EMPIRICAL FIELD AND LABORATORY EVALUATION OF A REAL-TIME ACOUSTIC SEA BED SURVEYING SYSTEM

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1. INTRODUCTION

Acoustic techniques are the most widely-used remote sensing methods for examination of the sea floor. On the basis of such data, attempts have been made to classify the sea bed in terms of its roughness, acoustic impedance (hardness) or some combination of these properties (Pace, [1]). The return of high-frequency sound signals provides information about near-surface sediments and the sediment-water interface. Lower frequency sources penetrate the sea bed, providing information on sub-bottom structures. Hence, echo-sounders have been used over the past 50 to 60 years (van Veen [2]) to provide bathymetric information and to examine sea bed morphological characteristics. Concurrent laboratory investigations have been undertaken on reflectance and backscatterance, to establish the response of sea bed material to incident acoustic signals (Pace [3]).

Recent research in this area concerns the processing of signals received by echo-sounders, to determine sea bed type. For example, an ultrasonic signal processor (USP) has been used in the development of a 'real-time' sea bed discrimination system (USP RoxAnn: Burns *et al* [4]; Emerson *et al* [5]; Chivers *et al* [6]).

The present contribution examines, for marine geological applications, intercomparisons between the output of a real time sea bed discrimination system (USP RoxAnn) and sedimentological/geophysical data sets. The latter have been obtained from shallow coastal waters and laboratory investigations.

2. SYSTEM DESCRIPTION

The RoxAnn system is operated using an ultrasonic signal processor (USP) (Burns *et al*, 1985). The principle of operation is that sea bed characteristics may be identified from the study of envelopes of the amplitudes of the directly-returned signal and the first multiple (hereafter referred to as first and second echo, respectively).

The RoxAnn system utilises the two return signals to differentiate ground types: the size of the tail of the first return echo (E1) associated principally with the roughness of the bed; and the area of the second return echo (E2) with acoustic impedance and, hence, the hardness of the bed material (Fig. 1). The first and last point of each of the integrals is calculated automatically by a logic control circuitry (Emerson *et al* [5]).

3. EXPERIMENTAL SET-UP AND DATA COLLECTION

The RoxAnn USP ground discrimination system has been used here in a number of field and laboratory investigations (Table 1).

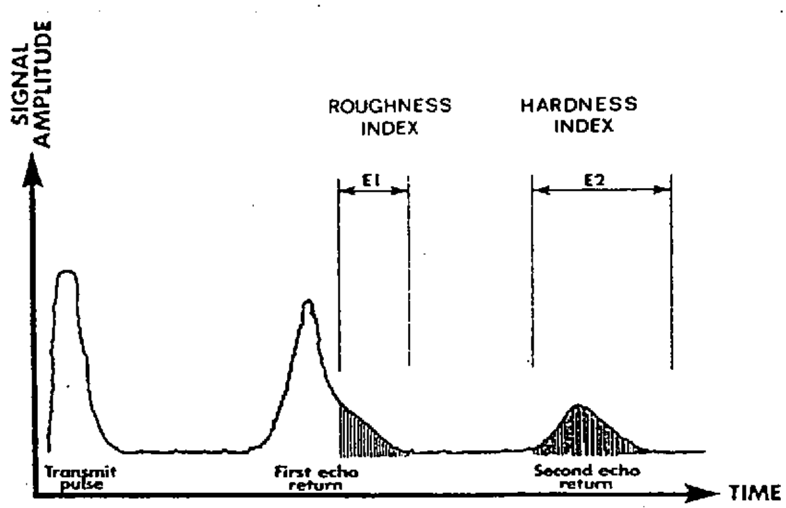

Figure 1. The parts of the return echo sounder signal integrated by USP (*from* Emmerson *et al* [5]).

