Baltic Marine Environment Protection Commission

Maritime Working Group MARITIME 18-2018
Hamburg, Germany, 25-27 September 2018

Document title	Underwater noise emissions from Baltic Sea Shipping in 2017
Code	12-5
Category	INF
Agenda Item	12 – Any other business
Submission date	14.09.2018
Submitted by	Finland
Reference	

Background

This is the first time modelled annual underwater noise emissions from Baltic Sea shipping are reported to the HELCOM Maritime WG. The noise values listed in this document represent noise energy emitted and thus they cannot be taken as representative of shipping noise experienced by marine fauna.

Emission reports of underwater noise should be considered in a similar manner as the emission reports of atmospheric pollutants. Underwater noise emission reports indicate the quantity emitted at the pollution source and consecutive impact assessments should be based on pollutant dispersion, or in case of noise, noise propagation modeling.

Underwater noise emissions from Baltic Sea shipping in 2017

Containerships, tankers and dry cargo vessels together are responsible for 76% of vessel noise (28%, 21% and 28%, @125 Hz band). However, the transport work of these three ship classes represent over 90% of total figure.

The largest source of underwater noise were RoPax vessels (450 millijoules per ton km) and lowest source tankers (141 millijoules per ton km).

More detailed information can be found in the attached report by the Finnish Meteorological Institute.

Action requested

The HELCOM Maritime 18 Meeting is invited to take note of the information.

Underwater noise emissions from Baltic Sea shipping in 2017

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Key Message

1. Containerships, tankers and dry cargo vessels combined are responsible for 76% of vessel noise (28%, 21% and 28%, @125 Hz band). However, the transport work of these three ship classes represent over 90% from total.
2. Applying similar performance metric as for energy efficiency (in mass per ton km cargo carried), unit noise energy emissions, over all three frequency bands considered, are the largest for RoPax vessels (450 millijoules per ton km) and lowest for tankers (141 millijoules per ton km).

1. Underwater noise emissions from ships

For the first time, modeled underwater noise emissions from ships are included in this reporting. The values listed in this document represent noise energy emitted and it cannot be taken as representative of shipping noise experienced by marine animals. Emission report of underwater noise should be taken at similar manner as the emissions of atmospheric pollutants. They indicate the quantity emitted at the pollution source and consecutive impact assessments should be based on pollutant dispersion, or in case of noise, noise propagation modeling.

Existing modeling tools in STEAM (Jalkanen et al., 2009, 2012, Johansson et al., 2013, 2017) were used and a recent noise model from Germany (Wittekind, 2014) was added to STEAM. The details of the methodology can be found in a recent paper (Jalkanen et al., 2018). The noise model is based on vessel technical properties and it describes separately contributions from vessel cavitation and machinery (Figure 1). Cavitation occurs when a fast-rotating propeller generates a large pressure difference between different sides of propeller blades and vacuum forms on the backside of the blade. Gas bubbles are formed which collapse generating loud noise. The noise quantities reported in this document include noise emissions at three specific frequency bands, 63, 125 and 2000 Hz, which are found to be relevant for animals. Two lowest frequencies are in the hearing range of several fish species and 2 kHz band is seen relevant for marine mammals, but it is outside the hearing range of most fish.

Figure 1 Noise contributions of a cargo ship according to Wittekind (2014). Low and high frequency cavitation contributions (Blue, Red lines) describe the contributions from vessel propeller whereas engine noise is depicted with Green color. Total source level is indicated with the Black line.

In Table 1, noise emitted is given as sum of energy emitted to water as noise in three different frequency bands (63, 125 and 2000 Hz). This allows cumulative description of noise in contrast to the logarithmic decibel scale which is used to describe instantaneous values.

Table 1. Emissions of noise energy from Baltic Sea shipping in 2017. Noise energy is given in gigajoules.

