BAY OF BENGAL PROGRAMME

DEVELOPMENT OF SMALL-SCALE FISHERIES

REVIEW OF EXPERIENCES WITH AND PRESENT KNOWLEDGE ABOUT FISH AGGREGATING DEVICES

BOBP/WP/23

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REVIEW OF EXPERIENCES WITH AND PRESENT KNOWLEDGE ABOUT FISH AGGREGATING DEVICES

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A review of experiences worldwide and of present knowledge about fish aggregating devices (FADs) was carried out by the BOBP during 1981. Nearly 150 institutions and experts were requested to contribute. This paper draws on these replies as also on other published material.

The paper describes a spectrum of FADs ranging from very simple and cheap traditional applications for nearshore waters to modern, highly sophisticated and expensive products for off-shore aggregation of tunas and tuna-like fishes.

Some of the experimental designs described here are worth considering for indicative fishing trials.

The preparation of this paper is an activity of the Bay of Bengal Programme for Small-Scale Fisheries Development, referred to in brief as BOBP. The BOBP is funded by the Swedish International Development Authority (SIDA) and the United Nations Development Programme (UNDP) and executed by the Food and Agriculture Organisation of the United Nations. Countries bordering the Bay of Bengal are members of the Programme. Its main aims are to develop, demonstrate and promote methodologies to improve the conditions of small-scale fisherfolk and to assess and monitor fishery resources.

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CONTENTS

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 "thigmo-tropism" 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)

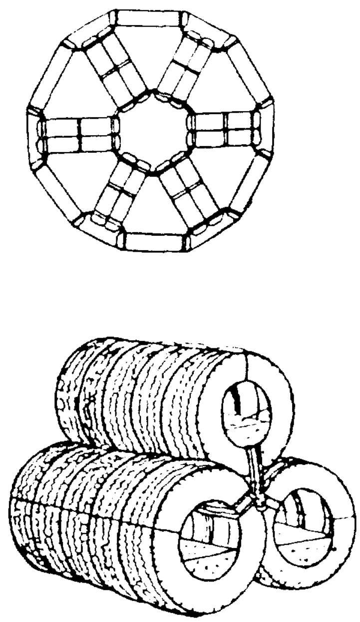
This is the simplest type of FAD, for it does not require any anchoring devices. It is instead kept stationary by its own weight or by additional stones or concrete filling. However, the negative buoyancy must be enough to keep it in place unaffected by wave-and-current forces. It must not be too compact,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



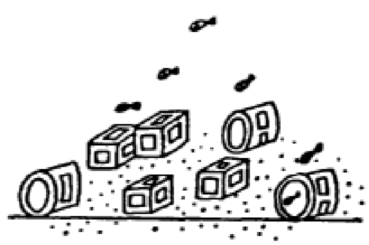
No precise information on performance is available. But these and the so-called "fish apartment" concrete block shelters (see below) have enjoyed a high reputation. It is estimated that nearly one million square metres of sea-bottom in Japanese waters is now covered with such artificial structures for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

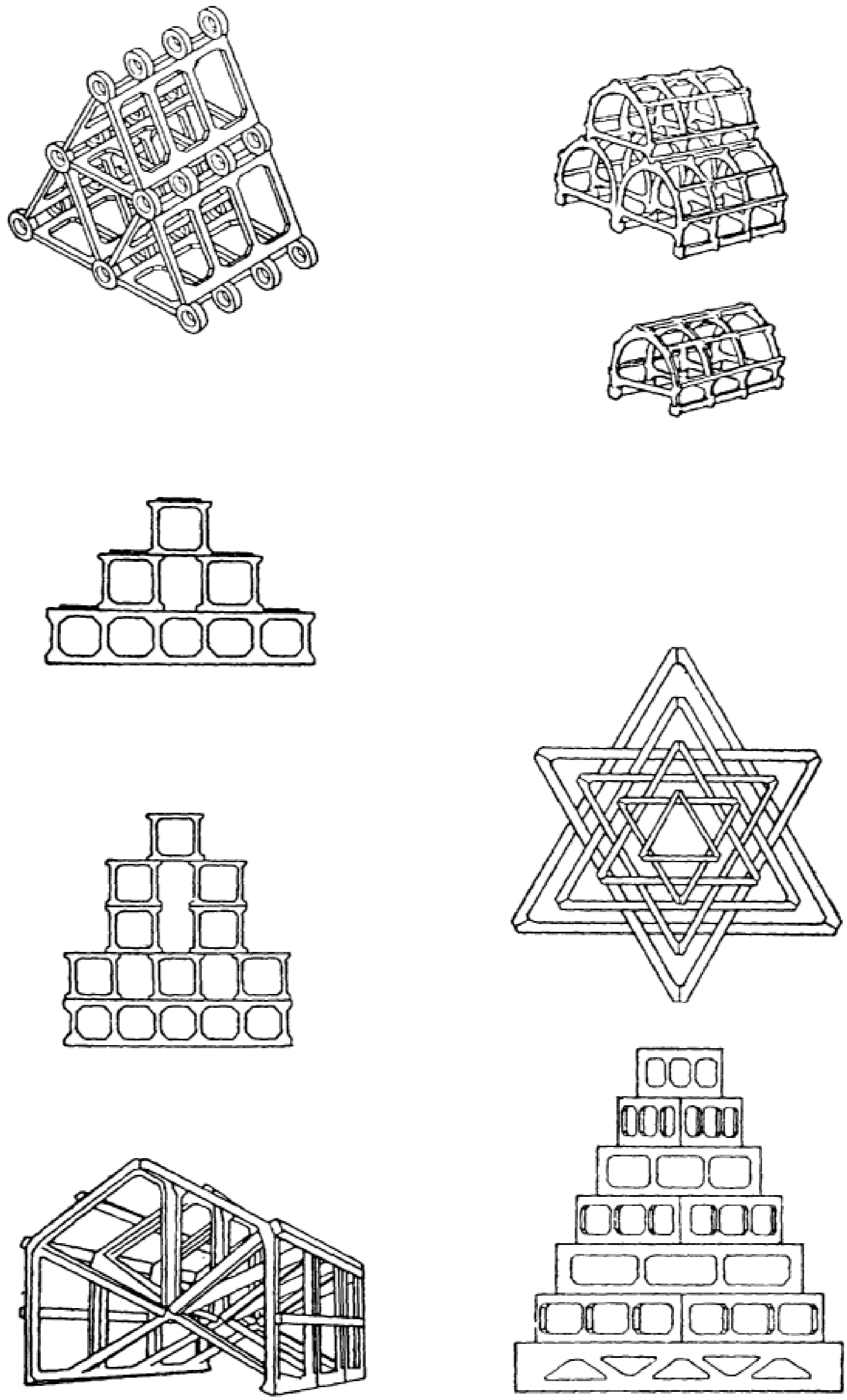
Mangrove/coconut tree.- In Sabah, East Malaysia, fishermen have practised the use of FADs by sinking bundled mangrove and/or coconut trees weighted with stones. After one or two weeks, fishing with handlines starts (ref. 30).

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

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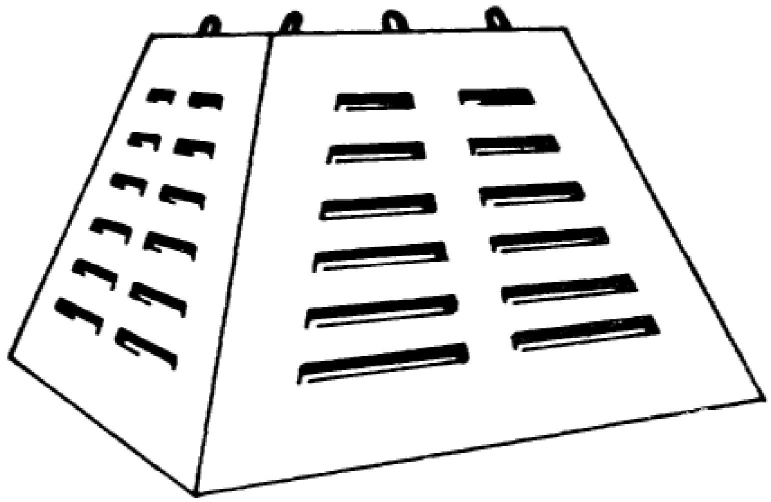
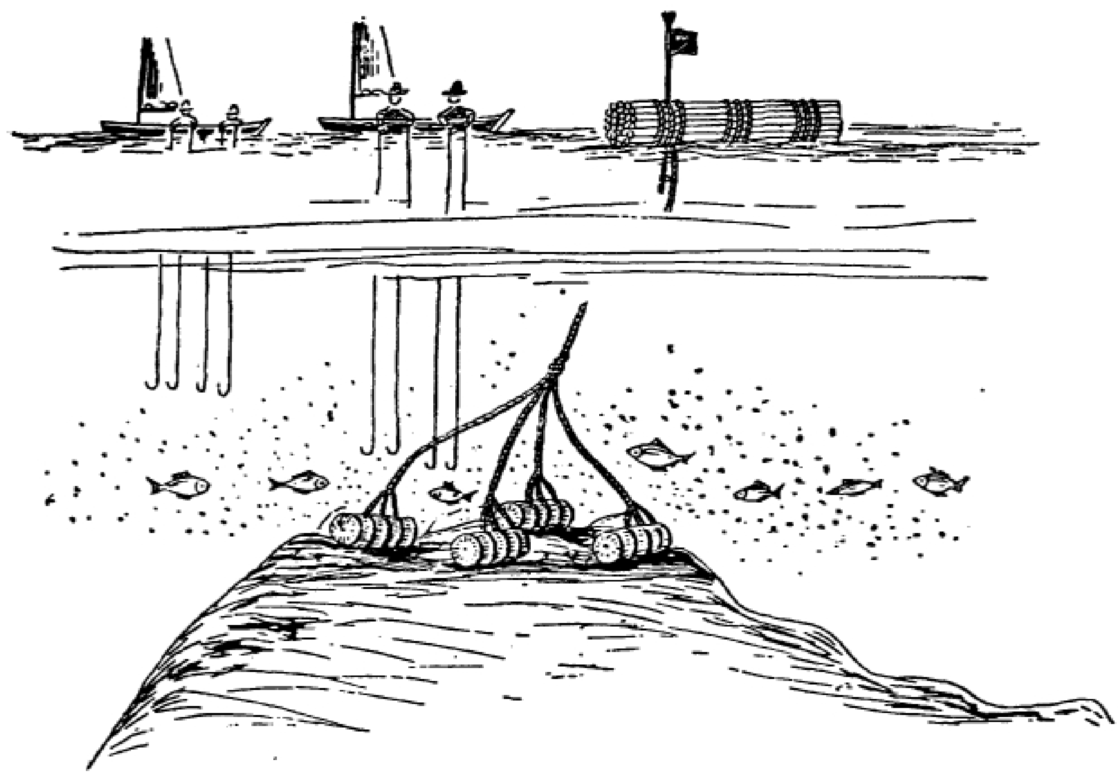
Figure 4



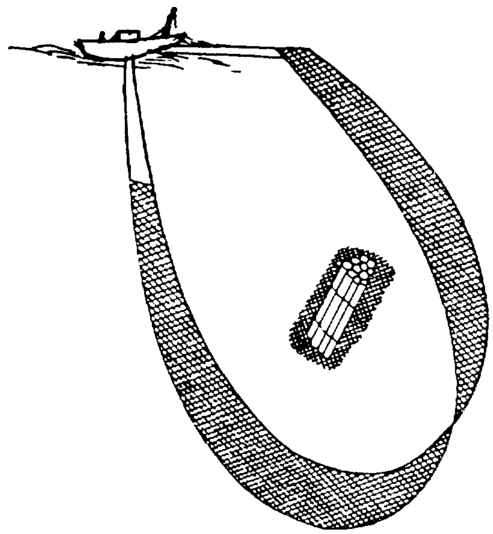
Shelter unit for spiny lobster used in Nagasaki, Japan

Figure 5



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

Figure 6

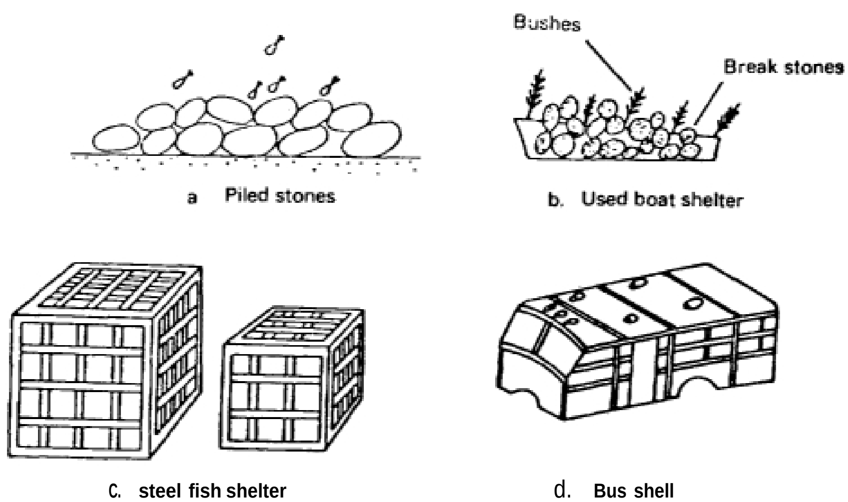


Bundled twigs

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



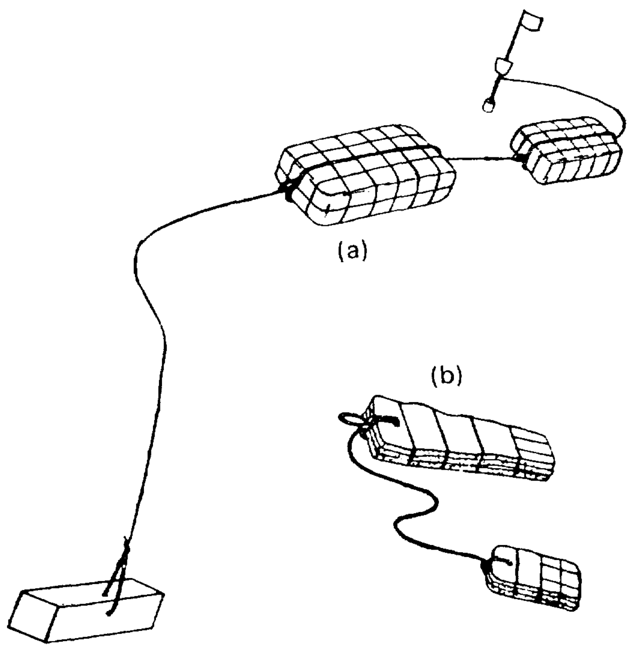
3.2 FADs anchored or drifting on or near the water surface (surface FADs)

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

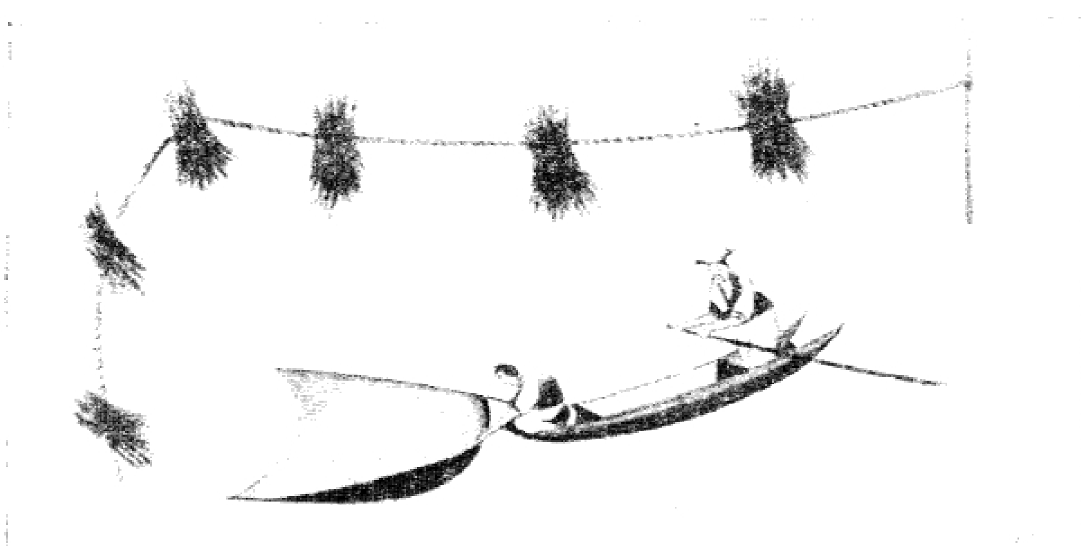


Rafts for 'Kannizzatti"—fishery off Malta

(a) original rafts made of cork

(b) modern rafts made of plates of sponge plastic packed in canvas

Figure 9



The Chinese brush fishery

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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	25	1	4	1	5	8	12	6		13	1	79
			(56)	(468)	(16)	(93)	(33.5)	(106)	(136)	(232.5)	(117.5)		(239)	(20)	(1,517.5)
Wahoo					1	2				4	2			7	16
					(21)	(29)				(54.5)	(21)			(108)	(233.5)
Yellow-fin tuna				1		2	42	19	3	8	9		28	1	113
				(135)		(12)	(349)	(130)	(35)	(71)	(63.5)		(221)	(11)	(1,027.5)
Skipjack tuna							8	1			1		1		11
							(40)	(4.5)			(4.5)		(4.5)		(53.5)
Bigeye tuna	1														1
	(115)														(115.0)
Rainbow runner					3	2	6	3	2	6		1	11	2	36
					(14)	(8)	(54)	(21)	(14.5)	(56)		(8.5)	(64)	(16)	(256.0)
Trigger fish												(200)			(200.0)
Sharks	1	1		1	1			1	1	2	1	1			10
	(25)	(30)		(75)	(30)			(86)	(35)	(52)	(65)	(22)			(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.

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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

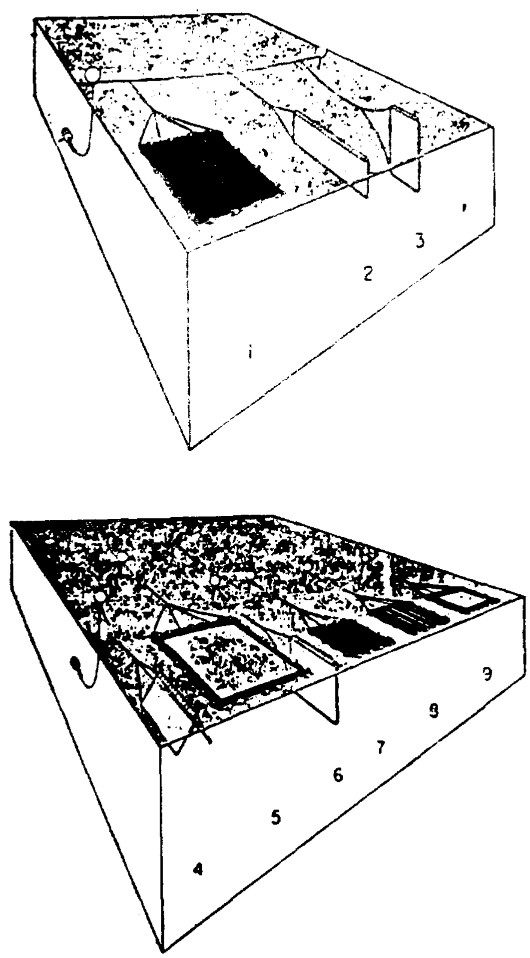
		Object characteristics			Catch characteristics				
					Weight of fish per collection (g)		Number of fish per collection		
Object type	Collection year	Immersed surface area (sq.m)	Outside dimensions (m)	Vertical displacement (m)	Median	Range	Median	Range	Number of collection
1	¶965	7,2	2.4x3.0	0.0	398	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.