Location	Bigbury Bay (June 1989)	Southampton Water (April 1991)	Folkestone/Dymchurch/ Sandgate (May 1991)	Laboratory Tank Experiments (June 1991)
Water depth	25 - 30m	3 - 15m	5 - 25m	5m
Echosounder used	38 Khz, 1kW 7 deg beamwidth	FURUNO FCV-262, 2kW dual freq. 28 Khz (22 deg) & 200 Khz (5.4 deg)	Raytheon DE719C 208 Khz 8 deg beamwidth	FURUNO FCV-262 2kW 200 Khz (5.4 deg)
Sea bed type	1. Plain sand 2. Sand ripples 3. Sand & rocks 4. Sand, rocks & ripples 5. Rocks 6. Bands of sand and sand ripples	1. Mud 2. Sand 3. Mixture of sand and mud with shell fragments	1. Mud and soft sand 2. Sand 3. 5-30mm sand on mud 4. Mud, sand & stones 5. Sand & stones 6. Gravel, shingle & stones 7. Weed & rocks 8. Weed	1. Flat concrete 2. Empty wooden tray 3. Sand 4. Gravel (10mm) 5. Gravel (20mm) (sediment deposits 10cm in thickness)

Table 1. Details of experimental instrumentation and data collection.

For the Bigbury Bay experiment, data were made available to the authors from ARE, Portland. The data set consists of RoxAnn hardness and roughness values and comparative side-scan sonar (Waverley Type 3000) images. Interpretation and navigation analysis of the sonographs was undertaken by ARE (see Voulgaris and Collins [7]) and a chart was produced showing different bed types and morphological features; this formed the basis for the comparison between the RoxAnn and sonar data.

For Southampton Water, RoxAnn output is compared against sea bed type. The classification of the seabed (Table 1) was based upon the grain size analysis of material collected using a van Veen-type grab (Voulgaris *et al* [8]).

Additional field information is available from a study undertaken by Hydraulics Research, Wallingford, on behalf of Shepway District Council at Dymchurch, Sandgate and Folkestone (HR Wallingford [9]). In this investigation, RoxAnn values are compared against visual descriptions of grab samples.

Data from a specific Ministry of Defence field trial were provided by ARE (Murphy [10]). The information were obtained by lowering a transducer to the sea bed, from a stationary vessel.

Laboratory investigations were undertaken using a 5 m cubed concrete tank filled with fresh water (at the Institute of Sound and Vibration Research (ISVR), Southampton University). A wooden tray 1.2 m x 1.2 m and 150 mm deep was constructed for the study; it was filled with graded sediment (Table 1) and placed on the floor of the tank.

4. RESULTS

4.1 Field Experiments

Definition of Sea Bed Types. Various data sets are available to compare sea bed types with RoxAnn E1 and E2 values (Table 1).

The Bigbury Bay data, relating to sandy sediments and rock, included featureless (smooth) and rippled areas of sea bed. Boundaries between these various sea bed types and morphologies are identified on the basis of side-scan sonar observations. Subsequently, centralised areas between these boundaries are examined in terms of their E1 and E2 characteristics. In total, some 3500 data points were selected for analysis. Mean and standard deviation, for E1 and E2, are used to define the limit of boxes on the classification chart (Fig. 2). The (RoxAnn) boxes are found to be well-defined (*ie* with little overlap) for the featureless beds (1,2 and 3), but are identified less clearly for those areas with bedforms superimposed (shaded). Such disparity may be related to the relative size of the 'footprint' of the echo-sounder beam width, in comparison with the morphological features present *ie* 3.5m and 2.6m in diameter (at these water depths) and wavelength, respectively.

There is a clear trend in the E1-E2 values for featureless areas of the bed in Bigbury Bay, with sand having low E1 and E2 values and rocks having higher E2 values and slightly higher E1 values. Areas of mixed sand and rock coincide with a marked increase in the E1 value.

The results obtained from Dymchurch, Sandgate and Folkestone, which cover a wide range of sea bed types, are shown on Figure 3. The hardness (E2) values are lowest for sand and mud/sand areas, whilst they increase in the presence of stones (mud, sand and stones). This increase is enhanced in the absence of mud (sand and stones). At the same time, the roughness (E1) increases in areas covered with seaweed.

Small differences in the relative position of the boxes, especially for the finer-grained material, emphasise the "site specific" nature of this approach to sea bed discrimination.

A frequency dependence in the derived E1 and E2 values is exemplified by the results from Southampton Water (Fig. 4), using echosounder frequencies of 28 kHz and 200 kHz over essentially the same sites.

