MÜLLER-BBM

BUNDESAMT FÜR SEESCHIFFFAHRT UND HYDROGRAPHIE

„Assessment approaches for underwater sound monitoring associated with offshore approval procedures, maritime spatial planning and the marine strategy framework directive – BeMo“

Technical Report

An example to discuss the assessment methodologies for continuous noise

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Federal Maritime and Hydrographic Agency (BSH)
Hamburg and Rostock, 2020

Research and Development Project, Order Nr. 10036955

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November 2020

The main objective of the R&D „ Assessment approaches for underwater sound monitoring associated with offshore approval procedures, maritime spatial planning and the marine strategy framework directive " is to give insights in issues of mitigation applied to reduce impact from percussive pile driving on the marine environment. Information and data in the technical report have been available by the German National Noise Registry and the Informationsystem marinEARS of BSH.

Authors are responsible for the contributions in the technical report.

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To be cited as: Müller, A., 2020: An example to discuss the assessment methodologies for continuous noise. Technical Report , R&D „Assessment approaches for underwater sound monitoring associated with offshore approval procedures, maritime spatial planning and the marine strategy framework directive – BeMo", Order Nr. 10036955, Bundesamt für Seeschiffahrt und Hydrographie (BSH).

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1 Situation and task

The TG Noise has been given the task by the EU to develop an Assessment Framework for Continuous Noise. During two workshops in October the contents were discussed controversially. From a neutral observer's point of view, there are two groups which pursue different concepts: those who have developed concepts (designed for masking) at JOMOPANS - and currently HELCOM - and the other group which wants to prepare a superordinate assessment for all influences (masking, disturbance, stress, etc.). An agreement, even a joint consideration of both concepts could not be reached. In the end, the following further course of action, among others, was determined:

Another workshop on DL3 [3] will take place on 4 December. The following is to be prepared for discussion:

- A list of the sound-sensitive key species for the respective regions with information on sound assessment possibilities, see e.g. [6].
- Examples for the assessment of masking.
- Examples for the assessment of " behavioural, stress”.

It is not the aim of this note to go into detailed individual points of previous discussion. Using an example of VHF Marine Mammels, an attempt is made to understand the differences between the concepts and to initiate a possible merging of the concepts.

2 Documents

[1] Minutes: 16th meeting of the EU Technical Group on Underwater Noise (TG Noise), 6th October 2020 – Online Webex

[2] Report: Thematic Sessions: Assessment framework of threshold values for impulsive and continuous noise 7th and 29th October 2020, Online Meeting (Webex),

[3] DL3: Technical Report, Assessment framework for threshold values for continuous sound and setting of threshold values Recommendations from TG Noise MSFD Common Implementation Strategy Technical Group on Underwater Noise (TG-NOISE), October 2020.

[4] Knudsen, V.O., R:S: Alford and J.W. Emling; Underwater ambient noise, J. Mar. Res, No. 7, p 410, 1048

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[6] "HELCOM 2019. Noise sensitivity of animals in the Baltic Sea. Baltic Sea Environment Proceedings N° 167" © 2019 Baltic Marine Environment Protection Commission (Helsinki Commission – HELCOM)

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porpoise (Phocoena phocoena) for single frequency-modulated tonal signals between 0.25 and 160 kHz," J. Acoust. Soc. Am. 128, 3211–3222. DOI: 10.1121/1.3493435

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3 Excess level and attention level

To be able to evaluate the sound effect in relation to continuous sound, possible parameters and metrics are listed without weighting hereafter:

- Hearing Threshold,
- (Critical) bandwidth of the auditory filter,
- Auditory integration time,
- Natural sound,
- Anthropogenic sound,
- Source Level, Received level,

The Sound pressure level SPL or equivalent continuous sound level L_{eq} (or average level) is defined by

$$L_{eq} = 10 \log_{10} \frac{1/T \int_0^T p(t)^2 dt}{p_0^2}$$

with p(t) representing the sound pressure, p_0 the reference pressure 1 µPa and T the averaging time. The value can be displayed as a single number (linear, frequency-weighted) or frequency-dependent (third octave, FFT, ...). Typical integration times for continuous sound are between one and thirty seconds. In the Jomopans project [14], one second was selected and a frequency range from 10 Hz to 20 kHz was chosen.

The definition of the Attention Level is according to [3]:

Sound level above which an adverse behavioural reaction is expected in a specified key species. In this paper we define the Attention Level as L_{AL}.

The definition of the Excess Level, see e.g. [9], is the exceedance of total noise above natural noise

$$\Delta L = L_{\text{Total}} - L_{\text{Natural}}$$

L_{Total} represents the sound pressure level at the point of interest with all sound contributions (shipping, wind, rain, ...) and is a directly measurable variable. L_{Natural} is only the contribution of non-anthropogenic noise (wind, rain, ...). The quantity cannot be measured directly, but can be estimated by statistical evaluation of measurements or by direct modelling.

