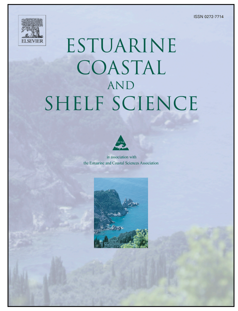
Accepted Manuscript



What can a low-cost fish-finder tell us about the seabed?

Noela Sánchez-Carnero, Daniel Rodríguez-Pérez, Alejo Irigoyen, Gastón Trobbiani, Ana M. Parma

PII: S0272-7714(18)30062-3

DOI: 10.1016/j.ecss.2018.10.001

Reference: YECSS 5991

To appear in: *Estuarine, Coastal and Shelf Science*

Received Date: 15 February 2018

Revised Date: 11 September 2018

Accepted Date: 5 October 2018

Please cite this article as: Sánchez-Carnero, N., Rodríguez-Pérez, D., Irigoyen, A., Trobbiani, Gastó., Parma, A.M., What can a low-cost fish-finder tell us about the seabed?, *Estuarine, Coastal and Shelf Science* (2018), doi: https://doi.org/10.1016/j.ecss.2018.10.001.

What can a low-cost fish-finder tell us about the seabed?

Sánchez-Carnero, Noela[1, 3]; Rodríguez-Pérez, Daniel[2]; Irigoyen, Alejo[1]; Trobbiani, Gastón[1]; Parma, Ana M.[1]

[1]Centro para el Estudio de Sistemas Marinos (CESIMAR)(CCT-CONICET-CENPAT). Bv. Brown 2915, Puerto Madryn, Argentina.

[2]Departamento de Física Matemática y de Fluidos, Facultad de Ciencias, UNED. C/ Paseo de la Senda del Rey, 9 - 28040 Madrid.

[3]Grupo de Oceanografía Física de la Universidad de Vigo. Campus Universitario Lagoas-Marcosende. 36200 Vigo.

Abstract

Low-cost non-scientific echosounders are commonly used for safety and other non-scientific purposes. These echosounders routinely record data which are rarely processed for later use, but which could provide interesting information about the seabed. In this work, we report on the use of a low-cost echosounder for bottom classification in five coastal rocky reefs of northern Argentine Patagonia. Underwater video transects were acquired over the same area as the acoustic data, in order to compare acoustic and visual classifications at or near the points where acoustic and video transects intersected (crossing sites). The reliability of these validation points decreases with the distance between the acoustic data points and the video transects as well as with the habitat heterogeneity as observed in the video. The shape of the depth-corrected acoustic echoes allowed easy discrimination between hard (or rocky) and soft (or muddy) bottoms by using a linear function as threshold optimized from a training set of crossing sites. The classification accuracy obtained using only validation points classified as most reliable was 96% (Cohen's kappa coefficient κ=0.88, indicating nearly perfect agreement). These results show that this low-cost methodology offers a suitable alternative to using scientific echosounders for mapping rocky-reef areas.

Key words: low-cost echosounder; sea bottom acoustic classification; rocky reefs; low-cost methodology

Introduction

The statistical analysis of acoustic data collected with scientific echosounders has become a standard approach for habitat classification since the 1980's (Anderson et al., 2008). A variety of scientific echosounders are used, ranging from the simplest and cheapest single-beam (tens of thousands of dollars) (Mamede et al., 2015; Rodríguez-Pérez et al., 2014, among others) to the sophisticated and expensive multibeam echosounders (up to hundreds of thousands of dollars) (Micallef et al., 2012; Sen et al., 2016, among others). All these scientific echousounders work in a similar way: sending an acoustic wave from a transducer and recording the signal when it returns from the bottom. The wide range of prices of the commercial products is due to the variability in the number and quality of the transducers mounted on the echosounders. The level of detail of the acquired information depends strongly on the transducer's central frequency, bandwidth, size, beamwidth and processing speed of the echosounder (Brown et al., 2011).

The same general scheme works for non-scientific echosounders, including the very low-cost ones (from around $1000) that are used in recreational boats, for navigation safety and as fish finders. These echosounders acquire the same acoustic intensity data as the scientific models, only with poorer signal-to-noise ratio and less stability of the acoustic signal. Moreover, low-cost echosunders have the relative advantage of recording the acoustic information usually in a simple file format. The number of recreational boats in the world seas is gigantic (for example, the USA has a fleet of more than 16 million boats (ANEN, 2009)), so information acquired by their low cost echosounders would represent a massive data source to tap into.