Identification of Boundaries. On the basis of intercomparison between side-scan sonar imagery and E1-E2 output, along a particular track in Bigbury Bay, the boundaries between different types of sea bed are seen to be identified with 'peakedness' in the RoxAnn output (Fig. 5). In the Figure, areas of plain sand

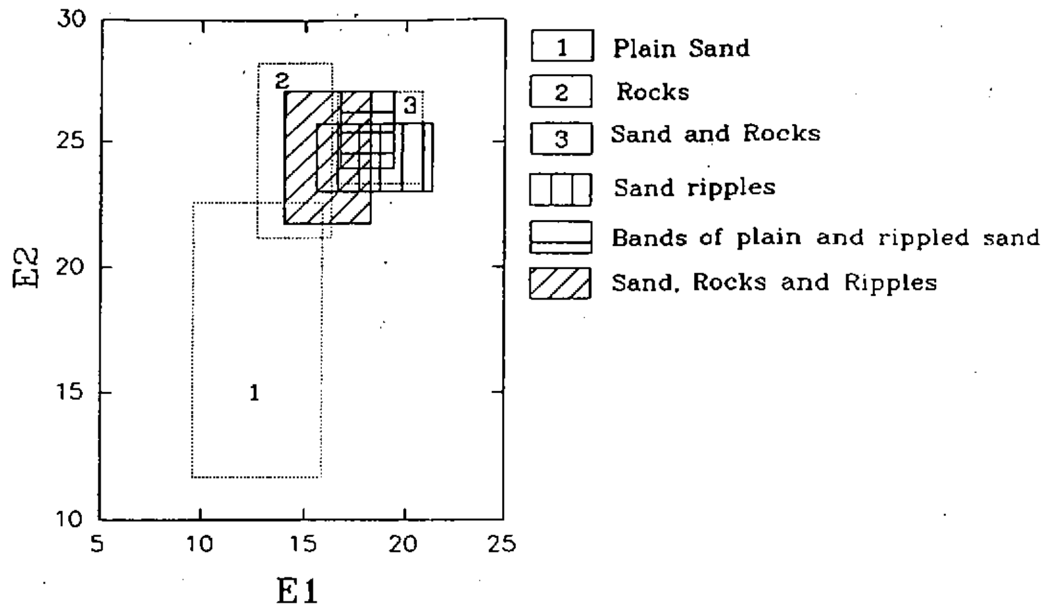

Figure 2. Bigbury Bay: boxes defining different sea bed types, on the basis of RoxAnn E1 and E2 values.

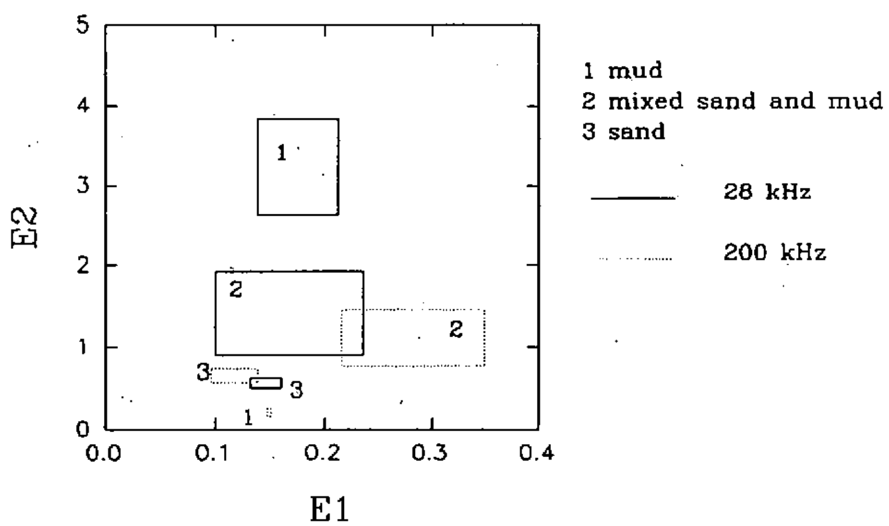

Figure 4. Southampton Water: boxes defining different sea bed types, on the basis of RoxAnn E1 and E2 values for different frequencies.

are seen to be bisected by a rippled bed. Some slight differences in elevation could cause abrupt changes in the E1 and E2 values, at the boundaries.