	E(noise, 63Hz) [GJ]	E(noise, 125 Hz) [GJ]	E(noise, 2000 Hz) [GJ]	Transport Work [10^6 tonne km]	Unit emissions [millijoules tonne^{-1} km^{-1}]
Total	257	136	2	900 189	
Baltic Proper	145	75	1	517 524	
Kattegat	69	38	1	200 449	
Gulf of Finland	29	16	0	131 509	
Gulf of Bothnia	12	6	0	44 198	
Gulf of Riga	2	1	0	6 509	
RoPax vessels	15	10	0	27 632	900
Vehicle carriers	16	6	0	51 369	436
Cargo ships	70	38	1	310 111	351
Container ships	61	38	1	149 580	672
Tankers	73	28	0	361 498	282
Passenger ships	0	0	0		
Cruisers	7	4	0		
Fishing vessels	1	1	0		
Service vessels	2	2	0		

In general, largest emitters of noise energy are the cargo ship and tankers, but also containerships contribute significantly to vessel noise emissions at 125 Hz band. Tankers and dry cargo ships emit more than 50% of the noise energy at the three frequency bands. However, they are also responsible for 51% of the transport work in the Baltic Sea area. If noise efficiency is considered (analogous to energy efficiency reported in grams of CO_2 emitted per ton km cargo carried), RoPax vessels have largest unit emissions of noise (900 millijoules per ton km), whereas lowest unit noise comes from tanker class of ships (282 mJ ton^{-1} km^{-1}). Figure 2 indicates the noise emission shares of various types of ships at 125 Hz frequency band.

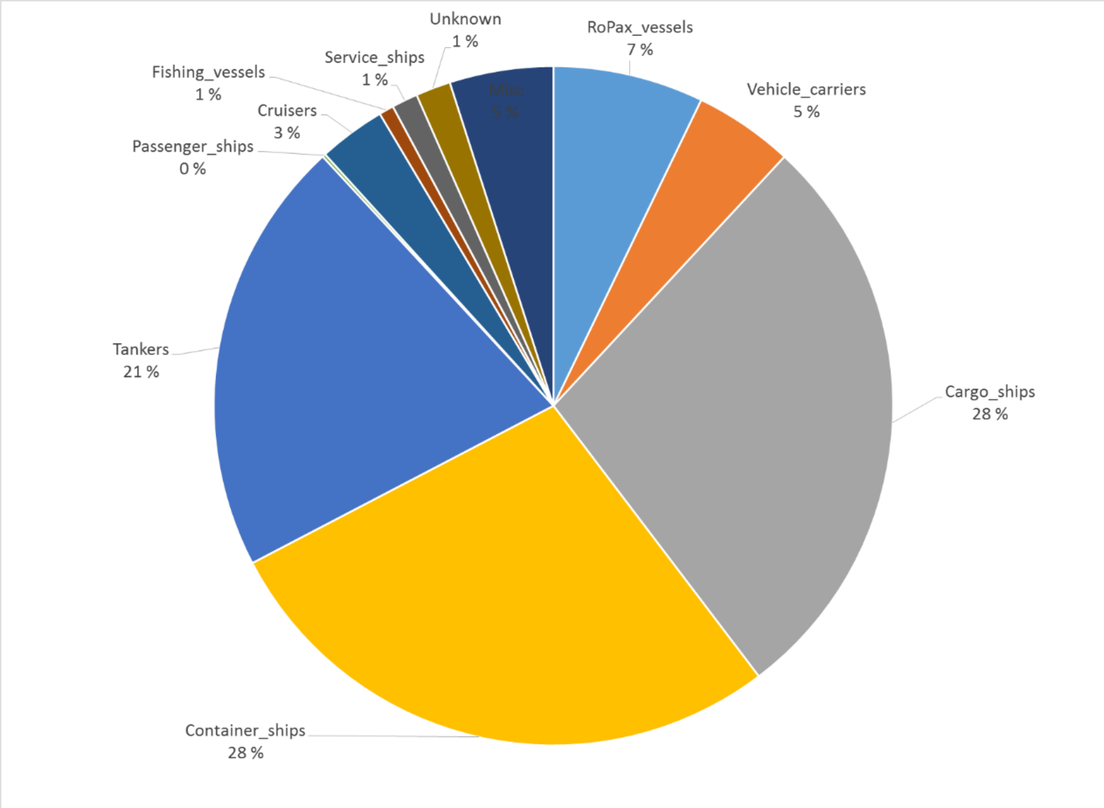

Figure 2 Share of emitted noise from various vessel types at 125 Hz band during year 2017

The geographical distribution of noise energies in 63, 125 and 2000 Hz bands are given in Figure 3, Figure 4 andFigure 5. It should be noted that the maximum values of the scales are not identical and differences of two orders of magnitude are shown.

