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AN OPEN DATASET FOR EXPLORING UNDERWATER SOUNDSCAPES AND VESSEL NOISE IN BARCELONA, CONSTANȚA AND LAGOON OF VENICE BASINS

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ABSTRACT

Understanding underwater soundscapes is essential for assessing the impacts of maritime noise pollution on marine environments. This paper presents the core components of an in-progress, comprehensive underwater acoustic database, designed to facilitate research on underwater soundscape modeling and its ecological effects. The database currently includes recordings from multiple European campaigns in Spain, Italy and Romania; offering cleaned and organized data, that is accessible through via an API and an integrated web interface. The platform enables users to explore detailed information about each campaign, vessel activity, sound pressure levels, spectral data, and audio spectrograms. It categorizes vessel types and their associated acoustic signatures, facilitating the analysis of soundscape dynamics and their potential environmental impacts. Developed with *PostgreSQL* and *FastAPI*, the database provides a scalable and efficient solution for managing and retrieving large datasets. Initially intended for soundscape research, it can also support studies on the ecological effects of noise pollution, contributing to a deeper understanding of its impacts on marine organisms. This work is part of the **DeuteroNoise** project under **JPI Oceans**. With plans for open access, the project aims to promote collaboration, advance soundscape research, and inform sustainable practices in maritime operations.

Keywords: *soundscapes, underwater noise polution, datasets, API.*

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1. INTRODUCTION

It is well known that underwater sound is complex and rich, originating not only from natural sources but also from anthropogenic activities, which disrupt essential processes for marine organisms. Understanding underwater soundscapes is therefore crucial for assessing the impact of noise pollution and developing strategies to mitigate its effects. Several datasets have been proposed to characterize the acoustic signatures of common vessel types [1,2]. However, despite the growing interest in anthropogenic underwater noise, limitations remain regarding database accessibility, availability, and heterogeneity. Existing datasets are rarely fully open, tend to be geographically limited, and often lack scalable storage and retrieval systems—challenges that hinder both advanced research and broader dissemination.

This paper presents an open and interactive dataset designed to facilitate underwater soundscape exploration and research. As part of the DeuteroNoise project, the

dataset consolidates recordings from multiple locations in Spain, Italy, and Romania [3, 4]. It contains cleaned and processed acoustic events (vessel passages), their related preprocessed features, spectral analysis, and sound pressure levels, along with extensive metadata such as vessel type, distance from the hydrophone, speed, tonnage, and more. Users can retrieve data through an API and an integrated web interface, ensuring seamless and intuitive access for researchers. The system, built with *PostgreSQL* and *FastAPI*, provides a scalable and efficient infrastructure for handling large acoustic datasets.

The paper is structured as follows: Section 2 reviews related work on ship noise characteristics, monitoring systems, and existing underwater acoustic datasets. Section 3 provides a detailed description of the dataset, including study sites in Spain, Romania, and Italy, as well as the types of data collected and the methodology used for acoustic and metadata processing. Section 4 presents the database architecture, API development, and the interactive web interface, highlighting its querying and visualization capabilities. Section 5 offers concluding remarks, outlining the key contributions of this work and future directions.

2. RELATED WORK

To better understand and mitigate these impacts, extensive research has been conducted on ship noise characteristics [1, 2, 5], monitoring systems [6, 7], and underwater soundscape studies [8–10]. However, data availability and accessibility remain significant challenges, as many datasets are either proprietary or limited in scope.

2.1 Ship Noise Characteristics & Monitoring Systems

Ship noise primarily originates from mechanical and hydrodynamic sources, including engines, propellers, and hull vibrations. The acoustic signatures of ships vary based on vessel type, size, operational conditions (such as speed), and environmental factors [11], moreover, research has shown that these noise signals can be used for vessel classification, maritime traffic monitoring, and impact assessment studies [12, 13].

Efforts to mitigate underwater noise pollution have led to various regulations and monitoring initiatives, such as the European Marine Strategy Framework Directive [1] (MSFD), which emphasizes the importance of tracking low-frequency underwater sound as an environmental indicator [14]. To enable data collection, hydrophones and accelerometers play a crucial role in underwater acoustic monitoring, supporting applications not only in anthropogenic noise studies but also in marine animal behavior research [15,16]. In the case of audio recordings, post-processing techniques such as machine learning and, more recently, deep learning algorithms have significantly improved ship noise recognition and classification [17, 18]. Additionally, accelerometers have been used to assess the impact of noise pollution on marine life by linking noise exposure to behavioral responses [19, 20].

