Report on the source level assessment for recreational boats

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Summary

1. Abstract

This document assessed the noise radiated by recreational and small fishing boats, which are typical in coastal areas, recorded in a shallow water environment such as the North Adriatic Sea, following, as closely as possible, the methodology recommended in the standards and the international standards and available literature review done on this subject.

2. Introduction

The Adriatic Sea presents a medium-high to very high cumulative human impact, with demersal fishing, hypoxia and pollution from land-based activities as major contributors (Micheli et al. 2013). Further it is one of the noise underwater hot-spot in the Mediterranean Sea (Maglio et al. 2016), being characterized by high ship traffic levels (Vaes and Druon, 2013). According to Adriatic Sea Tourism Report 2017 (ASTR, 2017), NAS is the area of the Mediterranean Sea with the highest increment of traffic (cruises, ferries, catamarans and recreational boats) in 2016 compared to the previous years, and this trend is expected to continue. Many harbours (ports and marinas) are here concentrated, with highly touristic zones being exposed to high levels of recreational traffic. Rako et al. (2013a) demonstated that an increase in the background noise in the Cres and Losinj Archipelago (NAS) is related to the seasonal variations in the nautical tourism and fishing activities; the same study identified recreational boats as dominant source of anthropogenic noise. Further, at the local scale, dolphin distribution showed a significant seasonal displacement from noisy areas characterized by the intense leisure boating (Rako et al. 2013b). This accords to the case of the shallow coastal area within the Inner Danish waters, where the motorised recreational vessels dominated the local soundscape due to their high numbers, high speed of movement and proximity to the coast; their noises generate most of the noise able to potentially elicit behavioural responses in harbour porpoises (Hermannsen et al., 2019).

These case studies clearly indicate that recreational boating is a factor of major concern for coastal acoustically sensitive marine fauna. Despite this, recreational vessels are currently not accounted for in the AIS-based underwater noise models used to predict the impact of vessels on underwater background-noise levels, leading to considerable underestimations, especially in coastal area (Hermannsen et al., 2019). On the other hand, the lack of a number of reliable measurements of the noise radiated by boating in coastal, shallow waters is a limiting factor for properly developing vessel noise impact models that account for recreational boating as a noise source.

Historically the measurements of the noise produced by vessels have been undertaken for military purposes. More recently, such measures have been reported by different authors (e.g. McKenna et al., 2012, 2013; Merchant et al., 2014; Hallett, 2004) and the recent publication of internationally agreed standards (ANSI/ASA, 2009b; ISO, 2012) encouraged many researchers to adopt a standardizing method as closely as possible. To determine the underwater noise levels of a ship, field tests are conducted where the noise level is measured following a specific method. The American National Standards Institute (ANSI) standard and the International Organization for Standardization (ISO) provides three grades of measurement standards with different requirements regarding the number of hydrophones used and their depths, distance between the measurement point and the vessel. The standards range from Grade A, which provides the most stringent set of conditions, to Grade C which allows for a reduced degree of measurement detail with corresponding increase in uncertainty. Nevertheless, the standards address mainly measurements in deep waters, whereas most of the coastal areas are in shallow waters characterized by the significant influence of bottom reflections on noise propagation. Furthermore, standards are mainly focused on the assessment of noise generated by large vessels. As result, the proper characterization of the small boat noise is substantially missing from the scientific literature, with few exceptions (Barlett & Wilson, 2002; Brooker & Humphrey, 2016).

The purpose of the present study is to assess the noise radiated by recreational and small fishing boats, which are typical of coastal areas, recorded in a shallow water environment such as the North Adriatic Sea, following, as closely as possible, the methodology recommended in the standards (Table 1).

Table 1: Underwater noise measurement standards

Internationally Recognized Standards	
ANSI/ASA S12.64-Part 1, 2009a	Quantities and Procedures for description and Measurement of Underwater Sound from Ships – Part 1: General Requirements
ISO 17208-1, 2016	Underwater acoustics -- Quantities and procedures for description and measurement of underwater sound from ships -- Part 1: Requirements for precision measurements in deep water used for comparison purposes
ISO 17208-2, 2016	Underwater acoustics -- Quantities and procedures for description and measurement of underwater sound from ships -- Part 2: Determination of source levels
ISO 17208-3, 2016	Underwater acoustics -- Quantities and procedures for description and measurement of underwater noise from ships -- Part 3: Requirements for measurements in shallow
ISO 18405:2017	Underwater acoustics — Terminology
ICES. Cooperative Research Report No. 209.	Underwater noise of research vessels: review and recommendations
ITTC recommended procedures and guidelines, 7.5-04, 04-01	Underwater noise from ships, full scale measurements
Rules of Classification Society	
DNV, 2010	Silent Class Notation, Det Norske Veritas (DNV), Rules for Ships, January 2010, Pt 6, Ch. 2
BV, 2014	Underwater Radiated Noise (URN), Bureau Veritas

3. Materials and methods

3.1 Study area and target boats

The study has been run along the eastern coast of the Cres and Lošinj archipelago (northeastern Adriatic Sea), an area of approximately 545 km2, which includes steep rocky shores and a seabed patched with muddy areas and sea grass flats. Sea depth is on average about 70 m (Arko-Pijevac et al., 2003). These waters represent a very important marine habitat in the northern Adriatic Sea, famous for its high biodiversity and the presence of the resident bottlenose dolphin (*Tursiops truncatus*) population (Bearzi et al., 1997). The area is also a well-known tourist destination in the northern Adriatic Sea with the city of Mali Lošinj, the largest city on any of the Adriatic islands, being the main urban area.

The recreational boat noise source level assessment was carried out on the 22nd and 25th of October 2020 during the non-tourist season to avoid the intense nautical traffic during the tourist season. The measurement test site was east of the island Oruda (Lat 44.549567, Long 14.659367), within the Cres-Lošinj SCI (HR3000161) Natura 2000 site, away from the shore to prevent unwanted reflections (see hydrophone and the two test run locations in Figure 1). The seabed depth was 80m and all recordings were made in the conditions of sea state < 2 (Beaufort scale) with no other boats visible in the study area.

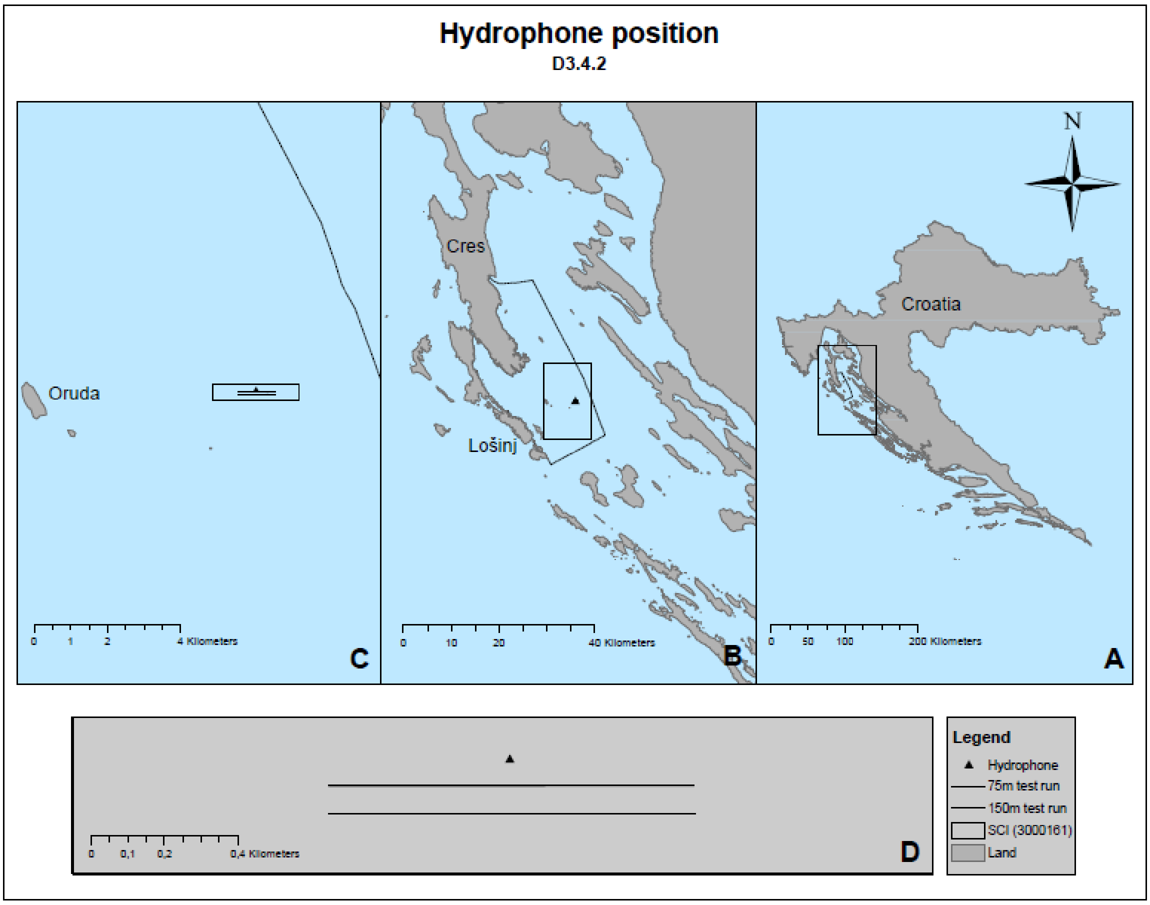

Figure 1: Measurement test site showing the hydrophone location and the 75m and 150m test run within the Cres-Lošinj SCI (HR3000161) Natura 2000 site.

The target boats used during the recreational boat noise source level assessment were speed boat (Table 2, Figure 2), motor yacht (Table 3, Figure 3), motor boat (Table 4, Figure 4), sailing boat on engine (Table 5, Figure 5), trawler (Table 6, Figure 6), gillnetter (Table 7, Figure 7) and tour boat (Table 8, Figure 8).

