Integrating echo-sounder and underwater video data for demersal fish assessment

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1. ABSTRACT

Effective management of demersal fish species includes accurate, spatially explicit assessments of their abundance and distribution. Non-extractive techniques, such as echo-sounders and visual census, are of particular importance in no-take marine reserves where direct sampling is restricted. This study is investigating the use of echo-sounders and Baited Remote Underwater stereo-Videos (stereo-BRUVs) in demersal fish assessment. Echo-sounders have the advantage of covering nearly the entire watercolumn and being able to cover vast areas in a relatively short period. However, "ground-truth" data is usually needed to produce species-specific identification and sampling the area close to the seafloor is problematic, particularly for demersal species in complex topography. In contrast, stereo-BRUVs allow identification to species level in most cases, but samples characterise a particular location within the field of view and the area of influence within the bait plume. The combination of co-located bathymetric and habitat maps, with quantifiable acoustic backscatter and species-specific visually ground-truthed relative abundance, holds potential to further these studies and provide a more cost- and labour-efficient sampling regime. The preliminary investigation into the relationship between active acoustic and stereo-BRUVs showed a significant correlation between the relative biomass recorded by the stereo-BRUVs and the acoustic energy recorded by the echosounder.

2. INTRODUCTION

Marine reserves require non-extractive, non-invasive techniques to collect information about species abundance and distribution. This study focussed on two non-destructive and fishery-independent approaches: video census and underwater acoustics, and how they relate and can be integrated.

The use of cameras in the study of fish species richness and abundance has been present since 1902 (Hardinge et al., 2013). These techniques offer a series of advantages compared to other methods. They are not constrained in terms of the benthic habitat that can be sampled, unlike destructive methods (like trawling), and depth is not a limitation factor, unlike diver operated video surveys. These characteristics help to minimise the observer biases and gear related selectivity (Hardinge et al., 2013, Fitzpatrick et al., 2012). Baited Remote Underwater stereo-Videos (stereo-BRUVs) are increasingly being applied to measure species richness and relative abundance of demersal fish (Schultz et al., 2014). Although this technique may be less effective in sampling small cryptic species when compared to diver operated stereo-video systems, stereo-BRUVS have shown better performance in recording rare, large predatory fish species (Moore et al., 2010). In addition, information can also be obtained about the lengths of fish (Hardinge et al., 2013) and therefore the length distribution within an assemblage. The relative abundance of fish can be estimated using the maximum number of individuals (MaxN) of a particular species that appeared in the field of view at any one point through the recording time, eliminating the possibility of recounting the same fish (Watson et al., 2010). The area of influence of a stereo-BRUV, based on the bait plume, will depend on the bottom current speeds, soak time and swimming speed of the organisms. For example, Ellis and DeMartini (1995) estimated the maximum distance of attraction at between 48 and 90 m for a 10 minutes soak, while Cappo et al. (2004) estimated 450 m for a 60 min period of time.

In the last two decades, the development of active acoustics systems, such as echo-sounders, has enabled scientists to attain a better understanding of the seafloor acoustic characteristics. These systems have also been used to make indirect estimations of fish abundance, based on the amount of energy reflected by the organism present in the water column. The echointegration method is used to estimate densities of individuals based on the calculation of the amount of energy backscatter and the ensonify water volume and its integration over a certain depth interval (Colombo and Machado, 2015, MacLennan and Simmonds, 2013).

The aim of this project was to investigate the usefulness of combining stereo-BRUVs and sonar data in providing more holistic information on the distribution of demersal fishes by comparing the patterns captured by an echo-sounder and stereo Baited Remote Underwater Video (stereo-BRUVs) in the area of Cockburn Sound.

3. METHOD

The study site was located in Cockburn Sound, a body of water off the southwest coast of Perth, Western Australia. At the study area, different benthic habitats including cobble reef and high relief reef have been described (Cockburn Sound Management Council (2004)).

