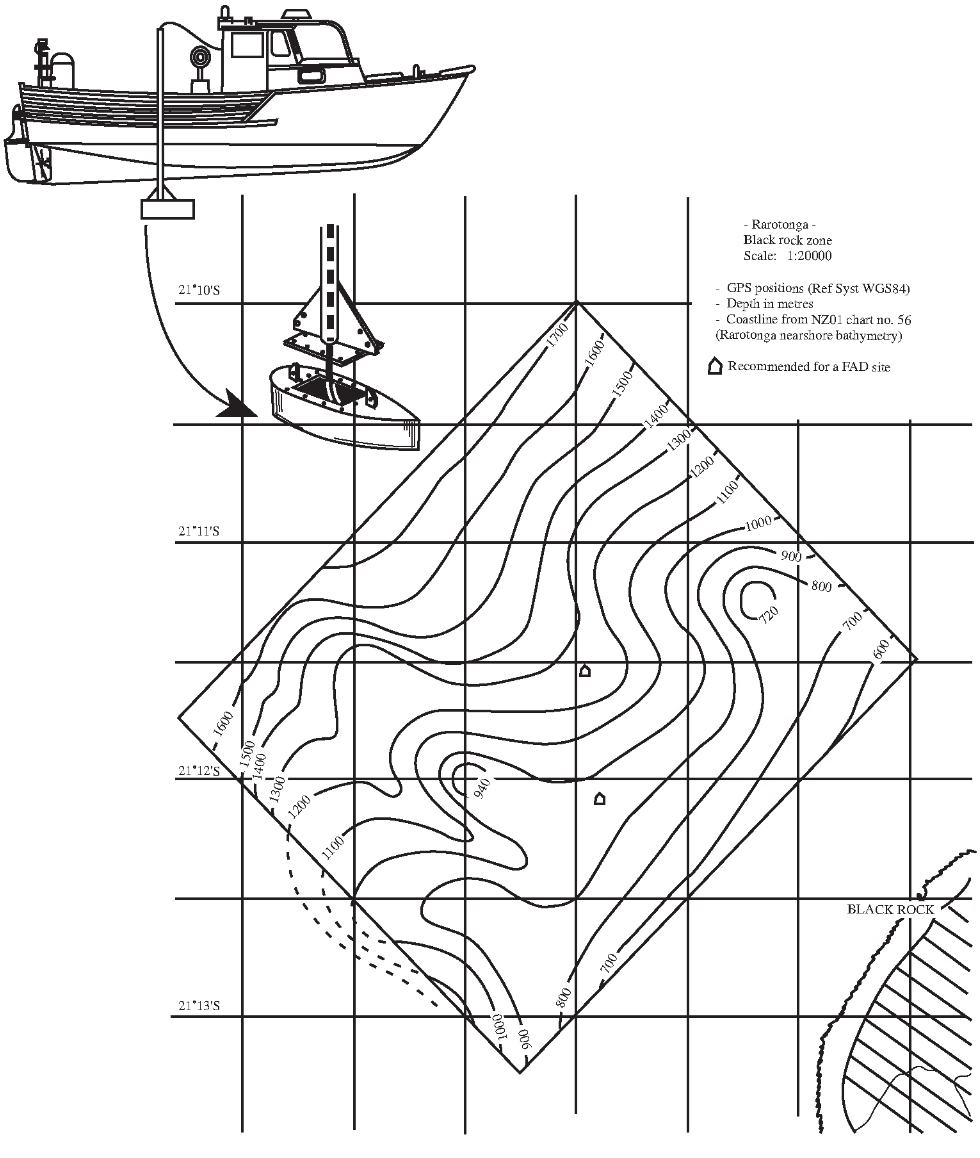
DEEP SEA FISHERIES
DEVELOPMENT

ISSN 1017-9259




# FISH AGGREGATION DEVICE (FAD) ASSISTANCE PROGRAMME

## Report of visit to the Cook Islands

23 November to 21 December 1990

SOUTH PACIFIC COMMISSION
NOUMEA, NEW CALEDONIA

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# FISH AGGREGATION DEVICE (FAD) ASSISTANCE PROGRAMME

# REPORT OF VISIT TO THE COOK ISLANDS

23 November to 21 December 1990

by

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et des pêches maritimes, New Caledonia

South Pacific Commission
Noumea, New Caledonia
1992

494/92

Original text: English

South Pacific Commission Cataloguing-in-publication data

Desurmont, Aymeric
Report of visit to the Cook Islands, 23 November to 21 December 1990 / by Aymeric Desurmont.

1. Fish aggregation devices--Cook Islands

I. South Pacific Commission. Deep Sea Fisheries Development Project

ISBN 982-203-277-3
639.2028 AACR2

Prepared for publication and printed at
South Pacific Commission headquarters, Noumea, New Caledonia, 1992

**SUMMARY**

Following the premature loss of several fish aggregation devices (FADs) deployed by the Cook Islands Ministry of Marine Resources (MRR) and recurring difficulties with conducting accurate FAD site surveys, the Government of the Cook Islands, in mid-1990, sought the assistance of the South Pacific Commission's Deep Sea Fisheries Development Project (DSFDP) in conducting a training programme for MMR staff in accurate FAD site survey, and proper FAD rigging and deployment techniques.

In response, SPC sought the co-operation of New Caledonia's *Service territorial de la marine marchande et des pêches maritimes* in making available, on attachment, Mr A. Desurmont, Masterfisherman with the Service and co-ordinator of the Territory's FAD programme. Mr Desurmont subsequently visited the Cook Islands for the DSFDP over six weeks during November and December 1990, and conducted the required training during actual field exercises.

During the training three potential FAD deployment zones were surveyed by echo-sounding and specific anchoring sites accurately plotted. One FAD was rigged and deployed successfully by MMR staff under Mr Desurmont's supervision. A feature of this work was the use of a Global Positioning System (GPS) receiver/plotter during the survey and deployment exercises. The equipment proved to be well suited to this work and its operation quickly learned by MMR staff. A simplified FAD mooring calculation method was devised that has application for some typical Pacific Island FAD deployments.

Several recommendations are made regarding MMR's future conduct of its FAD programme, including discontinuing the use of 3-strand ropes for FAD moorings in favour of 8- and 12-strand types.

## ACKNOWLEDGEMENTS

The South Pacific Commission acknowledges with gratitude the co-operation and assistance of the Government of the Cook Islands and the administration and staff of the Cook Islands Ministry of Marine Resources during the course of this visit. Particular thanks are offered to the Secretary for Marine Resources, Mr J. Dashwood, Fisheries Research Officer, Mr K. Passfield, and the members of the Ministry of Marine Resources FAD team, Richard Story, Sonny Tatauava and Sifa Fufofuka.

The Commission acknowledges too, the assistance of the New Caledonia Administration, and particularly the co-operation of the *Service territorial de la marine marchande et des pêches maritimes* in making available the valued services of Mr A. Desurmont. The success of this visit owes much to the professionalism and dedication to the task at hand demonstrated by Mr Desurmont.

## CONTENTS

# 1. INTRODUCTION

The South Pacific Commission's Deep Sea Fisheries Development (DSFD) Project is a mobile, field-based development programme which operates in the Pacific Islands at specific government request, and has the following broad objectives:

- To promote the development or expansion of artisanal and small- to medium-scale commercial fisheries throughout the region, based on fishery resources which are locally under-utilised, in particular deep-bottom resources of the outer reef slope and offshore aggregations of pelagic fishes;
- To develop and evaluate affordable, appropriate technology, fishing gear, fishing techniques and fisheries enhancement methods which will enable both subsistence and commercial fishermen to increase sustainable catch levels substantially;
- To provide practical training in fishing techniques and fisheries enhancement methods to local fishermen and government fisheries extension workers.

The project has worked in 17 countries and territories of the SPC region since its inception in 1978. The assignment detailed in this report was the Project's 66th country visit and the 4th time it has operated in the Cook Islands.

Fish aggregation devices have been in use in the Cook Islands since 1980 and are recognised there as making an important contribution to local fishing efforts. A cost/benefit study conducted on 1986 landing figures showed that with an average FAD unit costing around, NZ$4,000 to deploy and each FAD producing average increased catch values in the order of NZ$12,500, returns of 312 per cent on outlay were realised (Sims,1988). Few fishermen in the Cooks have any reservations about whether FADs increase small-scale fishing productivity and ease, and most of those who fish for the strong Rarotonga market have come to rely on FADs to provide productive fishing zones within safe and fuel-economic range of the island's boat harbours. But, in common with many other Pacific Island countries, the Cooks have suffered premature FAD losses and subsequent disruption to productivity. Although FAD survival rates have generally increased with growing experience and improved, materials and rigging experience, the Cook Islands Ministry of Marine Resources (MMR) has been concerned for some time with improving its FAD programme personnel's ability to conduct accurate site surveys and to calculate catenary mooring systems precisely.

Following a major Pacific Islands FAD review undertaken by the SPC Fisheries Programme during 1990 and a subsequent FAD workshop held during SPC's 22nd Regional Technical Meeting on Fisheries in 1990, the Cook Islands Government, at the request of MMR, sought the technical assistance of the DSFD Project in upgrading its FAD survey, mooring calculation and deployment capability. In response, the Commission enlisted the co-operation of New Caledonia's Territorial Government in making available Mr A. Desurmont, on secondment from his position as Masterfisherman with the *Service territorial de la marine marchande et des pêches maritimes* and co-ordinator of New Caledonia's FAD programme.

The secondment agreement provided for Desurmont to travel to Rarotonga for one month to work with the MMR FAD team, demonstrating the following skills:

– Accurate site survey techniques using an echo-sounder,

– Navigation skills essential for site survey and plotting of selected sites,

– Mooring component calculation,

– Recommended rigging methods,

– Deployment techniques suited to local craft.

## 2. BACKGROUND

### 2.1 General

The 15 islands of the Cook Islands (Figure 1), which fall naturally into the northern and southern groups, total about 240 sq km of land area, but because the islands are widely scattered the country's Exclusive Economic Zone, the sixth largest in the SPC region, encompasses some 1,969,448 sq km of ocean (SPC estimate).

The islands of the northern group are typical coral atolls. The southern group islands, apart from the tiny atolls of Manuae and Takutea, are of volcanic origin. Most of the southern islands have elevated, encircling reef platforms adjacent to the coast, and all are surrounded by recent coral reefs. The soils in these six islands range from heavily weathered and infertile in the older islands to the highly productive younger soils of Rarotonga. Most of the southern islands, particularly Rarotonga, support rich and varied vegetation. Subsistence and small-scale commercial agriculture is widely practised, with coconut, breadfruit, taro, arrowroot, citrus fruits, banana, papaya and pineapple grown.