An attempt at a quantitative analysis of the above characteristic is shown on Figure 6; here, E1 and E2

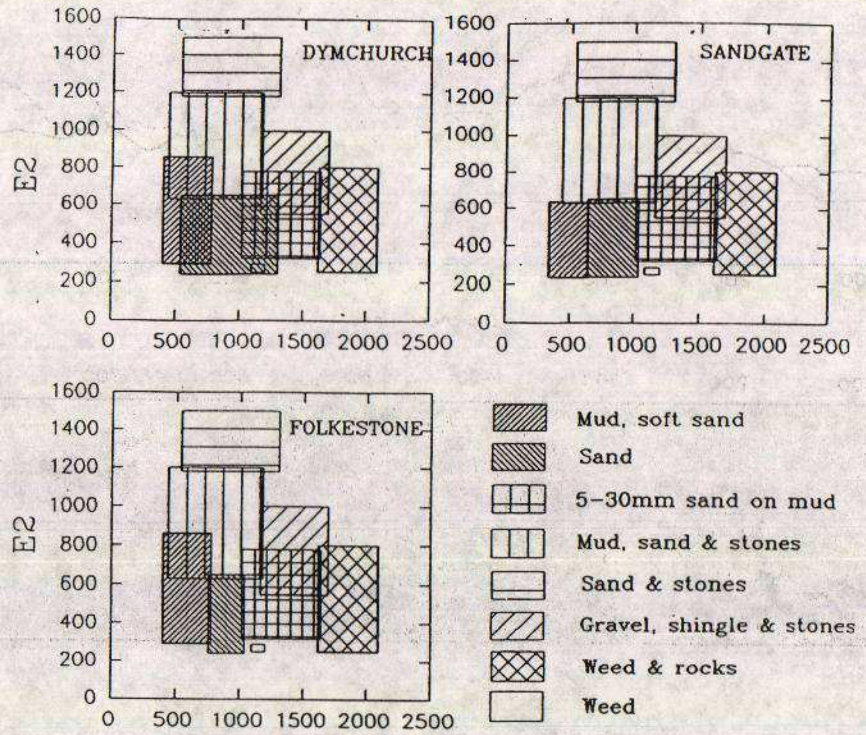

Figure 3. Dymchurch/Sandgate/Folkestone: boxes defining different sea bed types, on the basis of RoxAnn E1 and E2 values (survey areas shown on lower part of Figure) (data abstracted from HR Wallingford [9]).

values are displayed, together with the 'segmenting criterion' derived using Webster's [11] technique of analysis. Both are compared with boundaries identified on the side-scan image (*ie* sea bed types 1 to 6).

The recorded E1 and E2 values show peakedness; this, in turn, is represented as high values by the

