Use of Hydroacoustic Methods for the Identification of Potential Seabed Habitats for Small Pelagic Fish Schools in the Strait of Sicily

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Abstract

Contemporary data on both fish distribution and seabed characteristics can be used in ecological studies to investigate the distribution and the behaviour of both demersal and pelagic fish schools in relation to the nature of the sea bottom. In this study we describe a method to classify the sea bottom by a single-beam echosounder used during an echosurvey carried out on the north-western part of Southern Sicilian continental shelf. The study area was divided in two contiguous regions (labelled ZONE 1 and ZONE 2), characterized by different dominant texture, 'sand' for ZONE 1 and 'clayey-silt' for ZONE 2. The acoustic classification evidenced differences in terms of bottom types between the two investigated zones. Though the average bottom depth of the investigated transects is higher in ZONE 1, this area is dominated by substrates having greater backscatter, identifying relatively "harder" bottom types. On the contrary, in ZONE 2 "hard" substrate is confined to the shallower inter-transects regions, with the bulk of seabed deeper than 50 m classified as "soft" bottom. The acoustic classification of the seabed was already used in the context of a recent study, indicating a preference of small pelagic fish schools for soft bottom in ZONE 2, where their occurrence was higher and the bulk of total biomass was concentrated.

1 Introduction

A variety of remote hydroacoustic technologies, which employs a single or a multi-echo, are used to analyze and map seabed characters in term of texture and grain size [1, 2]. The most widespread commercial acoustic bottom classification systems are RoxAnn and QTC-View. They use normal incident echosounders and are based on the measurement, analysis and interpretation of the shape and energy features contained in the bottom acoustic signal [3, 4]. The knowledge of the bottom material and topography is very important in different scientific fields such as geology, offshore industry and fishery, mainly when the activity is focused on demersal fish. Over the last few decades there was a rapid increase in the use of hydroacoustic technologies also for schooling pelagic fish and for the biomass evaluation of pelagic fish populations [5, 6]. Echosounders commonly used to this aim work at fixed frequencies and are able to acquire information from both the fish distribution along the water column and the bottom seabed. Despite this, information from the sea bottom is usually discarded because the acoustic signal is used exclusively to obtain data about pelagic fish biomass and the structure of the fish schools, to the aims of the sustainable management of fisheries resources. However, the consensus that single species stock assessment alone is not sufficient to manage fisheries sustainably has been constantly increasing over the last two decades. Specifically, it has been argued the importance of the so-called ecosystem approach for the effective and sustainable management of fish populations [7, 8, 9, 10, 11]. For instance, the quality of scientific advice on exploited fish populations can be significantly improved by the knowledge of the effects of environmental conditions on the recruitment or fish populations. In this context, the contemporary collection of information on fish distribution and seabed characteristics could be greatly useful in multidisciplinary studies. To this aim, the use of a single beam echosounder was firstly investigated by D'Elia et al. [12], who also demonstrated the preference of small pelagic fish schools for softer (and finer) subtrates. In this study we describe the rationale of method therein used to classify the sea bottom by a single-beam echosounder (SIMRAD EK 500), based on the comparison between hydroacoustic bottom data and granulometric analysis of sediment samples.

2 Materials and methods

2.1 Study area and acoustic survey

Bottom acoustic information were obtained from hydro-acoustic survey conducted over the continental shelf of the Sicily Strait aboard the N/O Salvatore Lo Bianco in June 1998. The surveyed area was divided in two sectors, labeled 'ZONE 1' (north-western sector, over the Adventure Bank) and 'ZONE 2' (south-eastern sector, continental shelf off the central part of the Southern Sicilian coast) (Figure 1). These two sectors are characterized by different dominant seabed conditions, harder (and coarser) in ZONE 1, softer (and finer) in ZONE 2.

2.2 Backscattering signal by the seabed and bottom samples collection

The split-beam echosounder SIMRAD EK 500, originally designed for biological resources, was used to measure the backscattering signal from the seabed, using a transducer operating at the frequency of 38 kHz. The choice of this frequency is linked to its more frequent availability due to its common use in acoustic surveys aimed at biomass evaluations of small pelagic fish species. Raw data from the bottom (Sv) were analyzed using the post –processing software Echoview v.3 by Sonar Data and Matlab scripts. A GPS system, interfaced to the echosounder, was used to record the position of the bottom signal. The method of extracting bottom type information is based on the following considerations. First, there is a direct relationship between the mean diameter of the seabed material and bottom surface (and volume)

