

Benthic habitat mapping using multibeam sonar

Iain M. Parnum¹, Alexander Gavrilov¹ and Justy Siwabessy²

1. Centre for Marine Science and Technology, Curtin University, Perth, Australia
2. Geoscience Australia GPO Box 378, Canberra, Australia

Multibeam sonar (MBS) systems are recognised as one of the most effective tools available to map and characterise the seafloor as they can provide co-located high-resolution bathymetry and acoustic backscatter characteristics from a wide swath across a vessel's track. While the production of bathymetry maps from MBS is well developed, processing and analysis of MBS backscatter data has not yet reached its full potential. One of the main issues has been the variation of backscatter strength with incidence. A new approach to producing images of backscatter properties developed by the authors, called an 'Angle Cube', is compared with a standard method for correcting for incident angle. The resulting backscatter and classified maps show that advantages of using the angle cube method in processing multibeam sonar data for benthic habitat mapping.

Keywords: Benthic habitat mapping, multibeam sonar.

Introduction

The use of acoustic remote sensing techniques in seabed mapping and monitoring has proven to be a useful tool in contemporary marine resource management (Kenny *et al.*, 2003), particularly in turbid and deep water areas, where aerial and satellite remote sensing based on measuring the electromagnetic spectra is of limited use. Of the various sonar systems available, multibeam sonar (MBS) has proven to be one of the most effective tools in seafloor mapping studies (Kenny *et al.*, 2003). This is because MBS provides co-located high-resolution bathymetry and backscatter. High-resolution bathymetry gives the relief of the seafloor and acoustic backscatter imagery can be related to the morphological and composition characteristics of the seabed surface. Combining these two dataset provides information on the spatial variations of seafloor physical properties. One of the main issues has been the effect of the incidence angle the backscatter is collected from. When surveying the seafloor with a MBS system, data is collected from parallel overlapping tracks from different incidence angles. Over a homogeneous seafloor the backscatter signal will depend on the incidence angle. It is this angular dependence of backscatter strength which is often still evident after processing when standard methods are used. The aim of this work was to produce backscatter strength mosaics and habitat maps which represent the changes in seafloor properties rather than the incidence angle. This paper compares a new method for correcting MBS backscatter for the incidence angle with a conventional method.

Methods

Backscatter data were obtained using a Reson Seabat 8125 455kHz multibeam sonar. The first dataset used in this paper is four lines collected north of Woody Island, in Esperance Bay, Western Australia. The second dataset are 10 lines from a survey of Morinda Shoal in Queensland. Depth and backscatter strength were processed using the methods described in Gavrilov *et al.* (2005). Backscatter strength values calculated are relative.

Two methods for incidence angle correction were compared using the first dataset. The first one was based on Beaudoin *et al.* (2002) and is considered a 'standard' method for removing angular dependence of backscatter. This method involved calculating the mean angular dependence of backscatter strength over the dataset. The mean values at each

angle were then removed from the data collected with each sonar ping. The mean value at 30 degrees (over all of the data) was added to all data to make it more readily comparable to the second method. In the second method, referred to as the 'Angle Cube' method (Parnum *et al.*, 2007), backscatter strength data from the survey area was represented as a function of 3 dimensions: spatial coordinates X and Y, and the incidence angle, which produced a 3-dimensional sparse array of data. Then data in each angle layer were 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 (Burroughs & McDonnell 1998) was found to give satisfactory results, as the predicted values did not reveal any unrealistic values. Then the angle-average backscatter strength was calculated. After incidence angle correction the Woody Island corrected backscatter data were classified using a 'k-means' algorithm (Tso and Mather, 2001) with the number of classes set to 3 to correspond to the rock, rhodolith and sand seafloor classes observed.

Results

Figure 1 shows the initial results: bathymetry (a) and backscatter strength not corrected for incidence angle (b). The backscatter image shows the spatial distribution of the seafloor habitats (sand, rhodolith and rock) not observed in the bathymetry alone. However, the influence of the incidence angle is apparent in the backscatter image shown in Figure 1(b), particularly where data was collected directly under the vessel (sometimes referred to as nadir striping). Although removing the mean angular trend improves from the initial results (Figure 1(c)), it is inadequate at correcting for all incidence angle effects. This is evident in the resulting classification (Figure 1(e)). The 'Angle Cube' method used to produce the angle-averaged backscatter strength (Figure 1d) not only removed the effect of the incidence angle, it also improved classification accuracy as shown by Figure 1(f).

The angle cube method was tested on a larger dataset from Morinda Shoal, Queensland. Figure 2 shows the angle-averaged backscatter as calculated from the Angle Cube method draped over the bathymetry. An underwater video recording was made close along the central line of the surveyed area. Some example screen shots are shown in Figure 2. In the deeper southernmost area, the seafloor is sandy and covered by relatively short tropical seagrass of variable density. The spatial variation of seagrass density can be recognised by change in the backscatter level over this flat area. A very distinct boundary between two different habitats is seen closer to the foot of the coral reef. The video recording showed that the seafloor at the reef foot consisted of coral debris covered by a thin mat of dense algae. It appeared that acoustic backscattering from the coral rubble was noticeably stronger than that from seagrass in the southern part. Acoustic backscattering from the seafloor over the top of the coral reef is also strong, but much more variable due to large-scale roughness of the reef surface. Further to the north, where the reef flat starts to deteriorate, backscattering from the seafloor is somewhat weaker. Overall, the coarse changes in habitat type (seagrass, sand and coral) were identified by a combination of the bathymetry and backscatter collected by the MBS.

