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Technical Report 85

Epibenthic scattering project: design of field operation gear and project summary

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June 2006

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CRC for Coastal Zone Estuary & Waterway Management

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Prepared by Andrew Woods, Alec Duncan and Alexander Gavrilov
With support from Yao-Ting Tseng, Mal Perry, and Rob McCauley

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Contents

List of figures

List of tables

1. Introduction

The aim of this project was to develop innovative acoustic techniques as tools for seafloor habitat mapping. To achieve this aim it was recognised that a thorough understanding of the acoustic backscatter process from epibenthos was required and this project (ESP – Epibenthic Scattering Project) focused on obtaining this understanding.

Previous Coastal CRC milestone reports for the ESP (CA2.03, CA3.05, CA4.03, CA5.04, CA5.04 extension, CA6.03 and CA6.05—see reference listing) have detailed the research equipment used to gather the required data, the data processing performed and the results obtained.

From the commencement of the project, the *in situ* collection of spatially and temporally coincident optical and acoustic data was considered essential, and has been the primary requirement for the design of the current research system. Budget considerations dictated the use of two existing acoustic systems, essentially unmodified, which resulted in significant limitations to the fidelity of the acoustic data.

This report details recommendations for the design of an improved field research system and associated survey system. Brief introductions to these two systems were given in CA6.05, whereas this report provides more detailed recommendations.

This report also provides a review and summary of the data collected and processed so far and options for further work with the data.

2. Specifications for an improved research and survey system

General description

The mechanical configuration of the proposed research system is shown in Figures 1 and 2 (from CA6.05 report).

The general principle is to vertically separate the sonar transducers from the cameras in order to obtain a realistic sonar footprint and minimise problems due to transducer ring-down, while still placing the cameras within visual range of the seabed. The design also allows for a significant increase in the separation between the two stereo cameras and between the cameras and the flash, to give improved vegetation height measurement accuracy and fewer problems with optical backscatter.

This design uses wires to suspend a ring frame on which the stereoscopic cameras and strobe are mounted, several metres below a second frame on which the sonar transducers and a laser are mounted. The use of wires rather than a rigid frame makes the system much easier to deploy from a vessel, but increases the risk of misalignment caused by wave-induced motions or currents. To combat this problem, a laser mounted alongside the sonar transducers would provide a visual indication of where the centre of the acoustic beams is in the images. This laser needs to be of sufficient power to ensure the spot is visible in a wide range of lighting (ambient and strobe) and vegetation conditions.

The ring frame is of sufficient diameter that it is outside the main beam of the sonar transducers and has minimal effect on the acoustic signals reaching the seabed and returning to the sounder transducers. The transducers receive acoustic backscatter from the ring frame and also from parts of the wire suspension, but these returns occur much sooner than the seabed reflection and can easily be time-gated out.

The system can be suspended from a boat, as was done with the current ESP system, or alternatively it could be moored for longer-term monitoring experiments as shown in Figure 2. Deploying and recovering the moored system would be a complicated task that would be greatly assisted by the use of divers. A boat would need to be anchored near the moored system with the echosounder processor and data acquisition system on board the vessel.

The survey system should consist entirely of the acoustic component of the research system. Sonar transducers are fitted directly to the hull of the vessel of

choice or mounted over the side on a rigid pole, and surveys conducted over the desired area.

In situations where a different type of epibenthos or a different type of substrate is sampled, it may be necessary to redeploy the research system to collect ground-truthing data for that area and refine algorithms.

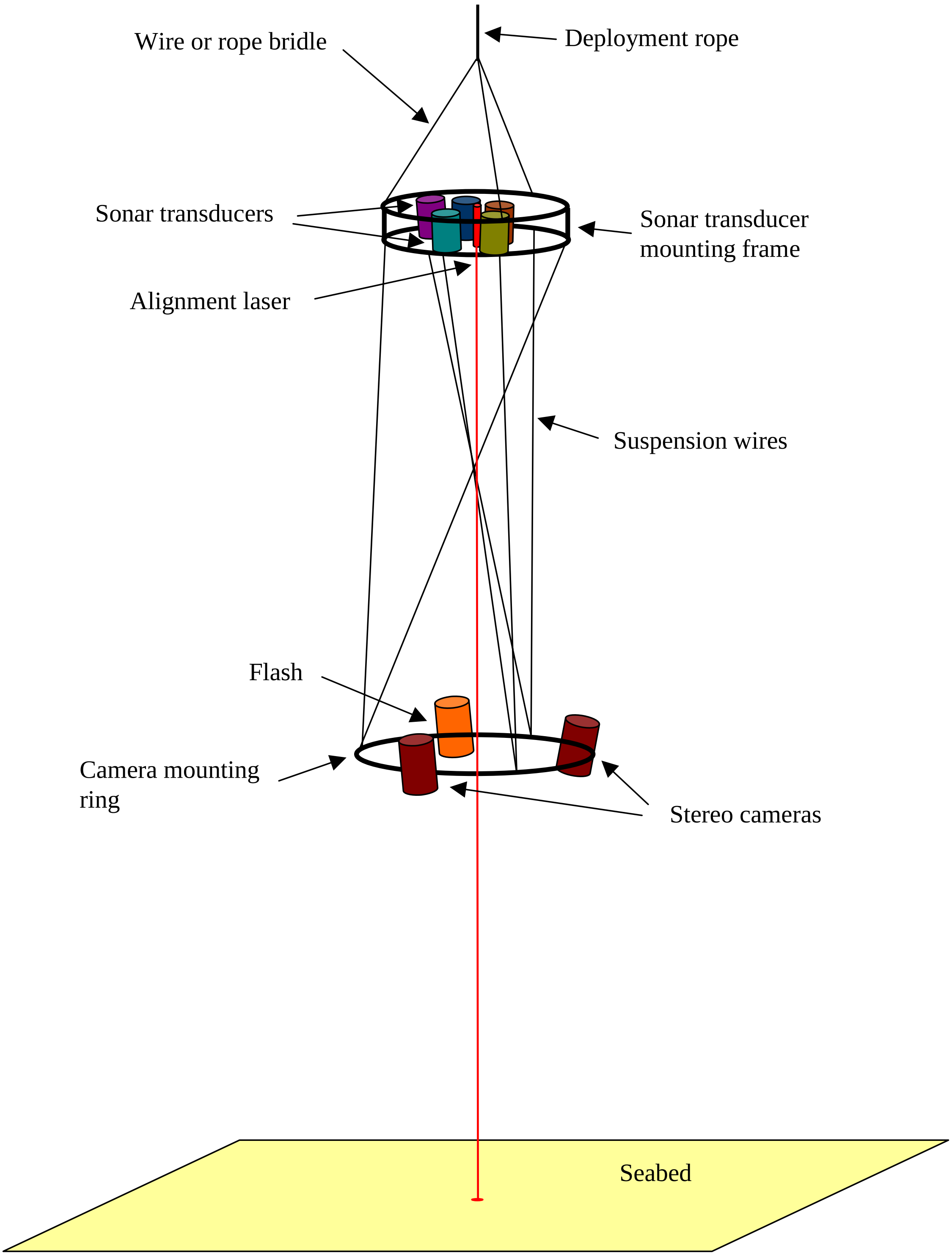

Figure 2. Proposed research system configuration (vessel deployment)

