Recommendation for the source level assessment

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Summary

1. INTRODUCTION

Recreational boating noise represents a considerable contribution to the overall underwater noise. Within the Adriatic Sea, recreational boating is especially intense in the summer months due to nautical tourism and the presence of numerous ports and marinas visited by these leisure boats along the coastline. Evaluating the noise inputs of leisure crafts to the local sea background noise is therefore essential when identifying the most dominant anthropogenic noise sources in this region.

Various internationally agreed standards have been issued over the past years and some are still being developed for the purpose of undertaking high precision measurements of radiated noise from the ships. It is a topic of extensive interest due to the acknowledgment of the potential impact they may have on the environment and the need to regulate them. So far ISO developed standards for radiated noise level (ISO 17208-1: 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) and source level (ISO 17208-2: Underwater acoustics -- Quantities and procedures for description and measurement of underwater sound from ships -- Part 2: Determination of source levels from deep water measurements) in relatively deep water. A third standard in the series (ISO 17208-3: Underwater acoustics -- Quantities and procedures for description and measurement of underwater noise from ships -- Part 3: Requirements for measurements in shallow water) is presently under development. In the absence of requirements for the measurements of noise from the small boats in shallow water environments such as the North Adriatic Sea, this document provides guidelines to follow for recreational boat noise assessment for the purposes of the Soundscape project.

According to the recent publications, carrying out such measurements represents a considerable challenge. In fact the methodology set out in the standards includes requirements that are not easy to meet in shallow waters as - for example - attention should be given to disentangle the source effects from the effects of seabed reflections. Procedures here recommended are based on the existing standards and published papers that compare different methods for small boat noise assessment in shallow waters. The available standards considered for this purpose are listed in Table 1 whereas the available literature reviews are cited in the list of references (*see list of references*).

Table 1. Consulted underwater noise measurement standards

Internationally Recognized Standards	
ANSI/ASA S12.64-Part 1, 2009	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 from deep water measurements
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 water
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 Rule Note NR614

2. MEASUREMENT METHODS

Boat noise sources include a) propeller noise, b) flow noise and/or c) machinery noise. Characteristics of each ship noise source depend also on the ship type, its propulsion and speed and on whether any noise quiting features are incorporated in the boat design. At low speed the dominant source is machinery noise which increases in level with ship speed while at greater speeds underwater noise is dominated by propeller noise (particularly for speeds above cavitation onset). In the mid speed range, flow noise may also be a contributor to underwater noise. In case of small boats, the underwater noise is related to the propeller cavitation, a so callled “cavitation noise“.

In shallow water, boat noise features are also affected by the characteristics of the sea bottom. This is why ANSI and ISO standards recommend the highest grade measurements to be conducted with a minimum water depth being 300m or three times ship length; 150 m or 1.5 ship lenght water depth is requested for middle grade measurement and 75 m or 1 time ship length for lowest grade measurements. This recommendation is set in order to ensure that measurements include acoustic contribution along the full lenght of the boat, bow-to-stern.

There are different options for the hydrophone configuration that might serve the scope of measuring boat emitted noise. There are bottom mounted or suspended from the surface buoys in addition to supporting platform for the hydrophone. It is generally suggested to measure boat noise by using multiple hydrophones in an array or string but the use of a single hydrophone measurement is also possible. The choice of three hydrophones allows to smooth the variabiliy caused by Lloyd's mirror surface image coherence effects by averaging the measured value. This choice usually refers to high grade and middle grade measurements. According to the standards, a ship-to-hydrophone degrees should be 15°, 30° and 45° in case of using three hydrophones (Brooker and Humphrey, 2016) and 45° in case of a single hydrophone measurement (Sipilä et al. 2019)

3. Standard noise test configuration

According to the available standards, a testing sequence should involve a boat sailing along the straight line track (figure 1), from the start point (COMEX) to the end (FINEX), passing the spot closest to the location where the hydrophones are deployed so called Closest Point of Approach (CPA). The CPA represents the closest horizontal distance the vessel passes to the hydrophone array index loaction as measured from the ship acoustic center (the location from which all underwater noise originates as if ship acoustic radiation is from a single point source). Accuracy of CPA is to be +/-10 m.