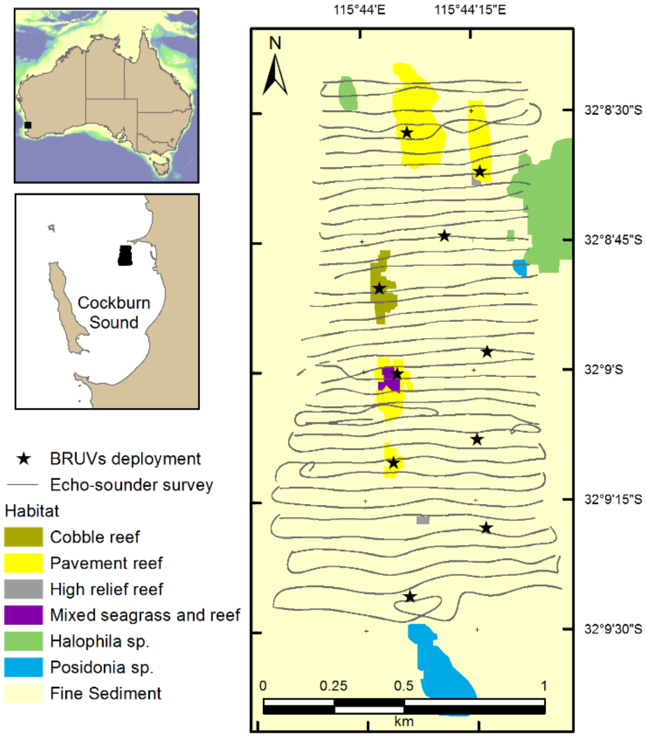

Figure 1: The study was located in the South-West coast of Australia, in Cockburn Sound. The benthic habitat classification is an adapted version of Cockburn Sound Management Council (2004).

Two small vessels were used during the survey, one collecting acoustic data at an average speed of 4 knots and another vessel deploying and retrieving the stereo-BRUVs. The acoustic survey was conducted following transects perpendicular to the coast, with around 50 meters of separation between them (Figure 1). Ten stereo-BRUVs were deployed in different benthic habitats and with at least 250 meters of separation between them to minimise the possibility of mixing bait plumes and reduce the likelihood of fish moving between sites within the sampling period (Figure 1). The acoustic survey was conducted either before the stereo-BRUVs were deployed or after at least 1 hour of their removal.

Three Biosonics single beam transducers (38, 120 and 420 kHz) were mounted on a small pontoon which was towed alongside one of the vessels (the GPS antenna was mounted in the centre of the pontoon) (Figure 2). The stereo-BRUVs systems consist of two video cameras mounted in a metallic frame which hold them at an inward convergence of 8° so both cameras had a common area of view (Figure 2). In the centre of the frame, a bait arm suspends a bait bag between cameras. Each video camera was equipped with an SD card with enough memory to record for at least 2 hours. The stereo-BRUVs technique used in this study was conducted following the same process reported by Harvey et al. (2007). The remaining bait was kept on board of the vessel after the removal of the stereo-BRUV to avoid a remaining plume after the retrieval.

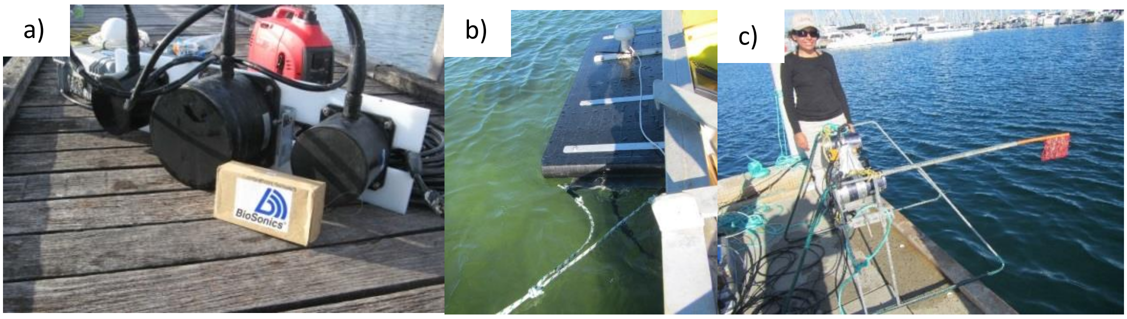

Figure 2: a) and b) Pontoon with the three transducers used in the survey. c) Stereo-BRUVs system

3.1 Data analysis

3.1.1 Stereo-BRUVs

The two video recordings were synchronised and analysed using the ‘EventMeasure Stereo’ (SeaGIS, 2011) software. An hour of the recording time was analysed, starting from the moment the stereo-BRUV reaches the seafloor. The reviewing process involved identifying the fish present in the videos and counting the individuals of each species using the MaxN approach. The analysis procedure was also conducted following Harvey et al. (2007). In this initial exercise, in some of the sampling points, not all fishes were measured. The average length of the measured fish was used to estimate the length of the rest of individuals. The length-weight relationship was used to estimate the weight of individual fish and finally the relative biomass for each sampling point.

