SURVEYING FAD DEPLOYMENT SITES AT RAROTONGA USING GLOBAL POSITIONING SYSTEM EQUIPMENT

Fish aggregation devices have been in use in the Cook Islands since 1980 and are recognised there as making an important contribution to local fishing efforts. A cost/benefit study on 1986 landing figures showed that with an average FAD unit costing around NZ$ 4,000 to deploy and each FAD producing average increased catch values in the order of NZ$12,500, returns of 312 per cent on outlay were realised (Sims, 1988).

Few fishermen in the Cooks have any reservations about whether FADs increase small-scale fishing productivity and ease, and few would like to have to fish for the strong Rarotonga market without having FADs to target. But, in common with many other Pacific Island countries, the Cooks have suffered premature FAD losses. Although FAD survival rates have generally increased with growing experience and improved materials and rigging, the Cook Islands Ministry of Marine Resources (MMR) has been concerned for some time with improving its FAD programme personnel's ability to conduct accurate site surveys and to calculate catenary mooring systems precisely.

Following the major Pacific Islands FAD review undertaken by the South Pacific Commission Fisheries Programme during 1990 and the subsequent FAD workshop held during the 1990 Regional Technical Meeting on Fisheries, the Cook Islands Government, at the request of MMR, sought the technical assistance of SPC in upgrading its FAD survey, mooring calculation and deployment capability. In response, the Commission's Deep Sea Fisheries Development Project enlisted the co-operation of New Caledonia's Territorial Government in making the author available on secondment from his position as Master Fisherman with the Service territorial de la marine marchande et des pêches maritimes and coordinator of New Caledonia's FAD programme. The secondment agreement provided for the author to travel to Rarotonga for one month to work with the MMR FAD team, demonstrating the following FAD skills:

- Accurate site survey techniques using an echo-sounder;
- Navigation skills essential for site survey and plotting of selected sites;
- Mooring component calculation;
- Recommended rigging methods;
- Deployment techniques suited to local craft.

It is generally well accepted that FAD deployment sites should be surveyed as accurately as possible, not only to ensure an accurate depth reading, but to determine the degree of bottom slope, regularity, and absence of ledges or crevasses nearby. Due to the depth and forces acting on the anchor during its descent, it is impossible to predict the exact spot the anchor will land. Because of anchor deviation, it is best to choose a site with a wide breadth and gentle rope.

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

Survey vessel

The vessel made available for the survey work was a wooden launch of the TON-7 type (Fig. 1) designed by I. Gulbrandsen and built for MMR by a Tongan boatyard. The vessel had been modified to MMR request. The deck was raised slightly, the cabin extended, and an hydraulic line hauler and monofilament long-line drum fitted to the working deck towards the stern. This extra weight on deck made the vessel quite tender. The first twelve days of the visit were mostly spent on preparing the vessel for sea after six months out of the
water, but fitted with her newly rebuilt 34 HD Yamaha diesel engine she worked well and served the purpose.

Electronic Equipment

The vessel was already equipped with:

— A VHF radio;
— An Autohelm electronic hand bearing compass;
— A SAT NAV unit and an SSB radio (not used during this survey).

Obtained especially for this survey and installed the day before the first survey trip was:

— A JRC, Model JLU 121 GPS receiver/plotter equipped with a CRT display. This GPS receiver utilises signals transmitted simultaneously from several satellites (from 3 to 5) to calculate position continuously (see note below), with an estimated error of less than 100 m. It took only a couple of hours to install on the boat and was giving a position within minutes of being activated.

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

This unit, a 2 kw output power model, is equipped with both 50 khz and 28 khz transducers suited respectively to fish finding and bottom surveying at depth. A mounting frame for the transducer was fabricated in welded aluminium in New Caledonia, allowing the transducer to be fitted to the side of the survey vessel by clamping and lashing.

Preparing for the surveys

The aim was to survey four potential deployment zones, determine their suitability, and chart ideal anchoring positions accurately within the zones.

GPS positions in latitude and longitude are referenced to the World Geodetic System (WGS) 1984, and in plotting these positions on marine navigation charts, which are normally referenced to local or regional datums, it is necessary to apply corrections. In this case the chart used by MMR for FAD work was the Nearshore Bathymetry Chart of Rarotonga, Miscellaneous Series No. 56, published by the NZ. DOL, which is referenced to a system known as International Spheroid 1924. So before plotting GPS positions on this chart, corrections had to be calculated. To determine the necessary corrections we contacted the Hydrographic Office of the Royal New Zealand Navy, which was able to give corrections only for standard British Admiralty (BA) navigation charts. However, by comparing the appropriate BA chart to the GPS position reading when at anchor in Rarotonga’s main harbour and to the bathymetric chart used by MMR, we were able to calculate that we should plot GPS positions on the bathymetric chart with a correction of 24 seconds (0.4 minutes) of latitude northwards and 48 seconds (0.8 minutes) of longitude westwards.
The sites were selected by MMR with regard to their reputation as productive fishing areas, history of previous successful FAD deployments, and accessibility to the main boat harbours on the island.

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

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

Once the transect lines were drawn on the survey plan, we took their extremities as waypoints and entered the coordinates into the GPS unit. The GPS could then direct the vessel from waypoint to waypoint with great accuracy.

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

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

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

Figure 2: Echo-sounding transects in the Arorangi zone
This preparatory survey planning can be summarised in five steps:

— Draw a 2-mile square on the chart which best covers the selected zone, with the edge of the square closest to land beginning at the 600 m contour.

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

— Make the end of each parallel line a waypoint; note the coordinates of each of these points.

