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AN ACOUSTIC APPROACH TO RESOURCE MAPPING OF PULAU PAYAR'S CORAL REEF

Jabatan Perikanan Malaysia

BOBP For Fisheries Management
BAY OF BENGAL PROGRAMME

Survey Report

AN ACOUSTIC APPROACH TO RESOURCE MAPPING OF PULAU PAYAR'S CORAL REEF

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PREFACE

This document discusses the rationale, the conduct and the results of a new approach – the hydro-acoustic method – tried out to map the reef substrate of four islands at Pulau Payar Marine Park, Kedah state, Malaysia.

The decision to adopt the method was taken after an October 1997 workshop held under the Special Area Management Plan of the Pulau Payar project, with support from the Bay of Bengal Programme (BOBP).

A private company carried out the reef mapping exercise, whose objective was to document the diversity of coral growth forms at Pulau Payar, map and quantify coral resources, and prepare an update on the coral reef status at Pulau Payar, assessing any damage to the reef.

The exercise was carried out in view of the plans by the Department of Fisheries, Malaysia, to inventory all the reefs in the country's islands.

Over the years, coral survey techniques have depended heavily on the SCUBA method which is considered risky, time-consuming and costly. Further, it is impossible to produce a broad-scale map with the SCUBA diving method. The author believes that the "new, repeatable and non-destructive hydro-acoustic survey approach" heralds a new era in corat studies.

The BOBP is a multi-agency regional fisheries programme which covers seven countries around the Bay of Bengal – Bangladesh, India, Indonesia, Malaysia, Maldives, Sri Lanka, Thailand. The Programme plays a catalytic and consultative role in developing coastal fisheries management in the Bay of Bengal to improve the conditions of small-scale fisherfolk in member-countries.

The BOBP is sponsored by the governments of Denmark and Japan. The executing agency is the FAO.

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ABSTRACT

A new approach was applied to mapping out the reef substrate of the four islets of Pulau Payar Marine Park, in Kedah State, Malaysia. A seabed classification system which harnessed the RoxAnn hydroacoustic signal processor, Differential GPS and a 200 kHz echosounder was able to translate the echo return into hardness and roughness indices, which then exhibited unique characteristics for each bottom type recorded. The system was able to discriminate six major reef substrates i.e. live coral, dead coral, soft coral, coral rubble, rock and sand. Live hard coral represents a total coverage of 19.30% from the *157.68* km total length of transect recorded from the Payar group of islands. The four main growth forms found were the massive (10.11%), the branching (7.11%), the encrusting *(1.51%)* and the foliose (0.57%). Table corals and columnar corals were also present but in a very small quantity (surface area) – the RoxAnn seabed classification system was not able to classify them as a separate group. As for the Pulau Segantang group of islands, soft coral was the dominant coral type, accounting for 34.65% of the total 4.12 km of track run. Live coral coverage at P. Segantang in this survey was negligible. It was also common to find small coral colonies growing on the boulders surface in shallower waters for both Payar and Segantang waters. They were grouped as a stand-alone coral substrate due to their unusual existence pattern. The real time trace data were also interpolated using Surfer®6.2 for thematic maps showing the depth contour, the 3D depth profile and the bottom surface area. The results were satisfactory, despite data distortion. The use of the hydroacoustic method for the mapping of coral reef substrate is independent of water depth, visibility, light penetration and time. Hence, the hydroacoustic method shows itself to be a better alternative to the conventional transect line method and satellite images in terms of time and cost spent and the results gained especially for large-scale surveys.

Foreword

One of the most interesting pilot projects in Bay of Bengal Programme's Third Phase, which has drawn much attention throughout the region, is the one at Pulau Payar Marine Park in Kedah State, Malaysia. Set up in 1985 to conserve marine resources in surrounding waters, such as coral reefs, and protect bio-diversity, Pulau Payar is considered a treasure house of marine fauna and flora.

The Pulau Payar project was implemented by the Department of Fisheries, Malaysia, with BOBP support. It developed and tested a number of methods and innovative approaches to improve the conservation and management of marine parks. Today, Pulau Payar stands out as a success story in resource conservation.

One of the technical experiments carried out under the project is described in this report. It discusses the rationale and the conduct of a new coral survey technique, the hydro-acoustic method, to map the reef substrate of the Park's four islands.

The project used the Rox Ann Hydroacoustic Signal Processing System, which is a state-of-the-art hydroacoustic remote sensing tool. The authors point out that the technology uses a powerful underwater sonic searchlight to detect and enumerate physical and biological features of coral reefs. This enables faster and more accurate ground-truthing and mapping than the traditional SCUBA surveys, which carry an element of subjective interpretation and observation, and therefore the possibility of human error.