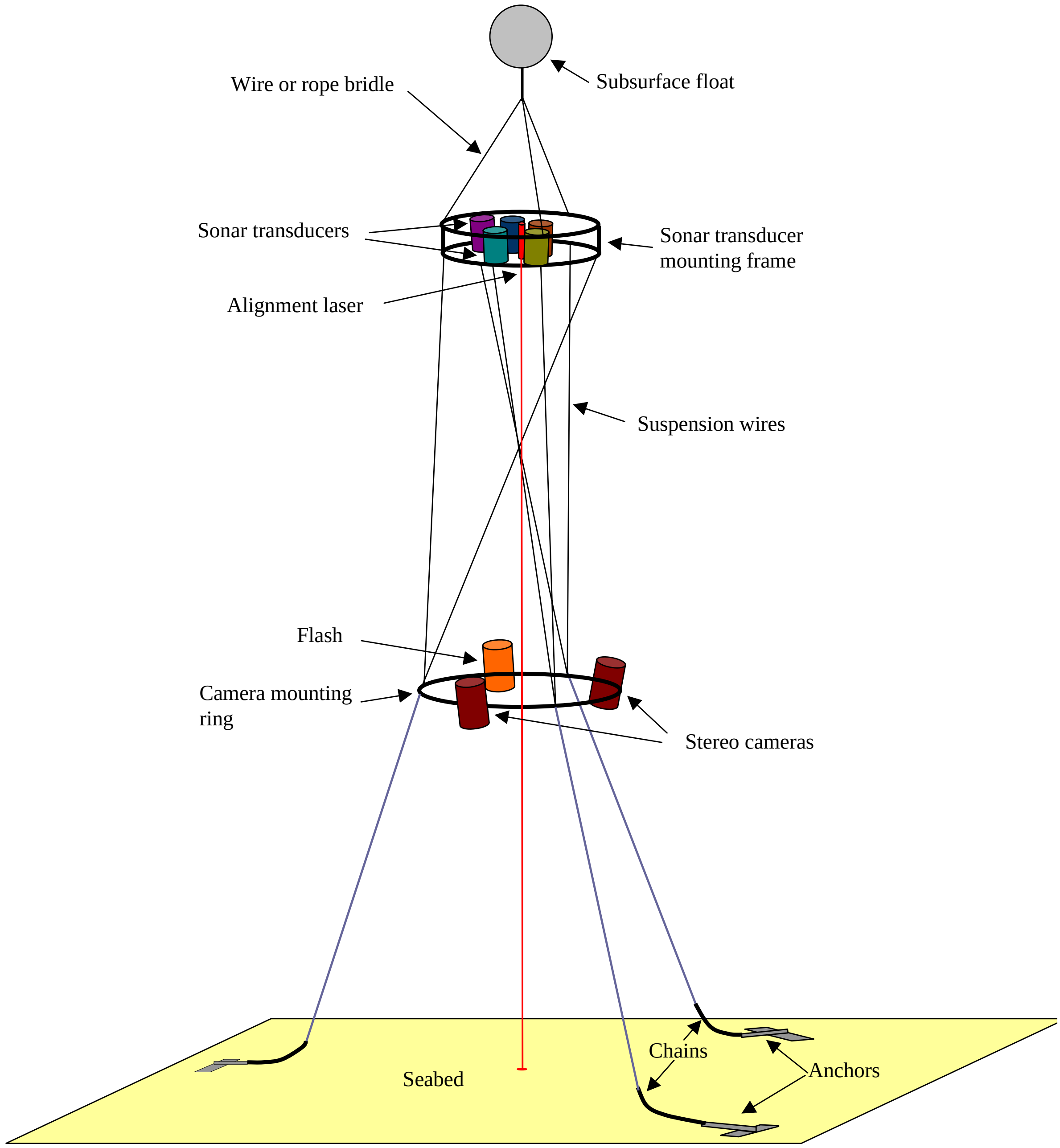

Figure 3. Proposed research system configuration (moored deployment)

Acoustic system

The choice of acoustic frequencies is a compromise between spatial resolution, depth capability and cost.

For a vertically oriented sounder, depth resolution improves as the frequency is increased, and consequently the acoustic wavelength is reduced. The beamwidth of the sonar transducer determines the horizontal resolution and is proportional to the ratio of the acoustic wavelength to the transducer diameter, so horizontal resolution also improves as the frequency increases. The same horizontal resolution can be achieved at a lower frequency, but this requires a larger, and therefore more expensive, transducer.

The disadvantage of using a high acoustic frequency is that the absorption of acoustic energy increases with increasing frequency, which results in a reduced maximum range for the sonar.

Another consideration is the scattering characteristics of the target. Most acoustic scatterers have a scattering strength that varies with frequency, so measurements at multiple frequencies can provide useful classification information.

These considerations, together with consideration of the options available from the different manufacturers led to a recommendation that the sonar system be based on the BioSonics DT-X digital scientific echosounder with the frequencies shown in Table 1.

Table 1. Recommended acoustic frequencies in order of decreasing priority

Priority	Frequency (kHz)
1	200
2?	420
3?	120
4	70
5	38

The choice between 420 kHz and 120 kHz for the second priority depends on the depth range over which the system is likely to be deployed. 420 kHz would be preferred for deployments where the sonar is within 50 m of the seabed (i.e. for the research system), whereas 120 kHz would be better for a survey system operating in water depths to several hundred metres. The preferred option for a system with maximum flexibility would be to include both of these frequencies.

From a scientific point of view, the more acoustic frequencies deployed the better, with two being considered the absolute minimum. The number of frequencies actually used therefore comes down to a matter of cost. As a guide, the overall cost for a single frequency (200kHz) DT-X system (February 2006) is approximately US$40 000 and the incremental cost of adding frequencies is approximately US$11 000 per frequency.

These costs are for single beam transducers, which are fine for this application. Split beam transducers are also available (at slightly more than double the single beam cost) and are useful when a range cell typically contains a single acoustic target. This is often the case in fisheries acoustics, in which case the split beam transducer allows the location of the fish in the beam to be determined so that the measured target strength can be corrected for the transducer beam pattern.

Specifications for the DT-X system are given in Appendix A, and a detailed quote (February 2006) is given in Appendix B.

Camera system

The existing ESP stereoscopic camera system uses a pair of Canon S50 five mega-pixel digital still cameras mounted with a separation of 75 mm between lenses. The cameras are fired remotely by way of the WEM (wet-end microcontroller) and firing is synchronised to within 10 ms. In the proposed new research system the physical separation of the two cameras would be increased, as shown in Figures 1 and 2. This would increase the measurement accuracy in the range axis.

One aspect that would enhance the usability of the camera system would be to enable full data communication with the cameras via the umbilical. The cameras are currently remotely fired; however, it is not possible to modify the settings of the cameras while they are deployed. Remote communication with the cameras (e.g. via USB) could allow full resolution test images to be directly downloaded from the cameras while deployed for image quality checking purposes, and optimisation of image capture settings (aperture, shutter period, focus and gain).

Digital still camera technology is advancing at a significant rate and it is possible that future cameras may offer useful advantages over the currently used cameras. Useful advancements might include: improved camera synchronisation capability and other data interface options. At the present time there does not

appear to be anything on the market which provides useful advancements in those areas above the existing cameras.

Data processing

BioSonics sell several software products for post-processing of data collected using the DT-X system. These include:

1. Data playback with simple analysis functions (Visual Analyser)
2. Seabed classification (Visual Bottom Typing), and
3. Submerged aquatic vegetation detection and analysis (EcoSAV)

All three of these products are potentially useful for coastal water habitat mapping, although items 2 and 3 have been developed for bottom types and species found in North American waters, and their effectiveness in Australian conditions needs to be evaluated.

In addition, it is envisaged that special-purpose algorithms developed using the research system would be used to analyse raw survey data.

Costing

A detailed costing of the BioSonics DT-X system for various combinations of frequencies is shown in Table 2.

