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Optimal seabed habitat mapping using multibeam acoustics with associated physical and visual sampling devices – at sea trials

Rudy J. Kloser[1] and John D. Penrose[2]

[1]CSIRO Division of Marine Research, Castray Esp, Hobart, Tasmania, [2]Centre for Marine Science and Technology, Curtin University of Technology, Bentley, Perth, WA.

Abstract

Australia is custodian to a large marine jurisdiction with associated seabed habitats that need to be managed for multiple use purposes. Mapping seabed habitats or their surrogates is a fundamental first step in this process, with methods that can map large areas of seabed such as multibeam swath mapping sonars representing attractive tools. A methodology of optimally mapping the seabed is presented using a swath mapper in conjunction with biophysical, geophysical and video/photographic devices. A Simrad EM1002 swath mapper was used in April 2000 to map selected sites on the shelf and upper slope. The swath mapper produced three data products (being, bathymetry, backscatter and sun illuminated bathymetry imagery) that were visually inspected to target the variety of substrate types. Limitations in the imagery were observed due to instrument frequency, beamwidth, pulse length, depth and across track resolution as well as changing oceanographic and weather conditions. The biophysical, geophysical and video/photographic sampling was targeted on the contrasting features in the imagery. The video/photographic sampling proved the best tool for understanding the backscatter images and their relation to geological and biological attributes. The swath mapper proved (not surprisingly) to be an invaluable tool for undertaking investigations of the seabed, providing higher resolution bathymetry and backscatter than our existing single beam devices. A significant advantage for habitat mapping was the reduction in time consuming direct and visual sampling by mapping out seabed regions of like character. The ability of the swath mapped bathymetry and backscatter to provide a surrogate for specific geological and biological attributes that are independent of instrument parameters, depth/slope and applicable to broad regions is part of ongoing work. This program of research will work towards the combination of outputs from the swath mapper (depth, seabed hardness and roughness) and other variables such as current/wave stress and water temperature (as an example) to produce predictive maps of biological communities.

Introduction

Australia is custodian to a large marine jurisdiction with associated seabed habitats that need to be managed for multiple use purposes. As such it is proposed as part of Australia's Ocean Policy to manage our marine jurisdiction using regional ecosystem-based management principles. A first step in this process was established with the IMCRA3.3 report that provided a provincial-scale regionalisation over the continental shelf of Australia. To map seabed habitats of the whole Australian Marine Jurisdiction (AMJ) will require the development of surrogates due to the large region and difficulty/expense of sampling the marine environment. These seabed surrogates will need to describe the geological and biological features and be able to detect changes in them that are of management significance. Acoustic methods of sensing the water column and seabed habitats provide a potential method for developing these surrogates when used in conjunction with direct capture and visual sampling methods.

Seabed habitat is defined by a mix of recent biological, hydrological and chemical processes layered over a geological framework. The seabed habitats can be described in general terms by sediment types, depth, latitude, longitude and hydrological processes (eg Peterson 1913; Snelgrove and Butman 1994; Coleman et al 1997). However the links between seabed structure and animal communities are frequently not well described because of difficulty of sampling broad areas of seabed, especially over rough ground and at depth. Simple normal incident single frequency acoustic methods provide a useful sampling tool to map the seabed seascape in terms of broad scale bathymetry and seabed hardness and roughness on flat seabeds with associated ground truthing (Pace *et al* 1982; Orlowski 1984; Chivers *et al* 1990; Lurton and Pouliquen 1992; Collins 1996, Kloser in press). These narrow beam systems have major deficiencies when being used for seabed mapping as presently they can only be used on flat seabeds as a sloping seabed changes the reflection properties of the returned echo, (Kloser in press). Also these systems have single beams of 7-15 degrees full beam angle and sample a very small footprint of the seabed. This requires extrapolation between sampling lines, (Siwabessy et al this volume). To improve the sampling resolution, depth resolution and account for seabed slope, multi-beam acoustic systems are being used.

In Australia, current national swath mapping efforts are underway within the Australian Geological Survey Organisation (AGSO) and the RAN Hydrographic Office (Hydro). AGSO have carried out swath mapping in deep water 500 – 6000 m over many years for geological surveying and UN Law of the Sea objectives, Exon and Hill, 1999. Recently AGSO have swath mapped the deep water 500 – 3000 m in the South East Australia region using the French IFREMER vessel *L'Atlanta* equiped with a Simrad EM12D. The RAN Hydro office have built two vessels *Leeuwin and Melville* equiped with shallow water Atlas Fansweep swath mappers. These are expected to be commisioned this year and will map the Hydrographic Services high priority areas on the continental shelf.

