Centre for Marine Science and Technology
Curtin University

In cooperation with

CRC for Coastal Zone Estuary and Waterway Management

Swath system deployed in Cockburn Sound for follow up trials of using snippets to classify seabed/benthos

(CRC Milestone Report Number CA4.02)

By:

P.J.W. Siwabessy, A.N. Gavrilov and I. Parnum

Centre for Marine Science and Technology (CMST), Curtin University, GPO Box U 1987
Perth 6845, WA

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PROJECT CMST 369

REPORT 2005-07

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Introduction

Background

As part of the Coastal Water Habitat Mapping Project with the Coastal CRC, a survey of selected areas of the Cockburn Sound (Western Australia) using the Reson SeaBat 8125 multibeam echosounder was performed over two days in July 2004 as a supplementary work to the previous survey conducted in March 2004 (see CMST Report 2004-21). Previous surveys that deployed cores, grab samples, sidescan sonar and video transects were used to help ground-truth information gathered.

This report comprises a trip report of the multibeam survey in the Cockburn Sound area conducted in July 2004 and a preliminary result of the analysis of the snippets data.

Area of Operations

The survey was located in the Cockburn Sound area, Western Australia (see Figure 1).

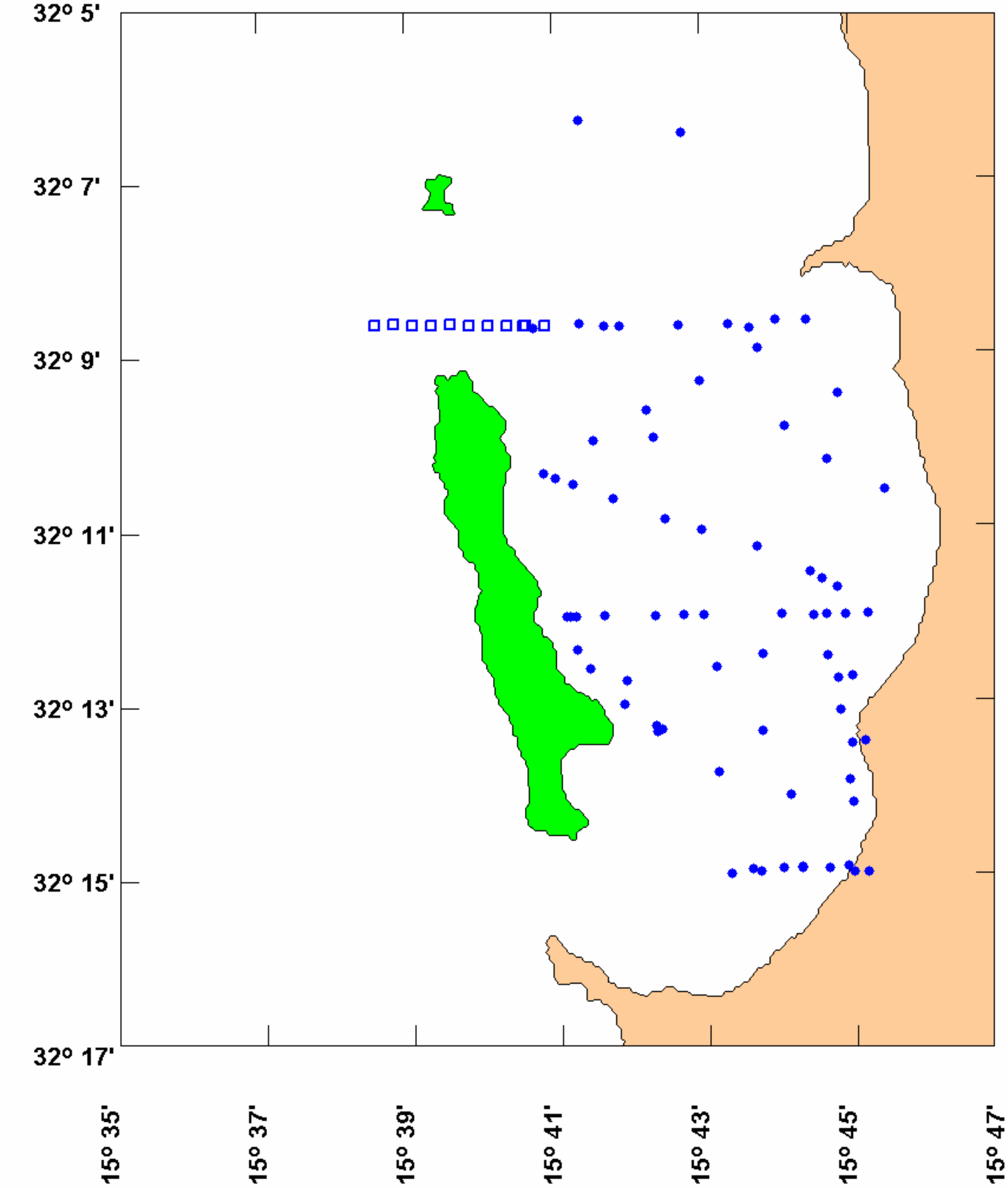

Figure 1. GA sampling sites. □ cores. ● grab samples.