The report documents through maps and brief text, facts and features concerning the reef substrate made possible by the hydro-acoustic method. It says “This project can be considered a milestone in coal research history as it combines the use of remote sensing tools and ground truthing.”

The BOBP made a special effort to obtain the best possible maps from the authors, and ensure good-quality printing. We hope that dissemination of this report improves better understanding of coral resources and their dynamics, creates awareness of the hydro-acoustic method for coral reef surveys and furthers the cause of marine resource conservation.

V S Yadava

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I. INTRODUCTION

Over the years, coral survey techniques have depended heavily on direct measurement and censusing with the SCUBA diving method. Given skilled and knowledgeable field workers, SCUBA diving is still the most reliable survey te~hnique to date, as it allows first-hand data collection. However, it is almost impossible to produce a broad-scale map with the SCUBA diving method,. Further, it poses high risks to the operator/diver, it is also time-consuming and costly. This method is also restricted by water depth, tidal currents, bad weather and poor visibility.

During the early 90s, the remote sensing technique was introduced as a new survey tool. Through GIS interpretation of various types of satellite images, thematic maps on physical characteristics of the water body can be obtained. As time passed, the resolution of satellite images increased, enabling more information to be gained, including the mapping of coral reef. However, remote sensing on coral reef is confined to the identification of general reef features in shallow water. The report on “Marine Park Island Management: Conceptual Plan For Peninsular Malaysia, 1994” clearly outlined the shortcomings of the use of satellite images. At present, more “ground truthing” works are needed to complement the remote sensing results from satellite images.

Scientists have been very innovative in exploring new survey tools for coral studies. Recent findings indicate that the hydroacoustic method is a promising approach, especially for large area surveys. Hydroacoustic techniques have been used over the past six decades, initially for undersea warfare. It is also a popular method utilised for years in fisheries resource surveys. The acoustic technology harnesses a powerful underwater sonic searchlight to detect, observe and enumerate physical and biological parameters of interest. Based on hydroacoustic theories and formulae, this technique is now being adopted to conduct reef surveys. It is a faster means of ground truthing and mapping compared to SCUBA diving. The other significant advantage of machinery surveys is that it minimises the possibility of human error due to subjective individual interpretation and observation during a SCUBA survey.

2. JUSTIFICATION

One of the many tasks of the Department of Fisheries, Malaysia (DOFM) is a reef inventory list of the islands in Malaysia. The Pulau Payar Marine Park, which consists of four islets, is well known for the great diversity of reefs over small areas. It thus highlights the need for an objective record of the inventory in the form of a thematic/GIS map. Under the Special Area Management Plan (SAMI-of the Pulau Payar Project, a workshop held in October 1997 suggested that the method used for reef surveys should allow for temporal comparison. An attempt to map out Payar’s reef resources using the hydroacoustic method was therefore initiated as a continuation of the SAMP Pulau Payar Project.

A DOFM proposal to obtain the expert services of Elcee Instrumentation Sdn. Bhd (EISB) was accepted by BOBP as a potential contribution to coral reef management in the region. EISB was to work in collaboration with the DOFMs senior research officer.

