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A COMPARISON BETWEEN ACOUSTICALLY DERIVED s_A ESTIMATES AND THOSE DERIVED FROM NETS

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In this paper, a comparative analysis of the area backscattering coefficients s_A derived from acoustics and nets is presented. The s_A values were integrated within a layer of 2-m thickness (0.5 m off the seabed) and correction made for the acoustic deadzone. This layer was comparable to the headline height of 2 m on average. The net data were converted to the equivalent area backscattering coefficients, $s_{A(catch)}$. Results showed that the two s_A estimates were equivalent in a sense that they both clustered around the 1-1 correspondence line. Substantial variations are observed however, which may involve uncertainties in target strength, net efficiency and spatial distribution of targets

1. INTRODUCTION.

This paper presents a comparison of acoustic backscattering measurements from an echosounder with comparable estimates derived from demersal net results from a fisheries survey in the North West Shelf of Western Australia. Comparatively few publications of such direct comparisons between the results of the two techniques are available and report a variety of relationships between results from the two techniques, involving issues of target strength assessment and target behaviour, amongst others.

2. METHODS.

2.1. Surveys.

The study area was surveyed from the FRV *Southern Surveyor* from the 7th of August 1997 to the 1st of September 1997 between 114°30'E and 119°E and between 18°30'S and 21°S (Fig.

1). A stratified random design was used to determine survey trawl locations for the study. Almost all of the trawl locations were randomly selected within each experimental management zone.

This paper reports on 71 trawls which were matched by good quality acoustic data. The duration of trawls was 30 min with a speed of 3 kt. The towed distance then became 2.8 km and the swept area became 0.055561 km^2. The demersal trawl used in this survey had mouth openings of around 40 m^2 with 20-m wingspread and 2-m headline height. Mesh sizes were 9 in at wings and belly, 6 and then 4.5 in at funnel leading to cod end, and 3.5 in at cod end. Scanmar net sensors were operational for all of the trawls to measure the door spread, wingspread and headline height.

Immediately after each trawl, catches were identified on board and sorted to a species level. Only very few unidentified fish were retained for later identification. All sorted species were individually wet weighed. Length-frequency data were collected for 14 pre-determined species of fish from genera Saurida, Epinephelus, Lutjanus, Nemipterus, Diagramma, Lethrinus and Parupeneus. The lengths of the fish were based on fork length.

Acoustic data was collected along the track from the FRV *Southern Surveyor* with a calibrated Simrad EK500 scientific echosounder. This paper will consider data from the 38 kHz hull mounted transducer of the echosounder. The pulse length, bandwidth and power during the operation were respectively set to 1 ms, 3.8 kHz and 2 kW.

2.2. Acoustic calibration and data quality control.

The acoustic system was routinely calibrated with a -33.6-dB, 60-mm copper sphere. Calibration procedures due to Foote [1,2] were as described in the operation manual of the Simrad EK500 echosounder [3]. Data quality control involved the specification of background and spike noise thresholds, correction for calibration and absorption changes, removal of corrupted data and editing of bottom lines [4]. Regions containing acoustic noise due to aeration and spike noise above the seabed due to a time jitter were excluded from the data set prepared for further analysis. A detailed analysis of all records to exclude occasional seabed returns from integration was carried out as was a small correction to exclude returns from plankton. A correction for the acoustic deadzone layers in which seabed returns were inseparable from fish returns in layers too close to the seabed was also carried out [5,6].

2.3. Acoustic data analysis.

The acoustic returns, s_V, were integrated in 0.5 m depth layers between 0 and 5 m above the line defined as the seabed and averaged horizontally over 0.05 nmi or 0.0926 km intervals. This gave the mean area backscattering coefficient, $\bar{s}_{Aj}$, of layer j over the horizontal interval. For layer j, the mean area backscattering coefficient was calculated by

$$\bar{s}_{Aj} = 4\pi 1000^2 \frac{\sum_{l=1}^{p}\left(2\sum_{k=1}^{d} s_{v(k,l)}\right)}{p} \quad [\mathrm{m^2 km^{-2}}] \qquad (1)$$

where s_v is the volume backscattering coefficient in linear scale, p is the number of pings and d is the number of volume backscattering coefficients within the layer j.

