SEABED MULTI-BEAM BACKSCATTER MAPPING OF THE AUSTRALIAN CONTINENTAL MARGIN

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A multi-beam sonar (MBS) has been used to map Australia's continental margin seabed from the marine national facility vessel Southern Surveyor on opportunistic transit and research voyages since 2004 with 0.35 M km^2 mapped. The MBS data are used to infer key ecological features based on bathymetry (e.g. seamounts, canyons, terraces, banks and deep reefs) and backscatter data for ecological hard (consolidated, e.g. rock for attachment of fauna) and soft (unconsolidated, e.g. mud for burrowing fauna) substrate. Seabed consolidation inference is consistent with a seabed scattering model. To consistently infer ecological significant hard and soft substrate from the backscatter data requires minimisation of errors due to changing absorption (~2 dB) with temperature and depth, calibration drift, changes in pulse length and estimates of area insonified due to seabed slope (<8 dB). Area insonified corrections were required for both across and along-ship slopes. Highest corrections were needed for along-ship slopes in canyon regions and large incidence angles (>60°). A data collection and processing framework is described that works towards a national backscatter mapping program for environmental seabed mapping. Data collected and automated processing for depth, sound absorption and area insonified at level 2 of a possible 5 level data processing hierarchy is available for viewing at http://www.marine.csiro.au/geoserver.

INTRODUCTION

Australia's continental margin, defined here from ~100 m to 1500 m, is a narrow strip characterised by high productivity and diversity of the mega epifauna [1]. This area also supports major ecological and economic (fishing, oil and gas) resources, is poorly understood yet heavily exploited in parts. A simple first step to assist management of this region is to map the spatial scales of the types of terrain and key components of the biotic assemblages to define marine habitat patches and key ecological bathymetric features (e.g. canyons, seamounts and deep reefs) and ecological significant hard and soft substrate type. Ecological hard (consolidated) terrain is potential habitat for attached fauna whilst ecological soft (unconsolidated) terrain is potential habitat for burrowing and soft sediment fauna [2]. Mapping with multi-beam sonars (MBS) is attractive as they can provide both high resolution bathymetry and from the backscatter, data to infer seabed type.

A MBS provides detailed bathymetry along the line of the vessel's track with swath widths of 2 to 5 times water depth and produces detailed acoustic backscatter maps of the seabed. Methods to process and interpret the data from MBS have been evolving. The processing of depth data, removing errors caused by ray bending, platform motion, fish schools, bottom detection method and noise have been developed (e.g. [3-5]). Advances are also being made in the processing and understanding of seabed backscatter from multi-beam instruments (e.g. [6-9]).

In-situ backscatter calibration of these instruments is not always possible but advances are being made [10]. For large instruments, relative calibrations are the normal procedure and data from reference sites can be used to calibrate and cross validate the measurements between beams [8]. A consistent methodology for interpretation of seabed backscatter is complicated by the facts that the mean echo and its statistics change with incidence angle for a given seafloor type (roughness and hardness), and that the sampling volume and area resolution of the instrument change with depth and incidence angle. Therefore, several core methods applied separately or in combination are used to analyse the acoustic backscatter based on seabed backscatter models, backscatter statistics and phenomenological characteristics in the data at various spatial scales [9, 11].

A backscatter processing method that minimises between beam instrument and calibration errors and maximise the spatial resolution, references the backscatter to a particular incidence angle (BS_{ref}) is adopted here [2, 12]. This method removes the effect of incidence angle on the backscatter response and results in a loss of information near normal incidence but has the advantage of better spatial resolution [2]. Near normal incidence the rate of change of backscatter with incidence angle provides information of seabed type if the seabed is homogeneous across that scale [13]. Interpretation of BS_{ref} for a simplified question of consolidated or unconsolidated sediment that is ecologically significant suggests relative errors less than +/- 2 dB [2] are necessary. To achieve this for large scale data collections requires correction of instrument biases and drift as well as absorption and incidence angle corrections. Instrument biases can be difficult to remove without detailed calibration (but see [12]). In this work we outline a national collection of backscatter from a Kongsberg EM300 MBS instrument mounted on the 65 m marine national facility vessel Southern Surveyor. We nest our collection and processing method into 5 levels being:

Level 1. Raw data collected from the instrument with at sea user adjustments.

Level 2. Automated depth cleaning, consistent backscatter corrections for absorption and incidence angle area estimates for a locally derived slope vector. Referencing the backscatter to an incidence angle of 40° (BS_{40}) to provide a user product.

