

**CAPTURE SECTION REPORT OF FISH AGGREGATING
DEVICE (FAD) SITE SURVEYS, CONSTRUCTION AND
DEPLOYMENT ASSISTANCE TO THE REPUBLIC OF NAURU**

4 April—2 May 1990;

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14—23 November 1997

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‘Pacific Community’ is the new name of the South Pacific Commission (SPC).

The new name became official on 6 February 1998, in commemoration of the 50th anniversary of the 1947 Canberra Agreement which originally established the SPC.

The change of name does not alter all the established SPC acronyms, but their meanings are modified.

‘Pacific Community’ applies to the total organisation, i.e, the member governments, the Conference, the CRGA and the Secretariat.

‘Secretariat of the Pacific Community (SPC)’ refers to those who provide the service to members of the community.

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SUMMARY

This report is a consolidation of activities carried out from 1990 to 1997 in the Republic of Nauru by the South Pacific Commission (SPC). Three Masterfishermen were involved. the work carried out in Nauru following specific requests for assistance from the Government of Nauru.

The first visit, conducted by consultant Masterfisherman Paul Mead, focused on surveying areas around the island of Nauru to depths of up to 1,500 m for suitable fish aggregating device (FAD) deployment sites. The areas to be surveyed were identified by local fishermen, as areas where tuna schools were frequently located. The Nauru Phosphate Corporation (NPC) assigned one of their launches with skipper to the project for the survey work. After the survey was completed and the soundings plotted, three sites were identified as being suitable for deploying FADs. Following this project, the SPC worked with the Department of Island Development and Industry (IDI) in compiling a list of materials required for constructing three FADs including the buoys.

In 1991, with all of the necessary materials in Nauru, Masterfisherman Paxton Wellington was assigned to Nauru to construct and deploy three FADs. The same NPC launch was used for initial confirmation survey work in the three areas previously identified. With a shortage of launch availability due to the imminent arrival of a cargo vessel, NPC provided three launches so that all three FADs could be deployed in one day.

The FADs stayed in place with the last going missing after 18 months. The FADs aggregated some fish initially, but they were not as successful as hoped. It was agreed that these FADs were deployed too close to shore (all were around 1 nm offshore) so the SPC was requested to come and conduct site surveys further offshore in deeper water.

Masterfisherman Peter Watt was assigned to Nauru in 1993 to undertake this survey work. Using a new echo-sounder that was purchased for the project, surveys were conducted in depths from 1,500—2,600 m, the actual working depth of the new echo-sounder. NPC provided the same launch for the survey work. A contour map of the island was produced following the survey with one likely FAD site identified at a depth of 2,600 m. Following this work the IDI identified two other likely sites from the survey map and ordered the necessary materials according to the SPC-recommended design.

Masterfisherman Peter Watt was again assigned to Nauru in 1997 to undertake the deployment of three FADs. Transect site surveys were conducted using the Nauru Fisheries and Marine Resources Authority's (NFMRA) new vessel F/N *Dogua*, at the three locations chosen, to select the actual position for each FAD. NFMRA hired an NPC launch and barge for the FAD deployments. When the sites were confirmed, two Indian-Ocean-style FADs were deployed from the barge in one day in depths of 2,450 m. The following day, a sparbuoy system was deployed in a depth of 1,500 m.

Two months after the deployments, good catches of small tunas were recorded which indicated that the FADs further offshore were possibly going to be more productive than the earlier FADs that were closer to shore. NFMRA is closely monitoring the catch to gather economic data that can be used to assess the benefits of the FADs over time.

RÉSUMÉ

Ce rapport récapitule des activités menées entre 1990 et 1997 dans la république de Nauru par la Commission du Pacifique Sud (CPS). Trois maîtres de pêche ont participé aux opérations conduites à Nauru, suite à des demandes expresses d'aide adressées par les autorités de cet État.

Sous la direction du maître de pêche intervenant en qualité d'expert-conseil, Paul Mead, la première mission a eu pour objet la recherche, autour de l'île de Nauru, de sites appropriés pour le mouillage de dispositifs de concentration du poisson (DCP), par des profondeurs allant jusqu'à 1 500 mètres. Ce sont les pêcheurs locaux qui ont désigné les zones à prospector, des zones où évoluent fréquemment des bancs de thons. La Nauru Phosphate Corporation (NPC) a affecté une de ses chaloupes et un pilote aux études de sites prévues dans le cadre du projet. Une fois ce travail terminé et les mesures de la profondeur effectuées, trois sites ont été retenus pour y mouiller des DCP. Suite à ce projet, la CPS a collaboré avec le Department of Island Development and Industry (IDI) à la compilation d'une liste du matériel nécessaire à la fabrication de trois DCP, y compris les bouées.

En 1991, tout l'équipement nécessaire ayant été réuni à Nauru, le maître de Pêche Paxton Wellington a été détaché à Nauru pour y faire fabriquer et mettre à l'eau trois DCP. La même chaloupe -celle prêtée par la NPC - a été utilisée pour confirmation des opérations de prospection sur les trois zones préalablement reconnues. Étant donné l'arrivée imminente d'un cargo qui allait entraîner une pénurie de chaloupes, la NPC a mis à la disposition du projet trois embarcations armées que les trois DCP puissent être mouillés en une seule journée.

Les DCP sont restés en place et le dernier d'entre eux a disparu au bout de dix-huit mois. Dans un premier temps, ils ont concentré quelques poissons, mais les résultats n'ont pas été aussi satisfaisants que prévu. De l'avis général, ils avaient tous été mouillés trop près du rivage (à environ 1 mille nautique des côtes); la CPS a donc été invitée à venir réaliser des études des sites plus au large, dans des eaux plus profondes.

Le maître de pêche Peter Watt a été détaché à Nauru en 1993 pour réaliser ces études de sites. À l'aide d'un nouvel échosondeur acheté à cette fin, elles ont été réalisées à bord de la chaloupe prêtée par la NPC, par des profondeurs de 1 500 à 2 600 mètres pour lesquelles est conçu le nouvel échosondeur. Suite à cette étude, une carte bathymétrique de l'île a été dessinée, un site a été sélectionné pour y mouiller un DCP par une profondeur de 2 600 mètres, et l'IDI, s'appuyant sur cette carte, a défini deux autres sites probables et a commandé l'équipement nécessaire, sur le modèle recommandé par la CPS.

Le maître de pêche Peter Watt a été à nouveau détaché à Nauru en 1997 pour procéder au mouillage de trois DCP. Des études de site le long de transects ont été réalisées à bord du *Dogua*, la nouvelle unité de la Nauru Fisheries and Marine Resources Authority (NFMRA) en trois endroits préalablement choisis, afin de sélectionner la position effective de chacun des DCP. La NFMRA a loué à la NPC une chaloupe et une barge afin de les mouiller. Après confirmation des sites, deux DCP du type océan Indien ont été mis à l'eau depuis la barge en une journée, par une profondeur de 2 450 mètres. Le lendemain, un DCP avec bouée en acier a été mouillé par une profondeur de 1 500 mètres.

Deux mois après leur mise en place, des bonnes prises de petits thons ayant été enregistrées, il est apparu que les DCP mis à l'eau plus au large seraient probablement plus productifs que ceux qui avaient été précédemment mouillés plus près de la côte. La NFMRA suit de près l'évolution des volumes de prises afin de réunir des données économiques qui pourront servir à évaluer les avantages à terme des DCP.

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1. Introduction and Background

This report is a consolidation of activities carried out from 1990 to 1997 in the Republic of Nauru by the South Pacific Commission (SPC). The report documents the changes that have occurred over the years in the procedures used for conducting site surveys. It is also a valuable record of the survey work conducted around Nauru, that can be used for future FAD deployments.

1.1 GENERAL

The Republic of Nauru comprises one land mass (Figure 1). It is a raised limestone island with a total land area of 21.1 km² (Anon. 1992), located between 00° 30' – 00° 34' S latitude and 166° 54' – 166° 58' E longitude. The island is an uplifted coral limestone atoll with a terraced rim, or *makatea*, containing many karsts, caves and sinkholes. There is a narrow coastal strip backed by coral cliffs and a relatively barren plateau interior with extensive deposits of phosphate (Douglas & Douglas 1989). A 50–300 m wide coral 'belt' surrounds the 19-km circumference of the island. This coastal reef is exposed at low tide. Much of the upper plateau has been stripped of vegetation and topsoil by phosphate mining operations; elsewhere soils are thin and calcareous.

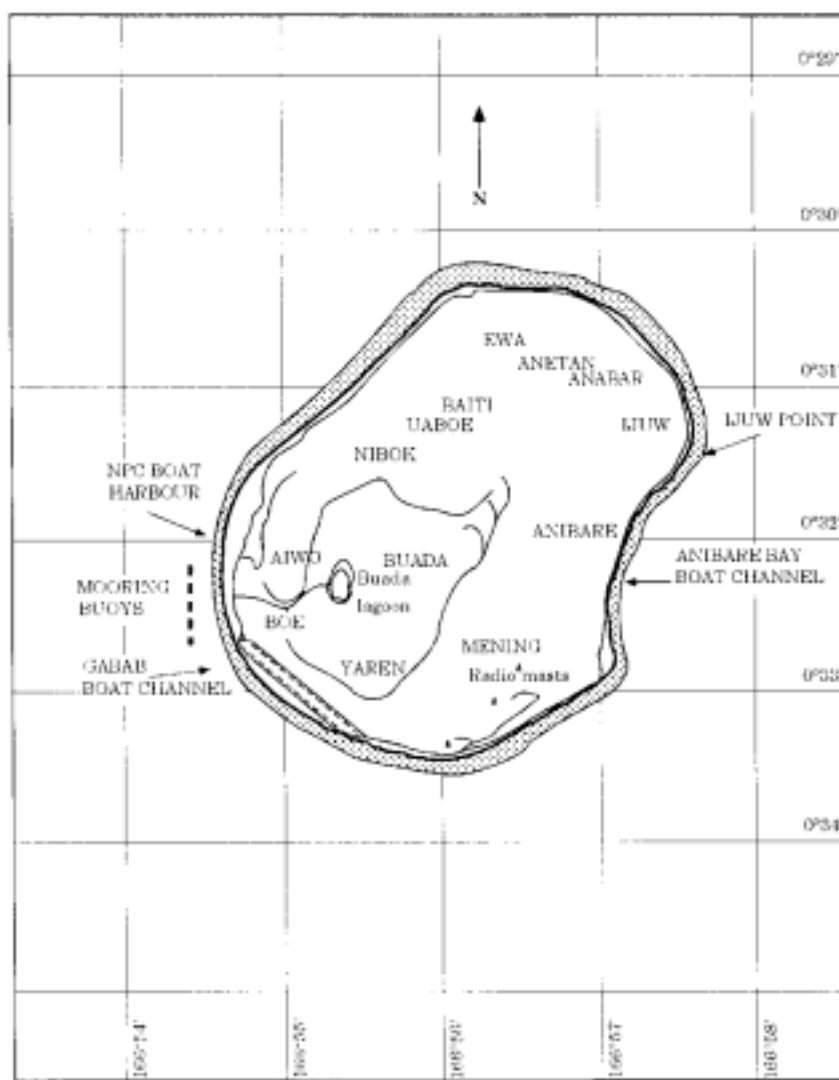


Figure 1: Nauru Island

Some 80 per cent of the total area of the island is phosphate bearing, but a large proportion of this has already been worked. Coconut and pandanus are common along the coastal belt. Coconuts, bananas and some vegetables are cultivated in the area of inland Buada village, where soils are more suitable and water more plentiful (Douglas & Douglas 1989). Apart from some small allotments held by the Government of Nauru, the Nauru Phosphate Corporation (NPC), and missions, the land is individually owned. This includes land mined for phosphate, for which the owners receive compensation and the right to resume use of the land when deposits are exhausted.

Light easterly winds prevail for most of the year, although between November and February conditions are variable and strong westerly blows are common. This period is generally the wettest season also. Average annual rainfall is 1,900 mm, but actual rainfall varies considerably and extended periods of drought can occur. The average mean daily temperature is 28° C and relative humidity is high throughout the year (Anon. 1992).

The 1992 census shows the population to be 9,919 people, 69 per cent being Nauruan (6,831 people) and 31 per cent being non-Nauruan (3,088 people, Anon. 1992). The population growth for Nauruans is estimated at 4.26 per cent according to the 1992 census. The currency in Nauru is the Australian dollar.

Economic activity is dominated by the mining industry. Royalties due to owners of mined land are paid into trust funds to ensure a continuing income when mining ceases. In recent years there has been a decline in production as stocks of phosphate become exhausted. With the imminent depletion of phosphate reserves in the foreseeable future, the Nauru Government is closely examining the marine resources available to them and their development potential.

1.2 EXISTING FISHERIES

Domestic fisheries to date have been limited due to there being no natural harbours to moor vessels. To overcome this, three man-made channels and a small boat-harbour have been excavated through the fringing coral belt, allowing sites for the launching of small outboard-powered trailer vessels. A small boat-harbour was constructed in 1904 by the Pacific Phosphate Company. The British Phosphate Commission took control of this harbour facility in 1920, with the Nauru Phosphate Corporation (NPC) taking it over in 1967 (Williams & MacDonald 1985).

There are two main styles of domestic fishing operations in Nauru. Nauruan, I-Kiribati and Tuvaluan fishermen use outboard-powered trailer vessels from 3–7 m, which they launch and haul each time they want to go fishing. The main fishing methods are trolling and shallow-water bottom handlining. Some Nauruans do some spear fishing from their vessels using scuba gear.

The second style of domestic fishing operations is based around fishermen in canoes handlining for tunas in mid-water using the drop-stone fishing method. The fishermen involved in this fishery are from Tuvalu and Kiribati, who fish during their time off from NPC. Fishing is concentrated around the mooring buoys for the phosphate vessels. The mooring-buoy system acts as a very effective fish attractor, and regular catches of rainbow runner (*Elegatis bipinnulata*), yellowfin tuna (*Thunnus albacares*) and wahoo (*Acanthocybium solandri*) are taken there. Cusack (1987) describes this fishery and the aggregating effect of the mooring-buoy system.

In the early 1980s, the Nauru Fishing Corporation was established and two 948 GRT purse seiners were purchased from Peru, with Peruvian skippers, engineers and crew. The commercial fishing venture involving the two purse-seine vessels, F/V *Austin Bernicke* and F/V *Victor Eoaeo*, was not successful due to their nets being too shallow and because markets were lost. Around 1986–87, F/V *Victor Eoaeo* sank off Nauru in a storm. The second vessel, F/V *Austin Bernicke*, was moved to the Philippines in 1987–88 where it was chartered to a local company. It has now been sold (Mr Anton Jimwereiy, pers. comm.).

1.3 INITIATION OF THE PROJECTS AND THEIR OBJECTIVES

The Government of Nauru requested assistance from the SPC on four occasions between 1990 and 1997. The request came as a result of the country's desire to develop and expand domestic fishing operations as a means of future economic growth. Specifically, the government requested assistance in initiating a fish aggregating device (FAD) deployment programme. The Nauru Government's particular concern was to secure technical assistance with the identification of sites offshore of the island which would be suitable for the anchoring of FADs, and with determining the design and material specifications for FAD buoys and moorings suited to local conditions.

The first visit to Nauru was conducted as part of the Deep Sea Fisheries Development Project. Consultant Masterfisherman. Paul Mead, was employed to undertake this assignment, and he worked in Nauru from 4 April to 2 May 1990. The objectives for this project were developed in consultation with the local responsible authority, Nauru's Department of Island Development and Industry (IDI), and were:

- to locate and chart potential FAD sites by echo-sounding;
- to complete a FAD buoy and mooring design suited to local conditions; and
- to prepare an associated list of required materials.

Also at that time it was realised that a follow-up, or second visit, would be required. The second visit would be to construct and deploy FADs at the identified locations around the island once the necessary materials for the moorings arrived on the island.

To complete the second part of the first project, SPC Masterfisherman, Paxton Wellington worked in Nauru from 15-26 October 1991. The objectives for this part of the project were:

- to actually rig three FAD buoys and moorings;
- to deploy the three FADs; and
- to train local personnel in rigging and deployment procedures (with the intention of establishing in Nauru, a competent FAD team capable of taking future responsibility for the project).