3. OBJECTIVES

To document the diversity of coral growth forms at Pulau Payar

2. To map and quantify the coral resources of Pulau Payar for resource management

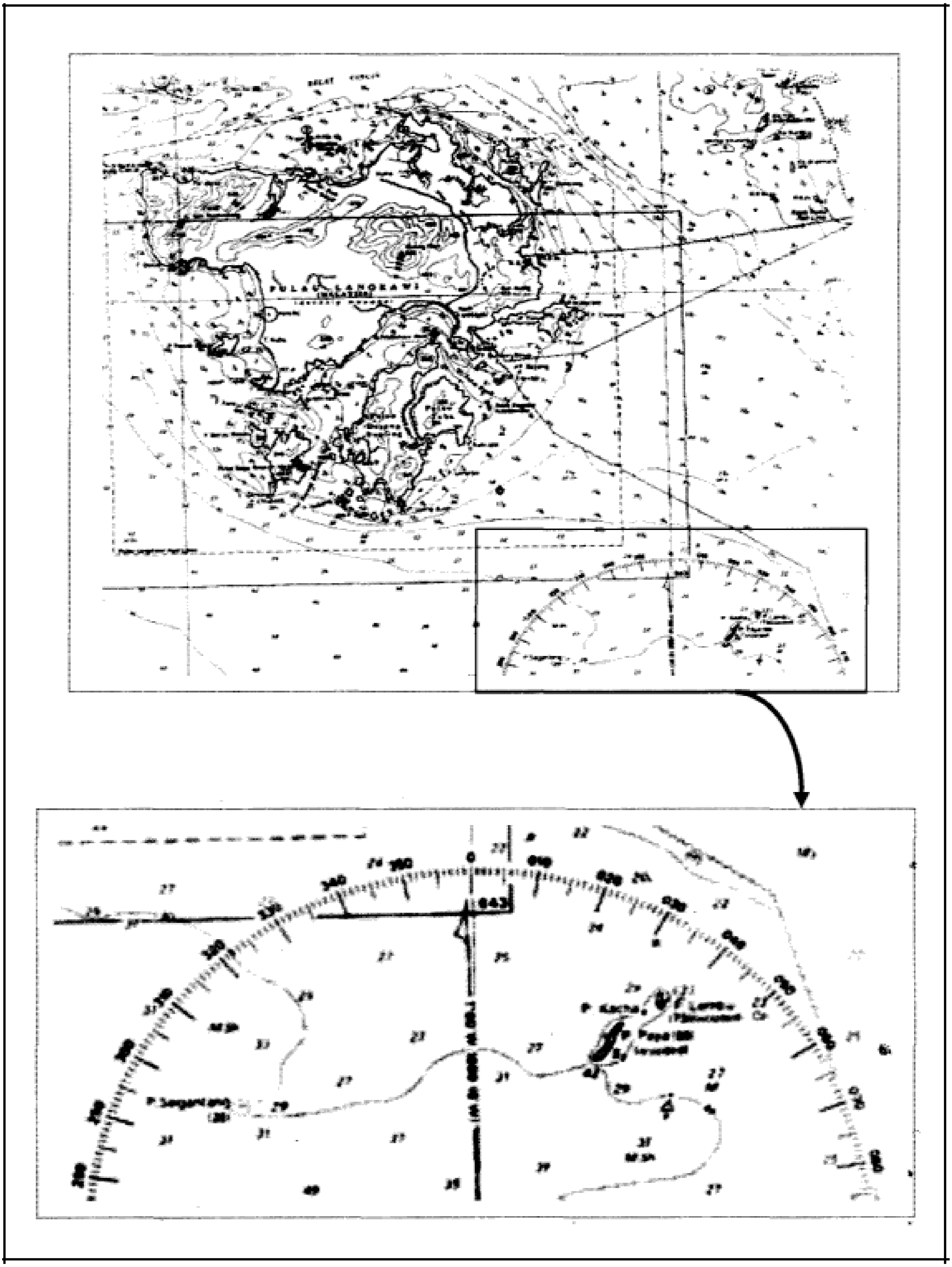
3. To assess the damage and update the current coral reef status of Pulau Payar.

4. MATERIALS & METHODS

4.1 Survey site

Located at 6°2- 6°05N and 99°54'- 100°04E(Figure 1), the P.Payar group of islands are situated between Pulau Pinang and Langkawi islands on the Straits of Malacca, which is one of the busiest straits with marine traffic. The reefs here are therefore seriously exposed to the possibility of oil spills and discharges from tankers passing by. A thematic map on the coral resources is a niatter of high priority. Furthermore, Pulau Payar Marine Park has the distinction of being the most well-documented coral reef. Hence it enables proof of the feasibility of this technology development. P.Payar Marine Park is one of the most frequently visited marine parks (Aikanaithan & Wong, 1994). By enabling comparison of the past coral cover with the current status of the reefs, it makes possible an assessment of the impact of ecotourism activity on the reef. This can lead to better management and regulation of such activities.

Figure 1: Location map showing the survey site



4.2. Materials

The survey equipment used is listed below:

Equipment	*Make*	*Brand*	*Specification*
Vessel	Boston Whaler	Challenger	- 24 footer, Twin 150HP outboard engine
Echosounder	Furuno	FCV522	- 500 Watts, Colour display
Transducer			- bronze, thru-hull 100 - width, single beam 200kHz.
Differential GPS	Fugro Omni Star	3000LR	- Virtual Base Station
GPS Receiver	Magellan	5000DXL	- 5 Channels
Hydroacoustic Signal Processing System	Marine Micro System	RoxAnnTM	- Single frequency 200 kHz
Laptop	Twinhead	Climnote3	- with 2 serial ports, 1 local port
Grab samplers	Wildco	Ekman	- Tall 6” x 6” x 9” with extra weights
Diving Gears			
Por%able Generator andfuel			
Back-up Battery and charger	Delco Voyager		- Marine grade 12VDC, deep cycle

4.3 Component Discussion

Vessel. A Boston Whaler with a 150HP twin outboard engine and shallow draft, provided by the Marine Park authority, was sufficient for an effective survey.

