vallam. When these lures are out, flying fish gather to deposit their spawn on the leaves and branches and can then be caught easily with dipnets.

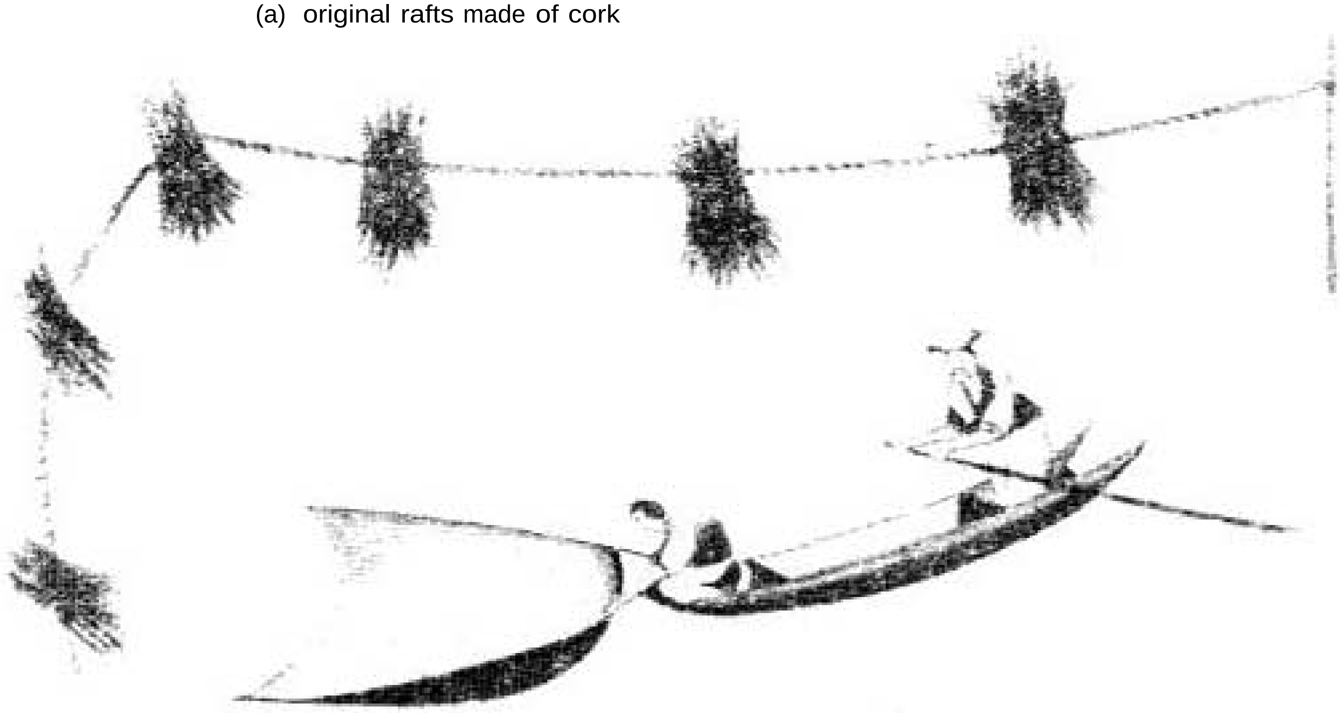
Anchored f/oats: In Malta, the "Kannizzatti" fishery has long been using anchored flcats. These are set at intervals along a course running cut from the coast into waters up to 600 fathoms in depth (ref. 7). (See Figure 8)

Brushwood: Brushwood has been used in many places to aggregate fish. These are subsequently caught with scoop nets (ref. 7). See Figure 9.

Figure 8



Rafts for 'Kannizzatti"—fishery off Malta
(a) original rafts made of cork



The Chinese brush fishery

Table 1: Daily fish catch of S/V CALAMAR during drifting May 1970
(Table indicates numbers of fish with weight in pounds in brackets)

Fish species	Date														Totals
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Flying fish	(200)														(200.0)
Dolphin			3 (56)	25 (468)	1 (16)	4 (93)	1 (33.5)	5 (106)	8 (136)	12 (232.5)	6 (117.5)		13 (239)	1 (20)	79 (1,517.5)
Wahoo					1 (21)	2 (29)				4 (54.5)	2 (21)			7 (108)	16 (233.5)
Yellow-fin tuna				1 (135)		2 (12)	42 (349)	19 (130)	3 (35)	8 (71)	9 (63.5)		28 (221)	1 (11)	113 (1,027.5)
Skipjack tuna							8 (40)	1 (4.5)			1 (4.5)		1 (4.5)		11 (53.5)
Bigeye tuna	1 (115)														1 (115.0)
Rainbow runner					3 (14)	2 (8)	6 (54)	3 (21)	2 (14.5)	6 (56)		1 (8.5)	11 (64)	2 (16)	36 (256.0)
Trigger fish												(200)			(200.0)
Sharks	1 (25)	1 (30)		1 (75)	1 (30)			1 (86)	1 (35)	2 (52)	1 (65)	1 (22)			10 (420.0)
Total	(340)	(30)	(56)	(678)	(81)	(142)	(476.5)	(347.5)	(220.5)	(466.0)	(271.5)	(230.5)	(528.5)	(155.0)	(4,023.0)

Source: R. S. Wolf in MFR paper 1090 in Marine Fisheries Review, September, 1974.