Following the successful completion of the first project, the Nauru Government again requested technical assistance from the SPC in 1993. This was prompted by the limited effect of the FADs to aggregate and hold fish. It was felt that the FADs were too close to shore and that FADs deployed further offshore should be trialled. Therefore, this request was to conduct additional site surveys further offshore. Masterfisherman Peter Watt was assigned to undertake the project and he visited Nauru twice, from 6-14 March and 28 April to 2 May 1993. The objectives of this project were:

- to conduct bottom-contour surveys around the island in order to determine whether it was possible to deploy FADs further offshore; and
- to plot potential sites for later relocation and FAD deployments.

In 1997, the Government of Nauru requested technical assistance in the deployment of three FADs. One site was recommended as a result of the previous surveys conducted by SPC in 1993, with the other two sites selected by IDI staff. To assist Nauru, consultant Masterfisherman Peter Watt undertook this assignment from 14-23 November 1997. The objectives of this assignment were similar to those in 1991, being:

- to conduct accurate site surveys at the three locations identified as deployment sites;

- to rig three FAD buoys and moorings;
- to deploy the three FADs; and
- to train local personnel in the method of conducting site surveys, and the procedures for rigging and deploying FADs.

2. Vessels and Survey Equipment

2.1 VESSELS

For the work to be conducted in Nauru, it was necessary to have the use of a reasonably stable and seaworthy vessel with a 24-volt power supply to operate the project's electronic equipment. The only vessels on the island which meet these specifications are directly under the supervision of the Nauru Phosphate Corporation (NPC) Harbourmaster. Following discussions, the Harbourmaster assigned NPC launch No.9 to the project with his most experienced skipper. This vessel was used to some degree during all project visits to Nauru.

NPC Launch No.9 (known as M/V *Erinimon* on the last visit—Figure 2) was a beamy, heavily built steel vessel of approximately 11 m, powered by twin, six-cylinder Caterpillar diesels. The maximum speed of the vessel was 13.5 knots. As this vessel was used for towing barges and for transferring goods to and from ships at anchor off Nauru, it had no electronic equipment at all. Two other launches similar to No.9 were used for FAD deployments during the 1991 visit.



Figure 2: M/V Erinimon at the NPC boat harbour with barge

There were two important restrictions applying to the use of the NPC launch for all projects: adverse weather conditions, and the arrival of ships to discharge or load cargo. The small passage from the boat harbour to the sea becomes extremely rough and dangerous in bad weather, and when ships are loading or unloading, the services of launch No.9 are required for normal docking and cargo duty. (Appendix A gives a more detailed description of the boat harbour, and docking procedures). Weather, especially strong westerlies, did hinder the operations of the project in 1993. However, careful planning around the work schedules.

for the loading and unloading of ships meant that no time was lost due to the NPC vessel being unavailable.

During the 1997 project, an 8 m x 12 m steel barge (see Figure 2) was used to carry and transport the FAD buoys, mooring materials and the anchors to the sites. The area of the barge was sufficient enough to carry two or three FADs at one time. M/V *Erinimon* towed the barge to the FAD sites and it was estimated that the vessel was able to tow the barge with two FAD mooring systems and two 1 t anchors at a speed of 6-8 knots.

Also during the 1997 visit, the newly formed Nauru Fisheries and Marine Resources Authority (NFMRA) provided one of their two new 7 m aluminium-hulled fisheries vessels (Figure 3) to conduct the FAD site surveys and assist in the FAD deployments. The two vessels were manufactured in Melbourne, Australia, and were part of a Technical Assistance Project of Japan's Overseas Fishery Cooperative Foundation (OFCF). The FAD project utilised the F/V *Dogua*, which is powered by twin 115 hp outboard Johnson outboard engines. The two engines provide a maximum speed of 30 knots. The vessel has an enclosed wheelhouse equipped with a JRC echo-sounder and Global Positioning System (GPS with plotter) model JFV-850, a JRC raster scan radar model JMA-2253 and a JRC VFF/FM radio telephone model JMS-25. Due to the lack of a safe harbour the vessel was launched and hauled daily, either with a four-wheel drive vehicle and trailer, or the crane at the Nauru Phosphate Company's wharf. This is a multi-purpose vessel which is utilised for search and rescue, training and research purposes by NFMRA.



Figure 8: The two new 7 m NFMRA search, rescue, research and training vessels

2.2 ELECTRONIC SURVEY EQUIPMENT AND ITS VESSEL MOUNTINGS

SPC echo-sounding equipment was used on all occasions. During the 1990 and 1991 visits a Furuno FCV 362 colour video sounder was used. This is a 2 kW output power unit equipped with both 28 kHz and 50 kHz transducers. It has accurate sounding ability to around 2,000 m. A removable side-mounting system (Figure 4) was fabricated by NPC's boilermaking crew to attach the 28 kHz transducer of the Project's Furuno sounder to the side of Launch No.9 (Figure 5).

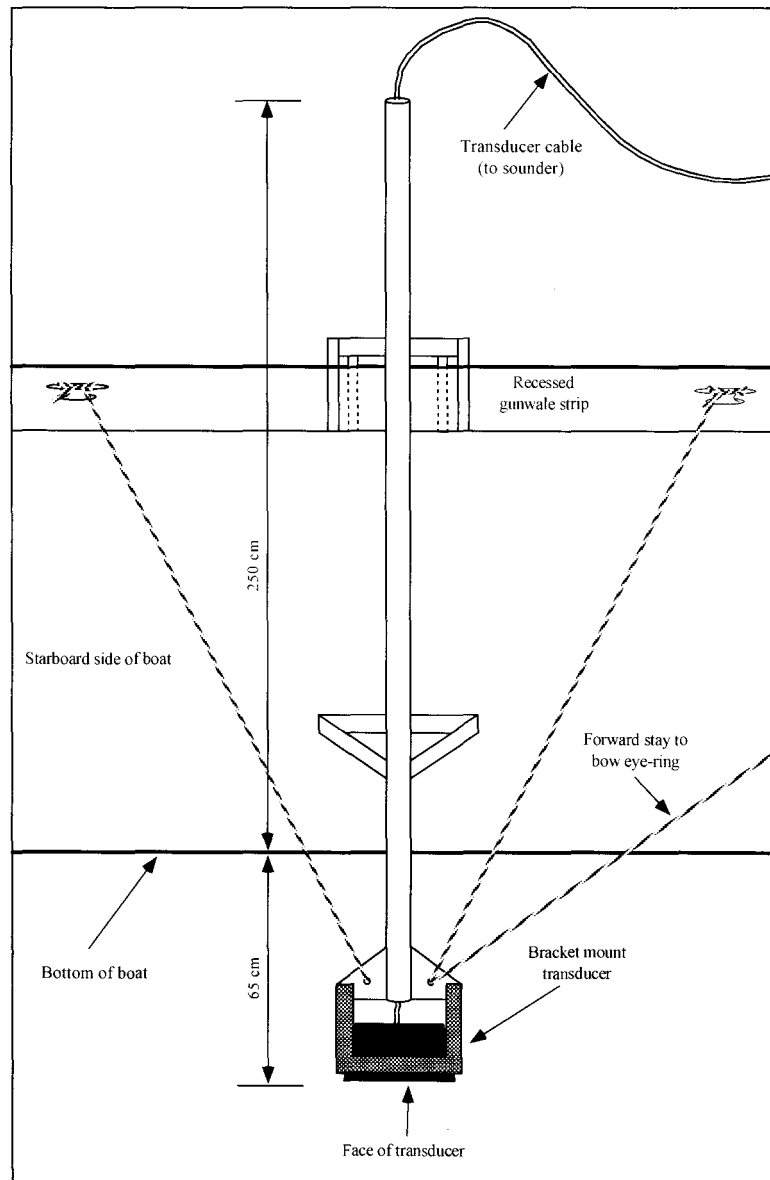


Figure 4: The transducer-mounting bracket designed for Launch No.9

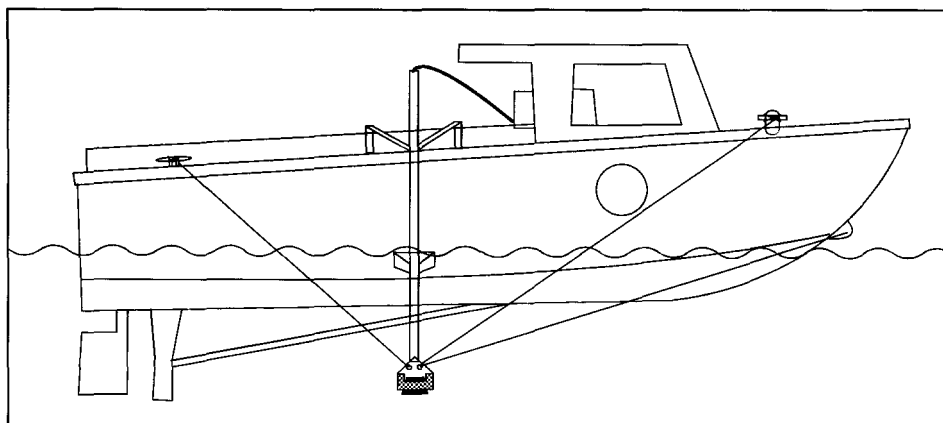
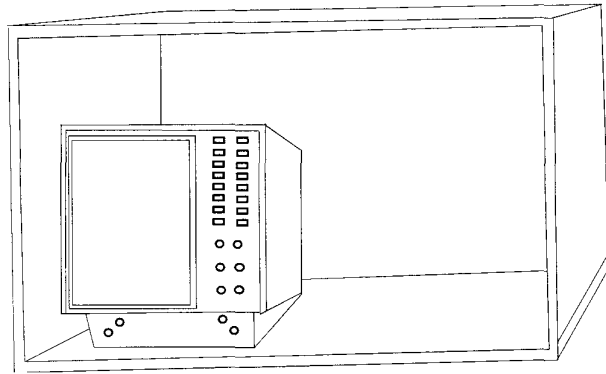


Figure 5: Launch No.9 with the transducer mounted

To protect the echo-sounder monitor when at sea, a weather-proof plywood box needed to be constructed. NPC's woodworking crew built the required box in which the echo-sounder monitor was mounted, with space available alongside for setting out navigation tools and worksheets (Figure 6). NPC's technicians also soldered the fittings on the ends of the echo-sounder's transducer and power cables.

Figure 6: The sounder box with the Furuno FCV 362 in place

During the 1990 visit to Nauru, an electronic hand-held compass for taking bearings from landmarks was used. This unit, an *Autohelm*, had a memory capacity which allowed bearings to be recorded automatically for later transfer to a chart.



A Trimble hand-held personal GPS navigator was used to plot positions during the 1991 visit. The GPS provided more accurate positioning compared to the hand-held compass used during the first visit. The GPS was giving readings accurate to ± 100 m, throughout the time it was used. Internal battery power was used but because alkaline batteries were not available, regular batteries were used, giving only 30–40 minutes of power to a set of 8 ‘AA’ size batteries.

For the 1993 assignment, a new echo-sounder was purchased in Australia and airfreighted direct to Nauru. The unit was a JRC colour echo-sounder model JFV-120, with 3 Kw output-power, equipped with a 28 kHz transducer. The maximum depth-sounding ability of the echo-sounder was 3,000 m. A collapsible aluminium mounting system was made in Noumea (Figure 7) for the transducer, based on the specifications provided by the manufacturer, and carried to Nauru by the Masterfisherman. This system was assembled on station. The only part that needed making in Nauru was the mounting bracket. This was made by NPC staff. Mounting of the transducer on Launch No.9 was done in a similar manner to the earlier visits (Figure 5).

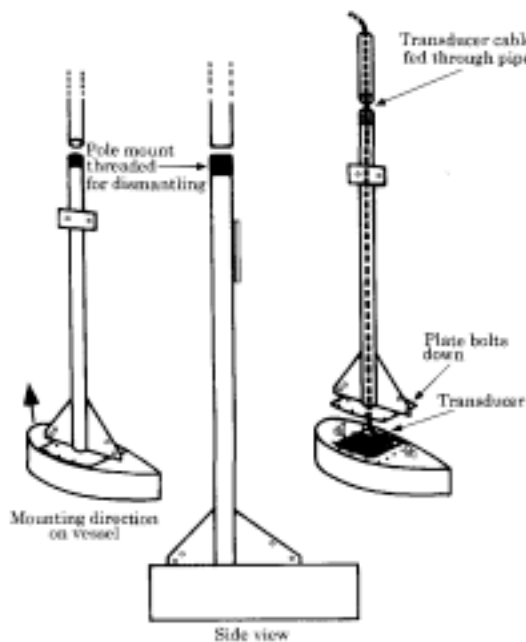


Figure 7: Portable transducer mounting made in Noumea for the project

Two weather-proof plywood boxes were made by NPC carpenters for housing the echo-sounder monitor and the new GPS (model JLR-4110 with plotter function and 500 waypoint memory). The two boxes were constructed with a sliding plexiglass plate in the front as a viewing screen.

In 1997, the same echo-sounder and transducer mounting were used as for the FAD surveys conducted in 1993. The echo-sounder was installed in the wheelhouse of the F/V *Dogua* and was wired to two 12-volt batteries. These two batteries were connected with a cable from one of the battery’s positive terminals to the other battery’s negative terminal to give 24 volts. The 28 kHz transducer was placed in its side-mounting bracket and

lashed aft of the wheelhouse of the F/V *Dogua*. The transducer bracket was secured with three ropes. One end of each rope was tied to the transducer case and the other end of each rope tied to the bow, the stern and the opposite side of the vessel by passing the rope under the hull. Care was taken to secure the mount so that the transducer was positioned vertically to ensure accurate depth soundings. The GPS unit installed in F/V *Dogua* was used for all navigation positioning during site surveys and deployments.

3. Site Surveys

3.1 SELECTION OF INITIAL AREAS TO BE SURVEYED IN 1990

It was agreed that the first survey efforts would concentrate on those areas locally regarded as consistently productive tuna-fishing grounds. Suggested areas for investigation had been marked on a chart provided to the consultant by the SPC Fisheries Development Officer at the time, who had some knowledge of traditional tuna fishing areas around the island through his former residence there. The Senior Project Officer confirmed that most of the fishing areas designated on the SPC chart were usually productive for tunas and other pelagic fishes. It was decided that these areas should be the first ones investigated.

3.2 SURVEY WORK CONDUCTED IN 1990

On the way to the first survey location, Ijuw Point, the northern extremity of Anibare Bay, the operation of the echo-sounder was tested. During this time a problem became apparent. Launch No.9 was not fitted with a mounted compass, and as the compass carried by the consultant Masterfisherman had been broken in transit to Nauru, the *Autohelm* handheld compass was the only directional device available. The *Autohelm* was found to suffer considerable magnetic deviation due to the steel boat. To overcome this, compass bearings were taken from several different positions on the boat and, after considerable trial-and-error, a position was located at the stem where near-zero deviation was experienced. All later compass bearings used for plotting sounded sites were taken from this position.

In order to obtain a general idea of the depth contours in a particular area the launch was run offshore in a fairly straight line by first locating two obvious marks on shore, usually one on the foreshore and the other higher up, which could be lined up to give a line of position. The boat was then run offshore with care taken to keep the two objects aligned and to maintain a constant boat speed. After this system was working properly, soundings and bearings were noted every 3–4 minutes. The usual procedure was to take two bearings, move back to the sounder, note the depth and time, write down the two bearings with the depth in metres and the time they were taken. After a couple of hours of practice this procedure became routine. On each line of position run offshore, care was taken to take each bearing from the same two shore-side marks for the entire run. By always using the same two landmarks, and always taking the bearings from left to right, confusion was avoided when writing down the compass readings. Shore-side marks from which bearings were taken are shown in Figure 8.

