Underwater noise generated by merchants ships in coastal waters of the Gulf of Gdansk

Karol LISTEWNIK[1]

[1] Polish Naval Academy, Poland

ABSTRACT

Currently, there has been a growing interest in monitoring underwater sound as pollution on the environment. The aim of the study was to gather experience in the measurement of commercial vessels and information about the changes in frequency and sound level for typical commercial vessels during normal operation at the selected point of shipping line. The paper presents description and chosen results of measurements campaign of underwater noise generated by commercial vessels during normal operating conditions. Measurement campaign was carried out in several multi-day cycles in a designated place on the shipping line at a depth of 20 m. The underwater noise measurements were recorded with regard to the current parameters of the ship: draught at the bow and stern, speed and route transition (by AIS) and environmental conditions: sea bathymetry, wind, sea state, sound speed profiles with temperature, density and depth.

Keywords: Underwater noise, ship-radiated noise I-INCE Classification of Subjects Number(s): 54.3

1. INTRODUCTION

Maritime transport covers more than 90% of world trade by volume, information about the shipping line plays a key role. The largest surface of our planet is covered by seas and oceans, access to the sea means direct access to the world's largest trade route and thus, the cheapest way of transport. Within the limits of Polish is located more than 800 km of coastline including the Szczecin and Vistula Lagoons and the Gulf of Gdansk. Poland has two large and well-developed complexes of ports: one of them is Szczecin - Swinoujscie and the second is Gdansk – Gdynia. Both are capable to take the largest commercial vessels and what is more offering well-developed and expanding shoreline infrastructure.

The result of this situation is that the noise generated into the aquatic environment caused by the technical activities is getting bigger. In recent decades there has been a significant, approximately 10 dB increase in underwater noise on the shipping routes [1]. This trend makes it increasingly are recorded cases of death and injury of marine mammals as well as the disappearance of fish populations on underwater noise polluted waters [2]. Considering the safety of navigation, in the case of: collision, grounding or damage of the hull as a result of an underwater explosion, vessels larger and faster than ever, with huge fuel tanks, provoke a serious ecological threat (regardless of material losses).

The aim of the research is to answer the question: what is real acoustic environment on the approaches to the ports? What is the variability of parameters of vessel traffic on the approach to the port? During the trials were measured the noise generated by ships in realistic scenarios and environment of the Gulf of Gdansk. A distant area of about 3 nautical miles from the main entrance to the harbor of Gdynia has been selected as a measuring area. Port of Gdynia is an international commercial seaport on the Gulf of Gdansk with big in and out going vessel traffic. It is the third largest seaport in Poland with more than three thousands visiting vessels a year. Port of Gdynia should be to the primary importance seaport for the Polish national economy.

2. METHOD OF DATA COLLECTION

Port of Gdynia supports the vessels of various types (passenger, cargo, fishery and research). Among the measured ships were: tankers, passenger ships, naval ships, sailing vessels, containers, general cargo

[1] K.Listewnik@amw.gdynia.pl

vessels, bulk carriers, tenders, Ro-ro cargo ships, tugs and vehicles carriers. During the entire measurement campaign measured over 60 commercial vessels.

Scheduled measurements were held in a few campaigns. Most of measurements were conducted during the summer period, because, relating to the whole year, in that time Port of Gdynia noticed the biggest traffic concentration. During summer period, Gdynia port is visited not only by standard trademarks and linear ships, but also by big cruise ships (passengers ships). All measurements were conducted using measuring modules IGLOO, as shown in Figures 1. These fully mobile modules are devices using for underwater multidimensional physical surveillance and reconnaissance. The modules contain: sensors, data recording and control system, placed in waterproof enclosures they are linked with base station by hybrid fiber-optic – electric cables. Recorded signatures are accumulated in the base station with simultaneous possibility to real-time preview of gathering data.

Figure 1 – IGLOO multi sensor modules

Modules are powered from the internal batteries. Batteries are charged by the hybrid cable.
To obtain correct results of acoustic measurements very strict conditions has to be fulfill. These conditions include:

- the acoustic sensor and recording system specifications,
- the measurement location and measurement procedure – measurement arrangement of modules is given in Figures 2,
- the recording of auxiliary data of target vessel and hydro-meteorological parameters of local environment,
- the initial data processing and the data format.

