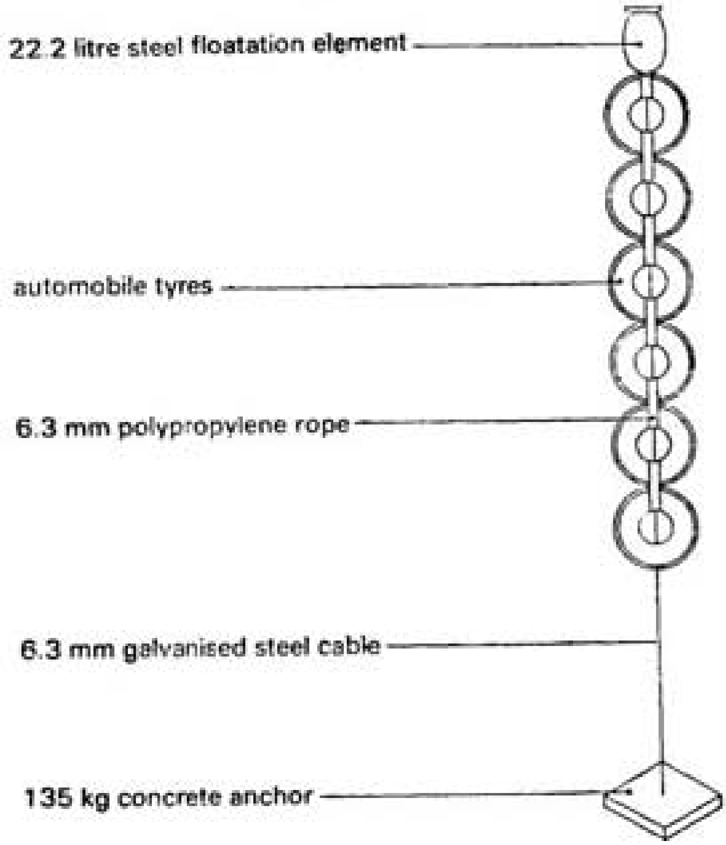
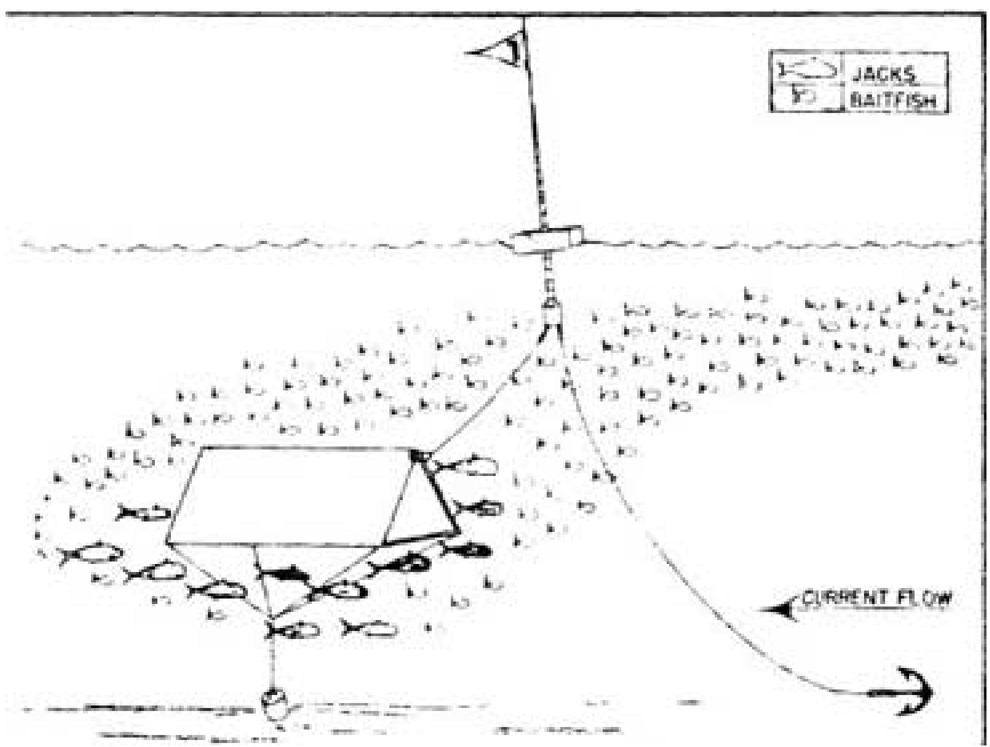
Figure 20



Diagrammatic representation of one mu/tityre midwater structure

Figure 21

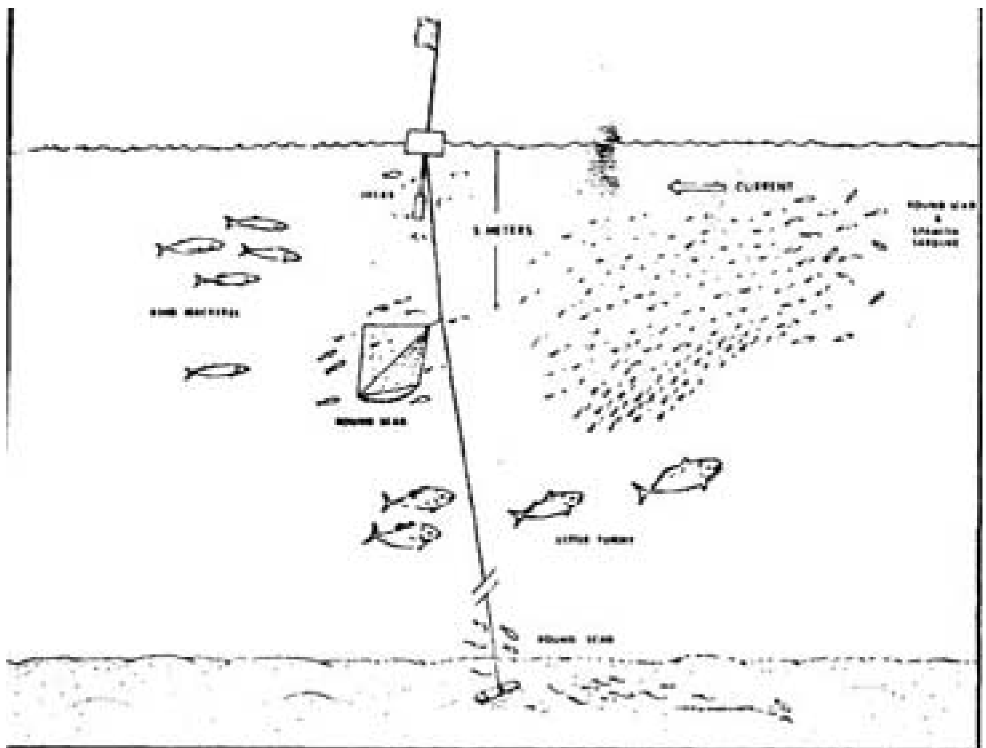


Tent-shaped prism and general position of bait fish and jacks in association with the artificial structure.