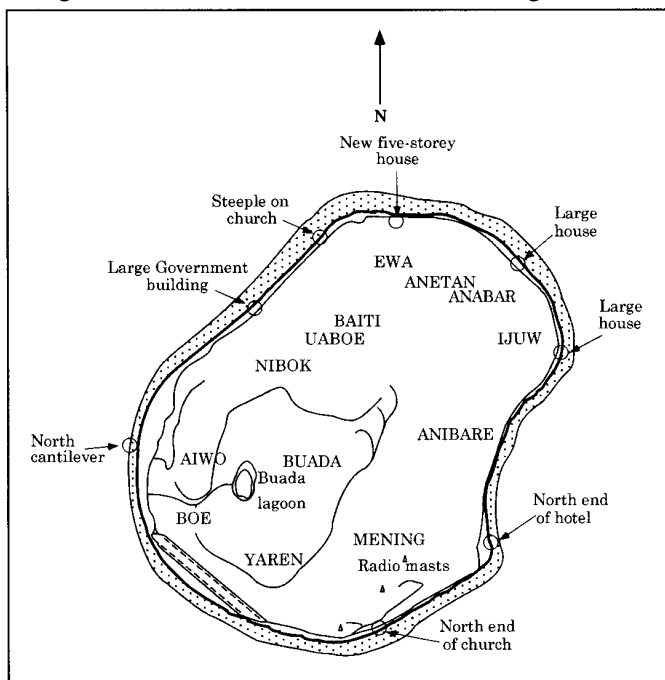


Figure 8: Landmarks used to plot bearings during echosounding surveys

A simple worksheet (Appendix B) was designed for recording the landmark bearings taken. It was found to be more efficient to complete the worksheet, and keep basic notes while at sea, than to attempt plotting the soundings on the chart at that time. Bearings, time, depth, and approximate position were noted on worksheets, but the soundings were plotted on a chart later, on shore. The positions, with depth noted, were plotted on a simple chart by using the estimated speed of the boat and steaming time along a line of position.

3.2.1 *Survey results: day one*

Soundings taken during the first day at sea aboard Launch No.9 were plotted on a chart (Figure 9) made up by enlarging the Nauru section of British Admiralty Chart No. 979 and photocopying a compass rose onto it. This was the only navigation chart of Nauru available with soundings on it. However, all soundings given on chart No. 979 were located within a half mile of the boat harbour. No other information concerning depths offshore of the island were located. The only bathymetric data available was in a paragraph in Anon. (1969) relating to the depths being around 275 m at a distance of one half mile off the coast. This was found to be incorrect as the survey showed the depth to be around 730 m at this distance from shore.

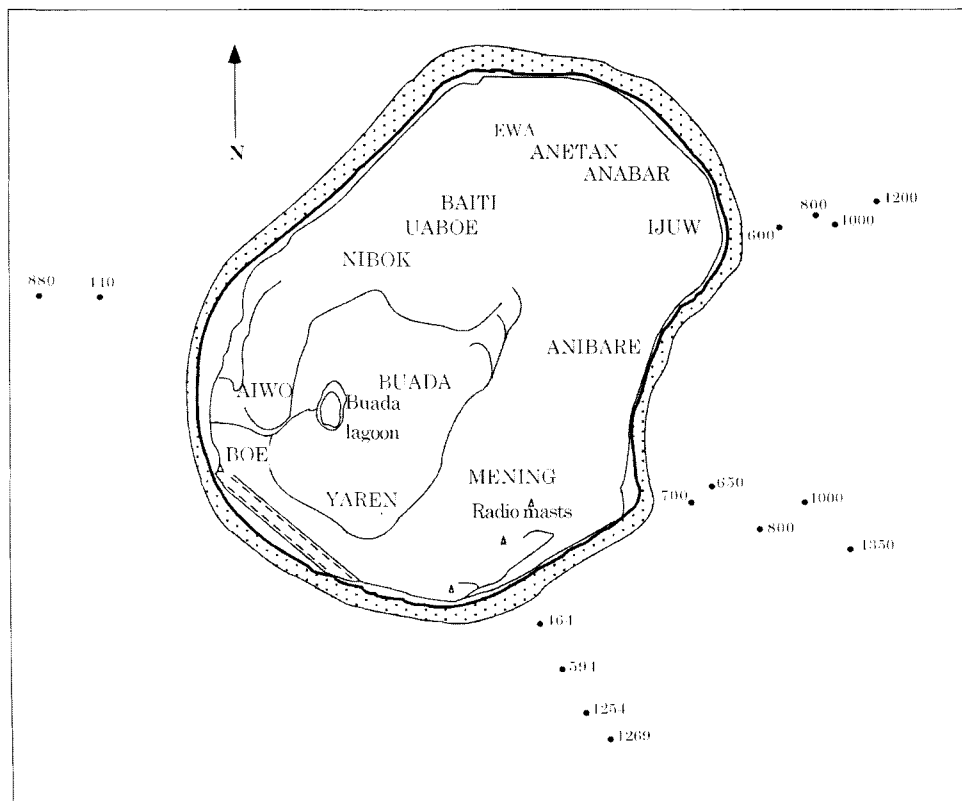


Figure 9: Soundings recorded during the first day's survey work

3.2.2 *Survey results: day two*

Due to experience gained on the first day of surveying, only one more good day at sea was required to provide enough depth recordings for the eastern side of the island to complete the survey. This work was completed and the soundings plotted for the second day (Figure 10). A rough contour map was then produced based on all of the recorded soundings (Figure 11).

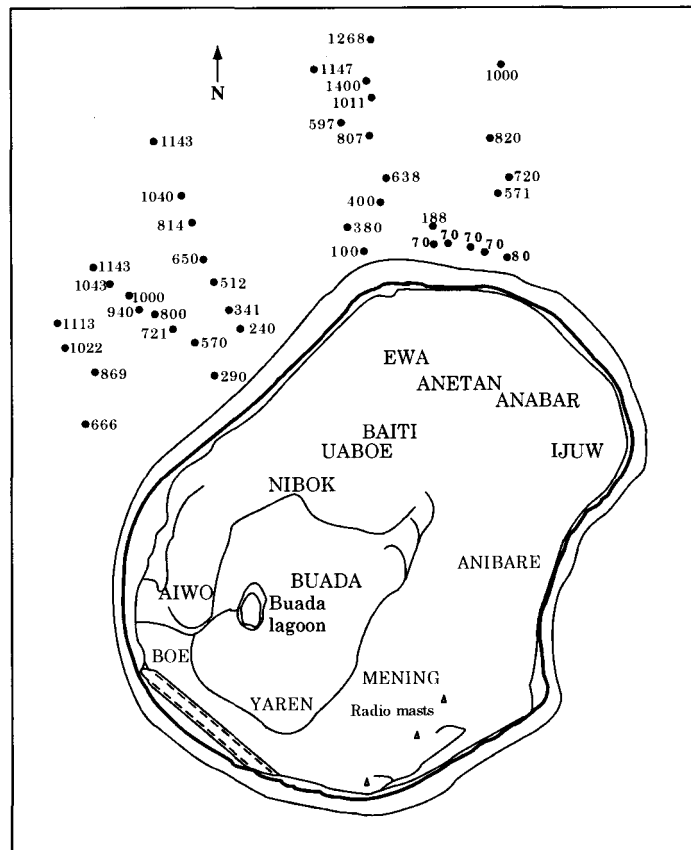


Figure 10: Soundings recorded during the second day's survey work

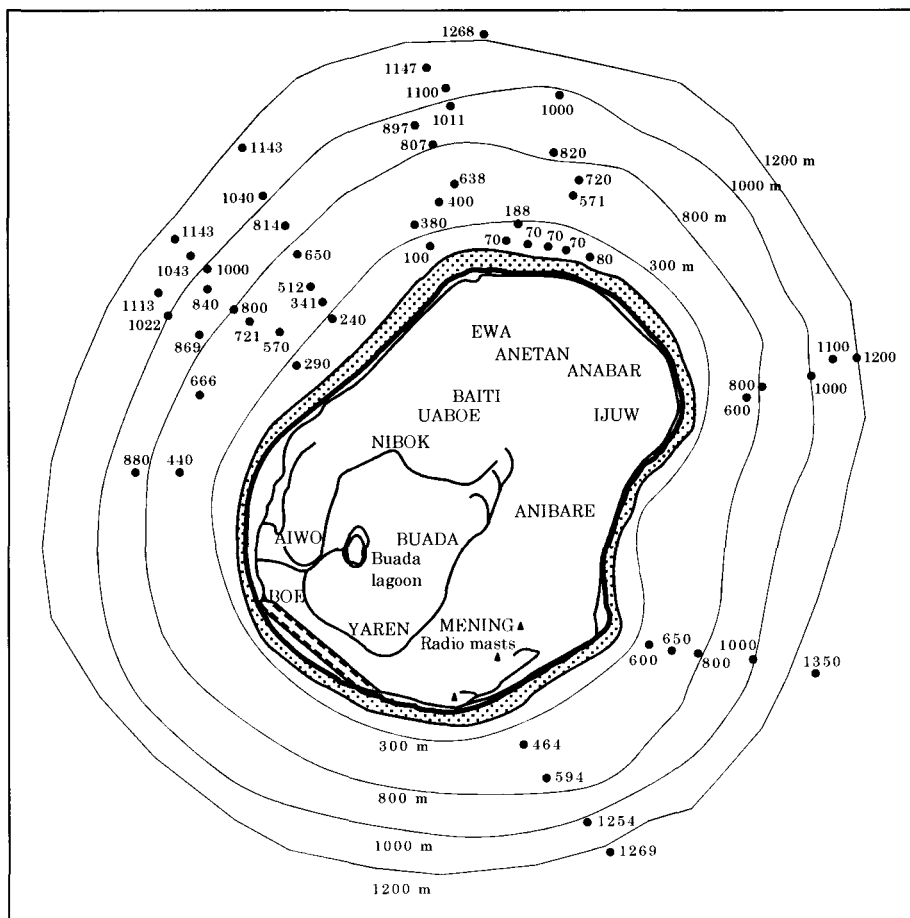


Figure 11: Rough bottom-contour map drawn from the recorded soundings

3.2.3 Results of the echo-sounding survey

It had become apparent during the echo-sounding surveys that down to the 800–900 m contour the bottom dropped off rapidly at a near 45° slope. Below this depth there was usually a more gradual slope until approaching the 1,400–1,600 m contours. After 1,600 m the slope in all areas surveyed was extremely steep, probably even steeper than the slope from the edge of the reef down to 800 m. As the project's sounder was rated to a maximum of 2,000 m, no survey work was attempted beyond this depth.

The pattern of bottom slope appeared to be similar at all locations around the island where soundings were taken and only slight variations occurred. The slope from the edge of the reef to the 800 m contour was steeper along the south and east side of the island than along the north and north-west side. A graphic representation of the bottom slope at survey areas A, B, and C, is given in Figure 12. Note that areas A, B, and C are shown in Figure 13.

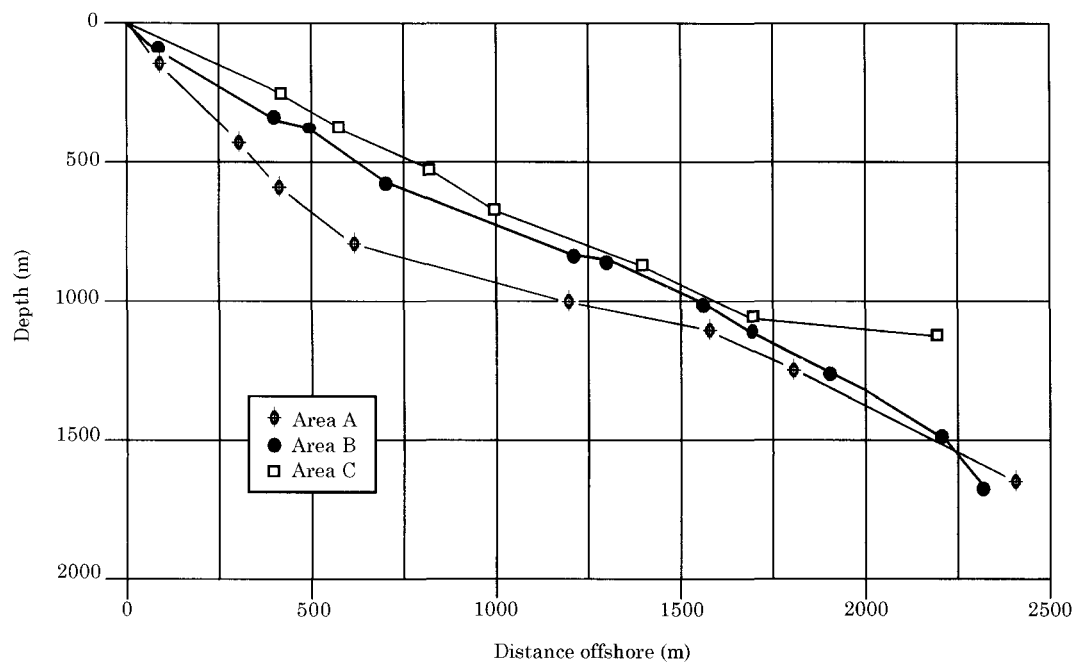


Figure 12. Bottom profile of survey areas A, B, and C.

3.2.4 Selection of FAD sites

Once the soundings were completed and plotted on the chart, three primary areas were selected as proposed FAD sites (Figure 13). The main reasons for selecting areas A and B were the continuous presence, during the consultant's stay, of relatively large surface schools of mixed yellowfin tuna (*Thunnus albacares*) and skipjack tuna (*Katsuwonus pelamis*). Discussions with local fishermen confirmed that this was usually true. Area C was chosen for mostly the same reasons, but also because it was off the edge of an obvious current line which runs out off the NW point and because the area is partially sheltered from SE winds.

In each of these areas the most gradual offshore slope, the best place to get an FAD anchor to hold, lay between the 1,000 and 1,200 m contours. These depth contours lay between the steeper inshore slope, which generally fell off rapidly from the edge of the reef down to 800 m, and the very steep outer slope which began at around the 1,600 m contour and dropped off rapidly to depths exceeding 2,000 m. Ideally, the area south of area D would be an excellent area for an FAD as it is sheltered from easterly winds, but Nauru has fairly continuous shipping which usually approaches and departs through this area. The harbourmaster had requested that an area roughly corresponding to that enclosed by the shaded area in Figure 13 be kept clear of FADs which could interfere with shipping.

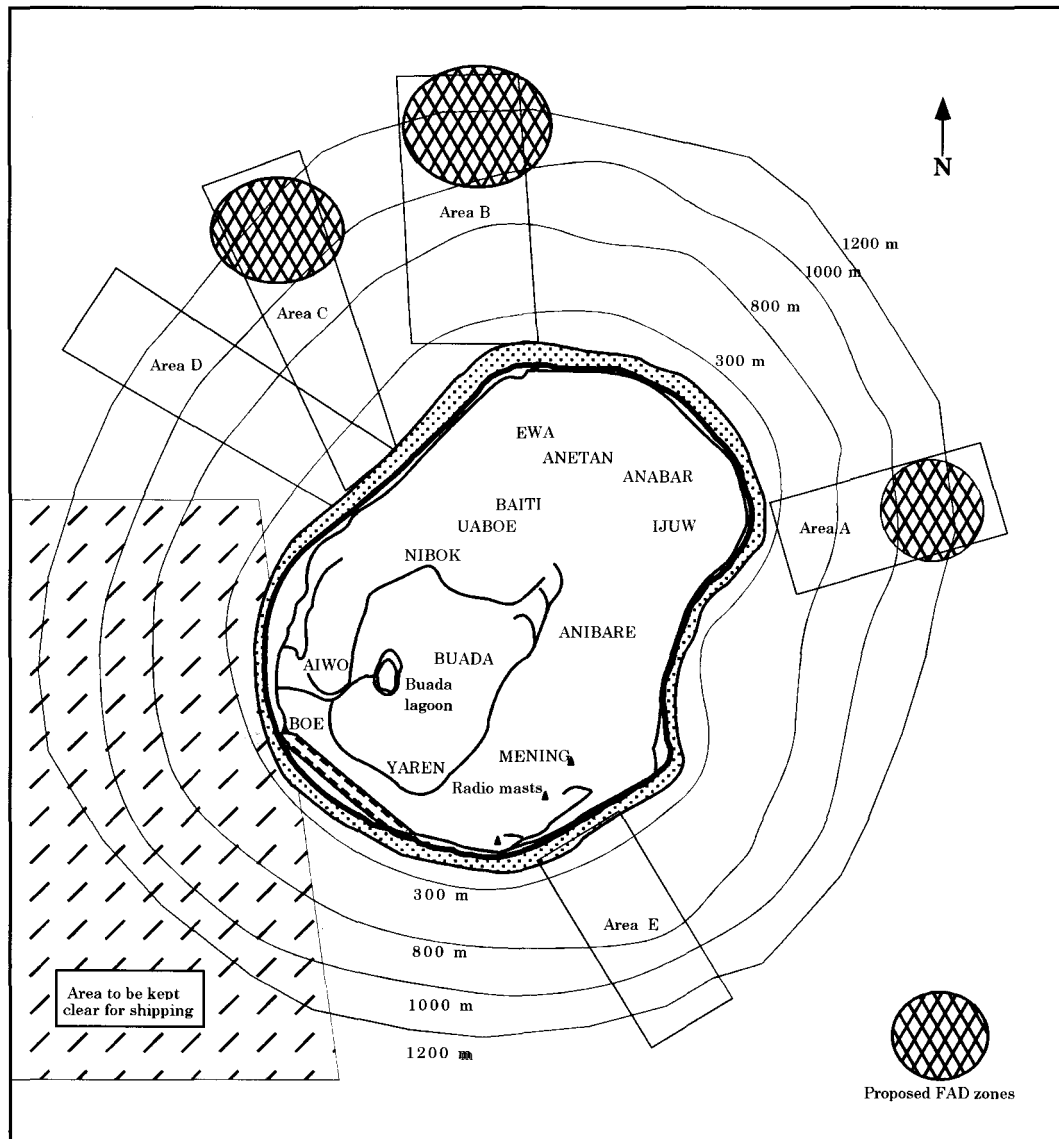


Figure 13: Proposed FAD sites selected after sounding survey

Other major features which were common to all sites, were the close proximity of the areas to the steep drop-off into depths exceeding 2,000 m, and the type and size of the typical vessel used for fishing offshore in Nauru. Having the FADs anchored near the deep water could have the fish-attracting advantage of a deep-water FAD, without the added expense of the rope required to anchor an FAD in 2,000 m or deeper. As the proposed FAD sites were approximately 1 nm offshore, they would, if equipped with a 3 m mast and radar reflector, be visible from small boats cruising just off the reef.

