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# IN-FIELD SETUP TO STUDY THE EFFECTS OF UNDERWATER NOISE ON MARINE FOULING COMUNITY

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## Abstract

Maritime traffic represents a growing cause of underwater acoustic pollution. Laboratory studies on noise impacts benefit from tightly controlled conditions, making it possible to reliably compare organisms exposed to sound with those kept in near-silent environments. By contrast, field-based experiments are often complex, particularly in confined and shallow systems such as the Venetian Lagoon, where preliminary surveys have revealed widespread background noise and a lack of quiet reference areas suitable for biological comparisons. Here we describe an experimental setup designed to evaluate the influence of noise on marine fouling communities. Two prototype structures (50×50×80 cm) were assembled: one made of stainless steel (internally lined with polyurethane) and the other of black nylon. Their capacity to attenuate a synthetic sound signal, generated by a submerged loudspeaker positioned 1 m from a hydrophone, was then assessed. Results indicated that the coated steel structure reduced sound levels by approximately 27 dB, while the nylon one achieved a reduction of about 11 dB. Based on these findings, we plan to build replicas incorporating a plexiglass panel (25×25 cm) to support fouling settlement and development. This system will enable comparative biological studies among environments with different levels of noise pollution.

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## 1. Introduction

Among the numerous threats to marine biodiversity conservation, anthropogenic underwater noise remains one of the least investigated While research on vertebrates has expanded over the past 25 years [1], the effects of acoustic pollution on invertebrates, the dominant components of marine ecosystems are still poorly understood [2]. In the context of achieving Good Environmental Status (GES), anthropogenic noise has been identified as an emerging pollutant within the European Union Directive 2008/56/EC (Marine Strategy Framework Directive, Descriptor 11) [3]. The overlap between human-generated and natural sound frequencies, known as masking, interferes with animal ability to communicate, orient, and detect prey. Furthermore, noise can adversely affect behavior, metabolism, physiology, development, and reproduction [4]. Most existing studies are conducted under laboratory conditions rather than in natural environments. Laboratory experiments are essential because they allow direct comparisons between organisms exposed to noise and those maintained under nearly silent (control) conditions. They also permit the application of advanced techniques such as Transmission Electron Microscopy, Magnetic Resonance Imaging, electrophysiological measurements of auditory responses, respirometry for metabolic assessment, and cellular or molecular analyses to evaluate stress responses [2]. Nevertheless, findings obtained in controlled settings cannot be fully transferred to real-world ecosystems. Field studies on invertebrates are limited by the smaller range of measurable parameters and often rely on artificial noise sources, such as air guns used in seismic exploration, while investigations focused on maritime traffic noise are still scarce [2]. To better understand the effects of ship-generated noise, some researchers have examined the settlement of biofouling organisms on vessel hulls, assessing whether spatial variations in acoustic emissions influence colonization patterns and overall fouling extent [5]. These studies highlight both the difficulty of conducting field research—especially when comparisons between exposed and unexposed organisms are required—and the need to broaden *in situ* investigations of soundscape impacts on ecosystems. Shallow and enclosed basins present challenges, as shown by preliminary soundscape measurements in the Lagoon of Venice (Italy), which revealed pervasive noise largely due to vessel traffic and the absence of silent control sites. As noted by Slabbekoorn and collaborators [6], echoing Rachel Carson's concept of a "silent spring," modern ecosystems may instead be experiencing a "noisy spring," where true acoustic quietness is increasingly rare. To address the lack of natural control conditions, we aimed to design an experimental system capable of generating relatively "silent" environments directly in the field, shielded from maritime noise. We developed submerged prototype structures coated with materials possessing different sound-insulating properties and evaluated their performance in areas affected by intense human activity. Preliminary results indicate that these prototypes differ in their capacity to attenuate both environmental noise and artificially generated sounds. Therefore, they represent a promising tool for investigating how noise influences the colonization and physiology of fouling organisms.

## 2. Materials and methods

### *2.1 Features of the box prototypes*

Two box-shaped prototypes were constructed as parallelepipeds with square bases (50 cm × 50 cm × 80 cm), made of nylon and steel to exploit their distinct acoustic characteristics (fig. 1). Each structure consisted of a frame of stainless-steel rods (inox 304), to which either a double 0.05 mm black nylon (polyethylene) layer or 1 mm thick stainless-steel sheets were attached. The nylon covering was black to replicate the dark internal conditions of the steel box. Inside the steel structure, 3 cm thick sound-absorbing polyurethane panels were installed. Both boxes were open at the bottom to allow seawater exchange. At the top, each box featured a small circular opening (1 cm diameter) sealed with a plug, enabling the passage of a hydrophone cable for acoustic measurements. These openings also allowed air to escape during immersion and permitted the insertion of probes to monitor physicochemical parameters inside the structures. Suspension cables were attached at the top for anchoring to a pier, while additional cables at the base held weights to ensure stability. A hook fixed to the roof supported the hydrophone and, in future experiments, panels used for fouling studies.

**Fig.1.** Prototype of the nylon (left) and steel (right) boxes used in the reported experiments, seen from the bottom side.

### *2.2 Site selection for comparative measurements*

For our comparative analysis we selected the Darsena Le Saline (Isola Morin, 2, 30015 Chioggia VE VE45°13'30.3"N 12°16'42.8"E), an area characterized by intense maritime activity (Fig. 2). This site serves as a marina for private leisure boats and is located near the southern inlet connecting the Adriatic Sea to the lagoon. Commercial and cruise vessels regularly pass through this entrance en route to the port of Chioggia, and the area is also continuously affected by public transport boats (vaporetti).


