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This document includes further clarification on the human-generated noise targeted by the indicator (p. 1, first para) as provided by Sweden. This document replaces document 4-4.

Background

Development work as needed for both the pre-core ambient and candidate impulsive noise indicators has in 2015 and 2016 been taken forward by Lead and co-Lead Countries and communicated to and reviewed by the Contracting Parties through the HELCOM Expert Network on Underwater Noise (HELCOM EN-Noise). Overall coordination taking place by the HELCOM Pressure Working Group.

For indicators to be included in the second holistic assessment (HOLAS II), GES boundaries and indicator concepts will be considered from a technical point of view and endorsement by relevant Working Groups and for adoption at HOD 51-2016 (14-15 December 2016). Since GES has not been defined for indicators on underwater noise, HOLAS II 5-2016 agreed that "to use a descriptive approach in the presentation of marine litter and underwater noise in the HOLAS II report due to the fragmented availability of data while also including a forward looking view on monitoring and ongoing knowledge building on these topics" (para 5.10).

Work on the continuous low frequency anthropogenic sound pre-core indicator has been led by Poland, with Denmark, Finland, Germany and Sweden as co-lead countries.

The HELCOM EN-Noise has held six on-line working meetings (16.11.2015, 16.03.2016, 20.05.2016, 23.06.2016, 01.07.2016 and 30.09.2016) addressing, among other issues, the improvement of the continuous low frequency anthropogenic sound indicator report[1]. Memos of those working meetings are available in the meetings folder of the underwater noise workspace.

The draft indicator report has been prepared by Sweden. Contributions and feed-back has been received from Finland, Poland, Denmark and Lithuania.

This document contains the HELCOM pre-core indicator 'Continuous low frequency anthropogenic sound indicator' as proposed by the HELCOM EN-Noise.

Action requested

The Meeting is invited to:

- take note of the progress of work;
- consider proposed indicator concept; Contracting Parties are invited to inform on the readiness to endorse the indicator definition;
- consider proposed assessment protocol; Contracting Parties are invited to inform on the readiness to endorse the assessment protocol.

[1] Current version as agreed by HOD 48-2015 to be shifted to pre-core indicator, para. 3.63 of the Outcome of HOD 48-2015.

This indicator will also be brought forward for consideration at STATE & CONSERVATION 5-2016 (7-11 November). The Contracting Parties are invited to provide a consolidated final response at the State and Conservation meeting.

Continuous low frequency anthropogenic sound

Key message

Note: The indicator on Continuous low frequency anthropogenic sound is not operational. The section Results includes available information on sound pressure levels and hearing sensitivity of animals but does not assess status. The section on Assessment protocol describes the proposed indicator concept and assessment protocol and the section on Good Environmental Status (GES) describes how GES could be defined.

Ambient noise in the context of the marine environmental health consists of both natural and anthropogenic sound. The indicator is related to the levels, and changes of continuous human-generated noise, e.g. shipping, continuous dredging, renewable energy operations and energy installations). The latter exemplified by oil and gas infrastructures. It is assumed that shipping is the dominating anthropogenic source in the offshore environment. Ships generate sound in a broad frequency range, which overlaps with the hearing frequency range of many marine species. The two 1/3-octave bands with center frequencies of 63 Hz and 125 Hz are recommended by the Marine Strategy Framework Directive (MSFD, 2008) to be used as proxies for ship activities. Thus, the indicator is defined in terms of establishing the trend of the sound pressure level for 1/3-octave bands of 63 and 125 Hz.

The field of research of anthropogenic noise impact on the environmental target is currently under development. It is anticipated that monitoring data must be accumulated for some years (decades), supplemented with dedicated effects studies, before the impact can be confidently determined. Preliminary evaluation has been made but the indicator concept is still under development. The largest uncertainty is on determining the impact as well as separating anthropogenic noise from natural sound.

Relevance of the core indicator

Sound is continuously present in the underwater environment, irrespectively of the status of the sea. Properties of underwater sound are extremely diverse and sound can be classified in many different ways. A commonly accepted division of underwater sound is into two categories as natural and anthropogenic where the first encompasses all kinds of events that are produced by either animals or geophysical processes, while the second is produced by human technical activity. Examples of geophysical processes are rain, wind waves, ice, thunder are seismic activity. Biological sounds (animal vocalization) are produced by cetaceans, seals, fish, and crustaceans. Anthropogenic sounds are generated by ships, piling, sonars, seismic airguns, underwater explosions and other operational infrastructure.

Continuous anthropogenic noise exerts a significant pressure on the marine environment due to its constant presence and covers all the water body. The noise from a ship is caused by the propulsion, machinery, and by the movement of the hull through the water. The relative importance of these three different categories will depend, amongst other things, on the ship type, speed and load (Breeding *et al*., 1996; Wales & Hitmayer, 2002; Wittekind, 2014).

Policy relevance of the core indicator

	BSAP Segment and Objectives	MSFD Descriptors and Criteria
Primary link	Maritime activities • Safe maritime traffic without accidental pollution	D. 11 Energy, including underwater noise 11.2. Continuous low frequency anthropogenic sound
Secondary link		
Other relevant legislation: United Nations Convention on the Law of the Sea (UNCLOS, 1982), Convention on Biological Diversity (Decision XI/18 A) and IMO Guidelines for the Reduction of Underwater Noise from Commercial Shipping to Address Adverse Impacts on Marine Life (MEPC.1/Circ.833, 2014). Council Directive 92 /43 /EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (Habitats Directive, 1992). International Convention for the Safety of Life at Sea (SOLAS, 1974)		

Cite this indicator

HELCOM, 2016. Continuous low frequency anthropogenic sound**.** [HELCOM core indicator report]. Online. [Date Viewed], [Web link].