A question from Helcom to TG Noise, see [1], refers to the cut-off value of the Excess Level:

Cut-off value for excess level. The suggested approach relies on defining a cut-off value for the excess. If the excess level is above this cut-off value, ship noise is considered to dominate. By definition, excess is non-negative (the excess is 0 dB in the total absence of ship noise), so the cut-off value must be a positive value. The

EN-Noise proposes 20 dB as the cut-off level and invites views on this choice. A decrease in SNR of 20 dB constitutes a significant deterioration of conditions for communication and choosing a lower value is likely to introduce more uncertainty in assessments through uncertainty in the soundscape modelling.

The question of the correct choice of cut-off value is not easy to make and one should examine this question in detail in relation to the species. Questions that arise:

- Is the natural background noise really relevant in each case? A comparison with audiograms is probably necessary.
- Is it really acceptable to allow higher sound levels in sea areas with naturally noisier background noise?

From a modelling point of view, I find the choice of 20 dB acceptable, since it can be expected that the prediction inaccuracy, including natural background noise, is not negligible, especially in the frequency range < 400 Hz over the broad frequency range.

I would like to take the opportunity to provide a bridge to merge the different concepts. The cut-off criterion can be expressed in formulas, as follows:

$$\Delta L_{\text{Cutt-off}} = L_{\text{Total}} - L_{\text{Natural}} = 20\,\text{dB}$$

The level thus determined (L_{Total}) is therefore the limit above which communication decreases. This value could be equated with the Attention Level. Shown in formulas:

$$L_{\text{AL}} = L_{\text{Total}} = L_{Natural} + 20\text{dB}$$

From a scientific point of view, I can well understand the consideration of the excess level, but I guess that you also need an absolute reference level.

As an example, the perception of sound in humans and the regulations you have to follow should give you an indication:

The A-weighted sound pressure level is a good measure to assess the human auditory perception. This means that one feels quite comfortable in an environment of 20 dB(A) to 35 dB(A) and can also relax (sleep). At 50 dB(A) acceptable working conditions are still given. Between 60-70 dB(A), communication is considerably more difficult. From 80 dB(A) at the latest 85 dB(A) hearing protection is already required. For noisy working environments, in principle the cumulative SEL is also considered over the day. If one had to apply the Excess Level to humans and chose a criterion of 20 dB above a hearing threshold or a very quiet background, this would certainly be a poor estimator of reduced communication.