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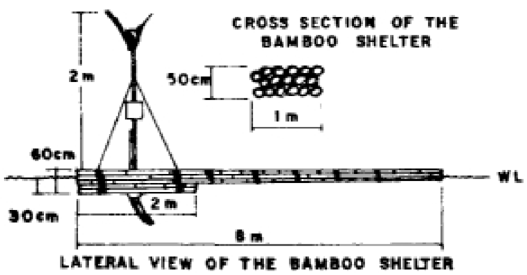
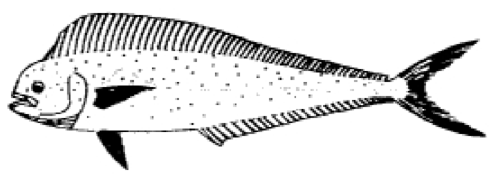
Bamboo rafts: One of the first studies of fish aggregating rafts was made by S. Kojima and published in 1956 **(ref. 2).** It describes a bamboo raft commonly anchored in the coastal area of the Japan sea. These rafts attracted mainly the common doiphinfish (Coryphaena hippurus), a fish that often prefers 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)

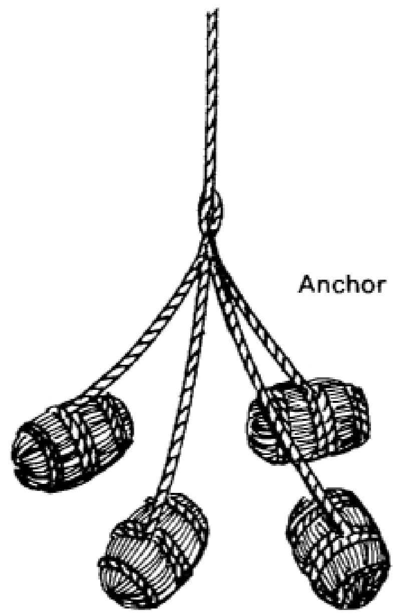
Figure 11



Construction of the bamboo shelter

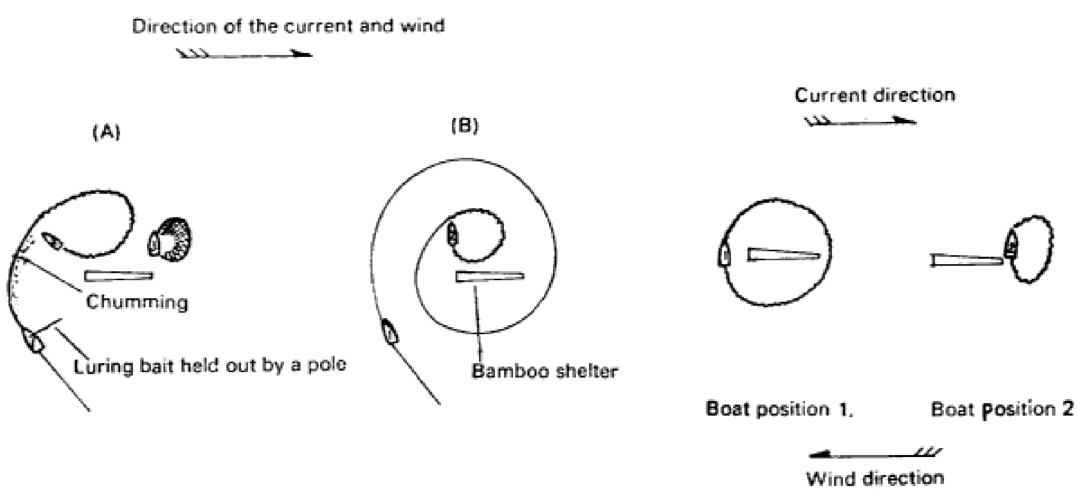


Common dolphinfish
(Coryphaena hippurus Linnaeus 1758)



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).

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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.

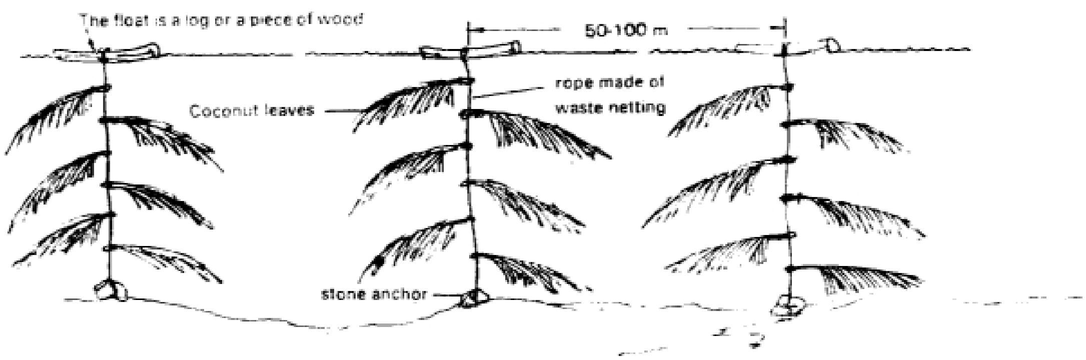
3.3 FADs anchored in the water column (mid-water FADs)

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



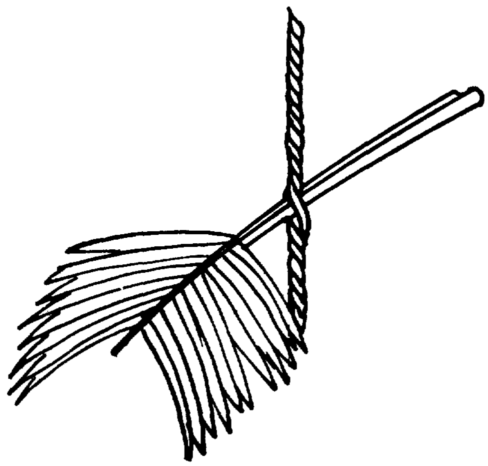
These FADs are anchored in shallow waters, from half a mile up to 2-3 miles off-shore. They usually have a simple arrangement with a stone as weight and an anchoring rope made of waste material. During the period of the review work, BOBP staff followed the use of such FADs, and the harvesting with the 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

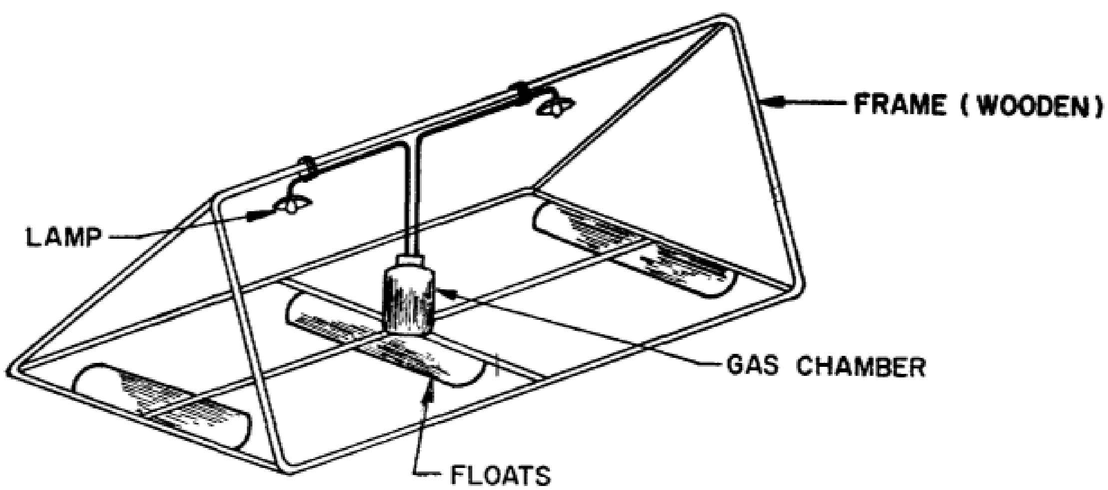


The method of inserting the butt ends of the coconut fronds between the strands of a! 2-ply rope in the "linjang"

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)

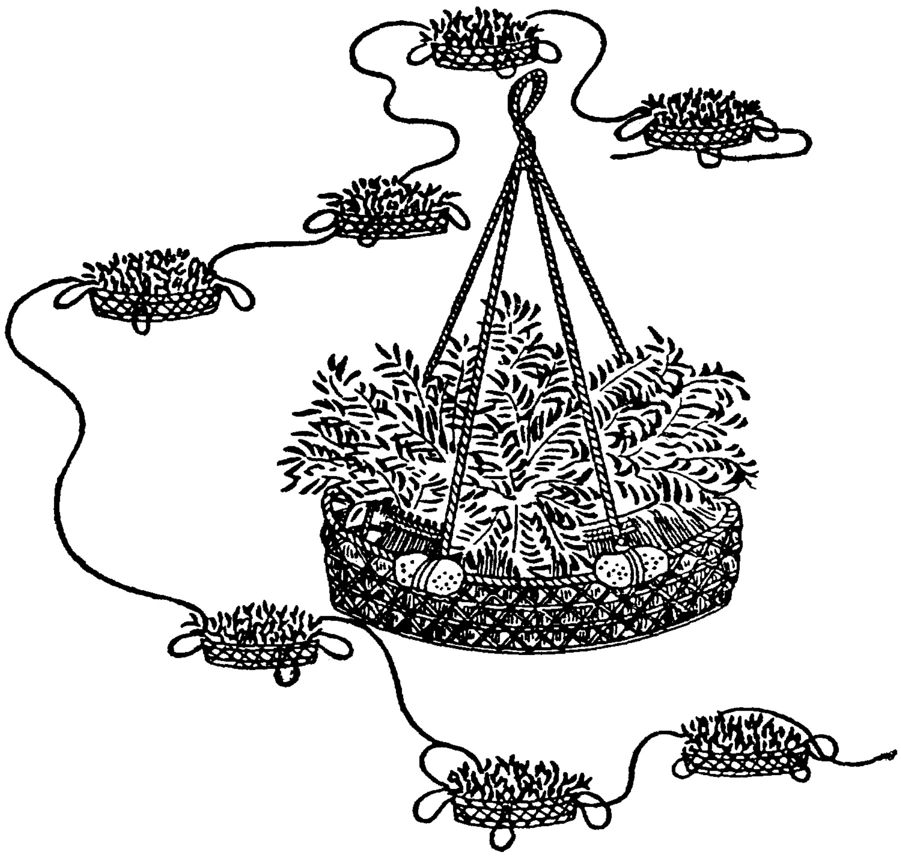
Figure 15



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.

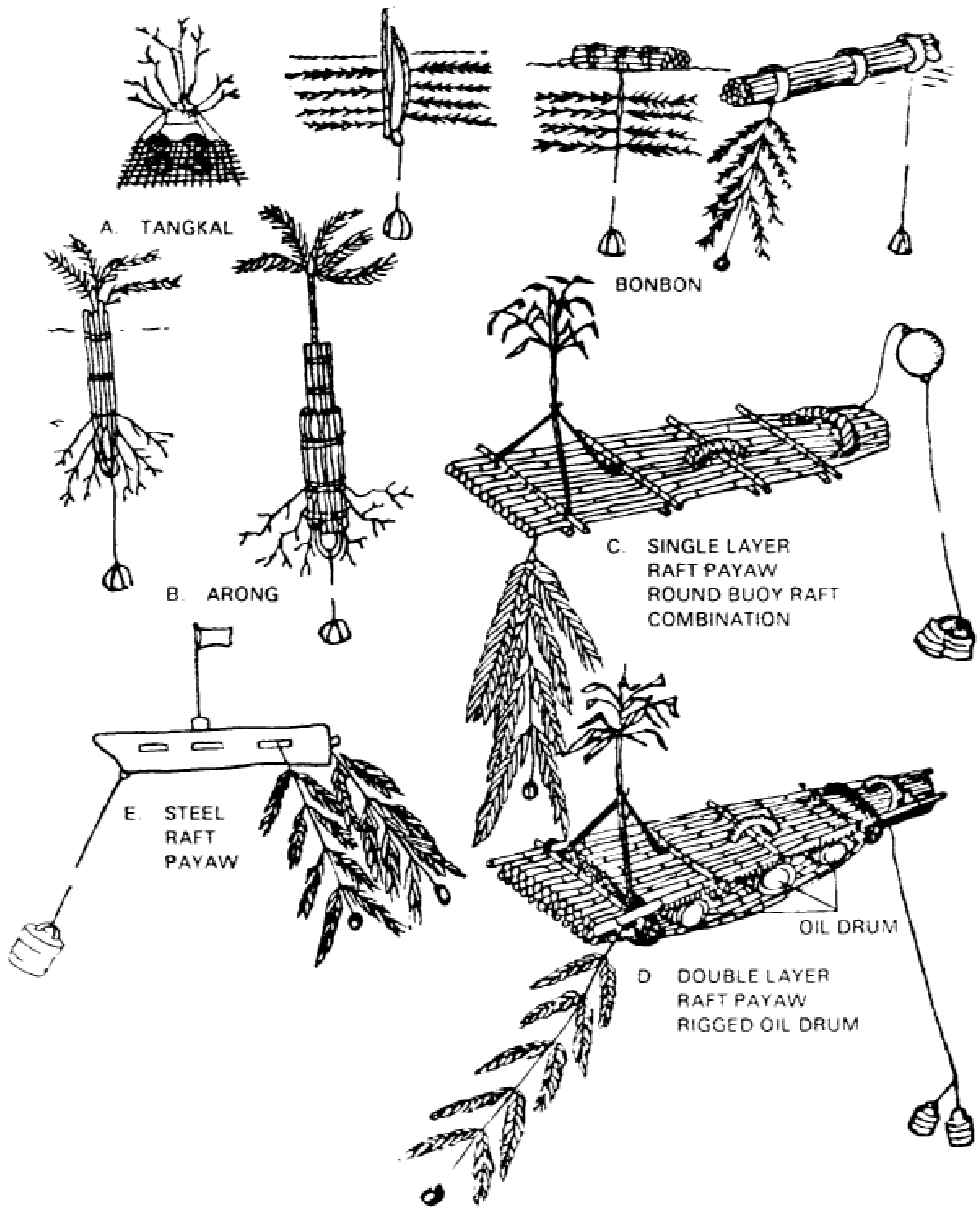
The Philippine "payaw" is probably the most well-known traditional mid-water FAD and has inspired many to produce tuna-rafts out of a variety of industrial products.

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

Figure 17

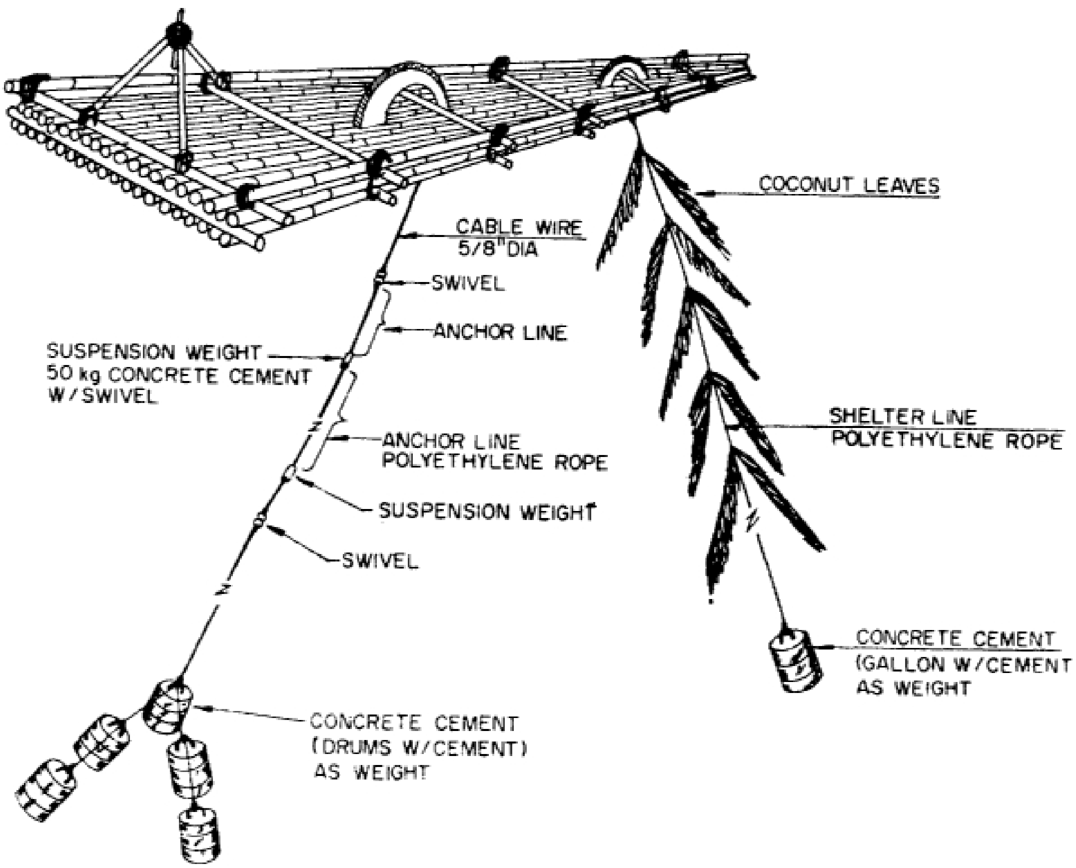


A variety of Payaw designs

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)



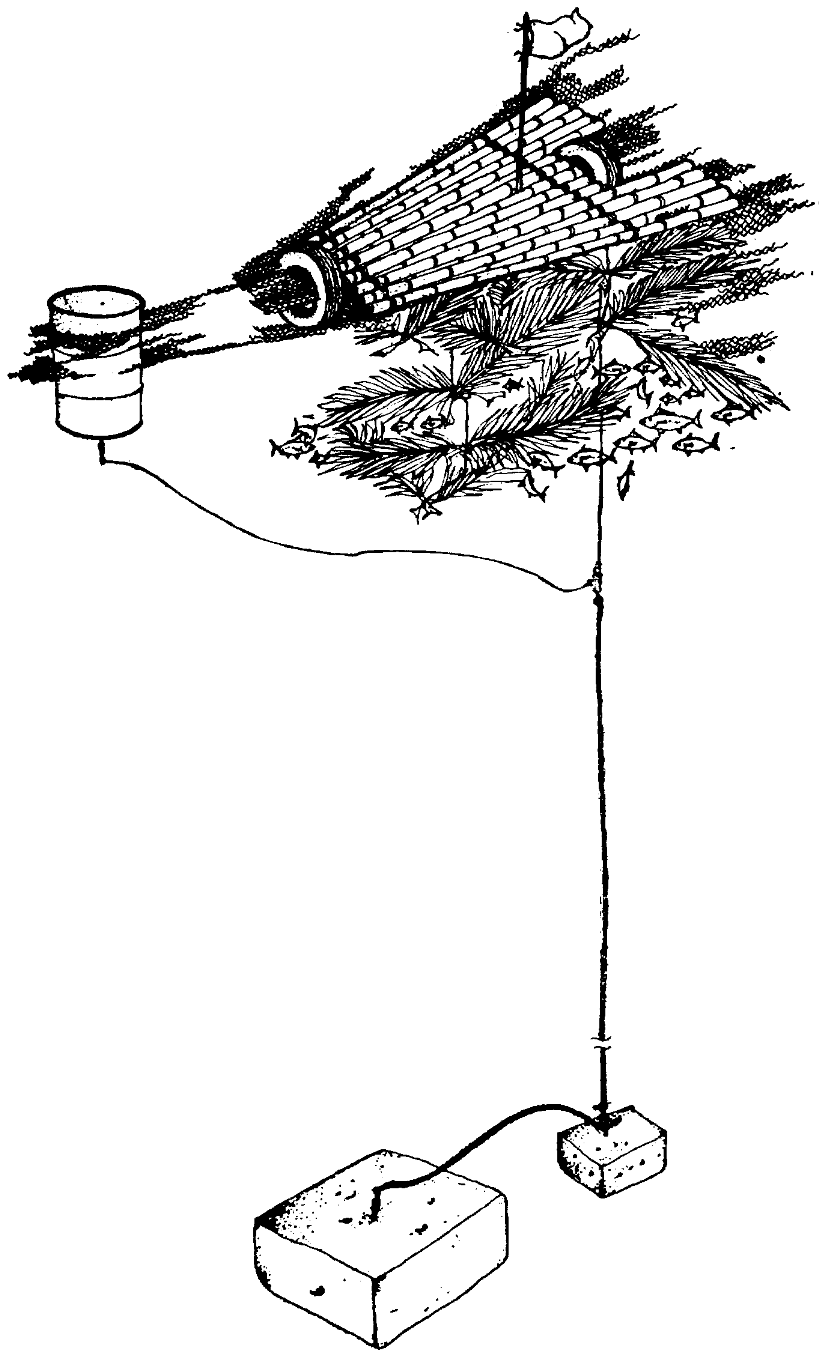
Payaws have of late been improved a great deal – especially their durability. Today's payaw is sometimes made of bambao, has one tyre around each end of the bamboo cluster and chains from the tyres to the anchoring line. Another modern variation (ref. 32) is to rig empty oil drums in a metalframe and 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 payaw, 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).

