Developing active broadband acoustic methods to investigate the pelagic zone of the Great Australian Bight

Arti Verma[1], Alec Duncan[2] and Rudy J. Kloser[3]

[1] Department of Imaging and Applied Physics, Curtin University, Perth, Australia
[2] Department of Imaging and Applied Physics, Curtin University, Perth, Australia
[3] CSIRO Oceans and Atmosphere, Hobart, Australia

ABSTRACT

Investigating the pelagic community of the Great Australian Bight (GAB) remotely and pervasively remains an elusive challenge to the scientific community. Advanced broadband acoustic sounders offer a new tool to help characterise and subsequently classify the dominant scatterers via the frequency dependence of their target strengths.

Broadband acoustic data were collected from the GAB for the first time on a recent scientific expedition on board RV Investigator in December 2015. A broadband sonar system (EK80), mounted on a custom designed vertical profiling acoustic platform was used to record acoustic data in the frequency range of 45 – 160 kHz. A processing method was developed to allow the system to be calibrated at depth with a reference target so that the frequency dependence of scattering from biological targets could be measured independently of their positions in the acoustic beam. The results of some initial tests of the method are reported here and include the measurement of the frequency dependent target strength of two targets at a depth of 600 m. The characteristics of these frequency response curves indicated that one was an animal with a gas inclusion whereas the other behaved like a fluid scatterer. No independent ground truthing was available to confirm this; however, these results indicate that the broadband acoustic method has considerable promise as a new tool to study the pelagic community of the region.

This study is being undertaken as part of the Great Australian Bight Research Program, a collaboration between BP, CSIRO, the South Australian Research and Development Institute (SARDI), the University of Adelaide, and Flinders University. The Program aims to provide a whole-of-system understanding of the environment, economic and social values of the region; providing an information source for all to use.

1. INTRODUCTION

The mesopelagic zone in the world's oceans, depth range 200 m – 1,000 m, contains a diverse range of species varying from 2 to 20 cm in size commonly referred to as micronekton. This diverse group of organisms consists of a wide variety of mesopelagic fishes, crustaceans, and gelatinous organisms that display complex temporal and spatial variability (Stanton et al., 1996, Brodeur et al., 2005). The micronekton communities form a connecting link between the lower planktons and apex predators and hence are critical to the distribution and abundance of the predators that prey on them. To characterise micronekton distribution and abundance and their temporal and spatial dynamics needs a combination of observations coupled to ecosystem models (Kloser et al., 2009, Lehodey et al., 2014). Active sonars offer non-intrusive, compact, remote sensing tools to survey and estimate the species-specific abundance and distribution of this community based on their acoustic scattering properties (Horne, 2000, Simmonds and MacLennan, 2008). However, classification and identification of these animals using acoustic techniques remain an unachieved goal for marine acousticians.

The morphology and behaviour of micronekton hold numerous complications in using acoustic scattering for their quantification. Many mesopelagic fishes and siphonophores (gelatinous organisms) possess gas-filled organs giving rise to similar resonance effects at a particular frequency depending on the organ morphology, membrane properties and depth (Kloser et al., 2002, Davison et al., 2015, Butler and Pearcy, 1972). Further, siphonophores may co-inhabit a region with fishes and in the absence of concurrent optical samples, the acoustic measurements may provide false estimates of the fish biomass due to high backscattering from the siphonophores' gas organ (Barham, 1963).

Earlier research suggests that each group of micronekton displays a unique frequency dependent response of backscattered energy, which can be exploited to identify the scattering source (Stanton et al., 1996, Stanton et al., 1998). This backscattering energy is logarithmically expressed as the Target Strength (TS, dB *re* 1m^2), $TS = 10\log|F_{bs}|^2$ where F_{bs} is the backscattered acoustic intensity. Conventional single and multi-frequency sonar systems have limitations when characterising the organism's frequency response spectra. New commercially available broadband sonars offer a possible way to characterise a range of scatterers by measuring acoustic responses continuously across a wide frequency range and comparing the responses to characteristic spectra obtained using numerical scattering. Moreover, broadband signal processing and pulse compression techniques provide high range resolution, accurate range measurement, a possible high signal to noise ratio and enhanced feature extraction resulting in better signal interpretation and target classification (Lew, 1996, Chu and Eastland, 2015, Chu and Stanton, 1998, Zakharia et al., 1996).

