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REVIEW OF THE GUIDELINES FOR THE REDUCTION OF UNDERWATER NOISE (MEPC.1/Circ.833) AND IDENTIFICATION OF NEXT STEPS

Report of the Correspondence Group

Submitted by Canada

SUMMARY

Executive summary:	This document contains the report of the Correspondence Group on the Review of the Underwater Noise Guidelines
Strategic direction, if applicable:	1, 2, 3, 4 and 6
Output:	1.16
Action to be taken:	Paragraph 43
Related documents:	SDC 8/WP.8, SDC 8/18 and SDC 9/INF.2

Background

1 In 2014, MEPC 66 approved the *Guidelines for the reduction of underwater noise from commercial shipping to address adverse impacts on marine life* (MEPC.1/Circ.833), the "Guidelines". The Guidelines were intended to provide general advice on the reduction of underwater radiated noise (URN) to designers, shipbuilders and ship operators and include information on how to reduce a ship's underwater noise through design considerations and operational measures.

2 In June 2021, MEPC 76 accepted the proposal from Australia, Canada and the United States to review the Guidelines and identify next steps to further prevent and reduce underwater radiated noise, and to encourage action. The issue was referred to the Ship Design and Construction (SDC) Sub-Committee for action.

3 In January 2022, SDC 8 established a Working Group (WG) on underwater noise reduction from ships and instructed the WG to consider the various documents submitted in detail and to develop a workplan for further consideration by the Sub-Committee.

4 The WG recommended the establishment of a Correspondence Group (CG) to the Sub-Committee to complete the review of the Guidelines and identify next steps in a timely manner. A proposed Terms of Reference (SDC 8/WP.8) was included.

5 SDC 8 agreed to establish a Correspondence Group on the review of the Guidelines and identification of next steps, under the coordination of Canada (SDC 8/18, paragraph 14.28) and with the terms of reference as set out in paragraph 7.

Participants

6 The Correspondence Group had representatives from the following Member States:

BELGIUM
BRAZIL
CANADA
CHINA
DENMARK
FINLAND
FRANCE
GERMANY
INDIA
ITALY
JAPAN
LIBERIA
MARSHALL ISLANDS
MOROCCO
NEW ZEALAND
NORWAY
POLAND
PORTUGAL
REPUBLIC OF KOREA
SINGAPORE
SPAIN
SWEDEN
THE NETHERLANDS
TÜRKIYE
UNITED KINGDOM
UNITED STATES

observers from the following intergovernmental organizations:

EUROPEAN COMMISSION (EC)
HELSINKI COMMISSION - BALTIC MARINE ENVIRONMENT PROTECTION COMMISSION (HELCOM)
INTERNATIONAL WHALING COMMISSION (IWC)

and the following non-governmental organizations in consultative status:

INTERNATIONAL CHAMBER OF SHIPPING (ICS)
INTERNATIONAL ASSOCIATION OF PORTS AND HARBORS (IAPH)
BIMCO
INTERNATIONAL ASSOCIATION OF CLASSIFICATION SOCIETIES (IACS)
FRIENDS OF THE EARTH INTERNATIONAL (FOEI)
INTERTANKO
WORLD WIDE FUND FOR NATURE (WWF)
INTERNATIONAL FUND FOR ANIMAL WELFARE (IFAW)
SUPERYACHT BUILDERS ASSOCIATION (SYBASS)
PACIFIC ENVIRONMENT
CLEAN SHIPPING COALITION (CSC)
INUIT CIRCUMPOLAR COUNCIL

Terms of reference

7 The Correspondence Group on the Review of the Underwater Noise Guidelines was instructed to:

.1 enable engagement of Inuit and other indigenous communities and the incorporation of Indigenous knowledge;

.2 identify comparable and common means of measuring, analysing and reporting of URN emissions from ships (e.g. existing and developing ISO standards and international standards);

.3 identify actions to further prevent and reduce underwater noise from ships, including options to integrate new and advancing technologies and/or vessel design solutions taking into account geographical characteristics;

.4 consider the impact and interrelation of the proposed actions in .3 above in the context of achieving other regulatory goals, including ship safety, energy efficiency, as well as the vision and mandate of the Organization to reduce pollution from ships;

.5 amend the 2014 Guidelines, using the framework in the annex to document SDC 8/14/1, taking into account outcomes of the above Terms of Reference and documents SDC 8/14, SDC 8/14/2, SDC 8/14/3, SDC 8/14/5, SDC 8/14/6, SDC 8/14/7, SDC 8/14/9 and SDC 8/14/10, and submissions relating to regulatory goals and work outputs outside of the Sub-Committee's mandate;

.6 consider ways to promote the work of the Organization to increase awareness, the uptake and implementation of the Guidelines and identify most appropriate tools, through the review of, inter alia, document SDC 8/14/2;

.7 identify areas that require further assessment and research;

.8 consider the next steps, taking into account document SDC 8/14/8 and the Work plan for the review of the 2014 Guidelines for the reduction of underwater noise and identification of next steps (SDC 8/18, annex 11);

.9 maintain and update the annex to document SDC 8/14/2 and provide a new compendium; and

.10 submit a written report to SDC 9.

Process of the work

8 The Correspondence Group (the "Group") organized its work in three rounds, based on a questionnaire developed by the Coordinator, which covered all aspects of work as set out in the Group's terms of reference.

9 In the last round of the Group's work, members were invited to review and approve in general, the draft revised Guidelines as they stood at that moment as the basis for further work under the SDC Sub-Committee and to consider and approve, in general, the Group's draft final report to SDC prepared by the Coordinator.

10 The Group was also presented with the final version of the report prior to its formal submission to the IMO Secretariat.

Work of the Correspondence Group

11 The Group produced the following nine outputs, responding to each of the Group's terms of reference:

.1 a statement on the engagement of Inuit and other indigenous communities and the incorporation of indigenous knowledge, with associated considerations (paragraph 36);

.2 a list of comparable and common means of measuring, analysing and reporting of URN emissions from ships (e.g., existing and developing ISO standards and international standards) (included in appendix 2 of the draft revised Guidelines – see annex 1);

.3 a provisional list of actions to further prevent and reduce underwater noise from ships, including options to integrate new and advancing technologies and/or vessel design solutions taking into account geographical characteristic (included in Table 1 of the draft revised Guidelines – see annex 1);

.4 provisional considerations of the impact and interrelation of the proposed actions in paragraph .3 above in the context of achieving other regulatory goals, including ship safety, energy efficiency, as well as the vision and mandate of the Organization to reduce pollution from ships (annex 4);

.5 proposed amendments of the 2014 Guidelines (annexes 1, 2 and 3);

.6 provisional suggestions to promote the work of the Organization to increase awareness, uptake and implementation of the Guidelines and identify most appropriate tools (annex 5);

.7 a provisional list of areas that required further assessment and research (annex 6);

.8 a provisional list of suggested next steps (annex 7); and

.9 an updated compendium (annex 8).

12 The Coordinator notes that annexes 4, 5, 6, and 7 are collated lists of ideas suggested by individual Member States, intergovernmental organizations and non-governmental organizations to address terms of reference 4, 6, 7, and 8, respectively, and do not necessarily reflect the views of the Group as a whole. Due to the time constraints of the work process, the Group did not discuss each idea listed in detail and these may need further consideration.

Main considerations and findings

13 Based on the process outlined above, the main considerations and findings of the Group are outlined in the following paragraphs 14 to 37.

14 In general, the Group welcomed the draft revised Guidelines, recognizing that significant progress was made with a view to improving their structure, effectiveness and clarity. Consideration of ways to improve uptake and implementation of the Guidelines was also given.

15 Group members agreed in general that the 2014 Guidelines needed restructuring of some sections/subsections to increase the uptake and effectiveness of the Guidelines. The key changes from the 2014 Guidelines are reflected in table 1:

Table 1 - Structure Comparison of the URN Guidelines	
2014 Guidelines structure	**Proposed new structure in the updated draft of revised Guidelines**
1. Preamble	1. Preamble
2. Application	2. Application
3. Purpose	3. Purpose
4. Definitions	4. Definitions
5. Predicting underwater noise levels	5. Underwater Noise Management Planning
6. Standards and references	6. Baseline URN Measurements
7. Design considerations	7. URN Goals Setting
8. Onboard machinery	8. URN Prediction
9. Additional technologies for existing ships	9. URN Reduction Approaches
10. Operational and maintenance considerations	10. Energy Efficiency and URN Reduction
	11. Evaluation and Monitoring
	12. Incentivization
	Appendix 1 Glossary
	Appendix 2 Summary of recognized URN measurement standards
	Appendix 3 Types of computational models for optimizing ship design and technical noise reduction approaches
	Annex 1 (To be developed): Underwater Noise Management Planning Integrated Tool
	Annex 2 (Draft proposed -To be further developed): Energy Efficiency Compliance Measures and URN relationships

16 Other main points of the Group's discussions regarding the structure were:

.1 revising the Guidelines to ensure clarity and rework sections that needed more or less input and details;

.2 including user-specific guidance for different audiences and clearly allocating responsibilities to the various stakeholders (either in the body of the Guidelines or in different sections, or both places);

.3 including further distinction on the applicability of measures for new versus existing ships; and

.4 reflecting the chronological sequence and adaptive management approach of a Noise Management Plan Framework.

17 Most members of the Group also agreed that the updated Guidelines should apply to ships of all sizes and types on the basis that these are best practices, with the inclusion of a "can be applied" statement.

18 On the question of whether the Guidelines should address the introduction of sounds from other navigational or oceanographic investigation purposes, the Group was more divided, but understood that their inclusion would further complicate the development of the Guidelines. Some Group members suggested that the Guidelines apply to and include any significant sound sources associated with regular operation, e.g., standard echosounders and acoustic anti-fouling systems.

19 The Group agreed that definitions in the 2014 Guidelines needed refinement and several members provided revisions and additional terms to be included. A suggestion was to keep only the key definitions in the section and move all additional terms that are perhaps not required for the understanding/use of the Guidelines in a glossary at the end or in an annex.

20 The draft revised Guidelines provided in annex 1 has been updated to reflect most of the latest suggestions of structure, content and language by the Group. In the following paragraphs, the Group's consideration of the main issues regarding the substance of the draft revised Guidelines is outlined. Hence, in the finalization of the work on the revision of the Guidelines, the following points should be considered further.

Underwater Noise Management Planning

21 The majority of the Group members agreed with the new section on Underwater Noise Management Planning (UNMP) and its content, noting that further work is required in terms of clarity and structure, such as separating subsections related to new ships and existing ships (as the approach to UNMP will be different for each); clarifying the definitions around "targets" and "goals"; and highlighting the importance of flexibility in selection of methodology for establishing baseline.

22 Some members of the Group had questions and concerns around the relevance of developing UNMP while URN requirements (e.g., URN goals/targets or regulations) are yet to be defined, as well as adding an administrative burden on shipowners.

Baseline URN Measurements

23 Most members of the Group showed broad support for the content of the Baselining section but noted that further work was required in terms of definition, purpose, methodology and structure, as well as recommending that further discussions be pursued on if/how regional considerations should be included in the Guidelines.

24 The Group agreed in general with providing URN measurement standards in appendix 2 of the revised Guidelines and some members suggested that consideration to provide this information in an IMO circular or public database instead of in the Guidelines be further explored. Some members supported the use of both computational and empirical methods to determine baseline. One member proposed an alternative based on the relationship between horsepower, ship speed and underwater noise derived from a large number of measurements given the difficulty of direct measurements for individual ships. Another member suggested the establishment of an Experience Building Phase to allow the best methodologies to be identified.

URN Goals Setting

25 Extensive discussions were undertaken by the Group around the concept of underwater noise vessel-based targets, the concept of regional underwater noise thresholds and the need to further clarify the distinction between the two. Group members were also divided on whether the section should include a statement about the complexity and the challenges of defining URN reduction targets.

26 Although this proposed new section will require further work in terms of content, most of the members agreed with the inclusion of a subsection on the URN goals, focusing on encouraging best practices both in terms of design and operation. While too premature for the work of this Group, some members also supported the idea that a ranking system for URN reduction measures similar to the work done under the IMO GHG strategy should be further considered.

URN Prediction

27 The majority of Group members were in support of the proposed section on Modeling URN Prediction, but noted that the section should further define, describe and differentiate models for a ship sound source based on design and operational settings from those used for modeling soundscape. Members also recommended moving the list of specific models to an appendix or reference list.

URN Reduction Approaches

28 Some of the Group members proposed to use the PSSA principles as a tool/mechanism for stricter control on international shipping activities. The principles do not prevent shipping within the designated area, but rather place specific controls to add extra protection. Current examples for PSSA measures include reduced speed, specified routes, bans on discharging waste and reporting of shipping activities, but could as well include restrictions on underwater radiated noise. This approach should be further discussed in the finalization of the Guidelines.

29 The majority of Group members agreed in general with the updated section on URN reduction approaches and provided many suggestions to reflect the current state of knowledge as well as advances in technologies to reduce URN impacts from shipping, as shown in the revised version of the Guidelines and table 1 of this section. Most of the Group members also agreed with the inclusion of a paragraph on improved voyage planning and on sensitive areas, but were divided on the question of whether a general list of sensitive areas should be provided. As such, this question, as well as the content of table 1, should be further discussed in the finalization of the Guidelines.

30 In order to provide shipowners/operators with easy and clear information on voyage planning regarding geographical and species characteristics and URN recommendations, members of the Group mainly suggested:

.1 updating the training protocols for seafarers to include information on where to find and how to apply such information; or

.2 having a multi-disciplinary international programme to create an evergreen document.

These options should be further discussed in the finalization of the Guidelines.

Energy Efficiency and URN Reduction

31 Based on terms of reference .5 for the Group and annex 1 to document SDC 8/WP.8 that highlighted the need to "identify and engage on areas of collaboration between SDC and the Pollution and Prevention Response Sub-Committee to continue the review of the Guidelines and provide recommendations/actions on the most appropriate technical or operational measures where co-benefits exist between energy efficiency improvements and URN reduction", members of the Group provided suggestions to add in the Guidelines, including a proposed annex on "Energy Efficiency Compliance Measures and URN relationships" (see annex 3). The Group also noted that a shipowner should give consideration to the adoption of measures that both increase efficiency and reduce URN but that URN measures should not come at the expense of mandatory IMO requirements on GHG reduction and energy efficiency.

32 The majority of Group members agreed that the section on energy efficiency and URN reduction should be kept as a stand-alone section, but a few members stated some concern about duplication of content from the preamble and design sections, or that this information could be integrated or moved closer to the sections relevant to designers and URN reduction measures. The section was therefore moved after Section 9 URN Reduction Approaches, as reflected in the latest version of the revised Guidelines.

Evaluation and Monitoring

33 Extensive discussions occurred regarding the section on Monitoring, as Group members noted that the section was not providing information to shipowners/operators but rather focused on Maritime Administrations and, as such, its relevance and purpose was questioned. Based on the Group's comments, the Evaluation and Monitoring section was divided into 2 subsections:

.1 Single vessel radiated noise; and

.2 Ocean Shipping Noise.

Further discussion should be pursued in the finalization of the Guidelines to reach agreement on the content and structure of this section.

Incentivization

34 Group members recommended adding a section regarding incentivization to present options that would encourage shipowners, designers, builders, suppliers and operators to quiet their shipping operations. Some key recommendations in finalizing the Guidelines include continuing discussion to reach consensus around:

.1 the format (with some members suggesting it could be more appropriate to share this information through an IMO circular);

.2 the structure (Group members' opinions varied as to whether the section should be kept as a stand-alone section, moved to the beginning of the Guidelines, combined with other sections, etc.); and

.3 the content (such as specifications on how incentivization can be implemented and other possible incentives that currently exist).

Annexes to the Guidelines

35 During the first two rounds of work, the Group discussed the development and content of two annexes:

.1 Noise Management Planning Integrated tool; and

.2 Energy Efficiency Compliance Measures and URN relationships.