The current (February 2006) hardware cost for the full research system is:

BioSonics DT-X with three transducers	$88 728
Stereoscopic camera pair and housings	$10 000
Laser and housing	$5 000
Strobe	$1 500
Frame system	$3 000
Underwater cables and connectors	$3 000
Umbilical (use existing)	n/a
Miscellaneous	$3 000
TOTAL	$114 228

The current (February 2006) hardware cost for the full survey system is:

BioSonics DT-X with two transducers	$77 189
Transducer mounting costs	$5 000
Differential GPS sensor	$2 500
TOTAL	$84 689

Table 2. Acoustic system detailed costing

Costing for Biosonics acoustic system
(120, 200 and 420 kHz)
Based on 28/2/06 quote

Assumed exchange rate (May 2006) 1.35

	3 Frequencies (200, 420, 120)		2 Frequencies (200, 120)		1 Frequency (200)	
Item	**US$**	**A$**	**US$**	**A$**	**US$**	**A$**
Hardware costs						
DT-X surface unit with acquisition software	$16,200	$21,870	$16,200	$21,870	$16,200	$21,870
200 kHz single beam transducer	$8,544	$11,534	$8,544	$11,534	$8,544	$11,534
Integrated orientation sensor for 200kHz transducer	$3,600	$4,860	$3,600	$4,860	$3,600	$4,860
420 kHz single beam transducer	$8,544	$11,534		$0		$0
120 kHz single beam transducer	$9,744	$13,154	$9,744	$13,154		$0
3 transducer multiplexing cable	$2,880	$3,888	$2,880	$3,888		$0
Toughbook computer	$4,700	$6,345	$4,700	$6,345	$4,700	$6,345
Deck cable	$1,922	$2,595	$1,922	$2,595	$1,922	$2,595
3 x calibration spheres (required for absolute target strength measurements)	$1,187	$1,602	$1,187	$1,602	$1,187	$1,602
Total hardware	**$57,321**	**$77,383**	**$48,777**	**$65,849**	**$36,153**	**$48,807**
Software						
Visual Analyser	$3,600	$4,860	$3,600	$4,860	$3,600	$4,860
VBT seabed classification	$3,600	$4,860	$3,600	$4,860	$3,600	$4,860
EcoSAV acquatic plant detection/analysis	$3,600	$4,860	$3,600	$4,860	$3,600	$4,860
Less three-pack software discount	-$2,400	-$3,240	-$2,400	-$3,240	-$2,400	-$3,240
Total software	**$8,400**	**$11,340**	**$8,400**	**$11,340**	**$8,400**	**$11,340**
Total hardware plus software	**$65,721**	**$88,723**	**$57,177**	**$77,189**	**$44,553**	**$60,147**

Note: Does not include differential GPS receiver

System capabilities and limitations

The field system used during the ESP had some limitations which did have an impact on the data collected during the field deployments. With regard to TAPS (the Towed Acoustic Projector System), it has a fixed burst length and a relatively low sampling rate that limited its resolution in the range direction to 12.5 cm at all frequencies. TAPS also had insufficient dynamic range, which led to the seabed return saturating the receivers. Temporal synchronisation of the data received was also limited, mainly by the fact that TAPS samples and transmits its six acoustic frequencies sequentially. The range resolution of the stereoscopic digital still camera system was also limited by a relatively small camera separation.

The new proposed acoustic system has a digitising rate of 41.6 kHz—which is equivalent to a sample every 1.8 cm, all frequencies, a minimum burst length of 100 microseconds—which means that at any one time returns are being received from a 7.5 cm range window (same as EQ60 200 kHz), and an analogue dynamic range of 160 dB. Unfortunately this system does not offer simultaneous sampling. The availability of multiple acoustic frequencies is believed to be essential in developing a sensory package which has the best chance of resolving useful habitat coverage information. The increased separation of the stereoscopic camera system would provide improved photogrammetry range resolution.

The proposed new system configuration (Figures 1 and 2) would allow easier field deployment and be less affected by sensor ring-down but would be subject to more movement between the acoustic and optical systems, which will introduce an extra step during data processing (using the laser spot).

3. Epibenthic Scattering Project summary

A great deal of high quality data was collected during the ESP, representing a unique collection of acoustic measurements with spatially and temporally synchronised stereo photographs. This chapter summarises the data collected, data processing performed, Matlab code developed and results. Reports of the three field deployments conducted (CA3.05, CA5.04 and CA5.04 extension) and the toolkit report (CA6.03) are also useful references for this chapter.

Data collected

The data collected from the three field trials is located in the following directory structure locations:

S:\CMST\Projects\350-399\369 CRC Coastal\ESP\FieldTrip 2004-08-10\

S:\CMST\Projects\350-399\369 CRC Coastal\ESP\Fieldtrip 2005-06-01\

S:\CMST\Projects\350-399\369 CRC Coastal\ESP\FieldTrip 2005-10-26\

Once the data is archived, the directory structure before ‘ESP’ may not be retained.

As of 24 May 2006, the data in the ESP directory totals 14.0 GB in size. There may be some duplication of data in the ESP subdirectories and therefore once the final archive is made, the amount of data may be somewhat smaller than this. The bulk of this data is images from the underwater stereoscopic digital still camera.

The data collected during each of the field deployments consists of temporally and spatially synchronised data from EQ60 single beam echosounder (two frequencies), TAPS (five frequencies), stereoscopic cameras (two images per stereo-pair), differential GPS, tilt sensor (three axis accelerometer), and WEM (Wireless Ethernet Module—system status, etc). The data from all of these sensors is in separate subdirectories (except TAPS, WEM, GPS and tilt which are grouped). A subdirectory titled ‘WEMandTAPS’ also exists which contains the raw data for WEM and TAPS converted to Matlab format. In the case of the camera images, the images from the left and right cameras are stored in separate subdirectories—‘camera1’ and ‘camera2’ respectively. Once the data has been synchronised (which has been conducted for all three lots of field data), the Matlab program ‘plotesp*.m’ is used to extract and display all the data corresponding to particular time steps. This program is described in the section on Matlab code below. The location and amount of pre-processed data is shown in Table 3.

Table 3. Amount and location (under the respective field data directory) of pre-processed field deployment data

Deployment date	EQ60	WEM, TAPS & GPS	Cameras
2004-08-10	632 MB 'ESP\FieldTrip 2004-08-10\eq60\exported_files'	78.7 MB 'ESP\FieldTrip 2004-08-10\WEMandTAPS'	2.28 GB 'ESP\FieldTrip 2004-08-10\uw3dimages_reorganised'
2005-06-01	506 MB 'ESP\Fieldtrip 2005-06-01\eq60-exported_sv_with_tvg_correction'	57.4 MB 'ESP\Fieldtrip 2005-06-01\WEMandTAPS'	1.84 GB 'ESP\Fieldtrip 2005-06-01\000\2005_06_01\Indexed-images'
2005-10-26	578 MB 'ESP\FieldTrip 2005-10-26\eq60-exported_sv_with_tvg_correction'	102 MB 'ESP\FieldTrip 2005-10-26\WEMandTAPS'	GB 'ESP\FieldTrip 2005-10-26\Indexed-images'

In some instances the stereoscopic camera images on the master archive (server) are modified from the original versions. If the original images are needed, they are available from the ESP field deployment raw data archive DVDs (one for each field deployment) of which one copy was provided to the Coastal CRC and another copy is kept by Curtin Centre for Marine Science and Technology (CMST).

Habitats sampled

Table 4 below (per CA6.03) provides a summary of the seabed habitats sampled during the three field deployments.

Examples of three of the habitats sampled are shown in Figures 3–5. There is incredible variability in the sampled habitats which cannot be completely summarised by three photographs. Please refer to the photographs referenced above for more information.