Echosounder and Transducer System. A bronze thru-hull transducer with 10°beam angle, 200kHz with a 500 watts output power colour echosounder, for resolution enhancement.

Differential Global Positioning System **(DGPS).** The normal GPS receives satellite signals to informusers about locations on earth. Depending on the prevailing SA (Selective Availability), such a receiver may generate errors up to 100m. The magnitude of this error is unacceptable for coral mapping work as the reefs found are mostly smaller than 50 meters. A much improved version of location readings is essential. DGPS works by placing a high-performance GPS receiver (reference station) at a known location. Since the receiver knows its exact location, it can determine errors in satellite signals. It does this by measuring the rangers of each satellite using the signals received, and comparing these measured ranges with the actual ranges calculated from its known position. The difference between the measured and calculated range is the total error. The error data for each tracked satellite is formatted into a correction message and transmitted to GPS users via a mobile (rover) unit. The correction message format follows the standard established by the Radio Technical Commission for Maritime Services (RTCM-SC 104). These differential corrections are then applied to the GPS calculations, thus removing most of the satellite signal errors and improving accuracy to !3m. More sophisticated receivers can achieve accuracy on the order of sub-meter.

RoxAnn Hydroacoustic Signal Processing Ssytem. The RoxAnn Hydroacoustic Sigital Processing System (RHSPS) is a state-of-the-art hydro-acoustic remote sensing tool. When connected to any single beam echosounder, it listens to and processes the signals returned from the transducer. These returned signals are simplified to the first echo (E, second echo E_{2}) and depth. The first echo received is a measure of the acoustic backscatter of the substrate, which is referred to as roughness. Rougher materials scatter more acoustic energy back towards the transducer, whereas a smooth substrate will act like a mirror and reflect away most of the acoustic energy from the transducer. The second echo return is a measure of the acoustic impedence of the substrate. The softer a substrate, the greater the acoustic impedence of the substrate. The timing diagram for E1 and E2 is shown in Figure 2. A complete RHSPS incorporates the input of real time, geo-referenced survey data i.e the longitude and latitude. For each valid E1 and E2 signal collected, RHSPS sends a RS232 string containing depth, E1 and E2 information to the PC/laptop for processing using the RoxMap Scientific Software. With the information gathered from E1 and E2, a RoxAnn Square is configured (Figure 3). It is a Cartesian graph, where E1 (index of roughness) is plotted along the Y-axis and E2 (index of hardness) is plotted along the Y-axis. Since every substrate will have a different range of E1 and E2 values, these areas can be 'boxed off' or classified with an assigned colour. With the addition of longitude, latitude, time and data information, tracks coloured according to substrate type are generated on built-in electronic charts.

Grab Sampler: A grab sampler is needed on board to classify non-coral substrate, whereas diving gears are required for ground-truthing corals found in deeper water.

Alternate and Back-up Power Supply. To power up the survey system for consistent and reliable acoustic data.

A schematic survey system setup is illustrated in Figure 4.

4.4 Methodology

The survey was carried out in three main stages: system mobilisation (including calibration and classification), data collection and post-processing.