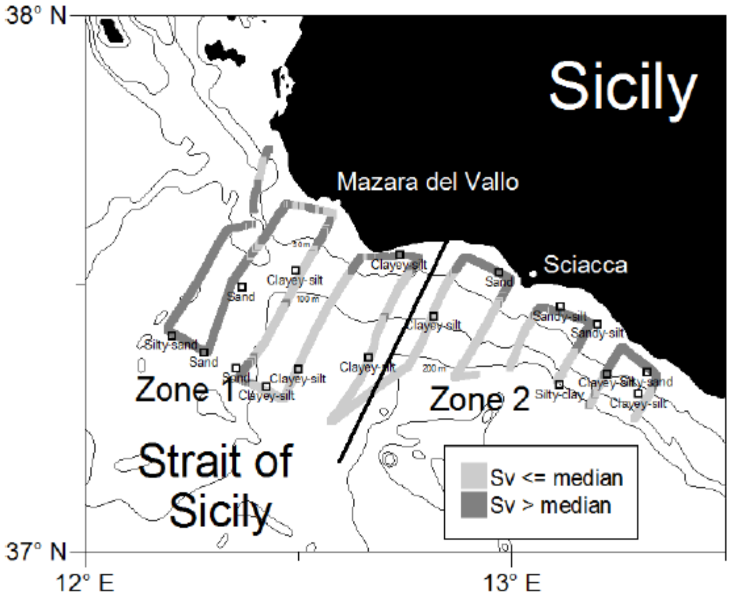

Figure 1: Study area, with Zone 1 (western sector) and Zone 2 (eastern sector) evidenced. Along the transects the acoustic classification of seabed based on bottom Sv is shown. "Hard" seabeds (Sv $>$ median value) is displayed in dark grey, "soft" seabeds (Sv $\leq$ median value) in light grey. The sediment sample sites are also shown with white. Shepard's and Folk's sediment classification labels are also given under the symbols.

backscattering value for normal incident echosounder [13]. It means that to a larger grain size corresponds a greater backscattering surface or volume coefficient. The reason for this is related to the bulk density of the sediment, which mainly depends on porosity. Clayey-silt and Silty-clay sediments have a higher porosity values than sand [14], so they bind more water and have lower density than sandy sediments. The bulk density is in relation to the acoustic impedance of a sediment: the higher sediment density, the higher acoustic impedance and the greater backscattering coefficient [15, 16]. The intensity of the energy scattered back to the instrument is also a function of the bottom roughness, due to the grain size of the particles. Gravel is rougher than sand which in turn is rougher than silt and clay [17]. Starting from this consideration, for each acoustic transect of Figure 1 the Sv volume backscattering values of the seabed line were extracted by means of Echoview software, using the maximum Sv algorithm. Then, a moving average to 50 terms (= acoustic pings), corresponding to about 200–250 m, was calculated to reduce variability in the Sv bottom values. The median value of these averaged Sv bottom data was used to classify the bottom type (0 for Sv bottom values $\leq$ median value, identifying 'soft' seabed areas, and 1 for Sv bottom value $>$ median value,

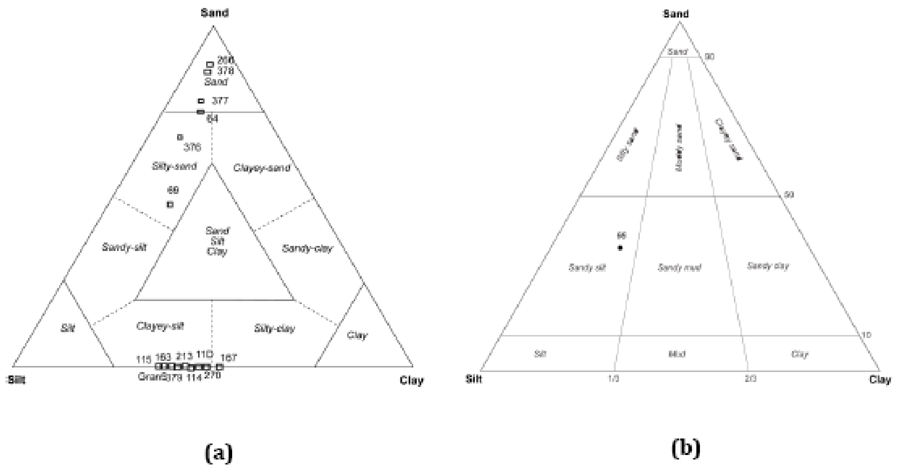

Figure 2: Shepard's (a) and Folk's (b) diagram, showing the classification into grain size for the analyzed samples.

identifying 'hard' seabed areas). In order to verify the results, physical sampling of the bottom was accomplished with grab and box-corer, in proximity of the acoustic prospected transects and a grain size analysis was conducted on the collected samples. The analysis of the particle size of sediment samples required a phase of sample pre-treatment, which included digestion with hydrogen peroxide, washing, separation of particles with a diameter lower than 500 µm and drying and subsequent analysis by a laser diffraction instrument (Fritsch model Analysette 22). The coarse sand-gravel fraction ($>$ 500 µm) was dried and divided in 2 fractions using a sieve with a 2 mm mesh size. Finally, the sieved particles were weighted by a simple balance. A final normalization process of the fraction, analyzed by the laser instrument, was necessary in order to obtain the correct compositional data. The analysis of particle size distribution were conducted using the Wentworth scale, and the classification into grain size class was based on the Shepard's method [18] for samples containing silt, clay and sand. The Folk's method [19] was used for the classification into grain size of sediment samples containing a fraction coarser than sand (diameter$>$2mm, little pebble or bioclastic granules).