3.3 ADDITIONAL SURVEY WORK CONDUCTED IN 1991

NPC Launch No.9 was being used for other duties and because of this busy schedule, the Harbourmaster advised that the boat would be free for a period of only 1.5 days during the time the Masterfisherman was in Nauru. It was therefore decided to confirm positions and depths from the previous survey using the half day which came in the afternoon, and to set the three FADs the following day.

Forty-four soundings were carried out for the three areas A, B, and C (Figure 13). The depth was noted on paper and the position was stored in the GPS memory as a waypoint number. It was only necessary to note the waypoint number and write the depth

corresponding to it at sea. When on land it was a simple matter to recall the positions from memory and plot the depths on the chart. Waypoint numbers with corresponding depths and position as plotted by the GPS Navigator are presented in Appendix C.

Areas A, B, and C were plotted for latitude and longitude on the chart. Using the GPS, positions were checked for accuracy of location and depth and a position chosen for the deployment at each of the three locations.

3.4 DEEPER-WATER SURVEY WORK CONDUCTED IN 1993

The earlier survey work carried out around Nauru focused on depths to 1,500 m, although some soundings were recorded to 1,800 m. For the 1993 survey work, the echo-sounder used had a rating to 3,000 m. However, during initial use the signal became weak at 2,200 m. After consultations with the manufacturer, the gain control was adjusted and the depth range extended to 2,600 m.

The survey work was to occur in March 1993. However, persistent bad weather made this impossible. During March, weather-proof boxes for project equipment and a mounting clamp for mounting the echo-sounder transducer were made. Dates were set for the Masterfisherman to return (April 1993) to conduct the site surveys.

To record the bottom contours around the island, Launch No.9 was run offshore on a straight line by locating two landmarks on shore which could be lined up to give a line of position. Depths and positions were recorded as the vessel was motored offshore taking care to keep the two objects aligned. As the earlier surveys had focused on depths from 400–1,500 m, this survey concentrated on depths from 1,500–2,600 m. The area northeast and south-east of the NPC boat harbour was omitted from the survey as this is where the cargo vessels regularly approach the island.

An additional bottom-contour survey was conducted at the request of the NPC harbourmaster. The survey consisted of plotting the exact positions and depths of existing mooring buoys for the cargo vessels and the surrounding area. The purpose of the survey was to calculate the exact position where anchors were to be deployed to ensure that the mooring buoys were placed properly for vessels to load and unload cargo. A NPC surveyor supervised running transects within the proposed survey area.

The results of the survey indicate that the bottom contour around the island from 1,550–2,600 m had a constant 30 degree slope. The pattern of the slope was similar at all locations to that of the first survey work from 400–1,500 m. As the project's echo-sounder only sounded properly to 2,600 m, no survey work was attempted beyond this depth, except for on occasion when depths to 2,900 m were reached. The few soundings beyond 2,600 m also indicated no change in the slope. Figure 14 shows the soundings taken and approximate depth-contour lines.

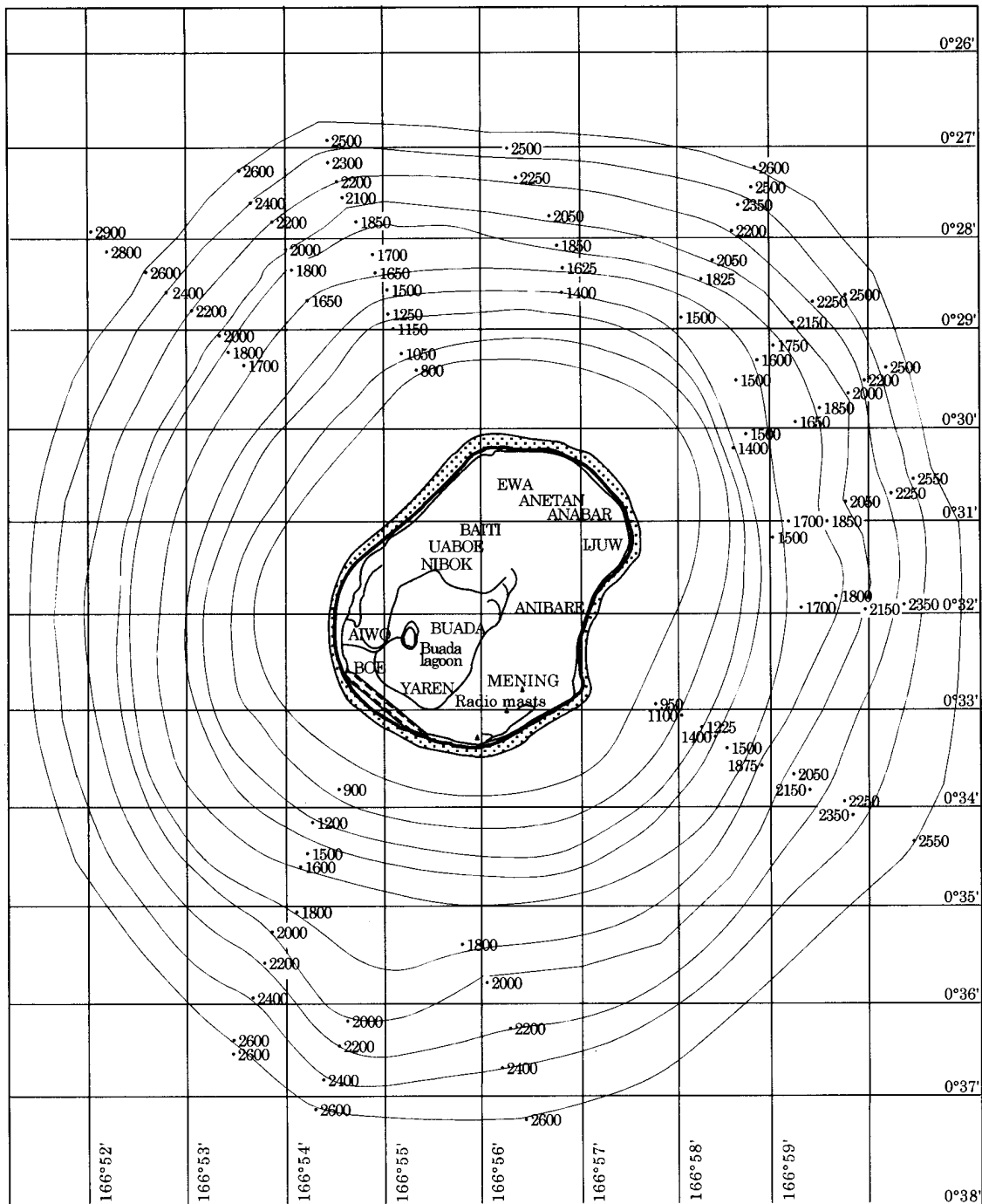


Figure 14: Rough bottom-contour map drawn from the recorded soundings in 1993

One potential FAD site was located approximately 3.5 miles offshore perpendicular to the end of the airport runway at Latitude 00° 36.5' S, Longitude 166° 53.5' E at a depth of 2,600 m. This was the only area where the slope was more gradual. A bottom profile of the survey area (Figure 14) was drafted utilising a map (Anon. 1978, Plate 7) as a reference. The positions recorded by the GPS in reference to the British Admiralty chart were corrected to refer to the map.

3.5 SITE SURVEYS CONDUCTED IN 1997

The senior officers of NFMRA selected three FAD sites (F, G, and H in Figure 17) from the positions and depths recorded around Nauru during the visit in 1993. One of these sites (F) was that suggested at the time of the 1993 visit. Surveys were conducted in a 1–2 nm zone around each selected site to confirm whether the sites were situated on bottom contours suitable for safe deployment of a FAD.

3.5.1 Site-survey method

The method utilised for surveying the FAD sites consisted of following north-south or east-west transects at intervals of 0.25 nm within a 1-2 nm area as shown in Figure 15. At intervals of 0.25 nm along each of these transects the depth was recorded from the echo-sounder onto a plotting chart (graph paper with 20 graduations per 0.25 nm interval). The plotting chart consisted of lines of latitude and longitude spaced apart on a scale equal to 0.25 nm. Care was taken to ensure that the survey vessel remained on the transect line. If for example the vessel was following an east-west transect line of 00° 30.00' S, and the GPS gave a read-out of 00° 30.007' S, this would indicate the vessel was too far south and should be steered north to correct the position along the transect line.

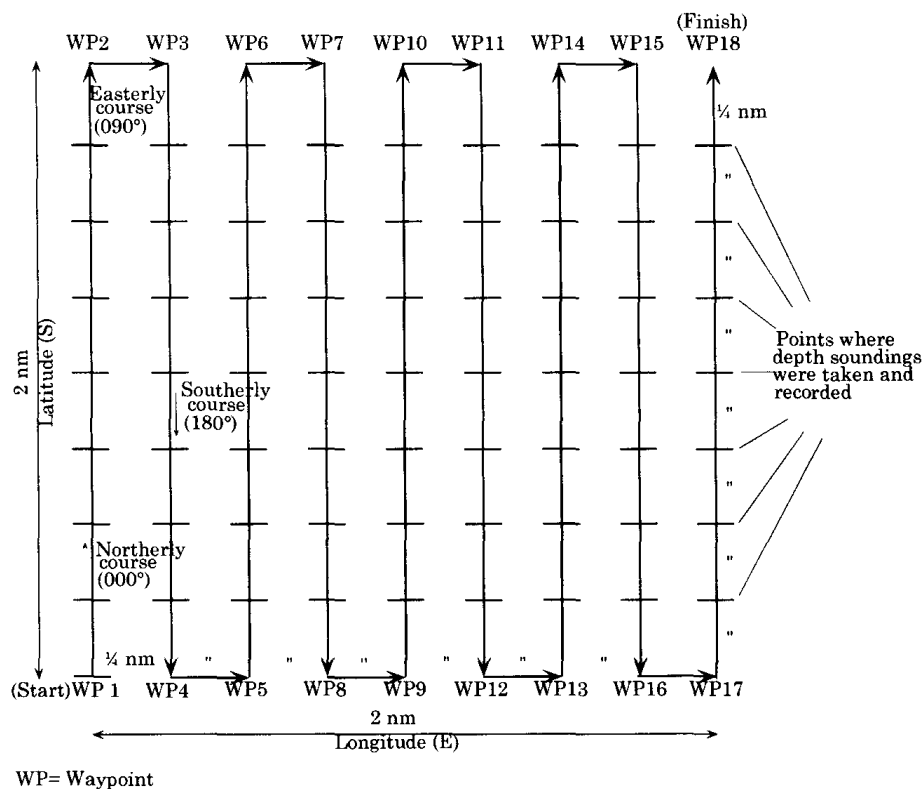


Figure 15: Method of running a transect survey for FAD sites

3.5.2 Interpolating position of contour lines from actual soundings

Once the survey was completed for each site zone the data marked on the plotting chart was interpreted to determine the bottom contour. Contour lines were drawn by connecting same depths recorded at 100 m intervals or deducing the 100 m interval by interpolation when the depths were something other than a multiple of 100 (Petaia & Chapman 1997). The method of interpolating a position is quite simple. For example, increment point 2,100 m between sounding points 2,150 m and 2,060 m is interpolated as follows:

- (a) Subtract the lower sounding from the higher sounding: $2,150 - 2,060 = 90$
- (b) Divide the result by the number of graduations on the graph paper between two quarter-mile soundings, in this case 20 graduations: $90 \div 20 = 4.5$
- (c) Subtract the lower sounding point from the increment point, in this case the 2,100 m isobath: $2,100 - 2,060 = 40$
- (d) Divide the result of (c) by the result of (b): $40 \div 4.5 = 8.8$

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 (2,100 m in this case) should be marked. Figure 16 shows how to interpolate the position of the isobath between two sounding points.

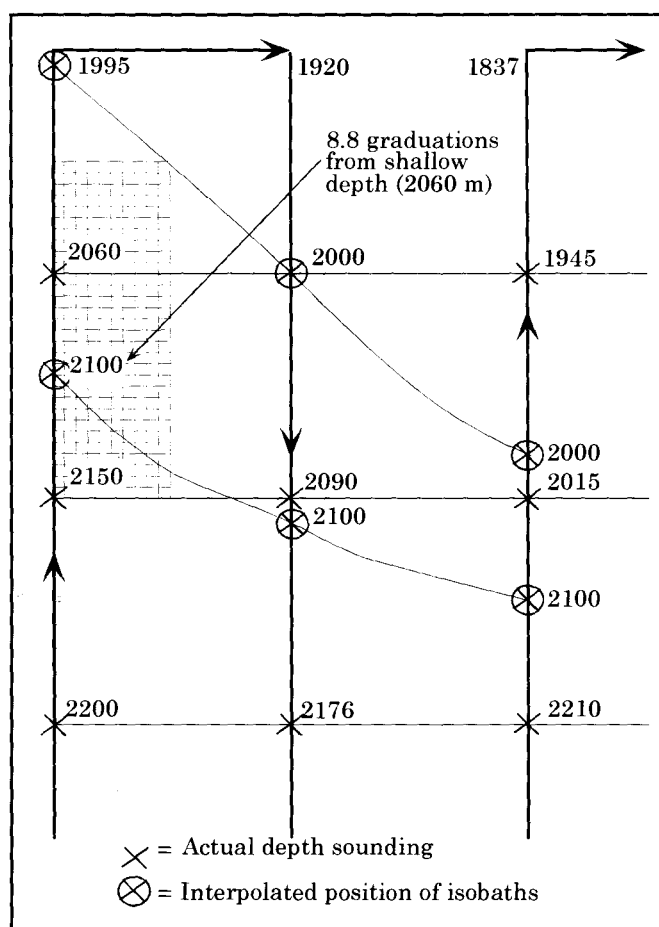


Figure 16: Plotting interpolated contour depth points between actual sounding depths, on graph paper

Once the contour of the seabed in the selected FAD site zone was determined, the flattest area was chosen for deployment.