Adjusting for the distance between the transducer and the trawl estimated from warp length data allowed a direct comparison of acoustic and net data, the area backscattering coefficient, $\bar{s}_{Aj}$, for trawl *i* and layer *j* was obtained by averaging the $\bar{s}_{Aj}$ values within the duration of the trawl deployment:

$$s_{Aij} = \tfrac{1}{n}\sum_{n} \bar{s}_{Aj} \qquad [\mathrm{m^2km^{-2}}] \tag{2}$$

where *n* is the number of $\bar{s}_{Aj}$ values available within the i^{th} trawl duration.

The area backscattering coefficient of the region swept by nets during the trawl duration resulted from summing up the area backscattering coefficients of all sequential layers falling in the swept area. The total height of these sequential layers in the vertical direction was therefore put identical to the headline height and was in general 2 m. The headline height was measured with Scanmar net sensors. The area backscattering coefficient for trawl *i* was then given by

$$s_{Ai} = \sum_{m} s_{Aij} \qquad [\mathrm{m^2km^{-2}}] \tag{3}$$

where *m* is the number of layers falling in the swept area.

2.4. Net data analysis.

The density estimates were converted to theoretical s_A values using the backscattering cross section, σ_{sl}, for species *s* and length group *l*:

$$s_{A(catch)} = \sum n_{sl}\sigma_{sl} \big/ A \qquad [\mathrm{m^2km^{-2}}] \tag{4}$$

and

$$\sigma_{sl} = 4\pi 10^{TS_{sl}/10} \qquad [\mathrm{m^2}] \tag{5}$$

where n_{sl} and TS_{sl} are respectively the number of catch and the target strength for species *s* and length group *l*, and *A* is the towing area in km^2.
The presence and type of swimbladder are species specific, hence net catches were categorised into 4 different groups namely physoclistous, physostomous, bladderless and "squid-like" species. As a guide to the target strength of bladderless and squid-like species, the expression for squid [7] and mackerel [8] were used. Equation (6) summarises these results. *L* is the total length for the first three and is the mantle length for the other in cm. Few crustacea were caught and have therefore not been included in this analysis. A number of species caught did not have length-frequency relationships assessed during the cruise. A method has been developed to estimate the contribution from these components of the catch.

$$\begin{array}{ll} TS = 20\log_{10} L - 67.4 \text{ (for physoclist [9])} & TS = 20\log_{10} L - 71.9 \text{ (for physostome [9])} \\ TS = 20\log_{10} L - 84.9 \text{ (for no bladder[8])} & TS = 20\log_{10} L - 75.4 \text{ (for squid - like [7])} \end{array} \tag{6}$$

3. RESULTS.

3.1. Estimated S_A values from nets.

Species caught in each trawl stations were grouped according to the swimbladder type they belonged to. Almost all of the trawl station results comprised species of 3 different types of swimbladder namely physostomous, bladderless and squid-like types. Only in one trawl station were physoclistous species present. These species belonged to the family Clupeidae. Species of this group have lower target strength than physostomous species of the same length as shown in equation (6)

3.2. Estimated S_A values from acoustics.

The net was operated as close as possible to the seabed with the headline height varying from 1.5 to 2.5 m and the average close to 2 m. It was therefore assumed that the net swept a vertical range between 0.5 and 2.5 m above the seabed.

Despite the fact that times of trawl deployment and recovery, and warp lengths of all trawl stations were available from the survey, it was of interest to see whether or not there was any significant difference if these times were horizontally shifted backward (delay) and forward (ahead) around the nominal position (Fig. 2). Consideration of this issue acknowledges the difficulty of assigning an exact value to the vessel-trawl separation distance. The nominal position was derived from the warp length and the water depth by a simple geometric calculation. 6 different lagged positions were compared to the nominal ones. Acoustic s_A estimates of trawl stations in the nominal position and those in lagged position are shown in Fig. 3. It is evident that there is no significant difference of the acoustic s_A estimates between lagged positions in a range interval of 5 min ahead to 15 min delay, and the nominal ones.

