A COMPARISON OF SINGLE BEAM AND MULTIBEAM SONAR SYSTEMS IN SEAFLOOR HABITAT MAPPING

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Abstract: *Multibeam and single beam sonar (MBS and SBS) systems were used to map the seabed habitats within the Mandu Mandu region of the Ningaloo Marine Park, Western Australia. Backscatter and bathymetry data were collected with the Reson SeaBat 8101 MBS operating at 240 kHz and the Simrad EQ60 SBS operating at 38 and 200 kHz. Backscatter data were classified into 3 classes using supervised classification. The accuracy of the results was assessed with data from video transects taken over the area. This study found that the habitat map produced from MBS backscatter was 90% accurate and those from SBS were approximately 80% and 70% accurate at 200 kHz and 38 kHz respectively. Misclassification in the map produced by MBS was highest across heterogeneous or boundary areas. Misclassification in the habitat maps produced from the SBS backscatter was primarily due to errors of interpolation. Although closer line spacing would have likely improved the accuracy of the SBS results, the distributions of backscatter data for the different classes shows MBS data to have better discrimination than data from SBS.*

Keywords: *Multibeam sonar, Single beam sonar, backscatter, habitat mapping*

1. INTRODUCTION

Multibeam sonar (MBS) and single beam sonar (SBS) systems have been shown to be useful tools in benthic habitat mapping [1]. In general, SBS is considered to be a less expensive system than MBS to map a survey area, but provides much lower spatial resolution. This study compares seafloor classification results obtained from backscatter data collected with MBS and SBS from the Mandu Mandu region of the Ningaloo Marine Park in Western Australia, which is aimed to assess the accuracy of the different systems. The RoxAnn technique was used for processing single beam backscatter data [2]. Data collected from the MBS were processed using algorithms developed by the Centre for Marine Science and Technology (CMST) [3, 4]. Backscatter data were classified into 3 classes using supervised classification. The accuracy of the results was assessed with data from video transects under taken in the area.

2. METHODS

2.1. Data collection

From late April to mid May 2006, the Australian Institute of Marine Science's vessel *Cape Ferguson* collected SBS data using a Simrad EQ60 sonar operating at 38 and 200 kHz. Multibeam data were collected by Fugro Survey PTY LTD from the same vessel using a Reson Seabat 8101 sonar system operating at 240 kHz . The sonar data sets were collected in conjunction with underwater video transects, which were used for the classification accuracy assessment.

2.2. Single beam sonar processing

The RoxAnn method of processing SBS data uses echo-integration approach to derive values for a tail part of the first echo return (E1) and the whole of the second echo return (E2). While E2 is primarily a function of the gross reflectivity of the sediment and therefore depends primarily on its acoustic impedance (or hardness), E1 is influenced primarily by backscatter from the small to meso-scale roughness of the seabed. Therefore, E1 and E2 can be related in principle to the acoustic roughness and hardness of the seabed respectively, although each of these parameters depends in general on both roughness and hardness.

Echoview software developed by Myriax has been used for quality control and processing of the SBS data. Following procedures described in [5], the two RoxAnn parameters E1 and E2 were derived using the Echoview software. Interpolation using Kriging [6] was used to produce gridded maps of E1 and E2 over the area from the along track single beam data. The grid cell size used was 50m.

2.3. Multibeam sonar processing

The MBS data were processed using the CMST MBS toolbox and the angle cube algorithm developed by the CMST [3, 4]. The CMST MBS toolbox uses the beam time series data (sometimes referred to as snippets) to calculate the backscatter strength based on the energy of backscatter pulses for each beam. This is done by integrating the squared amplitude of the snippet time series. The received backscatter energy is normalised by the energy of the transmitted pulse and corrected for receive gain, which makes the backscatter estimates independent of the system settings. In the normal operation mode, the MBS system applies time variable gain (TVG) to the received signals to compensate for spreading and absorption losses along beams. The CMST MBS toolbox removes the system TVG correction, as it is not always adequate to the actual conditions of acoustic propagation, and corrects the backscatter energy estimates for the actual spreading and absorption losses along each beam. Finally, the backscatter energy is corrected for the the footprint size of each beam to obtain estimates of the surface backscattering coefficient (referred to here as backscatter strength as used in the logarithmic scale).