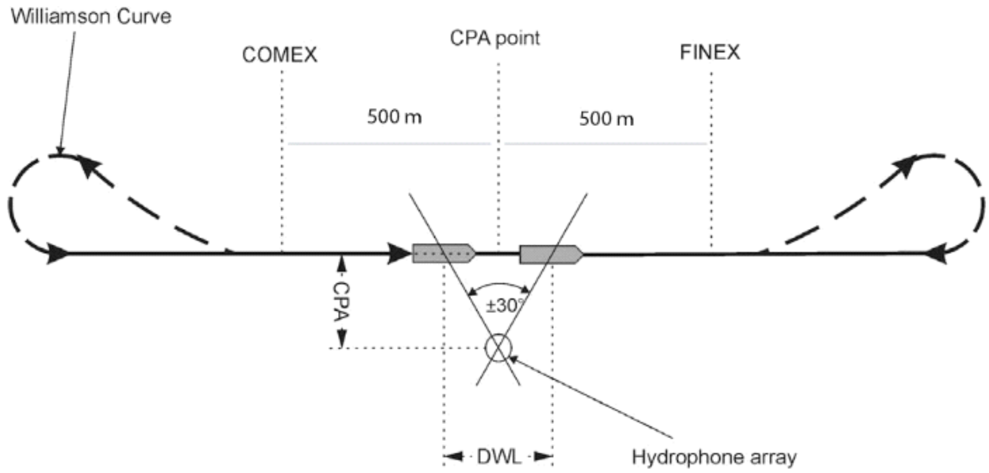

Figure 1

Different procedures propose the use of the run speed of 5 and 12 kts. During the test run, the boat should maintain the same speed and course. When the boat is at the Closest Point of Approach (CPA), the hydrophones are at the angles of 15°, 30° and 45° from the boat as measured from the sea surface (figure 2). Test runs should be made for both port and starboard aspect at three different CPA's to aid in accounting for propagation losses. Some standards propose 6 runs to be made for both port and starboard aspect for three CPAs: CPA1= 200 m or distance of 1 ship lenght; CPA2= 400 m or distance of 1.5 ship lengths and CPA3= 500m or distance of 2 ship lengths.

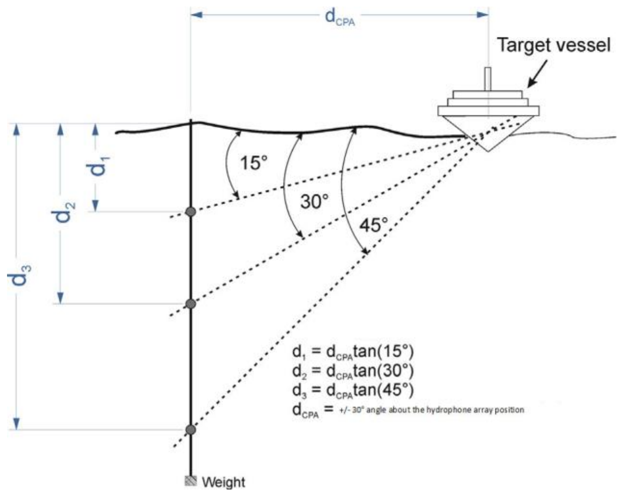

Figure 2. Recommended measurement system scheme

Wladichuk et al. (2018) have focused on small boats incuding pleasure boats similar to those that should be tested within the Soundscape project. Here a Whale Watch and Small Vessel Underwater Noise measurements were undertaken in Haro Strait by JASCO APPLIED SCIENCES as a part of ECHO Program Study Summary. For such study a CPA distance from the hydrophone of 110 m has been used. Along the track all boats moved at constant speed when passing from comex to finex separated 1000 m from each other (500m from both comex and finex to CPA). Then the boat performs a William turn to return along the same track assuring that both port and starboard side measurements were made.

