Noise emissions

This leaflet contains information related to noise emissions from shipping based on research work within the BONUS SHEBA project. The purpose is to populate knowledge and experience established from science and make the information more available. It has been prepared by Karl Jivén, IVL, on behalf of the Interreg CSHIPP project platform.

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THE BONUS SHEBA PROJECT

The BONUS project SHEBA brought together lead experts from the fields of ship emissions, atmospheric, acoustic and oceanic modelling, atmospheric and marine chemistry logistics and environmental law[1] to provide an integrated and in-depth analysis of the ecological, economic and social impacts of shipping in the Baltic Sea and to support development of the related policies on EU, regional, national and local levels.

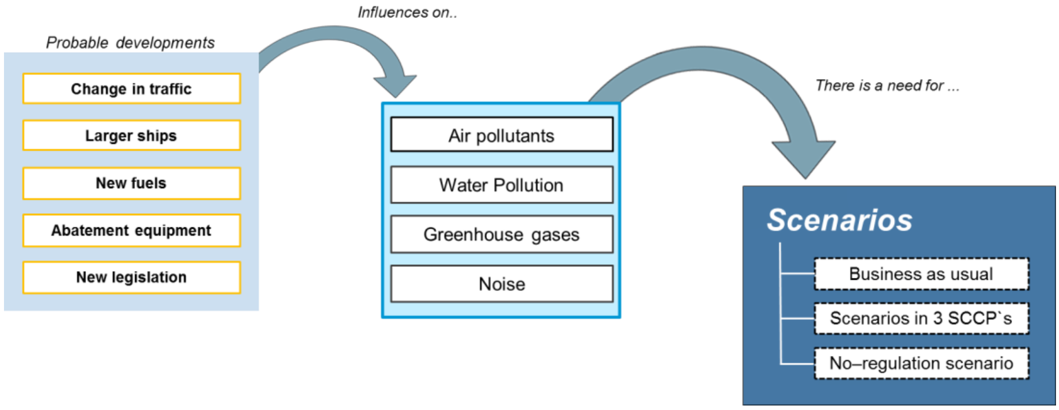

Figure 1 The model used for finding what the future air emissions will look like.

The Baltic Sea is one of the world's most trafficked sea areas and of great importance for both global and regional seaborne trade. Various ship types are constantly in route with cargo from or to the area. Also, passenger traffic in the Baltic Sea is extensive with ferries operating year-round covering many destinations. There are around 100 ports in the Baltic Sea located in fresh to salt water, of different size and with varying type of traffic. Although shipping is one of the most environmentally friendly modes of transport referring to CO_2 emissions to air per tonnes of cargo, shipping like all industries cause environmental impact which is affecting the Baltic Sea. The countries surrounding the Baltic Sea all use the area as waterway, for fishing, recreation and tourism and it is essential for their economies and development. To support a sustainable development of shipping in the area, a quantification of shipping's contribution to the environmental impact has been conducted within the BONUS SHEBA project.

The SHEBA project, which was an EU-BONUS funded project, has analysed the following sources and pathways of shipping induced pollution to the marine environment:

- **Noise pollution**
- Emissions to air (NOx, SOx, CO_2)
- Particulate matter (PM)
- Emissions to water (Bilge water, Ballast Water, Sewage, Grey water, Stern tube oil, Biofouling vs Antifouling paint and Food waste).

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NOISE

It is recognized that anthropogenic (human induced) noise might have adverse effects on the marine environment. Research unequivocally suggests that animals react to sound, sometimes with devastating results, but more commonly giving rise to strong avoidance reactions. The levels of underwater sound, and therefore associated effects on the marine ecosystem, have been increasing since the advent of steam-driven ships and to improve the living situation of the animals, the effects of sound must be understood and, in the future, effectively managed.