Due to the paucity of research in the last few decades not much is known about the distribution and abundance of the pelagic community of the Great Australian Bight region of Australia. The Great Australian Bight Research Program (GABRP) (Rogers et al., 2013) is consequently being carried out by a collaborative consortium of industry and research institutions to, in part, map its deep water habitat using the Marine National Facility's research vessel RV *Investigator*. This paper presents some preliminary results from the principal author's Ph.D. research work, the ultimate goal of which is to develop advanced broadband acoustic techniques for classification and quantification of micronekton, and to apply these techniques subsequently to the acoustics data collected from the Great Australian Bight region. Acoustic measurements were obtained using a broadband echo sounder (SIMRAD EK80) mounted on a vertically profiling platform facilitating close range observations of the mesopelagic habitat. Biological and optical sampling undertaken during the survey from the surrounding region have confirmed the presence of a diverse range of fishes (Myctophidae family), cephalopods, gelatinous organisms (siphonophores, salps), and crustaceans (euphausiids, pelagic decapods) (Kloser et al., 2016).

This paper presents some preliminary results of applying a broadband processing method to the acoustic data collected from the Great Australian Bight. As a demonstration of the technique, two individual targets were randomly selected from an echogram obtained with the calibrated lowered probe at 600 m depth, and their frequency dependent target strengths were measured. A comparison between these results and the results of numerical modelling were then used to infer information about the targets.

2. METHODOLOGY

2.1 The Great Australian Bight region

From 29 November to 22 December 2015, a multidisciplinary survey, using advanced acoustical, optical and net sensors was performed in the Great Australian Bight Region in the Southern Ocean (Kloser et al., 2016). This study contributes to Project 2.2 of the GABRP, which is being conducted to characterise and quantify the dominant contributors to the pelagic habitat of the Great Australian Bight region (GABRP, 2013).

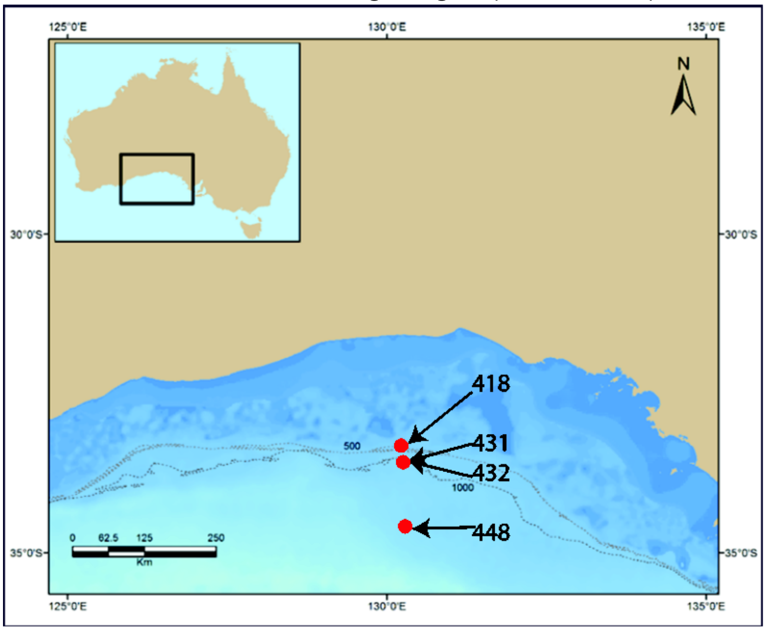


Figure 1: The survey location within the Great Australian Bight. Red circles mark the four deployments of the Broadband echosounder (EK80), identified by unique numbers 418, 431, 432 and 448.

2.2 Acoustic sampling and analysis

The Instrumented Corer Platform (ICP) is designed to accommodate many sampling devices aiming to record multidisciplinary samples simultaneously from deep waters (Sherlock et al., 2014). At four selected locations (see Figure 1) the integrated system was deployed to depths of 600 – 1,000 m and acoustics measurement were recorded for the entire deployment. The integrated system (Figure 2) consists of two split-beam broadband transducers: SIMRAD 70 kHz (ES70-18CD) and SIMRAD 120 kHz (ES120-7CD) (Simrad, 2016). The frequency ranges of the transducers were 50 – 90 kHz and 95 – 160 kHz, with beamwidths of 18° and 7° respectively at the centre frequencies of 72.5 and 127.5 kHz. The system was calibrated for the location of scatterers within the acoustic beam as a function of depth using a 38.1 mm diameter tungsten carbide sphere (WC20) (Demer et al., 2015). Raw data were processed using developed Matlab codes to provide the range, time reference, Target Strength (TS) and the phase angles. The calibrated Target Strength values were compensated for two-way spreading loss ($TVG = 40\log R$), absorption loss (Francois and Garrison, 1982) and the pulse compressed echograms were drawn with cut off of TS <= -70 dB. To demonstrate the effectiveness of the process, echograms were carefully inspected for single targets with high backscattered energy, and the frequency dependent target strengths of selected targets were subsequently investigated.


a)


b)

Figure 2: a) A broadband sonar system (Simrad EK80) mounted on the ICP.

b) Closer view of the two transducers ES70-18CD and ES120-7CD laid side by side.