Figure 2: Echo signal processing technique

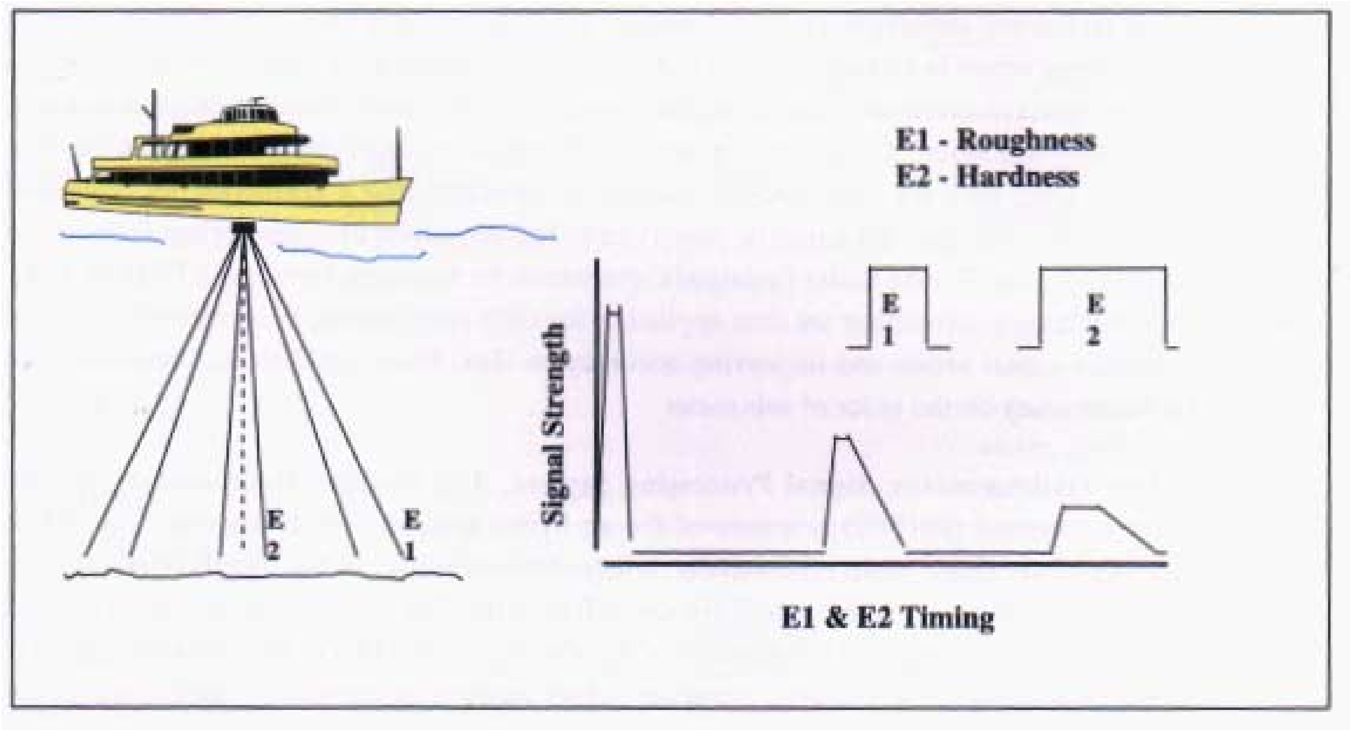


Figure 3: Typical Rox Square showing locations of some bottom types

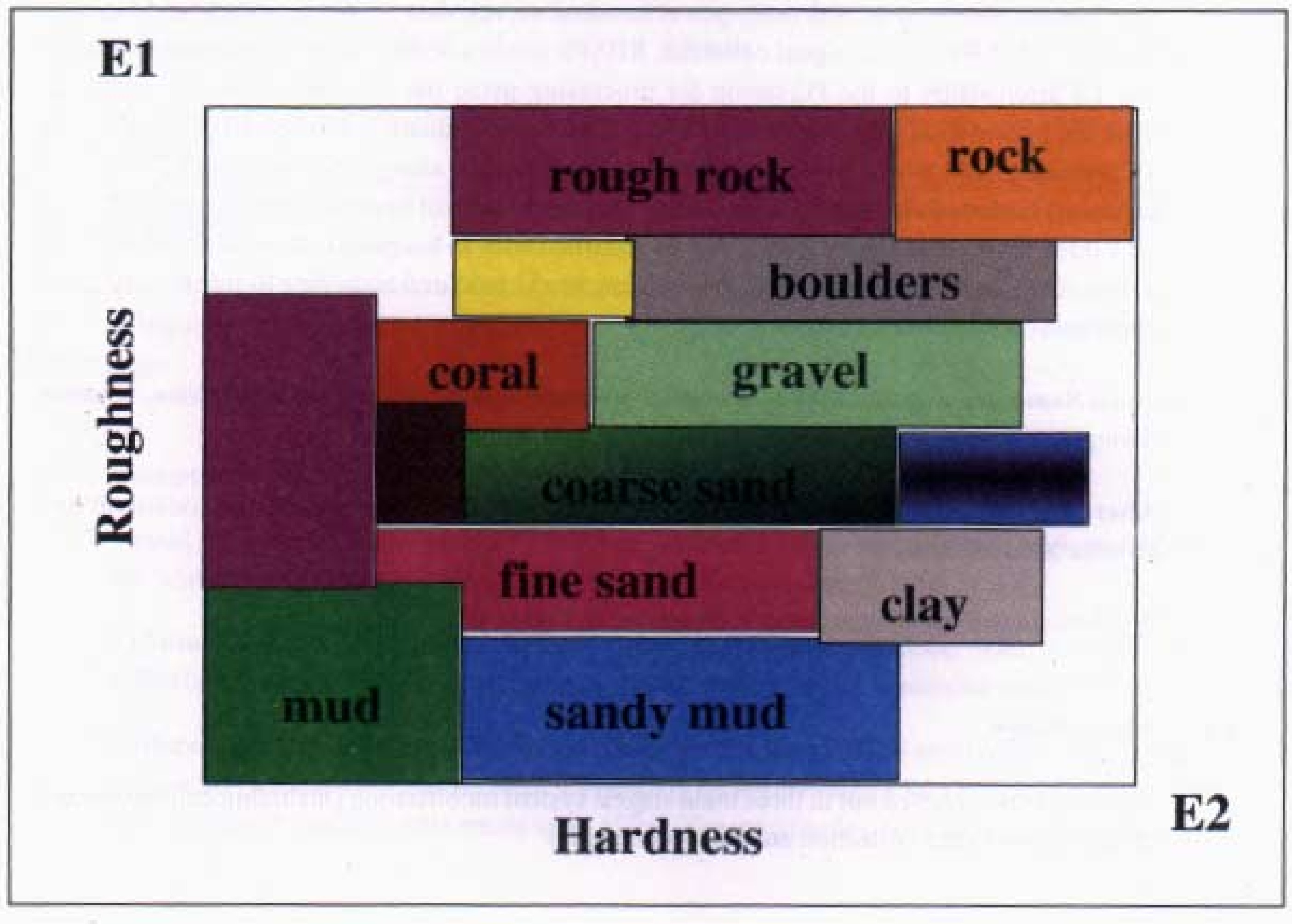
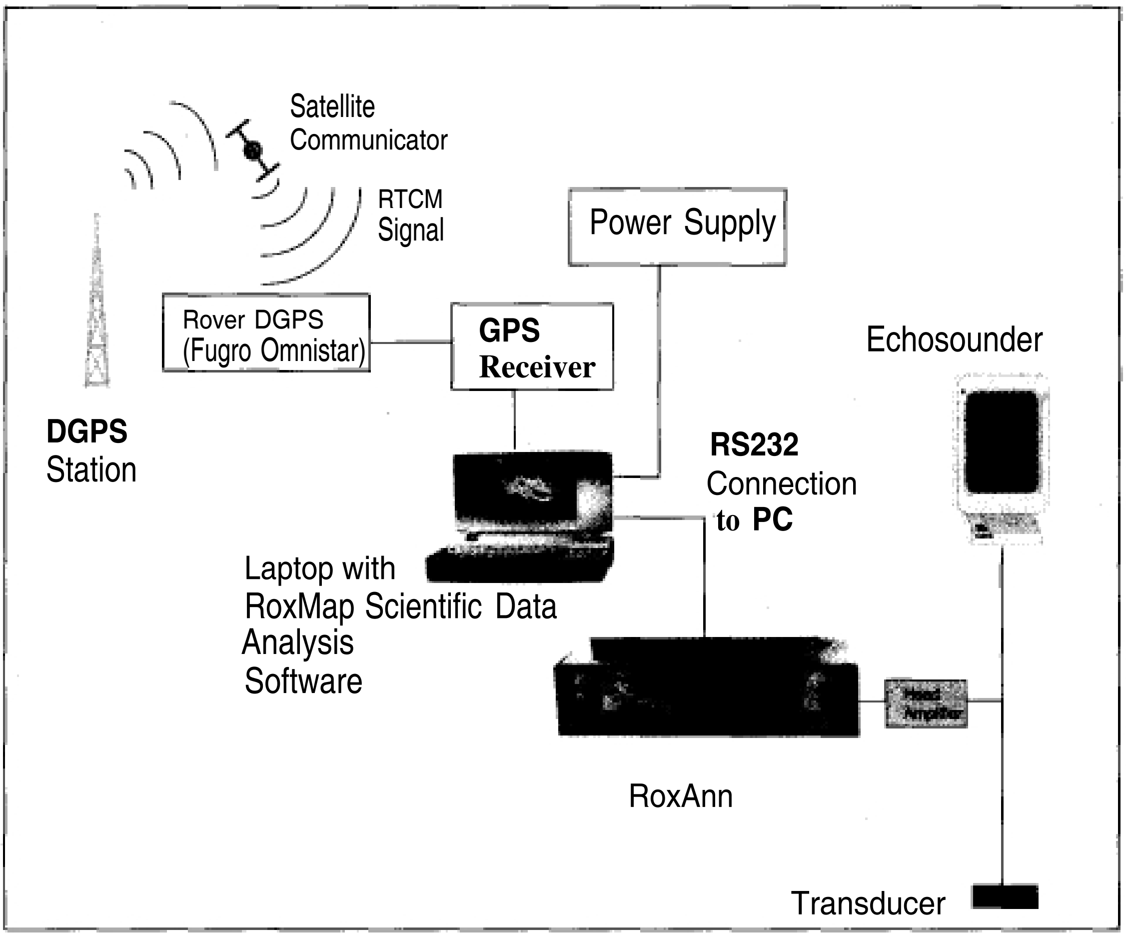


Figure 4: Set-up of the survey system



4.4.1 *Calibration of Survey System*

Calibration is crucial to synchronise the system component for communication; in the same times, set up an optimum E1 and E2 range. It was achieved by deploying the system on the survey vessel and initiating it at the Kuala Kedah cockle-mud ground in shallow waters (2.5m). A grab was used to verify the bottom type during calibration.