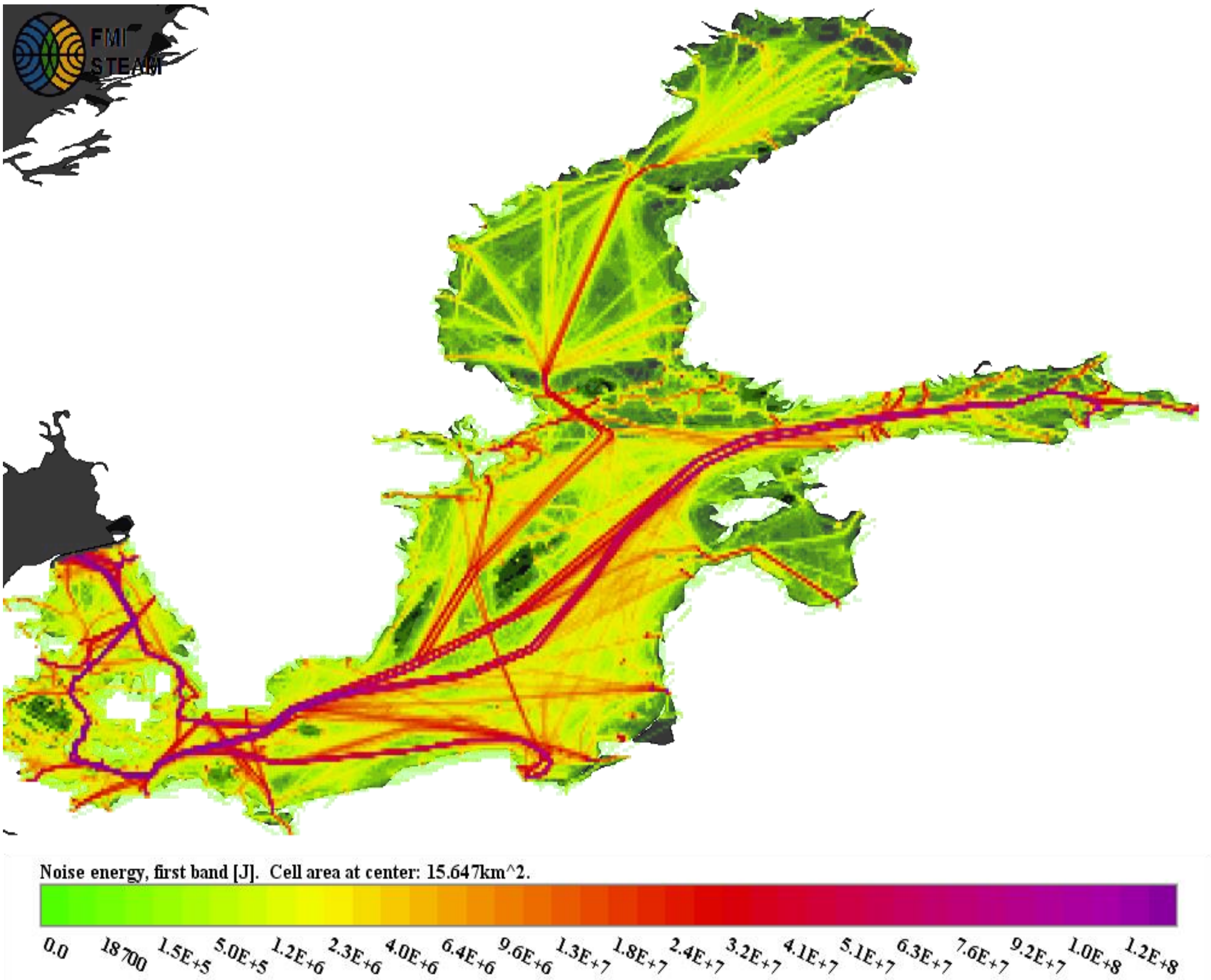

Figure 3 Noise energy emitted in the 63 Hz band by the Baltic Sea fleet in 2017. Unit is gigajoules per grid cell area (15.65 km²)