In this work we assess the use of acoustic data obtained with a very low-cost echosounder for seabed classification. As a first evaluation, and considering the high noise-to-signal ratio in these data, we only attempted to distinguish hard (rocky) versus soft (muddy) substrates. Our objective was to develop an accessible methodology for mapping rocky reefs, which are habitats of high scientific and conservation interest.
For this purpose, we collected acoustic data in a coastal area of Peninsula Valdés, in the Argentinian Patagonia, where small rocky outcrops emerge on a background habitat largely dominated by soft bottoms, providing shelter to a low-diversity assemblage of fishes, which are not found beyond a few meters from the reef holes and crevices (Irigoyen et al., 2011; Galván et al., 2009). These few species are quite popular for recreational divers and fishermen, thus it is very common to find boats equipped with low cost

echosounders around rocky reef areas.The acoustic data were used to classify bottom substrates and the resulting classification was validated using underwater video observations.

Material and Methods

Study area

The study was conducted in a shallow area of Golfo Nuevo, Península Valdés (Argentina) (Fig. 1) characterized by having a flat and featureless soft bottom occasionally interrupted by small, isolated rocky ledges that extend no longer than a few hundred meters harboring a distinctive benthic community (Irigoyen et al., 2011).

Five rocky reefs denoted as A-E (see Fig. 2 for their approximate location) were selected for this study. These reefs are straight breaks or ledges formed along the edge of submerged limestone platforms. Crumbled portions of the ledges determine both the width and structural complexity of the reef. The breaks along these reefs are up to 50 cm high and from 150 m to 400 m long.

Data collection

The acoustic survey was carried out on November 22nd 2013 from a 4.7 m long semi-rigid boat. Data were recorded with a Lowrance LCX-15MT echosounder working with a 200 kHz transducer, at maximum ping rate (a sound pulse emitted by the transducer) and with a depth range of twice the maximum expected depth; on average 6 pings were emitted per meter along the transect. The transducer was mounted on the boat stern at approximately 0.3 m below the water surface, using a portable mounting bracket and avoiding propeller turbulence, although this caused oscillations of the transducer due to boat's motion. GPS positions were recorded along with the acoustic signal. The boat speed was kept between 1 and 4 knots, ensuring the proper functioning of the echosounder and reducing the noise. Each reef was covered following a zig-zag boat track with the goal of collecting acoustic data along multiple transects running approximately perpendicular to the longitudinal reef axis and extending about 20 m on each side. The resulting coverage and transects' layout was variable among the reefs, and the separation between the transects at the points where they crossed the reefs ranged between 10 m and 50 m (see Fig. 2).

Underwater video transects, parallel to each reef's longitudinal axis, were recorded along both sides of the reef ledge using a low-cost drift camera system (Trobbiani et al., 2016). This approach ensured that the video transects crossed the acoustic transects at several points (i.e., crossing sites) along each reef. The video time was synchronized to the GPS time so that video observations could be later georeferenced and used in training and validation of the acoustic classification.

A total of 87 crossing sites were available for use as groundtruthing points. Acoustic data collected on reefs “A” and “B” (see Fig. 2) were homogeneously distributed along the reefs as the acoustic transects were regularly spaced perpendicularly to the reefs, covering a total length of 2500 m and crossing the video transects at 15 and 33 crossing sites, respectively (see Fig. 2); these reefs were the most densely covered. Reef “C” had acoustic transects distributed along the entire reef, but coverage was more scattered, with just 870 m of acoustic transects recorded and 12 crossing sites. Finally, the transects conducted on reefs “D” and “E” only covered portions of the reefs (with 560 m and 620 m of acoustic transect data, respectively) and intersected the video transects at 10 and 17 crossing sites, respectively (see Fig. 2).

The bottom type at each crossing site was identified by visual interpretation of the video image and classified as rocky or muddy bottom, the only two bottom types present in the study area according to divers (Irigoyen and Trobbiani, pers. obs.). The bottom identification was performed independently by two researchers, one of them an experienced diver in the area. Since acoustic data are not continuously recorded, but there is a distance between sequential pings (around 1.5 m in our data) that depends on ping rate and boat speed, the acoustic data point closest to each crossing site was used in the groundtruthing comparison. Thus, a reliability value (ψ) was assigned to each crossing site (from 1 to 3) taking into account the distance from the ping position to the closest video transect as well as the habitat heterogeneity in the surrounding area (Table 1).

Table 1. Reliability values as a function of the distance from the ping position to the closest video transect (Dist. A-V) and the level of habitat homogeneity

Reliability (ψ)	Dist. A-V	Habitat homogeneity
3	<1.5 m	High
2	<1.5 m	Low
2	>1.5 m	High
1	>1.5 m	Low

Preprocessing acoustic data

Echosounders usually store acoustic data in simple binary files, with a format specific to each commercial brand or even echosounder model. In the case of Lowrance LCX-15MT echosounders SLG, files are structured in data blocks, each block corresponding to a single echo (the acoustic response to a ping emitted by the echosounder). The analog echo intensity is sampled and encoded as integer numbers (LI_c), one for each sampling interval (bin). These numbers denote acoustic intensity in decibels (dB) relative to some undetermined intensity level, which is not required for comparative data analysis as in our case.