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

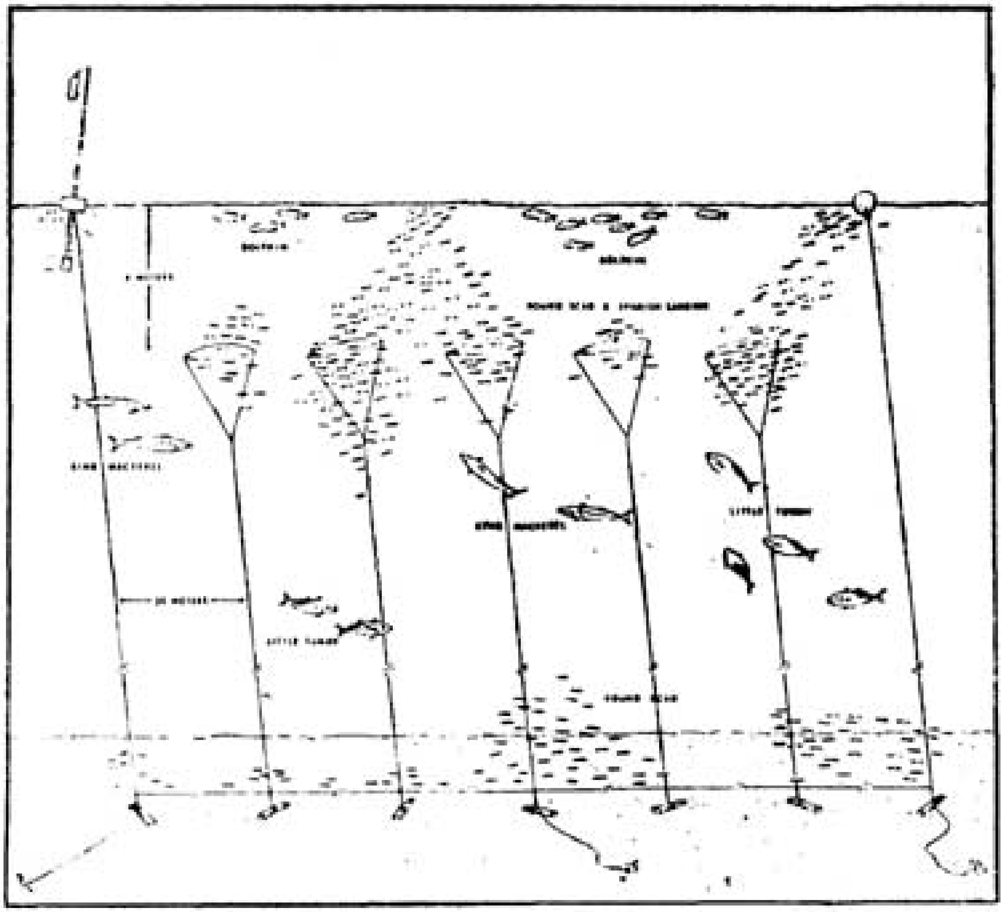


Vinyl pyramids; the mooring arrangement used for deploying single structures. The characteristic positions of fish around the structure are shown schematically.

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).**

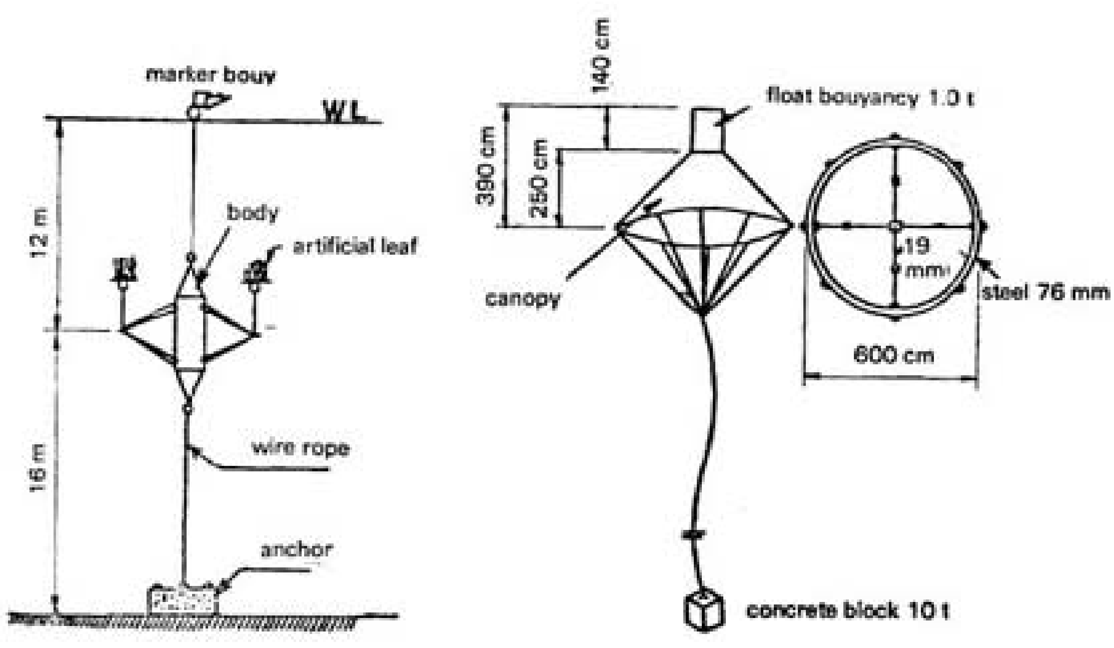
Figure 23



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

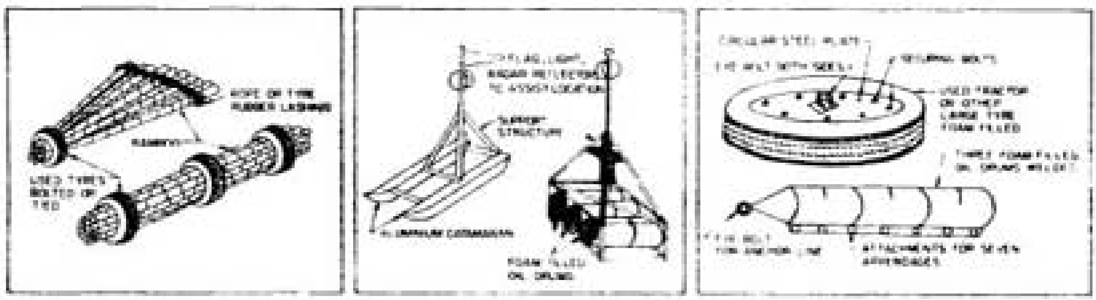


3.3(c) Modern FADs—under commercial trials: The payaw-type rafts and habong-type aggregating appendices have served as the main source of inspiration **for new designs using** modern technology. A number of such designs under commercial trials are described below.

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.

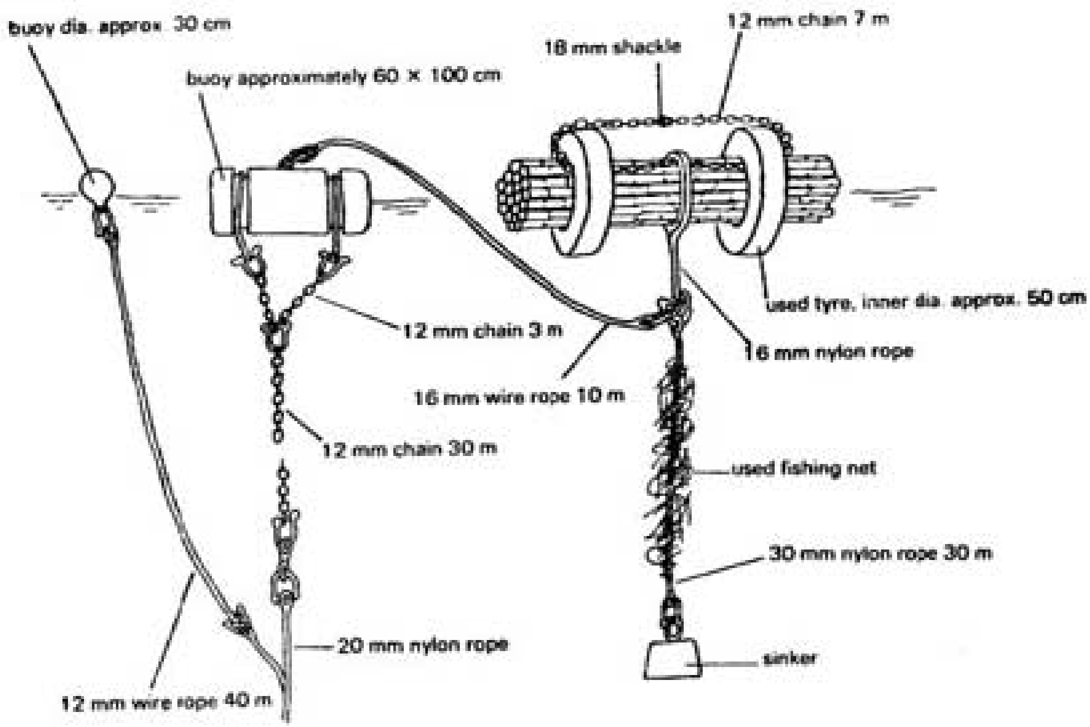
Another raft described by the same source (ref. 27) is more a payaw type (see Figures 27 & 28).

