WATER COLUMN FEATURES AND SEAFLOOR CHARACTERISTICS USING SIMULTANEOUS MULTIBEAM WATER COLUMN DETECTION

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ABSTRACT: Simultaneous mid-water and seafloor classification enables the study of the relationship between seafloor characteristics and water column features known as habitat interactions. Normally, the focus of these data is only on one part of either the water column or the seafloor. This water column data is usually filtered out to form an accurate bathymetric surface. Otherwise, this will cause data duplication or loss and degrade the accuracy of the data. This study aimed to produce a comprehensive map using a Multibeam Echosounder System (MBES). The data acquisition was carried out using WASSP WMB-160f MBES and a camera recorder was used for verification. Data comparison was carried out through bathymetric and backscatter analysis and filtered at the minimum threshold. The result showed that both data were able to be detected simultaneously at a comparable and effective result without neglecting any details behind. The water column data was at good resolution for detection below the 300 kHz, although the data obtained from this study did not show the real shape and size of the detected object. In addition, the seafloor could also be well detected and properly classified according to survey requirements.

KEYWORDS: *Water Column; Habitat Interaction; Underwater Map; MBES*

1.0   INTRODUCTION

Reflected signal gets distorted due to the various properties of water column and becomes noise in the original acoustic signal and these needs to be filtered out through the data processing procedure for a better bathymetric surface development. Several studies revealed that using a water column image in the form of three-dimension (3D) can provide a better understanding of underwater habitat [1]. The noises could be distinctly distinguished using the current imaging capability of the multibeam echosounders system (MBES) known as water column detection [2-3].

The characteristic of water column was previously regarded as a nuisance for the production of bathymetric surfaces and it was filtered out. However, those noises might be detected if an object could be visualized and studied. Deepening the water column study provides an opportunity for research surrounding its inhabitants. However, explanations regarding the interaction of seafloor characteristics and the water column features detected by MBES have not yet been addressed properly [4-6].

The ability to detect biological features integrated with seafloor characteristics data provides an opportunity for ecosystem studies to be conducted using MBES. In the case of tensile assessment costs, the data obtained are ideally used in various fields such as oceanography and fisheries with only one data collection process [2, 4].

The purpose of this study was to obtain data for water columns and seafloor characteristics simultaneously using MBES. Not waiving any data enables the seabed underwater map to have more complete character data which will increase the ability to analyze an organism interaction study.

2.0   METHODOLOGY

The study area was near island Agas (Pulau Agas) in Perak, Malaysia. The area was extending about 1.2 km² from the Island Sembilan (Pulau Sembilan) as shown in the Figure 1. This island is nearby a shallow reef and local fishery site, making this as an ideal study area.
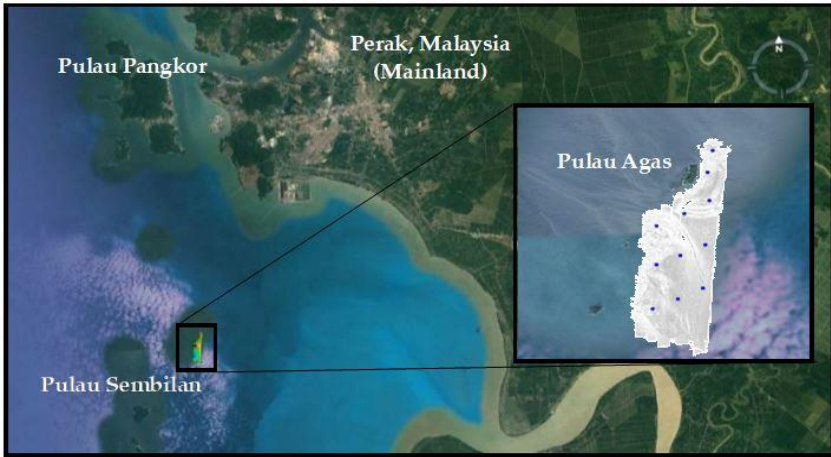
Figure 1: Study area with camera points marked in blue dots

In data acquisition, WASSP WMB-160f MBES was used and bathymetry (depth), backscatter and water column data were collected simultaneously. In addition to that, underwater visual images were collected using an underwater camera. The MBES operation settings during the data collection were 160 kHz with line spacing of 100 m. The arrangements were made to maintain at least 20% overlap of swath coverage. Sound speed profile was applied, vessel attitudes were measured and MBES calibration and installation angles were computed before the bathymetry was computed. The camera dumping locations were designed as such that they were distributed evenly throughout the survey area (Figure 1). These images were used in ground truthing the results and it is one of the widely used method [4-6].

