Spatial analysis of multibeam acoustic data for the prediction of marine substrates and benthic communities in temperate coastal waters.

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Abstract- The combined use of acoustic backscatter and bathymetric data generated by multibeam echo-sounders provides a powerful tool to investigate substrate characteristics at fine spatial scales across large areas. New methods are now required to assess the links between the identification of physical substrate classes from multibeam data with visually classified classes from AUV data. In this paper, we use statistical algorithms to describe the patterns between the physical covariates derived from both the multibeam data, and substrate type observed in AUV images. We then use these relationships to predict substrate type and describe the biological biotopes across the mapped extent of south eastern Tasmania.

Keywords: habitat mapping, marine management, multibeam, texture analysis, substrate prediction

1. INTRODUCTION

A recent and very significant development contributing to our understanding of the physical environment of shelf habitats has been multibeam sonar and the interpretation of its associated backscatter. This has opened up opportunities for developing a predictive capacity in this field where matching biological datasets are available. However, the effectiveness of this technique has yet to be fully tested as an appropriate surrogate for predicting patterns of biodiversity because of the lack of matching biological datasets collected at the same spatial scales and locations as fine scale acoustic surveys. In this context, the AUV (autonomous underwater vehicle) deployments reported here were part of a multi-disciplinary experimental program in eastern Tasmania, where the analysis of covariance is to be undertaken on co-located fine-resolution seabed habitat data, provided by the EM3002 multibeam sonar coverage's, and biological datasets collected at similar spatial scales by the AUV. This research is being undertaken by the University of Tasmania and Geoscience Australia as part of the Marine Biodiversity Research Hub, which is a collaborative program funded under the Commonwealth Government's Commonwealth Environmental Research Facilities (CERF) Program.

The combined use of backscatter and bathymetric data generated by multibeam echo-sounders provides a powerful tool to investigate substrate characteristics and has been shown to be useful in mapping seabed types (Lucieer, 2008). The derived seabed classifications from these data are strongly scale dependent and new methods to integrate both the physical and biological information at various spatial scales must be developed to be able to accurately assess the correlation of multibeam data to substrate characteristics and ultimately seabed biotopes. If relationships can be developed between the AUV images and the acoustically derived seabed properties then this may provide us with the capacity to develop models to predict marine substrates and associate biotypes where data is limited.

Acoustic methods for seabed assessment yield information on surrogate measures of habitat that show to be useful for biodiversity assessment. Whilst a number of definitions of habitat exist it is important to begin with the ability to map the seafloor substrates accurately as they form the foundation of seabed habitats. The procedural guidelines of Foster-Smith and Sotheran (2003) stress that misclassification of the field data can undermine data interpretation and is a major source of uncertainty in interpretation. In this instance this refers to the classification of the multibeam acoustic data which forms the first layer in subsequent biodiversity assessment. To be able to advance from substrate maps to habitat maps we need to include biological data into the analysis, which is the focus of this research.

Until recently, very little quantitative biological information, other than those collected by spatially coarse methods such as trawls, has existed about the benthic fauna on deep reef and their adjacent shelf sediment habitats in Tasmania (Barrett and Edgar, *In Press*). This is despite these areas often being core habitats for important fishery species such as rock lobsters, striped trumpeter and banded morwong on reefs, and scallops and flathead on the sediments. The IMOS (Integrated Marine Observing System) Autonomous Underwater Vehicle (AUV) has provided the opportunity to examine its value as a vehicle for collecting the biological data that can be appropriately matched to the scale of the multibeam acoustic data. To examine the relationship between the physical structure of the seabed and the associated biological assemblages, a range of physical characteristics of the seabed were derived from the multibeam bathymetry and backscatter for testing of correlations with the AUV derived imagery.

In this paper we investigate the development of three techniques 1) to quantitatively extract metrics about the seafloor from multibeam data (structure and composition) 2) to assess if these metrics relate to the fine scale data collected from as Autonomous Underwater Vehicle (AUV) 3) to see if these metrics can be used to develop a substrate prediction model to assist in the synthesis of multibeam imagery to make maps meaningful for biodiversity assessment.

This research was undertaken within the CERF (Commonwealth Environment Research Facility) Marine Biodiversity Hub - a commonwealth funded collaborative venture between leading Australian marine research groups, aimed at developing best methods to describe and predict the patterns of biodiversity in Australian waters for resource management and planning (www.marinehub.org) and supported by the IMOS national facility support program, through the provision of the AUV. Data presented here on the south-eastern coast of Tasmania were collected as part of a collaboration between the Tasmanian Aquaculture and Fisheries Institute (TAFI; University of Tasmania) and Geoscience Australia (GA), and was completed in two stages during 2008/09 (Nichol et al, 2009).

