Assessment of The Underwater Noise Levels from a Fishing Vessel Using Passive Acoustic Monitoring and Structure Hull Vibration

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1 Introduction

Sound is crucial to the survival of several species of the marine ecosystem [1], and vessels' underwater radiated noise (URN) has been reported to have a broad range of detrimental impacts on aquatic life [2]. In fact, the ocean ambient noise is increasing at a rate of 0.5 dB/year at low-frequency ranges (100 Hz), according to a 2005 study conducted by Ross [3]. So far, researchers have mainly focused their studies on the source characterization of large commercial vessels, considered as the main sources of URN.

This paper presents the results of a study carried out to investigate the URN from a small fishing vessel operating in the Province of Newfoundland and Labrador, Canada. The objectives of the study were i) quantify the URN from the small fishing vessel at different operating conditions, ii) understand the contribution of the vessel's main acoustic sources—i.e. prime mover and propeller—to the overall URN, and iii) evaluate the monopole source levels (MSL) of the vessel.

2 Method

The experimental measurements were performed in August and December 2021 of the coast of Petty Harbour-Maddox, Newfoundland.

2.1 Fishing vessel specifications

The fishing vessel is 34 ft in length overall. It is powered by a fast six-cylinder four-stroke diesel engine coupled to a four-blade propeller through a gearbox (gear ratio 2.4).

2.2 Measurement procedure

We followed the relevant ISO 17208 series to perform the MSL measurements and assess the results uncertainties [4], and simultaneously performed onboard structure-borne noise tests to evaluate the engine's contribution to the overall URN. The trials were performed where the vessel and hydrophone array was 225 m apart, titled the closest point of approach (CPA).

The ship was tested at two operating conditions: i) straight-line route and constant advance speed at engine's maximum continuous rating (2200 rpm), ii) Propeller disengaged, and only engine was on where vessel located at the CPA. The background noise level was measured when the vessel was located 2 Km from the array, and the engine was turned off [4].

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2.3 Passive acoustic measurement

We used an array of three icListen HF omnidirectional hydrophones attached to a surface buoy associated with GPS and a ballast drop-weight made by Ocean Sonics. The recordings were sampled at a rate of 32 KS/s. The system was deployed at 47°27'14.28" N and 52°36' 7.5" W at depths of 32 m, 63 m, and 94 m from the sea surface and the ocean floor was 160 m deep.

The source sound levels were analyzed in one-third octave and narrow bands in the frequency range of 10 to 10 kHz. Firstly, the background noise levels (BNL) were used to adjust the received sound levels (RSL). Secondly, the vessel's monopole source levels were obtained per the simplified approach proposed by ISO 17208-2 and by developing a numerical propagation loss model for a more accurate assessment [5].

2.4 Structure-borne noise

Four uniaxial accelerometers made by PCB Piezotronics were mounted in the engine room. Data was collected via National instrument card and analyzed using Matlab in a frequency range 1 to 8 kHz. The structure-borne noise was correlated with the RSL by estimating magnitude-squared coherence function using Welch's method. The data was normalized to create a reasonable comparison between the two different parameters.

3 Results

Table 1 shows the broadband RSL before starting the trails.

Table 1: Broadband levels (dB re 1 uPa @ 1 m) of background noise levels before every sea trial in August and December.

Date	63 Hz	125 Hz	250 Hz	2/8 kHz	0.01/10 kHz
Aug	99.61	97.36	95.17	87.97	99.34
Dec	102.33	100.68	95.24	86.68	102.36

Figure 1 shows the MSL of the vessel at maximum engine speed for both trials. The overall MSLs estimated by the PL model and ISO 17208-2 were similar at frequencies below 125 Hz, in contrast to high levels at higher frequencies for the PL model.

