# The irradiated noise underwater by the ships: a state of the art

Tommaso COPPOLA[a], Francesco DE LORENZO[b], Luigia MOCERINO[a,1]
[a] *University of Naples Federico II, Naples, Italy*
[b] *Fincantieri S.p.A., Trieste, Italy*

**Abstract.** The attention on a global scale to the preservation of the ecosystems and to the reduction of emissions connected to anthropogenic activities falls mainly on industrial activities and on the transport sector. The role of the maritime sector is crucial in this theme since it has impacts both on the balance of both marine and terrestrial ecosystems. Reduction of vessel emissions into the marine environment, including energy like the sound radiated underwater, has in recent years received growing attention. Underwater noise from shipping is generally considered as a major contributor to overall sea noise levels. Surface vessels radiate underwater noise mainly due to propeller cavitation; machinery on board and water flow around the ship hull. High sound levels are a potential threat for marine fauna as they can mask acoustic signals used to communicate, navigate and hunt, or even induce temporary or permanent damage to sensory organs. In this paper, we want to present the last developments in this field in which a big job will be made to clarify all the aspects.

**Keywords.** Marine Environment, underwater noise, submarine noise pollution, shipping activities, ship sources.

## 1. Introduction

The commercial success of a means of transport strongly depends on its environmental impact, which plays a fundamental role in the evaluation of every human activity.

The maritime sector, like all anthropogenic activities, is implementing profound operational changes aimed at safeguarding the ecosystem; as in all sectors, especially industrial ones, the shipping world is moving towards reducing the negative impact on the planet [1]. The reduction of pollutant emissions on a local or global scale, the use of cleaner fuels, energy efficiency, safeguarding marine flora through, for example, the use of non-harmful paints, ballast water treatment, are just a few examples.

In recent years, noise pollution has gained interest in the industrial sector: noise, in fact, not only has a direct impact on the crew in the workplaces, but also affects third parties. The theme of noise connected the maritime traffic can be evaluated from two different points of view: the indoor noise and the external noise to the ship [1][3][4]. The first afflicts crew and passengers, and it is at the heart of a design aimed at comfort on board and at high standard of quality in spaces of life and work of the crew [5]. The second, instead, affect third parties, in addition to the crew and passengers. The air and the water are exposes to this noise irradiated to the outside of the ship [9]. If the studies

[1] Corresponding Author, Luigia Mocerino, University of Naples Federico II, Naples, Italy; E-mail: luigia.mocerino@unina.it

and research put in place with regard to emissions of harmful substances both in water and in the air is now well underway in the shipping sector, the effect on aquifer fauna of the noise connected to a ship has only recently been addressed [5], [10]. The scientific community is working to prevent biodiversity loss and to safeguard marine flora and fauna [11]. The continuous noise connected to ship traffic is obviously not the only source of noise pollution: acute episodes such as the sonars, the oil exploration, the marine explosions, and wind power plants at sea, just a few examples.
The aim of this work is to highlight the noise pollution generated by a ship in an underwater environment: this problem has only recently been addressed as consequence of the growing environmental awareness that has led to ever-increasing attention on the environmental sustainability of anthropogenic activities.

The paper contains a state of the art on what are the current techniques and technologies useful for the characterization of a ship in terms of noise radiated into the water. As a first step, we will focus on the problem from a regulatory point of view.

As all the studies carried out on industrial noise, the whole so-called "noise chain" will be studied; this is composed of sources, transmission path, and receivers. Various design and operating characteristics of the ship affect the underwater noise during the operational phase (voyage, maneuvering, and mooring in port) including the type of boat, its size, the type of propulsion, the cruising speed. For each case, the main sources of underwater noise present on the ship will be analyzed individually. The main problems that will arise in the characterization of the propagation in water of the noise radiated by ships will be explained. A part of the discussion will be concerning the effects that the underwater noise emitted by the ships has on aquifer fauna, particularly on mammals and the influence of the transmission path.

## 2. Regulatory framework

The first international institution that introduced limits to the urn was the International Council for the Exploration of the Sea (ICES) that realized limit curves starting from the sensitivity to the sound of the cod; subsequently, the DNV introduced an additional class notation in this regard [7].

In 2004, the Marine Environment Protection Committee (MEPC) commenced discussions on the harmful impacts of underwater noise from ships on marine life.