2. METHODS

a)   Multibeam processing

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A Kongsberg EM3002(D) 300kHz multibeam sonar was used to map sections of the continental shelf along the coast of south eastern Tasmania in February and March 2009 to determine the extent of habitat variability, and provide detailed seabed information to assist the design of the AUV surveys (Figure 1). The study areas included representative habitats from a range of marine environments, water depths (18-120 m), and exposure to oceanic swells. These primarily included coastal reefs and adjacent shelf sediments, to more sheltered embayments.

The multibeam bathymetric grids at 2 m resolution were analysed to develop seven bathymetric input model variables (depth, slope, curvature, profile curvature, planar curvature, northness and eastness). The multibeam backscatter data were analysed with *eCognition* to produce several texture based input variables (GLCM mean, GLCM homogeneity, GLCM contrast, GLCM dissimilarity, Mean backscatter and the Standard deviation of backscatter). Texture features evaluate the texture of an image object based on the grey level co occurrence matrix (GLCM) (Haralick et al. 1973, Ivits et al., 2005). These variables assimilated the multibeam data into 13 derived products that could be used to examine the correlations with the AUV derived products.

The multi-resolution segmentation algorithm implemented in *eCognition* was used to divide the integrated bathymetry and backscatter grids into homogeneous spatial objects at two scales 30 and 60 (*eCognition*, 2005). From the Tasman Peninsula 1106 AUV records were analysed and topographic and texture variables were extracted to correspond with each of these individual sites for subsequent analysis.
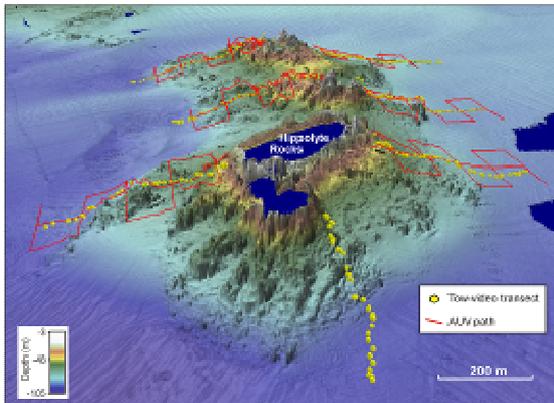

Figure 1. Multibeam sonar image of Hippolyte Rocks, Tasman Peninsula with survey lines for underwater video and AUV

b) AUV processing
The *AUV Sirius,* operated by the IMOS facility at the University of Sydney was employed to collect fine-scale imagery (each image ~ 2.1 m^2) over a range of depths and substrates mapped by the multibeam. Substrata, geomorphology and occurrence of sessile organisms were recorded from the digital still images. To quantify substratum type, geomorphology and biota % cover and abundance, individual AUV images were post-processed using the CPCe (Coral Point Count with Excel extensions (Kohler and Gill, 2006) freeware software package, but modified slightly to suit a temperate, rather than tropical, ecosystem. Initial scoring focussed on scoring every 100th image (approximately 50 m spacing), with subsequent scoring infilling areas of specific focus to increase replication as

needed. Each image was scored using 50 point counts, whereby substrata and species categories were counted for each point. The dominant substrata of mud, sand, gravel, cobble, boulders, rock, patchy reef/sand, sediment veneer and screwshell were identified. The pixel resolution of images, however, meant that many benthic fishes, large macroaglae, mobile invertebrates and large sessile invertebrates could only be identified to genus or morph type (e.g. sponges). Some key ecological taxa (e.g. scallops, sea-urchins, screw shells, and crayfish) were identifiable to species. These key taxa were counted within each image, and sized where possible. The sizes of key taxa were estimated using SeaGis PhotoMeasure™ system software. All seabed images were spatially geo-referenced and subsequently integrated with the multibeam sonar parameters to examine their relative contributions in explaining and predicting seabed complexity and diversity.

3. RESULTS

Using a range of statistical methods, we were able to use the physical variables we derived from the multibeam acoustic outputs to correctly classify a set of distinct substrate categories derived from the AUV imagery with accuracies as high as 66% using a supervised classification method. Support Vector Machine analysis yielded the best results follwed by Random Forests (63%), Classification Trees (61%) and K-Nearest Neighbour (60%). Backscatter variables alone were good predictors of unconsolidated substrates, whereas incorporation of variables derived from topography significantly improved the classification accuracies of consolidated substrates from 46% to 66%. Further examination showed that mean backscatter of the segments at both scales was distinct between the visually defined classes of the AUV as shown in Figure 2. Unsupervised classification of the multibeam derivative products produced classification accuracies of 58% predicting substrate class numbers and distributions consistent with the AUV visually derived classes.