3 Results and discussion

The results of the acoustic-based bottom type classification are displayed in Figure 1, together with information obtained from the analysis of sediment samples collected over all the investigated area. The acoustic classification shows the differences in terms of bottom types between the two zones along the investigated transects. ZONE 1 seabeds, at depth less than 100 m (the western sector, over the Adventure Bank) are dominated by substrates with greater scattering strength, indicating rela-

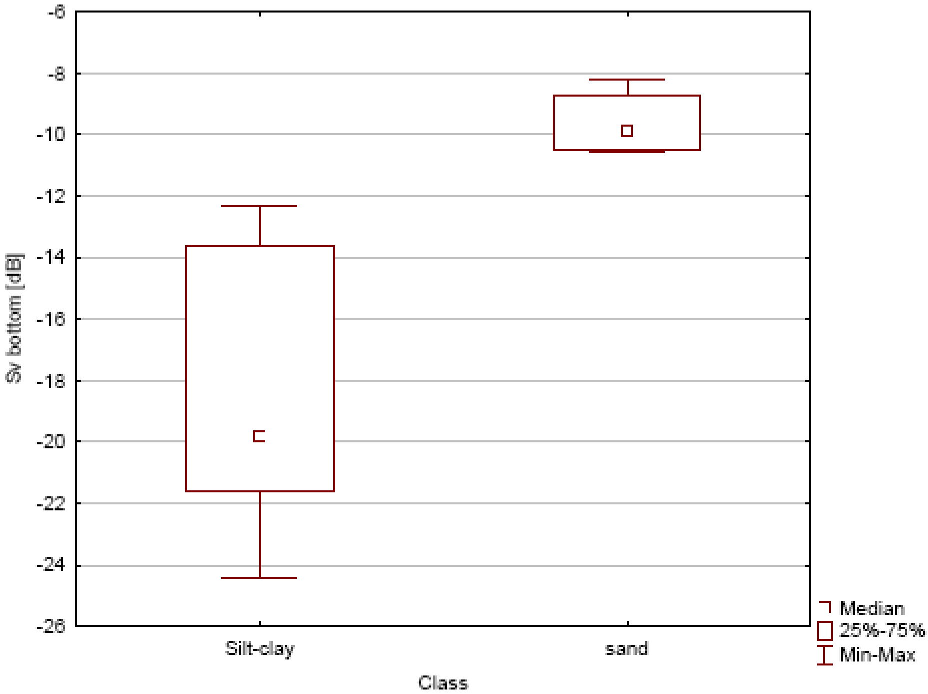

Figure 3: Box plots of bottom Sv for the sediment facies named "Silt-clay" (including sediment samples classified as clayey-silt) and "Sand" (including sediment samples classified as sandy-silt, silty-sand and sand).

tively 'harder' (and coarser) bottom types. In contrast, in ZONE 2 the 'hard' substrate is confined to the shallower inter-transect regions, with the bulk of the seabed deeper than 50 m classified as 'soft' bottom. The granulometric analysis of sediment samples is consistent with the results of the acoustic classification of the seabed (Figure 2 and Table 1). Although the sediment sample sites were available only in proximity of the acoustically prospected transects, it is worth noting that the use of the median value (-17.65 dB re m-1) of bottom backscattering volume strength permitted us to approximately separate finer (and softer) substrate locations (classified as clayey-silt and silty-clay), corresponding at bottom Sv values lower than the global median value, from coarser (and harder) sediment sites (facies: silty-sand, sandy-silt, and sand) matching with higher bottom Sv values (Mann–Whitney U-test, $p = 0.0055$; Figure 3). This paper highlights some important aspect in the application of echosounder data for seabed characterization. If the fisheries oriented instrument such as SIMRAD EK 500 echosounder is contemporarily used both for fisheries data and for bottom classification, its use in ecological studies could be very efficient and cost saving.

Table 1. Compositional data from the granulometric analysis of the collected samples.

Station	Latitude Nord (decimal)	Longitude East (decimal)	Depth (m)	% Clay	% Silt	% Sand	% Gravel	Grain size classification
114	37.33	13.22	57	46.1	53.9	0	0	Clayey-silt
163	37.44	12.82	96	38.8	61.2	0	0	Clayey-silt
270	37.36	12.66	186	49.4	50.6	0	0	Clayey-silt
11D	37.34	12.50	150	45.9	54.1	0	0	Clayey-silt
Gran5	37.55	12.74	29	34.5	52.2	13.5	0.0	Clayey-silt
379	37.31	12.43	136	42.1	57.9	0	0	Clayey-silt
213	37.53	12.49	96	40.8	58.7	0	0	Clayey-silt
63	37.55	12.90	28	42.7	57.3	0	0	Clayey-silt
66	37.46	13.11	28	18.0	47.0	17.2	17.4	Sandy-silt
376	37.40	12.20	68	9.2	19.8	71.0	0	Silty-sand
69	37.34	13.32	24	16.5	36.0	47.5	0	Silty-sand
377	37.37	12.28	73	7.0	17.0	76.0	0	Sand
64	37.52	12.97	30	8.0	17.0	75.0	0	Sand

Table 1: Compositional data from the granulometric analysis of the collected samples.

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