Level 3. Detailed bathymetric data cleaning for adjusting locally derived slope vector and updating absorption and incidence angle area corrections. Detailed backscatter data cleaning to remove aeration, noise and instrument setting errors.

Level 4. Calibration of the instrument, adjusting for between beam errors and instrument calibration drift using reference sites through a range of temperatures and depths.

Level 5. Detailed absolute calibration at regular intervals.

This paper focuses on level 2 processing where we describe sound absorption and incidence angle area corrections for the locally derived slope at a continental scale.

METHODS

Multi-beam mapping

Bathymetric and backscatter data were collected on opportunistic transit and research voyages using a Kongsberg EM300 multi-beam sonar operating at nominally 31.5 kHz with 135, 1° by 1°, beams on the national marine research vessel Southern Surveyor since 2004 (Figure 1). The mills cross transducers for the MBS were located on a gondola attached 1 m below the keel of the vessel to reduce interference from bubble sweep down (aeration).

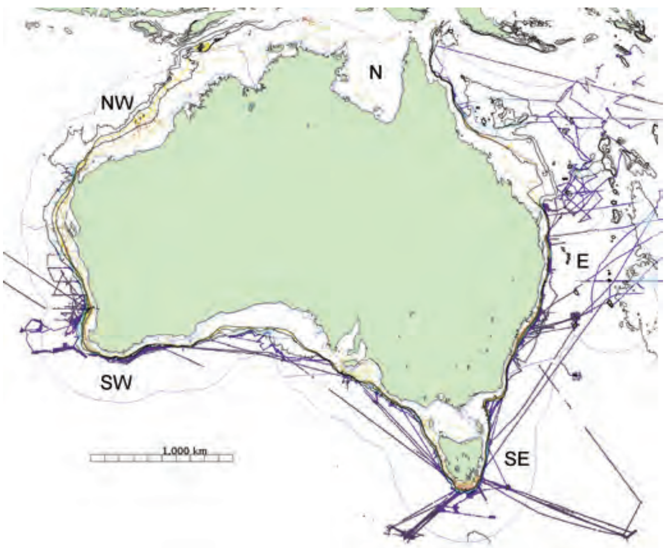

Figure 1. Data collected from the EM300 multi-beam sonar from research and transit voyages from the marine national facility vessel Southern Surveyor since 2004. Blue lines are the large marine domains of North West (NW), North (N), East (E), South East (SE) and South West (SW) with black lines at the 200 m, 700 m and 1500 m depth contours

During research voyages a dedicated MBS operator would monitor the instrument to check settings and update with the appropriate sound velocity and absorption files derived from the temperature profiles using expendable bathy thermographs (XBTs) or temperature and salinity profiles from a conductivity temperature depth probe (CTD) in the region. During transit voyages data were collected using standard settings with minimal human intervention and default sound velocity and absorption profiles. The default operation mode of the EM300 MBS was to set the beam operation into equi-distance mode where the beams were positioned to insonify the seafloor at equal distance assuming a flat seabed from the average depth. The pulse length was set depending on the depth mode as outlined in Table 1.

Table 1. Frequency and pulse length (PL) of the EM300 for incidence angles for the commonly used different operating modes, M, and emitted angle sectors, S

M	PL ms	S	Emitted Angles (θ_{ie})	Transmit Frequency kHz
1	0.7	3	-75 to -47.5 to 47.5 to 75	31.5, 33. 30
2	2	3	-75 to -47.5 to 47.5 to 75	31.5, 33. 30
3	5	9	-75 to -53.7 to -37.05 to -24.75 to -11.4 to 11.55 to 24.5 to 36.6 to 52 to 75	31, 32.5, 34. 32, 33.5, 30.5, 33, 31.5, 30

Processing of the data was done in the following order for the level 2 output where we focus on steps c. and d., the absorption and insonified area backscatter corrections for the target depth range of 150 to 1500 m:

a. Collection of data at sea
b. Correction of depth data for statistical outliers and adjusting to a locally sourced or derived sound velocity profile.
c. Correction of backscatter values to the locally sourced or derived absorption profile and corrected range data.
d. Correction of the estimated area insonified at the seabed incidence angle based on derived along-ship and across-ship slopes.