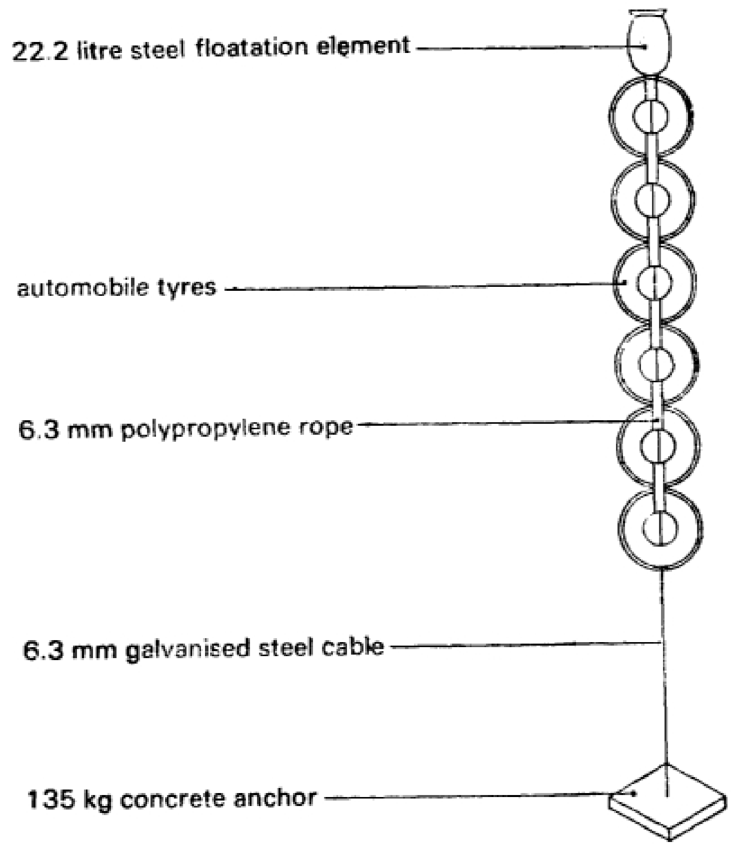
These structures were found to make the habitat more attractive to pelagic bait fish and to game fishes: "The mid-water structure area produced a markedly higher catch rate than either of the control areas and exceeded the catch rate for the existing benthic reef by 22%. Consistently, more and larger 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.

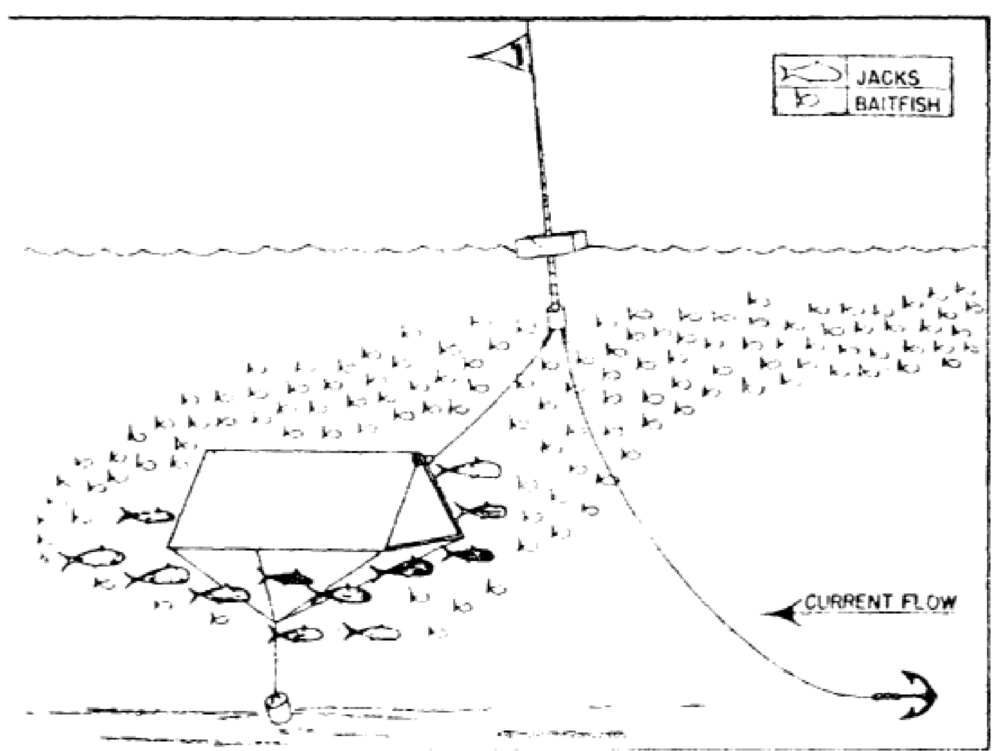
Prisms: In the Gulf of Mexico, two other structures—both painted white—were tested off Florida: prisms with vertical open slots on all three sides and prisms with vinyl cover on the two upper sides, creating a tent-shaped FAD. These structures were modelled on the successful 1968 experimental designs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

Figure 20



Diagrammatic representation of one mu/tityre midwa ter structure

Figure 21



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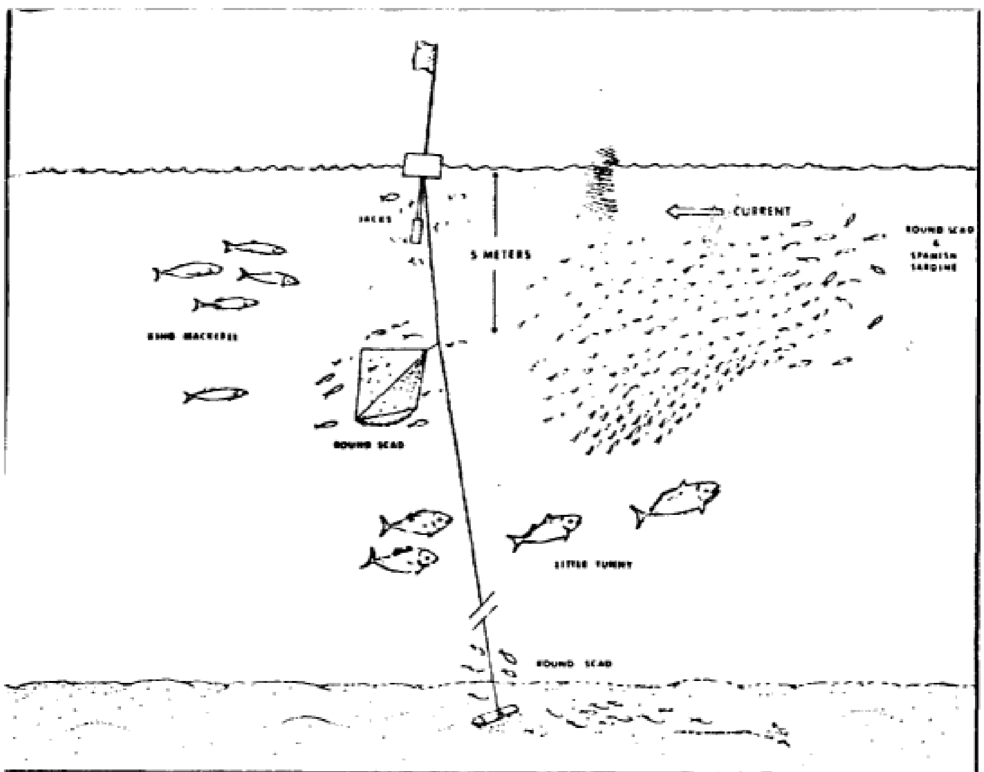
Tent-shaped prism and general position of bait fish and jacks in association with the artificial structure.

The surface and mid-water positions of the prisms were compared in the study. It showed that, on average, more than 10,000 individual fish were observed a day around the tent-shaped prisms. “Jacks” e.g. Amberjack (Seriola sp), Rainbow runner (Elegatis bipinnulatus), and Blue runner (Caranx crysos) constituted the bulk of the fish. Twice as many of these fish were found at the tent-shaped prisms as at open prisms. Also the mid-water positioning attracted more baitfish but fewer jacks than the surface positioning (ref. 6).

Pyramids and cones: White vinyl pyramids and cones were tested in another experiment in the same area in 1977 (ref. 8). These structures were deployed five metres below the surface. The cones were made of a collapsible frame covered with white vinyl cloth and the pyramids were made of a rigid negative-buoyant frame. These designs were easy to handle. (Figures 22 and 23)

Figure 22

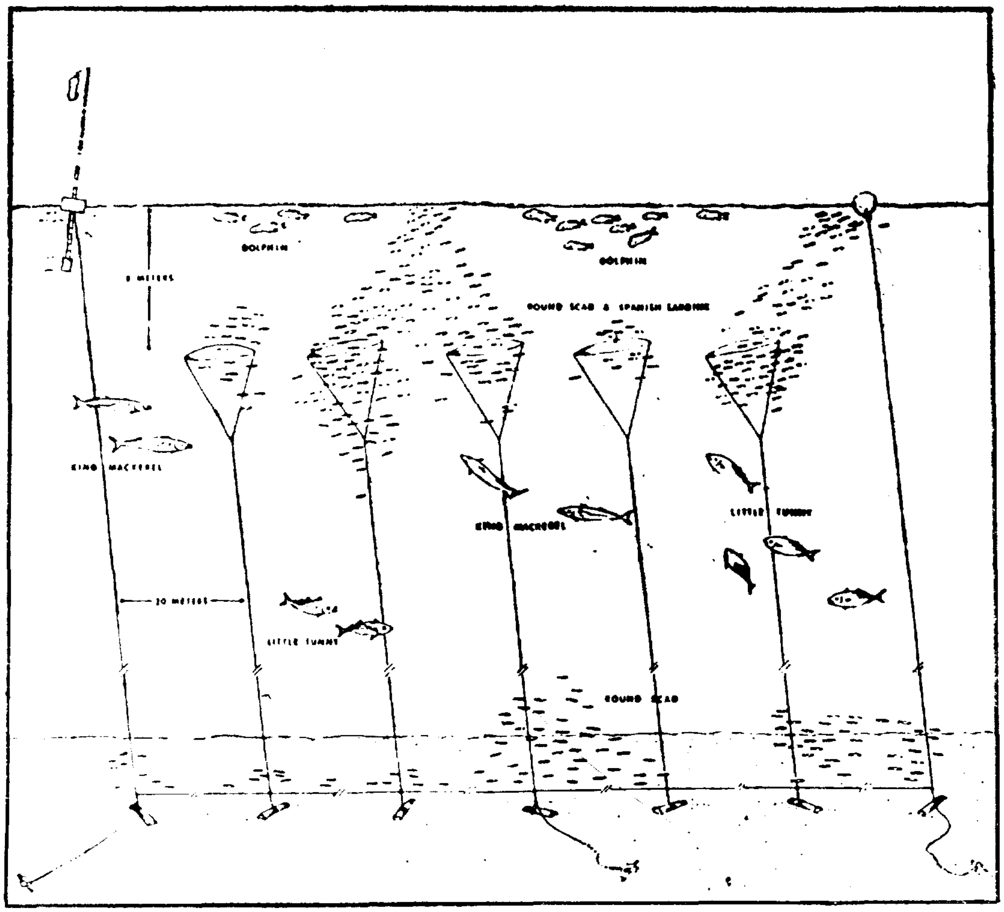


Vinyl pyramids; the mooring arrangement used for deploying single structures. The characteristic positions of fish around the structure are shown schematically.

This experiment showed that a largeF number of sport fish gathered around structure sites than in control areas. Comparing pyramids used single with cones used in groups, as in the pictures, it was seen that catches from multiples of cones were greater than catches from single pyramids. With these resLi lts as a base, the effect on catches of different FAD distances from the shore – and consequently of different water depths – was tested for multiples of cones in another experiment. Here also the structures produced larger catches than control areas at all depths. When comparing different bottom depths, it was found that better catches were produced at a bottom depth of 26 m than at either 18 or 32 m bottom depth. The different bottom depths resulted in an off-shore distance between the three sites of about 10 km.

Petroleum platforms: The underwater parts of petroleum platforms have been found to attract fish to all depths of the structure, but mostly between **9** m and 12 m of water. Examination of some platforms off California showed that there were 20 to 50 times more fish under the petroleum platforms than over a portion of the soft-bottom control area of the same size, and that the platforms had five times as much fish as nearby natural reefs (ref. **22).**

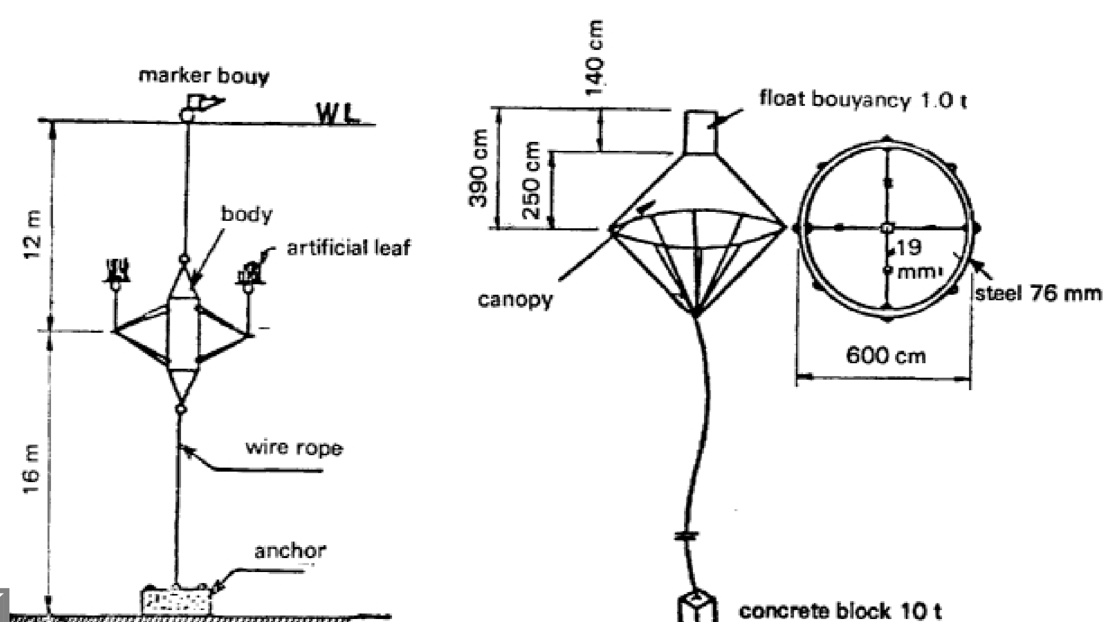
Figure 23



Vinyl cones; the mooring arrangement used for deploying multiple structures. The characteristic positions of fish around the structures are shown schematically.

Finally, here are two examples of complex floating mid-water or surface FADs from Japan. Illustrations are provided without comment – no information on performance is available. (Figure 24)

Figure 24



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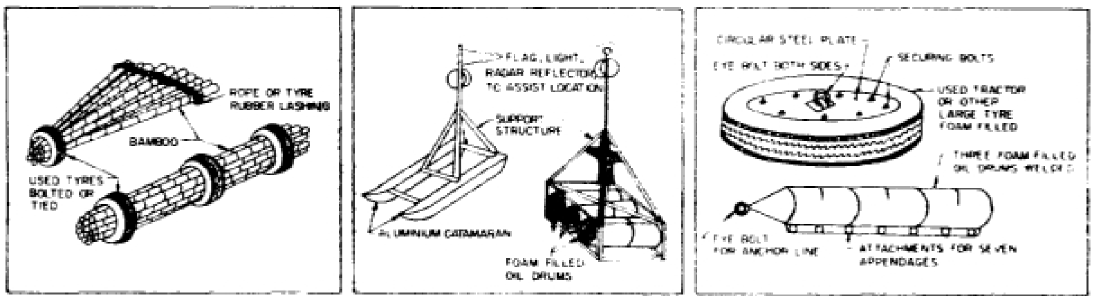
3.3(c) Modern FADs—under commercial trials: The payaw-type rafts and habong-type aggregating appendices have served as the main source of inspiration **for new designs using** modern technology. A number of such designs under commercial trials are described below.

Fiji

In the Fiji islands, five types of FADs are now on trial (ref. 26 and 20). Most rafts are made of bundles of bamboos and tied inside used tyres to different designs. Another type of raft is an aluminium kattumaram. A third on trial is made of three foam-filled oil drums welded inside a frame of angle iron, either by the side or in a line (see Figure 25). Appendages used are usually palm fronds with the bamboo rafts, and chains of used tyres with the metal rafts. Old ropes and netting material are also used. For anchoring, two or three oil drums filled with concrete are first fitted with 50 m of chain and a swivel, and then connected to a floating type rope with a midline swivel. The upper end of the rope has a terminal swivel, and to reduce the chances of chafing and vandalism, 20—30 m of chain or wire rope is inserted between the rope and the raft.

Figure 25



FAD raft types on trial in Fijian waters Illustrations by G L Preston

The results from the first year of trials (1981) have been encouraging (ref. 26). When harvesting with purse-seine around the rafts, catches have been as high as 55 tonne in a single cast. Purse-seine operators say this is certainly more than what they catch otherwise. Also pole-and-line boats are more successful around the rafts. Trolling has yielded an average of 100 kg/hour with four lines.

However, nearly 80% of the 120 rafts initially set out were lost, probably because of too thin rope, so now a thicker rope with breaking strength above 5 t. is used. The bamboo rafts have naturally a shorter life span than the metal structures but they are also cheaper. It is not clear which raft is the most cost-effective. The average life span of a bamboo raft is about one year in Fijian waters. However, where material is available, metal designs now seem to be preferred.

Japan

One raft described by Hokoku Marine Products, Japan (ref. 27) is similar to the above from Fijian waters. The differences are only minor and can be seen from Figure 26.

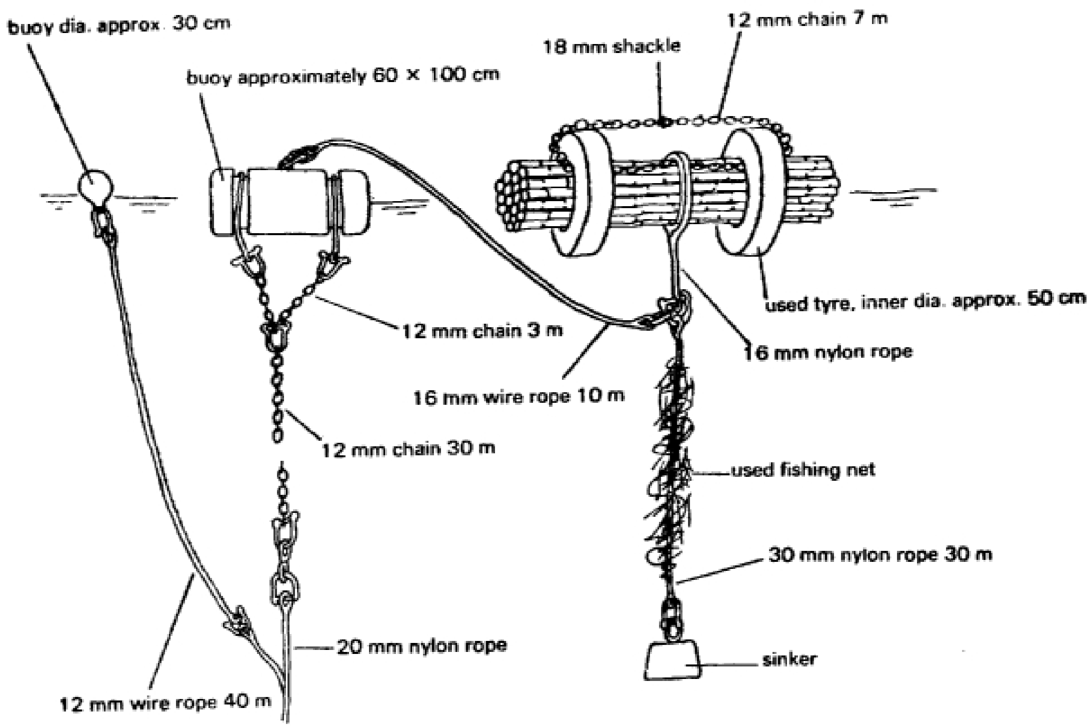
Another raft described by the same source (ref. 27) is more a payaw type (see Figures 27 & 28).

The raft in the last figure is similar to the raft commercially used since 1980 by some Japanese tuna purse-seiners: the design of this so-called “improved payaw” is given in Figure 29.

A – galvanized iron p!atform 2.5 x 8.0 m; B – flag; C – light; D – radar reflector; E – synthetic spherical float, 6 piecesx 2 lines=12 pieces; F—ring for detachment of raft; G—synthetic box-shape float covered with net; H – 5 floats of diameter 300 mm; I – 10 m lengths of appendages; J – chain weights; K – wire; L – 18 mm anchor rope, 1 Dan-rain 4.4 ton breaking strength; M – counterweight; N – **18** mm anchor rope, 2 Dan-rain; O – anchor chain 9 mm; P – anchor weights of concrete, each 480 kg.