3.1.2 Acoustic analysis

Only the 38 kHz frequency data was used in this study, the backscatter data was extracted from the raw files using a MATLAB program written by the authors. After the acoustic data was imported, ten pings were averaged to reduce the intrinsic high variability of the data. Two Acoustic Backscatter Coefficients (ABC) were calculated by integrating over the water column backscatter. One layer referred to here as the “watercolumn” layer, was the integral between 2 m below the water surface (to avoid erroneous data from surface waves and aeration) and 25 cm above the seafloor (to avoid epi-benthic structure, such as seagrass). The other layer referred to here as “demersal” layer was the integration from three meters to 25 cm above the seafloor.

To compare the BRUV and acoustic data, ABC data was extracted at each of the stereo-BRUV locations out to a radius of 100 meters. The distance of 100 m was selected to include acoustic data in areas of strong influence of the bait, even in the scenario of short periods of time (Ellis and DeMartini, 1995). Also, this radius avoided overlapping between sampling stations and therefore, they were considered to be independent. The subset of backscatter data for each station was tested for normality and the median value was used to be compared with the relative biomass recorded by the stereo-BRUVs. Cobble reef and pavement reef benthic habitats were grouped into a single ‘reef’ category to be compared with the sand habitat.

A correlation test was used to explore the relationship between the ABC and relative biomass recorded using stereo-BRUVs.

4. RESULTS

4.1 Stereo-BRUVS

Higher levels of biomass were observed in the pavement reef, and cobble reef areas (Figure 3), the sampling points located in the sandy bottoms had, in general, lower levels of biomass with a couple of exceptions.

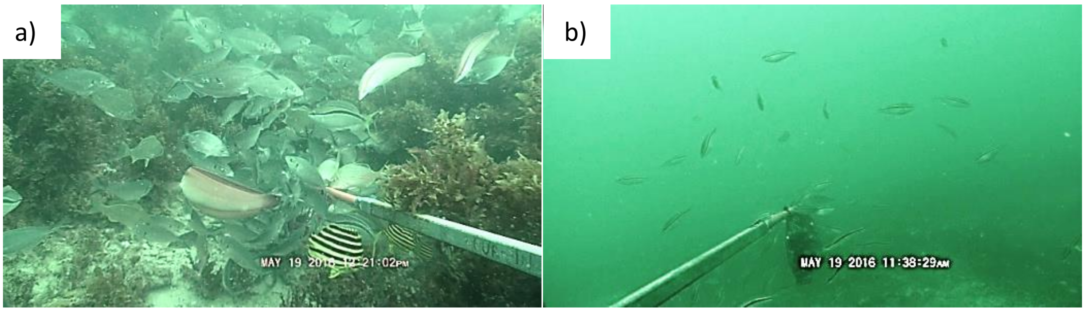

Figure 3: a) Examples of high (left) and low (right) levels of biomass recorded with the stereo-BRUVs.

4.2 Acoustic data

Higher values of acoustic backscatter were, generally, found on the west side of the study site where there is a greater variety of benthic habitats and also a change in the depth (Figure 4), lower values of backscatter were observed in general in the East part of the study area.

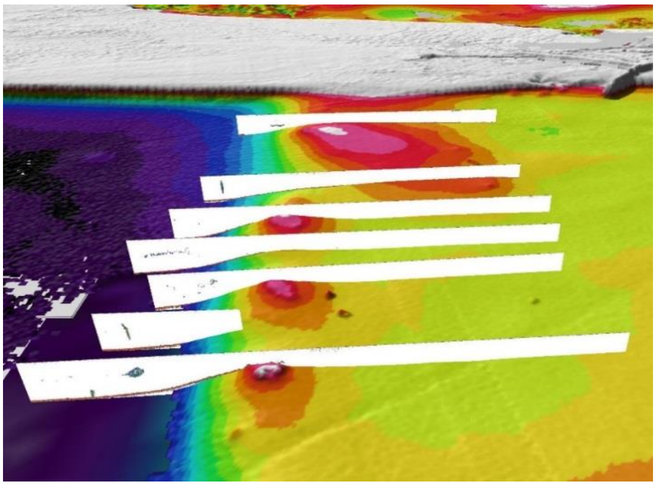

Figure 4: Visualisation of some of the echograms with a LIDAR bathymetry in the background. Higher values of backscatter can be observed on the left side of the echograms.