2.2 Underwater Soundscape Studies & Existing Datasets

Over the past decade, research in Europe has focused on assessing and mitigating underwater noise pollution, aligning with MSFD objectives [21]. Several initiatives have contributed to the development of baseline underwater noise assessments, particularly through real-time ocean noise monitoring projects, such as Listening to the Deep-Ocean Environment, LIDO [22], which adopts a global approach to real-time underwater sound monitoring. In parallel, the SATURN project, funded by the EU, has explored new ways to reduce underwater radiated noise from ships and other vessels, addressing the challenges of maritime noise pollution [23]. The DeuteroNoise project [24], under the JPI Oceans platform, provides cross-country studies across different sea areas, including Spain, Norway, Romania, and Italy.

Despite these efforts, access to large-scale, high-quality datasets remains limited. Some publicly available datasets, such as ShipsEar, provide recordings of vessel noise under various conditions, serving as a reference for noise characterization studies [2]. More recently, the DeepShip dataset has emerged as a benchmark for underwater vessel noise classification, containing extensive recordings from different ship classes [1]. However, these datasets are focused on specific regions, limiting their applicability to broader underwater soundscape research and diverse vessel types. Furthermore, none of these initiatives provide an interactive platform or an openly accessible retrieval system that allows researchers to explore, filter, and analyze data in real-time. In addition to serving scientific purposes, such a platform could also act as

[1] https://research-and-innovation.ec.europa.eu/research-area/environment/oceans-and-seas/eu-marine-strategy-framework-directive_en

an effective dissemination tool, raising public awareness about underwater noise pollution and its effects on marine life.

3. DATASET DESCRIPTION

The dataset, introduced in this paper, contains recordings collected so far across multiple European locations as part of the DeuteroNoise project, Figure 1. The recordings were conducted in Spain, Italy, and Romania, covering diverse maritime environments and vessel traffic conditions. In each case, recordings were taken in both noisy and less noisy areas. Calibrated hydrophone setups were used to ensure consistency and comparability across sites.

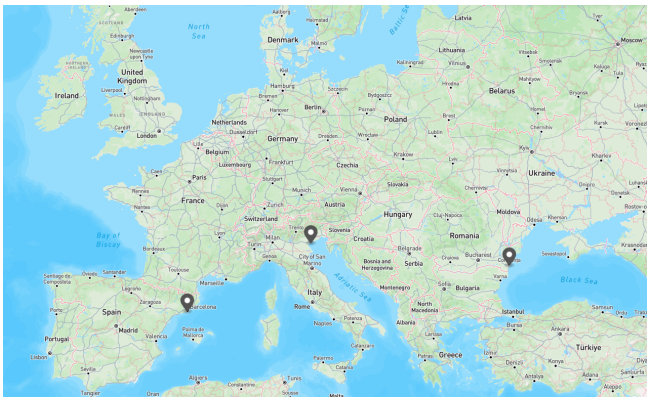


Figure 1. Map showing the geographic locations of the three coastal sites studied: Barcelona (Spain), Venice Lagoon (Italy), and Constanța (Romania).

3.1 Study Sites in Barcelona, Spain

The measurements along the Catalan coast include underwater acoustic recordings collected in Barcelona and Badalona, conducted by La Salle-URL.

- **Port of Barcelona**. As one of the busiest ports in the western Mediterranean, this port hosts cargo operations, cruise ships, and private vessels, contributing to high vessel density and noise pollution. To capture the acoustic footprint of this dynamic maritime environment, hydrophones were deployed at Espai Vela (Universitat Politècnica de Catalunya, UPC), a site directly in front of the port's coast. This location was chosen to maximize the capture of vessel noise.
- **Pont del Petroli – Badalona**. Located approximately 20 km northeast of the Port of Barcelona, off the coast of Badalona. This site features a 250-meter-long pier extending into the sea, providing a stable platform for acoustic monitoring. Unlike the port area, Pont del Petroli is positioned away from direct port activities, offering a less polluted marine environment for comparative studies. The anthropogenic noise in this area is minimal and does not contribute significantly to the dataset. However, its inclusion enables researchers to analyze underwater soundscapes with reduced anthropogenic influence, offering a more comprehensive perspective on the acoustic conditions of the Catalan coast.

3.2 Study Sites in Constanța, Romania

Underwater acoustic measurements in Constanța, Romania, were also conducted by La Salle-URL, focusing on maritime environments along the Romanian Black Sea coast.