Table 2: Characteristics of moored objects in the offshore waters of Costa Rica and the number and *weight* of fish collected beneath each object.

Objects listed by year and/n order of weight of catch

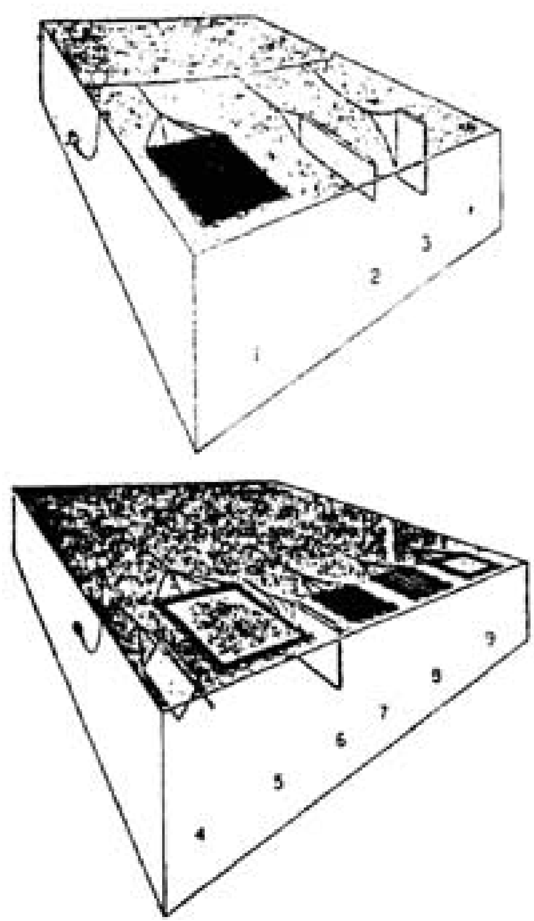
		Object characteristics			Catch characteristics				
					Weight of fish per collection (g)		Number of fish per collection		
Object type	Collection year	Immersed surface area (sq.m)	Outside dimensions (m)	Vertical displacement (m)	Median	Range	Median	Range	Number of collection
1	¶965	7,2	2.4x3.0	0.0	398	151—1,822	48	15—469	6
2	"	7.2	1.2 x 3,0	1.2	108	2—708	27	1—269	6
3		7.2	1.2x3.0	3.0	46	0.2—300	4	1—230	6
4	1966	4.50	0.75 x 0.75 x 1.5	0.75	1879	440—7,615	647	51—2,286	15
5	"	**2.25**	3.0 x 3.0	0.0	519	244—2,833	90	69—618	4
6		4.50	T.5x1.5	1.5	481	169—5,873	233	51.634	10
7		2.25	1.5 x 1.5	0.0	481	274—2,984	204	90—604	10
8		1.20	1.5 x 1.5	0.0	237	174—646	167	32—357	6
9		0.97	1.5 x 1.5	0.0	222	123—577	106	56—205	6

Free-drifting vessel: In the West Indies, free-drifting objects have for many years been sought for schools of common dolphinfish, wahoo (Acanthocybium solanderi), etc., often seen in the vicinity. With this background and to determine if a drifting vessel can attract commercially desirable fishes in commercially significant quantities, an exploratory vessel in 1970 conducted drift fishing in the Caribbean. It drifted 360 n.m. in 314 hours, with only the hull, supplemented with lights at night, to attract fish (ref. 9). After only one day of drifting, the vessel acquired a colony of tunas. The catch composition over the total period of drifting and fishing around the same vessel is tabulated on page 9. The catch results and observations during the drifting confirmed that a marine colony had established itself around the vessel. However, the results did not confirm that commercial quantities could be taken. This is because it was found difficult to use certain fishing methods from the vessel without disturbing the established colony. The trials were repeated in 1970 and 1971, but the results were still not encouraging. Thus nosignificant potential for a modern commercial fishery could be demonstrated with this method.

Objects of different shapes: Some experiments with surface-floating objects of different shapes have been carried out: Hunter and Mitchell (1969, ref. 5) tested a number of black plastic vinyl, polyethylene or polypropylene sheets of designs such as in Figure 10.

They found that more fish could be taken beneath the tent-shaped object, No. 4, than beneath any of the others. Table 2 summarises the experiments.

