S2: Acquisition and processing of multibeam bathymetry, backscatter and their derived variables

1.1. Multibeam Bathymetry Processing

A Simrad EM3002 300 kHz multibeam sonar (MBS) system was used on-board the *RV Solander* to acquire high resolution multibeam bathymetry and backscatter data across study areas from three different surveys in different years. A dual head configuration (EM3002D) was deployed in some areas and a single head configuration (EM3002) was used in some other areas. Water depths of the study areas dictated the sonar head configuration used. Motion referencing and navigation data were collected with an Applanix Position and Orientation system and a C-Nav GPS system (with a horizontal accuracy greater than ± 0.15 m). Multibeam data were recorded using Kongsberg's Seabed Information System (SIS) software.

The multibeam bathymetry data were processed using *Caris*™ *HIPS & SIPS* software, and included:

- applying algorithms that corrected for tide and vessel pitch, roll and heave, and
- software filters and visual inspection of each swath line to remove any remaining artefacts and noisy data (e.g. nadir noise and data outliers).

In one of the surveys, a further bathymetry editing process was conducted during the survey, using IVS Fledermaus 3D visualisation software. The HDCS files from *Caris*™ were imported into *IVS3D DMagic* to produce a Combined Uncertainty Bathymetry Estimator (CUBE) surface. This surface was edited manually within the *IVS3D* Editor tool. Final bathymetry surfaces were created within *Caris*™ using the edits from Fledermaus and then exported as a surface grid (bathymetric map) for display and further analysis and process.

To minimise tidal bursts, a co-tidal solution in *Caris™* was adopted. Finally, a bathymetry surface was created within *Caris™* and then exported as a surface grid (bathymetric map, i.e., bathy) for display and analysis. The bathymetry data were gridded at 10m spatial resolution.

1.2. Multibeam Backscatter Processing

Multibeam backscatter data were processed using the *CMST-GA MB Process* toolbox software co-developed by the Centre for Marine Science and Technology at Curtin University and Geoscience Australia (described in Gavrilov *et al*., 2005a, 2005b; Parnum, 2007). The fully processed backscatter data were corrected for transmission loss and insonification area. The process within the toolbox involved: removal of the system transmission loss; removal of the system model; calculation of the incidence angle; correction of the beam pattern; calculation of the angular backscatter response in a sliding window with a 50% overlap in a 1° bin and; removal of the angular dependence and restoration (normalisation) to the backscatter strength at an incidence angle of 25°. For consistency across its various multibeam datasets, Geoscience Australia has selected normalisation to an incidence angle of 25° to accommodate data acquired from deep waters where the swath coverage is reduced.

The toolbox calculates the backscatter coefficient corrected for transmission loss and insonification areas. Calculation of the insonification area is based on the equation given in Talukdar *et al*. (1995). With these measurements, the corresponding incidence angle and coordinates on the seabed (X-Y) and depth (Z) are calculated.

The final processed backscatter data were gridded at 10m spatial resolutions for the two study regions and then exported for display and analysis. In this study, 27 backscatter mosaics normalised to incidence angles between 10° and 36° (i.e., bs10, bs11, …, bs36), with a 1° increment, were generated at 10 m resolution. In some areas especially in deeper water, no acoustic returns or bad acoustic returns were observed at incidence angles greater than 36°. To avoid the ambiguity of the nadir effect, backscatter grids normalised to incidence angles less than 10° were excluded. For these two reasons, we only produced backscatter grids normalised to incidence angles between 10° and 36°.

1.3. Derived Environmental Predictors

Together with the primary multibeam bathymetry and backscatter data, a large number of secondary variables were derived from the bathymetry and backscatter data as the predictors of this study (Tables 1 and 2). These predictors were obtained either from square windows of different sizes or from image objects.

1.3.1. Window-based variables

The bathymetry and backscatter data of Oceanic Shoals areas were first resampled to 10m spatial resolution matching that of Bonaparte areas. The following derivatives of the bathymetry data were derived using 3X3, 5X5 and 7X7 windows separately (Table 1): Local Moran I (Moran, 1950; Anselin, 1995), slope, relief, surface area (Jenness 2004), Topographic Position Index (TPI, Weiss 2001), planar curvature and profile curvature. We derived the topographic relief by calculating the absolute bathymetry difference within the nominated window. The rugosity variable was calculated using the following equation:

$$rugosity = \frac{surface\ area}{planar\ area}$$

Where the planar area for a pixel is the pixel size; the surface area is the "true" surface area obtained from the bathymetry data (Jenness 2004).