Most members of the Group agreed with the proposed draft content of the annex 2 of the revised Guidelines, noting that it was a good starting point but that it needed to be further discussed and developed. Although the majority of members agreed that both annexes should be included in the Guidelines, some members were of the view that they should be developed externally, noting that the Group may not have the resources and/or expertise needed to develop these annexes in depth, and other members suggested the annexes be integrated into a single annex so to provide a single, streamlined tool. Therefore, it is recommended that this option be further discussed and agreed upon in the finalization of the Guidelines, using the preliminary content of annex 2 of the revised Guidelines as a basis to develop this annex further.

Other comments

36 In order to address the Group's ToR .1 "Enabling engagement of Inuit and other indigenous communities and the incorporation of indigenous knowledge;" the Group noted that the Inuit Circumpolar Council (ICC) was an active participant of the Group and that Group members were encouraged to consult with Inuit and indigenous communities before submitting their input to the Group. Some language in the revised Guidelines was also proposed and considered to reflect the incorporation of Indigenous knowledge.

37 Individual Member States, intergovernmental organizations, and/or nongovernmental organizations participating in the Group also made recommendations on the other ToRs identified in paragraphs 11.4,11.6, 11.7 and 11.8. Hence, the proposals listed in annexes 4, 5, 6 and 7 should be considered as part of future work to finalize the work of this output.

38 Specific comments to the content of the draft revised Guidelines were also submitted by some Group members in the final round. Since the process did not allow time for the Group to consider whether to include these comments in the revised Guidelines, they are collated in the annex to document SDC 9/INF.2 (Canada).

Proposals

39 Having considered the above matters, the Group agreed to recommend to the Sub-Committee the establishment of a working group at SDC 9 to continue advancing the work on revising the Guidelines, based on the draft revised Guidelines as set out in annex 1 of this report.

40 The continued revision and finalization of the Guidelines should be based on the findings and information contained in this report and other relevant work products, including information papers. It is important to further consider the issues highlighted in the "main considerations and findings" section, as summarized in paragraphs 14 to 35.

41 As the Group did not reach a consensus on each idea listed as set out in annex 4, 5, 6 and 7 of this report, the prioritization of the listed suggestions in these annexes should also be finalized in the continued work on this output.

42 In order to complete this work the following ToRs are proposed:

.1 consider the unresolved drafting proposals in the draft Guidelines, with a view to finalization, noting text options shown in square brackets or the removal (or modifications) of text shown in *italics*. If finalization cannot be achieved, develop recommendations for SDC to complete the review of the 2014 Guidelines;

.2 finalize and prioritize the list of provisional suggestions to promote the work of the Organization to increase awareness, uptake, and implementation of the Guidelines, as set out in annex 5;

.3 further consider the inclusion of a practical method for baselining when direct measurements are not feasible;

.4 further develop annexes of the proposed draft Guidelines, with a view to finalization; if finalization cannot be achieved, develop recommendations for SDC to advance the development of the two annexes of the proposed draft revised Guidelines, as set out in annexes 2 and 3 of this report; and

.5 finalize and prioritize the provisional list of suggested next steps to further prevent and reduce underwater radiated noise from shipping, as set out in annex 7, and formulate recommendations for next steps.

Action requested of the Sub-Committee

43 The Sub-Committee is invited to approve this report in general and, in particular to:

.1 consider the comments and proposals in paragraphs 14 to 41 and in annexes 4, 5, 6 and 7; and

.2 agree with the Group's recommendation to re-establish a Working Group to Review the Guidelines for the Reduction of Underwater Noise (MEPC.1/Circ.833) with the draft terms of reference set out in paragraph 42 to advance the work of the draft Guidelines, and take action as appropriate.

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ANNEX 1

THIRD DRAFT OF THE REVISED GUIDELINES FOR THE REDUCTION OF UNDERWATER NOISE FROM SHIPPING TO ADDRESS ADVERSE IMPACTS OF MARINE LIFE

1. Preamble

1.1. Commercial shipping is *one of* the main contributors to underwater noise. The international community recognizes that underwater radiated noise (URN) from ships *has substantially increased in recent decades due to increasing traffic levels and ship size.* It is also recognized that URN have adverse effects on critical life functions for a wide range of marine life, including marine mammals, fish, and invertebrate species, *upon which many coastal Indigenous communities depend for their food, livelihoods and cultures.*

1.2. The effective mitigation of URN impact from ships on marine life requires international collaboration and action at various levels, involving multiple stakeholders including, but not limited to, suppliers, designers, shipbuilders, shipowners and ship operators, maritime administrations, and classification societies. *Member States play an important role in setting expectations for noise reduction targets and establishing mechanisms and programs through which noise reduction efforts can be realized nationally.*

1.3. *Taking into account that sound is the main sensory mechanism used by aquatic fauna for social interactions, reproduction, navigation, detection of obstacles and preys, the most relevant noise sources from ships overlap with hearing ranges and the use of sound by different species. Depending on the group species, responses to underwater noise levels correspond to behavioral changes, masking issues and physiological responses. Although impacts of shipping noise have been assessed considering the environment-related characteristics of different regions and the noise sensitivity of different species, based on field observations, laboratory experiments, modeling approaches, and Indigenous Knowledge, further data on noise impact on ecological and commercial key species is needed.*

1.4. It is important to recognize that for both new and existing ships, the technical and cost-effectiveness of URN reduction measures considered either individually or in combination, will be strongly dependent on the design, operational parameters, and requirements relevant to a particular ship. A successful strategy to reduce URN should be a process which includes, to the extent possible, the designing stage, the baselining of URN measurements (predicted or actual), the development of noise reduction targets, and the implementation of technical and operational measures. The interactions and contributions between the implementation of URN reduction measures and other objectives such as, but not limited to, energy efficiency, biofouling reduction and ship safety should be carefully considered with the aim of maximizing overall benefits.

2. Application

2.1. These Guidelines can be applied to all commercial ships of all sizes and types, taking into account the design and construction of new ships, and the operation of any ships. The Guidelines may also be used to mitigate URN from non-commercial ships.

2.2. These Guidelines do not address the introduction of noise from naval and war ships and the deliberate introduction of sound for other navigational or oceanographic investigation purposes that can be considered under the United Nations Convention on the Law of the Sea (UNCLOS) such as sonar, seismic activities *or standard* *echosounders on commercial ships. However, it is acknowledged that these are contributing sources of noise that should require further consideration.*

3. Purpose

3.1. The purposes of these Guidelines are to:

.1 provide an overview of approaches applicable to designers, shipbuilders and ship operators to reduce the URN emissions *[achieve URN emission limits]* of any given ship and

.2 *assist maritime administrations such as member, coastal and port states and others in establishing mechanisms and programs through which noise reduction efforts can be realized.*

3.2. *Given the complexities associated with ship design and construction and the various approaches for reducing URN, these Guidelines focus on identifying primary sources of underwater noise generated by ships and a general approach that designers, shipbuilders, and shipowners and operators can undertake to reduce and mitigate URN from ships. These are associated with propellers, hull form, onboard machinery, wake flow as well as operational and maintenance aspects.*

3.3. These Guidelines propose a multi-faceted approach that can be applied to the design and construction of new ships and the retrofits and operation of existing ships, as far as reasonable and practical. In addition to ship and equipment designers, shipbuilders and shipowners and operators, maritime authorities, classification societies and others are encouraged to introduce and apply these Guidelines to their specific activities and consider any other technologies and operational measures not included in these Guidelines, which may be more appropriate for specific applications and have demonstrated to further reduce URN.

3.4. The development for ship quieter technologies and the scientific knowledge around the impact of URN on marine life will continue to evolve. Annexes 1 and 2 of these Guidelines will be reviewed and updated to ensure that relevant parties have the best available information to inform URN reduction efforts and linkages with energy efficiency compliance measures. Member States and Observers are encouraged to pass on experience and information received from equipment designers, ship builders and operators, scientific organizations, civil society, Indigenous knowledge holders, and others, to assist in improving and updating these annexes.

4. Definitions

For the purposes of these Guidelines, the following definitions apply:

Baseline URN: initial URN predictions or measurements representative of a ship's key operations, in context to the ship's main operational profile.

Cavitation: the reduction of the ambient pressure by a static or dynamic means that can be caused by the propeller or other devices, causing the formation and activity of bubbles in the liquid. The formation refers to both the creation of a new cavity or the expansion of a pre-existing one. When these bubbles are travelling to regions of higher ambient pressure, they collapse generating the major source of noise from powered ships.

Cavitation inception speed: the ship speed at which cavitation becomes detectable (either visually or acoustically).

Propeller noise: caused by flow phenomena on the propeller as it operates in the wake field of the ship hull. Propeller noise is composed of non-cavitating propeller noise and cavitation noise. Once cavitation occurs, it is typically the most dominant noise source.

Structure-borne noise: from structures connected to the machine; sound radiation emitted by the machine into the connected structures such as foundation, pipes, other coupled machines or linked auxiliary equipment.

Source Level: one of many different quantities depending on the type of acoustic level: airborne sound, vibration, or underwater sound. For underwater source levels see ISO 18405, Underwater acoustics – Terminology. In general, the Source Level is used to quantify how much sound (or vibration) is generated by a device (machinery or other entity such as a ship).

Underwater noise or underwater radiated noise (URN) level: for the purposes of these Guidelines refers to noise from any ships. URN level is reported in decibels as a sound pressure level and expressed as 10 times the logarithm of the square of the ratio of the root means square sound pressure to a reference pressure of 1 micro-Pascal. When it is reported as a ship source level, the sound pressure level is adjusted to the equivalent level at a theoretical distance of 1 m from the source.

Vibration isolation mounts: vibro-elastic elements (usually steel springs or rubber) used to isolate machinery vibration from the ship's structure by reducing the amplitude of vibrational energy. Vibration isolation mounts may also be used to protect the equipment from harmful vibration from outside the ship (e.g., shock inputs during rough weather).

Further definitions are provided by the following ISO standards and additional terms can be found in Appendix 1 Glossary.

ISO 18405:2017 Underwater acoustics – Terminology

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 17208-2:2019 Underwater acoustics — Quantities and procedures for description and measurement of underwater sound from ships — Part 2: Determination of source levels from deep water measurements.

5. Underwater Noise Management Planning

5.1. Noise Management Planning is a generalized approach applicable to any ship (new and existing) that includes possible strategies for URN reduction in the design, operation and/or retrofit. Given the complexities associated with ship design and construction and the various approaches to reducing URN, shipowners and designers should undertake Noise Management Planning at the earliest design stages. It involves establishing the baseline (predicted or actual) of a ship's URN (section 6), setting URN goals which should be specific and where possible, quantitative (section 7), and evaluating, alone and in combination, various technological, operational, and maintenance approaches (section 8 and 9).

5.2. Baseline predictions and/or measurements for new and existing ships (section 6), and noise monitoring (section 11) form the basis for an iterative and adaptive decision-making process. Failure to achieve a given objective such as URN goal should necessitate the application of additional measures. Goal setting is also expected to be iterative as technological options and operational and maintenance approaches continue to advance.

5.3. The output of Noise Management Planning should be a Noise Management Plan for any given ship which identifies and describes all noise sources, describes measures to be implemented (technological, operational, and maintenance) to meet URN reduction goals along with a description of the monitoring that will be conducted to evaluate the effectiveness of the selected approaches on an ongoing basis, with triggers for iterating the process if the URN goals are not achieved.

5.4. Noise Management Plans should include a combination of immediate, short-term, and long-term actions and are intended to be flexible and allow owners/ organizations to identify the measures needed and necessary to their ship given their operating environment and occurrence of potentially sensitive areas/species. Voyage planning (section 9.7) should reflect and incorporate the measures adopted in the Noise Management Plan.

5.5. Various parties have the following opportunities to support an effective Noise Management Plan including, but not limited to:

.1 Shipowners: develop Noise Management Plan, include URN requirements into ship design specifications and maintain ship to those specifications.

.2 Designers: design ships as defined by shipowners' operational plan to meet URN requirements.

.3 Ship builders: build ship to meet URN specifications.

.4 Ship operators: operate ship to meet URN goals and any additional regional requirements they are sailing in.

.5 Maritime authorities: take supportive actions that enable and advance Noise Management Planning, for example, regulating Noise Management Plans, setting URN targets, measuring noise levels, supporting innovation and adoption of noise reduction technologies, and communicating URN information and requirement.

.6 Classification societies: assist shipowners/builders through trials, notations, recertification and certification, etc.

5.6. Each of the following sections (sections 7-11) specifically addresses the process of Noise Management Planning and any differences in approach between new ships and existing ships. References and links to resources are also included where appropriate[1].

5.7. Annex 1 of these Guidelines provides a tool to support the Noise Management Planning process.

6. Baseline URN Measurements

6.1. As far as practicable, efforts should be made to determine a ship's baseline condition. For new vessels, the baseline URN condition should be predicted (computational/empirical/model tests) whereas for existing vessels, the baseline URN condition can be predicted and/or measured. Additionally, other factors, including the ship's typical operating speeds, primary geographical areas and identification of factors affecting operations that would impact a ship's baseline noise condition, should be identified. Such factors are operational (e.g., speed, time spent fully laden), some

[1] SDC 8/14/2 Compendium on Underwater Noise from Commercial Shipping provides a summary of international work on the issue of anthropogenic underwater ship noise and impacts on marine life.

relate to maintenance / equipment (e.g., cleaning, propulsion system limitations) and some to sound propagation (e.g., restricted waterways, strong currents, ice-coverage, shallow waters). Geographical areas and typical routes may not be possible to take into consideration at the design and construction stage.

6.2. URN should be measured to an objective standard for any meaningful improvement. Appendix 2 summarizes the availability of recognized measurement standards. These international standards have been used in research and to support port programs.

7. URN Goals setting

7.1. *Considering the characteristics of sound propagation in water, location and time dependent ambient noise levels, frequency range of different species and behavioral responses, a biology-based universal noise limit cannot be realized at this time.*

7.2. *Individual ship-based noise limits can be established by class, speed, tonnage or other and be based on current URN emissions (by class etc.) which can be gradually reduced over some period.*[2]

7.3. *Ship noise limit can be established using one of many of the existing class societies notations (Appendix 2). The harmonization of these notations and measurement methodologies will improve the marine industry's ability to comply with the requirements.*

7.4. *Placeholder: Introductory paragraph on noise regional thresholds*

7.5. *Placeholder: Concrete description of how to define a URN goal*

7.6. URN goals for a given ship should be established by considering guidance and best practices taking into account the results of baseline measurements and other factors described in Section 6.

8. URN Prediction

Single vessel radiated noise

8.1. URN computational methods have been applied to characterize the URN of new vessels in design stage, as well as for existing vessels, to understand and identify feasible and effective URN measures in design, construction, or operation of the vessel. Such methods may be used to analyse the noise sources on the ship, the noise transmission paths through the ship and estimate the total predicted URN levels.

8.2. URN Computational methods should integrate other analyses such that wake, drag, propeller performance, and other factors affecting energy efficiency and other emissions are considered at the same time as underwater noise. This will allow optimization with respect to URN, other emissions, and efficiency/performance.

8.3. This analysis can help shipowners, shipbuilders, and designers, to identify design features, hull-propeller pairings, and other noise control techniques that could be considered for the specific application, taking into account expected operational conditions.

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[2] MEPC 74/INF.36

8.4. Standardized model tests of propeller URN in combination with cavitation tests provide the possibility for manufactures, shipowners and shipyards to agree whether contractual specifications regarding the propeller contribution to URN are fulfilled before the ship is built.