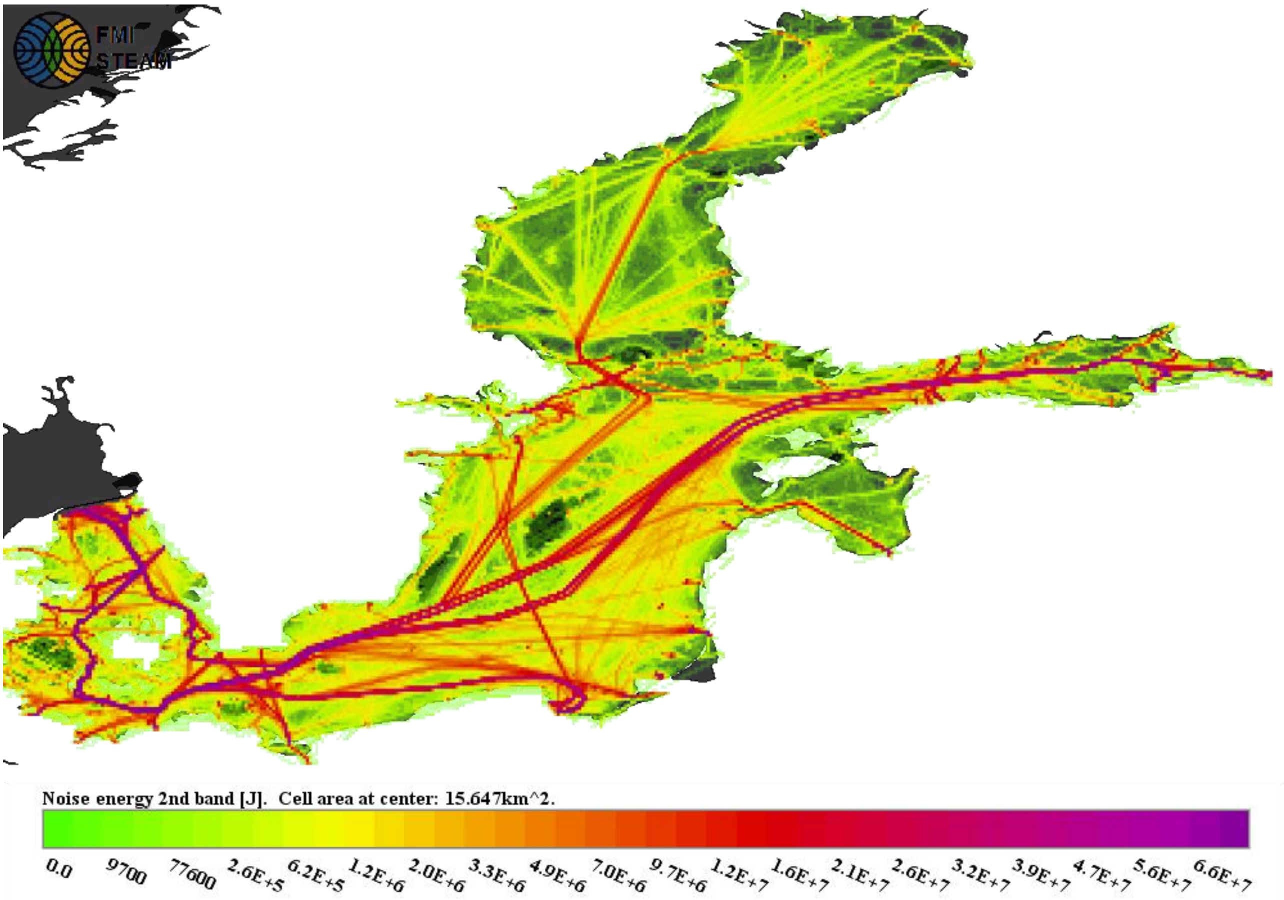

Figure 4 Noise energy emitted in the 125 Hz band by the Baltic Sea fleet in 2017. Unit is gigajoules per grid cell area (15.65 km²)

