

MANUAL ON FISH AGGREGATING DEVICES (FADs):

**LOWER-COST MOORINGS
AND
PROGRAMME MANAGEMENT**

by

Lindsay Chapman, Brendon Pasisi, Ian Bertram, Steve Beverly and William Sokimi



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INTRODUCTION AND BACKGROUND

Since the introduction of fish aggregating devices (FADs) into the Pacific from the Philippines in the late 1970s, regional FAD experience has passed through several distinct phases. Between 1979 and 1983, FAD effort centred on modifying the traditional Philippine payao system to withstand the harsher, deeper-water, high-energy ocean environments typical of the Pacific. The second period, from 1984 to 1990, saw the introduction and widespread adoption of the inverse catenary curve mooring system. SPC produced a manual in 1984 (Boy & Smith 1984) specifically looking at design improvements to FAD mooring systems, with a focus on the inverse catenary curve mooring system. Since that time, development efforts have focused on refining the inverse catenary curve mooring, developing strict material specifications, improving buoy technology, and establishing sound procedures for FAD site surveys and deployments.

In support of the developments in FAD mooring design that were occurring in the region in the 1980s and 1990s, SPC produced a series of three FAD manuals in the second half of the 1990s. The aim of this work was to come up with a cost-effective mooring design that would attain a lifespan of at least two years on average. Unfortunately, this aim was never fully met, with many FADs throughout the region lasting less than 12 months, some lasting 18 months, but very few going past 24 months. Coupled with this, FAD materials continued to increase in price in the 1990s. This resulted in donors, and in some cases governments, pulling back from funding FAD programmes, especially when there was no hard evidence to support the perceived benefits that FADs were providing to local small-scale fishermen.

At the First Heads of Fisheries Meeting (Noumea, 9 to 13 August 1999), FAD programmes were covered in some detail and the meeting urged the now Fisheries Development Section to seek funding to conduct experiments on FAD buoy and mooring configurations to reduce cost and increase the life of FAD units. A three-year FAD research project was initiated in 2001 through the New Zealand Pacific Initiative for the Environment fund. The FAD research project started in June 2001, and finished on 30 June 2004, and the results of this work form a major part of this manual.

Discussions at the Third Heads of Fisheries Meeting (Noumea, 18 to 23 August 2003) and the Fourth Heads of Fisheries Meeting (Noumea, 28 August to 3 September 2004) raised other areas of interest in relation to funding and implementing FAD programmes. SPC was asked to document mechanisms by which FAD user groups could be encouraged to play an active and sustainable role in user-management of FADs and to produce a guide for managing national FAD programmes (monitoring, maintenance, funding options, design improvements, including assessment of the efficiency of sub-surface FADs). These topics will also be covered in this manual.

Summary of SPC's three-volume manual series on FADs

In 1995, SPC started work on three manuals to look at different aspects of FADs and FAD programmes. Two volumes were published in 1996 and the third in 1998. Volume I covered planning FAD programmes (Anderson & Gates 1996), Volume II covered rigging deep-water FAD moorings (Gates et al. 1996), and Volume III covered deploying and maintaining FAD systems (Gates et al. 1998).

Volume I: Planning FAD programmes

This manual gives an introduction to FADs, which covers general information on the aggregation of fish around FADs and the fishing methods used. The potential benefits of FADs for fishermen are also explored with some unexpected problems identified. In looking at the planning of FAD programmes, the manual covers the need to identify whether FADs are needed at all, and if so, how many to set and where. To assess the need for FADs, the collection of information on local fisheries and fishermen's fishing activities is stressed. Once the need is identified, the method of site selection is covered, with a site selection checklist provided.



The need for FAD programme monitoring is stressed throughout the manual. This covers the type of information to be collected and the methods of collection, including marketing data on FAD catches so that their economic performance can be assessed. Socio-economic studies of the community or fishery to assess impact are also explored, with data analysis and interpretation also covered. Many types of data, data analysis and interpretation of data are covered including potential fish yields, FAD programme costs, cost profile of a FAD fishing operation, FAD programme returns, FAD cost-benefit analysis, and social benefits and costs of FAD programmes. The manual comes with a floppy disc with Excel files for calculating costs, used in conjunction with the last chapter of the manual.

Volume II: Rigging deep-water FAD moorings

This volume explores in detail the two recommended FAD designs that were promoted by SPC at the time. Buoy designs were covered, with the construction of a spar buoy and an SPC-modified Indian Ocean FAD buoy system covered in detail. The manual also covers the hardware recommended by SPC for rigging the mooring system, with galvanised anchor-type safety shackles used. Rope is the main component of the mooring line, and the manual explores the use of nylon (upper mooring) and polypropylene (lower mooring) 8-strand or 12-strand ropes and Nylite rope connectors. The use of the nylon and polypropylene rope combination allows for a catenary curve to occur in the mooring line. A table of rope lengths required for different depths is provided, and the need for supplementary buoyancy for shallower-water mooring systems is discussed. This manual concludes by looking at the anchor block used to moor the FAD system in place.



Volume III: Deploying and maintaining FAD systems



The final manual in the series looks at site selection and method, including the use of an echo sounder, planning and conducting a controlled survey with the echo sounder and GPS for position, plotting the data collected to come up with a bottom contour map, and selecting suitable positions for deploying FADs. The manual then looks at the deployment of FADs, including deployment techniques, factors affecting anchor placement, calculating buoy drift, deployment vessel and layout, loading the materials onto the deployment vessel, preparing FAD components, and the actual deployment procedure. The manual concludes with a chapter on the general and physical inspection of FADs in the water, maintenance and repairs, and record keeping.

FAD research project

The basic objectives of FAD programmes and the work that SPC has undertaken in the past have been to come up with a cost-effective FAD design that would have an average lifespan of at least two years. These objectives have not been fully realised, although materials that were thought to be more durable and last longer, and usually more expensive, have been used in the previous SPC recommended designs. The question of the financial benefit of FAD programmes has also been left largely unanswered. These same challenges led to the FAD research project being developed.

The FAD research project, which operated from June 2001 to July 2004, was funded by New Zealand under their Pacific Initiative for the Environment (PIE) fund. The project was implemented in Niue, and Rarotonga and Aitutaki in the Cook Islands. The specific requirements of this project (which, in itself, forms the basis of this manual) were:

- to develop a more cost-effective FAD mooring design with an average lifespan of at least two years, while reducing costs to a target unit level of NZD \$4500 (USD \$3000) for deep-water FADs (1000 m depth) and NZD \$3000 (USD \$2000) for shallow-water FADs (300 m depth);
- to conduct studies with selected coastal communities over the three-year life of the project, especially in areas where reef and/or lagoon marine protected areas (MPAs) have been declared and FADs deployed, to try to measure any benefits to the communities and the usefulness of FADs as a management tool;
- to collect catch and effort data from fishermen involved in FAD fishing (by fishing technique), and to conduct a cost-benefit analysis of the data to estimate the benefits or otherwise of the use of FADs; and
- to produce a technical manual and other literature, reports and articles to document the findings of the project, with the technical manual covering the new and recommended design for FADs based on the results of the project.

PLANNING AND IMPLEMENTING FAD PROGRAMMES

FAD programmes need to be carefully planned to ensure success, and they need to be ongoing to ensure continuity for the users. Five-year plans are the best arrangement with the bulk ordering of materials to minimise the costs of both the materials and the freight. However, in planning and implementing FAD programmes, social implications also need to be carefully considered, as these may influence the decisions on whether FADs are needed, and where they are placed.

FAD programmes and their purpose

It is important to identify at the start whether there is a need for a FAD programme. In looking at the need, it is important to understand the local fishermen's activities and the ways of the local fisheries. If people can make a reasonable living from current reef and lagoon fishing activities, will they also fish around FADs? Also, do fishermen have the fishing gear needed for fishing around FADs? If not, are they prepared to buy the equipment? These questions need to be answered in the planning stage, so that funds are not wasted on FADs that no one intends to fish around. Alternatively, if fishermen are interested or intend to fish around FADs, then there may need to be some training for the fishermen to introduce different fishing methods and gear they may not be familiar with to maximise the use of the FADs.

When looking at a FAD programme, one of the most important questions to be answered is 'what is its purpose'? That is, what are the perceived benefits that will come from such a programme and who are the beneficiaries? Some of the more common reasons for FAD programmes are to:

- relieve fishing pressure on inshore resources (reef and lagoon) by providing an alternative fishing location for those that have boats and canoes;
- assist subsistence, artisanal and commercial fishermen with boats and canoes to increase their catch and reduce their operating costs;
- improve safety at sea as fishermen are going to known locations to fish and there are likely to be other fishermen in the area;
- assist sportsfishing and charter operations with their fishing activities, which generally encourages more tourism; and
- increase food security by allowing those with boats and canoes to fish around the FADs, thus leaving more fish in the lagoon for those that do not have boats or canoes.

The purpose of FAD programmes, especially for the users of FADs, will be discussed more in the 'Funding FAD programmes' section of this manual (page 37).

Social implications to be considered

Once the purpose of the FAD programme is identified, the social implications need to be considered. The table below summarises the more common social implications or concerns that need to be sorted out, usually through group meetings and discussion.

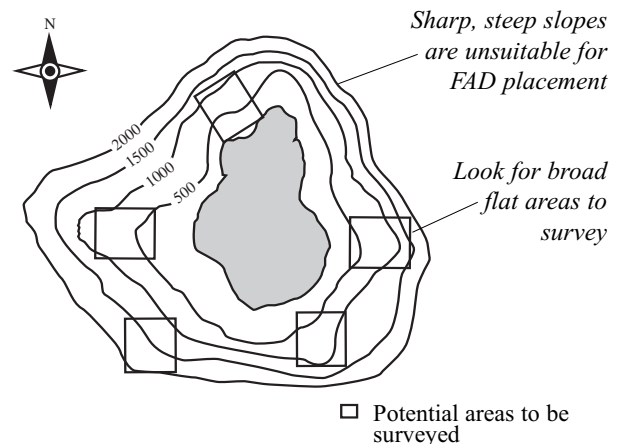
Issue	Social implications or concerns
Deploying FADs offshore (more than 1 km off the coast)	<ul style="list-style-type: none"> • Canoe fishermen cannot fish offshore FADs as they are too far out to paddle to — safety issues. • Canoe fishermen feel the FADs are stopping the fish from coming closer to the reef where they can catch them — causing conflict. • Canoe fishermen are jealous of the catches taken by boat fishermen from the offshore FADs.
Deploying FADs inshore (within 1 km of the coast)	<ul style="list-style-type: none"> • Both canoe and boat fishermen can fish these, although boats generally troll and canoes generally fish mid-water — potential for conflict. • Boats make waves when trolling which make it uncomfortable for canoe fishermen, plus they feel the boats scare the fish away — potential for conflict. • Canoe fishermen have traditional ‘tuna holes’ they fish — should the FAD be placed in these areas or well away from them? • Concerns by villagers that FADs are attracting fish from the reef which affects people fishing on the reef. • Concerns by villagers if a FAD is deployed close to one village and not to others — causes jealousy. • Concerns by villagers that FADs attract sharks that will come close to the reef.
Deploying both inshore and offshore FADs	<ul style="list-style-type: none"> • FADs for both canoe and boat fishermen — however, boat fishermen can still fish inshore FADs while canoe fishermen cannot fish the offshore ones — causes jealousy. • Fish caught on offshore FADs (boats) and not inshore ones (canoes), with canoe fishermen not able to get to offshore FADs to catch fish — causes jealousy.
Customary fishing rights	<ul style="list-style-type: none"> • Is there any traditional management system in place? If so, does it cover fishing grounds or locations outside the reef? Will there be conflict if a FAD is deployed in such an area?
Ownership and vandalism	<ul style="list-style-type: none"> • Some fishermen feel the FADs are theirs, even though they have not paid for them, and do not like others fishing around them. • Fishermen may vandalise FADs and cut them free to stop others from fishing around them. • Potential conflict between subsistence, artisanal, commercial and recreational fishermen, especially on weekends when FADs may become crowded.

Planning a FAD programme

Once the decision is made to proceed with a FAD programme and the social implications have been considered and acted on, the FAD programme can be planned. The plan should include the rough selection of deployment sites or areas, the number of FADs to be deployed and maintained initially, the number of spare FADs to be kept for replacement purposes, the spare parts needed for maintenance, and the pricing and ordering of materials. In most cases, a five-year period should be used for planning purposes.

Selecting suitable areas for FAD placement

In the planning stage of a FAD programme, marine charts of the area can be used as the main tools to identify initial areas that may be suitable. This should be done with input from local fishermen who know the area. In addition, other government departments need to be consulted to ensure that shipping lanes are avoided, and the Ports Authority may have regulations that restrict the placement of buoys around harbour entrances and passages. In some cases, the navy or coast guard may need to be consulted, and they may even dictate what areas can be considered for FAD placements. Once everyone has been consulted, and possible areas ruled out, marine charts can be used for area selection.



The main characteristics to look for on a chart are: areas with a gentle sloping sea floor rather than a steep dropoff; a reasonable depth of water (usually 750 to 1500 m for offshore FADs and 200 to 400 m for inshore FADs) that is within the range of the vessels going to fish the FADs; strength and direction of current (if this is shown), looking for low current areas; and the distance between areas so that FADs are spaced out (usually 10 to 12 nm apart) and not too close together.

The fishermen's input to the process can cover: the sea conditions and amount of time per year a particular area can be fished; the abundance of tunas and other pelagics in each area and the seasonality of this; and whether there are fishermen who will fish in these areas, and how often.

Number of FADs for a five-year programme

Once all of the above factors have been taken into consideration the number of FADs can be determined for the initial deployment, based on one per selected area. Working on a two-year average life for each FAD, this number would then be multiplied by 2.5 to bring this up to a five-year period. Therefore, if the initial plan is to set six FADs, then materials for 15 should be ordered for the five-year programme.

Using the above example, in addition to the materials for 15 FADs, spare floats for the buoy system and upper mooring hardware will be required for maintenance purposes. This will include materials for flagpoles, lights for finding the FADs at night, materials for aggregators and so on.

A lot of care needs to go into thinking through the likely materials that will be needed. These materials are covered in detail in the next section of this manual.

Pricing FAD materials

In the initial planning stage, it is usually not known what depth each of the FADs is going to be deployed in. The depth will not affect the numbers of each piece of hardware (shackles, swivels, chain etc) or the number of floats to be used on the buoy system, so the numbers of these items are easy to determine including spares for maintenance. However, it is much more difficult to estimate the amount of rope that will be needed for each FAD, and therefore the total amount of rope. The easiest approach to estimate this is to look at the chosen areas on the chart and choose a rough position with depth for each. You then add 20 per cent to this depth to come up with the actual length of rope needed for each location. The mooring designs used have a mix of negatively buoyant nylon rope on the top, and positively buoyant polypropylene rope on the bottom, which creates a catenary curve at the point where they are joined.

Once the length of rope is estimated for each location, it has to be split into the amount of nylon and polypropylene rope needed. A rule of thumb here is a:

- 30:70 split (nylon to polypropylene, or lead-core polypropylene to polypropylene) for FADs to be deployed in depths from 600 to 900 m;
- 25:75 split for FADs being deployed in depths from 1000 to 1600 m; and
- 23:77 split for FADs being deployed in depths greater than 1600 m.

For example, to set a FAD in 1000 m depth, 1200 m of rope is required. At a ratio of 25:75, this would mean 300 m of nylon and 900 m of polypropylene rope. Once this is calculated for each area, the amount of each type of rope is added up. These numbers are then multiplied by 2.5 to come up with the total length of each rope type for a five-year period.

When ordering ropes for FADs, it is best to get them in the longest lengths possible to reduce the number of splices or connections that need to be made. Most manufacturers or suppliers will supply ropes in 500 m coils, although the normal length is in 220 m coils. Therefore, the total length of each rope type as calculated above

needs to be divided by 500 or 220 to come up with the number of coils of each rope type. Other hardware items such as floats, swivels and shackles are sold by the piece, while chain is sold by the metre.

Some suppliers of FAD materials can supply completely assembled FAD units to the specifications they are given. However, ready-made FADs have some drawbacks as you can only deploy the unit in the depth of water it was designed for and, in some cases, the splicing or rope connections used by the supplier are different to those normally recommended. The best approach is to order the different components and do the construction on location, so that each FAD can be constructed to the actual depth of water once this has been decided after site surveys of the selected areas have been undertaken.

Once the numbers of each item have been agreed on for the five-year programme, including spares for maintenance work, a materials list can be compiled. The list should have the full specifications of each item required and the number of each item. The list can then be sent to suppliers of FAD materials in different countries to get quotes including freight and insurance, which some people overlook in the initial stage of pricing materials. Once the quotes have been received from the different suppliers, they need to be checked to ensure that all items have been quoted on and that the items quoted are the same as those on the list provided to them. Often a supplier will not have a specified item, so will quote on a similar or alternative item which may or may not be suitable. It is also useful to check how long the quote is valid for, especially if funding is not yet available.

Material	Quantity
<p>Ropes and thimbles</p> <ul style="list-style-type: none"> • List individually each size and type of rope and the length of each coil. • List individual sizes of rope connectors. 	<p>Number of coils Number of connectors</p>
<p>Hardware (chain, shackles, swivels, cotter pins etc)</p> <ul style="list-style-type: none"> • List individually each size with specifications for safety shackles, swivels and cotter pins. • List size and specifications of chain needed. 	<p>Number of pieces of each item Length of chain</p>
<p>Buoys and pressure floats</p> <ul style="list-style-type: none"> • List individually each size of float with any specification on pressure rating, centre diameters etc. 	<p>Number of pieces of each item.</p>
<p>Other items</p> <ul style="list-style-type: none"> • List individually all other items needed and any specifications. 	<p>Number of each item</p>

Budgeting and ordering the FAD materials

If there is no funding available for the immediate ordering of the FAD materials, the quotes can form the basis of a funding proposal to government or donor agency. The final stage is to place the order with the chosen supplier, once funding is available, and sort out how the payment is to be made, as many suppliers require pre-payment for goods before they ship them.

Whenever budgets allow, it is best to order in bulk to reduce the cost of each FAD. If you have to pay the freight on a whole container, you may as well fill it rather than have it half-empty, as the freight charge will usually be the same.

Funding of the FAD programme needs to be ongoing to ensure there is money available towards the end of the first five years, so that materials can be purchased in bulk for the continuation of the FAD programme. The funding approach needs to be planned and implemented during the first year of the FAD programme. This topic is covered later in this manual under the heading ‘Funding FAD programmes’.

(Note: the detailed specification of the materials required for SPC-recommended FADs is covered in the next section.)

NEW FAD DESIGNS FROM PAST AND PRESENT EXPERIENCES

The FAD research project looked at past designs for FAD buoy and mooring systems and tried to improve on these. In doing this, many of the components used in the previous SPC-recommended designs were used. To try to reduce costs, some alternative materials were trialled for the upper mooring, and three-strand ropes were used throughout. This section summarises the new SPC-recommended design FADs, based on the results of the FAD research project.

Buoy systems

The two buoy system designs described here have been developed by the SPC Fisheries Programme with assistance from the Fisheries Departments in both Niue and the Cook Islands. Both types have been tested in the field and are recommended as suitable for all deep-water FAD use.

The SPC steel spar buoy

The SPC steel spar buoy was designed in the 1990s at SPC's request by Lt Cmdr Richard Boy of the United States Coast Guard, as a robust, long-lasting buoy, capable of carrying both a navigation light and a radar reflector, and within the construction capabilities of small steel fabrication workshops found in the region. It is a non-directional, wave-riding buoy made from steel.

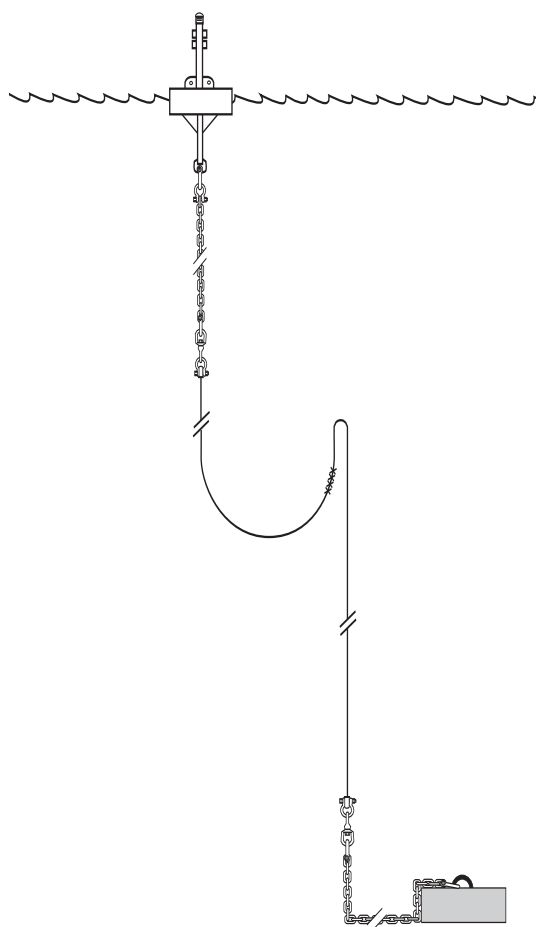
The design features the high buoyancy-to-drag ratio characteristic of wave-riding buoys. The buoyancy provided by the size of the hull is sufficient to support the weight of the buoy itself and the upper mooring, which includes 15 m of chain and a section of nylon rope. In addition sufficient reserve buoyancy is provided to ensure that the buoy is not submerged when the mooring is fully extended under the effect of currents, winds or high seas.

Anti-flooding and anti-capsizing features are incorporated in the buoy design. The hull is divided into three separate compartments, each of which can be leak-tested before the buoy is deployed. If cracks form in the hull or welded seams, flooding is likely to be confined to a single compartment, which reduces the chances of loss of the buoy and the mooring. Full construction notes as presented in SPC's FAD Manual Volume II (Gates et al. 1996) for making a steel spar buoy can be found at Appendix A.