The GPS position is only available for some pings because ping rate is usually faster than the GPS update rate. Hence, we assigned to each echo the previous recorded GPS position.

Because of the spherical symmetry of the sound wave emitted by the transducer and the attenuation through the water column, the echo intensity depends on the distance travelled and must be corrected to remove depth effects (Biffard et al., 2005, 2010; Caughey & Kirlin, 1996; Pouliquen, 2004; Rodríguez-Pérez et al., 2014) (see Fig. 3). Complete correction was approximated in two steps: a power adjustment was applied as

$$\textbf{(1)}\quad LI_p = LI_c + 30 \cdot \log_{10} R + 2\alpha R \ ,$$

where R is the calculated range and α the acoustic absorption coefficient (calculated following Ainslie & McColm, 1998), followed by an echo stretching performed by expressing time *t* (measured from the ping emission) in dimensionless units as:

$$\textbf{(2)}\quad \tau = t/(2R/c) - 1 \ ,$$

such that every echo begins at $\tau = 0$ and ends at $\tau = 1$, c being the velocity of sound in sea water. Other accidental effects caused by the acquisition hardware, vessel motion, etc. cannot be corrected and the affected echoes must be ignored. This caused some transects to appear less densely populated with valid echoes than others.

Although the echosounder software records bottom depth together with the acoustic data, we recalculated the depth using the algorithm defined in Sánchez-Carnero et al. (2012) in order to avoid making assumptions about the sound speed used by the echosounder.

Finally, in order to smooth the spatial variability of the intensity inherent to acoustic methods, medians of sequential echoes were locally calculated (with a running window of

21 echoes). The resulting set of spatially smoothed intensities sLI_P were used to look for features in the echoes likely associated with the type of substrate.

Acoustic classification criterion

Although many factors determine the echo characteristics from a specific bottom type, in general terms rocky and other hard bottoms show higher backscattering intensity than muddy and other soft bottoms, and also a wider echo due to the unevenness of the scattering surface. This fact is more prominent at the echo tails, where the bottom insonification is oblique and more dependent on the substrate hardness than on other bottom features such as roughness or slope (Heald and Pace, 1996; Rodriguez-Perez et al. 2014). As a result, echo tails can be classified into two groups, the top one corresponding to hard bottoms and the one below to soft bottoms (see Fig. 3). Thus the echo tail was used to discriminate between the two substrate types by defining a linear threshold separating the two groups.

Examination of the smoothed echoes indicated that the interval between τ=0.1 and τ=0.3 displayed the most separation between the two groups (see Fig. 3). Thus, a linear function within that interval was used as the classification criterion such that for each of the (smoothed) echoes, the fraction η of the time that the echo lay above or below that linear function ($0 < \eta < 1$) defined whether the bottom substrate was classified as hard (η > 0.5) or soft (η <=0.5). The parameters of the line were optimized using a search algorithm so as to maximize the classification success of the echoes in a training dataset corresponding to 23 crossing sites (26%) randomly chosen from the ones with highest reliability (ψ = 3).

The resulting linear threshold (LI_{thr}) in the time-adjusted variable τ and, equivalently, in time-adjusted bins was:

(3) $LI_{\mathrm{thr}}\,[\mathrm{dB}] = 100 - 87\,\tau$ with τ in (0.1-0.3)

All processes were implemented as a set of Octave (http://www.gnu.org/software/octave/about.html) scripts available as supplementary data.

Validation

To assess the correspondence between the substrate types classified from the acoustic data and from video observations, a confusion matrix was computed using the remaining 64 crossing sites as validation points. In order to remove the effects of random coincidence, the Cohen's kappa (κ) coefficient (Cohen, 1960) was calculated from the diagonal and marginal (row and column) sums of the confusion matrix as

$$\textbf{(4)}\ \kappa = (p_0 - p_e)/(1 - p_e)\ ,$$

where p_0 is the observed coincidence (sum of relative frequencies in the diagonal of the confusion matrix) and p_e the expected random coincidence (sum of the products of the per-row and per-column marginal frequencies of the confusion matrix).
Validation was performed at three levels: including all validation points, only those with high and intermediate reliability (ψ = 2, 3) and only the most reliable points (ψ = 3).