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 platform 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



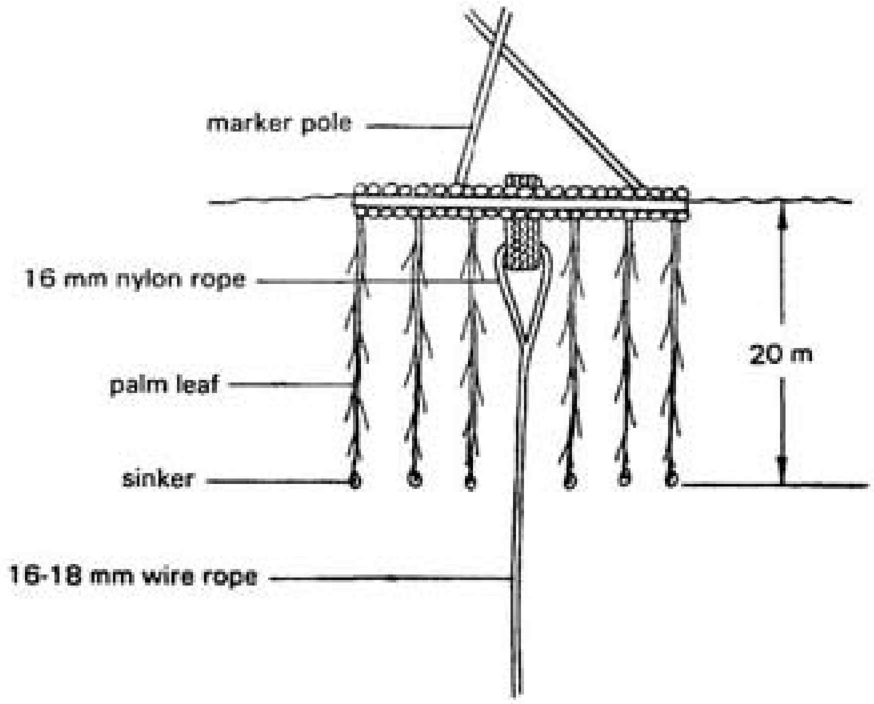
Modern raft from Japan

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



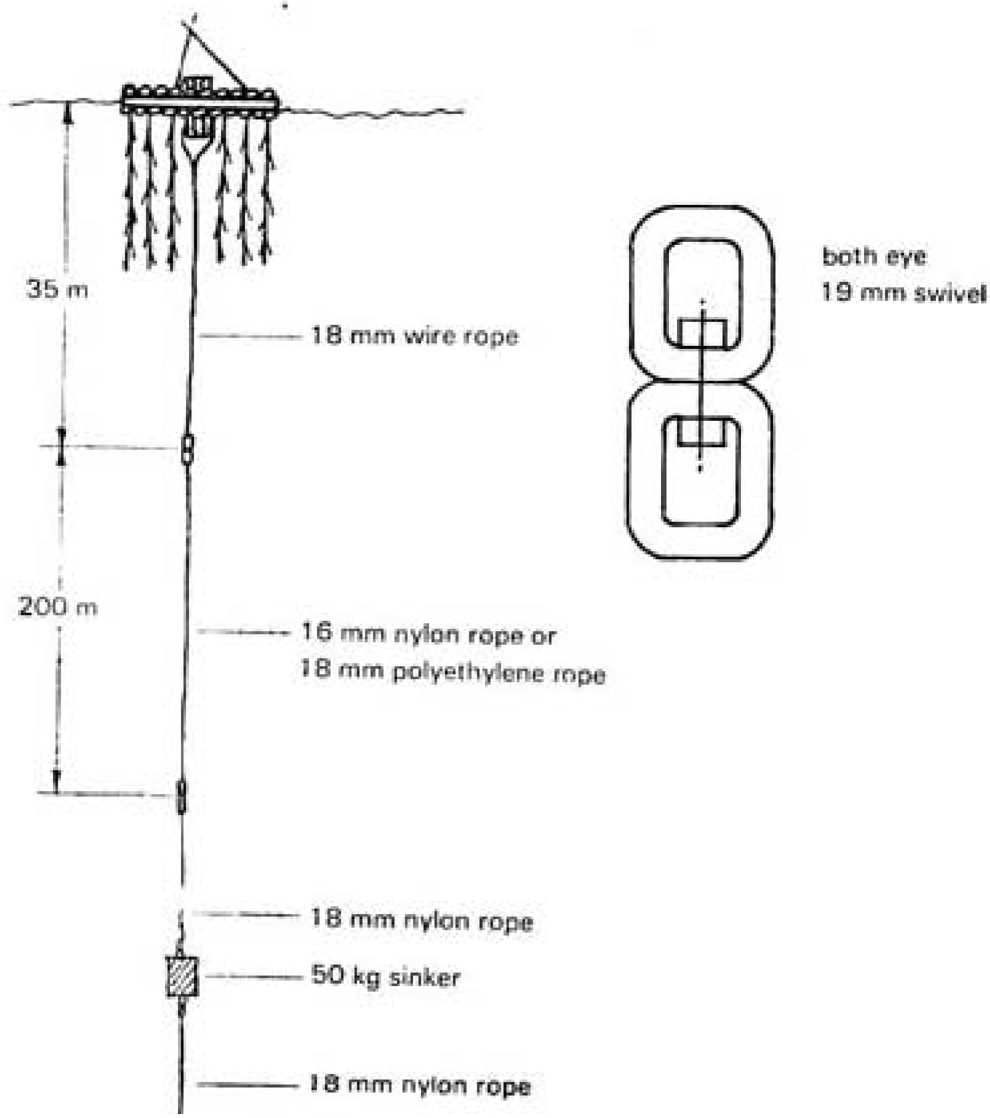
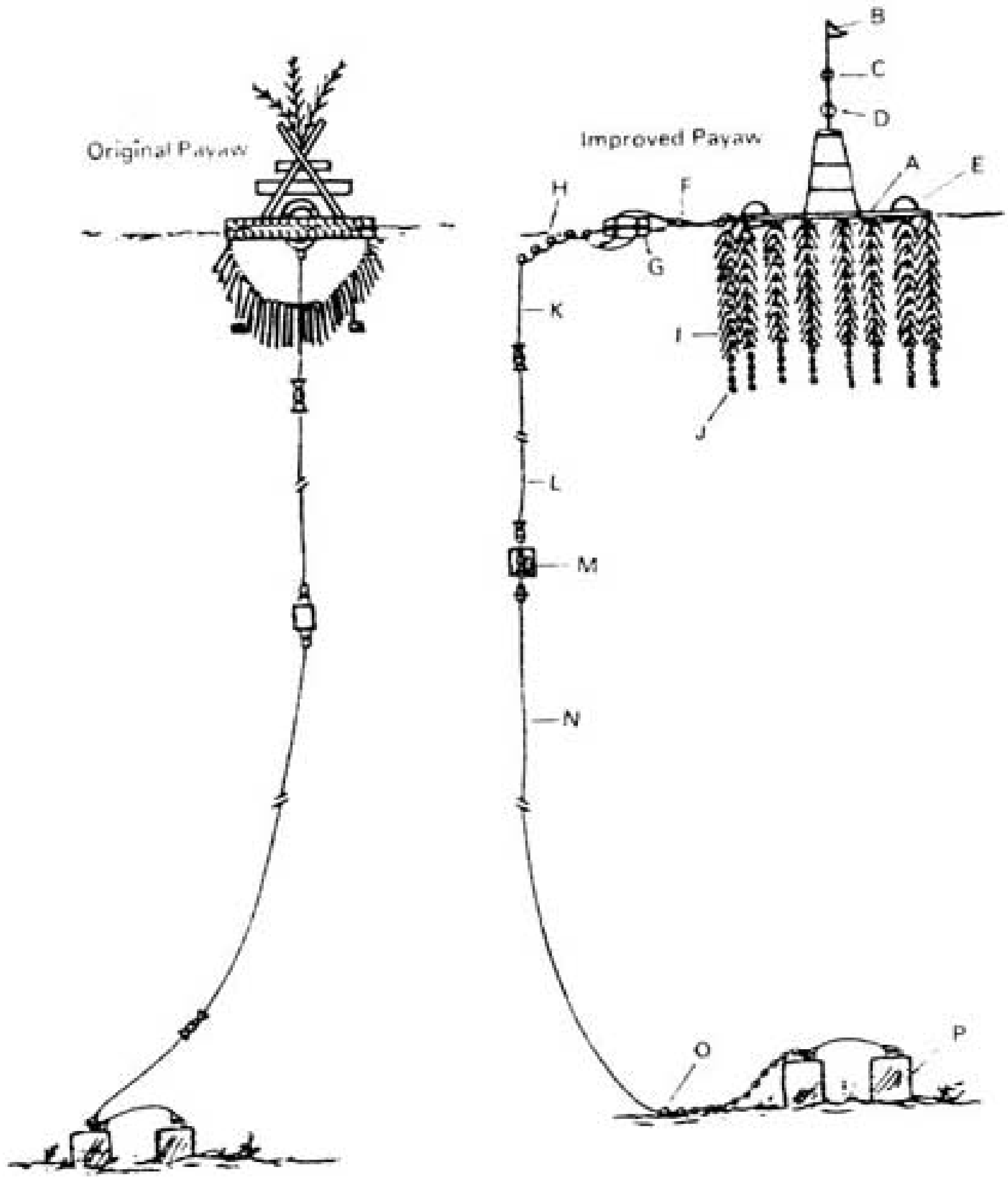