The islands lie within the hurricane belt and are influenced by the prevailing trade winds. In the north these winds are mainly from the east and in the southern group from east-south-east. During the hurricane season (November to March) humidity is high, but during the remainder of the year the southern group is generally cooler than the north. The mean annual temperature at Rarotonga is 24°C and the average annual rainfall 2,000 mm.

A 1986 census estimated the country's population at 17,614, with 9,820 on Rarotonga. This figure demonstrates a steady decline in population over recent years, abetted by Cook Islanders' status as New Zealand citizens and the immigration access this status gives to Australia and New Zealand. More than 20,000 Cook Islanders now live more or less permanently in New Zealand.

The local economy is heavily dependent on imports of foods, raw materials and manufactured goods. Imports during 1989 were valued at NZ$73,078,000, of which NZ$15,079,000 comprised foods. Exports in the same year were valued at NZ$4,665,400, of which market garden produce, tropical fruits and pearlshell were important components. Tourism also plays an ever-increasingly important role in generating foreign revenue; there were nearly 30,000 visitors to the islands in 1988 (Turua, 1990).

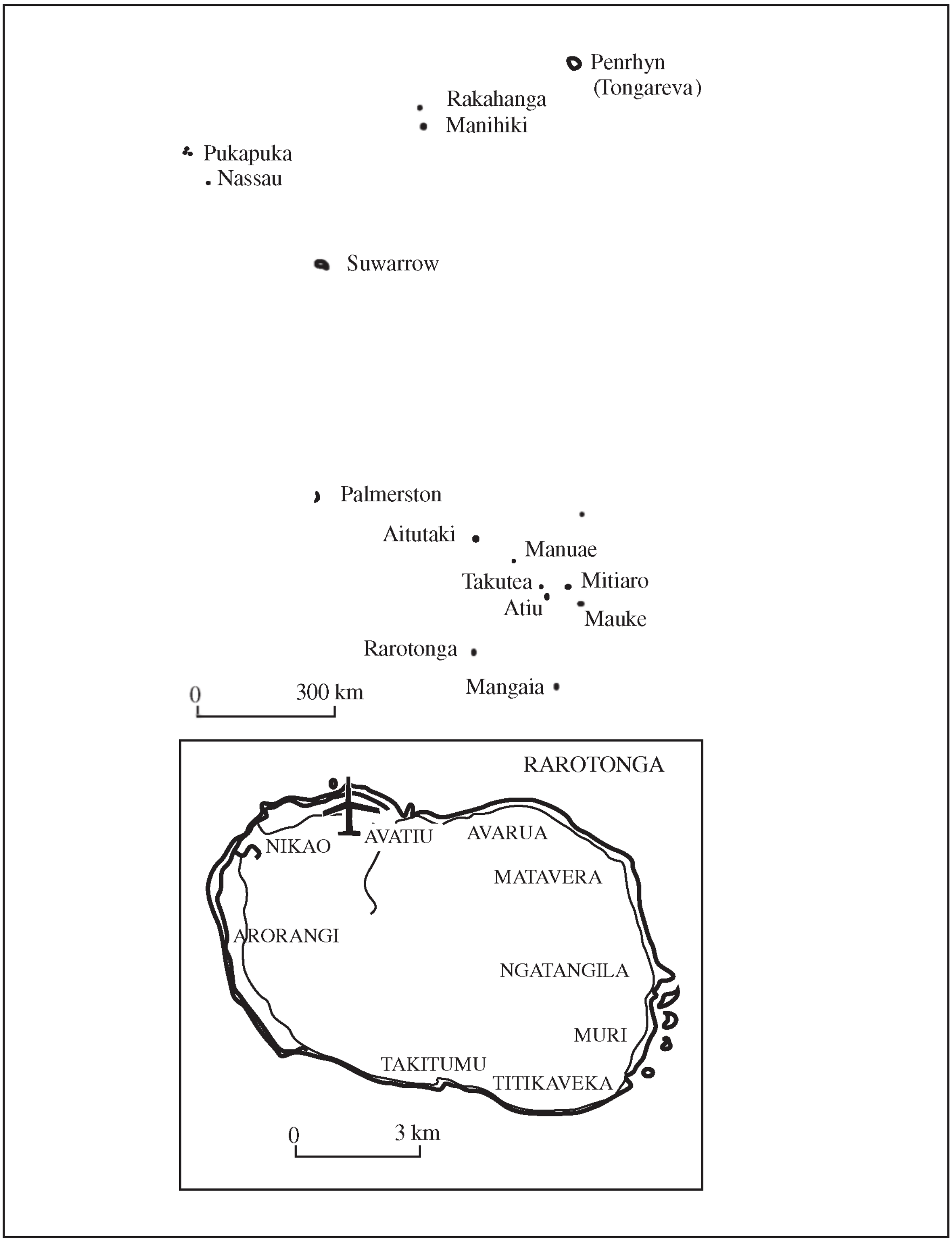


***Figure 1: The Cook Islands, with detail of Rarotonga (inset)***

## 2.2 Existing fisheries

Fisheries activities throughout the group are widespread and diverse, though generally at subsistence level. The main artisanal methods employed include gill-netting, bottom and mid-water handlining, trolling, the scooping of flying fish and spearfishlng. The annual artisanal catch in the southern group has been estimated at 800 to 1,000 t, comprising about 70 per cent 'reef fish', 10 per cent pelagic species and the balance 'miscellaneous' fish including sharks (Anon, 1980).

At many of the outer islands, catches by these various methods often exceed demand. Simple preservation techniques, such as salting and drying are regularly employed to hold surplus catches. At Rarotonga, where population has steadily increased with the flow of population from the outer islands, and where a cash economy prevails, the supply of local fish falls far short of demand and a number of attempts have been made to develop catch collection systems that would give outer island fishermen access to the Rarotongan market. Such schemes, both private and government, have met with only limited success, constrained by unsuitable shipping facilities and lack of catch handling infrastructure at the fishing sites.

The Cook Islands Ministry of Marine Resources, headquartered at Rarotonga with Fisheries Officers stationed on most islands in the group, has involved itself in a number of attempts to develop various fisheries as commercial activities in the outer islands, most notably the introduction of trochus or top-shell (*Trochus niloticus*) to Aitutaki in 1956 (and subsequently to other islands) and the support of pearl shell (*Pinctada margaritifera*) farming, and more recently pearl culturing, in the northern atolls of Manihiki and Penrhyn. MMR has also sought to boost offshore catches at Rarotonga and a number of the outer islands by undertaking a programme of fish aggregation device (FAD) deployments and more recently by conducting trials with a mechanised longlining system.

## 2.3 FAD programme

The MMR FAD programme has seen more than 30 units deployed since its inception in 1980 and has been counted a significant success in improving the productivity and efficiency of both subsistence and small-scale commercial fishing efforts. A study based on 1986 landing values for three FADs in place for an average 46 per cent of that year off Rarotonga (Sims, 1988) estimated that troll fishermen landed fish valued at NZ$93,060 from the FADs and downline fishermen NZ$26,548 from the same source; an increase of some NZ$37,500 over returns which might have been expected if the same fishing effort had been directed to non-FAD zones.

The fresh fish market on Rarotonga, driven by a vigorous hotel and restaurant trade, is strong; pelagic fishes such as wahoo and tunas typically sell for NZ$ 7/kg. It is generally recognised that the small-scale commercial fishermen on the island rely very much on FADs to produce their catches, as does a small game-fishing charter boat fleet.

At the time of this visit, eight FADs were on station in the Cooks, three offshore from Rarotonga and five at outer islands. Five more FADs were scheduled for deployment during 1990. The cost of placing a FAD on station was estimated to be around NZ$4,350, with the bulk of costs met through aid funds. MMR maintains a core staff of fisheries officers dedicated to FAD programme implementation; at the time of this visit the FAD team comprised Sonny Tatuava, Richard Story and boat skipper Sifa Fufofuka.

# 3. VESSELS, SURVEY EQUIPMENT AND FAD MATERIALS

## 3.1 Survey vessel

The vessel made available for the survey work was a wooden launch of the TON-7 type (Figure 2) designed by L Gulbrandsen and built for MMR by a Tongan boatyard. The vessel had been modified to MMR request. The deck was raised slightly, the cabin extended, and an hydraulic line hauler and monofilament longline drum fitted to the working deck towards the stern. This extra weight on deck made the vessel quite tender. The first twelve days of the visit were largely spent in assisting prepare the vessel for sea after six months out of the water. Fitted with a newly rebuilt 34 HD Yamaha diesel engine, the vessel worked well and was adequate to the task.

A steel launch operated by the Cook Island Harbour Board was used to assist with the deployment made, it having greater loading capacity than the TON-7. Radio contact was possible between the two vessels while at sea.

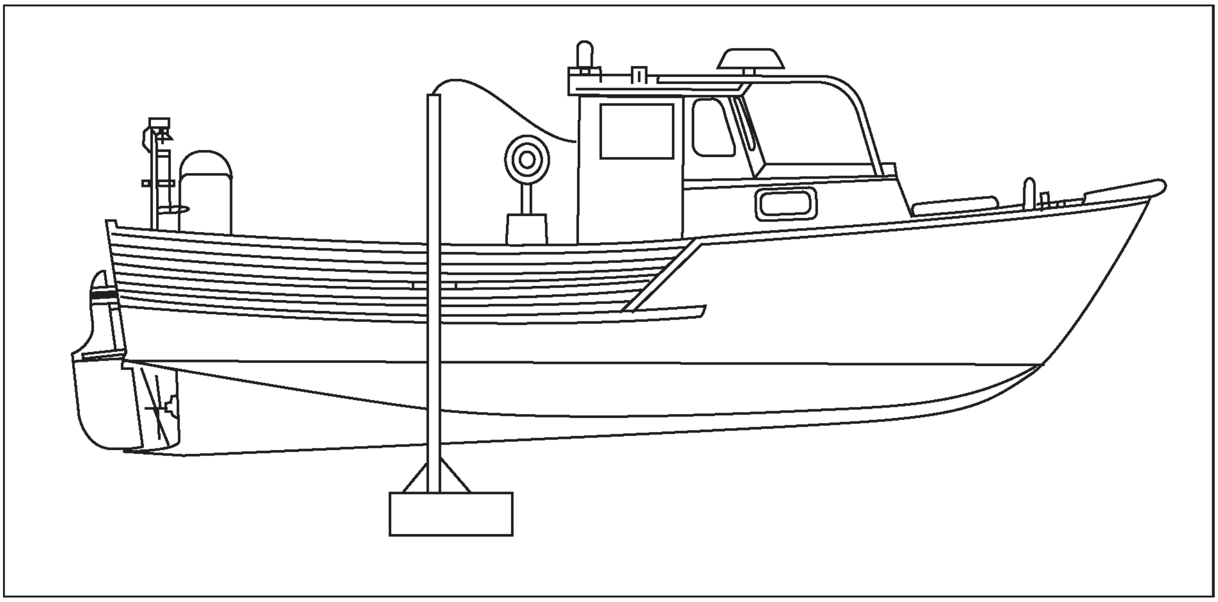

***Figure 2: The TON-7 fisheries launch used during the site surveys, showing the portable transducer mounting pole in place***

## 3.2 Survey equipment

The TON-7 was already equipped with:

- A VHF radio,
- An Autohelm electronic hand bearing compass,
- A SAT NAV unit (not used during this survey),
- A Codan SSB radio (not used during the survey),
- A Raytheon 24 mile radar.