Results

As is typically of the ledge reefs in our study area, the edge and top surface of the five reefs studied were characterized by hard substrate while the bottom surface bordering the ledges as well as the flat background area was dominated by soft substrates. Thus, the change in substrate type was often associated with a break in the bathymetry (Fig. 2). The two types of substrate however were not completely continuous but contained patches of the other substrate type as shown in Figure 2. They were clearly discerned in the video footage due to the marked contrast in the biota attached to the hard substrates and the two operators coincided in their visual classifications.

Of the 64 crossing sites used to validate substrate types classified from the acoustic data, 36 corresponded to muddy bottoms and 28 to rocky bottoms. Only two had the lowest reliability (ψ = 1) while the majority had either intermediate (38 points with ψ = 2) or high (24 points with ψ = 3) reliability. Using all these validation points, the accuracy of the acoustic classification was 83% (with a κ = 0.64, showing substantial agreement). The highest mismatch ratio was observed in reef C, with 33% of misclassified points, followed by reef A, with 23% of misclassified points. Reefs E and B showed less than 20% of misclassified points (14% and 17%, respectively). Finally, reef D showed 100% of its validation points correctly classified. When the least reliable validation points (ψ = 1) were removed, accuracy slightly increased to 84% (with a κ = 0.66, substantial agreement), reefs A and C again showing the worst agreement (no changes in the mismatch ratios). Using only the most reliable (ψ = 3) validation points, accuracy increased to 96% (with a κ = 0.88, nearly perfect agreement); only one point remained incorrectly classified in each reef C and E.

Discussion and conclusions

In this work we have presented a methodology that takes advantage of acoustic data obtained with a simple, low-cost non-scientific single-beam echosounder to classify the sea bottom substrate as rocky or muddy in order to map rocky-reef areas. The resulting classification showed a good agreement with the habitat type assigned by visual inspection of underwater videos: 83% accuracy, with a $\kappa = 0.64$, when using all available validation points (of varying levels of reliability), reaching a 96% accuracy ($\kappa = 0.88$) when only the most reliable validation points were used. This high classification success indicates that the data acquired with low-cost non-scientific echosounders contain useful information about bottom characteristics and the methodology presented offers a suitable option for mapping rocky reefs.

The potential of low-cost echosounders for mapping reef environments (coral reefs in those cases) had been noticed in a few published studies, which obtained accuracies of 61% (Moyer et al., 2005) or a κ of 0.56 (White et al., 2003) when classifying three bottom types, and 69% with seven bottom-type classes (Riegl & Purkis, 2005). The acoustic analysis in those cases was performed using QTC (Quester Tangent Maritime, Saanichton, British Columbia, Canada) or RoxAnn, both proprietary softwares which are the *de facto* standards for single-beam seabed classification.

Our results are comparable with those obtained using more expensive scientific echosounders. For example, Halley & Bruce (2007) working with a Simrad single-beam scientific echosounder (the most popular scientific echosounder), obtained $\kappa = 0.64$ and Che Hasan et al. (2012) obtained similar κ values (between 0.59–0.72) using multibeam echosounders. We should note however that most of these studies classified more than two bottom classes (and accuracy naturally decreases with the number of classes). Moreover, scientific echosounders are not only more expensive (acoustic equipment and specialized software) but, also in the case of multibeam ones, they require specialized personnel to operate them and data postprocessing is highly time consuming. By contrast, data acquired with fish-finders are simple enough to be processed automatically (as shown here) with a few free tools, allowing quick analysis and bottom classification without economical requirements.

The classification methodology presented in this paper shares some characteristics with methodologies widely used in commercial products. For example, it works with the first echo tail, like the RoxAnn's methodology (Voulgaris & Collins, 1990), although ours uses a morphological feature (the length of the echo above a threshold) instead of the total energy of the echo tail. Other classification methods also use features of the echo morphology (Freitas et al., 2011; van Walree et al., 2005) but they rely heavily on multivariate statistics while ours has a more direct physical interpretation.

The methodology presented here has been specifically tuned to differentiate between soft and hard bottoms for mapping rocky reefs in the study area. In this case we have not assessed different granulometries, e.g. differences between muddy and sandy bottoms, because there was no sand in our study area; a finer classification of substrates would probably require a second linear function with a different slope as backscattering is expected to be in intermediate between mud and rock.

In summary, the classification method presented in this paper exploits a simple shape feature of the echo tail that is informative about the substrate type. This has the advantage that the echo tail is where usual corrections (Eqs. (1) and (2)) are more exact (Lurton et al., 2002; Anderson et al., 2007), and the shape parameter we use (fraction of the time the echo lays above the threshold line) is robust with respect to unknowns about echosounder calibration.