This raft has been in commercial use since late 1980. Till November 1981 (ref. 34), these rafts faced no major problem in withstanding wind, waves and current. However, four platforms

Figure 26



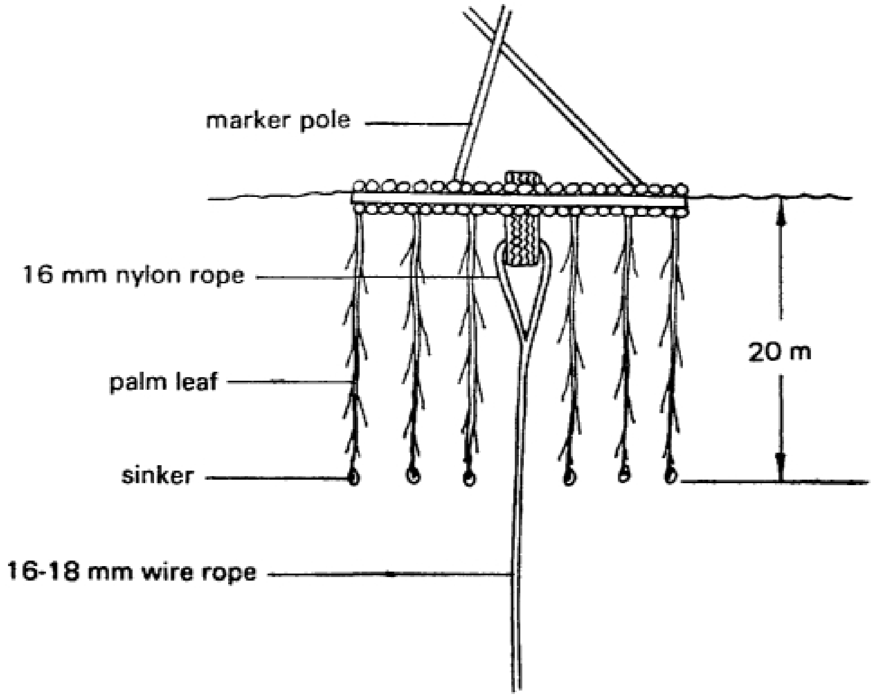
Modern raft from Japan

were lost for other reasons: one raft due to cutting of the anchoring line by a ship's propeller, and the three others due to a joining shackle breaking because of friction-chafing. Those rafts started to aggregate bonito, yellowfin tuna and other tuna-like fish 40 to 50 days after deployment. Catches taken by 500-tonne and 1000-tonne purse-seiners so far range from a low of 10 tonne to a high of 96 tonne with an average of about 30 tonne per visit. Catches consist of 70—80% bonito, 15—20% yellowfin tuna and 5—10% miscellaneous fish. The total cost for one complete construction, including anchors, chain rope, raft, mooring and buoys, but excluding the cost of actual deployment, was in 1981 Japanese Yen 900,000, at the time equal to about US $ 4000.

American west coast

Tuna-aggregating devices are also under commercial trials off the American west coast: the Inter-American Tropical Tuna Commission (IATTC) anchored five rafts off Mexico during late 1980 (ref. 33,16,18 and 17). The design is given in Figure 30. Unfortunately, three rafts were lost at early stages —two in storms, they were built of lumber and might have broken up; and one when the anchoring device broke as a result of a tuna boat seining around the raft itself. The lack of any ballast makes the raft capsize-prone and one raft capsized. However, one of these FADs withstood a hurricane with winds of up to 105 knots, so it is difficult to determine any single factor that limits the durability. This device was a '1.2 m x 3.6 m x 20 cm raft, made of plyboard and filled with foam. The mooring consisted of a swivel attached to a cross-piece on the raft, a 35 m long 12.6 mm wire rope and a rope section. The ends of the wire rope were spliced around thimbles. The rope section consisted mostly of 15.8 mm polypropylene rope in the upper section, with the lower sections of 18.9 mm and 22.1 mm rope. 25 mm galvanized swivels were inserted between rope coils and the ends of the rope were knotted to the

Figures 27 and 28



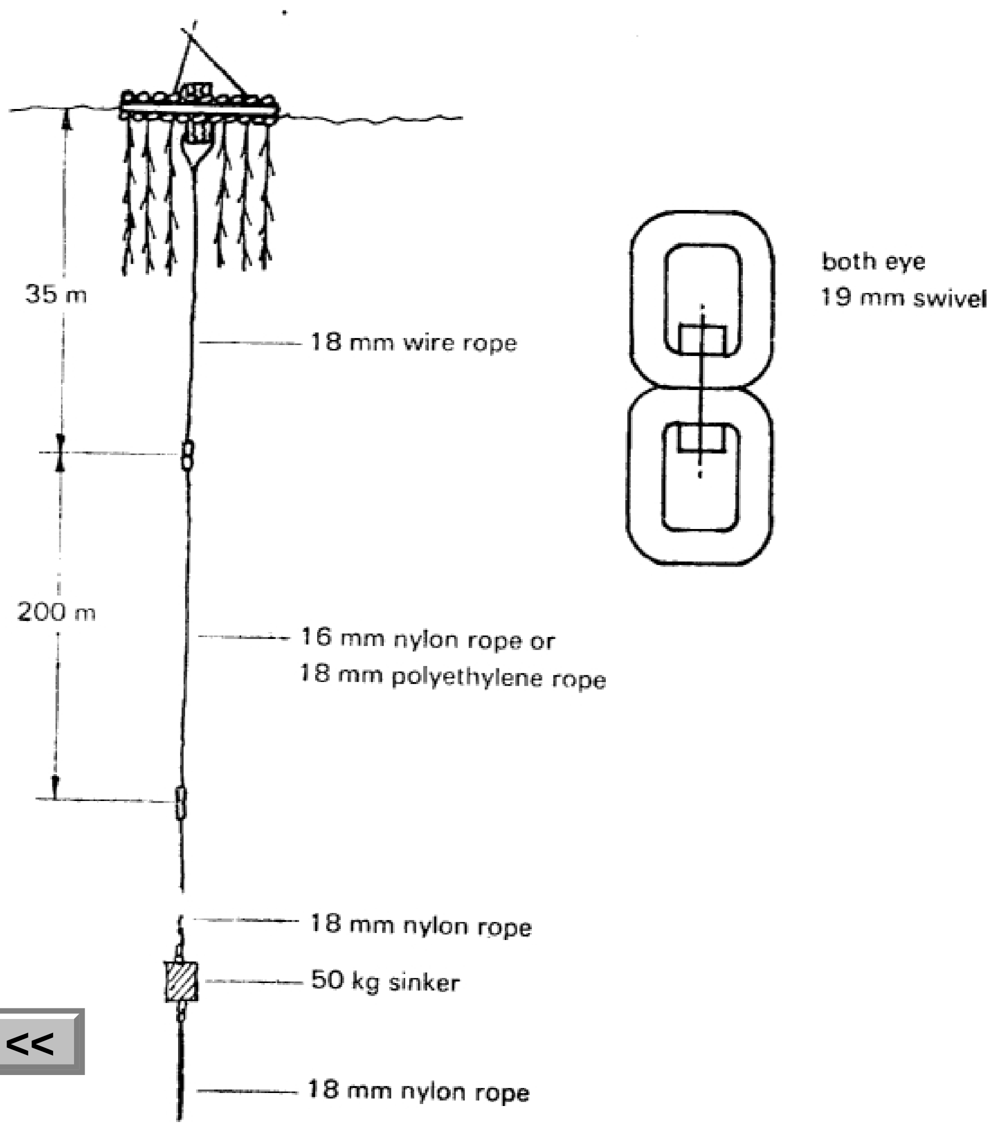


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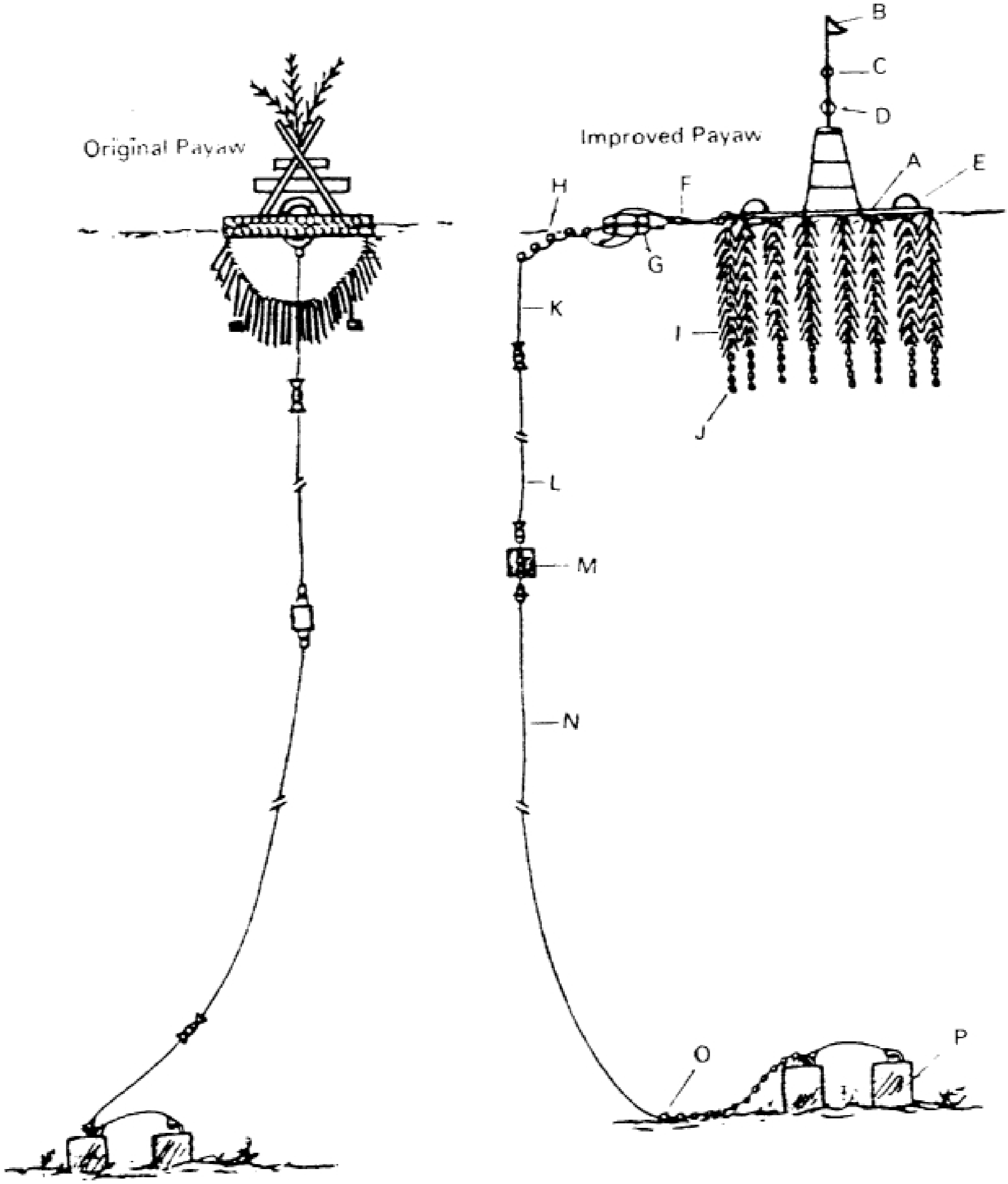
Figure 29



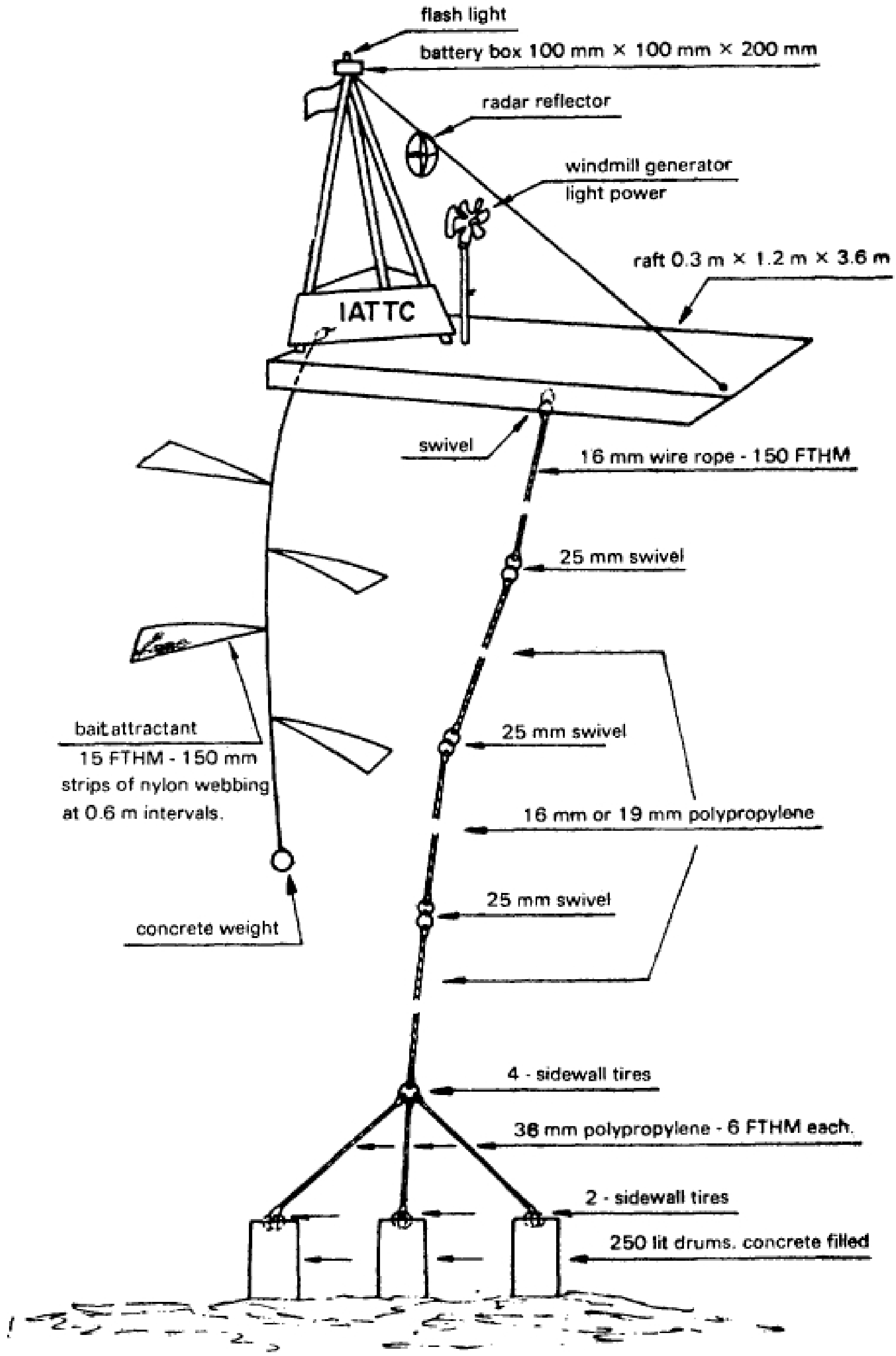
Drawing by Kanagawa International Fisheries Training Centre, Japan.

swivel eyes. At the lower end, the rope end was knotted around four tyre sidewalls. Three 25 mm polypropylene rope bridles led from the four tyre sidewalls to two tyre sidewalls embedded in concrete in each of three 245 litre drums. The mooring line had a scope of nearly 1:1.

Hawaii

Perhaps the earliest and the largest commercial trials with anchored FADs were started jointly by the Pacific Tuna Development Foundation and the Southwest Fisheries Center in Hawaiian

Figure 30



FAD set out off the North American west coast by the Inter-American Tropical Tuna Commission

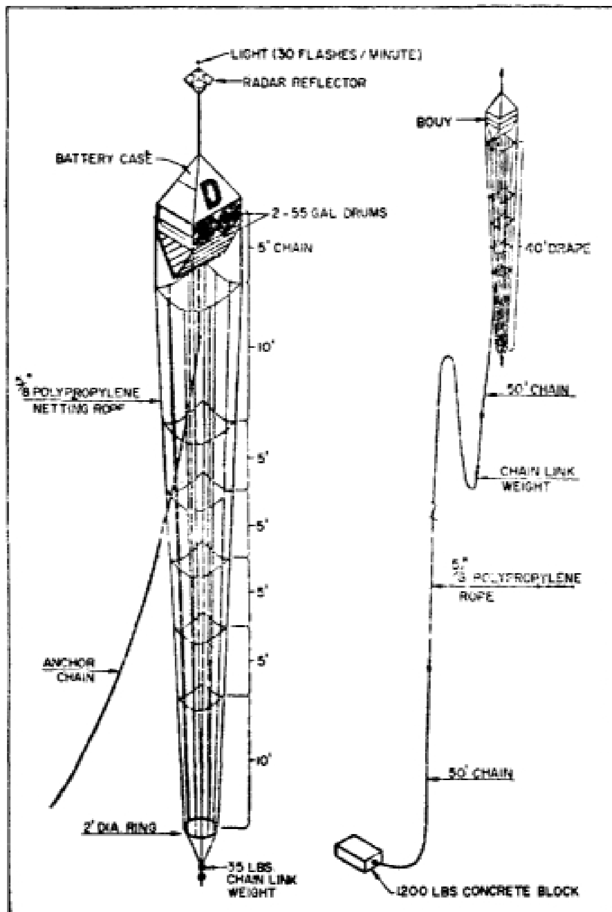
Information about the ability of these IATTC rafts to aggregate fish is not available.

waters in May 1977. The results were published in *Marine Fisheries Review,* September 1981. The following is a summary of that report (ref. 21). "The primary objectives of the project were to: (1) Develop and test anchored fish aggregating devices in open ocean areas and (2) Determine their effect on the skipjack tuna pole-and-line fishery in Hawaii. Secondary objectives were to determine the effects of buoy placement relative to distance from land, depth and bottom topography. Two types of FADs were used:

The first type had a buoy of two oil-drums filled with polyurethane foam and held together by bars of 7.5 x 7.5 cm angle iron. The underside of the frame was given a U-shape and fitted with wooden slots to provide space for small fish and to make the buoy more stable. (See Figure 31)

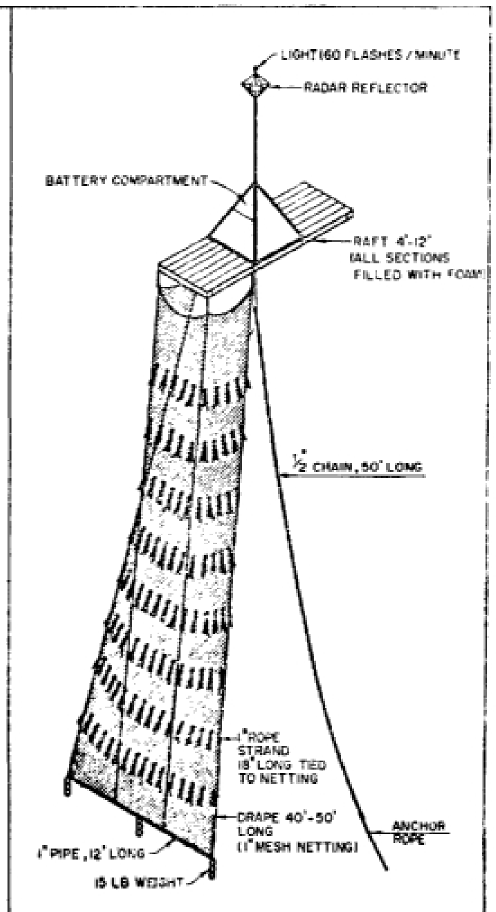
The second type had a raft made of 5x15 cm wooden planks in two layers with 10x10 cm cross pieces between, all bolted together, and the space was filled with polyurethane foam. (See Figure 32)

Figure 31



FISH AGGREGATING DEVICE, BUOY TYPE

Figure 32



FISH AGGREGATING DEVICE, RAFT TYPE

Both types were topped with pyramids of wood and angle iron with a radar reflector and a warning light. The anchor consisted of a 540 kg iron-reinforced concrete block with a 19 mm galvanized eye-bolt. The anchorline consisted of 15 m lengths of 13 mm galvanized chain at the top and bottom and intermediate section of 16 mm twisted polypropylene rope. The ratio of anchorline to depth was between 1.65: 1 and 1.80: 1. The scope caused a section of the buoyant anchorline to reach the surface periodically, so a chain link weight was added to the upper one-fourth to one-third of the anchorline to keep the excess line submerged at all times.