Personnel

1. Justy Siwabessy (JS), CMST Curtin University, Kent St, Bentley WA 6102.
2. Iain Parnum (IP), CMST Curtin University, Kent St, Bentley WA 6102.
3. Michael Kuhn (MK), Department of Spatial Sciences, Curtin University, Kent St, Bentley WA 6102.
4. Nigel Meikle (NM), Department of Spatial Sciences, Curtin University, Kent St, Bentley WA 6102.
5. Mal Perry (MP), Moreton, Fitzroy and Sydney. CMST Curtin University, Kent St, Bentley WA 6102.
6. Paul Kennedy (PK), FUGRO, 38 Guthrie St., Osborne Park, WA 6017.

Survey organiser

- Rob McCauley (RM), CMST Curtin University, Kent St, Bentley WA 6102.

CMST, GPO Box U 1987 Perth 6845, Secretary, Ann Smith.

Vessel

Data collection took place on the fishing boat, *FV Reliance.*

Itinerary

Fri 09 July 2004	RM, MP, NM mobilise and install all field gear onto vessel *RV Reliance*.
Sat 10 July 2004	JS, NM continue installation and measure all sensor offsets required.
Mon 12 July 2004	JS, IP, NM, MK run the survey.
Tue 13 July 2004	JS, IP, NM continue running the survey.
Wed 14 July 2004	JS, IP, NM demobilise all field gear.

Trip Objectives

GeoScience Australia (GA)

- Repeat GA transects with the Reson 8125 multibeam system along three EW transects at: 1) 32° 09' S; 2) 32° 12' S; and 3) 32° 15' S within Cockburn Sound (see Figure 1). If possible extend transect 1 to juts NW of Garden Island.

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1. Obtain data for calibration and further understanding of the Reson 8125 data
2. Gather data with the Reson 8125 multibeam system from different habitat types for seabed characterisation work.
3. Collect enough relevant data for Nigel Meikle to analyse for his honours thesis.
4. Collect data for Yao-Ting Tseng's work on seagrass/sand backscatter.
5. Perform transect requested by Rob McCauley using the Reson 8125 multibeam system

Methods

Multibeam setup

A diagram of the system is shown in Figure 2. The sensors required by the system used in this survey included TSS Meridian Surveyor Gyrocompass, TSS DMS2-05 motion sensor, RESON SVP 15 sound velocity probe and Fugro's DGPS system.

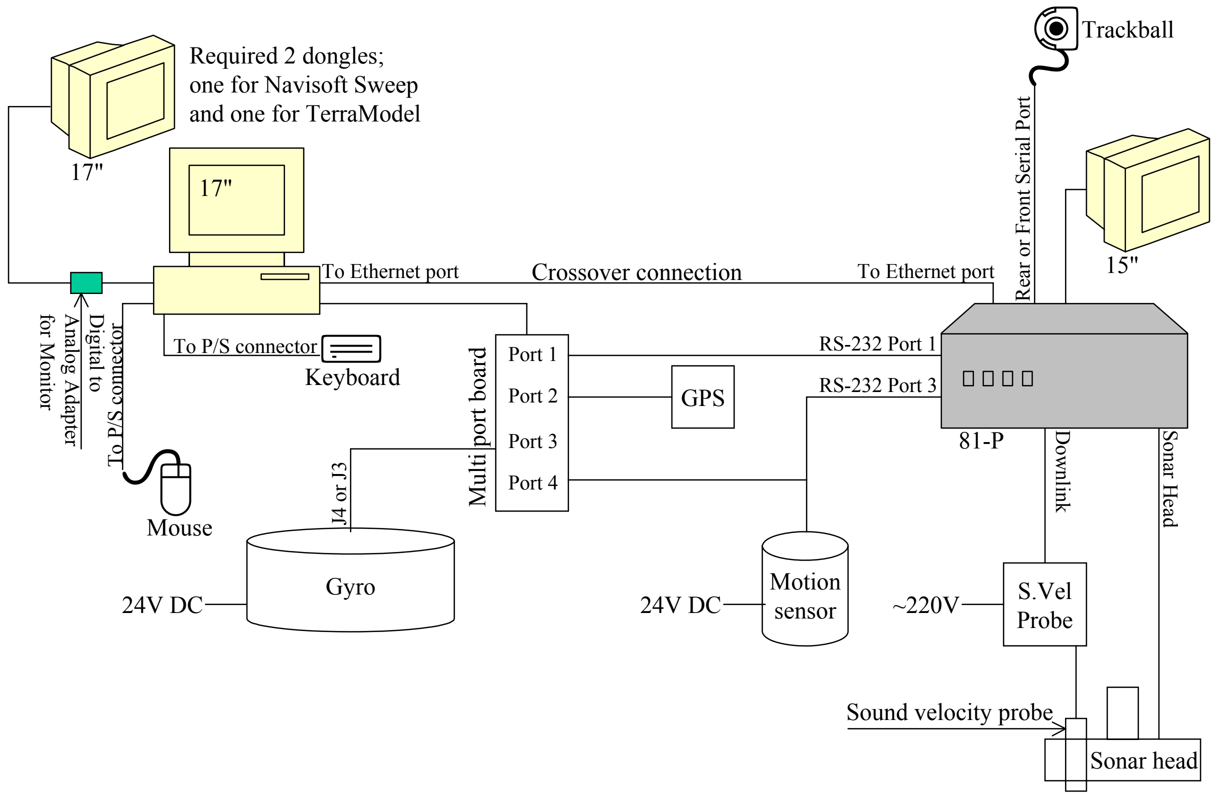


Figure 2. Connection diagram of the Reson 8125 multibeam system.