Results and confidence – based on current data

The BIAS project has carried out the first systematic mapping of the underwater soundscape and testing monitoring methods in the Baltic Sea. In total, autonomous loggers were deployed at 37 locations spread out in the Baltic Sea (Figure 1). The first measurements were taken in the beginning of 2014, and in 2015 stations were revisited to ensure coherence up to the possible implementation of new regular monitoring activities starting in 2016.

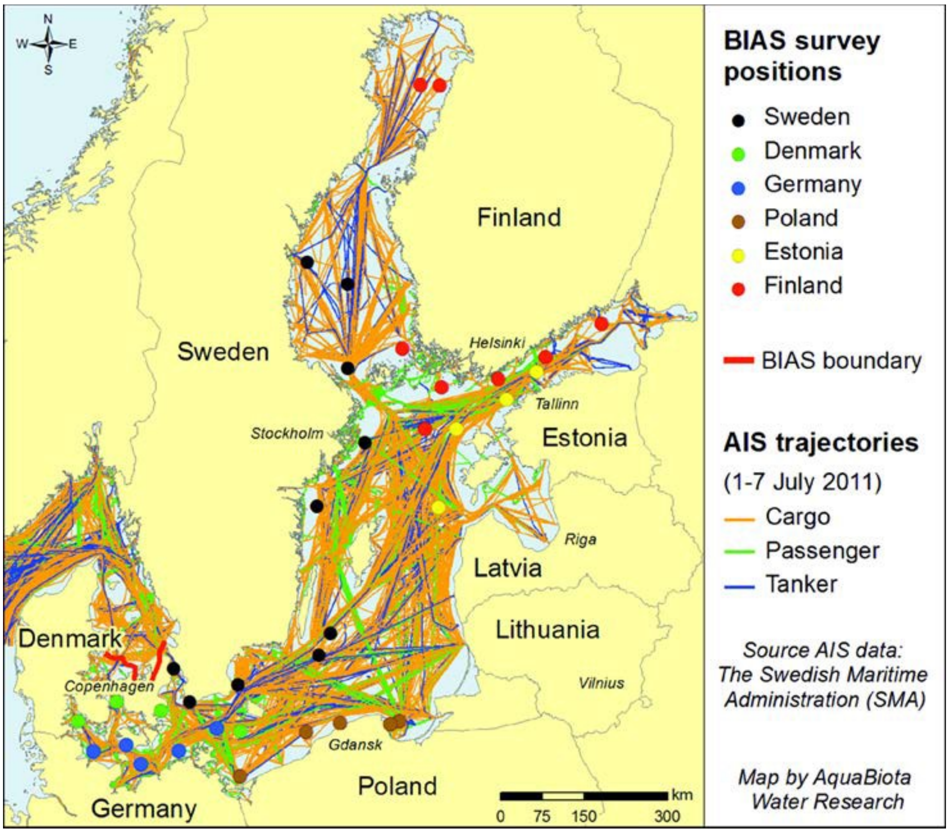


Figure 1. BIAS survey positions.

Some results based on pilot activities and research projects are also available and can be used in the development and implementation of the indicator in order to strengthen the concept and set provisional boundaries representing GES. There is some literature available presenting underwater background noise measurement results in the Baltic Sea areas as the Gulf of Finland (Poikonen & Madekivi, 2005, 2010), Gdansk and Bornholm Deeps (Klusek & Lisimenka, 2006, 2007, 2016), the Baltic Proper (Wille & Geyer, 1984, Wagstaff & Newcomb, 1987) and the Klaipėda Strait (Bagočius, 2013).

Preliminary results of BIAS measurements in the Finnish territorial sea area during October 2013 – March 2014 showed monthly average third octave levels of 63 to 83 dB re 1 µPa in the 63 Hz third-octave band and 66 to 96 dB re 1 µPa in the 125 Hz third-octave band (Figure 2).