The s_A estimates from acoustics and nets for all trawl stations available are shown in Fig. 4. Although the results cluster around the line representing equivalence there is a substantial range of variation between acoustic estimates and net estimates. For one particular net estimate, a range of one order of magnitude is found in the corresponding acoustic estimate. The substantial range of variation between the two s_A estimates may reflect the uncertainties in the parameters, notably the target strength used to determine the s_A estimates of the nets. Other possibilities influencing the differences between the two estimates could be due to the efficiency of the nets used in the survey and the influence of the detailed patchiness of the target population.

4. ACKNOWLEDGMENTS.

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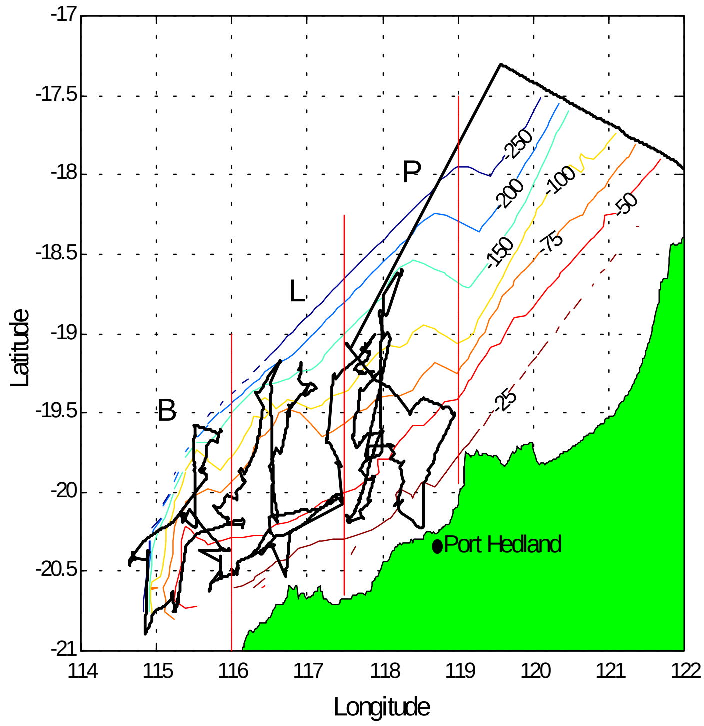

Fig. 1: The study area, bathymetry and transects used in the survey.

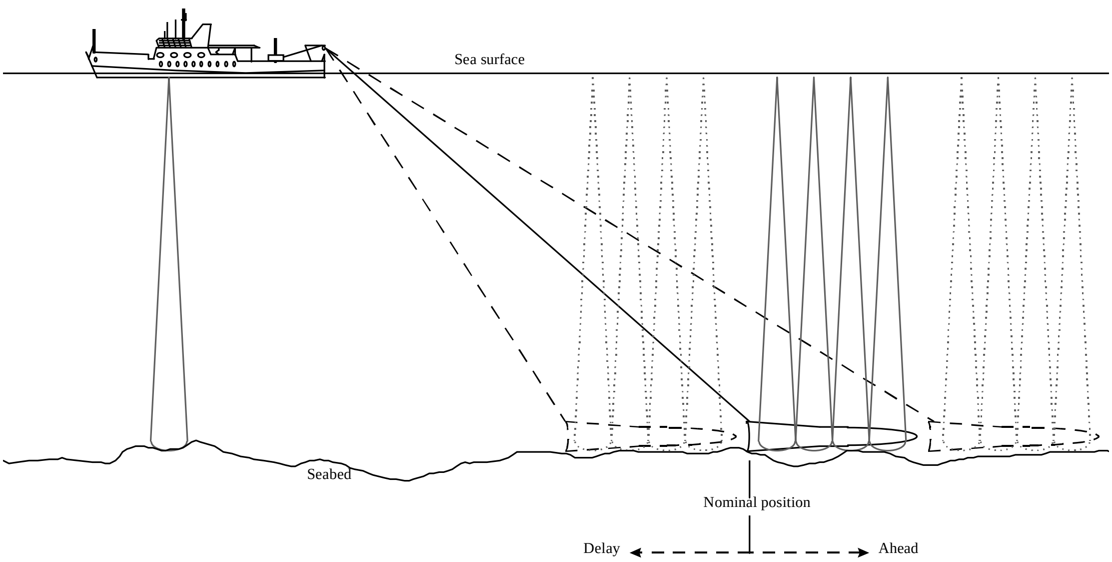

Fig. 2: Schematic explanation of nominal position of trawl and positions of trawl shifted backward and forward around the nominal one.