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

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

Survey procedure

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

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

The streamlined aluminium side-mount specially constructed for the echo-sounder transducer allowed good soundings to be made while travelling at 6 knots. However, the engine of the survey vessel had recently been rebuilt and the captain preferred to run it at low speeds, so all surveying was conducted at speeds around 4 knots.

Once back in port with all positions and depths recorded on the worksheet and chart, we prepared to draw a contour map of the surveyed zone. The first step was to prepare a chart showing the lines of latitude and longitude for the surveyed zone. For the sake of convenience this was drawn to the same scale as the bathymetric chart generally used by the FAD team. The transect lines were then transferred to this chart and the depths at each sounding point recorded in place.

Because we wanted to draw contours at each 100 m increment it was nearly always necessary to interpolate the soundings from two points and draw the appropriate contour between them. This was done with great care, using the scale of the survey chart and the actual distances between sounding points. Thus, if one sounding was 935 m and the next 1015 m, the actual distance between the sounding points was one-third of a mile, and the gradient was assumed to be constant, we could calculate the increase in depth per millimetre on our scaled chart and arrive at the 1,000 m contour point.
This charting was relatively simple for the Matavera and Aro-rangi zones where the contour lines followed a natural and logical pattern. It was more difficult in the Black Rock zone where many bottom irregularities were present. It was decided to draw the contour maps keeping the positions’ values given by the GPS, which meant that to match them with the bathymetric chart in use (in order to take bearings to shore, or for any other purpose), one would have to move them by 0.4° of latitude northwards and 0.08° of longitude westwards, e.g. 21°17S and 159°50W converted to 21°16.600’ S and 159°50.080’ W.

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

**Considerations in selection of anchoring sites**

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

By building the block as compactly as possible, and with a slightly larger base to give a low centre of gravity, the tendency of the anchor block to deviate during descent may be reduced. However, there is no way to eliminate this tendency entirely. It is generally accepted that when deploying a FAD by the recommended 'raft-first' method, with the mooring line paid out in a straight line between the raft and the deployment vessel, the drag of the mooring ropes and raft require that the vessel should pass over the anchoring site and continue on for one-third of the mooring length past the site before jettisoning the anchor.

Care must be taken in regard to currents affecting the deployment position. This can be compensated for to some extent by taking bearings from the vessel to the raft during the paying out. If the raft is being carried sideways by the current, adjustments can be made to the vessel’s course. If current direction can be determined before putting the raft in the water, it is best to steer the deployment vessel up stream of the drift of the buoy while paying out the mooring rope.

Of course, even when the anchor is released right on target there is margin for error.

Observations during previous deployments show that during a deployment in 1200 m with a 1 t block, the raft may move on the surface for up to 9 minutes, dragged by the weight of the descending block. Although the stretch and recoil of the mooring ropes account for some of this time, there is a significant period during which the block is under the influence of hydrodynamic forces, the drag of the mooring ropes, and currents in the upper water layer. The block may therefore deviate significantly from a direct vertical descent.

Therefore, when surveying to deploy a FAD in 1200 m, the target zone where all depths are acceptable for the planned mooring (that is, within 10 % of the working site depth) must be as broad as possible.

It must be noted here that all survey preparation, the running of the surveys at sea, the drawing of the contour plans, and eventual site selection, were conducted with the full and active participation of the MMR FAD team, with the author taking the role of observer after each skill was mastered.
Evaluation of equipment

**Furuno FCV 362 echo-sounder**

It is obvious that a reliable, deep-water capability echo-sounder is critical to accurate surveying of FAD deployment sites.

A unit such as the D3FD Project's Furuno FCV 362, with its 28 kHz transducer in use, is quite adequate to the task of sounding depths in excess of 1,500 m, but in average conditions could not be expected to give reliable readings to the manufacturer's given range of 2,000 m.

The critical factor is output power. The FCV 362 produces a 2 kw signal and, while other models and makes are available which produce 3 kw signals and greater, it must be remembered that higher output power also requires increased input power. The FCV 362 was chosen for general FAD survey work because its power draw is at the level that typical, medium-size fishing craft in the region can supply; this unit being purchased with the intention of using it widely in the region and necessarily on a wide range of fishing craft.

For this same reason the transducer mounting was designed not to be a permanent fixture, but to be removable. It is likely that a fixed transducer mounting, i.e. fixed to a vessel's hull, would operate with greater efficiency. This unit cost US$ 4,280 in 1990, which, compared to the cost of a FAD lost through inaccurate depth survey, would seem a good investment. Of course a unit like this, which has dual frequency capability, has a wide range of fishing applications as well.

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

**JRC JLU 121 GPS Receiver/Plotter**

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

This unit, which was purchased by the MMR in 1990 for around US$3,200, incorporates both a receiver and a plotter and has the capability to display digitised charts on the CRT screen. Thus the vessel's position is constantly indicated both in digital display of latitude and longitude as well as graphically on the plotting screen. A ball control allows for simple movement of a cursor on the screen.

Apart from the ship's own position the unit is able to give information on course made good, speed along route, speed toward destination, bearing and time to destination and so on. If the unit is not receiving adequate satellite signals an alarm notifies the operator. The corrections made between the GPS positions and the bathymetric chart used by MMR was a fairly simple process and was explained in detail to the FAD team. Recent publications of standard navigational charts typically include GPS correction figures. Because we moored the survey vessel in the same position each day we were able to check the reliability of the given GPS position; the greatest deviation noted was 0.07 miles.

Although some would argue that such sophisticated equipment is inappropriate in island fisheries activities, the experience in Rarotonga showed that with even minimal training, local personnel could make very good use of such equipment and conduct fairly complicated navigation exercises with great precision and reliability.

References