Mounting

The sonar head was side-mounted in the starboard side of the boat. As recommended, the motion sensor was placed very close to the centre of gravity of the boat whereas the gyrocompass was installed parallel to the centre line of the boat. The motion sensor and the gyrocompass were placed in the accommodation room right below the wheelhouse. The GPS antenna was fitted in the bow of the boat.

Using the software provided, the motion sensor was calibrated while the vessel was anchored at the jetty.

Sensor offsets

All sensor offsets were measured relative to the centre of gravity of the boat using a metal tape. A spirit level and a plumb bob were also used to allow for accurate measurements.

Survey planning

The survey took place in Cockburn Sound area. Transect lines and grid files were created using the Navisoft Planning and Presentation software. The grid file was prepared for each sub-area that allowed for a quality control.

To achieve the trip objective required by GA and trip objectives 2-3, 5 required by CMST, standard survey strategy was applied to maintain 50% overlap between adjacent transect lines i.e. $0.5 \times 3.5D$ where D is the water depth.

For the trip objective 1 required by CMST, two areas of flat sand at different water depths (5m and >20m) were predefined. Data in each area were collected twice; one with the maximum pulse length (292 µs), the other with the pulse length of 73 µs. A look-up table shown in Table 1 was prepared to provide the separation between adjacent transect lines and the survey area width required.

Table 1. Look-up table of transect line separation for calibration work.

Water Depth (m)	Width between transects (m)	Survey area Width (m)
5	3	35
10	6	70
15	9	105
20	12	140
25	15	175
30	18	210

<u>Initial setup and data collection</u>

The software used for data collection was Navisoft Survey. Using this software, the project file created using the Navisoft Planning and Presentation software was loaded and all available offsets were entered. Communication lines between PC and all sensors were checked. Data logging configuration was also checked, making sure that the folder and the filename were correctly specified and the GRD file (grid file) was selected. Data were collected along the lines provided in the project file loaded. Additional data were also collected along travelling tracks.

<u>Patch test</u>

The patch test is an independent measurement required to allow for "data alignment". The objective is to derive four other offsets i.e. latency, roll, pitch and yaw. For the latency, data were collected with the vessel traveling in the same direction, but at two significantly different speeds over a well-defined feature on the same line. It is required that one speed be at least double the other. Two independent sets of data for the roll offset were collected on reciprocal headings from one to another on the same line over a flat seafloor. Using the same line as was used for the latency, two sets of data for the pitch offset were collected with the vessel traveling at same speed, but in opposite directions on the same line. For the yaw offset, data were collected over a well-defined feature on two different parallel lines. The line spacing was set to allow the outer beams of one line to overlap the track for the other line (approximately 2 times water depth).

Data processing

<u>Bathymetry</u>

The Navisoft Calculate module within the Navisoft software was used to build the bathymetry. As a comparison, the Matlab code mentioned in the next section was also used to produce the bathymetry.

<u>Backscatter analysis</u>

The angular dependence (AD) of backscattering strength has been adopted here to interpret multibeam backscatter data. The angular correction procedure developed here is different from the frequently used Lambert-like correction. It is an empirical approach using the area-average angular dependence. The algorithm developed here employs a short sliding window to perform statistical averaging of the angular dependence. A Matlab toolbox developed within the CMST for the CWHM project comprises four modules as follows.

1. Matlab codes to convert multibeam data from XTF formatted files into Matlab formatted ones. Prior to the conversion into the Matlab formatted file, Reson formatted RAW files are converted into the XTF formatted files using the Navisoft software provided. Each XTF formatted file represents a single swath line. This Matlab module allows for a division of a single swath line into

multiple sections of a shorter length, if the number of data packets in a particular XTF formatted file is too large.

2. A set of Matlab functions for preliminary processing of the bathymetry and backscatter data. This includes:
    a. calculation of X,Y and Z coordinates of the points sampled on the seafloor for each beam and each ping within the swath line with correction for ship's relative motion (roll, pitch, heave, and yaw), for installation offsets of all sensors (sonar head, GPS receiver, and motion sensor) relative to the centre of ship's motion, and for time offsets in data communication;
    b. calculation of the actual angle of incidence (elevation and azimuth in the absolute coordinate system) corrected for ship's motion;
    c. determination of the peak backscatter intensity and calculation of the backscatter energy return by integrating the squared waveform of received signals (snippets);
    d. removal of Time Varying Gain (TVG) correction from the backscatter data (when TVG is applied to the amplitude of received signals in the sonar system);
    e. scaling of the backscatter characteristics (energy and peak intensity) using correction for the transmit power, system gain, and pulse width (for energy).

3. A set of Matlab routines and functions that combine sections of individual lines, calculate the backscatter coefficients for energy and peak intensity level, determine the true angles of incidence calculated relative to the local slope of the seafloor, and remove the angular dependence from backscatter images. The backscatter coefficients are calculated using corrections for spreading and absorption loss and corrections for the footprint size and the instantly insonified area for the backscatter energy and peak intensity level respectively. The backscatter coefficients and the angle of incidence are used to derive the backscatter angular dependence averaged over a predefined number of pings that constitute a spatial window of certain length along the swath line. Averaging is carried out within 1-degree bins from 0 to 60^0. The angular dependence derived within the window is attributed to its spatial centre. The overlap of neighbouring spatial windows is 50 per cent, which reduces the boundary effects of segment-wise averaging in the further procedure of building backscatter images corrected for the angular dependence. The next Matlab function removes the angular dependence from the backscatter coefficients for energy and peak intensity levels to build backscatter images, and at the same time preserve the absolute level of those coefficients through scaling of the resulting backscatter values (brightness/colour of pixels in the image) by the absolute backscatter levels calculated at $30\text{-}31^0$ in the average angular dependence. As a result, the obtained backscatter images are equalized with respect to slow across-track variations due to the actual angular dependence of seafloor backscattering and with respect to slow or rapid, but regular across-track variations due to unevenness of the sonar directivity pattern (including difference in the acoustic sensitivity of different beams).