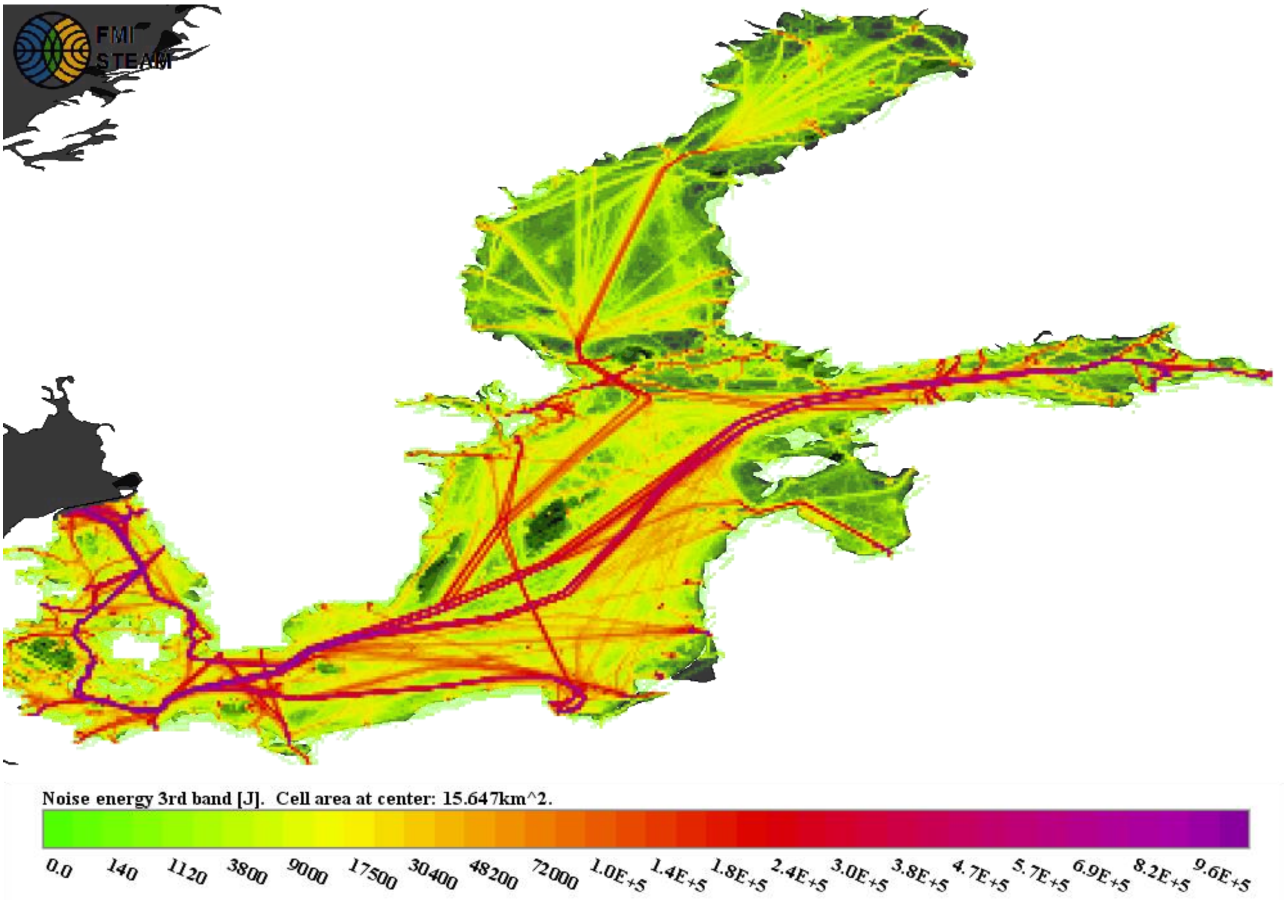

Figure 5 Noise energy emitted in the 2000Hz Hz band by the Baltic Sea fleet in 2017. Unit is gigajoules per grid cell area (15.65 km^2)

Obviously, largest emitted levels occur in main shipping lanes. Values exceeding 100 dB are well within the hearing range of cod (Nedwell et al., 2004), but propagation modelling of noise is required to determine the noise levels experienced by marine life and assess the impacts of noise in the Baltic Sea area. A noise source emitting one megajoule of energy for one year corresponds to 156 dB source level. Noise maps of this report are visual aids to illustrate the geographical distribution of noise emissions, but further propagation modelling should be done to indicate how noise travels underwater. Only then the impacts of noise can be assessed.

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Data

The emission estimates for the year 2017 are based on over 5.4 billion AIS-messages sent by 23 985 different ships, of which 7 671 had an IMO registry number indicating commercial marine traffic. The AIS position reports were received by terrestrial base stations in the Baltic Sea countries and collected to regional HELCOM AIS data server. Emissions are generated using the Ship Traffic Emission Assessment Model (STEAM).

For 2017, the temporal coverage was 99.3% without any significant data gaps. However, there was a significant reduction in the volume of received AIS data towards end of the year. Most of the messages originate from South-Western region of the Baltic Sea near the Danish and southern Swedish sea areas (Figure 6). For the most part of the year 2017, data flow was around 700 000 messages per hour, but data for Oct-Dec 2017 indicates 85-90% data loss. This drastic reduction in data volume occurred in all areas of the Baltic Sea and it is unlikely that it was caused by malfunction in AIS data reception. The quality of predicted emissions is unlikely to be impacted by this change, because previous tests with 95% data loss have had only minor influence on final results. However, further work is needed to investigate the impact further.