Similarly, from the backscatter data the Local Moran I, and three GLCM textural measures (Haralick et al. 1973): homogeneity, variance and entropy layers were calculated (Table 1). The slope, planar curvature and profile curvature layers were obtained using the Landserf software (Wood 1996). The homogeneity, variance and entropy layers were obtained using the ENVI software. The relief, TPI, surface area and Local Moran I variables were obtained using GIS scripts and function in the ArcGIS Desktop and ArcInfo Workstation software.

1.3.2. Object-based variables

We used the multi-resolution segmentation algorithm available in eCognition Developer^{TM} software (Benz et al., 2004) to divide the backscatter and bathymetry data into relatively homogeneous image objects. The segmentation algorithm was separately applied to individual study areas. For the bathymetry and backscatter data of the four Bonaparte areas, with a spatial resolution of 10m, we used a scale parameter of 2, a colour parameter of 0.5, a smoothness parameter of 0.5, and a compactness parameter of 0.5. For the data of the four Oceanic Shoals areas, with a spatial resolution of 2m, we used a scale parameter of 3 and the same settings of the colour, smoothness and compactness parameters. The scale parameter is used to vary the size of the image objects. The other three parameters define the homogeneity criterion, which can take into account both spectral and spatial properties of input layers. We used different settings of the scale parameter for the two study regions to take into account their respective spatial resolutions.

From the bathymetry data, we derived the topographic relief for all objects by calculating the absolute bathymetry difference within the objects. The averaged values of the objects for the following variables were also derived: bathymetry, Local Moran I, slope, rugosity, TPI, planar curvature and profile curvature (Table 2). From the backscatter data, three GLCM statistics were directly calculated within eCognition for all objects: homogeneity, entropy and variance (Table 2). In addition, the averaged values of the objects for backscatter and Local Moran I were also calculated (Table 2). It should be noted that we used the bathymetry and backscatter derivatives of 3X3 window to calculate these object-based variables.

Table 1: Window-based variables

	Variable	**Code**	**Description**	**Scales**	**Unit**
Bathymetry Derivatives	Local Moran I	bathy_lmi	An indicator of spatial autocorrelation	30m, 50m, 70m	
	Slope	slope	Slope gradient	30m, 50m, 70m[1]	degree
	Relief	releif	Topographic relief	30m, 50m, 70m	metre
	Rugosity	rugosity	“true” surface area in relation to “planar” surface area, an indicator of surface rugosity (Jenness 2004)	30m, 50m, 70m	
	TPI	tpi	Topographic (Benthic) Position Index (Weiss 2001)	30m, 50m, 70m	
	Planar Curvature	Plan_curv	The curvature of the surface perpendicular to the slope direction	30m, 50m, 70m	
	Profile Curvature	Prof_curv	The curvature of the surface in the direction of slope	30m, 50m, 70m	
Backscatter Derivatives	Local Moran I	bs_lmi	An indicator of spatial autocorrelation	30m, 50m, 70m	
	Homogeneity	bs_homo	GLCM Homogeneity (Haralick et al. 1973)	30m, 50m, 70m	
	Variance	bs_var	GLCM Variance (Haralick et al. 1973)	30m, 50m, 70m	
	Entropy	bs_entro	GLCM Entropy (Haralick et al. 1973)	30m, 50m, 70m	

Note: [1] a scale of 30m, 50m and 70m indicates window size of 3X3, 5X5 and 7X7, respectively

Table 2: Object-based variables

	Variable	Code	Description	Scales	Unit
Bathymetry Derivatives	Bathymetry	Bathy_o	Water depth	Object[1]	metre
	Local Moran I	bathy_lmi_o	An indicator of spatial autocorrelation	object	
	Slope	Slope_o	Slope gradient	object	degree
	Relief	relief_o	Topographic relief	object	metre
	Rugosity	rugosity_o	“true” surface area in relation to “planar” surface area, an indicator of surface rugosity (Jenness 2004)	object	
	TPI	tpi_o	Topographic (Benthic) Position Index (Weiss 2001)	object	
	Planar Curvature	plan_cur_o	The curvature of the surface perpendicular to the slope direction	object	
	Profile Curvature	prof_cur_o	The curvature of the surface in the direction of slope	object	
Backscatter Derivatives	Backscatter	bs_o	Backscatter intensity	object	dB
	Local Moran I	bs_lmi_o	An indicator of spatial autocorrelation	object	
	Homogeneity	bs_homo_o	GLCM Homogeneity (Haralick et al. 1973)	object	
	Variance	bs_var_o	GLCM Variance (Haralick et al. 1973	object	
	Entropy	bs_entro_o	GLCM Entropy (Haralick et al. 1973	object	

Note: [1] a scale of object indicates that the attribute was derived from the objects

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