Consequently, has been included in the agenda MEPC 59 (July 2009) a new item on “Noise from commercial shipping and its adverse impacts on marine life”. The basis for the new item was to develop a non-mandatory technical guidelines, aiming to minimize incidental noise from commercial shipping operations in the marine environment and thus to reduce potential adverse impacts on marine life. As a result, of this work, IMO, in 2014, recognizing that underwater noise associated with shipping was an issue that could be mitigated and has approved guidelines for commercial ships on ways to reduce underwater noise. This non-mandatory instrument is entitled “Guidelines for the Reduction of Underwater Noise from Commercial Shipping to Address Adverse Impacts on Marine Life” (MEPC.1/Circ.833) [6]. Through the establishment of “Particularly Sensitive Sea Areas”, the IMO has adopted specific measures to protect these environments. These areas are considered worthy to a special protection, due to their recognized ecological or socio-economic or scientific value, and because which may be vulnerable to damage due by ships. The 2005 Revised guidelines for the identification and designation of Particularly Sensitive Sea Areas (resolution A.982(24), as amended by resolution MEPC.267(68)), recognizes that noise from ships can adversely affect the marine environment and living resources of the sea.

In 2009, the ANSI and ASA (Fig. 1), Acoustical Society of America and American National Standards Institute issued guidelines for estimate and measuring underwater noise from ships [8].

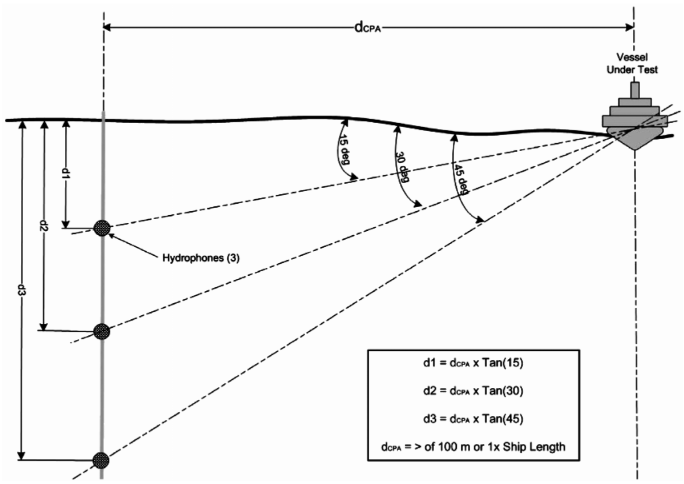



**Figure 1** Measurement layout suggested by ANSI/ASA

The additional DNV class “*SILENT Class Notation*”-2010- for new buildings set the limits for underwater noise levels are specified for five types of ship [7]:

- for vessels using hydro-acoustic equipment as important tools in their operation, survey vessels, ocean research vessels for example;
- for vessels carrying out seismic surveys using acoustic streamers;
- for vessels engaged in fishing;
- for research and particularly noise critical operations;
- for any vessel demonstrating a controlled environmental noise emission.

For each category, the register provides specific conditions during the measurements (Fig. 2) to certify the conformity of the ship.