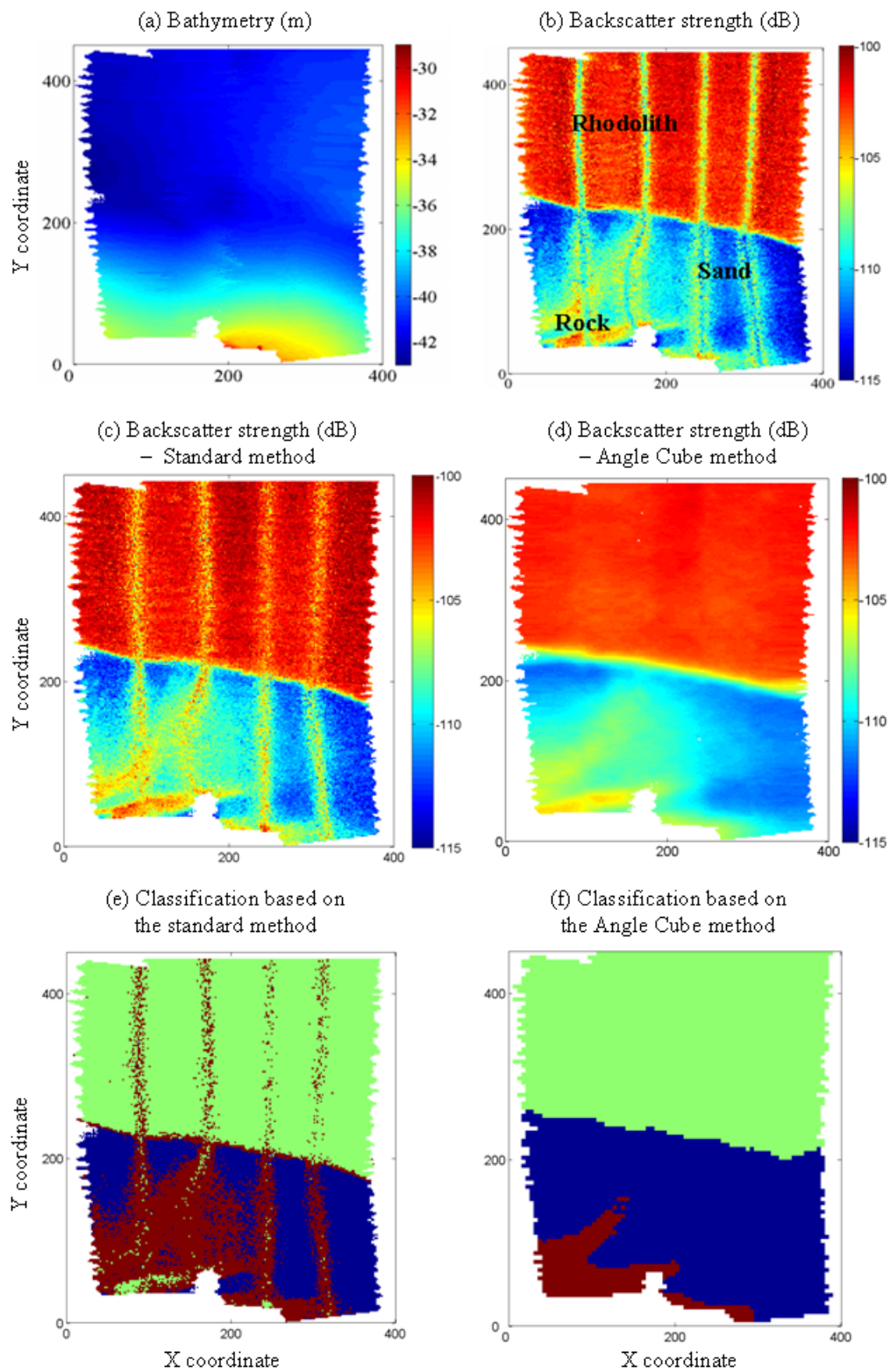


Figure 1: Results from part of a multibeam sonar survey in Esperance Bay (WA): (a) bathymetry, (b) backscatter strength (dB) not corrected for incident angle, (c) backscatter corrected using a standard method, (d) backscatter strength using the Angle Cube method, (e) resulting classification from (c), (f) resulting classification based on (d).