Figure 29



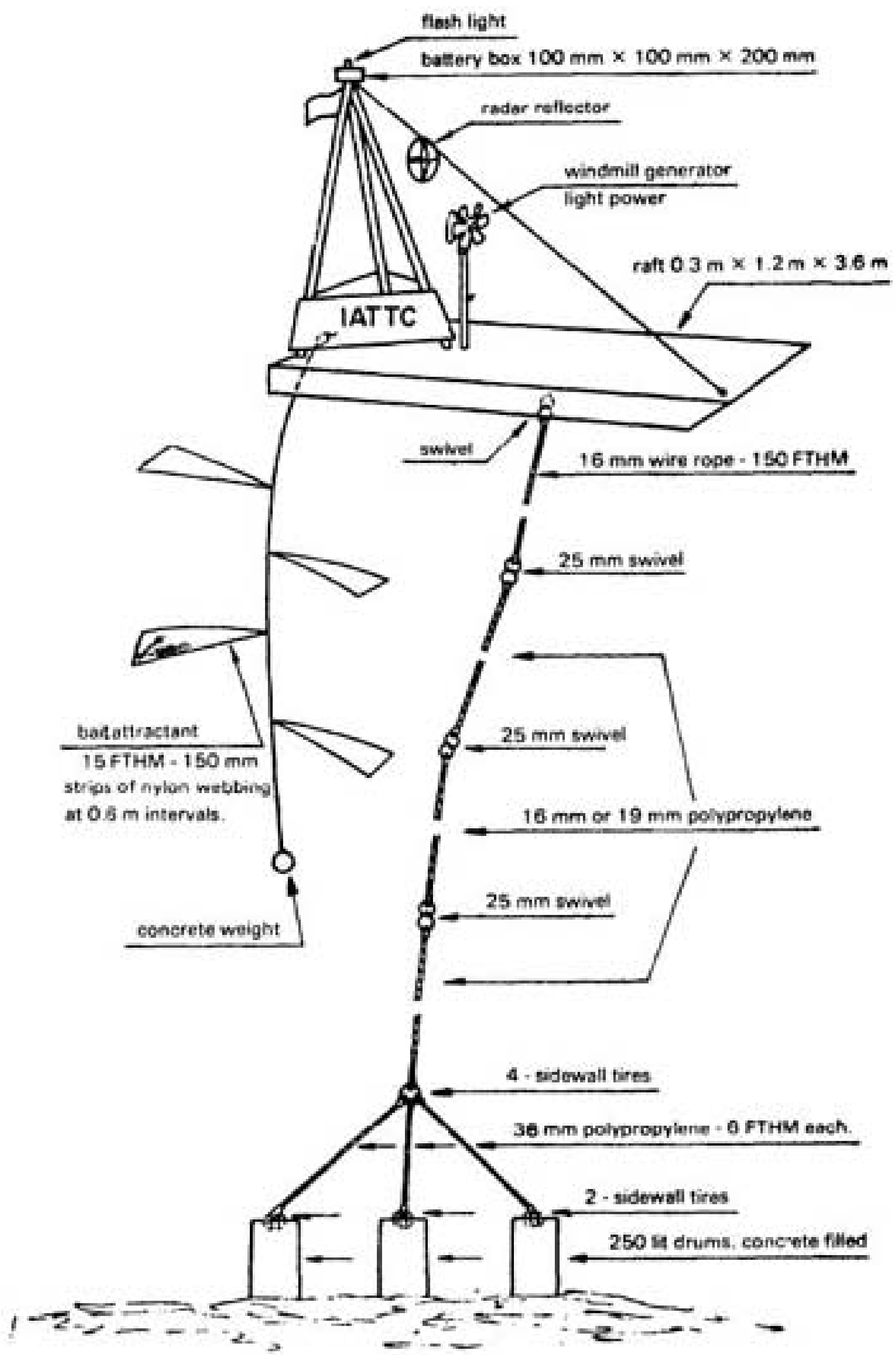
Drawing by Kanagawa International Fisheries Training Centre, Japan.

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

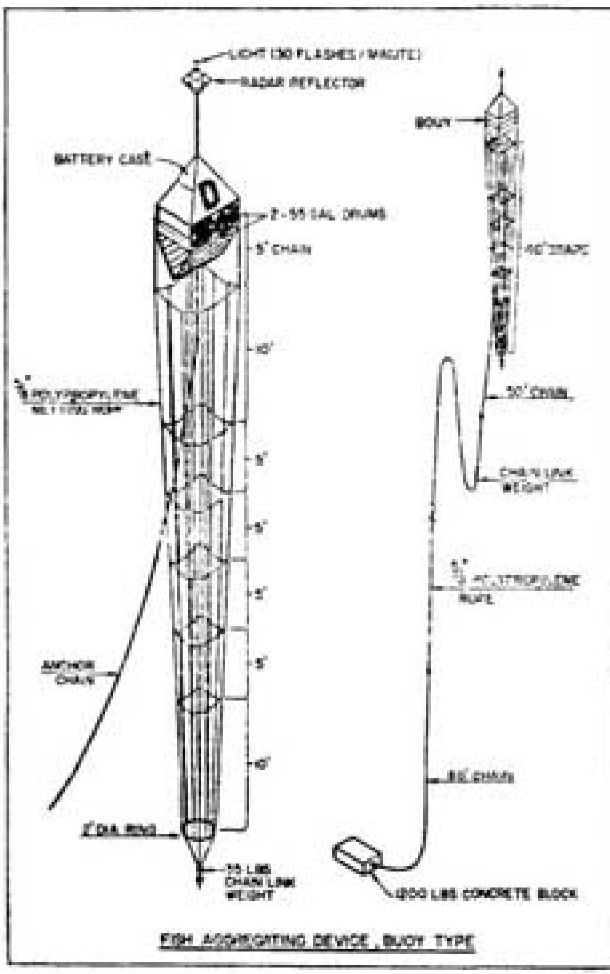
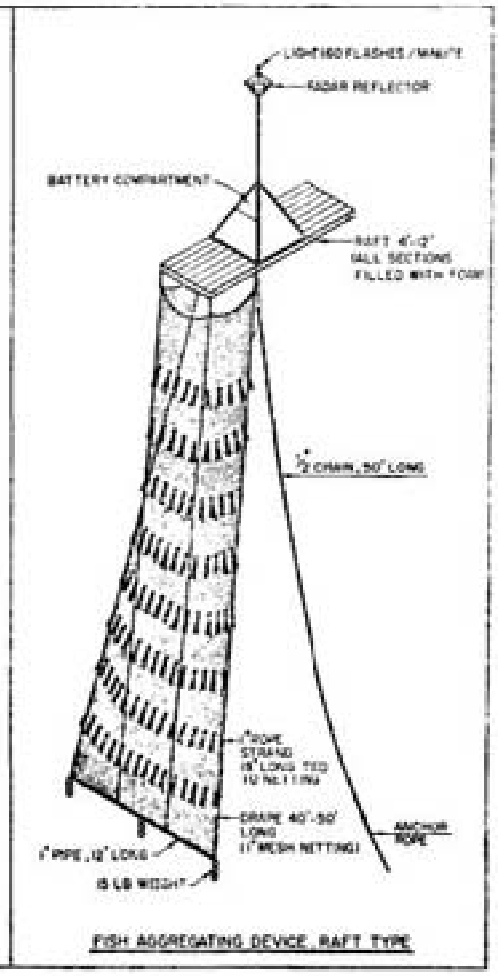