4.4.2 Classification of Reef Substrate Types

For the purpose of this survey, classification refers to a series of processes of assigning a specific colour to each bottom type or growth form to be determined, based on the range of E1 and E2 values consistently received and displayed on the RoxSquare. A laptop was used as data logger, navigational and display unit. During classification, the survey vessel was stationed on the desired bottom type with substantial surface area in order to "imprint" the system with the respective signal memory. Upon receipt of the echoes generated by the transducer, data were extracted by the RoxAnn Hydroacoustic Signal Processor (RHSP) and converted to classifiable readings. Then an optimum signal range for that particular bottom type was determined by drawing a box over the RoxSquare. Targeted for the survey were six common coral reef substate i.e. live hard coral, dead coral, coral rubble, soft coral sand and rock. Live hard coral will be classified further based on their growth forms. The six major growth forms to be identifled: plate/table, branching, foliose, massive, columnar and encrusting.

Upon completion ofthis ‘imprinting’ process, the system was connected to a Magellan 5000DLX GPS receiver and a Fugro OmniStar 3000LR. Differential Global Positioning (DGPS) modulator for accurate positioning data input. The use of DGPS will bring down the positioning error to 1-3 m instead ofthe normal 15-100 meters found in all GPS units. The system, complete with the DGPS, is now ready for transect run.

4.4.3 *Data Collection*

During the survey run, RoxMap Scientific was used to reveal the real-time position of the survey vessel and the previous track runs, besides recording the bottom type. The skipper could always refer to the laptop screen to double-check if the tracks formed were well - spaced between each other. The vessel ran at an average speed of 3.4 knots forming a continuous ‘U’ transect at 5-10 meter surface interval, perpendicular to each island. It enabled the seabed type at 3m-25m (±2m tidal variation), where most live coral and other important habitat are found to be recorded. Some transects parallel to each island were also run so as to plot an outline for the respective island besides serving the purpose of’cross-checking’ the ‘U’ transects.

4.4.4 *Post Processing and Generation of Thematic Map.*

Data collected in ASCII form were processed using Surfer62 TIN modelling software for thematic maps. All depth models were generated by interpolation using Kriging method, and substrate maps were interpolated using the Nearest Neighbour method with a Hewlett Packard Pentium 73 Vectra PC.

4.5 Project Activities

A summary for the survey activities in chronological order was as follows:

Day	*Date*		*Activity*
	20/4/98 (Mon)	am	- Mobilisation (Travel from KUL to AOR)
			- K Kedah to P. Payar
		pm	- Calibration at K. Kedah
		Night	- Group meeting
2	21/4/98	am	- Classification
		pm	- Classification
3	22/4/98 (Wed)	am	- Trouble shooting on DGPS and PCMCIA card slot
		pm	- YJ/CS: Lat/Lon for Segantang, Kaca, Lembu
4	23/4/98 (Thur)	am	- Trial run at Coral Garden and Japanese Garden
		pm	- Glass bottom boat

5	24/4/98			
	(Fri)	am	-	Transect l : Parallel Payar 1
			-	Transect 2: Parallel Payar 2
			-	Transect 3: Perpendicular Payar North, 1st quarter
6	25/4/98			
	(Sat)	am	-	Transect 4: Parallel Kaca
			-	Transect 5: Parallel Lembu
			-	Transect 6: Eastern Payar
			-	Transect 7: Marine Park Jetty-Banana Reef
				(Boat went to K.Kedah for fuel)
7	26/4/98			
	(Sun)	am	-	Transect 8: to patch up transect I
			-	Transect 9: South-West of Payar, lower quarter
		pm	-	Transect (10): Parallel Payar 3 (missing)
			-	Diving l :WS/Sharil, pauzi/Zakaria - From Marine
			-	Park Jetty to Langkai Coral
		am	-	Transect 10: Marine Park Jetty to Grouper Farm
8	27/4/98			
	(Mon)		-	Transect 11: Southern tip Payar
		pm	-	Transect 12: Northern tip Payar
			-	Transect 14: Parallel Kaca & Lembu
			-	Dive I: Pauzi/Zakaria - Boat Reef
9	28/4/98			
	(Tue)	am	-	Travel from Payar to Segantang
			-	Dive 3: Pauzi/Zakaria - Southeast of Segantang
		Noon	-	Transect 14: Parallel Segantang & Cupak
		pm	-	Transect 14: Parallel Payar
10	29/4/98			
	(Wed)	pm	-	EMP2000 water quality data collection
		Site l	:	Langkawi Coral
		Site 2	:	Northern tip, Payar
		Site 3	:	West Kaca
		Site 4	:	Kaca-Lembu channel
		Site 5	:	Eastern Lembu
		Site 6	:	Monroe rock
		Site 7	:	Coral Garden
		Site 8	:	Marine Park Jetty
			-	100 in Comparison transect
			-	Dive 5: Pauzi/Zabawi followed by Transect 15
11	30/4/98			
	(Thu)	am	-	Demobilisation