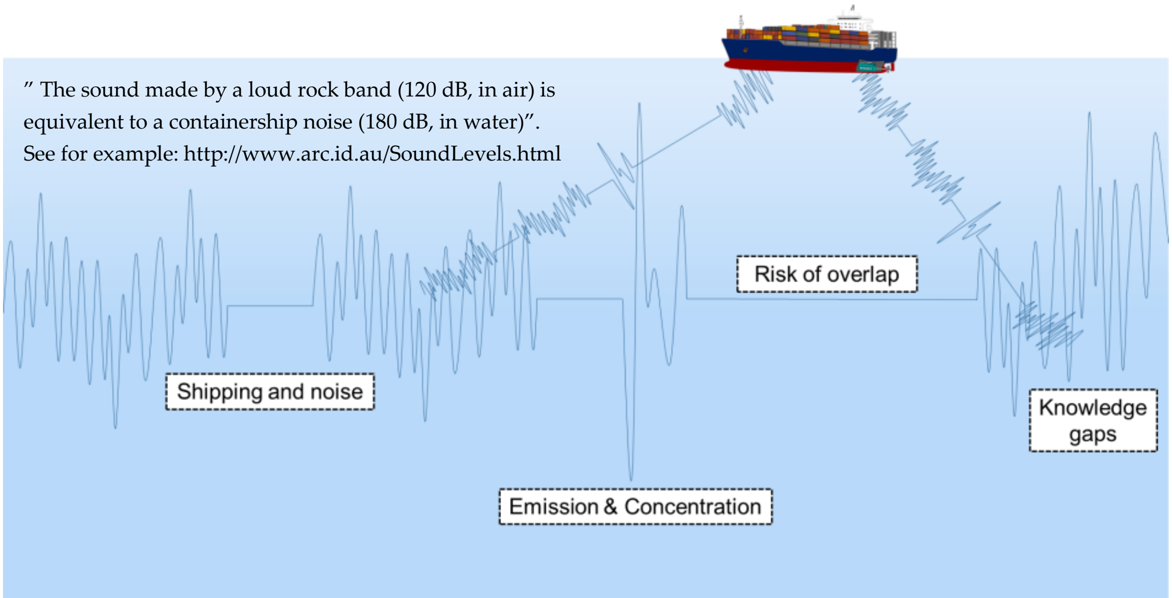


Figure 2 Schematic illustration ofareas important to consider related to underwater noise.

Underwater noise from shipping has different sources. The most relevant ones are linked to the ships` engines as well as of the general design of the ship. There is a trade-off between propeller noise and efficiency. Propeller efficiency improvements will lead to noisier designs. There are mandatory design requirements for energy efficiency in place, but no requirements to reduce noise emissions. Vessel operation at high speeds leads to underwater noise emissions. Little is known of the impacts, but the consensus is that the underwater noise levels are increasing.

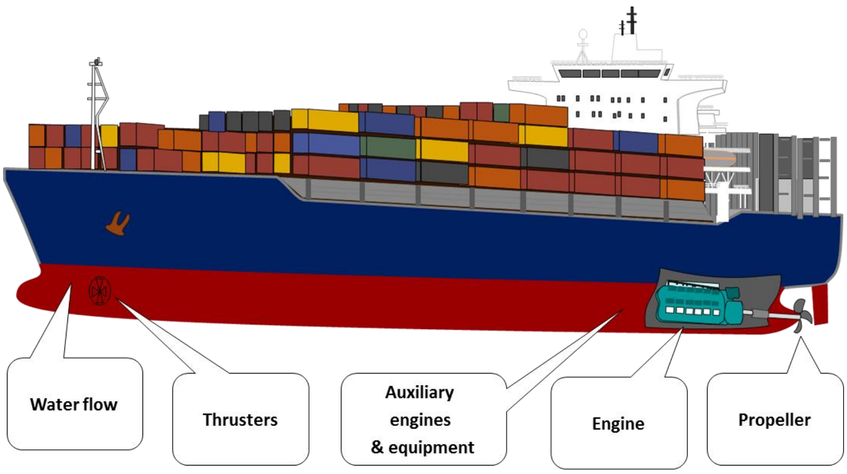
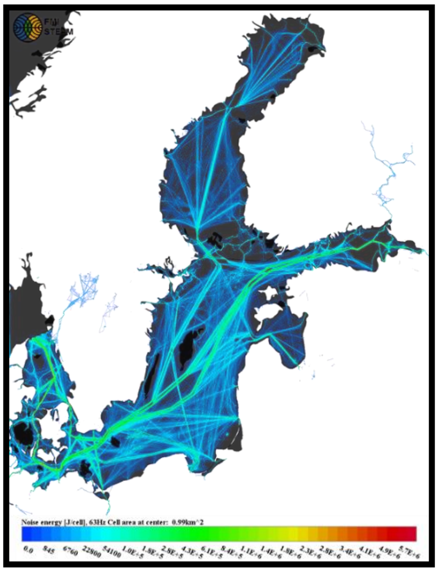