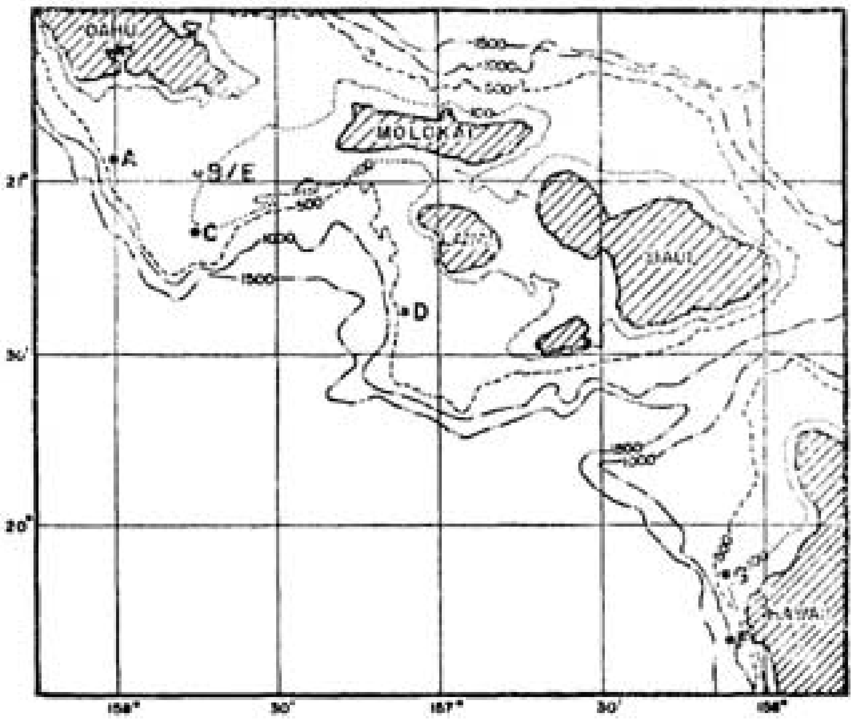
Figure 32



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.

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 visiting the rafts. 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

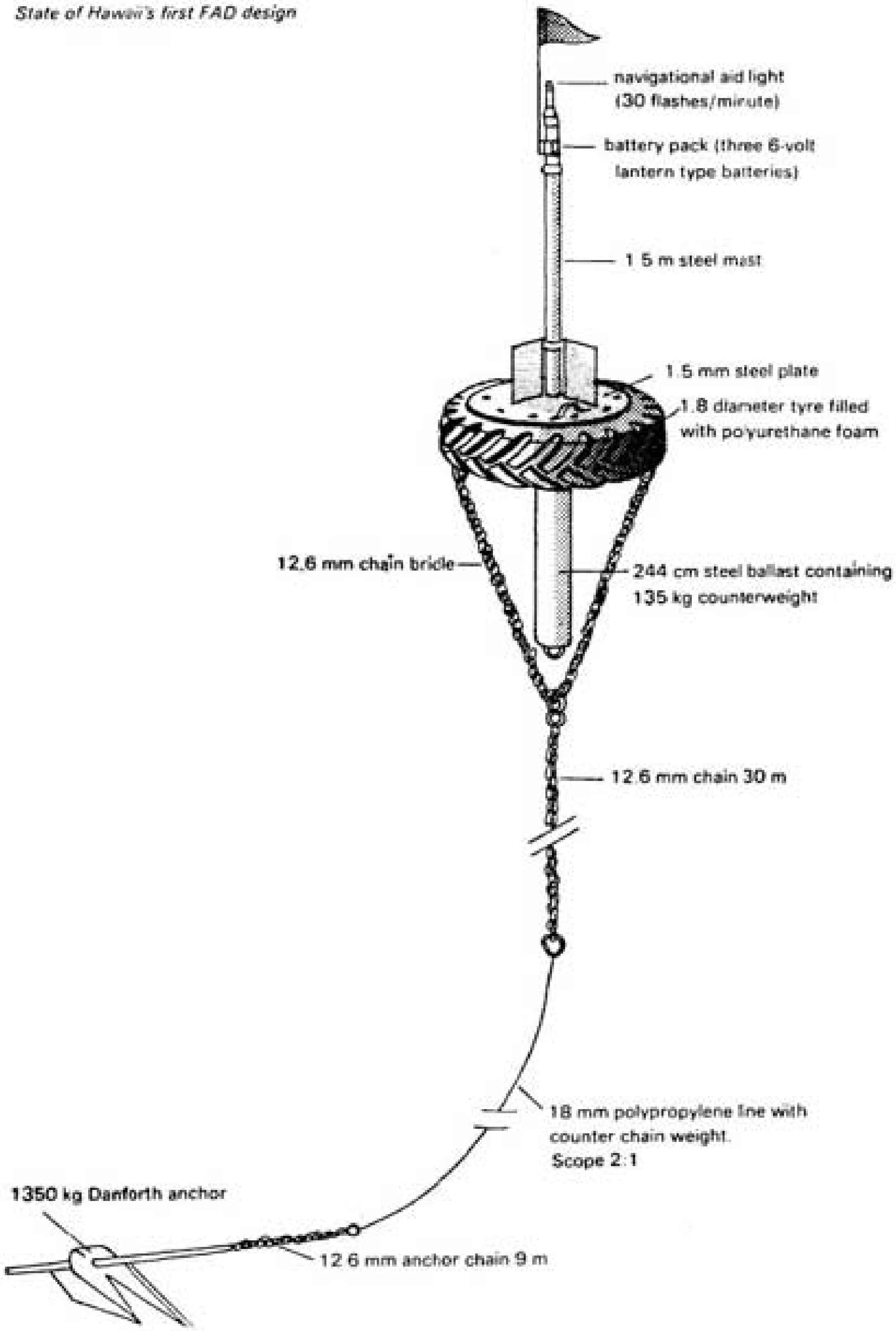
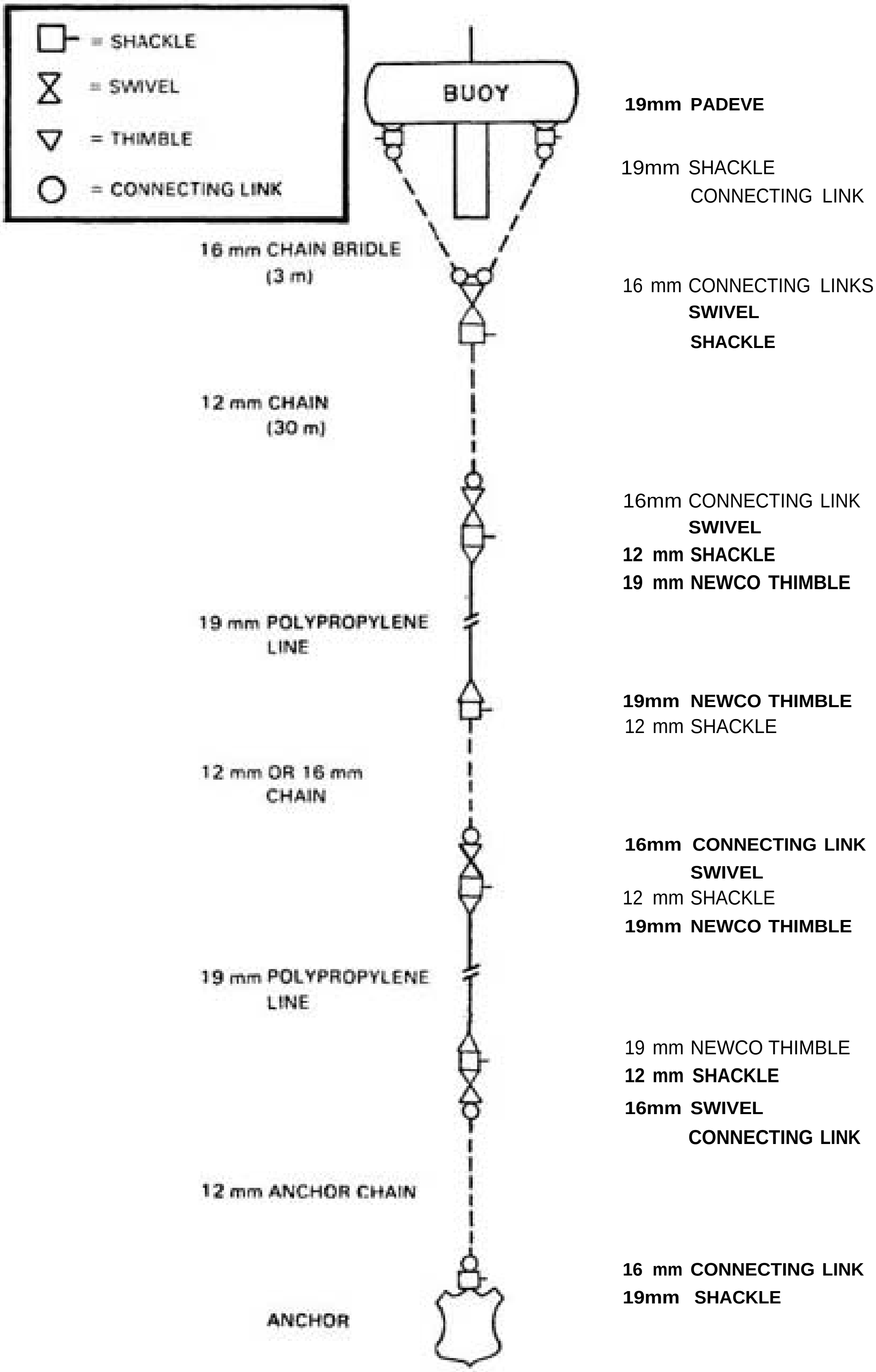
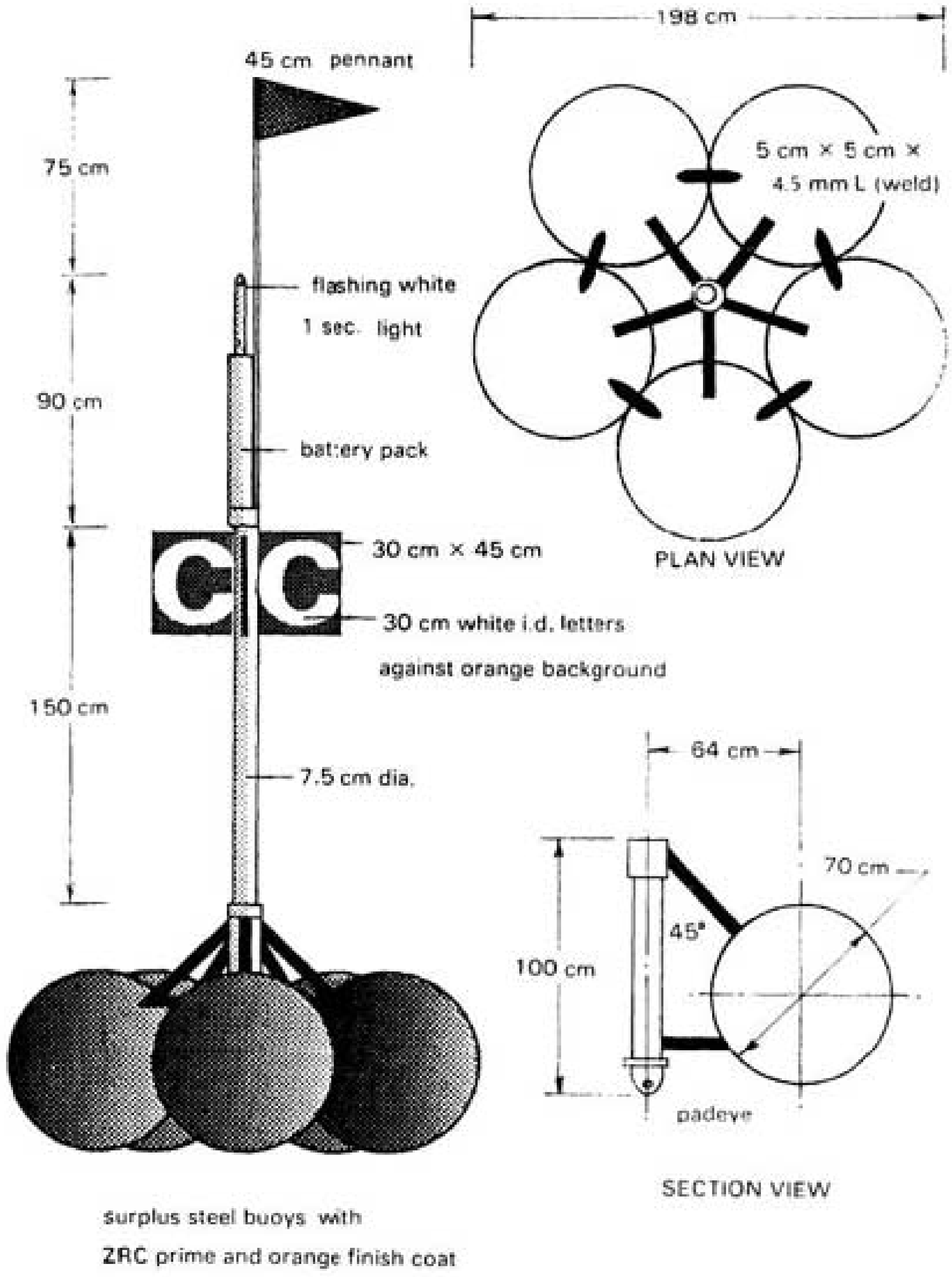