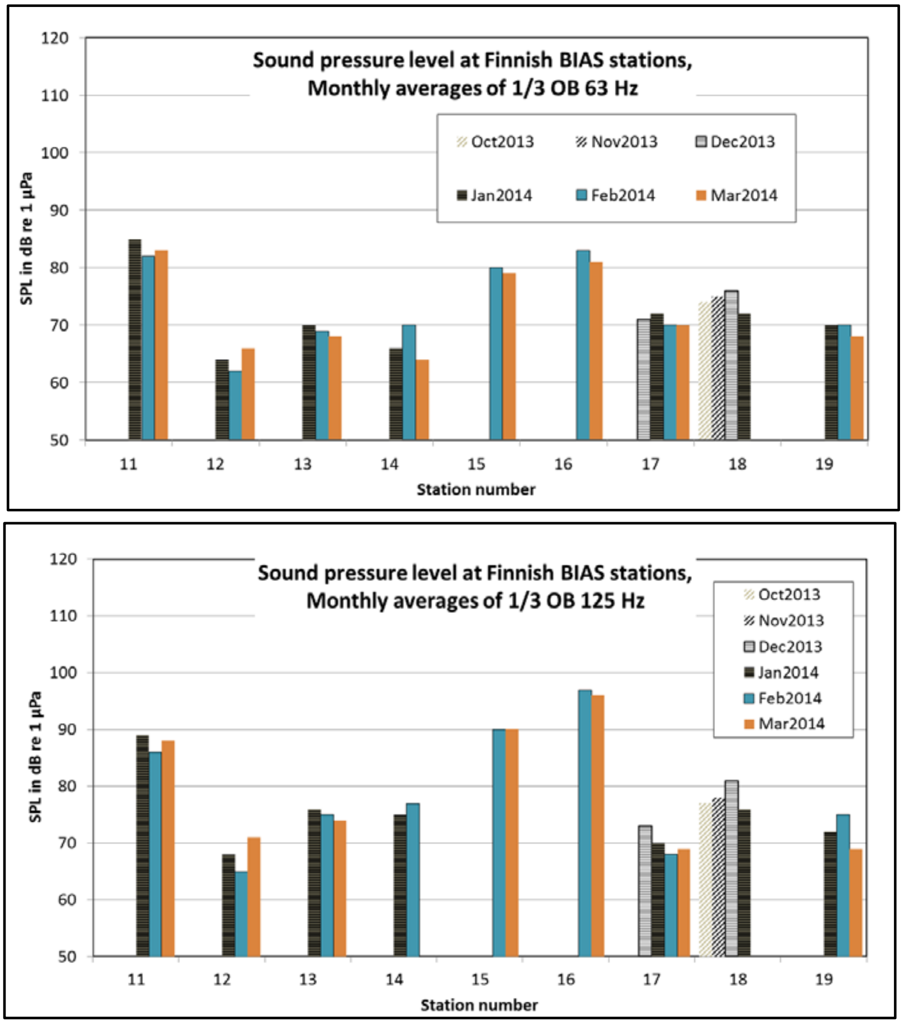


Figure 2. Sound pressure levels measured in the Baltic Sea. Monthly averages for 63 Hz (above) and 125 Hz (below) in the BIAS stations 11 and 12 (Bay of Bothnia), 13 and (Finnish Archipelago sea) , 15 and16 (Northern Baltic proper) and 17-19 (Gulf of Finland). (Source: Pajala J., BIAS preliminary results, 2nd BIAS Seminar on Underwater Noise, Helsinki 2014.)

The EU co-financed project BalticBOOST coordinated by HELCOM has produced a report *Noise Sensitivity of Animals in the Baltic Sea* (Schack *et al*., 2016). The report lists fish, seals and cetaceans occurring in the Baltic Sea and their sensitivity to noise. It is clear that there are several species from all animal groups that might be impacted by continuous anthropogenic noise. Shipping noise produce noise in a frequency interval (10 Hz to 20 kHz) that overlaps with the range used by different species (fish overlap in the lower end, marine mammals in the upper end, extending into the ultrasonic range) for communication and orientation. The main impact from this noise is regarded to be direct effects such as masking of important signals and exclusions of important habitats and as well as indirect effects such as elevated levels of stress hormones.

When comparing the ambient sound pressure levels (Figure 2) obtained along the Finnish coast line, to audiograms for fish (Figure 3), seals (Figure 4) and harbour porpoise (Figure 5), it is noticed that at the higher frequency band (125 Hz) the ambient noise levels were higher than some fish hearing threshold (cod and herring) indicating that fish can hear the noise.

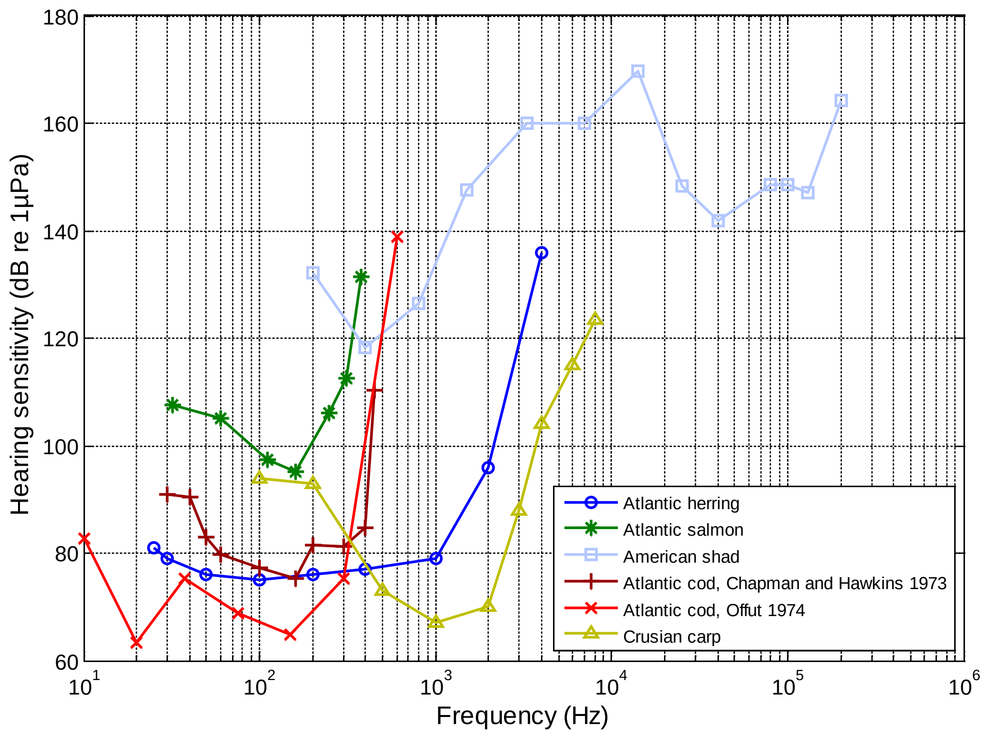


Figure 3. Sound pressure audiograms for five fish species that inhabits the Baltic Sea. Plot taken from Schack *et al.*, 2016.