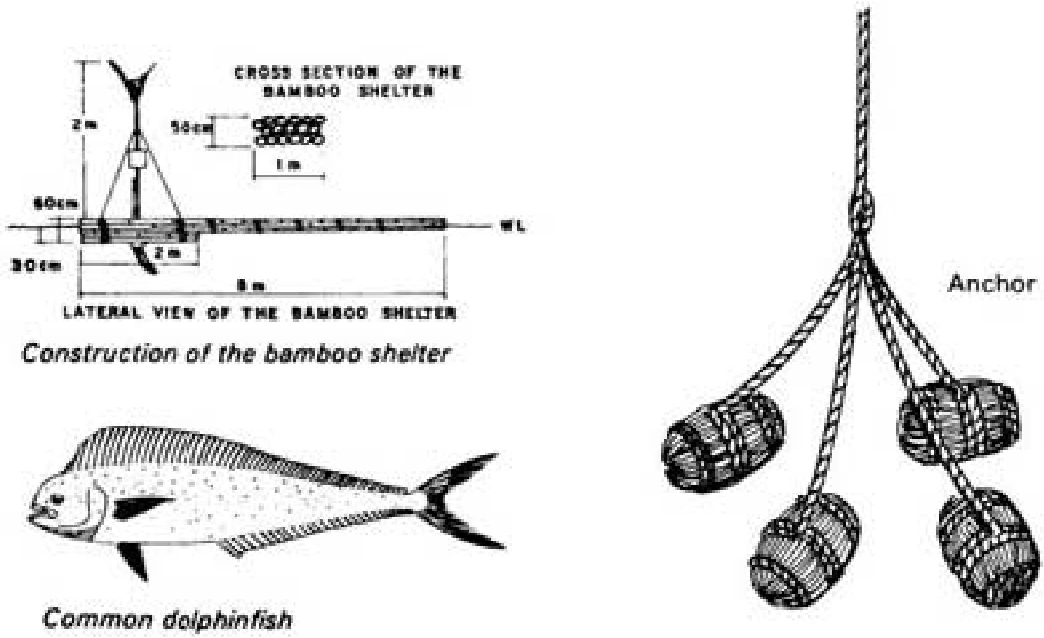
Figure 10



Floating black plastic objects moored in the offshore waters of Costa Rica; (1-3) moored in 1965 and (4-9) in 1966.

Bamboo rafts: One of the first studies of fish aggregating rafts was made by S. Kojima and published in 1956 **(ref. 2).** It describes a bamboo raft commonly anchored in the coastal area of the Japan sea. These rafts attracted mainly the common doiphinfish (Coryphaena hippurus), a fish that often prefers hiding in driftwood or bamboo. Such shelters are still in use, each bundle of bamboo measuring up to 8 m in length and 0.5 to 0.6 m in diameter. They are placed in **units of** 10—20 on the sea surface and are anchored with sandbags, stones, etc., each group being separated from the other by about one nautical mile. (See Figure 11)

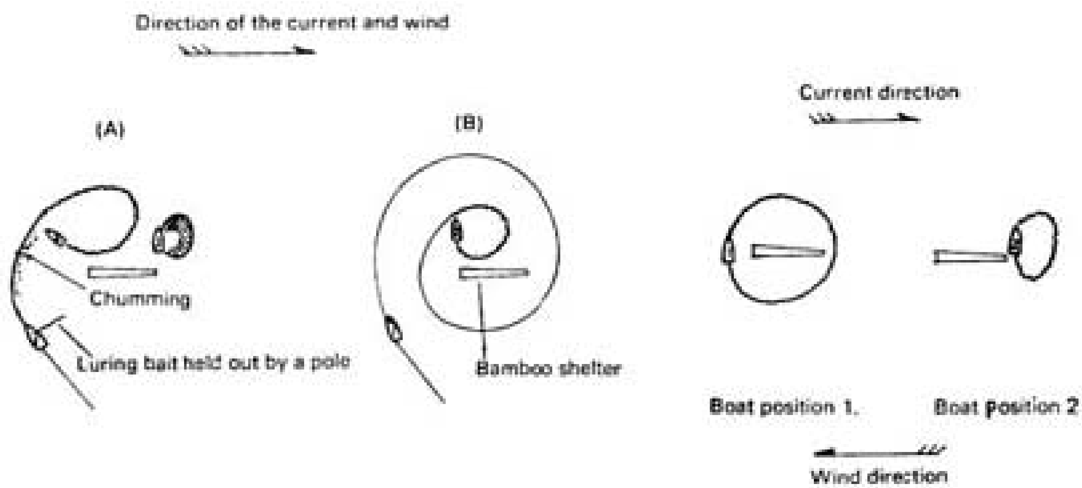
Figure 11



(Coryphaena hippurus Linnaeus 1758)

The gear used for harvesting from these rafts are usually purse-seines, but gillnets, handlines and longlines have also been used. The purse-seine is used in these two ways (Figure 12).

Figure 12



Schematic diagrams (A) and (B) show usual purse-seine operation for fish gathering around a bamboo shelter. In the morning and evening (A), the seine boat begins to encircle fish in a narrower area and closer to the bamboo shelter than it does in the daytime (B). Another purse-seine operation process for staying with a bamboo shelter is shown in the two diagrams at right. The bamboo shelter is first encircled together with the fish (boat position 1). Then it is pushed out of the enclosure as the net is hauled up (boat position 2).

Some other surface-floating rafts and lures of traditional materials also exist, but these, as well as modern structures, have been in use in connection with some kind of mid-water structure. The mid-water structure is in such cases the main fish attractor, so these designs will be described in section 3.3.

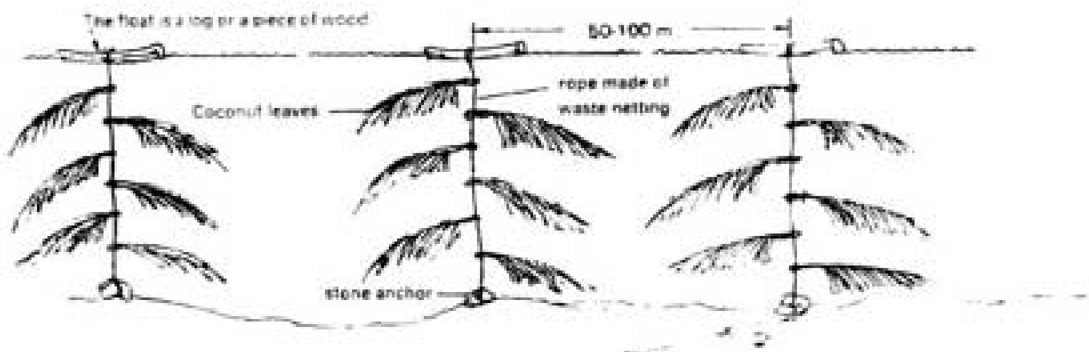
3.3 FADs anchored in the water column (mid-water FADs)

This is the most important group of FADs, the largest and possibly the group with the greatest scope for improvement and innovation. It contains the most successful types of traditional designs as well as the best modern types – both experimental and in commercial use.