These multi-beam systems provide detailed bathymetry along the line of the vessels track with swath widths of 2-10 times water depth as well as producing detailed backscatter maps of the seabed. The backscatter maps have lower spatial resolution than those produced by side scan instruments but due to beam forming, multi-beams can correct for seabed slope. Investigations using multi-beam backscatter maps to date have concentrated on geological mapping, eg Todd *et al* (1999). What is less certain is the ability of the bathymetry and associated backscatter images to be used as a surrogate for habitat maps of a given region and to determine the level of ground truthing required. More investigation is required to establish the relationship of the backscatter maps to the sediment and biotic communities. This will require the correlation of biological and geological sampling at the various acoustically defined seabed types over a range of depths, seabed slopes and ensonification slant ranges.

Methodology

In April 2000, CSIRO in conjunction with the National Oceans Office fitted a 95 kHz swath mapper (Simrad EM1002, Seatex positioning system) to the 65m CSIRO research vessel *MRV Southern Surveyor*. The Simrad EM1002 is a phase interpolated beamforming swath mapper using a rounded head to reduce sound velocity beam forming errors. It forms 111 beams that are effectively 2 by 2 degrees per beam. The seabed depth per beam is calculated using an amplitude or phase algorithm depending on the angle of incidence. A mean backscatter per beam value is calculate and sidescan values are collected by digitisation along the beam with 1-40 samples collected for each beam. The beams are electronically controlled for roll stabilization.

The swath mapper and existing three frequency (12, 38 and 120kHz) normal incident echo sounders (Simrad EK500) were used to map various shelf regions in the south east and south west of Australia. The sites were chosen based on historic knowledge as having high importance for fisheries and physical characteristics of depth, seabed morphology (slope and roughness), sediment type, latitude and longitude. At the commencement of each survey site the seawater propagation parameters of absorption and sound velocity were calculated from the formulae of Francois and Garrison (1982) and MacKenzie (1981), respectively, based upon temperature and salinity profiles obtained with a Neil Brown conductivity-temperature-depth recorder (CTD). The swath mapping transect lines were in general carried out orthogonal to the seabed slope aided by the EM1002 data collection software.

The completed swath survey was processed using the Simrad Neptune software to provide three data products of bathymetry, backscatter and sun illuminated imagery. These three data products were visually inspected on board and the biophysical, geophysical and video/photographic sampling targeted at contrasting features in the imagery. The precise location of the direct sampling devices used the vessels dynamic positioning system and a Sonardyne USBL. In general the location of sampling gears could be directed to within 5-10m for depths less than 300 m.

The physical sampling of the geological and biological characteristics were carried out with a variety of instruments. Surficial sediments were obtained with a Smith-McIntyre grab and Box Corer. Box core samples were collected to obtain geoacoustic parameters such as porosity, sound velocity and density. Lithology samples were collected with a rock dredge. In-fauna and epi-fauna specimens were collected with a benthic dredge. Single and stereo video footage were obtained with a vertical drop and towed video platform. The video imagery was used to characterise the biological communities and geomorphology. The stereo footage was collected to measure seabed roughness and sizing of benthic biota. Details of the collection instruments sampling and analysis protocols will be reported elsewhere. The 'at sea' visual inspection of the derived samples has been used here to interpret the swath imagery.

Results (preliminary)

Ten survey areas ranging in depth from 12m to 600m were mapped with the EM1002. In three areas, Maria Island, Big Horseshoe (SE) and Howe Reef (off shelf), swath mapping with the EM1002 was targeted to overlap areas previously mapped by AGSO with a 12 kHz EM12D. In total we collected 40 GBytes of swath mapped data and 9 GBytes of normal incident multi-frequency data. These sites provide ‘reference’ or ‘training’ areas for the calibration and cross-reference

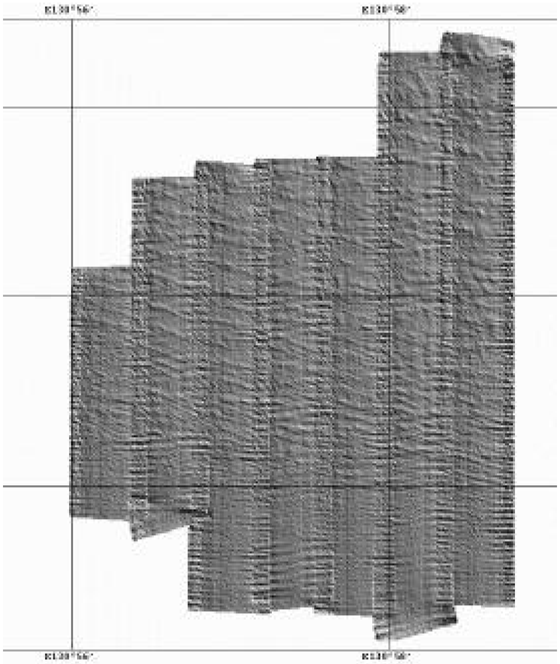

Figure 1. Example of 8 times vertical exaggeration sun illuminated bathymetry in the Great Australian Bight benthic protection zone, depth 135-145 m, showing the rippling on the outer beams due to a roll correction error.