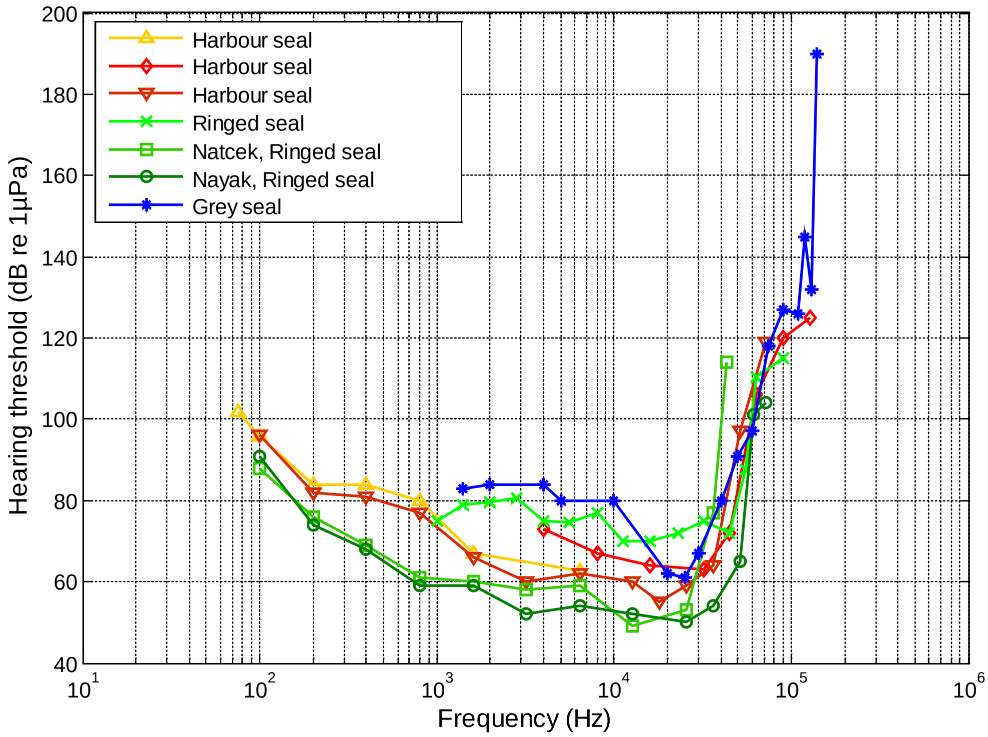


Figure 4. Hearing sensitivity for harbour seal (orange line from Kastak and Schusterman, 1998, red line from Møhl, 1968 and dark red line from Reichmuth et al. 2013; ringed seal (light green) from Terhune and Ronald, 1975, and ringed seal (darker green lines) from two individuals a young female (Nayak) and an older male (Natcek) from Sills et al., 2015; grey seal (blue line) from Ridgway and Joyce,1975.

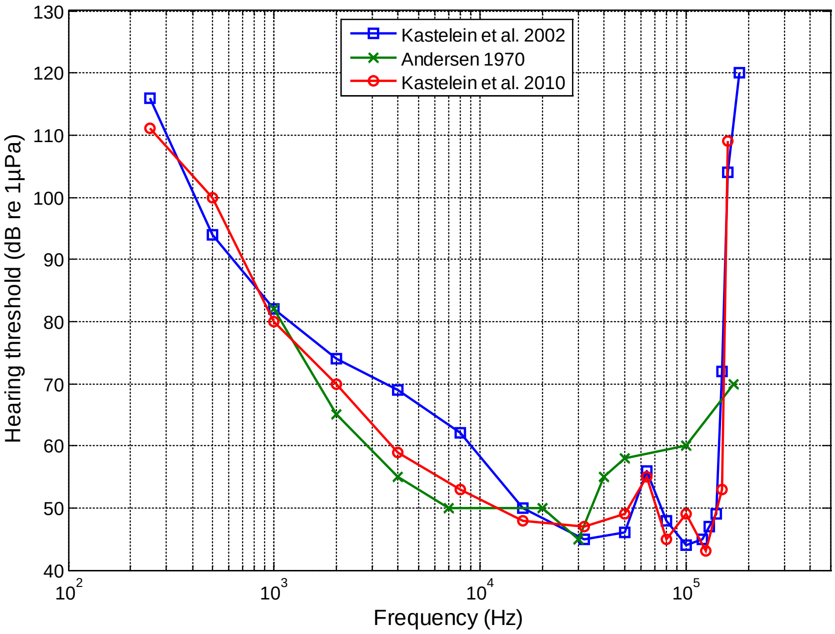


Figure 5. Audiograms of the single cetacean species resident to the Baltic Sea, the harbour porpoise. Plot taken from Schack *et al.,* 2016.

There are substantial gaps in our understanding of the effects of these sounds, especially for fishes and invertebrates. Currently, it is not possible to come to clear conclusions on the nature and levels of man-made sound that have potential to cause effects upon these animals (Stocker, 2001, Popper & Hawkins (*eds*.) 2012, 2014, 2016). It can be assumed that establishing evidenced-based results will take time, meanwhile regulation had to be based on reasonable assumptions and when necessary on the precautionary principle.

Confidence of the indicator status evaluation

Preliminary results from on-going projects and monitoring activities indicate that confidence of monthly averages, based on observational data are high enough to be used for assessing the statistical status of noise levels in the Baltic Sea. Regional standards for sensors, handling of data and signal processing have been established that will ensure that results will be trustable and comparable in the HELCOM region. Further, it has been demonstrated that annual and monthly soundscape maps can be drawn that covers the full area of the Baltic Sea. The benefit of the soundscape maps is that they extend the local measurement to the full Baltic Sea and thus they can be used to address impact in interest areas and/or specific periods. The combined use of soundscape maps and observations has not been fully investigated yet. The available results from observations and modelling shows that the prerequisites for managing anthropogenic sound is in place and can be used to establish statistical measures of the indicator.

Good Environmental Status

No boundary for GES has been set for the indicator, as not enough data have yet accumulated to evaluate the appropriate noise levels not to be exceeded in the Baltic Sea that would ensure that anthropogenic ambient noise only occurs at levels not adversely affecting the marine environment. However, the GES boundary is to prevent an unsustainable increase in noise induced by human activities in the Baltic Sea. As a first step in this procedure the levels have to be established.

The basic concept for setting the GES boundary considers the frequency and distribution of the noise events that do not have an impact on elements of the marine environment. An acceptable level of noise allows the ecosystem to achieve a Good Environmental Status (GES). Both the Baltic Sea Action Plan (BSAP, 2007) and the MSFD (2008) recognize humans as a part of the marine environment, implying that human activities at a sustainable level can be accepted however, when activities are carried out non-sustainably they generate a pressure with a deleterious effect on the environment.