Obtained by MMR especially for this survey and installed the day before the first survey trip was a JRC, Model JLU 121 GPS receiver/plotter equipped with a CRT display. This GPS receiver utilises signals transmitted simultaneously from several satellites (from 3 to 5) to calculate position continuously, with an estimated error of less than 100 m. It took only a couple of hours to install on the boat and was giving a position within minutes of being activated[1].

The survey vessel was already equipped with a video echo-sounder, but it was not sufficiently powerful to obtain accurate readings at the 1,000 m+ depths required. Instead, the DSFD Project's Furuno FCV 362 colour video echo-sounder was carried to Rarotonga.

This unit, a 2 kw output power model, is equipped with both 50 khz and 28 khz transducers suited to fish finding and bottom surveying at depth, respectively. A transducer casing and mounting pole were fabricated in welded aluminium in New Caledonia, allowing the transducer to be fitted to the side of the survey vessel by damping and lashing (Figure 3).

### 3.3 FAD materials on hand

In common with many Pacific Island countries, the Cook Islands have received FAD materials supplied by donor countries, some of which were far from ideal for FAD mooring construction.

*Ropes*

Two types of **floating ropes** were available: a black, Korean 22 mm, 3-strand polypropylene rope, and a pink, Taiwanese 22 mm, 3-strand rope of undetermined material. No manufacturer's specifications for these ropes were available.

Two types of **sinking ropes** were also available: a Korean 14 mm nylon yachting braid (braided sheath over core), and a single 250 m coil of 16 mm, 3-strand white nylon rope.

*Chain*

The only chain available was Korean 25 mm stud-link with a light galvanization.

*Shackles and swivels*

The swivels available were Japanese, 19 mm galvanized eye-and-eye types; 16 mm and 19 mm bolt-pin safety shackles (BTA shackles) were also on hand.

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[1] GPS positions in latitude and longitude are referenced to the World Geodetic System (WGS) 1984, and in plotting these positions on marine navigation charts, which are normally referenced to local or regional datums, it is necessary to apply corrections. In this case the chart used by MMR for FAD work was the *Nearshore Bathymetry Chart of Rarotonga, Miscellaneous* Series No. 56, published by the N.Z. Oceanographic Institute, which is referenced to a system known as International Spheroid 1924. So before plotting GPS positions on this chart, corrections had to be calculated. To determine the necessary corrections we contacted the Hydrographic Office of the Royal New Zealand Navy, which was able to give corrections only for standard British Admiralty (BA) navigation charts. However, by comparing the appropriate BA chart to the GPS position reading when at anchor in Rarotonga's main harbour and then to the bathymetric chart used by MMR, we were able to calculate that we should plot GPS positions on the bathymetric chart with a correction of 24 seconds (0.4 minutes) of latitude northwards and 4.8 seconds (0.08 minutes) of longitude westwards.

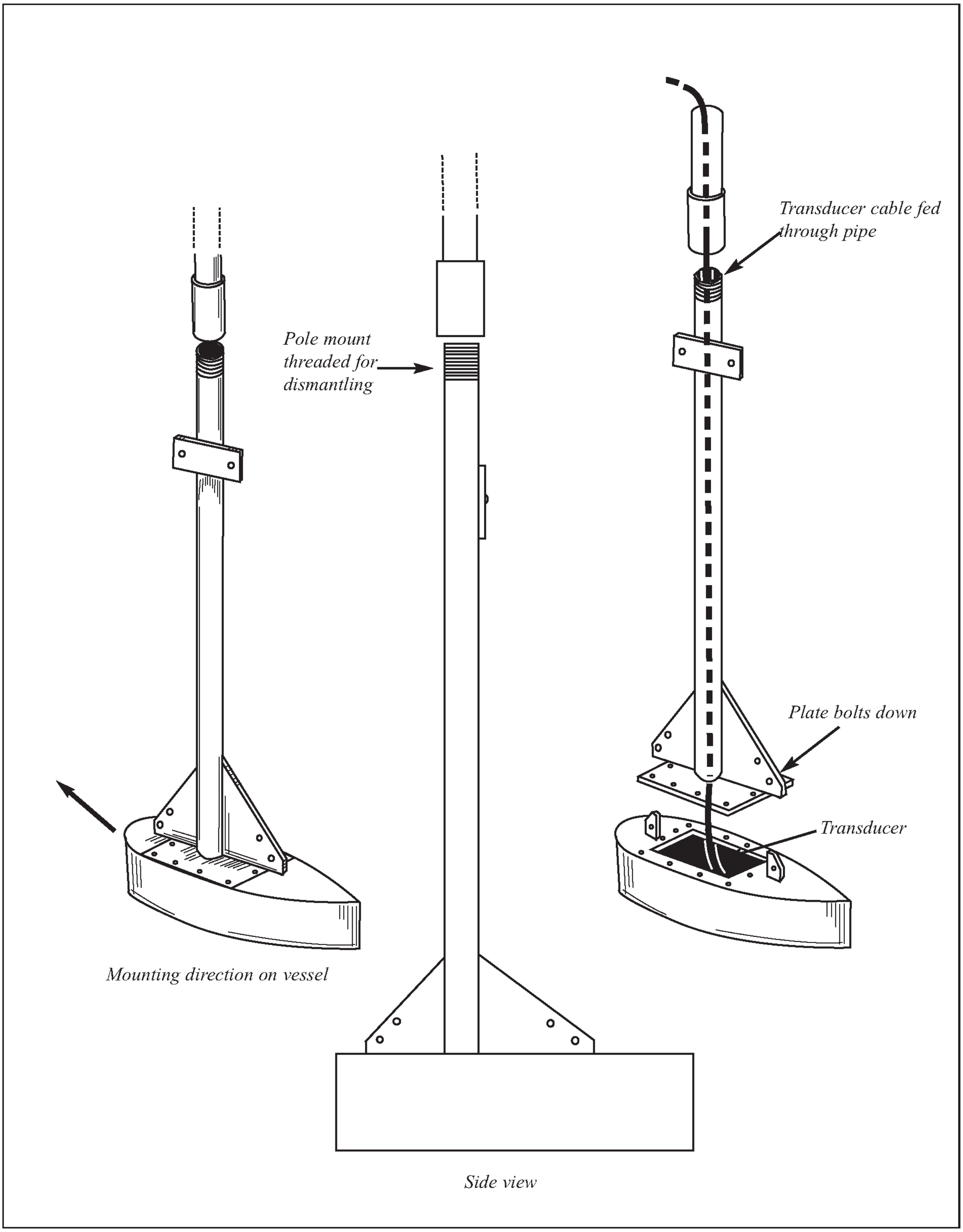


***Figure 3: Detail of portable transducer mounting and its assembly***

*Rope connectors*

Both Samson Nylite and NZ-made nylon block type rope connectors were in stock. Each of these types required the central core to be drilled out to take the 22 mm diameter pin of the 19 mm shackles but the nylon block connectors were already spliced to the mooring ropes, so these were used.

*Anchors*

A number of 80 cm x 80 cm x 90 cm concrete anchor blocks wore already cast and cured. The blocks had been reinforced with steel rods and a 2 m length of 25 mm chain half-encased. The block's estimated mass was between 1,000 and 1,200 kg.

*Raft*

The Cook Islands have experimented with a number of FAD raft designs; the most recent type, and that in current use, is a welded steel cylinder approximately 2 m in diameter x 0.6 m in depth, incorporating a steel mast and counterweight spar. Some strengthening of the counterweight/mooring attachment point was carried out before making use of this raft, asdescribed in Section 6.4.

# 4. PROJECT OPERATIONS

## 4.1 Work programme

In Consultation with MMR, it was decided that, after preparing the TON-7 for sea and mounting the newly-acquired GPS unit and the Project's echo-sounder, some time would be devoted to training the boat captain and the MMR FAD team in the operation of this equipment. In practice the team became familiar with the basic operation of both units within one day.

Discussions were also held concerning the selection of potential FAD deployment zones for detailed bottom surveying: the selection criteria being the usual ones of historical abundance of fish; history of previous productive FAD deployments in the zone; and access to the island's main boat harbours. Four survey zones were selected, as shown in Figure 4.

After three of these zones had been completely surveyed and deployment sites selected, the Limited time left available made it necessary to undertake training in FAD mooring calculation, rigging and deployment as a practical exercise, with the aim of completing one deployment before the visit ended. Subsequently one mooring was rigged under supervision and the deployment of this FAD undertaken in the Arorangi zone. The following section describes each aspect of the methods and training conducted.

## 4.2 Surveying the FAD sites by echo-sounding

### *4.2.1 Preparation for the survey*

It is generally well accepted that FAD deployment sites should be surveyed as accurately as possible, not only to ensure an accurate depth reading, but to determine the degree of bottom slope, regularity, and absence of nearby ledges or crevasses. Determining the actual area of the bottom to be surveyed at a potential site is also a critical factor; it depends on site depth and thus the time the anchor will take to reach the bottom, because deviation of the anchor block on descent must be allowed for. Although accuracy of vessel position when the anchor is jettisoned may be achieved, experience in some countries has shown that in typical FAD deployment depths an anchor block may deviate from the target by hundreds of metres during descent.

Even a casual observation of the rugged, eroded volcanic cones of Rarotonga island suggests that these features may be mirrored underwater. It became apparent during this visit that this was indeed the case, and that inability to survey the bottom with precision had probably contributed to earlier FAD losses off the island. A good part of this visit, therefore, was devoted to training the local FAD team in a precise survey method utilising a reliable deep-water echo-sounder and the Global Positioning System (GPS) receiver/plotter for accurate navigation, site plotting and relocation.

At first it was planned that the survey would begin at the centre of a zone, distance from shore (2 miles) being the chief factor in identifying the zone's centre point. It was thought that by making soundings in a spiral pattern from that point, suitable deployment sites could be found. During the first survey attempt it soon became obvious that this approach would be inadequate; the steepness and irregularity of the bottom slope required a thorough survey of the entire selected zone to ensure identification of the optimum deployment site.