.1 Model-scale cavitation tests[3] offer at present the most accurate prediction of URN source levels of cavitating propellers showing good to acceptable agreement with sea trials on URN source levels. However, scale effects and the effect of facility dependent background and reverberation noises should be considered carefully, and further improvements on these topics are expected from on-going studies. Furthermore, as these model tests focus on cavitation noise only, the impact of a cavitation noise mitigation measure can be well evaluated. The impact of this mitigation measure on the total ship noise requires knowledge of the other noise sources such as machinery and structure-borne noise.

.2 The ship, its propeller, and special appendages (such as shaft bracket, fin stabilizer, etc.) could be model tested in a cavitation test facility such as a cavitation tunnel for measuring the design aspects with respect to cavitation induced pressure pulses, cavitation inception speed and radiated noise.

8.5. URN model predictions should be assessed, when possible, with scaled or full-size model validation tests preferably in controlled environments.

8.6. Types of computational models for optimizing ship design and technical noise reduction approaches are provided in Appendix 3.

Soundscape modeling

8.7. The modeling of ship source noise levels and the generation of sound maps based on ship characteristics and design parameters, traffic data and environmental conditions are key to the monitoring and evaluation activities.

8.8. Comparative parametric point source and propagation models to produce integrated continuous underwater noise sound maps (i.e., soundscape modeling) are a powerful tool to identify underwater noise in different sea areas where URN may have significant deleterious effects. They also identify associated met-ocean conditions where URN from ships has the major impact and ascertain if noise reduction goals are met. Sound propagation loss is influenced by several environmental parameters (e.g., sea state, sound speed profile, sound absorption, currents, and in shallow water, bathymetry and the properties of the sea bottom), there exist a variety of underwater sound propagation models to address the objectives of the specific application.

.1 Sound models that can account for change in sound propagation in ice-covered waters will support the development of knowledge about the impacts of shipping noise in ice-covered areas.

8.9. In some jurisdictions, it may be appropriate for authorities to consider promoting the development of regional and national soundscape modeling programs, combining advanced ship noise source level models with propagation models to produce sounds maps to understand how different shipping activities contribute to the soundscape and

[3] ITTC – Recommended Procedures and Guidelines, Model-Scale Propeller Cavitation Noise Measurements, 7.5–02–03–03.9

potential management options to reduce URN from ships. Such models should be considered into Noise Management Planning.

8.10. In-situ measurements to validate noise emissions from modeling is important to obtain robust evidence of predicted cumulative noise emissions. Permanent or seasonal monitoring may be necessary in specific locations.

9. URN reduction Approaches

The primary sources of underwater noise generated by ships are associated with propellers, hull form, onboard machinery, wake flow as well as operational and maintenance aspects. At typical operating speeds, or near the design ship speed, most of URN is caused by propeller cavitation, but onboard machinery and operational aspects are also relevant, especially below cavitation inception speed. Propeller noise itself can be a dominant contributor to overall URN. The optimal underwater noise mitigation strategy for any ship should at least consider all relevant noise sources and mitigation strategies, including any that are not covered in these Guidelines, which may be more appropriate for specific applications.

PLACEHOLDER - introductory paragraph to reflect the status of research from the various projects addressing URN reduction and link to the Compendium

Design and technical noise reduction approaches

The greatest opportunities for reduction of underwater noise will be during the initial design and build stages of the ship. For existing ships, it is unlikely to be practical to match the underwater noise performance achievable by new designs, with the notable exception of retrofitting propellers in some cases. The following design considerations are therefore primarily intended for consideration for new ships. However, consideration should be given to retrofitting existing ships when reasonable and practicable. Table 1 summarizes the design and technical noise reduction approaches that are applicable to new and/or existing ships. Further information on relative cost to implementation, effectiveness, advantages/co-benefits and disadvantages are presented in MEPC 74/INF.28.

Hull design and modification

9.1. Flow noise around the hull may have an influence on URN, however, the hull form influences the inflow of water to the propeller. Uneven or non-homogeneous wake fields are known to increase propeller cavitation. Therefore, the ship hull form with its appendages should be designed such that the wake field is as homogeneous as possible. This will reduce cavitation as the propeller operates in the wake field generated by the ship hull. Also, noise from the structure of the ship excited by the fluctuating pressure of propeller could not be negligible.

9.2. Consideration should be given to structure-born noise, to reduce hull URN. Some mitigation measures could be optimization of scantling, decoupling coating, and structural damping.

Propeller design and modification

9.3. Propellers should be designed and selected to minimize cavitation while considering and optimizing effects on energy efficiency. Cavitation can be the dominant URN source and may increase underwater noise significantly. At typical operating speeds, cavitation can be reduced under normal operating conditions through good design, such as optimizing propeller load, ensuring uniform water flow through propellers (is influenced by hull design), and careful selection of the propeller characteristics such as: diameter, blade number, blade area, pitch, skew, rake, and sections. Analyses and study of hull-propeller interaction can optimize design of propeller, hull and vessel performance altogether.

9.4. Noise-reducing propeller design options are available for many applications and should be considered. However, it is acknowledged that the optimal propeller with regard to underwater noise reduction cannot always be employed due to technical or geometrical constraints (e.g., ice-strengthening of the propeller, mass). It is also acknowledged that some design principles for cavitation reduction can cause decrease of efficiency. Some new state-of-the-art propellers design and concepts have been developed including high skewed propellers, forward-skew propellers, contra-rotating propellers and unconventional propeller with blade tips curved forward.

9.5. Some emerging technologies are available to reduce required propulsion power like wind-assisted or hull-lubrication by means of air injection. Those technologies can be considered for possibly reducing the propeller loading and cavitation noise. Considerations should be given that propulsion load reduction does not have adverse effect in URN, for instance by producing cavitation on suction side in same power load level. Air bubble injection into the stern and propeller is also used for reducing the URN.

Wake flow improvement

9.6. Improving hydrodynamic performance by optimizing hull form design, hull and propeller appendages (e.g., Propulsion Improving Device/ Energy Saving Device or asymmetric stern design) can increase performance and fluid inflow to propeller and reduce URN.

9.7. In order to improve the inflow of ship propeller, there are many devices that could be used, but these may cause cavitation and as such, should be carefully designed either for new ships or existing ships. Cavitation performance of such devices could be evaluated, and model tested in a cavitation test facility along with the propeller cavitation test.

.1 Installation of wake conditioning devices and rudder design.

.2 Pre-Swirl Stator (PSS), some stators before the propeller that can decrease the Blade Passing Frequency (BPF) of propeller noise and increase the propeller efficiency.

.3 Pre-Shrouded Vanes (PSV), a Vanes and some stators before the propeller that can improve the cavitation performance of propeller and increase the propeller efficiency.

.4 Hub Cap with Fins may be useful to improve the wake of ship propeller. It can save the energy of propeller wake and increase the propeller efficiency. Hub Cap with Fins can also help to avoid the hub vortex cavitation, etc.

Machinery design and modification

9.8. Consideration should be given to the selection of propulsion system and onboard machinery along with appropriate structure-borne sound levels control measures, proper location of equipment in the hull, and optimization of foundation structures that may contribute to reducing underwater radiated and onboard noise affecting passengers and crew.

9.9. Designers, shipowners and shipbuilders should request that manufacturers supply information on the airborne sound levels and vibration produced by their machinery to allow analysis by methods described in section 8 and recommend methods of installation that may help reduce URN.

9.10. Consideration should be given for the appropriate use of vibration isolation mounts as well as improved dynamic balancing for reciprocating machinery such as refrigeration plants, air compressors, and pumps. Vibration isolation of other items and equipment such as hydraulics, electrical pumps, piping, large fans, vent, and air conditioning ducting may be beneficial for some applications, particularly as a mitigating measure where more direct techniques are not appropriate for the specific application under consideration.

9.11. Resilient mount can reduce the vibration from machinery to the supporting structure and reduce the structure-borne noise. Because of the propulsion and thrust transfer arrangement, resilient mount for engines can be mostly considered for four-stroke engines with geared drive, and not the two-stroke engine with direct drive. Flexible coupling between the engine and gearbox can reduce vibration in a geared drive, and further reduce the structure-borne noise. Vibration isolators are more readily used for mounting diesel generators to their foundation for reducing structure-borne noise. In some cases, the adoption of a diesel-electric system should be considered as it may facilitate effective vibration isolation of the diesel generators which is not usually possible with large direct drive configurations.

9.12. Alternative power and propulsion systems can help reduce URN. Electric propulsion (e.g., diesel-electric, fuel cell and full electric or battery) is identified as an effective configuration option for reducing underwater noise. The use of high-quality electric motors and installations help to reduce vibration being induced into the hull from the electric motor. Electric propulsion can be utilized in alternative propulsions such as podded (or azimuth thruster pod design), which can further enhance hydrodynamic performance and further reduce URN.

Maintenance and operational approaches

Although the main components of URN are generated from the ship design (i.e., hull form, propeller, the interaction of the hull and propeller, and machinery configuration), operational adjustments and maintenance measures should be considered as ways of reducing noise for both new and existing ships. Operational approaches could be particularly important for ships that lack design features or technologies to reduce noise, or for all ships that operate in sensitive marine areas where additional measures need to be taken to decrease the adverse impacts of shipping noise on marine wildlife. Table 1 summarizes the operational and maintenance approaches that are applicable to new and/or existing ships.

Maintenance approaches

9.13. Propeller maintenance (and cleaning/coating): Maintaining the surface quality/finish of propellers, such as when polishing is done properly, removes marine fouling and vastly reduces surface roughness, helping to reduce propeller cavitation.

9.14. Hull maintenance (and coating): Reducing hull roughness and maintaining a smooth underwater hull surface, by utilizing proper coatings, cleaning, and proactive in-water ship hull grooming[4], may also improve a ship's energy efficiency by reducing the ship's resistance and propeller load.

9.15. Machinery vibrations induce structure-borne noise. Proper maintenance of the moving parts and machinery, helps to keep the vibration and noise low and prevent increasing the noise from operating those machinery.

Operational approaches

9.16. Optimizing the ship's trim to reduce the required power and therefore propeller cavitation noise.

9.17. Optimize voyage planning: Careful voyage planning facilitate berthing and operations plans and communication as such, operators can adjust and optimize vessel routeing, speed and sail time, reduce time at anchor and the ensonification of port and coastal areas and when it can be safely done, facilitate the use of alternate route to avoid and slow down in sensitive areas and during critical times of year to decrease impacts of URN on marine life and communities who depends on them. Hydrographic offices should consider marking and updating sensitive marine areas in charts to enable the seafarers and harbor users to plan voyages to minimize the impact of their ship's URN on marine life.

.1 Best practices include reviewing the list of sensitive areas to determine whether ships transit through or have operations in such areas. *These may include but are not limited to: sea-ice covered regions, including Inuit Nunaat, busy ports and shipping lanes overlapping with important or critical habitat for endangered, threatened, or protected species, Important Marine Mammal Areas (IMMAs), Marine Protected Areas as defined by the Convention of Biological Diversity and other national/regional area-based protection.*

Ship speed

9.18. In general, for ships equipped with fixed pitch propellers, reducing ship speed can be a very effective operational measure for reducing underwater noise, mainly due to reduced cavitation. This is especially the case when speeds are slower than the cavitation inception speed, but even small reductions in power can greatly reduce cavitation. Thus, shaft power limitation or engine power limitation would be expected to reduce URN in situations where these limits are below the ship's usual operating power.

9.19. For ships equipped with controllable pitch propellers, there may be no reduction in noise with reduced speed. Therefore, consideration should be given to optimum combinations of shaft speed and propeller pitch.

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4 Swain, G., Erdogan, C., Foy, L., Gardner, H., Harper, M., Hearin, J., Hunsucker, K.Z., Hunsucker, J.T., Lieberman, K., Nanney, M. and Ralston, E., 2022. Proactive In-Water Ship Hull Grooming as a Method to Reduce the Environmental Footprint of Ships. Frontiers in Marine Science, p.2017

9.20. However, there may be other, overriding reasons for a particular speed to be maintained, such as safety, operation, and energy efficiency. Significantly reducing the speed of an existing ship may result in undesirable increases in emissions, e.g., of NOx and black carbon. This is due to the engine speed dropping significantly below its optimal design condition. Consideration should be given in general to any critical speeds of an individual ship with respect to cavitation and resulting increases in URN.

Table 1 Summary of design, technical, operational and maintenance URN reduction approaches applicable to new and/or existing ships as far as practicable. This list is not exhaustive and should not restrict any other design options that a shipowner may consider as a solution. Further information is available in MEPC 74/INF.28.

URN Reduction Approaches	**New ship**	**Existing ship**	*Feasibility*
Optimize ship hull form (and appendages) design for hydrodynamic performance and homogenous wake field to reduce cavitation	**x**		
Optimizing propeller design to reduce cavitation, optimizing load, ensuring a uniform water flow and hull-propeller interaction and careful selection of the propeller characteristics such as: diameter, blade number, blade area, pitch, skew, rake, and sections and innovation material	**x**	**x**	
Emerging technologies like wind-assist technologies to reduce propeller loading and cavitation noise	**x**	**x**	
Air injection to propeller	**x**	**x**	
Wake flow improvement	**x**	**x**	
Careful selection of onboard machinery and installation with appropriate structure-borne noise levels control measures, proper location of equipment in the hull, and optimization of foundation structures	**x**		
Machinery installation and isolation for instance resilient mount and flexible coupling in four-stroke engines with a reduction gear, vibration isolation mounts and improved dynamic balancing for reciprocating machinery	**x**		
Optimizing the ship's trim to reduce the required power and therefore propeller cavitation noise	**x**	**x**	
Improving voyage planning (optimum route, coordinated across fleets, sensitive marine areas/sea-ice covered region)	**x**	**x**	
Reducing speed for ships equipped with fixed pitch propellers	**x**	**x**	
Ship routeing to avoid sensitive marine areas including well-known habitats or migratory pathways	**x**	**x**	
Propeller maintenance (and cleaning/coating)	**x**	**x**	
Hull maintenance (coating and grooming)	**x**	**x**	

10. Energy Efficiency and URN Reduction

10.1. Careful consideration should be given to the interrelationships between energy efficiency and URN while adhering to regulatory obligations and ensuring that the level of URN will meet set goals as established in the Noise Management Plan and compares favorably with ships of the same type and similar size.

.1 The Energy Efficiency Management Plan[5] could be integrated with the ship's Noise Management Plan to facilitate shipowners and operators to consider synergies and adoption of measures that both increase efficiency and reduce URN.

.2 Dual optimization will eventually reach a point when either URN or GHG will have to take a design precedence, URN measures should not come at the expense of mandatory IMO requirements on GHG reduction and energy efficiency.

10.2. *Scrutiny should be given to the co-design of hull and propeller as a unit, such that a uniform wake flow is created to reduce propeller cavitation, as this will also increase energy efficiency, and reduce emissions.*

10.3. *Reducing propeller cavitation is an effective means of reducing URN. Measures aimed at reducing applied or installed propulsion power and propeller thrust loading, with the appropriate safety caveats[6], are options to improve energy efficiency, reduce emissions, and typically results in URN reduction. Wind assistance, optimized hull design and regular maintenance, aimed at reducing hull resistance, and periodical hull cleaning to avoid fouling and reduce hull resistance are all effective measures for reduced emissions and URN.*

10.4. URN reduction measures should be in line with the IMO's GHG reduction strategy, many of the energy efficiency improvement options to meet energy efficiency regulations (EEDI, EEXI and CII) may result in an improvement in URN performance and provide positive synergies with climate policies. These include:

.1 Reductions in propeller cavitation attributable to improved flow into the propeller, reductions in ship speed to improve efficiency for ships fitted with fixed pitch propellers, and optimisation of ship draught and trim.

.2 Reductions in the size of main machinery.

.3 Reductions in the size and number of auxiliary generators.

10.5. Designer, builders, shipowners and operators should investigate and address the risk of increasing URN with new ship design to achieve lower EEDI or CII.