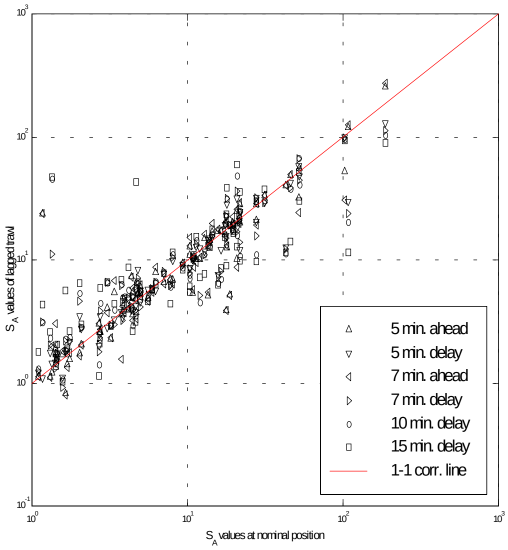

Fig. 3: Comparisons between the acoustic s_A estimates at the locations provided from the vessel's logbook (on x-axis) and those from several lagged locations of trawls (on y-axis).

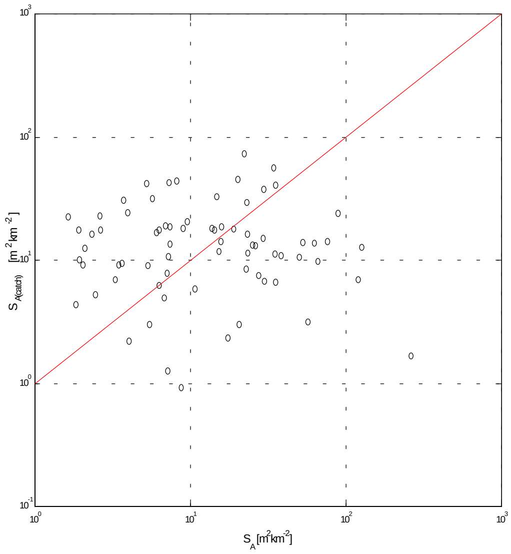

Fig. 4: Scatterplot of acoustic s_A estimates with a correction for the dead zone (abscissa) and net s_A estimates (ordinate) 71 trawl stations. —— is the 1-1 correspondence line.

REFERENCES.

[1] Foote, K.G., "Optimizing copper spheres for precision calibration of hydroacoustic equipment." *J. Acoust. Soc. Am.* 71(3), 742-747, 1982.

[2] Foote, K.G., "Maintaining precision calibrations with optimal copper spheres." *J. Acoust. Soc. Am.* 73(3), 1054-1063, 1983.

[3] Anon., *Simrad EK500 Scientific Echo Sounder Instruction Manual.* Simrad Subsea P2170E, 1993.

[4] Kloser, R.J., J.A. Koslow and A. Williams, "Acoustic assessment of the biomass of a spawning aggregation of orange roughy (*Hoplostethus atlanticus*, Collet) off South-eastern Australia, 1990-93." *Mar. Freshwater Res.* 47, 1015-1024, 1996.

[5] Ona, E. and R.B. Mitson, "Acoustic sampling and signal processing near the seabed: the deadzone revisited" *ICES J. Mar. Sci.* 53: 677-690, 1996.

[6] Kloser, R.J., "Deeply-towed transducer improves precision of acoustic surveys of benthopelagic fish." *ICES J. Mar. Sci.* 53: 405-413, 1996.

[9] Foote, K.G., "Fish target strengths for use in echo integrator surveys." *J. Acoust. Soc. Am.* 82(3), 981-987, 1987.

[7] Arnaya, I.N., N. Sano and K. Iida, "Studies on acoustic target strength of squid III: measurement of the mean target strength of small live squid." *Bull. Fac. Fish. Hokkaido Univ.* 40(2), 100-115, 1989.

[8] Edwards, J.I., F. Armstrong, A.E. Magurran and T.J. Pitcher, "Herring, mackrel and sprat target strength experiments with behavioural observations." *Int. Coun. Explor. Sea CM* 1984/B:34, 21pp., 1984.