A schematic diagram of the methodology is shown in Figure 2. After the data acquisition, the data were cleaned, filtered and visualized on the QPS Fledermaus software in UTM zone 47N coordinate system. Matlab software was used with in-house M-files coding and further, analyzed by QGIS and ArcGIS software. Besides water column and backscatter processing, water column discrimination for bathymetric surface process would support one another for four mains essential steps in this study.

In the water column discrimination, the data were separated into two main parts namely the water column and seafloor. Firstly, the sounding data from the MBES were processed to obtain the seafloor data or bathymetry correctly. Similarly, the backscatter data were also processed through comparison of the data from the bathymetry surface developed. Then, these data were viewed in terms of trends

and conformity between two data and verified using the camera data. For the first exploration of the seafloor, an unsupervised classification technique was used, and the habitat classification was conducted.
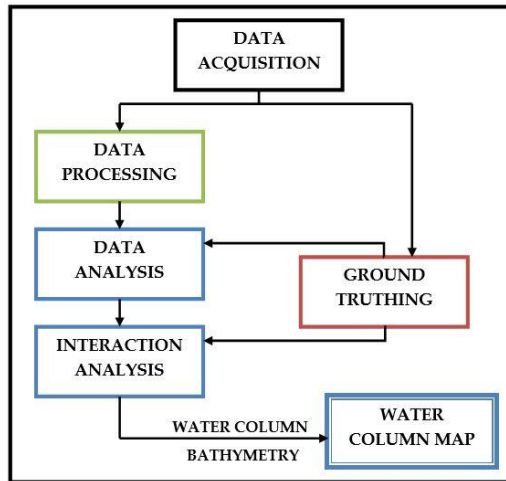

Figure 2: Data acquisition and processing flow chart

The next result from the initial process was data discrimination and it was used to process water column data. The changes in morphology with bathymetry data was one of the methods used to identify the condition of the water column detection. Apart from camera images, raw data from the sonar were also viewed and compared to authenticate the status of the data. Before the removal process was carried out, the threshold for the water column was estimated by counting backscatter targets [7-8]. The product from this process was overlaid over the other to get a complete picture of the habitat. The interaction between the habitats and water column was the focus, reflecting the key objective of this study which was to seek the sustainability and the relationship between the habitat and the water column. Finally, by combining all the surfaces, a comprehensive map was formed.

3.0   RESULTS AND ANALYSIS

A clean and an accurate bathymetric surface of the area were created (Figure 3). In the formation of a clean surface and right water column detection, two data categories were filtered and separated. Therefore, ground discrimination and mid-water filtration were applied [9-10].
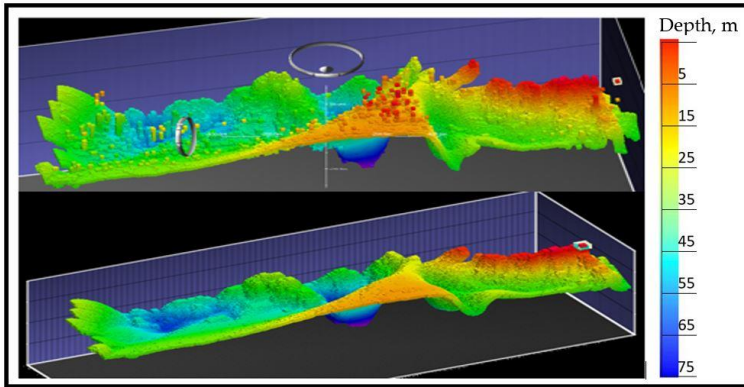
Figure 3: Bathymetric map associated depth data with Water column data, before (top) and after (bottom) discrimination

The average depth of the area was about 30-40 m. The results (Figure 3) showed two near trenches to the right of the diagram. Its formation was naturally due to the flow of current and the wave. The diversity inclination of the inclined angle and the non-glazed rough surface could be seen clearly. The surface shape was also a factor that was attributed to the amount of water column to be detected for a fishery area.

In the backscatter image, most of the values were concentrated around the range of 45 - 145 DN. Figure 4 shows the results of the backscatter processing. There were five classes identified from the underwater camera results (coral, rubble, rocks, sand and silt) and seven classes were identified with the unsupervised classification. These differences were obtained due to the slight DN value variations at the boundary of the silt vs sand and rubbles vs sand area. These areas were very small and did not cause any significant impact in the final results (Figure 4).