4. A Matlab program that combines a number of swath lines covering the seafloor area of interest and interpolates the bathymetry and backscatter data into nodes of a regular grid with a predefined cell size. Because the overlap of adjacent swath lines in a survey is recommended to be as large as 50% of swath width, a large number of grid cells within the surveyed seafloor area are sampled twice at commonly different angles of incidence. Since the bathymetry measurements are more accurate at near-nadir angles of incidence, the bathymetry readings attributed to those angles are more preferred and have larger weights in the griding procedure than the bathymetry readings of the same area obtained at grazing angles. The weighting coefficients decrease linearly with the increase of incidence angle (beam number counted from two inner-most beams). For the backscatter images, justification of the griding procedure is less certain, because, in contrast to bathymetry, the resulting backscatter values (both energy and peak intensity levels) are subject to the angular dependence and the procedure of its compensation. In the current version of the Matlab routine developed for griding the Reson 8125 data, a Distance-and-beam-weighting algorithm is

applied to grid the bathymetry data and a Median algorithm is used for griding the backscatter data. Searching of original samples is carried out within each cell of the grid.

Results

Survey narrative

JS, IP, NM, MK met on dock at 07:00 on 12 July 2004. Gyrocompass was turned on and took 1.5 hours before it was eventually ready. After the gyrocompass was ready, the boat headed off to the GA northernmost transects and the multibeam data were collected on the way. 15 minutes after leaving for the first survey area, the Navisoft software did not recognise the GPS connection. After the Navisoft software was reinstalled, the GPS connection was back alive. Similar problem happened again 10 minutes later. The Navisoft software was again reinstalled and the GPS connection came back alive. All these delayed the survey for approximately 2 hours behind the schedule and caused the patch test to be deferred the next day. The actual survey in the northernmost transect eventually began at around 10:39. 18 lines in the northernmost transect were accomplished. The survey went on in the GA centre transects. Multibeam data were also collected while travelling to this survey area. Only 4 lines in this survey area were completed.

On 13 July 2004, JS, IP, NM met on dock at 06:00. After the gyrocompass was ready, the boat steamed off to the GA northernmost transects to complete the survey in this area. Multibeam data from 10 lines were achieved. All these lines were gap-filling lines. The survey moved on to the GA centre transects to complete the multibeam survey in this area. Total of 27 lines including gap-filling lines were completed in this area. The survey continued in the last area, GA southernmost transects. The survey was completed in this last area with 23 lines of multibeam data. The patch test was conducted right after the completion of the multibeam survey in the GA southernmost transects. Patch test data from 15 lines were collected in the required area, i.e., flat bottom for roll and slope bottom for latency, pitch and yaw. After the completion of the patch test data collection, the boat headed off to the flat sand area to collect multibeam data to meet trip objective 1 requested by CMST. Multibeam data were collected from 28 lines in a 5m-deep flat sand bottom and from 16 lines in a 20m-deep flat sand bottom. Each area was surveyed twice at different pulse lengths, i.e., 292 and 73 μs. In addition, snapshot data were also collected in the first sand bottom area. The survey went on in Owen Anchorage to meet trip objective 2 requested by CMST. Multibeam data from 5 lines running along different seabed habitat types were collected. Before heading back to the dock, multibeam data were acquired along 2 lines at a drop-off across the channel to meet trip objective 5 requested by CMST. Note that trip objective 4 requested by CMST for Yao-Ting TSENG’s work using the SIMRAD EQ60 singlebeam echosounder was not accomplished due to the problem with the mounting pole. The pole together with the singlebeam head was removed from the boat for safety reason.

Figure 3 shows the survey area together with the multibeam swath.

Static and patch test offsets

Adopting sign conventions as required by the system as shown in Figure 4, all sensors offsets as required by the Reson 8125 multibeam system are presented in Table 2.