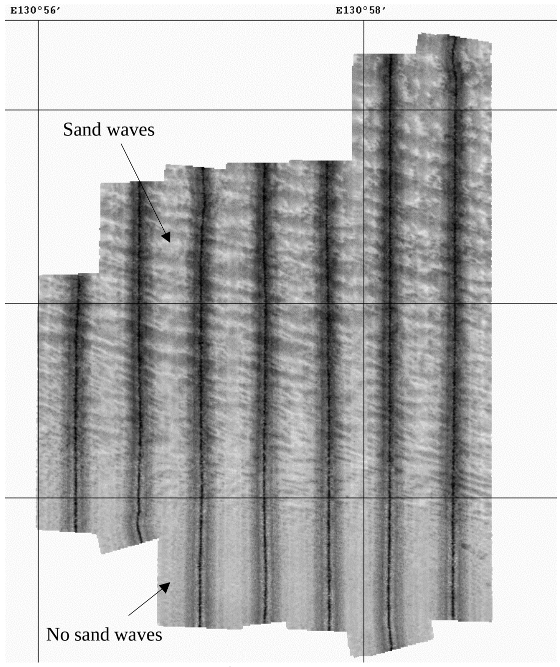

Figure 2. Example of mean acoustic backscatter per beam in regions with and without large sandwaves. High backscatter is black. The dark high backscatter nadir beam shows the vessels track. Note the uneven backscatter across the swath