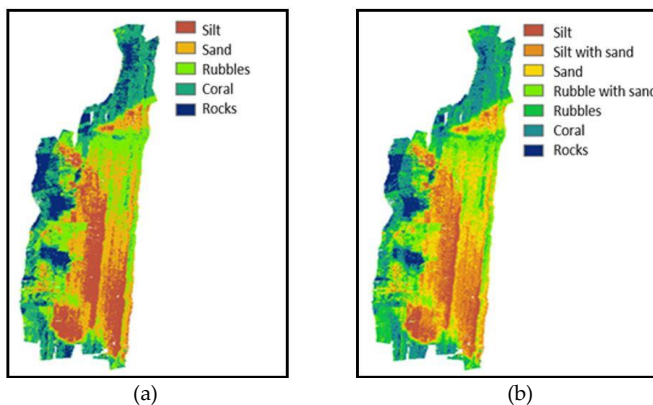(a)   (b)

Figure 4: Unsupervised classification of backscatter imagery, (a) 5 classes and (b) 7 classes

In the process of classification, unsupervised technique was used for first time exploitation of the study area. Based on the backscatter pattern detected and the recording images, there were five (5) and seven (7) possible classes for seafloor characteristics used. In classification for 5 classes, each class detected was unique for each character, and classification using 7 classes provided more space analysis for the class that gradually changed from one type to another This allows for the definition of mixing character in a class. This is helpful to the study because the human limit to differentiate the two adjacent areas can significantly affect the results.

3.1 Interaction Analysis

Morphological disparities of the selected locations were observed by comparing the water column and bathymetry profile along the same profiler plane. The profile lines created across the data set were approximately 35 - 50 m long and going through the marked areas and evenly distributed in the entire survey site. Sample profiles are shown in the Figure 5.
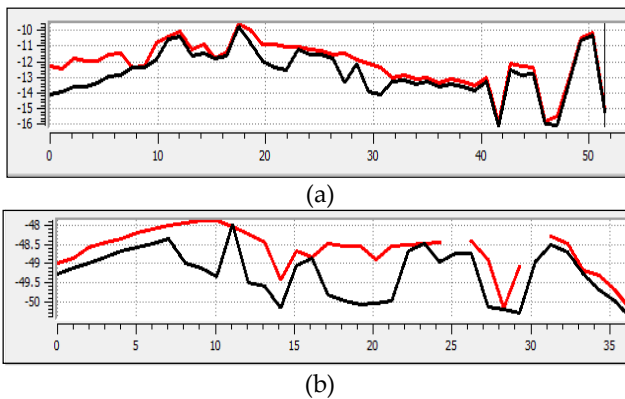

(a)

(b)

Figure 5: Examples of profile data from potential areas of (a) shallow water and (b) deep water bottom profile comparison with water column line in red and bathymetry line in black

According to Figure 5, the water column profiles observed were always higher than the bathymetry profiles which represented the mid-water contents. The average difference was 7 m while the maximum was about 10 m and minimum 5 m. There are two reasons for these uneven profiles, which are formed from suspended mid-water content that alter the depth [2, 4] and, the structure of the surface, which is the main attraction for the inhabitants to occupy [11-12]. In some areas, especially at the lower levels, no difference was observed.

Table 1: Correlation determination data that averaged through samples taken in six divisions of study area

Division	Volume, m³	Depth, m	Backscatter, DN
I	6.375	4.935	16.543
II	12.125	5.555	23.906
III	13.324	10.106	20.817
IV	11.306	5.258	12.481
V	18.667	9.322	22.823
VI	16.780	5.724	20.691

A correlation determination was performed for the plotted tables (Table 1) using the average data across the survey site. The interaction relationship is studied from the aspects of backscatter, depth and volume between the divisions. The average values were calculated at each location, which came from 54 points that were evenly distributed along the surveyed area. Figure 6 shows the correlation comparison of water column and seafloor data.
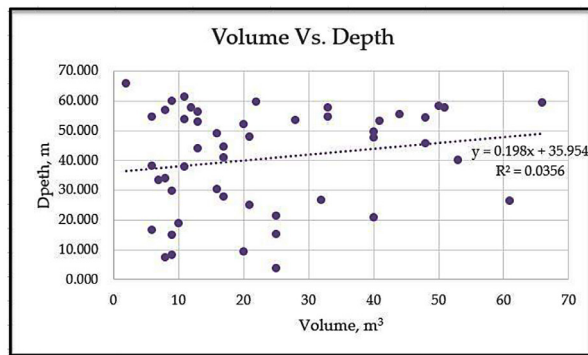
(a)
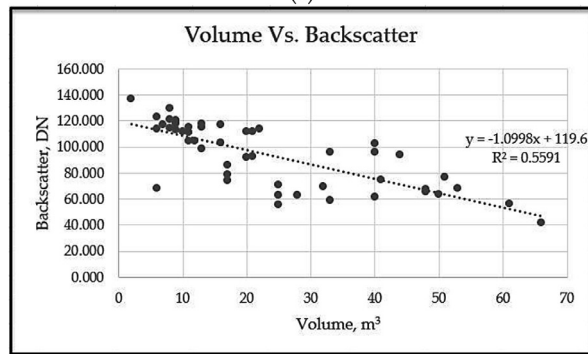
(b)

