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UNDERWATER NOISE SURVEY IN THE TURKU ARCHIPELAGO

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ABSTRACT

The Archipelago Sea is located to SW Finland. The ecosystem is especially sensitive to anthropogenic pressures because of shallowness (mean depth 23 m). Our purpose was to conduct a measurement campaign to get a better understanding of underwater sound (UWS) in the area. We conducted recordings of UWS in 58 locations, 1–4 months in each. The locations were selected both close to shipping lanes and silent, sensitive areas. Recordings were conducted using logging hydrophones. Sound pressure level (SPL) was analyzed in one-minute periods ($L_{eq,60s}$). The frequency range was 10–20 000 Hz. The main outcome was the mean monthly equivalent SPL, $L_{eq,M}$, including the whole frequency range. The analysis produced altogether 272 study months. The range of the $L_{eq,M}$ values was 86–128 dB [re 1 μPa]. The smallest $L_{eq,60s}$ in all locations was below 90 dB, which represents the natural components of UWS. Exceedance represents the anthropogenic component. Exceedance took place in 271 locations out of 272. Our study shows that anthropogenic UWS is broadly distributed in the Turku Archipelago. Reduction of UWS by technical means or behavioral regulations seem to be justified to reduce the pressures to the marine ecosystems.

Keywords: *underwater acoustics; underwater noise; anthropogenic sound*

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1. INTRODUCTION

Marine ecosystems face a multitude of stressors, including anthropogenic (human made) underwater sound (UWS), which is widely recognized to cause negative impact to marine life. UWS caused by maritime transport can be perceived as noise (harmful sound) among some organisms. One of the main sources of UWS is commercial shipping. In a ship, UWS is mainly caused by propeller, engine, gear, thrusters, and echo sounding.

The Archipelago Sea, (Northern Baltic Sea) consists of approximately 50 000 islands within a relatively small area of 8 300 km^2. The ecosystem is especially sensitive to anthropogenic pressures, e.g., due to heavy shipping, nutrient and contaminants load, and natural shallowness (mean depth of only 23 m). There are no published studies on UWS in the Archipelago Sea.

Our purpose was to conduct a measurement campaign to get a better understanding of UWS in the Archipelago Sea.

Figure 1. Location of Turku Archipelago.

2. MATERIALS AND METHODS

2.1 Study areas

We conducted long-term measurements of UWS in 58 locations. The measurement locations were chosen in a diverse manner so that different conditions were covered:

- Ship lanes and expected noisy areas
- Expected silent areas
- Shallow areas
- Protected areas and habitats of sensitive species

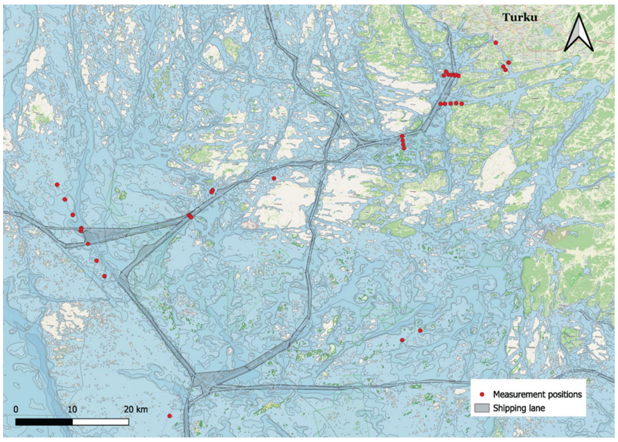

Figure 2. Measurement locations in the Archipelago Sea. In some locations, measurements were made in multiple depths.

2.2 Measurements and procedures

The survey covered years 2023–2025. The recordings were conducted year-round to record also the seasonal variation. The recordings were conducted in multiple locations at the same time using 20 battery operated hydrophone loggers (Soundtrap ST600 STD/HF, Ocean Instruments Ltd., New Zealand). The hydrophone has a flat measurement bandwidth within 20–60 kHz (±3 dB). The device records signal to files stored in four microSD 512 GB memory cards providing a total capacity of 2 TB. The apparatus uses a loss-less compression file format in the memory card, which corresponds to 6 TB of standard sound file format (.wav). The apparatus is shown in **Fig. 3**.
The sampling frequency was 48 kHz so that spectrum could be determined up to 20 kHz. The device can be set to continuous recording mode or sampling mode (sampling with desired time periods). We used continuous mode. The apparatus can be used at water depths down to 200 m. With these settings, the device was capable of recording 4 months of sound signal continuously. To minimize the risk of damage to the equipment, the hydrophone loggers were deployed to the measurement locations using acoustic releaser (Sonardyne LRT, UK), moorings, and sacrificial anchors, without surface markers. The hydrophone was placed approximately two meters above the sea floor (**Fig. 4**). The equipment was recovered using the releaser and deck unit shown in **Fig. 3**.