3.5.3 Results of site surveys

The first FAD site survey was conducted in a 1 x 1.25 nm area surrounding the proposed site position of Latitude 00° 36.50' S, Longitude 166° 53.75' E (site F–Figure 17). The depth of the site was 2,600 m. Five transects were traversed in a north-south direction. While recording the depths and positions along the transects every 0.25 nm, it became apparent that it would be difficult to deploy the FAD in 2,600 m as the echo-sounder was rarely able to record any depths deeper than 2,600 m. Depths recorded along the transects indicated that the bottom contour of the area dropped off after 2,500 m. The FAD site selected within the survey zone was Latitude 00° 36.25' S, Longitude 166° 53.75' E in a depth of 2,500 m (Figure 18). The immediate area surrounding this site was the flattest within the survey area. Another consideration in determining this site was that an echosounder can have as much as a 5 per cent error in recording depths when it has reached maximum range. This meant that there was a possibility of as much as a 125 m error in the depths which were recorded.

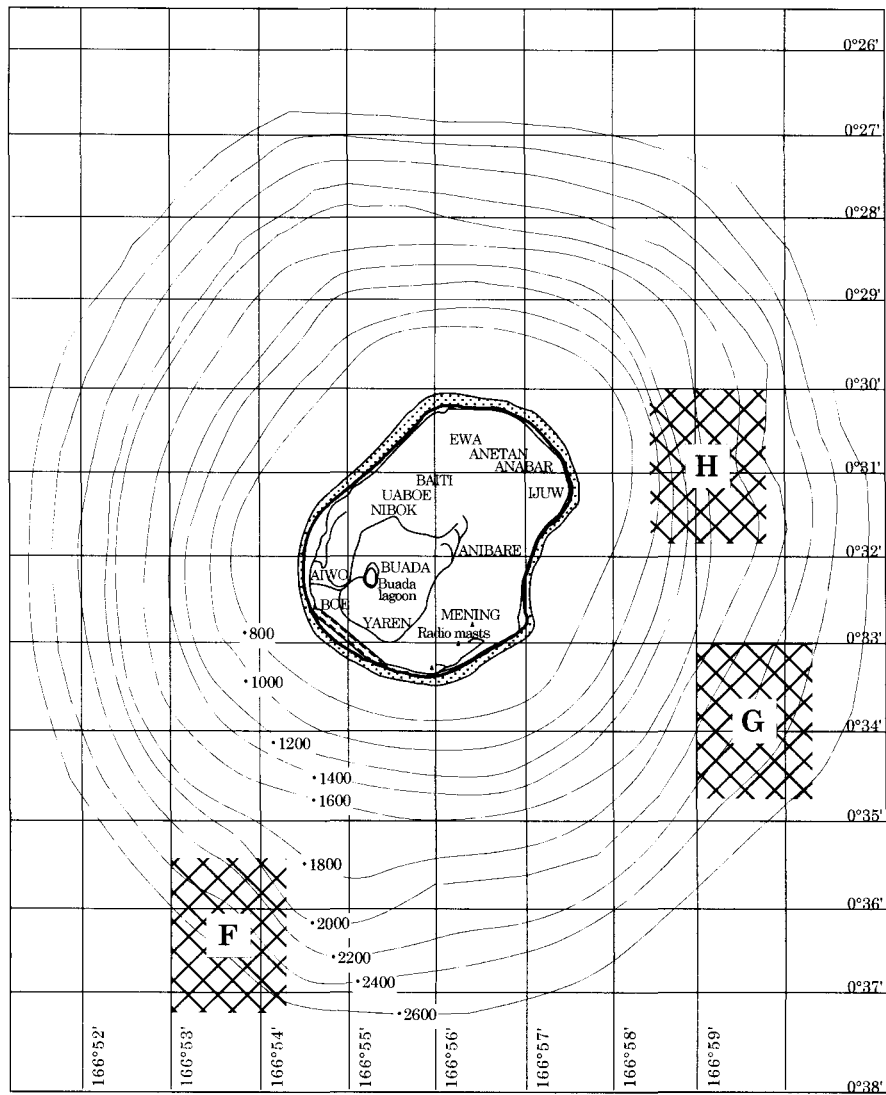


Figure 17: The three areas where site surveys were conducted and the FAD deployment sites selected

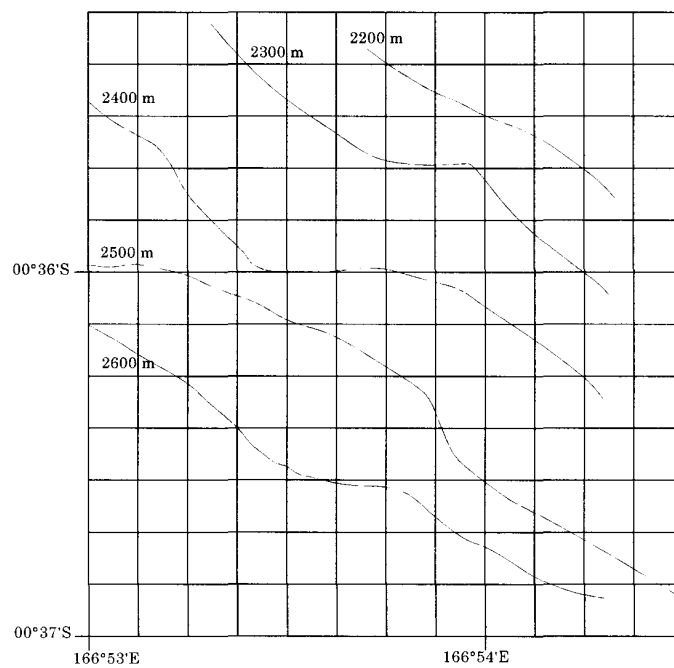


Figure 18: Contour map for survey site F

The second FAD site survey was conducted in a 1.25 x 1.75 nm area surrounding the proposed site position of Latitude 00° 34.50' S, Longitude 167° 00.00' E (site G-Figure 17). The depth of the proposed FAD site was 2,500 m. Six transects were traversed in a north-south direction at 0.25 intervals within the site zone. Similar to the first site survey, the echosounder was not able to record depths deeper than 2,600 m properly. The results of the survey indicated that the bottom contour of the area dropped off steeply after depths of 2,400 m. The FAD site selected within the survey zone was Latitude 00° 34.25' S, Longitude 167° 00.00' E in a depth of 2,400 m (Figure 19). The results of the bottom-contour survey indicated that the area surrounding this site had a gradual slope.

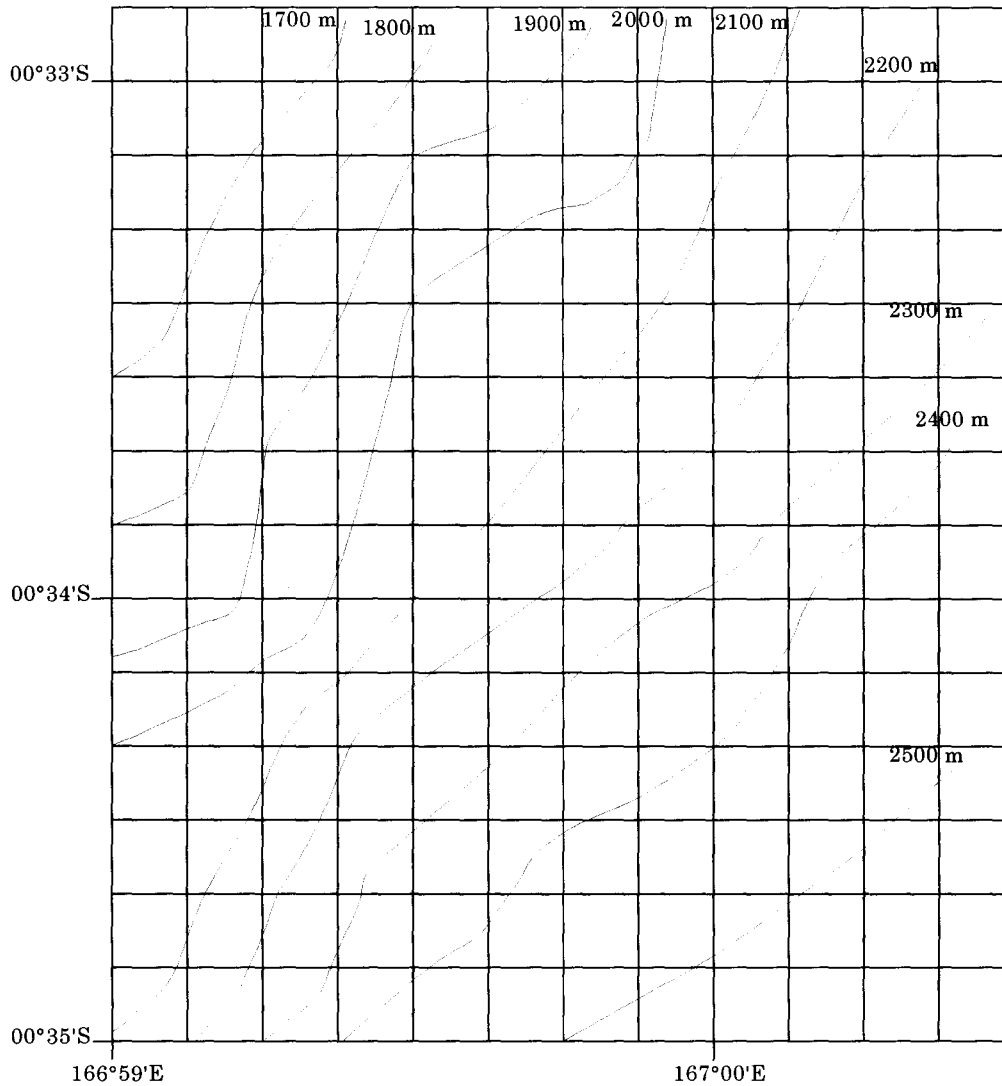


Figure 19: Contour map for survey site G

The third FAD site survey was conducted in a 1 x 1.50 nm area surrounding the proposed site position of Latitude 00° 31.00' S, Longitude 166° 59.00' E in a depth of 1,500 m (site H-Figure 17). Five transects were traversed in a north-south direction at 0.25 nm intervals within the site zone. Soundings along the transects indicated that the bottom contour of the entire zone dropped off at a 30-40 degree slope towards the east. The FAD site selected within the survey zone was Latitude 00° 30.75' S, Longitude 166° 59.25' E in a depth of 1,500 m (Figure 20). The area surrounding this site had a more gradual slope than the rest of the survey zone.

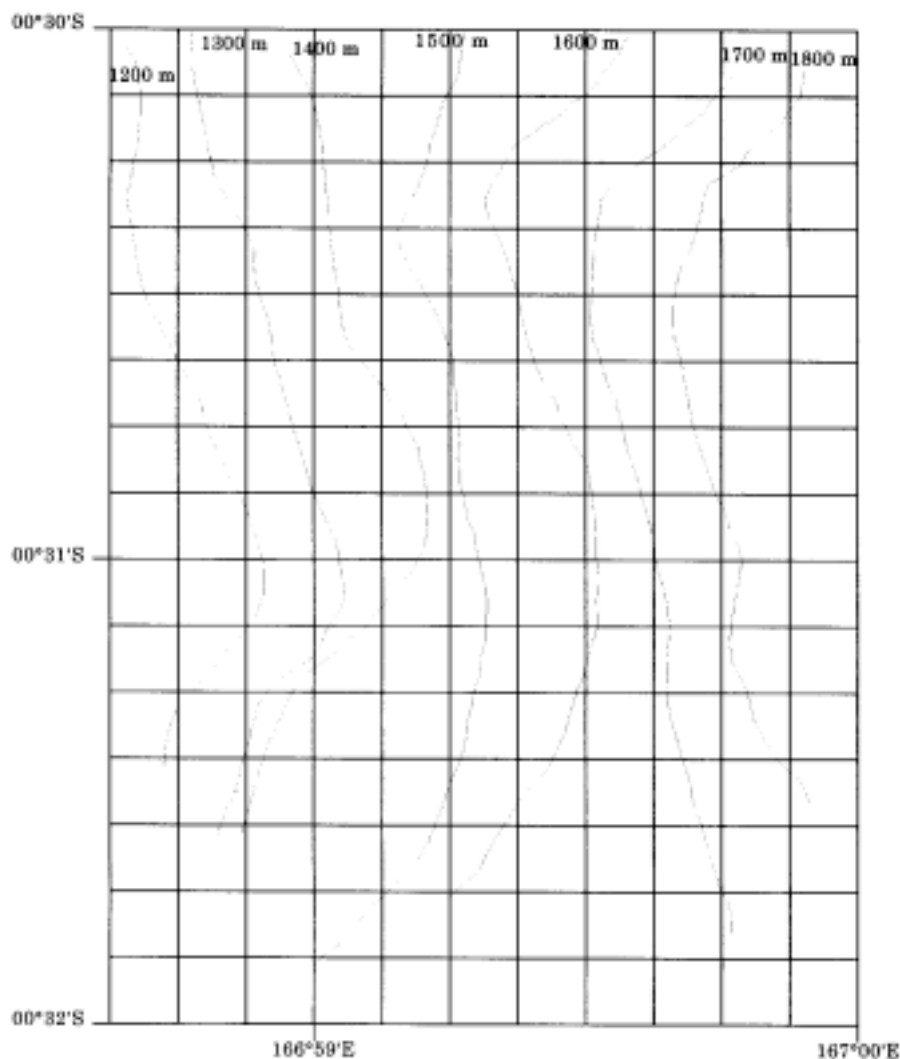


Figure 20: Contour map for survey site H

4. FAD Construction and Deployment in 1990 and 1991

This section draws heavily on the experience and work of Boy & Smith (1984, 1985).

4.1 LOCAL AVAILABILITY OF FAD BUOY AND MOORING MATERIALS IN 1990

Following the survey work conducted in 1990, an onshore investigation was undertaken as to what FAD materials were locally available. In consultation with the Harbourmaster, a tour of the main NPC hardware store and his own boatyard stores was arranged. Although there were several different sizes of chain in stock in the main store, there was only a short length of the type recommended for FAD moorings. There were also 16 mm and 19 mm shackles in stock but they were common screw-pin type, not safety shackles.

The smallest rope in stock was 24 mm, three-strand, regular-lay polypropylene, but there was not enough in stock to make up even one mooring. No forged swivels were in stock, but there was a good stock of galvanised wire thimbles. In the boatyard store there were rolls of rope, spools of cable, and a large quantity of chain. Unfortunately it was all too big. There were spools of 70 mm cable, which is used for anchoring the island's deep-water mooring buoys. The smallest chain was 25 mm and all of the braided nylon rope was 70 mm. However, there was a good stock of used 25–75 mm chain which had been discarded, but which would make excellent anchors for FADs.

Discussions were held on Nauru regarding the type of buoy to be used and whether the buoys could be constructed in Nauru by the boilermakers at NPC. Several designs were discussed and advice was sought from Lieutenant R. L. Boy, Ocean Engineer with the US Coast Guard's Civil Engineering Division, and an authority on deep-water mooring technology. It was agreed that once Lt. Boy's technical advice was received, a complete gear list (including buoy design) would be calculated and forwarded to IDI so that all required components could be ordered.

4.2 MATERIALS USED IN 1991

Materials were purchased by the IDI in Nauru according to advice provided by the SPC following the 1990 visit. The rope lengths were calculated based on a deployment depth of 1,100 m. All necessary materials were on hand when the Masterfisherman arrived. The mooring system used was the catenary curve system that SPC recommended at the time in Boy & Smith (1984, 1985).

4.2.1 Buoys

Three steel spar buoys (Figure 21) were fabricated by the NPC boilermakers according to specifications provided at the time by SPC. A fourth foam buoy was imported, with the associated hardware made locally (Figure 22). As three FADs were planned to be deployed, the fourth was kept as a replacement that could be used when maintenance was being carried out on the existing FADs.