Table 4. GPS coordinates and habitat types for all field deployment locations

Field deployment	Site number	Time	Latitude	Longitude	Seabed habitat description
First: 10 August 2004	Site1	11:30	32º 08.252' S	115º 44.406' E	Seagrass and sand
	Site 2	12:45	32º 08.251' S	115º 44.414' E	Seagrass and sand
	Site 3	14:15	32º 09.263' S	115º 45.079' E	Reef and algae
Second: 1 June 2005	Site 1	11:35	32º 07.226' S	115º 45.032' E	Patches of seagrass and patches of rubble
	Site 2	12:00	32º 07.132' S	115º 45.220' E	Patches of seagrass and patches of rubble
	Site 3	12:50	32º 06.323' S	115º 44.215' E	Uniform seagrass coverage
	Site 4	14:30	32º 07.649' S	115º 39.830' E	Large algae on rocky seabed
	Site 5	16:00	32º 09.064' S	115º 45.830' E	Muddy seabed
Third: 26 October 2005	Site 1	08:30	32º 06.323' S	115º 44.215' E	Seagrass and sand

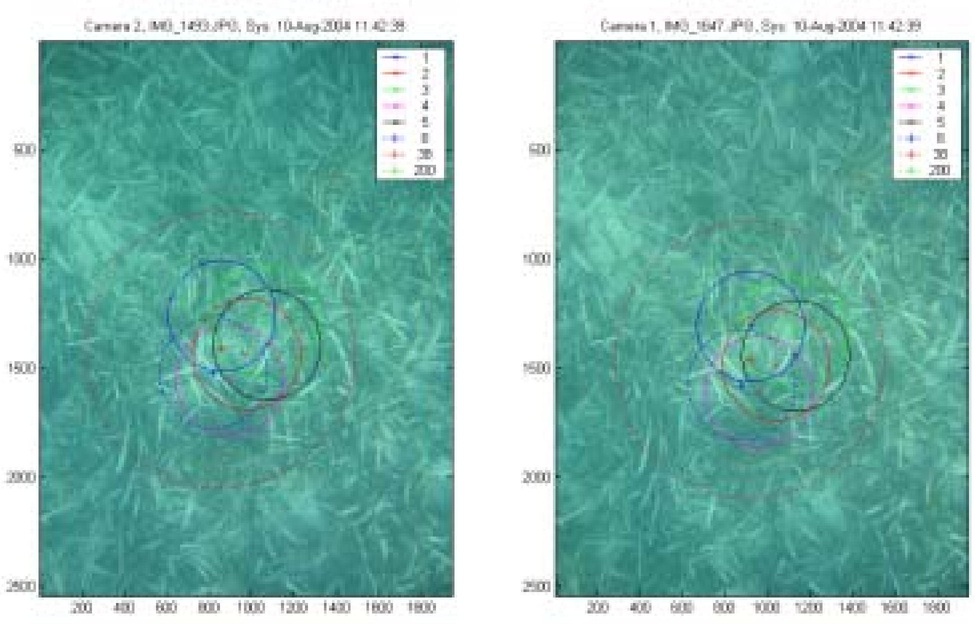

Figure 3. Example stereoscopic image of sea grass habitat in Cockburn Sound

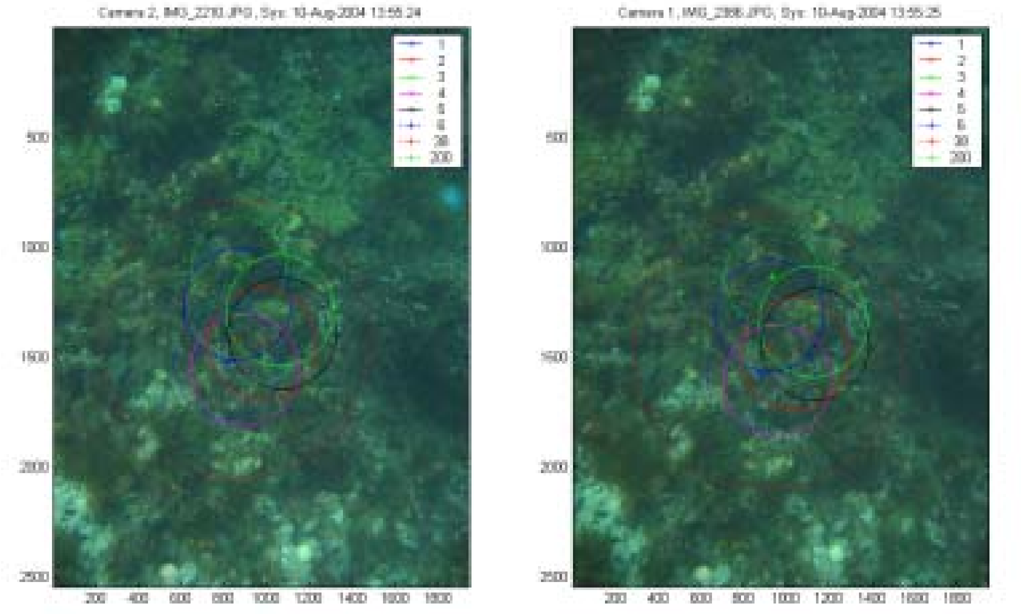

Figure 4. Example stereoscopic image of reef habitat in Cockburn Sound

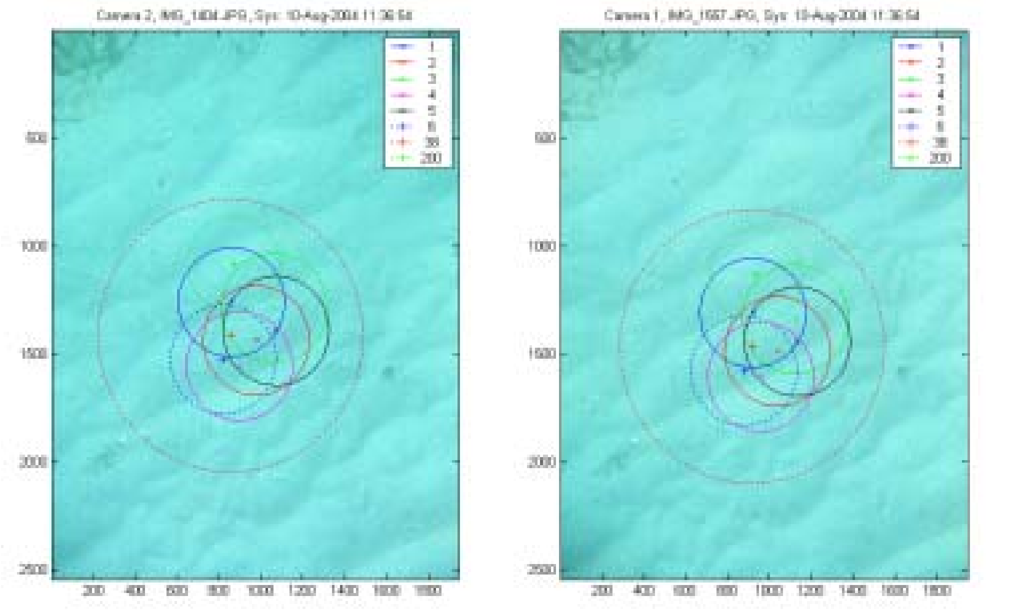

Figure 5. Example stereoscopic image of bare sand habitat in Cockburn Sound

Data processing and analysis method

Processing and analysis of the acoustic and video data collected in the ESP were carried out using a library of routines written in Matlab. The Matlab routines execute the following operations:

1. Synchronisation of video and acoustic data. The firing of the EQ60 and TAPS sonars and the underwater stereo camera were synchronised in time by the system controller. However, several different clocks are used to time-stamp data from different data sources, all of the system components were not always active, and the trigger rate of the sonar was sometimes set higher than the trigger rate of the stereo camera. Therefore, to associate photographs of the seafloor taken by the camera with the acoustic backscatter pulses, a set of Matlab functions were written which retrieved timing of different system components and searched for the most logical fit of timing data.