Figure 5: Simple depth contour line, P. Segantang

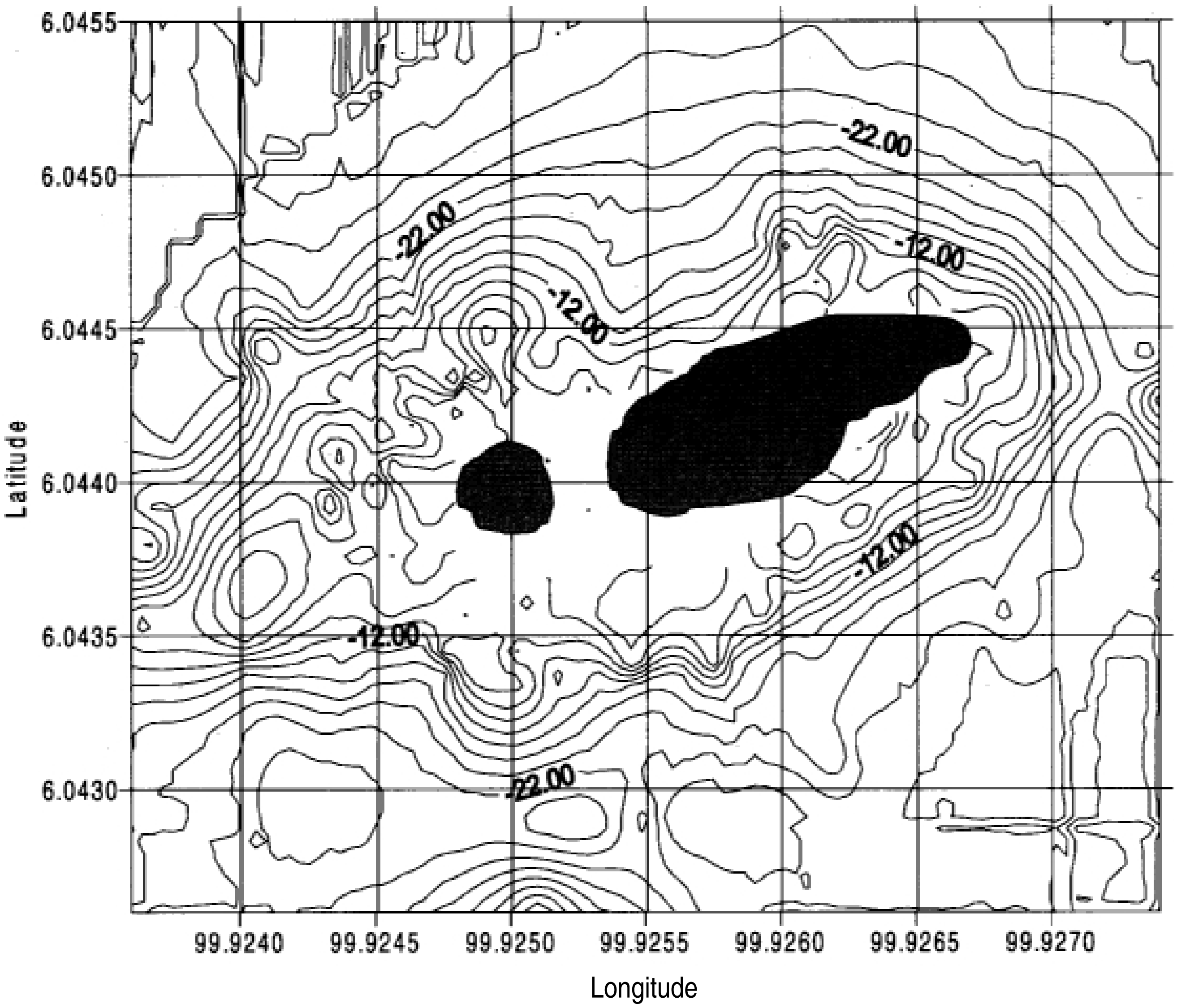


Figure 6: Simple depth contour line, Pulau Payar (Group of Islands)