Figure 3 Typical sources for ship generated noise

Noise can affect fish/mammals in many ways, starting from masking of communications (which may lead into difficulties in mating, avoiding predators) to physical symptoms (like temporary or permanent hearing loss) or ultimately, death.

The BONUS SHEBA project built on the experience of previous research efforts in the field of underwater noise and generated a computer model-based estimate of underwater shipping noise. The noise generated by ships' propellers, propulsion machinery and hull are described with a simple model which uses actual traffic data and performs a vessel-specific noise estimate for the Baltic Sea fleet. The noise source spectra of ships were estimated from long term measurements by hydrophone deployed near a major shipping lane south of the island Öland. The derived source estimates were subsequently used in a noise propagation model to compute maps of the shipping-generated noise in two test areas, illustrating the effect of e.g. traffic density, bathymetry and sound speed variations on the noise level.

The results from the modelling work in SHEBA suggest that shipping generates substantial noise emissions and induces high noise levels in wide areas around the shipping lanes. The results from the modelling also indicate substantial differences in noise levels within the modelled areas and show some seasonal differences. The shipping-induced noise levels are substantially lower in shallow areas far from the shipping lanes than in deeper areas where traffic is intensive.

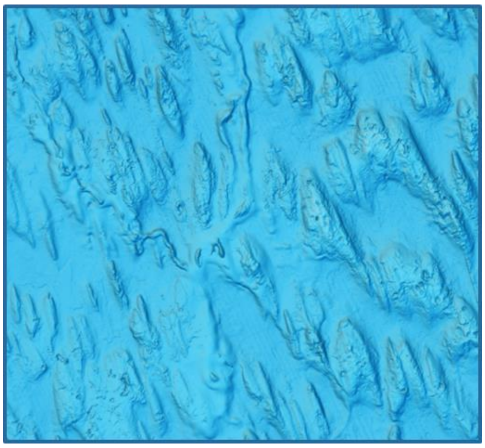


Within the SHEBA project, a shipping model was combined with an underwater noise model, which enabled to determine the current levels of underwater noise in the Baltic Sea area due to ships.

The model was used to study currently existing shipping noise and its results can be used further to understand how noise spreads under water. For that kind of study, another model is needed which describes the propagation of noise under water.

It is not enough to determine the amount of noise (e.g. noise energy) and where ships exist, but we also need to find out the size of the area which is impacted by noise. For that reason, a noise propagation model needs to describe the spreading of noise in 3D seafloor environment.

Figure 4 Noise emission energy map of the Baltic Sea shipping. This map indicates the accumulated noise energy in the 63 Hz frequency band during April 2014.



Similar to atmospheric pollution, emission levels are not equal to the levels experienced by population.