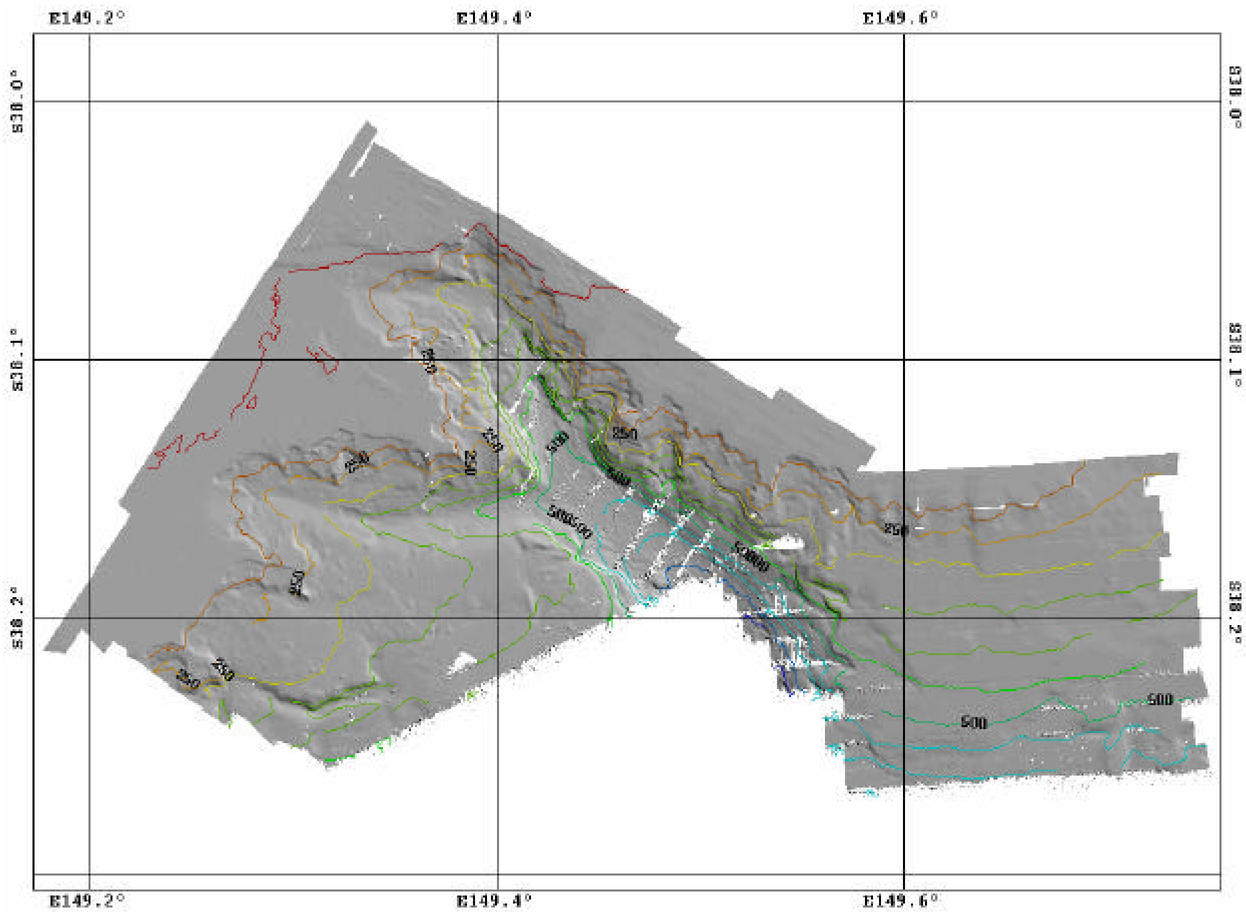

Figure 3. Sun illuminated bathymetry of the Big Horseshoe, a productive fishing ground showing the depth limitation of the swath mapper at approximately 600 m.

distribution of backscatter of acoustic instruments from other vessels in future seabed mapping exercises.

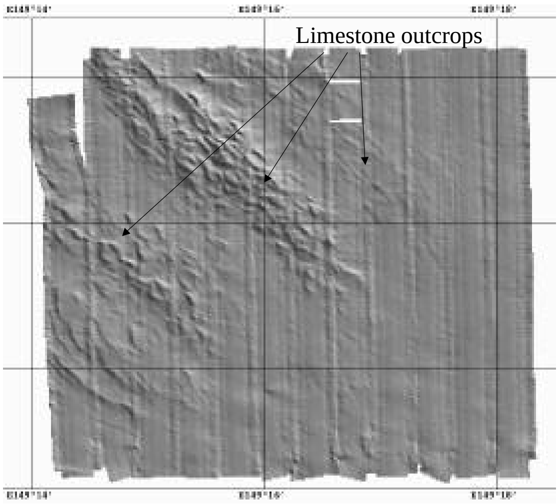

Figure 4. Sun illuminated bathymetry with 8 times height exageration showing limestone outcrops of 0.5 to 1 m height, north-south lines are swath mapper artifacts. Depth 110 – 120 m.

Figure 5. Limstone outcrop fauna image taken from a digital video. Lasers are used for sizing objects

Throughout the survey we operated the system at 140 degrees swath width, 5.5 times water depth. A problem in the outer beams between 60 to 70 degrees caused a vessel-roll related 'depth ripple'. This depth rippling effect of up to 1 m peak to peak amplitude was clearly seen in the sun illuminated maps, Fig 1. The backscatter imagery was also characterised by uneven strength across the swath profile, Fig. 2. An absorption coefficient of 35dB/km was used for most of the voyage that should have corrected the backscatter response based on the temperature and salinity profiles. The EM1002 was capable of recording data of useable quality to a depth of about 600 m in fine sea conditions. Generally, however, the depth limitation was closer to 400 m because data quality suffered where the seabed was steeply sloping and when sea conditions deteriorated, Fig. 3.

Of particular note was the ability of the system to highlight small-scale seabed features such as limestone outcrops of 0.5 - 1 m or less in height, Fig. 4. These are generally important for supporting communities of large sponges and other attached erect invertebrates that provide complex habitats for fishes, Fig. 5. The swath-mapper also revealed topographic patterns at scales of 100s of metres to kilometres that are not easily detected by single beam instruments. These include complex, rippled soft sediment substrata that dominate the seabed near Maria Island and in the Great Australian Bight Benthic Protection Zone, Fig. 2.

Discussion

In summary, although its performance was impressive, the Simrad EM1002 did not perform to all of its technical specifications. Some of the problems encountered were due to the temporary instalation of the equipment on our survey vessel. Whilst others associated to the limited swath width (3.5 times swath width) of the sonar and the uneven backscatter profile have not been resolved to date.

The bathymetric and backscatter images were of good enough quality to deliniate the major seabed characteristics and target our biophysical, geophysical and visual samplers. The detailed bathymetry of the instrument revealed a level of seabed classification that could not be ascertained with single beam acoustic devices.

The consistency and relationship of seabed type to instrument settings, depth, seabed slope and acoustic slant range for backscatter measurements will be investigated by repeat measurements over the ground truth sites selected and compared to model predictions of the backscatter returns (Jackson *et al* 1986). Further the ability for the acoustic devices to represent a surrogate for seabed type suitable for habitat description will also be explored.

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