A single 345 cm length of 10 cm galvanized steel pipe forms both the buoy's mast and its mooring attachment point. The mooring attachment spar (the section of the pipe that extends below the buoy), the mooring attachment pad-eye, and the weight of the upper chain collectively stabilise the buoy and provide a righting capability that prevents capsizing.

The single-piece galvanised-pipe combination mast and mooring attachment, the compartment walls of the hull, and the support gussets, provide strength to the mooring attachment and reduce the chance of the pipe being bent as it works to right the buoy in rough seas. The design also includes a set of sturdy lifting eyes welded to the top of the hull, which make it possible to load and deploy the buoy without damaging it.

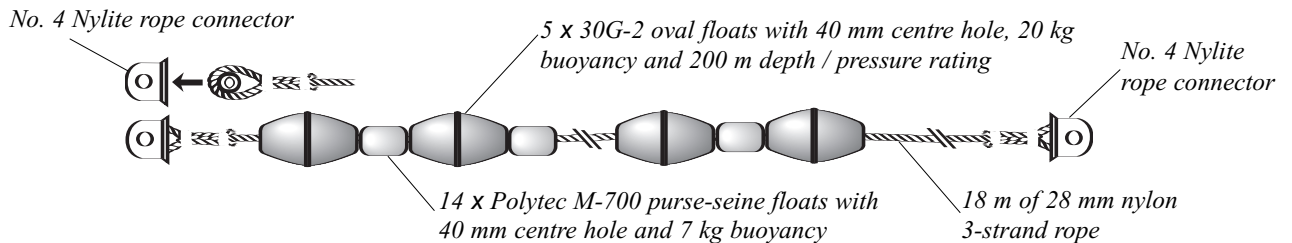
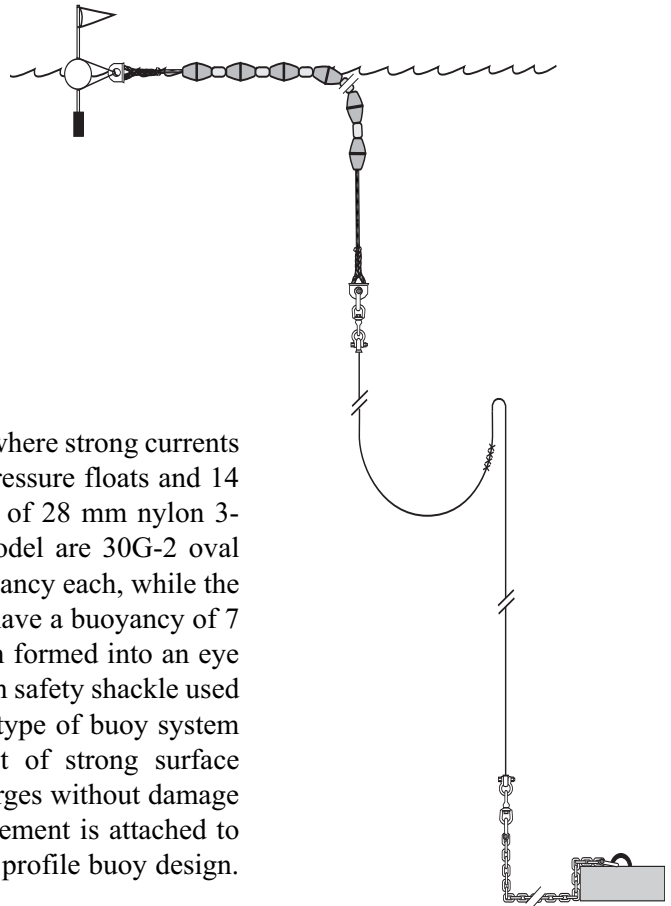
Although the steel spar buoy was not used during the FAD research project, it is still considered a suitable design buoy system for offshore FADs.



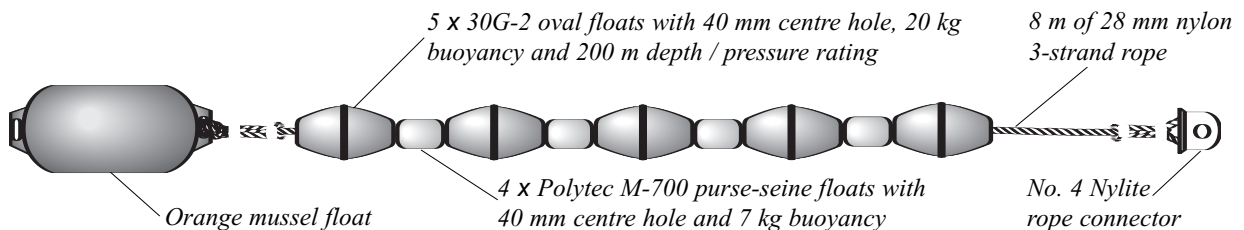
The new SPC Indian Ocean FAD buoy system

In Volume II (Gates et al. 1996) of the SPC FAD manuals, an SPC-design Indian Ocean FAD buoy system was recommended. This design was used in many countries in the late 1990s and early 2000s, but, some problems were encountered with the wire cable breaking where it came out of the PVC coating. In other instances, it was believed that when the buoy system was pulled under by the current to a depth where the purse-seine floats were being crushed, they did not retain enough flotation to bring the buoy system back to the surface.

The new design, specifically for deployment in areas where strong currents are common, is rigged by stringing 15 hard plastic pressure floats and 14 soft purse-seine floats alternately on an 18 m length of 28 mm nylon 3-strand rope. The pressure floats used in the SPC model are 30G-2 oval floats with a pressure rating to 200 m with 20 kg buoyancy each, while the purse-seine floats used are Polytec M-700 types and have a buoyancy of 7 kg each. Both ends of the 28 mm nylon rope are then formed into an eye splice, with a No. 4 Nylite rope connector and a 28 mm safety shackle used for attachments. The buoyancy and low drag of this type of buoy system places less strain on the mooring under the effect of strong surface currents. In extreme currents, the buoy system submerges without damage and resurfaces when currents ease. A flagpole arrangement is attached to the end of the buoy system to aid in locating this low profile buoy design.



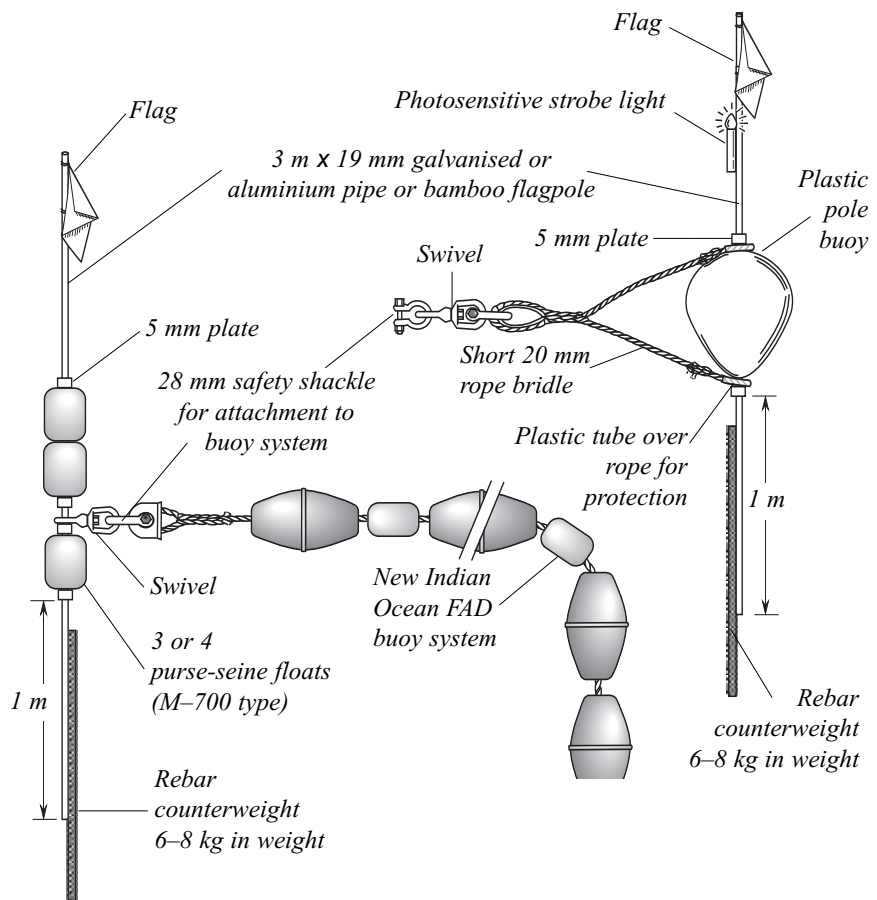
A second buoy design was also used on inshore FADs, as canoe fishermen, sitting at sea level, needed a more visible buoy system. This design followed the same principle as the offshore design, but incorporated a large mussel float at the end. The buoy system was rigged by stringing 5 pressure floats and 4 purse-seine floats on 8 m of 28 mm nylon 3-strand rope. An eye splice was formed in one end of the rope, with the other end spliced directly onto a bright orange mussel float. Connection of this buoy system to the upper mooring hardware was made with a No. 4 Nylite rope connector and a 28 mm safety shackle.



Because this type of buoy system cannot capsize, it does not need a stabilising counterweight beneath it.

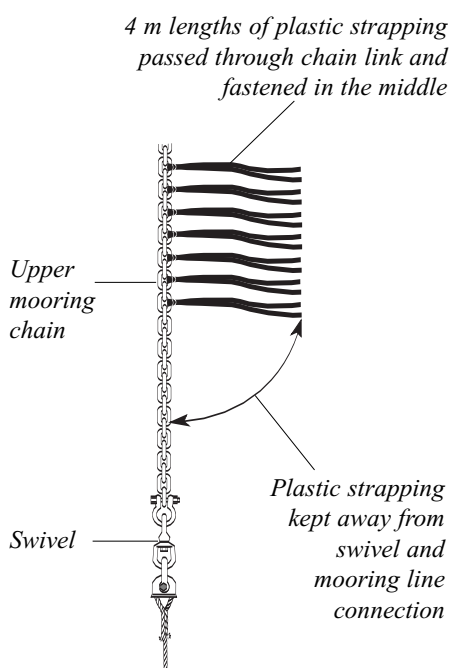
Flagpole arrangements

The new Indian Ocean FAD system has a very low profile, almost flat on the ocean surface, and this makes it hard to see. To make it more visible, a flagpole is attached. There are many ways to make up a flagpole arrangement, using three or four purse-seine floats, or a teardrop-shaped plastic pole buoy, on a 3 m length of galvanised or aluminium pipe, or even bamboo. The floats are positioned on the pipe or bamboo with a stopper on either side to keep them in place. A counterweight is needed on one end of the pipe or bamboo to make it stand vertically, with a flag attached to the top. A small photo-sensitive strobe light can also be attached to the flagpole.



Appendages/aggregators

It is widely believed that appendages attached to or below the FAD buoy system increase the effectiveness of the FAD in aggregating and holding fish. This has yet to be demonstrated by research, but is supported by anecdotal accounts from throughout the Pacific.



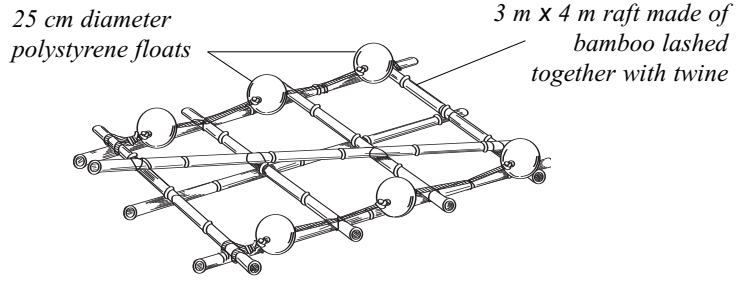
A wide variety of materials and configurations have been used to rig appendages. Coconut fronds, rubber tyres, plastic strapping, old rope and netting have all been used. Plastic strapping, of the type used to bind cartons, has proved to be an effective material when attached below the spar buoy system. It is durable, inexpensive, presents minimal drag on the FAD system and is simple to attach to the mooring. Attaching a separate raft or aggregator to the buoy system has also proven to be effective.

Steel spar buoy system appendages

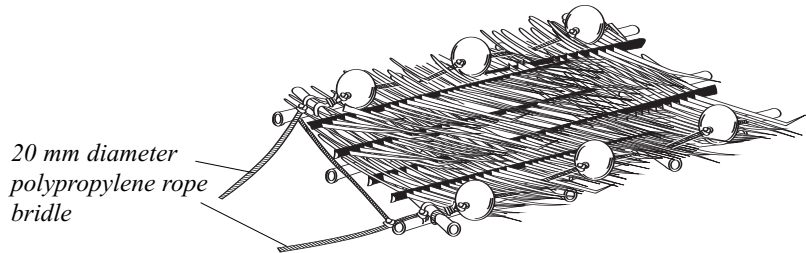
For the SPC steel spar buoy FAD system the appendages should be attached to the upper mooring chain. Four-metre lengths of plastic strapping are pulled through and knotted to individual links of chain. Lengths of strapping which are longer than 4 m tend to break off. The simplest method for fastening the strapping is to pass the strapping through the chain link and make an over-hand knot. The strapping should be knotted at the mid-point of the 4 m length so that each of the two free ends is 2 m long.

Rafts and separate aggregators for all FAD designs

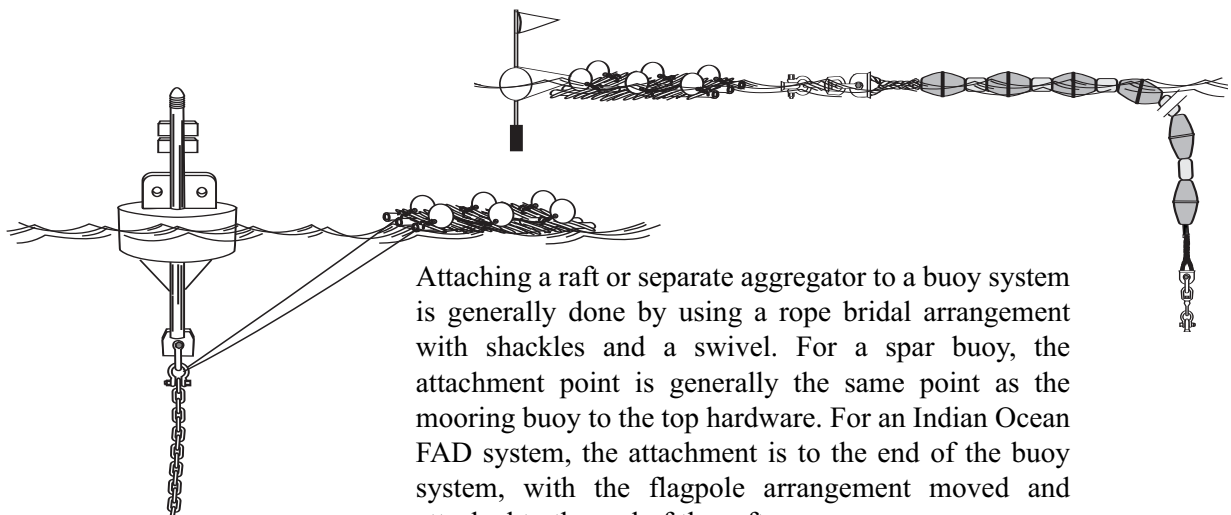
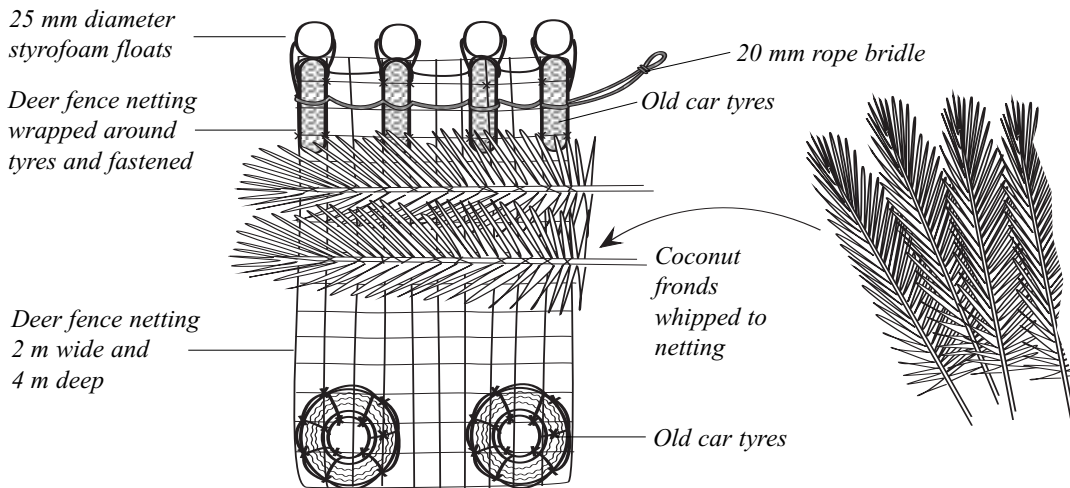
Rafts or separate aggregators should only be used in areas of low current. A raft can be made out of bamboo with purse seine or polystyrene floats attached to provide additional flotation. Coconut fronds are used to cover the raft to provide shade, while other materials including coconut fronds or ropes with plastic strapping can be hung under the raft. Wire mesh covered in coconut fronds hung vertically in the water with floats on the top is another form of aggregator that seems to work well.



Bamboo frame for raft

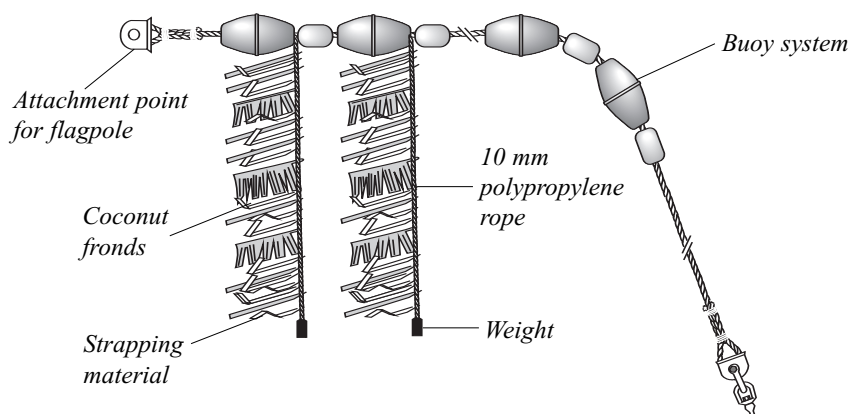


Raft covered with coconut fronds



Attaching a raft or separate aggregator to a buoy system is generally done by using a rope bridal arrangement with shackles and a swivel. For a spar buoy, the attachment point is generally the same point as the mooring buoy to the top hardware. For an Indian Ocean FAD system, the attachment is to the end of the buoy system, with the flagpole arrangement moved and attached to the end of the raft.

For the Indian ocean FAD system, weighted ropes can be hung under the system with coconut fronds or plastic strapping attached. If these are used, they need to be clear of the swivel at the buoy and mooring line connection to avoid tangling and causing the swivel to stop functioning.



The catenary curve mooring system and its components

Each of the SPC FAD systems incorporates an inverse catenary curve mooring. Catenary curve moorings can be considered to consist of three separate sections: the upper mooring, the catenary curve, and the lower mooring. Each section is important to the function of the mooring.

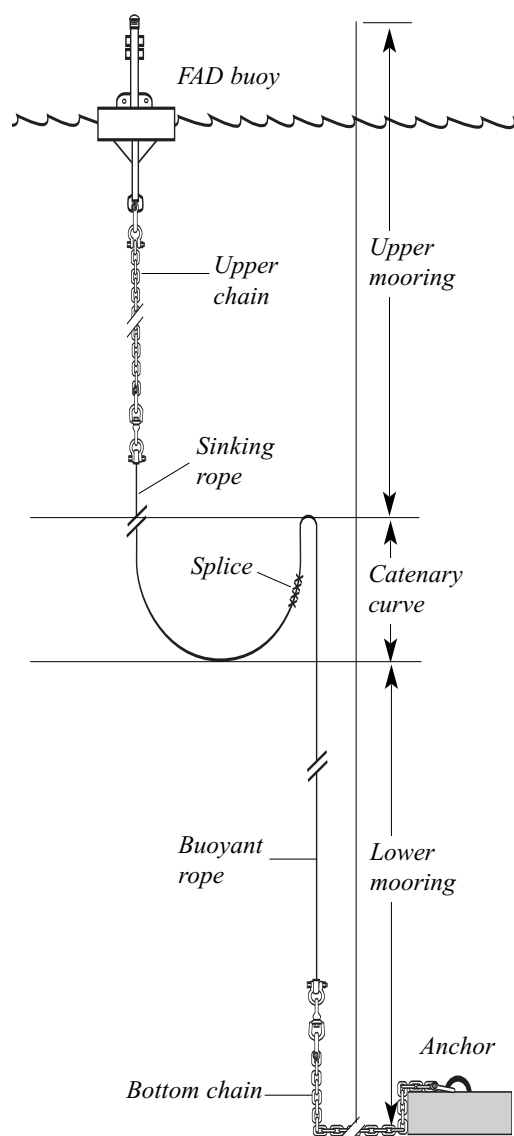
The upper mooring section consists of a chain or rope, sinking nylon rope or lead-core polypropylene rope and connecting hardware. Chain forms the link between the buoy system and the mooring line and acts as a counterweight for a spar buoy. Nylon rope is used on the new Indian Ocean FAD system, and this connects directly onto the upper mooring line.

The nylon rope or lead-core polypropylene rope stretches and recoils in response to forces produced by waves. A swivel, placed between the chain or rope and the sinking nylon rope or lead-core polypropylene rope, responds to the motion of the buoy and prevents twisting of the chain, or rope, and mooring line.