Figure 35



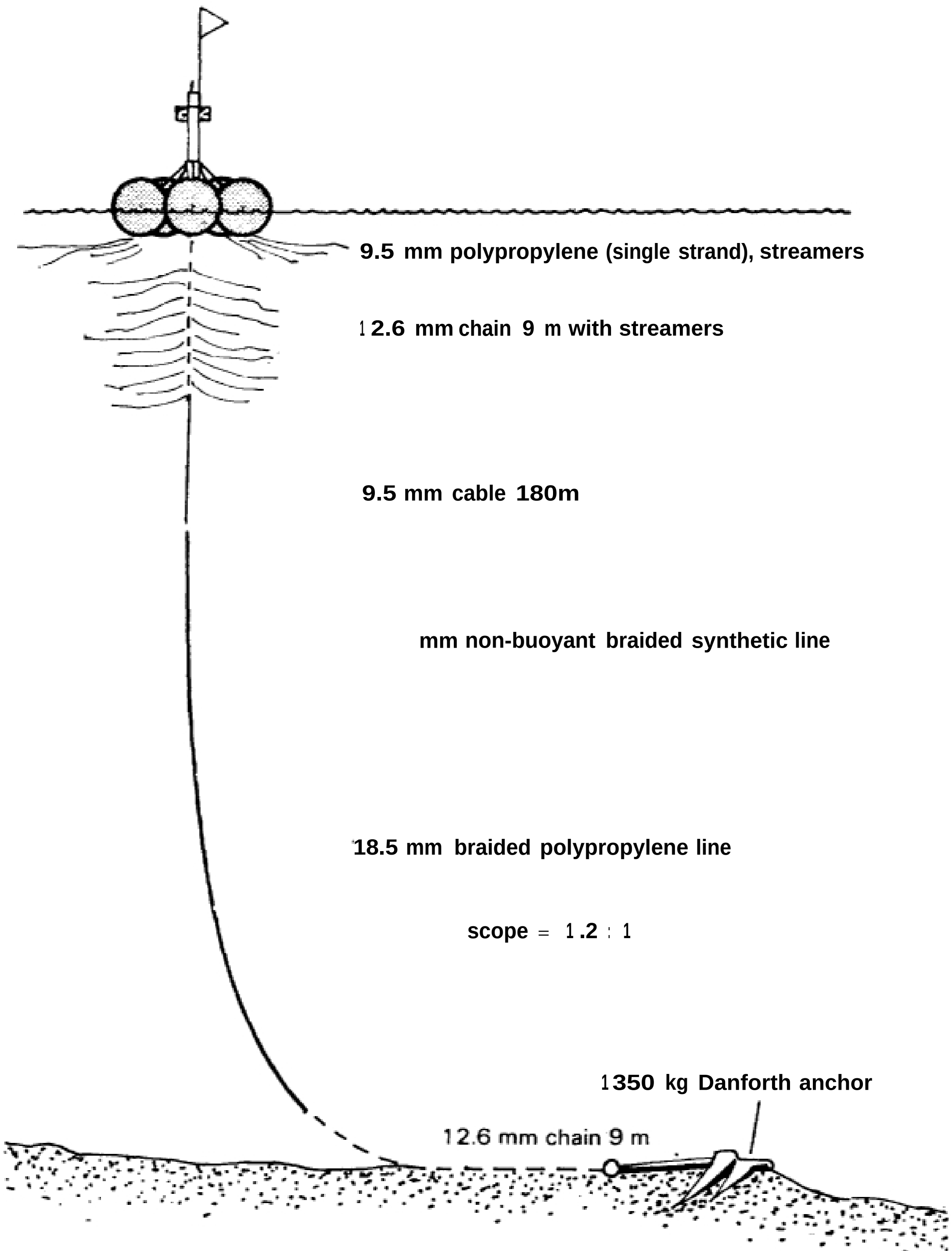
HAWAII FISH AND GAME MOORING DETAILS

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. Apartfrom 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.