Regarding the application of the acoustic method in our study area, the interest of this work is twofold. Firstly, it offers a non-invasive/non-destructive, extremely low-cost methodology to spatially map rocky reefs, which makes it accessible to any research group. Rocky reefs are focus areas for conservation due to their richness (in terms of biodiversity and biomass) and vulnerability to different anthropogenic pressures (Witman & Dayton, 2001; Sala Gamito et al., 2012).

The low technical requirements is a second strength of the method, making it adaptable to casual surveys carried out by non-specialists. Thus, there are potentially many users of boats equipped with low-cost echosounders, who could passively register acoustic data, and share them with researchers to make or improve substrate maps. These maps would be a first requirement to evaluate alternatives for monitoring and management of coastal environments (Bax & Williams, 2001; Hill et al., 2014; Sánchez-Carnero et al., 2016). There are already examples of thematic collaborative networks, such as the Reef Life Survey Program (www.reeflifesurvey.com), that enroll stakeholders to keep the cartography of coastal regions updated with minimum government investments.

Along these lines, there has been recently a call to develop low-cost and fast methodologies to advance our knowledge of marine ecosystems worldwide (Meyer et al., 2015; Lefcheck et al., 2016). Our low-cost and accessible methodology is consistent with these initiatives.

Acknowledgment

This work was partially supported by the Agencia Nacional de Promoción Científica y Tecnológica (ANPCyT) (grant number PICT 2012-0297).

ACCEPTED MANUSCRIPT

References

Ainslie, M. A., & McColm, J. G. (1998). A simplified formula for viscous and chemical absorption in sea water. *The Journal of the Acoustical Society of America*, *103*(3), 1671-1672.

Anderson, J. T., Holliday, V., Kloser, R., Reid, D., & Simard, Y. (2007).Acoustic seabed classification of marine physical and biological landscapes. *ICES Cooperative Research Report*, 286. 198 pp.

Anderson, J. T., Holliday, D. V., Kloser, R., Reid, D. G., & Simard, Y. (2008). Acoustic seabed classification: current practice and future directions. *ICES Journal of Marine Science*, *65*(6), 1004-1011.

Asociación Nacional de Empresas Náuticas ANEN. El sector Náutico en España. La Náutica Deportiva y de Recreo 2009. 29pp, 2009.

Bax, N. J., & Williams, A. (2001). Seabed habitat on the south-eastern Australian continental shelf: context, vulnerability and monitoring. *Marine and Freshwater Research*, *52*(4), 491-512.

Biffard, B. R., Chapman, N. R., Bloomer, S. F., & Preston, J. M. (2005). Single beam echosounding: Considerations of depth and seabed slope. *The Journal of the Acoustical Society of America*, *117*(4), 2442-2442.

Biffard, B. R., Bloomer, S. F., Chapman, N. R., & Preston, J. M. (2010, September). The role of echo duration in acoustic seabed classification and characterization. In *OCEANS 2010* (pp. 1-8). IEEE.

Brown, C. J., Smith, S. J., Lawton, P., & Anderson, J. T. (2011). Benthic habitat mapping: A review of progress towards improved understanding of the spatial ecology of the seafloor using acoustic techniques. *Estuarine, Coastal and Shelf Science*, *92*(3), 502-520.

Caughey, D.A., & Kirlin, R.L., (1996). Blind deconvolution of echosounder envelopes. In: IEEE International Conference on Acoustics, Speech, and Signal Processing, vol.6, pp. 3149–3152.

Che Hasan, C., Ierodiaconou, D., & Monk, J. (2012). Evaluation of four supervised learning methods for benthic habitat mapping using backscatter from multi-beam sonar. *Remote Sensing*, *4*(11), 3427-3443.

Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and psychological measurement*, *20*(1), 37-46.

Freitas, R., Ricardo, F., Pereira, F., Sampaio, L., Carvalho, S., Gaspar, M., ... & Rodrigues, A. M. (2011). Benthic habitat mapping: concerns using a combined approach (acoustic, sediment and biological data). *Estuarine, Coastal and Shelf Science*, *92*(4), 598-606.

Galván, D. E., Venerus, L. A., & Irigoyen, A. J. (2009). The reef-fish fauna of the northern Patagonian gulfs, Argentina, southwestern Atlantic. *The Open Fish Science Journal*, *2*(1), 90-98.

Halley, V., & Bruce, E. (2007). Thematic accuracy assessment of acoustic seabed data for shallow benthic habitat mapping. *International Journal of Environmental Studies*, *64*(1), 93-107.

Heald, G.J., & Pace, N.G., (1996). An analysis of first and second backscatter for seabed classification. In: Proceedings of 3rd European Conference on Underwater Acoustics.

Hill, N. A., Lucieer, V., Barrett, N. S., Anderson, T. J., & Williams, S. B. (2014). Filling the gaps: Predicting the distribution of temperate reef biota using high resolution biological and acoustic data. *Estuarine, Coastal and Shelf Science*, *147*, 137-147.