As a general rule, to ensure that the roll of the survey vessel does not affect the depth sounder readings unduly, it is recommended to take soundings while travelling perpendicular to the reef slope. So, for each of the areas charts were prepared on which the echo-sounding transects to be run were marked. The transects generally were planned as beginning in 600 m depth and extending for two miles seaward. To make the plotting of intermediate sounding positions simpler, it was decided that the transects would be run either parallel to the lines of latitude and longitude, as for the Ngatanglia zone (see Figure 4), or at an approximately 45° angle to these lines (approximate because 1° of latitude does not have the same length as 1° of longitude at 21° South) as for the Black Rock, Arorangi and Matavera zones (see Figure 4).

Once the transect lines were drawn on the survey plan, the extremities were taken as waypoints and the co-ordinates entered into the GPS unit. The GPS could then direct the vessel's captain from waypoint to waypoint with great accuracy. This procedure is illustrated for the Arorangi zone in Figure 5.

A worksheet was also prepared for each zone on which all the planned sounding positions were recorded before going to sea. Depending on the zone and the precision required due to bottom features, soundings were made at either every sixth or every third of a mile. For the largest survey zone, at Arorangi, this technique required a transect track of more than 25 miles, with about 150 soundings.

In the Black Rock zone, this sounding frequency was thought to be insufficient, owing to indications of abrupt changes in bottom topography, and extra soundings were made. The extra soundings did reveal dramatic changes in bottom contours, emphasising the importance of precise surveying and precise positioning ability.

In the Matavera zone the soundings of the selected area revealed that a likely deployment site was indicated just beyond the zone boundary and, as a result, the survey was extended to include this area.

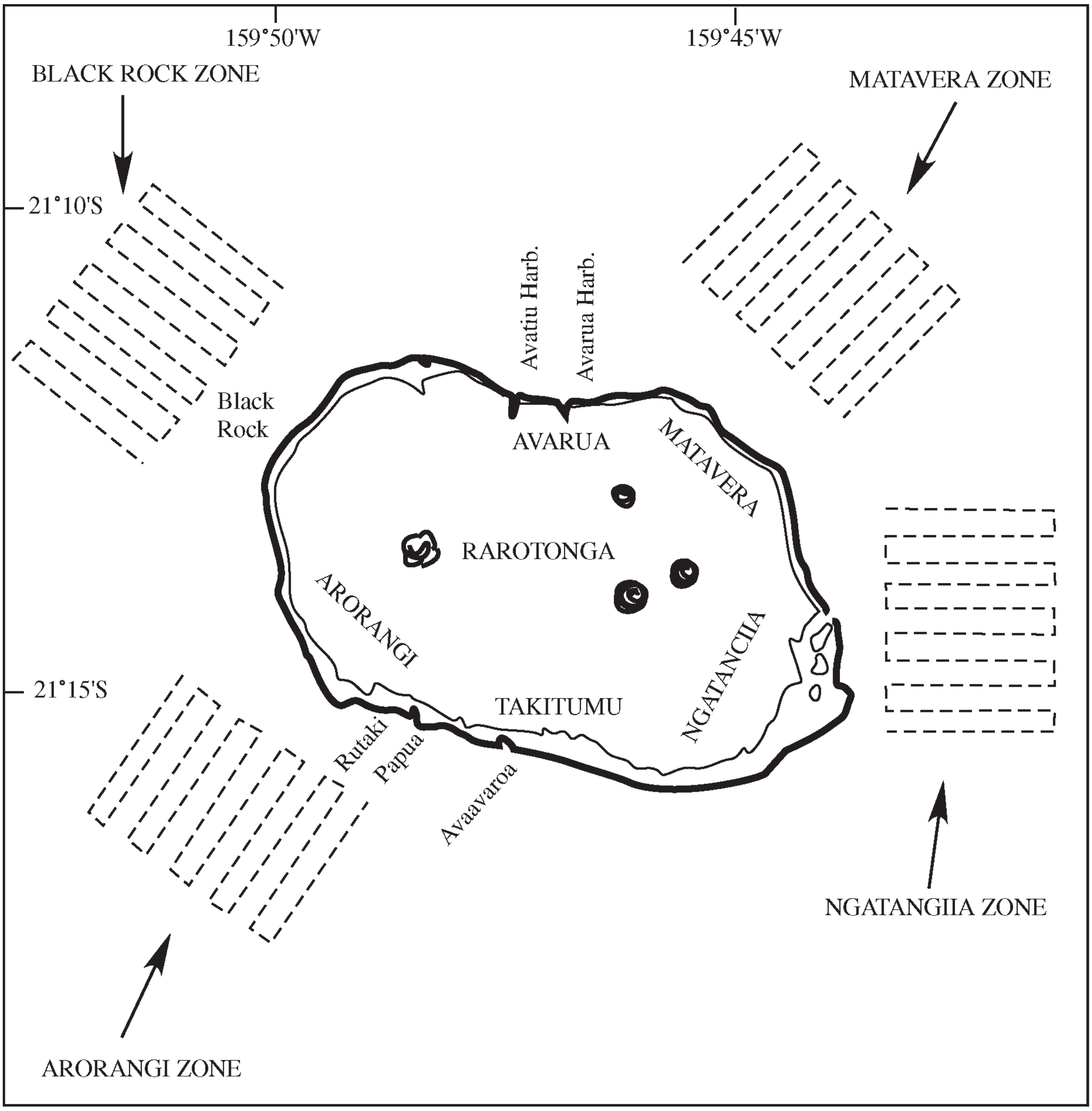


***Figure 4: The four FAD survey zones around Rarotonga***

This preparatory survey planning can be summarised in five steps:

- Draw a 2-mile square on the chart which best covers the selected zone, with the edge of the square closest to land beginning at the 600 m contour. If the planned transects are found, when at sea, to cover areas either too deep or too shallow, the GPS unit can be used to move th6 transects offshore or inshore quickly.

- Draw parallel lines within the 2-mile square, spaced at one-quarter to one-third of a mile intervals, perpendicular to the natural bottom contour lines.

- Make the end of each parallel line a waypoint; note the co-ordinates of each of these points.

- Prepare a worksheet with provision for recording soundings at each required interval (one-sixth or one-third of a mile) along the transect lines.

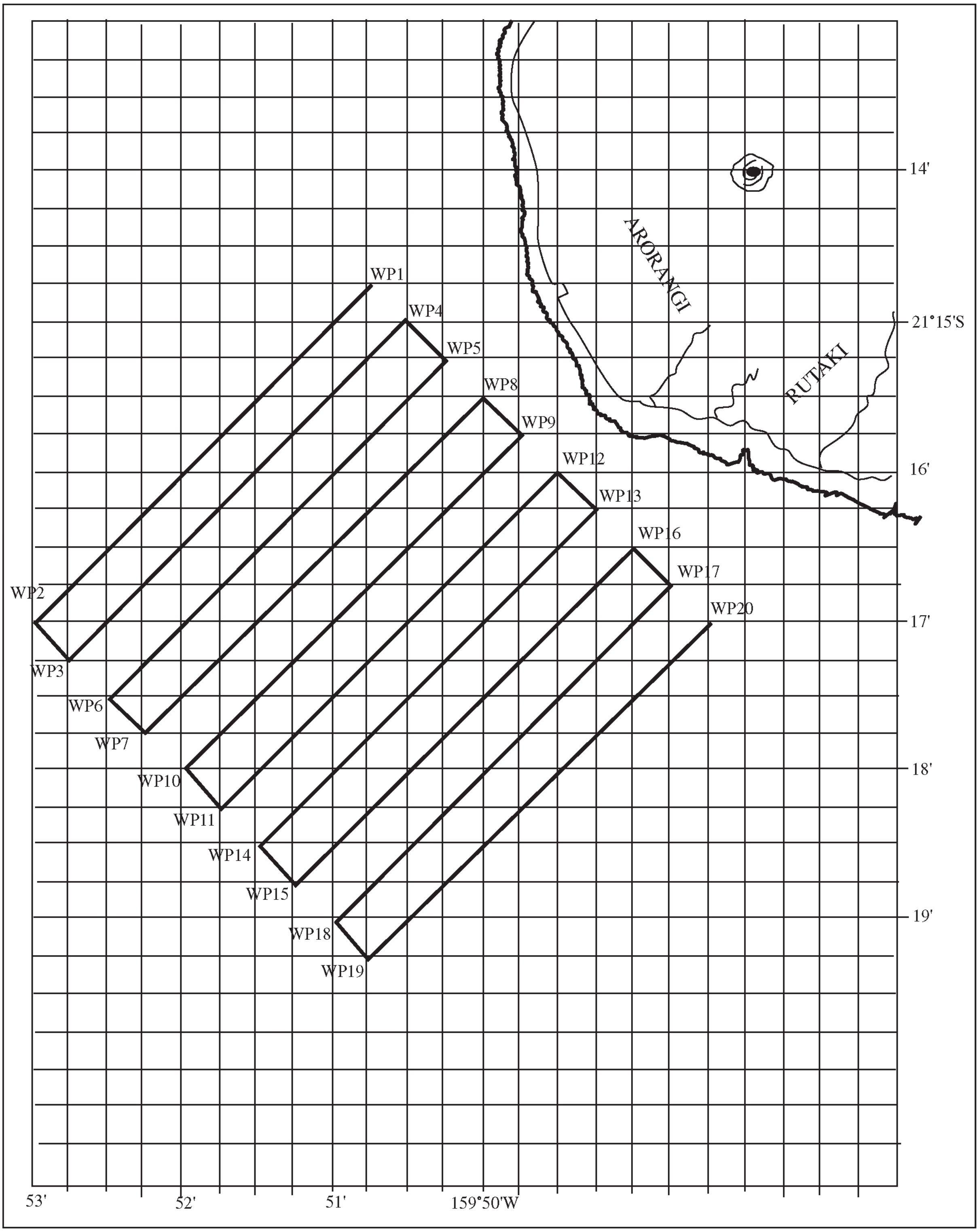


***Figure 5: Transect track and waypoints plotted for the Arorangi zone survey***

- Enter all the waypoints into the GPS unit so that the track to follow will be displayed on the screen. All sounding points could be entered, but this is unnecessary as the GPS unit allows easy calculation of each sounding point as the vessel is under way.

#### *4. 2.2 Survey procedure*

The boat left port on the morning of each survey day with a chart of the selected zone already prepared and marked with the transect lines, matching soundings worksheet, and the GPS unit operating with waypoints already entered, once at the first waypoint, the boat captain steered the vessel along the transect lines, guided by the GPS display, while the second member of the FAD team manipulated the GPS's cursor to get bearing and distance to the next waypoint and called for depth readouts as each sounding point along the transect was reached. The third member of the team operated the video echo-sounder and recorded depths at each sounding point.

Although this operation could quite easily be handled by two men, each of the three FAD team members was given a survey role in order to familiarise them all thoroughly with the procedure.