2. Classification of seafloor habitats. The Matlab function 'Pre_Classification' displays stereo pairs of the seafloor images accompanied with sonar data to allow the seafloor type (habitat type) to be visually classified. Each image pair of the seafloor was manually classified by a 2-digit classification number corresponding to the seafloor type. A number of basic types of seafloor cover were defined, which were sand, seagrass, reef rock and algae. The first digit in the classification number corresponds to the seafloor type that dominates within the area insonified by the sonars. The second digit characterises various mixtures of different habitats. It is set at zero if the seafloor type is uniform within the observed area.

Other numbers indicate the presence of other seafloor types according to a cross-reference table associating different 2-component mixtures with a certain number. For example, if the seafloor cover consisted of pure sand, the classification number would be '10'. If patches of seagrass were observed on sand within a minor area of the sonar footprint, the classification number would be '12'.

As a result of classification, the acoustic backscatter pulses were associated with the habitat type through the classification number for further processing and correlation analysis. The classification scheme used for the processing of data from each of the three field-deployments is summarised in Appendix 3 of *Epibenthic Scattering Project (ESP): Report on experimental deployments and outcomes for toolkit* (CRC Report CA6.03, part 2).

3. Calculation of backscatter characteristics. The output backscatter data from the single-beam sonar systems is represented in the units of the volume backscatter coefficient. This is because these acoustic systems are primarily used to estimate the target strength of biological objects such as zooplankton, fish schools or individual fish in the water column. The Matlab routines 'Process_EQ60_data' and 'Process_TAPS_data' convert the volume backscatter coefficient into the surface backscatter coefficient using the power and gain settings of the system, and the estimates of transmission loss (spreading and absorption) and the insonified area, according to the formula:

$$S_A = P_t R^4 \exp(2\alpha R) \big/ P_r R_0^2 A$$

where P_t is power of the transmitted signal at the reference range R_0, P_r is the power of the received signal, R is the distance from the sonar head to the seafloor surface, α is the absorption coefficient, and A is the insonified area of the seafloor.

The first backscatter return from the substrate is localised in the full-length backscatter signals represented in the units of the surface backscatter coefficient. The front of the bottom backscatter pulse is determined at the time when the steepness of the backscatter signal exceeds a predefined threshold. The tail of the first backscatter return is limited to the moment when the backscatter level decreases by 40 dB relative to the peak level. Then a number of different backscatter characteristics are calculated from the signal pulse form of the bottom return. Among those characteristics, the principal ones are:

1) Peak level: $S_P = \max\{S(i)\}$,
2) Backscatter energy: $S_E = \partial T \sum_i S_A^2(i)$, and
3) Effective pulse width: $I = \partial T \sum_i (i - i_c)^2 \cdot S_A(i) \big/ \sum_i S_A(i)$,

Where *i* is the sample number of S_A, ∂T is the sampling interval, and i_c is the sample number of the mass centre of the backscatter pulse, which is defined as:

$$i_c = \mathrm{int}\left\{ \sum_i i \cdot S_A(i) \big/ \sum_i S_A(i) \right\}.$$

In addition to those three major characteristics, other statistical characteristics of the backscatter pulses were calculated, such as the standard deviation, skewness, kurtosis and some others. As a result, for each habitat type characterised by the classification number, a set of backscatter characteristics is

created to examine the robustness of each backscatter characteristic and their combination with respect to acoustic discrimination of different seafloor habitats.

4. Analysis of correlation between backscatter characteristics and habitat types. A set of Matlab programs has been developed to implement different approaches to segmentation of acoustic backscatter characteristics in order to distinguish different habitats acoustically observed on the seafloor. The most straightforward method of acoustic classification using correlation between each specific backscatter characteristic with the habitat types was first examined in order to determine the backscatter characteristics which were most robust with respect to distinguishing different habitat types.

More sophisticated methods of classification implemented in Matlab programs involve multi-parameter acoustic data clustering based on different techniques, such as K-means and genetic programming. Before applying the clustering procedure, the sensitivity of backscatter characteristics to seafloor types and their interdependence is examined using a principal component analysis that allows us to establish combinations of backscatter characteristics which form more isolated clusters in a multivariable space. After applying one of the clustering procedures to the backscatter characteristics, the results of acoustic seafloor segmentation are compared with the visual classification data. The percentage of misclassification by using acoustic segmentation is calculated for each class of habitats.

Matlab code and routines

A range of software written in Matlab was developed for the ESP. The main routines are summarised in Table 5. It should be noted that in some instances the code makes use of a common Matlab library developed in-house by Curtin CMST.

Table 5. Main Matlab routines used in ESP data processing

Matlab routine name	**Description**
'PlotESP'	Extracts and displays all the data corresponding to a particular time step.
'Pre_Classification'	Displays stereo pairs of the seafloor images accompanied with sonar data to allow the seafloor type (habitat type) to be visually classified.
'Process_EQ60_data'	Converts the volume backscatter coefficient data from the EQ60 into the surface backscatter coefficient using the power and gain settings of the system, and the estimates of transmission loss (spreading and absorption) and the insonified area. Calculates various statistical characteristics of backscattered signals.
'Process_TAPS_data'	Converts the volume backscatter coefficient data from the TAPS into the surface backscatter coefficient using the power and gain settings of the system, and the estimates of transmission loss (spreading and absorption) and the insonified area.
Photo_Distance.m	Estimates height of objects (seagrass canopy, rocks, etc.) on the seafloor using a photogrammetry technique.

Results

The most significant results of processing and analysis of the ESP data have been demonstrated in the previous milestone reports (see reference listing—in particular *Epibenthic Scattering Project (ESP): Report on experimental deployments and outcomes for toolkit*, CRC Report CA6.03, part 2). It is important to note that the simplest method of 1-D segmentation of backscatter data by a single characteristic that is most robust with respect to discrimination of habitats provides acceptable results for certain habitat classes. In particular, classification of the seafloor by the effective pulse width of acoustic backscatter is capable of distinguishing sand and seagrass with a high level of likelihood, up to 90% of true classification (see Figure 6).

Adding more backscatter characteristics for multivariate clustering did not significantly improve the discrimination ability of backscatter analysis for these types of habitats. However, if different habitats such as reef rock with or without

an algae cover appear in the areas surveyed acoustically, the single parameter approach cannot provide reliable discrimination results. Segmentation of backscatter characteristics in a multivariate space slightly improves the discrimination capability of backscatter analysis, but the improvement is yet insufficient for robust acoustic classification of the seafloor (see Figure 7).