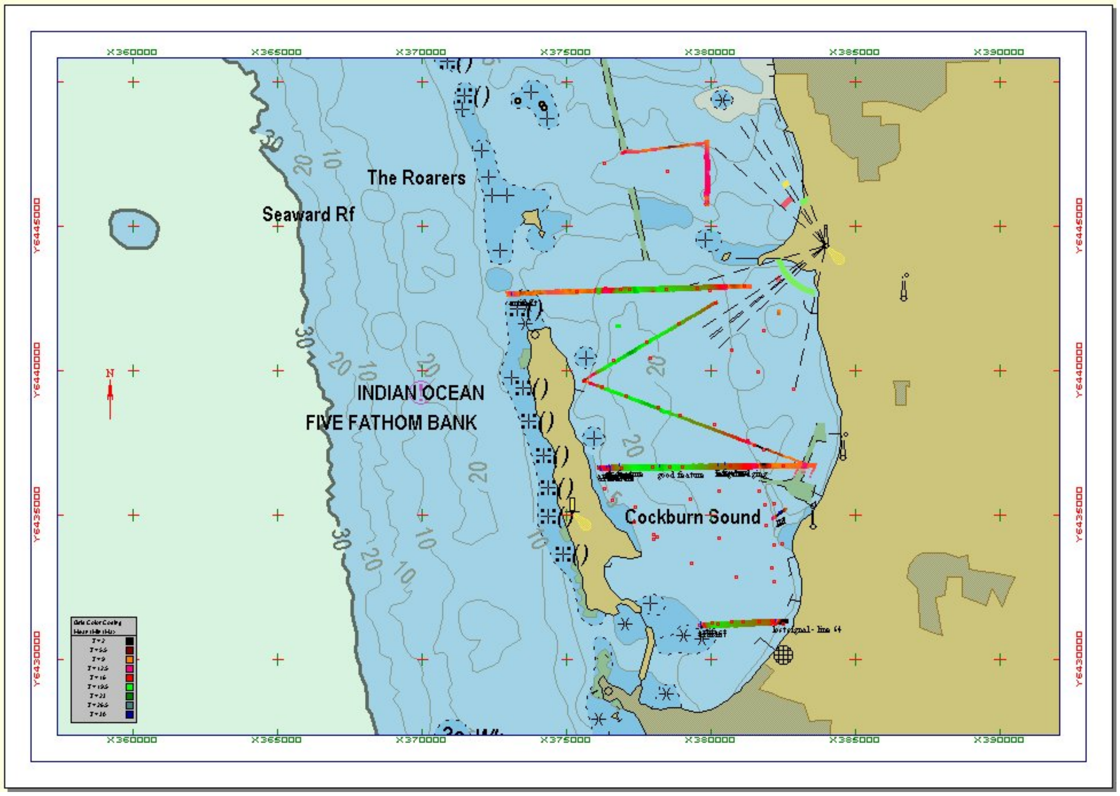


Figure 3. Survey area.

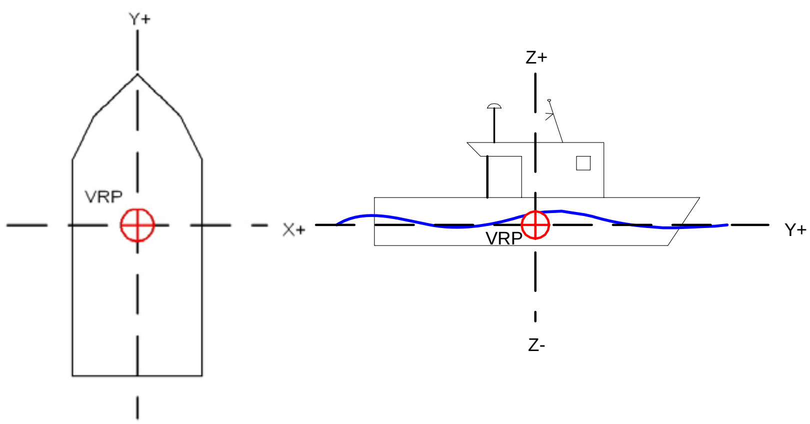
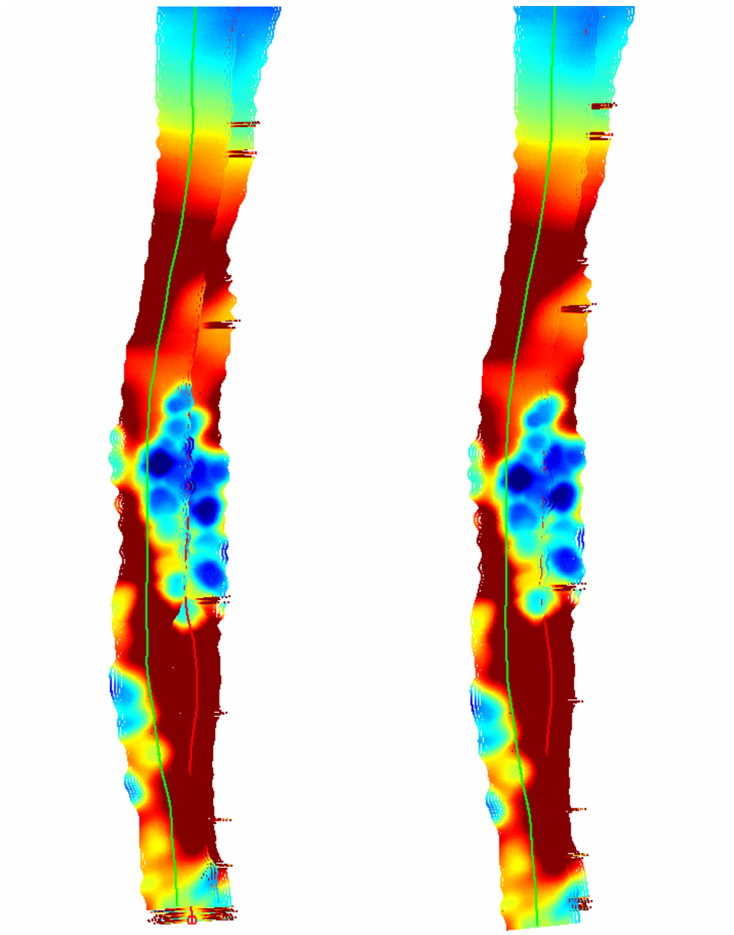


Figure 4. Sign conventions.