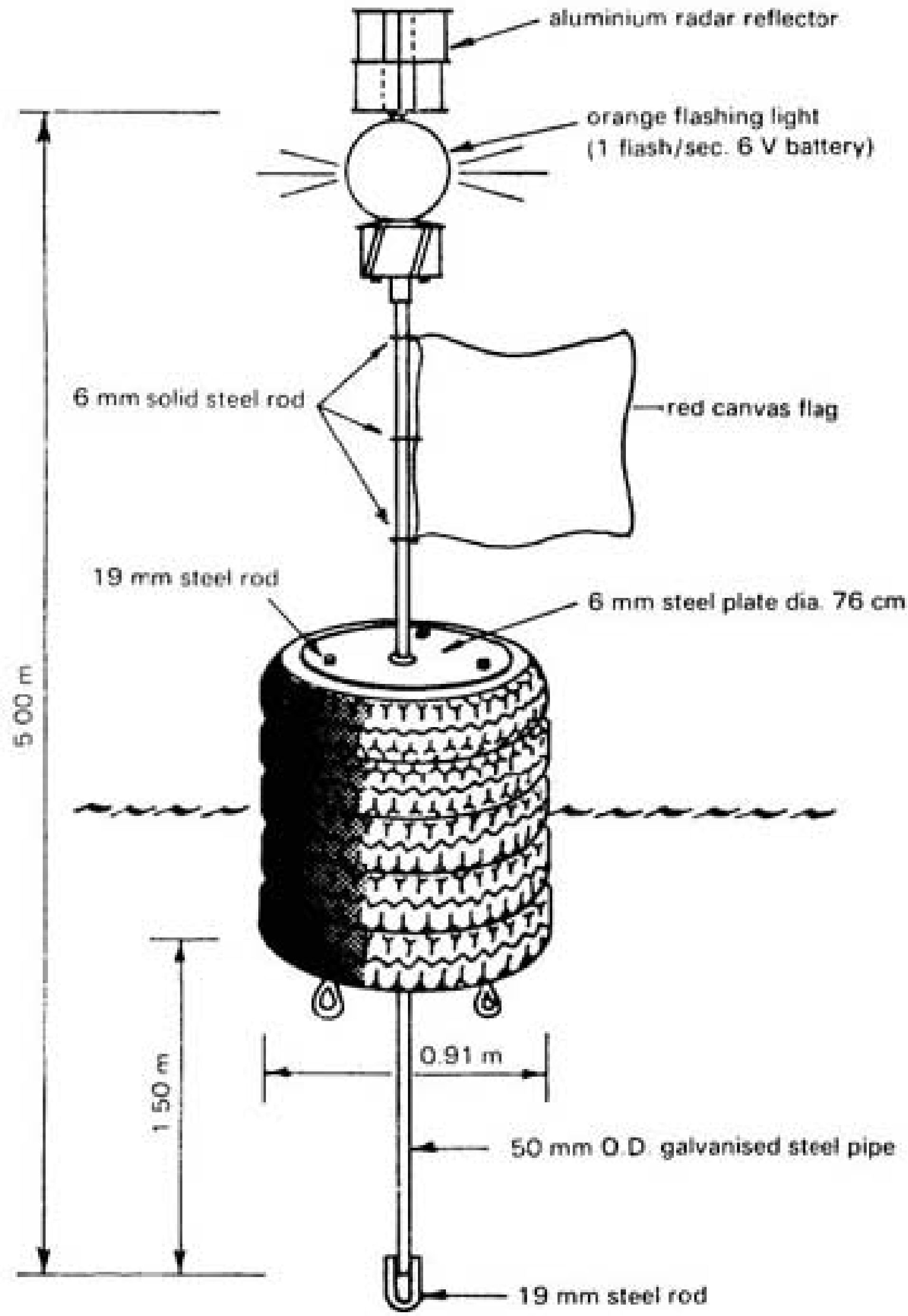
Another FAD type reported from Australia has been set off Sydney at 100 fathoms, mainly to assess the value of such devices for anglers. The attracting appendix here Consists of a black plastic mesh 15 m long and 4 m wide. This mesh is attached 4 m beneath the surface to the buoyed chain running to the 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).