Processing methods

The acoustic depth data were corrected for sound speed errors, outlier identification and vessel-induced motion artefacts following standard procedures using MB system's software [14]. Anomalous backscatter data were evident when there were inconsistent measured depths due to aeration under the hull of the vessel. These values were excluded from further computations based on the level of processing. For level 2 processing, backscatter data were removed for anomalous depth data only. The backscatter as calculated by the MBS at the centre of each beam was georeferenced based on the edited bathymetry and referenced as an incidence angle to the seabed by the locally derived slope as outlined below. Absorption corrections were as outlined below. No corrections for transmit and receive beam pattern errors (± 2 dB) were done for this data set at level 2 processing.

Based on software developed by Caress et al. [14] the acoustic backscatter was referenced to a seabed incidence angle of 40°, $BS_{40°}(\theta_i)$, by calculating the mean incidence angle profile $\overline{BS(\theta_i)}$ for 1000 ping bins and subtracting it from the instantaneous backscatter $BS(\theta_i)$ then referencing to the mean backscatter at 40° incidence $\overline{BS(\theta_{40°})}$ where [2]

$$BS_{40°}(\theta_i) = BS(\theta_i) - \overline{BS(\theta_i)} + \overline{BS(\theta_{40°})} \text{ dB} \quad (1)$$

The length of the 1000 ping average assuming a 10 knot steaming speed varies with depth being approximately 5 n.miles, 10 n.miles and 15 n.miles in length at 200 m, 1000 m and 1500 m depths respectively. For pings which sit between the mid-point of two bins the correction is interpolated in time between the two bin averages. The $BS(\theta_{40°})$ data were "despeckled" using a 3 beams x 3 pings boxcar median low-passed filter and gridded data with overlapping tracks were weighted by incidence angle, acknowledging that inner and outer incidence angles are subject to greater variation and error respectively (Table 2). Note that this weighting only occurs when there is data from more than one incidence angle within a grid location placing more weight on data from incidence angles with less statistical variability and or susceptance to noise [2, 15]. The referenced seabed incidence angle of 40° was chosen based on both experimental and model evidence for improved discrimination across substrate types whilst minimising potential errors due to, noise, statistical variation and compensation for absorption and area insonified estimates [2].

Table 2. Weighting of overlapping incidence angle data used for gridding to suppress centre beam normal incidence variability and noise in outer beams at large angles of incidence

Angle (deg.)	0	14.9	15	45	60	80
Weight	0.1	0.1	0.8	1.0	0.2	0.1

Absorption error correction

The real time EM300 algorithms calculate a bottom backscattering strength, BS, following the sonar equation [16]. The BS is calculated from the received echo level (EL), transmitter source level (SL), the two-way transmission loss (2TL) and the logarithm of the resolvable area $A(\theta_{ie})$ on a flat seabed at emitted incident angle, θ_{ie}, where

$$BS(\theta_{ie}) = EL(\theta_{ie}) - SL(\theta_{ie}) + 2TL(\theta_{ie}) - 10\log_{10}A(\theta_{ie}) \text{ dB} \quad (2)$$

where $2TL = 40\log R + 2\alpha R$, for range, R (m), and absorption, α (dB km^{-1}). The error in measured seabed backscatter as a function of depth (D), incidence angle (θ_{ie}) on a flat horizontal seafloor due to the difference in the applied, $\propto_a$, and derived, $\propto_d$ absorption is,

$$Error_{\propto} = \frac{2D}{\cos\theta}(\propto_a - \propto_d) \text{ dB} \quad (3)$$

The sensitivity of EM300 backscatter measurements to absorption estimates is explored using both the Francois and Garrison (F&G) [17] and the Doonan [18] equations at a reference incidence angle of 40° assuming a flat horizontal seabed. The main difference between F&G and Doonan equations is the estimation of the relaxation frequency for magnesium sulphate. In the frequency range 10 to 120 kHz the absorption due to magnesium sulphate is the dominant factor [17].

When using the EM300 multi-beam the frequency at a given incidence angle changes depending on the mode (Table 1). It is assumed that the EM300 internal algorithms correct for the variation of absorption across frequencies and that the EM300 reference frequency is 31.5 kHz. Estimates of absorption at depth when no temperature and salinity profile was available was done using the temperature and salinity profiles derived by inference based on the satellite altimetry, SST, and all available subsurface information interpolated within a 0.18 degree grid scale [19].