The target boats were chosen based on boats present or passing through the Cres and Lošinj archipelago (Rako et al., 2013c) to get an overall idea of the local boat noise source level.

Table 2: Characteristics of the speed boat

Characteristics of the hull	
Length	5,75 m
Breadth	2,30 m
Draught	40 cm
Building material	RHIB/fibre-reinforced plastic
Type of hull	monohull
Characteristics of the engine	
Type of engine	Honda BF 100
Number of engines	1
Number of cylinders	/
HP and type fo mounting	100 HP outboard
Power	74,57 kW
Maximum speed/rpm	29/30kn/5400rpm
Characteristics of the propulsion	
Number of propellers	1
Number of blades	3
Type of propeller	fixed
Speed/RPM during test runs	
Cruising speed	15,1kn/3500rpm
High speed	24,9kn/4900rpm

Figure 2: Speed boat used during the recreational boat noise source level assessment

Table 3: Characteristics of the motor yacht

Characteristics of the hull	
Length	8,5m
Breadth	2,10m
Draught	60cm
Building material	RHIB/fibre-reinforced plastic
Type of hull	monohull
Characteristics of the engine	
Type of engine	Honda BF 250
Number of engines	1
Number of cylinders	6
HP and type fo mounting	250 HP outboard
Power	186,42 kW
Maximum speed/rpm	35kn/5500rpm
Characteristics of the propulsion	
Number of propellers	1
Number of blades	3
Type of propeller	fixed
Speed/RPM during test runs	
Cruising speed	19kn/3700rpm
High speed	25kn/4400rpm

Figure 3: Motor yacht used during the recreational boat noise source level assessment

Table 4: Characteristics of the motor boat

Characteristics of the hull	
Length	5m
Breadth	2m
Draught	35cm
Building material	fibre-reinforced plastic
Type of hull	monohull
Characteristics of the engine	
Type of engine	Yamaha 15 F15 4-Stroke
Number of engines	1
Number of cylinders	2
HP and type fo mounting	15 HP outboard
Power	/
Maximum speed/rpm	7 kn/6000rpm
Characteristics of the propulsion	
Number of propellers	1
Number of blades	3
Type of propeller	fixed
Speed/RPM during test runs	
Cruising speed	5,6kn
High speed	6,3kn

Figure 4: Motor boat used during the recreational boat noise source level assessment

Table 5: Characteristics of the sailing boat on engine

Characteristics of the hull	
Length	10,10m
Breadth	3,4m
Draught	1,70m
Building material	fibre-reinforced plastic
Type of hull	
Characteristics of the engine	
Type of engine	Nanni Diesel
Number of engines	1
Number of cylinders	3
HP and type fo mounting	29,5 HP inboard
Power	30ps
Maximum speed/rpm	6kn/3200rpm
Characteristics of the propulsion	
Number of propellers	1
Number of blades	3
Type of propeller	fixed
Speed/RPM during test runs	
Cruising speed	6,1kn/2000rpm
High speed	6,6kn/2400rpm

Figure 5: Sailing boat on engine used during the recreational boat noise source level assessment

Table 6: Characteristics of the trawler

Characteristics of the hull	
Length	13,70m
Breadth	4,2m
Draught	1,8m
Building material	wood
Type of hull	monohull
Characteristics of the engine	
Type of engine	IVECO
Number of engines	1
Number of cylinders	/
HP and type fo mounting	220 HP inboard diesel
Power	109 kW
Maximum speed/rpm	9,2kn/1900rpm (1:1,48 gearbox ratio)
Characteristics of the propulsion	
Number of propellers	1
Number of blades	4
Type of propeller	fixed
Speed/RPM during test runs	
Cruising speed	7kn/1100rpm
High speed	7,1kn/1200rpm

Figure 6: Trawler used during the recreational boat noise source level assessment

Table 7: Characteristics of the gillnetter

Characteristics of the hull	
Length	7,5m
Breadth	2m
Draught	85cm
Building material	fibre-reinforced plastic
Type of hull	monohull
Characteristics of the engine	
Type of engine	Diesel Fiat AIFO
Number of engines	1
Number of cylinders	4
HP and type fo mounting	87,78 HP inboard diesel
Power	65,46 kW
Maximum speed/rpm	8nm/2000rpm
Characteristics of the propulsion	
Number of propellers	1
Number of blades	3
Type of propeller	fixed
Speed/RPM during test runs	
Cruising speed	7,1kn
High speed	8,1kn

Figure 7: Gillnetter used during the recreational boat noise source level assessment

Table 8: Characteristics of the tour boat

Characteristics of the hull	
Length	13m
Breadth	3,82m
Draught	65cm
Building material	wood
Type of hull	monohull

Characteristics of the engine	
Type of engine	1 x 4 taktni Jedwo Radni/IVECO AIFO 8361
Number of engines	1
Number of cylinders	6
HP and type fo mounting	150 HP inboard diesel
Power	85/200 kW/min-1
Maximum speed/rpm	8,5 miles (1:15 gearbox ratio)

Characteristics of the propulsion	
Number of propellers	1
Number of blades	3
Type of propeller	fixed

Speed/RPM during test runs	
Cruising speed	7,9kn/1800rpm
High speed	8,4/2100rpm

Figure 8: Tour boat used during the recreational boat noise source level assessment

3.2 Underwater noise measurement

Recordings of underwater noise were made with a stationary acoustic recorder (RESON TC 4032 SN TL81403-3/Develogic Sono.Vault SN1106) sampling at a rate of 48 kHz, 24 bit and gain 5. The recorder was moored at a depth of 60 m, 20 m above the seafloor (Figure 9). All standards and rules preferred measurements to be carried out with three hydrophones mounted above each other. In that way, underwater sound was measured with three different slant angles between the boat and the hydrophone, allowing to smooth the influence of surface reflections (Lloyd's Mirror effect) by averaging these three measured levels. However, most of those requirements were for measurements in deep waters and the Cres and Lošinj archipelago is relatively shallow. Therefore, in this study, a hydrophone depth of 60 m was chosen, in accordance with Hasenpflug et al. (2019); following these authors the boat noise characterization obtained by one hydrophone at the optimal depth of 60 m is fully comparable to the average noise measured with three hydrophones positioned at different depths and angles, which is especially true when considering the Lloyd's mirror effect.

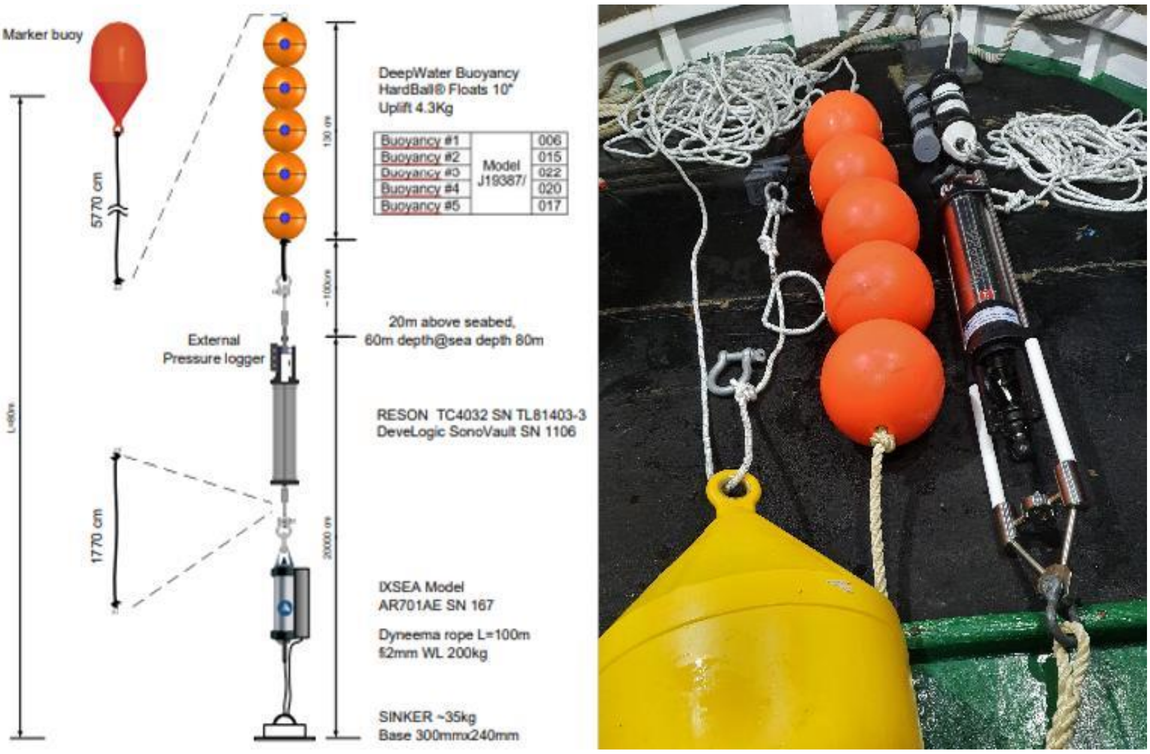

Figure 9: Hydrophone setup

The maneuvering of the target boat during the measurements followed the relevant standards and classification society rules. The target boat under test transited along a predetermined straight-line track from the start point (COMEX) to the end point (FINEX). The distance between COMEX and FINEX was 1000m. The target boat was passing the closest point of approach (CPA) to the hydrophone 500 m into the track (Figure 10). After reaching FINEX, a Williamson turn was performed to return along the same track so that measurements of radiated noise from both port and starboard sides were made. Between the COMEX and FINEX points the target boat must maintain a constant speed and running conditions with minimal use of rudder to maintain course along the track.