The measurements were conducted in similar environment conditions (sea state no more than 2-3, wind force less than 3 B). The measurements were performed at a depth of approximately 20 m. the largest number of ships were vessels measured as opportunity ship. The operator panel is presented on Figure 3.

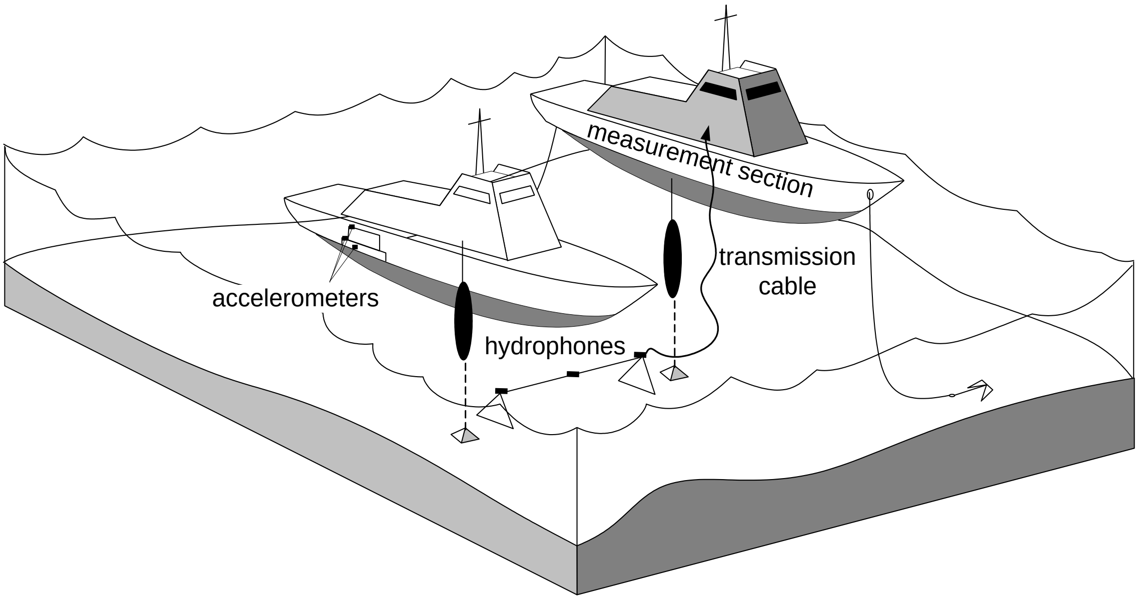

Figure 2 – Visualization of modules during measurements

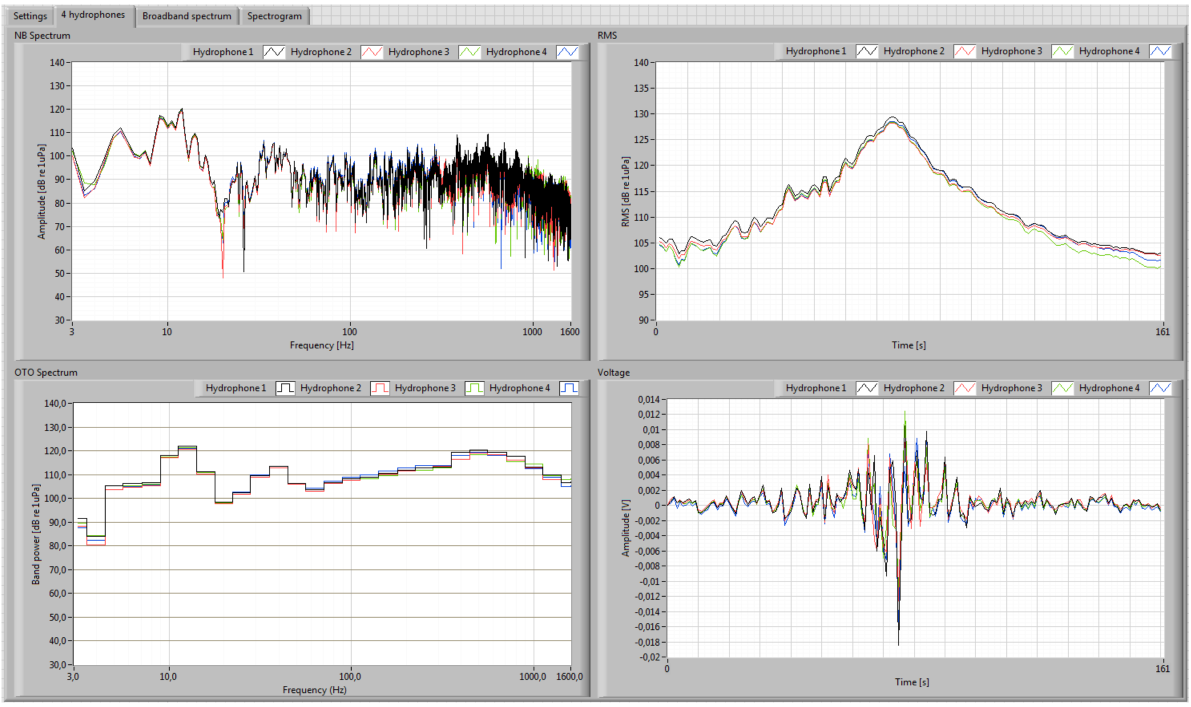

Figure 3 – The operator panel, the upper left diagram: NB narrow band analysis, upper right diagram: RMS signal level, lower left diagram: one-third octave analysis OTO, lower right diagram: preview recorded time signal

Assumptions were that: acoustic signature is measured in shallow water with sea bottom at 20 m depth. In fact, the water depth was varied from 18 - 22 m because the place of foundation of the measuring module was on the waters regularly dredged. This cause that 20 m isobaths line is irregular and very tortuous. The ship should sail in a straight course, with constant speed and machinery parameters. The actual track target – ship must be measured, for opportunity ship with AIS (Automatic Identification System) and for dedicated ship with AIS and additionally dGPS. Ultimately achieved an average accuracy of the reference position of the ship about 6 m. Speed and course is reported from GPS or AIS over ground. The bottom of the sea