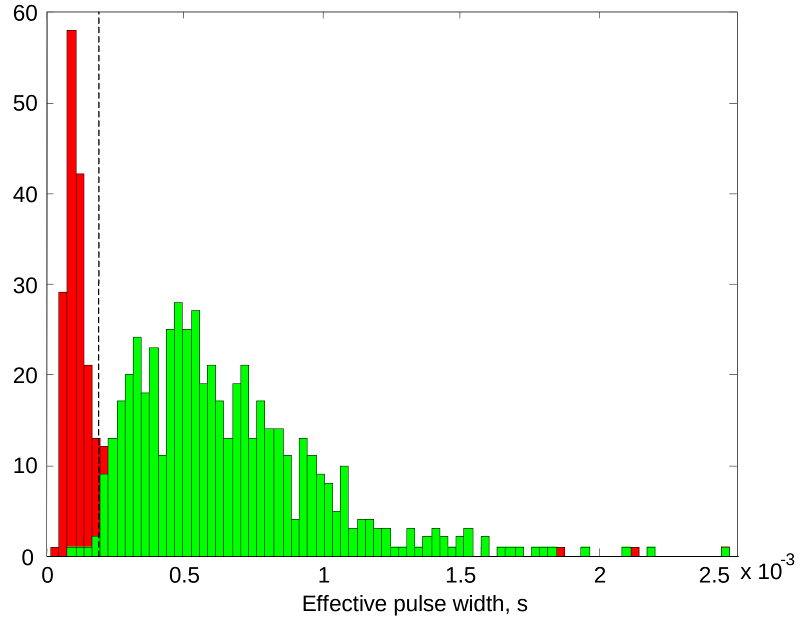

Figure 6. Histogram of the effective pulse width measured at 200 kHz over the seafloor areas covered by sand (red) and seagrass (green). Brown columns are an overlap of red and green data

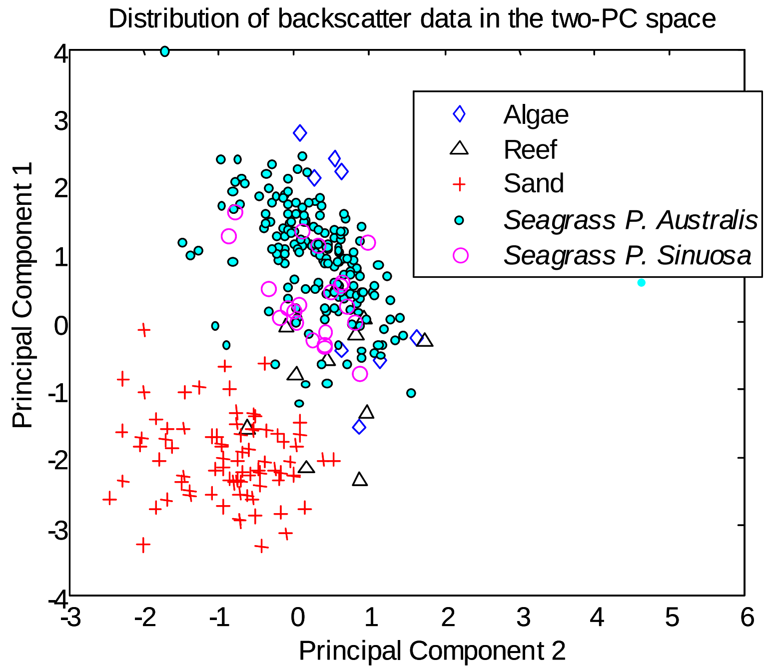

Figure 7. Distribution of 5 classes against first two principal components of PCA

Developed intellectual property

Intellectual property developed during the ESP includes:

- Electronic and software design of the sub-sea ESP field deployment system including the method of synchronising all system components via the wet-end microcontroller—as outlined in *Epibenthic Scattering Project (ESP): Experimental design report* (Coastal CRC Milestone Report CA2.03).
- The top-end PC-based ESP system software ‘ESPañolito’—as outlined in *Epibenthic Scattering Project (ESP): System design report* (Coastal CRC Milestone Report CA6.05).
- Method of synchronising the two consumer digital still cameras to an accuracy of 10 ms for the purpose of taking stereoscopic photographs.
- Matlab code and programs developed for the purpose of processing the ESP data – as outlined in the earlier section on Matlab codes.

4. Future work

Future work falls into two categories: (i) further processing of the existing data set; and (ii) expansion of the project, as described in section 2 of this report and in Coastal CRC Milestone Report CA6.05.

Further processing of existing data

The PhD thesis work of Mr Y.-T. Tseng continues past the official closure of the Coastal Zone CRC. His work will be reported in the PhD thesis listed in the references and possibly in other publications.

Processing of ESP data to date has focussed on the development of improved classification techniques, but there are many other possible uses for the data. In particular, the original ESP objectives included the development of methods to extract biologically significant parameters such as seagrass canopy height, biomass, and transpiration rate from acoustic data. The feasibility of extracting this information from the data set has not been fully explored to date, and this is recommended to be the focus of further work on the existing data. Such a study would be of suitable duration and complexity to be accomplished through a PhD project.

Funding options

Several funding options are being actively explored to fund the continuation of the ESP work.

A research proposal has been submitted to the Australian Institute of Marine Science that coordinates planning of the Ningaloo Research Program to be implemented in 2006–2010 for the Office of Science and Innovation of the Western Australian Department of the Premier and Cabinet. The proposed project titled ‘Application of acoustic methods to habitat mapping and biodiversity assessment’ aims at acoustic characterisation and mapping of seafloor habitats off the fringing reef in the Ningaloo marine park using bathymetry and backscatter data from multi- and single-beam sonar surveys. The techniques planned to employ are based on the methods developed within the Coastal Water Habitat Mapping project of the Coastal CRC, including those examined

in the ESP. The project cost proposed is $364 000 of which $60 000 was allocated for acoustic work.

The decision on the overall research plan of the Ningaloo project and final selection of the particular projects to be implemented within the program have not made yet, but seafloor mapping with a single-beam sonar has already been conducted in the first complex survey in April 2006 and the first set of acoustic backscatter data from the Ningaloo marine park has been collected. It is most likely that the proposed acoustic project will be included, either entirely or partly, in the complete Ningaloo research, and acoustic surveys will be continued in the next stages of the this program.

Several other funding options may be available to CMST for purchasing hardware, such as the BioSonics system, which may be of use across several projects. Two examples of such projects include the monitoring of krill in the Perth Canyon and a future WA Fisheries / Fisheries Research and Development Corporation project studying bight-redfish, a deep-water commercial fish species found off southern Western Australia. While these programs on their own would not provide sufficient funds for the specific project hardware discussed here, they would contribute to the pool of funds available for hardware purchases. The ESP work does not require dedicated access to a sounder system hence a collective purchase would reduce the funds needed to continue the project work.

5. Conclusion

The Coastal CRC Epibenthic Scattering Project has collected a unique data set in which the acoustic data are fully ground-truthed by high-resolution stereoscopic image pairs. The project has revealed some important results with respect to acoustic discrimination of seagrass from sand in areas of Cockburn Sound, Western Australia. The feasibility of extracting biologically significant parameters (such as seagrass canopy height and biomass) from the data set has not been fully explored to date, and this is recommended to be the focus of further work on the existing data.

Budget considerations in the design of the original ESP system dictated the use of two existing acoustic systems, essentially unmodified, which resulted in significant limitations to the fidelity of the acoustic data. The proposed new research system would overcome many of the limitations of the original design and allow a significantly improved dataset to be collected.

There are several options for funding the continuation of the project which are currently being actively explored.

6. References

Milestone reports

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CA3.05: Woods, A.J., Duncan, A.J., Tseng, Y.-T., McCauley, R.D. & Gavrilov A.N. (2004) *Epibenthic Scattering Project (ESP): Report of first field deployment.* Milestone Report CA3.05, Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management, Brisbane.

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Tseng, Y.-T., Gavrilov, A.N. & Duncan A.J. (2005) Classification of acoustic backscatter from marine macro-benthos. *Proceedings of Boundary Influences in High Frequency, Shallow-water Acoustics Conference*, University of Bath, UK, 5–9 September 2005.

Tseng, Y.-T., Gavrilov, A.N., Duncan, A.J., Harwerth, M. & Silva, S. (2005) Implementation of genetic programming toward the improvement of acoustic classification performance for different seafloor habitats. *Proceedings of IEEE Oceans '05 conference*. Washington DC, 18–23 September 2005.