The streamlined aluminium side-mount specially constructed for the echo-sounder transducer allowed good soundings to be made while travelling at six knots. However, the engine of the survey vessel had recently been rebuilt and the captain preferred to run it at low speeds, so all surveying was conducted at speeds around four knots.

Once back in port with all positions and depths recorded on the worksheet and chart, we prepared to draw a contour map of the surveyed zone. The first step was to prepare a chart showing the lines of latitude and longitude for the surveyed zone. For the sake of convenience this was drawn to the same scale as the bathymetric chart generally used by the FAD team. The transect lines were then transferred to this chart and the depths at each sounding point recorded in place. Because we wanted to draw contours at each 100 m increment it was necessary to interpolate the soundings from two points and draw the appropriate contour between them.

This charting was relatively simple for the Matavera and Arorangi zones where the contour lines followed a natural and logical pattern. It was more difficult in the Black Rock zone, where many bottom irregularities were apparent. It was decided to draw the contour maps keeping the position values given by the GPS, which meant that to match them with the bathymetric chart in use (in order to take bearings to shore, or for any other purpose), one would have to move them by 0.4° of latitude northwards and 0.08° of longitude westwards (e.g. 21°17'S and 159°50'W converted to 21°16.600'S and 159° 50.080'W).

Although a little cumbersome, the GPS positions were used on the contour maps prepared for the use of the MMR FAD team in locating FAD deployment sites. As the FAD team intends to use its GPS for future FAD deployment work, it will be more convenient for it to use contour maps with values matching the GPS.

#### *4.2.3 Considerations in selection of anchoring sites*

It is generally accepted, on the basis of hydrodynamic principles and direct observation, that a concrete anchor block will, on release from a deployment vessel, tend to deviate from the vertical during descent to the bottom. The deeper the chosen site, the more deviation may be expected. Several factors probably influence the degree of deviation from a vertical fall, including the shape of the block, the drag of the mooring ropes and the raft at the surface and, to a lesser extent, the prevailing current. Because some deviation should be allowed for, careful consideration must be given to the area of 'safe ground' surveyed at the selected site and the point at which the block is released to 'aim' it at the chosen anchoring site.

It is also generally accepted that, when deploying a FAD by the recommended 'raft, first' method, with the mooring line paid out in a straight line between the raft and the deployment vessel deviation during descent caused by the drag of the mooring ropes and raft require that the vessel should pass over the anchoring site and continue on for one-third of the mooring length past the site before jettisoning the anchor (Boy and Smith, 1984).

It is during the paying out period that most consideration must be given to the way current is affecting deployment vessel position. This can be compensated for to some extent by taking bearings from the vessel to the raft during the paying out. If the raft is being carried sideways by the current, adjustments can be made to the vessel's course. If current direction can be determined before putting the raft in the water, it is best to steer the deployment vessel up-current while paying out the mooring rope.

Field observations of previous deployments show that, with a 1 t anchor block deployed, in 1,200 m, the time the raft takes to stop moving at the surface may be up to nine minutes. This indicates that even allowing for the stretching and recoil of the mooring lines, the anchor block will be influenced by hydrodynamic forces, the drag of the mooring ropes and raft, and currents for a significant period, and thus have opportunity to deviate from a vertical fail. It would be extremely difficult to calculate the direction and degree of deviation, but experience elsewhere has indicated that anchors deployed in such depths may deviate from a vertical descent by hundreds of metres. Therefore, when surveying to deploy a FAD in 1,200 m, the target zone where all depths are acceptable for the planned mooring (that is, within 10 per cent of the working site depth) should make allowance for this. In addition, of course, it would be inadvisable to deploy in a zone where abrupt changes in depth or regularity occur close to the boundary of the target zone.

All survey preparation, the running of the surveys at sea, the drawing of the contour plans and eventual site selection were conducted as training exercises, with the full and active participation

### *4.2.4 Evaluation of equipment*

*Furuno FCV 362 echo-sounder*

It is obvious that a reliable, deep-water capability echo-sounder is critical to accurate surveying of FAD deployment sites. A unit such as the DSFD Project's Furuno FCV 362, with its 28 khz transducer in use, is quite adequate to the task of sounding depths in excess of 1,500 m, but in average conditions could not be expected to give reliable readings to the manufacturer's given range of 2,000 m. The critical factor is output power. The FCV 362 produces a 2 kw signal and, while other models and makes are available which produce 3 kw signals and greater, it must be remembered that higher output power also requires increased input power. The FCV 362 was chosen for general FAD survey work because its power draw is about at the level that typical, medium-size fishing craft in the region can supply; this unit being purchased with the intention of using it widely in the region and necessarily on a wide range of fishing craft. For this same reason the transducer mounting was designed not be a permanent fixture, but to be removable. It is likely that a fixed transducer mounting, i.e. fixed to a vessel's hull, would operate with greater efficiency. This unit cost US$4,280 in 1990, which compared to the cost of a FAD lost through inaccurate depth survey would seem a good investment. Of course a unit like this, which has dual frequency capability, has a wide range of fishing applications as well.

The FCV 362 has the complete range of capabilities typical of late-model sounders, including dual frequency/split-screen display, frequency shifting, phased ranging, bottom and fish alarms etc., but proved quite simple to operate, with clearly marked, easy-to-manipulate controls; its colour video display easy to read.

*JRC JLU 121 GPS receive/plotter*

Although the navigation required for charting FAD deployment sites can be achieved by coastal navigation with bearings to landmarks, and perhaps assisted by radar, the precision and ease of the Global Positioning System can make precise bottom surveying relatively simpler and certainly more accurate. The system has a high degree of reliability and accuracy and when conducting transect sounding surveys as we did, the ability to have steering directions from waypoint to waypoint proved invaluable. A day spent in training the MMR FAD team in the basic operation of the JRC JLU 121 unit was sufficient for them to use it effectively at sea.

This unit, which was purchased by the MMR in 1990 for around US$3,200, incorporates both a receiver and a plotter and has the capability to display digitised charts on the CRT screen. Thus the vessel's position is constantly indicated both in digital display of latitude and longitude and graphically on the plotting screen. A ball control allows for simple movement of a cursor on the screen. Apart from the ship's own position, the unit is able to give information on course made good, speed along route, speed toward destination, bearing and time to destination and so on. If the unit is not receiving adequate satellite signals it stops giving a readout. The corrections made between the GPS positions and the bathymetric chart used by MMR entailed a fairly simple process which was explained in detail to the FAD team. Recent publications of standard navigational charts typically include GPS correction figures. Because the survey vessel was moored in the same position each day, it was possible to check the reliability of the given GPS position; the greatest deviation noted was 0.07 miles.

## 5. SELECTION OF DEPLOYMENT SITES

Coastal zones to be surveyed for potential FAD deployment sites were selected by MMR, the general criteria being previous history of successful FAD use in the area, including regular ocurrence of target species, and relative ease of access to the sites for local fishermen.

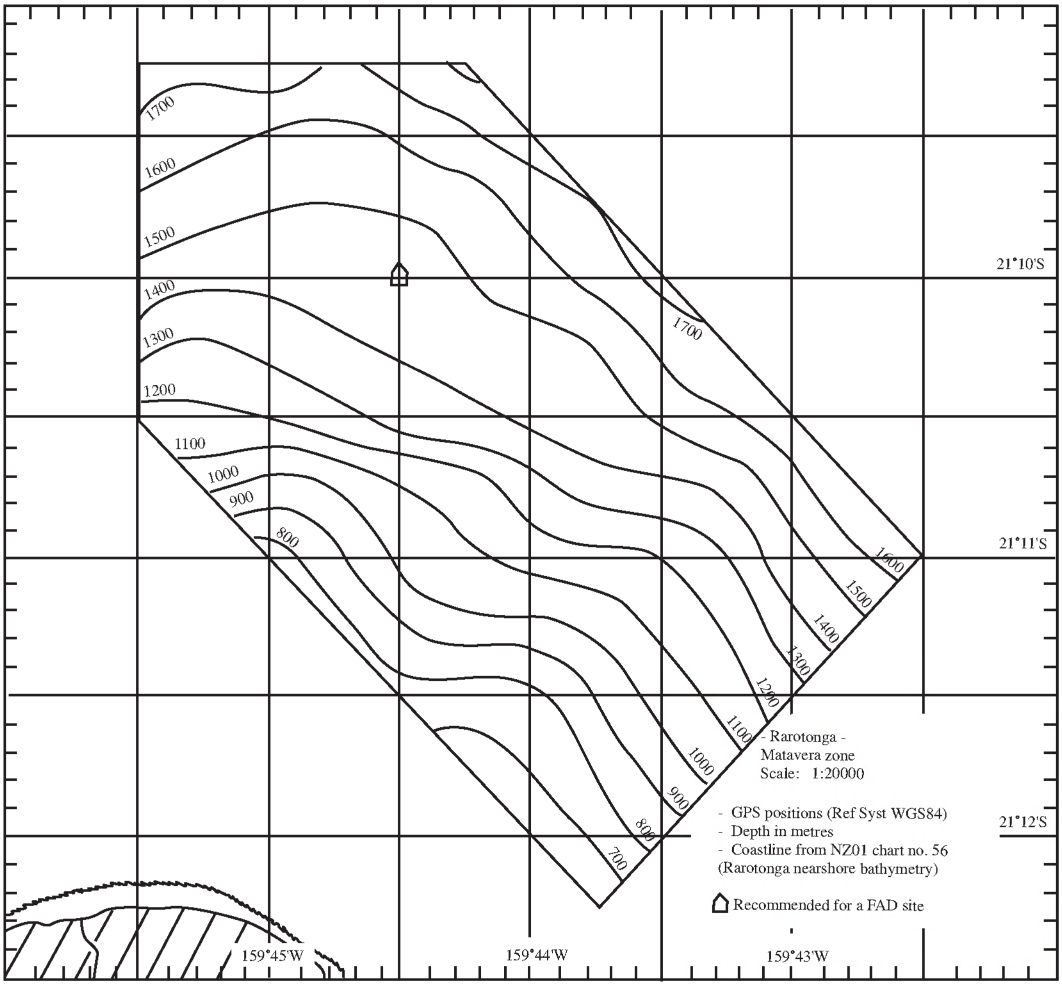


***Figure 6: Chart drawn for the Matavera zone, showing selected deployment site***

Since this position may place the FAD close to the shipping lane entering Avatiu Harbour, it will be necessary to check the site's suitability with local shipping authorities.