3. RESULTS

The echograms were carefully examined for the presence of single targets within a range of 5 m to 15 m from the transducers. An echogram obtained with the profiler at a depth of ~600 m was selected for analysis (Figure 3). As shown in the figure, the echogram has numerous acoustic scatterers and a region of high echo level between 12.5 and 15.5 m. This high echo level region appears as a red line at 14 m and is from the calibration sphere (WC20), which was suspended below the transducers. The calibration sphere serves as a standard target with known acoustic response, and comparing the measured TS response with this known acoustic response allows the broadband sounder to be calibrated. Two single targets within the red rectangle drawn in the echogram, from a depth of ~600 m were selected for analysis of their scattering characteristics. The areas within the red rectangles were processed using the single target detection algorithm to detect single targets with a minimum TS of -70 dB, and their target strengths were measured and r plotted as a function of frequency.

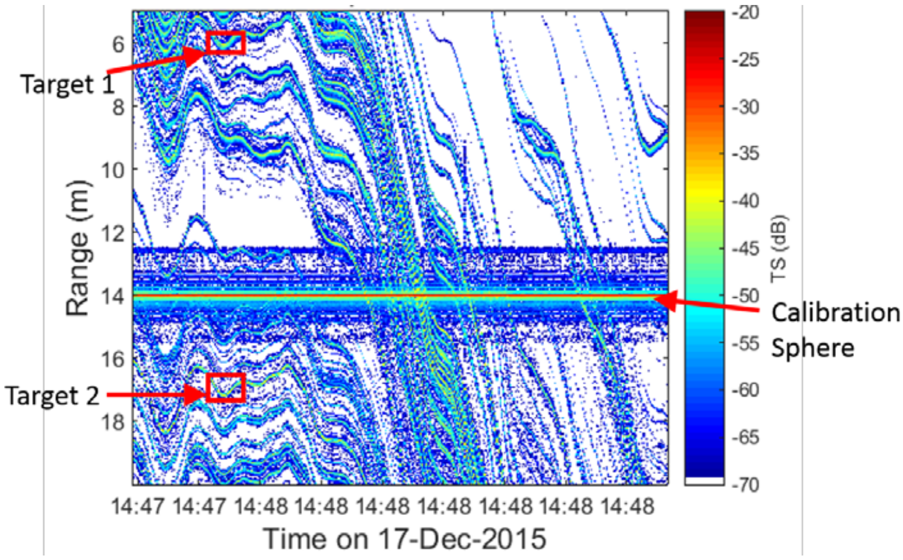
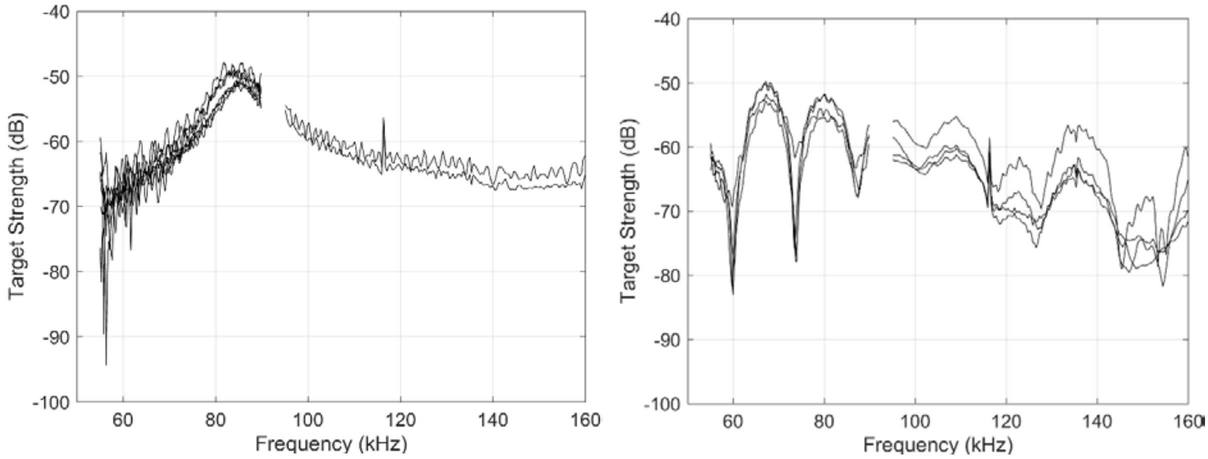