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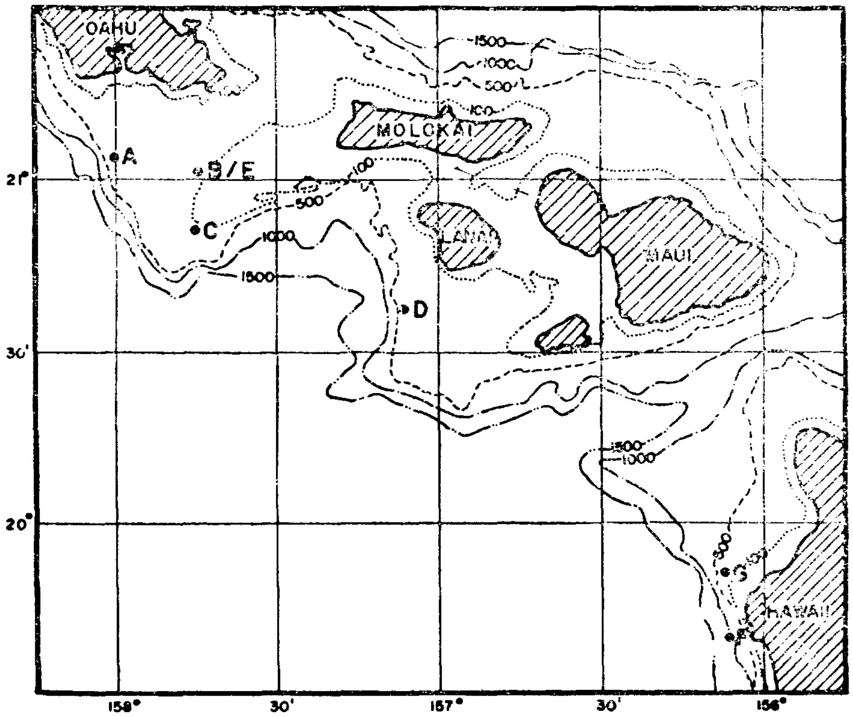
The locations of the anchoring sites can be seen in Figure 33.

Figure 33



Fish aggregating devices off Oahu, Lanai and Hawaii

These FADs were monitored and maintained monthly, but more frequently at the peak of the skipjack fishing season. On each visit the FADs were fished by trolling. Catch data were collected from commercial pole-and-line and recreational trolling fishing boats visitingtherafts. In addition, echo sounders were used to detect subsurface schools.

Fish began to gather very early—one to three weeks after anchoring. Common dolphinfish (Coryphaena hippurus) and wahoo (Acanthocybium solanderi) were the first species caught.

Two to five weeks after deployment, schools of yellowfin, skipjack and eastern little tunas started to appear. The first to show up were individuals, each weighing a half to two kg, later larger individuals joined. Simultaneously, a variety of other fishes appeared.

As the aggregates of fish grew, so did the fishery around the rafts; in some cases 30—50 boats visited the same FAD on one day.

Test fishing by trolling at different distances away from the rafts showed that up to 1 km away the catches were significantly higher. This proved that the raft successfully aggregated fish,

The commercial pole-and-line fishery was initially reluctant to report catches around the rafts, as the boats that first fished the FADs found catches so good that they did not want others to be there. However, after a while the effectiveness of the FADs was widely known. At the peak of the 1978 skipjack season the pole-and-line fishery around the rafts contributed 40—60% of the monthly cannery landings in Hawaii. The tuna held by the rafts were however smaller, and for a few months of fishing season for other migrating fish, the effort was diverted away from the rafts. The catch composition by pole-and-line fishery was:

– Skipjack tuna	89.7%;	1—5.5 kg/piece
– Yellowfin tuna	9.3%;	1—5.5 kg/piece
– Eastern little tuna	0.6%;	1—5.5 kg/piece
– Common dolphinfish	0.3%;	4.5—13.5 kg/piece

The trolling fishery did not experience as dramatic catches as the pole-and-line fishery, but the number of trolling days without *any* catch was significantly reduced through fishing on the FADs.

Another interesting fishery attracted to the raft was the local speciality "drop-stone" fishery for very large 50—200 lb (25—90 kg/fish) yellowfin tuna accompanying schools of porpoise. Here a handline with bait and a chum bag attached to a stone is lowered to 55—110 m where the chum bag is jerked open to expose the bait and chum. In the path of schools of porpoise at one raft, such "drop-stone" units were able to catch three to four of the very large yellow-fin tunas per day.

In general, it seemed that smaller fishes below 1.5—2 kg remained at the buoys and occupied the water column down to around 75 m. Larger individuals of mainly yellowfin and skipjack tuna seemed to venture several miles from the FADs in daytime but returned in the evening. It was evident that several tuna schools were present at the same buoy at the same time.

It was thus seen without doubt that the FADs were a boon to the pole-and-line fishermen, particularly with respect to more economical use of baitfish, reduction of time lost in baiting and searching for tuna schools, and reduced fuel costs. The buoy test resulted in two important side benefits. "One was the heavy use of the buoys by trolling boats, the other was the use of the buoys by drop-stone commercial fishermen, who were able to extend the fishing for the porpoise-associated tunas from one to several days and to fish in the absence of porpoise schools".

The buoy designs seemed adequate. However, in one case, the two-oil-drum structure was dragged by heavy current. It was suggested that the buoy be made of three oil drums instead of two and that the anchor weight be increased to 900—1350 kg. Other modifications suggested were attachment of the anchorline to the forward end of the buoy, increasing ballast weight to improve stability and extending the appendage drape to 180 metres.

On the basis of the positive proceedings of this pilot project, the State of Hawaii's Department of Land and Natural Resources (DLNR), Division of Fish and Game (now Division of Aquatic Resources), implemented a project with 26 buoys. Their "first generation" of FADs deployed during 1980 were each constructed of one 6 ft. diameter 22 in. wide rubber tyre, enclosed by steel plates over the open sides and filled with polyurethane foam. Other features of the buoy can be seen in Figure 34.

The mooring line configuration is given in Figure 35. The top of the bridle was shackled to the two pad-eyes through a split chain connecting link. The lower end of the bridle was connected to a bronze swivel by a split chain connecting the links and the swivel was shackled to 30 m of 38 mm chain. The lower end of the chain was attached to a swivel through a split chain link and the swivel was shackled to the rope and fitted with a 19 mm Newco bronze thimble. Similar links were made below the intermediate chain weight and at the anchor chain. The top of the intermediate chain weight was linked without any swivel.

The FAD was moored to a 1350 kg Baldt or Danforth anchor to which 9 m of 13 mm chain was attached with a 19 mm shackle and split chain link. The body of the mooring line consisted of 19 mm polypropylene medium-lay rope. The rope sections were connected to each other by a single splice consisting of about 10 tucks (ref. 17).

These FADs were moored around the main Hawaiian Islands in early 1980 in depths ranging from 450 to 2,200 metres. During the first year '12 buoys were lost, the reason in most cases was believed to be strong winds or heavy currents severing the anchoring line.

The catches between April 1980 and November 1981 around these buoys were estimated at more than 675 tonne. The total catch consisted of skipjack tuna 57%, yellowfin tuna 28%, common dolphinfish 5%, billfishes 7% and others 3%. A cost benefit ratio of 1: 3 has been estimated, based on the value of the catch. If, however, fuel savings and other "indirect" benefits are also considered the ratio may be near 1:6 (Katekaru, December 1981, ref. 28).

Following the loss of nearly half of the buoys, a new design was developed in 1981. The production cost of this so-called "pentasphere-FAD" (Figures 36 and 37) was about US $ 700 each. This design has now replaced the "tyre type".

Figure 34

State of Hawaii's first FAD design

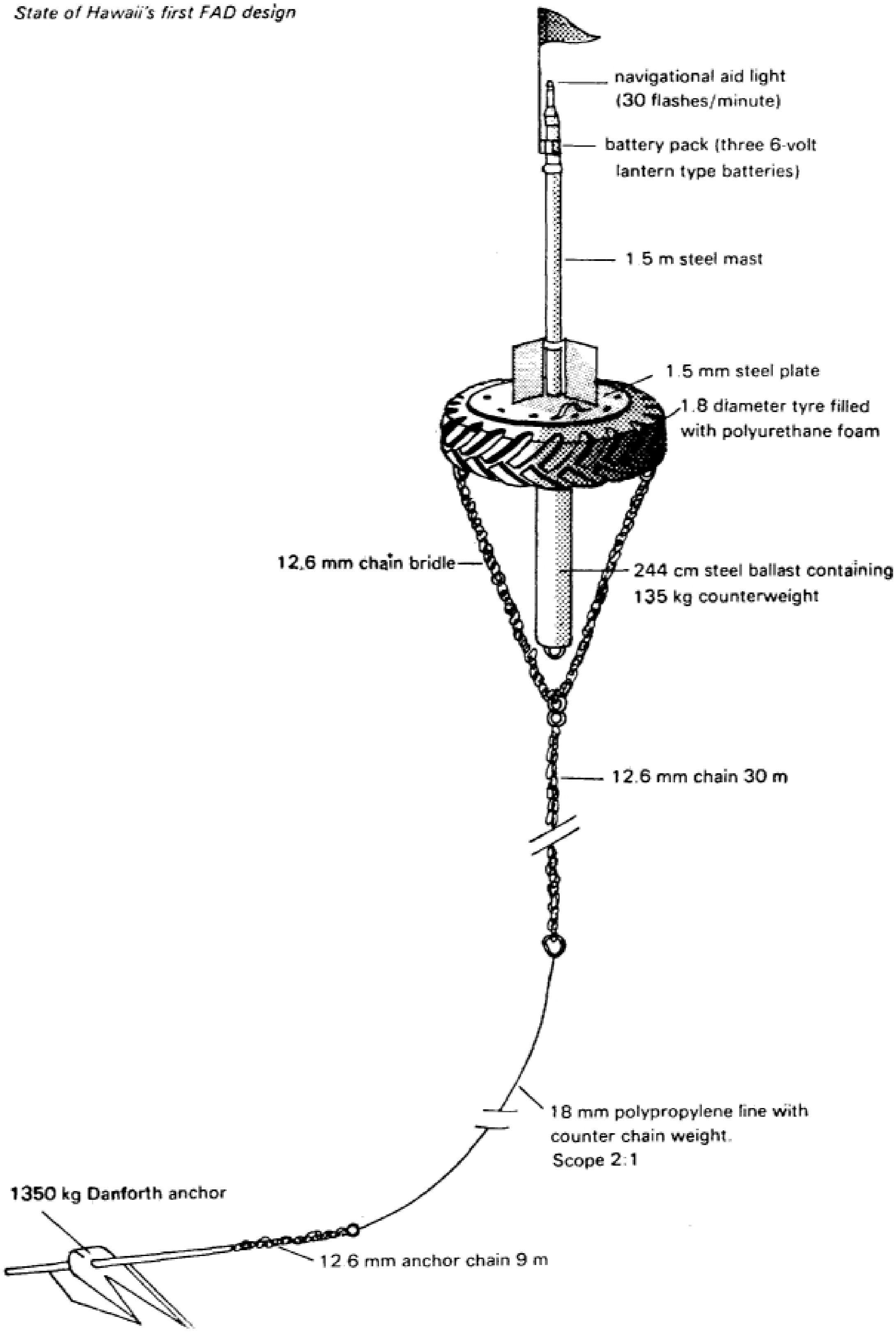
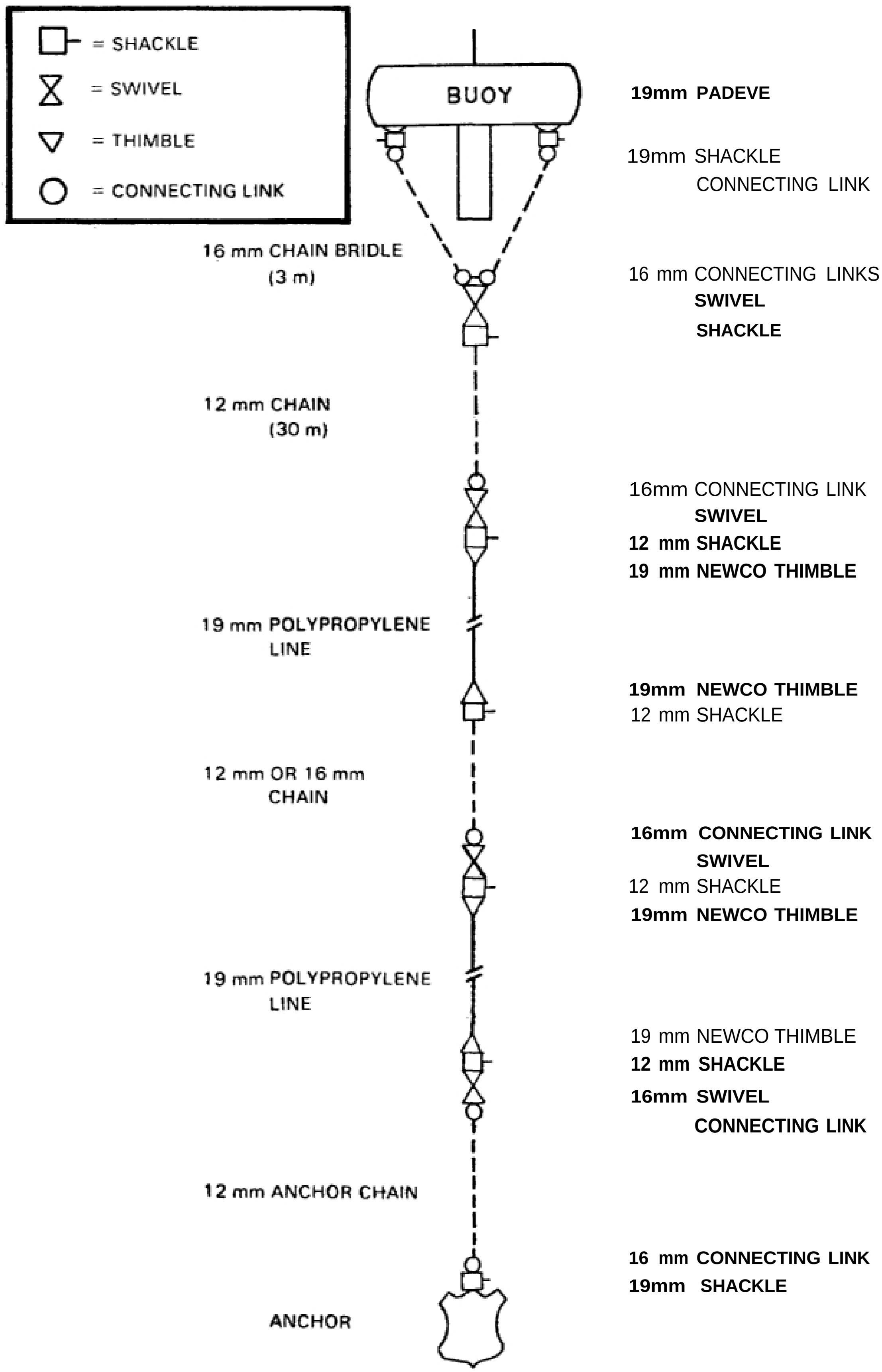


Figure 35



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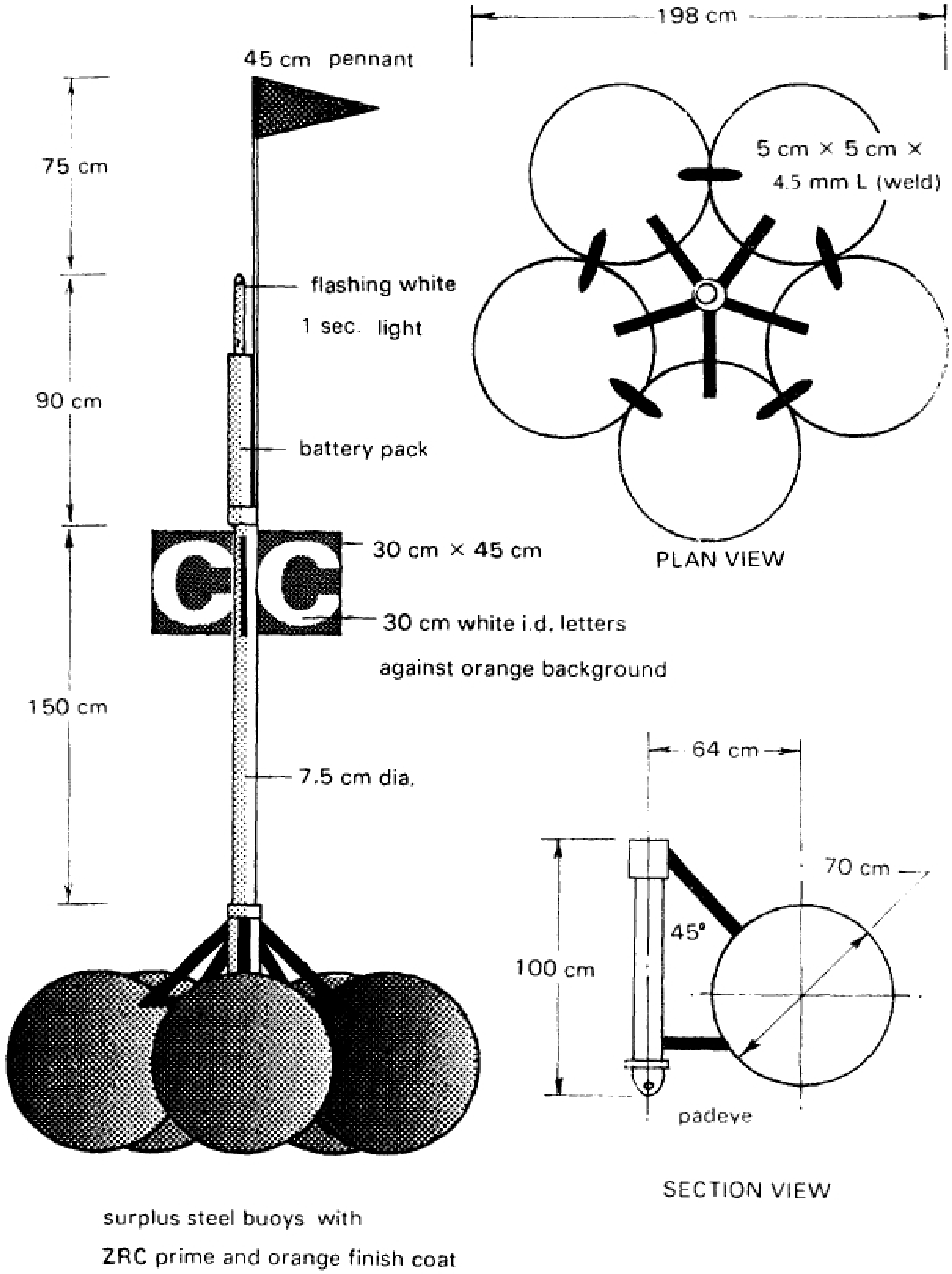
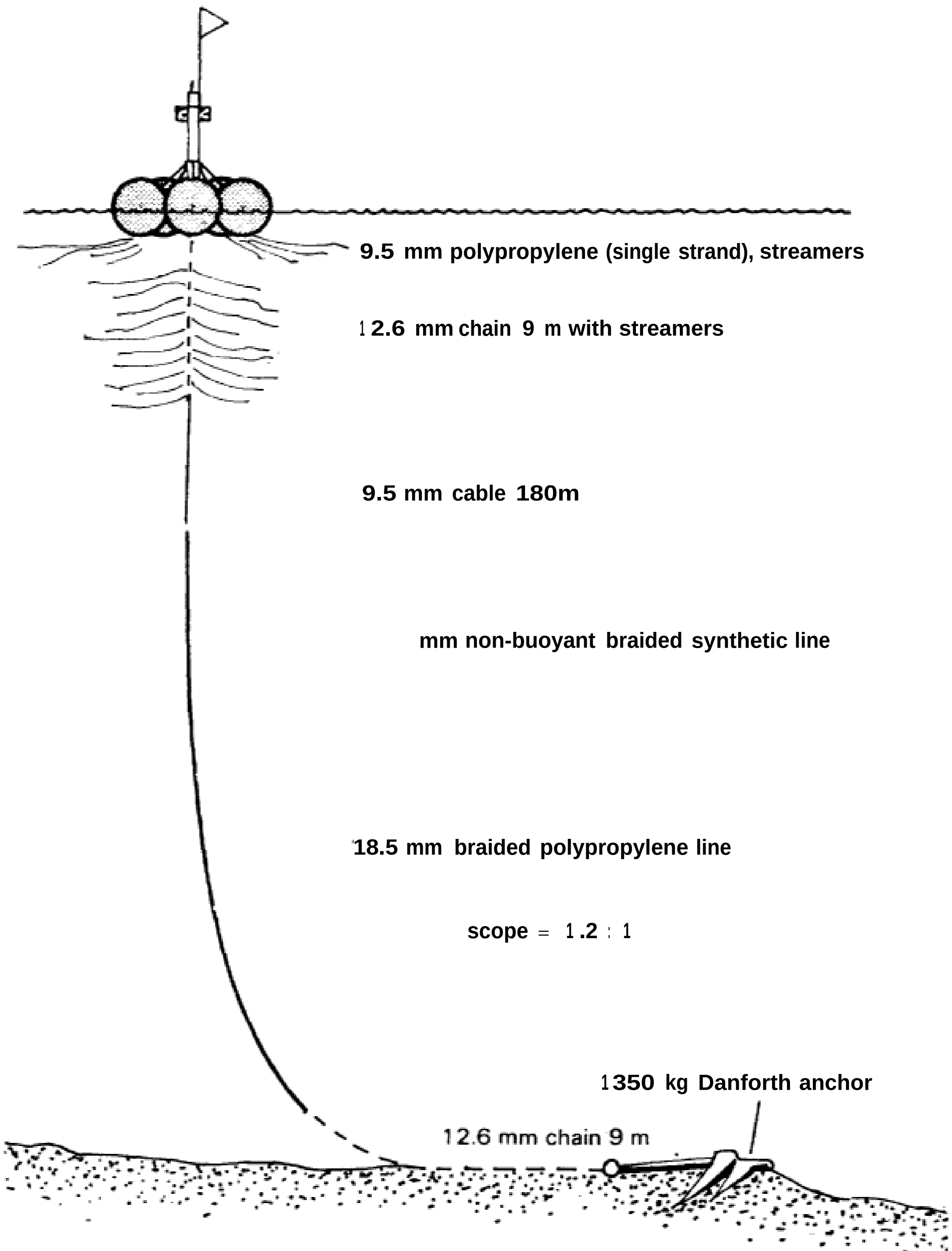
HAWAII FISH AND GAME MOORING DETAILS

Figure 36



State of Hawaii's "Pentasphere" buoy design 1981
Illustration by A. Z. I('atekaru

Figure 37



Mooring details of State of Hawaii's "Pentasphere FAD
Illustration by A. Z. Katekaru

Ma/dives

In the Maldives, another FAD project was launched in 1980 by the Ministry of Fisheries together with FAO, using some of the experiences from Hawaiian and other Pacific waters. Ten FADs of five different designs were constructed and deployed at different times during 1981 and early 1982 (FAD ref. No. 36). The first six FADs were of design types “oil drum”, “spar buoy”, “wood box” or “vessel hull”. By April 1982 all six were lost after a life-span in water of between 1 and 206 days. Reasons for loss were assumed to be “human interference”, “storm/severed anchorline” and “subsurface topography”.

