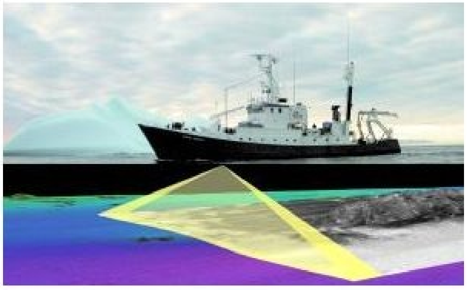
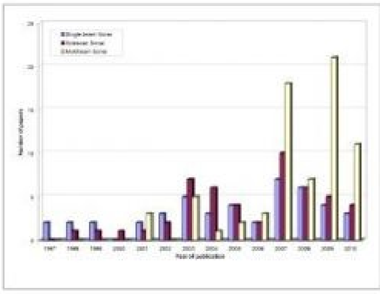
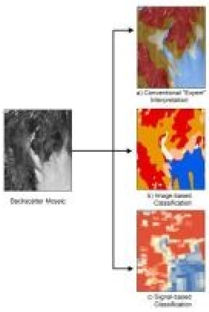
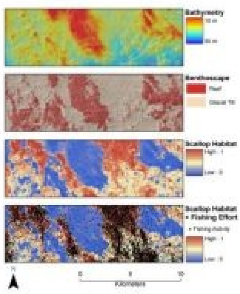
UTILISATION OF MULTI-BEAM BACKSCATTER FOR ECOLOGICAL STUDY OF THE SEAFLOOR

Benthic Habitat Mapping









The establishment of multi-beam echo sounders (MBES) as a mainstream tool in ocean mapping has revolutionised approaches towards nautical charting, seafloor geotechnical/geological surveys and benthic habitat mapping. The resolution of bathymetric and backscatter data collected by MBES has improved significantly in recent years through technological improvements of these acoustic systems. Furthermore, developments in data collection and processing of MBES backscatter have resulted in the increasing preferential use of multi-beam technology over conventional side-scan sonar or single beam sonar for these applications. This article explores some recent developments in the methods used to generate benthic habitat maps using multi-beam sonar systems.

In recent years we have witnessed the emergence of the field of benthic habitat mapping (i.e. the process of producing maps showing the spatial extent of different seafloor habitat characteristics). This has largely been driven by technological advancements in acoustic survey systems which have improved our ability to image and map the seafloor environment. New methods have been tested to segment, classify and combine these acoustic data with biological ground truth sample data to generate benthic habitat maps to meet the needs of a wide range of end-users.

Through the application of innovative data analysis techniques, McGregor GeoScience Ltd (McGregor) offers services which integrate data from across the core hydrographic, geophysical and environmental sectors of the company. The end products are purpose-made maps reflecting spatial patterns in benthic biological and surficial geological characteristics to meet the specific needs of clients. This approach uses various state of the art backscatter and bathymetric classification tools to process and segment the seafloor acoustic data. These are ground-truthed using an extensive suite of benthic sampling and imaging tools, to generate the final map products.

Multi-beam Echo Sounders

In addition to bathymetric data, MBES systems are also capable of measuring the signal strength of the return echo from the seafloor, commonly referred to as backscatter data (Figure 1). MBES backscatter imagery is roughly similar to side-scan sonar backscatter imagery, although the backscatter data from a MBES was, until recently, of an inferior quality compared to the imagery from an equivalent side-scan system. However, recent on-going developments in data collection and processing of MBES are dramatically improving the quality of the imagery.

MBES backscatter data can be used to infer the environmental characteristics of the seafloor (e.g. seafloor hardness, surficial sediment characteristics, benthic habitat characteristics), and over the past decade many results have been published. A recent review of this literature, written by Brown et al (2011), examined and compared the use of different acoustic systems for generating benthic habitat maps. Out of the papers that were reviewed, the vast majority of studies used MBES to generate the maps, with the majority of these studies published since 2007 (Figure 2). This recent increase in the application of MBES for seafloor habitat mapping is the result of a combination of the technological development of these acoustic systems, more affordable systems entering the marketplace, and improvements in data post-processing procedures and software packages.

MBES Backscatter Processing

Over the past few years, several commercially available software packages have been released which offer advanced tools for the creation of backscatter mosaics. These tools allow the production of properly corrected backscatter mosaics through removal of angular range artefacts, which is an essential first stage in utilising this type of data for thematic map production. Using the mosaic imagery, segmentation of the backscatter data has conventionally been done by expert interpretation, whereby the imagery is divided into regions of similar texture or backscatter strength 'by eye' (Figure 3). This has been the conventional method for the production of seafloor geological maps since the implementation of MBES systems in the 1990s.