Figure 21: Steel spar buoy design

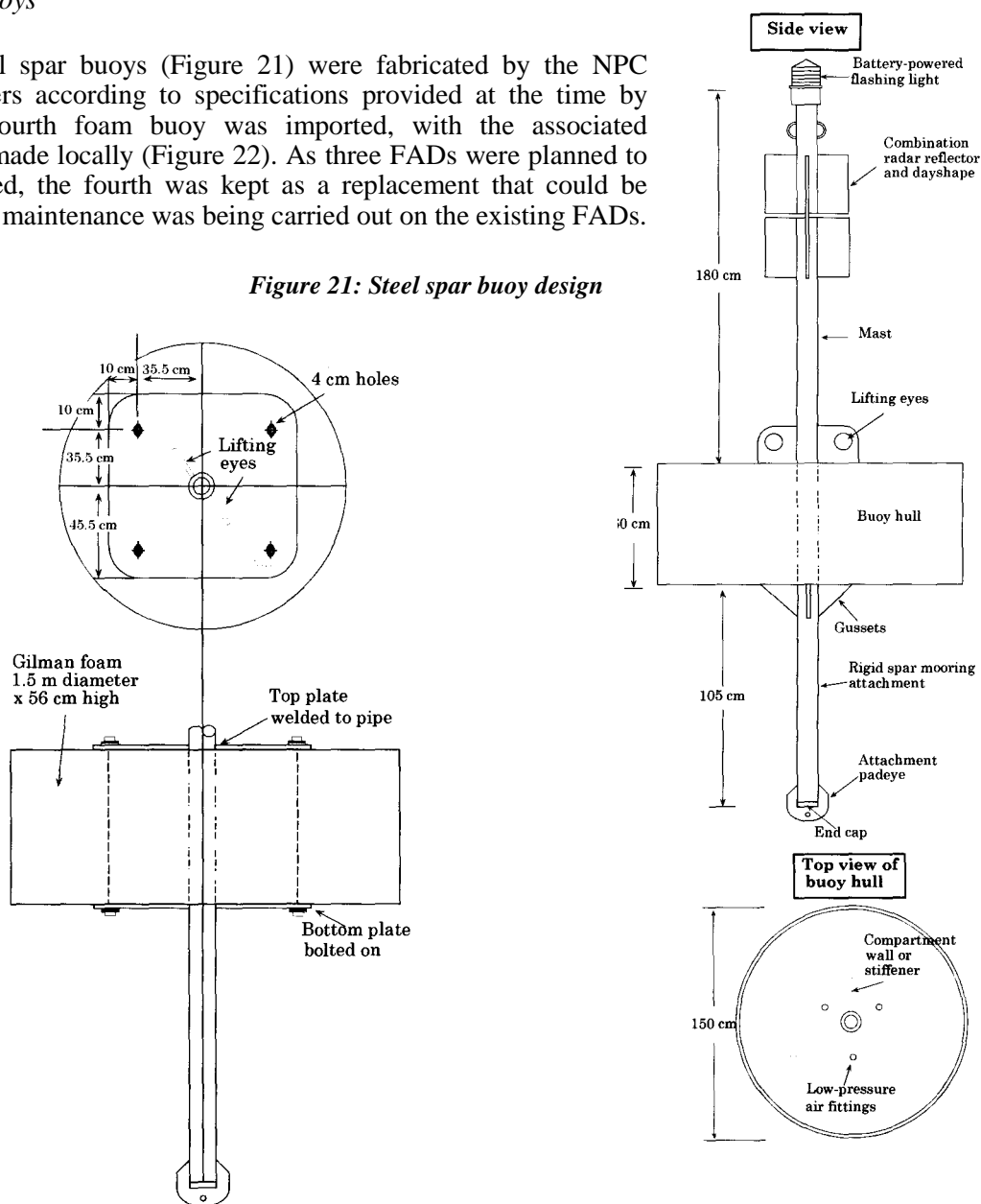


Figure 22: Foam buoy with steel hardware

The three steel spar buoys 150 cm in diameter and 60 cm high, were made from 5 mm steel plate. The mast was 180 cm high made from 10 cm diameter pipe with a radar reflector bolted to the top. The counterweight was 105 cm long and was a continuation of the mast with the top chain of the mooring used for the weight. A full description of a steel spar buoy (see Figure 21) and its construction can be found in Gates et al. (1996). The buoys were painted orange and had Republic of Nauru, IDI, and telephone number printed on them.

A Gillman foam buoy, 150 cm diameter and 56 cm high was imported. Top and bottom plates with mast were constructed by the NPC boilermakers and then bolted in place (see Figure 22). The foam buoy was of a similar size and design to the steel spar buoys. This buoy was painted yellow on top, with red anti-fouling paint applied to the bottom half.

McDermott flashing lights with amber globes were fitted to all buoys. These lights were equipped with six alkaline batteries and had an estimated life of around one year of service. The lights were also fitted with a photo-sensitive cell which automatically turned off the light in daylight hours. The light was rated for visibility of 2–3 nm on a clear night.

4.2.2 Ropes and hardware

The mooring systems for all three FADs (Figure 23) consisted of:

Upper chain: 30 m of 16 mm black, proof-link chain. Although galvanised chain was ordered, it was not sent, so zinc anodes were attached to the buoy.

Nylon rope: 440 m of 19 mm, 8 strand rope.

Polypropylene rope: 1,000 m of 22 mm, 8 strand rope. Lower chain: 3 m of 16 mm, black, proof-link chain.

Thimbles: Samson Nylite, size 3 (19 mm) were used for connections between rope and chain.

Swivels: 2 x 16 mm forged eye and eye swivels were used; one at the top (between the nylon rope and upper chain), the other between the lower chain and the polypropylene rope.

Shackles: 19 mm safety shackles were used throughout the mooring. A 22 mm shackle was used for the connection between the buoy and upper chain as this is the point where excessive wear may occur due to the movement of the buoy in the sea. A 32 mm shackle was used between the anchor and chain.

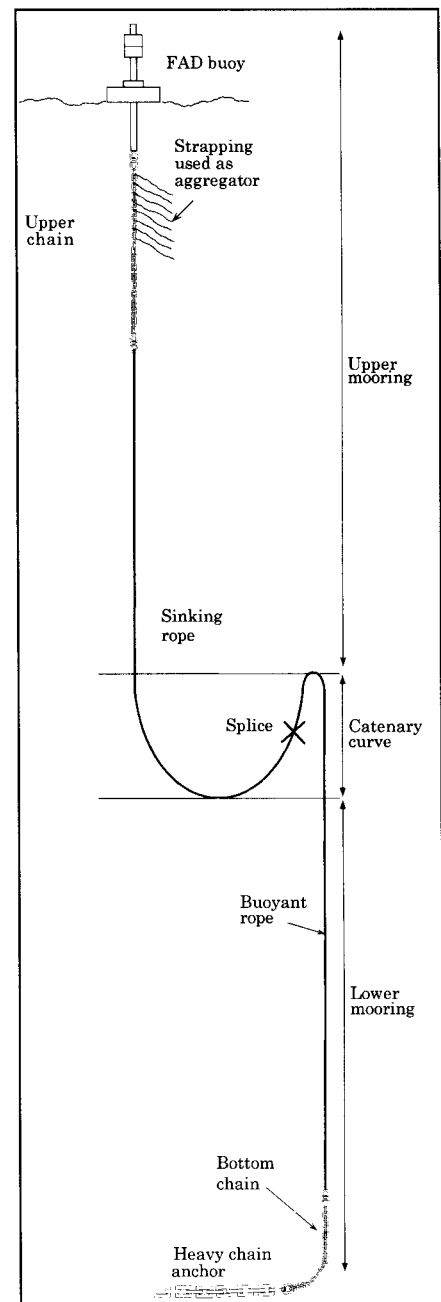


Figure 23: The catenary-curve FAD design deployed by the project

4.2.3 Anchors

With the surplus of used, large heavy-weight chain being readily available, it was the obvious choice for anchors. According to a table of weights for chain, in the Harbourmaster's office, a 36 m length of 75 mm stud-link chain weighs 1.4 t. Because of corrosion from being previously used, it was estimated the weight would be around 1.3 t. It was also felt that for FAD deployments on a fairly steep slope, the chain anchor may be better than a single block as it would settle into any holes or get caught on rocks or coral on the sea bottom. Therefore 36 m lengths of 75 mm stud-link chain were used on each FAD as the anchor.

4.3 CONSTRUCTION OF FADs

The NPC Harbourmaster kindly offered the use of a section of the NPC boathouse for all the preparatory work on the FADs. He also made available some of his crew and equipment for use when it was necessary to move or lift heavy items. When assembly of the FADs started, the swivels on hand were deemed to be of poor quality and new ones were airfreighted in from Australia.

On the top chain, starting 3 m below the buoy, plastic strapping was tied onto the chain for use as an aggregator (Figure 23). Four-metre lengths of strapping were doubled and tied directly on to the chain links for approximately 10 m down the length of the chain. For the three FADs, 2,000 m of strapping was used.

Zinc anodes were attached to the buoys for corrosion protection, and to the upper chain because the chain sent was not galvanised. The anodes were welded to the underside of the two steel buoys. For the foam buoy, the anode was bolted to the counter weight.

The polypropylene rope was taken out and laid out in large coils on lifting straps. After splicing the nylon rope to the polypropylene, it was coiled down on top of the polypropylene rope. Finally, the Samson Nylite connectors were spliced to either end of the ropes to form the connecting points for the top and bottom chain. After completing the splicing, the coils were tied up in preparation for loading the launches.

A forklift was used to haul the chain anchors to the boathouse. After positioning all gear so as to make it easy for the cranes in the boathouse to lift items onto the launches, lifting straps were rigged and made ready. Except for the shackles connecting the rope to the upper and lower chains, the rest of the connections were joined and welded.

4.4 DEPLOYMENT OF FADs

There was only one day that the NPC launches were free, so the Harbourmaster agreed to make three launches available to deploy the FADs. Loading of the launches commenced at 0600 hours on 24 October 1991. After helping the Masterfisherman load Launch No.9, the NPC crew loaded the other two FADs quite quickly on the other two launches. The workers are used to handling heavy equipment, so once they saw what was to be done, the loading went along very fast. Once the launches were loaded, the final connections were made and all other connections double checked.

The three launches left the dock at the same time and proceeded to area C (Figure 13). While the two other launches watched, Launch No.9 found the site position using the GPS and echo-sounder and deployed the first FAD. The buoy was placed into the water at a position up-current from the site. The rope was then run out in a large circle (nylon rope first, followed by the polypropylene rope) so that when all the rope was in the water, the launch was back to where the buoy was floating. After checking the position with the GPS, and the depth with the echo-sounder for the correct location, the anchor was deployed.

This method reduces the strain on the buoy and mooring during deployment because the anchor is dropped close to where the buoy is and it is only the rope that is pulled through the water. The buoy does not move at all on deployment and comes tight naturally in the current after the anchor is on the bottom. After waiting for the FAD to settle in, the position was checked again and noted. Given the nature of the catenary-curve mooring system (Figure 23) and the scope in the rope, the buoy could move up to 1.1 nm depending on the direction of wind and currents.

The three launches then moved to Area B and made ready to set the second FAD. Because Launch No.9 had the echo-sounder and GPS, it stayed close to the launch that was setting the FAD. Again, the NPC crew was very competent so there were no problems with the next two deployments. After setting the second FAD, the boats moved to Area A and deployed the third one.

The positions of the three FADs were as follows (Figure 24):

Area C: Latitude 00° 29.69' S, Longitude 166° 54.86' E in a depth of 1,034 m; Area B:

Latitude 00° 29.30' S, Longitude 166° 55.77' E in a depth of 1,015 m; and Area A: Latitude

00° 30.98' S, Longitude 166° 58.45' E in a depth of 959 m.

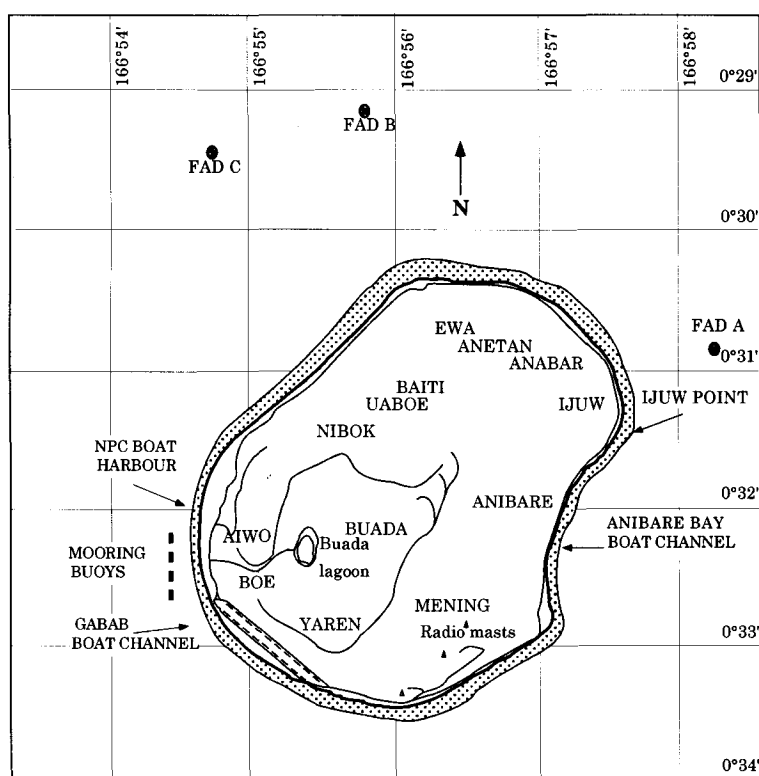


Figure 24: Locations of the three FADs deployed off Nauru in October 1991

4.5 LIFESPAN AND PRODUCTIVITY OF THE THREE FADs

Reports from IDI staff in Nauru indicated the FADs remained on station from October 1991 until the last FAD drifted from its site in April 1993. Initial reports of catches around the FADs were very promising, but after a few months the fishermen reported fewer and fewer fish being caught. It was speculated that the FADs were positioned too close to the island's fringing reef and therefore did not properly aggregate pelagic schools. Reports from local fishermen regarding the distance offshore where schools of fish were usually sighted also indicated the FADs might be too close to the island. Poor catches around the FADs deployed within 1 nm of the fringing reef prompted the Nauru Government to make a further request for technical assistance to the SPC in 1993.

5. FAD Construction and Deployment in 1997

This section draws heavily on the experience and work of Anderson & Gates (1996) and Gates et al. (1996) as well as the previous projects conducted in Nauru and the early work reported in Boy & Smith (1984).

5.1 MATERIALS USED

The site depths of 2,600 m, 2,500 m and 1,500 m were selected by the IDI staff. Materials were ordered according to the recommended SPC design as specified in Gates et al. (1996) for these depths. All materials were on hand when the Masterfisherman arrived in November 1997.

5.1.1 Buoys

The spar buoy that was built but never used during the deployments in 1991 was stored outside the NFMRA office (Figure 25). Although it was over five years old there was little evidence of deterioration of the steel due to corrosion. NFMRA decided to use this buoy for the FAD to be placed in shallower water.

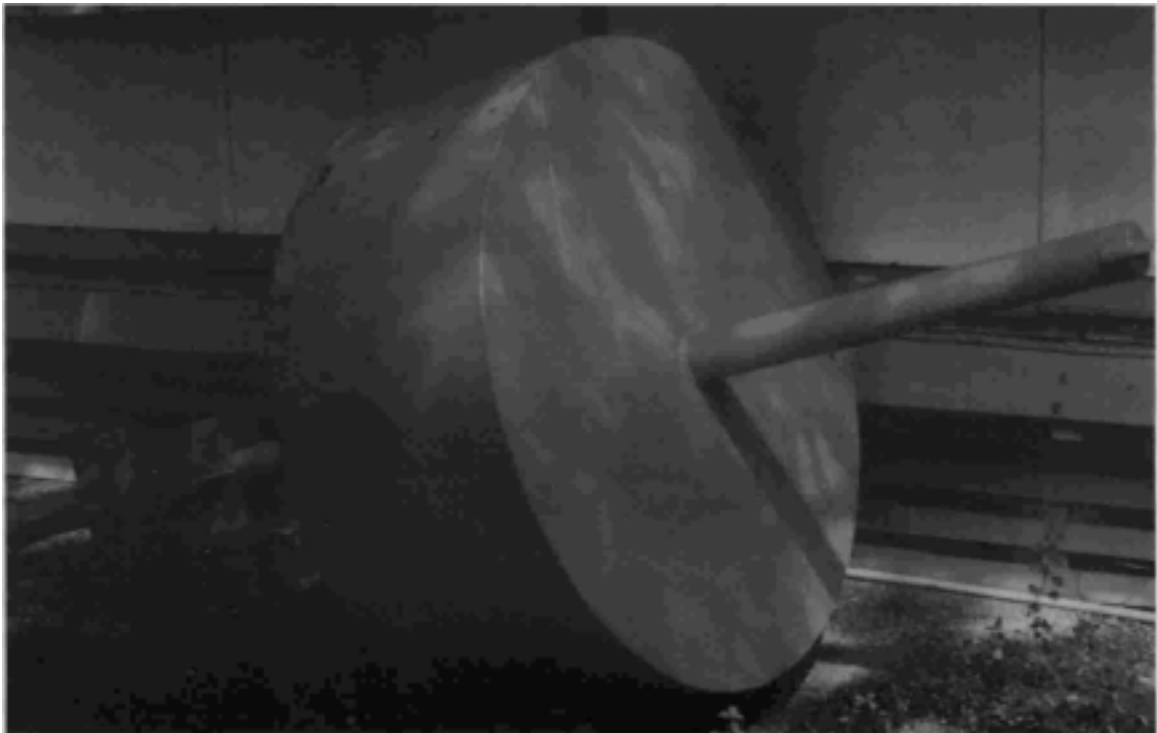


Figure 25: Spar buoy stored outside NFMRA's office

The Indian-Ocean-buoy design (Figure 26) was chosen for the other two FADs. It is also recommended by the SPC for deep-water moorings (Gates et al. 1996). This buoy is rigged by stringing 50 or more purse-seine floats on a 30 m length of 16 mm steel wire rope coated with 8 mm of PVC (making 32 mm diameter). The PVC is watertight and eliminates the possibility of corrosion of the wire rope. An eye (Figure 27) is formed on either end of the wire rope using cable clamps and a thimble. The eyes are used to attach a flagpole at one end and the upper part of the mooring rope to the other. As this type of buoy cannot capsize there is no need for a counterweight to stabilise it. Therefore there is no need for 15 m of upper mooring chain.