3.3 (a) Traditional: There are some well-established traditional uses of mid-water FADs. Examples will be given from India, Indonesia, Japan, Malaysia and the Philippines.

On the east coast of India, a simple, but very efficient, mid-water FAD made of coconut leaves and designed in Figure 13 is used:

Figure 13



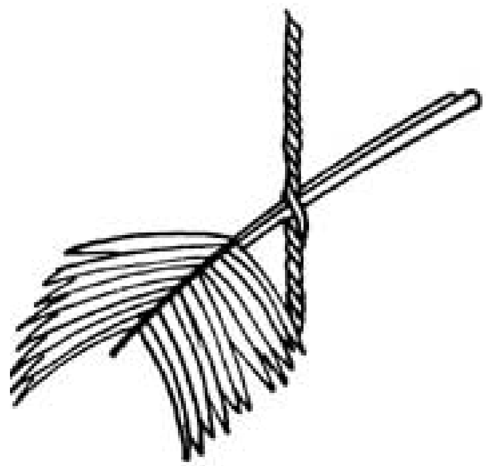
These FADs are anchored in shallow waters, from half a mile up to 2-3 miles off-shore. They usually have a simple arrangement with a stone as weight and an anchoring rope made of waste material. During the period of the review work, BOBP staff followed the use of such FADs, and the harvesting with the so-called Mada Valai or Mara Valal, a type of bag net used by kattumarams. (The fishing method is described in section 5 – "Harvesting methods"). Over nearly six weeks from deployment up to the end of the fishing season (which ended because of deterioration of leaves and the increasing force of winds and waves causing too high turbidity), 14 visits were made to a set of three FADs. The catch from these fishing sessions totalled 225 kg worth about Rs. 1,200. The cost of these FADs was about Rs. 75 but nearly Rs. 250 was spent on repairs, so the net profit was around Rs. 875. To earn this money, 11 men in four kattumarams spent three hours each on 14 occasions, which meant 462 man-hours. The net income thus worked out to nearly Rs. 2 per man-hour at sea. The catch consisted mainly of smaller mackerel species, sardines and occasional pomfrets.

In Indonesia (ref. 31), the most common traditional FAD is a similar type of rope and coconut frond arrangement. It is known as "Rumpon". However, the Rumpon is used also in connection with larger gear and craft than in India. Also, when fished by boatseine or purse-seine, the Rumpon is not always anchored but sometimes hung from a bamboo raft or a canoe. Before harvesting, the Rumpon is left in the water from a few hours up to several days.

In Malaysia and on the east coast of Thailand a similar construction of palm fronds attached to a rope is the basic type of FAD. In Malaysia it is sometimes called Tua but more commonly "Unjang", with a different prefix depending on how the leaves are attached; some "Unjang" have the fronds hung at one fathom distance all along the rope, others have them in one bundle 2—3 fathoms below surface (ref. 3). (See Figure 14.)

The main difference, however, between the Malaysian FAD and the Indian and the Indonesian varieties lies in the harvesting. In Malaysia the fishermen carry with them a smaller Unjang to which the fish aggregated is attracted over and then "moved" to some kind of enclosing net. See also section 5, "Harvesting methcds".

Figure 14

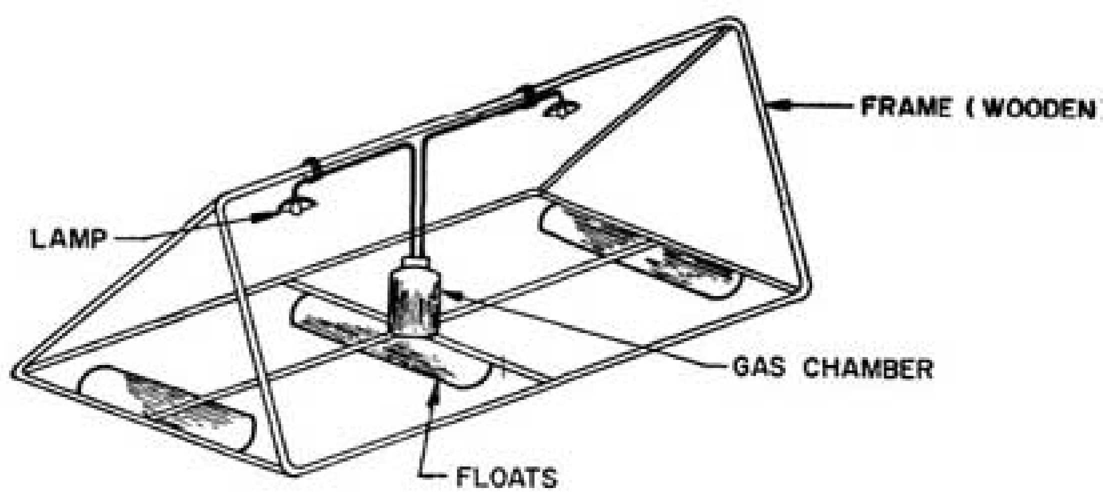


The method of inserting the butt ends of the coconut fronds between the strands of a! 2-ply rope in the "linjang"

Nowadays purse-seiners, before setting their net, transfer the fish from the anchored lure line to a lure line carried on a smaller boat by detaching the anchored lure line from its buoy, inserting an intermediate line and letting the lure sink. The fish will then gather round the drifting lure and the purse-seine is then set around this lure line (ref. 29).

