South Pacific Commission

Coastal Fisheries Programme

CAPTURE SECTION REPORT OF FISH AGGREGATING DEVICE (FAD) SITE SURVEY, CONSTRUCTION AND DEPLOYMENT ASSISTANCE TO THE FISHERIES DEPARTMENT OF TUVALU

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and

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by

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SUMMARY

Tuvalu faces increasing subsistence and artisanal fishing pressure on inshore fish resources, coupled with the need to sustain and manage these resources effectively. To address these issues, the Government of Tuvalu, as part of its National Development Plan for fisheries, is focusing on alternative small-scale and cost-effective fishing methods that will target under-utilised offshore fish resources, such as tunas.

On the basis of this, the Tuvalu Government, through its Fisheries Department, sought the assistance of the South Pacific Commission's Capture Section, to conduct in-country training for Fisheries Department staff in all aspects offish aggregating device (FAD) site surveys, construction, deployment and programme planning. In response to this request, the Commission's Fisheries Development Officer, Mr Satalaka Petaia, visited Tuvalu on two occasions to complete this assignment.

Phase I of this assignment focused on FAD site-survey training. The first week was spent ashore in a classroom environment, providing the Fisheries Department officers with all the relevant background information on site surveying procedures and techniques. Most of the second week was spent in the field on board the survey vessel, F/V *Manaui,* to provide the participants with practical hands-on experience in FAD site survey procedures and the operation of survey equipment. During the practical training, the two central Islands, Vaitupu and Nui, were surveyed. The final two days were spent plotting and interpreting bottom-contour maps produced from the data collected during the site surveys. Potential FAD deployment sites were identified for both islands in the surveyed areas.

On the second visit (Phase 11), the project focused on FAD construction and rigging, ropelength and buoyancy calculations, as well as deployment methods and techniques. Materials were on hand to construct two complete FAD mooring systems. However, only one suitable buoy was available. As a result, only one deployment took place, off Nanumanga Island, with the other mooring system ready for deployment off Nukufetau Island when a suitable buoy was available. Following the FAD deployment, further site surveys were conducted at Nanumanga, Nukufetau and Nui Islands at the request of the Fisheries Department. The plotting of contour maps, based on the data collected, made it possible to identify suitable FAD deployment sites.

RÉSUMÉ

Les ressources halieutiques côtières de Tuvalu sont soumises à des pressions croissantes de la part des unités de pêche vivrière et artisanale, alors que, de surcroît, elles doivent être préservées et gérées efficament. Pour faire face à ces problèmes, les pouvoirs publics de Tuvalu, dans le cadre de leur plan national de développement de la pêche, s'intéressent à d'autres méthodes de pêche artisanale et rentable, qui cibleront des ressources halieutiques de pleine eau sous-exploitées, telles que les thonidés.

C'est dans ce contexte que les autorités de l'île, par le truchement de leur service des pêches, ont sollicité l'aide de la section Techniques de pêche de la Commission du Pacifique Sud pour assurer la formation sur place des agents du service des pêches dans tous les domaines liés aux dispositifs de concentration du poisson, à savoir, les études de sites, la construction, le mouillage et l'élaboration de programmes. En réponse à cette demande, le spécialiste du développement de la pêche côtière de la Commission, Monsieur Satalaka Petaia, s'est rendu à deux reprises à Tuvalu pour mener à bien cette mission.

La phase 1 de sa tâche a été axée sur la formation à l'étude de sites de DCP. La première semaine s'est déroulée à terre dans une salle de classe; les agents du service des pêches se sont familiarisés avec les procédures et les techniques employées en la matière. La majeure partie de la deuxième semaine s'est déroulée en mer à bord du navire F/V Manaui, utilisé pour ces études de sites, sur lequel les participants ont acquis une expérience pratique des procédures d'étude de sites de DCP et sur l'emploi du matériel nécessaire à la réalisation de cette étude. Lors de cette phase pratique, les deux îles du centre, Vaitupu et Nui ont servi de cas de figure. Les deux derniers jours ont été consacrés au tracé et à l'interprétation de cartes de topographie sous-marine, obtenues à partir des données recueillies lors des études de sites. Des sites potentiels de mouillage de DCP ont été répertoriés pour ces deux îles.

Lors de la seconde mission (phase 2), le projet a porté sur la construction et le montage de DCP, sur les calculs de longueur et de flottabilité de la corde ainsi que sur les méthodes et les techniques de mouillage. Le formateur disposait de tout le nécessaire pour fabriquer deux dispositifs complets d'amarrage de DCP. Cependant, comme il ne disposait que d'une bouée satisfaisante, un seul mouillage a pu avoir lieu au large de l'île de Nanumanga, l'autre système d'amarrage étant prêt à être mouillé au large de l'île de Nukufetau, dès qu'une bouée convenable serait disponible. Suite au mouillage du DCP, d'autres études de site ont été menées au large des îles de Nunumanga, de Nukufetau et de Nui, à la demande du service des pêches. Les cartes de topographie sous-marine obtenues à partir de données qui avaient été recueillies ont permis de répertorier des sites appropriés pour le mouillage de DCP.

ACKNOWLEDGEMENTS

The South Pacific Commission acknowledges with gratitude the co-operation and assistance of the Government of Tuvalu and the administration and staff of the Tuvalu Fisheries Department during the course of these visits. Thanks are offered to the Fisheries Extension staff and the hardworking crew of the extension vessel, F/V *Manaui,* in particular Mr S. Sauni, Fisheries Extension Officer; Mr. K. Saloa and Mr. F. Homasi, Assistant Fisheries Extension Officers; Mr. T. Talapai, Captain; and Mr. S. Petaia, Chief Mate.

The Commission acknowledges, too, the assistance and co-operation provided by the Island Council members on Vaitupu, Nui, Nanumanga and Nukufetau Islands, for providing the important guidance and information on local fishing activities and potential FAD sites.

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1. Introduction and Background

1.1 GENERAL

Tuvalu is an archipelago composed of nine distinct coral atolls in the South Pacific. The exposed land-mass lies between 5° and 11° South latitude and 176° and 180° East longitude. The population is approximately 9,600 people, with around 30 per cent of the population living on the main island and capital, Funafuti. The remaining 70 per cent of the population occupy the outer islands. The limited vegetation on the islands is primarily coconut woodland. Land for agricultural use is largely unavailable due to the infertile soils derived from the calcareous sands and gravels.

Tuvalu is characterised as having a marine tropical climate, with prevailing trade-winds blowing from the southeast. Strong 'westerlies' blow during the cyclone season of November to April. Temperatures vary slightly and range from 25° to 31° C. The islands receive an annual rainfall ranging from 260 to 340 cm per year (Rowntree, 1995). Subsistence agriculture and fishing are widely practised. Tuvalu's marine environment consists of fringing or patch reefs in the shallower waters surrounding atoll islets; patch reefs and relatively barren coralline sand flats within shallow lagoon waters; and a vast surrounding area of deep open ocean.

Tuvalu is among the least developed nations of the world, with few opportunities for economic development. Tuvalu controls an Exclusive Economic Zone (EEZ) covering approximately 900,000 km^2, and has a higher ratio of sea-to-land area than any other nation (Rowntree, 1995). Of the 900,000 km^2 of EEZ, only 26 km^2 are land (Figure 1). Although there may be a resource through mineral deposits, Tuvalu's vast and largely unexploited marine resources base offers essentially the only known option for development.

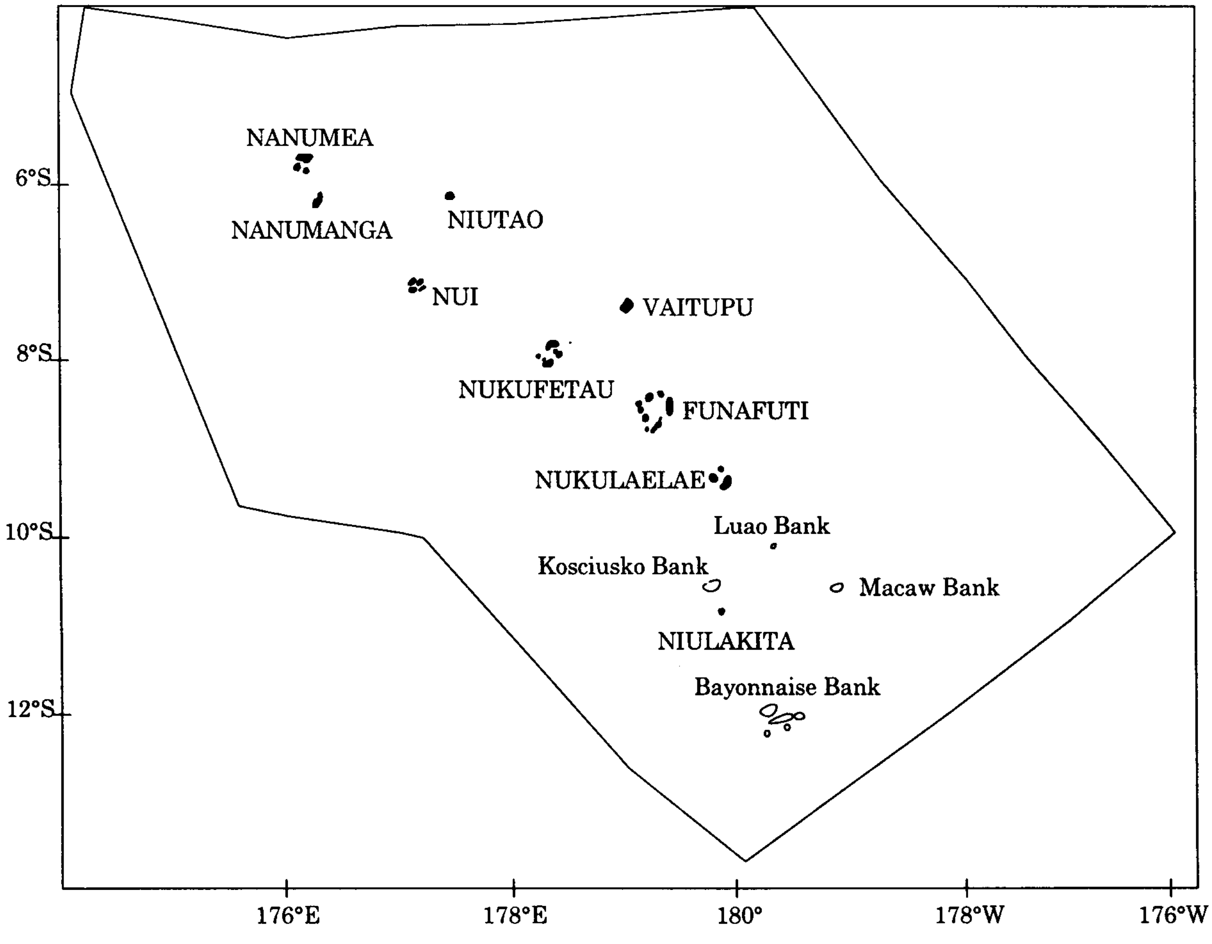


Figure 1: Tuvalu Islands, with declared 200-mile EEZ

The local economy is heavily dependent on imports of foods, raw materials and manufactured goods. Export is based on copra, handicrafts, and small amounts of fresh and frozen fish (Rowntree, 1995).