The aggregating of fish around these buoys was, however, successful. The FAD with the longest lifespan is said to have yielded over 350 tonne during its 206 days in position before being lost in a storm. Even during months with normally low yield in their respective areas, catches around some FADs were satisfactory.

The fish most commonly found aggregated were skipjack, yellowfin, common dolphinfish, rainbow runner, frigate mackerel and little tunny. Skipjacks caught reportedly varied in weight from 1 to 5 kg, yellowfin from 4 to 8 kg and frigate mackerel up to 2 kg.

The other four FADs subsequently built were of the “rubber tyre” type. These were deployed and in April 1982 all four of them were still in position, the first having been deployed more than two months earlier. The design of the rubber tyre type FAD was also adjusted according to the experiences of the first six FADs and the assumed reasons for their loss. The life span in position of the rubber tyre FADs is therefore expected to considerably exceed that of the others. The advantages of the rubber tyre FADs over the other designs are said to be:

- little resistance to strong currents
- very buoyant due to the foam filling
- can remain vertical even in strong currents
- high longevity
- can be made less attractive to vandalism
- the water resistant foam always maintains its buoyancy
- rubber tyres facilitate approach for servicing and minimise risk of vessel damage.

The FAO consultant in the Maldives, C. Peters, describes the rubbertyre FAD as follows (ref. 36) “Old scrap tyres were individually filled with polyurethane foam and bolted together. The resultant cavity was also filled with foam and a thin sheet of steel plate was used to cover and secure both openings of the cavity. A galvanized steel pipe is located through the centre of the cavity! foam and welded to both the steel plates, so that one end of the pipe is used for a mast and the other to attach ballast. The three bolts which passed through the tyres were welded to the steel plate with the ballast-end of each bolt as an eye used to attach the anchorline. The mast was equipped with a red canvas flag, a radar reflector, and blinking orange light. The ballast consisted of three links of heavy anchor chain. The bait attractant was made from old nylon fish netting sewn directly to three lengths of chain attached to the three bolts. The lower ends of these chain sections met at a common point which was connected to a single length of chain to the polypropylene rope. This single length of chain also had netting secured along its length.

“This FAD is the strongest of all types, it remains vertical and is not dragged under water as it offers only little resistance to strong currents. This FAD is also very buoyant since every available space is filled with foam. Four tyres per FAD were used so that, with ballast, two tyres were submerged and two above the water. The buoyancy remained essentially the same with the addition of 40 m of 9.5 mm steel chain weighing approximately 80 kg.

“By using a bridle arrangement to connect the FAD to the anchorline, the FAD remains in a vertical orientation when under the influence of strong currents. The shape of the tyres facilitates water flow. The tyres last an indefinite time, being completely resistant to water damage, vessel collision, worms, etc. This type of FAD also resists human interference since all metal-to-metal points of contact are welded. Since the polyurethane foam is resistant to water absorption, the FAD buoy need not be watertight, therefore old scrap tyres with holes are encugh. The FAD body, being made of rubber, facilitates servicing without fear of damage to the vessel. This aspect is also favourable when considering the possibility of collision with a wood or fibreglass vessel. The tyres were painted orange to give them high visibility."

Alterations to this design are suggested in the report. "The chain sections connecting the FAD to the synthetic fibre rope have been lengthened to 15 m to increase overall mooring line strength and to increase bait attraction. Therefore, the basic design has been slightly modified, increasing overall buoyancy to compensate for the additional chain weight. Five tyres are used in place of the four-tyre design of the Maldives and the mast is about one metre longer to increase visibility."

The total cost of these rubber tyre FADs has for each of them been less than US $1500, including the buoy, anchorline assembly for 2000—3000 metres each and local labour. Their longevity and aggregating ability are now to be documented but there is no reason to believe that these buoys should be less effective than others. The design is £hown in Figures 38 and 39.

Samoa

FADs have been reportedly successful in Samoan waters also. There, a modification of the Hawaiian raft was tried but a rather different design of raft, as shown below, has also been in use since mid-1980. (See Figure 40.)

The intention of this arrangement is that the raft shall not easily twist. The twin hull design plus the three-chain arrangement with one chain shorter and attached at a centre bow point will help ensure this. This design can be expected to stay in direction even in mild winds or weak currents. Breakage in the mooring will probably first occur when the upper part of the main line (chain, wire or rope) is not strong enough to withstand the dynamic stretching forces caused by waves.

These rafts placed in deep waters near fishing villages have greatly increased catches and reduced fuel consumption (ref. A). In 1981, Western Samoa fishermen caught a surplus of tuna that was exported to canneries in American Samoa. This was a result mainly of increased catches around aluminium FAD buoys of the above design.

Further trials with purse-seining for skipjack and yellow fin tuna have recently been showing such promising results that additional FADs for this fishery may be set 30—40 miles offshore.

Australia

In Australia, interest in FADs is growing. Apart from a number of artificial reefs along the Australian coast, three mid-water structures have been reported to be on trial.

Off the southern coast of Western Australia, FADs made after the Hawaiian design but adapted to local conditions were towards the end of 1981 reported (ref. B) to yield large catches of tunas. During their first year at anchor, almost one-third of the area's tuna catch of 1300 tonne had been taken within a 5 km radius of the FADs.

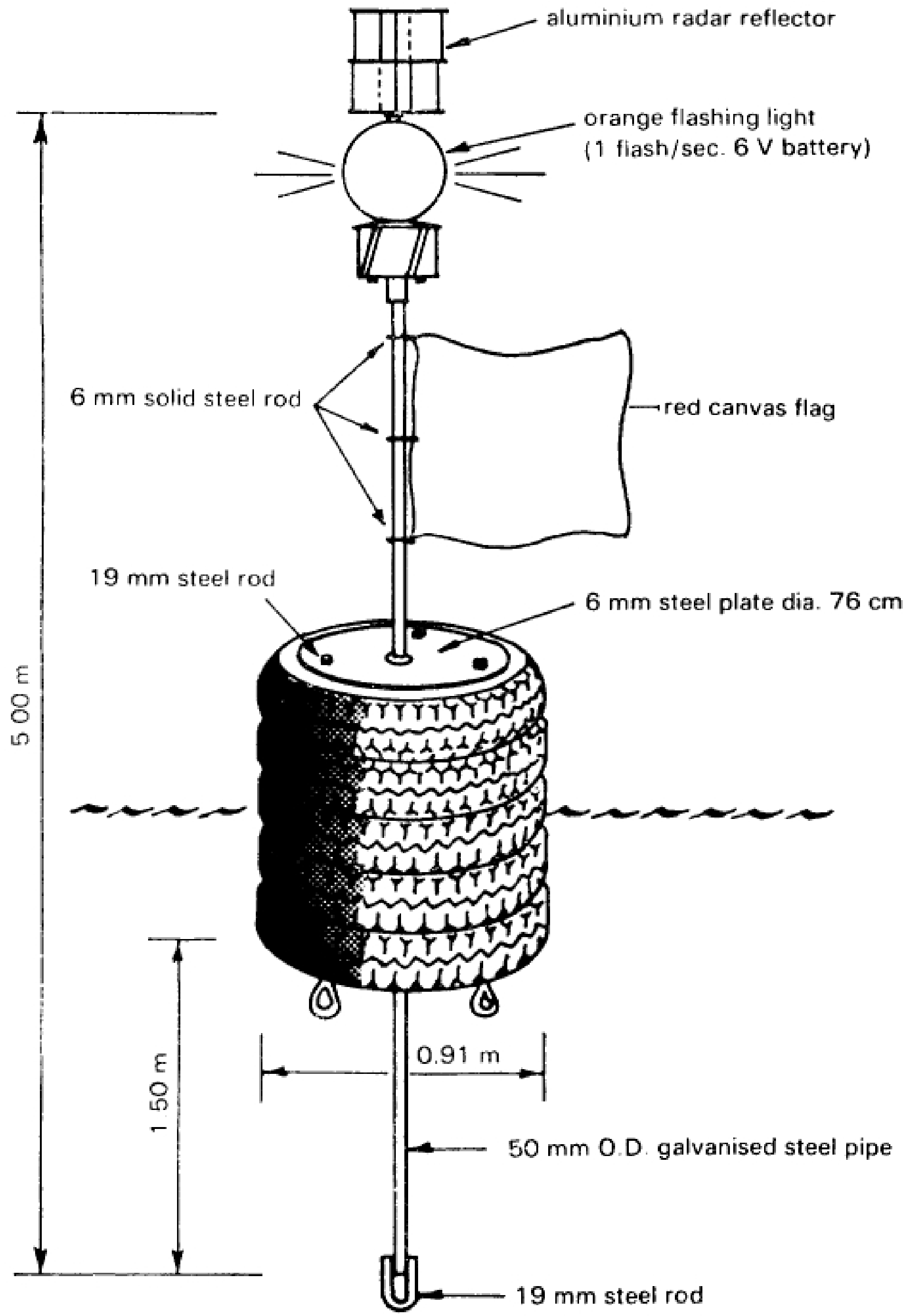
Another FAD type reported from Australia has been set off Sydney at 100 fathoms, mainly to assess the value of such devices for anglers. The attracting appendix here Consists of a black plastic mesh 15 m long and 4 m wide. This mesh is attached 4 m beneath the surface to the buoyed chain running to the seafloor. Pelagic fish such as yellow fin and striped tuna, kingfish, common dolphinfish, wahoo and marlin are expected to be attracted by the mesh. (Figure 41)

The third FAD in Australian waters is the one being tested by the Tasmanian Fisheries Development Authority in 150 metres of water close to the main drop-off of the continental shelf in south-eastern Tasmania.

This recently moored 1.5 m diameter buoy supports a 3 m plastic pole, buoy and pole painted fluorescent orange. Beneath the buoy is 30 metres of rope threaded with lengths of plastic straps (ref. C).

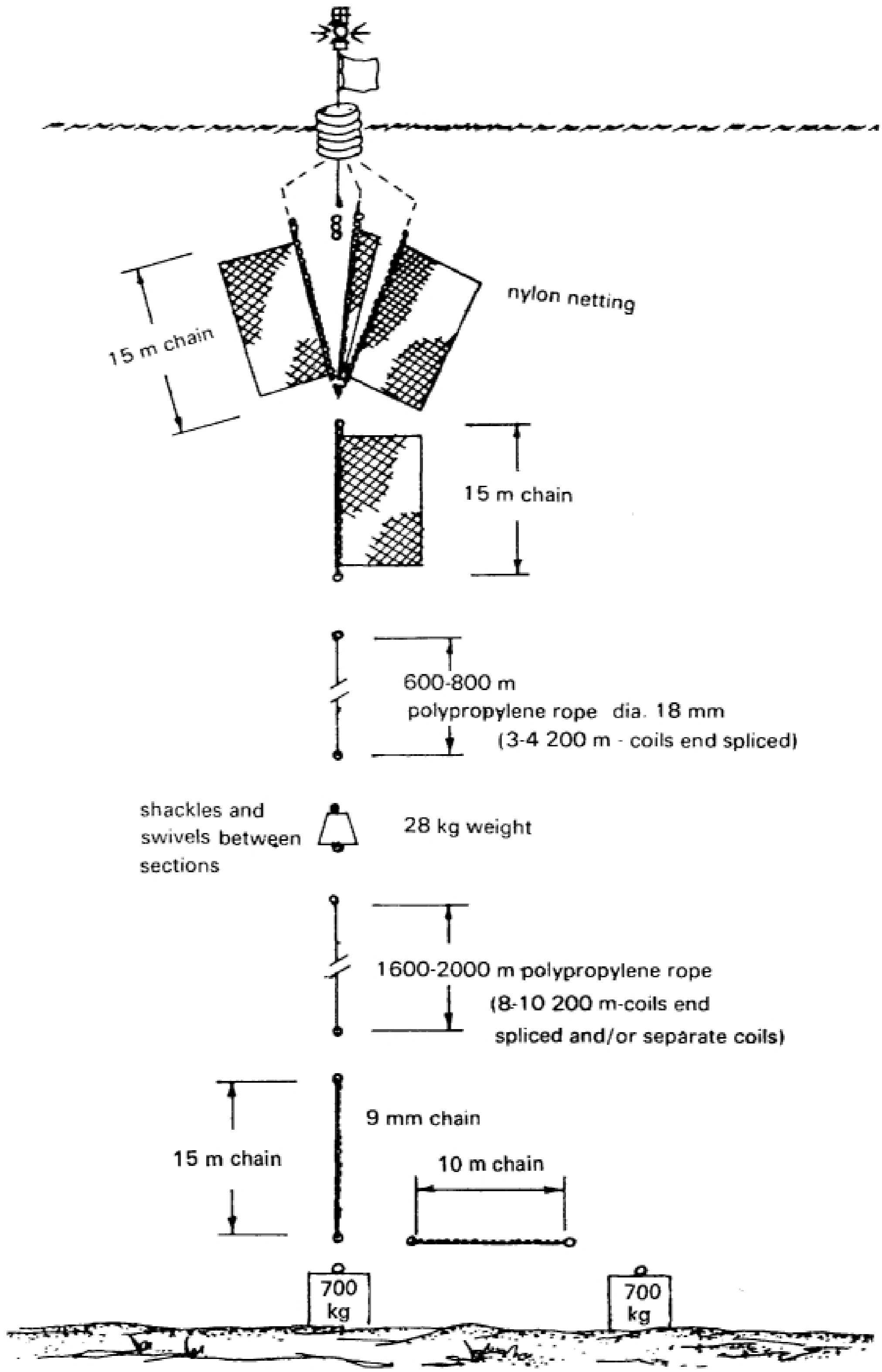
Figure 38

Tyre FAD used in Ma/dives 1982



Tyres individually filled with polyurethane foam, and cavities filled when assembling.

Figure 39



lyre FAD mooring details

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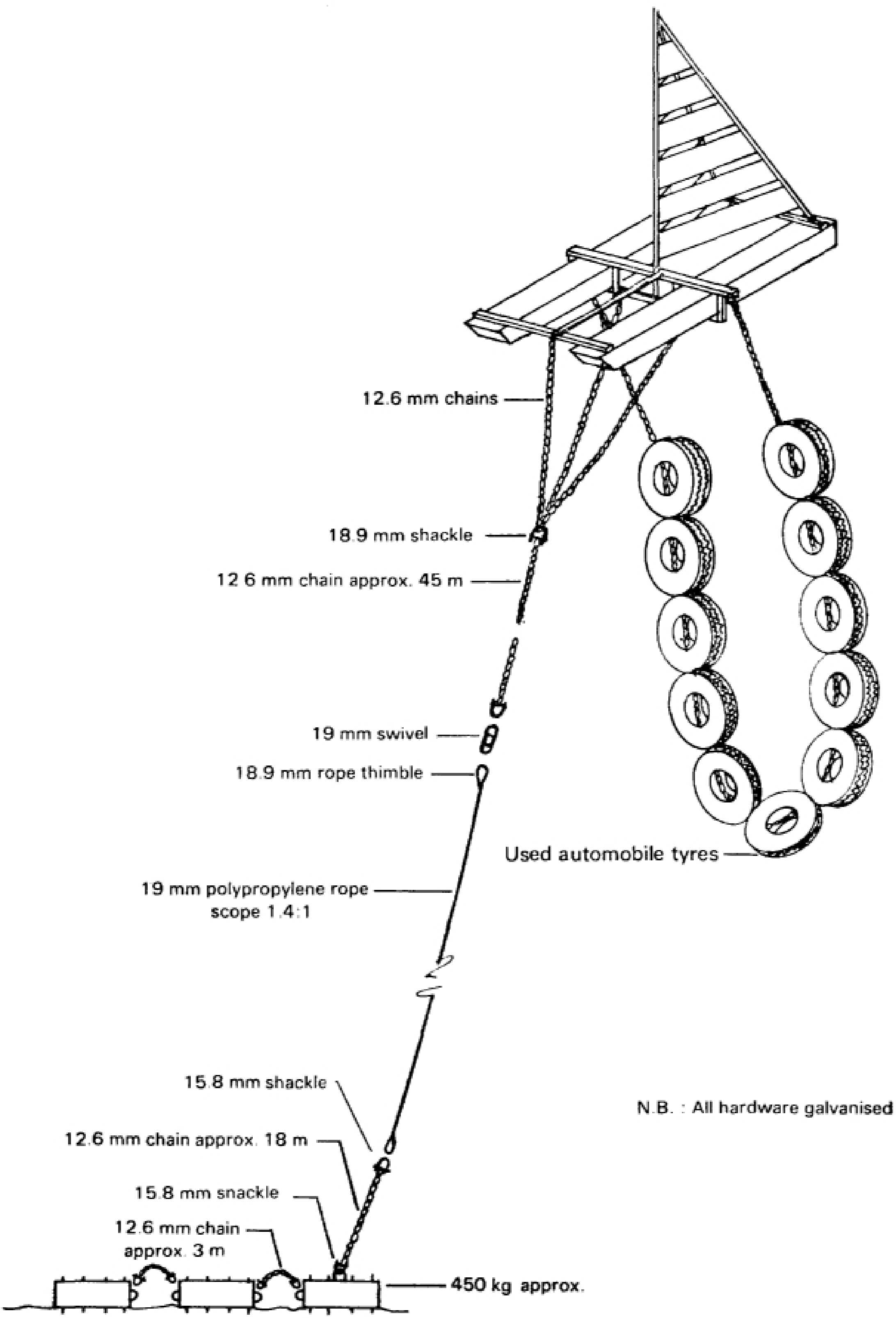
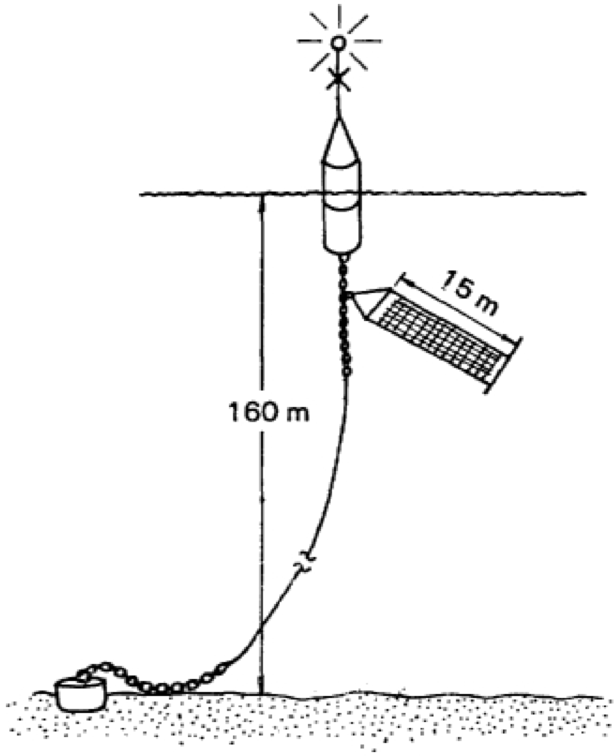
Figure 40



FAD used in Samoa

Figure 41



FAD type from Australia

New Zealand

New Zealand's first FAD was moored six miles off the east coast early 1982 by Sanford (Tauranga) Ltd. The design is described as "similar to aggregating rafts already used successfullyin other parts of the Pacific" (ref. D). Catch data indicating its efficiencyare not yet available.