- **Port of Constanța**. Constanța hosts three major commercial ports—Constanța, Midia-Navodari, and Mangalia—which collectively handle over 80% of the naval traffic in the region. Additionally, three marina port facilities (Constanța, Eforie Nord, and Mangalia) contribute seasonally to background noise levels through recreational boating and tourism activities. These areas are key contributors to underwater noise pollution, making them valuable for studying the impact of maritime traffic on the Black Sea's acoustic environment. Recordings were collected near one of the entrances to Constanța Port, an area regularly transited by tugboats, cargo ships, and dredgers.
- **Mamaia Area**. Located north of Constanța, this area offers a relatively quiet marine setting in contrast to the high vessel activity near Constanța Port. During the winter months, the area experiences minimal anthropogenic noise, making it an ideal location for studying natural underwater soundscapes. However, in the summer season, the presence of motorboats and recreational vessels near the beach increases noise levels, introducing seasonal variations in the acoustic environment. Although the contribution of this site to the dataset

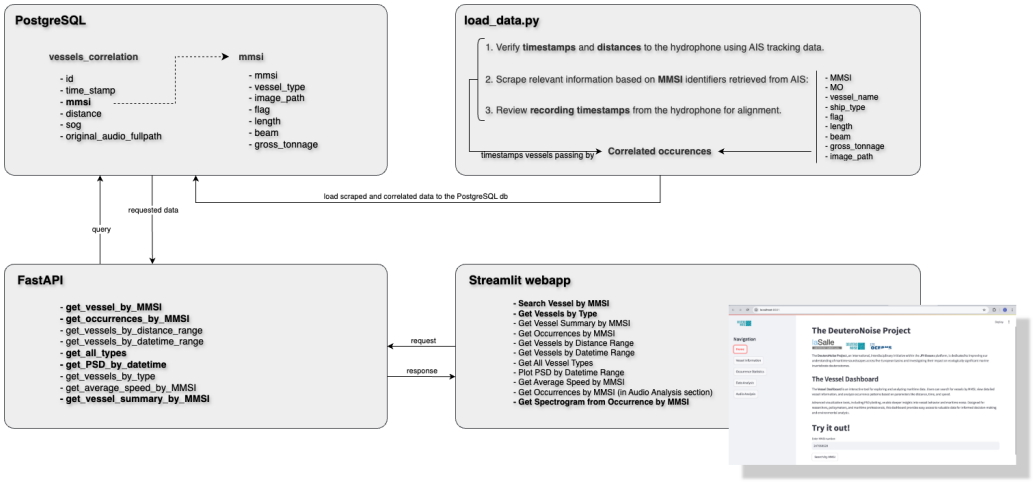


Figure 2. Data pipeline and interactive visualization architecture for vessel noise analysis in the DeuteroNoise project.

is minimal, it provides a valuable perspective on the acoustic conditions along the Constanța coast.

3.3 Study Sites in Lagoon of Venice, Italy

Underwater acoustic recordings in Italy were collected by Università degli Studi di Milano - Bicocca, focusing on the Lagoon of Venice.

- **The Lagoon of Venice**, the largest lagoon in the Mediterranean, spans approximately 550 km², with 85% covered by water, 6% by islands, and 7% by salt marshes. This area presents seasonal variations in underwater noise, with increased levels during summer due to heightened tourist activity and recreational boating. Additionally, the lagoon houses a port for cargo and cruise ships and a petrochemical industry, both of which contribute to the anthropogenic noise footprint.

3.4 Types of Data Collected

During audio data collection, an Automatic Identification System (AIS) continuously tracked vessel activity near the hydrophone locations. This allowed for the synchronization of acoustic recordings with vessel metadata, enabling precise correlation between ship movements and their underwater noise. The dataset consists of the following components:

3.5 Raw and Processed Audio Recordings

All underwater acoustic recordings were captured using the *URec384k - Underwater Acoustic Recorder* hydrophone, which was calibrated against the AS-1 hydrophone (sensitivity: -209.7 dB re V/μPa). The calibration process yielded a URec384k sensitivity of -195.2 dB re V/μPa. The hydrophone exhibits a frequency response range of 10 Hz to 190 kHz and includes an adjustable preamplifier, which was set to +50 dB re 1 μPa to enhance sensitivity. The URec384k system consists of an AS-1 hydrophone with an integrated memory card for data storage. It is powered by three D-type batteries, offering an autonomy of over 24 hours, with a theoretical maximum of 72 hours for our extended deployments. For all recordings, a sampling rate of 48 kHz was chosen to balance data quality and storage efficiency. Audio was recorded in 15-minute or 10-minute segments.