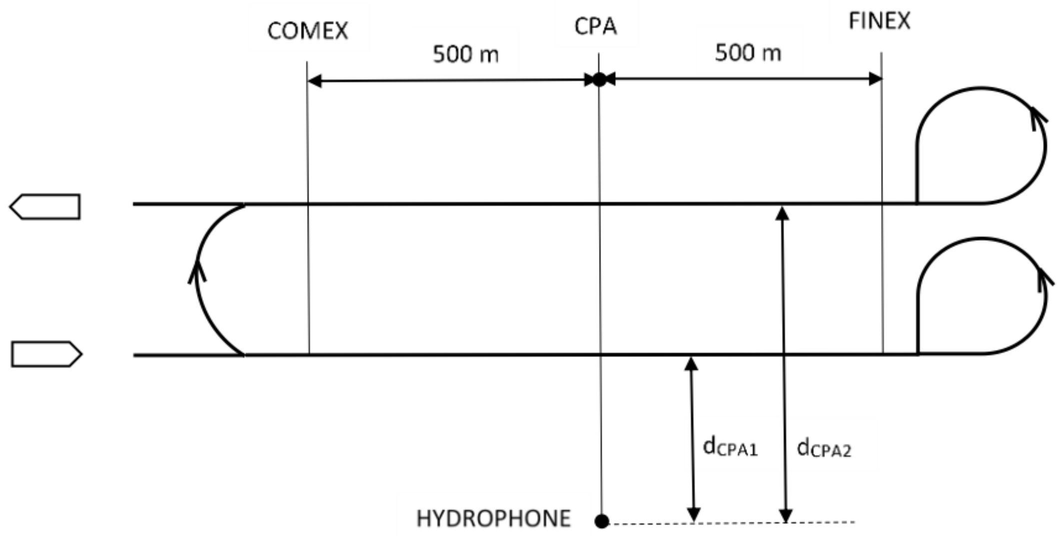

Figure 10: Recommended test site and target boat's course configuration

Measurements were taken for two predetermined straight-line tracks which allows to measure the target boats sound pressure level (SPL) under two different slant angles (Figure 11). The CPA was located at 75m (d_{CPA1}) and 150 m (d_{CPA2}) from the hydrophone. When the target boat was at the CPA, the hydrophone was at the angle of 38° (first line track) and 22° (second line track) from the target boats acoustic reference point.

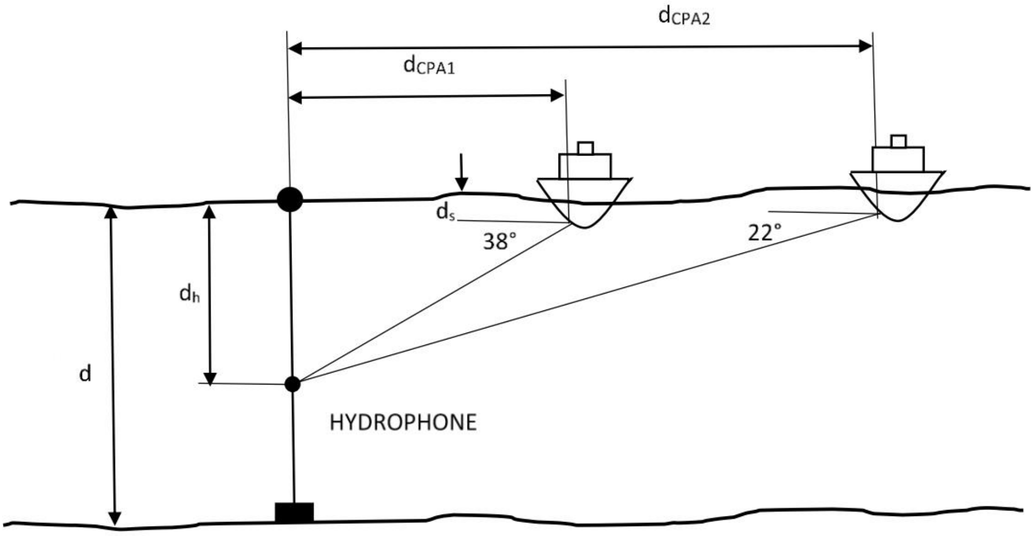

Figure 11: Recommended hydrophone configuration

Boat noise source level measurements were recorded for cruising and high speed from all seven target boats used in this study (see Table 2-8 for more details). Each target boat had 16 test runs in total. Eight test runs for cruising and high speed separately, two port runs and two starboard runs at d_{CPA1} and d_{CPA2}. This will help to average test runs to decrease measurement uncertainty. CTD measurements were taken on both test days in the morning before any target boat noise measurements were taken.

A differential GPS system was setup on the target boat that recorded the time and location in 1 sec intervals. The GPS time was synchronized with the hydrophone time before deployment so that the GPS data could subsequently be used during data post-processing to extract the data window length (DWL) used for the analysis (Figure 12). The DWL is the distance between two points along the track either side of the CPA point defined by a ± 15° angle from the hydrophone position for the nearer track (d_{CPA1}) and ± 7° for the farer track (d_{CPA2}).

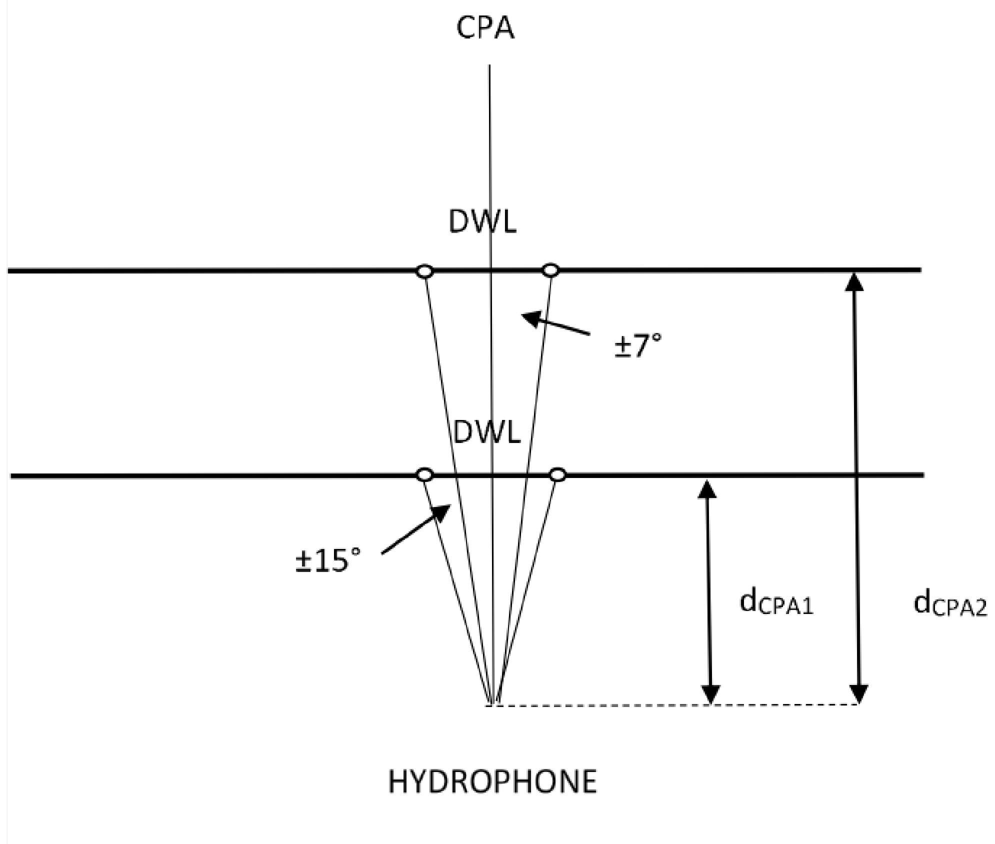

Figure 12: Data window length

Just before testing each target boat type, the background noise was recorded for 10 minutes. The target boat under test was at least 1000 m away from the hydrophone with its engine turned off and no other boats or man-made noise were present in the vicinity of the study area.

3.3 Noise analysis

The analysis procedure started with the definition of the time window in the recordings. The start and end GPS coordinates of the DWL was marked on the transect lines. The GPS coordinates from the target boat tracks that fell between those two points represent the DWL. The start and end time of the DWL was extracted from the time related to the first and last coordinate recorded within the DWL for each test transect. The DWL .wav files for each target boat and for two different speeds (16 test runs for each target boat, see above) were extracted from the acoustic recordings.

Each file was further processed by a script MATLAB® (version 2020a), performing a third-octave filtering in the bands from 12.5 to 20000 Hz (according to the standard IEC 61620). Then the results of the analysis of each pair of DWL traces relative to each side (port and starboard) were logarithmically averaged with each other to define an average SPL value. At the end only the values of SPL in the range of 50 Hz to 20 kHz were considered (SPL = $20\log_{10} P_{RMS}/P_{ref}$ expressed in dB re 1µPa, where P_{ref}=1µPa).

A correction *per* each of the 1/3 octave bands of noise produced by each test run recorded during the trial was automatically applied during data analysis by the MATLAB® script to account for background noise, in accordance with the ISO and ANSI Standards: (i) if a boat SPL level was less than 3 dB re 1µPa above background noise for the corresponding 1/3 octave band, then the data were considered unusable; (ii) if the difference between the boat SPLs and the background noise level was between 3 and 10 dB re 1µPa then the background noise was subtracted (in terms of power) from the SPL data; (iii) if the difference was greater than 10 dB re 1µPa then no correction was required. Per each tested boat type, the background noise used for this calculation was recorded just before testing it, as explained above.

In order to calculate the value of SL (Source Level) two different procedures:

- According to the TL calculations suggested by two notations of classification societies
- calculated by evaluating the local Transmission Loss

were used and then the results were compared with each other. Procedures are described below.

3.3.1 Noise analysis calculated according to the TL calculations suggested by two notations of classification societies

The source level of a ship was determined as a source level of a singular monopole source at one- meter distance from the source.