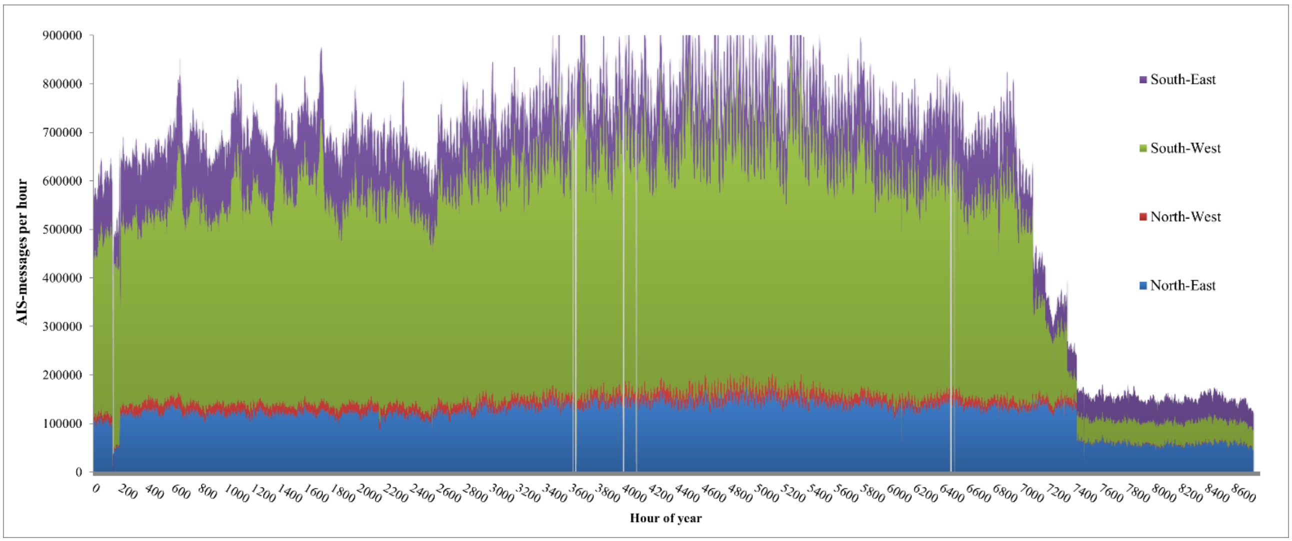

Figure 6 AIS-data hourly coverage in different parts of the modelling region for 2017.

Metadata

Fuel and vessel operational procedures can have a large impact on exhaust emissions. Emission factors for ships are in accordance with the latest literature and are believed to represent a reasonable estimate of the resulting emissions. Marine currents, fouling and sea ice can have a significant impact on emissions, but these effects have not been accounted for in this study.

Some uncertainty in predicted emissions arises from the large number of small vessels for which technical details are unavailable or incomplete. However, the internet contains some basic vessel characteristics even for such small and unknown ships[1] and by using an automated vessel characteristics extraction routine, it has been verified that the group of unknown ships are in fact small vessels and as such do not cause significant margins of error for the modelled annual emission totals. Nevertheless, only a fraction of recreational boating activity can be studied with AIS. According to a recent estimate[2], there exists over 250 000 boats in more than 3 000 locations in the Baltic Sea area which are not required to carry AIS onboard. It is likely that the total number of AIS targets observed during the year 2017 represents about 10% of the total waterborne vessels, but describes the activity of commercial ship traffic very well because AIS is mandatory for large vessels.

The STEAM3 model code has been updated to include discharges to water and underwater noise emissions. Large number of new properties can be reported, ranging from scrubber wash water to anti-fouling paint releases. Modeling tools for vessel noise have been developed within the BONUS SHEBA project are ready to be applied as part of regular HELCOM ship emission reporting. New quantities have been calculated only for year 2017, for now, but data for earlier years can also be produced which facilitates observing trends in various emissions.

[1]For example, www.marinetraffic.com and www.vesselfinder.com usually yield the ship type and physical dimensions for vessels that have no IMO-number..
[2] Sustainable Shipping and Environment of the Baltic Sea region (SHEBA) project, Deliverable 1.3 “Activity data for the Baltic pleasure boats”.