Figure 3. Hydrophone (530x60 mm, 2.6 kg with 12 A-batteries), acoustic releaser (AR, 490x64 mm, 1.8 kg with batteries), AR controller unit, and AR transmitter.

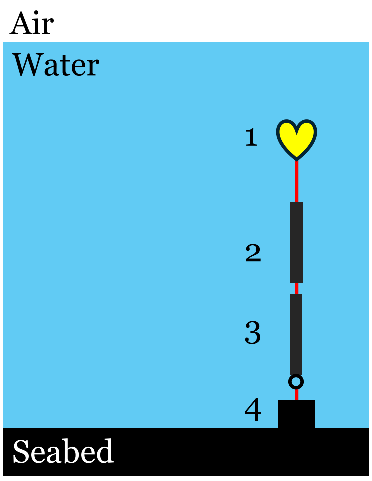

Figure 4. Underwater sound recording system usually consisted of four components coupled with rope: 1. Float, 2. Hydrophone logger, 3. Acoustic releaser, 4. Anchor (25kg concrete block).

2.3 Data handling and signal analyses

The recordings of each measurement position were several months long, which creates a large amount of signal data. The download of data from the memory cards was made using a program provided by the manufacturer. Hydrophone logger stores the files into a compressed file format (.sud), each being 3-hours long.
The files contain the start and end time of measurement. The internal time drift of hydrophones is ±0.4 seconds per day. Therefore, the operator corrected the internal clock before every recording.
The conversion to standard sound file format (.wav) was made during the download process from memory card to computer. Files were read directly from the hydrophone to the computer. Four computers optimized for rapid data handling (Dell 16" Precision 7680, Intel Core i7-13850HX, 64 GB Ram) were applied. The usual download duration was approximately 4 hours per 1 month of signal.
The .wav-files were analyzed using a custom-made Matlab script. The signal was analyzed in 60-second periods by calculating the equivalent sound pressure level (SPL), $L_{eq,60s}$ [dB re 1 µPa] for each one-third octave band within 10–20000 Hz. An example of an SPL profile is shown in **Fig. 5**. The reported result in this study was monthly equivalent sound pressure level, $L_{eq,M}$ [dB], within 10–20 000 Hz. All levels had reference SPL of 1 µPa.
The data was accepted to monthly analysis, if the measurement duration was longer than 1 week on this calendar month.

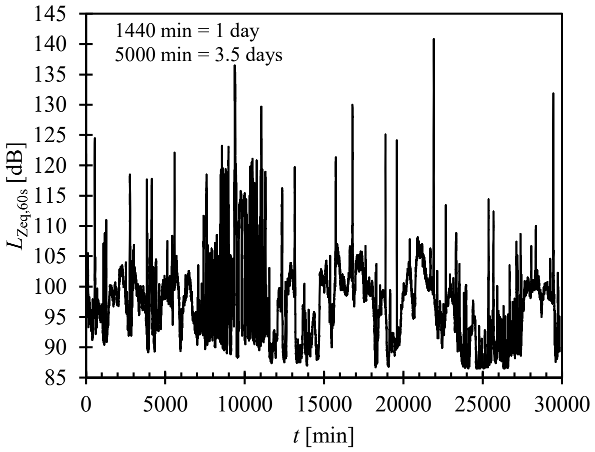

Figure 5. Example of the SPL profile of one monthly data covering 21 days. The graph depicts the equivalent unweighted SPL, $L_{eq,60s}$, within 10–20 000 Hz as a function of time, t.

3. RESULTS

The measurements were conducted in 58 locations. Since many measurements locations were active for several calendar months, the number of monthly data reached 272 study months.
The monthly equivalent SPLs within 10–20 000 Hz are shown for all study months in **Fig. 6**.
The statistical distribution of study months data is shown in **Fig. 7** for the three investigated sound parameters (median, the faintest and the loudest). The average spectra of corresponding parameters are shown in **Fig. 8**.

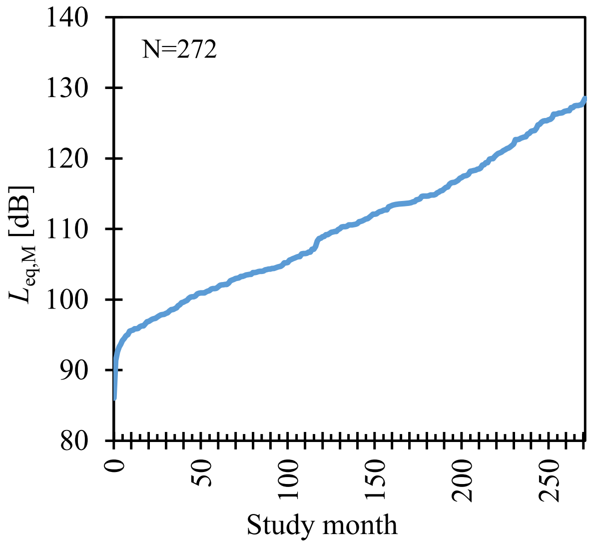

Figure 6. Monthly equivalent SPLs, $L_{eq,M}$, of the 272 study months (rank ordered).