Per each boat, the radiated noise level (RNL) was calculated as:

$$\textbf{(1)}\ RNL_{CPA1} = \overline{SPL}_{CPA1} + X \cdot log_{10}\left(\frac{r_1}{r_0}\right) \text{ expressed in dB re } 1\mu\text{Pa}$$

Where:

SPL_{CPA1} equals to the averaged sound pressure level corrected by background noise for the nearer track (d_{CPA1}) from the hydrophone position;

X is a geometrical parameter, here both the values of 18 (as suggested in DNV Notation) and 19 (as suggested in BV notation for water depth lower than 100m) were tested, as suggested by the recommendation D.3.4.1 of the present project,

r_0 is the reference distance (r_0 = 1 m);

r_1 is the slant range between the boat and the hydrophone, as:

$$r_1 = \sqrt{{d_{CPA1}}^2 + {d_H}^2}$$

(2) $RNL_{CPA2} = \overline{SPL}_{CPA2} + X \cdot log_{10}\left(\frac{r_2}{r_0}\right)$ expressed in dB re 1µPa m

Where:

SPL_{CPA2} equals to the averaged sound pressure level corrected by background noise for the farer track

(d_{CPA2}) from the hydrophone position;

X is a geometrical parameter, here both the values of 18 and 19 were tested in accordance with a spherical spreading assumption, as suggested by the recommendation D.3.4.1 of the present project;

r_0 is the reference distance (r_0 = 1 m);

r_2 is the slant range between the boat and the hydrophone, as:

$$r_2 = \sqrt{{d_{CPA2}}^2 + {d_H}^2}$$

RNL_{CPA1} and RNL_{CPA2} were calculated both *per* the port and starboard runs leading to a total of four RNL values. Further, *per* each RNL, the **Source Level (SL)** was defined. In order to calculate the **Source Level (SL)** of each boat as the level of equivalent monopole sound source in unbounded sea environment, **each radiated noise level of the boat (RNL) was corrected for the sea surface reflections (Lloyd mirror effect)**, as:

(3) SL = RNL + ΔL expressed in dB re 1µPa

Sea surface reflections were modelled by introducing a second fictive source, opposite in phase, symmetrically above sea surface (mirror source). Since the SPL measured at the hydrophone is the sum of the sound waves coming from the sound source and from its image, the system behaves as an acpustic dipole, leading to acoustic interferences between direct and reflected paths, producing alternatively constructive and destructive interferences at the measuring point.

Here the used model allowed contribution from the mirror source to be mathematically corrected, rendering boat as a monopole sound source in unbounded sea environment. Since the distance from the boat and its mirrored source to the hydrophones was much larger than the source depth (ship acoustic reference point), **the simplified formula (4) for ΔL was used (Ainslie, 2010) in accordance with ISO 17208.**

$$(4)\ \Delta L = 10 \cdot log_{10}\left(\frac{1}{2} + \frac{1}{4 \cdot k^2 \cdot {d_s}^2 \cdot sin^2\,\alpha}\right)$$

Where:

k is the wave number $(k = \frac{2 \cdot \pi \cdot f}{c})$;

f is the central frequency of the third-octave-band,

ds is the depth of the ship acoustic reference point from where the sound is considered to originate; in particular here the depth of ship acoustic reference point ds equal to 0,7 x draught of the boat if the engine is "inboard" and draught of the boat if the engine is "outboard";

c is the average sound speed in water calculated by using the CTD data;

α is the slant angle of the hydrophone.

Finally, the four sets of SL values relative to the two sides (port and starboard) and the two distances from the hydrophone (75 and 150 m) were arithmetically averaged with each other, obtaining a single SL value *per* each boat type running at a given speed.

3.3.2 Noise analysis calculated by evaluating the local conditions

In order to have the best data quality, this case the Source Level (SL) of each boat was calculated as

(5) SL = SPL + OC expressed in dB re 1μPa

Where OC (Overall Correction) is here defined as the contribute given by the Transmission Loss and the ΔL as calculated by applying the model described in 2.3.3

SLs_{CPA1} and SLs_{CPA2} were calculated both *per* the port and starboard runs leading to a total of four SL values *per* each tested boat speed. Finally, **the four sets of SL values relative to the two sides (port and starboard) and distance from the hydrophone (75 and 150 m) were arithmetically averaged** with each other, obtaining a SL value *per* each boat type running at a given speed.

3.3.3 Overall Corrections calculations

The overall correction (OC; as previously defined) has been calculated for frequencies below 250 Hz with a model based on the parabolic equation RAM (Collins, 1993) and for frequencies above 250 Hz with a model based on ray theory Bellhop (Porter & Liu, 1994). The software models both the interaction with the sea surface (considered as a flat perfectly reflecting surface) and the bottom (considered as flat with its own acoustic impedance).

For this specific case, the following parameters have been used:

Source depth: 60 m (the source is placed in the hydrophone position as reciprocity is valid)

Sound velocity profile: as from Figure 13 for the two trials days

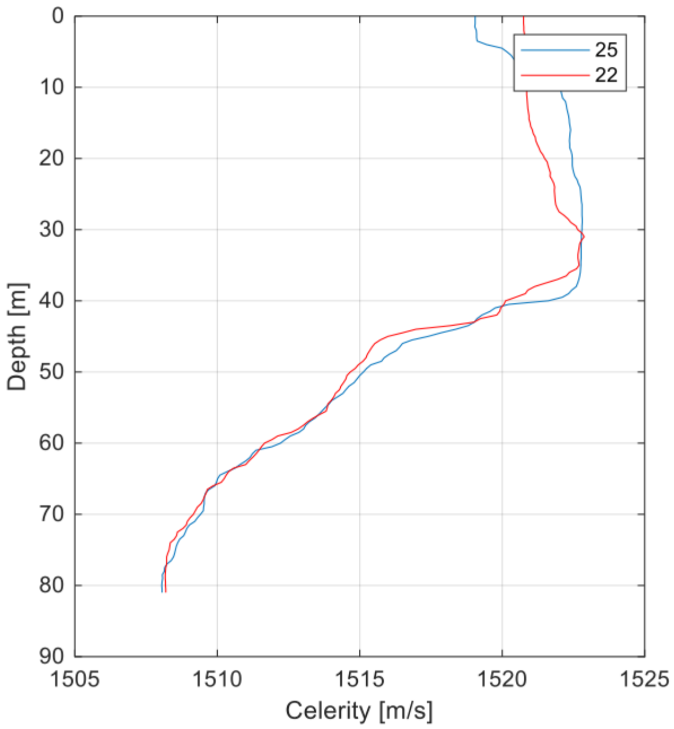

Figure 13: Sound velocity profile as given by onsite measures for the two different test days.

Frequencies: 1/3 octave bands from 12.5 Hz to 20kHz. For each band the lower, upper and central frequency are simulated and the results averaged.

Sea depth: 81 m

Bottom composition: silt with the parameters taken from Table 9.

Table 9: Sea bottom parameters from Jensen et al. 2000.

Bottom type	p (%)	ρ_b/ρ_w -	c_p/c_w -	c_p (m/s)	c_s (m/s)	α_p (dB/λ_p)	α_s (dB/λ_s)
Clay	70	1.5	1.00	1500	< 100	0.2	1.0
Silt	55	1.7	1.05	1575	$c_s^{(1)}$	1.0	1.5
Sand	45	1.9	1.1	1650	$c_s^{(2)}$	0.8	2.5
Gravel	35	2.0	1.2	1800	$c_s^{(3)}$	0.6	1.5
Moraine	25	2.1	1.3	1950	600	0.4	1.0
Chalk	-	2.2	1.6	2400	1000	0.2	0.5
Limestone	-	2.4	2.0	3000	1500	0.1	0.2
Basalt	-	2.7	3.5	5250	2500	0.1	0.2

$c_s^{(1)} = 80\,\tilde{z}^{0.3}$
$c_s^{(2)} = 110\,\tilde{z}^{0.3}$
$c_s^{(3)} = 180\,\tilde{z}^{0.3}$

$c_w = 1500$ m/s, $\rho_w = 1000$ kg/m^3

For each frequency, OC versus range and depth matrix was calculated. From that matrix the needed values of OC for each boat are calculated by taking into account the source depth and the distance from the hydrophone at the CPA. Examples of OC vs range and depth are given in Figure 14 and 15.