1.2 EXISTING FISHERIES

Fishing activities throughout Tuvalu are widespread and diverse, though generally at subsistence and artisanallevels. However, a number of small-scale semi-commercial and commercial fishing activities are already in place, and these are fully supported by the National Government. The main artisanal methods employed include handlining, droplining, gillnetting, trolling, scoop netting for flying fish, and spearfishing. Most fishing activities are carried out either from motorised open skiffs or from traditional sailing and paddling canoes. The bulk of the catch at all levels is harvested from coastal areas, with a small amount from offshore fishing areas.

On most of the outer islands, catches by these various methods often exceed demand. Simple preservation techniques, such as salting and drying, are regularly used to preserve surplus catches. At Funafuti, the capital, where the 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 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 market in Funafuti. Such attempts, both private and Government, have met with only limited success, constrained by unsuitable shipping facilities and lack of catch-handling infrastructure on the outer islands.

The National Fishing Corporation of Tuvalu (NAFICOT), a statutory body set up by the Government in the mid 1980s, is charged with the responsibility to develop the commercial fishing sector. Like other commercial fishing enterprises in the region, it has faced a lot of problems since its inception. The Corporation once operated a pole-and-line fishing vessel, F/V *Te Tautai*, which mainly worked out of Fiji and the Solomon Islands. The Tuvaluan Government is trying to sell the vessel, and it is currently not fishing.

More recently, NAFICOT is operating a fleet of 9 m fishing vessels around Funafuti, exploiting the offshore fish resources (tuna and deep-bottom snapper) around the island. The corporation is currently exporting fresh-chilled bottom fish in small quantities to Hawaii and the Marshall Islands on a trial basis. In full recognition of the role of NAFICOT, as well as the importance of marine resources to the country, the Government is now developing appropriate strategies that would enhance and improve the corporation’s future operation and its commercial capacity to fully utilise the marine resources within Tuvalu’s EEZ.

One such strategy is the development of a national programme to assist local fishermen through the construction and deployment of fish aggregating devices (FADs). Tuvalu’s experiences have shown that FADs do increase the availability of tunas to local fishermen, thus increasing their catches.

1.3 NATIONAL FAD PROGRAMME

The Tuvalu Fisheries Department (TFD) FAD programme was initiated in the early 1980s by an SPC Masterfisherman, Pale Taumaia. Since that time, the TFD has seen more than 20 units deployed, and they have been regarded as an important tool to enhance and increase fishing activities and production. However, with the very limited knowledge on FAD technology during the early stages, regular FAD losses occurred. This, coupled with high costs involved with the purchase of FAD materials, caused the National FAD Programme (NFADP) to be suspended for a number of years.

The NFADP was revived in the early 1990s, with the implementation of a three-year bottom-fishing project funded by the United States Agency for International Development (USAID), of which FAD deployment was one component. In all, nine FADs were deployed by the project, one for each island in the group. Most of these FADs remained on station for three years. In fact two of the FADs were still in place at the time that this project was conducted (four years after deployment).

Funding as well as limited technical know-how and the loss of staff trained in FAD technology, are the two major problems faced by the TFD in effectively implementing their NF ADP.

1.4 INITIATION OF THE PROJECT AND ITS OBJECTIVES

Tuvalu, with its limited land mass, high population growth rate, and heavy reliance on inshore marine resources as its main source of protein, recognises that in order to sustain near-shore resources in the long term, emphasis should be placed on developing costeffective fishing strategies that focus on the exploitation of offshore under-utilised resources, in particular the pelagic offshore resource (tuna, etc).

FADs have proven to be very successful in attracting tuna, thus increasing the domestic landings of tuna to the local markets in Tuvalu. However, with the loss of many of the FADs deployed under the USAID programme, landings were decreasing as fishermen had to search for surface schools of tuna to fish. This, coupled with the loss of staff appropriately trained in FAD construction and deployment, led the Tuvaluan Government to seek assistance from the South Pacific Commission's (SPC's) Capture Section of the Coastal Fisheries Programme. The objectives of this project were:

- to train local Fisheries Officers on all aspects of FAD site-surveying techniques (using echo-sounding equipment), construction and rigging of moorings, (as well as rope and buoyancy calculations) and the method of deployment;
- to conduct site surveys around the central Islands of Tuvalu, and identify potential FAD deployment sites through producing a bottom-contour map of the surveyed sites;
- to actually deploy one or two FADs on selected sites based on the availability of materials; and
- to assist where possible in the development of Tuvalu's National FAD Plan.

Originally all of the objectives were to be addressed in a single visit. However, at the time of this visit, not all of the required materials were available. This led to the project being split into two phases, firstly to undertake site surveys and secondly to construct and deploy FADs.

2. Vessel, Survey Equipment and FAD Materials

2.1 SURVEY VESSEL AND EQUIPMENT

The vessel that was made available for the survey and deployment work was a 19 m fibreglass boat, F/V *Manaui* (Figure 2), powered by a 163 hp Yanmar diesel engine, which had been donated to the Tuvaluan Government by the Government of Japan. The vessel was equipped with:

- a Global Positioning System (GPS): JRC, Model JLU 121 receiver/plotter equipped with a CRT display;
- a Furuno SAT NAV unit (not used for deployment and survey work);
- a remote steering system (automatic pilot) with a gyro compass fitted;
- a Furuno 24 mile radar; and
- a Furuno colour echo-sounder (model FCV 361), with a maximum depth range of 1,000 m.

In addition the vessel had lifting gear (derrick) of 1000 kg safe working load (SWL), which was very useful for the deployment of the anchor block. The vessel also had sufficient working space towards the stern, which made the vessel very suitable for FAD work.

Figure 2: The TFD's extension vessel, F/V Manaui, used for FAD site surveying and deployment activities by the project

Before the visit was undertaken, it was found that the vessel's echo-sounder was inoperable. The TFD therefore requested the Commission to provide a suitable echo-sounder with transducer for the project. The Commission's Furuno FCV 362 deep-water colour echo-sounder was dispatched to Tuvalu well in advance of the first visit to meet this request.

2 .2 FAD MATERIALS

FAD materials had been ordered from a New Zealand-based company. The specifications and quantity of materials required had been prepared by the TFD in close consultation with the Commission's Capture Section. These specifications were in line with recommended SPC FAD design-material specifications (Boy & Smith, 1984 and Gates et al., 1996). The materials ordered were:

- Yellow 22 mm polypropylene 8-strand plaited rope in 220 m coils;
- White 19 mm nylon 12-strand plaited rope in required length;
- 13 mm diameter long-link, hot-dip, galvanised low-carbon steel (Hdg-Ics), for the upper mooring section;
- 19 mm diameter long-link, hot-dip, galvanised low-carbon steel (Hdg-Ics), for the lower mooring section;
- 19 mm hot-dip, galvanised low-carbon steel (Hdg-Ics) forged eye-and-eye swivels;
- 22 mm hot-dip, galvanised low-carbon steel (Hdg-Ics) forged eye-and-eye swivels;
- 16 mm, 19 mm, and 22 mm low-carbon steel (Hdg-lcs) safety shackles with stain less-steel cotter pin; and
- Samson nylite rope connector to suit rope of 19 mm and 22 mm diameter (each of these required the central hole to be drilled to fit the pins of the 19 mm and 22 mm safety shackles).

A number of 450 kg concrete anchor blocks had already been constructed, cast and cured. The anchor blocks had been reinforced with steel rods and an anchor bail as described in Gates et al. (1996).

The design of the rafts to be used had not been decided, as several styles were being trialled. The most recent ones being trialled were the Indian Ocean design (Figure 3), and the Tongan design (Figure 4). The latter design had been trialled over a number of years and appeared to be working very well in the sea conditions around Tuvalu. The former design, whilst proven to be successful in some regions, had not been fully assessed by the TFD for Tuvaluan conditions.

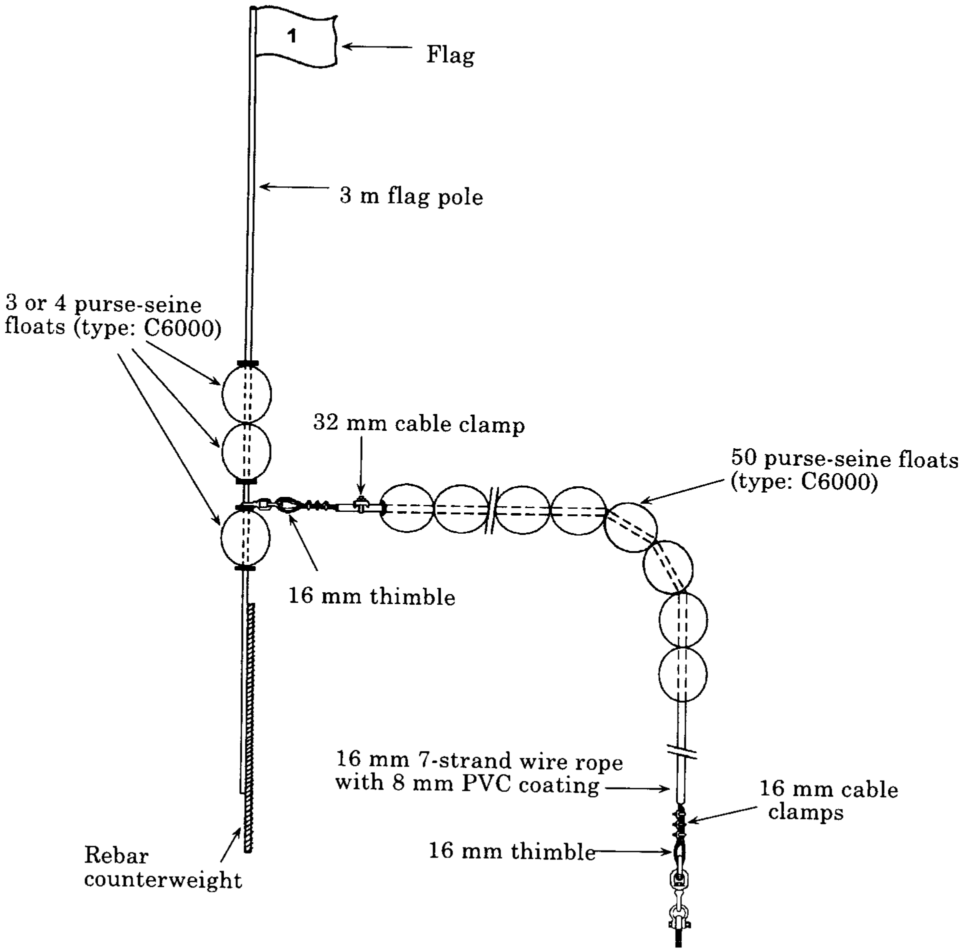


Figure 3: Details of Indian Ocean raft design

Figure 4: Tongan raft design

3. Project Operations—Phase I

The initial request from the Government of Tuvalu was to provide FAD technical assistance covering Phase I and Phase II activities concurrently. However, this was not possible, as FAD materials ordered from New Zealand were not on site during the first visit, which resulted in FAD construction and deployment activities being deferred.