Corrections for incidence angle

Corrections for the area insonified were required for both the along-ship and across-ship directions. The real time EM300 MBS area only approximates the area for across-ship slopes and this will be in error for rugged terrain or noisy real time bathymetric data. Therefore the EM300 applied area compensation that is derived assuming the nearest range is normal incidence was removed [16].

Area compensation was then applied based on two criteria. Firstly, calculating the locally derived slope in the across-ship direction, $Ø_{yi}$, at the centre of each beam, i, based on the corrected per ping depth data using the automated depth corrections. Secondly, calculating the locally derived slope in the along-ship, $Ø_{xi}$, and across-ship direction based on a topographic grid of 50 m. The grid size was selected based on the target depth range (200 m to 700 m) for the mapping and a need to smooth the slope estimates from high local deviations due to potentially incorrect bathymetry. For small beamwidths as used in MBS the area, A_i, insonified at the centre part of each beam, i, for an emitted angle, θ_{ei}, was approximated by the minimum of the area estimated near normal incidence, A_{ni}, and oblique incidence A_{oi}

$$A_{ni} = \frac{\psi_y l_x R}{\cos(\theta_{ei} - \phi_y)} \quad (4)$$

$$A_{oi} = \frac{c\tau l_x}{2\sin(\theta_{ei} - \phi_y)} \quad (5)$$

where ψ_x is the -3dB beam-width (radians) in the along-ship direction, for sound speed, c ms^{-1}, range, R m, and pulse length, τ ms. The insonified length, l_{xi}, at the centre of each beam, i, in the along-ship direction, was approximated as the minimum of near normal incidence length, l_{nx} m, and oblique incidence, l_{ox} m

$$l_{nx} = \frac{\psi_x R}{2\cos(\phi_x)} \quad (6)$$

$$l_{ox} = \frac{c\tau}{2\sin(\phi_x)} \tag{7}$$

where ψ_x is the -3dB beam-width (radians) in the across-ship direction [20]. This estimate of insonified area as a rectangle is an approximation and yields a less than 0.6 dB error [21].

Seabed Model

The APL-UW [22] seabed scattering model combines the most dominant dimensionless seabed scattering mechanisms of homogeneous sediment volume scattering coefficient $S_v(\theta)$ and surface roughness coefficient $S_s(\theta)$ as a superposition of incoherent scatter to estimate the seabed backscattering strength $S_b(\theta)$, where:

$$S_b(\theta) = 10log_{10}[S_s(\theta) + S_v(\theta)] \text{ dB} \tag{8}$$

$S_b(\theta)$ was calculated for seabed incidence angles, θ, of 0° to 80° at transmitted frequency of 31.5 kHz and geoacoustic properties of 6 seabed types derived from a synthesis of historic physical seabed samples (table 3.2, [22]).

RESULTS

Since 2004, 0.35 M km^2 of seabed in Australia's five marine domains has been mapped with the MBS, representing 6% of the total. Within the target seabed depth range of 100 m to 1500 m and 200 m to 700 m, 11% and 18% of the seabed has been mapped respectively. This low amount of seabed mapping is mainly due to the wide slope regions in the North West, South West and East bio-regions. In the South East region where the slope is narrow, 75% of the 200 to 700 m seabed has been mapped and 37% in the 100 to 1500 m depth range (Table 3).

Table 3. Area in 1000 km^2 of Australia's five marine domains (Figure 1) and the associated targeted areas of the continental margin from 100 m to 1500 m and 200 m to 700 m. The area mapped in 1000 km^2 and the proportion of the total in each marine bioregion since 2004 from opportunistic transit and research voyages are given

	Marine Bio-Region					
Area 1000 km^2	**East**	**North**	**North West**	**South East**	**South West**	**Total**
Total	2026	626	1068	1157	1292	6168
100 m to 1500 m	502	45	399	86	208	1239
200 m to 700 m	109	4	129	16	45	303
Mapped area total	120	7	29	88	109	352
100 m to 1500 m	39	1	24	32	44	140
200 m to 700 m	12	0	13	12	16	54
Proportion mapped total	5.9%	1.1%	2.7%	7.6%	8.4%	5.7%
100 m to 1500 m	7.8%	2.3%	5.9%	37.4%	21.1%	11.3%
200 m to 700 m	11.1%	0.0%	10.0%	75.0%	36.0%	17.7%

Absorption correction

At the example depth of 400 m, 10° C, 31.5 kHz, 35 salinity and 7.8 pH, the measured absorption is 7 dB km^{-1} and 6.5 dB km^{-1} for the F&G and Doonan equations respectively. There is a potential 0.5 dB uncertainty in the absorption estimate between the two absorption equations for those reference conditions (Figure 2). The absorption coefficient is sensitive to input parameters of temperature, depth, frequency and salinity (Figure 2). The exact nature of this sensitivity needs to be explored for expected ranges of these parameters and the effect on the integrated absorption at depth. The effect of pH on the measured absorption is significantly less than the other parameters and is not shown.