The term 'trend' describes a complex issue when it comes to underwater sound and the effects. TG Noise (van der Graaf *et al*., 2012) therefore defined the term as 'general direction in which something is developing or changing'. Following this, 'trend' refers to year-to-year (or longer) changes in ambient noise levels. Ambient noise consists of natural and anthropogenic sounds. Knowledge of their statistical properties and temporal and spatial coverage, is necessary for the evaluation of effects of anthropogenic noise.

Linking this core pressure indicator on underwater noise to a GES requires thresholds, coherent with status indicators for biodiversity. Currently it is not possible to quantitatively link the effects directly to underwater noise causes in marine animals and further studies are needed. As this relates to species-specific features, a regional approach is necessary to recognize the links between pressure and status responses of underwater noise. Underwater noise is not the only pressure affecting the marine species and cumulative effects should optimally be considered. To develop the GES boundary further, management based on interim targets will be necessary, preferable based on thresholds of sound pressure levels for a specific sub-region and for time period.

Assessment protocol

The indicator is defined in terms of establishing the trend of the sound pressure level for 1/3-octave bands of 63 and 125 Hz. This definition describes a change of pressure rather than pressure. Further, the recommendation to assess the effect of underwater noise, is to combine observational data with soundscape modelling. It has also been suggested that masking is of major concern related to continuous noise. Further, the negative effects of continuous noise should be assessed on population level provided that the species is abundant. The assessment should be focused on harmonizing the methodologies in the HELCOM region and to establish statistical estimates of the noise.

The indicator should be evaluated using a combination of monitoring of sound and soundscape maps. The indicator proposes to use three approaches (criteria) to evaluate GES:

1. Spatially Sonified Area: in large areas of the Baltic Sea the distribution of species are not well known. The possibility to regulate the sound level, based on a specific species based thresholds are limited. Areas that are regarded to be ecologically valuable, regardless of occurrence of specific sound sensitive species, can be regulated based on the precautionary principle based on polluted area. The

first criteria assess the proportion of interest area in percentage for which a sound pressure level is exceeded a certain percentage of, based on one or more n:th exceedance levels for a specific frequency and depth interval (e.g. 100% of the area is covered with noise that exceeds 90 dB re 1 µPa 5% of the time, the proportion is presented as a function of sound pressure level);

2. Temporally Sonified Area: Due to the local appearance of some species an assessment should be done in an interest area. The second criteria presents the proportion of interest area for which the exceeded sound level surpass the given sound pressure level (threshold) for a specified time period, frequency interval and depth interval;
3. Low Activity Area: Areas where it is known that ship traffic is low can be monitored by yearly ship density maps, which are based on AIS and VMS data.

If sound activities changes in an area the criteria can also change.

The first criteria is used for evaluating the impact in areas where there is a general need to regulate the noise levels, such as Nature 2000 areas or in areas where no specific sound sensitive species are known to be present.

The second criteria is used for evaluating the impact on specific species such as cod. The threshold level is set to reflect a sound pressure level that potentially can affect the species. This criteria is used when there is a known threshold level. The threshold can be related to for example masking. Sound pressure levels louder than the threshold would potentially decrease the communication range and hence affect the fitness of the species.

The third criteria is used in areas where it is known that number of ships is low. The assessment can be done by using yearly produced AIS-maps.

The optimal combination of maps and observations has not yet been investigated. It is recommended that observations are meanwhile maintained on a yearly bases.

Relevance of the indicator

Continuous low frequency anthropogenic sound assessment

Continuous low frequency anthropogenic sound is assessed by using a pressure-based indicator. The use of measurements and models will be essential to reach GES.

Policy Relevance

At international level, marine biodiversity is to be protected and prevented from any kind of pollution (UNCLOS, 1982). Underwater noise is considered as pollution, it is not ‘substance’ but ‘energy’. The International Maritime Organization (IMO) added “Noise from commercial shipping and its adverse impact on marine life” as a high priority item to the work programme of its Marine Environment Protection Committee (MEPC). In 2014, the MEPC approved Guidelines for the reduction of underwater noise from commercial shipping to address adverse impacts on marine life (IMO, 2014).

At EU level, the non-binding European Commission Guidelines for the establishment of the Natura 2000 network in the marine environment consider noise as a source of pollution that affects the marine environment and biodiversity (European Commission, 2007). The guidelines identify several sources of underwater noise pollution, including the propeller and machinery noise of ships. Moreover, the indicator provides information mainly to cover the requirements of EU MSFD purposes.

At HELCOM area level, noise was not highlighted as a specific segment in the 2007 BSAP, however consecutive HELCOM Ministerial Declarations have highlighted the need to focus attention to the pressure on the marine environment from anthropogenic noise in the HELCOM Community.

The HELCOM 2013 Ministerial Meeting agreed that:

- the level of ambient and the distribution of impulsive sounds in the Baltic Sea should not have negative impact on marine life;
- human activities that are assessed to result in negative impacts on marine life should be carried out only if relevant mitigation measures are in place.

Accordingly, the Ministerial Meeting agreed that as soon as possible and by the end of 2016, using mainly already on-going activities, to:

- establish a set of indicators including technical standards which may be used for monitoring ambient and impulsive underwater noise in the Baltic Sea;
- encourage research on the cause and effects of underwater noise on biota;
- map the levels of ambient underwater noise across the Baltic Sea;
- set up a register of the occurrence of impulsive sounds;
- consider regular monitoring on ambient and impulsive underwater noise as well as possible options for mitigation measures related to noise taking into account the ongoing work in IMO on non-mandatory draft guidelines for reducing underwater noise from commercial ships and in the Convention on Biological Diversity (CBD) context.

In 2016, the Regional Baltic Underwater Noise Roadmap 2015-2017 was adopted (Annex 3 of the Outcome of HELCOM 37-2016) of aiming at making every effort to prepare a knowledge base towards a regional action plan on underwater noise in 2017/2018 to meet the objectives of the 2013 Ministerial Meeting, and of the EU MSFD for HELCOM countries being EU members.