11. Evaluation and Monitoring

Single vessel radiated noise

11.1. As part of a Noise Management Plan (section 5), shipowners and operators should develop a monitoring approach to evaluate periodically the effectiveness of ship noise reduction efforts in comparison with baseline measurements (section 6) and URN goals (section 7) and to guide and enhance activities aimed at noise reduction

[5] MEPC 70/18/Add.1 Annex 10

[6] MEPC.1/Circ.850/Rev.3

(section 9). Such evaluation may include forms of URN measurements, simulations, modeling, or other scientific methods of data gathering and evaluation.

11.2. Consideration should be given to measuring the ship's URN from the identified noise sources at expected range of typical operating conditions (to determine if the URN goals of the ship are being met. These enable ship operators to optimize vessel operation and adjust URN levels appropriately along a route (e.g., by optimization of the ship's trim, thereby reducing the required power, or by reducing speed, when safe to do so both possibly resulting in reduced propeller cavitation noise). Furthermore, technical experts' support for measuring and monitoring URN will be necessary.

11.3. Ship-specific noise data gathered, and results of applied measures should be made widely available to member states and stakeholders, including researchers, and interested communities when possible. *[where and how remains to be address]*

11.4. Development in real-time dynamic voyage optimisation tools which provide personalized analytical information to increase efficiency, save on fuel and costs, and reduce emissions show promise for adaptive management and should further consider optimization options for noise reduction.

Ocean shipping noise

11.5. Monitoring Programmes, composed of observational measurements and models, can be used to assess a ship's URN and can provide temporal and spatial information to guide operational and technical mitigation responses and adaptive decision-making. Such monitoring should be coordinated with local regional fora for standardized procedure and comparable indicators and may be a requirement under regional laws. See the Compendium for a list of reference.

11.6. Efforts should be made to establish monitoring programs in understudied areas to establish baseline measures and better understand impacts of changes in underwater shipping noise.

.1 Monitoring capacity developed in partnership with ports should be encouraged along shipping lanes and used in incentive programs to complement other URN monitoring programmes, where possible.

.2 Efforts should be made to support community-led efforts to understand underwater noise from shipping and its impacts on marine species and coastal communities.

11.7. Other real-time environmental or port-based systems for shorter-term local operations, such as ferries, could also be examined to evaluate noise reduction.

11.8. Member States, classification societies, designers, shipbuilders, shipowners, and ship operators should contribute data, where possible, to the global understanding of ship noise emissions, including through established monitoring programmes of ship source levels and/or ambient noise. Data quality should be evaluated according to recognized guidelines e.g., classification society.

12. Incentivization

12.1. Maritime administrations, financial and insurance institutions and others should promote establishing incentive schemes to support the implementation of underwater noise monitoring programmes and noise reduction efforts by suppliers, designers, builders, shipowners and operators, where considered appropriate.

.1 This could be, for instance, based on quiet ship class notations, recognition of a URN Noise Management Plan, URN reduction targets, vessel and engine technologies and maintenance, ship speed reduction programs, Onshore Power Supply (OPS) in port or other voluntary sustainability certifications which include evidence of URN noise performance or complementary benefits on efficiency and maintenance (e.g., preventing biofouling by water cleaning of ship hull and propeller could increase efficiency and eliminate erosion of the propeller, rudder, and stern hull, and minimize the transfer of invasive species).

.2 Example of incentives are discount on the port dues, discount or extra services or products, promotion, among others.

12.2. Suppliers, designers, builders, shipowners and operators should make themselves aware and strive to achieve incentives related to environmental performance on underwater noise.

Appendix 1 Glossary

Ambient sound: sound that would be present in the absence of a specified activity. It is location-specific and time-specific. In the absence of a specified activity, all sound is ambient sound. Ambient sound includes ambient noise. Ambient sound can be anthropogenic (e.g., shipping) or natural (e.g., wind, biota).

Commercial ship: any ship which is not a recreational craft. Commercial relates to ships that are primarily operating for profit and does not include war ships or state-owned ships that are not in commercial services.

Decibel:

Existing ship: a ship which is not a new ship.

Frequency range: a continuous range or spectrum of frequencies that extends from one limiting frequency to another. Expressed in units of cycles per second or Hertz (Hz). The typical frequency range for ship URN is from 10 to 10,000 Hz and most URN limits have a frequency range from 10 to 50,000 Hz.

Hearing range: the range of frequencies the ear or any other sensory organ of an animal can detect.

Hydrodynamic flow noise*:* the noise generated by the (non-cavitating) turbulent flow, including the noise by entrained air bubbles, over the hull, appendages, and propeller and in the wake of the ship.

Indigenous Knowledge*:* a systematic way of thinking applied to phenomena across biological, physical, cultural, and spiritual systems. It includes insights based on evidence and acquired through direct and long-term experiences and extensive and multigenerational observation, lessons, and skills. It has developed over millennia and is still developing in a living process, including knowledge acquired today and in the future, and it is passed on from generation to generation. Under this definition, Indigenous Knowledge goes beyond observations and ecological knowledge, offering a unique 'way of knowing'.

Masking: where noise interferes with the detection and perception of other sounds important to marine fauna. Masking may, among other effects, cause a reduction or loss of communication range for marine species.

New ship: a ship for which the building contract is placed, or in the absence of a building contract, the keel of which is laid, or which is at a similar stage of construction, on or after the date of these Guidelines

Non-commercial ship: Any ship not primarily operating for profit.

Machinery noise: The machinery induced underwater noise generated by machinery inside the ship's hull. This contribution to total URN can be generated by machinery airborne sound, or structure-borne sound (i.e., vibration) from propulsion and auxiliary equipment.

RNL (Radiated Noise Level):

Ship operational profile: may be expressed in terms of the ship's loading condition, heading, sea state and speed.

SPL (Sound Pressure Level):

Appendix 2 Summary of recognized URN measurement standards

1. It is intended that given the noise measurement standards listed below, shipowners, designers and operators and other stakeholders will use the most appropriate noise measurement standard for their context.

2. ANSI S12.64 and ISO-17208-1 are two versions of the same standard. S12.64 was developed first by a group from the United States with international assistance. It included three grades: survey, engineering, and precision, with the latter being the most accurate methodology. ISO-17208-1 was taken from S12.64 and adopted for international use, with the primary difference being the removal of the three grades. Both standards are for the measurement of the Radiated Noise Level (RNL) of a ship in deep water. ISO-17208-2 provides a methodology to take data measured using ISO-17208-1 and convert the measured RNL to Monopole Source Level (MSL). These two standards would be most relevant to the measurement of ship noise. Both standards would be necessary, when using MSL metrics.

URN Measurement Standards Summary

Standard or Organization	**Date Issued**	**Scope**	**Methodology**	**Minimum Water Depth**
ICES-CRR-209[7]	May 1995	Applies only to fishery research vessels (R/V). This document provides guidance on ambient noise, fish hearing, ship noise, fish reaction to ship noise, URN instrumentation, noise mitigation for R/V's.	The intended methodology for results in sound pressure level at 1 meter in 1 Hertz (narrowband) spectrum. No distance correction process is given.	Not specified
ANSI/ASA S12.64[8]	Sept 2009	Applies to any ship of any size with speed less than 50 knots. (This is the first standard for URN measurement of commercial ships.)	Results are in sound pressure level at 1 m assuming the ship is modeled as a point source using spherical spreading. There are three grades of measurement: Precision, Engineering, and Survey. Uses three hydrophones located in the water column with a beam aspect.	*Prec.*: 300 m or 3x L *Eng*: 150 m or 1.5x L *Survey*: 75 m of 1x L Where L is overall ship length.

[7] International Council for the Exploration of the Seas (ICES), Cooperative Research Report 209, "Underwater Noise of Research Vessels, Review and Recommendations", dated May 1995.

[8] American National Standards Institute (ANSI) / Acoustical Society of America (ASA) S12.64-2009; "Quantities and Procedures for Description and Measurement of Underwater Sound from Ships – Part 1: General Requirements, dated September 2009.

Bureau Veritas, DNV GL[9]	November 2015	Applies to commercial ships which includes any vessel engaged in commercial trade or carrying passengers for hire.	Results are in sound pressure level at 1 m using calculated propagation loss with the ship modeled at a monopole sound source	Not specified
ISO-17208-1[10]	March 2016	Same as S12.64 (above)	Methodology and results are mostly the same as S12.64 but with a single grade between the precision and engineering grades of S12.64. Uses three hydrophones located in the water column with a beam aspect.	Greater of 150 m or as given in Note (1)
ITTC Guidelines 7.5-04[11]	September 2017	Applies to measuring underwater noise from surface ships.	Results are in sound pressure level at 1 m assuming spherical spreading and adjusted by a distance normalization.	300m or three times ship length for highest grade; 150 m or 1.5 times ship length for middle grade; 75 m or 1 times ship length for lowest grade.
Lloyds Register[12]	Feb 2018	Applies to any ship which had URN measured and certified in accordance with LR's *SHIPRIGHT* notation.	Deep water correction provided assuming measurements in accordance with ISO-17208-1. Shallow water shall be performed as given in ISO-17208-1. Uses three hydrophones located in the water column with a beam aspect.	Greater of 60 m or as given in Note (2)

9 Achieve Quieter Oceans by Shipping Noise Footprint Reduction (AQUO) and Suppression of UW Noise Induced by Cavitation (SONIC), "Guidelines for Regulation on UW Noise from Commercial Shipping

10 International Standards Organization (ISO), 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", dated March 2016.

11 International Towing Tank Conference (ITTC), Recommended Procedures and guidelines - Underwater Noise from Ships - Full scale measurements.

12 Lloyd's Register (LR), "Additional Design Procedures, Additional Design & Construction Procedure for the Determination of a Vessels Underwater Radiated Noise", February 2018.

Bureau Veritas[13]	July 2018	Applies to any self-propelled ship.	Results are in sound pressure level at 1 m using calculated transmission loss with the ship modeled at a monopole sound source. Uses three hydrophones located in the water column with a beam aspect.	Greater of 60 m or as given in Note (3)
China Classification Society[14]	October 2018	Applies to ships applying for CCS class notation.	Results are in sound pressure level at 1 m assuming spherical spreading and using calculated transmission loss.	When the single-hydrophone method is used, the keel clearance is in general not to be less than 40m and not less than 60m for a multiple-hydrophone method.
ISO-17208-2[15]	July 2019	This document specifies methods for calculating an equivalent monopole source level by converting radiated noise level values obtained in deep water according to ISO 17208-1.	This is not a ship measurement standard, must use ISO-17208-1 for field measurements.	N/A
DNV-GL[16]	July 2019	Applies to all ships looking to achieve the DNV-GL *SILENT* notation.	Deep water methodology to follow ISO-17208-1 (given above). Shallow water uses unique method with a single bottom mounted hydrophone and distance correction performed using actual site measured transmission loss or the relationship 18xLog(r) where r	150 m (for deep water testing regardless of ship length) 30 m (for shallow water testing)

[13] Bureau Veritas (BV), "Underwater Radiated Noise", Rule Note NR 614 DT R02 E, dated July 2018.

[14] China Classification Society, "Guidelines for underwater radiated noise of ships", October 2018.

[15] International Standards Organization (ISO), ISO-17208-2-2019; "Underwater acoustics — Quantities and procedures for description and measurement of underwater sound from ships — Part 2: Determination of source levels from deep water measurements" dated July 2019.

[16] Det Norske Veritas / Germanischer Lloyd (DNV/GL), Class Guideline DNVGL-CG-0313, "Measurement procedures for noise emission", dated July 2019.

			is the distance between the ship and hydrophone.	
DNV-GL[17]	July 2020	Applies to all ships looking to achieve the DNV-GL *SILENT* notation.	Results are in sound pressure level at 1 m assuming the ship is modeled as a point or line source as determined during the evaluation. This document only provides the limits and need to conduct measurement according to DNVGL-CG-0313 (above).	N/A
ABS[18]	May 2021	Applies to self-propelled commercial and research ships	Results are in sound pressure level at 1 m using spherical spreading for deep water and calculated transmission loss (by provided equation) for shallow water. Uses three hydrophones located in the water column with a beam aspect.	Greater of 60 m or as given in Note (4)
RINA[19]	2021	Applies to all ships looking to achieve the RINA *DOLPHIN QUIET* or *TRANSIT* notations.	Results are in sound pressure level at 1 m assuming the ship is modeled as a point source using spherical spreading. Uses three hydrophones located in the water column with a beam aspect.	150 m or as given in Note (5)
Korean Register[20]	July 2021	Applies to new and existing ships that have applied for the optional notation URN (Underwater Radiated Noise) for the ship's underwater radiated noise	Results are in sound pressure level at 1 m	At least 60 m

[17] Det Norske Veritas / Germanischer Lloyd (DNV/GL), Rules for Classification, Ships, Part 6, "Additional class notations, Chapter 7 Environmental Protection and Pollution Control", dated July 2020.

[18] American Bureau of Shipping (ABS), "Underwater Noise and External Airborne Noise", dated May 2021.

[19] Registro Italiano Navale (RINA), Dolphin Quiet Ship and Dolphin Transit Ship, dated 2021.

[20] Korean Register: Guidance for Underwater Radiated Noise (July 2021)

WATER DEPTH NOTES:

1. 1.5 x overall ship length which is the longitudinal distance between the forward-most and aft-most part of a ship.
2. 0.3 x v^2 where v is ship speed in m/s or 3 x $(B \times Dt)^{½}$ where B is ship width and Dt is ship draft both in meters.
3. 0.3 x v^2 where v is ship speed in m/s. Deep water is 200 m or 2x the ship length unless the ship is greater than 200 m then 1.5 times the ship length.
4. 0.3 x v^2 where v is ship speed in m/s. Deep water is the greater of 150 m or 1.5x the ship length.
5. Measurements can be performed in shallow water as long as adequate procedure for actual transmission loss has been agreed with RINA.

Appendix 3 Types of computational models for optimizing ship design and technical noise reduction approaches

.1 **Flow characteristics:** Computational Fluid Dynamics (CFD) can be used to predict and visualize flow characteristics, cavitation and hydroacoustic sources around the hull and appendages, generating the wake field in which the propeller operates. Also, propeller analysis methods such as lifting surface methods or CFD can be used for predicting cavitation.

.2 **Noise radiation**: Finite Element Analysis (FEA) and Boundary Element Method (BEM) and Statistical Energy Analysis (SEA) can be used to estimate radiated noise due to flow field, cavitation, and machinery excitations. Bathymetry, sea bottom, sea surface and the elastic ship structures can be accounted for. Other methods to predict radiation include hybrid methods, wave-based methods, and Energy Flow Method (EFM). Most methods can be used both for structures and fluids.

.3 **Noise propagation**: the noise path from source to receptor, depends on the environment and some sound characters. Methods, such as ray theory, normal modes, wavenumber integration or parabolic equations can be used for modeling long range propagation of sound.

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ANNEX 2

NOISE MANAGEMENT PLANNING INTEGRATED TOOL

Annex 1 to the Guidelines:

Noise Management Planning Integrated tool (To be developed)

The aim of this annex would be to present an interactive tool (similar to a flowchart or other visual support), based on the material in previous sections that would take a ship operator through the steps of understanding the URN from their ship, the implications for marine life in the area where it is operated, and the various steps that could be taken to optimally reduce URN. The output would provide the necessary information in a structured way to enable the operator to prioritize actions to reduce the acoustic footprint of the ship and evaluate the expected benefits that would be associated with these actions.

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ANNEX 3

ENERGY EFFICIENCY COMPLIANCE MEASURES AND URN RELATIONSHIPS

Annex 2 to the Guidelines:
(to be developed)

Annex 2 to the Guidelines: Energy Efficiency Compliance Measures and URN relationships

The aim of this annex would be to present a matrix of compliance approaches for EEXI/EEDI/CII and what is currently understood regarding their URN relationship. The matrix would provide linkages to more in-depth studies, as appropriate, and would identity relationships that are unknown. The matrix would build from information in MEPC 74/INF.28 and, if possible, would exist in an evergreen document that would allow for updates.