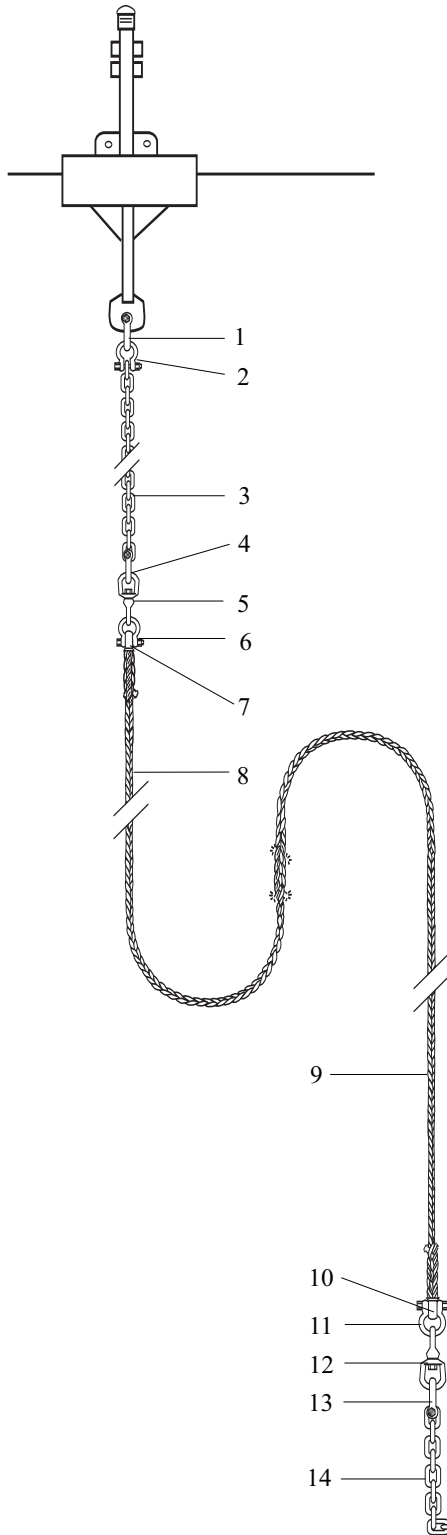
The catenary curve section forms around the point where the nylon rope or lead-core polypropylene rope and polypropylene rope are spliced together end to end. The offsetting sinking and buoyant properties of the two ropes cause the curve to form, although this is only in times of calm weather and very little current. Wind, wave action and current will stretch the mooring line out and remove the catenary curve. The sinking property of the nylon or lead-core polypropylene rope is used to maintain the catenary curve at a safe depth.

The lower mooring section consists of buoyant polypropylene rope, chain, and connecting hardware. The buoyancy of the rope must be sufficient to lift at least 3 m of the connecting lower hardware, thus preventing the rope from abrading on the sea floor. Forces exerted on the buoy system and mooring by wind, waves and currents near the surface are transferred down the mooring to the chain, which rises and sinks in response. A swivel placed between the polypropylene rope and the chain prevents twists in the chain and mooring rope.

Once a FAD is deployed, it is normally only possible to inspect and maintain the upper 10 to 20 per cent, from the buoy to part-way down the upper mooring rope. Maintenance methods are covered later in the manual.



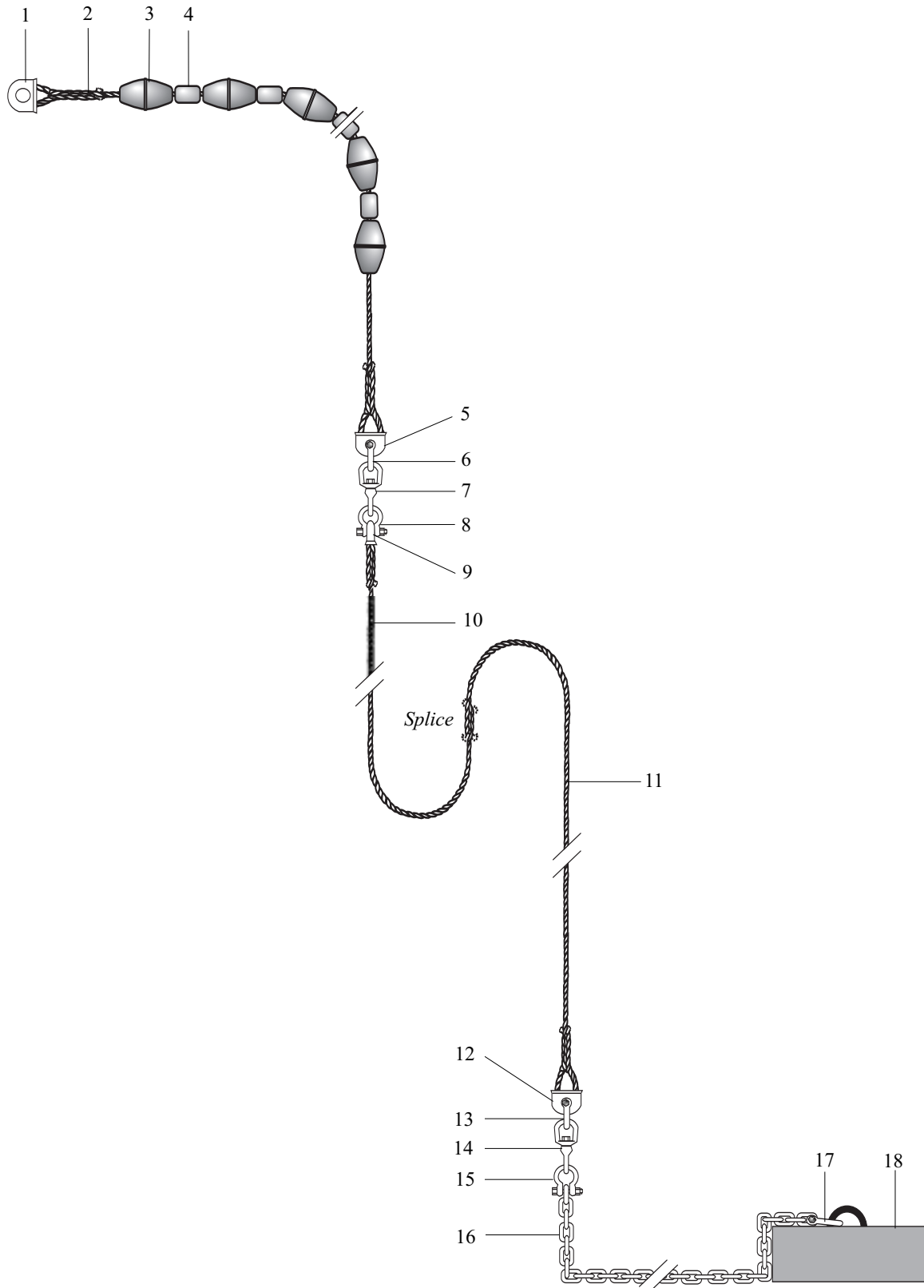
Steel spar buoy FAD system mooring arrangement and components





















Components	Description and material	Size
1	Safety shackle with stainless steel (SS) cotter pin; Hdg-lcs*	25 mm 1 in
2	Safety shackle with SS cotter pin; Hdg-lcs*	16 mm or 19 mm 5/8 in or 3/4 in
3	Long-link chain; Hdg-lcs*	15 m of 13 mm 50 ft of 1/2 in
4	Safety shackle with SS cotter pin; Hdg-lcs*	16 mm or 19 mm 5/8 in or 3/4 in
5	Forged swivel (eye and eye); Hdg-lcs*	22 mm 7/8 in
6	Safety shackle with SS cotter pin; Hdg-lcs*	22 mm 7/8 in
7	Rope connector; Samson Nylite, size 3	22 mm 7/8 in
8	Sinking rope, nylon 8–12 strand plaited or 3-strand twisted nylon or lead-core polypropylene	20 mm 13/16 in
9	Buoyant rope, 8–12 strand plaited or 3-strand twisted polypropylene	20 mm 13/16 in
10	Rope connector; Samson Nylite, size 3	22 mm 7/8 in
11	Safety shackle with SS cotter pin; Hdg-lcs*	22 mm 7/8 in
12	Forged swivel (eye and eye); Hdg-lcs*	22 mm 7/8 in
13	Safety shackle with SS cotter pin; Hdg-lcs*	22 mm 7/8 in
14	Long-link chain; Hdg-lcs*	6–10 m of 20 mm 18–30 ft of 3/4 in
15	Safety shackle with SS cotter pin; Hdg-lcs*	25 mm 1 in
16	Anchor; concrete block	2000 kg 4400 lb

* Hdg-lcs: Hot-dip galvanised low-carbon steel

New Indian Ocean FAD system mooring arrangement and components



Components		Description and material	Size
1		Rope connector; <i>Samson</i> Nylite, size 4	28 mm 1 1/8 in
2		3-strand twisted nylon rope	18 m of 28 mm 60 ft of 1 1/8 in
3		15 x 30G-2 oval pressure floats with 40 mm centre hole	200 m rating and 20 kg buoyancy, 660 ft rating and 44 lb buoyancy
4		14 x Polytec M-700 floats with 40 mm centre hole	7 kg buoyancy 15 lb buoyancy
5		Rope connector; <i>Samson</i> Nylite, size 4	28 mm 1 1/8 in
6		Safety shackle with SS cotter pin; Hdg-lcs*	28 mm 1 1/8 in
7		Forged swivel (eye and eye); Hdg-lcs*	22 mm 7/8 in
8		Safety shackle with SS cotter pin; Hdg-lcs*	22 mm 7/8 in
9		Rope connector; <i>Samson</i> Nylite, size 3	22 mm 7/8 in
10		Sinking rope, 3-strand twisted nylon or lead-core polypropylene, or 8–12 strand nylon plaited	20 mm 13/16 in
11		Buoyant rope, 3-strand twisted or 8–12 strand plaited polypropylene	20 mm 13/16 in
12		Rope connector; <i>Samson</i> Nylite, size 3	22 mm 7/8 in
13		Safety shackle with SS cotter pin; Hdg-lcs*	22 mm 7/8 in
14		Forged swivel (eye and eye); Hdg-lcs*	22 mm 7/8 in
15		Safety shackle with SS cotter pin Hdg-lcs*	25 mm 1 in
16		Long-link chain or normal chain; Hdg-lcs*	6–10 m of 20 mm 18–30 ft of 3/4 in
17		Safety shackle with SS cotter pin; Hdg-lcs*	25 mm or 28 mm 1 in or 1 1/8 in
18		Anchor; concrete block	2000 kg 4400 lb

* Hdg-lcs: Hot-dip galvanised low-carbon steel

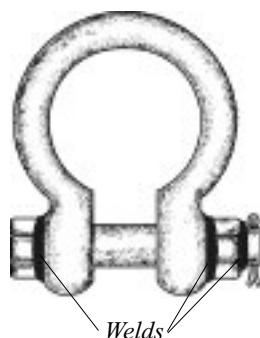
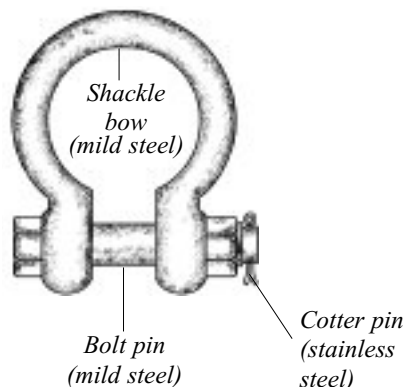
Hardware and hardware connections

The preceding figures show the arrangement of the standard components of the two SPC FAD systems. All of the components specified are widely available, so obtaining the proper components should not present a problem. Substitutions may be made in some circumstances, as long as the replacement component will perform as required.

Anchor-type safety shackles

Anchor-type safety shackles are used to make all connections. The large bow on this type of shackle makes it easy to connect different-sized hardware, and allows the components to move without binding.

Safety shackles incorporate a bolt secured with a nut and have a cotter pin (split pin) which keeps the nut from coming unscrewed. Shackles are often sold with each part made from a different grade of steel; a bow of mild steel, an alloy steel bolt, and the cotter pin from some other grade of steel. Be specific when ordering shackles. Specify bows and bolt pins of mild steel, and stainless steel cotter pins, as shackles with alloy bolts corrode faster.



In most cases shackles in the lower mooring should be welded closed after the mooring has been rigged. Weld both the bolt and the nut to the shackle bow, and then weld the nut to the bolt. Use mild steel rod for the welds, and do not use more voltage than needed to make the welds. High voltage can cause metal fatigue, and could cause the shackle to fail prematurely. Note that the connection of the chain to the anchor block should not be made until the anchor is ready to deploy. In this case, unless there is a welder on the deployment vessel, it is not possible to weld this safety shackle closed.

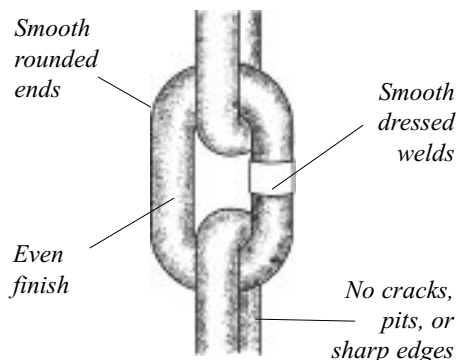
It is usually advisable not to weld the shackles in the upper mooring. If the upper mooring is to be inspected and maintained regularly and worn shackles replaced (as is good practice), or if the upper mooring is to be periodically replaced, then the shackles should not be welded, but fixed with a stainless steel cotter pin.

The recommended shackles are sufficiently strong to withstand at least two years in seawater.

Chain

The SPC steel spar buoy FAD system requires chain in the upper mooring to link the buoy and the upper mooring rope. Both systems require bottom chain to link the lower mooring rope to the anchor.

Hot-dip galvanized, low-carbon steel chain is recommended. Long-link or open-link type chain is most suitable because the larger link openings allow easier fitting of other hardware. However, this type of chain is harder to come by so regular-link chain may need to be used.



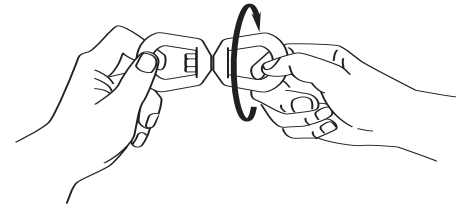
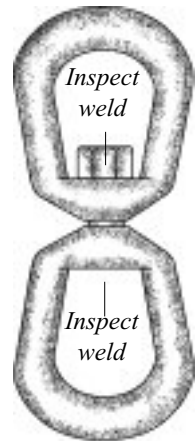
Chain should also be assessed visually. Good-quality chain has solid, complete, smoothly dressed welds, and smooth, evenly rounded corners. Links work smoothly and do not bind.

Swivels

Both FAD systems require at least two swivels: one between the upper chain or rope and the upper rope connection, and the second between the lower rope and the bottom chain connection.

Hot-dip galvanized, forged eye-and-eye large-bow swivels made from low-carbon steel are recommended. Look for the same quality indicators as on chain: a complete, smoothly dressed weld, no jagged edges, and smooth, rounded corners.

Examine the weld on the lifting eye and the connecting bolt and nut. Make sure welds are complete and do not have any cracks or fissures. Test the swivel's action.



Good quality swivels spin easily by hand

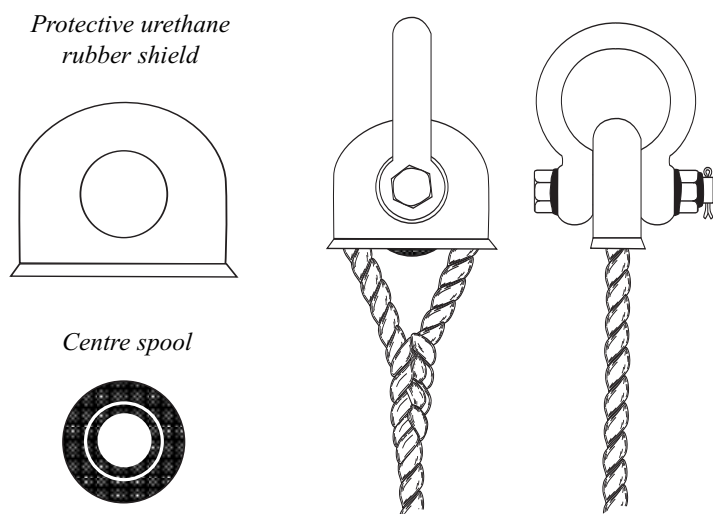
Good-quality swivels spin easily by hand. When constructing the mooring, arrange each swivel with the head of the connecting nut upward, otherwise the swivels may bind.

Rope connectors

Rope connectors are used to connect rope to other mooring components. Rope connectors ensure that the eye-splices formed at the rope ends are secured against working loose. The best connector designs also prevent contact between the hardware and the rope, safeguarding the rope from abrasion.

Modified Samson Nylite rope connectors are recommended. Samson connectors are easy to fit and provide maximum protection for the rope. They incorporate a self-lubricating centre spool and a urethane rubber protective shield. The eye-splice is fitted onto the spool, which is inserted in the protective shield and then fitted with a shackle.

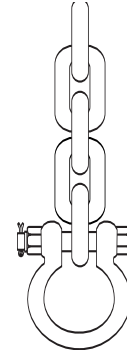
The centre spool has a hole through it for a shackle pin, but it is designed for a smaller pin than that used in FAD construction, so you will have to drill out the hole in the centre spool to take the larger-diameter pin of the standard safety shackle. This modification is best done with a drill press or lathe. Use a hot-dip galvanized anchor-type safety shackle made of low-carbon steel



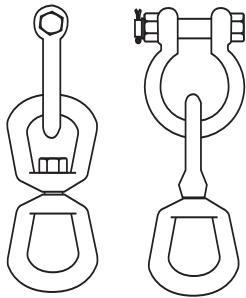
Hardware connections

Chain to shackle connections

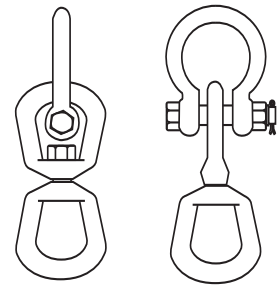
The chain to shackle connection should be made bolt-pin through link.



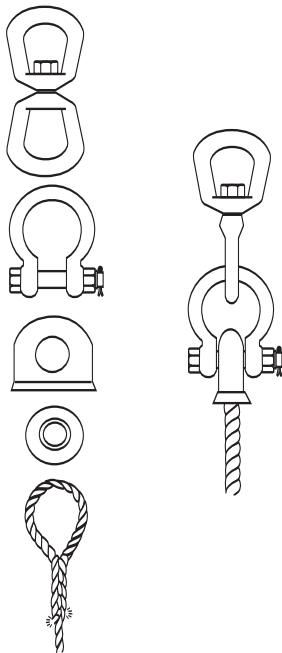
Shackle-to-swivel connection



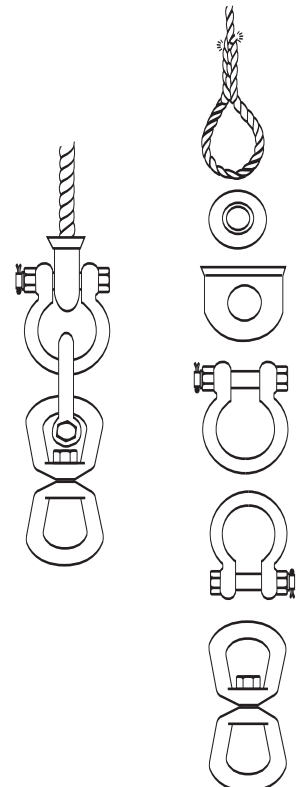
The recommended connection between the shackle and the swivel is the bow-to-eye connection, but if the bow will not fit through the top eye of the swivel the bolt-pin-to-eye connection may be used.



Swivel-to-rope connector connections



One shackle joins the rope connector and the swivel in the upper mooring and in the lower mooring. However, if this does not work, two shackles can be used to join the rope connector and the swivel.



Mooring ropes

Catenary curve moorings are rigged from a combination of sinking and buoyant ropes. The properties of each rope perform specific functions or impart specific features to the mooring. As more than 90 per cent of any deep-water FAD mooring is comprised of rope, consideration of the properties and performance characteristics of rope to be used is very important. For a detailed description of rope properties and performance refer to Volume II of the SPC FAD manuals (Gates et al. 1996).

Nylon

One of the recommended materials for the upper mooring rope is nylon, as it sinks in seawater. Nylon is one of the strongest, most widely available, synthetic fibre ropes. Nylon is elastic. It will stretch up to 17 per cent of its length under a working load equal to 20 per cent of its ultimate breaking strength. Nylon rope can withstand both the routine cyclic loading (stretch and recoil) caused by ocean swells, and the shock loading (strong, sudden jerks) which will affect a FAD mooring during rough seas and stormy weather.

Nylon is also durable. It resists surface wear and internal abrasion caused by flexing and stretching. Nylon also withstands ageing and deteriorates only slightly from exposure to sunlight. Nylon does tend to stiffen somewhat with prolonged immersion in seawater.

Polypropylene

The recommended material for the lower mooring rope is polypropylene, as it floats. Its buoyant property can be used to lift weight. Polypropylene has moderate breaking strength, which actually increases slightly in seawater. It has good elastic properties and can be stretched by about nine per cent of its length and still return to its original length. Polypropylene has excellent shock loading capabilities.

Polypropylene is fairly durable. The single most important exception to its durability is that it does deteriorate with exposure to sunlight. Some manufacturers offer treatments which increase polypropylene's resistance to sunlight.