3.1 TRAINING WORKSHOP

As soon as the Commission’s Fisheries Development Officer (FDO), Mr Satalaka Petaia, arrived in Tuvalu, a work programme (Appendix A) was developed in close consultation with the TFD. The first part of the work programme focused on training counterparts and vessel crew on site selection and surveying procedures; the operation of echo-sounding equipment; FAD deployment methods and procedures; FAD designs, construction and arrangements; supplementary buoyancy and mooring rope calculations; the catenary-curve mooring system; and other aspects of FAD technology. This part of the training activity was conducted onshore as part of a four-day workshop. This was planned in order to give the local Fisheries Officers and vessel crew a basic understanding of the FAD systems, before the actual practical work in the field was carried out. The four-day workshop programme outline is at Appendix B.

3.2 SURVEY EQUIPMENT-INSTALLATION AND TESTING

The second part of the work programme focused on the installation and testing of the survey equipment (echo-sounder and GPS). The echo-sounder display unit was mounted in the wheel house in place of the vessel’s own inoperable echo-sounder (Figure 5). A transducer casing and aluminium mounting pole (Figure 6) were positioned on the port side of the vessel, one third of the length of the boat from the bow, by clamping and lashing (Figure 7). The echo-sounder was powered by its own two 12 volt batteries, connected in series to produce 24 volts.

Figure 5: The F/V Manaui wheel-house, showing the mounted survey equipment

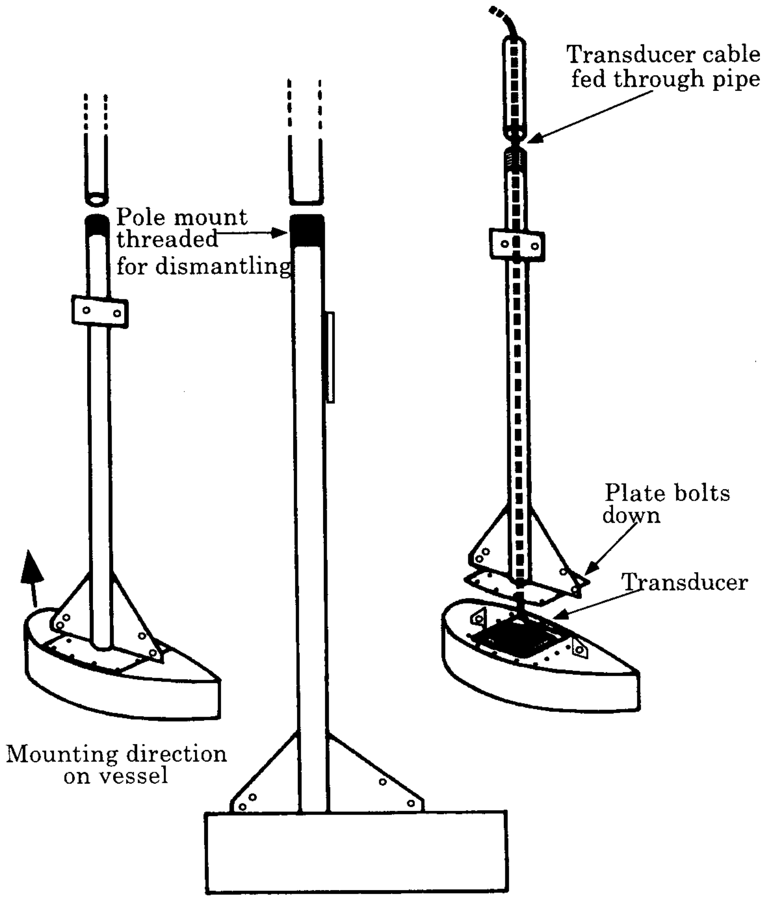


Figure 6: Details of portable transducer mounting and its assembly

The GPS display unit was already mounted in the wheel-house, away from other navigation and communication equipment. This was to avoid unnecessary interference in receiving signals transmitted from satellites. The GPS aerial was mounted directly on top of the wheel-house, 9 m above sea-level.

Before the GPS equipment was used, it was corrected according to the World Geodetic System (WGS), to local datum. This was necessary because GPS positions in latitude and longitude are referenced to WGS, while marine charts are often referenced to local or regional datum. Because GPS corrections are not listed on the marine chart, these were calculated by taking the GPS position of a charted landmark, and then comparing it with the landmark's charted position. The difference between the two positions was the GPS correction. These corrections were entered into the GPS in order to correspond with charted positions.

After the installation of the echo-sounder was complete, the F/V *Manaui* set to sea to test all equipment. The echo-sounder was able to record depths of up to 2,000 m, while the GPS gave accurate readings after the initial corrections were entered.

Figure 7: Transducer equipment mounted over the port side of the vessel

3.3 SURVEYING METHODS AND PROCEDURES

3.3.1 Preparation for the survey

Before the actual site-surveying activities were conducted, the crew of the vessel were familiarised with the use and operation of the survey equipment. This was done during the cruise to the two central islands to be surveyed, Vaitupu and Nui. On arrival there, discussions were held with Island Council members on the selection of potential FAD sites to be surveyed. This type of discussion is important, as local fishermen know where the good fishing grounds are, as well as the general bottom contour around their island. Prior to selecting potential FAD sites to be surveyed, the area was carefully studied on the navigation chart. This was to provide a general idea of the depths and bottom contour before the actual site survey was conducted.

In order to ensure an accurate depth reading, and to be able to determine the degree of bottom slope, regularity, and nearby crevasses of a particular locality, it is important that FAD deployment sites be surveyed thoroughly and accurately. The steeper the slope, the harder it is to place the anchor in the desired depth or location. A vessel can be accurately positioned where the anchor needs to be dropped. However, the anchor may still deviate by hundreds of metres from the spot targeted due to ocean currents and the time the anchor takes to reach the bottom.

3.3.2 Methodology and procedures

Once the most appropriate site/area had been determined, the coordinates or way-points for starting and finishing the area to be surveyed (a square with sides 2 nm long) were determined. A ‘working sheet’ was then prepared, using normal graph paper, with lines of latitude and longitude divided into intervals of a quarter of a mile or minute. In most cases the surveys started in shallower (500 m) and went to deeper (2,000 m) isobaths. The weather and sea conditions dictate the speed at which a vessel can travel when doing surveys. During calm-to-moderate seas, with the transducer mounted at the side, the survey vessel maintained a speed of 4–6 knots.

With the coordinates of the starting point entered into the GPS, the vessel cruised in a north –south direction (180°) or the reciprocal course south -north (0°) along the transect following the line of longitude, recording depth readings from the echo-sounder every quarter of a minute of latitude. At the end of every transect, the vessel changed course to the east (90°) cruising on a latitude line for a quarter of a mile, recorded depth, and then changed again to a northerly or southerly course as before. Desurmont (1992), and Beverly & Cusack (1993) describe the method of running a transect survey, and this is also shown in Figure 8.

Alternatively, the vessel can also cruise on either a westerly or easterly course along the latitude line, following the full length of the transect, then change course at the end of the transect to cruise north or south for a quarter of a mile along the longitude line (depending on whether the transect was started at the eastern or western end of the site to be surveyed), and then change again either to a westerly or easterly course as before.

Each person had a task. The first person operated the GPS to obtain the bearing and distance to the next way-point, and called for depth readouts as each coordinate along the transect was reached. The second person (Captain or Chief Mate) was responsible for steering the vessel on a straight course along the trl;lnsect lines, guided by the GPS display. A third person (Captain or Mate) operated the echo-sounder and was responsible for adjustments and fine tuning of the equipment, as well as recording depth readings at each sounding point.

This whole operation can easily be conducted by two to three people, but, as this was a training exercise, all the crew members were given the opportunity to familiarise themselves with all the survey procedures. This arrangement enabled them to acquire handson experience in all aspects of FAD site-surveying techniques and procedures.