Role of the pressure from ambient noise on the ecosystem

Low frequency ambient noise in the oceans may have increased by around 15 dB in the last half a century due to human activities (Andrew *et al.*, 2002). Sound in water travels as a wave in which particles of the medium are alternately forced together and apart. The sound can be measured as a change in pressure within the medium, which acts in all directions, described as the sound pressure. The unit is Pascal, i.e. Newton per square meter.

The sound pressure level (SPL) of sound of pressure *p* is given in decibels (dB) by:

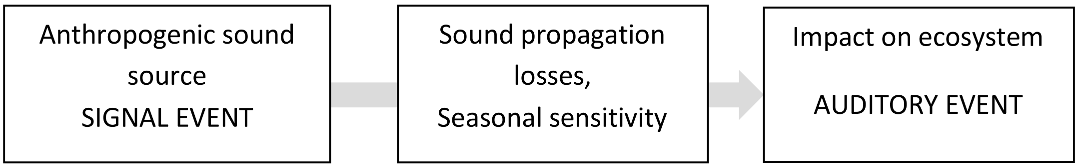
$$SPL\ [dB] = 20\ \log_{10}(p/p_0)$$

P is the measured acoustic pressure and P_0 is the reference pressure, where in underwater acoustics equal 1 μPa. As the dB value is given on a logarithmic scale, doubling the pressure of a sound leads to a 6 dB increase in sound pressure level.

Each sound wave has both a pressure component and a particle motion component, indicating the velocity and the acceleration of the molecules in the sound wave. Depending on their receptor mechanisms, marine life is sensitive to either pressure or particle motion or both.

It is difficult to define GES using current knowledge of impacts of anthropogenic noise on marine biota, and so initial indicators were chosen to reflect the environmental pressures, rather than the absolute status. This is particularly the case for Indicator 11.2.1 (Continuous low frequency sound), where not enough data are available to evaluate the impact of a masking effect on absolute levels of background noise for specific species. If the long term trends are known, then it may be possible to draw some conclusions about changes in the level of pressure on the environment. A downward trend in this indicator was more likely to lead to GES than an upward trend.

Source: ENV.D.2/FRA/2012/2005: Impacts of noise and use of propagation models to predict the recipient side of noise, Task 6 Report, 2014.



The indicator is for monitoring of the level of anthropogenic noise (signal event). When evaluating the impact level (auditory event) not only the acoustic environment but also species-specific hearing should be considered.

Human pressures linked to the indicator

Human activities in the marine environment inevitable generate sound that affects marine species. There are several anthropogenic sources that generate loud sound levels. The two most wide spread are commercial ships and fishing vessels but also energy installations, renewable energy sources and continuous dredging contribute to the total noise budget. A non-controllable source is the leisure boats. These tend to be present near shore and during the summer season. At present, there is no method to deal with these. The long-term trend is that the overall transported gross tonnage is positive. This implies that the commercial fleet will change in character and so will supposedly the sound levels. It can be expected that the anthropogenic sound levels will change in the long term.

Monitoring requirements

Monitoring methodology

Measuring standards are very important to agree on in order to have operational indicators. Regional standards for measurement of ambient noise have been developed for the Baltic Sea (BIAS, 2014). This is the only existing standard for ambient noise up today.

General information about monitoring of noise by the HELCOM members is described in the HELCOM Monitoring Manual.

Current monitoring

Currently, Denmark, Estonia, Finland and Sweden are carrying out regular monitoring activities on noise. Germany and Latvia will most probably start these activities in 2017, whereas in Poland a pilot project under the state monitoring programme for the Baltic Sea for monitoring underwater noise is ongoing.

Description of optimal monitoring

Based on provisional mapping activities carried out by the BIAS project, some general recommendations on monitoring of ambient noise can be provided. To meet the need for simpler methods for monitoring noise, detailed recommendations on monitoring are available from the project.

Monitoring is defined as a combination of measuring and modelling. The measured ambient noise includes continuous and impulsive noise. Using only measurements the dominant sources can seldom be identified, and determining whether the measured sound is of natural and anthropogenic origin is also difficult. Acoustic modelling is needed to serve these purposes, and the measurements can serve both for the set-up and the validation of modelling tools. The initial results show that there is an annual variation present that has an effect on the temporal distribution of sound and that should be taken into account in the evaluation of the impact.

Optimal monitoring is unattainable. Efficient monitoring makes use of a combination of measurements and modelling. The optimal combinations of these have not been evaluated yet. The results from one year of measurement show that 15-minute data per hour is sufficient to establish reliable estimates. However, the recording interval should be as long as possible.

The indicator evaluates monitoring data on the amount anthropogenic noise at the frequencies 63 Hz, 125 Hz and 2000 Hz. The ongoing BIAS analysis has shown that the 63 and 125 Hz frequency bands represent shipping noise in the Baltic Sea. The maximal energy is found in the interval 200 to 500 Hz. The 2000 Hz frequency band needs further studies before finally being accepted. However, it is recommended to use the additional 2000 Hz frequency band until this question is resolved. Considering monitoring of other frequency bands may also be considered relevant at a later stage when the frequencies most relevant from the perspective of effects on the Baltic Sea ecosystem specific fish and marine mammals have been clarified.

Sensors should be deployed at two types of locations, near to shipping lanes where individual signatures from ships are obtained and in locations where noise from distant shipping dominates. Due to strong vertical stratification of the Baltic Sea water masses and seasonally formed acoustic waveguides (subsurface waveguide during winter and deep-water one in summer) it is highly desirable to perform measurements at two depths above and below the thermo- and/or haloclines or by modelling taking the complex acoustic environment into account. Guidance was given on the deployment strategy by the TSG Noise (Dekeling *et al*., 2014). It might also be adequate to deploy in special areas such as marine sanctuaries and Nature 2000 areas. The measurement should be conducted following regional standards for rig design, sensor specifications, sensor handling, data handling and signal processing (Verfuss *et al*., 2015 and Betke *et al*., 2015). The BIAS project has established these. Soundscape maps are used to extend the areal coverage to the full Baltic Sea. The maps will be used to calculate statistical properties in specific areas as well as a function of time. Monthly and annual soundscape maps should be drawn. Relevant statistical measures are n:th exceedance levels (n = 5, 10, 25, 50, 75, 90, and 95%). The soundscape maps should be produced for 63, 125 and 2000 Hz. Maps for the full water depth, for top layer (0 - 30 m) and bottom layer (30 to bottom) should be drawn. A proposal on these terms for a monitoring programme for underwater noise in the Baltic Sea was presented to STATE & CONSERVATION 4-2016 (doc. 6J–2 Rev1).