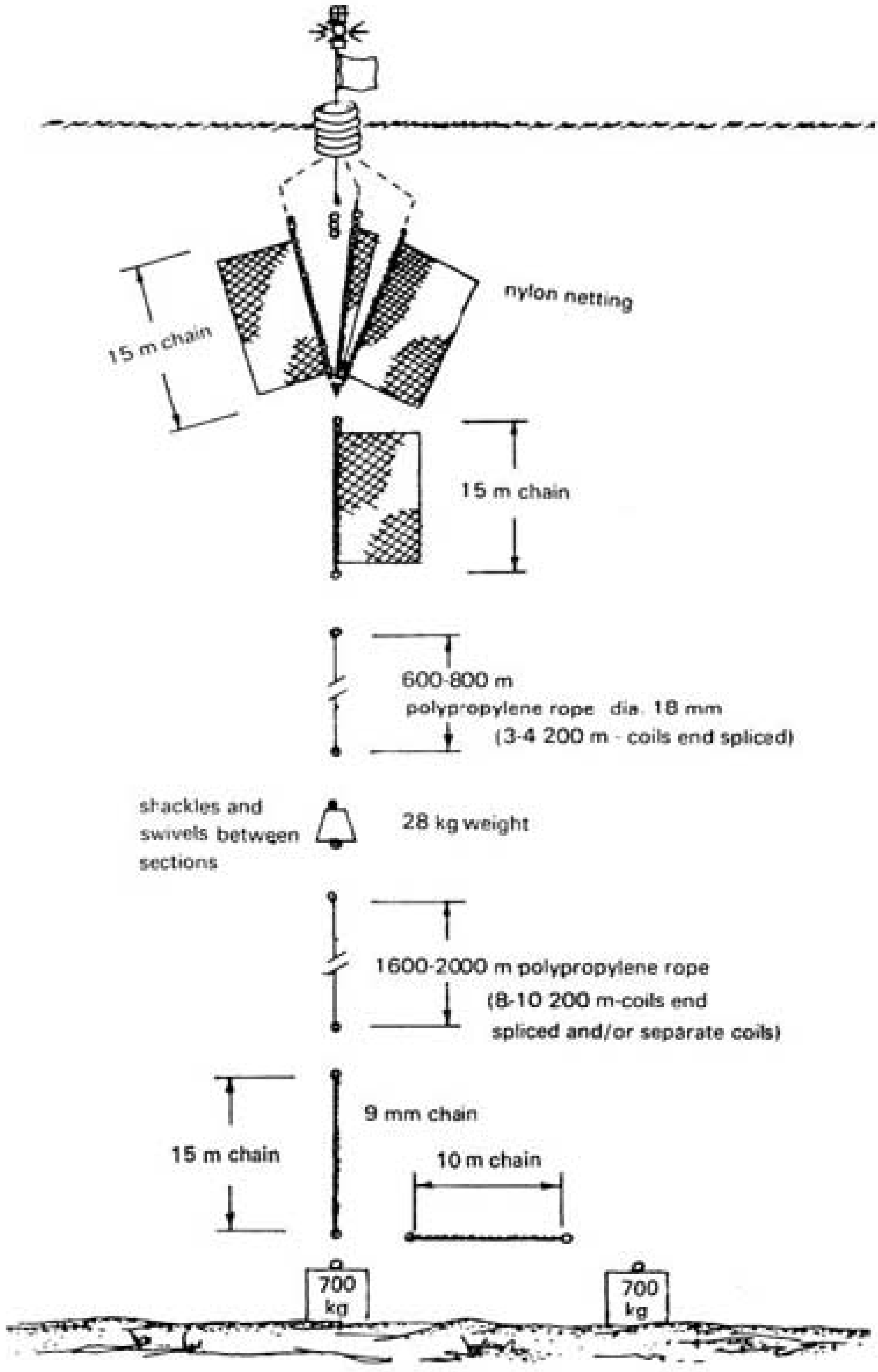
Figure 38

Tyre FAD used in Ma/dives 1982



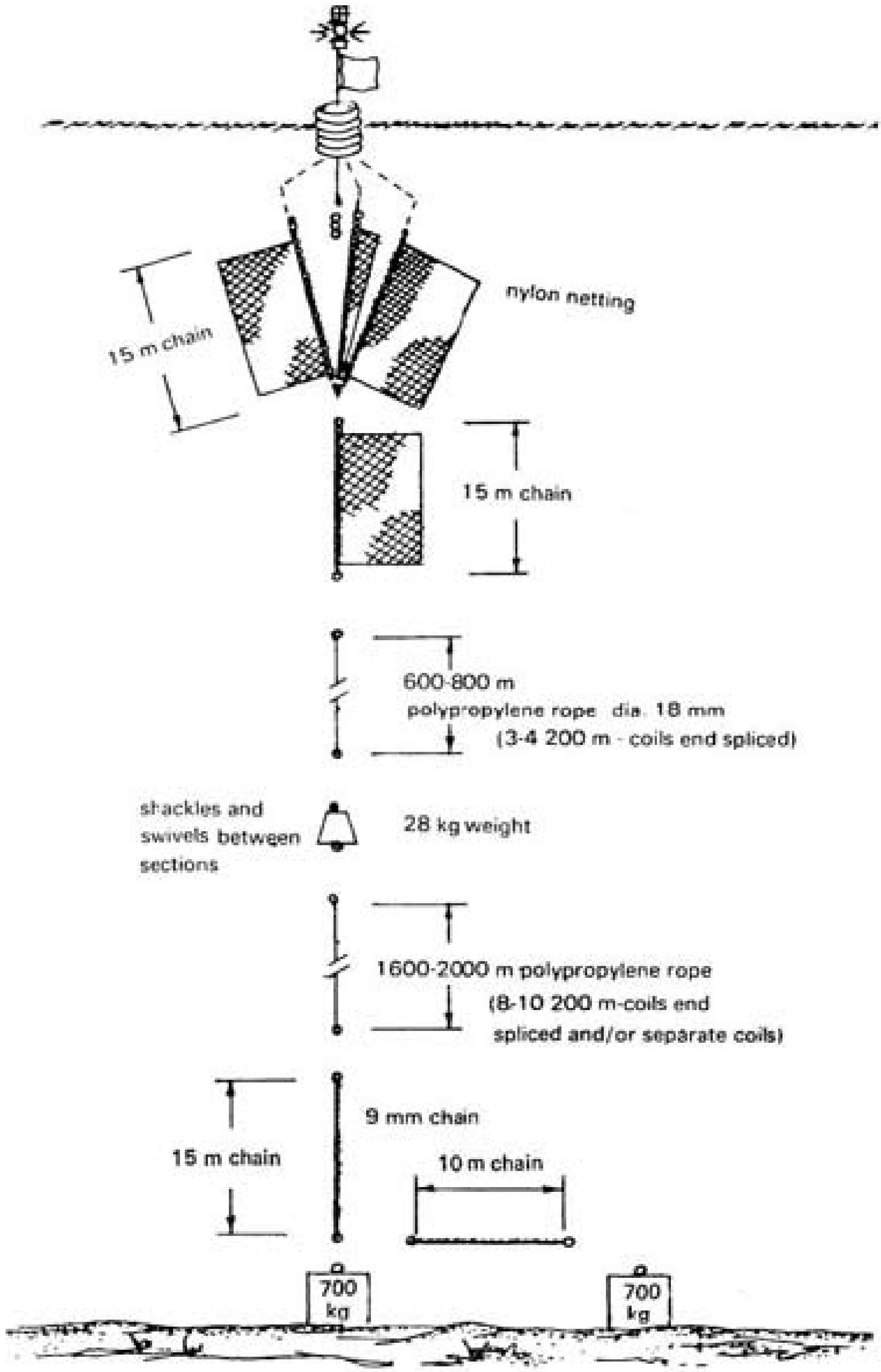
Tyres individually filled with polyurethane foam, and cavities filled when assembling.

Figure 20



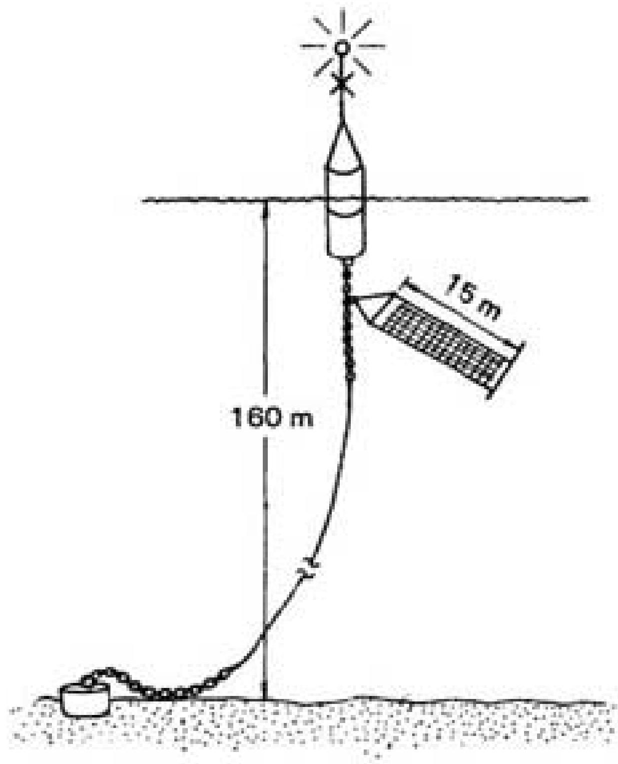
lyre FAD mooring details

Figure 39



lyre FAD mooring details

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 ½ 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 $(\frac{1}{2} \times a)$ 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.

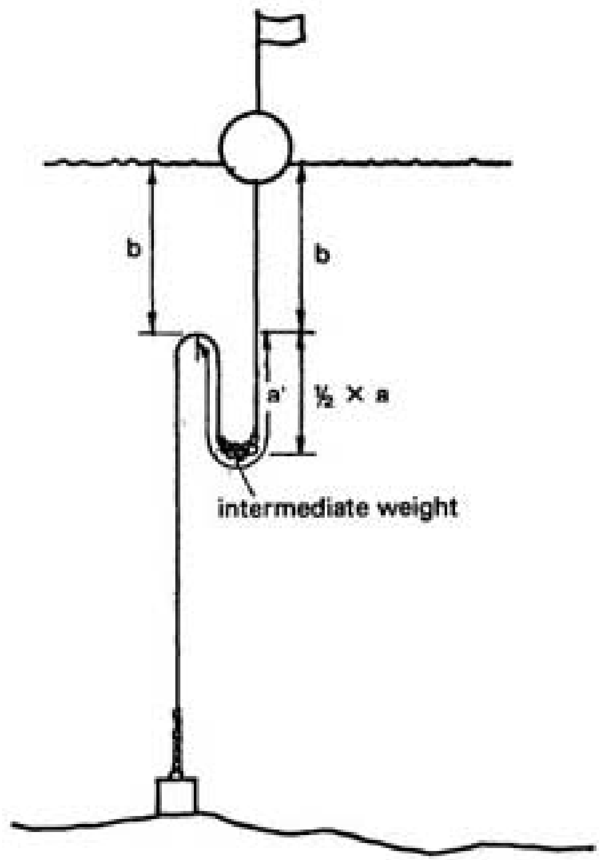
It has been stressed that the intermediate weight must be attached so that it cannot entangle the rope. There appears to be a risk that at times of slack water one weight can bring together different parts of the rope, with entanglement as result. Ideas are now being brought up as to how this problem 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.