At an informal workshop held in Hawaii in October 1980 (ref. 17) and convened by Richard S. Shomura, National Marine Fisheries Service, Honolulu Laboratory, a few other current FAD designs were presented as follows:

Palau

Around Palau, east of the Philippines, an FAD was patterned similar to that of the Hawaii state system, but with a few modifications: The ballast and mast were made of a single length of 4 in. (102 mm) pipe which projected 8 ft. below and 6 ft. above the buoy. The attachment for the mooring line was a single L-shaped steel plate bolted onto the underside of the buoy.

The mooring line consisted of a 20 ft. long $\frac{1}{2}$ in. chain which was looped through a hole in the attachment and shackled. The lower end of the chain was shackled to a 3/4 in. galvanized swivel and, in turn, to the main section of a 5/8 in. polypropylene rope fitted with a galvanized thimble. The lower end of the rope section was shackled to a swivel and about 6 metres of 12 mm chain which was shackled on to a 1,000 lb marine anchor. An intermediate weight of large chain links was shackled on to the line with a galvanized swivel attached at the lower end of this chain. The rope sections were connected to one another by double splices and three or four swivels spaced along the lengths of the rope section. All shackle pins were secured with galvanized wire.

Six FADs of this design were moored late July and early August 1980, in depths of 600 to 2,000 fathoms, all with line scope 1.6: 1. It is believed that one FAD broke loose because the anchoring fine chafed against some steep ridges.

Guam

In Guam, two FADs were made initially from three oil drums filled with foam and with four leg supports to the ballast pipe. Chain bridles attached to the middle of the buoy were linked to 25m of chain with shackles and a swivel. The rest of the mooring was similar to that of the NMFS but the anchor was made of a T-shaped concrete block.

These two devices were anchored at 300 and 510 fathoms in December '1979 and January 1980. Owing to insufficient intermediate weight, the excess rope floated to the surface. The first device broke free within a week but was retrieved. The floating line could have been cut by the propeller of a fishing boat. Additional weight was added to the mooring line of the second buoy as a corrective measure. This device broke free in May 1980. It was assumed that the break had occurred either at the intermediate weight or at a splice.

The design was then changed to a tyre platform type and the rope size increased to 19mm. Additional pad-eyes were placed on the buoy to permit small boats to tie up to it. One of the two buoys deployed in April and June 1980 broke free towards the end of the year. The break had occurred at the junction between the bridle and the upper chain section. The shackle was missing.

Marianas

Five FADs were deployed in the Marianas, each made of three-drum buoys with the mooring line attached to the end of the ballast pipe.

The mooring line consisted of 50 ft. lengths of chain at the buoy and anchor, with a main section of 5/8 in. polypropylene rope that contained an intermediate weight. Swivels were shackled to the ends of the chain section, including both ends of the intermediate weights and another in the rope section below the intermediate weight. A concrete block weighing three tonne was used as an anchor.

These FADs were anchored during February—March 1980, but were all lost by the end of the same year. The FADs had been deployed without the aid of a depth recorder; consequently, one device was set too deep and got submerged; two were set too shallow and were probably lost as a result of the line chafing on the bottom at the intermediate weights. Two others showed signs before their disappearance of having been run over by passing vessels.

The workshop in Hawaii also discussed definite and probable causes for losses of FADs and recommended corrective measures. These will be referred to later.

4. SELECTION OF SITES FOR AND ANCHORING OF FADS OF MODERN TECHNOLOGICAL DESIGN

Since there are so many different designs and sizes of FADs, the problem of selection sometimes centres not on picking the right site but on picking the right FAD for a location where fish are likely to aggregate. However, when evaluating site suitability, factors such as exposure to wind, waves and current and the bottom topography and material must be considered. Wind and waves can damage a raft, currents can pull the raft beneath the sea surface. If the bottom is not fairly flat, the current can pull the whole FAD into deeper waters and submerge the raft. Or the anchoring chain can become entangled as currents change, resulting in the rope chafing against the bottom material and breaking. With chosen/available anchoring system, if the bottom material is not appropriate, the FAD can also drift into deeper waters or run aground. All these factors have to be carefully considered when choosing an FAD — site, system and dimensions.

Thus, when anchoring a raft or buoy of moderate or large size, there are a few technical aspects that have to be considered:

- type and weight of anchor
- material, dimension and length of anchoring line
- types of connections between parts, their materials and dimensions
- shock absorber for anchoring line

- possibilities for recovery of anchoring device if raft or buoy is lost
- possible risks of FAD loss.

Type and weight of anchor: Modern rafts and buoys usually have anchors made of concrete, sometimes reinforced with iron of appropriate weight. A number of rafts and buoys use 500 kg anchor weights. However, the Hawaiian pilot programme found that in rough weather even a 544 kg (1200 lb) concrete anchor was dragged 4 km over flat bottom. For their second phase with 26 buoys the anchor weightswere increased to 900—1350 kga buoy. In some other projects, the anchoring weight was distributed over two or three pieces linked together, thereby reducing the risk of dragging. Using concrete-filled oil drums still involves the risk of drifting; the drums may start rolling, unless some kind of "branches" such as iron bars are attached.

Material, dimension and length of anchoring line — The material and thickness of anchoring line used so far have varied greatly. For a light traditional inshore FAD there is no need for any sophisticated arrangement. But when a raft or buoy of a larger type — and invariably higher cost — is to be anchored, it is of vital importance to select the best anchoring system available. For if a raft were to break loose, not only is the raft/buoy lost but the whole FAD and the investment are lost too. So, many FAD-builders have put great effort into devising a system that is secure. This has had the following result:

If a synthetic rope is chosen as anchoring line it has been found, through trial and error, that a polypropylene rope at least 16—20 mm thick is needed for an offshore structure (ref. 32, E, 14, 33, 27, 24).

The lower and upper ends of the anchoring line are often substituted with wire rope and chain. Negative buoyancy in the form of a chain at the upper end helps to keep the anchor line clear of the fish aggregating appendage and protects it from breakage due to shark bite or other kinds of vandalism. It has been suggested that for this reason the upper 50 m be chain or steel wire. Also a strong unit of **this kind is needed close to the raft** where the dynamic shock by wave action will be the greatest.

When the anchoring line has a net positive buoyancy, there is a risk that in slack water floating rope can be entangled in the appendage or the raft, or cut off by a ship's propeller or fishing gear. This can be avoided by introducing an intermediate weight on the anchoring line. To achieve that a certain depth zone from the surface is kept free from slack rope, the position of the intermediate weight on the rope should be at a distance below the raft equal to the length of the intended slack-free depth zone (b in Figure 42) plus half the length of line in excess of total water depth ($\frac{1}{2}$ x a) at the site.

The intermediate weight in water should negate the buoyancy of the rope corresponding to the depth zone intended free from slack rope (b) plus the buoyancy of the rope in excess of the total water depth (a) at the site.

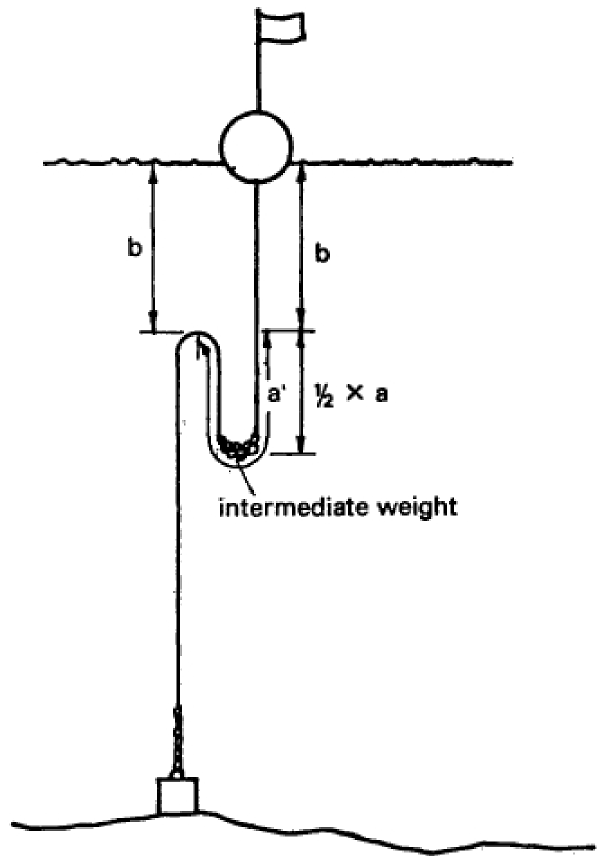
It has been stressed that the intermediate weight must be attached so that it cannot entangle the rope. There appears to be a risk that at times of slack water one weight can bring together different parts of the rope, with entanglement as result. Ideas are now being brought up as to how this problem can be overcome by distributing the necessary weights over a longer piece of the rope (ref. J).

At the lower end is the risk of the rope being torn off by contact with bottom material. Therefore the rope here is often substituted with galvanized hardware, metal wire or steel chain. The dimensions estimated necessary and used are galvanized steel chain 13 mm to 16 mm; or wire of similar strength.

The eyebolt of the anchoring weight and the connecting shackle need to be of material thicker than that required for the rest of the chain. This is because of the more frequent chafing here. The chain should be at least 15 metres long but in some cases has been longer.

The length of chain required varies of course with bottom topography and material. On a coral bottom for example, as currents change, a chain or a rope can easily get entangled with the coral.

Figure 42



Anchoring line.

At times even the full length of the chain or wire can get caught in the bottom material, and expose the rope to risk of chafing. The rope can then get torn, and the FAD break loose, despite every precaution. It is nearly impossible, even with the most up-to-date acoustic equipment, to find a location in deep waters where the rope faces no risk of entanglement. The risk can possibly be avoided by using steel rods kept upright by some floatation or simply by the buoyancy of the rope.

Types of connections between parts, their materials and dimensions: To prevent twist and unlay of wire/rope due to raft/buoy turning with changes in current and wind, a number of swivels should be fitted along the anchoring line. The thimbles, shackles and swivels so far used in the connections are of dimensions 16 mm (3/4") to 18 mm (5/8").

Shock absorber for anchoring line: Even if the upper and lower ends of an anchoring device are designed to resist high tension due to stretching shocks, there should be some kind of a shock absorber to protect the rope between the end sections. This protection is sometimes provided by the intermediate weight hung on the rope to control the rope's slackness.

Possibilities for recovery of anchoring device if raft or buoy is lost: The chances of recovering an anchoring device if raft/buoy is lost depend on how the anchoring system is designed. Some are furnished with a side-buoy to enable attachment and detachment of raft/buoy (figs. 17C, 19, 26, 29). To stay afloat in case of loss or damage of raft/mainbuoy, a sidebuoy must be buoyant enough to compensate for the weight of the anchoring device and the force of the current.

The value of the anchoring device for an off-shore structure includingselection of site and actual deployment is considerable. Sophisticated methods to make possible the recovery of anchoring line when there is no trace on the surface have been discussed but no practical trials have taken place. So far the costs involved in bringing in a vessel especially equipped for the purpose have been prohibitive. Also, since the value of one catch can exceed the total cost of a new raft, it is obviously more important to quickly replace a successful FAD than to spend time in trying to recover a lost anchor line.

Possible risks of FAD loss: In view of the slim chances of recovery, it becomes even more obvious how essential it is to avoid losses. The earlier mentioned workshop in Hawaii in December 1980 (ref. 17) also analysed the reported losses of FADs in various waters. Of 33 reported losses, 17 definite and four probable failures were identified:

Shackle failure: Shackle failure – the pin working itself loose – was a definite cause of two of 33 FAD losses. Such failures can be delayed to some extent by securing the pin with a galvanized wire, but there is always the possibility that the wire could be too small and corrode soon, or that some of the shackles could be overlooked and not be secured at all. In some shackles the pin was found to have been completely corroded.

Rope splice slipping: This was found to be a definite reason in one case and a probable reason in another. Poor splicing, particularly single short splices and splices that are loose, could be pulled free, especially when using slippery synthetic ropes of such materials as polypropylene or nylon. Because several rope splices are needed along the anchoring line, it is essential that they be secure. It was recommended that for added security the rope ends should be double-spliced, each splice made at least 15 to 18 inches (38 cm to 45 cm) long and seized with twine at two or three places. Knots should *never* be made since they can weaken the rope up to 30%.

Cable grip failure: Being the definite reason for one loss and a probable reason for two others, cable grip failure was believed to be due to insufficient or uneven tightening of the bolts. Another risk with cable grips could be corrosion of the bolts.

Electrolysis: Electrolysis between copper nico-press sleeves and galvanized steel wire was the definite reason for four raft losses.

Rope twist: In another case, rope twist as a result of not using any swivel between the top chain section and the rope section caused the rope to break near the splice. The rope was twisted by buoy rotation and/or rotation of the rope. This was probably the reason for one more loss. Such failures can be avoided by using swivels at all critical places; at the end of the top and bottom chain sections and at the lower end of the intermediate weight. Only swivels of the best quality should be used.

Rope cut by propeller: This happened in one or possibly two oases since not enough intermediate weight was attached to keep the slack rope well submerged.

Rope chafing: At least four losses of FADs were caused by rope chafing. The suspected reason for chafing was misplacement of buoys; they were placed too near bottom ridges or anchored in water shallower than intended. In the case of shallow water, the chafing is believed to have occurred when the intermediate weight reached the bottom. Another possible explanation is that the bottom chain became entangled and forced the rope down to direct contact with bottom material.

Submerging: One buoy was set too deep and the raft got submerged in consequence.

Rafts hit by vessels: Two buoys were run over by tugboats. One steamed too close to the buoy and with its towline damaged the raft. In the other case the raft was just not observed.

5. HARVESTING METHODS

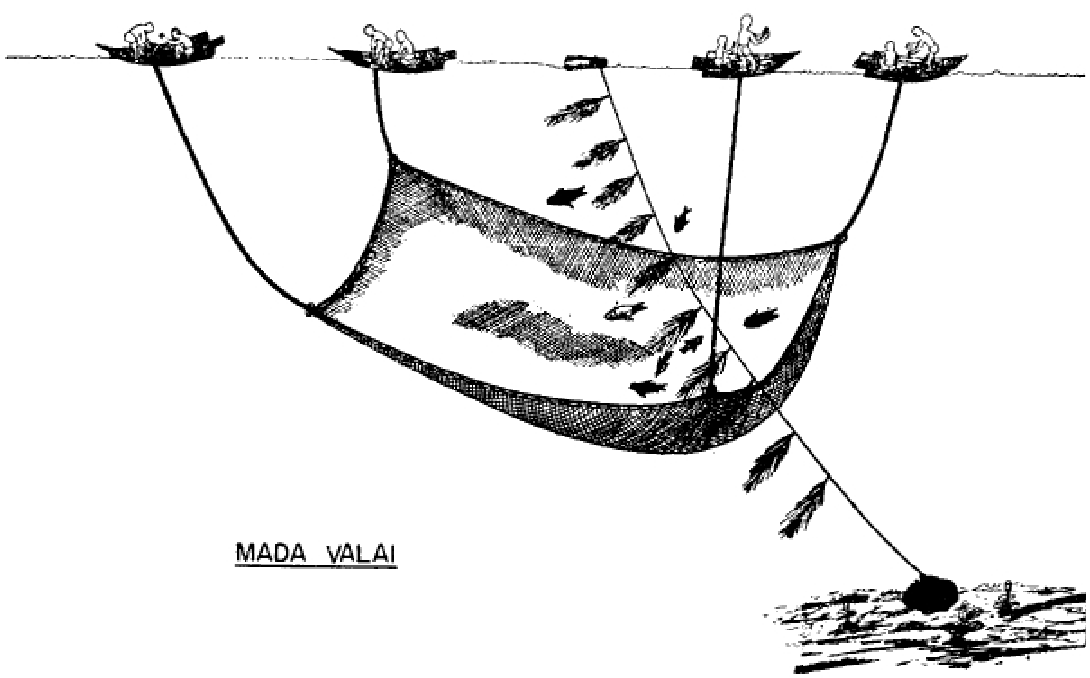
FADs placed on the bottom (bottom FADs): The most common methods to fish around these FADs are gillnetting, handlining and longlining. These methods can be used for FADs without any changes or adaptions in fishing techniques.

FADs anchored or drifting on or near the water surface (surface FADs): The flying-fish fishery along the east coast of South India is a well-known traditional fishery with devices as described on pages 7-8. The harvesting procedure is that when the bundles of branches and leaves are set out, flying fish gather to deposit their spawn on the leaves and branches. Then dip-nets are used to scoop up the fish.

Modern surface FADs are harvested the same way as modern mid-water FADs (described below).

FADs anchored/n the water column (mid-water FADs): The traditional FAD design described on page 13 is used along the east coast of India asfollows : A Mada Valai orlift-bagnet is operated by four kattumarams, two with two or three crew, one of them the head fisherman, and two with three or four crew. On the down-wind or down-current side and next to the FAD rope, each kattumaram is given one corner of the net. On a signal from the head fisherman, who decides when they are all in proper position, the net is pushed into the water from the kattumaram carrying it and sinks to the bottom. Two kattumarams start paddling as fast as they can against the current, one on each side of the FAD and one sidewise. The fourth one, with the headfisherman, stays stationary. In this way the net is spread, and since the two kattumarams on the lee-side of the FAD will drift away from it, the FAD will be at the centre of the net-covered area. When the net is hauled in, the two kattumarams on the up-wind current side stay close together, reducing the chances of fish escaping. (See Figure 43)

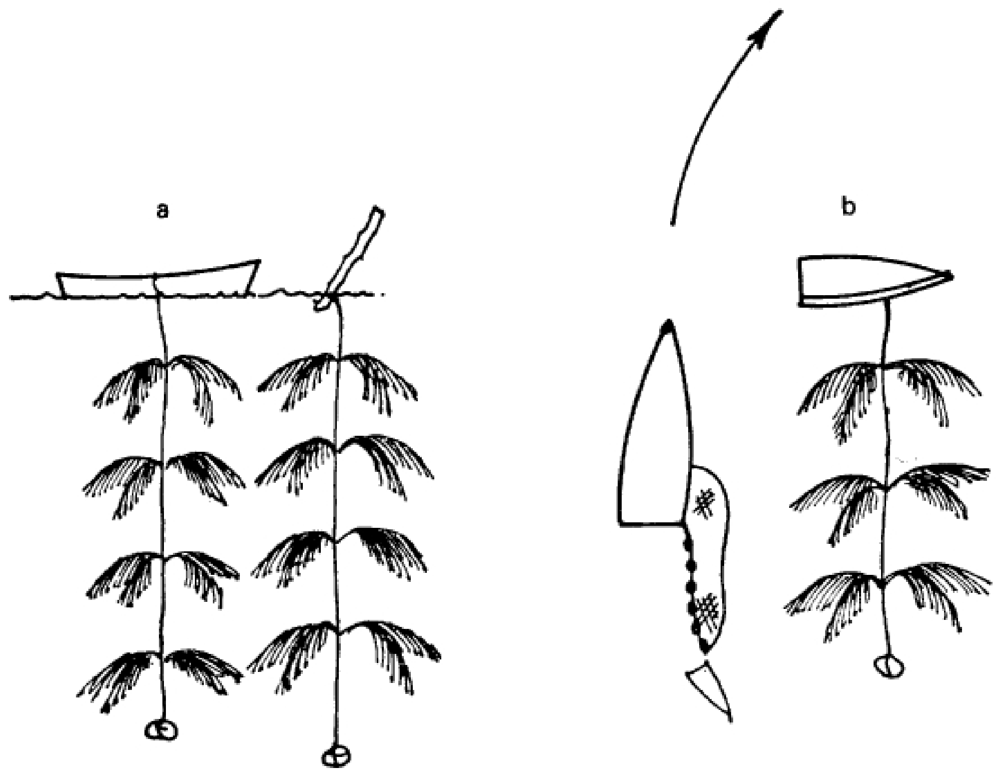
Figure 43



As a curiosity it is interesting to note that this fishery was described in 1924 by J. Hornell. It was then carried out exactly as it is done today. The drawing above is taken from his report (ref. F).