The GPS used in this survey was the F180 system different from Starfix GPS normally provided for all CRC-related surveys. In all other surveys using the Starfix GPS, all GPS offsets have been measured from the GPS antenna relative to the center of gravity of the boat. In this survey, all GPS offsets were measured likewise. This is true for the Starfix GPS since it provides GPS data of the antenna. These offsets are shown in Table 2 as figures in double strikethrough. Figure 5(a) shows a tremendous misalignment between two adjacent lines with these GPS offsets. With these offsets, the patch test offsets derived using the Navisoft Patch Test module are unrealistic as shown in Table 3 as figures in double strikethrough. It was found just recently that the F180 GPS system was corrected for the antenna offsets. Hence the GPS data provided were the position of the F180 box unit installed inside the wheelhouse. Therefore, the GPS offsets from the F180 box unit relative to the centre of gravity of the boat as also shown in Table 2 should have been used. Applying these correct offsets to the data, the misalignment between adjacent swath lines reduces significantly as shown in Figure 5(b) and the patch test offsets as given in Table 3 become more realistic.

Table 2. Sensor offsets.

Sensor	Sensor Offsets (m)		
	X	**Y**	**Z**
Sonar Head	2.99	-1.65	-1.38
DGPS	~~-0.60~~ 0.4	~~10.33~~ 3.42	~~3.61~~ 2.94
Motion Sensor	0.00	2.36	0.21



(a)

Figure 5. Part of swath lines 149 and 150 showing spike noises and misalignments due to wrong GPS offsets (a), and better alignments (b).

Table 3. Patch test offsets.

Latency (ms)	Roll (^{o})	Pitch (^{o})	Yaw (^{o})
~~868~~	~~-0.09~~	~~9.77~~	~~10.69~~
-370	-0.20	1.50	-2.30

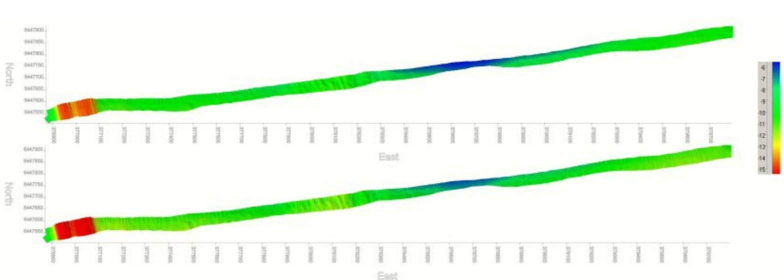
Bathymetry and snippets

The Navisoft software and our Matlab code were used to produce the bathymetry in two different areas namely the Owen Anchorage and an area along the drop-off across the channel. The Matlab code was also used to examine the snippets data. Data used for the analysis were swath lines 145-150 and 151-152 for the Owen Anchorage area and the drop-off area respectively.

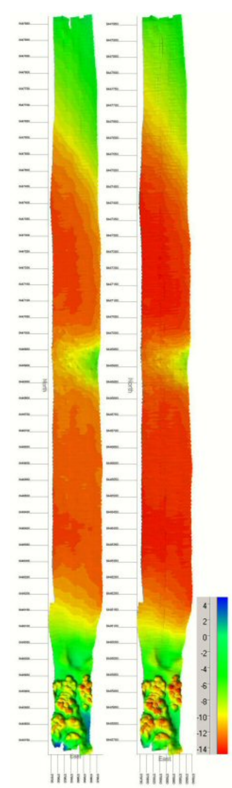
The pulse length used to collect the multibeam data in these two areas was 73 µsec, greater than that used in the previous surveys and that recommended in the operation manual. This is due to the fact that the sampling rate of the backscatter signal is unchangeable, fixed to 35 µsec. To be able to reconstruct the backscatter signal sampled with this sampling rate, the pulse length of the transmitted pulse must be equal to or greater than twice the sampling rate i.e. 70 µsec.

In general, the quality of the data was reasonably good. The spike noise was often observed however (see Figure 5).

The bathymetry of the two areas of interest was produced using the Navisoft software and our Matlab code as shown in Figure 6. Bathymetry images at the top of Figure 6(a) and at the right hand side of Figure 6(b) were derived using the Navisoft software. Those at the bottom and at the left hand side were produced using our Matlab code. A similar grid size of 1 m by 1 m was adopted to process the bathymetry using both softwares. The bathymetry produced using both softwares was not corrected for tide. Both softwares did not remove spike noises since our Matlab code was not able to do so. However, a depth filter was applied to both softwares. It is evident that the bathymetry derived using our Matlab code is slightly deeper, by approximately 0.5 m, than that produced by the Navisoft software. Further investigation of this slight disagreement is still underway. The agreement however is also evident by the fact that similar features appear in the bathymetry produced by both softwares.



(a) Drop-off area



(b) Owen Anchorage

Figure 6. Images of the bathymetry from the Drop-off area (a) and the Owen Anchorage (b). The top and the left hand side ones produced by the Navisoft software. The bottom and the right hand side ones derived using our Matlab code.