3.6 Metadata on Vessel Occurrences and Scraped Data

AIS data was retrieved in real time to provide vessel metadata, which was then correlated with the acoustic recordings. The main AIS fields collected include MMSI, time, longitude, latitude, Speed Over Ground (SOG), and name. Allowing for vessel identification, positional tracking, and speed analysis. Additionally, for

each recorded vessel, *VesselFinder*[2] was used to scrape extended metadata: vessel type, length, beam, gross tonnage, flag, and vessel image.

3.7 Sound Pressure Level (SPL) Measurements and Spectral Analysis

To accurately associate vessel passages with their corresponding acoustic signatures, vessel movements were correlated with the AIS dataset. Automated algorithms were then employed to:

- Detect vessel passages (determining the start and end of each ship's movement near the hydrophone).
- Identify peak noise levels during the passage.

Following this, an active listening procedure was conducted to manually validate and adjust the data, ensuring accurate alignment between vessels and the noise recordings. Once vessel passages were detected, labeled, and cleaned, an initial spectral analysis was performed. This involved computing spectrograms (time-frequency representations of acoustic signals) and frequency spectra (extracted acoustic features for each vessel passage). These results are included in the dataset for use in underwater soundscape analysis, vessel classification, and noise impact assessment.

4. DATABASE ARCHITECTURE, API DESIGN & USER INTERACTION

4.1 Database Structure and Storage Management

The database is built using *PostgreSQL*, structured to efficiently store and manage detailed vessel-related acoustic data. It comprises two primary relational tables: `mmsi` and `vessels_correlation`. The `mmsi` table contains static vessel data, including vessel type, dimensions, tonnage, flag, and visual information (e.g., vessel images), whereas the `vessels_correlation` table records dynamic data such as timestamps, distance to hydrophones, vessel speed (SOG), and references to audio excerpts.

Due to the large size of the acoustic dataset—approximately 190GB of raw audio data, projected to grow up to around 250GB—audio files are stored externally on dedicated hard drives, referenced within the database by file paths. Shorter excerpts (typically 30 seconds to 3 minutes) are extracted from 15-minute audio recordings, providing manageable audio samples for analysis. Additionally, large numerical data arrays, such as spectrogram values and Sound Pressure Level (SPL) measurements, along with supplementary metadata, are managed in external CSV files. The database stores high-level references and metadata, optimizing storage efficiency, details are shown in Figure 3.

4.2 API Development and Functionalities

A RESTful API developed using *FastAPI* provides dynamic and flexible access to the dataset. It enables users to efficiently query and retrieve data tailored to specific research needs, including:

- Retrieval of detailed vessel metadata by MMSI identifiers.
- Extraction of vessel occurrence data filtered by parameters such as MMSI, vessel type, distance ranges, and datetime intervals.
- Computation of statistical summaries, including average vessel speed and average distances to hydrophones.
- Access to processed acoustic metrics such as Power Spectral Density (PSD) values.

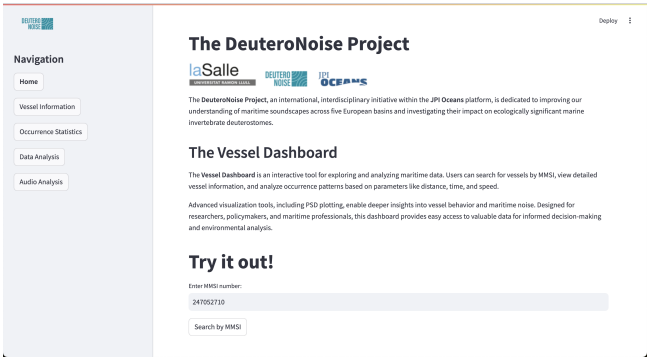
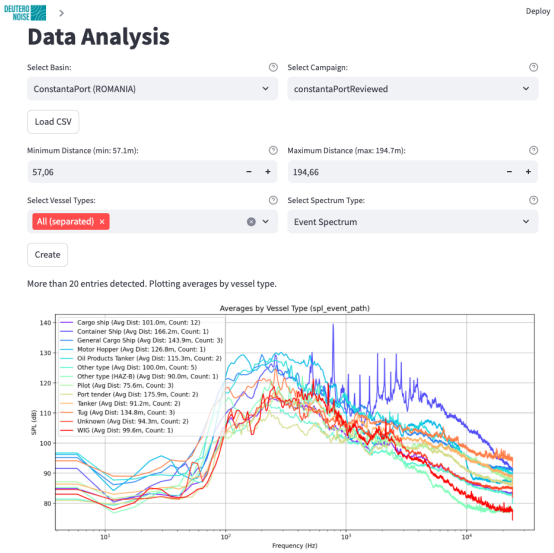
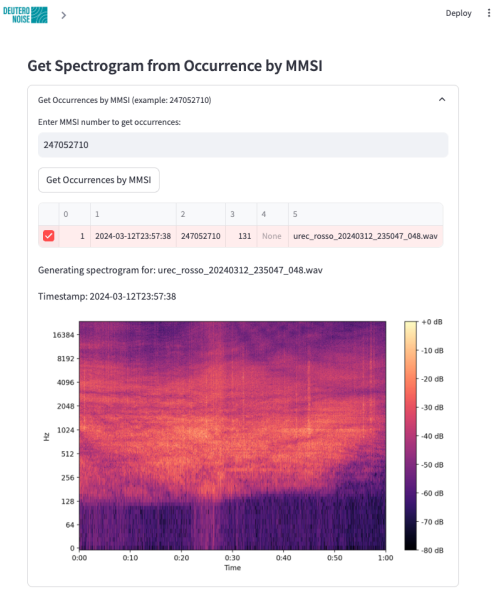