**Figure 2. A.** Venice Lagoon. Red square: city of Chioggia. **B.** Measurement site at the Darsena Le Saline (Chioggia, Italy) (red square) **1**: City of Chioggia; **2:** Port of Chioggia; **3:** Southern harbor mouth.

### *2.3 In field measurements of box acoustic properties*

Acoustic testing of the prototypes was conducted in April 2024, a period typically marked by high tourist traffic. The boxes were suspended from a pier and submerged so that the hydrophone (Aquarian Scientific AS-1) positioned inside each structure was at a depth of 1 m. A custom underwater loudspeaker (AKUASOUND akuad_16) was placed 1 m away from the hydrophone at the same depth (Fig. 3). The sound insulation performance of each box was evaluated by recording noise levels with the hydrophone placed inside the structures while the loudspeaker emitted signals at three different intensities (Table 1). For comparison, measurements were also taken with the hydrophone outside the boxes, maintaining the same depth and distance from the sound source. Background lagoon noise was recorded with the loudspeaker turned off.

## 3. Results

A summary of the measurements collected during the field campaign is presented in Table 1. Background noise levels remained relatively constant at approximately 108 dB. Across all tested intensities, the steel prototype consistently demonstrated greater sound attenuation than the nylon one. The internal noise difference between the two structures was about 16 dB, with minor variations attributable to fluctuations in environment conditions. The superior performance of the steel box is due not only to the intrinsic shielding properties of steel but also to its higher reflectivity and the presence of the polyurethane lining. The experimental tests employed sound levels (approximately 144–158 dB) significantly higher than environmental noise (108 dB), allowing the reduction of interference from external sources such as passing boats during measurements.

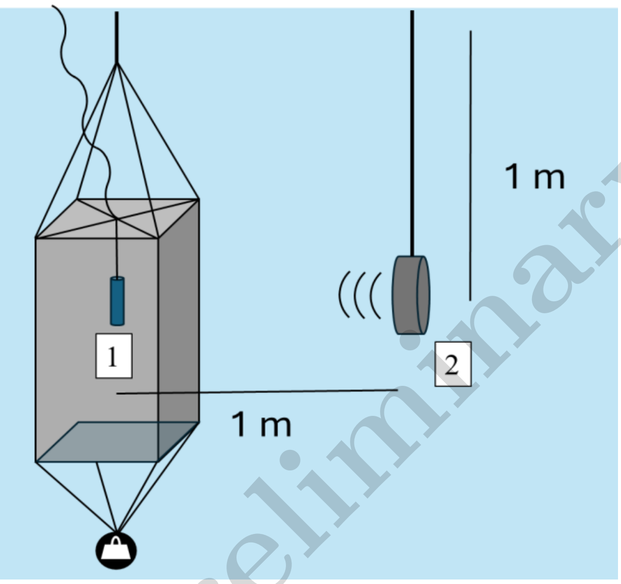


**Figure 3.** Experimental setup for measuring the acoustic properties of the prototype boxes. **1:** Hydrophone; **2:** Loudspeaker.

## 4. Discussion and conclusions

Our results show that the two prototypes can decrease noise levels by roughly 27 dB (steel) and 11 dB (nylon), confirming their effectiveness in creating distinct acoustic conditions directly in the marine environment. This makes them suitable for field experiments aimed at assessing the impact of sound on marine organisms. Both structures ensure comparable internal darkness, a key factor influencing the settlement and growth of many species. Future work will investigate how noise affects the ability of biofouling larvae to attach to substrates placed within the boxes. This is particularly relevant for species such as ascidians—dominant components of fouling communities in the Venetian Lagoon [7]—whose larvae preferentially settle in low-light conditions [8]. We also intend to examine noise-induced changes in gene expression in the colonial ascidian *Botryllus schlosseri* by placing colony replicates inside the structures. Although the boxes are positioned beneath a pier and therefore receive limited sunlight, reducing the risk of water heating, continuous monitoring of seawater physicochemical parameters will be necessary to ensure that differences between treatments are attributable solely to acoustic conditions. The open-bottom design allows adequate water circulation, while the depth of the structures ensures effective sound attenuation, particularly in the coated steel prototype. In summary, structures with varying sound insulation and absorption capacities provide an innovative approach for conducting comparative studies on noise pollution in marine environments where background noise is pervasive.

**Table 1.** Underwater noise levels, expressed as equivalent continuous sound pressure level (Leq), measured in different conditions. The "Control" refers to the noise level measured when the hydrophone was outside the box and loudspeaker on. Bgd: Background; Ny: Nylon.

| Hydroph. position | Leq | | |
|---|---|---|---|
| Control | 144,70 | 151,97 | 157,29 |
| Ny | 133,48 | 141,53 | 145,72 |
| Steel | 117,82 | 124,56 | 129,39 |
| Bgd noise | 107,85 | 107,85 | 107,85 |
| \|Pure\| differences | | | |
| Ctrl-Ny | 11,22 | 10,44 | 11,57 |
| Ctl-Steel | 26,88 | 27,41 | 27,9 |
| Ctrl-Bgd | 36,85 | 44,12 | 49,44 |
| Ny-Steel | 15,66 | 16,97 | 16,33 |
| Nylon-Bgd | 25,63 | 33,68 | 37,87 |
| Steel-Bgd | 9,97 | 16,71 | 21,54 |

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