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Uncalibrated Multibeam Echosounder capabilities for fish schools measuring and tracking. An application in the nearby of an Adriatic offshore structure

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***Abstract* – This work aims to investigate the potential capabilities of an uncalibrated Multibeam Echosounder (MBES) in fish school detection, reporting an experience regarding an offshore gas platform in the Adriatic Sea. If, on one hand, the Split-beam Echosounder technology is traditionally used for the purpose of biomass evaluation, on the other hand, recent improvements in Multibeam Echosounder (MBES) technologies and advancing in water column data processing have made possible to detect schools and obtain some relevant metric information, with the advantage that a wide surrounding environment could be quickly surveyed. The possible results that can be obtained with this technology, strength points and weaknesses are presented in this paper. A reflection on other possible usages is given, and a replicable raw-data processing method for schools detection and their metric characterization is presented as well.**

I. INTRODUCTION

The MBES has been historically used with hydrographic purposes, such as submerged obstacle detection, bathymetry and seabed characterization (e. g. [1], [2], [3], [4]). Recently, technological advancements in MBES components and data elaboration have made possible to improve the use of MBES for biological target detection and tracking, and the extraction of some relevant metrics from the collected water column (cfr. [5], [6]). This upgrade allowed eco-biologists to start considering MBES as an attractive technology to be used in new oceanographic studies, to investigate fish behavior and provide additional valuable ecological information (e. g. [7], [8]).

Nevertheless, MBES calibration is a crucial point for the improvement of data quality [9], especially in fish school characterization, where the reference technology has been for long time, and currently it still is, split-beam Echosounder (e. g. [10], [11]).

Since these instruments are often expensive, it is reasonable to recycle such technologies to fully exploit them, taking into account their limitations and potentials. In this context, this research aims to repurpose a hydrographic MBES to investigate an offshore platform and its habitat, quantifying and characterizing at best fish school assemblages and considering expected species in such an environment. Capabilities and limitations of the uncalibrated MBES in fish schools' characterization and measuring are addressed, as well as issues tied to the structure itself (e.g. sound wave reflection and refraction on platforms' poles) and the planning of the survey (i.e. overestimation of the fish presence by detecting the same school more than one time).

Moreover, a replicable MBES survey and data processing is described, and assumptions on targets' classification are made considering expected species in such an environment.

Finally, ongoing research are shortly discussed as well as possibilities of MBES calibration and targets' classification by integrating ground truth information.

II. THE STUDY ZONE

The investigated structure is a three leg gas platform and one of the 130 structures (gas platforms, pipelines and wellheads) constructed in the Adriatic Sea since 1960s. The structure relies in the central Adriatic zone at a distance of 45 km from the coastline far away from Ancona (Marche region, Figure 1), at 76 m depth. It is currently unmanned and the composition of the seabed is mostly muddy. Some of these platforms, just like the one studied here, are subjected to a regular monitoring program with surveys planned and pursued by the CNR-IRBIM from the late 1990s, at monthly rate. The objective of these monitoring plans are multiple, one of all is, for example, the study of the ecological role of these structures on the fish assemblage (cfr. [12], [13]). In this paper, we did not considered a multiannual dataset from the selected platform, since the aim of this work was to explore the capabilities of the MBES analysis. Therefore, only one survey from the 30th of July 2019 was taken as example.

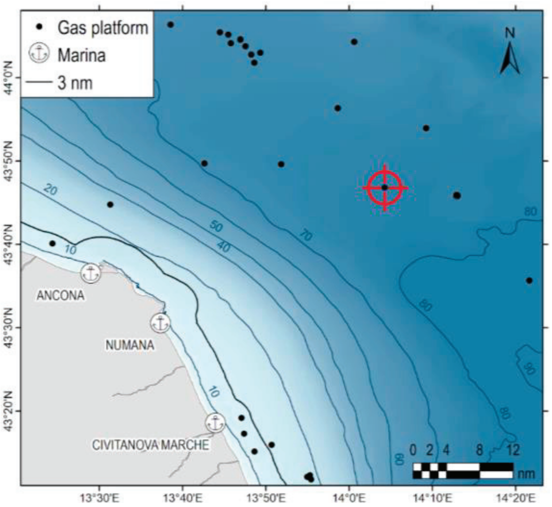


Fig. 1. Position of the investigated platform in the central Adriatic Sea.