Irigoyen, A. J., Eyras, C., & Parma, A. M. (2011). Alien algae *Undaria pinnatifida* causes habitat loss for rocky reef fishes in north Patagonia. *Biological Invasions*, *13*(1), 17-24.

Lefcheck, J. S., Brandl, S. J., Reynolds, P. L., Smyth, A. R., & Meyer, S. T. (2016). Extending rapid ecosystem function assessments to marine ecosystems: a reply to Meyer. *Trends in ecology & evolution*, *31*(4), 251-253.

Lurton, X. (2002). An introduction to underwater acoustics: principles and applications. Springer Science & Business Media.

Mamede, R., Rodrigues, A. M., Freitas, R., & Quintino, V. (2015). Single-beam acoustic variability associated with seabed habitats. *Journal of Sea Research*, *100*, 152-159.

Meyer, S. T., Koch, C., & Weisser, W. W. (2015). Towards a standardized rapid ecosystem function assessment (REFA). *Trends in ecology & evolution*, *30*(7), 390-397.

Micallef, A., Le Bas, T. P., Huvenne, V. A., Blondel, P., Hühnerbach, V., & Deidun, A. (2012). A multi-method approach for benthic habitat mapping of shallow coastal areas with high-resolution multibeam data. *Continental Shelf Research*, *39*, 14-26.

Moyer, R. P., Riegl, B., Banks, K., & Dodge, R. E. (2005). Assessing the accuracy of acoustic seabed classification for mapping coral reef environments in South Florida (Broward County, USA). *Revista de Biologia Tropical*, *53*, 175-184.

Pouliquen, E. (2004, July). Depth dependence correction for normal incidence echosounding. In *Proceedings of the Seventh European Conference on Underwater Acoustics, ECUA*.

Riegl, B. M., & Purkis, S. J. (2005). Detection of shallow subtidal corals from IKONOS satellite and QTC View (50, 200 kHz) single-beam sonar data (Arabian Gulf; Dubai, UAE). *Remote Sensing of Environment*, *95*(1), 96-114.

Rodríguez-Pérez, D., Sánchez-Carnero, N., & Freire, J. (2014). A pulse-length correction to improve energy-based seabed classification in coastal areas. *Continental Shelf Research*, *77*, 1-13.

Sala Gamito, E., Ballesteros i Sagarra, E., Dendrinos, P., Di Franco, A., Ferretti, F., Foley, D., ... & Guidetti, P. (2012). The structure of Mediterranean rocky reef ecosystems across environmental and human gradients, and conservation implications. *PLoS One, 2012, vol. 7, num. 2, p. e32742*.

Sánchez-Carnero, N., Aceña, S., Rodríguez-Pérez, D., Couñago, E., Fraile, P., & Freire, J. (2012). Fast and low-cost method for VBES bathymetry generation in coastal areas. *Estuarine, Coastal and Shelf Science*, *114*, 175-182.

Sánchez-Carnero, N., Rodríguez-Pérez, D., Couñago, E., Le Barzik, F., & Freire, J. (2016). Species distribution models and local ecological knowledge in marine protected areas: The case of Os Miñarzos (Spain). *Ocean & Coastal Management*, *124*, 66-77.

Sen, A., Ondréas, H., Gaillot, A., Marcon, Y., Augustin, J. M., & Olu, K. (2016). The use of multibeam backscatter and bathymetry as a means of identifying faunal assemblages in a deep-sea cold seep. *Deep Sea Research Part I: Oceanographic Research Papers*, *110*, 33-49.

Trobbiani, G. A., & Irigoyen, A. J. (2016, June). " Pepe": a novel low cost drifting video system for underwater survey. In *Oceanic Engineering (SAISOE), IEEE/OES South American International Symposium on* (pp. 1-4). IEEE.

van Walree, P. A., Tęgowski, J., Laban, C., & Simons, D. G. (2005). Acoustic seafloor discrimination with echo shape parameters: A comparison with the ground truth. *Continental Shelf Research*, *25*(18), 2273-2293.

Voulgaris, G., & Collins, M. B. (1990). *USP RoxAnn ground discrimination system: a preliminary evaluation* (Vol. 5, p. 33pp). ARE Portland UTH Tech Memo 36/90. RE005314. University of Southampton, Department of Oceanography, Marine Consultancy Services, Technical Report No: SUDO/TEC/90.

White, W. H., Harborne, A. R., Sotheran, I. S., Walton, R., & Foster-Smith, R. L. (2003). Using an acoustic ground discrimination system to map coral reef benthic classes. *International Journal of Remote Sensing*, *24*(13), 2641-2660.