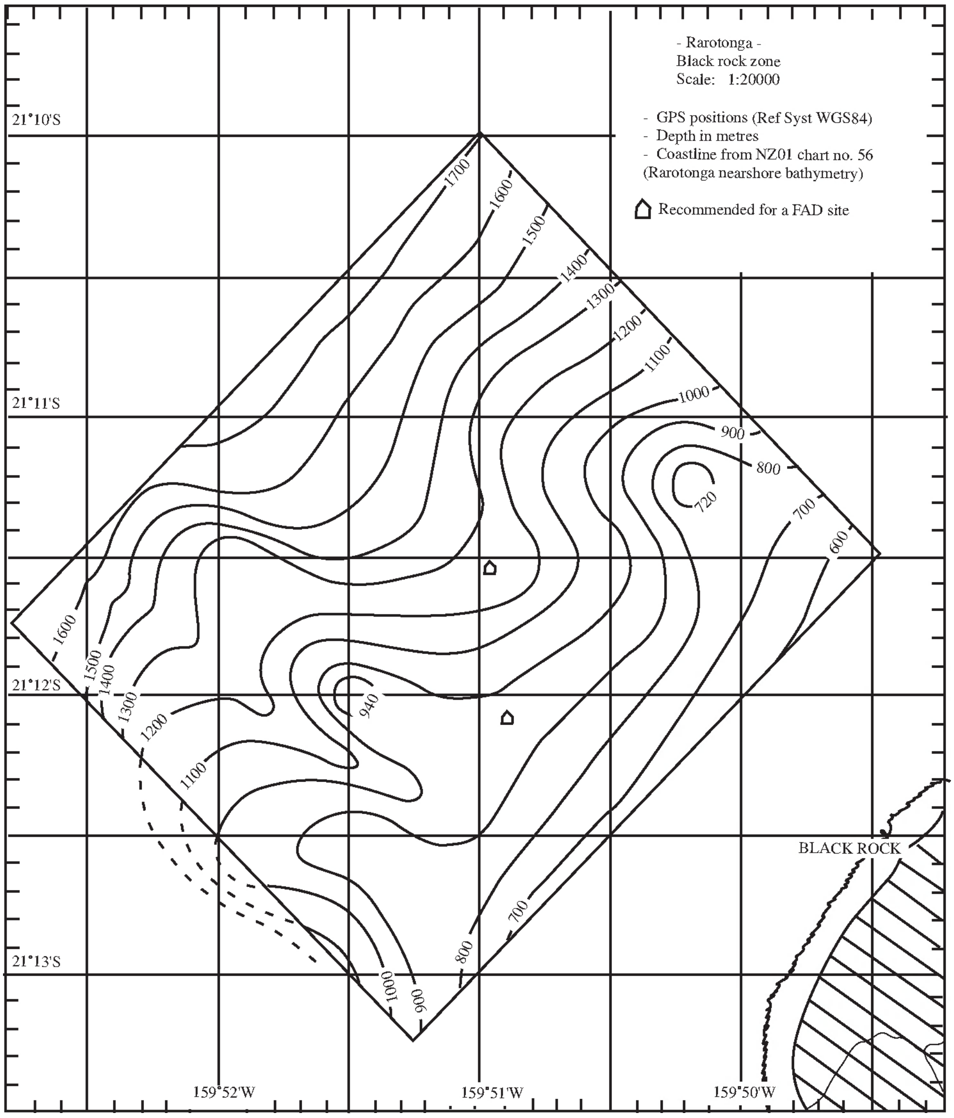


***Figure 7: Contour chart drawn for the Black Rock zone, showing selected deployment site***

In the Black Rock zone the safest ground for a FAD deployment would be at position 21˚12.125'S and 159˚50.875' W at 950 m depth. Although close to the reef (the buoy static should be between 1 and 1.6 miles from the reef depending on current and wind conditions), the proximity of a steep drop-off on the south-western side of the site is likely to produce some upwelling which might prove productive of fish. This site would also be sheltered, as the prevailing winds are ESE.

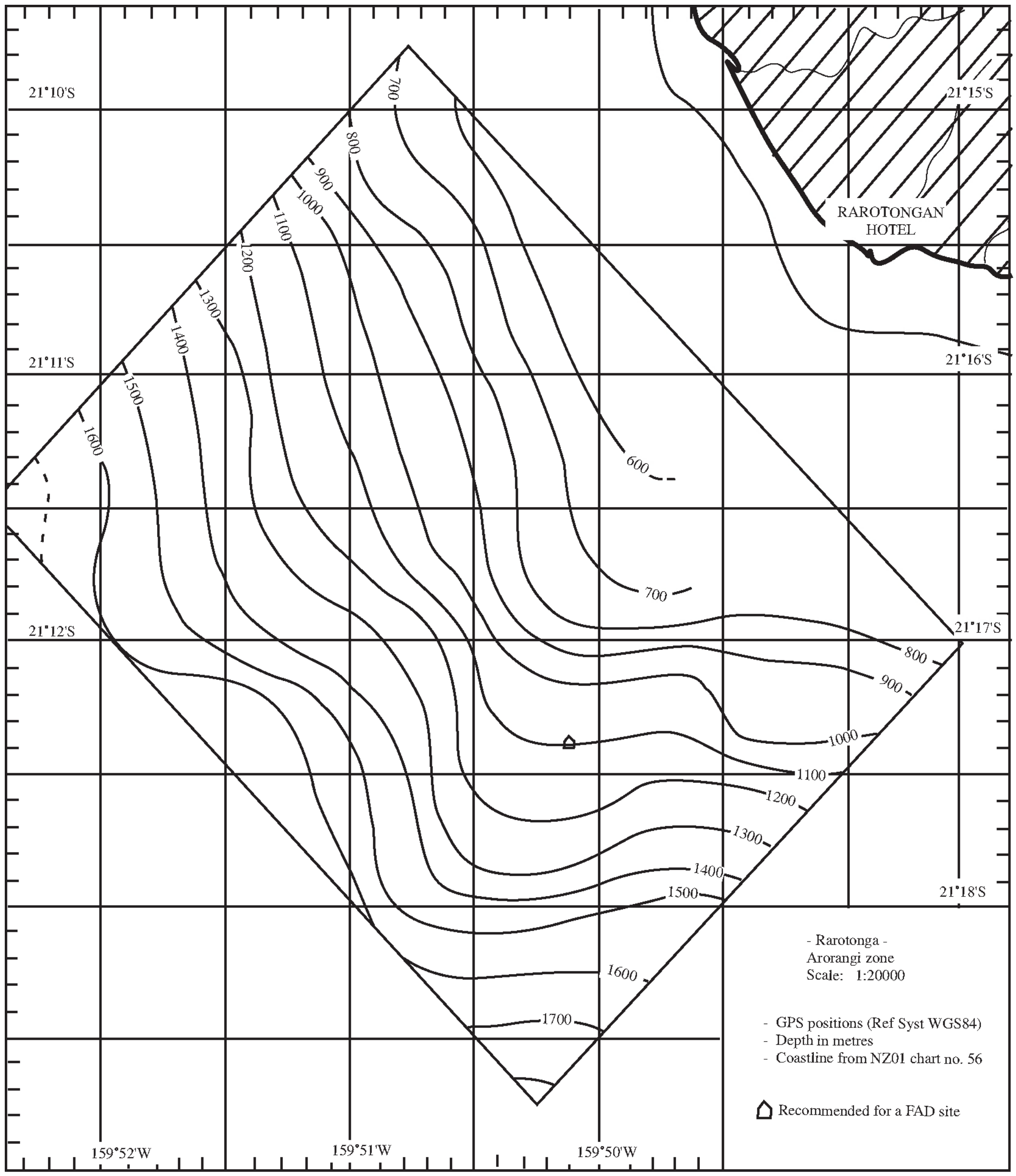


***Figure 8: Contour chart drawn for the Arorangi zone, showing selected deployment site***

For the Arorangi zone, in which a FAD was to deployed during this visit, the position 21˚17.500'S, 150˚50.250'W was selected, with a depth around 1,150 m. Anchored in this depth, some 2 miles from the reef, the FAD raft could be expected to lie between 1.6 and 2.4 miles offshore.

## 6. FAD MOORING CALCULATION AND RIGGING

### 6.1 General

Following the attention given to training in FAD-site survey procedures, the time remaining allowed for the rigging and deployment of only one FAD. It was decided in consultation with MMR that the deployment, to be conducted as a training exercise, should be in the zone most favoured by fishermen — the Arorangi zone.

It was apparent that the local FAD team had experienced difficulty in working through mooring calculations for the catenary curve type mooring recommended by SPC for deployment at this depth range (1,150 m), despite having access to SPC's Handbook No. 24 *Design improvements to fish aggregation device (FAD) mooring systems in general use in Pacific Island countries* (Boy and Smith, 1984). It was decided, therefore, that in view of the limited time available, an attempt would be made to devise a simpler, but adequately accurate, means of figuring required rope lengths for deployment at such depths.

### 6.2 A simplified method for calculating catenary curve FAD moorings

It is widely appreciated that catenary curve moorings are useful for FAD tethering because they incorporate a reserve of slack line which provides a safeguard against excessive strain coming onto any part of the mooring during conditions of severe weather or current as well as providing for errors in site depth estimation. The formation of a catenary curve depends on utilising the sinking and floating properties of nylon and polypropylene rope, respectively. By linking these two types of rope in the correct proportions, the curve formed will be neutrally buoyant; that is, it will not tend to sink, nor to float. The reserve of slack line will thus remain suspended at a predetermined depth below the surface, where it will be safe from damage by boats, fishing lines or vandals.