4. Shallow water noise test configuration

While preference is for deep waters as well as for a multiple hydrophone array in case of high precision measurements, this is not viable when the overall region is characterized by the shallow water with the average depth around 70m, as is the case of the Cres – Lošinj area where the measurements will take place. As result alternative methods have to be applied in other areas as when the requirements of the existing standards are unable to be met. The precision of these alternatives have been tested by the here consulted studies. Hasenpflug and his colleagues (2019) compared the boat noise levels measured by using one and three hydrophones in Herdla fjord (Norway). According to their results, the boat noise characterisation obtained by an optimal hydrophone depth of 60 m is fully comparable to the average noise measured with three hydrophones positioned at different depths and angles, as proposed by ISO 17208); this is especially true when considering Lloyd's mirror effect. Similar results have been found by Sipilä and his colleagues (2019) while assesing the shallow water effects on ship underwater noise measurements in costal waters of Helsinki. Comparable boat noise measurments have been obtained by these authors using an array of three hydrophones deployed at different depts and a single hydrophone, accounting for distance corrections and bottom reflections.

5. RECOMMENDATIONS FOR THE BOAT NOISE LEVEL ASSESMENT IN THE NORTH ADRIATIC SEA

RECOMMENDATION 1: Select suitable test site and test-time according to the depth location and the seasonal weather.

Try to (i) minimize the sea traffic in the vicinity, considering the surrounding shipping activities, (ii) expand the distance from shore, preventing unwanted reflections.

RECOMMENDATION 2: Prepare a test datasheet.

The following informations sould be included in the datasheet:

Vessel Information including vessel's name, hull number, class number, etc., as well as the vessel's main dimensions, propulsion characteristics and propeller Information.

Operating conditions of vessels to be tested including speed, draft, machinery configuration, engine output.

Measurement Test Site Characteristics including geographical location, water depth, sea bottom conditions, water column acoustic properties (salinity, water temperature, and density that varies with the water depth to derive the sound speed) as well as wind speed, sea surface conditions and weather conditions.

Measurement Test Position including the position of both the vessel under test and the support vessel or recording buoy. Recording systems are to be synchronized to GPS accuracy before deployment and re-checked after retrieval.

Measurement System including Hydrophones (number, type and model) and deployment (method and hydrophone depths, including sketches to show the deployment configuration).

Shipping activities near the vicinity including the presence of any vessels (their speed, size, and distance from the test site area) operating in the acoustic range/vicinity of the test site (in case this could be achieved by means of an Automatic Identification System data) and the presence of any distant noise-generating industrial activity (seismic exploration or offshore construction such as wind farms and hydrocarbon production activities).

RECOMMENDATION 3: Use a single omnidirectional hydrophone (hydrophone sensitivity: -165 to -215 dB re 1V/µPa) **bottom mounted at depth of 60m** (Figure 3.)

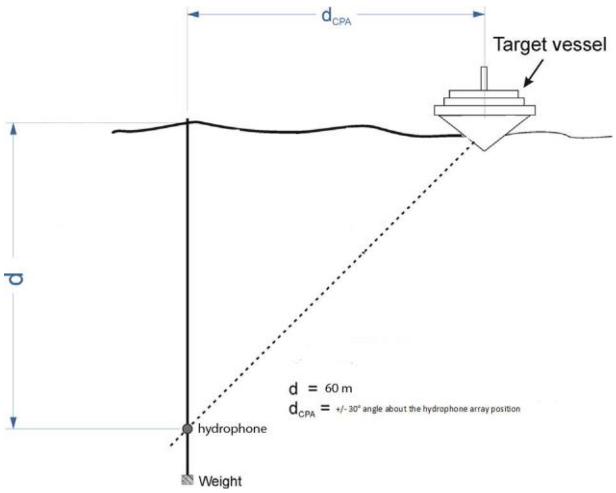

Figure 3. Measurement system scheme

RECOMMENDATION 4: Measure the background noise before and after each measurement test run.

This measurement is to be carried out for at least 1 minute with the vessel under test located at a distance of at least ≥ 2000 m (approximately 1.08 nautical mile) from the hydrophones, with its engine turned off, with the same hydrophone deployment and data acquisition methods. This is to enable the comparison of the sound pressure level radiated from the vessel under test to the background noise level during the period of the measurement test.

RECOMMENDATION 5: Perform at least 2 transits of the testing boats, from COMEX (POINT A) to FINEX (POINT B) passing at the constant speed across CPA. Distance between COMEX (POINT A) TO FINEX (POINT B) is 1000m; CPA should be located at a minimum distance of 100m from the hydrophone, as shown on the schematic diagram of figure 1.