At night the functions of the drifting lure line are replaced by a lighted buoy. (See Figure 15)

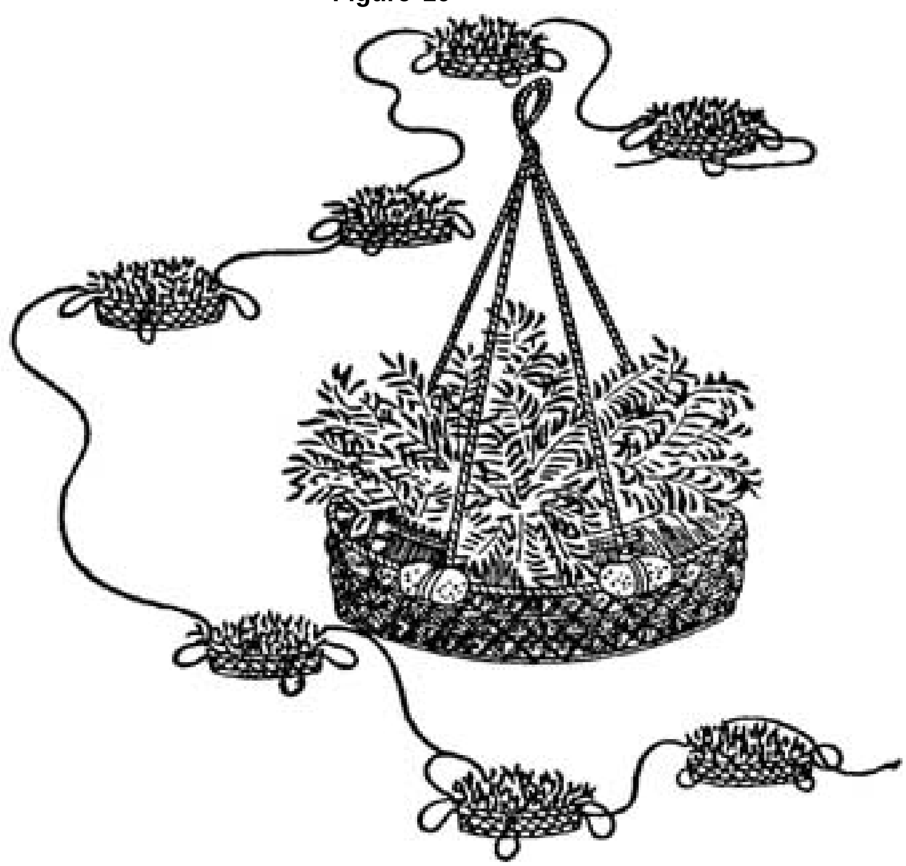
Figure 15



LIGHT BUOY

A traditional Japanese mid-water FAD is significantly different from the palm leaf type: one used to capture cuttlefish is described here (ref. 25). It consists of about 15 knitted bamboo-baskets, attached with lines to a headrope of about 700 m. These baskets are filled with branches of box-tree, peach tree, azalea and/or bush clover. A few days after release cuttlefish settle here to spawn.

Figure 16



Japanese bamboo baskets

There are a few similar fishing aids, such as abalone basket net, etc.