Backscatter strength produced by the CMST MBS toolbox can be corrected for angular dependence with an algorithm that corrects data for a section-average angular response [3]. A more advanced method was developed in [4] and referred to as the 'angle cube' algorithm. The angle cube method represents backscatter data from the survey area as a function of 3 dimensions: spatial coordinates X and Y, and the incidence angle, which produces a 3-dimensional sparse array of data. Then data in each angle layer are interpolated into each node of the X-Y spatial grid, producing a 3-dimensional matrix, or an angle cube. Of the commonly used interpolation techniques, Kriging was found to give satisfactory results, as the interpolated predictions did not reveal any unrealistic values. Finally, the angle average backscatter strength is calculated, for this dataset the backscatter was averaged over 5-60°, backscatter collected at incidence angles greater than 60° were noise. As the MBS used was not calibrated, the backscatter values are relative.

2.4. Classification

Three classes were observed in the video transects, namely 'rhodolith', 'sand' and 'mixed' in Mandu Mandu. Class descriptions are presented in Table 1. A cluster analysis was adopted here to classify backscatter characteristics which were the RoxAnn E1 and E2 parameters for the SBS and backscatter strength for the MBS. A supervised clustering technique with Bayesian distance was used. A training set was set up comprising distinct seabed habitats identified from video footages and results of video analysis conducted by AIMS. The mean of E1 and E2 for the single beam and the mean of backscatter strength for the multibeam, and their covariance matrices were estimated from the training set. The seed centroids were derived from the training set . Using these seeds, the supervised clustering technique was eventually performed on the rest of the data.

Table 1: Habitat class descriptions

Class	Description
rhodolith	All hard seabeds, such as rhodolith, rubble, coralline, hard rock/reef  
sand	Relatively flat sand 
mixed	Sand (dominant) mixed with sparse "rhodolith". Sand waves/dunes or sand with big ripples.  

3. RESULTS

Fig. 1 shows the bathymetry and backscatter data obtained during the MBS survey of Mandu Mandu in the Ningaloo Marine Park in Western Australia. The track lines from the SBS survey used for this study are also shown in Fig. 1, as well as the video transects used for the classification accuracy assessment. The seafloor backscatter strength processed by the CMST MBS toolbox and the angle cube algorithm demonstrates the extent of the different seafloor substrates without artefacts of the system settings and angular dependence of backscatter.

The MBS backscatter data interpolated into the locations of the SBS measurements were compared with the RoxAnn parameters E1 and E2 at 38 and 200 kHz (Fig. 2). There was a noticeable correlation between the MBS backscatter values and E1, particularly for the 200-kHz SBS data. This correlation is reasonable as both MBS backscatter and E1 values are derived from the first bottom returns and are sensitive to changes in the seafloor roughness. The correlation is greater at higher frequency of SBS because of a closer operating frequency between the MBS and SBS (240 and 200 kHz).On the other hand, there was no significant correlation between the E2 parameter and the MBS backscatter. This is also reasonable as E2 is more sensitive to changes in the bottom reflectivity at vertical incidence rather than the seabed roughness.