4. DISCUSSION

The variation of SPL between locations was large. The contribution of anthropogenic sound on SPL is evident. In one location, the SPL was only 86 dB $L_{eq,M}$, which suggests that anthropogenic sound was not present in that location during the studied month. In all other locations, the SPLs were within 91–128 dB, indicating elevated SPLs originated from anthropogenic noise sources. Our data suggests that the SPL of natural soundscape in the Archipelago Sea is under 90 dB L_{eq} within 10–20000 Hz. This is further suggested by the $L_{eq,60s}$ values, which represents the faintest minute during the whole measurement period. This level represents the natural baseline in normal weather conditions without anthropogenic noise. The same baseline ($L_{eq,60s,min}$) was

observed several times in all 272 study month data. This was also demonstrated on Fig. 5.
The frequency content of anthropogenic sound is broadband since the elevation of SPL from the baseline was observed within 10–20 000 Hz.
Our study is unique because UWS has not been investigated before in the Archipelago Sea. The collected data gives a good understanding of the distribution of UWN. Because our survey included a very large area, and each area has different maritime activities, we cannot provide deeper analysis of data in this paper. Similarly, the deeper analyses between different months of the year cannot be presented. The work is still ongoing so that the current data is preliminary. The results will be openly published.
Our study shows that anthropogenic UWS is broadly distributed in the Turku Archipelago. Reduction of UWS by technical means or behavioral regulations seems justified to reduce the pressures to marine ecosystem.
It is important to minimize the negative impacts of UWS to marine life. Therefore, International Maritime Organization (IMO) [1] has stated that sound emission from vessels should be surveyed, and potential noise control methods should be considered and applied.

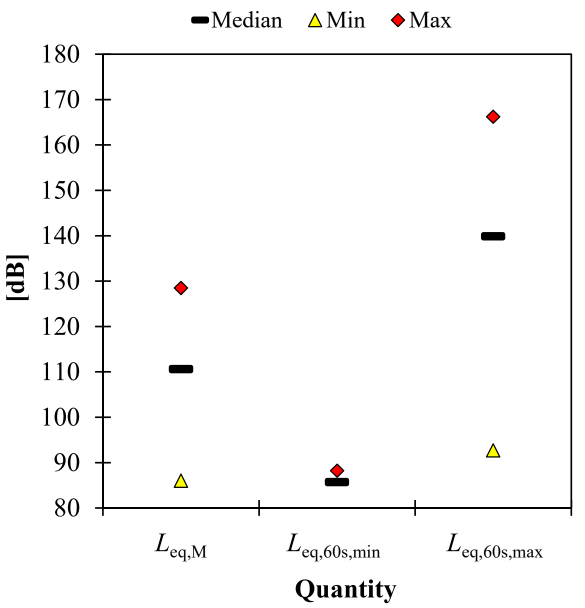

Figure 7. Statistics (median, minimum and maximum values) of all data including 272 months of recordings. $L_{eq,M}$ is the monthly equivalent SPL, $L_{eq,60s,min}$ is the faintest minute during the month and $L_{eq,60s,max}$ is the loudest minute during the month.

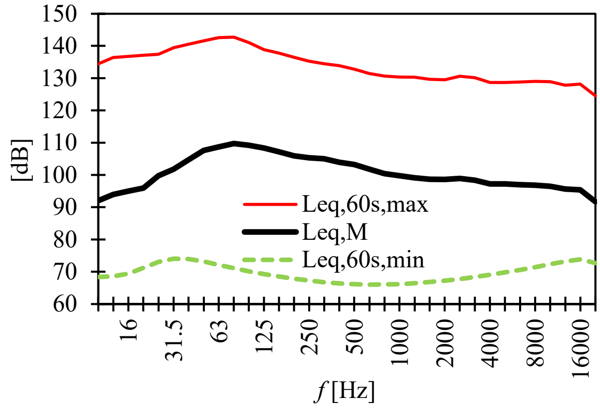

Figure 8. Average sound pressure levels as a function of frequency, f, based on 272 study months. $L_{eq,M}$ is the monthly equivalent SPL, $L_{eq,60s,min}$ is the faintest minute during the month and $L_{eq,60s,max}$ is the loudest minute during the month.

In our next project (URNECO 2024–2026), our first purpose is to survey the radiated noise levels of Finnish ships and ship components. Measurements are challenging because Baltic Sea is shallow, and most standards are designed for sea depths over 150 m. Based on the measurements, we can estimate potential noise control needs. Our second purpose is to assess potential technical noise control measures for different ship components.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

[1] International Maritime Organization IMO, Revised guidelines for the reduction of underwater radiated noise from shipping to address adverse impacts on marine life. MEPC.1/Circ. 906, 22 August 2023, London, UK.