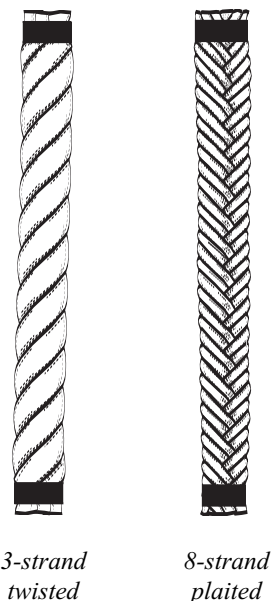
Lead-core polypropylene

Lead-core polypropylene rope was trialled as alternative sinking rope for upper mooring line construction, to replace the more expensive nylon rope. The elastic and shock loading properties of the polypropylene rope appeared unaffected by the lead-core.

Rope construction

Different rope constructions can produce dramatically different characteristics — even in ropes that are identical in every other way. The rope constructions most commonly seen in FAD moorings are 3-strand twisted and either 8- or 12-strand plaited. The use of 3-strand twisted rope has been discouraged by SPC in the past, with 8- and 12-strand plaited ropes recommended for use in Volume II of the SPC FAD manuals (Gates et al. 1996). Untwisting, kinking and hocking (caused by rope twisted against its regular lay) are the potential problems identified with 3-strand twisted ropes, and these could lead to mooring failure.

From 1995 to 2004, however, many countries have used the more expensive 8- and 12-strand plaited ropes for their FADs, but many of these broke free within 18 months of deployment, and many in less than 12 months. This point probably indicates that the main 'weak-point' in the FAD construction was not the 3-strand twisted rope, as some have thought.



The FADs deployed as part of the research project used all 3-strand twisted ropes or galvanised wire cable (tried and found to be no good) for the upper mooring and all 3-strand twisted ropes for the lower mooring. Only one FAD was lost as a result of the 3-strand twisted rope hockling. Another five FADs were lost as a result of cyclones that created phenomenal seas, and none of these FADs were recovered. Therefore it would appear that 3-strand twisted rope is a cheaper alternative to the 8- and 12-strand plaited ropes and has the same life expectancy when used for the mooring line of FADs.

SPC, therefore, recommends that when using a steel spar buoy where there is a chance of the buoy spinning, 8- or 12-strand plaited ropes be used in preference to 3-strand twisted ropes, although the latter can still work effectively. For the new Indian Ocean FAD system, 3-strand twisted rope is recommended in preference to 8- and 12-strand plaited rope, as the profile of the buoy system basically eliminates the chance of it spinning in the water.

Mooring calculations

The length of buoyant polypropylene rope and sinking nylon or lead-core polypropylene rope required to rig an inverse catenary curve mooring for any FAD depends on the site depth, the length of the catenary curve, the weight of the nylon rope, and the buoyancy of the polypropylene rope. Determining what rope lengths must be used to ensure that the mooring maintains the catenary curve at a set depth below the surface and buoys up a section of bottom hardware to keep the lower rope away from the seabed, requires careful calculation. The table below summarises the rope lengths for FADs deployed in depths from 700 to 2000 m.

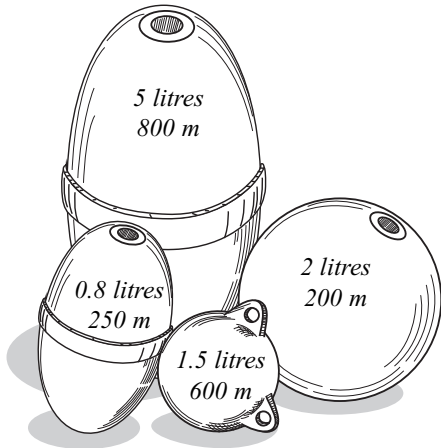
Table of rope lengths needed for FAD site depths from 700 to 2000 m

Site depth (m)	Total rope length (site depth + 20%) (m)	Length of nylon or lead- core polypropylene rope (m)	Length of polypropylene rope (m)
700*	840	250	590
800*	960	290	670
900*	1080	310	770
1000*	1200	315	885
1100*	1320	330	990
1200*	1440	360	1080
1300	1560	390	1170
1400	1680	420	1260
1500	1800	450	1350
1600	1920	470	1450
1700	2040	480	1560
1800	2160	495	1665
1900	2280	525	1755
2000	2400	550	1850

* FADs set in these depths require supplementary buoyancy as described below

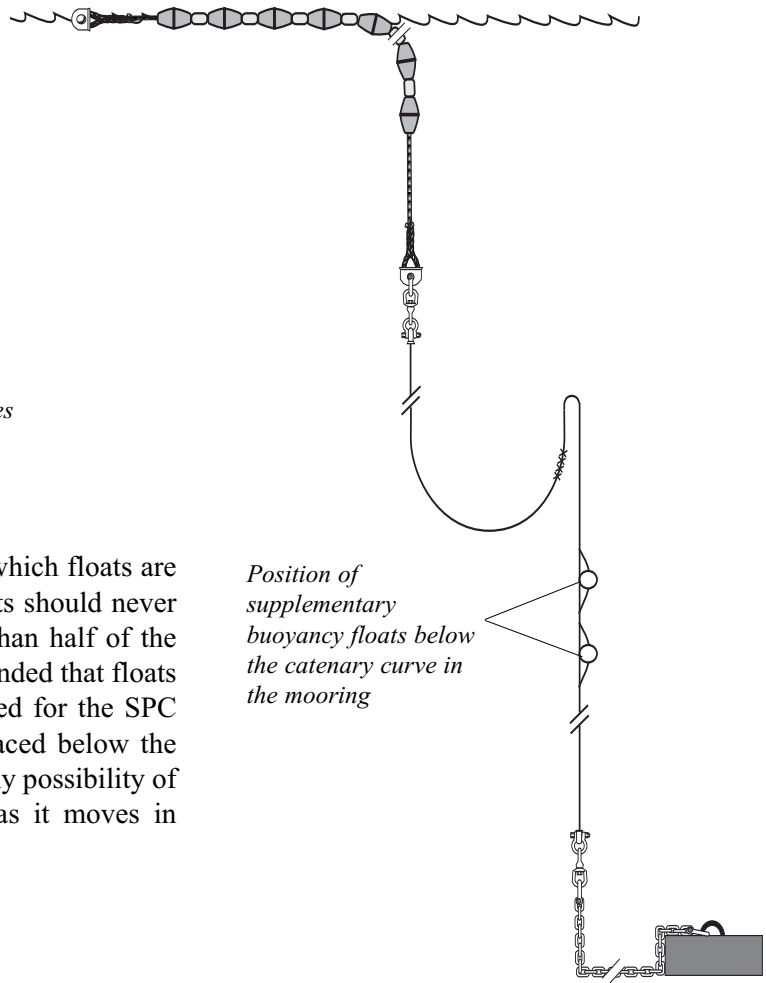
Supplementary buoyancy

If a site depth is less than 1200 m, it makes it impossible to use enough polypropylene rope to provide the buoyancy necessary to lift 3 m of chain/hardware clear of the seabed. For these sites, pressure-resistant floats are used to supplement the buoyancy of the polypropylene rope. Floats come in a variety of sizes and depth ratings. Both of these variables are important for mooring adjustments. The size, and therefore the buoyancy, of an individual float will determine the number of floats required. A one litre float can lift 1 kg.



Floats are available in a variety of shapes, sizes and depth ratings

The depth rating will influence the point at which floats are attached to the mooring. For safety, the floats should never be positioned deeper on the mooring rope than half of the depth for which they are rated. It is recommended that floats with a depth rating of at least 800 m be used for the SPC FAD systems. The floats should also be placed below the lowest point of the catenary curve to avoid any possibility of them entangling this part of the mooring as it moves in changing currents.



Position of supplementary buoyancy floats below the catenary curve in the mooring

Table of supplementary buoyancy required for site depths from 700 to 1200 m, and the point at which the pressure-resistant floats should be attached to the mooring.

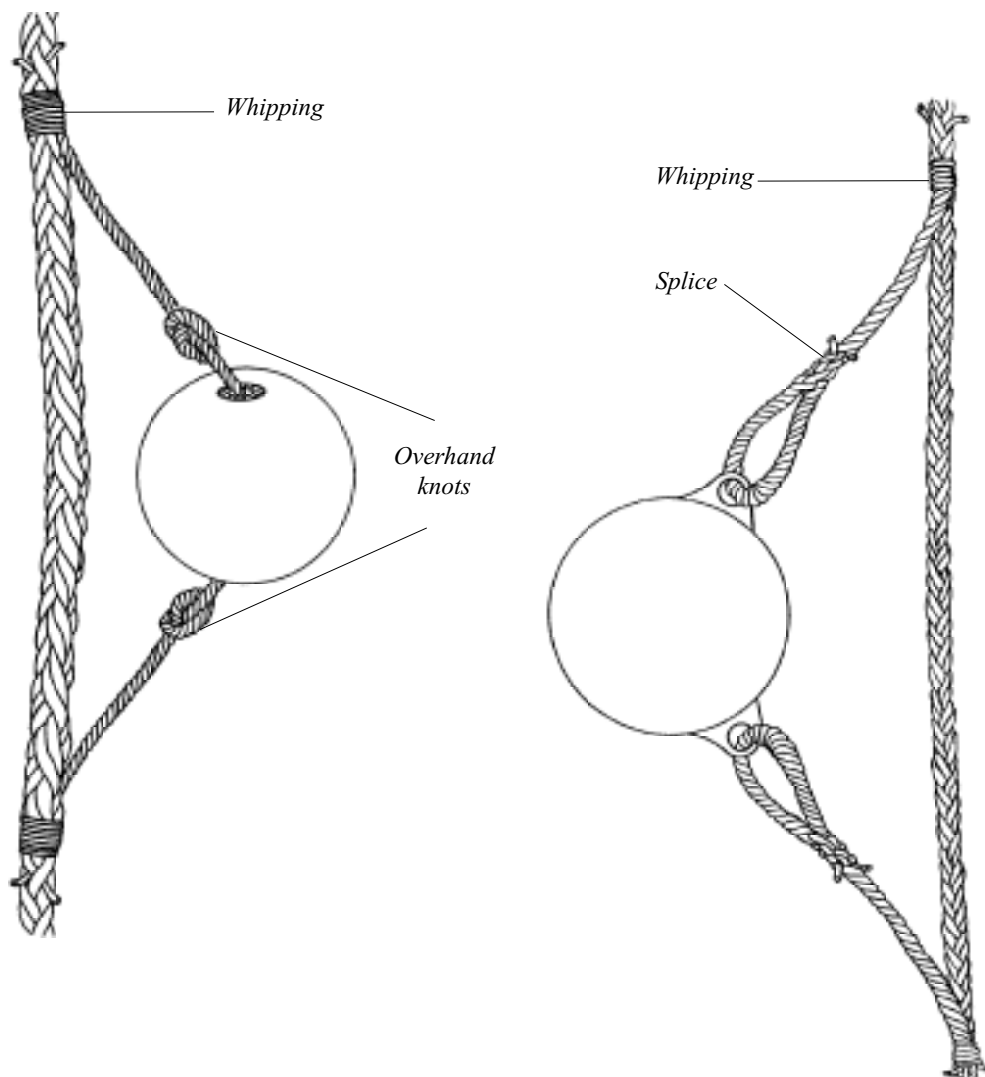
Site depth (m)	Minimum supplementary buoyancy needed (litres)	Distance of float from seabed (m)
700	12	400–430
800	10	480–510
900	8	570–600
1000	6	660–690
1100	4	750–780
1200	2	840–870

Pressure-resistant float attachment

There are two basic types of pressure-resistant floats: those with a hole through the centre and those with two ears or lugs with holes through them. To attach these to the mooring line, about 2 m of polypropylene rope is required. The diameter of the polypropylene rope should be slightly smaller than the diameter of the hole(s) in the float. It is simplest to use 3-strand ropes, but plaited ropes can also be used. Three-strand ropes can easily be spliced into 3-strand mooring line, or woven into 8- or 12-strand mooring lines.

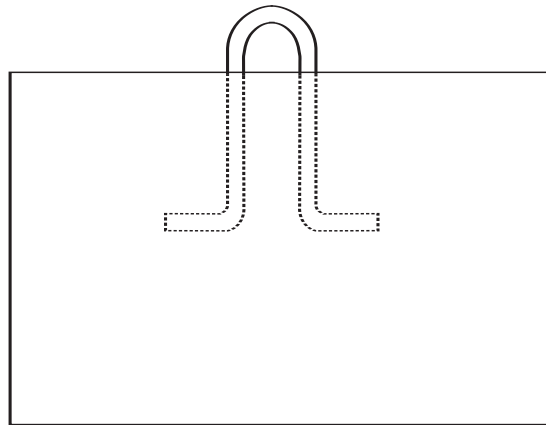
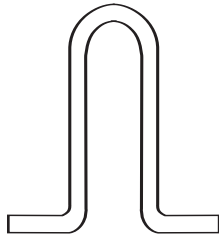
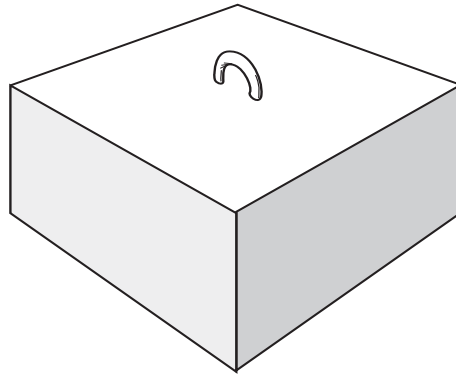
For floats with a centre hole, the rope is run through the hole so the float is in the middle of the rope, and an overhand knot is tied on each side of the float. This keeps the float from moving along the rope. The two ends are then spliced or woven into the mooring rope. For floats with ears or lugs, the rope is cut in two equal lengths. These are then spliced onto the ears or lugs using an eye splice. The two remaining ends are spliced or woven into the mooring rope. Whip the ends of the float ropes to the mooring rope after they have been spliced or woven in.

The ropes should be attached with some slack between the float and the mooring rope. This will lessen the likelihood of friction between the float and the mooring rope. If multiple floats are required for supplementary buoyancy, position them at least two metres apart along the mooring line.



Anchor system

Well-constructed massive anchors are essential for holding FADs on station. Commercial anchors are generally too expensive for FAD moorings. Suitable anchors can be made up from surplus steel or concrete. Concrete anchors are recommended for FAD moorings. They are especially well-suited for the rocky bottoms which characterise FAD sites in island countries. Cement is widely available and relatively inexpensive. Anchors constructed with care will outlast the life of most FAD moorings.



The holding power of concrete in seawater is 1:2. In other words, a 2000 kg concrete anchor has a holding power of 1000 kg in seawater.

Square, block-shaped concrete anchors (120 cm x 120 cm x 60 cm) with a mass (weight) of 2000 kg (4400 lb) are recommended. The concrete anchor is designed with the base dimensions greater than the anchor's height. This gives it a low centre of gravity which helps prevent it from tipping or tumbling down sloping seabeds.

Always construct anchors with a proper steel bail, or connecting point. Connect the anchor to the mooring's bottom chain with a safety shackle. Appendix B provides details for constructing a concrete FAD anchor (adapted from Gates et al. 1996).

SITE SELECTION AND DEPLOYMENT

Once a FAD programme is planned and the materials ordered to the specifications outlined in the previous sections, it is time to select the deployment sites by conducting site surveys. Once the sites are selected, the FAD systems can be rigged for each site depth, and the FADs deployed.

Conducting site surveys and selecting deployment sites

Site surveys need to be conducted to produce a bottom contour map that will indicate the slope of the sea floor and any obstacles in the immediate area. Conducting site surveys is explained in detail in SPC's FAD Manual Volume III (Gates et al. 1998), and only summarised here. Once the bottom contour map is drawn, potential FAD deployment sites can be chosen, if there are any suitable places for them.

Equipment needed for site surveys

To conduct site surveys, a suitable deep-water echo sounder and a GPS unit are required. The specifications of the echo sounder will be dictated by the depth of water the intended FADs are to be set in. If FADs are to be deployed in depths of up to 2000 m, then the echo sounder needs to be able to sound down to around 2500 m, to ensure that the site survey will cover depths both deeper and shallower than the intended deployment depth. The most appropriate transducer should be chosen for the echo sounder, so that it has the power and discrimination to operate effectively in deeper water. When working in depths over 1500 m it is best to have an echo sounder transducer with a 3 kW power rating and a frequency of 28 kHz. Most echo sounders operate from a 12- or 24-volt power source, so good car batteries (preferably heavy duty) are needed to power the sounder for six to eight hours at a time without needing to be recharged, unless the survey vessel can charge the batteries from its power supply.



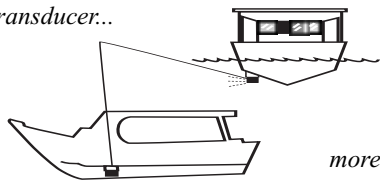
The GPS unit is used for navigating the vessel during the site survey. There are many different makes and models of GPS around, although for this type of work a console-mounted unit with plotting facility would be better than a small hand-held unit.



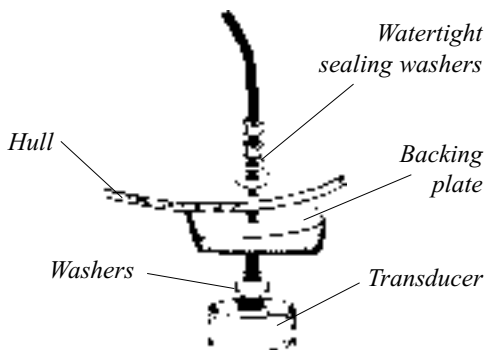
Preparing to conduct a site survey

A suitable vessel is needed to conduct the site survey from. The echo sounder and GPS units need to be mounted or positioned on the vessel for ease of operation, while keeping them out of the weather and away from saltwater spray. The 12- or 24-volt power source needs to be hooked up to both units and they should be checked out before heading to sea to make sure they are working properly. The transducer for the echo sounder also needs to be mounted securely. It is best to mount it permanently through the hull of the vessel, so that it points directly at the sea floor and not at an angle. Alternatively, if the echo sounder is to be used on different vessels, the transducer can be mounted on a pole or pipe with protective cover for the transducer body, which in turn is mounted on the side of the vessel with the protected transducer body at a depth of around one metre. This can be done with ropes to position the transducer and pole, or brackets that are attached to the side of the vessel.

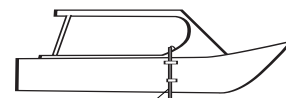
Through-hull mounting allows best placement of transducer...



...but requires more elaborate and permanent installation

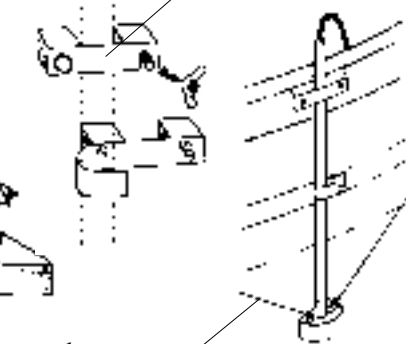
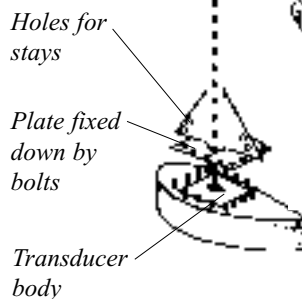


Transducer cable fed through pipe



Pipe is then fixed to side of boat...

...using clamps or brackets...

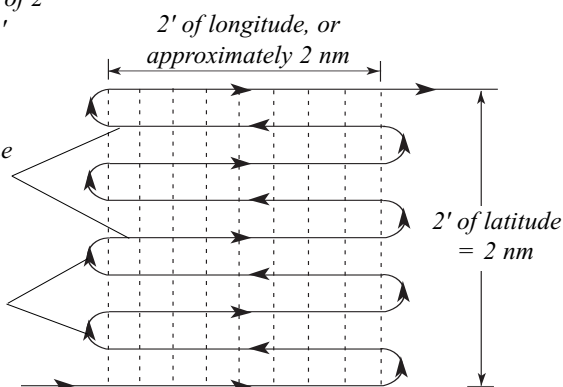


The survey itself entails the vessel doing a transect survey of approximately four square nautical miles (2' of latitude by 2' of longitude) in the selected area chosen from the chart, with transects every 0.25 of a minute. It is best to conduct the site survey in a north-south or east-west direction, following lines of latitude or longitude.

A survey area of 2' of latitude x 2' of longitude...

...contains nine 2' (≈ 2 nm) transects...

...plus eight turning circles, each about 0.4 nm long



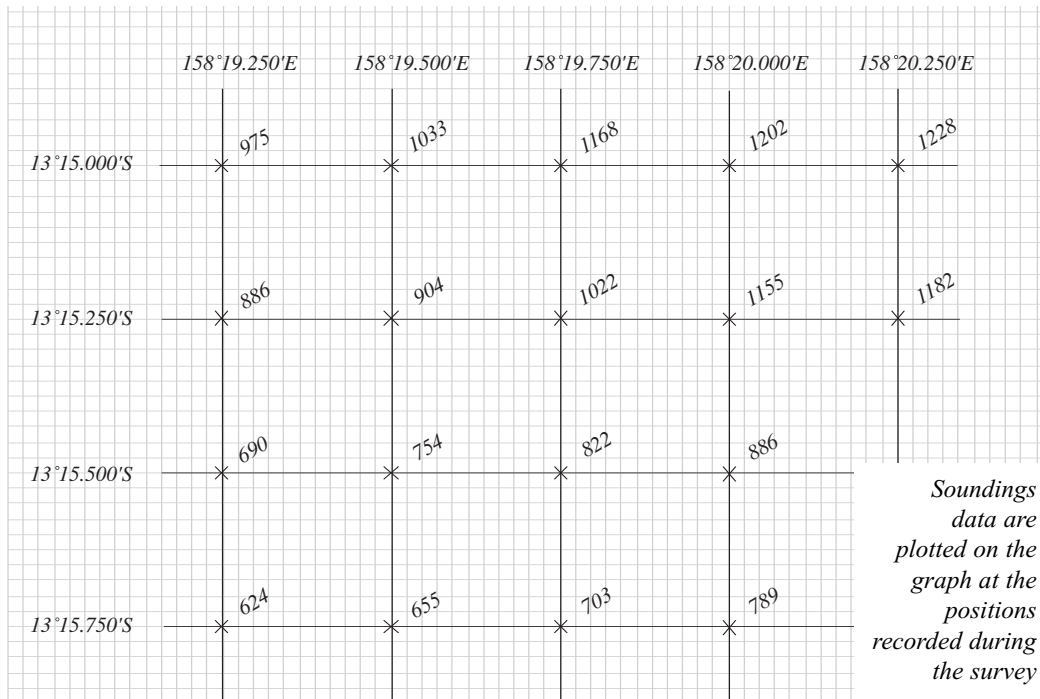
Conducting a site survey

Good weather is needed to conduct site surveys so that accurate readings can be made from the echo sounder. Once the vessel is ready with the echo sounder and transducer positioned and operational, it can go to the area to be surveyed. At the starting point of the survey, the depth is recorded and the vessel steers a north-south or east-west course, following a line of latitude or longitude. The GPS, rather than the compass, is used for steering as it is easy to see on the GPS when the vessel is deviating from the chosen line of latitude or longitude. That is, if the vessel is steering along the line of latitude 12° 35.500' N, and the GPS shows a deviation from this line, the vessel can be steered to correct this. As the vessel steers this line, the depth is recorded at each 0.25' interval of longitude along the transect.