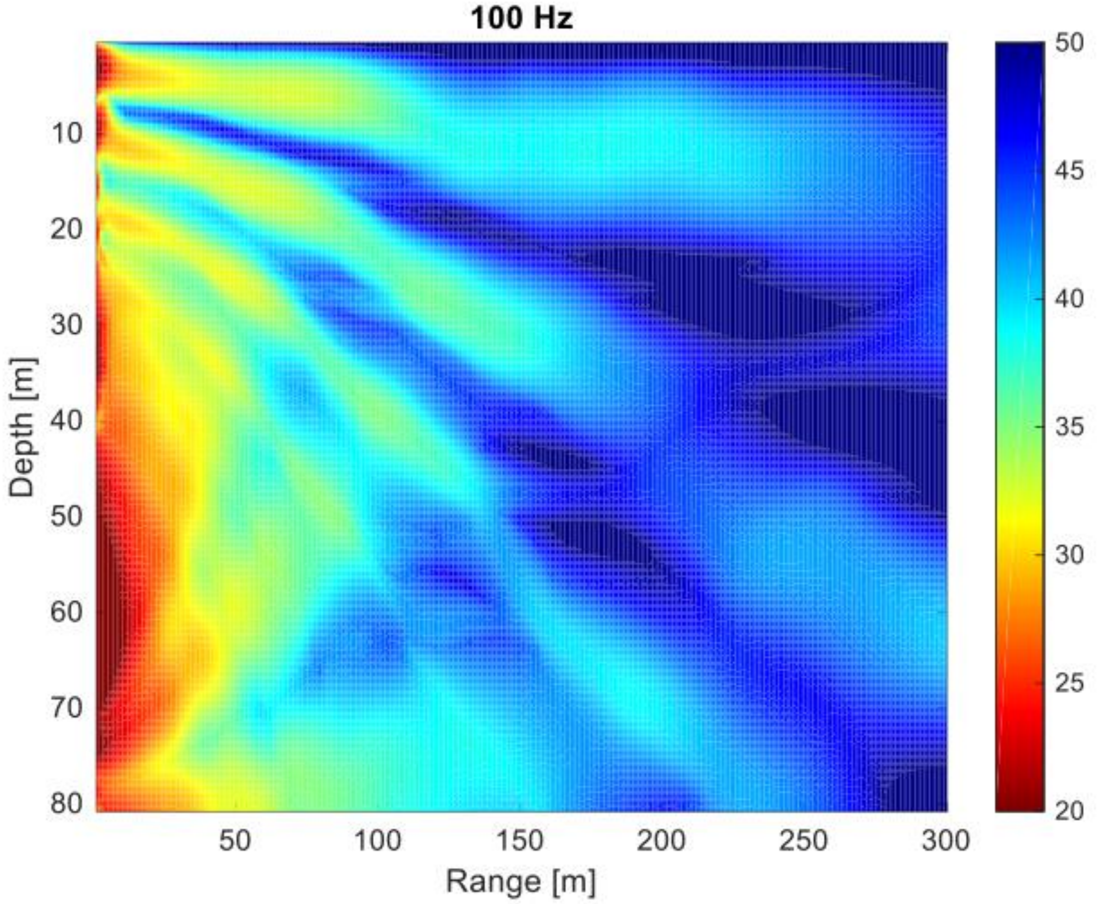

Figure 14: Example of OC vs Range and Depth at 100 Hz

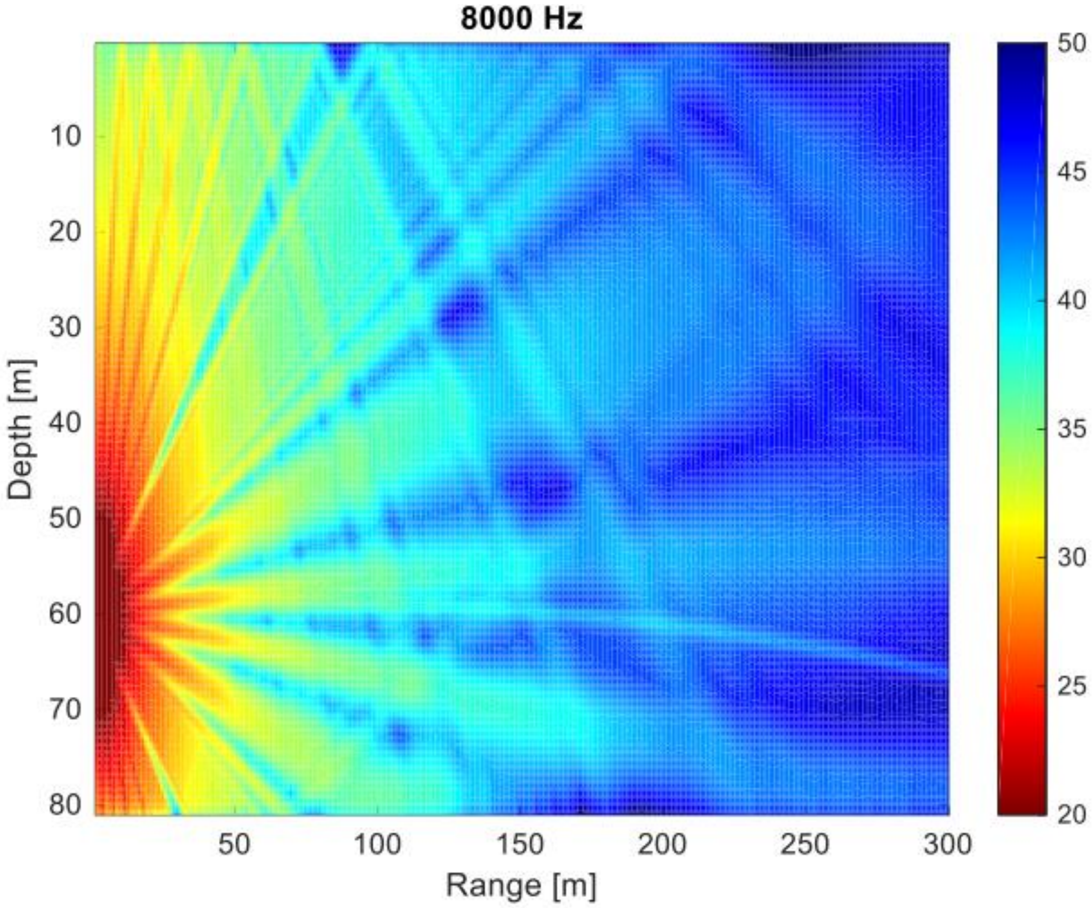

Figure 15: Example of OC vs Range and Depth at 8000 Hz

For a given boat a OC curve was therefore estimated for each frequency as shown in the example in Figure 16.

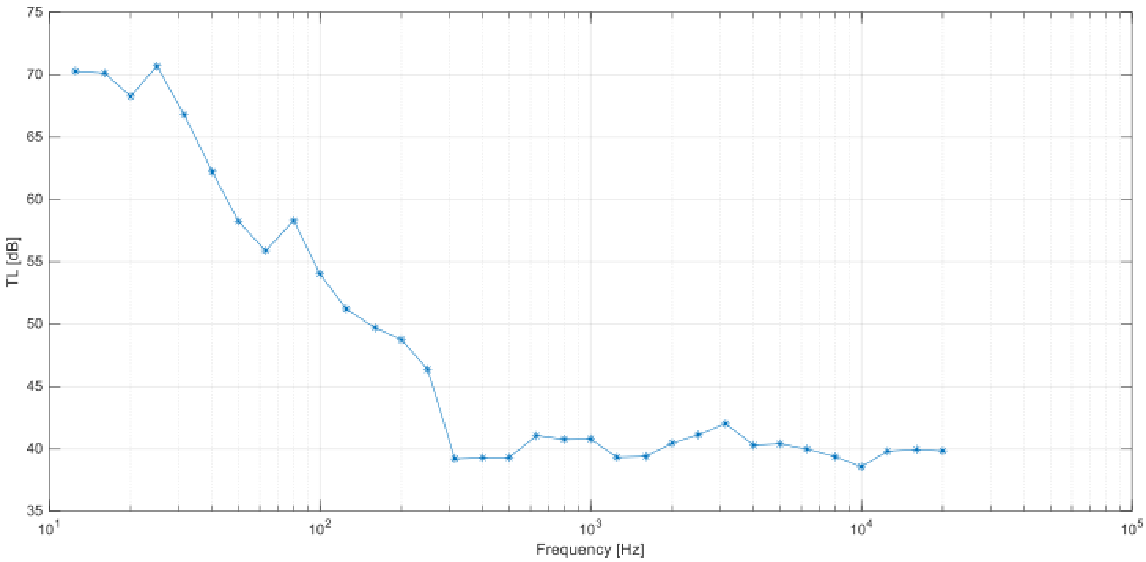

Figure 16: Exple of the overall correction (TL + ΔL)

4. Results

The **source levels** of the speed boat (Table 10), motor yacht (Table 11), motor boat (Table 12), sailing boat on engine (Table 13), trawler (Table 14), gillnetter (Table 15) and tour boat (Table 16) were calculated both for a propagation factor of X = 19 dB re 1µPa according to the rule for URN in shallow waters (BV, 2014), X = 18 dB re 1µPa (DNV, 2010) (see §2.3.1) and according to the transmission loss model calculated on the base of the local conditions (see §2.3.2 and §2.3.3).

All source levels were calculated for frequencies of 63 Hz, 125 Hz, 250 H and 4000 Hz for port and starboard side at d_{CPA1} and d_{CPA2}. A graph comparing the overall correction based on a propagation factor of X = 19 dB re 1µPa, X = 18 dB re 1µPa and the ΔL, as well as according to the model is provided *per* each boat type: the speed boat (Figures 17), motor yacht (Figures 18), motor boat (Figures 19), sailing boat on engine (Figures 20), trawler (Figures 21), gillnetter (Figures 22) and tour boat (Figures 23).

Table 10: Source Level – Speed boat

	Cruising speed: 15,1 kn				High speed: 24,9 kn			
SL calculated with propagation factor X = 19								
Frequency (Hz)	**63**	**125**	**250**	**4000**	**63**	**125**	**250**	**4000**
SL – Port – dCPA1 (dB re 1 µPa)	152	159,4	147,2	143,6	151,3	142,2	142	150,1
SL – Starboard – dCPA1 (dB re 1 µPa)	154,2	160,6	146,7	142,8	149,7	141,2	142,2	149,1
SL – Port – dCPA2 (dB re 1 µPa)	155,3	162,6	150,3	144,2	149,5	0	142,2	153,6
SL – Starboard – dCPA2 (dB re 1 µPa)	156,2	162,3	150,2	144	148,5	0	143,1	152,1
SL total correct (dB re 1 µPa)	**154,4**	**161,2**	**148,6**	**143,7**	**149,8**	**141,7**	**142,4**	**151,2**
SL calculated with propagation factor X = 19								
Frequency (Hz)	**63**	**125**	**250**	**4000**	**63**	**125**	**250**	**4000**
SL – Port – dCPA1 (dB re 1 µPa)	150	157,5	145,2	141,6	149,3	140,3	140	148,1
SL – Starboard – dCPA1 (dB re 1 µPa)	152,2	158,7	144,7	140,8	147,7	139,2	140,2	147,1
SL – Port – dCPA2 (dB re 1 µPa)	153,1	160,4	148,1	142	147,2	0	140	151,4
SL – Starboard – dCPA2 (dB re 1 µPa)	154	160,1	148	141,8	146,3	0	140,9	149,8
SL total correct (dB re 1 µPa)	152,3	159,1	146,5	141,6	147,7	139,7	140,3	149,1
SL calculated with propagation factor X dependent on frequency								
Frequency (Hz)	**63**	**125**	**250**	**4000**	**63**	**125**	**250**	**4000**
SL – Port – dCPA1 (dB re 1 µPa)	148,1	156,5	143,3	146,9	147,5	139,3	138,1	153,4
SL – Starboard – dCPA1 (dB re 1 µPa)	150,4	157,7	142,8	146,1	145,9	138,2	138,3	152,5
SL – Port – dCPA2 (dB re 1 µPa)	149,3	160,5	147	150	143,5	0	138,9	159,3
SL – Starboard – dCPA2 (dB re 1 µPa)	150,2	160,2	146,9	149,8	142,6	0	139,8	157,8
SL total correct (dB re 1 µPa)	**149,5**	**158,7**	**145**	**148,2**	**144,9**	**138,7**	**138,8**	**155,7**