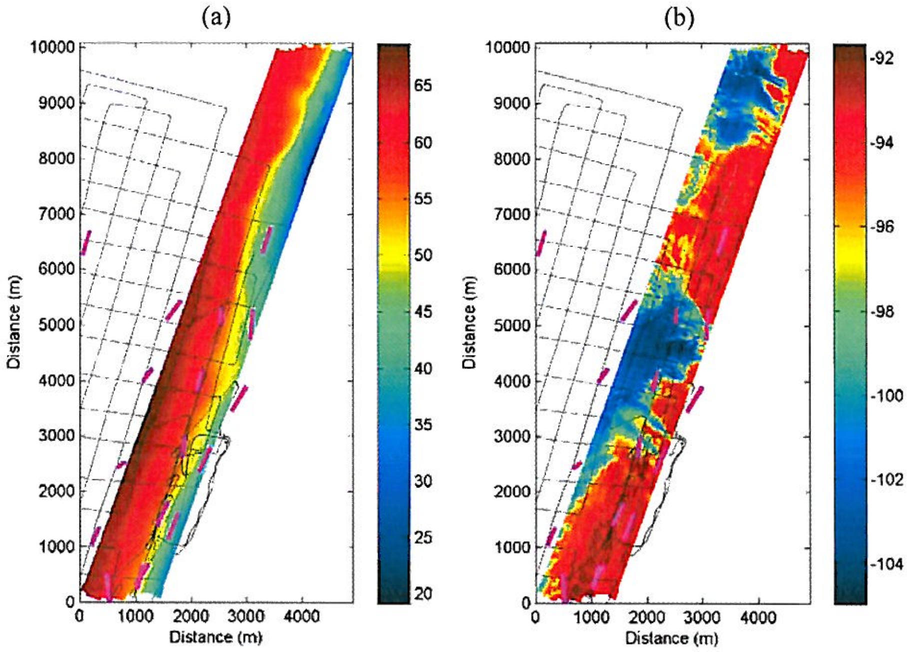

Fig. 1: (a) Bathymetry [m] and (b) backscatter [dB] from the multibeam sonar survey of the Mandu Mandu region of the Ningaloo Marine Park. Black lines are the track lines of the single beam survey and magenta lines are video transects.

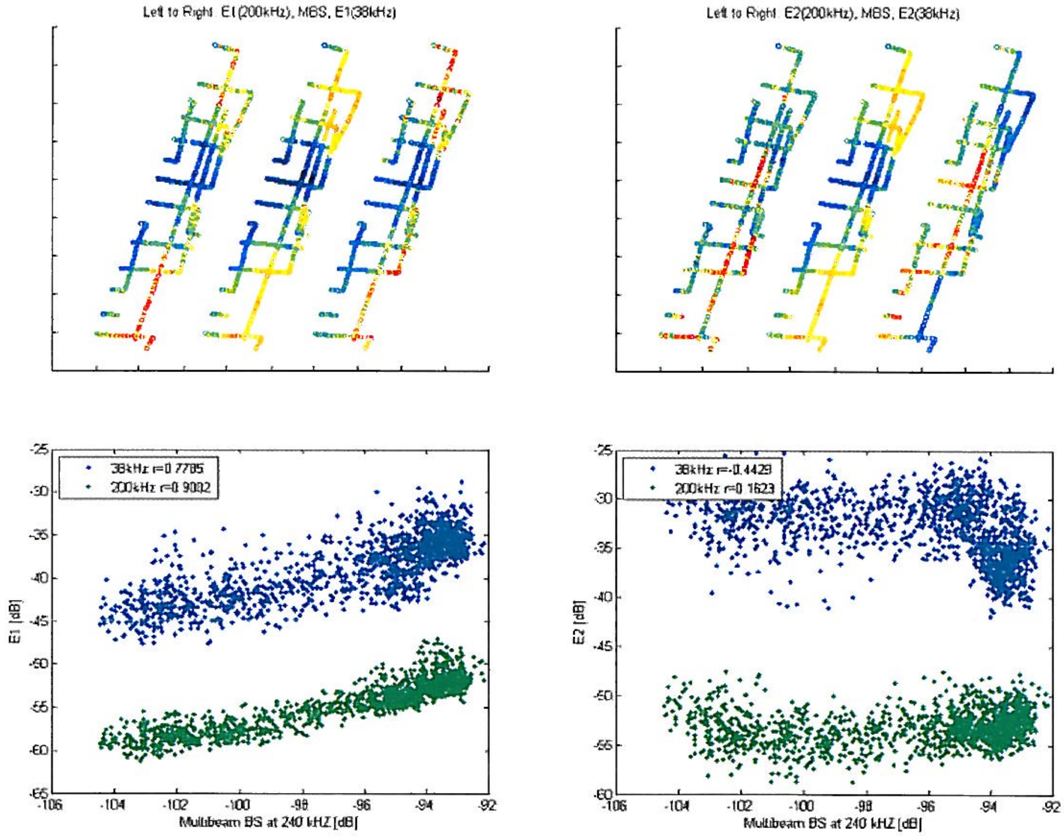

Fig. 2: A comparison of the backscatter from the multibeam sonar data (240 kHz) and E1 and E2 calculated from single beam sonar data at 38 and 200 kHz.

The distributions of E1 and E2 derived from the 38 and 200 kHz SBS data and 240 kHz MBS backscatter from areas of sand and rhodolith are compared in Fig. 3. The plots show the separation in the sand and rhodolith classes to be largest in the MBS backscatter data, followed by the E1 values and then the E2 values. This larger separation of the two different classes in the MBS backscatter data is due to the inclusion of backscatter from oblique incidence angles in contrast to the SBS data.