in the measuring area covered mud and sand. The ambient noise should be measured at least 1000 m before and after the CPA (Closest Point of Approach). Hydrophones should not lie on the seabed and should be installed no more than 1 m distance from the bottom of the sea. All these requirements relate to the standard of NATO AMP-15.

3. CHOSEN RESULTS OF MEASUREMENT CAMPAIGN

Measurement campaign carried out in 2013 in the Gulf of Gdansk included vessels with a large spread of parameters. This was due to a large range size of vessels. As measure of the size of ships was taken Gross Tonnage. Gross Tonnage measured ship was located between 260 and 114000. Length varied between 30 - 290 m, a width of 9 – 50 m and dipping 2.9 - 15.2 m. Change the speed of vessels ranged between 2.5 to 20 knots.

All data presented are the result of a maximum of one-third octave (OTO) analysis. To be able to compare the data obtained from measurements of different vessels used a formula that all data were recalculated according to the AMP-15 procedure a Radiated Noise Level (RNL) defined by [3]:

$$RNL = SPL\ (r) + 20\log_{10}(\frac{r}{r_{ref}}) \tag{1}$$

and expressed in units: dB re 1 µPa^{2}m^2,

where:

r – the closest distance from the sound source (hull of ship) to the sensor,

r_{ref} = 1 m is the reference distance.

Figure 4 illustrates the dependence of the speed of sound levels measured ship.