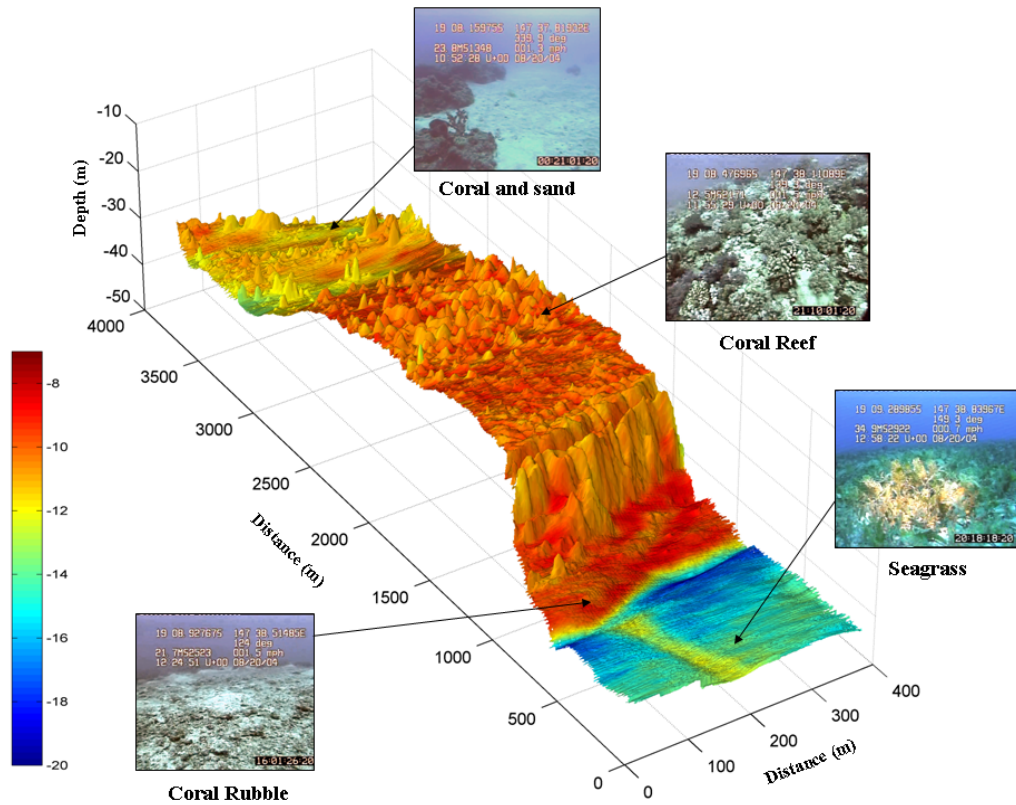


Figure 3: Backscatter strength draped over bathymetry (1m grid size) from Morinda Shoal, Queensland. Example screen shots from the towed underwater video.

Conclusions

MBS backscatter can identify changes in seafloor habitat type, but can also be dependent on incidence angle. The standard method to correct this is to remove the mean angular trend, but this has been shown here to be inadequate. Ideally data from each point in the grid would have been sampled within a range of incidence angles, but this is logistically uneconomical. However, using spatial interpolation, the angular dependence of backscatter can be approximately reconstructed at each point of the grid, which can then be visualised as an angular cube and used for seafloor segmentation. This is the principle behind the Angle Cube method used in this paper. Ultimately, this study demonstrated that the combination of high-resolution bathymetry and backscatter strength data, as collected by MBS, is an efficient and cost-effective tool for benthic habitat mapping in coastal zones.

Acknowledgments

The authors would like to thank the CRC for Coastal Zone, Estuary and Waterway management for providing funding; the Centre for Marine Science and Technology for providing logistical support; and Dr Thomas Stieglitz for helping with the collection of data from Morinda Shoal.

References

- Beaudoin, J.D., Hughes-Clarke, J.E., Van Den Aemele, E.J. and Gardner, J.V. (2002). Geometric and radiometric correction of multibeam backscatter derived from Reson 8101 systems, *Canadian Hydrographic Conference*, Canadian Hydrographic Association, Ottawa, Ontario.
- Burroughs, P.A. and McDonnell, A. (1998). *Principles of geographic information systems*, Oxford University Press, pp. 356.
- Gavrilov, A.N., Duncan, A.J., McCauley, R.D., Parnum, I.M., Penrose, J.D., Siwabessy, P.J.W., Woods, A.J. and Tseng, Y-T. (2005). Characterization of the Seafloor in Australia's Coastal Zone using acoustic techniques, *Proceedings of the International Conference "Underwater Acoustic Measurements: Technologies & Results"*, Crete, Greece.
- Kenny, A.J., Cato, I, Desprez, M., Fader, G, Schuttenhelm, R.T.E. and Side, J. (2003). An overview of seabed-mapping technologies in the context of marine habitat classification, *ICES Journal of Marine Science*, **60** (2), pp. 411-8.
- Parnum, I.M., Gavrilov, A.N. and Siwabessy, P.J.W. (2007). Analysis of multibeam data for the purposes of seafloor classification, *Proceedings of the Second International Conference "Underwater Acoustic Measurements: Technologies & Results"*, Crete, Greece.
- Tso, B. and Mather, P.M. (2001). *Classification methods for remotely sensed data*, 1st edn, Taylor and Francis, London, pp. 332.