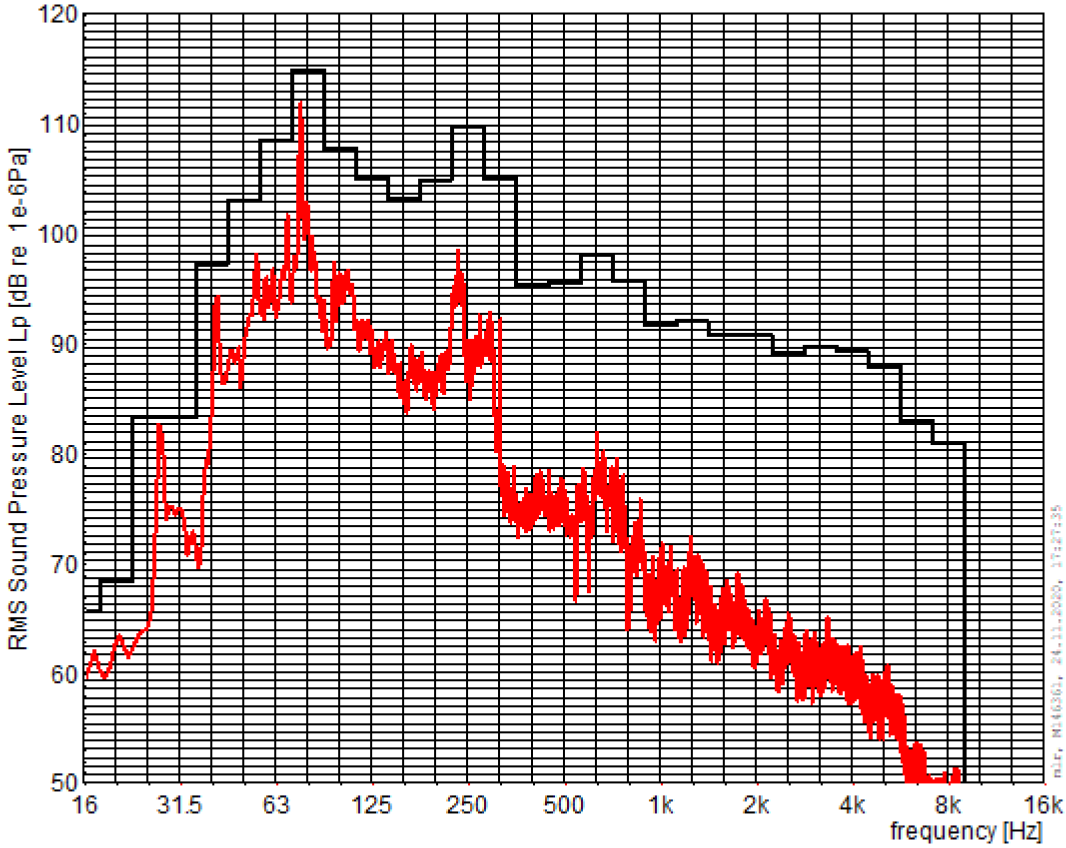

Figure 1: Exemplary diagram of sound pressure spectrum generated by a ship in in unknown distance. The spectrum is shown as FFT and in third-octave bandwidth. In the frequency range significantly below 1000 Hz, spectral lines of the propulsion system with propeller and propulsion engine, gear, etc. are typically observed. In the higher frequency range above 1 kHz the flow and cavitation noises dominate which have a rather broadband frequency character. At high frequencies at several kHz, the spectrum may still increase due to cavitation. Audible cavitation-induced modulations of the propeller speed/blades can be investigated with a modulation analysis.

In addition to the A-weighted sound pressure level, the C-weighting of the sound pressure level, for example, has been introduced for the assessment of sound. The difference between the C-weighted sound pressure level and the A-weighted sound pressure level is a measure of the annoyance of low-frequency sound. These low-frequency "disturbing" contributions of exhaust noise e.g. from ships are well known, especially in urban ports. Very tonal sounds are also perceived as disturbing. Therefore, in regulations there is an explicit "tone addition" in dB to the determined sound pressure levels to appreciate this annoyance.

Figure 1 shows a "typical" frequency spectrum of the emitted sound of a ship. In the frequency range below 1000 Hz, spectral lines of the propulsion system can be seen, in the frequency range above 1000 Hz the spectrum based on the respective thirds is almost equally distributed. This is helpful for the study of the VHF (Very High Frequency) species, as the spectral distribution corresponds to that of the natural background noise.

4 Example for VHF marine mammals

4.1 Preliminary remark

VHF Species have been selected which can hear very well over a wide frequency range up to 160 kHz. The active communication range (echo localisation) of the harbour porpoises occurring in the North Sea and Baltic Sea ranges between 100 and 160 kHz [7] and is thus clearly outside the frequency range of the intended investigations. In some scientific studies the influence of ship noise is pointed out [8] and scientifically investigated with regard to communication masking [12].

Other species such as the harbour seals, which can hear very well in the frequency range up to 10,000 Hz, have been considered in [15].

In the following, a simple academic example is used to apply the methodology to a VHF species. Explanations with greater scientific insight can also be found in [12].

4.2 The simple approach

Figure 2 shows the result of a simple calculation of ship noise (based on power spectrum density level) at a distance from the receiver (VHF Species) of 500 m, 1000 m and 10000 m. For the estimation, the Silent E curve of a classification society [16] was used, which is a good estimate for the mean source level of merchant ships. The sound propagation calculation was carried out with an empirical formula according to Thiele & Schellstede [17], determined for the North Sea, which is valid in the frequency range up to 10,000 Hz and should cover a range of up to 80 km. The result was compared with a Southall *tone* audiogram for VHF Marine Mammels [10]. Furthermore, the critical ratio determined by Kastelein for harbour porpoise is shown [12]. The ambient noise was simulated by a simple Knudsen sea state curve [4] and for the very high frequency range an approximation [5] of the thermal noise was introduced.

Definitions [14] necessary to interpret the example:

Critical Band (CB)

Critical band or auditory filter: one of an array of bandpass filters that are assumed to exist in the peripheral auditory system [20]. The frequency band of sound, being part of a continuous-spectrum noise covering a wide band, that contains sound power equal to that of a pure tone centred in the CB and just audible in the presence of the wideband noise.

Critical Ratio

Critical ratio (CR) The difference between the sound pressure level of a pure tone just audible in the presence of a continuous noise of constant spectral density and the sound pressure spectrum level for that noise expressed in dB.