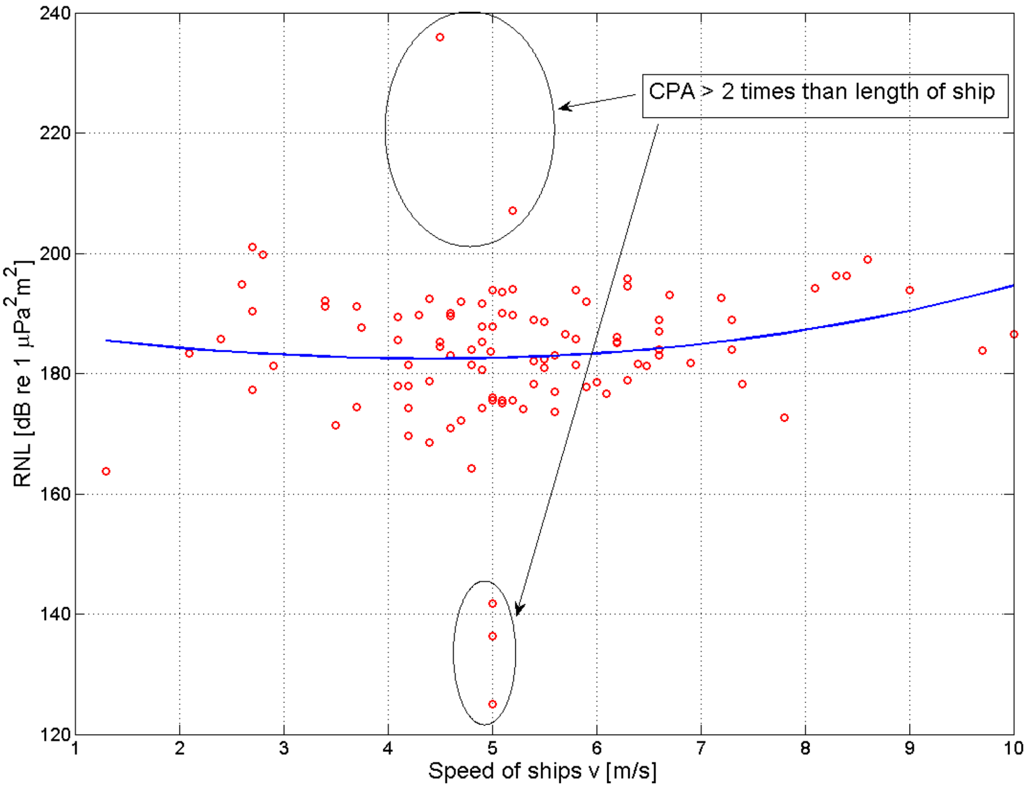

Figure 4 – RNL versus speed of ship

Ellipses indicate results that differ from the rest. These results were obtained at the measurement points that were distant from the vessel measured more than twice the length of the vessel. This suggests that the accepted standard method by applying the calculation RNL does not meet the expectation. At 105 conducted measurements of ships, the result of 48 (the largest number) is in the range of 180.5 do 191.6 dB and shown in Figure 5.

Figure 6 ilustrated size of ships (Gross Tonnage) during trial. The largest number of ships because 51 was located at limit to 12000, 21 was located between 12000 to 23000 and 19 between 34000 and 46000.

In general, among the collected data can not be seen depending on the maximum level of global OTO recalculated to 1 m RNL on the size of the ship. In Figure 7, it is see that ships with the largest Gross Tonnage fall below the average RNL. This may be due to the fact, that they belong to a group of passenger ships, where special attention is given to comfort including acoustic environment. The biggest differences between the trend lines for ships measured in close distances and for all measured cases does not exceed 2 dB. However, as can be seen the levels (RNL) of the span for the same parameters is substantial. On figure 8 it is seen that for the same ship, the same speed, the same external conditions of measurement and difference of RNL is more than to 10 dB. Moreover, it can be seen difference in characteristics depending on whether the vessel enters or departs from a port. It can be caused the fact that ship entering the port loses speed by inertia and the main drive is running unloaded. The same ship when leaving the port remains very similar operating parameters, but results of underwater verification measurements are different. These differences have been observed in many cases.