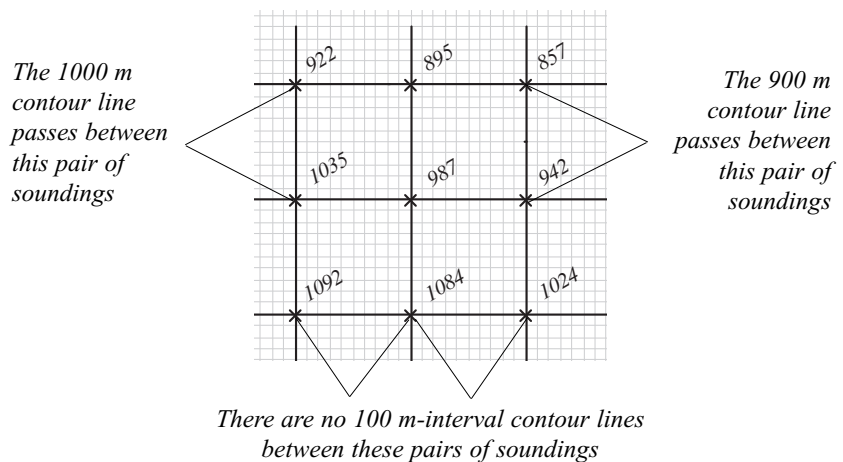
At the end of each 2' transect, the vessel moves to the start of the next (0.25' from the previous point) and continues the same process, steering along the line of latitude or longitude, recording the depth every 0.25'. This continues until the full survey area is covered. If more than one survey is to be completed in a day, the vessel moves to the starting point of the next area to be surveyed and the same process is undertaken with the depth reading recorded each 0.25' interval.

Producing a bottom contour map from the survey data collected

To produce a bottom contour map, all that is needed is a piece of graph paper, a ruler, a pencil and a calculator. The 2' square is marked on the graph paper using the marked gridlines. It is best to use as large a scale as the graph paper will allow when marking the outer square. The latitude and longitude of each transect are marked on the border of the square. This then provides the grid for the 81 points of the survey. The depths are then written in on the corresponding latitude and longitude position.



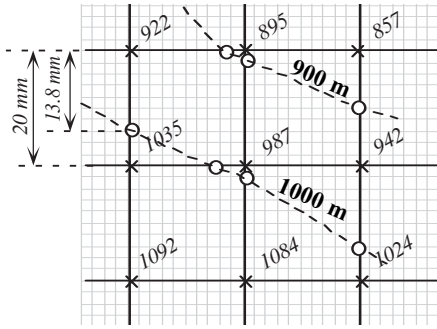
Once all of the depths have been marked, the contour lines need to be drawn in. Contour lines connect points of the same depth, usually in 100 m increments. Therefore the contours would be at say, 500, 600, 700, 800 m and so on. The problem is that these depths usually fall between those that have been recorded, so the actual point needs to be interpolated by splitting the difference between depth readings.



Here is a simple example. If one depth reading is 995 m and another is 1005 m, we can estimate — assuming that the slope is regular — that the 1000 m contour lies exactly halfway between them.

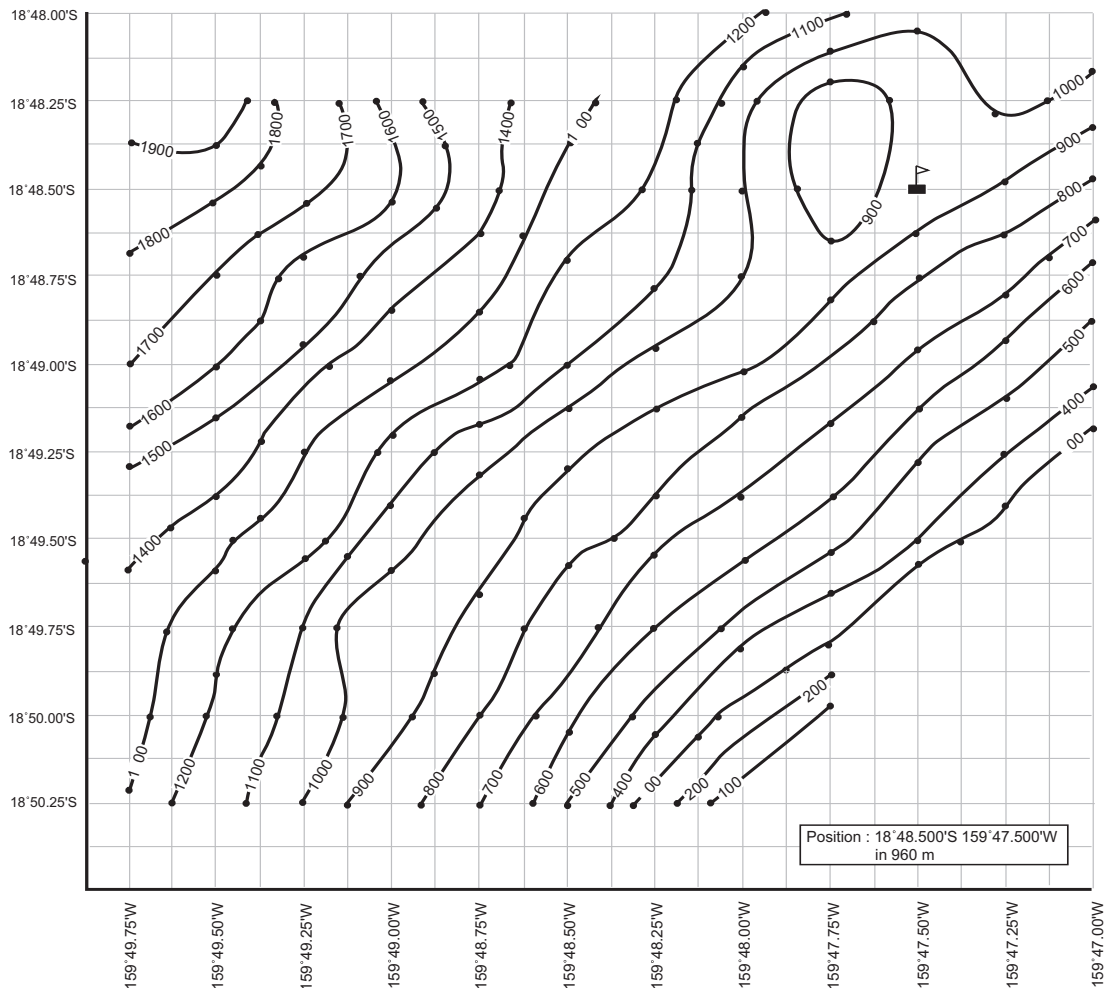
A more complicated example would be to have one depth reading being 922 m, with the next being 1035 m. Again we can see that the 1000 m contour lies somewhere between them, but this time it is not so conveniently situated at the halfway point.

A simple calculation needs to be done to work out where it lies between the two readings:



- a) subtract the lower sounding from the higher sounding:
 $1035 - 922 = 113$
- b) subtract the lower sounding from the contour depth:
 $1000 - 922 = 78$
- c) divide the result of (b) by the result of (a):
 $78 \div 113 = 0.69$

This tells us that the 1000 m depth can be estimated to be situated at 0.69 of the distance between the two readings, starting from the lower reading. If the distance on the graph paper between the two readings is 20 mm, the 1000 m depth is thus 0.69×20 mm, or 13.8 mm distant from the lower reading, in the direction of the higher reading. The 1000 m mark is plotted at this position by counting millimetres on the graph paper or by using a ruler and then drawing a dot. This process is continued until all of the dots are filled in for each depth. The contour lines are drawn by connecting the dots of the same depth.



Selecting suitable FAD deployment sites

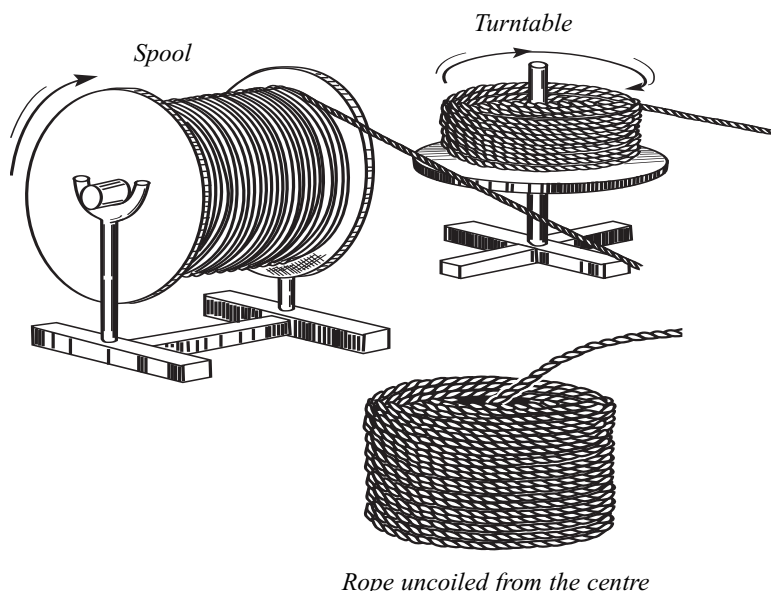
The bottom contour map gives a flat representation of what the sea floor looks like. Contour lines close together indicate a steep dropoff or ridge, while widely spaced contour lines indicate a more gentle slope. The best locations for deploying FADs are those on flat or gently sloping areas away from pinnacles, steep dropoffs or other obstacles or bottom anomalies.

Rigging and deploying FADs

Once a site has been chosen for each FAD and the materials have been purchased, the FADs can be rigged and deployed.

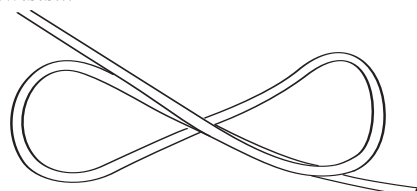
Rigging FADs ready for deployment

FADs can be rigged for each of the selected sites according to the depth of water at each site. The buoy system can be made up ready for attaching to the upper mooring hardware. The ropes being used need to be cut to the required lengths and spliced together. It is best to use a turntable or spool arrangement for uncoiling the rope. If this is not possible, then the rope should be uncoiled from the centre of the coil.



When uncoiling rope, it is best to flake it out in a large 'figure-of-eight' to avoid any kinks or twists forming in the rope. This can be done in a clean, uncluttered, covered area onto a piece of canvas or a tarpaulin, or into a large box designed to hold all of the rope for a FAD mooring system. As the end of one rope is reached, the start of the next rope can be spliced onto it.

Figure-of-eight flakes will not introduce twists...



...and is best for 3-strand rope

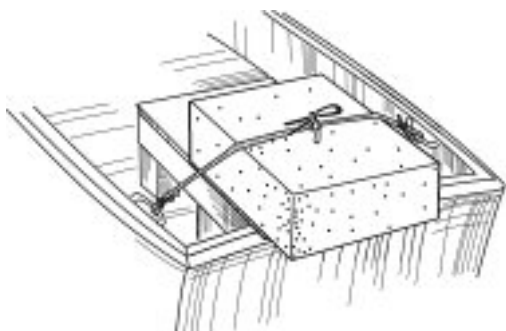
When flaking rope into a box or onto a canvas or tarpaulin that will be lifted onto the deployment vessel, the polypropylene rope needs to be on the bottom and the nylon or lead-core polypropylene rope on the top. This will allow the sinking rope to be deployed first after the buoy system, which is the normal deploying sequence. Both ends of the mooring line need to be exposed, so the eye splices can be made and the connection of the upper and lower hardware made at the appropriate time.

The connecting hardware can also be assembled. The top hardware (Nylite rope connector, shackles and swivel) can either be attached to the upper mooring rope or the buoy system. The chain and lower hardware (rope connector, shackles and swivel) can also be assembled and attached to the lower mooring line. This will allow the shackles to be welded if this is to be done.

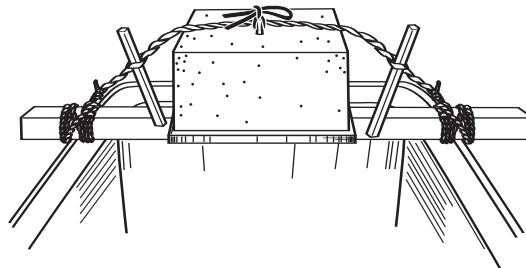
Readying the deployment vessel

A suitable FAD-deploying vessel needs to be equipped with a GPS and deep-water echo sounder so that the selected location and depth can be located.

The vessel must have the anchor block positioned in a way that allows it to be easily deployed, while maintaining the stability of the vessel at all times. Usually the anchor block is placed on a structure or platform on the stern of the vessel, so that it is in a convenient position for release. The anchor block is secured with multiple ropes to stop it from moving. The best way to secure the anchor block is by using Spanish windlass knots.

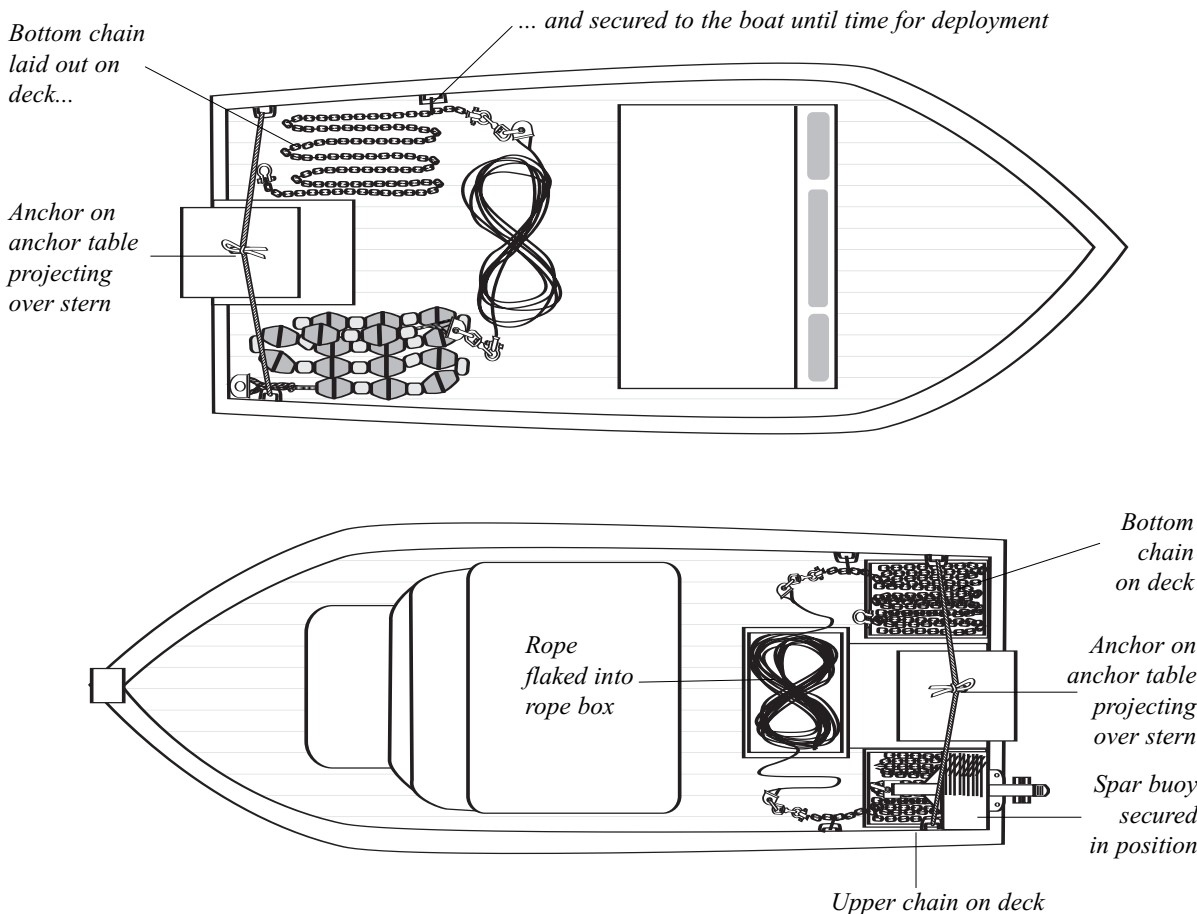


Anchor positioned for easy heaving overboard



Spanish windlass

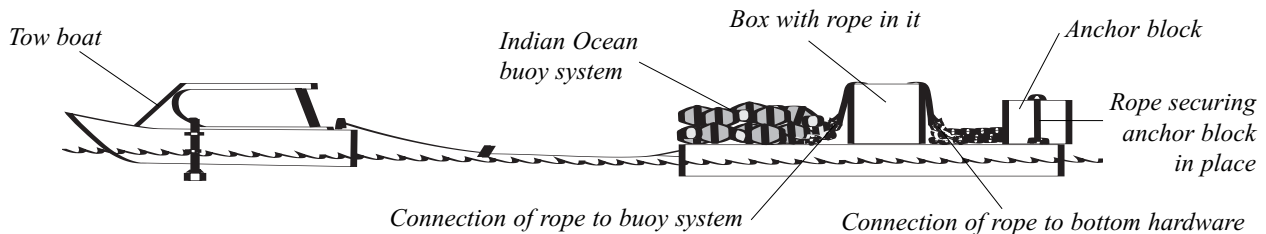
The buoy system is loaded on board in a position that makes it easy and safe to deploy. The Indian Ocean buoy can be placed anywhere safe as it is light, flexible and easily handled. However, if a steel spar buoy is being used, it should be placed in a position where it can be easily deployed, and secured so it cannot move during the trip to the deployment site. If the mooring line is in a box, or wrapped in a canvas or tarpaulin, then this is lifted on board and placed in a suitable location. If the mooring line is loose, it needs to be transported to the vessel and carefully flaked onto the back deck in a clear open area. Again, the polypropylene rope should be on the bottom and the nylon or lead-core polypropylene rope on the top.



The buoy system can then be connected to the upper mooring. However, the lower mooring chain should not be connected to the concrete anchor block until the last minute in case any problems are encountered.

The vessel is now ready to head to sea to conduct the deployment.

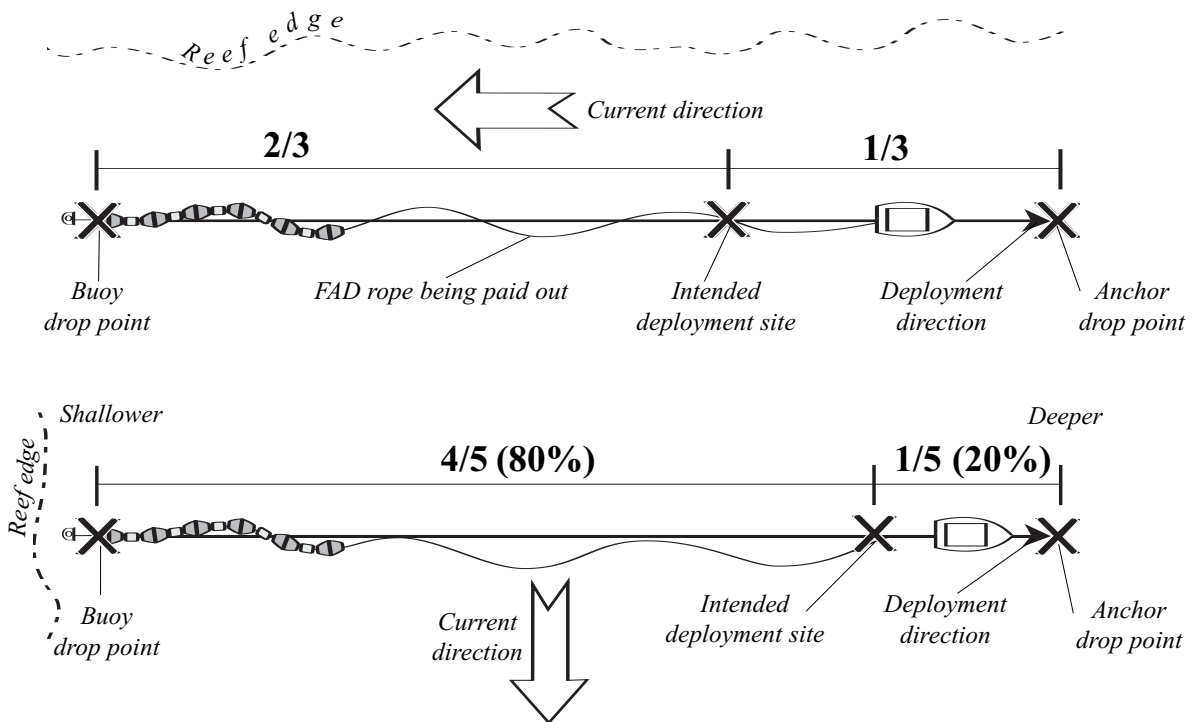
If there is no suitable vessel for deploying FADs, a barge or other floating platform can be used. The vessel towing the barge is fitted with the GPS and deep-water echo sounder, and the FAD materials are loaded onto the barge. Again, the mooring block is positioned at the back of the barge or platform for ease of deployment.