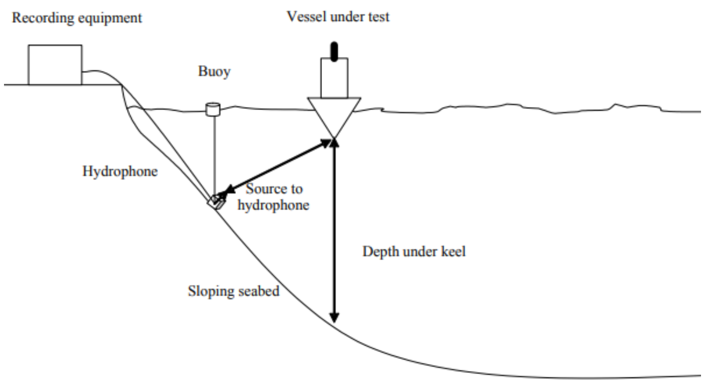



**Figure 2** Schematic drawing of measuring situation for surface vessel, DNV 2010.

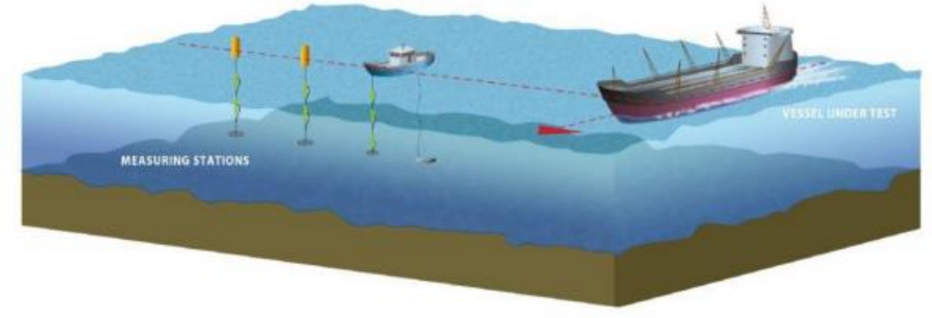
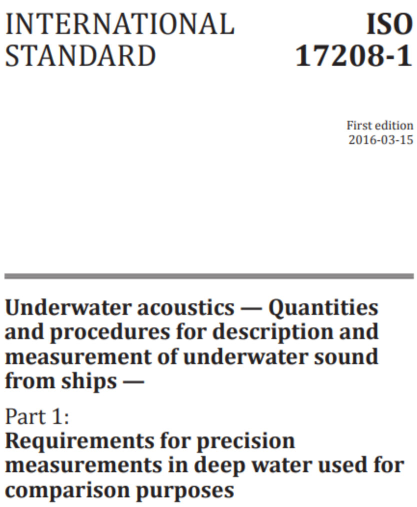



**Figure 3** Possible deployment configuration for measuring the radiated noise in shallow water, with a series of fixed recording stations located at positions along a transect (NPL UK)

In 2012, the European Commission has funded a collaborative research program called AQUO (Achieve Quieter Oceans) to provide policy makers with practical solutions and guidelines to reduce underwater shipping noise & protect marine life; the project has demonstrates the feasibility of controlling shipping noise & its potential impacts on marine life [11][12].

In 2014 the NPL UK, National Physical Laboratory published a good practice guide (Fig. 3) for underwater ship noise measurement [13].

Finally, in 2016, the ISO (International Organization for Standardization), shall be made public its requirements (Fig. 4) for deep-water measurement for Underwater Ship Noise (ISO 17208-1:2016) [17]; this standard have been recognized from the three major ship classification societies: DNV (Det Norkes Veritas), RINA (Registro Italiano Navale) and BV (Bureau Veritas) respectively in 2010, 2014 and 2014.


INTERNATIONAL STANDARD

**ISO 17208-1**

First edition
2016-03-15

**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**

**Figure 4** ISO 17208-1:2016

## 3. Impact of Underwater Radiated Noise on marine fauna

Emitting sounds is one of the main ways that marine animals have to communicate and interact with the external environment: exchanging information between peers, finding food, identifying dangers and predators, and above all orienting oneself in space are just a few examples.

The anthropogenic activities connected with the sea generate noises that often overlap with typical sound range, for example, of the mammals. Large commercial ships, in particular, emit low-frequency sounds that are perceived by those who use low-frequency sounds for long-range communications such as whales, and cetaceans in general; low frequency sounds also disturb seals, sea lions, many fish and some invertebrates. Instead, maritime traffic annoys less dolphins and porpoises that communicate at high frequencies.

Obviously characterizing the auditory perception of large mammals is very complicated given the evident difficulty of experiments in the laboratory; in addition to that, the high perception range, from a few Hz to 100 kHz, certainly complicates things. In **Figure 5** It can be seen that the range of emission frequencies of the Odontocetes is centered on the maximum sensitivity while the range of vocalization of the Misticeti is centered at lower frequencies. This further complicates the study of the problem proper why it highlights how the impact of noise on marine life must be studied over a wide range of frequencies (from a few tens of Hz to 100 kHz) [15].

The most common effects on wildlife are increased stress levels, loss of orientation, altered communication and temporary or permanent hearing loss [16].