Emissions ≠ Concentration

In case of noise, emitted noise is:

a) Reflected from water/air(ice) interface,

b) Dampened or reflected by the seafloor (depending on bottom material; rock, mud, sand)

=> *3D map of seafloor needed (called bathymetry, see image)*

c) Affected by thermal and salinity layering of seawater

d) Dampened differently depending on noise frequency

Figure 5 Image from: Baltic Sea Bathymetry Database, *Baltic Sea Hydrographic Commission.*

IS UNDERWATER NOISE A PROBLEM?

There are both natural sounds and those which occur because of human activity. Examples of natural underwater sounds are lightning, wind, rain, waves, breaking of sea ice sheets, volcanoes and earthquakes. For anthropogenic underwater noise, many other sources exist like ship traffic (engine, hull, propeller noise), underwater constructions (explosions, pile driving), dredging (excavation of the seafloor), oil exploration (air guns, sonars), boating and energy production (wind power).

In certain ways, underwater noise pollution has similar features as atmospheric pollution. Both have natural and anthropogenic sources, both disperse to wide areas and both can have harmful impacts on humans and environment.

Contrary to noise studies, a methodology exists how to assess the harmfulness of polluted air to humans, but the impacts of noise on animals are poorly known. Evaluating how harmful noise is can be significantly more difficult to determine than the human health effect.

First, animals are not able to communicate with us and tell about the level of discomfort they may experience because of loud noise. Loud enough noise can kill instantly both humans and animals, but this requires enormously loud noises which are not encountered in the Baltic Sea area.

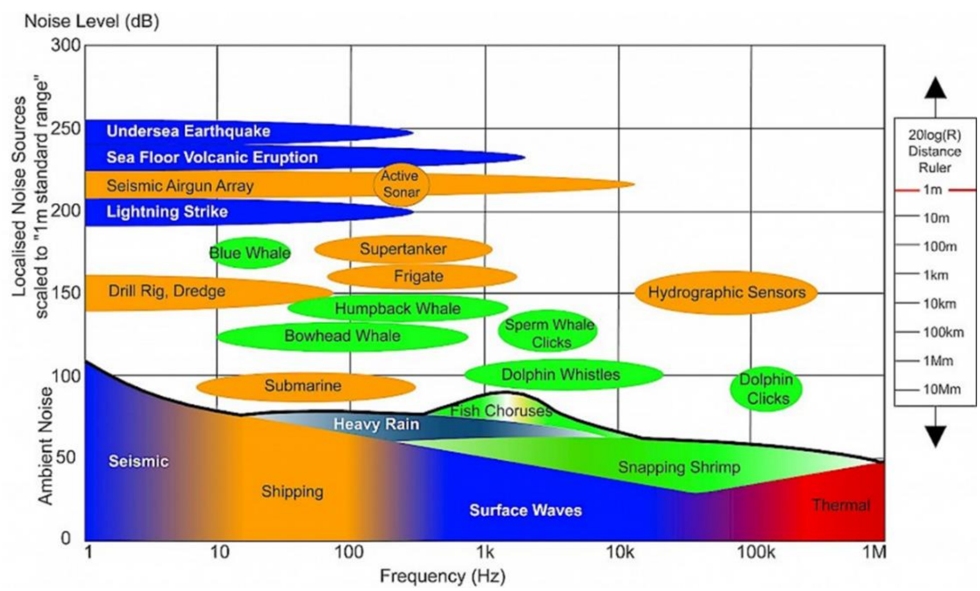
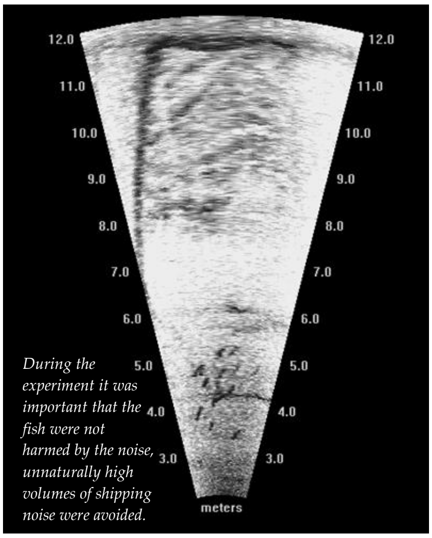


Figure 6 Man-made noise can overlap with noises of marine animals as it might lay in their hearing range.