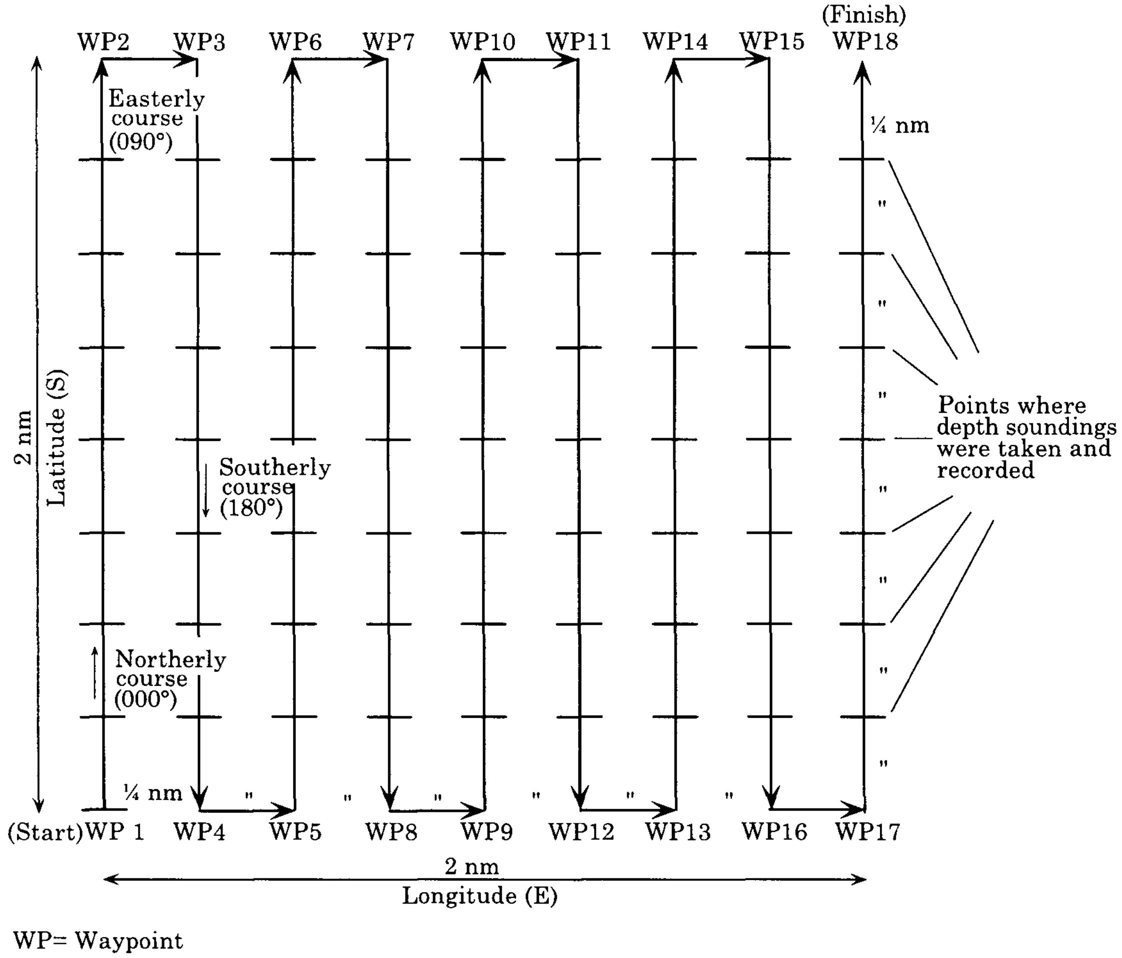


Figure 8: Method of running a transect survey for FAD sites

3.3.3 Producing and interpreting contour maps

On arrival in port with depth readings and positions recorded on the working sheet, the crew drew a contour map of each survey zone. This activity was undertaken as a training exercise to enable everyone involved to learn how to interpret and plot contour maps based on the data collected during the survey. The contour maps were drawn on graph paper, with the lines of latitude and longitude marked and divided into intervals of a quarter of a mile. The graph paper used had 20 space lines between two quarter-of-a-mile transects (other graph paper may only have 10 spaces).

Each of the soundings was marked on the graph paper. The contour lines were then drawn at 100 m increments or isobaths between the marked depths. To do this, the two recorded sounding points were interpolated and the appropriate contour depth was marked between them on the graph paper. For example, increment point 1,100 m between sounding points 1,150 m and 1,060 m is interpolated as follows;

(a) Subtract the lower sounding from the higher sounding: 1,150 – 1,060 = 90

(b) Divide the result by the number of graduations on the graph paper between two quarter-mile soundings, in this case 20 graduations: 90 ÷ 20 = 4.5

(c) Subtract the lower sounding point from the increment point, in this case the 1,100 m isobath: 1,100 – 1,060 = 40

(d) Divide the result of (c) by the result of (b) 40 ÷ 4.5 = 8.8

The answer of 8.8 is the number of graduations from the shallower depth reading marked on the graph paper to where the actual contour point (1,100 m in this case) should be marked. Figure 9 shows how to interpolate the position of the isobath between two sounding points.

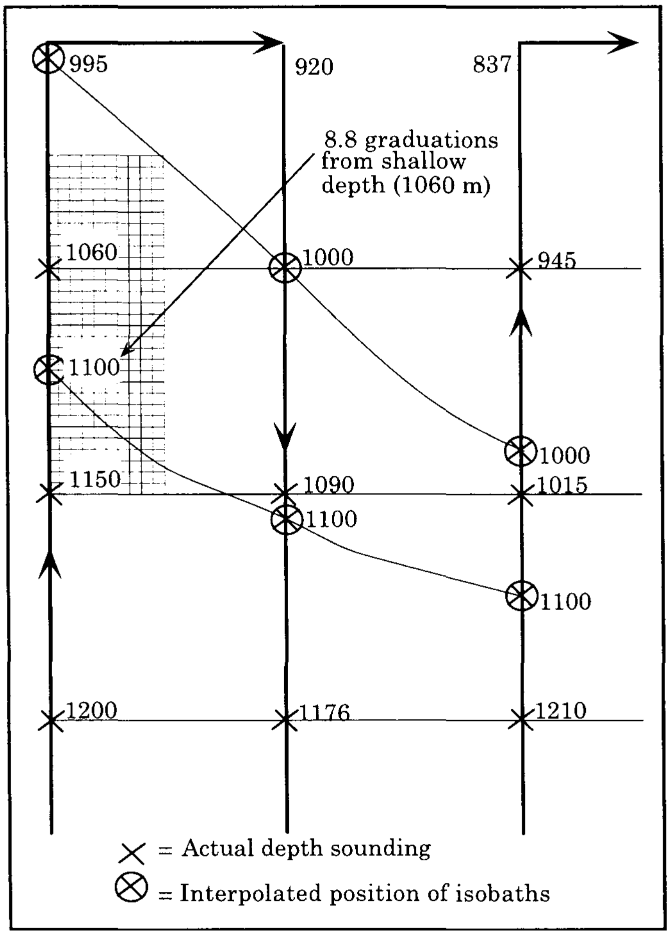


Figure** 9: **Plotting interpolated contour depth points between actual sounding depths, on graph paper

When plotting bottom contour lines, care must be taken to follow the depth readings carefully, to ensure that the contour lines are drawn accurately and reflect the actual bottom contour of the area surveyed. Producing the contour plots for the areas surveyed at Vaitupu (Figure 10) and Nui (Figure 11) was relatively simple, since the bottom contour lines followed a natural and logical pattern. In both cases, the seabed consisted of ridges with some relatively steep inclines and some flat areas. It appeared to be quite steep at depths ranging from 500 m to 1,200 m, with a more gradual slope at depths beyond 1,200 m.

At the Vaitupu survey area (Figure 10), two potential FAD sites were selected. The first position ‘A’ was at latitude 7° 27.000' S, longitude 177° 38.125' E, at an approximate depth of 950 m. The second position ‘B’ was at latitude 7° 28.250' S, longitude 177° 37.250' E, at an approximate depth of 1,602 m. In fact the area between latitudes 7° 26.250' and 7° 28.500' S, and longitudes 177° 37.250' and 177° 36.750' E, of the surveyed zone would be suitable for FAD deployment sites.

In the area surveyed off Nui (Figure 11) three potential FAD sites were identified. The first position ‘A’ was at latitude 7° 13.750' S, longitude 177° 6.870' E, at an approximate depth of 1,270 m. The second position ‘B’ was at 7° 13.500' S, longitude 177° 6.370' E, at a depth of approximately 1,720 m. The third position ‘C’ was at latitude 7° 12.810' S, longitude 177° 6.870' E, at a depth of approximately 1,280 m.

4. Project Operations-Phase II

In May 1996, Phase II of the project was commenced, as FAD materials had arrived from New Zealand. This phase focused on the construction of FADs; mooring rope and buoyancy calculations; and FAD deployment techniques and procedures. In addition, site surveys were conducted off Nui and Nukufetau Islands at the request of the TFD. An outline of the work programme for Phase II is at Appendix C.

4.1 FAD MOORING CALCULATION

The mooring calculations were based on the depth reading obtained from the Nanumanga site survey conducted by TFD staff after Phase I was completed. The position of the site selected was latitude 6° 19.750' S, longitude 176° 18.500' E, at an approximate depth of

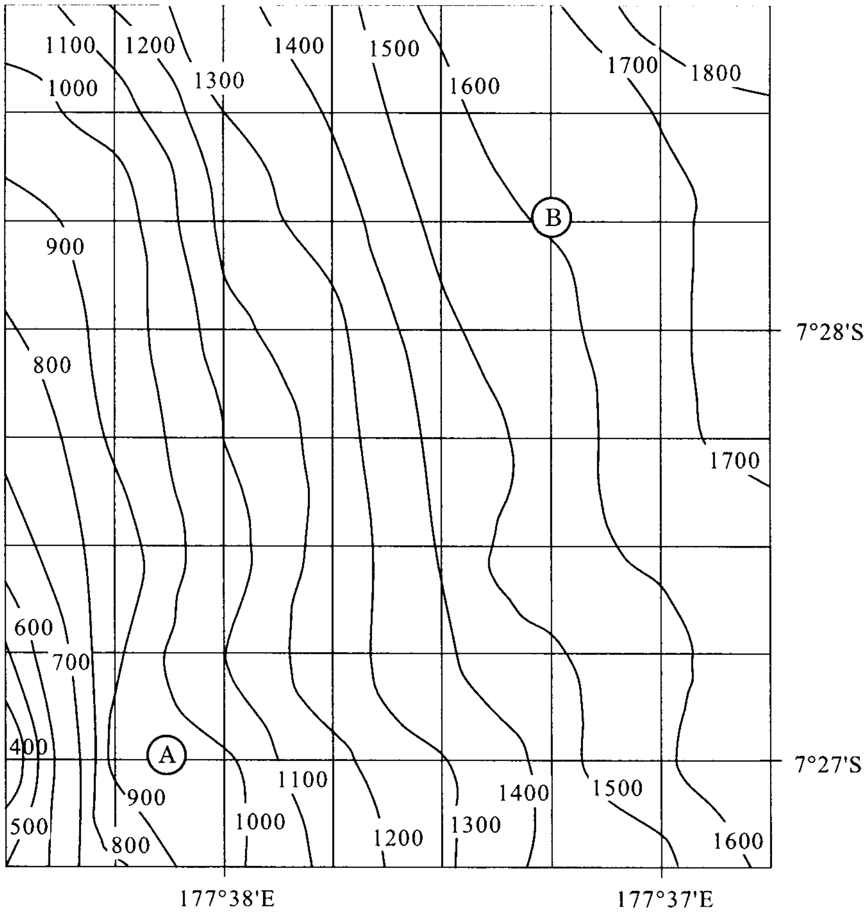


Figure 10: Bottom contour map for the Vaitupu Island survey zone, with suitable FAD sites marked

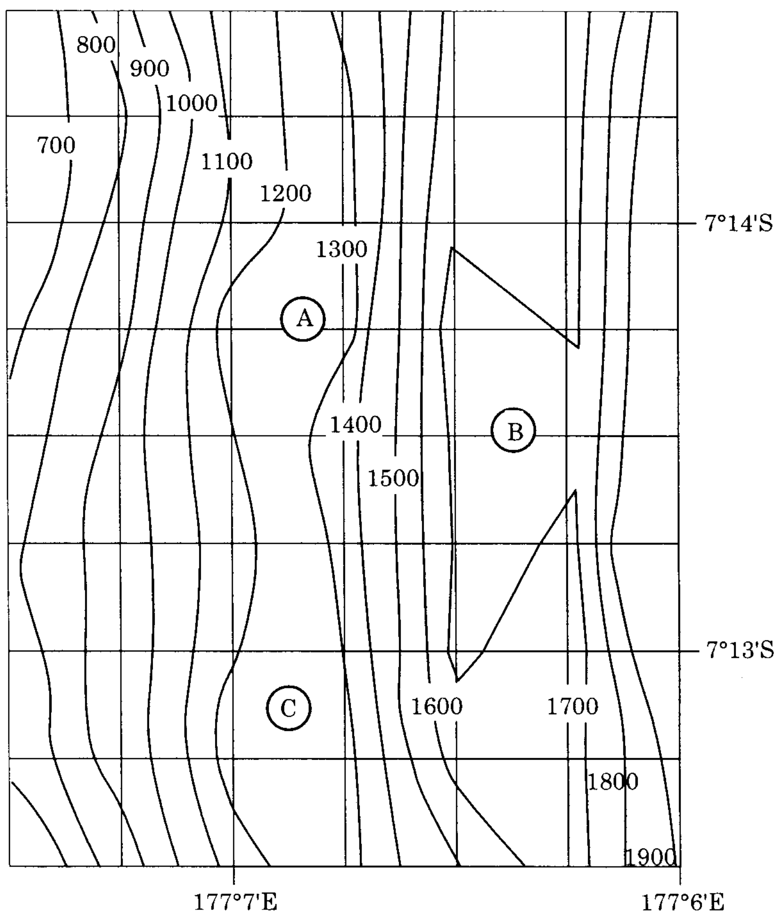


Figure 11: Bottom contour map for the Nui Island survey zone, with suitable FAD sites marked