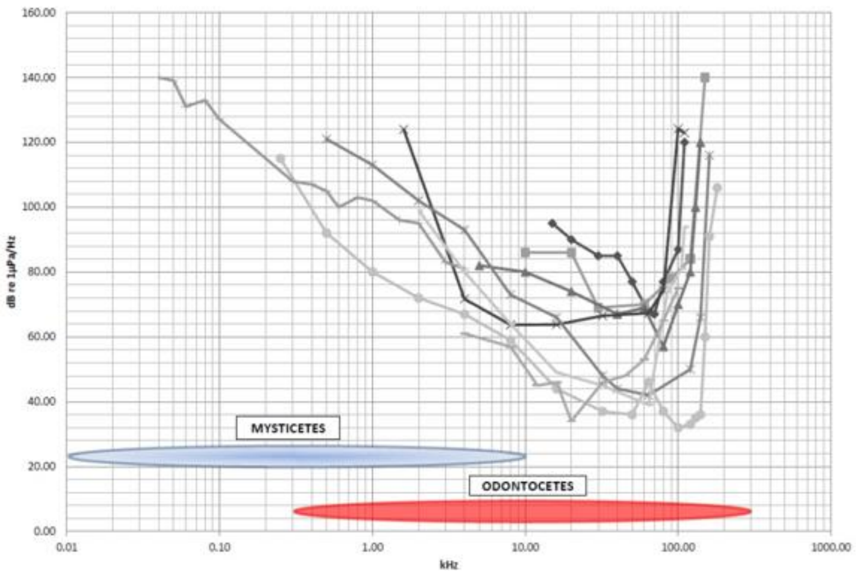



**Figure 5** Sensitivity audiogram for Odontocetes and Mysticetes.

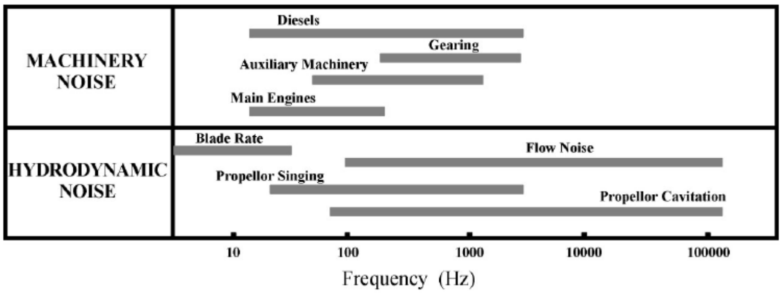



**Figure 6** Frequencies of the main categories of underwater irradiated noise

## 4. Ship source and transmission path

The difficulties encountered in addressing the issue of noise radiated in water by ships are the characterization of the sources, of the transmission path and of the receivers.
From the engineering point of view, much can be done for the characterization of the sources and the emission reduction methodologies. The noise that a ship radiates in water is essentially due to two types of sources: machines and hydrodynamic phenomena (Fig. 6). Essentially the main engines and auxiliary engines belong to the first category, each in its own frequency ranges; to the second category belong the propellers both in cavitation conditions and in normal operating conditions and the noise of the flow around the hull, appendices included.

Once the characteristics of the transmission path have been identified, propagation models help in the study of the dissipative phenomena present.
The study of the propagation at sea of the noise connected to a ship is perhaps the crucial point of the study. The characteristics of the water in which one operates greatly influences the phenomenon: the aspects to be taken into consideration are essentially the conductivity, temperature and depth of the water. All three parameters vary from area to area of the world, but the conditions on the free surface are also fundamental. In addition to these average conditions, a good propagation model should take into account: location of the sources, sound pressure value, source emission frequency, and sound speed gradient with varying depth, salinity and pH of sea. All this makes it difficult to define a universal standard for the implementation of repeatable measurements [17].
Types of computational models that may assist in these studies are:

- Computational Fluid Dynamics (CFD) can be used to predict and visualize flow characteristics around the hull and appendages [6];
- Statistical Energy Analysis (SEA) can be used to estimate high-frequency transmitted noise and vibration levels from machinery;
- Finite Element Analysis (FEA) and Boundary Element Method (BEM) to estimate low-frequency noise and vibration levels from the structure of the ship excited by the fluctuating pressure of propeller and machinery excitation [6].

The existing solutions to reduce the radiated noise in the water are different, but the most interesting ones are:

- **Minimize cavitation**, with relatively low costs, optimizing the shape, configuration and size of propulsors;
- To use, on new boats, an **azimuthal propulsion** that reduces noise and vibrations and produce big improvements also as regards the wake field ;
- **Improvement in hull shapes**, with costs not too low.

In operational terms, we have:

- **Speed reduction** by optimizing routes, moorings and navigation speed;
- **Routeing**, avoiding areas with sensitive fauna particularly at the long-range transmission.