A proposed draft table is suggested on the next page.

Energy Efficiency Compliance Measures and URN relationships (Draft for further discussion/development)

The proposed table below uses the structure of the Ship Energy Efficiency Management Plan (SEEMP) according to MARPOL Annex VI, Chapter 4, Reg 22, which requires ships SEEMP to identify the measures that will be used to increase energy efficiency.

SEEMP Energy efficiency measures	**Known categorical relationship to URN** (Select ONE: Contradictory, Conditionally contradictory, Beneficial, Conditionally beneficial, neutral, Unknown, N/A)	**Co-benefit ranking (small, medium, large)** (When co-benefit is known i.e., Beneficial/Conditionally beneficial, rank the potential scale of co-benefit, select ONE: Small, Medium, Large, Unknown, N/A)	**Description of relationship** (Describe the known relationship and/or conditionality in plain text)	**References** (List relevant literature)
Fuel-efficient operations				
Improved voyage planning (careful planning and execution of voyages/ Guidelines for voyage planning, adopted by resolution A.893(21))	Beneficial	Unknown, too many factors, but potentially large	Slowdown in noise-sensitive environment (e.g., ECHO program in the Salish sea) have resulted in positive protection of the marine environment.	Matthews, M.-N. R., Z. Alavizadeh, D.E. Hannay, L. Horwich, and H. Frouin-Mouy. 2018. Assessment of Vessel Noise within the Southern Resident Killer Whale Critical Habitat: Final Report. Document number 01618, Version 2.1. Technical report by JASCO Applied Sciences for the Innovation Centre, Transport Canada/Government of Canada. https://iaac-aeic.gc.ca/050/documents/p80054/129319E.pdf

Weather routeing	N/A			
Just in time (maximum notice of berth availability and facilitate the use of optimum speed/ Optimized port operation)	Conditionally beneficial	Unknown	If optimum speed result in slowdowns in noise-sensitive areas will/could lead to co-benefit	
Speed optimization (Reference should be made to the engine manufacturer's power/consumption curve and the ship's propeller curve)				
Optimized shaft power (operation at constant shaft RPM can be more efficient)				
Optimized ship handling				
Optimum trim				
Optimum ballast				
Optimum propeller and propeller inflow considerations	Conditionally beneficial	Small-Medium	Optimum propeller and propeller inflow for a specific ship, when employed, reduces cavitation, thus increasing the propeller's efficiency, potentially minimizing the production of URN. Propeller and propulsor design which are known to enhance efficiency and reduce URN include: - Reduction of Turns per Knot (TPK) - Contracted Loaded Tip Propellers (CLT) - Contra-rotating Propellers - Kappel Propellers - Water Jets for high power density for fast, shallow draft ships	1.MEPC 74/INF.28
Optimum use of rudder and heading control systems (autopilots)				

Hull maintenance	Beneficial	Small	Regular hull maintenance can lead to minimal ship resistance increases.	1. MEPC 74/INF.28;
Propulsion system	Conditionally beneficial	Unknown		
Propulsion system maintenance	Conditionally Beneficial	Small-large if regarding propeller maintenance	Propeller maintenance will result in improved efficiency and potentially minimize production of URN.	
Waste heat recovery	Unknown	Small to medium		
Improved fleet management –	Unknown	Unknown		
Improved cargo handling	Unknown	Unknown		
Energy management	Unknown	Required under Annex VI – SEEMP		
Fuel type	Unknown	Unknown		
Other measures				
Innovative Technologies	Unknown	Small-medium		MEPC/Circ.815 – Guidance on treatment of innovative energy efficiency technologies for calculation and verification of the attained EEDI
Compatibility of measures				
Age and operational service life of a ship				
Trade and sailing area				

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ANNEX 4

PROVISIONAL CONSIDERATION OF THE IMPACT AND INTERRELATION OF THE PROPOSED ACTIONS TO FURTHER REDUCE URN IN THE CONTEXT OF ACHIEVING OTHER REGULATORY GOALS, INCLUDING SHIP SAFETY, ENERGY EFFICIENCY, AS WELL AS THE VISION AND MANDATE OF THE ORGANIZATION TO REDUCE POLLUTION FROM SHIPS (TOR 4)

The revised Guidelines address this consideration with the addition of a new section 10 and updated wording throughout the different sections of the Guidelines, in particular the considerations of co-benefits between URN and energy efficiency. Members of the CG also made the following proposals, but noted that due to time constraints in the work process, they did not discuss each proposal. All proposals need to be reviewed for feasibility and other considerations before any amendment of the guidelines be considered.

- Ensure that regulatory URN goals are developed, and that measures adopted by shipowners/operators to meet URN goals are described in Noise Management Plans.

- Describe which actions/measures align with related goals in Table 1 of the Guidelines.

- Cite the IMO Biofouling Guidelines and the Anti-fouling Convention for reference in the URN Guidelines; as anti-fouling on the hull and propeller is one of the best tools to mitigate both air emission and URN, more detailed regulations on fouling should be added; and

- Include information on the possibility of integrating a ship's (required) Energy Efficiency Management Plan with the Noise Management Plan described in these Guidelines.

IMO processes/technical groups to share information and to take into consideration other IMO regulatory goals were also proposed, such as:

- Having a standing agenda item on underwater noise at MEPC or SDC, so that the Guidelines and Annexes can be updated as appropriate, recognizing that best practices and technologies will evolve quickly as the Guidelines are implemented;

- Developing a sub-committee between URN/GHG for joint reporting;

- Sharing URN documents to relevant sub-committee/work items via the IMO secretariat assistance;

- Recommending a Polar Code amendment to Part IIB to reflect the existence of the Revised URN Guidelines and their relevance to the polar regions.

- Recommending to the IMO to assess the wider impacts of the various environmental protection measures and deciding policy with respect to priority, for example: reduction of the toxicity of anti-fouling paint, and limitations on in-water hull cleaning. As it is not always possible to achieve all environmental and safety objectives simultaneously, a mechanism for setting priorities could take the form of an ongoing impact assessment by IMO of all measures currently under consideration. Priority could then be assigned by IMO with respect to, for example, whether measures should be mandatory or for guidance.

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ANNEX 5

PROVISIONAL SUGGESTIONS TO PROMOTE THE WORK OF THE ORGANIZATION TO INCREASE AWARENESS, UPTAKE AND IMPLEMENTATION OF THE GUIDELINES AND IDENTIFY MOST APPROPRIATE TOOLS, THROUGH THE REVIEW OF, INTER ALIA, DOCUMENT SDC 8/14/2 (TOR 6)

In response to ToR 6, members of the Group made the following proposals, but noted that due to time constraints in the work process, they did not discuss each proposal. All proposals need to be reviewed for feasibility and other considerations before any amendment of the guidelines be considered.

- Updating the training protocols for seafarers to include information on where to find and how to apply such information related to sensitive areas and recommended routeing to reduce URN in voyage planning; (training protocols are designed according to the STCW Convention): https://www.imo.org/en/OurWork/HumanElement/Pages/STCW-Conv-LINK.aspx);

- Class societies could provide information or training to increase awareness, uptake and implementation of the Guidelines;

- Increasing and improving information-sharing and training/education to inform the different stakeholders of the use of these models would be beneficial as many builders and operators are not familiar with the modeling methods.

- Creating a module on underwater noise for IMO's Integrated Technical Cooperation Programme;

- Conducting a briefing of the revised Guidelines in appropriate forums;

- Sharing the revised Guidelines with entities that provide green certification (e.g., Green Marine) and encouraging them to adopt criteria that would foster uptake/implementation of the Guidelines;

- Increased uptake could be achieved through both short- and longer-term measures. Operational measures could include slowing down and avoiding particularly important areas for sensitive species such as cetaceans. Developing a system to provide mariners with the best, up to date information, on cetacean distribution would also be a useful outreach tool. Consideration should also be given to vessels that have achieved class society sound reduction notations. Achieving such notations may negate the need for the aforementioned operational measures.

- Developing a procedure that may embed the following steps: 1) Set up URN goals and specify clear steps/instructions for shipowners and other stakeholders on how to comply with them; 2) Identify a specific procedure to perform the measurements; 3) Make use of numerical modeling for simulation and prediction purposes, and; 4) Establish a rigorous monitoring plan to check the achievement of the URN goals;

- Separating the Guidelines into sections relevant to each audience and from the onset defining clearly the two main "audiences": Audience #1 - designers, builders, owners, operators; Audience #2 - port states, flag states, classification societies (and other organizations). One option would be to separate requirements for Maritime Administrations and Operators similar to what was done for the amendments in MARPOL Annex I (Regulation 43A).

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ANNEX 6

PROVISIONAL LIST OF AREAS THAT REQUIRED FURTHER ASSESSMENT AND RESEARCH (TOR 7)

In response to ToR 7, members of the Group made the following proposals, but noted that due to time constraints in the work process, they did not discuss each proposal. All proposals need to be reviewed for feasibility and other considerations before any amendment of the guidelines be considered.

<u>URN and GHG / URN and Biofouling</u>

- A study assessing the overall impact of the IMO GHG regulations on URN. This should consider the impact of the regulations that have been implemented to date (EEDI), the regulations that will come into effect later this year (EEXI and CII) and the likely longer-term trends attributable to the increasing reductions in GHG required by EEDI and CII. The study should also consider the potential effect of the yet to be decided mid- and long-term measures. This would better inform IMO with regard to the likely long-term global trends for URN both with respect to overall sound energy attributable to ships, but also any changes to the prevalence of certain sound frequencies. With this information, IMO would be in a better position to fine-tune subsequent versions of the URN reduction Guidelines.

- Provide clarity about the different URN measurement methods and their comparability, possible effects of URN measures on energy efficiency and GHG reduction measures.

- Further research on anti-fouling systems and best practices that work in tandem to address and reduce URN.

<u>Impacts of URN on species and habitats</u>

- Further research and gathering of information for different areas needed: standardization of biological monitoring and different factors to be considered, definition of habitats etc. - to make results comparable.

- Further assessment of real-time information systems for protected species sightings could be a useful approach for states to collaborate.

- Further research on the impacts of URN on species and habitats, in conjunction with efforts by other organizations and authorities with responsibility for those species and habitats.

<u>URN Targets</u>

- Further research and assessment on URN Target setting & application. Noise emission thresholds and targets need to be evaluated thoroughly before being defined within the Guidelines.

- Further research and assessment on options to include a grading system/scale (e.g., high URN reduction goal settings grant a higher grade) linked to the URN goal of the ship type/ship class.

Other

- Establish a methodology for defining baseline metrics for each class and ship type.

- An experience building phase to establish baselines and facilitate the necessary research of all possibilities for ultimate impact on implementation.

- Establish a standard for the measurement of cavitation inception speed.

- Small research project on impact of cleaning propeller and hull on ship noise.

- Consider an online database with limits for Class, Size and Vessel Type.

- Further research on the environmental effect of local slow steaming (URN/GHG combined).

- Establish harmonization of URN measurement standards between Class Societies. This might connect to incentivization and flag states, port states and port authorities' responsibilities for supporting measurement and monitoring of URN.

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ANNEX 7

Provisional list of suggested next steps, taking into account document SDC 8/14/8 and the Work plan for the review of the 2014 Guidelines for the reduction of underwater noise and identification of next steps (ToR 8)

In response to ToR 8, members of the Group made the following proposals, but noted that due to time constraints in the work process, they did not discuss each proposal. All proposals need to be reviewed for feasibility and other considerations before any amendment of the guidelines be considered.

<u>General</u>

- Continue the review of these amended Guidelines, the update of best practices and information on new technologies and the inclusion of a phase for sharing experiences like measurement techniques and suppliers' equipment shared before purchase.

<u>Noise Management Plans</u>

- Require vessels to have a noise management plan that reflects the components described in the revised Guidelines. This would follow a similar approach to the GHG policies which requires shipowners to develop Energy Efficiency Plans, which document the measures the ship will take to meet efficiency goals (now regulations).

- Recommend that the MEPC develop a 5-grade scale (A-E, similar to the Carbon Intensity Indicator) for URN, linked to the URN goal in the ship's Noise Management Plans. Any vessel receiving a "D" rating three years in a row, or a vessel receiving an "E" during any annual review should be recommended to install ship design upgrades or conduct significant operational improvements to reduce URN. Consideration should be made with regards to separate scales for new and existing ships.

- Carry out an in-depth discussion on the elaboration and maintenance of the Noise Management Plan, in the Recognized Organizations views, and discuss sensitive areas in a later stage.

- Suggest the establishment of an awareness campaign of the revised Guidelines and that the concept of an Underwater Noise Management Plan be considered to gain experience with this new process in practice and to implement lessons learned if it is agreed to internationally regulate noise emissions.

- Baselining: Consider indirect control by horsepower and ship speed, using the relationship between horsepower, ship speed and underwater noise derived from a large number of measurements taken at the port, rather than by measuring individual ships.

- Consider including methods which can be taken with the current technology level, such as appropriate ship operation in consideration of regional characteristics and protected areas (e.g., slow steaming) in the management plan.

Providing relevant information to shipowners/operators to assist with voyage planning

- Consideration needs to be given to how best to provide this information and keep it updated.

- A multi-disciplinary international program to create an evergreen document that compiles the impacts of noise on fauna may be an avenue to explore.

- Make available the information on sensitive fauna within Marine Protected Areas (MPAs) that already exist on web-based services such as EMODNET for the EU waters or NOAA for the US waters for ships approaching MPAs.

Developing underwater radiated noise goals/reduction targets

- One way to classify ships is to compare the integrated sound energy over a year to a kilometre per tonne. This could enable similar indexing to noise that we have with GHG (CII) with metric of sound energy (Joule/Year) per kilometre per tonne. In the long-term, this could be used to introduce a classification of ships based on URN index similar to CII (classes A to F).[21]

- Consider a class-wide approach where ships within a class report their URN and are compared to establish norms like the Carbon Intensity Indicator (CII). Noise emissions levels and spectra ranges for all classes of vessels from data collected from ship measurements could be used as the basis of identifying desired levels for new builds and retrofits. The level of the absolute limit can be based on ship noise databases compiled by various organizations.

- The Classification societies have recently introduced various class notations for quiet ships and if copies of acceptance trials results could be acquired for these, the noise measurement results could then form the basis of a set of voluntary target noise levels for various ship types.

- Information that will result from current OSPAR, HELCOM, and EU Marine Strategy Framework Directive work is the amount of noise reduction that will be required to meet threshold values. This will be an important factor to consider and inform target setting.

- The current process to set threshold values (TVs) within the MSFD framework will give important input to inform target setting. First TVs will be adopted in October 2022.

- Use existing knowledge and processes currently underway to establish ship-based URN targets that can inform goal setting in a standardized Noise Management Plan.

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[21] This method should be noted with more data for a typical commercial ship. Sound energy is a small quantity based on Joule. And adopting such a definition, the conversion formulae from "source level" to "sound energy" could be addressed. The relationship of sound power level Lw and source level Ls:Lw=Ls+11 dB,
Sound power:W=10^(Lw/10)*Wref,
Wref=0.67E-18 watt,
Sound energy: E=W*T.

URN Monitoring/Evaluation

- Recommend that the MEPC require an underwater noise evaluation for the design and construction of all new-build vessels.

- To make CII possible, the fuel monitoring system with IMO-DCS should be installed on a ship. To monitor URN, there should be a similar on-board sensor and recording system and the installation of such systems should be mandatory.