Noise can become a problem even before it causes physical injuries. The behavioural changes, communication problems, hearing loss and increased stress of fish may lead to problems in mating and breeding and may lead to fish avoiding noisy areas.

For the noise impacts, we can use existing data on the noise levels which can be heard by fish. The hearing abilities of various species are different; fish can hear low frequency shipping noise very well, whereas seals may not be impacted by this frequency range as much as the fish but are sensitive to higher frequencies instead.

It may very well occur that certain fish spawning grounds are overlapping with areas of high shipping noise, which may lead to a situation where the fish relocate to other, less noisy areas. The difficulty with this kind of studies is that the knowledge of harmful level of noise to fish is not very well known.



To understand the noise impact on fish, an experiment was conducted within the SHEBA project. An underwater loudspeaker was used to playback shipping noise to a group of fish. Noise level was adjusted and any changes in fish behavior were observed using an echo sounder. This equipment is like underwater radar which is able to see fish movements.

This experiment helped us to see whether fish flee in panic from the noise source, whether they got wary of possible disturbances by changing their movement patterns or if they ignored the noise completely.

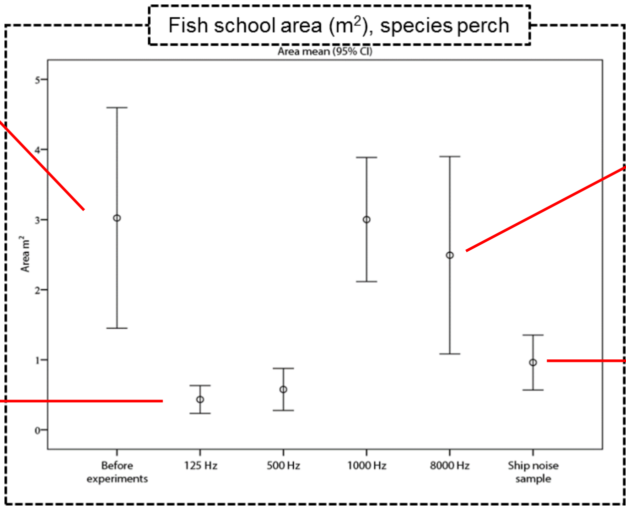
Adjusting the volume would helped to understand at which noise levels changes in fish behavior start to occur. This knowledge could be used as a tool for identifying the noisy areas which suffer from excessive shipping noise and help us to find ways to decrease the noise impact on marine life.

Figure 7 Images © Heikki Peltonen/Finnish Environmental Research Institute.

No additional sound, fish swim as a loose group

125 Hz sound played back to fish. The fish school packs tightly together, swim no longer in loose formation.

Same happens with 500 Hz noise.



At higher frequencies, the tight school disperses.

No reaction at 8 kHz, exceeding the hearing range of fish.

Recorded shipping noise played back to fish, the school packs to a tight formation again.

Figure 8 Results from underwater sound experiments within the BONUS SHEBA project

Regardless of the work done in BONUS SHEBA, significant knowledge gaps still exist in studies of underwater noise. For example, shipping is only one source for underwater noise and several others exist. Even small boats emit noise when operated, but the extent of this is poorly known and they are not covered by current legislation, either.

To manage underwater sound properly, we would need more work in all areas of underwater noise; how it is produced in ships, which design features need to be changed to mitigate noise emissions, how changes of vessel operations affect emitted noise, how noise travels in realistic conditions and how animals perceive sound.

For a long time, underwater noise has been mostly a subject of military research, but there is a clear need to develop civilian research in this area to manage sound effectively. This is important for a proper stewardship of marine resources.