Multi-stage concept for monitoring

A German group of specialists has described the basic concept of designing optimal monitoring, in line with the recommendations of BIAS (Anonymous, 2015) as follows:

a) comprehensive evaluation of performed measurements for determining the actual state and for quantifying required approaches for the sound monitoring regarding the requirements of the MSFD; this was partly done in the BIAS project;
b) on the basis of item a) a concept for a “short-term” implementation shall be developed (this is to run for a restricted number of years). This approach will be coordinated regionally;
c) preparation of a “long-term” plan for fulfilment of the requirements of the MSFD (descriptor 11.2) with regard to measuring and modelling.

Data and updating

Access and use

Underwater acoustic measurement generates large amount of data. A sensor that is continuously recording with a sample rate of 20 kHz generates about 4TB of raw data per year. With several sensors this scheme will generate a substantial amount of data that have to be stored. This unavoidable fact puts special requirements on the data storing compared to other types of environmental monitoring.

In most cases the raw data are processed by applying signal processing, which extracts relevant statistical measures. For example the second indicator of the MSFD dictates that averages of the sound pressure should be deduced for two specific frequencies. Thus, the data storage has two main purposes, first to store raw data and secondly to give access to data for signal processing use. It should be stressed that raw acoustic data were classified by national defences in the Baltic Sea region and hence cannot be shared publicly (BIAS data sharing platform and data storage device, downloadable from BIAS web page). In the BIAS project it was agreed to make 20 second averages publicly available (BIAS data sharing platform and data storage device, downloadable from BIAS web page).

The decimated and quality assured data should be stored on a regional data storage device that offers easy upload and download for the regional managers. The data storage should preferable be handled by either an intergovernmental organization or by an appointed regional member state.

Metadata

Experiences from on-going project BIAS showed that using standardized metadata formats and handling are important for the quality of the results. The large amount of data increases the possibility to introduce errors. In the BIAS-project the recommendation was to add metadata in the file headers of the measured data. This procedure assures that data and metadata are kept together. An important reason for applying metadata is to make results traceable, comparable and reliable as well as to facilitate use at a later stage. The metadata for the measured data are also needed for calibration of the acoustic modelling. The transfer of measured data to the modelling is automated and the metadata assure that the measured data is correctly used in the models.

Auxiliary Metadata

The acoustic soundscape complex environment dependent on several factors. To describe the detailed information on sources, acoustic medium and receivers are needed. All of which has to be addressed to estimate the impact on marine life.

Information of the source properties is crucial especially when modelling the soundscape where source models (acoustic ship models) are used to estimate the ambient anthropogenic noise. The present source models are based on observational data and provide a statistical description of the ships. Research is on-going to improve the source models and it can be expected that more accurate models will be available in the future. There are indications that the design of the commercial fleet is changing. With the introduction of new ships it is expected that ships will be quieter. However, since a ship usually operates over more than 20 years it will take time before the new more quiet ships dominate the sea. It is thus important to store information on the source models that was used in the acoustic modelling to be able to interpret the results of the models and not at least to re-run models using new and better source models.

The majority of the continuous anthropogenic sound in the offshore areas are generated by commercial ships. Initial results from on-going project shows that most of the noise is generated by the commercial ships but in some regions the fishing fleet dominates. AIS and VMS data are thus necessary to employ when modelling noise. The AIS and VMS data also includes information on the ship, e.g. position, ship type, length, draught and speed. The AIS and VMS data is thus crucial for modelling. Yearly data should be stored.

The acoustic environment consists of both static and dynamic properties (model layers). Bathymetry and sediments are examples of static properties. Both can be expected to be improved in the future and as result increase the accuracy of the model's result. To be able to compare model results metadata as well as the data layers should be stored.

The dynamic properties that influences the acoustics are water properties (temperature and conductivity), wave height, rain, and ice conditions. These have an effect on the sound propagation (transmission loss) and natural ambient noise levels. Yearly data sets should be stored as well as metadata.

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(Archive)

References

Andrew, R. K., Howe, B. M., Mercer, J. A., & Dzieciuch, M. A. (2002). Ocean ambient sound: comparing the 1960s with the 1990s for a receiver off the California coast. Acoustics Research Letters Online, 3: 65-70.

Anonymous. (2015). Acoustic Monitoring of Environmental Noise for the North Sea and for the Baltic Sea, Strategic planning in Germany, Report No. M100004/64, March 2015

Bagočius, D. (2013). Underwater noise level in Klaipėda Strait, Lithuania. *Baltica*, 26 (1), 45–50. Vilnius. ISSN 0067-3064.

Betke K., Folegot T., Matuschek R., Pajala J., Persson L., Tegowski J., Tougaard, J., Wahlberg M. (2015). BIAS Standards for Signal Processing. Aims, Processes and Recommendations. Amended version. 2015. Editors: Verfuß U.K., Sigray P.

BIAS Standards for noise measurements. Background information, Guidelines and Quality Assurance. (2014). Available at: http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.showFile&rep=file&fil=BIAS_standards_v3-2.pdf

Breeding J. E., Pflug, L. A., Bradley E. L., Walrod M. H., McBride W. (1996). Research Ambient Noise Directionality (RANDI) 3.1 - Physics description. Technical Report NRL/FR/7176-95-9628, Naval Research Laboratory, USA.