The change in the measured backscatter at 1500 m water depth when the backscatter is referenced to 40° incidence angle for errors in absorption of 0.5, 1 and 1.5 dB km^{-1} is 2 dB, 3.9 dB and 5.8 dB respectively (Figure 3).

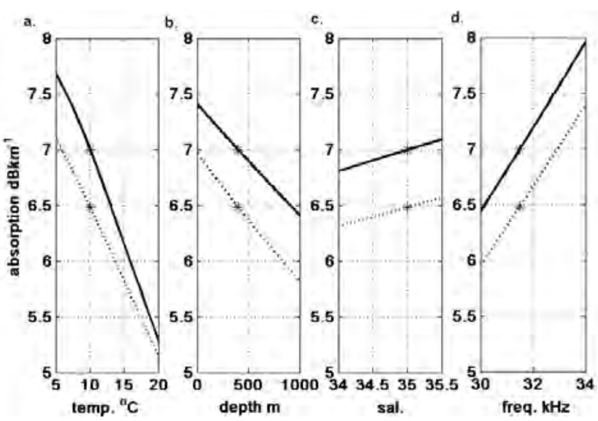

Figure 2. Variation of absorption using the F&G (solid line) and Doonan (dashed line) equations for variations in (a) temperature, (b) depth, (c) salinity and (d) frequency. The absorption at the example depth, 400 m, temperature, 10°C, salinity, 35, and frequency 31.5 kHz is noted with an asterisk *

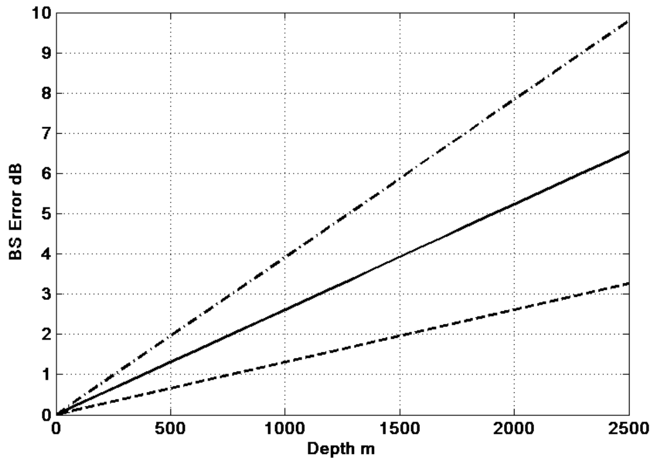

Figure 3. Error in measured backscatter referenced to 40° incidence angle for absorption error of 0.5 (dashed), 1.0 (solid) and 1.5 (dot-dashed) dB km^{-1}

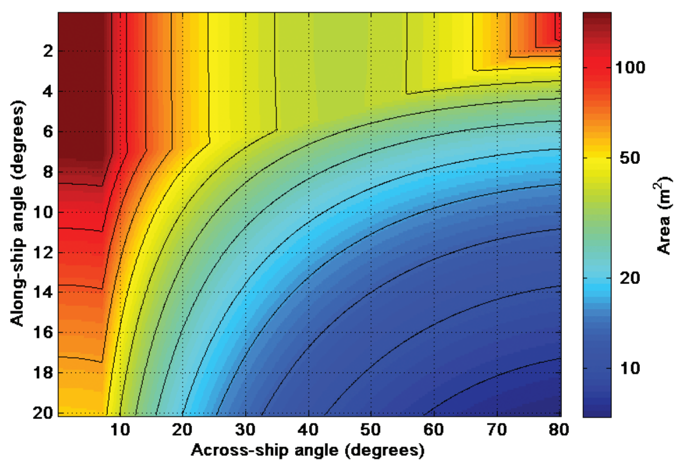

Figure 4. The variation in the area insonified ($10\log_{10}A(\theta_{ei})$) based on equations (4) to (7) at a depth of 700 m and pulse length of 2 ms for across-ship seabed incidence angles of 0° to 80° and along-ship seabed incidence angles of 0° to 20°. Contour intervals are at 1 dB

