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EXPERIMENTAL SETUP FOR THE IN-FIELD ASSESSMENT OF UNDERWATER NOISE EFFECTS ON MARINE FOULING

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ABSTRACT

Maritime traffic is an increasing source of underwater noise. The in-lab study of noise effects takes advantage of controlled environmental conditions, allowing robust comparisons between noise-treated animals and organisms maintained in condition of silence. *Vice versa*, in-field experiments can be a challenge, especially in close and shallow basins, such as the Venetian Lagoon, where preliminary measurements showed a diffuse underwater noise and the absence of silent places useful for comparative biological studies. We present here a setup aimed at the study of noise impact on marine fouling. We built two prototype structures (50x50x80cm): one in stainless steel (with a polyurethane inner coating), the other in black nylon. We then tested, using a hydrophone located inside each structure, their ability to reduce the propagation of a synthetic noise produced by an immersed loudspeaker 1 m far from the hydrophone. Measurements showed that the steel coated structure reduced the noise of about 27 dB, whereas the nylon structure of about 11 dB. Based on these analyses, we will build replicas of these structures where we will insert a plexiglass panel (25x25 cm) as support for fouling attachment and growth. This setup will allow comparative biological analyses between noise polluted and less polluted environments.

Keywords: *box prototype, in-field measurement, Lagoon of Venice, maritime noise insulation.*

1. INTRODUCTION

Among the many factors of risk for the conservation of marine biodiversity, the underwater noise of anthropic origin is one the most underestimated. In fact, whereas studies on vertebrate species increased in the last 25 years [1], many aspects of the impact of noise pollution on invertebrate fauna, the most abundant component of marine ecosystems, have not yet been studied [2].To achieve the Good Environmental Status (GES) of our marine environments, anthropic noise has been included among the emergent pollutants of the marine environment in the European Union Directive 2008/56/EC Marine Strategy Framework Directive Descriptor 11 [3]. The overlap of anthropogenic and natural frequencies, a phenomenon known as masking, disrupts animals' ability to communicate, navigate and detect prey. Additionally, it negatively affects their behavior, metabolism, physiology, development, and reproductive activities [4]. Most studies focus on experiments in laboratory conditions rather than in the field. In-lab studies are paramount because they allow comparison of noise-exposed organisms with those maintained in an almost silent (control) environment. Moreover, they enable the use of cutting-edge techniques, such as imaging through Transmission Electron Microscopy or Magnetic

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Resonance Imaging, electrophysiology for evaluating auditory evoked potentials, respirometry for measuring the metabolic rate, cellular/biochemical/molecular parameters for evaluating the physiological state of stressed animals [2]. However, results from in-lab studies cannot be directly extrapolated to the natural environment. In-field studies on the effects of underwater noise on invertebrates are constrained by a comparatively limited set of parameters that can be analyzed. These studies actively use artificial noise sources, such as air guns used in seismic surveys, whereas research on maritime traffic noise remains scarce [2]. As a strategy to study the effects of maritime noise effects on marine fauna in a controlled manner, researchers investigated the ability of biofouling organisms to adhere to vessel hulls to verify if spatial differences in noise emission exist and how they might influence the settlement of fouling species and the overall extent of biofouling on a vessel [5]. These few studies evidence 1) how difficult it is to study noise effects in field, especially when comparative data (*i.e.*, from noise exposed *vs* non-exposed organisms) are necessary, and 2) the need to expand the range of in field studies that evaluate the effects of the soundscape on ecosystems. Close and shallow basins are challenging environments, as evidenced by preliminary soundscape measurements in the Lagoon of Venice (Italy) (data not shown). These measurements revealed pervasive underwater noise, primarily from maritime traffic, dominated, with no silent areas available to serve as controls. As Slabberkoon and collaborators [6] pointed out, referring to the "silent spring" of Rachel Carson's book written in 1962, we are experiencing a "noisy spring" with possible detrimental impact on our ecosystems, so that a silent underwater world can be considered a myth. To overcome this lack of silent control areas, we aimed to develop an experimental set-up to create "silent" conditions in the field (*i.e.*, protected by the maritime traffic noise). We developed submerged prototype structures covered with materials with different noise shielding properties and we tested their efficacy positioning them in sites affected by intense marine traffic or other anthropic activities. Our preliminary results show that prototypes have different insulating properties with respect to both the background soundscape of the lagoon and different levels of noise artificially produced. Thus, these structures could be effective to investigate the effects of noise on the ability of fouling organisms to colonize a substrate, as well as to evaluate the noise effects of noise on their physiology.

2. MATERIALS AND METHODS

2.1 Features of the box prototypes

We built two box prototypes, in the form of parallelepipeds with square base (50 cm x 50 cm x 80 cm), of two materials, nylon and steel, with different acoustic properties (Fig. 1). The boxes had a skeleton of steel rods (Inox 304) on which a double 0,05 mm black nylon (polyethylene) layer and 1 mm thick stainless-steel sheets (Inox 304) respectively, were attached. The nylon was black to create inside the box the same dark environment as in the steel box. Internally the steel box was coated with 3 cm thick panels of sound-absorbing polyurethane. The two boxes were open at the bottom side, allowing seawater circulation. On the top, they were equipped with a small round aperture (1 cm in diameter) closed by a plug, allowing the passage of the hydrophone cable for measuring their acoustic properties. The apertures also allow the passage of air during the box immersion in seawater and of probe cables for the measurements of seawater physical-chemical parameters inside the boxes. Each box was equipped with cables at the top for suspension from a pier and cables at the bottom to support a weight, ensuring stable positioning in the water. A hook was attached to the roof of each box as a support for the suspension of the hydrophone and, in future experiments, of panels with fouling to be analyzed.