900 m. The calculations were based on the concept of catenary-curve mooring systems as described in Gates et al., (1996). The catenary curve is the central feature of this mooring system; it is formed in the slack rope where the negatively- and positively-buoyant ropes are joined, as shown in Figure 12. The curve makes it possible to build excess rope into the mooring and to store it safely below the surface. The extra rope helps lessen the strain of rough seas or strong currents on both the mooring and the buoy, and provides a measure of safety against uncertainties of depth at the selected mooring site.

The mooring-rope length and buoyancy calculations for this type of system are simple and straightforward. Before the actual calculation process was carried out the following working principles were established:

- .the length of rope making up the catenary curve is 25 per cent of the site depth (the total length of rope is 25% more than the site depth, which was 900 m);
- 75 per cent of the 'slack' rope in the catenary curve is nylon (negatively buoyant) rope;
- the top of the catenary curve is held at 150 m below the surface;
- there are 30 m of hardware from the surface buoy to the start of the nylon rope;
- three metres of bottom hardware need to be lifted off the bottom through buoyancy, to protect the rope from coming in contact with the sea floor (the weight of the 3 m of hardware to be lifted was 29 kg in air);
- the weight of steel in sea-water is 86.9 per cent of its weight in air (multiply by 0.869); and
- one metre of polypropylene rope in sea-water can buoy up 11.6 per cent of its actual weight in air.

A calculation sheet, Appendix D, was used for all calculations, and a summary of the calculations is presented in Figure 12.

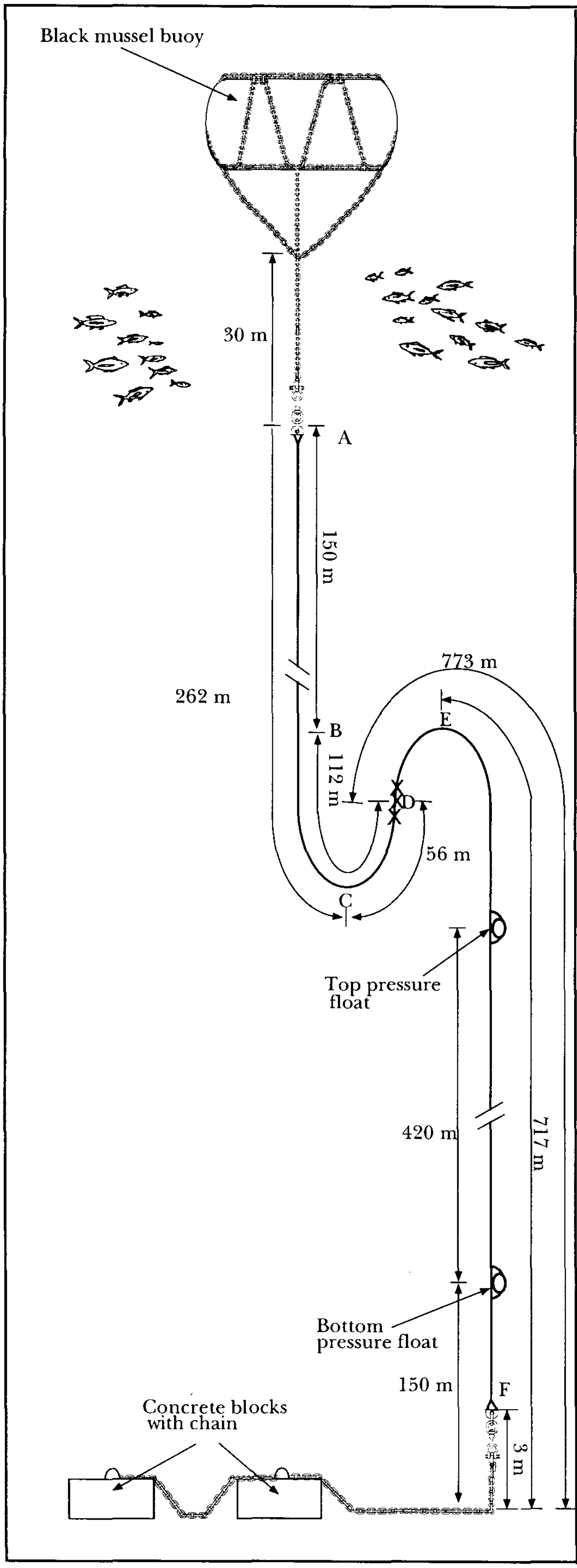
4.2 FAD ASSEMBLY AND RIGGING

Once the exact length of mooring ropes, number of supplementary buoyancy floats, and types of hardware had been determined, the FAD assembly and construction work commenced. Two FAD units were constructed, one for Nanumanga Island and the other for Nukufetau Island. The Nanumanga FAD was constructed and deployed at the pre-determined site, based on the calculations previously presented. The second FAD unit for Nukufetau Island was assembled during the second and final week of the visit after further site surveying had been conducted. However, it was not deployed as there was no suitable buoy available.

Both FAD units were assembled according to the mooring design and material specifications indicated in Volume II of the SPC FAD manual (Gates et al., 1996), except for the buoy. All materials were consistent with the manual's recommended specifications.

The only buoy available at the time was a black plastic cylindrical-shaped mussel buoy previously purchased from New Zealand (see Figure 12). The buoy was lashed firmly with chain at both ends so that the upper mooring chain (30 m) was suspended right at the centre of the buoy. The chain lashings at both ends of the buoy were welded to ensure that they would not break when they came under strain from adverse weather conditions.

Two types of rope were used, white nylon 12-strand plaited rope (19 mm dia.) for the upper (sinking) section and yellow polypropylene 8-strand plaited rope (22 mm dia.) for the lower (floating) section. These ropes were ordered from a supplier in New Zealand, with the nylon rope arriving stacked in a box, and the polypropylene rope in 220 m coils.



Rope buoyancy calculations:

From calculations below, EF = 717 m

Weight of 1 m of rope in air = 0.204kg

1 m of rope supports 11.6% of its weight in sea-water (multiply by 0.116)

Buoyance of rope = 717 x 0.204 x 0.116
= 16.96kg

Rope length calculations:

AB = Site depth- (EF + 30 m + 3 m)
= 900 m- 750 m
= 150m

BC and CDE = $\frac{\text{Site depth} \times 0.25}{2}$
= $\frac{900\text{ m} \times 0.25}{2}$
= 112 m (rounded down)

ABCD = AB + BC + CD
= 150 m + 112 m + 56 m
= 318 m

DEF = DE + EF
= 56 m + 717 m
= 773 m

ROPE SECTIONS		VERIFICATION	
Upper chain	30 m		
AB	150 m	Site depth	900 m
BCD	168 m		
DEF	773 m	Catenary curve	224 m
Lower chain	3 m		
TOTAL	1124 m	**TOTAL**	1124 m

Supplementary buoyancy calculation :

Weight of 3 m of hardware in air = 29 kg

Steel weighs 86.9% of its weight in sea-water

Weight of hardware in sea-water = 29 x 0.869
= 25.2 kg

Buoyancy of rope EF = 16.96 kg of hardware

Supplementary buoyancy needed = 25.2– 16.96
= 8.24 kg

Pressure floats (1500 m) available had 1.7 kg of buoyancy, so 5 floats were needed

Placement of top and bottom float:

Top float located just below catenary curve
= 717– 112– 35 (5 % safety factor)
= 570 m from bottom (or 203 m from rope splice)

Bottom float located at 50% of its depth rating
900– 750 = 150 m from bottom

Figure 12: Configuration of complete catenary-curve mooring system, showing all calculations for the different components

Although the ropes were of different construction (ie one being 8-strand and the other 12-strand) no difficulties were encountered with making the end-to-end connection splice. Most members of the Tuvalu FAD team were taught how to splice 8- and 12-strand ropes as part of the FAD construction programme. Only the Captain and Chief Mate of the extension vessel, who had both spent many years as merchant seamen, were proficient in splicing ropes of this construction.

The eye splices connecting the rope to the upper and lower hardware were protected with Samson Nylite connectors (Figure 13). Only one end-to-end splice (joining nylon and polypropylene), 3—4 connecting splices for the 220 m coils of polypropylene rope (depending on required length of rope) and two eye splices (one at each end of the completed mooring line) were made for each FAD unit. Before the splices were made, all ropes were measured and cut to the required length and the positions for supplementary buoyancy (pressure floats) marked on rope section EF (refer Figure 12). All splices were whipped and then covered with waterproof tape (Figure 13).

Figure 13: Rope-to-hardware connection, showing an eye splice protected with nylite connector and black waterproof tape

The hardware used was of different sizes, made of hot-dip, galvanised, low-carbon steel (Hdg-Ics). Hardware was connected and arranged as per the recommendations in the SPC FAD Manual Volume II (Gates et al., 1996) and shown in Figure 14. Safety shackles with stainless-steel cotter pin, sizes 25 mm, 22 mm, 19 mm, and 16 mm, were used on all connections. All shackles were welded at both ends of the bolt to prevent nuts from working free, and then locked with the stainless-steel cotter pins.

Two different-sized swivels were used: 22 mm and 19 mm. The 22 mm was used in the upper hardware and the 19 mm used in the lower hardware (Figure 14). Long-link chain was purchased in two sizes: 19 mm and 13 mm. The 19 mm was used for the lower section connected to the anchor blocks and the 13 mm was used for the upper section connected to the buoy.