Figure 3: The calibrated Target Strength echogram (TS min gain -70 dB) shows numerous scattering sources at a depth of 600 m. The high level of echo at 14 m is associated with the calibration sphere suspended below the transducers. Two different single targets (within red rectangles) Target 1 and Target 2 at different range 6.14 m and 16.72 m were selected for analysis of their acoustic signatures.

3.1 Characteristic frequency dependent target strengths

The frequency dependent target strengths of the two targets are plotted in Figure 4. The first, located at ~6 m range, has a scattering response with a single, broad resonant peak at 83 kHz (Figure 4 (a)). The single resonant peak is consistent with an animal that has a gas inclusion. This resonant frequency is a function of the depth, shape, and size of the enclosed gas, the volume of which can be estimated using appropriate acoustic scattering models (Medwin and Clay, 1998, Davison et al., 2015, Kloser et al., 2016).The second example, from a scatterer at a range of ~17 m, has a very different scattering response, with a target strength that oscillates around -60 dB across the whole frequency range (Figure 4(b)). The TS response with the frequency of the second target is consistent with a fluid filled animal, scattering from which generates a hump like pattern, with series of peaks and nulls. Transmitted signals scattered back from an animal at different times results in frequency dependent constructive or destructive interferences which lead to the formation of peaks or nulls. (Stanton et al., 1996, Jech et al., 2015).



a) b)

Figure 4: The frequency spectrum of the target strength of the two selected single targets labelled as Target 1 (a) with resonant scattering at 83 kHz and Target 2 (b) which oscillates around -60 dB. The plots have been compensated for the animal position within the beam. The TS response for each off-axis curve was calculated, and the averaged response is drawn.

4. DISCUSSIONS AND CONCLUSIONS

This paper shows the possibilities in exploiting broadband systems for target classifications using the TS frequency response curve. The frequency dependent TS plots (Figure 4) show that targets with a similar appearance in an echogram can belong to entirely different groups of scatterers, with contrasting anatomical structure (Stanton et al., 2010). In this case, we have shown the different frequency spectra from what appear to be gas filled and fluid filled organisms. Interpretation of these TS frequency response plots is complemented by the outputs from numerical scattering models that provide a means of relating the measured results to the physical characteristics of the scatterer, which could further be used to estimate the species biomass and abundance (Davison et al., 2015, Jech et al., 2015, Stanton et al., 1998, Lehodey et al., 2010, Kloser et al., 2016). In summary, the performance of broadband sonar systems for target identification is demonstrated here.

Application of the pulse compression technique realised enough range resolution and a high enough signal to noise ratio to generate high-quality echograms. This helps to resolve micronektons lying closer to each other and delineate their acoustic characteristics. However, the exact source of these backscattered energy curves cannot be ascertained from this deployment due to the absence of coincident optical sampling. We intend to explore the pelagic habitat with the broadband echosounder mounted on the PLAOS facilitating concurrent acoustic-optical sampling (Marouchos et al., 2016)

In future, the consistency and the relationship of the scatterer TS response curves to the acoustic parameters, depth, and orientation of the scatterer will be investigated by comparing these results to the output of selected scattering models. Further, the ability of the instrument to estimate the regional biomass and abundance and accurately represent the distribution of the micronekton community will also be explored.

5. ACKNOWLEDGEMENTS

This study is being undertaken as part of the Great Australian Bight Research Program, a collaboration between BP, CSIRO, the South Australian Research and Development Institute (SARDI), the University of Adelaide, and Flinders University. The Program aims to provide a whole-of-system understanding of the environment, economic and social values of the region; providing an information source for all to use. In particular, we thank Tim Ryan, Lars Nonboe Andersen and Gordon Keith for the software support. Matt Sherlock for redesigning the ICP to install the broadband echosounder and the whole crew of Marine National Facility (MNF) for monitoring and managing the deployments.

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