Figure 3. Landing page of the DeuteroNoise interactive dashboard, providing tools for vessel identification, occurrence statistics, and acoustic analysis.

[2] `https://www.vesselfinder.com/`



(a) Interactive analysis of vessel noise at Constanța Port (Romania), displaying average SPL spectra by vessel type.



(b) Spectrogram for a selected vessel occurrence (MMSI: 247052710), showing acoustic signatures over time.

Figure 4. Overview of the DeuteroNoise dashboard: (a) SPL spectrum analysis by vessel type; (b) spectrogram visualization for a selected vessel event.

4.3 Interactive Web Interface and Visualization

An intuitive and interactive web interface built using *Streamlit* [3] complements the API, allowing users to visually explore and analyze the acoustic dataset, Figure 4. The interface provides multiple interactive features tailored for diverse users, from researchers to policy-makers, enabling easy exploration and analysis of complex maritime acoustic data. Core interface features include:

- **Vessel Dashboard:** Quick retrieval and visualization of vessel details, including vessel type, dimensions, tonnage, flags, and images, based on MMSI identifiers.
- **Dynamic Data Exploration:** Filtering of vessel occurrence events by customizable parameters such as distance to hydrophones, vessel types, and specific time ranges, , Figure 4a.
- **Spectrogram Visualization:** Interactive generation and analysis of spectrogram plots from selected audio excerpts, facilitating detailed examination of vessel acoustic signatures, Figure 4b.
- **Statistical Summaries:** Immediate access to summarized data, such as vessel occurrence counts, average vessel speeds, and average distances to hydrophones, supporting comparative analyses.

Furthermore, users can navigate and explore recorded campaigns across various basins (e.g., Spain, Italy, Romania), filtering data by geographical area, specific campaign identifiers, and vessel categories. Interactive tables and spectral plots further enhance user capabilities for detailed acoustic event analysis.

5. CONCLUSION

This paper introduces a comprehensive, openly accessible dataset specifically designed for exploring and analyzing underwater soundscapes and vessel-generated noise. The database consolidates acoustic recordings collected

[3] https://streamlit.io/

from various campaigns conducted in Spain, Italy, and Romania as part of the DeuteroNoise project. Key features of the dataset include detailed vessel metadata, organized and preprocessed acoustic excerpts, interactive spectrogram visualizations, and querying capabilities through an integrated API and user-friendly web interface. By combining *PostgreSQL* for structured storage with *FastAPI* and *Streamlit* for dynamic data retrieval and visualization, the platform provides researchers, policymakers, and the general public with tools for underwater noise assessment.

Future developments include expanding the geographical scope of the dataset by incorporating additional recording locations across Europe. There are also plans to integrate more sophisticated spatial querying features, as well as further enhance automated vessel classification algorithms through machine learning techniques. Overall, this initiative aims to support soundscape research, facilitating a deeper understanding of human impacts on marine ecosystems, and to increase public awareness about underwater noise pollution. By providing open, interactive access and encouraging community-driven collaboration, the dataset stands as a valuable resource for both scientific advancement and the promotion of sustainable maritime practices.

6. ACKNOWLEDGMENTS

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