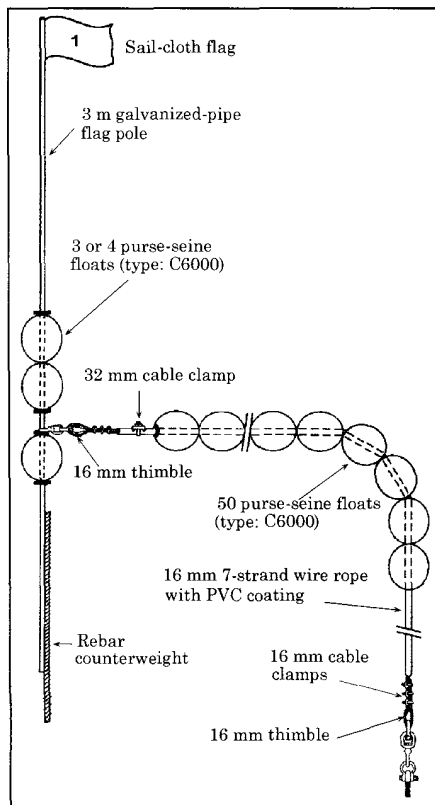


Figure 26: Indian-Ocean-style buoy system



Figure 27: Eye splice formed using cable clamps at end of wire cable

5.1.2 Buoy materials and hardware

The SPC's Capture Section was storing a large number of series 6,500 purse-seine floats which were given to SPC member countries in 1997 provided the freight charges for moving them were covered by each country. NFMRA took 120 of these purse-seine floats and had them shipped to Nauru. Used series 5,000 purse-seine floats were also purchased from Casamar, Guam for US \$4.00 each.

Materials for rigging the two Indian Ocean rafts and the mooring system were ordered from wellknown fishing suppliers in the region. Andrew Tuke Wholesale Ltd, in New Zealand supplied all . ropes and original hardware including the 30 m lengths of steel wire cable with PVC covering, and the cable clamps. Gates et al. (1996) lists all components and specifications for SPC's two recommended mooring designs, and NFMRA's order followed these recommendations.

Unfortunately, the supplier did not send the materials which were specified in the order. It specified that all the hardware components should be fabricated from hot-dipped galvanised steel. If different types of steel are used together in a mooring system, corrosion is accelerated. The bottom mooring chains sent were black steel. The specified shackles were 19 mm and 22 mm hot-dipped galvanised safety shackles. The supplier sent 16 mm and 22 mm hot-dipped galvanised screw-pin shackles. The shackles were rejected as the threads on the screw-pin and the shackle bow would quickly corrode in a marine environment allowing the pin to fall out. Alternative shackles and chain were ordered from Casamar in Guam and airfreighted to Nauru.

5.1.3 Ropes

Catenary-curve mooring systems were used for the Nauru FADs. This mooring system utilises a combination of sinking nylon rope and buoyant polypropylene rope to build scope into the mooring. The offsetting sinking and buoyant properties of the two ropes cause a curve to form where they join (Figures 23 & 30). The NFMRA ordered 12-strand polypropylene and nylon ropes and they came in 500 m coils. The specifications of the ropes were checked to ensure there was sufficient buoyancy in the polypropylene rope to lift at least 3 m of bottom hardware off the seabed (Appendix D). No added buoyancy was required on these moorings. The ropes were also checked to ensure that the breaking strength was at least 6,400 kg. The SPC's revised work sheets (Appendix D) for ropelength calculations for catenary-curve moorings were used to determine the rope lengths for each FAD site. Rope lengths for the three FAD mooring sites were:

- 2,600 m site-polypropylene rope 2,593 m, nylon rope 680 m;
- 2,500 m site-polypropylene rope 2,493 m, nylon rope 680 m; and
- 1,500 m site-polypropylene rope 1,445 m, nylon rope 430 m.

5.1.4 Anchors

As for the 1991 FAD deployments, NPC's discarded 50 mm and 75 mm chain was used for the anchors for all three FADs. These old chains were at a dump in the interior of the island. To ensure that each anchor chain had sufficient weight, the NPC marine crew brought a 50,000 kg maximum-capacity scale for weighing the chain. The scale was attached to a crane and to the anchor chain. When the crane lifted the chain off the ground a digital readout of the weight was recorded. The chain was then cut using an oxyacetylene torch. The scaled anchor chains for the three FADs weighed: 1,200 kg, 1,000 kg, and 960 kg.

5.2 CONSTRUCTION OF THE FADs

The Indian-Ocean-design buoys were constructed outside the NFMRA office. Given the distance offshore (3.5 nm), and the length of rope and the possible drag on it, the Masterfisherman decided to string extra floats on the wire rope to increase the visibility of the raft on the surface of the ocean and its buoyancy. One buoy had 70 series 6,500 purse-seine floats, whilst the second had a combination of 80 series 6,500 and 5,000 purseseine floats.

Most of the eye splices and end-to-end splices were completed by the NPC marine crew at the NPC boathouse. The Masterfisherman assisted with the splicing of ropes for the third FAD and he checked all other splices and found them to be satisfactory. When splicing was completed, the ropes were coiled over lifting slings so that they could be loaded onto the deployment vessel.

The chain to be used for the anchor was cut at the dump site and transported to the NPC boathouse. All other FAD materials including the buoys, hardware, and ropes were also transported to the NPC boathouse in preparation for loading onto the deployment vessel using the over-head cranes.

The NPC vessels to be used for the deployment work were only available for two days as two cargo vessels were scheduled to arrive at the island. It was therefore decided that the two Indian-Ocean-style FADs would be deployed the first day and the spar-buoy system on the second day.

5.3 DEPLOYMENT OF THE FADs

The M/V *Erinimon* (Launch No.9) and a steel barge were lowered into the boat harbour using the overhead cranes. All the materials for the two Indian-Ocean FADs were also lowered by the cranes onto the deck of the barge. The materials were arranged on the deck so that one complete FAD could be deployed from the starboard stern, and the other from the port stern of the barge (Figure 28). The anchor chains were laid out in three metre loops across the stern of the raft. The crane was used to layout the chains along the deck as the chains were too heavy to move manually. After the chains were in position, ropes were tied at the top end of the chain loops to cleats on the deck of the steel barge. The purpose of tying the chain loops to the deck was to control the speed of the anchor chain running off the deck when it was deployed. Each rope would be untied as a loop of chain ran overboard.



Figure 28: Loading the barge with two Indian-Ocean-style FAD systems, one on the port side and the other on the starboard

The mooring ropes were placed in front of the anchor chains (towards the bow of the barge-Figure 28). Each mooring rope was made into a huge continuous coil on the deck by the NPC marines. Care was taken to ensure the ropes were coiled properly to eliminate any tangles during deployment. The end of each polypropylene rope was then shackled to an anchor chain, and the nylon ends shackled to the Indian-Ocean buoys. The hardware connections were all double-checked to ensure the nuts on the safety shackles were tight and the stainless-steel cotter pins were bent over. The Indian-Ocean buoys were then placed along the port and starboard gunnels of the barge. Once the two FADs were properly arranged on the deck, the bow of the barge was tied to the stern of M/V *Erinimon* (Figure 29), which towed the barge out to sea where it was met by the NFMRA vessel, F/V *Dogua*. The crew on both vessels had hand-held two-way VHF radios for communication.

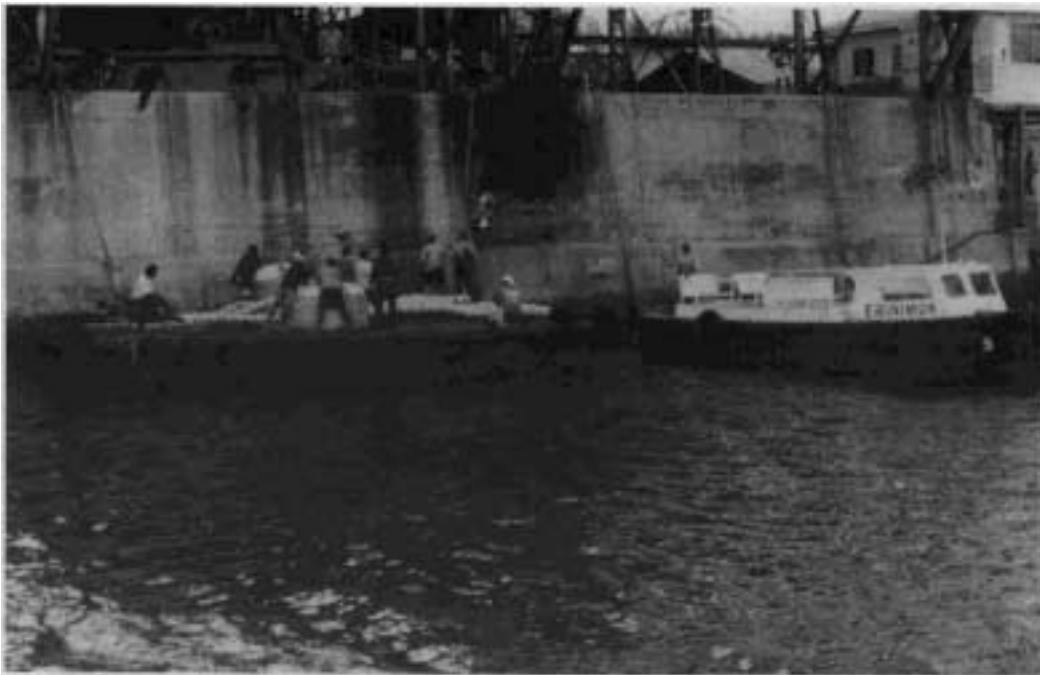


Figure 29: M/V Erinimon ready to tow the barge to the deployment site

F/V *Dogua* was equipped with the GPS and echo-sounder. Positions of the intended FAD sites were programmed into the GPS memory as waypoints so that the FAD deployment vessels could return to the exact position of the site. F/V *Dogua* was steered along the course heading given by the GPS to the site, with M/V *Erinimon* following with the barge in tow. When F/V *Dogua* reached the position given by the GPS for the FAD site, the echosounder was turned on to re-confirm the depth recorded during the site survey. Once the depth and position were confirmed, the crew members on the barge were instructed to deploy the FAD buoy.

F/V *Dogua* then proceeded to motor away from the site position with the M/V *Erinimon* following close behind paying out the mooring rope (nylon rope first). A large circular course was set out by the Masterfisherman for both vessels to follow using the GPS. The course was plotted to ensure that the rope was never paid out over an area deeper than the intended FAD site depth. Due to the extreme depths of both FAD sites a circular deployment method was used to reduce the strain on the mooring system when the anchor was dropped and to ensure the rope was always in a safe depth zone. Figure 30 shows the Indian-Ocean-style FAD deployed off Nauru.

Figure 30: Indian-Ocean-style FAD deployed off Nauru

When all the mooring rope was paid out, both vessels motored back to the FAD site position. Sometimes it is difficult to calculate the exact distance required for paying out the mooring rope. If for example all the rope was already paid out before the vessels reached the site, the rope would be towed to the correct position. Or if it was obvious that there would be excess rope when the site was reached the vessels would steer in a 'zig-zag' pattern to payout the remaining rope before reaching the site. When the GPS and echo-sounder on F/V *Dogua* confirmed that both vessels were back at the FAD site, the crew on the barge were instructed to deploy the anchor chain. After waiting for the anchor to settle on the bottom, the position and depth under the FAD buoy were recorded.

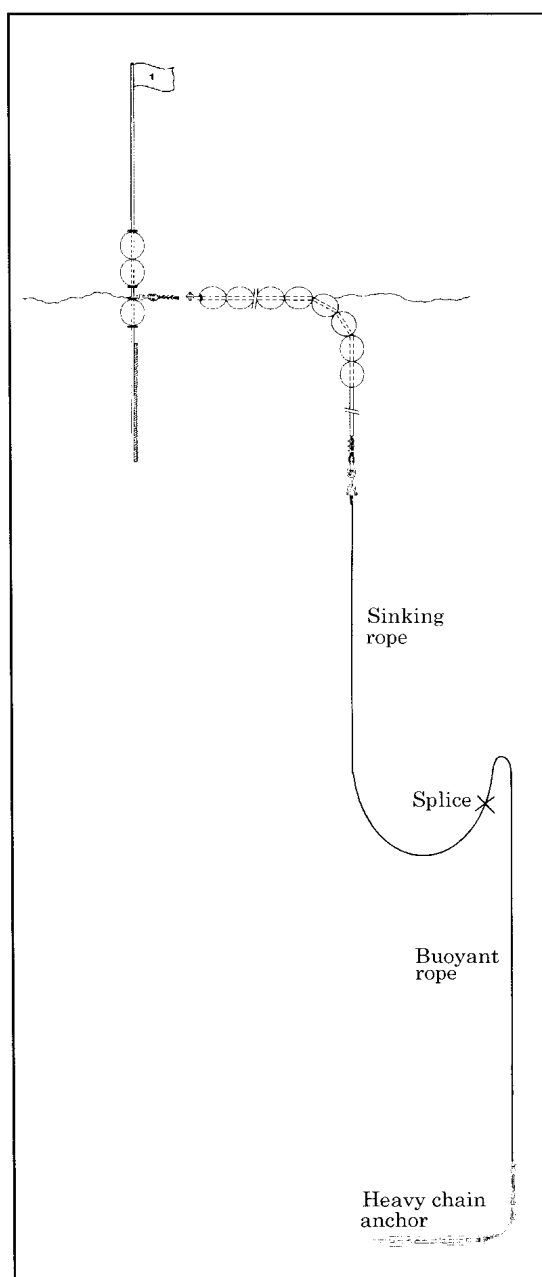
The same deployment procedures were followed for all three of the FADs. The positions (see Figure 17) and depths at the three FAD buoys after deployment were:

Area F: Latitude 00° 36.00' S, Longitude 166° 53.80' E in a depth of 2,450 m;

Area G: Latitude 00° 34.10' S, Longitude 166° 59.80' E in a depth of 2,450 m; and

Area H: Latitude 00° 30.75' S, Longitude 166° 59.25' E in a depth of 1,450 m.

It should be noted that given the nature of the catenary mooring system, the scope in the rope, and the depth of water in which the FAD was deployed (2,450 m), the buoy on these deeper moorings could move up to 2.25 nm depending on the direction and strength of wind and currents.



It was noted after the deployment of the Indian-Ocean-style buoys that the counterweight for the flagpoles was not sufficient to hold the flag upright in the water, especially during periods of strong current. Extra weights had to be attached to the bottom of the flag pole.