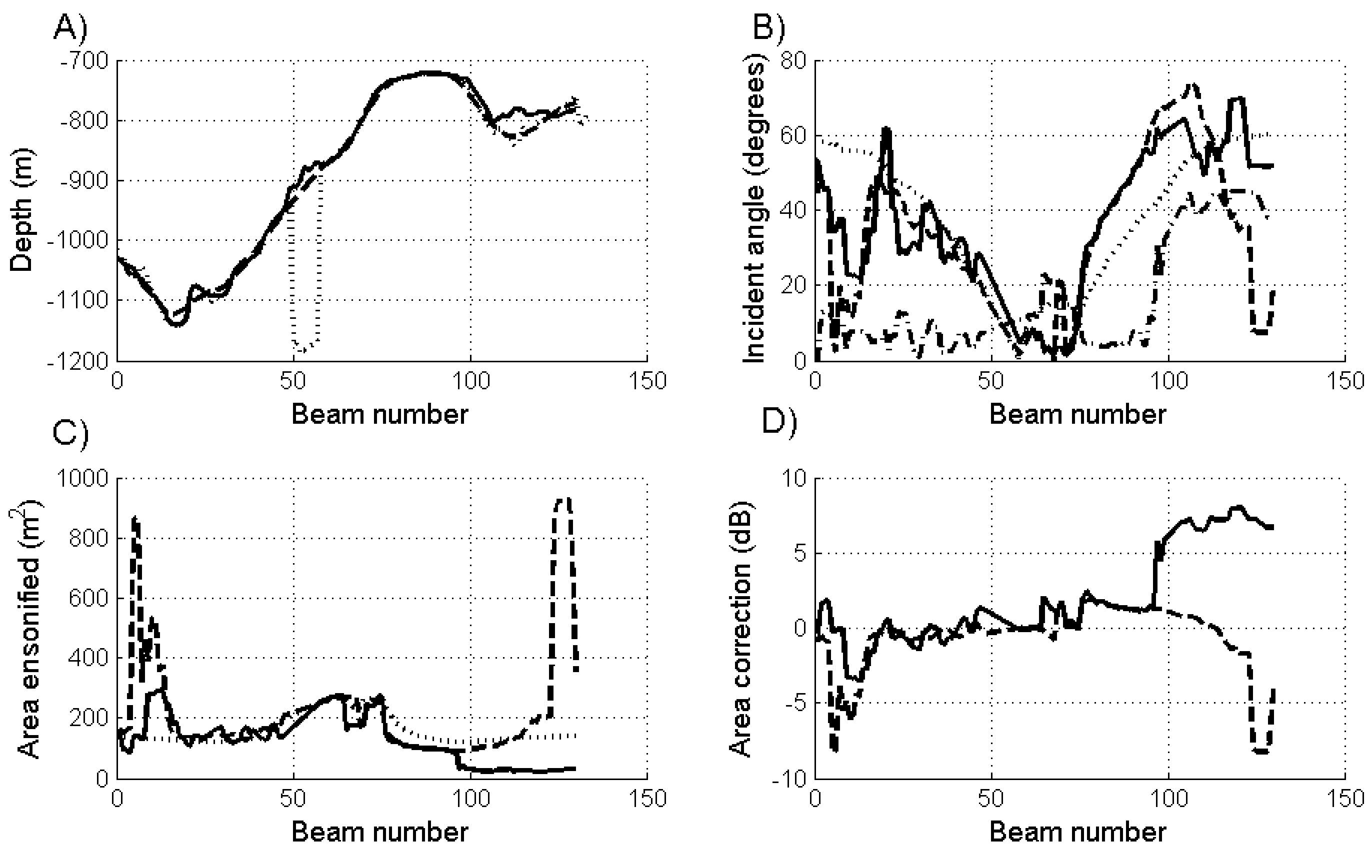

Figure 5. Example of the correction in backscatter for one EM300 ping referenced to the beam number through a canyon feature for a) bathymetry, b) the estimated seabed incidence angle, c) estimated area insonified for each beam and d) the error between the different area estimates. The dotted lines indicate values derived from the real time EM300 instrument algorithms, dashed lines are derived using only the across-ship bathymetry and slope corrections, solid lines are the values from the bathymetry and slope corrections using the topology grid and the dot-dashed line is the along-ship slope estimate

Corrections for incidence angle

The correction of the area insonified will be variable depending on the difference in the assumed and derived across-ship and along-ship seabed incidence angle. The greatest variation is for large seabed incidence angles and along-ship slopes (Figure 4). For the EM300 operating at 2 ms pulse length and an along-ship slope of 10° the backscatter error at 700 m depth is < 1 dB or as high as 5 dB at 0° and 60° incidence respectively (Figure 4).