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ANNEX 8

REPORTS AND DOCUMENTS THAT COULD BE RELEVANT FOR THE REVIEW OF THE 2014 GUIDELINES (UPDATED ANNEX 1 OF SDC 8/14/2 - URN COMPENDIUM)

*(*Note: Updates in the table are highlighted in yellow)*

Document	Synopsis	Relevance
Ainslie, M. A., Martin, S. B., Trounce, K. B., Hannay, D. E., Eickmeier, J. M., Deveau, T. J., ... & Borys, P. (2022). International harmonization of procedures for measuring and analyzing of vessel underwater radiated noise. *Marine pollution bulletin*, *174*, 113124. (https://static1.squarespace.com/static/52aa2773e4b0f29916f46675/t/61b9000d9028581a7ff05e8d/1639514127932/Ainslie_et_al_2021_International+harmonization+of+URN+procedures.pdf).	To reduce environmental pressure on the SRKWs, Vancouver Fraser Port Authority offers incentives for quieter ships. However, the absence of a widely accepted underwater radiated noise (URN) measurement procedure hinders the determination of relative quietness. This article reviews URN measurement procedures, summarizing results to date from two Canadian-led projects aimed at improving harmonization of shallow-water URN measurement procedures.	ToR .2 ToR .4 **New outline section:** Implementation and monitoring – estimations of URN **Key themes:** *Measuring URN* *Certifications/Standards*
LIFE-PIAQUO Project. (2022). *Underwater noise impacts reduction of the maritime traffic and real-time adaptation to ecosystems.* LIFE18 ENV/FR/000308 (https://webgate.ec.europa.eu/life/publicWebsite/index.cfm?fuseaction=search.dspPage&n_proj_id=7204).	The LIFE-PIAQUO project objectives are to develop and test different tools to reduce underwater noise pollution and their impacts on Mediterranean aquatic biodiversity. It is structured around five goals: the first two target the shipping industry while the other three concern public stakeholders such as governments, harbours and Marine Protected Areas (MPAs).	ToR .2 **New outline section:** Implementation and monitoring – estimations of URN **Key themes:** *Measuring URN*
Merchant, N.D., Putland, R.L., André, M., Baudin, E., Felli, M., Slabbekoorn, H., Dekeling, R. (2022) A decade of underwater noise research in support of the European Marine Strategy Framework Directive. Ocean & Coastal Management 228, 106299. https://doi.org/10.1016/j.ocecoaman.2022.106299	Underwater noise from human activities is now widely recognized as a threat to marine life. Nevertheless, legislation which directly addresses this source of pollution is lacking. The first (and currently only) example globally is Descriptor 11 of the Marine Strategy	ToR .3 **New outline section:** Noise baselining – understanding the ship's URN emissions **Key themes:** *Knowledge collaboration*

	Framework Directive (MSFD), adopted by the European Union in 2008, which requires that levels of underwater noise pollution do not adversely affect marine ecosystems. The MSFD has stimulated a concerted research effort across Europe to develop noise monitoring programmes and to conduct research towards specifying threshold values which would define 'Good Environmental Status' (GES) for underwater noise. Here, the authors chart the progress made during the first decade of Descriptor 11's implementation: 2010–2020.	
Parsons, M. J., Lin, T. H., Mooney, T. A., Erbe, C., Juanes, F., Lammers, M., & Di Iorio, L. (2022). Sounding the Call for a Global Library of Underwater Biological Sounds. *Frontiers in Ecology and Evolution*, 39. (https://www.frontiersin.org/articles/10.3389/fevo.2022.810156/full?fbclid=IwAR0tIzE4tQo8bAzm6LMmb_ScJHm_FAL3RF9loMcsTbyi7h9COuSnVa3rZv0)	There is a need to document, quantify, and understand biotic sound sources–potentially before they disappear. A significant step toward these goals is the development of a web-based, open-access platform that provides: (1) a reference library of known and unknown biological sound sources; (2) a data repository portal for annotated and unannotated audio recordings of single sources and of soundscapes; (3) a training platform for artificial intelligence algorithms for signal detection and classification; and (4) a citizen science-based application for public users.	ToR .2 ToR .3 **New outline section:** Noise baselining – understanding the ship's URN emissions Noise baselining – understanding the ship's URN emissions **Key themes:** *Measuring URN*
Trickey, J.S., Cárdenas-Hinojosa, G., Rojas-Bracho, L. et al. Ultrasonic antifouling devices negatively impact Cuvier's beaked whales near	Ultrasonic antifouling devices are commercially available, installed globally on a variety of	ToR .4 **New outline section:**

Guadalupe Island, México. Commun Biol 5, 1005 (2022). https://doi.org/10.1038/s42003-022-03959-9	vessel types as a method for biofouling control. The study show that they can be an acoustic disturbance to marine wildlife, as seasonal operation of these hull-mounted systems by tourist vessels in the marine protected area of Guadalupe Island, México resulted in the reduced presence of a potentially resident population of Cuvier's beaked whales (Ziphius cavirostris).	URN Reduction approaches **Key themes:** *Impacts to marine mammals* *Relationship biofouling* *Field trial*
Arranz, P., Aguilar de Soto, N., Adsen P.T. & Sprogis, K.R. (2021). Whale-watch vessel noise levels with applications to whale-watching guidelines and conservation. *Marine Policy, 134,* 104776. (https://www.sciencedirect.com/science/article/pii/S0308597X21003870).	The aim of this study was to (i) measure the underwater acoustic noise signatures of a range of whale-watching vessels off Exmouth, Western Australia and off Tenerife, Canary Islands (Spain), (ii) evaluate the impacts of such source signatures in light of ambient noise conditions in these habitats, and (iii) use such data to inform a discussion of best practice noise limits for cetacean tourism vessels.	ToR .2 ToR .3 **New outline section:** Implementation and monitoring – estimations of URN **Key themes:** *Measuring URN*
Cruz, E. Lloyd, T., Bosschers, J., Lafeber, F.H., Vinagre, P. Vaz, G., (2021). *Study on inventory of existing policy, research and impacts of continuous underwater noise in Europe.* EMSA report EMSA/NEG/21/2020. WavEC Offshore Renewables and Maritime Research Institute Netherlands. (https://www.emsa.europa.eu/newsroom/latest-news/item/4569-sounds.html)	This study consolidates information on the subject of continuous URN from shipping, in order to derive recommendations for a future multi-stakeholder strategy within Europe. The study focused on four main subject areas, with noise sources, environmental impact and policy providing the basis for the main goal, mitigation. An extensive literature review was combined with stakeholder consultation in the form of a questionnaire and interviews.	ToR .2 ToR .3 **New outline section:** Noise baselining – understanding the ship's URN emissions **Key themes:** *Measuring URN*

De Jong, C. & Hulskotte, J. (2021). A slow steaming scenario in the North Sea region. In TNO 2021 R10560. https://www.health.belgium.be/sites/default/files/uploads/fields/fpshealth_theme_file/a_slow_steaming_scenario_in_the_north_sea_region.pdf	The objective was to investigate the potential for reducing air emissions as well as underwater noise with a so-called operational 'slow steaming' scenario in the North Sea region.	ToR .2 ToR .3 **New outline section:** Energy efficiency and URN reduction **Key themes:** *Energy efficiency* *Modeling/testing*
DRDC. (2021). *Results from off-board noise prediction study in ORCA-class training vessel*. (https://cradpdf.drdc-rddc.gc.ca/PDFS/unc351/p812595_A1b.pdf).	Defence Research and Development Canada (DRDC) performed a trial to measure both on-board vibrations and off-board underwater noise produced by an ORCA-class patrol vessel. Analysis of the trial data shows that it is possible to accurately reconstruct the off-board noise spectrum using few hulls and machine-mounted accelerometers.	ToR .4 **New outline section:** Noise baselining – establishing URN goals Implementation and monitoring – estimations of URN **Key themes:** *Field trial* *Measuring URN*
Duarte, C. M., Chapuis, L., Collin, S. P., Costa, D. P., Devassy, R. P., Eguiluz, V. M., ... & Juanes, F. (2021). The Soundscape of the Anthropocene ocean. *Science 371*(6529), eaba4658. (https://epic.awi.de/id/eprint/53691/1/DuarteEtAl_2021full.pdf).	Oceans have become substantially noisier since the Industrial Revolution. Shipping, resource exploration, and infrastructure development have increased the anthrophony, whereas the biophony has been reduced by hunting, fishing, and habitat degradation. This should prompt management actions to deploy existing solutions to reduce noise levels in the ocean, thereby allowing marine animals to reestablish their use of ocean sound as a central ecological trait in a healthy ocean.	ToR .2 **New outline section:** Noise baselining – understanding the ship's URN emissions Noise baselining – understanding critical habitats and impacts on marine mammals **Key themes:** *Measuring URN* *Impacts to marine mammals*
Eickmeier, J., Tollit, D., Trounce, K., Warner, G., Wood, J., MacGillivray, A. and Zizheng Li. (2021). Salish Sea Ambient Noise Study: Best Practices (2021). Vancouver, British Columbia, *Technical report for Vancouver Fraser*	This high-level review aims to help understand and address key environmental and anthropogenic factors that contribute to ambient	ToR .2 **New outline section:** Implementation and monitoring – estimations of URN

Port Authority, Enhancing Cetacean Habitat and Observation (ECHO) Program. (https://repository.oceanbestpractices.org/bitstream/handle/11329/1572/2021-03-15%20OBPS%20Salish%20Sea%20Ambient%20Noise%20submission.pdf?sequence=2&isAllowed=y)	noise. Key findings highlight that early and frequent quality assessment protocols are imperative, weather and tidal information should be collected proximate to the hydrophone, vessel traffic was the dominating influence at all locations across all measured frequencies, and validated noise models should augment empirical data collection.	**Key themes:** *Impacts to ocean ambient noise* *Modeling/testing* *Measuring URN*
Erbe, C., Schoeman, R.P., Peel, D. & Smith, J.N. (2021). It Often Howls More than It Chugs: Wind versus Ship Noise Under Water in Australia's Maritime Regions. *Journal of Marine Science and Engineering, 9*, 472. (https://www.nespmarine.edu.au/system/files/Erbe_Peel%20et%20al_E2_It%20often%20howls%20more%20than%20it%20chugs_2021_%20OPEN.pdf).	Authors in this article developed a model for ship noise in Australian waters, which could be used by industry and government to manage marine zones, their usage, stressors, and potential impacts. They also modelled wind noise under water to provide context to the contribution of ship noise.	ToR .2 **New outline section:** Implementation and monitoring – estimations of URN **Key themes:** *Modeling/testing* *Measuring URN*
Erbe, C. Duncan, A., Peel, D. & Smith, J.N. (2021). Underwater noise signatures of ships in Australian waters. *Report to the National Environmental Science Program, Marine Biodiversity Hub*. CMST Curtin University. (https://www.nespmarine.edu.au/system/files/Erbe%20et%20al_2021_E2_M1_NESP%20ship%20noise%20analysis_FINAL.pdf).	This technical report supports a project that quantifies underwater noise from ships in Australian waters, with the ultimate goal of guiding the management of noise impacts on marine fauna. This report presents the field recordings and the methodology developed for computing ship source spectra and source levels.	ToR .4 **New outline section:** Implementation and monitoring – estimations of URN Noise management – examining and evaluating options for operations and maintenance **Key themes:** *Field trial* *Measuring URN*
Hildebrand, J.A., Frasier, K.E., Bauman-Pickering, S. & Wiggins, S.M. (2021). An empirical model for wind-generated ocean noise. *The Journal of the Acoustical Society of America, 149*, 4516. (http://www.cetus.ucsd.edu/docs/publications/HildebrandJASA2021.pdf).	This study provides an empirical model for wind-generated ocean noise. The model may be used to estimate baseline sound measurements in the ocean and evaluate what ocean sound levels would be in the absence of anthropogenic noise.	ToR .3 **New outline section:** Noise baselining – understanding critical habitats and impacts on marine mammals **Key themes:** *Impacts to ocean ambient noise*

JASCO Applied Science. (2021). *Analysis of Ship Efficiency versus Underwater Radiated Noise*. (https://tcdocs.ingeniumcanada.org/sites/default/files/2021-08/Analysis%20of%20Ship%20Efficiency%20versus%20Underwater%20Radiated%20Noise.pdf[22]).	This study was to determine whether a vessel's underwater radiated noise (URN) level can be reduced without compromising efficiency. For this investigation, efficiency was quantified using the Energy Efficiency Design Index (EEDI). From this study it was concluded that the primary result of EEDI is a reduction in the average vessel speed, i.e., slow steaming that reduces the greenhouse gas emissions of individual vessels. The net effect of this change on the total emissions is unclear and requires further investigation.	ToR .2 ToR .3 **New outline section:** Energy efficiency and URN reduction **Key themes:** *Energy efficiency*
JASCO Applied Sciences. (2021). *Towards a Standard for Vessel URN Measurement in Shallow Water*. (https://tcdocs.ingeniumcanada.org/sites/default/files/2021-08/Towards%20a%20Standard%20for%20Vessel%20Underwater%20Radiated%20Noise%20%28URN%29%20Measurement%20in%20Shallow%20Water.pdf[23]).	The scope of this white paper is to analyze and illustrate the issues that complicate vessel URN measurements in shallow water. It provides an overview of the issues associated with making shallow water URN measurements; documents the results of acoustic propagation modeling numerical experiments; and recommends the hydrophone geometries to employ for at-sea measurements that will be performed in summer 2021.	ToR .3 ToR .4 **New outline section:** Noise baselining – understanding the ship's URN emissions **Key themes:** *Modeling/testing* *Measuring URN*
MacGillivray, A. & de Jong, C. (2021). A Reference Spectrum Model for Estimating Source Levels of Marine Shipping Based on Automated Identification System Data. *Journal of Marine Science and Engineering, 9*(4),	Robust sound mapping tools not only require accurate models for estimating source levels for large numbers of marine vessels, but also	ToR .4 **New outline section**: Implementation and monitoring

[22] If the document is not accessible, access this link: https://tcdocs.ingeniumcanada.org then "browse documents"; use categories "Marine" and "Underwater Noise" to search for the desired report.

[23] Ibid.