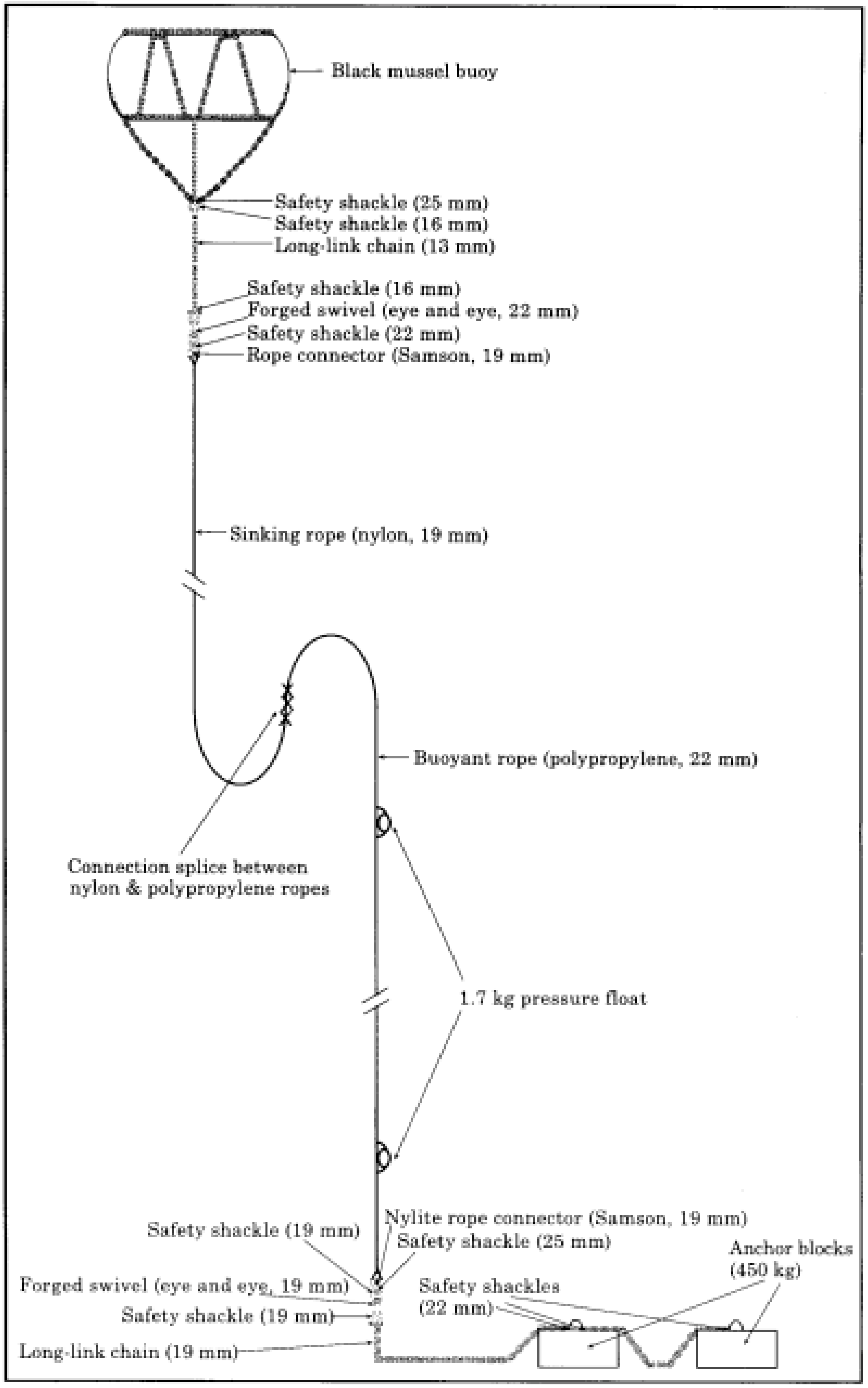


Figure 14: Hardware connection and arrangement for the catenary mooring system used in Tuvalu

The type of anchor used for FAD mooring in Tuvalu was concrete blocks with steel reinforcement, as recommended in Gates et al., (1996). Because the lifting gear (derrick) on F/V *Manaui* was only capable of lifting 500 kg, two blocks of 450 kg each were constructed (Figure 15).

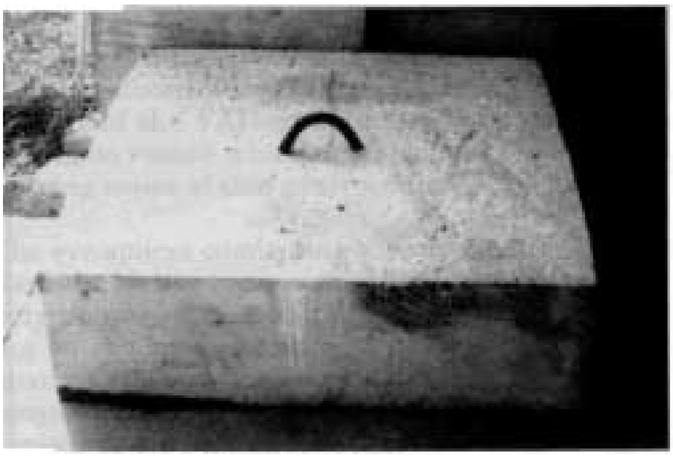


Figure 15: Concrete anchor block used for FAD mooring in Tuvalu

These were constructed by the TFD two months before the visits, with specifications and cement-mixing ratios provided by the Commission's Capture Section. The anchor blocks were fixed with concrete-reinforcing bar bails, as no low-carbon steel round stock was available.

An appendage or aggregator was constructed from used plastic strapping from boxes and pieces of old bait-fish net. These were tied to the upper chain away from the swivel to prevent them from becoming tangled in the swivel.

4.3 FAD DEPLOYMENT TECHNIQUE AND PROCEDURES

A complete FAD unit was loaded onto the deployment vessel alongside the jetty, with the anchor blocks first, followed by the bottom hardware and section of polypropylene rope, the section of nylon rope, and then finally the top hardware and mussel buoy. The two anchor blocks were loaded on to the vessel by a forklift and then positioned on wooden pallets on the after-deck, at the starboard side, close to the lifting gear (derrick). The hardware was stored on deck, whilst the mooring ropes were coiled in a figure-of-eight style into the fish holds located at the after-deck.

The GPS, echo-sounder and transducer were next to be installed on the vessel. These were installed in the same positions as for Phase I of this project. The Commission's echosounder was used again during this trip, as the department's echo-sounder was still out of order. All hardware connections were welded on the boat before departure.

On the way to the deployment site, which was approximately a one-day trip by boat, the crew were carefully briefed on the deployment technique as well as the procedures that were to be employed during the actual FAD deployment operation. Each crew member was assigned specific tasks to perform during the operation. Considering the limited space at the after-deck of the vessel, the 'anchor last' method was used for deployment.

When the deployment site was reached, a quick site-confirmation survey was conducted. This was to re-confirm the depth sounding and the position of the FAD deployment site that was previously selected by TFD staff. Everything was found to be correct, so the deployment commenced.

The 'straight-line or tow-away' deployment technique was used. This method required three way-points to be entered into the GPS unit, one being the point where the buoy would be dropped (A), the second being the position of the selected FAD site (B), and the third being the point where the anchor would be dropped (C). The position of the deployment site was known, whilst the positions for the other points were estimated based on the length of the whole mooring, the site depth, and the weather conditions at the time of deployment.

The vessel steamed down-wind to position (A) approximately two-thirds of the length of the whole mooring rope from the FAD site. At this position the vessel turned upwind and released the buoy and top hardware. The vessel then steamed slowly into the wind in a straight line, paying

paying out the rope (polypropylene first, then the nylon) as the vessel passed over the FAD site (B) and continued to position (C) around one-third the length of the mooring rope from the selected FAD site. At this position the anchors were lifted off the deck with the vessel's lifting equipment and dropped overboard from the starboard side of the vessel.

Thirty minutes after the deployment operation had been completed, and the buoy was stationary, the final position was taken. The buoy was actually 0.04 nm west (latitude 6° 19.750' S, longitude 176° 18. 460' E) of the intended position of the FAD. As the day was very calm at that time, it was assumed that the anchor landed very close to the intended position.

4.4 ADDITIONAL SITE SURVEYS AT NUIAND NUKUFETAU ISLANDS

On the way back from deploying the Nanumanga FAD, the project team called at Nui and Nukufetau Islands to conduct additional FAD site surveys. These were undertaken as a result of a request by the TFD, to take advantage of having the equipped vessel and crew in the area. The team called at Nui Island first, and surveyed the area at the northern tip of the island. On completion of the Nui Island survey, the team proceeded to Nukufetau Island. After consultation with the council members, the survey covered the area west of the main settlement. Figures 16 and 17 show the contour maps produced for the Nui and Nukufetau Island sites respectively.

The method and procedures employed to survey these two areas were exactly the same as those used during Phase I of the project. These last two surveys were conducted by the local FAD team. From these site surveys, additional FAD sites were identified for both islands.