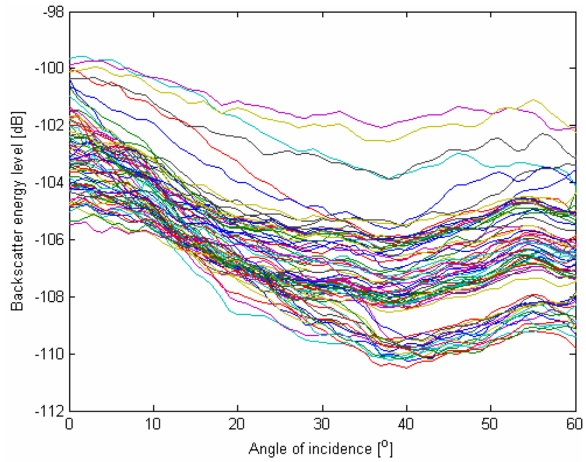


Figure 7. Angular dependence of backscatter energy level within swath line 149. A sliding window of 100 points and a 50% overlap adopted.

It is essential to make correction for the angular dependence in order to make sense of the backscatter reflected from different seabed habitat types. Our Matlab code employs a sliding window to derive the angular dependence. A sliding window of 100 points with 50% overlap was used here. A representative example of the angular dependence derived from swath line 149 is shown in Figure 7. As reported in the milestone report CA3.03 (see CMST Report 2005-03), the levels at near-nadir angles between 0-10 were underestimated. This however was not observed here. This confirmed the essential of the pulse length selected due to the fixed sampling rate provided by the Reson 8125 multibeam system.

Figure 8 shows the backscatter energy after the correction for the angular dependence and the bathymetry from the same swath line used in Figure 7. It is obvious that the backscatter energy and the bathymetry are independent. Higher backscatter energy levels are in the northern end of the line around 6447.8 km Northing at a water depth of 10 m.

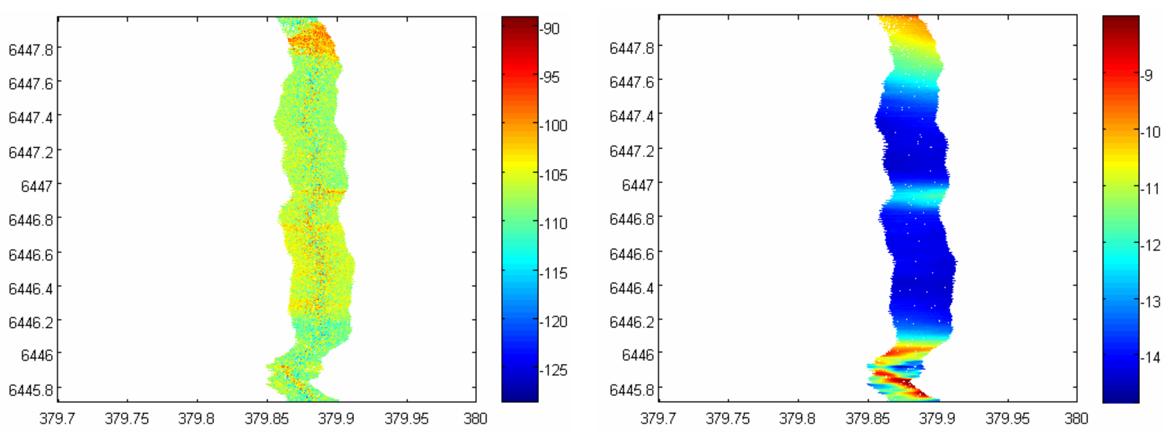
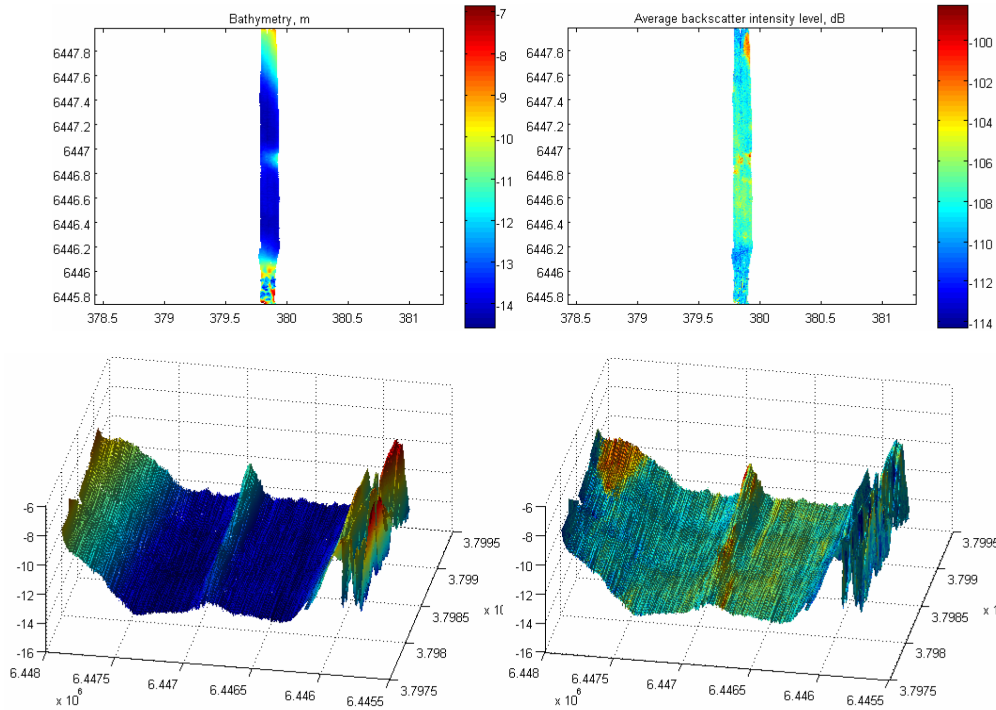


Figure 8. Corrected backscatter energy (a) and the corresponding bathymetry (b) of swath line 149.