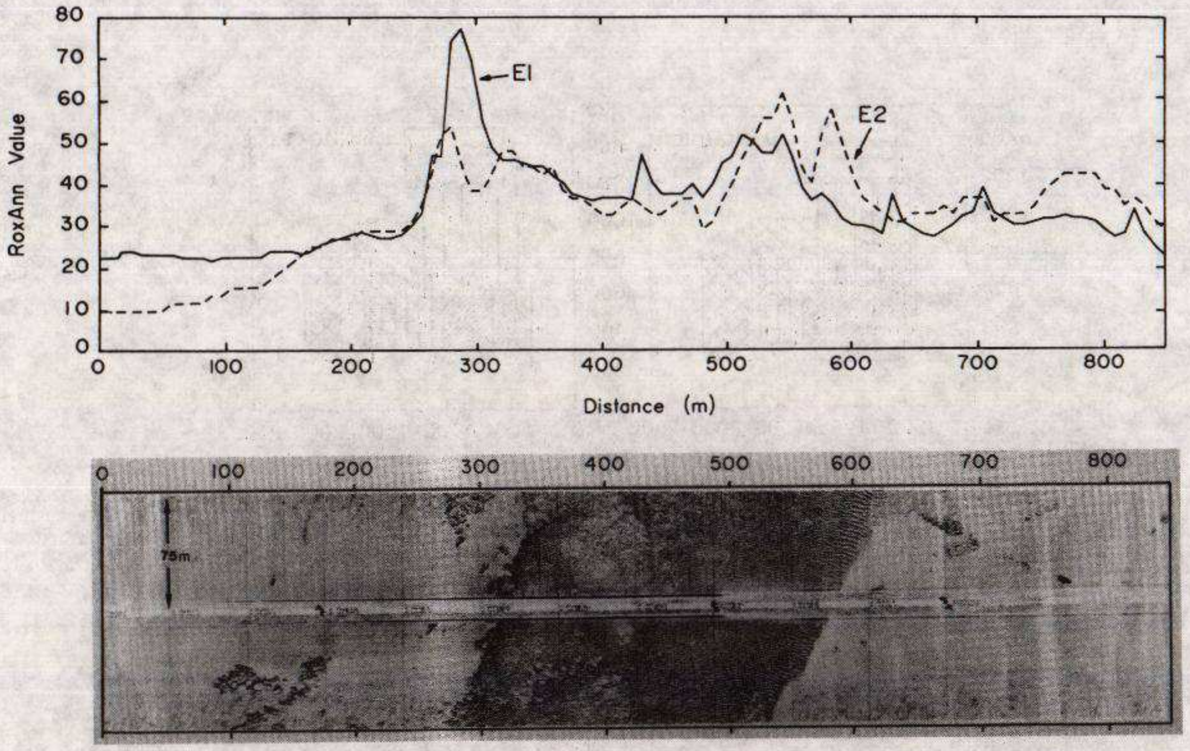

Figure 5. Bigbury Bay: example of E1 and E2 output (upper) along a single track, together with the corresponding side-scan sonar image of the sea bed (lower).

segmenting criterion. On occasions, there is correspondence between the criteria and boundaries identified on the sonar record (*eg* A, B and C on Fig. 6); on others, the relationship is not defined clearly (D and E). These observations indicate the vagaries in the identification of these particular features on the E1-E2 records.

4.2 Laboratory Experiments

Laboratory examination of the RoxAnn was undertaken over artificial beds consisting of sand, gravel (10 mm and 20 mm) and hard surfaces. Envelopes of the first and second echoes were recorded (Voulgaris *et al* [8]). The tests show the system able to discriminate sea bed types (Fig. 7), but with relative displacement in the (hardness and roughness) indices to those measured in the field.

The laboratory tests show, also, the RoxAnn output to be time-variable over a fixed bed; this is considered to be a function of instability in the echo-sounder signal output.

4.3 Range Dependence Experiment

The data set represents variations in E1 and E2 values at different transducer heights above the sea bed, ranging from 2.7 m to 31 m. The results are shown on Figure 8 and indicate a depth-dependence in E1 and E2 over the same sea bed type. Approaching the sea bed, there is a gradual reduction in both E1