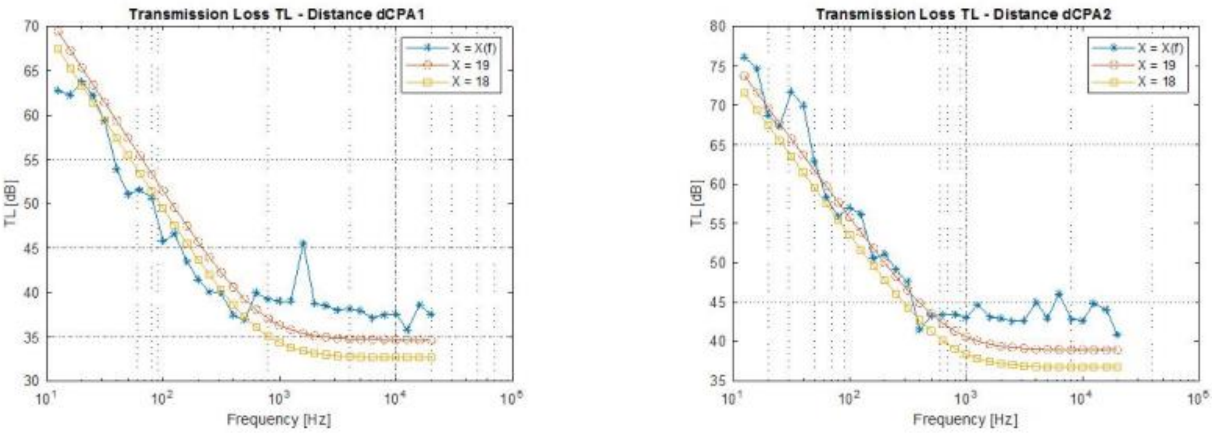

Figure 17: Overall correction (Transmission Loss + ΔL) for the speed boat

Table 11: Source Level – Motor yacht

	Cruising speed: 15,1 kn				High speed: 24,9 kn			
SL calculated with propagation factor X = 19								
Frequency (Hz)	**63**	**125**	**250**	**4000**	**63**	**125**	**250**	**4000**
SL – Port – dCPA1 (dB re 1 µPa)	147,1	150,4	154,1	151,3	143,6	147,4	157,6	151,4
SL – Starboard – dCPA1 (dB re 1 µPa)	146,8	149,5	154,9	150,8	145,5	145,7	151,1	150,2
SL – Port – dCPA2 (dB re 1 µPa)	151,2	152,6	155,6	152,4	148,7	148,7	157,2	152,9
SL – Starboard – dCPA2 (dB re 1 µPa)	150,3	151,1	154,5	151,9	147,5	147,5	153,7	152,5
SL total correct (dB re 1 µPa)	**148,9**	**150,9**	**154,8**	**151,6**	**146,3**	**146,9**	**154,9**	**151,7**
SL calculated with propagation factor X = 19								
Frequency (Hz)	**63**	**125**	**250**	**4000**	**63**	**125**	**250**	**4000**
SL – Port – dCPA1 (dB re 1 µPa)	145,2	148,4	152,1	149,3	141,6	145,5	155,6	149,5
SL – Starboard – dCPA1 (dB re 1 µPa)	144,8	147,5	152,9	148,8	143,5	143,8	149,1	148,2
SL – Port – dCPA2 (dB re 1 µPa)	149	150,4	153,4	150,1	146.5	145,8	154,9	150,7
SL – Starboard – dCPA2 (dB re 1 µPa)	148,1	148,9	152,3	149,7	145,3	144	151,5	150,3
SL total correct (dB re 1 µPa)	**146,8**	**148,8**	**152,7**	**149,5**	**144,2**	**144,8**	**152,8**	**149,7**
SL calculated with propagation factor X dependent on frequency								
Frequency (Hz)	**63**	**125**	**250**	**4000**	**63**	**125**	**250**	**4000**
SL – Port – dCPA1 (dB re 1 µPa)	146,8	150,8	153,1	154,7	143,2	147,8	156,7	154,9
SL – Starboard – dCPA1 (dB re 1 µPa)	146,4	149,9	153,9	154,2	145,1	146,1	150,1	153,7
SL – Port – dCPA2 (dB re 1 µPa)	148,7	153,9	155,6	158,3	146,2	149,4	157,1	158,8
SL – Starboard – dCPA2 (dB re 1 µPa)	147,8	152,4	154,5	157,9	145	147,5	153,7	158,4
SL total correct (dB re 1 µPa)	**147,4**	**151,8**	**154,3**	**156,3**	**144,9**	**147,7**	**154,4**	**156,4**

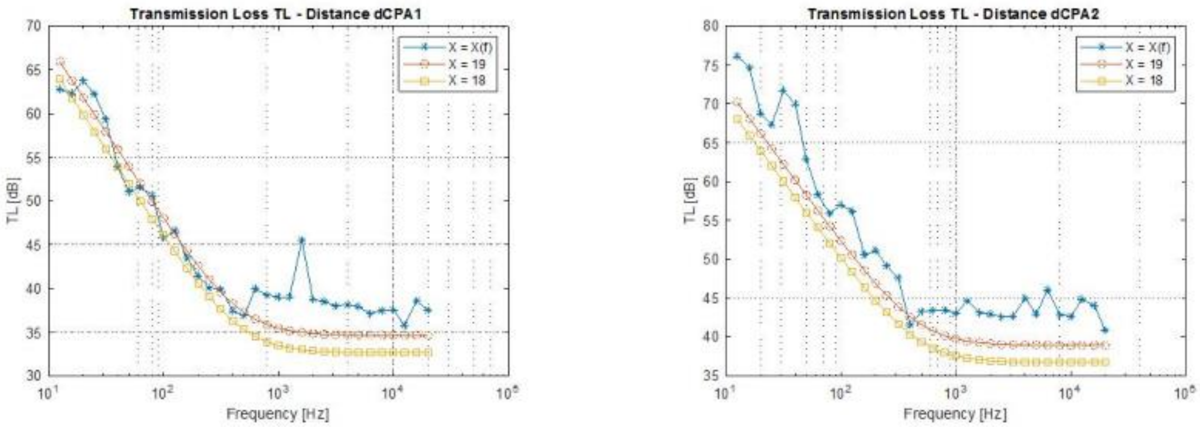

Figure 18: Overall correction (Transmission Loss + ΔL) for the motor yacht

Table 12: Source Level – Motor boat

	Cruising speed: 15,1 kn				High speed: 24,9 kn			
SL calculated with propagation factor X = 19								
Frequency (Hz)	**63**	**125**	**250**	**4000**	**63**	**125**	**250**	**4000**
SL – Port – dCPA1 (dB re 1 µPa)	177,2	145,2	141,1	137,3	179,8	148,9	140,8	144,2
SL – Starboard – dCPA1 (dB re 1 µPa)	178,4	145,9	141,7	136,3	180,1	149,5	142,1	142
SL – Port – dCPA2 (dB re 1 µPa)	170,2	147,2	144,1	137	183,1	151,6	143,7	143,6
SL – Starboard – dCPA2 (dB re 1 µPa)	170,8	149,5	144,1	138,5	182,4	153,1	144,8	143,6
SL total correct (dB re 1 µPa)	**174,2**	**147**	**142,8**	**137,3**	**181,3**	**150,8**	**142,9**	**143,3**
SL calculated with propagation factor X = 19								
Frequency (Hz)	**63**	**125**	**250**	**4000**	**63**	**125**	**250**	**4000**
SL – Port – dCPA1 (dB re 1 µPa)	175,2	143,2	139,1	135,3	177,8	146,9	138,8	142,2
SL – Starboard – dCPA1 (dB re 1 µPa)	176,5	143,9	139,7	134,3	178,1	147,6	140,2	140
SL – Port – dCPA2 (dB re 1 µPa)	168	145	141,9	134,8	180,9	149,4	141,5	141,4
SL – Starboard – dCPA2 (dB re 1 µPa)	168,6	147,3	141,9	136,3	180,2	150,9	142,6	141,4
SL total correct (dB re 1 µPa)	**172,1**	**144,9**	**140,7**	**135,2**	**179,3**	**148,7**	**140,8**	**141,2**
SL calculated with propagation factor X dependent on frequency								
Frequency (Hz)	**63**	**125**	**250**	**4000**	**63**	**125**	**250**	**4000**
SL – Port – dCPA1 (dB re 1 µPa)	175,6	144,6	139,4	141	178,3	148,2	139,1	147,9
SL – Starboard – dCPA1 (dB re 1 µPa)	176,9	145,3	140,1	140	178,6	148,9	140,5	145,7
SL – Port – dCPA2 (dB re 1 µPa)	166,6	147,4	143,1	143	179,5	151,8	142,7	149,6
SL – Starboard – dCPA2 (dB re 1 µPa)	167,2	149,7	143,1	144,5	178,8	153,3	143,8	149,6
SL total correct (dB re 1 µPa)	**171,6**	**146,7**	**141,4**	**142,1**	**178,8**	**150,6**	**141,5**	**148,2**