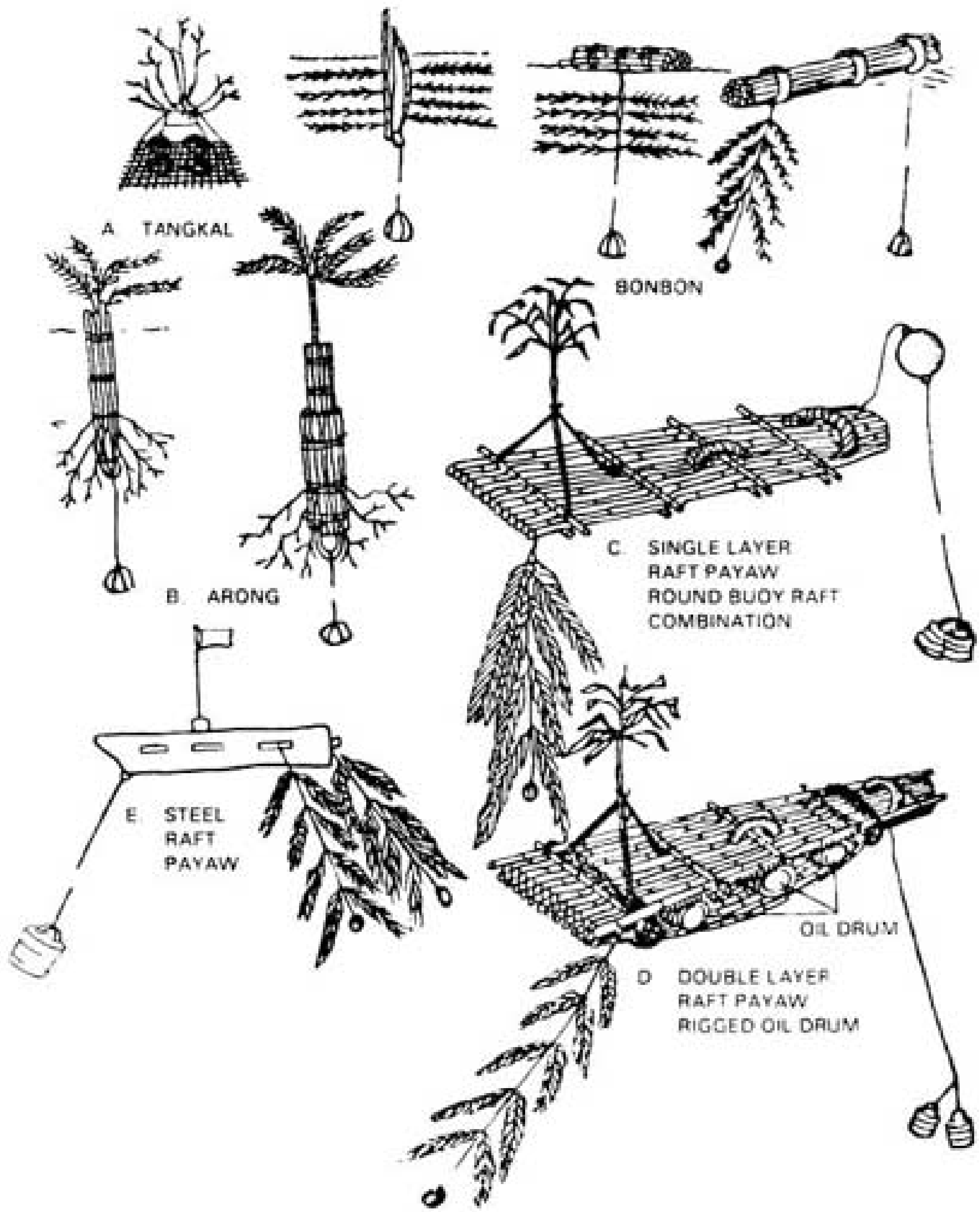
The Philippine "payaw" is probably the most well-known traditional mid-water FAD and has inspired many to produce tuna-rafts out of a variety of industrial products.

The payaw consists of a bamboo raft, of which there are many designs; some of them are shown in Figure 17.

The simplest type of payaw has a raft made of 5—8 bamboos under which a bundle of twigs hangs. This device was floated in near-shore Waters across known migratory paths of fishes and simple handliries or enclosing nets were used for the harvesting.

On a somewhat bigger and anchored payaw the fish attractor, the so-called "Haybong". is attached to the raft separate from the anchor line. The haybong is a rope, sometimes up to 300 m long, to which a number of bamboo and/or coconut and/or other palm leaves are attached. The haybong

Figura 17

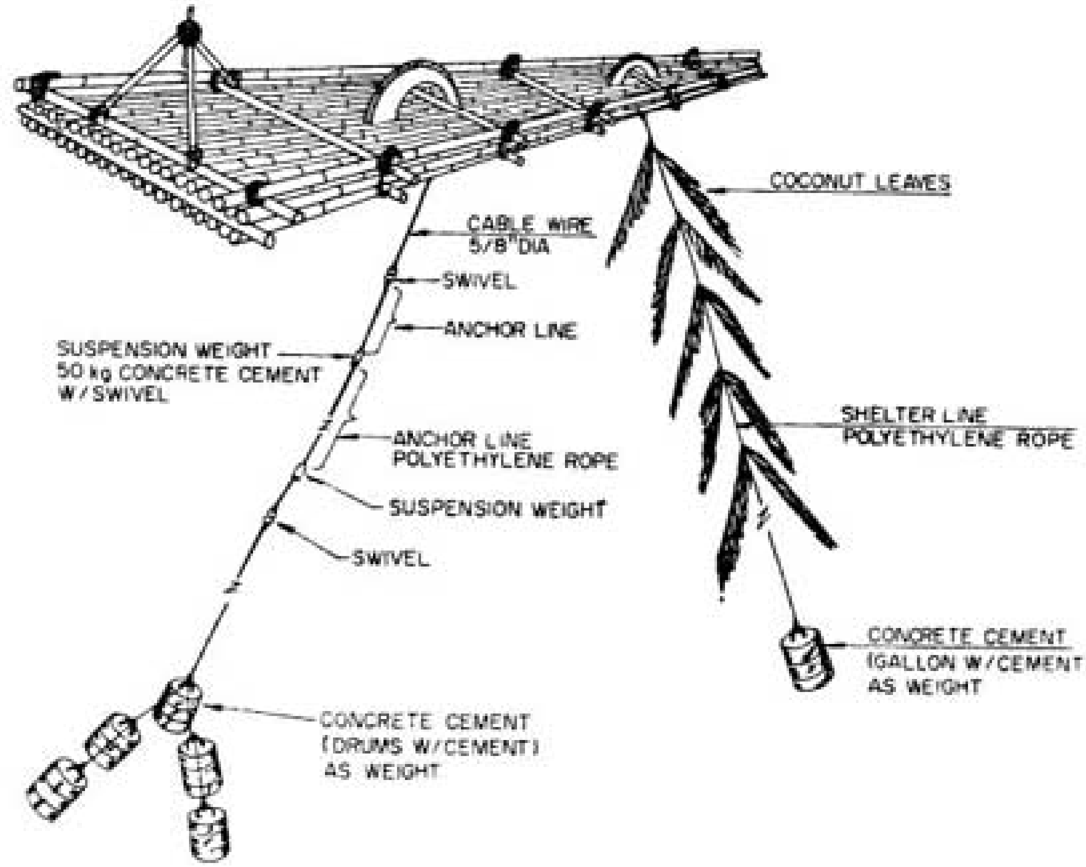


A variety of Payaw designs

is secured to the underside of the bamboo raft and has a weight at the lower end of the rope to keep the whole structure vertical (ref. 15).