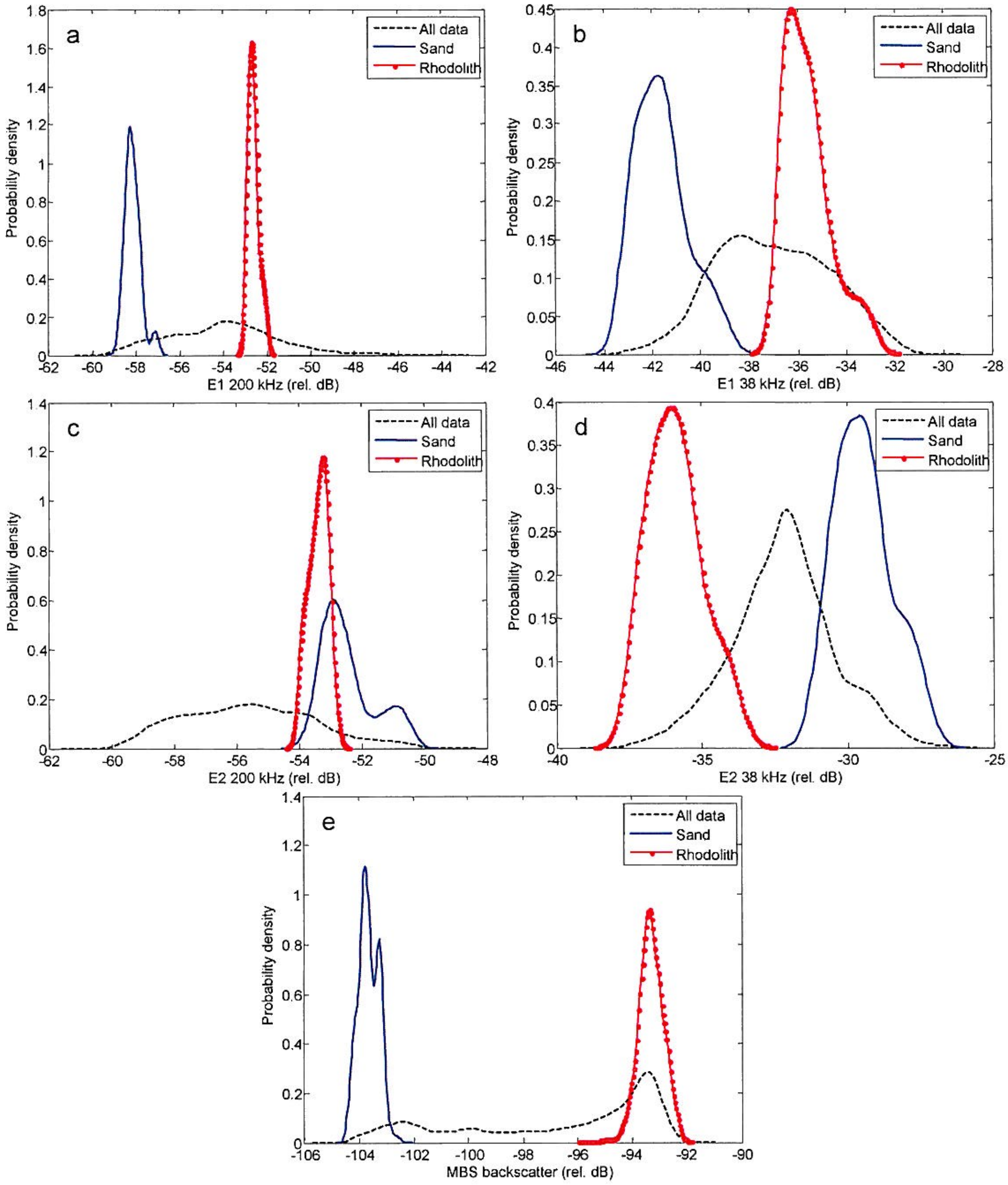

Fig. 3: Probability density distributions of all data sand, rhodolith of E1 for (a) 200 kHz and (b) 38 kHz; and E2 of (c) 200 kHz and (d) 38 kHz and (e) 240 kHz multibeam backscatter.