The correction to the seabed backscatter is most apparent in complex terrain where high across-ship and along-ship slopes are encountered (Figure 5). Figure 5a shows the beam number corrections that are required to the bathymetry data using the ping based and topographic grid based methods. Based on the bathymetric corrections the seabed incidence angle for each beam can be calculated (Figure 5b). In this example there are differences between the applied and derived across-ship incidence angles of 55°. In the along-ship direction the derived seabed slope is a maximum of 45°. The difference in the applied and derived area insonified changes markedly depending on the incidence angle used (Figure 5c). Backscatter corrections in this complex topography varies between +8 to -8 dB for the different incidence angle approaches (Figure 5d). The backscatter area correction that includes both across-ship and along-ship seabed incidence angles should be more precise.

Removal of the incidence angle relationship is done after the corrections for bathymetry and adjustments to the seabed backscatter for absorption, seabed incidence angle and area. An empirically derived 1000 ping average is applied to the data where the average backscatter to seabed incidence angle is derived and a low pass filter applied (Figure 6).

Figure 6. EM300 backscatter for a vessel track at ~ 200 m depth for (a) raw, (b) backscatter referenced to 1000 ping average at 40° incidence angle to the seabed, (c) after low pass filtering. Dynamic range is -20 dB dark and -40 dB light. The inserts highlight the effects of the median 3 beams by 3 pings box car filter on the backscatter

Model seabed backscatter

The expected dynamic range of seabed backscatter at 31.5 kHz for consolidated (rough rock) and unconsolidated sediment (clay) at a seabed incidence angle of 40° is -6 dB to -28 dB based on the APL94 model [22] (Figure 7). In this instance consolidated seabed is characterised as -6 to -15 dB and unconsolidated -18 to -28 dB at 40° incidence angle. The transition zone between the definition of consolidated and unconsolidated is 3dB and accuracy in the estimated backscatter of 1-2 dB is required to minimise misclassification errors. This model of seabed types highlights the improved discrimination of the reference seabed incidence angle of 40° and is consistent with previous model estimates and measurements using a similar instrument at a higher frequency (Kloser et al. 2010).

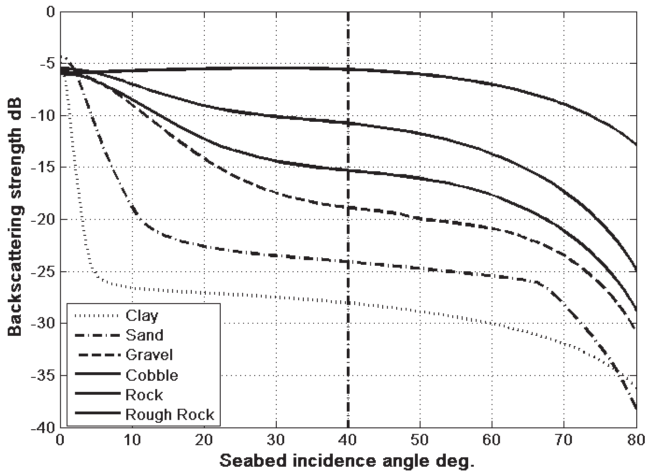

Figure 7. Estimated seabed backscatter at 31.5 kHz based on the APL94 [22] seabed model for consolidated (cobble, rock and rough rock) and unconsolidated (gravel, sand and clay) seabed assuming geoacoustic parameters as outlined in table 3.2 of APL94 [22]. The reference seabed incidence angle of 40° is highlighted

DISCUSSION

In this paper we have outlined a seabed backscatter mapping program based on opportunistic transit and research voyages of the marine national facility vessel Southern Surveyor since 2004. Based on this opportunistic sampling 100% coverage of the wide upper slope regions in the North West, and East marine bioregions has not been possible with less than 11% mapped in the 200-700 m range. For these regions alternative sampling strategies should be considered to provide representative coverage. In the South East region, systematic sampling has meant that 75% of the 200-700 m depth range is mapped. The processing of the data has been nested in a 5 level scale and only level 2 processing to minimise errors due to incorrect sound absorption and area compensation has been discussed here. The objective of distinguishing consolidated from unconsolidated sediments is reported to require relative measurement accuracies of better than 2 dB for a 100 kHz MBS [2]. This error requirement is consistent with the scattering model predictions at 31.5 kHz where the differentiation of consolidated and unconsolidated material is ~3 dB [22].