369. (https://www.mdpi.com/2077-1312/9/4/369).	an objective assessment of their uncertainties. As part of the Joint Monitoring Programme for Ambient Noise in the North Sea (JOMOPANS) project, a widely used reference spectrum model (RANDI 3.1) was validated against statistics of monopole ship source level measurements from the Vancouver Fraser Port Authority-led Enhancing Cetacean Habitat and Observation (ECHO) Program.	**Key themes**: *Modeling* *Monitoring*
MaREI, University College Cork. (February 2021-January 2025). Saturn: Solutions at Underwater Radiated Noise Project.	SATURN will examine; i) which sounds pose the greatest threat to aquatic species and how they are produced and propagated; ii) the short and long-term effects of URN on invertebrates, fish, and marine mammals; and iii) the most promising options for reducing the negative impacts of URN. SATURN will also develop and progress standards for terminology and methodology across all disciplines working on URN, producing recommendations for effective underwater sound management.	ToR .2 **New outline section**: Implementation and monitoring – estimations of URN Noise baselining – understanding critical habitats and impacts on marine mammals **Key themes**: *Modeling/testing* *Measuring URN* *Knowledge collaboration* *Impacts to marine mammals*
MARIN. (2021). *Orca patrol vessels: design and evaluation of new propellers*. (https://tcdocs.ingeniumcanada.org/sites/default/files/2021-08/Orca%20class%20patrol%20vessels%20-%20design%20and%20evaluation%20of%20new%20propellers.pdf[24]).	This report describes a demonstration project showing a general approach for reducing underwater noise generation from commercial shipping by optimizing the design of the propeller for improved cavitation performance and efficiency. The work completed includes numerical simulations and model testing of the existing and re-designed propeller.	ToR .2 **New outline section:** Noise baselining – understanding the ship's URN emissions Noise management planning – propeller noise **Key themes:** *New technologies* *Modeling/testing*

24 Ibid.

Sezen, S., Uzun, D., Ozyurt, R., Turan, O., & Atlar, M. (2021). Effect of biofouling roughness on a marine propeller's performance including cavitation and underwater radiated noise (URN). *Applied Ocean Research, 107,* 102491. (https://doi.org/10.1016/j.apor.2020.102491.).	This study aims to investigate the effects of biofouling-related roughness on a propeller's hydrodynamic and underwater radiated noise (URN) performance. The results showed that roughness has detrimental impacts on the propeller's performance characteristics and indicated that the URN levels might be reduced up to 10 dB between 1 kHz and 2 kHz.	ToR .2 **New outline section**: Implementation and monitoring – estimations of URN **Key themes**: *Modeling/testing* *Measuring URN*
The Specialist Committee on Hydrodynamic Noise. (2021). *Final Report and Recommendations to the 29th ITTC, 2021.* (https://ittc.info/media/9500/sc-hydrodynamicnoise.pdf).	This report summarizes the work of the Specialist Committee, some of which includes: progress made on computational prediction methods in modeling cavitation and turbulence structures in the flow field, and a review of possible benchmark cases for model-scale noise measurements.	ToR .2 **New outline section**: Implementation and monitoring – estimations of URN **Key themes**: *Modeling/testing* *Measuring URN*
Western Pacific Marine Ltd. (2021). *BC Ferries Quiet Vessel Ferry Design, A Case Study.* (https://www.portvancouver.com/wp-content/uploads/2021/05/2021-10-04-BC-Ferries-Quiet-Vessel-Case-Study.pdf).	To promote the uptake of underwater noise reduction solutions with shipowners and operators, the Vancouver Fraser Port Authority-led ECHO Program reviewed the approach that BC Ferries – one of the world's largest ferry operators – took in setting underwater radiated noise reduction goals through the design and construction of its new major ferries replacement program. The case study outlines the key steps undertaken and challenges experienced by BC Ferries and highlights lessons that may benefit other shipowners who are considering the inclusion of underwater radiated	ToR .2 **New outline section:** Noise management planning – examining and evaluating options for operation **Key themes:** *New technologies* *Certification/Standards*

	noise reduction targets in new vessel builds.	
ZoBell, V., Frasier, K.E., Morten, J.A., Hastings, S.P., Peavey Reeves, L.E., Wiggins, S.M. & Hildebrand, J.A. (2021). Underwater noise mitigation in the Santa Barbara Channel through incentive-based vessel speed reduction. *Scientific Reports, 11*(1), 1-12. (https://www.nature.com/articles/s41598-021-96506-1?proof=t%3B).	This study quantified the effectiveness of a vessel speed reduction program on reducing underwater radiated noise. This work estimated broadband (5-1000 Hz) received levels, monopole source levels, and sound exposure levels of vessels participating in two types of vessel speed reduction programs.	ToR .2 **New outline section:** Noise management – examining and evaluating options for operations and maintenance **Key themes:** *Measuring URN* *Modeling/testing*
DRDC. (2020). *ORCA Benchmark Underwater Radiated Noise Simulation (BURNSi) Measurement Trial Plan*. (https://cradpdf.drdc-rddc.gc.ca/PDFS/unc347/p812171_A1b.pdf).	Defence Research and Development Canada (DRDC) – Atlantic Research Centre carried out a set of trials in July 2019 and measured both onboard vibrations and off board underwater noise levels generated by an ORCA-class training ship available from the Royal Canadian Navy (RCN) on the West Coast. The measurements showed onboard vibration levels can be used to predict the underwater radiated noise from the vessel and that it is possible to monitor propeller cavitation.	ToR .2 ToR .4 **New outline section:** Noise baselining – understanding the ship's URN emissions Implementation and monitoring – possible approaches for monitoring of URN **Key themes:** *New technologies* *Field trial*
DRDC. (2020). *ORCA Underwater Noise Measurement Trial Plan*. (https://cradpdf.drdc-rddc.gc.ca/PDFS/unc342/p811524_A1b.pdf).	In support of the TC project on understanding noise issues with respect to local resident whale populations, a trial is required to measure both onboard vibrations and offboard underwater noise. The trial objectives include establishing a baseline acoustic signature level for this type of vessel in support of any future noise reduction activities, measuring onboard vibrations for potential correlation with offboard noise leading to capabilities for cavitation monitoring or onboard	ToR .2 ToR .3 ToR .4 **New outline section:** Noise baselining – understanding the ship's URN emissions Implementation and monitoring – possible approaches for monitoring of URN **Key themes:** *New technologies* *Field trial*

	acoustic signature prediction, and developing further understand for the prediction of onboard to offboard transfer functions for a variety of ship types.	
International Whaling Commission. (2020). *Report of the pre-meeting on advancing efforts to address underwater noise from shipping, virtual meeting, 11 May 2020.* SC/68B/Rep/06. (https://archive.iwc.int/pages/view.php?search=&k=&modal=&display=list&order_by=field3&offset=3493&per_page=240&archive=0&sort=ASC&restypes=&recentdaylimit=&foredit=&ref=17616).	The workshop focused on low-frequency noise from large ships, assessment frameworks for ambient sound, and collaboration with other organizations to address shipping noise.	ToR .2 **New outline section**: Implementation and monitoring – estimations of URN **Key themes**: *Modeling/testing* *Measuring URN* *Knowledge collaboration*
Jong, C., Harmsen, J., Bekdemir, C., & Hulskotte, J. (2020). Reduction of emissions and underwater radiated noise for the Belgian shipping sector. In TNO 2020 R11855. https://www.health.belgium.be/sites/default/files/uploads/fields/fpshealth_theme_file/reduction_of_emissions_and_underwater_radiated_noise_for_the_belgian_shipping_sector_tno-2020.pdf	The study investigated the options for reducing greenhouse gas (GHG) and pollutant emissions as well as underwater noise from commercial shipping, with a focus on the Belgian fleet.	ToR .2 ToR .3 **New outline section:** Energy efficiency and URN reduction **Key themes:** *Energy efficiency* *Modeling/testing*
MacGillivray, A.O., J. Zhao, M.A. Bahtiarian, J.N. Dolman, J.E. Quijano, H. Frouin-Mouy, & L. Ainsworth. (2020). *ECHO Vessel Noise Correlations Phase 2 Study: Final Report. Document 02283, Version 1.0. Technical report by JASCO Applied Sciences, ERM Consultants Canada, and Acentech for Vancouver Fraser Port Authority ECHO Program.* (https://www.portvancouver.com/wp-content/uploads/2021/01/2021-01-29-Vessel-Noise-Correlations_Phase-2_Final.pdf). MacGillivray, A.O., L. Ainsworth, J. Zhao, H. Frouin-Mouy, J. Dolman, & M. Bahtiarian. (2020). *ECHO Vessel Noise Correlations Study: Final Report. Document 02025, Version 2.1. Technical report by JASCO Applied Sciences, ERM, and Acentech for Vancouver Fraser Port Authority ECHO Program*.	The vessel noise correlations studies were undertaken to evaluate potential statistical correlations between vessel operational and design characteristics and vessel underwater radiated noise levels. Two phases of the study were undertaken, utilizing an extensive database of vessel source levels collected on behalf of the ECHO Program and Transport Canada. The studies developed a statistical model to assess the power of these parameters at predicting vessel noise levels by major commercial vessel categories.	ToR .2 **New outline section**: Implementation and monitoring – estimations of URN **Key themes**: *Modeling/testing* *Measuring URN*

(https://www.portvancouver.com/wp-content/uploads/2020/05/2020-05-26-ECHO-Program-Vessel-Noise-Correlations-Study.pdf).		
Sprogis, K. R., Videsen, S., & Madsen, P. T. (2020). Vessel noise levels drive behavioural responses of humpback whales with implications for whale-watching. *ELife, 9,* e56760. (https://elifesciences.org/articles/56760.pdf).	The authors of this article tested the hypothesis that vessel noise level is a driver of disturbance, using humpback whales as a model species. They conducted controlled exposure experiments on resting mother-calf pairs and concluded that vessel noise is an adequate driver of behavioural disturbance in whales and that regulations to mitigate the impact of whale-watching should include noise emission standards.	ToR .3 **New outline section:** Noise baselining – understanding critical habitats and impacts on marine mammals **Key themes:** *Impacts to marine mammals*
Vard Marine Inc. (2020). *Echolocation Devices and Marine Mammal Impact Mitigation*. (https://tcdocs.ingeniumcanada.org/sites/default/files/2020-11/Echolocation%20Devices%20and%20Marine%20Mammal%20Impact%20Mitigation.pdf[25]).	The objectives of this study were to characterize Underwater Radiated Noise (URN) from echolocation sources used on commercial and recreational vessels, and to develop recommendations for design and operational measures which may mitigate the URN impact on marine mammals. This information, which is currently not readily available to policy makers and regulators, will help TC prioritize further research and analysis related to underwater noise reductions.	ToR .2 **New outline section:** Noise baselining – understanding URN the ship's URN Noise Management planning – Echosounder noise Implementation and monitoring – estimations of URN emissions **Key themes:** *New technologies*
Zhang, G., Forland, T.N., Johnsen, E., Pedersen, G. & Dong, H. (2020). Measurements of underwater noise radiated by commercial ships at a cabled ocean observatory. *Marine Pollution Bulletin, 153,* 110948 (https://www.sciencedirect.com/science/article/pii/S0025326X20300667).	Noise measurements in the field is of significance for evaluating the shipping noise impact. To model the impact, it is recommended to consider the shipping noise propagations, given by the variations of the measurements at the	ToR .4 **New outline section**: Implementation and monitoring **Key themes**: *Measuring URN Monitoring*

[25] Ibid.

	ocean observatory in this paper. This paper provides the measurements as well as the source of the data.	
ACENTECH Inc. (2019). *Quieting Ships to Protect the Marine Environment Workshop Final Report.* (to be posted on Ingenium).	In late January of 2019, Transport Canada hosted a technical workshop entitled "Quieting Ships to Protect the Marine Environment". Around 140 subject-matter experts from around the world gathered at this event for two and half days. The purpose of the workshop was to identify the state of knowledge on quiet ship technology, provide an opportunity for international collaboration, and exchange research ideas. This report highlights the recommendations and outcomes of the workshop.	ToR .3 **New outline section:** Noise baselining – understanding the ship's URN emissions **Key themes:** *Knowledge collaboration*
Chamber of Shipping America (CSA), World Wildlife Fund – Canada (WWF), World Maritime University (WMU) and Transport Canada. (2019). *Filtering through the noise: Benchmarking Study on the Implementation of the International Maritime Organization's Underwater Vessel Noise Guidelines*. (to be posted on Ingenium).	In order to further inform discussions underway at the IMO's Marine Environmental Protection Committee (MEPC), a benchmarking study was conducted in 2019 which involved one-on-one interviews with international stakeholders, including shipping industry representatives. The report highlights various issues and recommendations regarding awareness and uptake of the Guidelines.	ToR .1 **New outline section:** Noise baselining – understanding the barriers to uptake **Key themes:** *Awareness of Guidelines*
CISMaRT, Transport Canada. (2019). *Report on CISMaRT/Transport Canada Workshop on Ship Noise Mitigation Technologies for a Quieter Ocean*. (http://cismart.ca/wp-content/uploads/2018/08/CISMaRT-TC-Underwater-Noise-Workshop-Report-draft-v2.0.pdf).	The report summarizes a workshop that was held to better define the problem and understand the gaps in mitigation technologies for underwater noise from ships. The workshop comprised a short course on underwater noise from ships, invited presentations from leading	ToR .3 **New outline section:** Noise baselining – understanding the ship's URN emissions **Key themes:** *Knowledge collaboration*

	figures with special expertise in some aspects of underwater noise from ships, and breakout sessions.	
DFO. (2019). *Evaluation of the effects on underwater noise levels from shifting vessel traffic away from Southern Resident Killer Whale foraging areas in the Strait of Juan de Fuca in 2018*. (https://waves-vagues.dfo-mpo.gc.ca/Library/40812431.pdf).	Between August 20 and October 31, 2018 the Vancouver Fraser Port Authority and Transport Canada led a voluntary program where all outbound deep sea vessels and inshore vessels (tugs) in a portion of the Strait of Juan de Fuca were requested to shift their outbound tracks southwards, and further away from areas of critical importance to the endangered Southern Resident Killer Whale (SRKW) population. The main goal of this study was to investigate the efficacy of lateral vessel displacement to reduce the impact of underwater vessel noise on SRKW at three locations off Port Renfrew, Jordan River and Sooke.	ToR .2 **New outline section:** Noise management planning – examining and evaluating options for operation **Key themes:** *Impacts to marine mammals* *Field trial*
Erbe, C., Marley, S.A., Schoeman, R.P., Smith, J.N., Trigg, L.E. & Embling, C.B. (2019). The Effects of Ship Noise on Marine Mammals—A Review. *Frontiers in Marine Science, 6*, 606. (https://www.frontiersin.org/articles/10.3389/fmars.2019.00606/full).	This article provides an overview of this literature, showing that studies have been patchy in terms of their coverage of species, habitats, vessel types, and types of impact investigated. The documented effects include behavioral and acoustic responses, auditory masking, and stress.	ToR .3 **New outline section:** Noise baselining – understanding critical habitats and impacts on marine mammals **Key themes:** *Impacts to marine mammals*
JASCO Applies Sciences. (2019). *Study of Quiet-Ship Certifications: Analysis using the ECHO Ship Noise Database*. (https://tcdocs.ingeniumcanada.org/sites/default/files/2021-	This study uses the large ship noise database, acquired by the Vancouver Fraser Port Authority's Enhancing Cetacean Habitat Observation (ECHO) program, to assess the conservativeness of five	ToR .3 ToR .4 **New outline section:** Noise baselining – establishing URN goals **Key themes:** *Certifications/Standards*

07/STUDY%20OF%20QUIET%20SHIP%20CERTIFICATIONS_0.pdf[26]).	vessel noise certification societies. The general findings are that the society limits are conservative for faster categories (e.g. container ship) but not for slower vessels such as tankers. Harmonizing the certification society thresholds and developing category-dependent thresholds would be useful.	
LANTEC Marine Inc. (2019). *Report of Simulation Manoeuvring Analysis – Vessel Low Speed Transits in Areas Identified as Whale Sensitive Habitat*. (https://tcdocs.ingeniumcanada.org/sites/default/files/2020-01/FINAL_REPORT_OF_MANOEUVRING_ANALYSIS_MINIMAL_SAFE_VESSEL_TRANSIT_SPEED_IN_AREAS_IDENTIFIED_AS_SENSITIVE_WHALE_HABITANT.pdf[27]).	TC commissioned this study to use vessel manoeuvring simulations as a mechanism to determine, in an empirical manner, the minimum safe transit speeds that can be adhered to by various vessel types with special consideration to the unique physical, weather, and prevailing navigational conditions in four known areas of concern for whale populations.	ToR .2 **New outline section:** Noise management planning – examining and evaluating options for operation **Key themes:** *Impacts to marine mammals Modeling/testing*
Leaper, R. (2019). The Role of Slower Vessel Speeds in Reducing Greenhouse Gas Emissions, Underwater Noise and Collision Risk to Whales. *Frontiers in Marine Science, 6*, 505. (https://www.frontiersin.org/articles/10.3389/fmars.2019.00505/full).	This article models work on GHG emissions and on the relationships between underwater noise, whale collision risk and speed. It also examines different speed reduction scenarios that would contribute to GHG reduction targets, and the other environmental benefits of reduced underwater noise and risk of collisions with marine life.	ToR .2 ToR .3 **New outline section:** Energy efficiency and URN reduction **Key themes:** *Energy efficiency*
MSFD Common Implementation Strategy Technical Group on Underwater Noise (TG-Noise). (2019). *Management and monitoring of underwater noise in European Seas - Overview of main European-funded*	This 2nd communication report builds upon the 2017 TG Noise compilation paper providing new information and updates regarding the	ToR .3 **New outline section:** Noise baselining – understanding the ship's URN emissions