RECOMMENDATION 6: Assure that both port and starboard sides are tested by performing two runs as shown in figure 1.

RECOMMENDATION 7: Perform two testing speeds (6 knots for slow speed measurements and 15 knots for high speed measurements or cruise speed for boats that cannot achieve this speed like sailing boats).

6. Data acquisition

RECOMMENDATION 8: Set the following settings for recordings

Frequency range: up to 24 kHz

Resolution: 16bits but if possible 24bit

Calibration: the calibration of the measurement chain needs to be conducted using the appropriate calibrator at the beginning of measurements; the SonoVault instrument used for this purpose will be calibrated with a 42 AC pistonophone.

System self noise: at least 10 dB below the lowest noise level to be measured over the frequency or the frequency range of interest.

7. Data Processing

RECOMMENDATION 9: Consider for the analysis the underwater radiated sound pressure level collected during the data window length (DWL). DWL is defined as the distance between two points along the track either side of the CPA defined by a ± 30° angle from the hydrophone position (see figure 1).

RECOMMENDATION 10: Analyze the data in 1/3 octave bands for all the frequency range up to 20 kHz plus additionally avg over the range 20Hz to 20 kHz. The analysis should be done for the narrow band (typically 1 Hz) in this frequency range.

RECOMMENDATION 11: Calculate the arithmetically average of the radiated underwater noise intensity spectrum obtained from the multiple data sets to provide an overall averaged one-third spectrum.

8. The most relevant measurements to be calculated

SPL (Sound Pressure Level) – measured by the hydrophone at the testing facility

$SPL = 10\log_{10} P^2_{RMS}/P^2_{Ref}$ dB Expressed in unit dB re 1µPa^2, where P_{ref}=1µPa

RNL (Radiated Noise Level) – is SPL adjusted by a distance normalization, often assuming spherical spreading to an equivalent 1m distance.

The noise level of a ship is determined as a source level of a singular monopole source (MSL) at one-meter distance from the source. The radiated noise level (RNL) of a vessel is calculated from the background noise corrected sound pressure level (SPL´) at the hydrophone by

$RNL = SPL' + X\log_{10}(r/r_0)$

Expressed in dB re 1µPa^2 m^2 where X is a geometrical parameter, r is the range between the vessel and the measurement location, and r_0 is the reference distance (r_0 = 1 m). The latter term on the right hand side of Equation 1 represents the geometrical transmission loss in water. For spherical propagation in unbounded medium the parameter X = 20 dB, and for cylindrical propagation, e.g. in shallow water environment, the parameter X = 10 dB. Based on practical experience, alternative figures for the parameter X are presented such as X = 18 dB in DNV rule and X = 19 dB in the BV rule for Underwater Radiated Noise for shallow water.

Source level (SL) is level of equivalent monopole source in unbounded ocean. Corrisponds to the SPL corrected for spreading and propagation losses (Lloyd Mirror, absorption, sea bottom refections, etc). It is calculated from the radiated noise level by making corrections due to sound absorption and reflections from the sea surface and bottom. In the DNV method, the surface correction is neglected.

$SL = SPL' + PL$

PL results from numereous results (geometrical spreding losses, absorption losses, sea surface and sea bottome reflection effects. If possible Pl should be measured at the test range and that value should be used to convert SPL to SL. Othrewise standard estimations or numerical modelling results are needed to determine PL.

Unit for SL is dB re $1\mu Pa^2 m^2$

9. TESTED BOAT CLASSES

A samples of noise produced by a boat types representative of most frequent boat classes (figure 4; Rako et al. 2012) using the Cres – Lošinj area will be recorded. Boat class is defined based on size, type of movement and engine horsepower (HP):

Class 1, motor boat (size and HP: 1 - 5 m / max 20 HP; MB) and sailing boat on engine (8 – 20 m / 18 – 100 HP, SailB)

Class 2, motor yacht (4 - 30 m / 40 – 200 HP; MY) and speed boat (7 – 15 m / 130 – 320 HP; SB)

Class 3, trawler (TW) and gillnetter (GN); 7 – 20 m / 50 – 250 HP, diesel engin

Class 4, tour boat (TB); 10 -25 m / 130-300 HP, diesel engine

Class 5, sailing boat on sails (SS).