III. MATERIALS AND METHODS

Data described here were recorded using a Multibeam Echosounder Simrad Kongsberg EM2040CD. Subsequently, schools were individuated, purged from noise, extracted and measured using Echoview software (Echoview Software Pty Ltd, Hobart, Australia).

For this survey a frequency value of 300 kHz was used, data were recorded on 10 parallel lines (in N-S direction), and Multibeam heads were opened of 80° and 10° outward and inward respectively in order to obtain an almost complete covering for each line (about 150 m width). A total squared area of side 1.5 km and centred on the platform was examined. Before starting the survey, a sound velocity vertical profile was created and integrated into the Seafloor Information System software (SIS, Kongsberg) used to monitor data in real time during their acquisition. A *medium* filter was applied directly while acquiring, since no exceptional peaks or pits were expected on the seabed.

Once data were acquired, a bathymetric map of the sounded zone was extracted and elaborated from the raw data using CARIS software (Teledyne, Canada), while Echoview was used to extract fish schools.

In Echoview Software, two paired lines at a time were examined, and the following semi-automated procedure step by step was applied:

- calculation of Maximum Intensity function for both the heads: this allows to evidence in a 2D echogram where echoes are stronger;
- visual combined examination of echograms coming from the two heads and the Maximum Intensity diagram in order to isolate ping subset where a school is supposed to be located;
- examination of the ping subsets with eventual use of specific filters to cut out noise;
- automated detection of the schools by setting thresholds on schools' dimensions: a spherical minimum target of radius 0.8 m was used;
- visualization of extracted schools on a 3D scene, pruning, basing on shapes, of eventual noise, and extraction of metric variables;
- masking of the ping subset over the identified school and export of each school as 3D point file.

After the extraction of all sounded schools, their position and metrics were visually examined to individuate possible duplicates of the same school, moving during the survey. These duplicates were selected to be inserted in a unique track. Some recent technological advancements on data elaboration allow the tracking of a moving school (called "region") by means of tracking of its mass or geometrical center. In this work the Echoview tool called "3D Region Track" was used, allowing to identify the same school while it was moving.

For each aggregation three elements were considered:

1. position with respect to the center of mass or the geometric center of the region;
2. date/time: mean between a valid start and end time for all pings detecting the 3D region;
3. volume of the 3D region;
4. intensity of the signal: mean of S_v on the 3D region.

Moreover, for the track individuation it is necessary to define: a certain confidence level on position and velocity prediction using two separate constant value parameters that range from 0 (totally unconfident) and 1 (totally confident), and a maximum distance after which the regions are no more considered to be inserted in the same track.

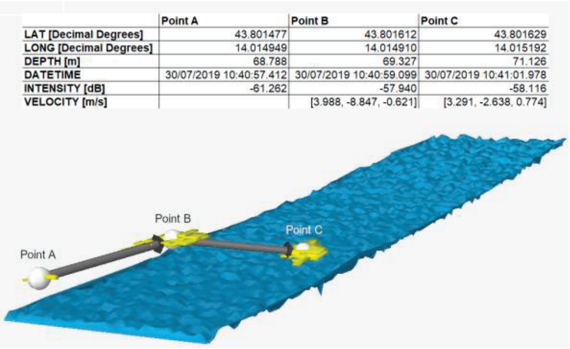
Once tracks were identified, extracted schools were pruned from the duplicates belonging to the same track, and only the last position (the last aggregation) individuated in the schools' group was kept.