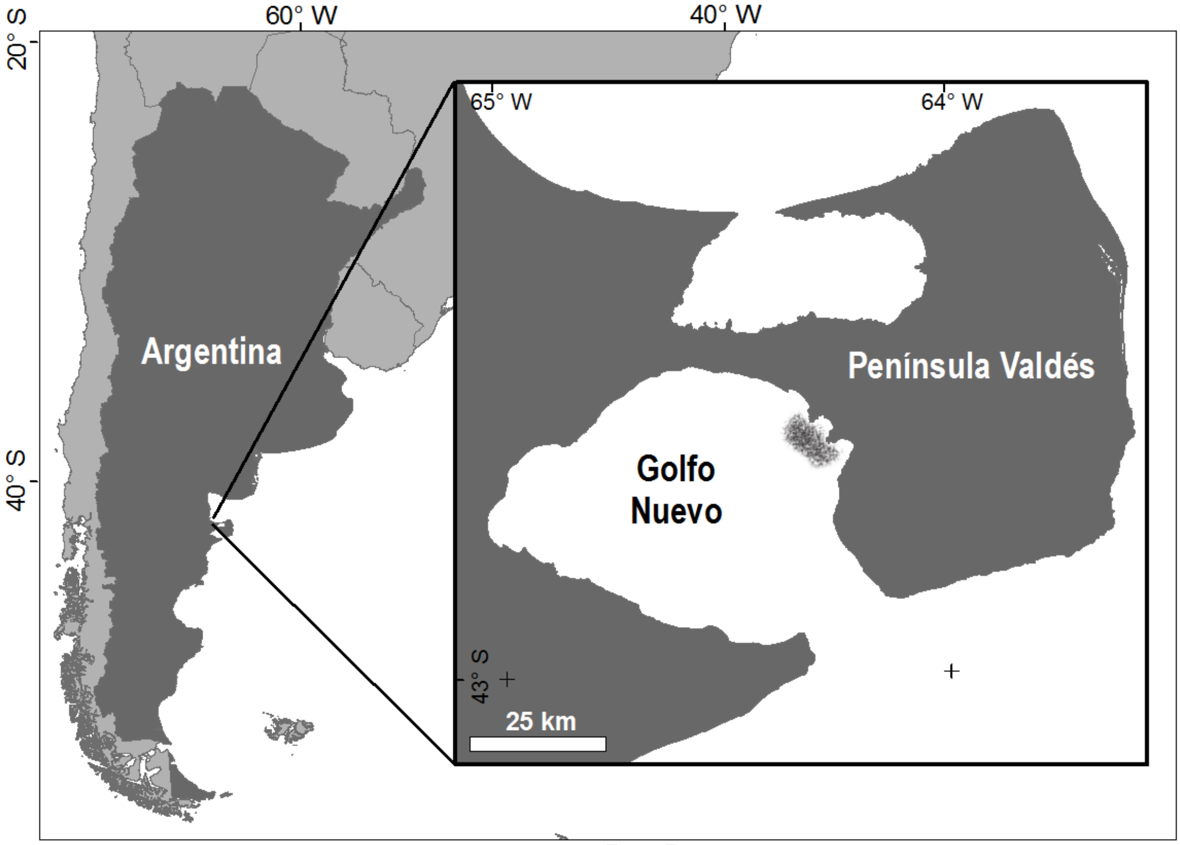
Witman, J. D., & Dayton, P. K. (2001). Rocky subtidal communities. *Marine community ecology*, 339-366.