Figure 6: Scatter plot and linear regression of the (a) water column detected volume vs. depth and (b) water column detected volume vs. backscatter

The data obtained were inversely proportional because the backscatter reading was in DN, as shown in Figure 6 (b). It can also be seen from the data that water column aggregation played a role as well. The lower probability of backscatter readings occurred once the aggregation was high. It may also be caused by the surrounding of the aggregation detected. The denser the aggregation, the more it was reflected as a signal. The volume of inhabitant occupation would indirectly determine habitat preferences of the study area. Besides, the aggregation often occurred at shallow water area (Figure 6 (a)).

3.2   Complete Map Presentation

The thematic surfaces formed from bathymetric data, backscatter and water columns have been arranged with each other. Finally, a more complete underwater map of the environment and water column features can be produced (Figure 7).
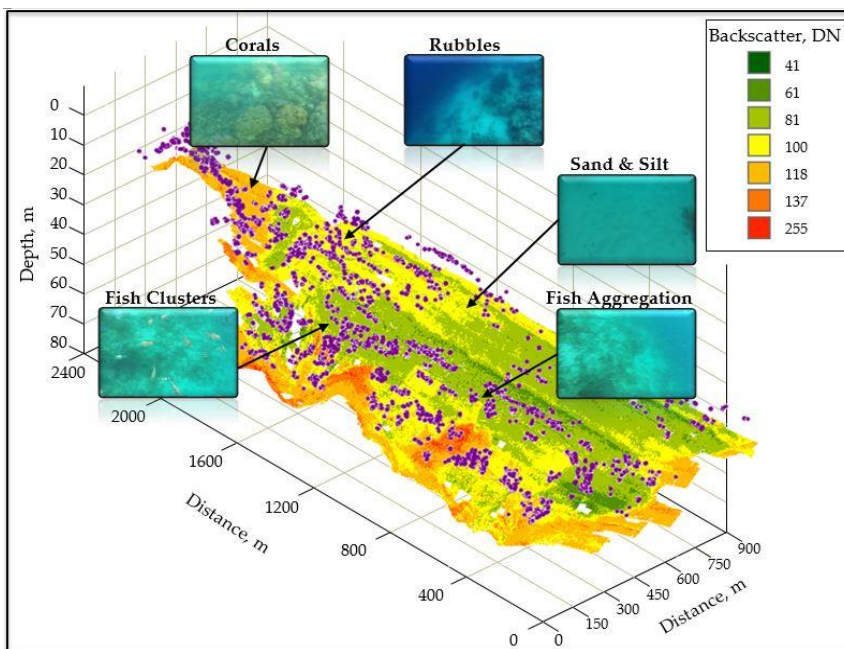

Figure 7: Map of underwater water column features and seafloor characteristics

Firstly, the classification of 7 classes have been selected in the model to enhance the gradual transitions between the sediment types and at the same time permitted the definition of the mixed sediments which match to images recorded by the camera. The results of distribution of the classes were; 8.86% silt, 17.04% coral, 17.05% sand, 16.15% rubbles,

5.28% rocks, 17.57% rubble with sand and 17.04% were silt with sand. There have been many water column features concentrated on rough areas (with 87%) while the flat bottom area was only about 13%.

In terms of the seafloor bathymetry model, the rough area tended to be at the shallow area. The roughness detected was connected to the detection of water column features. Most of the living features sheltered at shallower water for their survival and natural needs for solar energy. The sunlight is the source of energy in the coral area that forms a basic food chain for an ecosystem [13].

According to Figure 7, the water column features appearance was not as much as expected. The habitat environment was one of the factors that led to this result. An initial estimate of the study was to find vegetative areas, as the previous study findings have a high diversity impact. Besides, the behavior of the water column features also played a role in the detection. Fish are very sensitive to noise, and studies have shown that they will keep away from the sounds and foreign objects including the movement of the ship's passage, this phenomenon is called as vessel avoidance behavior [14].