Devising a simplified mooring calculation method requires that certain working principles must be established in regard to the proportions of the mooring. These principles, or 'rules of thumb', are based on typical mooring materials and deployment depths for Pacific Island FADs.

| WORKING PRINCIPLES | REASONS |
|---|---|
| 1. The total length of the catenary curve will be 20% of the site depth. | It is considered that a 20% reserve of line will be sufficient to compensate for depth error and provide sufficient slack line to alleviate stress on the mooring in rough sea conditions. |
| 2. The catenary curve will comprise 75% nylon (sinking) rope and 25% polypropylene (floating) rope. | Catenary curve FAD moorings calculated in full for this depth range and the typical 16 to 24 mm ropes in use in the Pacific always fall between these proportions. |
| 3. The upper part of the catenary curve will be held at 150 m below the surface | Rope held at this depth will be safe from surface interference of accidental damage. |

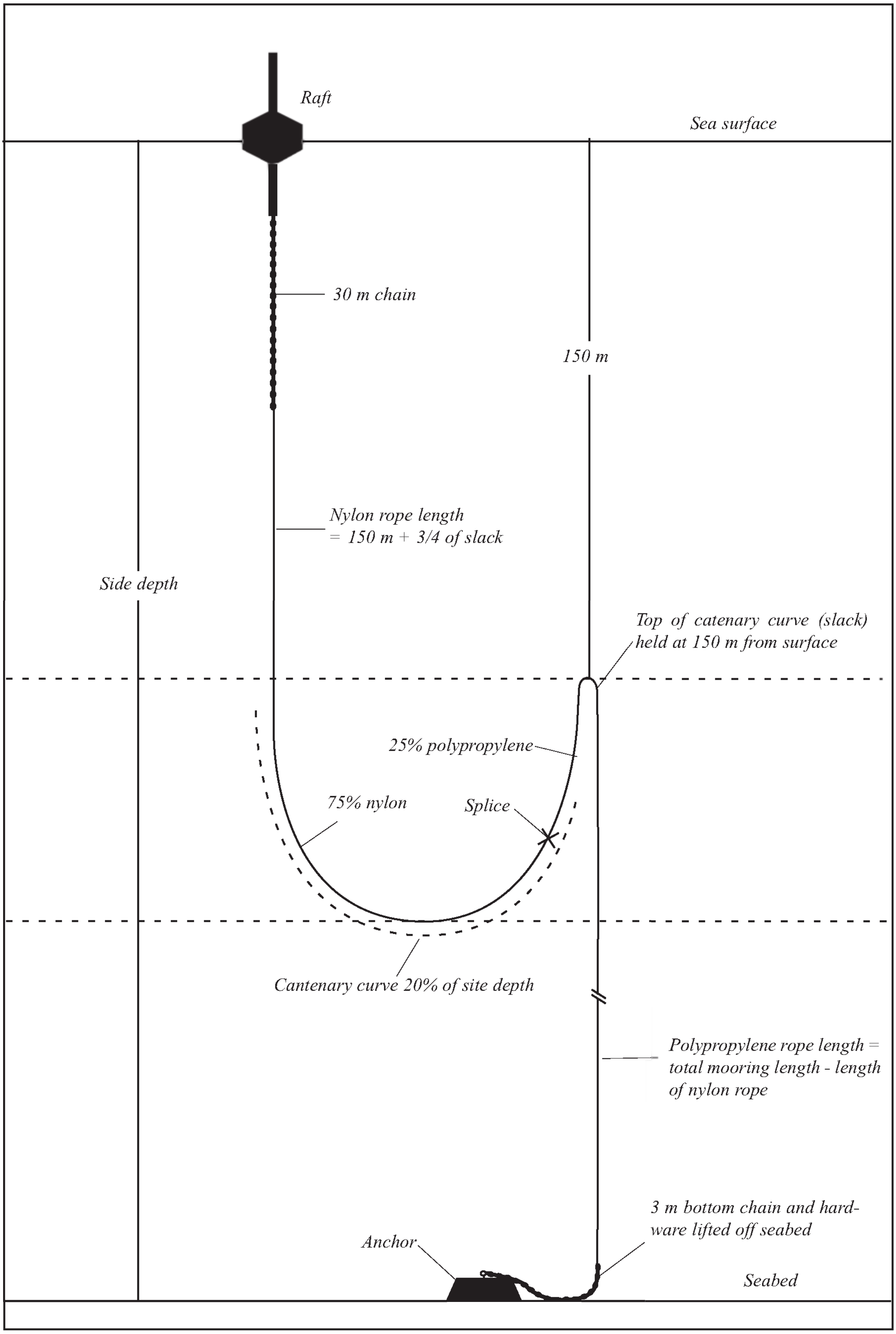


***Figure 9: The sections of a FAD mooring system for calculation by the simplified method.***

With these working principles established, it is relatively simple to calculate mooring components, using the following steps:

1. *Calculate slack = 20% of site depth.*

2. *Calculate total length of mooring = depth plus slack.*

3. *Calculate length of nylon rope required = 150 m plus 3/4 of slack.*

4. *Calculate length of polypropylene required = total mooring length less length of nylon rope.*

In addition to the mooring calculation steps outlined, it is also necessary to ensure that the length of buoyant polypropylene line will be sufficient to lift at least 3 m of bottom chain and hardware off the bottom, and so ensure that the rope itself never contacts the bottom.

1. The simplest way to determine if the length of polypropylene calculated will actually have sufficient buoyancy to lift 3 m of bottom chain and hardware is to consider the following:

2. Polypropylene ropes used for FADs are always at least 20 mm in diameter.

3. Three metres of recommended 19 mm chain and hardware weigh about 20 kg in air and about 18 kg in seawater.

4. One metre of 20 mm diameter polypropylene rope has sufficient buoyancy to lift 0.018 kg.

5. To lift 18 kg will require 1,000 m of 20 mm polypropylene (0.018 x 1,000 = 18).

6. The section of polypropylene from the bottom of the mooring to the top point of the catenary curve should be considered as the section required to lift the hardware. This is simply calculated as: site depth less 150 m.

7. If this section of polypropylene is less than 1,000 m, or if the 3 m of chain and hardware used weigh more than 20 kg in air, then extra buoyancy will have to be added to the polypropylene rope.

8. The best way to add extra buoyancy is by attaching pressure-resistant floats.

9. As 50 m of 20 mm polypropylene will support 1 kg, and a 1 litre float will support the same weight, we can say that we have to add 1 litre of buoyancy for every 50 m short of 1,000 m in the polypropylene lifting section.

This may be summarised as:

- If depth minus 150 m is less than 1,000 m, add 1 litre of buoyancy per 50 m short of 1,000 m.

- If the 3 m of bottom chain and hardware weigh more than 20 kg in air, add 1 litre of buoyancy per extra kilogram.

The type of buoys to use are ones that are pressure-resistant to at least 800 m. They should be attached to the polypropylene rope somewhere below the lower limit of the catenary curve. The tower limit of the curve can be calculated as:

*depth — (150 m + 1/2 length of catenary curve)*

If the floats used will lift a little more than 3 m of chain and hardware, this is acceptable.

## 6.3 Applying the simplified mooring calculation method to the Arorangi FAD mooring

The survey of the selected Arorangi deployment site indicated a depth of 1,150 m. By applying the calculation method outlined in Section 6.2, the following equations are arrived at:

*Catenary curve (slack) = 1,150 m* x *20 % = 230 m*

*Total rope length = 1,150 m + 230 m = 1,380 m*

*Nylon rope length = 150 m + 75% of 230 m = 322 m**

*Polypropylene rope length = 1,380 m — 322 m = 1,058 m*

* Note: 322.5 m rounded to 322 m.

As mentioned in Section 3.3, only one 250 m coil of suitable nylon rope was to hand in MMR stock. To rig the mooring using this available 250 m would mean that the top limit of the catenary curve would be only 72 m from the surface, rather than the recommended minimum of 150 m. It was decided in consultation with MMR that this depth would be acceptable for this

## 6.4 Rigging the mooring

*Anchor block*

The bottom chain was embedded in the block during pouring, the block being reinforced with lengths of steel rebar. Although not the recommended way of attaching the chain it was deemed suitable for use.

*Shackles*

The recommended 19 mm shackles were on hand and were used for all connections.

*Swivels*

As per recent technical recommendations by SPC, two swivels were used in the upper mooring, one directly beneath the buoy and the other at the termination of the upper chain. The cylindrical buoy in use in the Cook Islands tends to rotate on station and the double swivel arrangement should cope with this rather than transferring twist to the mooring.

*Shelter material*

A 20 m length of 12 mm polypropylene rope was spliced into the main mooring line about 20 m below the chain connection. Mussel rope and lengths of other scrap rope were attached to this, taking care that none of this material could reach either of the upper swivels or the surface.

*Connections*

Because most final connections could only be made once all sections of the mooring were loaded on the deployment vessel and welding was not possible on board, safety shackles with stainless steel cotter pins were generally used. Only the final bottom shackle and that directly below the buoy were welded ashore.

*Buoy connection*

The original connection on the buoy was fabricated from 19 mm steel rod, butt-welded to the counterweight; this was considered not to be sufficiently strong, so the connection was modified by welding 7 mm thick steel plates to either side of the eye and to the lower end of the counterweight. This was then dried through to take the jaw-and-eye swivel.

*Preparing the three-strand polypropylene rope*

The three-strand polypropylene rope on hand caused a great deal of difficulty. Five coils of this rope (1,250 m) had already been spliced together by the MMR FAD staff. This rope was very stiff and there were kinks apparent even in the short lengths taken from the coils for splicing. It seemed-likely that if the rope was paid out directly from the inside of the coils as recommended, a kink would be created with every turn which was taken from the coils. Although it might be expected that the swivels would alleviate the twist in the rope close to them, it seemed likely that the middle sections of rope would remain kinked after deployment and eventually hockle when placed under strain.

If eight- or twelve-strand ropes were in use, this problem would not arise because these ropes are 'soft' enough to absorb all the kinks. But with the stiff three-strand rope, it was decided to attempt to take out the kinks before deploying. To do this the five spliced coils were loaded onto the TON-7, two small floats and a ball-bearing swivel were attached to one end and the line streamed out behind the boat as it went ahead. Once all the line was in the water, a second swivel was fitted and the line tied off to the boat. The line was then towed by the boat at around two knots until the swivel stopped spinning, at which time it was presumed that the twists were removed from the rope. The tension placed on the line in this operation would probably be less than that coming into play during deployment.

However, when the rope was retrieved it proved to be very badly kinked and had to be faked down on deck in worse condition than before. Fifty metres of the rope at either end were so badly kinked that it had to be discarded. This is an indication of what might happen to three-strand ropes when setting a FAD with the ropes paid out directly from the coil.

To straighten out the ropes each splice was cut out. It was decided that, to remove the twists and kinks, we would have to physically rotate each 220 m pile of rope once for every twist in it. A turntable was built (see Figure 10) using a sheet of plywood big enough to take one coil of rope at a time. As the turntable was rotated by hand, the rope was untwisted and faked down into a large box which would later be loaded on the deployment vessel. As some sections of the rope had a twist every 30 cm or so, to untwist the 1,080 m of polypropylene took one whole afternoon, with most of the Fisheries staff taking turns to help.

***Figure 10: MMR staff taking the twists out of the three-strand rope using the turntable***

The 250 m nylon rope was still in the coil and it was decided to fake this into the box as well. One of the MMR FAD team devised a system for rotating the coil as the rope was taken from it by mounting it on an FAO-design wooden fishing reel laid in its side and fixed between two benches (see Figure 11). With the handle removed, the reel arms formed an ideal turntable. Using this method it is better to take the rope from the outside of the coil rather than from the inside as is usually recommended.