The engine radiated noise levels higher than the BNL by 35 to 45 dB over the broadband at no propeller trail. The narrowband analysis of the structure-borne and underwater radiated noise illustrated a high coherence between the signals. The engine's frequencies were detected in the underwa-

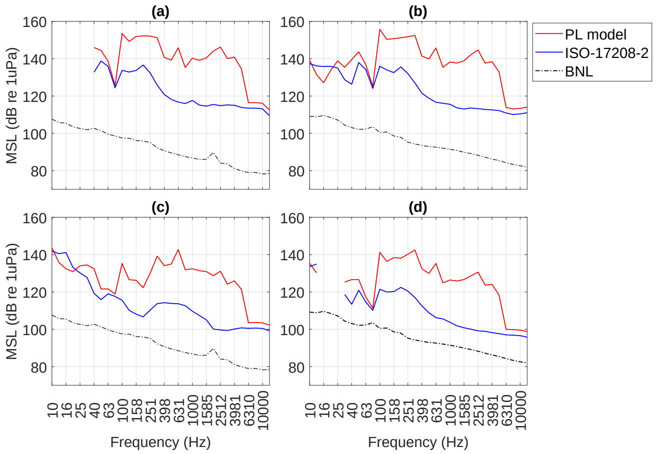

Figure 1: Monopole source levels estimted using ISO 17028-2 and propgation loss model. For August trial, (a) Vessel ran at 2200 rpm between two points and (c) No-propeller and engine on at 1400 rpm. For December trial, (b) Vessel ran at 2200 rpm and (d) No propeller trial at 1600 rpm

ter radiated noise measurements, as shown in Figure 2. The cylinder firing frequency divided by the 2.4 gear ratio demonstrates the single blade frequency equal to 13.9 Hz, which dominates the underwater radiated noise. In comparison, the main contributor of the engine was the tonal frequency at 101.3 Hz, which corresponds to the engine firing frequency.

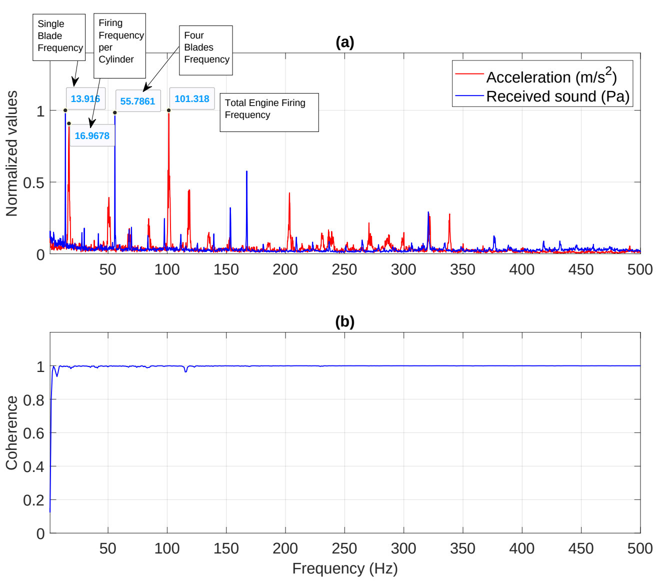

Figure 2: (a) Normalized PSD narrowband of received sound pressure and acceleration. (b) The coherence between both values

4 Discussion

BNL were high at frequencies below 80 Hz for both August and December trials. We can notice that there was no significant difference in the BNL measured at the two dates over the frequency range of interest.

The MSL is higher when using the propagation loss model, compared to the MSL calculated in accordance with the recommendation by the ISO 17208-2. The discrepancy is evident at frequencies above 125 Hz, where the MSL is higher of more than 20 dB, when calculated using the propagation loss model. The ISO 17208-2 corrected equation added weight to the low frequencies to adjust the sea surface interference. On the other hand, the propagation loss model provided useful information about sound propagation at higher frequencies, showing that the ISO 17208-2 method underestimate the MSL in this range.

The no-propeller trials on both days showed the significant contribution of the internal engine to the overall radiated noise generated by the vessel. The engine radiated noise is 40 dB higher than the BNL. This contribution is confirmed by the outcomes of the narrow band analysis.

5 Conclusions

The results from these measurements show that the studied fishing vessel, which is a typical fishing vessel in the NL fleet, generates URN levels that are potentially dangerous for the ecosystem. In addition, our results show that onboard engines contribute to the overall URN at high frequencies. With regard to the MSL assessment, the current standard seems to estimate well the low frequencies, but underestimate higher frequencies. Further tests should be conducted to confirm this.

Acknowledgments

Research funding was provided by the Ocean Frontier Institute, through an award from the Canada First Research Excellence Fund.

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