Aggregation was also found in places of flat bottom area, apart from the crossing repeatedly under the sensor, hence, the fish schooling attitude refers to their not leaving the area entirely but only keep changing direction around their turf [4].

4.0   CONCLUSION

From this study, it is found that the habitat structure is one of the key factors in organism distribution. While in the interaction analysis, there is no solid evidence and reason found behind the aggregation of fish groups in this study. However, this study finds that both characteristics of the seafloor and water columns can be tracked simultaneously and produce a good complete map model. Further studies on water columns will definitely have a higher impact if it can be identified as a known feature. The ability to generate and visualize data images accurately with the latest technology is relevant to understand the water column characteristics and sound coastal zone management. As the technology is advancing rapidly, recent studies show that data usage in water columns is extending beyond other areas of study to a wider field such as fisheries and oceanography.

ACKNOWLEDGMENTS

REFERENCES

[1] K. Colbo, T. Ross, C. Brown and T. Weber, "A review of oceanographic applications of water column data from multibeam echosounders,"*Estuarine, Coastal and Shelf Science*, vol. 145, pp. 41-56, 2014.

[2] M. Cox, D. Demer, J. Warren, G. Cutter, and A. Brierley, "Multibeam echosounder observations reveal interactions between Antarctic krill and air-breathing predators," *Marine Ecology Progress Series*, vol. 378, pp. 199–209, 2009.

[3] T. C. Weber, M. E. Lutcavage, and M. L. Schroth-Miller, "Near resonance acoustic scattering from organized schools of juvenile Atlantic bluefin tuna (Thunnusthynnus)," *The Journal of the Acoustical Society of America*, vol. 133, no. 6, pp. 3802–3812, 2013.

[4] M. Parsons, I. Parnum and R. McCauley, "Visualizing Samsonfish (Seriola hippos) with a Reson 7125 Seabat multibeam sonar", *ICES Journal of Marine Science*, vol. 70, no. 3, pp. 665-674, 2013.

[5] I. Parnum, "Benthic habitat mapping using multibeam sonar systems," Ph. D dissertation, Department of Imaging and Applied Physics, Centre for Marine Science and Technology, Curtin University of Technology, Perth, Australia, 2008.

[6] S. O. C. Boulay, "Analysis of Multibeam Sonar Data for Benthic Habitat Characterization of The Port of Tauranga, New Zealand," M.S. thesis, Department of Earth and Ocean Sciences, University of Waikato, Tauranga, New Zealand, 2012.

[7] K. Mussai, "Imaging and counting of targets with a high resolution multibeam sonar," M.S. thesis, Department of Electrical Engineering,University of Cape Town, Cape Town, South Africa, 2010.

[8] M. D'Elia, B. Patti, A. Bonanno, I. Fontana, G. Giacalone, G. Basilone and P. Fernandes, "Analysis of backscatter properties and application of classification procedures for the identification of small pelagic fish species in the Central Mediterranean," *Fisheries Research*, vol. 149, pp. 33-42, 2014.

[9] C. Brown, S. Smith, P. Lawton and J. Anderson, "Benthic habitat mapping: A review of progress towards improved understanding of the spatial ecology of the seafloor using acoustic techniques", *Estuarine, Coastal and Shelf Science*, vol. 92, no. 3, pp. 502-520, 2011.

[10] G. Ercilla, D. Casas, J. Vázquez, J. Iglesias, L. Somoza, C. Juan, T. Medialdea, R. León, F. Estrada, S. García-Gil, M. Farran, F. Bohoyo, M. García and A. Maestro, "Imaging the recent sediment dynamics of the Galicia Bank region (Atlantic, NW Iberian Peninsula)", Marine Geophysical Research, vol. 32, no. 1-2, pp. 99-126, 2011.

[11] K. Mann and J. Lazier, *Dynamics of Marine Ecosystems*. New York, NY: John Wiley & Sons, 2013.

[12] V. Lucieer, N. Hill, N. Barrett and S. Nichol, "Do marine substrates 'look' and 'sound' the same? Supervised classification of multibeam acoustic data using autonomous underwater vehicle images," *Estuarine, Coastal and Shelf Science*, vol. 117, pp. 94-106, 2013.

[13] M. A. Z. Fuad, "Coral Reef Rugosity and Coral Biodiversity. Bunaken National Park-North Sulawesi, Indonesia,"M.S. thesis Department of Natural Resources, International Institute for Geo-information Science and Earth Observation, Enschede, The Netherlands, 2010.

[14] V. Draštík and J. Kubečka, "Fish avoidance of acoustic survey boat in shallow waters", *Fisheries Research*, vol. 72, no. 2-3, pp. 219-228, 2005.