4.3 Comparing stereo-BRUVs and acoustic data

Figure 5 shows a box plot of the watercolumn and demersal ABC and relative biomass in the sampling points grouped by benthic class. A general pattern of higher values of ABC and biomass can be observed in the reef classes, however, a Wilcoxon's signed-ranks test indicated the difference between the two habitat classes were only significant for the demersal layer of the ABC ($w=25$, $p<0.01$, two-tailed test).

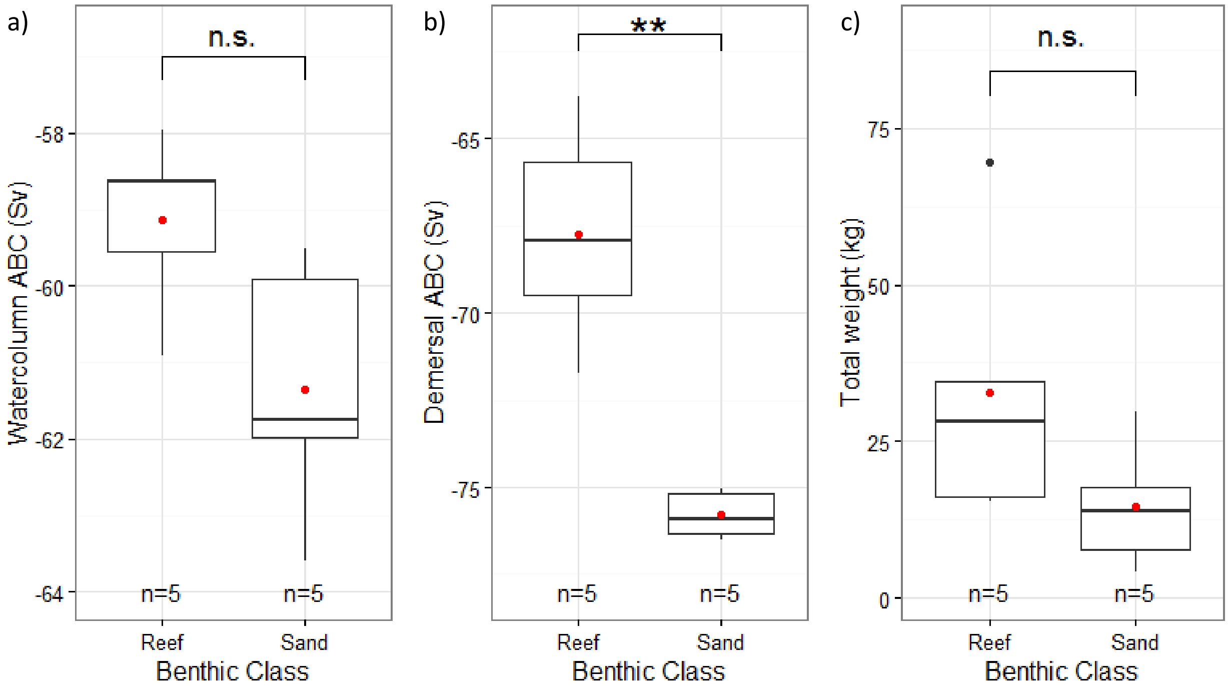

Figure 5: Distribution of a) watercolumn ABC, b) demersal ABC and c) relative biomass (stereo-BRVUs) grouped by benthic habitat class. The upper and lower "hinges" correspond to the first and third quartiles (the 25th and 75th percentiles). Whiskers extends from the hinge to the highest/lowest value that is within 1.5 * IQR of the hinge, where IQR is the inter-quartile range. Data beyond the end of the whiskers are outliers and plotted as black points, the mean is plotted as a red point.

The stereo-BRUVs and acoustic data were compared spatially in Figure 6, which shows the total relative biomass derived from the stereo-BRUVs' recordings as a bubble plot on top of ABC (watercolumn and demersal) data gridded at a 50 m resolution. This suggests a general agreement in the spatial variation in ABC and BRUV biomass.