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

We selected for our comparative analysis the Darsena Le Saline (Isola Morin, 2, 30015 Chioggia VE VE45°13'30.3"N 12°16'42.8"E), a site affected by intense maritime traffic (Fig. 2). The site is a dock for tourist private boats located close to the southern lagoon mouth, connecting the Adriatic Sea to the lagoon. Cargo and cruise ships enter the lagoon through the mouth and pass daily in front of the Darsena Le Saline on their way to Chioggia docks. The site is also affected by the continuous traffic of boats (vaporetti) for public transportation.

Figure 2. A. Venice Lagoon. Red square: city of Chioggia location. **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

The acoustic properties of the two prototypes were checked in April 2024; usually the tourist traffic is high in this season. The prototypes were suspended to a pier and immersed in seawater so that the hydrophone (Aquarian Scientific AS-1) located inside each box was at a depth of 1 m. An underwater customized loudspeaker (AKUASOUND akuad_16) was placed 1 m far from the hydrophone, at a depth of 1 m (Fig. 3). We measured the box acoustic isolation capacity when the hydrophone was inside each box, with loudspeaker on. The speaker was connected to an amplifier for playback of audio tracks, used to reproduce noise at three different dB levels (Table 2). Measurements of loudspeaker noise propagation were taken by putting the hydrophone outside the boxes (at the same depths and distance from the loudspeaker). The lagoon background noise was also measured with loudspeakers off.

3. RESULTS

A synthesis of the different measures obtained during the infield campaign is reported in Table 2. The background noise was stable at about 108 dB, whereas the steel box showed a greater sound insulation capacity with respect to the nylon prototype at all the noise intensities tested. The difference in internal noise between the steel and nylon boxes remained constant at approximately 16 dB for all intensities used apart from minor fluctuations due to ambient levels variations, as expected. Since steel has a greater shielding capacity than nylon as well as greater reflective properties, the difference in levels measured in the steel box compared to those in the nylon box is also due to the presence of the polyurethane coating. The tests were carried out using reproduction noise levels (from approximately 144 to approximately 158 dB) considerably higher than the background noise present in the lagoon in the absence of passing boats (108 dB); this allowed us to reduce, during the measurements, the interferences due to any occasional external noises (including the passage of boats).

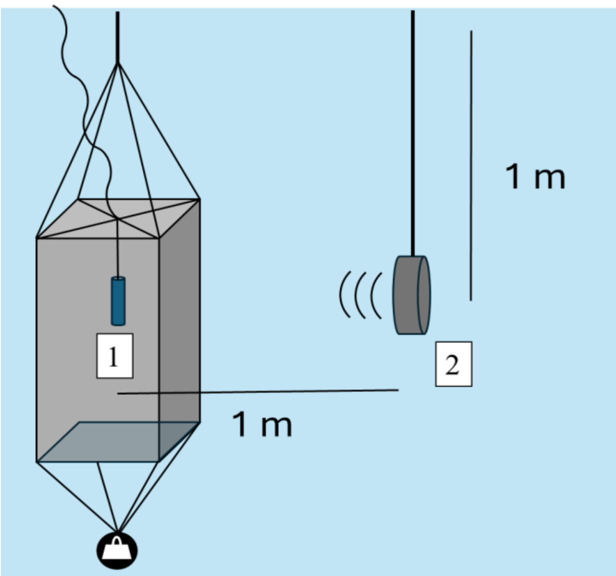

Figure 3. Experimental setup for measuring the acoustic properties of the prototype boxes. **1:** Hydrophone; **2:** Loudspeaker.

4. DISCUSSION AND CONCLUSIONS

We have demonstrated that the two prototypes are able to reduce noise levels by about 27 dB and 11 dB for steel and nylon, respectively. This confirms their ability to create different acoustic environments directly in the sea and therefore their suitability for carrying out experiments related to the verification of the acoustic impact in the field on marine species. Both prototypes provide the same level of darkness inside, an important factor influencing fauna recruitment and growth. We are planning a follow-up experiment to test how noise impairs the ability of biofouling larvae to attach to panels located inside the prototypes, considering that larvae of many invertebrate species (such as ascidians, the most common biofouling component of the Lagoon of Venice; [7]), select preferentially for adhesion poorly lightened sites [8]. We also plan to study how noise can impact on the transcriptome of the colonial ascidian *Botryllus schlosseri*, inserting colony replicates inside the boxes. Although the boxes immersed under the pier will be scarcely exposed to sunlight and so heating of internal seawater will be avoided, a continuous monitoring of the chemical-physical parameters of the seawater using multiparametric probes will be necessary to verify only noise differences between prototypes, while box internal environment remains similar. The boxes are opened at the bottom, guaranteeing sufficient seawater circulation; at the same time, they are sufficiently deep to allow the noise insulation and absorption in the coated steel box. In conclusion, boxes of different insulation/adsorption capacity can represent a new strategy for comparative studies on noise pollution in pervasively noisy seas.

Table 2. 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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