Combining all lines (145-150) after the correction for the angular dependence, the corrected backscatter energy level was grided with the cell size of 1 m by 1m. The result together with the bathymetry is presented in Figure 9. It is again clear that the backscatter energy and the bathymetry are not dependent.



(a) Bathymetry

Figure 9. Grided backscatter energy (a) and the corresponding bathymetry (b) of the Owen Anchorage area.

A higher intensity of the backscatter is observed in the northern end and in the middle of the Owen Anchorage area. The difference in the backscatter intensity between those two areas and all other areas is profound, certainly indicating the difference in seabed habitat types. The UWA team has classified the seabed habitat from the footage taken from the previous survey in March 2004. Figure 10 shows the classification of the seabed habitat types around the area of interest. The video line that coincides with the high backscatter intensity in the northern end of the Owen Anchorage area reveals highly dense seagrass. On the other hand, sandy bottom has been observed in the other video line that coincides with lower backscatter intensity. Good agreement is also observed between the video-derived seabed habitat types and the backscatter intensity in the Drop-off area shown in Figure 11. Three patches of the high backscatter intensity appear in the western end and in the middle of the Drop-off area.

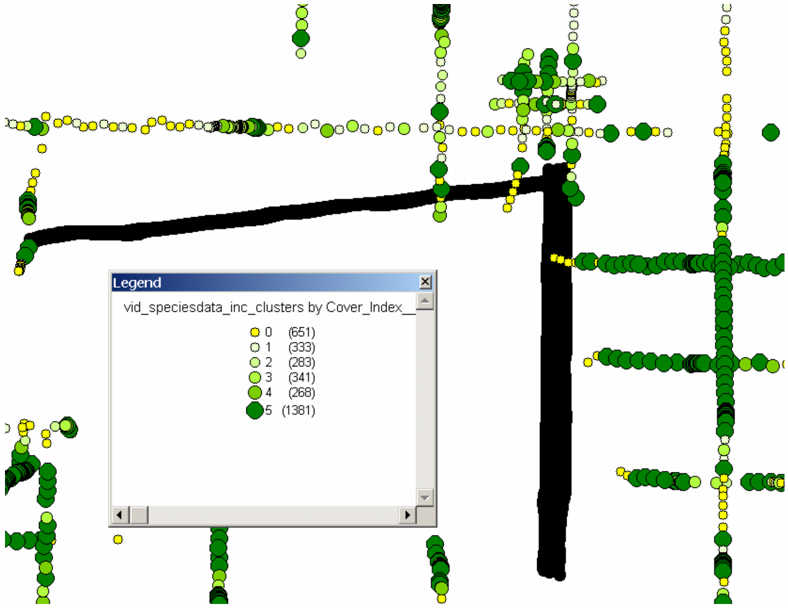


Figure 10. Seabed habitat types classified from the footage taken with the UWA underwater video system. Yellow circle is sandy seabed and all others are seagrass-covered seabed; the bigger the circle, the denser the seagrass.

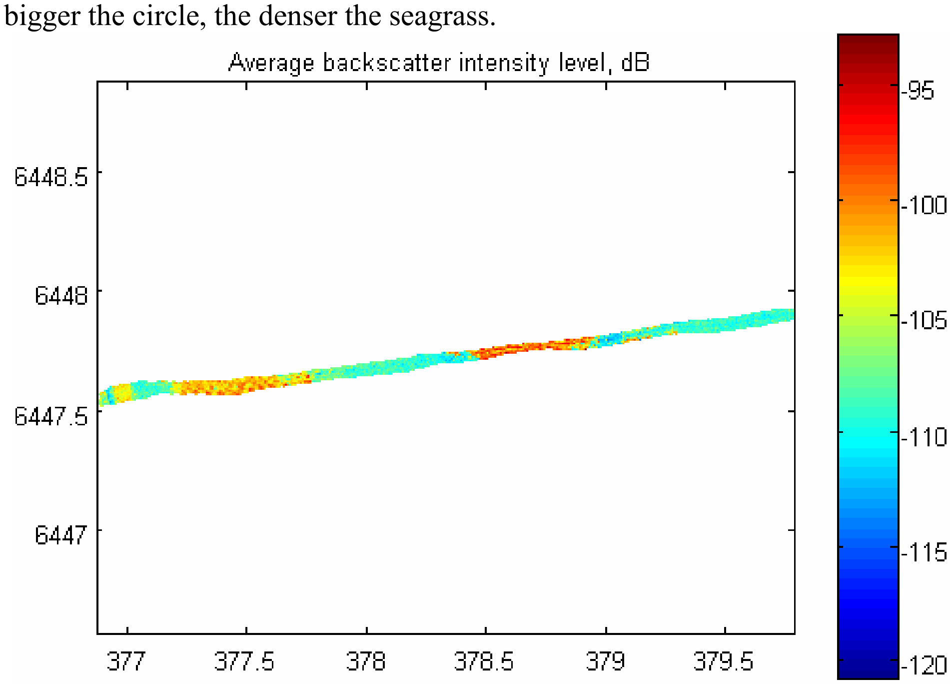


Figure 11. Grided backscatter energy of the Drop-off area.