More recently, automated methods of segmenting MBES backscatter data have been explored, driven largely by the advantages of performing objective classification of the backscatter data and therefore eliminating the subjectivity of the expert segmentation process. Automated segmentation methods can be broadly divided into two types; 1) image-based segmentation based on the division of a backscatter image into regions of similar backscatter characteristics (e.g. surface features, backscatter intensity, textural features etc.); 2) Signal-based segmentation where changes in the backscatter intensity, with increasing grazing angle from nadir, are analysed to classify the data in some way (Figure 3).

There are numerous examples of image-based segmentation methods (Brown and Blondel, 2009), and a commercial implementation of this type of approach is available through QTC-Swathview, a software package produced by Quester Tangent, British Columbia, Canada. The software uses image-based segmentation methods to divide compensated backscatter imagery into acoustic classes based on acoustic similarity. The significance of the acoustic classes can then be validated through in situ ground-truthing using a variety of methods (i.e. underwater video and photographs, sediment samples etc.), and appropriate seafloor classification labels attributed to each acoustic class (Figure 3).

Signal-based segmentation methods have also been recently commercially implemented in the form of Geocoder, an analysis tool developed by the Center for Coastal and Ocean Mapping/Joint Hydrographic Center (CCOM/JHC) at the University of New Hampshire, USA. Geocoder is designed to make fully corrected backscatter mosaics and also analyse the angular response of the backscatter as an approach to remote seafloor characterisation (Angular Response Analysis – ARA). The variation of the backscatter strength with the angle of incidence is an intrinsic property of the seafloor, which can be used as a method for acoustic seafloor characterisation. Although multi-beam sonar systems acquire backscatter over a wide range of incidence angles, the angular information is usually lost during standard backscatter processing and mosaicking.

Signal-based classification (ARA in the case of Geocoder) works by extracting several parameters from stacks of consecutive sonar pings. The average angular response is then compared to models that link acoustic backscatter observations to seafloor properties. The inversion of the model can produce estimates of various seafloor geotechnical properties, which can be used to predict the substrate properties of the seabed (Fonseca et al., 2009). These predicted outputs (i.e. seafloor impedance, roughness and sediment grain size) offer potential benefits for improved thematic map production. Geocoder has been licensed for implementation in a number of hydrographic software packages, and this approach shows a great deal of promise for seafloor characterisation based on MBES backscatter characteristics (Figure 3).

Applications

The value and utility of MBES backscatter data when producing benthic habitat maps is now widely acknowledged, and recent studies have begun to use the automated segmentation routines described above. A novel methodology has been developed by Brown et al (2012), which utilises classified backscatter data (using image-based classification methods) along with the multi-beam bathymetric data and other secondary derived data layers (i.e. slope, curvature etc.). This methodology, termed 'the Benthoscape approach', utilises and classifies the data in a similar way to that used for the production of landscape maps from multispectral satellite data. The data layers are used to classify the seafloor into broad bio-physical classes (i.e. Benthoscape classes) using objective classification techniques. The same data layers are also used to generate species-specific habitat maps using species distribution modelling techniques.

Figure 4 shows an example of this approach applied to a dataset from German Bank off south-west Nova Scotia, Canada. In this example, the seafloor is classified into discrete benthoscape classes identified from an extensive underwater photographic and video dataset, and the objective classification proved to be over 70% accurate when validated against the ground-truthing data. In addition, scallop habitat suitability maps were also created based on scallop observations from the video ground-truthing data. The output maps display predicted habitat suitability ranging from 1 (highly suitable) to 0 (unsuitable) over the extent of the MBES dataset. Accuracy proved very high for this area (>70%), and when validated against vessel monitoring data from the scallop fishing industry a strong correlation was found between fishing activity and habitat suitability. This approach is now being used by McGregor GeoScience for commercial application for a number of clients.

The results from this, and other recent, habitat mapping studies utilising multi-beam sonar datasets offer very promising advancements in the field of benthic habitat mapping. It is now recognised that establishing an understanding of the spatial characteristics of the benthic environment is an essential first step towards implementing effective management strategies for ocean systems, and the demand for these types of map products will undoubtedly increase in coming years to help inform and facilitate management decisions in coastal and offshore regions.

Further Reading

- Brown, C.J., Blondel, P., 2009. Developments in the application of multi-beam sonar backscatter for seafloor habitat mapping. Applied Acoustics. 70, 1242-1247.
- Brown, C.J., Smith, S.J., Lawton, P., Anderson, J.T., 2011. 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. 92, 502-520.
- Brown, C.J., Sameoto, J.A. and Smith S.J. (2012) Multiple methods, maps and management applications: Purpose-made seafloor maps in support of Ocean Management. Journal of Sea Research. 72, In Press