The last step of our method implies 3D visualization of the extracted schools. Since MBES is able to capture not only specific targets but also the surrounding environment, from the same survey a 3D points' file of the platform structure was obtained. Platforms' points were imported along with the schools' points and the bathymetric surface in Fledermaus software (QPS, Netherlands) in order to visualize schools' shape, depth, and relative position respect to the platform.

IV. RESULTS AND DISCUSSION

The 30th of July 2019 we started recording data at 10:40 AM (UTC) and we completed the recognition at 12:10 AM (UTC).

After the elaboration of raw data using Echoview software, three schools were automatically individuated as a unique moving school, or track (Figure 2). Position, date-time, recorded intensity (S_v), and velocity were reported for each point composing the track. The last point of the track (Point C) corresponds to the aggregation no. 1, whose position is reported in Figure 3, and metrics in Table 1. The final total number of sounded schools is 13, and their spatial distribution is reported in Figure 3.



	Point A	Point B	Point C
LAT [Decimal Degrees]	43.801477	43.801612	43.801629
LONG [Decimal Degrees]	14.014949	14.014910	14.015192
DEPTH [m]	68.788	69.327	71.126
DATETIME	30/07/2019 10:40:57.412	30/07/2019 10:40:59.099	30/07/2019 10:41:01.978
INTENSITY [dB]	-61.262	-57.940	-58.116
VELOCITY [m/s]		[3.988, -8.847, -0.621]	[3.291, -2.638, 0.774]

Fig. 2. 3D track visualization in Echoview: schools are in yellow and connecting vectors (with direction) are in grey. The last position of the track is identified by the point C. The table reports the position, time, backscatter intensity, and estimated velocity of the 3 involved schools.

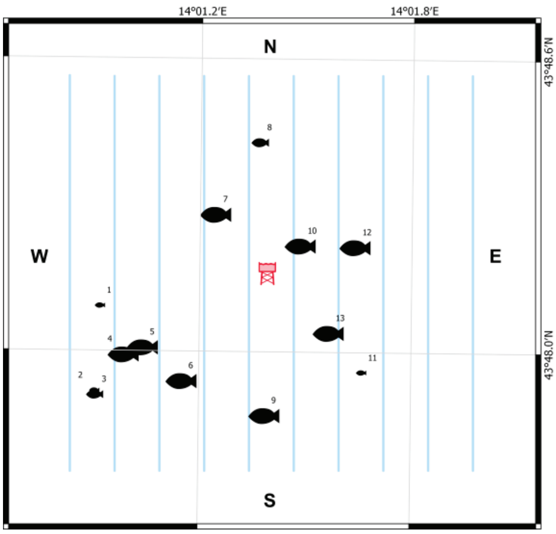


Fig. 3. Position of fish aggregations observed during the survey of the 30th of July 2019. Dimensions of markers is proportional to schools' volume.

From the 3D visualization of the schools in Fledermaus, reported in Figure 4, it is possible to perceive the shape and dimension of the sounded aggregations. Bathymetric map of the entire sounded zone and the point cloud relative to the platforms' structure are also visible.

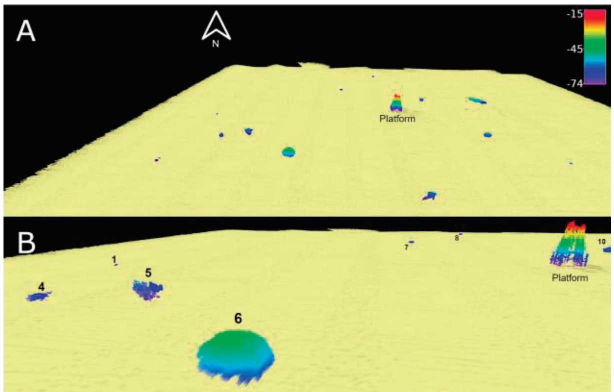


Fig. 4. Fledermaus 3D overview of extracted schools distribution around the gas platform (A), and a close up view of aggregation no. 6, located in the South-West portion of the investigated zone (B).