For understanding biodiversity patterns, variables derived from multibeam products were found to be useful predictors of the spatial distribution of benthic biota. For example, results from the Boosted Regression Tress (BRT) analyses show depth and predicted substrate were important variables determining the distribution of canopy algae, which was more likely to be found on contiguous reef and boulder substrates and only to depths of up to approximately 50 m. Other variables derived from topography and backscatter were important for predicting the distribution of invertebrates. Six archetypes best represented the response of the 23 common taxa to environmental gradients. The predicted distribution of the algae archetype was consistent with canopy algae predicted by BRT. Dominant sponges taxa also grouped together and add a high probability of occurrence on reefs typically in deep water and on complex relief (Figure 3).
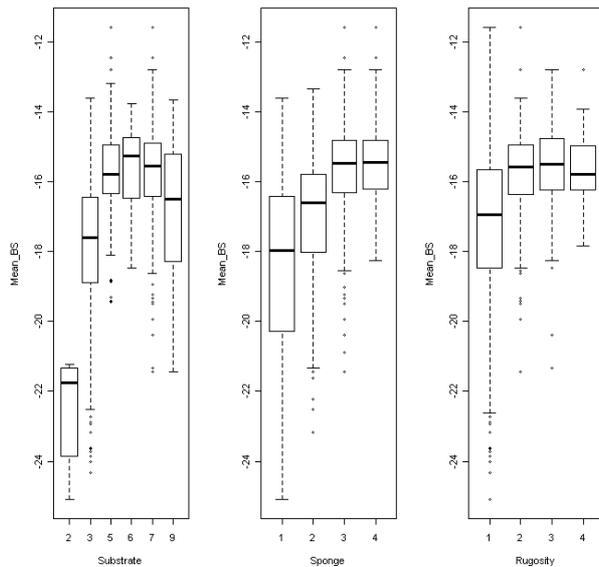
Figure 2. Mean backscatter BS of segmentation 30 showing acoustically distinct classes from AUV visually defined classes of Substrate, Sponge and Rugosity.
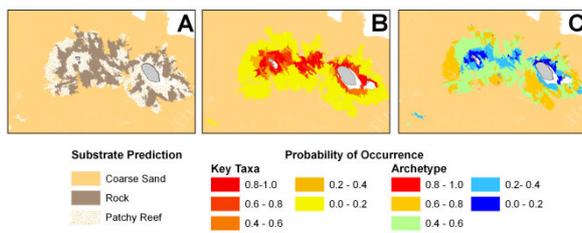

Figure 3. Predicted substrate result for the Hippolyte Rocks using Support Vector Machine Model Result B) Predicted probability of occurrence of canopy algae using BRT C) Predicted probability of occurrence of Dominant Corals using Archetype analysis.

4. DISCUSSION

In this research a method for combining multibeam data with AUV imagery has been developed for the classifcation and prediction of marine substrates in South Eastern Tasmania at 2 m resolution. The techniques described here allow for the quantifiable classification of multibeam data into substrate classes that have associated uncertainty products, which is imperative for mapping fine scale habitat features and identifying change in benthic substrates between acoustic surveys.

From the AUV analysis extensive new bio-physical data identifying the complexity and diversity of seabed substrates and their biological assemblages within this region have been uncovered. From the combined analysis we have learnt that thirty percent of low relied bedrock reefs were in <45 m water depth, where algal assemblages dominated the biota, particularly the kelp *Ecklonia radiata*. The remaining seventy percent were below 45 m depth and covered in spectacular and diverse sponge assemblages. Shelf sediments were often covered with extensive beds of the invasive screw shell (*Maoricolpus roseus*), providing a novel substratum for sponges and other invertebrates to extend their distribution beyond the reefs. These methods are currenlty being extended to examine the comparison of different predicitive modelling

aproaches using various components of the multibeam data for different substrate types and therefore seabed biotopes.

Five object based variables and six texture based variables were examined for their prediction capability to discriminate six different habitat classes visually classified from AUV imagery. The results of this preliminary methodology show that there is a strong correlation between the AUV classes and the multibeam data. This methodology is unique in that it allows us to 'break down' the integrated acoustic (backscatter and bathymetric) image into meaningful statistics whereby the correlation of textural objects and topographic parameters can be quantified in their ability to discriminate classes based on the AUV analysis. This may allow us to extrapolate the results from the fine-scale imagery of the AUV system over limited areas of multibeam data. To create reliable models of biodiversity prediction for our inshore systems it is necessary to be able to assess the accuracy of the acoustic data which forms the foundation of broad scale assessments

This research provides a technique for quantitatively interpreting the acoustic imagery into detailed spatially-explicit (i.e. full- coverage) seabed maps. The prediction models are strengthened through utilising the AUV imagery firstly to link the datasets with the common substrate class and secondly to value-add to the detailed biological data from the AUV analysis. The AUV data is strengthened in its utilisation as we can extrapolate the biological grouping based on the relationships developed with the multibeam parameters into limited areas, which is more valuable than the spatially limited point maps that could be determined by the AUV alone.

5. CONCLUSION

This methodology will advance the research that answers fundamental questions about the utility of high resolution acoustic data in explaining and predicting patterns of marine benthic biodiversity and the ability to complement this data with high resolution underwater imagery.

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