Figure 18

TYPICAL PAYAW (FISH SHELTER)



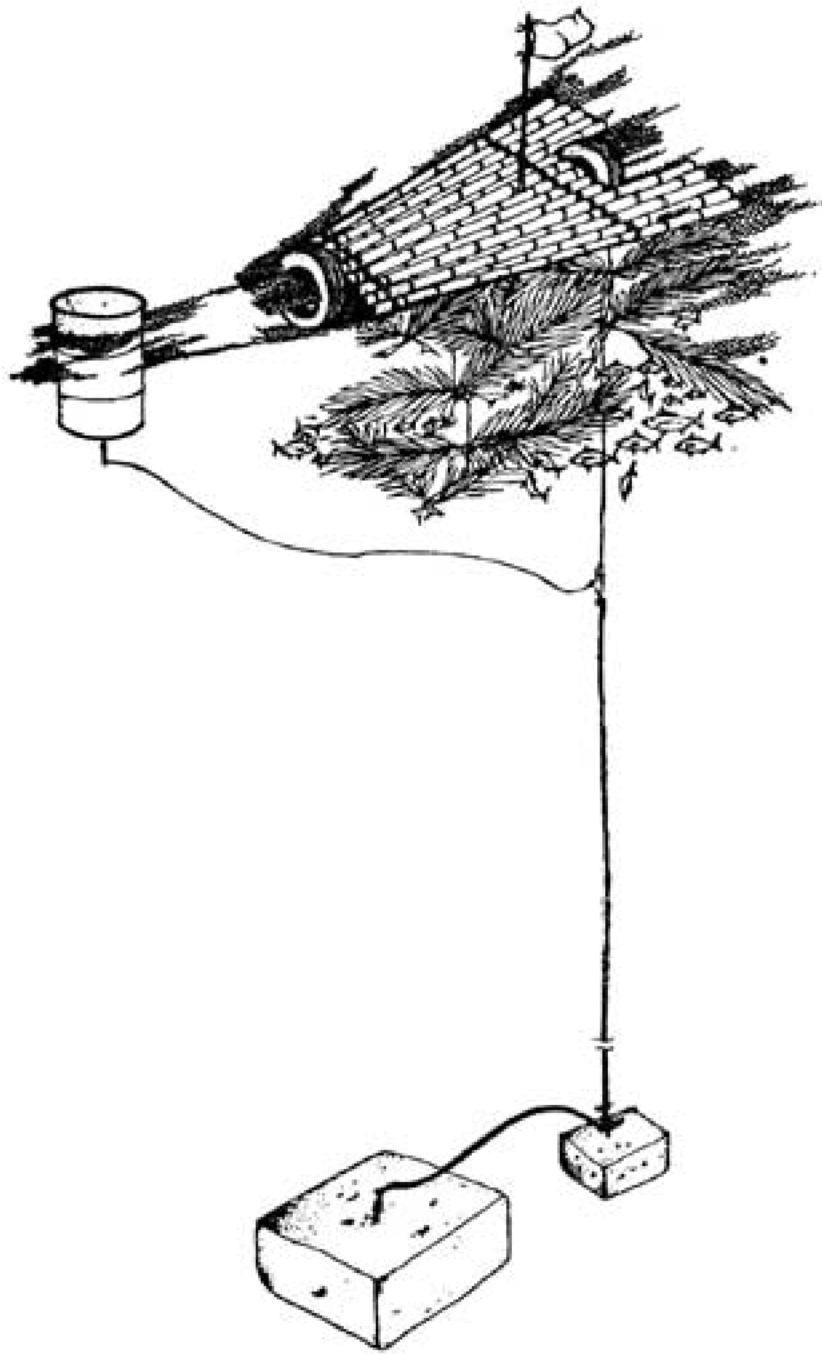
Payaws have of late been improved a great deal — especially their durability. Today's payaw is sometimes made of bambao, has one tyre around each end of the bamboo cluster and chains from the tyres to the anchoring line. Another modern variation (ref. 32) is to rig empty oil drums in a metalframe and cover the frame with bamboos in such a way that it is more streamlined. When bigger rafts are built for the purse-seine fishery, the floating raft is sometimes made of (ref. 12) two layers of bamboo, 10 to 15 m long and 2 m wide. The underside is rigged with coconut or palm fronds and the whale structure is anchored with a steel barrel filled with rock and cement. Such rafts are sat out 30 to 60 km off-shore. If there are several, about 11 km separate one raft from another.