Detected schools had medium-big dimensions, with mean surface value of 1872.77 m^2 and a mean volume of 1501.62 m^3 (Table 1). Nearly all the schools were recorded in the first 20 m from the seabed, at a mean depth of 63.99 m, which is in line with some fish species expected to populate this geographical zone.

In particular, in the nearby of the platform, it is expected to sound pelagic species like *Trachurus trachurus* or *Boops boops*, tending to aggregate in medium-big schools with relevant height in the surrounding of the platform. It is also expected to encounter nekton-benthic species like *Trisopterus minutus capelanus* and *Pagellus spp* tending to aggregate in small size schools, located in the proximity of the seabed. All these species show a certain affinity and attraction level towards the platform environment (e. g. [14], [12]).

Several studies have attempted to quantify the attractive effect exerted by offshore platforms towards different finfish species, demonstrating as well the tendency of fish to migrate up and downward from the bottom (during the day) to the surface (during the night) of the water column (e. g. [15], [16], [17]).

Table 1. Metrics of extracted schools.

School	Surface (m^2)	Length NS (m)	Length EW (m)	Minimum Depth (m)	Maximum Depth (m)	Height (m)	Volume (m^3)	Geometrical center LAT	Geometrical center LONG	Geometrical center Depth (m)	Roughness (m^{-1})	n. of vacuoles	Tot. V of vacuoles (m^3)
1	53.50	3.46	3.74	65.30	66.93	1.63	12.12	43.796528	14.016786	66.10	4.40	0	0.00
2	408.75	5.59	10.74	45.31	51.38	6.07	158.70	43.808704	14.020122	48.28	2.29	0	0.00
3	1985.21	22.70	16.46	59.48	68.49	9.01	916.72	43.799005	14.022165	64.20	2.15	3	1.85
4	219.70	11.52	8.25	63.53	66.56	3.03	71.23	43.805000	14.026000	65.08	3.08	0	0.00
5	31.32	3.33	5.33	64.39	66.08	1.69	6.20	43.802219	14.028040	65.20	5.05	0	0.00

Table 1. Continuation.

6	584.88	11.29	13.14	59.65	68.69	9.04	330.90	43.803848	14.027231	63.94	1.77	1	0.30
7	1257.82	13.88	15.49	51.89	62.21	10.31	449.53	43.801276	14.028350	57.41	2.80	1	0.21
8	868.93	13.68	13.52	64.72	73.31	8.60	377.34	43.803109	14.025806	69.35	2.30	0	0.00
9	341.89	9.29	10.48	67.38	74.30	6.92	187.38	43.807115	14.028465	71.17	1.83	0	0.00
10	497.81	14.84	19.54	72.33	75.44	3.11	218.84	43.799789	14.029831	74.24	2.28	0	0.00
11	549.21	22.74	16.84	63.78	69.11	5.33	212.60	43.806810	14.031537	66.16	2.58	1	0.46
12	169.24	6.66	22.79	72.86	76.09	3.23	49.18	43.797269	14.031685	74.60	3.44	0	0.00
13	66.37	5.40	6.00	49.95	52.67	2.72	18.67	43.799312	14.031776	51.27	3.56	0	0.00

A broader reflection could be done regarding the recorded values of backscatter strength.

Depending on the dimensions of the sounded object, and its position respect the source of the sound wave, it is possible to face two possible situations, showed in Figure 5: if metrics of schools exceeds beam width, the volume target backscattering strength (S_v, expressed in dB re 1 m^2/m^3) must be used, conversely, if the metrics of the target are considerably smaller than the inspected volume, the reference parameter is the point target backscatter strength (*TS*, expressed in dB re 1 m^2).