Deployment sequence

Good weather, preferably with winds of less than 10 knots, is needed to deploy a FAD accurately and safely. When the deployment vessel reaches the deployment location, the depth and position are checked with the deep-water echo sounder and the GPS. The wind and current direction are also checked before the deployment sequence is started.

Deploying is usually done in one of two ways — setting into the current which usually is running parallel to the reef, or setting from shallow to deep water, usually perpendicular to the reef. In both cases, the FAD buoy will be deployed first, followed by the nylon or lead-core polypropylene rope, polypropylene rope and finally the anchor block.



When deploying into the current, the FAD buoy is deployed two-thirds of the mooring line length down-current of the intended deployment point, and the anchor block deployed one-third the mooring line length up-current from this point. For a 1200 m mooring line, the buoy would be deployed 800 m down-current and the anchor

block 400 m up-current of the chosen deployment site. However, when setting from shallow to deep, it is best to use an 80:20 ratio. That is, the buoy would be deployed 80 per cent of the mooring line length (960 m) in shallower water from the chosen deployment site, and 20 per cent (240 m) past the site in deeper water. This is to reduce the chance of the anchor tending to settle in deeper water than intended, caused by the rope being bowed-out by the current running across it.

After the calculations are made, based on the deployment approach to be used and the length of mooring line, the starting and finishing points for deploying are entered into the GPS as waypoints. If a GPS with plotter is available, these are entered as event marks. The vessel goes to the starting point and deploys the buoy system. At this time, the final connection of the bottom hardware to the anchor block is made, although the securing ropes holding the anchor block in place are not released. The vessel then motors towards the deployment site as the sinking rope is paid out, followed by the floating polypropylene rope. Once all the rope is out, the bottom hardware is lowered into the water, the securing ropes on the anchor block are released, and the anchor block is dropped.

When using a towed barge or similar arrangement for deploying FADs, the same basic approach is used. Once the towing vessel and barge are at the starting point for deploying, the tow rope should be made as short as possible to ensure safety during the operation. Walkie-talkies or VHF radios may need to be used for communication between the towing vessel and barge. Once in position the same sequence is followed with the buoy system deployed, followed by the nylon and polypropylene rope and finally the bottom hardware and anchor block.

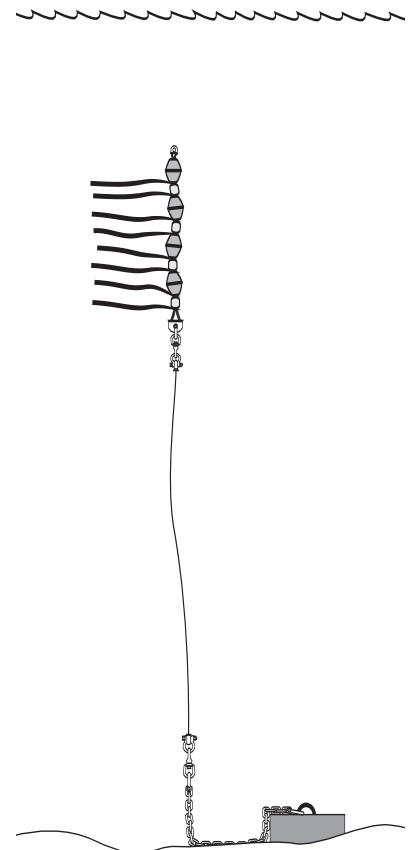
Depending on the sea conditions and current, it will usually take 10 to 15 minutes for the concrete block to reach the bottom and the mooring to settle. Once the buoy system has settled it needs to be checked to make sure no damage occurred during the deployment. The depth of water at the buoy system is taken and recorded, along with the buoy's position. Aggregators and the flagpole are then attached if these are being used.

Sub-surface FADs

Although sub-surface FADs were not part of the FAD research project, and SPC has done no work on them, they are mentioned here because they do exist and they have potential. This is an area that needs research and development.

Some experimenting has been done with sub-surface FADs. They have a straight-line mooring, with the mooring line shorter than the depth of water they are set in so that the buoy system is secured to the sea floor at a pre-determined depth or distance from the surface. The mooring can be made of all polypropylene 3-strand rope or 8- or 12-strand rope, as there is no catenary curve in the mooring line. Depending on the size of the buoy system and the amount of buoyancy used, the diameter of the rope can be smaller than that recommended for the spar buoy and new Indian Ocean FAD systems.

Sub-surface FADs are generally set in shallower waters, often less than 300 m. This is partly due to the difficulty in finding the FADs as there is no surface float. A GPS is needed. An echo sounder can also be used to find the buoy once in the vicinity of the FAD. In strong currents, the FAD buoy is pulled deeper in the water column at an angle, hence making it even harder to find in these conditions. Pressure floats must be used to ensure the FAD will keep its buoyancy, as there is no way to undertake maintenance on these systems. Aggregators also need to be attached before deploying, as once the FAD is deployed, it is not touched again.



MAINTAINING, MONITORING AND FINANCING FAD PROGRAMMES

The ongoing maintenance of FADs is essential to the longevity of each device, and the FAD programme as a whole. So too is the monitoring of FADs, especially the collection of catch data from those who are using the FADs. Ownership of FADs has often been debated with governments taking the main initiative on this. Financing and cost recovery from the users of FADs is another area that has been talked about over the years, with no clear guidelines developed on how this can work.

Fishermen are the main people using FADs, so it is important that the fisheries department works with them in maintaining, monitoring and possibly funding the FADs. Fishermen are usually very happy to help check the buoy system and aggregators, and in changing batteries on lights, especially if they are allowed to tie to the FAD for mid-water fishing activities. Fishermen are also willing to add aggregator materials that they often provide themselves, although this needs to be monitored to ensure there is not too much being added, causing excessive drag on the mooring system. There needs to be clear communication and cooperation between fisheries staff and fishermen to maximise the benefits from FADs while minimising costs.

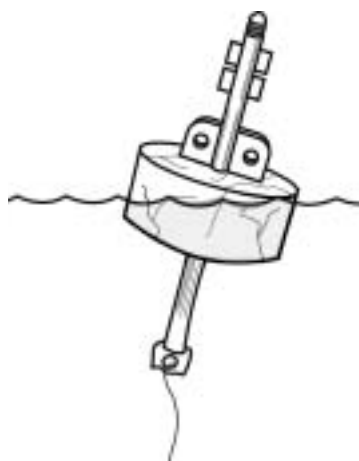
Maintaining FADs

Regular maintenance of FADs is essential — once a month if possible. A record sheet should be completed each time maintenance trips are undertaken, so that an ongoing record of the maintenance work undertaken and needed in the future for each FAD unit can be built up. If materials used are recorded on the sheet, it is easier to know how many replacement items are needed when placing orders for materials in the future. Maintenance should include the appendage or aggregator. A sample maintenance record sheet is provided at Appendix C.

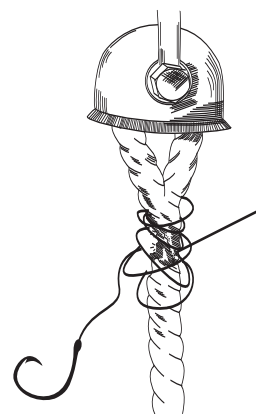
Maintenance is mainly replacing worn hardware, such as shackles and swivel, or repairing damage to the buoy system or upper mooring rope. Tangled fishing line and lures are removed as well as any growth on the rope. Repairs are also made to the aggregators, with coconut fronds replaced or new materials added.



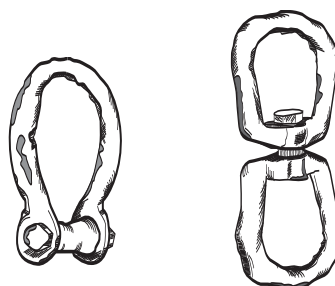
Floats broken



Leaky or partially flooded buoy



Partially cut mooring rope

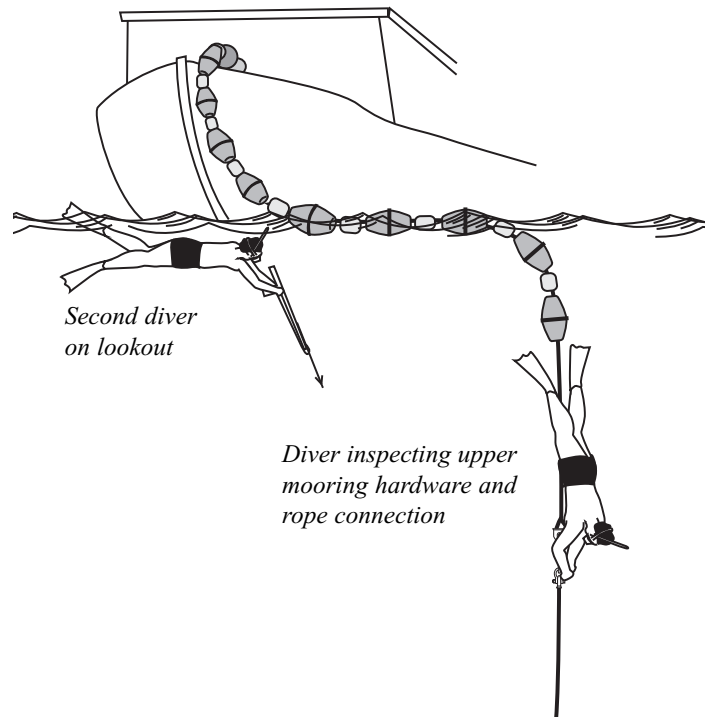


Badly worn hardware components

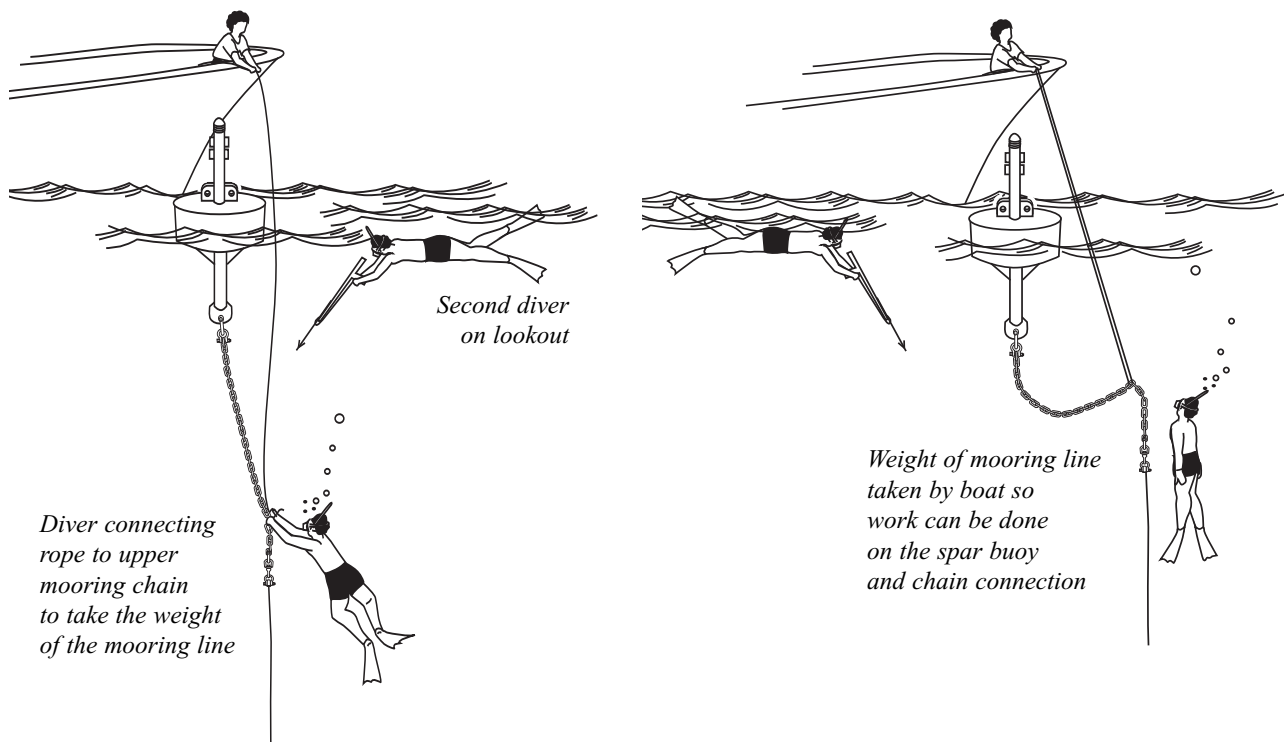
There are several methods to maintain the upper 10 to 20 per cent of the mooring. The most common methods used are diving, both with snorkel and with SCUBA, or using lifting equipment on the maintenance vessel. The approach used is generally based on the size of the maintenance vessel and the available equipment in the country.

Surface inspection and repairs

A snorkel and face mask will allow a surface inspection of the buoy system to be made. Free diving will allow inspection of the upper mooring hardware and/or mooring rope to the depth the diver is able to reach safely. This approach is generally used when inspecting the buoy system and the aggregators. For any dive work, there should be at least two divers in the water in case of difficulties. If sharks are known to be around a FAD, one of the divers should have a speargun with power head, this person's role being to keep watch over the others inspecting or working on the FAD mooring or aggregator.

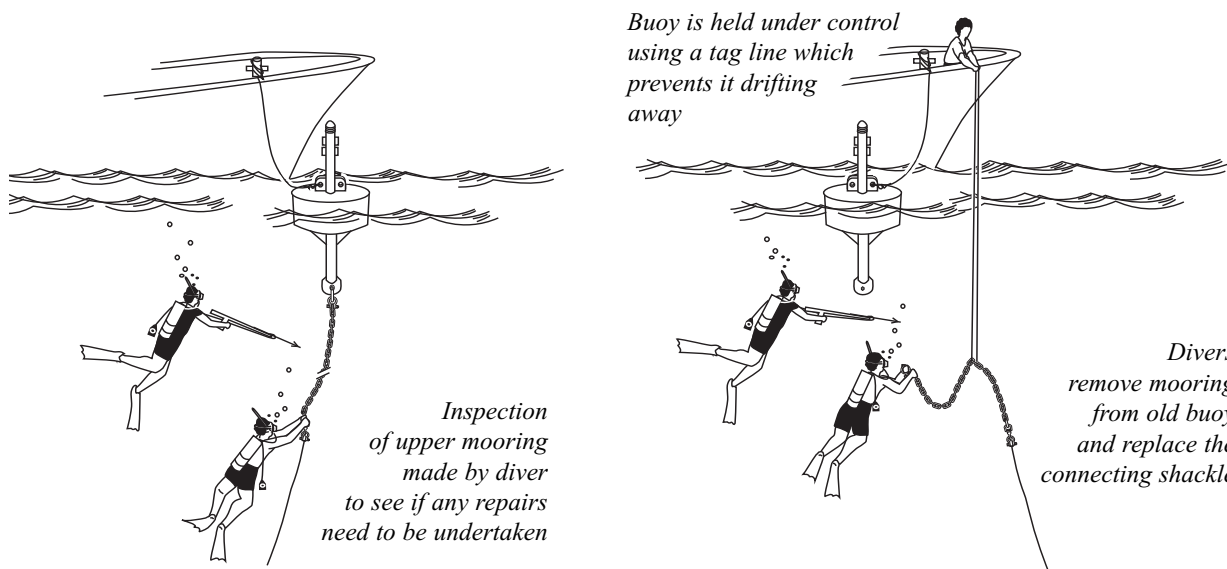


When repairs need to be made to an Indian Ocean FAD buoy system or the aggregators, they can be pulled on board the maintenance vessel as they are easy to handle. Repairs to a spar buoy are more difficult, especially from small vessels. Generally, maintenance on a spar buoy is undertaken with the buoy in the water. To do this, a rope is taken from the maintenance vessel and attached to the upper chain, 4 to 5 m down. Alternatively, the rope can be passed through a link in the chain and taken back to the boat to create a slip-line. The rope is then pulled to take the weight of the mooring and secured to the boat. This takes the weight off the spar buoy and allows repairs to be made. Once the repairs are completed, the rope is either released and untied from the chain, or if a slip-line is used, released from the boat and the rope hauled in.



Underwater inspection and repairs

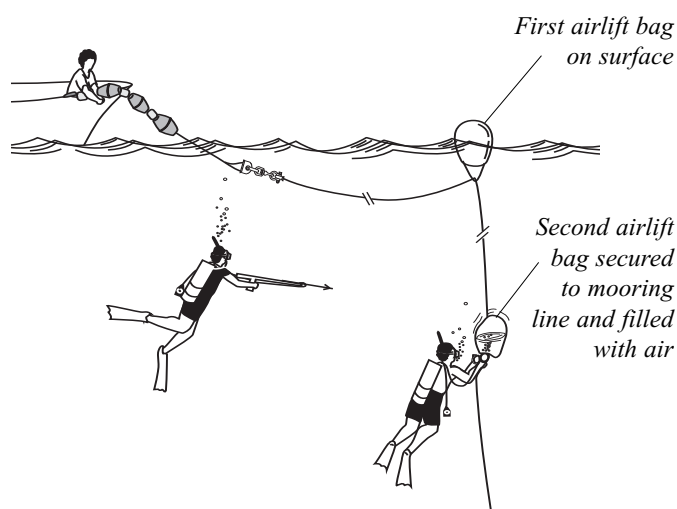
SCUBA gear can be used to increase the depth the diver can get to and work at. This is generally less than 30 m (100 feet). For safety reasons, at least two divers should be in the water at all times, one with a speargun with power head for protection from sharks. If repairs are needed on the buoy system or aggregator, then the above approach is used.



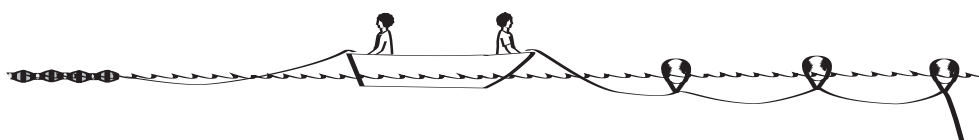
The upper hardware and mooring line are inspected as the divers descend. Tangled fishing gear is removed and inspections made of all connections and the upper rope. If repairs need to be made, a diver needs to bring a rope from the maintenance vessel and attach it to the mooring below the point that needs repair or replacing. The rope is pulled tight to take the weight of the mooring, thus taking the load off the part of the mooring to be repaired. Once the repair is made the rope is released and removed from the mooring.

Using airlift bags

In the Cook Islands, a series of airlift bags are used to float the mooring line to the surface for inspection. Two SCUBA divers descend to 30 m and attach an airlift bag to the mooring line. Air is then forced into the bag from the diver's regulator. The airbag slowly ascends taking the mooring line to the surface while the divers stay at 30 m. When the airbag reaches the surface, a second airbag is attached to the mooring line, filled with air and allowed to ascend. This process can be continued several times so that the top 100 m-plus of nylon or lead-core polypropylene rope can be inspected.

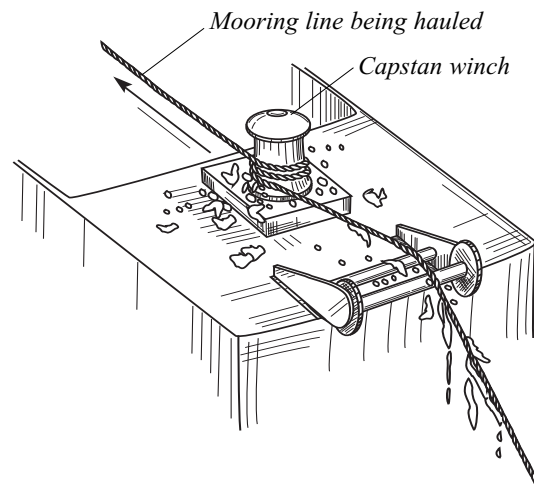


The divers return to the maintenance vessel and help the crew to do the inspection and repairs. The rope, which is near the surface with no weight on it, can either be pulled on board, or the crew can just pull the vessel along the rope, inspecting and cleaning it as they go. Repairs can be undertaken as the weight of the mooring is taken by the last airbag, which is left attached to the mooring line until all work is completed. Once repairs are complete, the air lift bag that has been supporting the mooring line is removed, and the mooring system allowed to settle back into its previous position.



Using a capstan winch

In Niue, the maintenance vessel is fitted with a large capstan winch on the stern for inspecting FADs and the upper mooring rope. All of the FADs in Niue are of the new Indian Ocean design, so that the buoy systems can be easily handled and hauled on board the maintenance vessel. The remaining rope on the buoy system is hauled by hand until the upper mooring rope (nylon or lead-core polypropylene) is reached. This rope is then wound around the high-power and low-gear-ratio capstan and slowly hauled. As the rope comes up, growth is removed as well as any fishing gear tangled on it. Usually the top 100 m of rope is hauled in for offshore FADs, and around 40 m of rope is hauled in on inshore FADs. Any repairs are undertaken on the hardware and rope before it is fed back over the side of the vessel, followed by the buoy system.