Therefore, recordings of a representative boat for motor yacht (MY), speed boat (SB), trawler (TW), gillnetter (GN), motor boat (MB) and sailing boat moving on engine (SailB) will be recorded. Sailing boat on sails will not be recorded due to the fact that it is not using engine for its propulsion.

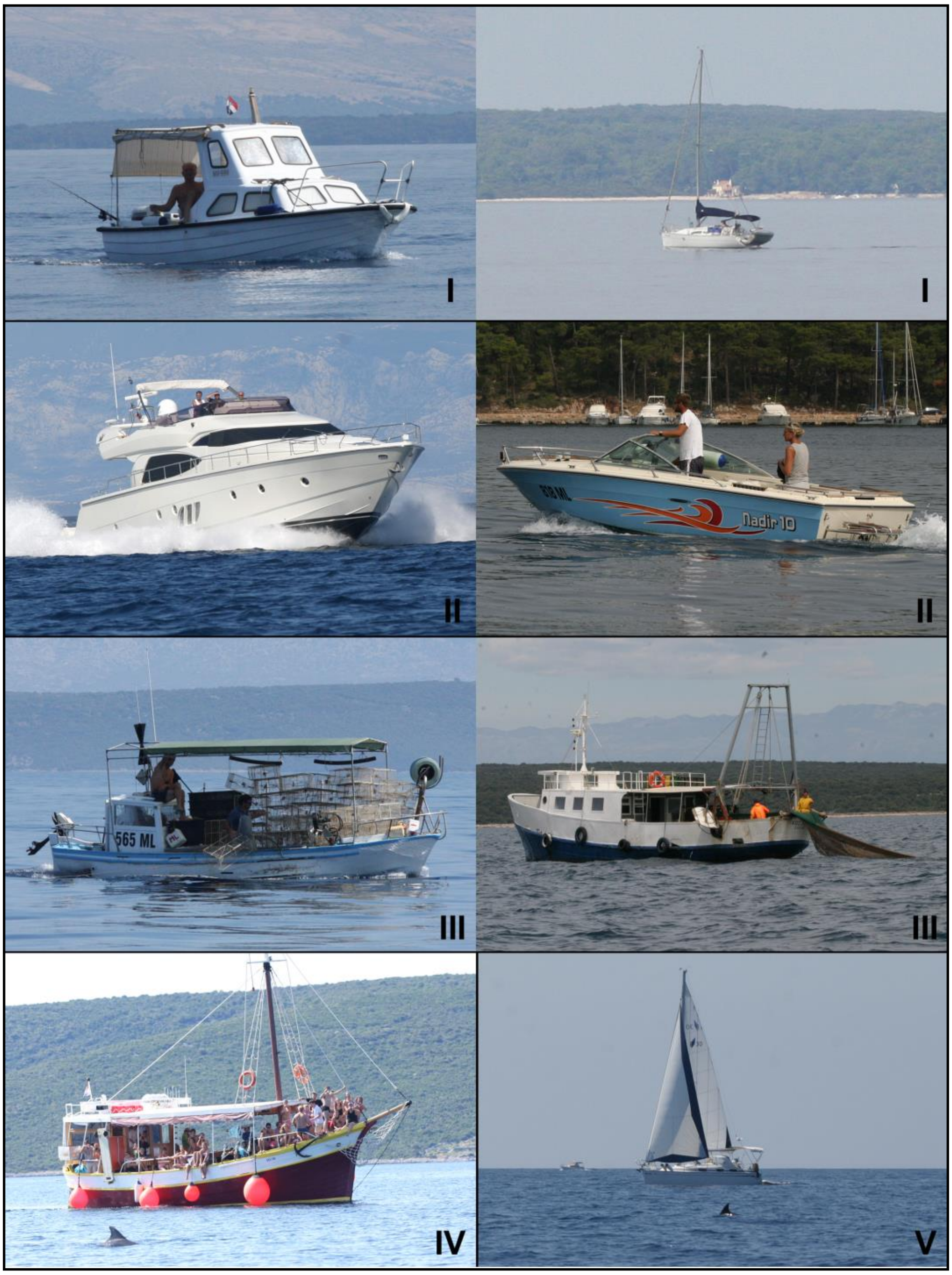

Figure 4. Representative boat types

10.REFERENCES

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