## 5. Conclusions

The paper presented the necessary basis for an in-depth study of the problem of noise radiated into the water by ships or, in general by maritime and offshore activities. The presentation of the state of the art for the characterization of radiated noise in water is fundamental for future numerical applications, such as software development or dedicated calculation codes; finally, it is important for the development of new campaigns to monitor the noise in the water of ships and marine vehicles.

## References

[1] Mocerino L., Quaranta F., Rizzuto E.: Climate changes and maritime transportation: A state of the art. Nav International Conference On Ship And Shipping Research, (221499) (2018).

[2] De Lorenzo, F., Tomàs A. O., and White P R. "Underwater noise limits and measurement of underwater radiated noise from merchant vessels." ICSV 24 (2017): 23-27.

[3] De Lorenzo, F., D’ambra, Measurement of underwater radiated noise from merchant vessels and related issues. 18th International Conference on Ships and Shipping Research, NAV 2015, Pages 621-628.

[4] De Lorenzo, F., Pedone L., Outdoor noise and underwater noise, Euromaritime Paris 2013.

[5] Borelli, D., Gaggero, T., Rizzuto, E., & Schenone, C., Holistic control of ship noise emissions. Noise Mapping, 3(1), 2016.

[6] MEPC.1/Circ.833 7 April 2014 Guidelines For The Reduction Of Underwater Noise From Commercial Shipping To Address Adverse Impacts On Marine Life.

[7] DNV, Rules for Classification of Ships, Silent Class Notation 2010. Part 6 Chapter 24.

[8] ANSI/ASA. (2009). Quantities and Procedures for Description and Measurement of Underwater Sound from Ships–Part 1: General Requirements.

[9] Coppola, T., M ocerino, L., Rizzuto, &, Viscardi, M., & Siano, D, Airborne Noise Prediction of a Ro/Ro Pax Ferry in the Port of Naples. In *Technology and Science for the Ships of the Future: Proceedings of NAV 2018: 19th International Conference on Ship & Maritime Research* (p. 157). IOS Press, 2018.

[10] Murena, F., Mocerino, L., Quaranta, F., & Toscano, D., Impact on air quality of cruise ship emissions in Naples, Italy. *Atmospheric Environment*, 2018, 187: 70-83.Faggio, A., Viscardi, M., Coppola, T., & Rizzuto, E, A numerical code for underwater noise propagation. In: *MATEC Web of Conferences*. EDP Sciences, p. 05017, 2018.

[11] Audoly, C., Rousset, C., Rizzuto, E., Mullor, R. S., Hallander, J., & Baudin, E, Mitigation measures for controlling the ship underwater radiated noise, in the scope of AQUO Project. In: *OCEANS 2015-Genova*. IEEE, 2015. p. 1-6, 2015.

[12] Audoly, C., Rousset, C., Baudin, E., & Folegot, T. (2016). AQUO project-Research on solutions for the mitigation of shipping noise and its impact on marine fauna–synthesis of guidelines. In Proc. 23rd International Congress on Sound and Vibration ICSV, Athens, Greece.

[13] Robinson, S. P., Lepper, P. A., & Hazelwood, R. A. (2014). Good Practice Guide for Underwater Noise Measurement.

[14] Badino, A., Borelli, D., Gaggero, T., Rizzuto, E., & Schenone, C., Normative framework for ship noise: present and situation and future trends. Noise Control Engineering Journal, 60.6: 740-762, 2012.

[15] Rossi, E., Licitra, G., Iacoponi, A., & Taburni, D., Assessing the underwater ship noise levels in the North Tyrrhenian Sea. In *The Effects of Noise on Aquatic Life II* (pp. 943-949). Springer, New York, NY, 2016.

[16] Southall, B. L., Hatch, L., Scholik-Schlomer, A., Bergmann, T., Jasny, M., Metcalf, K., ... & Perera, M. E. (2018). Reducing Noise from Large Commercial Ships: Progress and partnerships. Coast Guard Journal of Safety & Security at Sea, Proceedings of the Marine Safety & Security Council, 75(1).

[17] Jalkanen, J. P., Johansson, L., Liefvendahl, M., Bensow, R., Sigray, P., Östberg, M., ... & Pajala, J. (2018). Modelling of ships as a source of underwater noise. Ocean Science, 14(6), 1373-1383.