Tseng, Y.-T., (2005) Settings of genetic programming toward the improvement of acoustic classification performance for different seafloor conditions. *Proceedings of Underwater Acoustic Measurements Conference,* Heraklion, Crete, Greece, 28 June – 1 July 2005.

Theses

Tseng, Y.-T. (in development) *Investigation of the acoustic backscatter characteristics of marine macro-benthos*. PhD thesis, Curtin University of Technology.

Appendix A: Specification for BioSonics DT-X digital scientific echosounder

DT-X

DIGITAL SCIENTIFIC ECHOSOUNDER

BioSonics, Inc. – World Leader in Portable Digital Scientific Echosounder Technologies

FISHERIES / PLANKTON RESEARCH, STOCK ASSESSMENT AND BEHAVIORAL STUDY
SUBMERGED AQUATIC VEGETATION MONITORING
BOTTOM / SEDIMENT CLASSIFICATION
BATHYMETRY

- Wired or Wireless **Ethernet** Control
- Rugged, Weather Resistant Surface Unit With Programmable **Linux**-based Embedded Processor
- Digital, Real Time, Streaming Hydroacoustic Data
- BioSonics Renowned **Digital Transducers**, Split-Beam And Single-Beam
- Standard Frequencies: 38, 70, 120, 200, 420, 1000 kHz
- Transducer Sidelobes To -35 dB
- Multi-Frequency And Multi-Transducer Operation From A Single Surface Unit
- All New **Visual Acquisition 5** Software
- Software Controlled Variable Transmit Power
- Instantaneous Dynamic Range To 160 dB
- Noise Floor Less Than -145 dB
- Stable Ping Rate To 30 PPS
- Range: To more than 1000 meters
- Raw Data Stored Directly To Internal Or External Hard Disk
- GPS, Heading/Pitch/Roll And Other External Sensor Input
- Fast Data File Previewer with High Resolution Color Echogram and Oscilloscope
- Compatible With BioSonics **Visual Analyzer**™ ,***EcoSAV***™, **VBT**™, **Visual Bathymetry**™ Sonar Data **Echoview**™ and **SONAR 5**™ Processing Software

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BioSonics is an authorized reseller of **Panasonic** TOUGHBOOK computers.

V2.0

DT-X

DIGITAL SCIENTIFIC ECHOSOUNDER

BioSonics, Inc. – World Leader in Portable Digital Scientific Echosounder Technologies

DT-X and DE-X Digital Scientific Echosounder Systems Technical Specifications

DIMENSIONS
- Surface unit: 49 cm X 39 cm X 19 cm (19 in X 15 in X 8 in)
  - 13.6 kg (30 lbs)
- Digital transducer (typical): 18 cm dia. X 17 cm (7 in X 6.5 in)
  - 4 kg (9.5 lbs)
- Analog Transducer (typical): 7 cm dia. X 18 cm (2.75 in X 7 in)

ANALOG and DIGITAL TRANSDUCERS™
- Low side lobes, up to -35 dB
- Standard Frequencies: 38, 70, 100, 120, 200, 420, 1000 kHz
- Split-beam or Single-beam technology
- Standard beam widths: 6° to 10° (@ -3dB)
  - Other beam widths available
- Circular or elliptical beam patterns
- Capable of multiplexing up to 5 transducers / 5 distinct frequencies using a single surface unit
- Detachable Cable
  - Length to 60 m (200 ft) analog, 150 m (500 ft) digital

DYNAMIC RANGE
- Greater than 160 dB of analog dynamic range
- Instantaneous 126 dB of digital dynamic range
- High dynamic range allows storage of data with no TVG applied
  - Appropriate TVG applied during analysis allows both volumetric and point-source analysis
  - Appropriate TVG applied to real-time and post-collection display

NOISE FLOOR
- -140 dB noise floor (typical)

TRANSMIT POWER
- 1,000 Wrms, standard
- 100 Wrms, low power

PULSE DURATION
- 0.1 – 1.0 ms, user selectable

PULSE REPETITION RATES
- 0.01 - 30 pulses/second, typical
  - Fast multiplex up to 5 transducers, 5 frequencies
  - Programmable pulse and multiplex options

ECHOGRAM and OSCILLOSCOPE DISPLAY
- User selectable echo level threshold
- User controlled energy color steps on-screen display
- User selectable echogram / oscilloscope viewing options
  - Multi-channel / Multiplexed options

POWER REQUIREMENTS
- 85-264 VAC @ 47-440 Hz or
- 10-14 VDC
- 30 W consumption (typical)

SURFACE UNIT
- Portable System
- Weatherproof case for echosounder surface unit
- Visual and Audio operating cues
- Ethernet connection to the viewing / data recording computer
- Integrated DGPS or user supplied signal (NMEA 0183 compliant)

ADDITIONAL FEATURES
- Self-diagnostics and calibration at power-up
- Internal / external trigger
- Autonomous, unattended and remote-access configuration options

SOFTWARE FEATURES
- Windows user interface (98/ME, 2000/XP)
- Embedded LINUX OS for echosounder operation
- Real-time color video echogram and oscilloscope display
- User controlled pulse duration, transmit power, pulse rate, automatic or manual calculation of acoustic variables (e.g., absorption coefficient, speed of sound).
- Bathymetry
- Automatic bottom tracking, manual editing
- Target tracking
- Target strength analysis
- Echo counting
- Simultaneous echo integration and target recognition
- Aquatic macrophyte assessment (SAV)
- Seabed classification
- EMS deconvolution
- Population and biomass estimation
- On-screen help

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Appendix B: Quotation for BioSonics DT-X system

International Sales Quote

Date: 28-Feb-06
Bio Reference: 6037
Customer Number: 787
Quote Total: $40,454.00

BioSonics®

Bill To:
Alec Duncan
Curtin University of Technology
Centre for Marine Science & Technology
GPO Box U1987
Perth, Western Australia 6845
AUSTRALIA
Phone: +61 8 9266 3569
E-Mail: a.duncan@cmst.curtin.edu.au

Ship To:
Alec Duncan
Curtin University of Technology
Centre for Marine Science & Technology
GPO Box U1987
Perth, Western Australia 6845
AUSTRALIA
Phone: +61 8 9266 3569
E-Mail: a.duncan@cmst.curtin.edu.au

Line #	Stock #	Description	Qty	Unit Price	Extended Price
1	DT-SURF-I	DT-X Echosounder Surface Unit with BioSonics Acquisition Software ***	1	$16,200.00	$16,200.00
2	DTCA-25-I	DT-X Digital Signal Deck Cable 25'	1	$1,922.00	$1,922.00
3	DTT-2006-I	200 kHz 6° DT-X Single Beam Digital Transducer	1	$8,544.00	$8,544.00
4	TARG-200-I	200 kHz Standard Calibration Sphere (tungsten carbide)	1	$500.00	$500.00
5	DGPS-JRC-I	JRC DGPS212W Differential GPS Sensor	1	$1,200.00	$1,200.00
6	COMP-PAN-I	Panasonic ToughBook 29 Computer w/DVD/CD-R/RW *Pentium M 778 1.6G LV(Centrino),13.3 Touch XGA, 512MB, 80GB, 802.11a/b/g, WinXP SP2 with CD-RW / DVD-ROM Combo Drive* *Includes installation and configuration of client-owned/purchased BioSonics Software.*	1	$4,700.00	$4,700.00
7	SW-VISAN-I	BioSonics Visual Analyzer Processing Software	1	$3,600.00	$3,600.00
8	SW-VBT-I	BioSonics VBT Seabed Classifier Processing Software	1	$3,600.00	$3,600.00
9	SW-2PK-I	Two-Pack Software Discount ****	1	($1,200.00)	($1,200.00)