The Indonesian Rumpon: The Rumpon is harvested with ringnet, encircling gillnet, boat-seine or purse seine. (See Figure 44)

Figure 44



Left.' Transfer of fish from anchor to mobile lure line. Right . shooting the gear.

The Malaysian Unjang: In Malaysia, a few sophisticated traditional methods are used for fishing from the "Unjang". The original text, together with Figures 45 and 46 taken from ref. 3, describe how the main Unjang is submerged from a canoe, and this Unjang drifts over a net which is then lifted up. This net is called Pukat Tangkul.

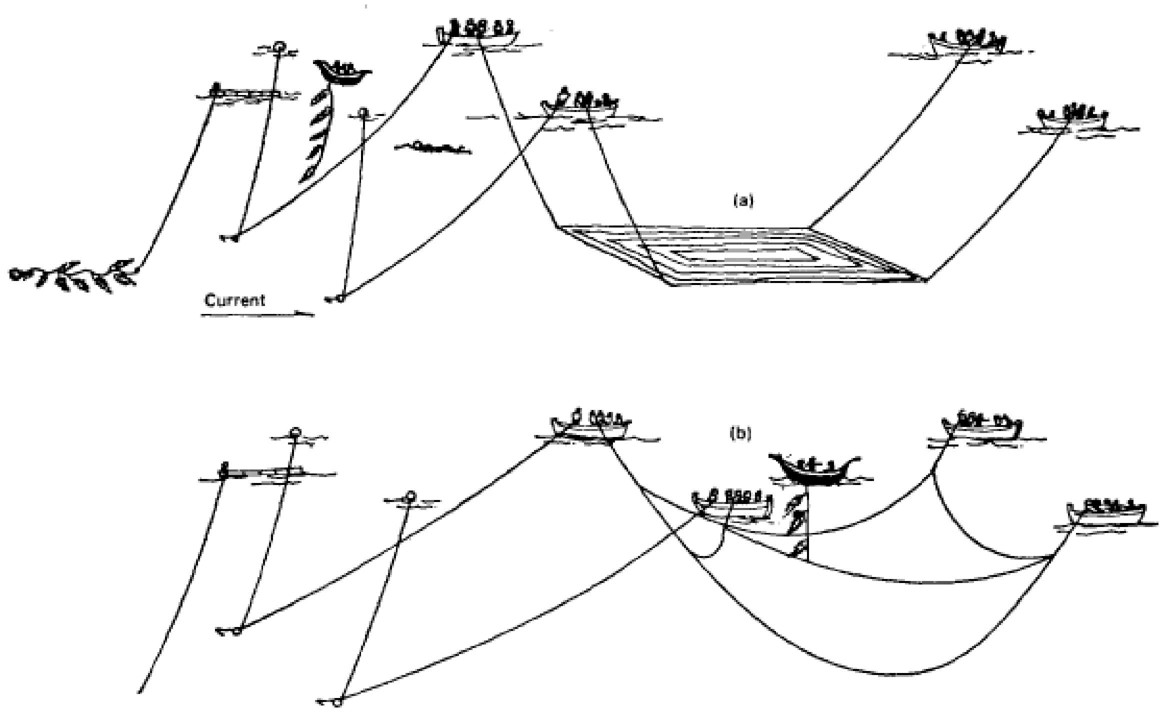
Another net is the bottom-set Pukat Sudu but it is not as common as the Pukat Tangkul. The use of the Pukat Sudu is also described in ref. 3. Similarities can be seen with the Pukat Tangkul, but the net design is like that on Figure 47. It is kept to the bottom until the anchoring stones together with the Unjang are drifted in position above it. Then the Pukat Sudu is also raised quickly, thereby enclosing the fish. For fishing the Pukat Sudu only two boats are needed, plus a canoe for the Unjang. (See Figure 48)

Japanese cuttlefish baskets: They are simply raised fast, or fished with a boat-seine as described on page 15.

Payaws of different types and modern-designed rafts and buoys are usually harvested by:

- trolling
- live bait pole-and-line fishing
- purse-seining
- longlining
- gillnets
- scoop nets
- handlining.

Figure 45



Operation of the pu/rat tan gku/.

a) The net is p/aced on the bottom and the cinjang besar let down to the bottom. The up-current boats are ho/ding the net out by their anchor ropes. The juru se/am's (head fisherman) boat on the left has lowered the urijang anak the juru se/am is diving to try to hear if the fish are following.

6) The net is raised round the unjang anak. having been carried some distance by (he current, The up boats on the left have paid out their anchor ropes to keep the net spread but not streamed out. The juru se/am has climbed back into this boat and is directing the hauling. If a//has gone well, the fish are in the bag

Figure 46

PUKAT TANGKUL (LIFT NET)

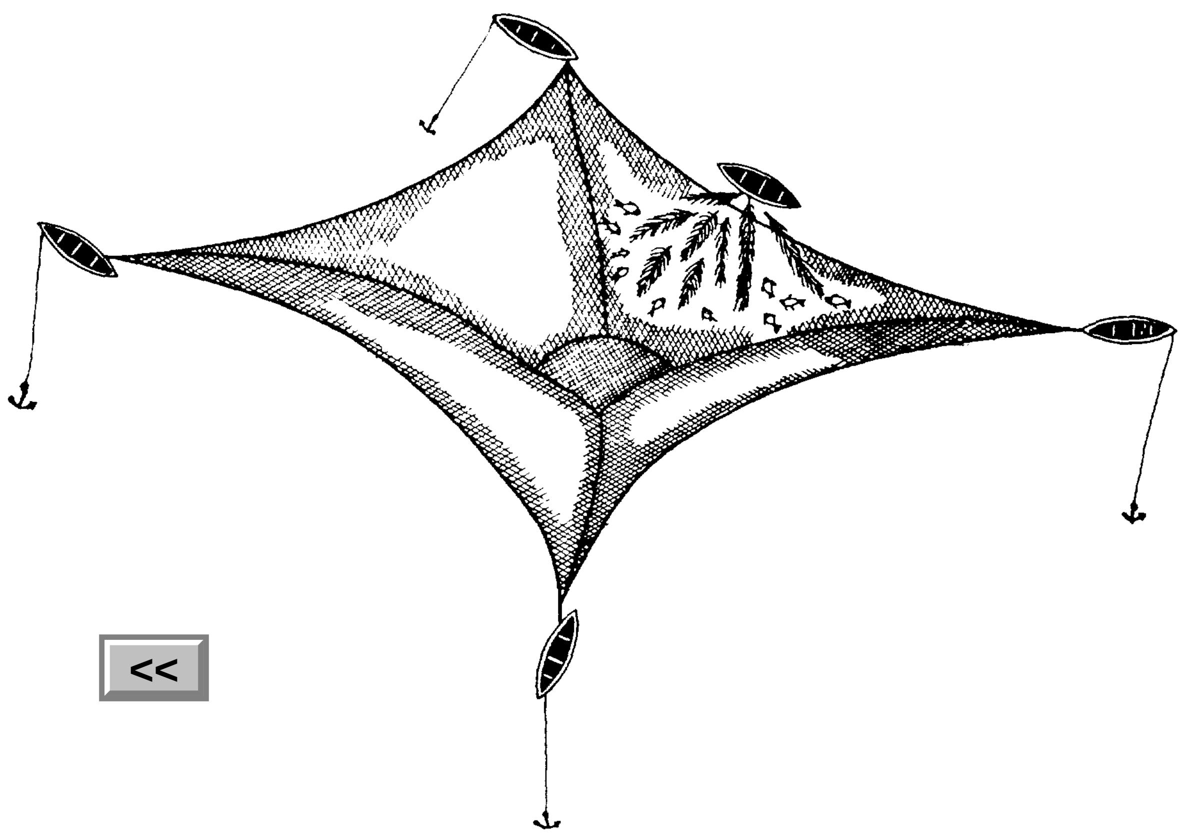


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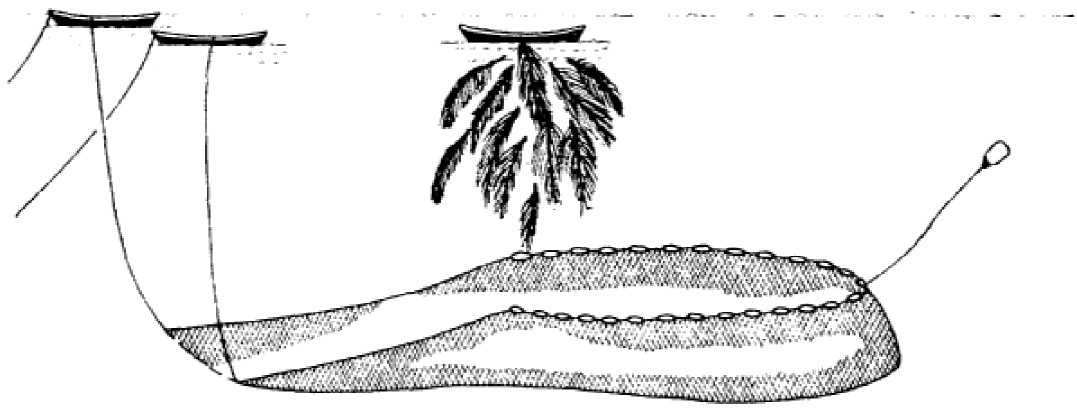
Figure 47

PUKAT SUDU (BOTTOM NET)



Fishing near FADs by these methods can usually be done in the normal manner. In the Hawaiian pilot programme, for example —as described on pages 28-30 it was found that at least three different fisheries benefited greatly; the trolling and the pole-and-line fisheries, plus the local speciality "dropstone" fishery (also described on page 30).

Also, purse-seining is a highly efficient method to harvest FADs. The purse-seining around FADs is a sophisticated version of the traditional methods described earlier, used since long in South Asia. For such harvesting the FAD must be designed so that the appendage can easily be detached before the operation and attached again after it. As the fishing vessel nears the raft, the appendage is carefully detached and temporarily fixed to another buoy which the fishing vessel has brought with it. Or, if the FAD is furnished with a side buoy, the whole raft is detached and no extra buoy is needed. This unit is then left to drift away from the anchoring line, taking with it the fish aggregated in the appendage. After a while the appendage has drifted far er.cugh and the purse-seine is set out in the normal manner. After closing the net and while hauling it in, the buoy and the appendage are lifted aboard the vessel. The appendage is attached again to the anchoring line after the catch is recovered.

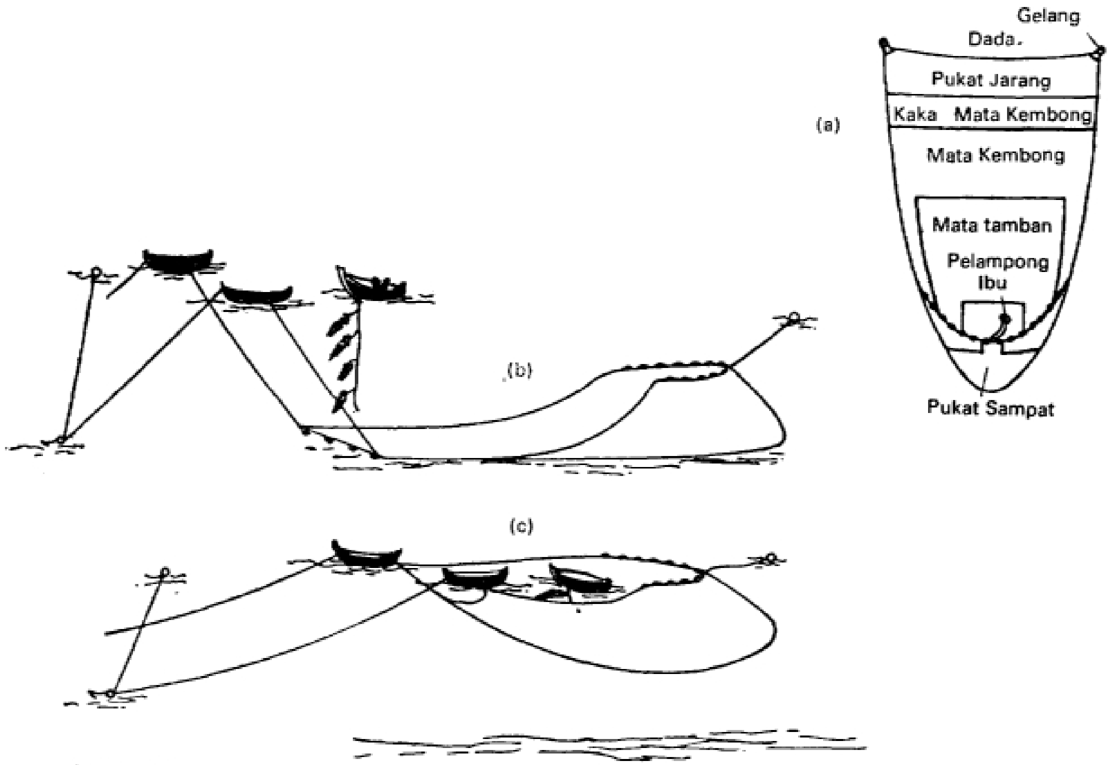
Experience has shown that a raft needs about a month free from fishing, after intensive purse-seining around it, to rebuild considerable aggregates of fish. Because of this, commercial purse-seiners operating on rafts are now trying to maintain at least 30 rafts per vessel.

Ref. 14 describes how a purse-seiner fishes from a payaw (design on page 1 8) in Philippine waters. Two hauls are described in this report—the first one yielding 36.3 tonne, and the second haul at another payaw yielding 3.6 tonne.

Another payaw type used by Japanese fishing vessels, and its catches, are described on page 23. The method used so far is purse-seining in the vicinity of the raft.

The Philippine payaw combines modern fishing methods with traditional; as the waters around the Philippine islands are very deep, the rafts do not have to be anchored very far off-shore. Thus even smaller units can reach the payaw for handlining, etc. They do not compete for the fish with the purse-seiners, since the purse-seiners fish more near-surface than the smaller craft that engage in handlining. Commercial pole-and-line companies, however, must nowadays make their rafts non-perishable and non-detachable to avoid their rafts being used by purse-seiners also. This action on the other hand proves the superiority of fishing from FADs over other methods.

Figure 48



"Pukat Sudu.

***a)** a diagram of the net, showing the arrangement of the differe'nt parts as net would appear from above when spread out to dry,*

***b)** the operation of the net: the two up-current boats hold the net spread out while the /uru se/am sampan drifts over the net with (he unjang.*

***c)** the two up-current boats start hauling and the net begins to come tip. Once the stones on the dada are off the bottom, the current no longer tends to hold the whole net down,"*

6. OTHER GENERAL CONSIDERATIONS

Biological: FADs will clearly make the fish easier to catch, so the enormous advantages of FADs for fishing lightly exploited stocks are obvious. But as and when a fish stock becomes heavily exploited, one has to assess whether FADs in a certain area actually increase the total yield or merely relocate and concentrate catches to fewer fishing units. One should also examine whether FADs aggregate and yield a greater proportion of young fish than other fishing methods, and the impact of this on total catch. Some fears have been expressed on this score (ref. '12, 14, and 37, quoted on page 19).

Maintenance, ownership and access rights are other matters that need highly individual solutions. In India, the villages often have their traditional FADs so close that they can be seen from the shore: this automatically prevents poaching. The people who operate the nets used with these FADs sometimes together invest the little money and work needed to produce such FADs.

The few off-shore structures already in commercial use are usually paid for either by a private fishing company orby the state. Enforcement of some kind of restricted access to off-shore structures will probably prove extremely difficult. In the Philippines, special caretakers sometimes visit payaws. Poaching by purse-seiners, however, involves catches of such high value that arms on board are becoming common.

Legal aspects and hindrance for vessels: The owner(s) of an FAD might keep its position a secret to avoid theft of construction or aggregated fish. This can endanger ships and fishing vessels, particularly at night if the buoy/raft is not properly marked with a radar reflector and light. Who has to pay if an accident occurs is not clear. Only one incident with FADs is recorded; in July 1977, an experimental fish buoy broke loose, causing the buoyant polypropylene rope to surface. A local charter vessel got entangled in the rope and its propeller was damaged. The institution concerned with the experiments paid for repairs to the damaged vessel.

Economy: There is very little published about such factors as the investment, cost of operation, energy consumption, catch values and catch volumes, or earnings, in relation to FADs. It is therefore difficult to quantify the benefits from FADs or their exact value for different fishing methods. Only in general terms, as in the two examples here, are FADs said to lessen expenditures.

FADs obviously reduce scouting time for any fishing method. The “improved payaw” and its performance described on pages 23 & 26 is a good example of one very successful application. Here it seems that a few catches will cover the cost of the raft. As referred to on page 30, the Hawaiian State FAD project, covering three or four fishing methods, reportedly recorded an overall cost/benefit ratio between 1 : 3 and 1: 6.

Regarding traditional FADs, the system monitored in south India by BOBP staff (palm leaves) yielded fish worth around Rs. 2 per man-hour of fishing. (See page 13) This figure does not consider the fact that the owners of nets and kattumarams get a larger share, thereby reducing the share for the others to maybe Rs. 1.25—1.50 per man-hour.

Employment.' As concluded earlier, fishing FADs can reduce operational costs. If the stocks thus fished are only lightly exploited then new fishing opportunities may be created. But if the stocks are already exploited to their optimum sustainable yield, an extensive use of FADs may hit employment by restricting the catch to fewer units who will on the other hand increase their profits. (Regulation, a licensing system or fishing quotas may be necessary.)

Design of appendage: The importance of the design, material, size and vertical and horizontal extension of the appendage for the aggregating ability of a raft FAD has not been analysed. Nor have used and tried appendage designs been compared from that point of view. Also, the biological/fish behavioural factors that determine the efficiency of an appendage of specific design are not well known.

Ways to decrease the maximum stress in rough weather on an expensive anchoring system should be considered. One option may be to deliberately let the raft and its appendage break loose from the anchoring device, thereby reducing the stress imposed by wind, waves and current working on the raft. This would be especially preferable in areas where the quality of maintenance is low for different reasons, or where investment capacity is low, or where supply of mEterial is irregular and because of these factors, cheap rafts are preferred. The technique for this could be to design the raft’s attachment to the anchorline as the weakest point in the system. With less resistance from only a marker buoy left, the anchoring line may manage through a storm and only the raft plus the appendage need to be replaced. It would be worthwhile to assess how much the maximum stress on the anchoring system can be reduced in this way.

Cost-benefitratio.' It is not always true that construction costs for an FAD should be minimised. To use materials in dimensions that are expected to be only just sufficient but with little safety margin, for the purpose of saving money, is not very wise. Any miscalculation of the strength of the system or unexpected stress on it can then lead to a complete loss of the investment. The value of the catches that would have been taken, if the FAD had been built stronger and remained in place, would also be lost.

The design, size and deployment of anchors: Many losses of FADs can be prevented if the anchors are deployed without inducing twists or unlay of ropes and/or kinks on wires. Ensuring correct design and size of anchors to prevent dragging can also reduce FAD loss.

Chafing: It is important to make the anchoring line stay clear of all bottom material to avoid the chafing which eventually leads to the breaking loose of the FAD. The use of steel rods instead of a chain between anchor and rope may be tried – the steel rods kept upright by small floats or simply by the buoyancy of the rope.

Corrosion: The problem of corrosion will come up if FADs' lifespans are considerably extended through improvements. It has been shown (ref. G) that corrosion rates in chains can be considerably reduced by fitting sacrificial anodes. Mooring chains, however, represent a particular problem since the "earth effect" of the chain depends on contact between adjacent links which may or may not be in contact. A programme including experimental anode installations was carried out between 1974 and 1978 and is described in ref. G. These long-term experiments "showed very clearly that two corrosion zones existed, one at the mud line and the other at intermediate areas along the length of the chain. The experiments also showed that prevention of corrosion was possible by the application of sacrificial anode techniques, and that on chain lengths and swivels previously subject to rapid corrosion, the corrosion rate dropped virtually to zero following the application of cathodic protection."

The small-scale FAD has not so far been given much attention by development efforts. This is probably because it does not yield as much profit as the larger-scale off-shore FAD. Nevertheless the smaller FADs may benefit some coastal fisheries in developing countries where a decrease in fuel consumption is vitally important to improve small-scale fisheries. Numerous experiments as well as the use of simple traditional FADs show that smaller FADs in shallower waters are also successful. The low investment cost here could make a modern "package" available for another category of fishermen. This is something to which planners and development programmes should pay attention.

Some of the experimental designs described here are worth considering for indicative fishing trials. As reviewed in this paper, the FAD as a modern fishing aid offers a variety of ways to produce and use an improved fishing ground. There is still plenty of room for innovations and new ideas.

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