Corrections for incorrect sound absorptions are required given the large temperature range experienced from Australia's tropics to temperate regions. A consistent method has been applied when processing data from transit voyages where no direct temperature and salinity profile of the region is available. This method should reduce relative measurement errors. What remains uncertain is which of the F&G and Doonan absorption equations are more correct. For fisheries research the Doonan equation at 38 kHz is recommended based on a statistical reanalysis of historic data [18]. There is an approximate 0.5 dB difference between these two equations that can increase to errors of 3 dB at 2500 m. To resolve which equation is more appropriate will require new experiments in appropriate temperature, salinity and depth ranges.

Significant corrections for the area insonified were necessary to correct for across-ship and along-ship slopes. The real time EM300 algorithms to estimate the area insonified can be in significant error when the estimated bathymetry is incorrect. This is due to the assumption in the real time EM300 algorithms that the shortest range signal is derived from normal incidence. Corrections for both across and along slope are required which is most pronounced in canyon systems of highly variable topography. Errors of +8 to -8 dB can be observed in the data set. It is normal practice to map out a region with a MBS perpendicular to the overall slope therefore minimising along-ship slope errors. In canyon and seamount systems this is not always possible and backscatter corrections using the topology are required. The magnitude of predicted errors for along-ship slopes was highest in the outer beams (incidence angles >60°). At 700 m depth the predicted error in backscatter for a 10° along-ship slope was 5 dB at 70° incidence angle (Figure 4). The predicted errors for estimating the area insonified are themselves subject to errors. Estimating the local along-ship and across-ship slopes relies on good bathymetry. To remove noise it is necessary to smooth the slope over a number of points that may or may not be consistent with the insonified area at all incidence angles. We have assumed that the area insonified can be treated as a rectangle and not an ellipse by integrating the transmit and receive beam patterns ([6, 21]). For narrow beams this error has been shown to be less than 0.6 dB but can be significantly higher near normal incidence and for wider beams [21]. Further, the exact area insonified will be related to the seabed materials the detailed transmit and received beam patterns and the processing methods internal to the MBS at each incidence angle [6, 8].

Despite all the uncertainties expressed above there is a consistent large difference in seabed backscatter between consolidated and unconsolidated seabed that is readily detected using this method and a given MBS instrument within a specified region and appropriate seafloor sampling [2, 23]. There is commonly a greater than 7 dB difference at 40° incidence angle between unconsolidated sand and consolidated rock substrate. This large relative difference is easily detected with a MBS at the time of mapping. Greater uncertainty in classification of seabed types arises in fine scale differences between substrate types and moving between instruments, depths, regions and over time. This highlights the need to establish reference seabed sites over various depths which can be mapped (with MBS, video and physical samplers) at regular intervals (potentially annually) around the continental margin. These reference sites would not only ensure appropriate calibration and classification of the seabed backscatter data but also monitor natural and human induced changes to the seabed [23]. In this study, seabed sites close to major ports have been opportunistically remapped. Based on the processing method outlined here these sites will be used to evaluate instrument measurement variability and substrate discrimination resolution. It that way it should be possible to associate an error estimate to the backscatter value to guide usage and future needs for mapping.

The overarching goal of the mapping program was to maximise the transit times on the Marine National Facility (MNF) vessel Southern Surveyor and the EM300 MBS at minimal cost. In this work we have nested the data collection into a 5 level processing method and due to cost only processed to level 2 with largely automated processing (http://www.marine.csiro.au/geoserver). At level 2 processing a user can determine where mapping has occurred and know that a consistent processing method has been applied for the absorption, area insonified and the effect of incidence angle. Estimates of consolidated and unconsolidated sediments can then be done as outlined in Kloser et al. [2]. At level 2 processing artefacts in the data remain as no visual analysis has been done to remove aeration and incorrect instrument settings. Depending on how the data is to be used it will be necessary to process the data to level 4 for consistent relative estimates and level 5 for absolute backscatter estimates. As part of a national mapping data set we recommend the data is processed to levels 4 and 5.

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