A few descriptions of methods for harvesting from payews are given in section 5. Included there is one of the more recent and complete published descriptions of this fishery — "The commercial harvesting of tuna attracting payaws : a possible boon for small-scale fishermen" (ref. 14). In that description a design of payawcurrently harvested bypurse-seiners is also given. (See Figure 19)

E. O. Murdy describes this raft as "made of two layers of bamboo lashed together in a V-shape. It is approximately 4 m in length and 1.5 m at the widest end. There is a slight elevation between the two layers designed to lessen the resistance to water flow. The V-shape also aids in this. The anchorline is attached to a tyre secured to the bamboo about 3 m from the apex. These payaws are anchored at 1100 fathoms; consequently, the anchorline is the major expense in this venture, comprising about 90% of the total cost of the structure. The first 40 m of the anchorline is made of wire to prevent cutting by vandals and this is attached to a swivel which in turn is attached to a 16 mm nylon rope extending down to a swivel connected to a 40 kg counterweight. The counterweight acts as a shock absorber and takes some of the strain off the anchorline. The main anchor (400 kg) is connected by nylon rope to the counterweight.

"Because of the high cost of the anchorline and because strong winds and currents tend to destroy the bamboo raft portion of the structure, a buoy is added so that the anchorline is not lost even if the raft is. The buoy, an 80-gallon water tank, is secured by nylon rope to the swivel where the wire meets the nylon rope.

Figure 19



The pa yaw, a raft made of two layers of bamboo lashed together in a V-shape, is used by tuna fisherman off certain islands of the Philippines to attract schools of yeiowfin, skipjack and little tuna. (E.O. Murdy, courtesy ICLARM Newsletter, Jan. 1980)

"The most important feature of the payaw is a hanging line, with coconut leaves tied to it at two-metre intervals. This weighted hanging line or haybong, normally 20 to 25 metres long, serves as the fish attractor."

Purse-seiners operating in the Philippine waters often have 15—30 payaws each, of this or similar design, usually anchored at 2000—3000 metres. Some fishing companies prefer bamboo rafts to steel rafts, as bamboo is said to attract fish better. These payaws are often fished also by the traditional craft, the bancas, using handlines in about 30 fathoms to catch small tunas (ref. 37).

Fish which aggregate under payaws are mainly yellowfin, skipjack, and little tunas (ref. 14). A few clupeids, scombroids, and carangids are also found (ref.25). Skipjack plus yellowfin and big-eye tunas are mentioned in ref. No. 12. Apart from these, frigate tuna, barracuda, rainbow runner, spanish mackerel, swordfish, shark and porpoise are said to aggregate around payaws (ref. 32). In the vicinity of the payaw described above, E. 0. Murdy also observed (ref. 14) sergeant-major, pilot fish and common doiphinfish.

Tunas form a major part of catches from the off-shore rafts. Tunas by nature are long-swimming, but will be stationary (ref. 1 5) if the temperature is favourable, if there is a stationary object to provide shade, and if food is abundant. A payaw fulfills all these three requirements. However, the catches sometimes contain a large proportion of young fish (ref. 12 and 14). Some fear has been expressed that if this fishery expands in areas where there are many juvenile tunas, "raft fishing could make rapid inroads into the stocks unless stringent conservation measures were instituted" (ref. 12). Recently, government and industry people in the Philippines attributed the substantially decreasing catches by ring-netters to the interception of tunas and round scads at payaws set in more off-shore areas by the larger purse-seiners (ref. 37). This being one of the reasons has resulted in recommendations by an FAQ tuna biologist to analyse catch data "to determine long-term changes in catch composition and catch rates of tunas and other species".

3.3 (b) **Modern FADs — experimental:** Many of the modern designs of mid-water FADs are similar to the payaws. However, a few other modern designs will first be explained. These mid-water structures have not yet been commercially used, but trials have shown their ability to aggregate fish.

Multityre: In May '1975 (ref. 10), 30 mid-water structures, of the type shown here, were deployed off South Carolina in shallow water (average 13.5 m) near a group of seven earlier sunken steel vessels of size about 4 x 5 x 30 m. The purpose was to evaluate if these mid-water FADs could increase concentration and availability of pelagic fishes already associated with the benthic artificial reef. (See figure 20).

These structures were found to make the habitat more attractive to pelagic bait fish and to game fishes: "The mid-water structure area produced a markedly higher catch rate than either of the control areas and exceeded the catch rate for the existing benthic reef by 22%. Consistently, more and larger schools of bait fish and surface-feeding game fish were observed in the vicinity of the mid-water structures than in any of the other study areas" (ref. '10).

PVC pipes: Similar results were experienced off the state of Mississippi during 1974—77, where the lower part (about 4.5 m long) of five ships was sunk for creating an artificial reef. This "126.7 m saucer" (ref. '11), having only a limited vertical profile, initially attracted only reef-type fish. To improve its attractiveness for pelagic fishes, this artificial reef was supplemented with a large number of mid-water structures made of PVC pipes of dimensions 3 m x 0.5 cm. 160 of these PVC attractors were attached to cables from the original shipwreck. They were placed in position by divers and filled with air from regulators.

The catches of truly pelagic fish were found to be higher around the structures than in open waters, some kilometres away. One advantage of using these PVC pipes was their low cost and easy deployment.

Prisms: In the Gulf of Mexico, two other structures—both painted white—were tested off Florida: prisms with vertical open slots on all three sides and prisms with vinyl cover on the two upper sides, creating a tent-shaped FAD. These structures were modelled on the successful 1968 experimental designs of Hunter and Mitchell, described earlier. (See figure 21).