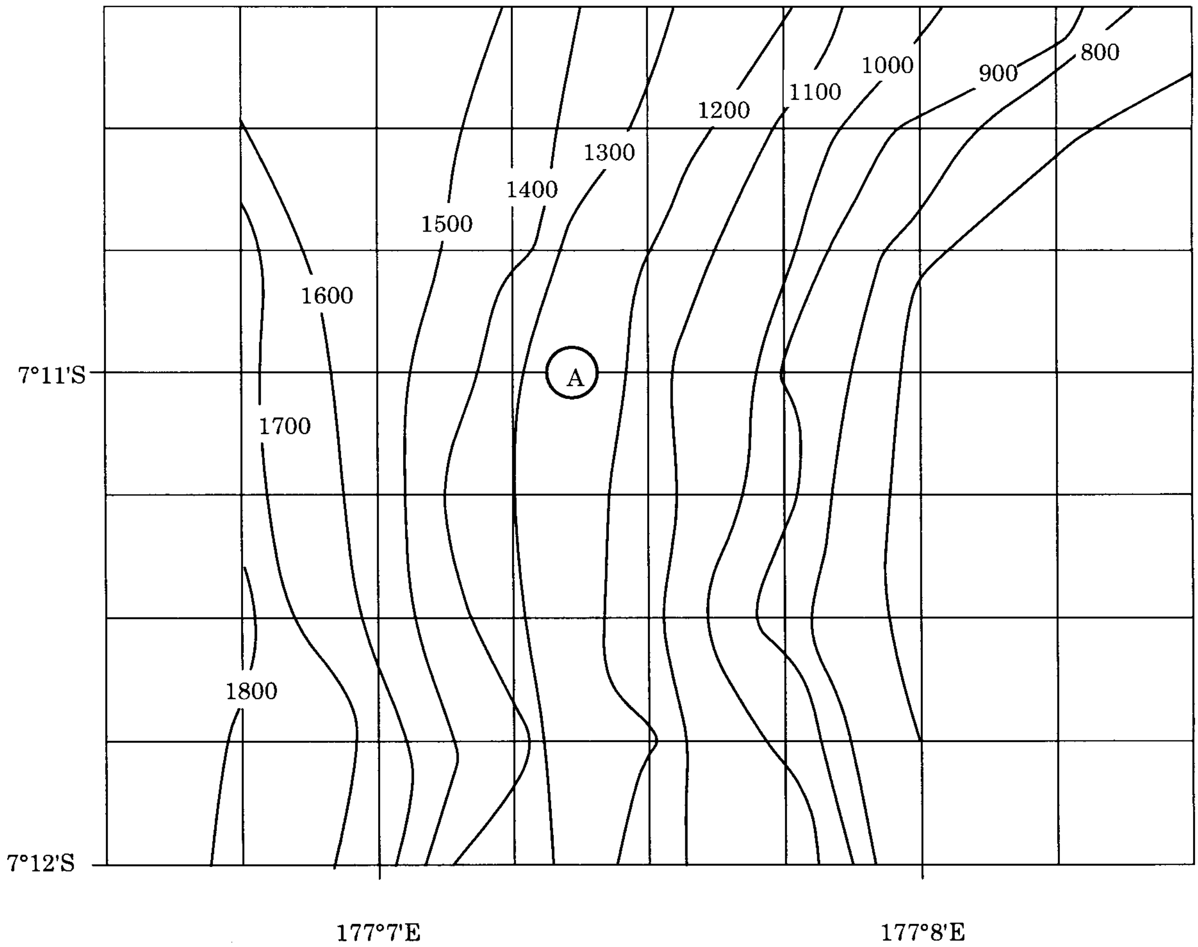


Figure 16: Contour map of second site surveyed at Nui Island

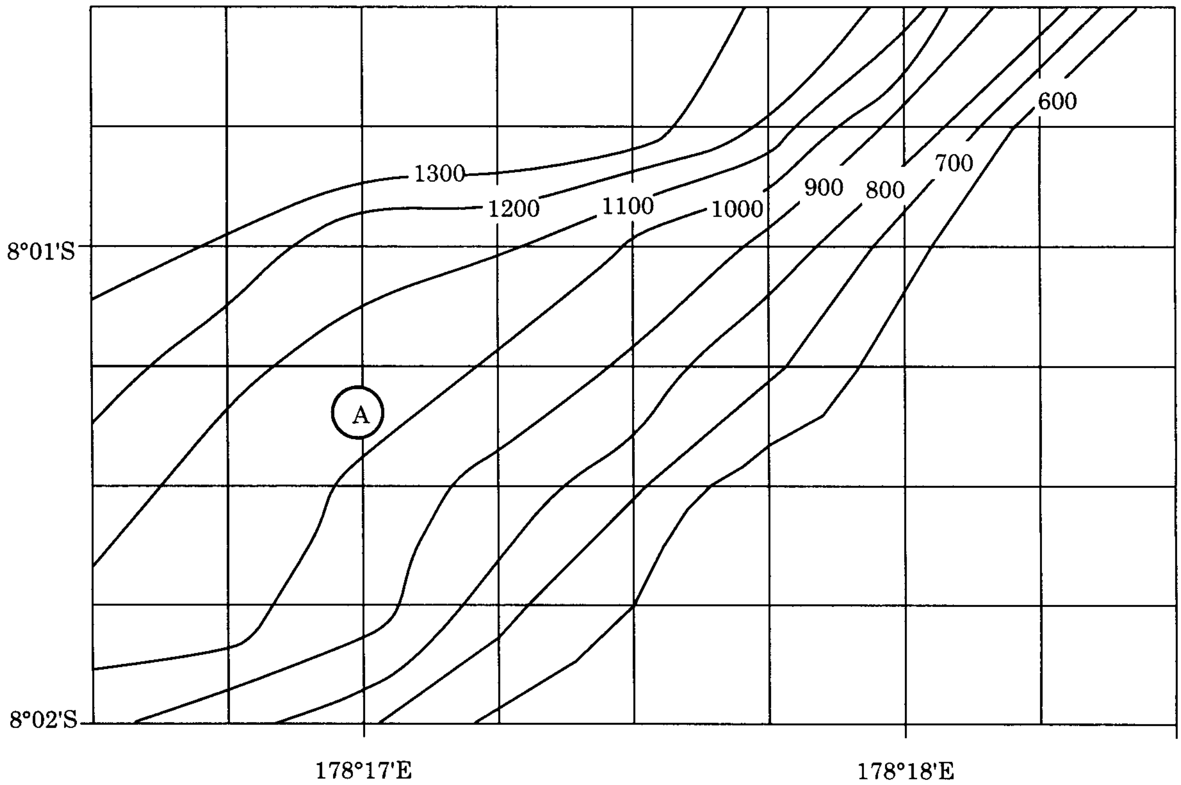


Figure 17: Contour map ofsite surveyed at Nukufetau Island

5. Conclusions and Recommendations

The following conclusions and recommendations stem from the work carried out by the Capture Section in Tuvalu during both phases of this assignment.

5.1 CONCLUSIONS

During both phases of the project, the TFD was unable to provide a suitable echo-sounder for site surveying and deployment work, and therefore relied on an echo-sounder from the Commission to conduct the project. This meant that when the SPC officer left with the echo-sounding equipment after the conclusion of Phase II, the TFD was unable to continue with its National FAD Programme. The TFD did have an echo-sounder on the project vessel. However, this was not operable, was only rated to 1,000 m and was not really suitable for deep-water FAD work.

Tuvalu continues to face a lack of funding support, from both the National Government and aid donors, for the implementation of fisheries programmes, such as a National FAD Programme. No data had been collected as part of past FAD deployments, thus making it very difficult to assess the effectiveness of the FADs in attracting fish, how much the FADs were being used by local fishermen, and the economic benefits from having FADs. This type of data is essential to attract funding for an ongoing FAD programme.

To date, there has been no routine maintenance programme in place to service the FADs once deployed. Additionally, there did not appear to be any programme in place to set out the future ofa National FAD Programme for Tuvalu, including the purchase of materials, staff requirements, actual work programme and funding requirements. This made the current project seem quite *ad hoc* in its approach and implementation. The SPC FAD manual Volume I (Anderson & Gates, 1996) describes the planning and programming required for a National FAD Programme.

The extension service that the TFD provided as part of the FAD programme was very limited. It focused mainly on liaison with the Island Council in each location with regard to the selection of suitable areas in which to conduct site surveys. There appeared to be scope for expanding this extension service in the future to include training on fishing techniques associated with FADs, as well as FAD deployment technology (with a focus on maintenance), with villagers from the islands where FADs are to be deployed. TFD officers could also focus on an awareness programme for FADs, as it appeared that in some locations, villagers were uncertain about benefits obtained from these devices and their potential and effectiveness.

Over the years several staff of the TFD have been involved in FAD training, both overseas and in-country (such as in the current project). This training covers FADs and their construction and deployment, as well as fishing techniques associated with FADs. However, staff move on and in many cases they do not pass on their experiences/skills, or are not provided with the opportunity to pass these on before they depart. This is a common problem in many countries in the Pacific.

5.2 RECOMMENDATIONS

Based on the results of this project, it is recommended that:

(a) A suitable deep-water colour echo-sounder be acquired as soon as possible to continue the National FAD Programme. The echo-sounder should have the following specifications and capabilities: maximum depth range of at least 2,000 m; at least 2 kw output power; equipped with either a 28 khz or 15 khz signal frequency (a Furuno Model FCV 361 or 362 as used by the Commission would be suitable);

(b) Spare parts be ordered for all electronic survey equipment and the TFD's existing echo-sounder should be fixed as a matter of urgency;

(c) A National FAD Programme planning document be developed by the TFD for the controlled development and implementation of an ongoing FAD programme. The planning document should include:

- a work programme for 3-4 years setting out the objectives, how the objectives will be met, and an outline of the timing of events,
- the materials required for the programme (FAD materials as well as electronic equipment for the survey and deployment vessel),
- an outline of the data required to be collected and how collection is to be designed and implemented, including the keying of data into a database and the analysis of data,
- a maintenance and monitoring programme for FADs (once deployed) to maximise the life-span of these units,
- funding requirements and the source of funding,
- staffing requirements to conduct the programme,
- training requirements for any staff involved in the different aspects of the pro gramme, such as database development and data analysis;

(d) A commitment for funding be given by the Tuvaluan National Government from its core budget for a 3–4 year period. As part of this, Island Councils could be included in the process and provide funds for FADs in their area, with full or partial jurisdiction over the use and maintenance of these FADs;

(e) The TFD expand its extension service to include training on fishing techniques associated with FADs, as well as FAD deployment and maintenance technology, with villagers from the islands where FADs are deployed;

(f) A FAD awareness programme be developed by the TFD and implemented both in Funafuti and in the other islands where FADs are to be deployed;

(g) The TFD develop an internal programme to allow the exchange of experiences and skills within the department's staff so that these are not lost when staff leave; and

(h) Additional site surveys be conducted, whenever the opportunity permits, to allow the most suitable deployment sites to be identified at each island in the country.

6. References

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Appendix A

OUTLINE OF WORK PROGRAMME-PHASE I

Tuesday, 10 October 1995

Briefing: Acting Secretary, Natural Resources
Acting Director of Fisheries

Wednesday, 11 October 1995

Discuss work-plan and schedule with counterparts and Acting Director of Fisheries
Assist with development of National FAD Programme plan
Develop internal FAD workshop programme

Thursday, 12 October 1995

Test survey equipment and vessel
Install survey equipment
Continue working on FAD programme plan

Friday, 13 October 1995

Commencement of internal FAD workshop (Day 1)
Counterpart familiarisation with survey equipment

Saturday, 14 October 1995

FAD workshop (Day 2)
Maintenance work on vessel

Sunday, 15 October 1995

Review of last four days' activities and workshop programme *Monday,*

16 October 1995

FAD workshop (Day 3)
Continue working on FAD programme plan

Tuesday, 17 October 1995

FAD workshop (Day 4) *Wednesday,*

18 October 1995

Preparation for trip to outer islands
Departure for outer islands (site surveying)

Thursday, 19 October 1995

Consultation with Nui Island council members
Site surveying at Nui Island

Friday, 20 October 1995

Consultation with Vaitupu Island council members
Site surveying at Vaitupu Island

Saturday & Sunday, 21 & 22 October 1995

Arrival at Funafuti. Unloading of equipment from boat
Review of outer island trip

Monday, 23 October 1995

Plotting of bottom-contour maps and identification of potential FAD sites (training exercise)
Equipment maintenance/cleaning

Tuesday, 24 October 1995

Review of two weeks' activities
Briefing: Secretary of Natural Resources
Director of Fisheries
Packing of equipment
Departure from Tuvalu

Appendix B

OUTLINE OF WORKSHOP PROGRAMME—PHASE I

FAD programme planning process

FAD concept and theories

Potential benefits of FADs

How FADs work

Inverse catenary mooring design

Site-surveying procedures and methods (theory)