26 Ibid.

27 Ibid.

projects and other relevant initiatives. 2nd Communication Report. December 2019. (https://www.eucc.net/uploads/12/Management%20and%20monitoring%20of%20underwater%20noise%20in%20European%20Seas%20-%20Overview%20of%20main%20European-funded%20projects%20and%20other%20relevant%20initiatives_FINAL.pdf).	main European-funded project and other relevant initiatives since then. This aims to be useful to experts, policy makers, and to those supporting Member States authorities in implementing the MSFD. In particular, for monitoring measures regarding underwater sound.	**Key themes:** *Knowledge collaboration*
Southall, B.L., Finneran, J.J., Reichmuth, C., Nachtigall, P.E., Ketten, D.R., Bowles, A.E., Ellison, W.T., Nowacek, D.P. & Tyack, P.L. (2019). Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects. *Aquatic Mammals, 45(2)*, 125-232. (https://sites.duke.edu/oceansatduke/files/2021/04/Paper1.pdf).	This article evaluates Southall et al. (2007) in light of subsequent scientific findings and proposes revised noise exposure criteria to predict the onset of auditory effects in marine mammals. Estimated audiograms, weighting functions, and underwater noise exposure criteria for temporary and permanent auditory effects of noise are presented for six species groupings, including all marine mammal species.	ToR .2 **New outline section:** Noise baselining – understanding critical habitats and impacts on marine mammals **Key themes:** *Impacts to marine mammals* *Modeling/testing*
Vard Marine Inc. (2019). *Methods to Reduce Underwater Radiated Noise of Small Vessels.* (https://tcdocs.ingeniumcanada.org/sites/default/files/2020-11/Methods%20to%20Reduce%20Underwater%20Radiated%20Noise%20of%20Small%20Vessels_0.PDF[28]).	This report presents the results of a review of technical and operational means of mitigating the underwater radiated noise (URN) from small vessels. The report summarizes a literature survey, which provides limited information on vessel and propulsion types, size and speed influences on noise levels, and the importance of overall traffic levels on noise and its effects on animal behaviours.	ToR .2 **New outline section:** Noise management planning - examining and evaluating options **Key themes:** *Measuring URN* *New technologies*
Vard Marine Inc. (2019). *Ship Underwater Radiated Noise.* (https://tcdocs.ingeniumcanada.org/sites/default/files/2019-	This report presents the results of a review of means of mitigating and predicting the underwater radiated noise (URN) from ships. The main outcome	ToR .2 **New outline section:** Noise management planning - examining and evaluating options

28 Ibid.

07/Ship%20Underwater%20Radiated%20Noise%20v5.pdf[29]).	of the work undertaken is a matrix of URN mitigation measures. Measures are categorized in four main areas, covering propeller noise reduction; machinery noise reduction; flow noise reduction; and other, where the first three categories are not easily applied.	**Key themes:** *Measuring URN* *New technologies*
JASCO Applied Sciences. (2018). *Assessment of Vessel Noise within the Southern Resident Killer Whale Critical Habitat*. (https://tcdocs.ingeniumcanada.org/sites/default/files/2020-01/2018_TP_15401E_-_ASSESSMENT_OF_VESSEL_NOISE_WITHIN_THE_SOUTHERN_RESIDENT_KILLER_WHALE_CRITICAL_HABITAT.pdf[30]).	This study assesses the effectiveness of mitigation strategies designed to reduce exposures of marine fauna to vessel noise in the southern Salish Sea. The report provides a quantitative assessment of all mitigation strategies tested.	ToR .2 **New outline section:** Noise management – examining and evaluating options for operations and maintenance **Key themes:** *Impacts to marine mammals* *Modeling/testing*
JASCO Applies Sciences. (2018). *M/V Cygnus Underwater Radiated Noise Level Measurements in Conception Bay, NL*. (https://tcdocs.ingeniumcanada.org/sites/default/files/2020-01/COAST_GUARD_CYGNUS_NOISE_ANALYSIS_TRANSPORT.pdf[31]).	This report investigates underwater noise levels generated by the Coast Guard patrol vessel Cygnus. The purpose of the analysis was to determine whether cleaning of the vessel's hull and propeller have any impact on noise generation. The main conclusion is that cleaning activities did not affect vessel noise generation, although more conclusive evidence could have been obtained with a larger number of passes per trial available for data analysis.	ToR .2 **New outline section:** Noise management – examining and evaluating options for operations and maintenance **Key themes:** *Measuring URN* *Modeling/testing*
Weilgart, L.S. (2018). *The Impact of Ocean Noise Pollution on Fish and Invertebrates*. (https://www.oceancare.org/wp-	This review of 115 primary studies encompasses various human-produced underwater noise sources, 66 species of fish and 36	ToR .3 **New outline section:** Noise baselining – understanding critical

29 Ibid.

30 Ibid.

31 Ibid.

content/uploads/2017/10/OceanNoise_FishInvertebrates_May2018.pdf)	species of invertebrates. Noise impacts on development include body malformations, higher egg or immature mortality, developmental delays, delays in metamorphosing and settling, and slower growth rates. Other impacts were reviewed such as damage to hearing structures, DNA integrity and masking of communication.	habitats and impacts on marine mammals **Key themes:** *Impacts to marine mammals*
Wiśniewska, D. M., Johnson, M., Teilmann, J., Siebert, U., Galatius, A., Dietz, R., & Madsen, P. T. (2018). High rates of vessel noise disrupt foraging in wild harbour porpoises (Phocoena phocoena). *Proceedings of the Royal Society B: Biological Sciences, 285*(1872), 20172314. (https://royalsocietypublishing.org/doi/full/10.1098/rspb.2017.2314).	Authors of this report used animal-borne acoustic tags to measure vessel noise exposure and foraging efforts in seven harbour porpoises in highly trafficked coastal waters. Tagged porpoises encountered vessel noise 17–89% of the time. If such exposures occur frequently, porpoises, which have high metabolic requirements, may be unable to compensate energetically with negative long-term fitness consequences.	ToR .3 **New outline section:** Noise baselining – understanding critical habitats and impacts on marine mammals **Key themes:** *Impacts to marine mammals*
EU Technical Group on Underwater Noise (EU TG-NOISE). (2017). *Thematic workshop: Towards thresholds for underwater noise Common approaches for interpretation of data obtained in (Joint) Monitoring Programmes.* Workshop report Torrelodones, Spain, 9-10 November 2017. (https://circabc.europa.eu/sd/a/aff4d312-ed1d-47c1-a420-db799990ade6/TG%2520Noise%2520Workshop%25209-10%2520Nov%25202017%2520Report_FINAL.pdf)	This workshop focused on the evaluation of possible uses of the data collected by monitoring/registration of underwater noise and to provide advice on how these data can be used to obtain a better understanding of the environmental impacts of underwater noise. There was no attempt to define thresholds. At this stage, methodologies that can be used in future, common assessments need to be assessed and further developed, and ensuring that common methods are being used at Union level is a priority.	ToR .2 ToR .3 **New outline section:** Noise management – examining and evaluating options for operations and maintenance **Key themes:** *Measuring URN* *Modeling/testing*

Gassmann, M., Kindberg, L.B., Wiggins, S.M. & Hildebrand, J.A. (2017). Marine Physical Laboratory Technical Memorandum 616: Underwater noise comparison of pre- and post-retrofitted Maersk G-Class container Vessels. (http://www.cetus.ucsd.edu/docs/reports/MPLTM616-2017.pdf).	This report quantified reduction in sound pressure levels and monopole source levels of 11 Maersk ships pre- and post-retrofitting. Pre-retrofit monopole source levels were 6 dB higher in the low-frequency (8-100 Hz) band than post-retrofit vessels.	ToR .2 ToR .3 **New outline section:** Energy efficiency and URN reduction **Key themes:** *Energy efficiency*
Gassmann, M., Wiggins, S.M. & Hildebrand, J.A. (2017). Deep-water measurements of container ship radiated noise signatures and directionality. *The Journal of the Acoustical Society of America,* 142(3), 1563-1574. (http://www.cetus.ucsd.edu/docs/publications/GassmannJASA2017.pdf).	This study identifies a propagation loss model to estimate monopole source levels in deep water using ship measurements from multiple spatial aspects in compliance with ship noise standards (ANS/ISO).	ToR .3 ToR .4 **New outline section:** Noise baselining – understanding the ship's URN emissions **Key themes:** *Modeling/testing* *Measuring URN*
HELCOM. (2016). *Noise sensitivity of animals in the Baltic Sea. Document to HOD 51-2016.* (https://portal.helcom.fi/meetings/HOD%2051-2016-400/MeetingDocuments/6-6%20Noise%20Sensitivity%20of%20Animals%20in%20the%20Baltic%20Sea.pdf).	This report was prepared as part of building a knowledge base on underwater noise according to the Work Plan in the Regional Baltic Underwater Noise Roadmap 2015-2017. The report reviews the available knowledge on species in the Baltic Sea sensitive to impact of anthropogenic noise, maps concerning species distribution, includes an updated map of biologically sensitive areas for noise sensitive species, and more.	ToR .3 **New outline section:** Noise baselining – understanding critical habitats and impacts on marine mammals **Key themes:** *Impacts to marine mammals*
Hemmera Envirochem Inc. (2016). *Vessel Quieting Design, Technology, and Maintenance Options for Potential Inclusion in EcoAction Program Enhancing Cetacean Habitat and Observation Program .* (https://www.portvancouver.com/wp-content/uploads/2017/01/Vessel-Quieting.pdf).	The ECHO program commissioned this study to explore what kinds of technologies, maintenance and design options exist to make ships quieter, and what options and criteria can be used to encourage quieter vessels and help reduce underwater noise in the Port of Vancouver.	ToR .2 **New outline section:** Noise management planning – examining and evaluating **Key themes:** *New technologies*

Miksis-Oldsa, J., Nichols, S. (2016), Is low frequency ocean sound increasing globally? The Journal of the Acoustical Society of America 139(1):501-511 DOI:10.1121/1.4938237 https://www.researchgate.net/publication/291557060_Is_low_frequency_ocean_sound_increasing_globally	This paper summarizes a series of measurements that confirm that URN in the Equatorial Pacific and South Atlantic is decreasing. The paper also notes that recent observations in the North East Pacific show a level or slightly decreasing trend in low frequency noise	ToR .3 **New outline section:** Noise Baselining **Key themes:** *URN Measurement*
Veirs, S., Veirs, V., and Wood, J. D. (2016). Ship noise extends to frequencies used for echolocation by endangered killer whales. *PeerJ*, *4*, :e1657. (https://peerj.com/articles/1657/).	This study estimated underwater sound pressure levels for 1,582 unique ships that transited the core critical habitat of the endangered Southern Resident killer whales during 28 months between March, 2011, and October, 2013. Within all ship classes spectrum levels vary more at low frequencies than at high frequencies, and the degree of variability is almost halved for classes that have smaller speed standard deviations.	ToR .3 **New outline section:** Noise baselining – understanding critical habitats and impacts on marine mammals Noise management planning – examining and evaluating operation and maintenance **Key themes:** *Impacts to marine mammals* *Field trial*
Dyndo et al. Wiśniewska, D. M., Rojano-Doñate, L., & Madsen, P. T. (2015). Harbour porpoises react to low levels of high frequency vessel noise. *Scientific Reports*, *5*(1), 1-9. (https://www.nature.com/articles/srep11083).	The authors showed that low levels of high frequency components in vessel noise elicit strong, stereotyped behavioural responses in porpoises. Such low levels will routinely be experienced by porpoises in the wild at ranges of more than 1000 meters from vessels, suggesting that vessel noise is a, so far, largely overlooked, but substantial source of disturbance in shallow water areas with high densities of both porpoises and vessels.	ToR .2 **New outline section:** Noise baselining – understanding critical habitats and impacts on marine mammals **Key themes:** *Impacts to marine mammals*
UNEP/CBD/MCB/EM/2014/1/2. (2014). *REPORT OF THE EXPERT WORKSHOP ON UNDERWATER NOISE AND ITS IMPACTS ON MARINE AND COASTAL*	The Conference of the Parties to the Convention on Biological Diversity requested the Executive Secretary, in collaboration	ToR .3 **New outline section:** Noise baselining – understanding critical

BIODIVERSITY. (https://www.cbd.int/doc/meetings/mar/mcbem-2014-01/official/mcbem-2014-01-02-en.pdf).	with Parties, other Governments, and organizations including the International Maritime Organization (IMO), Convention on Migratory Species (CMS), International Whaling Commission, indigenous and local communities and other relevant stakeholders, to organize an expert workshop. This report summarizes the workshop which aimed to improve and share knowledge on underwater noise and its impacts on marine mammals, in order to assist Parties and other Governments in applying management measures as appropriate.	habitats and impacts on marine mammals **Key themes:** *Knowledge collaboration* *Impacts to marine mammals*
ACCOBAMS-MOP5/2013/Doc24. (2013). *Methodological Guide: Guidance on underwater noise mitigation measures*. (https://www.cbd.int/doc/meetings/mar/mcbem-2014-01/other/mcbem-2014-01-submission-accobams-01-en.pdf).	This guide was prepared by a Working Group from ACCOBAMS (Agreement of the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic area, concluded under the auspices of the Convention of Migratory Species of Wild Animals). It aims to improve and facilitate the use of the Guidelines to Address the Impact of Anthropogenic Noise on Cetaceans in the ACCOBAMS Area.	ToR .2 **New outline section:** Noise management planning – examining and evaluating options for operation **Key themes:** *Measuring URN*
Aguilar Soto, N., Johnson, M., Madsen, P. T., Tyack, P. L., Bocconcelli, A., & Fabrizio Borsani, J. (2006). Does intense ship noise disrupt foraging in deep-diving Cuvier's beaked whales (Ziphius cavirostris)?. *Marine Mammal Science, 22*(3), 690-699. (http://www.marinebioacoustics.com/files/2006/Soto_et_al_2006.pdf).	This paper reports preliminary data from an onboard acoustic digital tag attached to a Cuvier's beaked whale, showing that elevated received noise levels with ultrasonic components from a passing large ship coincided with an unusual foraging dive. Given the logistical difficulties in mounting a proper vessel-disturbance study	ToR .2 ToR .3 **New outline section:** Noise baselining – understanding critical habitats and impacts on marine mammals **Key themes:** *Impacts to marine mammals*

	involving beaked whales, and the paucity of data on these susceptible species, this case study provides an impetus to define a specific hypothesis about how they may respond to shipping noise and to design experiments to address this problem.	
Sasajima, T. & Ukon, Y. (1989). ITTC comparative tests on pressure fluctuation (19th ITTC). In *Proc. of Int. Workshop on Cavitation, Shanghai,* p59-67. (https://www.cnki.com.cn/Article/CJFDTotal-SDYW198903001.htm)	Pressure fluctuation induced by unsteady propeller cavitation is one of the most predominant vibration sources. Cavitation Committee of International Towing Tank Conference (ITTC) has been continuously reviewing the theoretical and experimental prediction methods. In this paper, the accuracy of the existing prediction methods and the parameters which affect the model test results are discussed, especially with referring to the results of the comparative tests on the "Sydney Express" propeller, organized by Cavitation Committee.	ToR .2 **New outline section:** Noise baselining – understanding the ship's URN emissions Noise management planning – propeller noise **Key themes:** *Measuring URN* *Modeling/testing*
Brown N.A. (1976). Cavitation noise problems and solutions. *Proc. International Symposium on Shipboard Acoustics,* pp.21–38.	In this paper, the author discusses the nature of propeller cavitation noise and means for estimating its intensity. Several external means for achieving noise reduction are discussed: hydrodynamic design to minimize cavitation, baffling, compliant coating and air emission. These have been shown either directly or indirectly to be of practical value.	ToR .2 **New outline section:** Noise baselining – understanding the ship's URN emissions Noise management planning – propeller noise **Key themes:** *Modeling/testing*