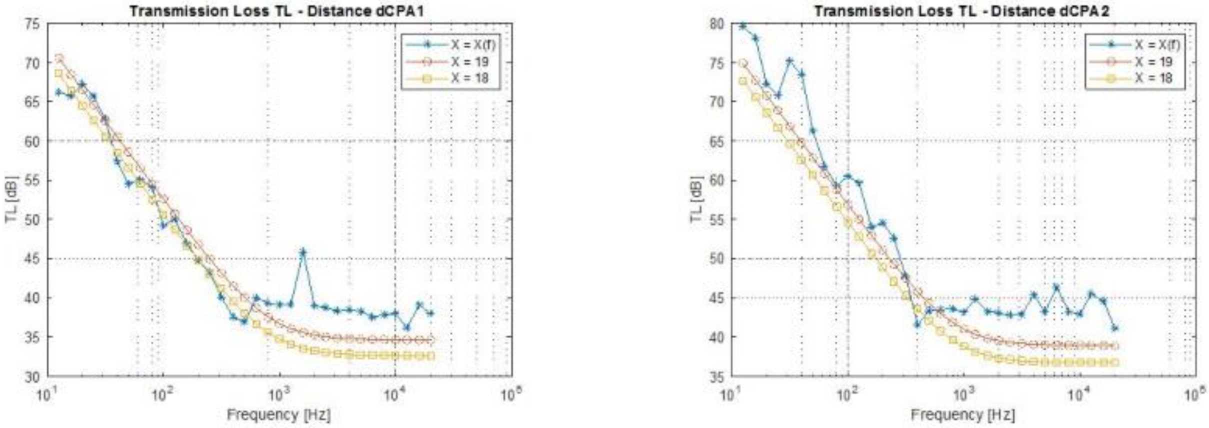

Figure 19: Overall correction (Transmission Loss + ∆L) for the Motor boat

Table 13: Source Level – Sailing boat

	Cruising speed: 15,1 kn				High speed: 24,9 kn			
SL calculated with propagation factor X = 19								
Frequency (Hz)	**63**	**125**	**250**	**4000**	**63**	**125**	**250**	**4000**
SL – Port – dCPA1 (dB re 1 µPa)	138,9	136,3	126	127	134,1	126,6	135,1	134,2
SL – Starboard – dCPA1 (dB re 1 µPa)	139,3	137,4	128,5	127,6	137,2	126,7	134,2	134,9
SL – Port – dCPA2 (dB re 1 µPa)	143	137,2	0	128	141,4	133,6	136,5	136,3
SL – Starboard – dCPA2 (dB re 1 µPa)	148,9	141,6	127,1	128,2	140,8	134,3	136,5	137
SL total correct (dB re 1 µPa)	**142,5**	**138,1**	**127,2**	**127,7**	**138,4**	**130,3**	**135,6**	**135,6**
SL calculated with propagation factor X = 19								
Frequency (Hz)	**63**	**125**	**250**	**4000**	**63**	**125**	**250**	**4000**
SL – Port – dCPA1 (dB re 1 µPa)	136,9	134,3	124	125	132,1	124,6	133,1	132,2
SL – Starboard – dCPA1 (dB re 1 µPa)	137,4	135,4	126,6	125,6	135,2	124,7	132,3	133
SL – Port – dCPA2 (dB re 1 µPa)	140,7	135	0	125,8	139,2	131,4	134,3	134,1
SL – Starboard – dCPA2 (dB re 1 µPa)	146,7	139,4	124,9	126	138,6	132,1	134,3	134,8
SL total correct (dB re 1 µPa)	**140,4**	**136**	**125,2**	**125,6**	**136,3**	**128,2**	**133,5**	**133,5**
SL calculated with propagation factor X dependent on frequency								
Frequency (Hz)	**63**	**125**	**250**	**4000**	**63**	**125**	**250**	**4000**
SL – Port – dCPA1 (dB re 1 µPa)	136,1	134,4	123,1	130,2	131,4	124,7	132,1	137,4
SL – Starboard – dCPA1 (dB re 1 µPa)	136,6	135,5	125,6	130,9	134,5	124,8	131,3	138,2
SL – Port – dCPA2 (dB re 1 µPa)	138,1	136,3	0	132,8	136,6	132,7	134,3	141,1
SL – Starboard – dCPA2 (dB re 1 µPa)	144,1	140,7	124,9	133	136	133,3	134,3	141,8
SL total correct (dB re 1 µPa)	**138,7**	**136,7**	**124,5**	**131,7**	**134,6**	**128,9**	**133**	**139,6**

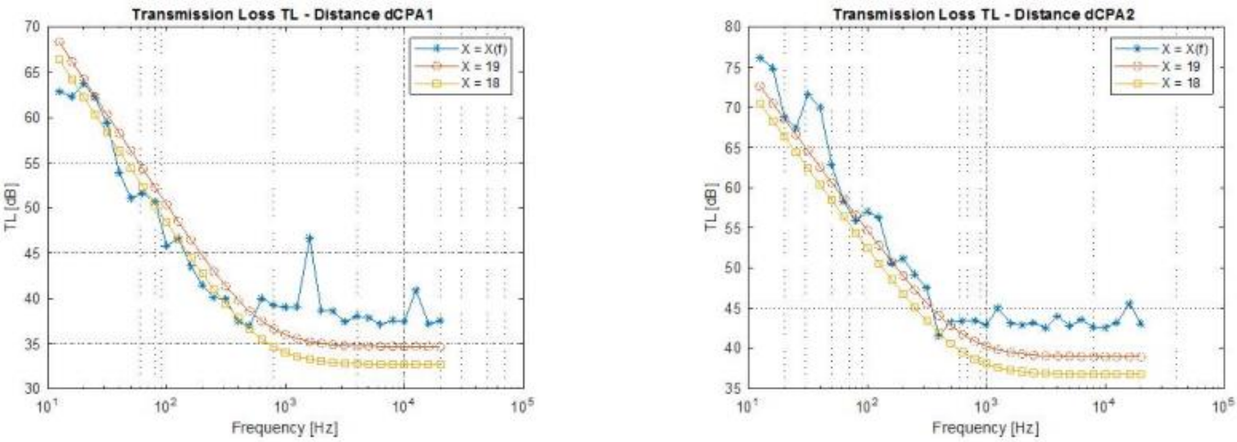

Figure 20: Overall correction (Transmission Loss + ∆L) for the sailing boat

Table 14: Source Level – Trawler

	Cruising speed: 15,1 kn				High speed: 24,9 kn			
SL calculated with propagation factor X = 19								
Frequency (Hz)	**63**	**125**	**250**	**4000**	**63**	**125**	**250**	**4000**
SL – Port – dCPA1 (dB re 1 µPa)	150	146,6	145,2	131,6	149,6	146,7	146	133
SL – Starboard – dCPA1 (dB re 1 µPa)	153	148	144,8	133,1	153,3	151,8	145,7	133,9
SL – Port – dCPA2 (dB re 1 µPa)	155,4	147,9	144,4	132,5	157,7	147,8	146,4	133,4
SL – Starboard – dCPA2 (dB re 1 µPa)	156,2	151,9	146	134,6	159,1	153,4	146,9	135,3
SL total correct (dB re 1 µPa)	**153,6**	**148,6**	**145,1**	**133**	**154,9**	**149,9**	**146,3**	**133,9**
SL calculated with propagation factor X = 19								
Frequency (Hz)	**63**	**125**	**250**	**4000**	**63**	**125**	**250**	**4000**
SL – Port – dCPA1 (dB re 1 µPa)	148	144,6	143,3	129,7	147,7	144,7	144	131
SL – Starboard – dCPA1 (dB re 1 µPa)	151	146,1	142,8	131,1	151,3	149,9	143,7	131,9
SL – Port – dCPA2 (dB re 1 µPa)	153,2	145,7	142,2	130,3	155,5	145,6	144,2	131,2
SL – Starboard – dCPA2 (dB re 1 µPa)	154	149,7	143,8	132,4	156,9	151,2	144,7	133,1
SL total correct (dB re 1 µPa)	**151,4**	**146,5**	**143**	**130,9**	**152,9**	**147,8**	**144,2**	**131,8**
SL calculated with propagation factor X dependent on frequency								
Frequency (Hz)	**63**	**125**	**250**	**4000**	**63**	**125**	**250**	**4000**
SL – Port – dCPA1 (dB re 1 µPa)	150,1	147,1	143,6	134,3	149,8	147,1	144,4	135,6
SL – Starboard – dCPA1 (dB re 1 µPa)	153,1	148,5	143,2	135,7	153,4	152,3	144,1	136,5
SL – Port – dCPA2 (dB re 1 µPa)	153,5	149,6	144,2	137,6	155,9	149,5	146,2	138,5
SL – Starboard – dCPA2 (dB re 1 µPa)	154,3	153,6	145,8	139,7	157,2	155,1	146,7	140,4
SL total correct (dB re 1 µPa)	**152,8**	**149,7**	**144,2**	**136,8**	**154,1**	**151**	**145,4**	**137,8**