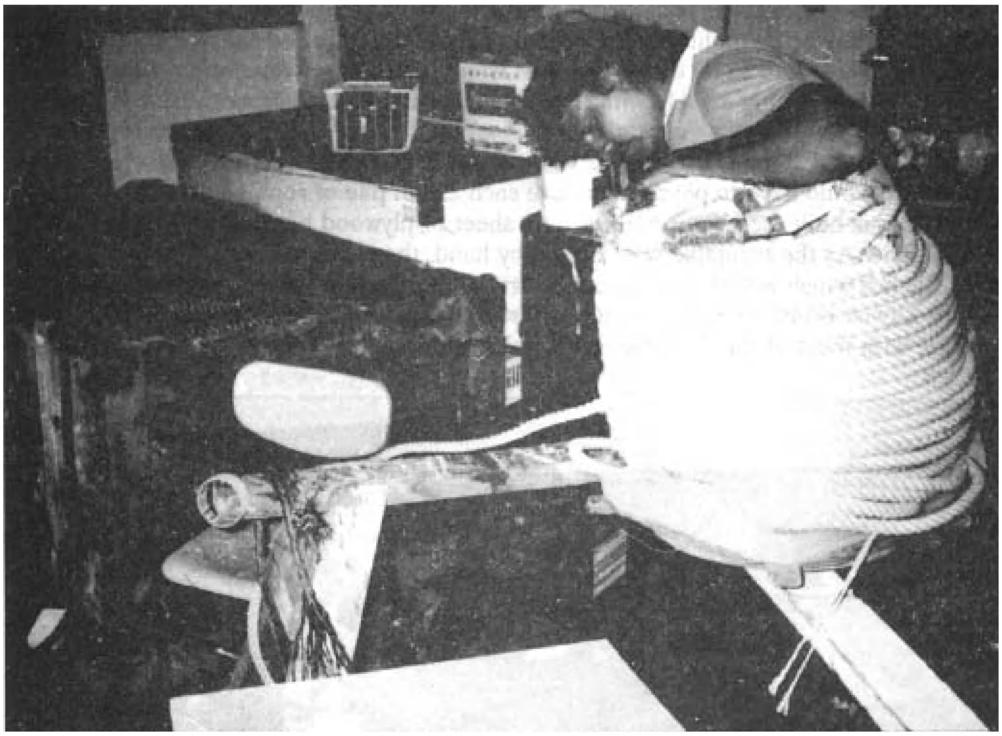

***Figure 11: Richard Story using an FAO wooden handreel to take the nylon rope from the coil***

# 7. FAD DEPLOYMENT

## 7.1 Boats and equipment

As the anchor block was too heavy to carry on the TON-7 it was necessary to charter a steel launch operated by the Harbour Board to carry the anchor to the deployment site. A crane was hired to load the anchor block onto a stack of wooden pallets at the stern of the tug, enough pallets being used to place the bottom edge of the block at a level just above the transom top. A two-ton chain block was used to tension a heavy rope holding the block down on the pallets. A length of steel angle was placed on the pallets behind the block. In the event that the block proved difficult to jettison, the heavy rope could be passed behind the steel angle and by applying tension with the chain block, the anchor pushed off the stern (see Figure 12). The large plywood box holding the mooring ropes was loaded just behind the cabin of the tug and the raft lashed securely to the deck behind it. The weight of the anchor left the tug with only a little freeboard and it was decided that the tug would go to sea with the load only in calm conditions.

## 7.2 Deployment method

The intention was to deploy by the recommended raft-first technique, that is to place the raft in the water, pay out all the mooring rope in concentric circles or a straight line and then jettison the anchor at a site calculated to drop the block on site.

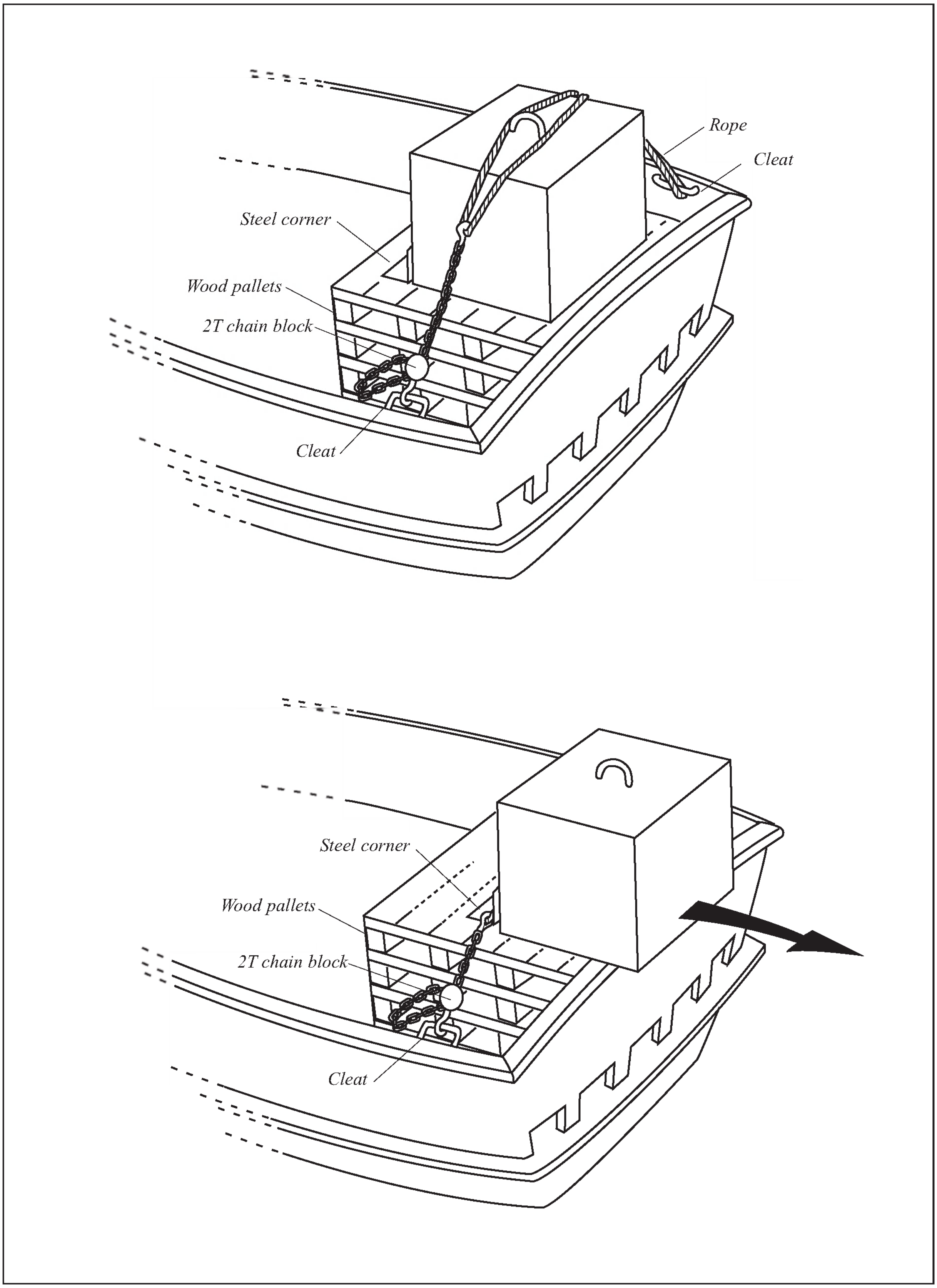


***Figure 12: Top – The anchor block secured in place on board the tug, supported by pallets***
***Bottom – Using the chain block to force the anchor over the stern.***

The TON-7 and the tug went to sea maintaining contact by VHF radio. The GPS unit was used to navigate to the deployment area. As the tug captain deemed it necessary for safety to steam against the seas in the < 12 knot south-east wind prevailing, a straight, south to east deployment track was plotted which would avoid the tug having the sea abeam. Two waypoints were entered into the GPS unit; one would be the point where the raft would be placed in the water and the other the spot where the anchor would be jettisoned. Calculation of these two waypoints was based on the site depth (1,150 m) and the length of the completed mooring (1,380 m, or approximately three-quarters of a mile). Knowing that the block could be expected to reach the bottom at one-third of the distance separating the raft and anchor at the surface, it was calculated that the raft should be put in the water half a mile before the deployment site, the mooring then paid out in a straight line from that spot to a point quarter of a mile past the site and the anchor then deployed. The tug was directed to these sites and notified by radio when to deploy the raft and anchor. Some error occurred due to the delay experienced in pushing the anchor off the tug, during which time the tug drifted slightly off the mark. However, the error was minor and, with the accurate knowledge of the bottom contours gained during the site survey, deemed not to have affected the accuracy of the deployment beyond acceptable limits. After the anchor was jettisoned 8 minutes 30 seconds elapsed before the raft stopped moving on the surface.

It is during this period that the greatest strain is placed on the mooring ropes, as the weight of the descending anchor and the drag of the raft through the water stretch the ropes. In calmer seas it might have been possible to pay out the mooring rope in concentric circles and thus avoid some of the strain placed on the mooring.

## 8. RECOMMENDATIONS

### 8.1 Site survey

- MMR should obtain a suitable echo-sounder with capacity to 1,500 m or more. Such a unit should have at least 2 kw of output power and be equipped with either 28 khz or 15 khz signal frequency. If a dual frequency unit is to be purchased, the most useful second frequency would be 50 khz, which WRI give good returns both for bottom fish and mid-water fish at FADs.

- A second antenna and power cane for the GPS unit should be obtained. This would allow the use of the GPS on any local vessel with suitable power supply.

- Any FAD deployment plan should allow sufficient time to conduct a thorough site survey.

### 8.2 FAD rigging

- As there is plenty of 3-strand polypropylene rope left to be used, there will be a need to acquire matching 3-strand nylon rope (minimum diameter should be 18 mm). When all stocks of 3-strand rope are used up, 8- or 12-strand ropes should be ordered for future FAD use.

- If any essential component is not available, postpone the rigging or deployment of any FAD until the component is obtained.

- Ensure that no hardware components can become entangled with ropes or attracting material added to the ropes.

- Avoid the use of counterweights added to line.

- Smaller chain of 14 mm diameter should be used below the raft so that the length of chain here can be increased to 15 m or more without increasing weight.

- A larger shackle (25 mm) should be used directly beneath the raft because this section undergoes most movement and wear.

- The connecting eye below the raft in the present design should be strengthened.

- Always use enough nylon rope to ensure that the top of the catenary curve is held at least 150 m below the surface.

- A supply of pressure-resistant buoys rated to 800 m and with buoyancy around 5 kg should be obtained to add to the polypropylene line if the calculated length is insufficient to lift 3 m of chain and hardware off the bottom.

- An identification mark should be welded onto the raft so that, if it is lost and recovered, the finder may notify MMR. The recovery of lost FADs, perhaps complete with failed ropes or connecting components, may reveal the cause of loss.

- A precise record should be made of each FAD's design, deployment details and inspection and maintenance carried out.

- All ropes should be taken from the coils before splicing and faked down into as large a box as can be carried on the deployment vessel.

- Concrete block anchors should be poured with a thick steel pad eye protruding to serve as an attachment point. Cross-pieces should be welded to the section of the pad eye embedded in the block.

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