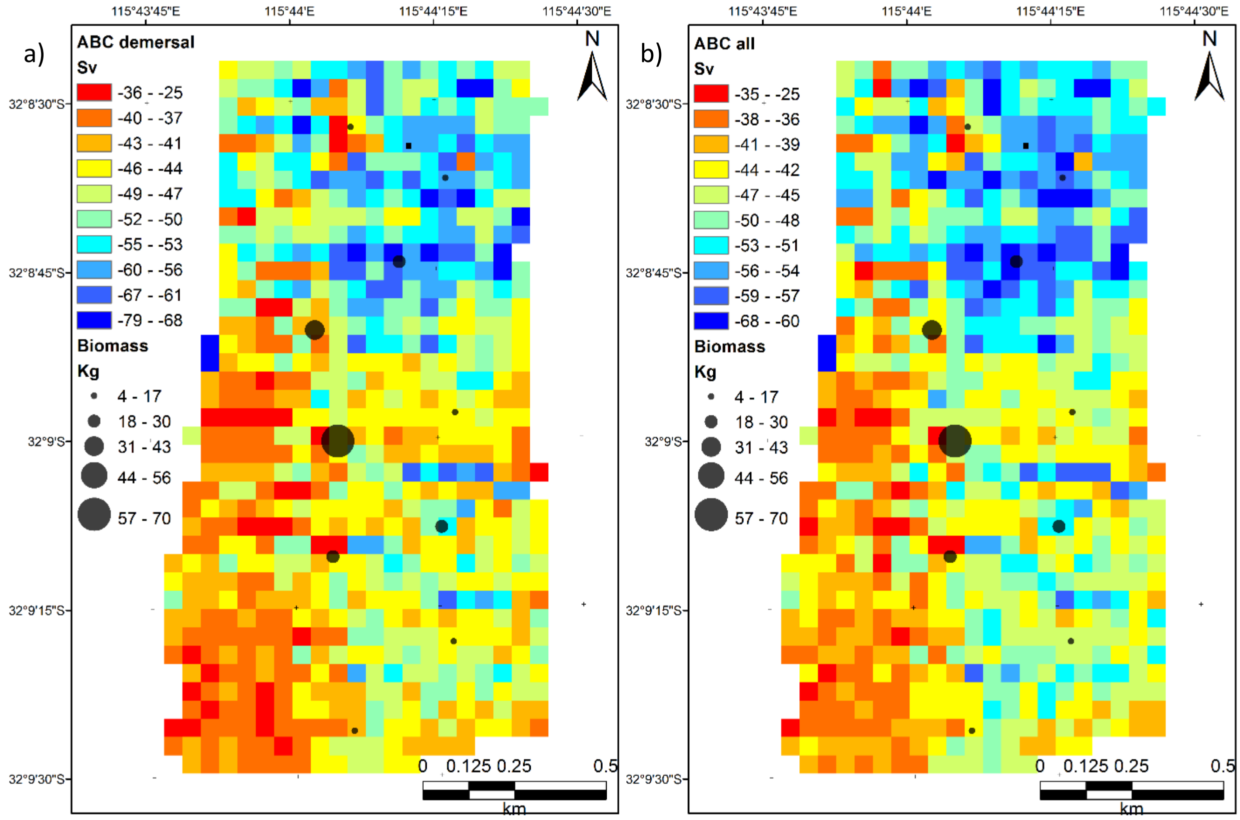

Figure 6: Acoustic data gridded at a 50m resolution, red tones indicate higher values of backscatter energy; the graduated circles represent the relative biomass recorded with the stereo-BRUVs, a) Watercolumn layer, b) Demersal layer.

A significant correlation was found between the median value of the ABC and the relative biomass recorded by the stereo-BRUVs for both the watercolumn (rho=0.72 p<0.05, r2=<0.35), and the demersal layer (rho=0.72, p<0.05, r^2=0.22). A linear polynomial local fitting was added to the plot as reference but the linear regression was not significant for the data (Figure 7).