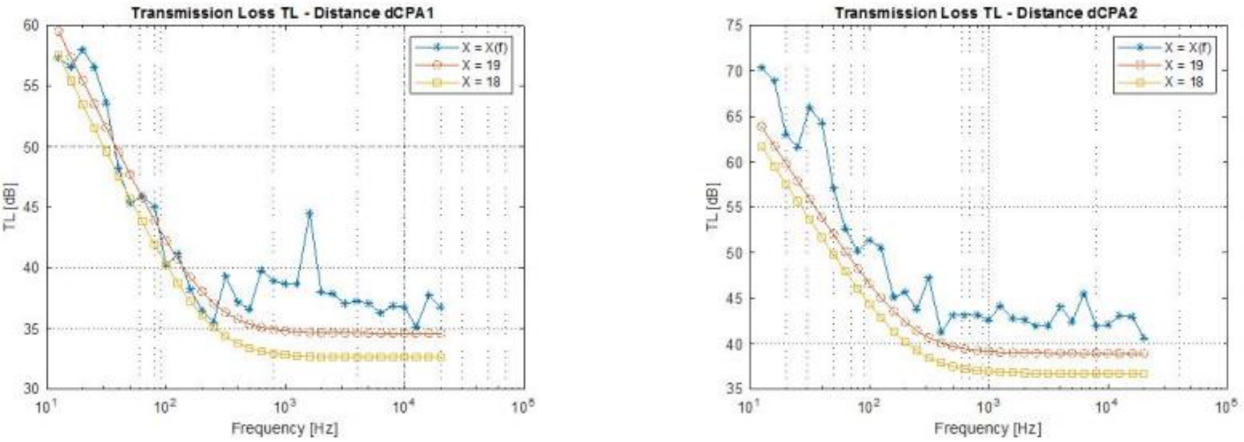

Figure 21: Overall correction (Transmission Loss + ΔL) for the trawler

Table 15: Source Level – Gillnetter

	Cruising speed: 15,1 kn				High speed: 24,9 kn			
SL calculated with propagation factor X = 19								
Frequency (Hz)	**63**	**125**	**250**	**4000**	**63**	**125**	**250**	**4000**
SL – Port – dCPA1 (dB re 1 µPa)	170,5	147,1	154,6	139,2	167,8	155	159,2	137,4
SL – Starboard – dCPA1 (dB re 1 µPa)	169,2	145,3	152,7	138,8	167,5	151,8	159,3	140,4
SL – Port – dCPA2 (dB re 1 µPa)	154	146,5	154,8	137,6	172,8	152,1	160,2	138,1
SL – Starboard – dCPA2 (dB re 1 µPa)	156,6	146,9	155,5	138,7	171,1	152,5	160,6	140,2
SL total correct (dB re 1 µPa)	**162,6**	**146,5**	**154,4**	**138,6**	**169,8**	**152,8**	**159,8**	**139**
SL calculated with propagation factor X = 19								
Frequency (Hz)	**63**	**125**	**250**	**4000**	**63**	**125**	**250**	**4000**
SL – Port – dCPA1 (dB re 1 µPa)	168,5	145,1	152,6	137,3	165,8	153	157,2	135,4
SL – Starboard – dCPA1 (dB re 1 µPa)	167,2	143,3	150,7	136,9	165,5	149,9	157,3	138,4
SL – Port – dCPA2 (dB re 1 µPa)	151,8	144,3	152,6	135,4	170,6	149,8	158	135,9
SL – Starboard – dCPA2 (dB re 1 µPa)	154,4	144,7	153,3	136,5	168,9	150,3	158,4	138
SL total correct (dB re 1 µPa)	**160,5**	**144,4**	**152,3**	**136,5**	**167,7**	**150,8**	**157,7**	**136,9**
SL calculated with propagation factor X dependent on frequency								
Frequency (Hz)	**63**	**125**	**250**	**4000**	**63**	**125**	**250**	**4000**
SL – Port – dCPA1 (dB re 1 µPa)	170	147,4	153,6	142,7	167,3	155,3	158,1	140,8
SL – Starboard – dCPA1 (dB re 1 µPa)	168,8	145,6	151,7	142,3	167	152,1	158,2	143,8
SL – Port – dCPA2 (dB re 1 µPa)	151,4	147,8	154,7	143,5	170,2	153,3	160,1	144
SL – Starboard – dCPA2 (dB re 1 µPa)	154	148,1	155,4	144,7	168,5	153,7	160,5	146,1
SL total correct (dB re 1 µPa)	**161,1**	**147,2**	**153,8**	**143,3**	**168,3**	**153,6**	**159,2**	**143,7**

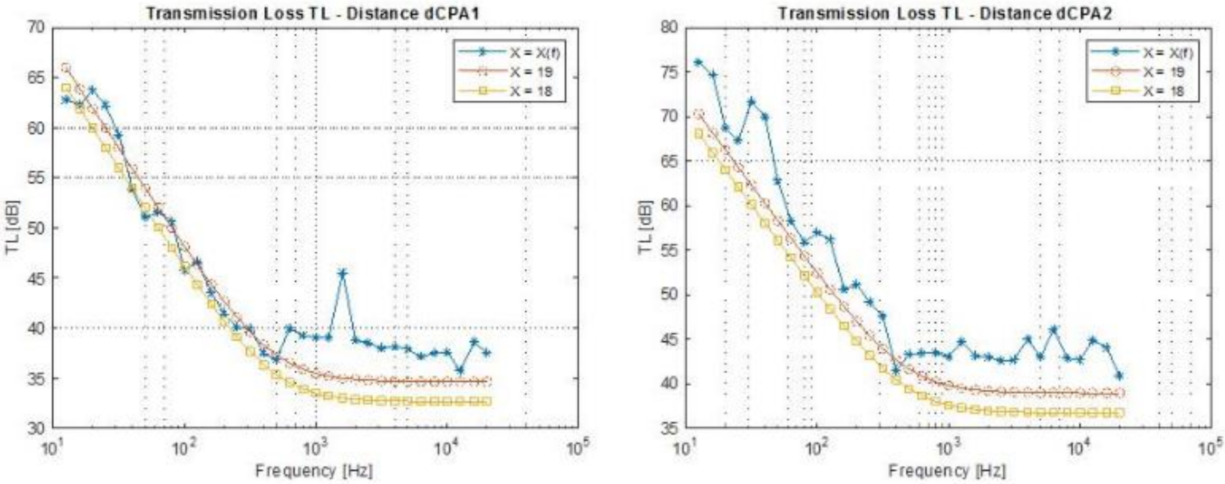

Figure 17: Overall correction (Transmission Loss + ∆L) for the Gillnetter

Table 16: Source Level – Tour boat

	Cruising speed: 15,1 kn				High speed: 24,9 kn			
SL calculated with propagation factor X = 19								
Frequency (Hz)	**63**	**125**	**250**	**4000**	**63**	**125**	**250**	**4000**
SL – Port – dCPA1 (dB re 1 µPa)	146,1	166,1	163,8	146,7	149,9	167,8	164,6	147,3
SL – Starboard – dCPA1 (dB re 1 µPa)	146,1	165,3	163,3	148,1	151,6	167,7	167,3	149,7
SL – Port – dCPA2 (dB re 1 µPa)	152,5	164	168,3	148,2	154,7	170,8	170,8	150,1
SL – Starboard – dCPA2 (dB re 1 µPa)	152	166,4	165,9	149,9	151,4	172,3	167,8	151,5
SL total correct (dB re 1 µPa)	**149,2**	**165,5**	**165,3**	**148,2**	**151,9**	**169,7**	**167,6**	**149,7**
SL calculated with propagation factor X = 19								
Frequency (Hz)	**63**	**125**	**250**	**4000**	**63**	**125**	**250**	**4000**
SL – Port – dCPA1 (dB re 1 µPa)	144,1	164,1	161,8	144,7	147,9	165,8	162,6	145,3
SL – Starboard – dCPA1 (dB re 1 µPa)	144,1	163,3	161,3	146,1	149,7	165,7	165,4	147,8
SL – Port – dCPA2 (dB re 1 µPa)	150,3	161,8	166,1	146	152,5	168,6	168,6	147,9
SL – Starboard – dCPA2 (dB re 1 µPa)	149,7	164,2	163,7	147,7	149,2	170,1	165,6	149,3
SL total correct (dB re 1 µPa)	**147,1**	**163,4**	**163,2**	**146,1**	**149,8**	**167,6**	**165,5**	**147,6**
SL calculated with propagation factor X dependent on frequency								
Frequency (Hz)	**63**	**125**	**250**	**4000**	**63**	**125**	**250**	**4000**
SL – Port – dCPA1 (dB re 1 µPa)	143,4	164,2	160,8	150	147,2	165,9	161,7	150,6
SL – Starboard – dCPA1 (dB re 1 µPa)	143,4	163,5	160,3	151,4	148,9	165,8	164,4	153
SL – Port – dCPA2 (dB re 1 µPa)	147,7	163	166,1	153	149,9	169,9	168,6	154,9
SL – Starboard – dCPA2 (dB re 1 µPa)	147,1	165,5	163,7	154,7	146,6	171,3	165,6	156,3
SL total correct (dB re 1 µPa)	**145,4**	**164**	**162,8**	**152,3**	**148,2**	**168,2**	**165,1**	**153,7**

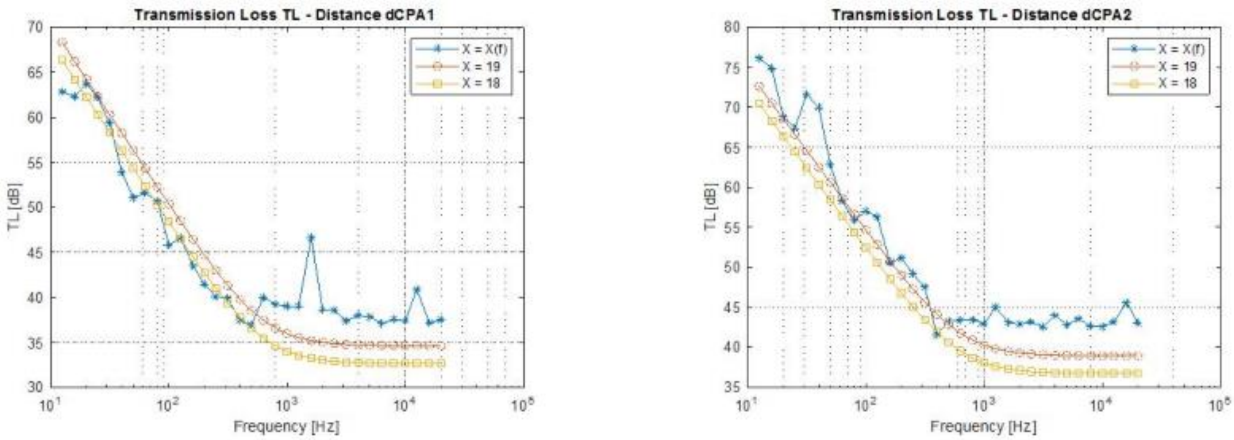

Figure 17: Overall correction (Transmission Loss + ∆L) for the tour boat

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