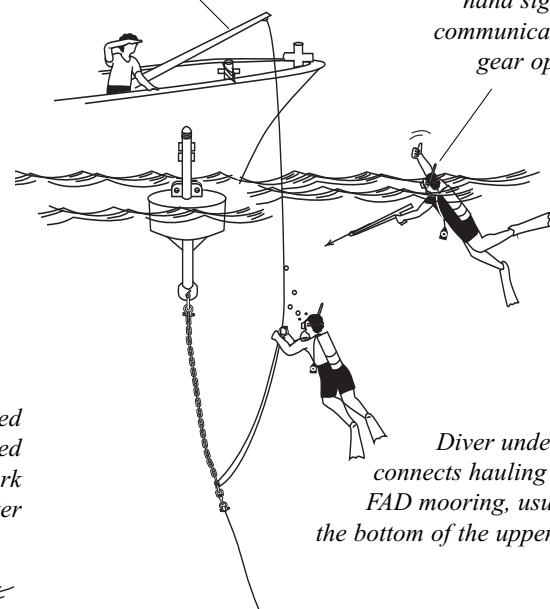
If a spar buoy is used, divers will be needed to take a rope and fasten it to the mooring, so this can be hauled to the side of the boat. Once the connection of the chain to the upper mooring rope is on board, the rope can be wound around a capstan and hauled. Repairs on the spar buoy can be undertaken in the water, unless the vessel has lifting gear capable of lifting the spar buoy on board.

Using a derrick and deck winch

Some vessels have a derrick and deck winch that can be used for FAD maintenance work. Depending on the size of vessel and safe lifting load of the equipment, a spar buoy may be lifted on board for repairs. First though, divers are needed to attach the winch cable to the mooring so that this can be hauled up and secured to take the load of the mooring. Work can then be done on the buoy either on board the boat or in the water. Once repairs are complete, the mooring line is released.

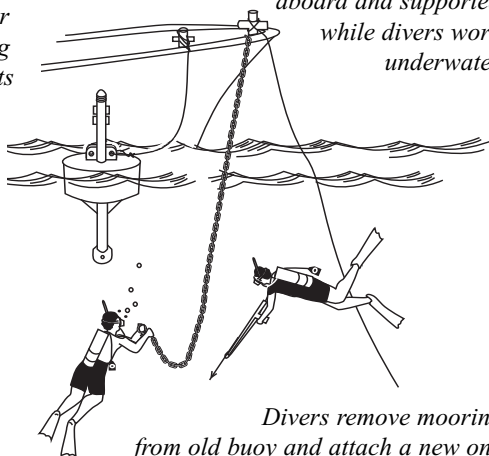
Winch or capstan rigged to haul via the boat's lifting boom

Diver at surface uses hand signals to communicate with gear operator



Buoy is held under control using a tag line which prevents it drifting away

Mooring line is hauled aboard and supported while divers work underwater



In all cases, a maintenance repair sheet should be completed as the maintenance vessel returns to port or as soon as the vessel ties up. It is essential that this be done, especially noting the work undertaken, materials used, and wear points that need to be attended to on the next service.

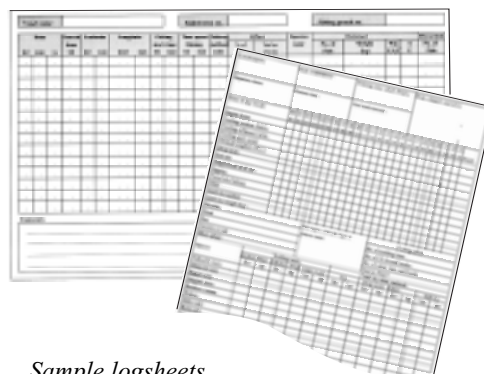
Monitoring FADs

It is important to monitor the fishing activity around FADs so that quantitative and qualitative data can show the benefits that have been generated by having a FAD programme. This data can then be used to support the case for ongoing funding by governments or donors.

The simplest method of monitoring FADs and their productivity is to collect catch and effort data from those who are fishing around the FADs. This data collection can be done in several ways, all of which require a lot of work and cooperation between the fishermen and the fisheries department. The collected data can be analysed to show the cost-benefits to fishermen and the community from having a FAD programme in place. The cost of collecting the data can be high depending on the approach undertaken. Whichever method is chosen, fisheries departments must build into their recurrent budgets sufficient funding to employ data collectors if they want to run a successful and meaningful FAD programme.

Logbook system

A logbook was developed for the FAD research project. Fishermen were requested to complete the logbook, with one page completed for each fishing trip. Data collected included the fishing area, name of boat, number of crew, date, the time spent fishing by different fishing methods, and the catch by species for each fishing method. Completion of the logbook was voluntary, and the staff of the fisheries department worked hard to encourage fishermen to complete the log, and helped them when they could.



Sample logsheets

Getting all fishermen to complete voluntary logbooks is very difficult. Therefore it is best to work with a representative sub-set of fishermen who are willing to do this. The catch and effort of the whole fleet can then be calculated after estimating what portion of the total fishing effort around the FADs the sub-set of fishermen represents.

The fishermen in the sub-set may need some training in completing the logbook and a copy of the data should be left with them for their own records. The staff of the fisheries department need to keep in close contact with the fishermen and offer support wherever they can. As this is an ongoing process that takes quite a bit of the fishermen's time, something needs to be given back to them. The best thing is to provide regular summaries of the data collected so they can see how their data is being used. Incentives can also be offered, but this could lead to fishermen not completing the logbook unless the incentives keep coming.

Alternatively, a logbook system could be made mandatory, with all fishermen required to complete it. This would take a lot of effort by the fisheries department to get everyone involved and cooperating. There are problems with this approach though, as some fishermen will write down anything and make up data just to meet the requirement. This is not the best approach unless there is good cooperation between the fishermen and the fisheries department.

Survey of fish landings

An alternative to logbooks is to have fisheries staff interview fishermen at the wharf or launching ramp when they come in from fishing. The fisheries staff complete a survey form which consists of the same data as in the logbook. The staff must have scales to weigh the catch for recording. Fisheries staff will have to work outside regular work hours to fit in with the times fishermen are returning from fishing. This includes evenings and weekends.

Ownership of FADs

Governments, through their fisheries department, implement national FAD programmes for all to use. However, fishermen can sometimes get very possessive when it comes to who can fish around FADs. In some countries, fishermen feel that a FAD close to their village, or set off their side of the island, belongs to them or the people from their area, and others are not welcome. This is an issue that has resulted in many FADs being lost or damaged through vandalism, as disgruntled fishermen cut FADs free or break the lights, so that others cannot fish them or even find them. This type of thinking needs to be changed through education, so that a FAD programme can be implemented successfully for the good of all users.

Some sectors are contributing to the cost of the FADs, and then they may feel they have greater rights to fish the FADs than those who are not contributing. Again, this type of thinking needs to change through education, as the fishermen's contribution is not just for the good of others, but for themselves as well, as without the FADs their livelihood is affected the same as the others.

Some fishing companies will set their own FADs for their industrial fishing vessels (purse seiners and pole-and-line vessels). These tend to be set farther offshore, away from where small-scale fishermen operate. Although a company has paid for the FADs and is doing the maintenance with no government assistance, there is still a need for government to request or insist that the fishing company allows other non-industrial vessels to fish these FADs. However, if a company vessel comes to fish on a FAD set by its company, then it should have priority.

If small-scale fishermen, individually or in a group, want to put out their own FAD, this should be encouraged, provided it is for general use. If FADs are not for general use, conflict is bound to eventuate, possibly resulting in the loss of the FADs through vandalism.

The main exception is when FADs are deployed sub-surface, so there is no surface buoy system for fishermen to locate. If this type of FAD is used then the only way to find it is with GPS coordinates and an echo sounder. If people do not give out the position, then others cannot find sub-surface FADs. Over time, however, people will learn where these are just by following others who know the locations. Eventually, enough people will know the positions so they will end up being more or less for general use.

Funding FAD programmes

Cost recovery or the funding of FAD programmes has been an issue discussed by many governments in the region, with no clear direction or decision made. What has emerged is the understanding that there is both public and private good derived from national FAD programmes. As mentioned at the start of this manual, the question of the purpose of the FAD programme has to be clearly understood to be able to identify the main beneficiaries, and to ascertain if they have the ability to contribute to the FAD programme. This needs to be worked out in the first year, so that funds can be built up over the life of the five-year programme to allow its continuation in the future.

In looking at contributions to the FAD programme by beneficiaries, two areas need to be covered: financial contribution and in-kind contribution (providing local materials, helping with maintaining aggregators, or time to help with FAD rigging and deploying). Community surveys were conducted during the FAD research project. One of the questions FAD users were asked was whether they would be willing to contribute to the cost of maintaining FADs. The results showed that subsistence fishermen were willing to provide in-kind contributions, while commercial fishermen were more inclined to provide money.

If the main purpose of a FAD programme is for public good, for example food security, protection of inshore resources, or to assist subsistence fishing activities, the government should bear the main cost of the programme. Alternatively, if the main purpose of the FAD programme is for the good of the private sector, for example to support small-scale commercial fishing, sportsfishing or charter fishing operations, the private sector or users of the FADs should bear the main cost of the programme.

Financing mechanisms

There is a range of financing mechanisms, including cost recovery from the private sector that governments can explore to fully or partially fund a national FAD programme, including ongoing maintenance. Most mechanisms require a bank account into which funds are paid and allowed to accumulate. The operation of such an account would need to be transparent to all who are contributing to ensure the funds are used specifically for the FAD programme. Funding mechanisms include:

Direct government contribution: The fisheries department builds in a specific budget line for FADs with an annual allocation. It is best if this annual allocation is placed in a separate account that can be carried forward each year to allow the funds to build up for use when needed, especially for the bulk purchase of materials from time to time.

Export levy on fish sales: The fisheries department (or other government department) collects a levy on all export sales of fish, which will mainly be tunas. The levy could be a percentage (possibly 1 to 2%) of the estimated value of the fish being exported, with each species having a nominal value for ease of calculating the levy amount. This levy would be paid into an account for funding a FAD programme.

Development fee on fishing licences: Many countries license foreign fishing vessels, or larger domestic vessels, to fish within that country's EEZ (exclusive economic zone). There are no perceived benefits from these operations for small-scale fishermen. However a 'development fee' could be placed on each licensed vessel (say \$500 to \$1000 per licence annually), with these funds paid into an account for funding a FAD programme. Small-scale fishermen would then see a direct benefit to them from foreign fishing access.

Licensing or registration of domestic fishing vessels: The fisheries department could introduce a licensing or registration system for all small-scale and medium-scale fishing vessels involved in full-time or part-time fishing activities. This would include sportsfishing and charter fishing operators. An annual fee could be charged (from \$50 to \$500) for the licence/registration with this fee paid into an account for funding a FAD programme.

Financial contribution from fishing clubs and associations: Some fishing clubs or associations collect an annual membership fee. The membership fee could be increased by a set amount for all members, with this additional amount contributing only to the FAD programme. This contribution could be through an annual payment into a FAD bank account, or through the direct purchase of materials needed for the FAD programme.

In-kind contribution from fishing clubs and associations: In addition to, or in place of, a financial contribution, the ongoing maintenance of the FAD buoy system and aggregators could be done by the club's members, as they would be the main people fishing around the FADs. Members could donate local materials for aggregators and the club could purchase strobe lights and change the batteries when needed. This would need to be done in close cooperation with the fisheries department, with the two working together on major repair work and the purchase of materials.

In-kind contribution from fishermen: Where there are no fishing clubs and associations, some fishermen may want to provide local materials for use in FAD aggregators. Some fishermen may also be willing to volunteer their time to help fisheries staff maintain and repair FADs.

Sponsorship of FADs: The fisheries department or the private sector could approach businesses in the country to sponsor one or two FADs. This would generally be for the purchase of materials, or even the purchase of specific materials that the company handles, such as ropes or hardware components.

If the government is not going to fully fund a FAD programme, some of the above funding mechanisms may be used by government to establish an ongoing FAD programme in full consultation with local fishermen and their clubs or associations. It will take a lot of cooperation and willingness on all sides to implement a successful ongoing national FAD programme.

CONCLUDING REMARKS

FAD programmes can help small-scale fishermen and be cost effective, if they are properly planned and implemented with regular maintenance to extend their lifespan. The results of the FAD research project support this even though several of the experimental designs trialled were unsuccessful. Some of the new Indian Ocean FAD systems survived cyclones in Niue and the Cook Islands in 2004 and early 2005, which is a good sign when hoping to achieve a minimum of a two-year average lifespan for FAD units.

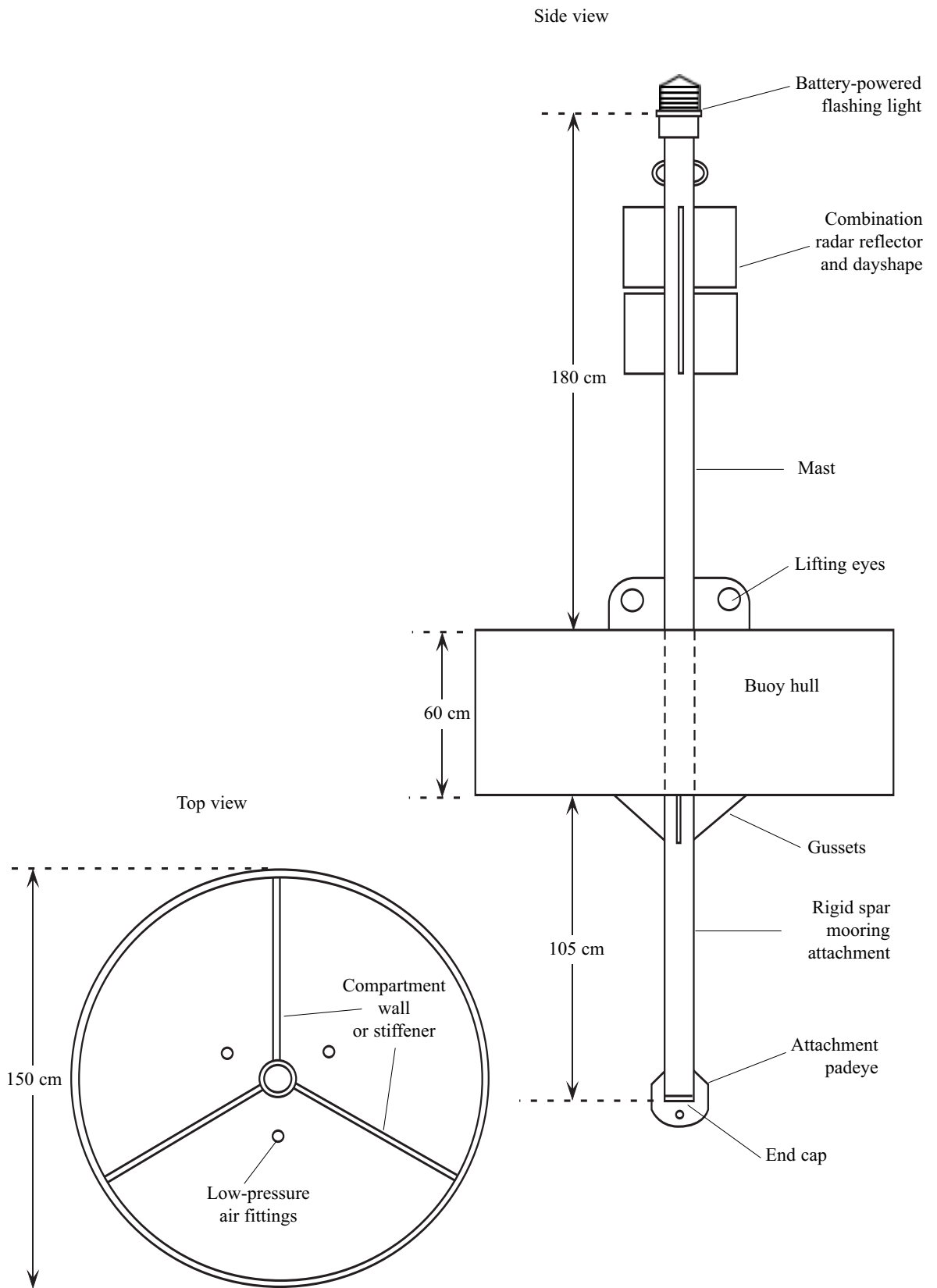
Coupled with the FAD maintenance programme is the need to have fishermen involved wherever possible to assist. They are the people regularly at the FADs and they know what is happening and when there are problems with the FADs. Fisheries departments need to work with fishermen to collect catch and effort data, with the emphasis on a smaller amount of high-quality data from a sub-set of interested fishermen rather than a large quantity of low-quality data from a wider, uninterested group.

There is scope for further development of FAD designs, especially sub-surface FADs in shallower waters closer to the reef edge. The funding of FAD programmes is an area that each government or FAD implementing agency needs to look at closely, as there is both public and private good derived from FAD programmes.

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- Anderson, J. & P. Gates. 1996. South Pacific Commission fish aggregating device (FAD) manual. Volume I: Planning FAD programmes, South Pacific Commission, Noumea, New Caledonia. 46 p.
- Gates, P., P. Cusack & P. Watt. 1996. South Pacific Commission fish aggregating device (FAD) manual. Volume II: Rigging deep-water FAD moorings, South Pacific Commission, Noumea, New Caledonia. 43 p.
- Gates, P., G. Preston & L. Chapman. 1998. Secretariat of the Pacific Community fish aggregating device (FAD) manual. Vol. III: Deploying and maintaining FAD systems, Secretariat of the Pacific Community, Noumea, New Caledonia. 43 p.

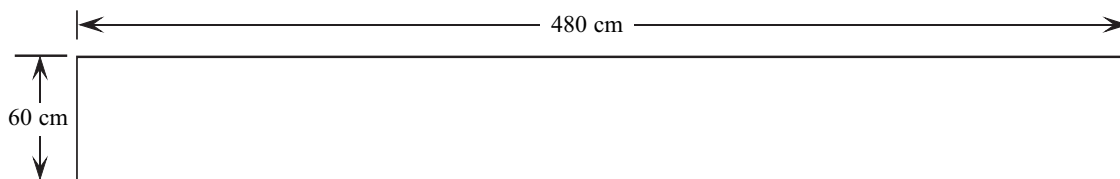
Construction details for steel spar buoy (adapted from Gates et al. 1996)



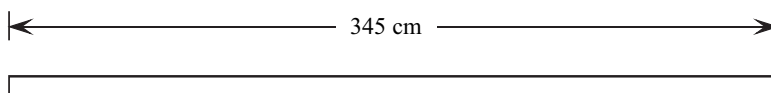
Cutting components

Outer buoy wall

Cut the outer buoy wall from 5 mm steel plate, 60 cm by 480 cm.

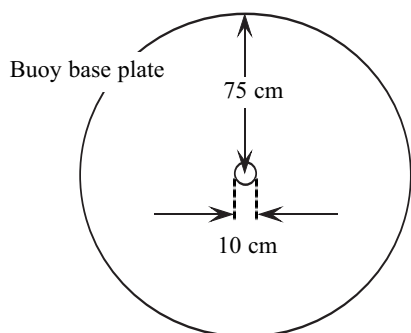


Mast and attachment spar

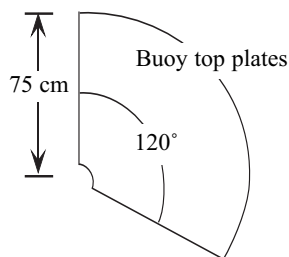


The combination mast-mooring attachment spar is constructed from a single piece of 10 cm, schedule 40 pipe, 345 cm long.

Hull

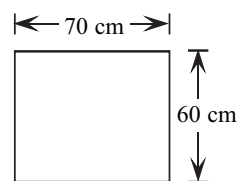


Cut a circular base plate of 75 cm radius from 5 mm steel plate. Cut a 10 cm diameter hole at the plate centre for the through-pipe mast.



Cut 3 top plates of 75 cm radius and 120° arc from 5 mm steel plate. Cut a 5 cm radius arc from the inner point of each plate.

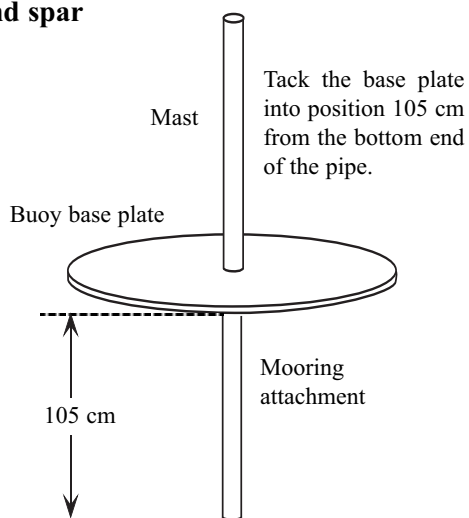
Compartment walls



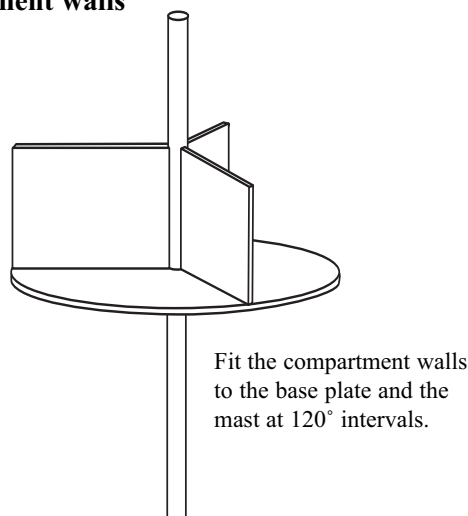
Cut 3 walls of 60 cm x 70 cm from 5 mm steel plate.