For Information and Sales Support, Contact Bob McClure, Director of Marketing & Sales: bmcclure@biosonicsinc.com
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Page 1 of 3

International Sales Quote

Date:	28-Feb-06
Bio Reference:	6037
Customer Number:	787
Quote Total:	$40,454.00

Optional Items

10	BF-4-I	BioFin Dead Weight Towing Vehicle 4'	0	$3,000.00	$0.00
11	SSTC-I	50' Stainless Steel Towing Cable w/Eye	0	$432.00	$0.00
12	SWIV-I	Aluminum Swivel Transducer Mount	0	$420.00	$0.00
13	DT-MPWET2-I	Multiplexing WET Digital 2-Transducer Cable	0	$2,280.00	$0.00
14	SW-ECO-I	BioSonics EcoSAV (Aquatic Plants) Processing Software	0	$3,600.00	$0.00
15	SW-3PK-I	Three-Pack Software Discount	0	($2,400.00)	$0.00
16	DTT-4206-I	420 kHz 6° DT-X Single Beam Digital Transducer	0	$8,544.00	$0.00
17	DTSP-4206-I	420 kHz 6° DT-X Split Beam Digital Transducer	0	$20,160.00	$0.00
18	DTT-1206-I	120 kHz 6° DT-X Single Beam Digital Transducer	0	$9,744.00	$0.00
19	DTSP-1206-I	120 kHz 6° DT-X Split Beam Digital Transducer	0	$21,960.00	$0.00
20	DTT-3810-I	38 kHz 10° DT-X Single Beam Digital Transducer	0	$11,784.00	$0.00
21	DTSP-3810-I	38 kHz 10° DT-X Split Beam Digital Transducer	0	$27,384.00	$0.00
22	DTT-706-I	70 kHz 6° DT-X Single Beam Digital Transducer	0	$10,584.00	$0.00
23	DTSP-706-I	70 kHz 6° DT-X Split Beam Digital Transducer	0	$22,560.00	$0.00
24	DTSP-2006-I	200 kHz 6° DT-X Split Beam Digital Transducer	0	$20,160.00	$0.00
25	TARG-420-I	420 kHz Standard Calibration Sphere (tungsten carbide)	0	$205.00	$0.00
26	TARG-120-I	120 kHz Standard Calibration Sphere (tungsten carbide)	0	$482.00	$0.00
27	TARG-38-I	38 kHz Standard Calibration Sphere (tungsten carbide)	0	$593.00	$0.00
28	TARG-70-I	70 kHz Standard Calibration Sphere (tungsten carbide)	0	$593.00	$0.00
29	DT-MPWET3-I	Multiplexing WET Digital 3-Transducer Cable	0	$2,880.00	$0.00
30	DT-MPWET4-I	Multiplexing WET Digital 4-Transducer Cable	0	$3,840.00	$0.00
31	DT-MPWET5-I	Multiplexing WET Digital 5-Transducer Cable	0	$5,200.00	$0.00

Subtotal:	$39,066.00
Estimated Shipping & Handling:	$1,388.00
Other:	$0.00
Total (USD):	**$40,454.00**

*** Your tuition to a BioSonics training course is waived with the purchase of a surface unit.

**** A $1,200.00 discount is applied to your order if you purchase two software packages

***** A $2,400.00 discount is applied to your order if you purchase three software packages.

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Appendix C: Post-processing software available from BioSonics

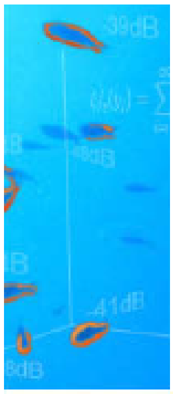
BioSonics® proudly announces the release of

Visual Analyzer 4.1

Free Upgrade for all existing users & Free Demos for new users!!

Enhanced features in version 4.1

- Blazing-fast echogram playback and analysis.
- Compatible with any current Windows™ operating system, including Windows 98/ME, 2000 and XP.
- State of the art analysis algorithms for echo integration, single-echo recognition and counting, split-beam target strength analysis and automatic bottom tracking.



Completely FREE and 100% compatible with existing systems

- An absolutely free upgrade is offered to all current users of Visual Analyzer version 4.02 and under.
- Fully functional demo versions available for new users.
- Compatible with all BioSonics DT and X-series systems data.

Contact BioSonics NOW to get your FREE copy!

- To request your copy of Visual Analyzer 4.1, just click on the following link:

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- Or call us today: 206-782-2211.

REQUEST YOUR FREE UPGRADE NOW!!

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DT-X DIGITAL SCIENTIFIC ECHOSOUNDER

- Stock Assessment and Behavioral Study
- Submerged Aquatic Vegetation Assessment
- Bottom/Sediment Classification
- Bathymetry
- Fisheries/Plankton Research

Leading the way in innovative hydroacoustics

v1.5

UNDERWATER HABITAT ASSESSMENT

BioSonics, Inc. – World Leader in Portable Digital Scientific Echosounder Technologies

Proudly Announcing

VBT™ 2

Visual Bottom Typing

Proven acoustic technology for measurement and classification of bottom and sediment characteristics.

Why VBT?

You asked for efficiency & ease of use…

- BioSonics graphical user interface puts all processing options in view.
- Five bottom / sediment classification routines available.
- Batch processing enhances rapid analysis.

You work in 'real-world' conditions…

- Bottom Classification Library. Classification based on actual acoustic references from your environment.
- Enhanced "depth-below-surface" transducer deployment compensation.
- Enhanced handling of tidal correction and other real-world variables.

Seeing is believing…

- All New Rapid Data File Player with fast, high-resolution color echogram and oscilloscope
- Software based display thresholding and noise filtering

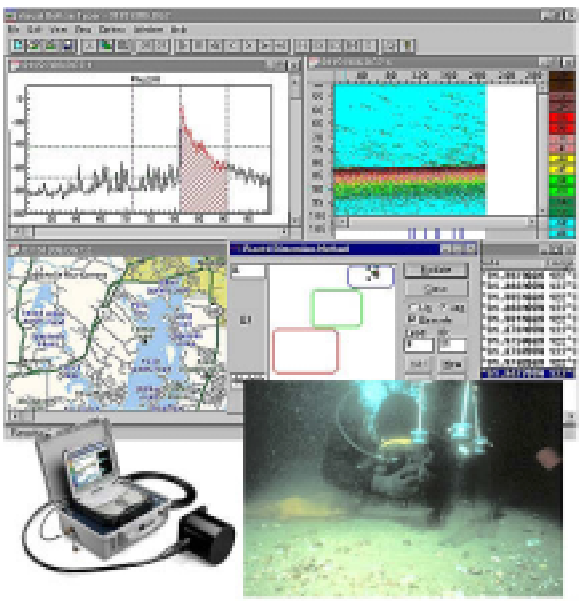
You want the best data acquisition performance…

- The BioSonics X-Series echosounder system provides enhanced Real-Time-Packet output & high-resolution time-stamping.
- BioSonics Visual Acquisition 5 provides real-time GPS Loss Warning indicator.
- The new pause/resume feature allows the system to be used easily, under challenging field conditions.

You know good value…

- Acoustic technology increases sampling power, collecting more high-quality data in less time.
- Acoustic data can be further analyzed for aquatic animal and submersed vegetation information using BioSonics Visual Analyzer™ and *EcoSAV™* software.

Your Time is Valuable. Logical, Rapid, Friendly Tools for Bottom Classification, Reporting, and Export. Maximize Your Data Collection Efforts with Hydroacoustics.



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