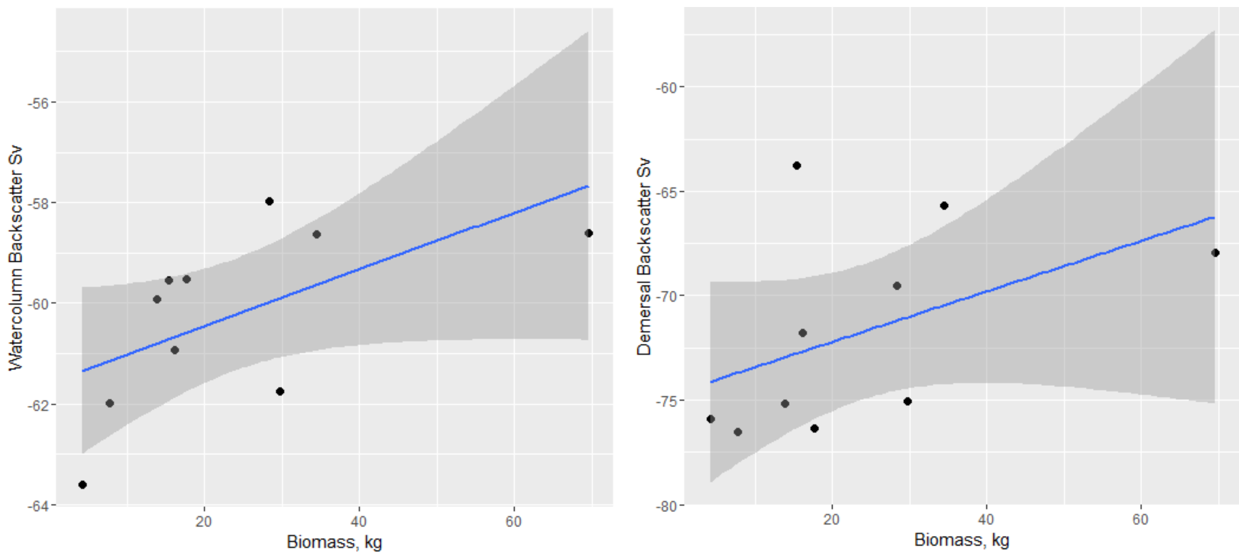

Figure 7: Biomass stereo-BRUVs vs Backscatter energy with polynomial local fitting surface and confidence intervals (95%).

5. DISCUSSION

In this study, a significant correlation was found between the acoustic watercolumn ABC data and the relative biomass estimated from the stereo-BRUVs recordings, however, the relationship was not very strong with only a 0.56 in the case of the demersal layer. Different factors might be contributing to this discrepancy; one of them is the possible underestimation of ABC coefficient caused by the confusion of fish erroneously identified as seabed (Demer et al., 2009, Foote, 2009). In some of the sampling stations, for example, a significant proportion of the biomass recorded by the stereo-BRUVs compromised eagle rays and stingrays. These organisms tend to remain near the seafloor digging holes in the soft-bottom to predate epibenthic communities (Thrush et al., 1991) which might difficult the differentiation between the echoes produced by this organisms and the seafloor.

Previous studies in the nearshore waters of Western Australia have shown the importance of seagrass and limestone reef areas, with higher levels of fish biomass and richness when compared to flat sand or silt substrate (Howard, 1989, Wakefield and Johnston, 2009). A similar pattern was found in the present study, for both the BRUVs and acoustic data, however the difference between sand and reef were only significant for the demersal layer of the ABC. With an increased number of samples, the patterns observed using water column ABC and stereo-BRUVs may become statistically significant.

The response of fish to baited equipment can be species-specific and affected by a number of factors, including individuals response time, feeding behaviours, current activity, schooling behaviour and propagation of the bait plume (Sheaves, 1995, Harvey et al., 2007, Cappo et al., 2006), thus soak time is a factor in numbers of fishes present at any given time. Similarly, after the stereo-BRUVs has been retrieved, there may be a period while species abundance is affected by prior presence of the bait and the remaining bait plume. As a result, when acoustics transects were conducted post stereo-BRUVs deployment, a minimum time of 1 hour was allowed before the transect commenced to minimise any bias. However, the length of the bait effect in the watercolumn has not been studied and it might last longer than an hour increasing the correlation with the acoustic data in those stations.

Another limitation of this study was the attempt to relate species and length specific abundance captured by the stereo-BRUVs with unspecified acoustic biomass estimates. An accurate estimation of distribution and abundance of fish using echo-integration methods, will required an *in situ* calibration of the echosounder, and the measurement of backscattered amplitudes to each target type based on species and length distribution (Demer et al., 2009, D'Elia et al., 2014, Foote, 2009, MacLennan and Simmonds, 2013). Thus, the relationship is currently considered as indicative.

6. CONCLUSIONS

These preliminary results showed a significant correlation between the acoustic data and the relative biomass recorded by the stereo-BRUVs, in particular with the watercolumn backscatter. These results lead to an initial conclusion that these two techniques can be combined as complementary methods to better understand demersal fish distribution and abundance. Future directions for this research included increasing the area cover with the echo-sounder and the number of sampling points for the stereo-BRUVs to increase the power of our hypothesis testing.

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