Making the buoy

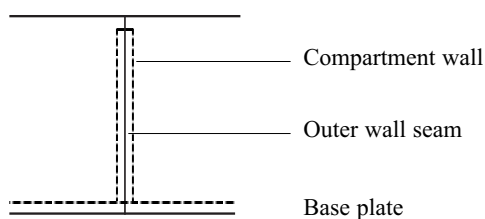
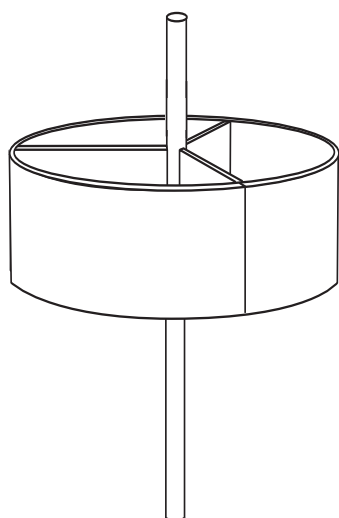
Base plate and spar



Compartment walls

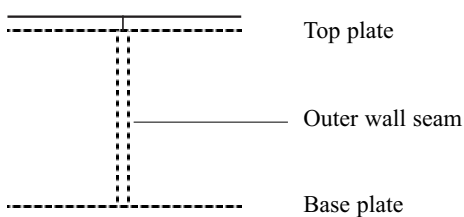
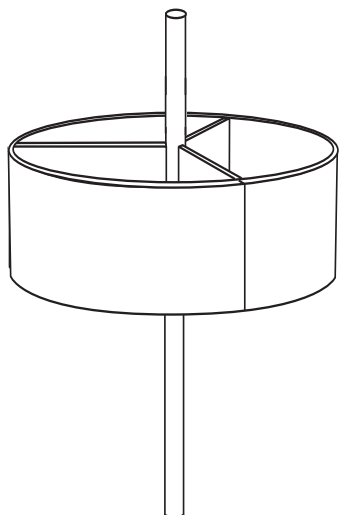


Outer buoy wall



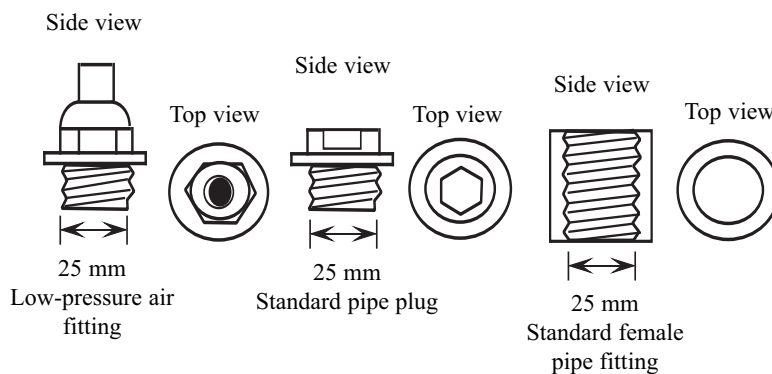
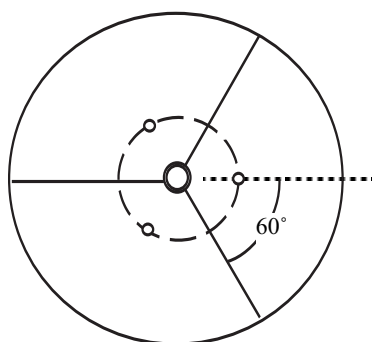
Fit the outer buoy wall into place, butted against the base plate, and level with the top edge of the compartment walls. Arrange the outer buoy wall so that the two ends will meet along a compartment wall. After the outer wall is fitted, weld along all seams.

Buoy top plates



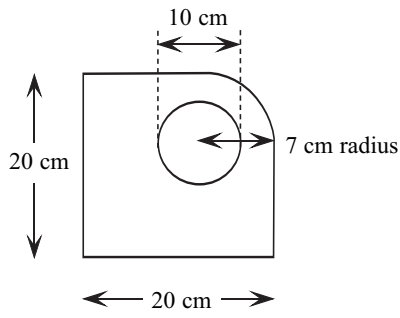
Fit the three top plates onto the buoy, flush with the top edge of the outer buoy wall and with both edges aligned with compartment walls. Leave a slight gap between the edges of adjacent plates. Weld the plates so that the weld seals off each compartment and renders it watertight.

Leak-test fittings

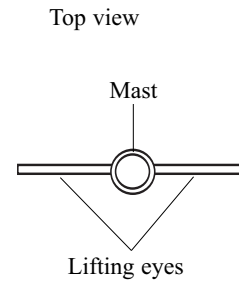
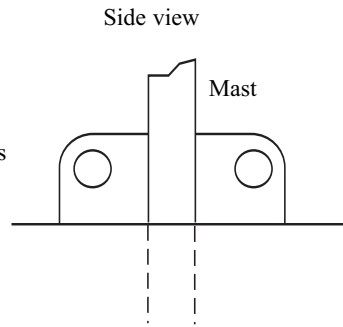


In each top plate, drill a hole to suit a threaded 25 mm female pipe fitting along the midline, 20 to 25 cm from the mast. Weld a fitting into each of the three holes. Screw in a 25 mm low-pressure air fitting into each hole and leak-test each compartment. When all compartments are watertight, replace the air fitting with a stranded 25 mm pipe plug.

Lifting eye

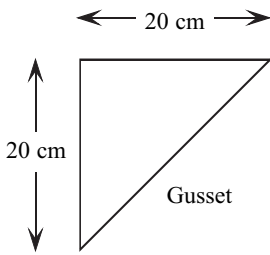


Make up 2 lifting eyes from 5 mm steel plate.

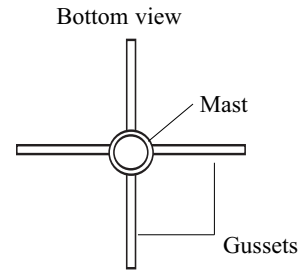
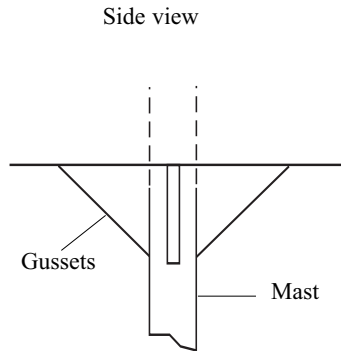


Arrange lifting eyes opposite each other, against the buoy hull on either side of the mast.

Support gusset

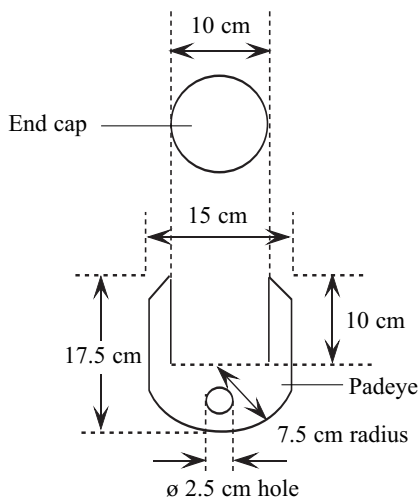


Make up 4 gussets from 5 mm steel plate.

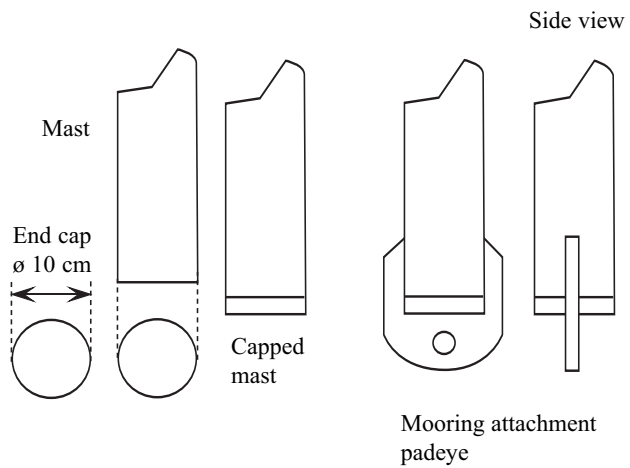


Arrange gussets at right angles to each other, weld the top edge to the base of the buoy hull and weld the upright side to the mast.

Mooring padeye

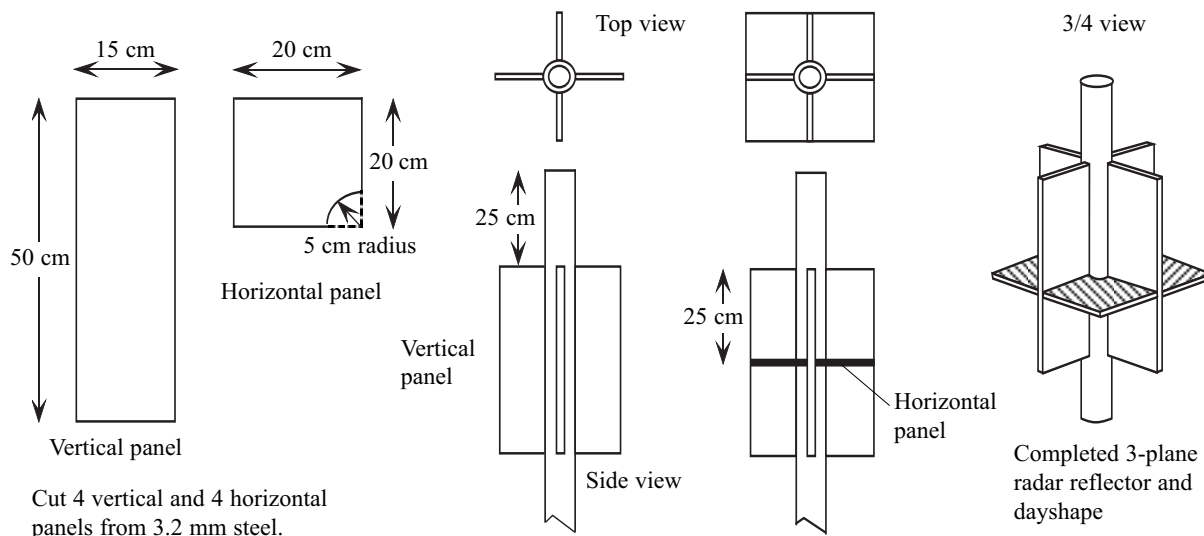


Make the end cap and padeye from 25 mm steel plate.



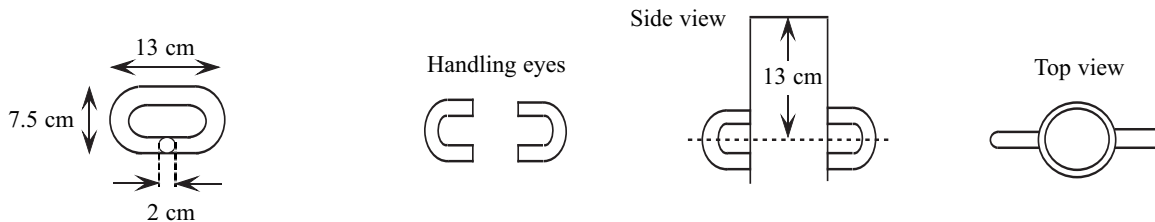
Seal the mast with the end cap, then centre the padeye on the capped mast and weld it into place.

Combination 3-plane radar reflector and dayshape



Weld vertical panels to the mast at right angles to each other, with the tops 25 cm from the top of the mast. Then centre and weld horizontal panels between pairs of vertical panels.

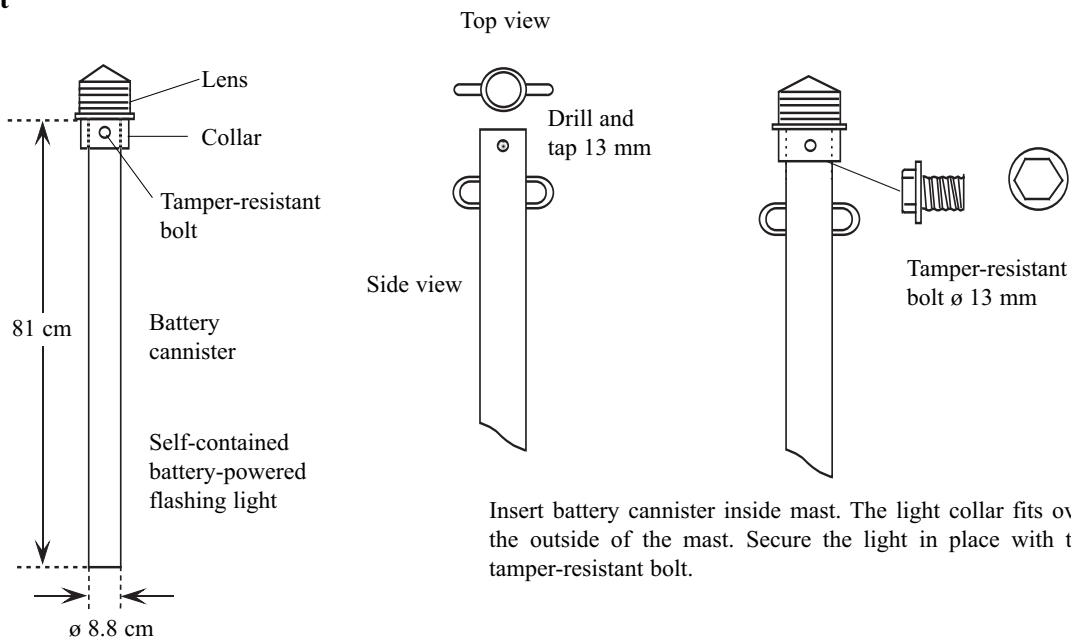
Handling eye



Weldless end link \varnothing 2 cm

Cut the end link in half to make 2 handling eyes. Weld the handling eyes on opposite sides of the mast, centred 13 cm from the top end.

Flashing light



Insert battery cannister inside mast. The light collar fits over the outside of the mast. Secure the light in place with the tamper-resistant bolt.

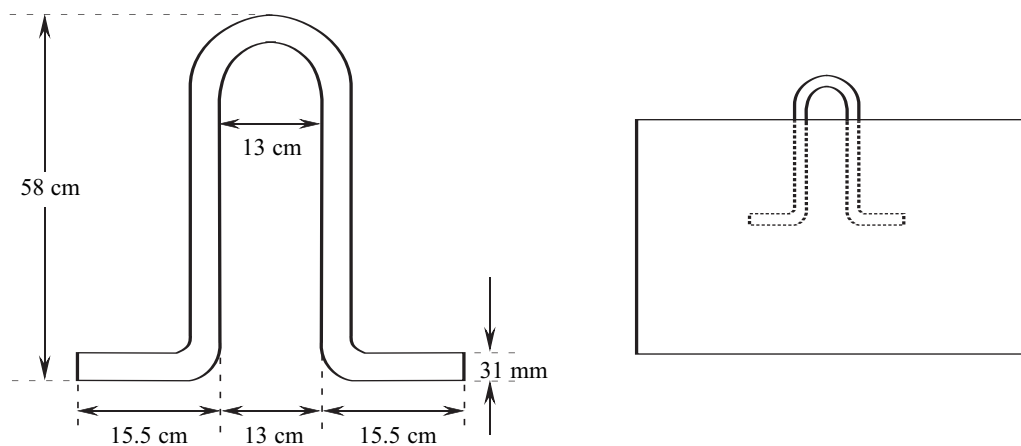
Construction notes for a concrete FAD anchor (adapted from Gates et al. 1996)

The two essentials for making high-quality concrete anchors are the correct mix (cement, sand, aggregate, and water), and proper curing of the concrete. Unsuitable mixes and incorrect curing are the two most common reasons for anchor failure. A proper mix ratio and correct curing will produce an anchor that is impermeable to seawater.

Concrete requires 28 days of moist curing to attain its maximum strength. Moist curing requires that the concrete be kept constantly damp. This is best done by covering the block with sacking and having water trickle onto it through a hose.

Anchor attachment point (bail)

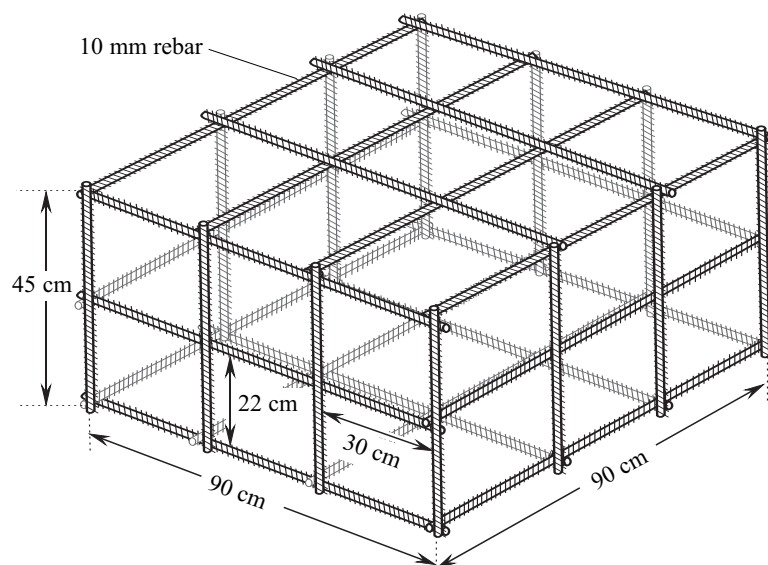
Construct the anchor bail from a single piece of smooth, low-carbon steel roundstock, bent as shown. Make the ‘wings’ on either end of the bail 5 times as long as the diameter of the roundstock. For example, for a bail made from 32 mm roundstock, the wings should be at least 15.5 cm. If smooth roundstock is not available, concrete reinforcing bar will do. Make sure that the bail is positioned in the block so that the bow of the connecting shackle will fit through it.



Total length of roundstock: approx. 163 cm

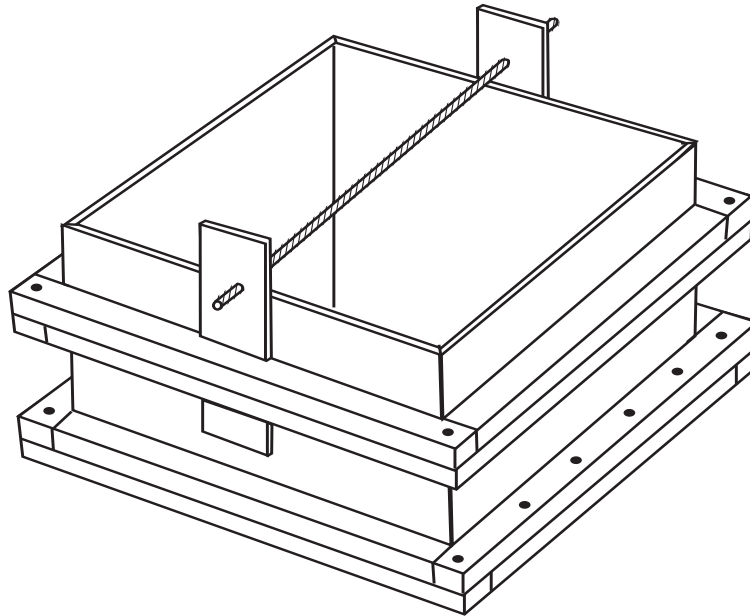
Reinforcing concrete anchors

Reinforcing the anchor will strengthen the concrete against cracking, both on impact during deployment, and while in service. Reinforcing consists of a rebar cage constructed from Size 4 (10 mm) rebar. Wire or tack-weld the rebar together so that the cage forms a single unit. No bar should be closer than 7.5 cm to any external surface. The 7.5 cm cover of concrete forms a barrier and protects the steel from corrosion caused by seawater. The spacing of the rebar should not exceed 30 cm or be less than 22 cm.



Forms

Use plywood and solid timber to construct wooden forms for pouring the anchors. Build several forms, because pouring several anchors at once is more efficient and makes it easier to maintain quality standards. The forms should be strong enough to maintain the anchor's shape and to prevent leakage of wet concrete. They should also be easy to remove without prying on the anchor, and should be designed so that they can be disassembled and stored for later use. The inside measurement of the form should be at least 15 cm larger than the outside measurement of the rebar reinforcing cage.



Form for 120 cm x 120 cm x 60 cm concrete anchor block

Mixing concrete

General-purpose cement (Type 1 Portland Standard) is the most widely available, and is the type most often used for making self-mixed concrete. Select good-quality aggregate, because sand and gravel (or crushed stones) comprise 65 to 75 per cent of concrete. Concrete is strongest and most dense when aggregate materials (sand and gravel) contain particles of varying sizes. For concrete anchors, the recommended maximum size of the coarse aggregate is 20 mm. Avoid using crushed coral or crumbly rock as aggregate. Coral is porous; it traps air and will break easily. Crumbly rock will break up under minimal pressure. Whenever possible, avoid using coral sand as it is porous and weak. River sand is good for fine aggregate. Check that the aggregate is clean and free of contaminants, especially silt and organic matter which can prevent the concrete from bonding. Wash the aggregate repeatedly with fresh water if it appears dirty or salty.

The standard weight of a cement bag is 50 kg. To make a large batch of concrete, use a bag of cement as a measuring standard. Find a bucket or container large enough to hold the entire bag of cement. Jiggle the bucket so the cement forms a level surface and then mark the bucket. The bucket can then be used to measure all the other dry materials. To make an 2000 kg concrete anchor you will need 8.5 bags (50 kg each) of cement, 13 bags (50 kg each) of sand, 17 bags (50 kg each) of stone (maximum size of 20 mm), and 196 litres of fresh water (23 litres per bag of cement).

Sample maintenance record sheet

Date: DD/MM/YY	FAD identification:	Skipper and crew of launch:
Amount of fuel used:	Other costs:	Fisheries staff doing services:
Next FAD maintenance date:		
MAINTENANCE OF BUOY AND MOORING		
Condition of buoy system and any repairs done:		
Condition of safety shackles and any repairs done:		
Condition of swivel and any repairs done:		
Condition of rope connector(s) and any repairs done:		
Condition of eye splice(s) and any repairs done:		
Condition of upper rope/wire cable and any repairs done:		
Condition of anodes (if used) and any repairs done:		
Condition of flagpole, light etc. and any repairs done:		
List all fishing gear found on the FAD buoy system, aggregator and mooring line:		
MAINTENANCE OF AGGREGATOR		
Current (strength and direction):	Bait species and number (est.) around aggregator:	Pelagic fish and bird activity:
Type of aggregator used:		
Condition of aggregator:		
Condition of bridle/connection to FAD:		
Repairs or additions/changes to aggregator:		
Comments:		