Classification maps produced from the cluster analysis are shown in Fig. 4 and results of the classification accuracy assessment are summarised in Table 2. It was found that the MBS backscatter data were the most accurate, followed by the results of the SBS 200 kHz and then the SBS 38 kHz. Based on the video data collected results from MBS were highly accurate in recognising sand and rhodolith respectively. Misclassification in the map produced by MBS was highest across heterogeneous and boundary areas, such as the mixed areas. Misclassification in the habitat map produced from the SBS backscatter was primarily due to errors of interpolation. However, the larger separation between classes seen in MBS backscatter indicates that MBS backscatter is better at discriminating the different classes found in this survey area. The ground-truth data was not comprehensive enough to consider the classification accuracy assessment to be absolute, but does provide an indicative accuracy of the different sonar systems, especially relative to each other.

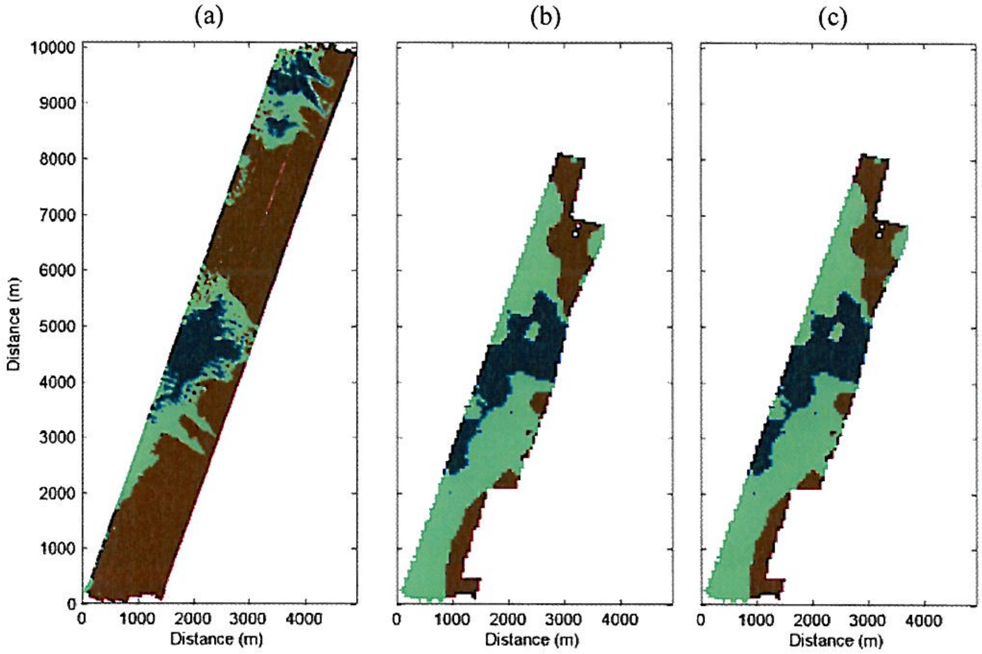

Fig. 4: Classification maps of the Mandu Mandu region produced from cluster analysis of (a) MBS backscatter, (b) SBS 200 kHz and (c) SBS 38 kHz. Classes are: rhodolith (brown), sand (blue) and mixed (green).

Table 2: Summary of classification accuracy derived from confusion matrices.

System	Classification accuracy (%)			
	Overall	User's		
		rhodolith	mixed	Sand
SBS 38kHz	69	68	82	57
SBS 200kHz	84	93	92	67
MBS 240kHz	91	93	80	100

4. CONCLUSIONS

It has been demonstrated that both SBS and MBS systems are reasonably accurate in seafloor habitat mapping. The MBS system, however, offers better resolution and coverage and in turn better classification accuracy than the single beam system can provide. Although closer track line spacing would have likely improved the accuracy of the SBS results, the distributions of backscatter characteristics for the different classes shows MBS to have considerable better discrimination than the data from SBS. This is most likely to be due to the inclusion of backscatter characteristics from oblique incidence angles in the angle cube algorithm, which are more sensitive to changes in the seabed roughness than those at vertical incidence. While MBSs are inherently more expensive system than SBSs, the results show that the track line spacing for a SBS survey needs to be considerably smaller than that of a MBS survey to have comparable results. As the costs associated with surveys are related predominantly to vessel time, the cost-benefit of using a MBS system with respect to ship time needed is considered to be an important factor when choosing a sonar system for seabed habitat mapping.

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