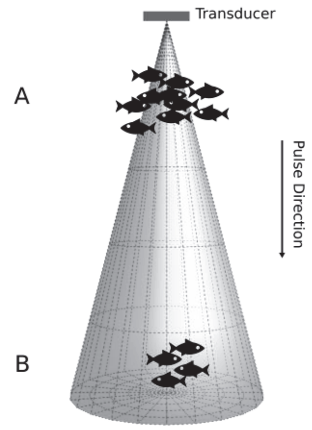


Fig. 5. Volume (A) and point (B) target typical situations.

Due to the fact that our schools, taking account of maximum investigation depth, were generally bigger than the beam width (the base of the cone delimiting the beam had a diameter of about 0.48 m), the case encountered was always a volume target situation and, for our investigations, the S_v parameter was considered. Moreover our Multibeam is not calibrated, so the S_v values must be intended ad S_v uncalibrated values (S_{vu}) and all the measurements strictly related to this variable (e.g. fish school density), cannot be taken in consideration. On the other hand, it is possible to evaluate the presence/absence of the aggregation in the water column, and measure with a high degree of confidence metric parameters such as area, volume, lengths along main directions (cfr. [18], [19], [20]).

For what concerns a raw evaluation of fish schools' density, even if the S_{vu} values are not reliable, the number of vacuoles can still provide an insight of it, and it is possible to observe from Table 1 that, unless schools no. 6 and 12, there were no or few vacuoles in the sounded aggregations.

S_v values also play a role in tracking individuation: in this specific case, it can be noted that the proposed method performs a comparative observation between schools (Figure 3), so, even if S_v values cannot be trusted as a whole, the comparison of uncalibrated S_v (S_{vu}) values is still reasonable.

V. CONCLUSIONS AND PERSPECTIVES

In this paper we tried to understand what we can and what we cannot do with an uncalibrated MBES in the field of fish school identification and mass evaluation, fish species identification, and schools tracking.

First of all, the metrics of extracted fish schools were perfectly reasonable, since they scarcely depend on the intensity of received signal (S_v), so it is reasonable to advance hypotheses on fish aggregations presence, dimensions, and their position basing on the acquired data. For what concerns mass evaluation, at the present time, the operation is not allowed since sound intensity values are untrustworthy. Similarly, due to the MBES geometry and functioning, it is not possible to perform the single fish tracking inside an aggregation because the point targets composing the aggregations cannot be individually isolated [21]. However, tracking a school as an entire region can easily overcome the issue of considering more times the same aggregation during the survey. Moreover, the MBES itself does not allow species identification, due to the high number of parameters required, or rather, information we can achieve, also from a calibrated MBES is always limited to the shape or particular feature of the specie (e. g swim bladder). So, fish species identification could be quantified with major precision by integrated methods involving more than one technology at a time (cfr. [22], [23], [24]).

Undoubtedly, the calibration of our instrument could be useful in order to advance in interesting tasks still under discussion in the scientific community as the ones mentioned before [9]. Calibration can be done separately for each component of the Multibeam system, knowing the exact efficiency of each component, or the sounder can be calibrated as a unique tool. A very complete review of protocols for standard-target Multibeam calibration is given in [21]. At present, we are planning the calibration of our Multibeam using a standard-target field method in comparison with data coming from a split-beam SBES.

However, the results that we have obtained from our survey are still usable to formulate hypotheses as they gave some interesting information about aggregations and fish behavior.

This information, integrated with those obtained through other sampling methods (e.g, videocameras, catch sampling) could be useful for deployment, maintenance and decommissioning operations of oil and gas platforms, or the monitoring of artificial reefs: fishes often find in these structures shelter and food, and their beneficial effect on aquatic life is evident (e. g. [25], [26], [27]). For what concerns studies on fish aggregations' concentration on natural reefs then, the application on MBES techniques could represent a completely non-invasive approach, useful to preserve natural marine resources. The same workflow and investigation could be applied to artificial reefs as well, if the purpose of the structures is the conservation and repopulation of some fish species.

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