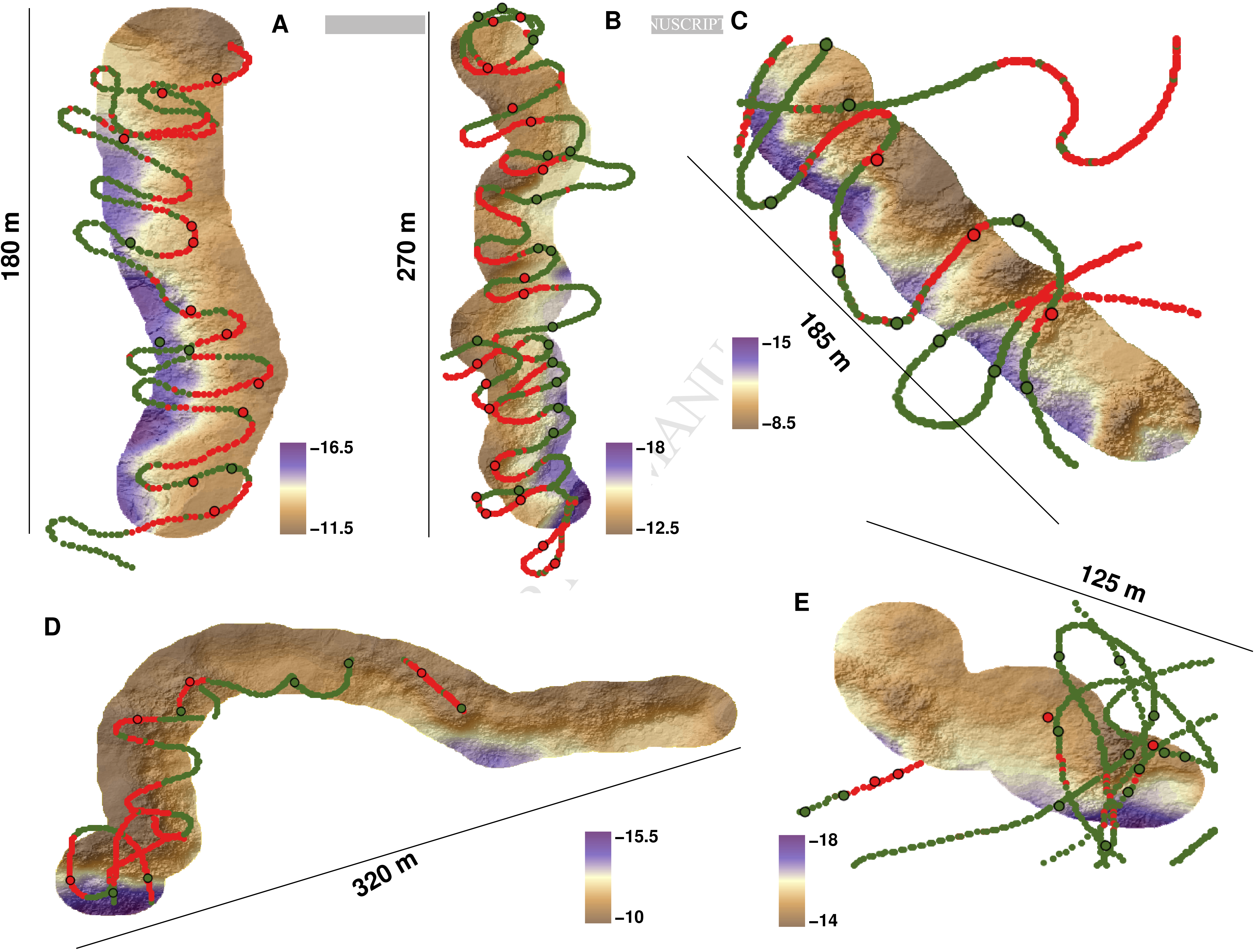
Figures

Figure 1: Study area in Golfo Nuevo (Península Valdés) showing the approximate location of the five rocky reefs (shaded area in the zoomed inset). The exact location of the reefs is not included in order to safeguard these vulnerable areas of fishing interest.

Figure 2: Classified acoustic data and validation points in rocky reefs A-E. The background images show the bathymetry of each reef (notice the differences in range among the reefs), to provide qualitative reference of the distribution of bottom classes with depth. The series of colored dots show the locations of spatially smoothed echoes used for acoustic classification; slightly larger colored points denote crossing points with the video transects used for validation, together with their classification into rocky (red) or muddy (green) substrate.

Figure 3: (A) Flow diagram of the methodology applied. Key steps of the process are shown graphically: (B) depth correction, removing depth dependency in the echoes; (C) median smoothing applied to the depth-corrected echoes to remove noise in the acoustic data; (D) acoustic threshold classification using a linear function.


60° W
40° W
20° S
40° S
Argentina
65° W
64° W
Península Valdés
Golfo
Nuevo
43° S
25 km


A
B
C
D
E
180 m
270 m
185 m
125 m
320 m
−16.5
−11.5
−18
−12.5
−15
−8.5
−15.5
−10
−18
−14


A
VIDEO ACQUISITION
ACOUSTIC DATA ACQUISITION
Extraction of video frames at the crossing points
Decoding acoustic data, GPS assignation to ping
Echo corrections
Bottom identification by two researchers
Bottom detection
Spatial median application
Validation set
Training set
Define acoustic classification criterion
Acoustic classification
Results validation
B
LI(dB)
Shallow echo
Deep echo
t(s)
Depth correction
Echo streching
0
τ
1
C
LI(dB)
0
τ
1
D
LI(dB)
Harder bottom
Softer bottom
0
τ
1

HIGHLIGHTS

Low-cost non-scientific fish-finders can provide information about bottom substrate

The tails of bottom echoes from rocky reef areas are different for hard and soft bottoms

Low-cost echosounders allowed classification of hard and soft bottoms with 96% accuracy