Plotting bottom-contour maps based on depth sounding (exercise)

Interpretation and selection of suitable FAD sites

SPC FAD mooring designs and arrangements

FAD construction and rigging (theory)

Mooring-rope and buoyancy calculations (exercise)

Survey equipment use and operation

FAD deployment methods and techniques (theory)

FAD maintenance

Appendix C

OUTLINE OF WORK PROGRAMME-PHASE II

Thursday, 23 May 1996

Arrive Funafuti

Friday, 24 May 1996

Briefing with Director of Fisheries
Inspection of FAD materials available
Inspection of Nanumanga bottom-contour map (result of survey conducted by TFD staff) and identification of suitable FAD site
Calculation of mooring rope and supplementary buoyancy

Saturday, 25 May 1996

Construction of Nanumanga FAD—practical training sessions

Monday, 27 May 1996

Construction of Nanumanga FAD—practical training sessions

Tuesday, 28 May 1996

Arrangement and preparation of vessel deck ready for FAD materials
Loading of FAD materials onto F/V *Manaui*

Wednesday, 29 May 1996

Installation and testing of survey equipment
Vessel maintenance

Thursday, 30 May 1996

Preparation and loading of vessel supplies
Departure from Funafuti for outer islands

Friday, 31 May 1996

Steaming to Nanumanga Island

Saturday, 1 June 1996

Arrive Nanumanga Island
Consultation with Nanumanga Island Council members
Deployment of Nanumanga Island FAD before departing for Nui Island

Sunday, 2 June 1996

Steaming towards Nui Island

Monday, 3 June 1996

Arrival at Nui, conduct of site survey straight away
Departure from Nui for Nukufetau Island

***Tuesday,* 4 *June* 1996**

Arrival at Nukufetau Island, conduct of site survey straight away
Depart Nukufetau for Funafuti

***Wednesday,* 5 *June* 1996**

Start construction of FAD for N ukufetau-practical training

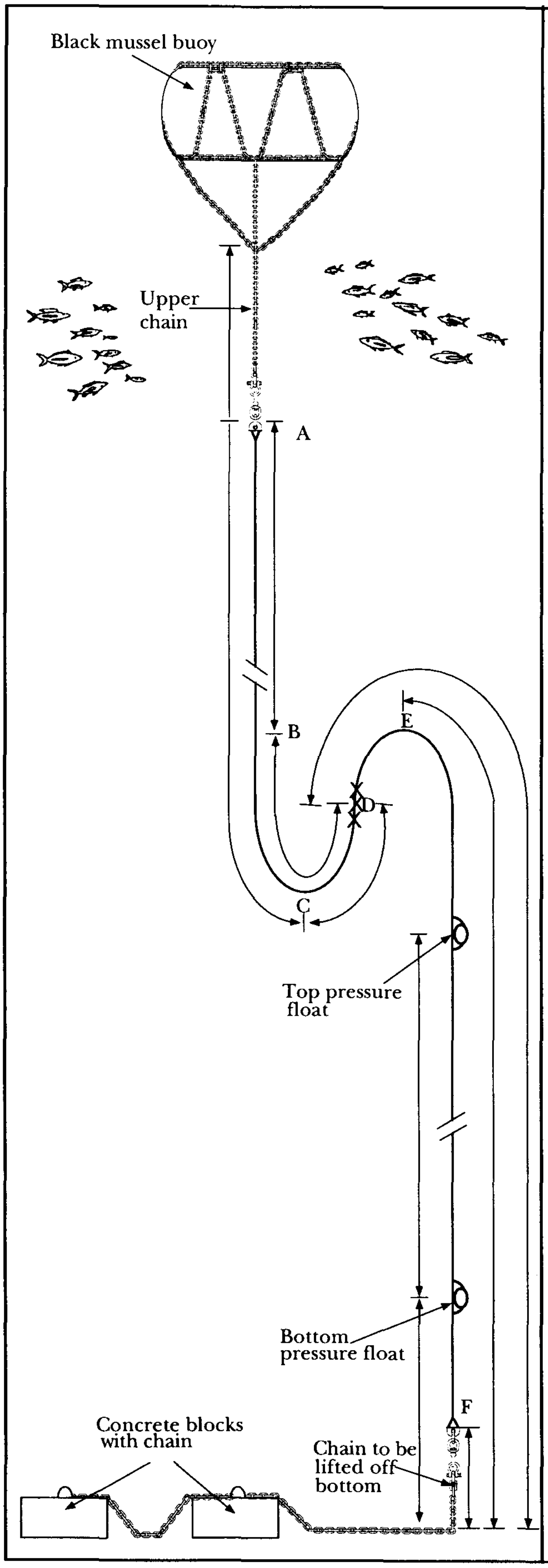
***Thursday,* 6 *June* 1996**

Continue with construction of Nukufetau Island FAD
Review of two weeks' activities

***Friday,* 7 *June* 1996**

Packing of survey equipment
Final briefing with the Director of Fisheries Depart
Tuvalu

SAMPLE WORK SHEETS FOR MOORING-ROPE AND BUOYANCY CALCULATIONS



Rope buoyancy calculations:

From calculations below, EF = m

Weight of 1 m of rope in air = kg

.... m of rope supports .... % of its weight in sea-water (multiply by .....)

Buoyance of rope = ... x .... x ....

= ....kg

Rope length calculations:

AB = Site depth – (EF + ... m + ... m)

= .... m – .... m

= .... m

BC and CDE = $\frac{\text{Site depth x .....}}{2}$

= $\frac{\text{..... m x .....}}{2}$

= .... m (rounded down)

ABCD = AB + BC + CD

= .... m + ... m + ... m

= .... m

DEF = DE + EF

= .... m + ... m

= .... m

ROPE SECTIONS		**VERIFICATION**	
Upper chain	.... m		
AB	.... m	Site depth	.... m
BCD	.... m		
DEF	.... m	Catenary curve	.... m
Lower chain	.... m		
TOTAL	.... m	**TOTAL**	.... m

Supplementary buoyancy calculation :

Weight of .... m of hardware in air = ... kg

Steel weighs .... % of its weight in sea-water

Weight of hardware in sea-water = ... x ....

= .... kg

Buoyancy of rope EF = ... kg of hardware

Supplementary buoyancy needed = ... – ....

= .... kg

Pressure floats (.... m) available had .... kg of buoyancy, so .... floats were needed

Placement of top and bottom float:

Top float located just below catenary curve

= .... – .... – .... (.... % safety factor)

= .... m from bottom (or .... m from rope splice)

Bottom float located at .... % of its depth rating

.... – .... = ... m from bottom

Site Name: **PRELIMINARY INFORMATION**		
Recommended minimum lengths appear in 2, 3 and 4, below		
Site depth	(1)	
Length of upper chain/cable	(2)	15 m
Length of nylon rope from upper chain to catenary curve	(3)	150m
Length of hardware/chain to be lifted off the seabed	(4)	3m

ROPE CALCULATIONS	
(1) Length of nylon rope from upper chain to catenary curve (AB):	
(2) Length of catenary curve (BCDE): preliminary calculation: 20 % of site depth BCDE = site depth x 0.2 =	 .... x 0.2 = ... m
(3) Length of nylon in the catenary curve (BCD): preliminary calculation: 75% of catenary curve BCD = BCDE x 0.75 =	 .... x 0.75 = ... m
(4) Total length of nylon (ABCD): ABDC=AB+BCD=	.... + ... = ... m .... + ... = ... m
(5) Length of polypropylene in the catenary curve (DE): preliminary calculation: 25% of catenary curve DE = BCDE x 0.25 =	 .... x 0.25 = ... m
(6) Length of polypropylene segment (EF): EF = site depth - (upper chain + AB + 3 m lower chain) EF= EF=....m	 .... - (.... + ... + ...)
(7)Totallength of polypropylene (DEF): DEF = DE + EF =	 .... + ... = ... m

Now that the lengths of ropes for the mooring have been calculated, determine whether there is sufficient buoyancy in the polypropylene segment (EF) to lift 3 metres of hardware/chain off the seabed.

BUOYANCY CALCULATIONS

Weight in air of bottom hardware:
3mchain: ....kg
1 swivel: ....kg
2 shackles: ....kg
Total weight in air: ....kg

Weight in seawater of 3 m of bottom hardware:

Weight in seawater = weight in air x 0.867
Weight in seawater =............. x 0.867 =........ kg

Calculation of weight to be lifted off the seabed plus a 5 kg safety margin

Weight to be lifted = weight in seawater + 5 kg safety margin
Weight to be lifted =........... + 5 kg =..........kg

Weight in air of polypropylene: either weigh a minimum of 30 metres of polypropylene or use rope specifications given by supplier:

Weight in air of 1 m polypropylene = $\frac{\text{weight of roge}}{\text{length of rope}}$ =
Weight in air of 1 m polypropylene = ... kg/m

Buoyancy in seawater of 1 m polypropylene:

Buoyancy in seawater of polypropylene = weight in air x 0.116
Buoyancy in seawater of polypropylene = ...x 0.116 = ...kg/m

---

Buoyancy of the polypropylene segment (EF) that lifts the bottom hardware:

Buoyancy = length of polypropylene (EF) x buoyancy in seawater of polypropylene
Buoyancy = ... m x....... kg/m =.........kg

Calculations to determine the needs for supplementary buoyancy:

Weight to be lifted =........... kg
Buoyancy of polypropylene segment (EF) =.................kg

If buoyancy of EF is ~ than weight to be lifted: supplementary buoyancy is necessary.

Complete supplementary buoyancy calculations (see next page).

SUPPLEMENTARY BUOYANCY CALCULATIONS

Calculation supplementary buoyancy:

Supplementary buoyancy = weight to be lifted -buoyancy of polypropylene (EF)

Supplementary buoyancy =...............kg — ......kg = ...kg

(1 litre of buoyancy lifts **1** kg of weight)

Float information: brand, size, type	**Buoyancy**	**Rated depth**

Number of floats needed to supply supplementary buoyancy:

Number floats = Sunnlementary buoyancy =.....................floats
Float buoyancy

CALCULATIONS FOR PLACEMENT OF FLOATS ON POLYPROPYLENE SEGMENT(EF)

1) Calculation for placement of shallowest float on EF:
(shallowest float must be below the bottom of the catenary curve)

Distance from the bottom hardware to the shallowest float:

Distance = EF – (50% of catenary curve BCDE) – 30 m safety margin
Distance = … – (0.5 x...............) – 30 m = ...m

2) Calculation for placement of deepest float:

Maximum depth for deepest float = ½ x depth rating = 0.5 x......................=....... m

Placement of deepest float =
Site depth – (3 m bottom hardware + maximum depth for deepest float)

Placement =… – (3 m + .) =..... m

Floats should be placed anywhere on EF between calculation (1) and (2)