DOI: 10.61782/fa.2025.0634

FORUM ACUSTICUM
EURONOISE 2025

NUMERICAL QUANTIFICATION OF THE BIVALVE PRESENCE IN GRANULAR SEDIMENTS ON COASTAL SEABEDS

Andrés Prieto[1*] **Pablo Rubial**[2]
[1] CITMAga, Universidade da Coruña, Department of Mathematics, Campus Elviña, A Coruña, Spain
[2] Kreios Space, Spain

ABSTRACT

A seabed environment has been numerically studied by computing the hydroacoustic scattered field, enabling the seabed classification [1] and quantifying the bivalves buried within the seabed. The echosounder has been represented as an end-fire array with an axis-symmetric directivity pattern. The seabed domain has been modelled as a poroelastic medium using the Biot-Stoll model, which quantifies the energy dissipation caused by the sediment grains [2] but written in a simplified displacement-based formulation, where only the compressional waves with the lowest absorption rates have taken into account. Since the underwater coupled problem involves a bilayer unbounded configuration (seawater and granular seabed), a displacement-based Finite Element Method combined with a Perfectly Matched Layer [3] technique has been used to compute the time-harmonic solutions where the bivalves are enclosed in a localized narrow spatial domain, which reduces the computational cost of the numerical simulations. Assuming, additionally, that the coupling interface between the fluid and granular media is planar, the scattering field in the seawater has been evaluated at the far field using a Green's representation formula utilizing the explicit evaluation of the fundamental solution of the Helmholtz equation in bilayer media [4].

Keywords: *Underwater Acoustics, Granular Media, Scattering Fields, Finite Element Method, Perfectly Matched Layers*

**Corresponding author*: *andres.prieto@udc.es.*

1. INTRODUCTION

Underwater hydroacoustic measurements are widely used in sonar applications not only for detecting target objects (such as vessels or fisheries) but also to characterize the nature of the seabed and quantify the presence of algae or bivalves. However, the coastal environment usually presents challenges due to varying sediment types and hydrodynamic conditions, which can affect the accuracy of acoustic measurements (see Figure 1).

Figure 1. Coastal environment with the presence of bivalve shells in a sandy surface.

2. SEABED MODELLING

Poroelastic media [2] has been used extensively for the mathematical modelling of seabed sediments and, more recently, including specific models for granular sediments. Most of these models are based on the Biot-Stoll theory, which incorporates various parameters that affect the acoustic properties of the seabed, such as porosity, permeability, and their elastic material coefficients, which encompass the vibro-acoustic behaviour of the seabed sediment.

Under the time-harmonic assumption and since the transducer is insonifying the water column in a linear regime, the underwater coupled acoustic problem can be modelled using a linear model. This time-harmonic model involves a bilayer unbounded configuration consisting of seawater and granular seabed sediment, where the bivalves are buried. To address this complex scenario, a displacement-based Finite Element Method discretized by a Raviart-Thomas discretization has been considered. Since the original physical domain is unbounded, the computational domain must be truncated within the finite element framework. With this purpose, the Perfectly Matched Layer technique [3] has been utilized to compute the scattering time-harmonic displacement field generated from a set of buried bivalves (see Figure 2.

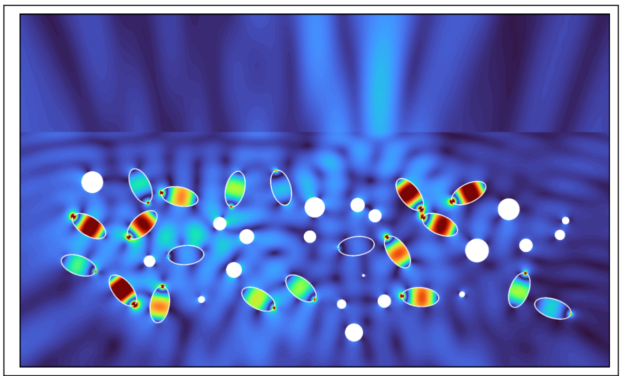

Figure 2. Scattering field generated by a set of bivalves buried in the seabed granular sediment.

Those bivalves are assumed localized in a narrow spatial domain, which reduces the computational cost of the numerical simulations. Additionally, assuming that the coupling interface between the fluid and granular media is planar, the scattering field in the seawater has been evaluated at the far field using a Green's representation formula. This approach utilizes the explicit evaluation of the fundamental solution of the Helmholtz equation in bilayer media [4], and it allows us to compute efficiently the frequency-response function (FRF) associated with the observed intensity field values measured at the echosounder location. Thanks to the proposed approach, a variety of scenarios can be simulated *in silico* and evaluate numerically their associated FRF to characterize numerically the acoustic signature of a specific configuration of bivalves buried in the seabed sediment (see Figure 3).

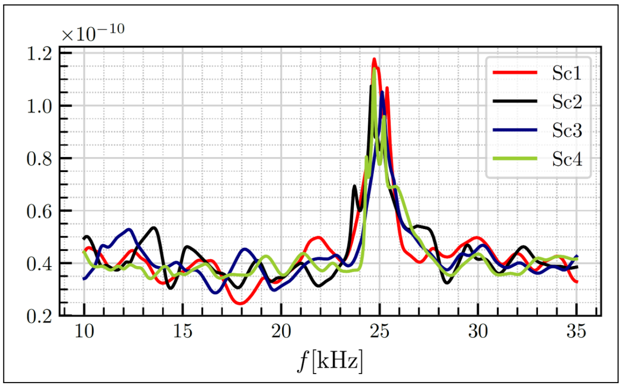

Figure 3. Frequency response function associated to different bivalve scenarios.

3. ACKNOWLEDGMENTS

Both authors are grateful for the financial support of the NumSeaHy project TED2021-131660B-I00, which is supported by MICIU/AEI/10.13039/501100011033 and the European Union Next Generation EU/PRTR. This project is also an endorsed UNESCO project (no. 42.4) of the 2021-2023 United Nations Decade of Ocean Science for Sustainable Development.

4. REFERENCES

[1] J. Tarrío-Saavedra, N. Sánchez-Carnero, and A. Prieto, "Comparative study of FDA and time series approaches for seabed classification from acoustic curves," *Mathematical Geosciences*, vol. 52, no. 5, pp. 669–692, 2020.

[2] M. Kimura, "Study on the Biot-Stoll model for porous marine sediments," *Acoustical Science and Technology*, vol. 28, no. 4, pp. 230–243, 2007.

[3] A. Bermúdez, L. Hervella-Nieto, A. Prieto, and R. Rodríguez, "Perfectly matched layers for time-harmonic second order elliptic problems," *Archives of Computational Methods in Engineering*, vol. 17, pp. 77–107, 2010.

[4] L. M. Brekhovskikh and O. A. Godin, *Acoustics of Layered Media, Vol. 2*. Berlin: Springer, 1990.