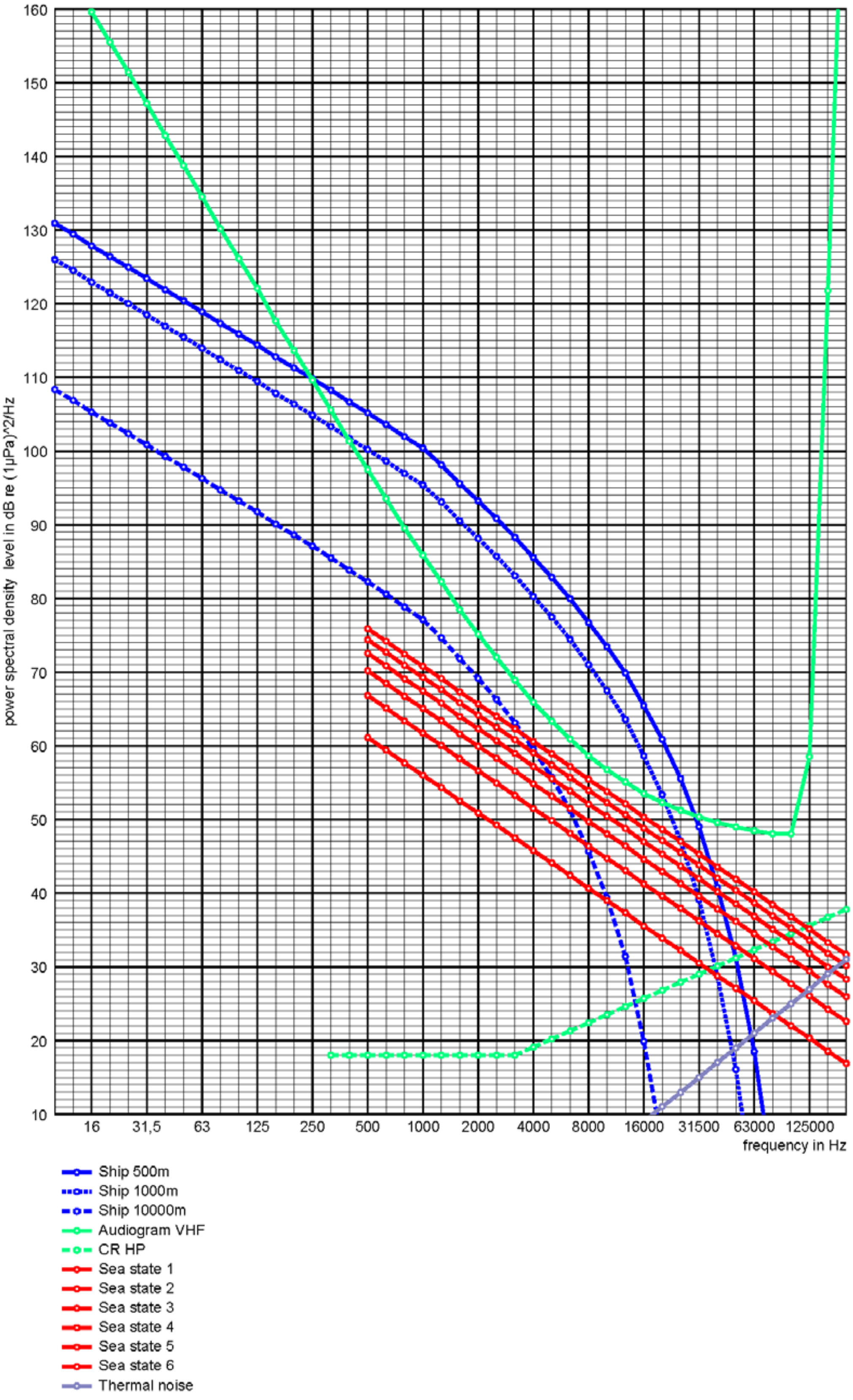

Figure 2: Shipping noise at different distances from the receiver (animal), compared to the hearing curve of VHF marine mammels and natural background noise. CR_HP: *critical ratio* for the harbour porpoise.

The result shows quite clearly that in the middle frequency range between 2,000 Hz and 8,000 Hz the ship is still audible at a distance of 500 m to 1,000 m. If one takes the critical ratio and the auditory (critical) bandwidth at the respective frequency into account, here using the example of a porpoise (dashed green curve), one is about 35 dB above the hearing threshold. It should be noted, however, that in the case of sea state 6, hearing is limited via the SNR. Because of the background noise, the hearing threshold would be raised, see e.g. [11], and the remaining level difference would be only 15 dB at e.g. 8 kHz. Good to have this 15 dB to recognize a ship.

It is the task of bio acousticians to decide from which level and in which frequency range sound levels are critical for which problem. If only the excess level is considered, the distance of 10 km at 2 kHz would still appear critical. However, the level is only just above the hearing curve.

The impact range of the continuous noise of vessels seems to be small for VHF species. For modelling purposes, it must be assumed that large grids are used. In paper from Farcas [9], a grid of about 1 km^2 was mentioned.

5 Conclusion

The concepts "Attention level" and Excess level can be combined. There is a need to determine appropriate thresholds or frequency weightings for the key species to be identified. It is necessary to consider the respective hearing ability (frequency ranges for hearing, localization, communication) in detail.

The VHF species do not appear to be key species for continuous sound.

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