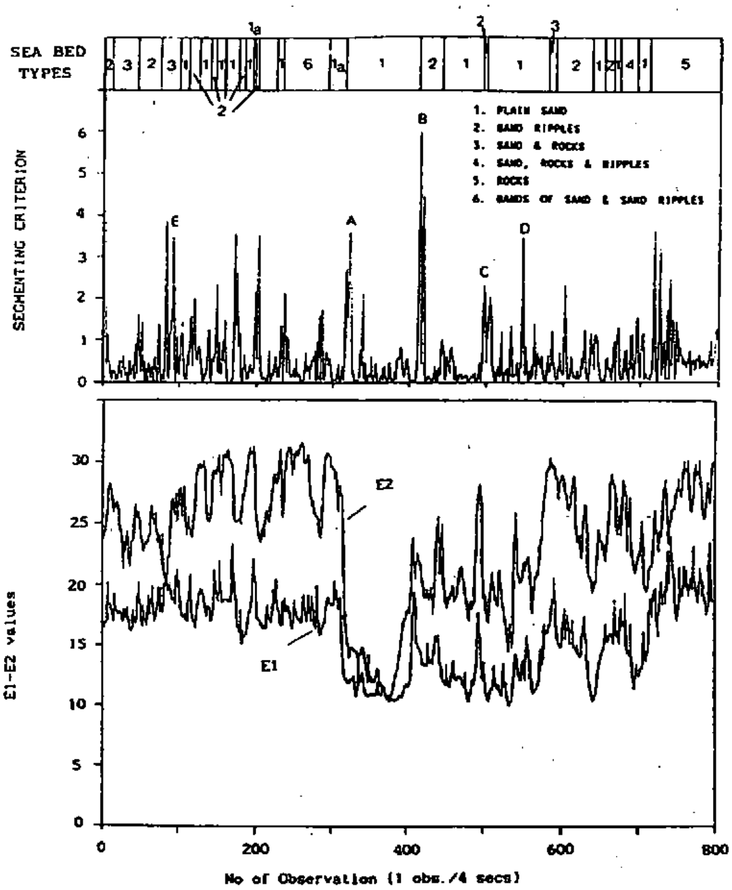

Figure 6. Bigbury Bay: variation in sea bed type (upper), segmenting criterion (middle) and E1-E2 values (lower) along a particular survey track.

and E2 values; this changes to relatively abrupt increases at between 10 and 15 m above the sea bed. This observation has implications in the interpretation of data collected over areas incorporating a wide range of water depths.

5. SUMMARY

Empirical field and laboratory evaluations of a USP RoxAnn system were undertaken. On the basis of statistical analyses, the system was found to be capable of discriminating between the mean characteristics of various sea bed types, for a particular location. Transfer of the calibration (*i.e* 'user' setting *etc*) from one area to another was limited, however, in relation to: the complex nature of the same sea bed type in different areas (near-surface layering, compaction, mixing proportions *etc*); the presence of ripples and dunes, which leads to a more complicated signal response - in relation to the 'footprint' of the echosounder beam; and localised marine growth (seaweed).

The derived hardness and roughness indices were found to be frequency and time dependent.

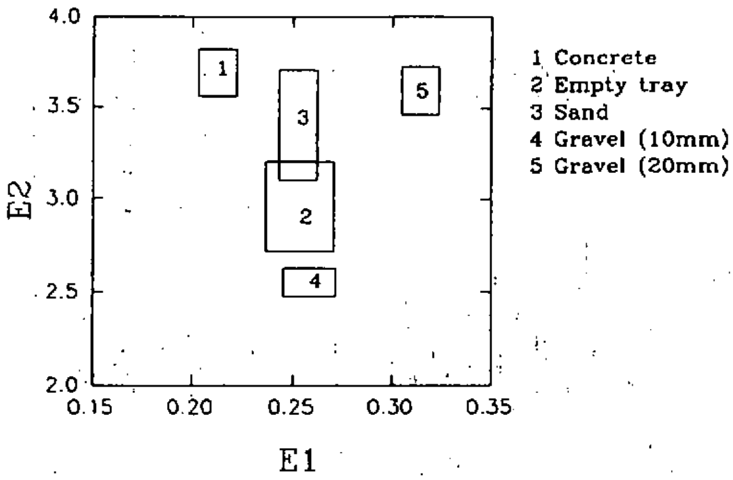

Figure 7. Laboratory tank experiment: boxes defining different sea bed types, on the basis of RoxAnn E1 and E2 values.

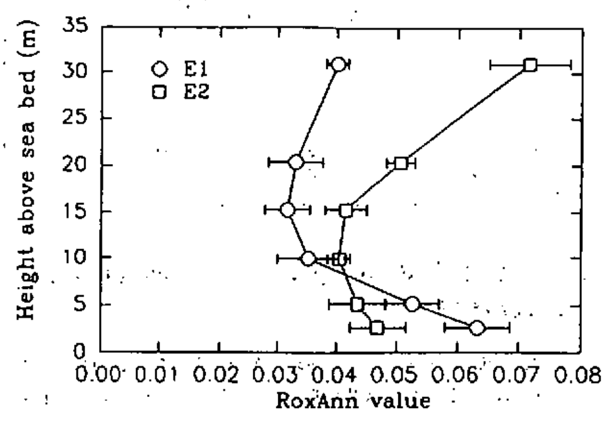

Figure 8. Range dependence: mean and standard deviation in RoxAnn E1 and E2 values (with statistical values derived from between 114 to 217 recordings).

Although, the present investigation has concentrated upon the RoxAnn system, some consideration should be given to the stability/instability of the energy of the echo-sounder output signals. Overall, in view of the problems of interpretation, there is an identified need for more rigorous experimental and theoretical investigations to be undertaken.

6. ACKNOWLEDGEMENTS

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