5.4 LIFESPAN AND PRODUCTIVITY OF THE THREE FADs

Two FADs were deployed on 19 November and the third on 20 November 1997. At the time of writing this report (March 1998) all three FADs were on station. Catches recorded by NFMRA staff on fishermen's landings from fishing around the FADs show that over 24.5 t of tuna were caught in December 1997, and January and February 1998. Most of the catch was taken from one FAD (area F—over 23.5 t), although small numbers offish were present at the other FADs as well.

6. Discussions and Conclusions

The NFMRA now has three FADs on station around Nauru. In achieving this, many lessons have been learnt by NFMRA and the SPC relating to the location of suitable sites. This report highlights the process and changes the SPC went through in conducting site surveys. The method that was used in 1997 was developed by the SPC in other countries, and allows more precise selection of the best site in a given area. However, to do this accurately a echo-sounder is required that has the capability to take readings in the desired depths and a GPS for accurate positioning. NFMRA has a suitable GPS but lacks a suitable echo-sounder.

The original FADs deployed in 1991 did not attract fish the way it was hoped. Fish were aggregated initially, but catches dropped soon after. Anecdotal information also indicates the FADs sometimes seemed very close to the reef. This would be true in certain weather and current conditions as it is estimated from the rope length to the site depth ratio that the buoy could move up to 1.1 nm. If the anchor was 1-1.25 nm off the reef then the buoy could in theory come to within 0.45–0.70 nm of the reef. Given the experience of these early deployments it was agreed that they were stationed too close to shore and their ability to aggregate fish was hindered accordingly.

Based on the results of the first deployments, the current FADs were deployed further offshore. Initial catches indicate that these FADs are aggregating fish far better than the first ones. This would indicate the FADs need to be deployed as far as practical off the island to increase their chances of aggregating fish. It has also been noted that the FAD at location F is more productive than the other two at areas Hand G. This could be due to the fact that FADs Hand G are only 3.5 nm apart and they may be 'competing' for or sharing the same school of fish. Given this possibility, it would be best if only one FAD was in the area, and possibly a better location could be found through more extensive site surveys. Given the size of the island, two FADs should be adequate but they should be kept as far apart as possible or practical. It has been reported from other fisheries that FADs should be 10–14 nm apart so that each will act as a separate entity in aggregating fish.

Most of the materials purchased for the current FAD deployments were used. This means there are limited spares on hand to replace a lost FAD. There are enough materials to construct another Indian-Ocean-style-buoy system apart from the actual purse-seine floats. These could be purchased from Guam so that a spare buoy system is on hand.

The conducting of regular maintenance is also an important part of any FAD programme. A spare buoy system should be kept on hand so that maintenance can be carried out when required on the existing FAD buoys. Each buoy should be inspected every 3–6 months. It is important that materials be purchased for at least two FAD buoy systems and at least

one complete FAD mooring system for around 2,500–3,000 m. To support the purchase of materials on a regular basis, equivalent to one complete unit per year, the Government of Nauru should be encouraged to increase future budgets for NFMRA to cover this.

A common failure of many FAD programmes in the region is lack of data collection. Without accurate data collected on catches taken from FADs it is impossible to calculate the cost benefit of having FADs. This is very important when trying to justify the expense of replacement FADs to government in a time of shrinking budgets. NFMRA is collecting data from fishermen using the FADs. This is very encouraging and it should be continued as a priority activity of NFMRA. This data should cover all users of the FADs, whether commercial, recreational or charter (sports-fishing) operations and be as detailed as possible (including species, number of lines, time spent fishing, and fishing methods used).

As more fishermen start to fish around the FADs, alternative fishing methods should be trialled to target the deeper-swimming larger tunas. I-Kiribati and Tuvaluan fishermen use their traditional drop-stone fishing method around the NPC mooring buoys to target the tunas in mid-water. This method should be trialled around the FADs as well as the Hawaiian equivalent, the palu-ahi method. In addition, vertical longlining trials should also be undertaken with a training programme implemented by the NFMRA to train local fishermen in all methods.

To complement the move to have fishermen go further offshore to fish, a sea safety programme should also be implemented. Fishermen need to be made aware of the dangers involved and the simple precautions that can be taken. As part of a sea safety programme certain safety appliances should be required to be carried through appropriate legislation. Life jackets for all on board, day and night flares, a radio, food and water, spare fuel, basic tools and spare parts for the outboard are just a few of the basics needed when heading to sea in small craft. Another important component of gear is a parachute sea anchor which can be used for fishing as well as for safety. A 3 m parachute system should be sufficient for most small craft on Nauru. The few dollars spent on safety equipment are a cheap alternative to the cost of search and rescue operations or possible loss of life.

7. Recommendations

During the course of the different projects in Nauru, many recommendations were made. Most of the early recommendations were taken into account by the projects that followed, or have become outdated. Therefore, the recommendations below are formed from the most recent project, taking account of what has transpired over the five visits, and look to the future needs and requirements for the continuation of the current FAD programme in Nauru. Based on the work carried out in Nauru, it is recommended that:

- (a) If NFMRA wishes to continue a FAD programme, they purchase a suitable echo sounder with a depth rating to at least 3,000 m but preferably to 4,000 m;
- (b) All future deployments of FADs be made as far as practical off the island;
- (c) More extensive site surveys be conducted around Nauru to locate other suitable FAD deployment sites;
- (d) In future only two FADs be kept in the water but they should be placed as far apart as practical;
- (e) Materials be purchased for at least two buoy systems and at least one complete mooring system for a depth of 2,500–3,000 m;

- (f) At a minimum, 120 good used purse-seine floats be purchased from Guam so that one or two spare Indian-Ocean-buoy systems can be constructed;
- (g) A maintenance programme be established to service the current FADs with inspections of the buoy systems conducted every 3-6 months;
- (h) Future budgets for NFMRA include funding for the purchase of necessary FAD materials equivalent to one complete unit per year;
- (i) NFMRA continue their data collection programme on catches taken around the FADs as a priority activity and that they ensure that they collect a range of data from all user groups (commercial, recreational and charter or sports-fishing) covering their respective fishing activities;
- (j) NFMRA establish a training programme for introducing fishing techniques associated with FADs, such as vertical longlining, palu-ahi and drop-stone;
- (k) NFMRA conduct some workshops to introduce the concept of safety at sea and the basic requirements and safety appliances that small craft should carry;
- (l) NFMRA work with other government departments to draw up legislation to cover small craft and the carrying of basic safety equipment when heading to sea; and
- (m) The possibility of purchasing lightweight parachute sea anchors of around three metre diameter be investigated by NFMRA.

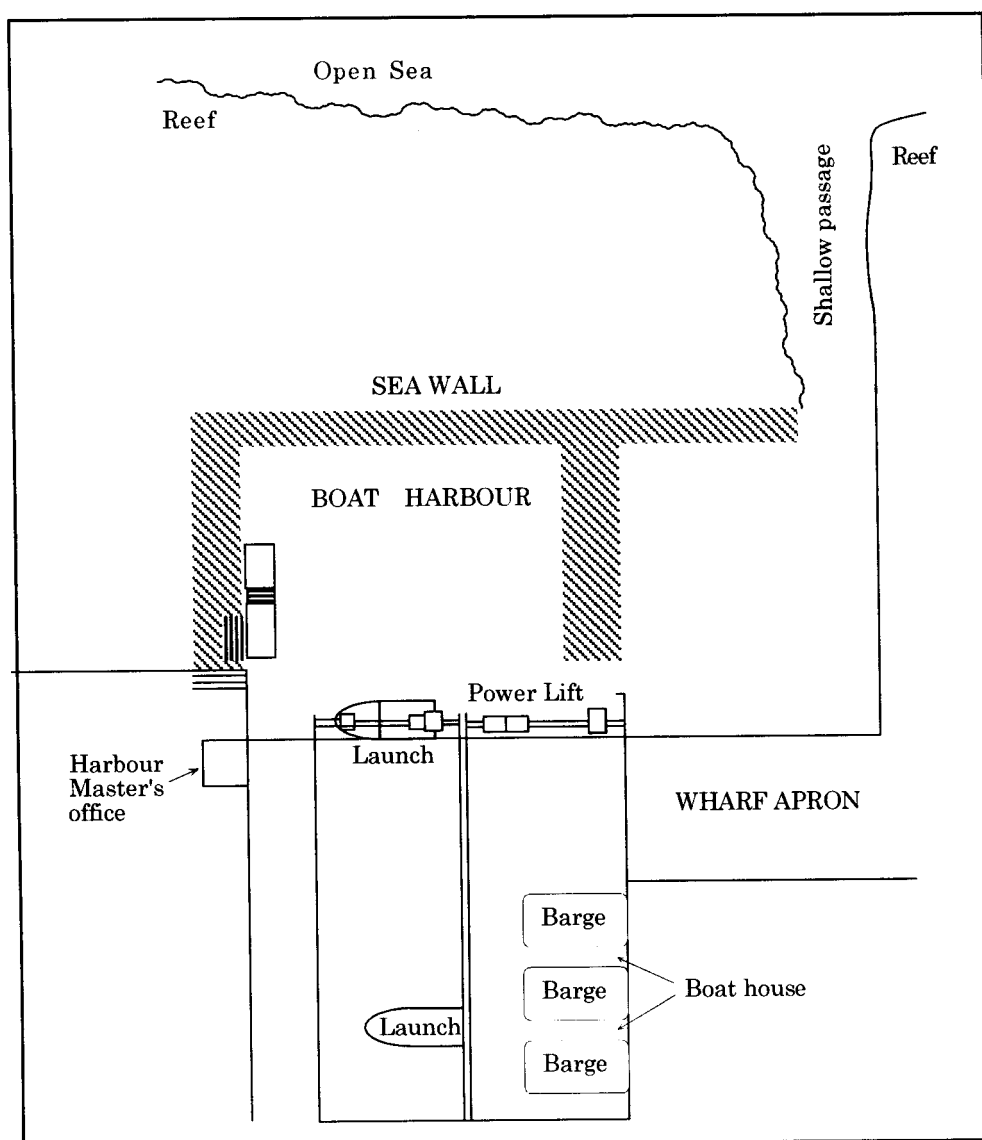
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BRIEF DESCRIPTION OF THE NPC BOAT HARBOUR

The boat harbour on Nauru contains an area of approximately 30 x 80 m enclosed by a solidly constructed concrete wall. The enclosed area is partially divided by an extension of the seaside wall which runs from the middle of the main seawall back towards shore, with a 15 m passage between the end of it and the shore-side wall (see diagram below). Although the water inside this area is reasonably sheltered from the main force of the sea, access to the open sea is by a shallow, narrow passage that breaks in periods of heavy swell. During heavy seas the water inside the entire boat harbour is affected by rough seas and surge. All boats and barges supervised by the Harbourmaster are stored in a large boathouse approximately 10 m above sea level in the inner harbour. Access by these vessels to and from the sea in the enclosed area is provided by two powerful electric-powered overhead cranes. Each electric crane is self-propelled and runs on steel rails mounted on massive steel beams running the length of the building and extending approximately 3 m out over the water. When launched, boats are simply hooked to the winches on each end of a crane, hoisted up approximately 1–2 m, carried to the sea end of the building and lowered into the water.



WORKSHEET DESIGNED TO RECORD LANDMARK BEARINGS

WORKSHEET		
Location	Off Ijuw Point:	
House:	Depth:	Time:
Hotel:		
House:	Depth:	Time:
Hotel:		
House:	Depth:	Time:
Hotel:		
House:	Depth:	Time:
Hotel:		
House:	Depth:	Time:
Hotel:		
House:	Depth:	Time:
Hotel:		

SOUNDINGS RECORDED DURING 1991 SURVEY WORK**Soundings for Area C**

WAYPT NO.	DEPTH (M)	LATITUDE SOUTH	LONGITUDE WEST
1	293	0° 30.524'	166° 55.404'
2	380	0° 30.374'	166° 55.303'
3	470	0° 30.328'	166° 55.287'
4	593	0° 30.230'	166° 55.248'
5	751	0° 30.093'	166° 55.200'
6	823	0° 29.915'	166° 55.120'
7	957	0° 29.822'	166° 55.059'
8	1126	0° 29.672'	166° 54.975'
9	1250	0° 29.568'	166° 54.882'
10	1406	0° 29.444'	166° 54.744'
11	1154	0° 29.385'	166° 54.817'
12	1073	0° 29.331'	166° 54.846'
13	1039	0° 29.369'	166° 54.908'
14	1025	0° 29.440'	166° 54.948'
15	996	0° 29.496'	166° 54.982'
16	1034	0° 29.543'	166° 55.013'

Soundings for Area B

17	265	0° 29.294'	166° 55.772'
18	462	0° 29.688'	166° 54.858'
19	529	0° 29.626'	166° 56.147'
20	669	0° 29.551'	166° 56.136'
21	751	0° 29.449'	166° 56.120'
22	789	0° 29.352'	166° 56.088'
23	851	0° 29.290'	166° 56.074'
24	972	0° 29.223'	166° 56.049'
25	1025	0° 29.117'	166° 56.038'
26	880	0° 29.078'	166° 56.004'

Soundings for Area A

27	289	0° 31.117'	166° 57.861'
28	400	0° 31.163'	166° 57.881'
29	505	0° 31.206'	166° 57.964'
30	553	0° 31.236'	166° 58.082'
31	601	0° 31.237'	166° 58.119'
32	669	0° 31.268'	166° 58.165'
33	746	0° 31.292'	166° 58.221'
34	803	0° 31.285'	166° 58.301'
35	909	0° 31.300'	166° 58.374'
36	904	0° 31.287'	166° 58.398'
37	967	0° 31.310'	166° 58.504'
38	832	0° 31.313'	166° 58.575'
39	587	0° 31.156'	166° 58.351'
40	736	0° 31.245'	166° 58.123'
41	746	0° 31.279'	166° 58.256'
42	861	0° 31.181'	166° 58.332'
43	919	0° 31.008'	166° 58.389'
44	959	0° 30.984'	166° 58.449'

SAMPLE WORK SHEETS FOR MOORING-ROPE AND BUOYANCY CALCULATIONS

FAD buoy

Upper chain

A

B

C

D

E

Top pressure float

Bottom pressure float

F

Concrete blocks with chain

Chain to be lifted off bottom

Rope buoyancy calculations:

Weight of 1 m of rope in air = kg
..... m of rope supports% of its weight
in sea-water (multiply by)
Buoyance of rope = xx
= kg

Rope length calculations:

AB = Site depth - (EF + m + m)
= m - m
= m

BC and CDE = Site depth x

$$\frac{\quad}{2}$$

= m x

$$\frac{\quad}{2}$$

= m (rounded down)

ABCD = AB + BC + CD
= m + m + m
= m

DEF = DE + EF
= m + m
= m + m
= m

ROPE SECTIONS	VERIFICATION
Upper chain m	Site depth m
AB m	Catenary curve m
BCD m	
DEF m	TOTAL m
Lower chain 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)	15m
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 $BCDE = \text{site depth} \times 0.2 = \dots \times 0.2 = \dots \text{ m}$		
(3) Length of nylon in the catenary curve (BCD): preliminary calculation: 75% of catenary curve $BCD = BCDE \times 0.75 = \dots \times 0.75 = \dots \text{ m}$		
(4) Total length of nylon (ABCD): $ABDC = AB + BCD = \dots + \dots = \dots \text{ m}$ $\dots + \dots = \dots \text{ m}$		
(5) Length of polypropylene in the catenary curve (DE): preliminary calculation: 25% of catenary curve $DE = BCDE \times 0.25 = \dots \times 0.25 = \dots \text{ m}$		
(6) Length of polypropylene segment (EF): $EF = \text{site depth} - (\text{upper chain} + AB + 3 \text{ m lower chain}) \dots - (\dots + \dots + \dots)$ $EF = \dots - \dots = \dots \text{ m}$ $EF = \dots \text{ m}$		
(7) Total length of polypropylene (DEF): $DEF = DE + EF = \dots + \dots = \dots \text{ m}$		

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:

3 m chain:.....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 = $\frac{\text{weight of rope}}{\text{length of rope}}$ =

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 xkg/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 less 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 =kgkg = 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 = $\frac{\text{Supplementary buoyancy}}{\text{Float buoyancy}}$ = floats

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 = $1/2 \times \text{depth rating} = 0.5 \times \dots = \dots \text{m}$

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)