The MARS Database – Source Levels Measured for the Fleet Navigating the St. Lawrence Estuary

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1 Introduction

Merchant ships can radiate noise underwater over a wide range of frequencies. Those sounds can travel long distances underwater since the sound absorption of water is low at low and medium frequencies [1] and the celerity profiles usually produce a natural waveguide for the sound to travel into. With the increase of the maritime traffic over the last few decades, the shipping noise became a concern for its impact on the marine life.

The MARS (Marine Acoustic Research Station) project [2] (www.projet-mars.ca/en) is designed to improve the knowledge on the shipping noise and to propose reduction methods. Via this project, over 1000 ship acoustic signatures have been measured using hydrophone networks, and a coherent database of ship signatures have been built.

2 Method

2.1 The MARS station

The MARS station consists of 4 vertical arrays of 3 hydrophones that have been deployed near the shipping lanes in the lower St. Lawrence Estuary. They have been placed strategically to allow 2 sets of measurements on port and starboard sides with a minimal trajectory deviation (around 1.2 km in 2021 and 0.4 km in 2022). This way, it allows to produce acoustic signatures in respect to the ANSI/ASA S12.64-2009 [3] and ISO-17208-1 [4] standards without having to make multiple time-consuming passes in front of a single array as the standards suggest.

Five shipowners were partnering with the MARS project to make their ships pass their ships in an optimized trajectory near the station using a set of waypoints.

The arrays have been deployed in 2021 and 2022 with the setup shown in Figure 1. The hydrophones were recording at a sampling frequency of 16kHz.

2.2 Numercal treatment

Ships passing through the station are detected using their position received via AIS (Automatic Identification System) by a ground station in Mont-Joli operated by MTE Instruments. Analysis of the AIS data allows to estimate the time, the distance and the speed at the closest points of approach (CPA) in front of each array.

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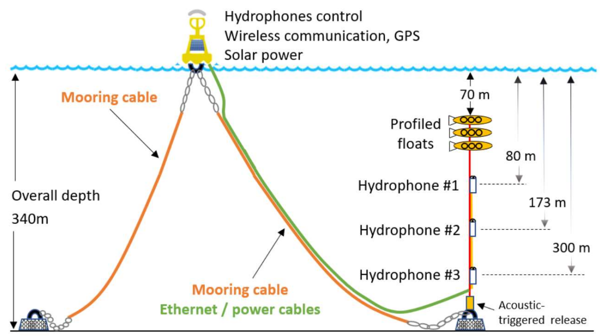

Figure 1: Example of the optimized setup of the hydrophone arrays deployed in 2021 and 2022 with a communicating buoy to transmit recordings.

Acoustic signatures are obtained following the Grade A processing method of ANSI/ASA S12.64-2009 [3]. A spectrogram is computed for the data acquisition window (±30° centered on the CPA as shown in Figure 2) with a timestep of 1s. Background noise adjustments are made by rejecting signal-to-noise ratios less than 10 dB based on the third octaves bands. The transmission losses (TL) are added to the spectrogram which is then averaged on the time axis to produce the ship source levels at a hydrophone. Those spectra are power averaged (1) on each vertical array and the 4 arrays are averaged (2):

$$L_{array\ i} = 10 \log_{10}\left(\frac{1}{3}\sum_{j=1}^{3} 10^{L_{hydrophone\ i,j}/10}\right) \quad (1)$$

$$L_{signature} = \frac{1}{n_i}\sum_{i=1}^{n_i} L_{array\ i} \quad (2)$$

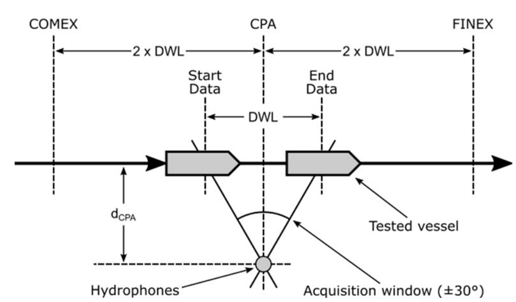

Figure 2: Metrics of a trajectory in front of an array.

Two metrics are used: RNL (Radiated Noise Levels) signatures made using spherical TL, as described by the standards and MSL (Monopole Source Levels) signatures, made using TL obtained with the wavenumber integration model SCOOTER [5].

An automatic processing system has been developed at ISMER using Matlab R2022 to generate these signatures. Post-processing tools has been developed to allow the manual revision of the ship trajectories, concordance of the CPA with the recordings and platform noise detection to ensure the quality of each signature.

3 Results and discussion

3.1 The MARS database

173 high-quality signatures were made from the passages that followed the optimized trajectory in 2021 and 2022. A few non-partner ships that happened to pass close to the arrays in 2022 were also included. The number of ships by type for these signatures is shown Table 1. Since the fleet of the ship-owner partners consisted mostly of bulk carriers, some ship types such as container ships and tanker were underrepresented.

Table 1: Ship types of the optimized trajectory signatures

Ship type	2021	2022
Bulk carrier	25	70
Cargo (general)	4	26
Merchant coastal	3	19
Tanker	5	8
Container ship	0	8
Other	0	5

An additional 983 passages were detected of the remaining traffic in or nearby the upstream shipping. Processing of these data is in progress and will be included to the MARS database after a manual validation have been thoroughly completed. This will allow to have a more extensive view of the shipping noise in the St. Lawrence Estuary and have a better representation of each ship type.

3.2 Comparison to the existing literature

The distribution of the high-quality signatures of the MARS database is presented in Figure 3. It was compared to an extended database of Simard 2016 [6] containing 710 single array signatures and to the MacGillivray 2020 [7] database containing 6295 single hydrophone spectra made with seabed platforms in shallow waters.

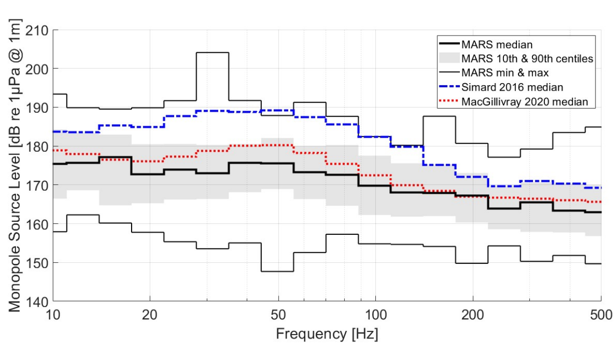

Figure 3: Distribution of the MARS high-quality signatures of the optimized trajectory passages in 2021 and 2022 in comparison to an extended database of Simard 2016 and MacGillivray 2020

We are in concordance with MacGillivray 2020 [7] results with the assumption that the ships measured are longer (thus noisier) for open sea ports that it is for the MARS fleet where a portion of the ships have to go through the Welland Canal locks in the St. Lawrence Seaway that allow a maximum length of 225.6 m. There is a disparity with Simard 2016 [6] where the median MSL is noticeably higher which is currently being investigated.

4 Conclusion

The MARS database provides a reference database of ship acoustic signatures representative of the fleet operating in the St. Lawrence Estuary. Such database is critical to the design and implementation of mitigation measures to reduce the underwater noise radiated by ships. It also allows further scientific analyses such as making new and improved models of ships underwater source levels.

Acknowledgments

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