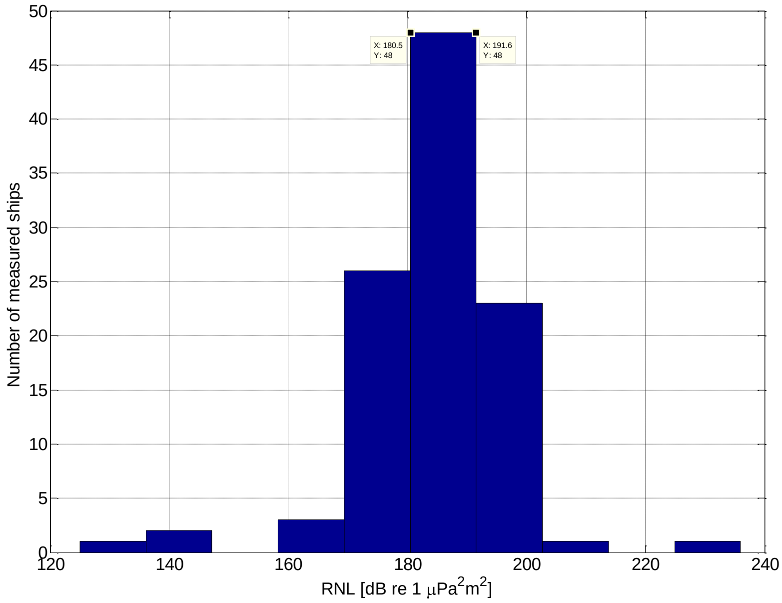

Figure 5 – Histogram of RNL

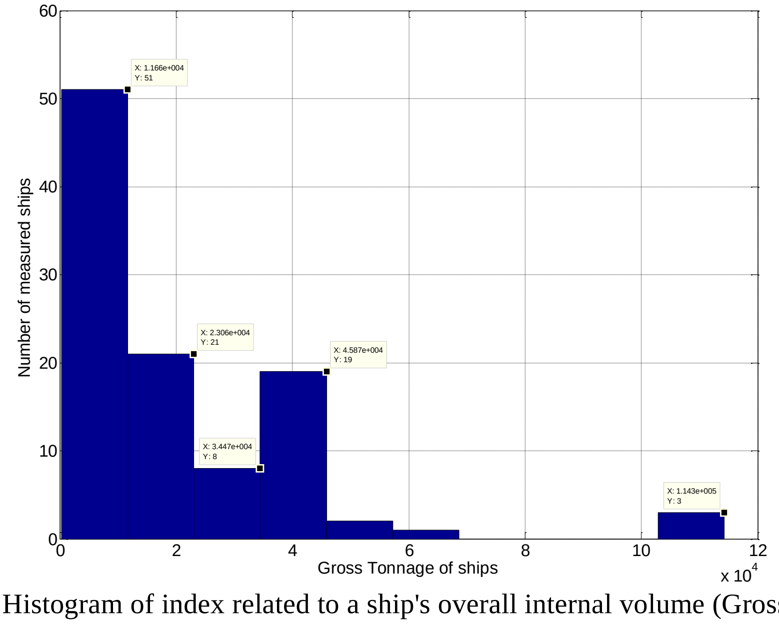

Figure 6 – Histogram of index related to a ship's overall internal volume (Gross Tonnage)

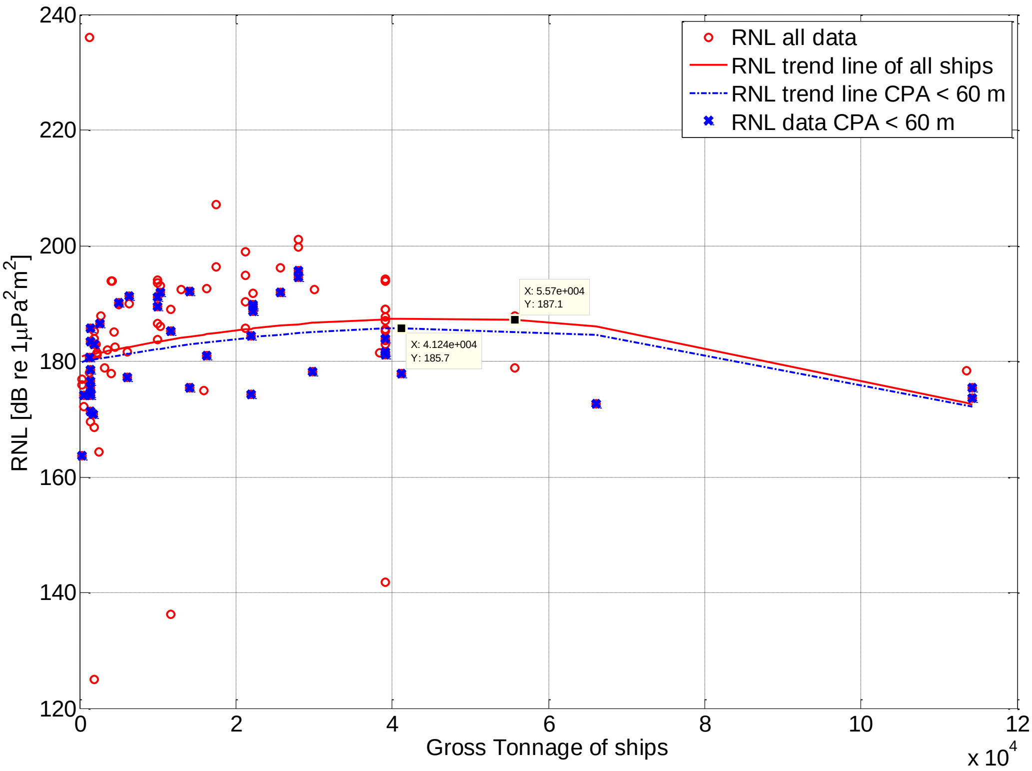

Figure 7 – RLN versus Gross Tonnage

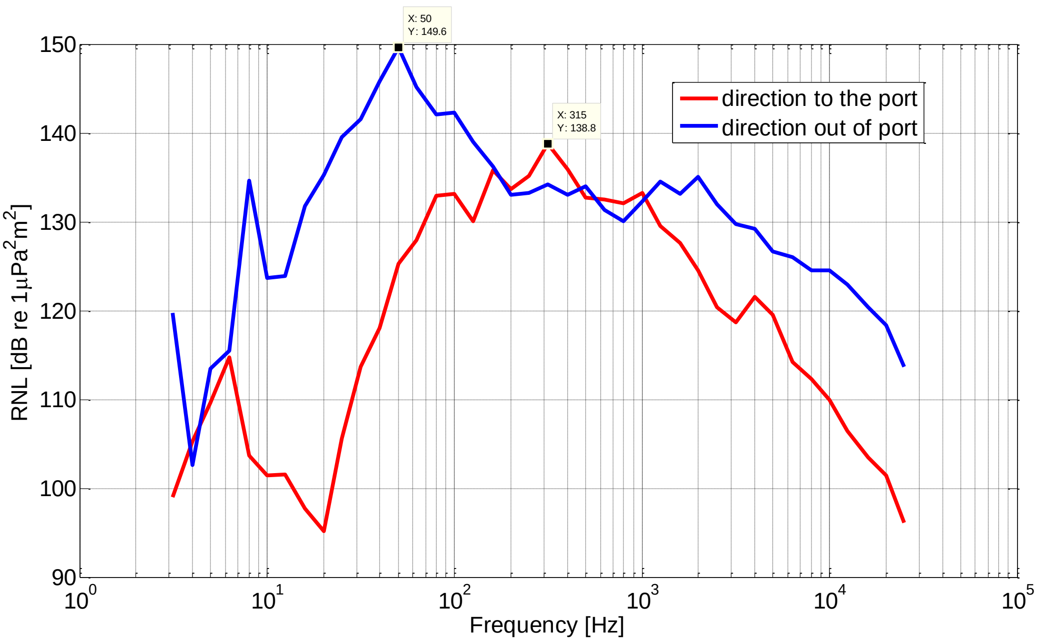

Figure 8 – RLN versus speed of chemical tanker enters to the port and departs from a port

4. CONCLUSIONS

These data reflect the selected statistics of vessel traffic on the Gulf of Gdansk, as recorded during the measurement campaign, all vessels entering and leaving the port.

During the study, particular attention was applied to the monitoring, registration and of hydro-meteorological conditions, geographical position, bottom type, and sound profile in water column. The procedure of explaining the differences in the structure of the sound coming from the measured vessel allow to define appropriate criteria for comparison.

Collected data provide a solid basis for collecting information on the sound generated in the water by commercial vessels on the approach to the harbor. This provide a basis for database additions of acoustic signatures of ships and vessels, and in the future with the increasing number of measurements, all kinds of marine objects.

The study indicates work towards understanding the interaction between the sound generated by ships into the sea and received by the underwater sensors. The collected material will be used to analyze the impact of the basic characteristics of vessels, the parameters of their motion, the relative position of the ship and underwater sensors and environmental parameters on the acoustic characteristics of vessels.

So far, the collected data show a low stability of vessel traffic parameters and settings of devices and mechanisms inside the hull on the approach to the harbor, but the diversity of gathered results may be relevant characteristics of vessel traffic on the approach to the harbor.

ACKNOWLEDGEMENTS

This project has been funded by Polish Ministry of Defense.

REFERENCES

1. M. A. McDonald, J. A. Hildebrand, and S. M. Wiggins, 2006. Increases in deep ocean ambient noise in the pacific west of San Nicolas Island, California. Journal of the Acoustical Society of America 120(2): 711- 718.
2. MCR International: Final Report Describing Measurements of Ship Noise Taken from R/V Song of the Whale in the English Channel and the Hebrides in June and August 2011, Kelvedon, UK, 2011.
3. C. de Jong et al.: Measuring ship acoustic signatures against mine threat. Proceedings of Meetings on Acoustics, Volume 17, 2012.