BSAP. (2007). HELCOM Baltic Sea Action Plan. Available at: http://helcom.fi/baltic-sea-action-plan.

CBD (2012). UNEP/CBD/SBSTTA/16/INF/12. Scientific synthesis on the impacts of underwater noise on marine and coastal biodiversity and habitats.

European Commission. (2007). Guidelines for the establishment of the Natura 2000 network in the marine environment. Application of the Habitats and Birds Directives. Available at: http://ec.europa.eu/environment/nature/natura2000/marine/docs/marine_guidelines.pdf

IMO. (2014). IMO Guidelines for the Reduction of Underwater Noise from Commercial Shipping to Address Adverse Impacts on Marine Life (MEPC.1/Circ.833, 2014).

Klusek, Z., Lisimenka, A. (2006). Are the Knudsen curves acceptable in the Baltic Sea? Hydroacoustics, p. 77-85..

Klusek Z., Lisimenka A. (2007). Ambient Sea Noise in the Baltic Sea, Proceed. of the 2nd Intern. Conf. & Exhibition on Underwater Acoustic Measurements: Technologies & Results, Heraklion, Crete, p. 625-634.

Klusek Z., Lisimenka A. (2016). Seasonal and diel variability of the underwater noise in the Baltic Sea. J. Acoust. Soc. Am., vol. 139, 1537-1556.

McDonald, M. Hildebrand, J. and Wiggins, S. (2006). Increases in deep ocean ambient noise in the Northeast Pacific west of San Nicolas Island, California. Journal of the Acoustical Society of America, 120: 711-718.

MSFD. (2008). Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive).

Pajala J. (2014). BIAS preliminary results, 2nd BIAS Seminar on Underwater Noise, Helsinki 2014.

Poikonen, A., Madekivi, S. (2005). Recent hydroacoustic measurements and studies in the Gulf of Finland. Proceedings of the International Conference "Underwater Acoustic Measurements: Technologies &Results" Heraklion, Crete, Greece, 28th June – 1st July 2005.

Poikonen, A., Madekivi, S. (2010). "Wind-generated ambient noise in a shallow brackish water environment in the archipelago of the Gulf of Finland", J. Acoust. Soc. Am., vol. 127, 3385–3393.

Popper, A. N., Hawkins, A. D. (eds.). (2012). The effects of noise on aquatic life, Springer Science+Business Media, LLC, New York.

Popper, A. N., Hawkins, A. D. (2014). Assessing the Impact of Underwater Sounds on Fishes and Other Forms of Marine Life, Acoustics Today, Spring 2014.

Popper, A. N., Hawkins, A. D. (eds.). (2016). The Effects of Noise on Aquatic Life II, Springer Science+Business Media New York 2016.

Renilson Marine Consulting Pty Ltd. (2009). Reducing underwater noise pollution from large commercial vessels. Commissioned by the International Fund for Animal Welfare. 40pp.

Schack, H., Ruiz, M., Andersson., M.H. (2016). Noise Sensitivity of Animals in the Baltic Sea. BalticBOOST report, p 62.

Stocker M. (2001). Fish, Mollusks and other Sea Animals' use of Sound, and the Impact of Anthropogenic Noise in the Marine Acoustic Environment, Web published at http://www.msa-design.com/FishEars.html#_edn47.

UNCLOS. (1982). United Nations Convention on the Law of the Sea.

Van der Graaf, A.J., Ainslie, M.A., André, M., Brensing, K., Dalen, J., Dekeling, R.P.A., Robinson, S., Tasker, M.L., Thomsen, F., Werner, S. (2012). European Marine Strategy Framework Directive - Good Environmental Status (MSFD GES): Report of the Technical Subgroup on Underwater noise and other forms of energy.

Verfuß, U.K., Andersson, M., Folegot, T., Laanearu, J., Matuschek, R., Pajala, J., Sigray, P., Tegowski, J., Tougaard, J. (2015). BIAS Standards for noise measurements. Background information, Guidelines and Quality Assurance. Amended version.

Wales, S. C., Heitmeyer R. M. (2002). An ensemble source spectra model for merchant ships. Journal of the Acoustical Society of America, 111:1211–1231.

Wagstaff R. A., Newcomb J. (1987) Omnidirectional Ambient Noise Measurements in the Southern Baltic Sea During Summer and Winter, in Progress in Underwater Acoustics, ed. by Mercklinger, Plenum Press, New York – London 1987, p. 445.

Wille, P.C., Geyer D. (1984) Measurement on the origin of the wind-dependent ambient noise variability in shallow water, J. Acoust. Soc. Am. 75 (1), 173-185.

Wittekind, D. K. (2014). A simple model for the underwater noise source level of ships. Journal of Ship Production and Design, 30(1):1–8.

Additional relevant publications

Dekeling, R.P.A., Tasker, M.L., Van der Graaf, A.J., Ainslie, M.A, Andersson, M.H., André, M., Borsani, J.F., Brensing, K., Castellote, M., Cronin, D., Dalen, J., Folegot, T., Leaper, R., Pajala, J., Redman, P., Robinson, S.P., Sigray, P., Sutton, G., Thomsen, F., Werner, S., Wittekind, D., Young, J.V. (2014). Monitoring Guidance for Underwater

Noise in European Seas, Part II: Monitoring Guidance Specifications, JRC Scientific and Policy Report EUR 26555 EN, Publications Office of the European Union, Luxembourg, 2014, doi: 10.2788/27158.

Dekeling, R.P.A., Tasker, M.L., Ainslie, M.A., Andersson, M., André, M., Castellote, M., Borsani, J.F., Dalen, J., Folegot, T., Leaper, R., Liebschner, A., Pajala, J., Robinson, S.P., Sigray, P., Sutton, G., Thomsen, F., Van der Graaf, A.J., Werner, S., Wittekind, D. and Young, J.V. (2013). Monitoring Guidance for Underwater Noise in European Seas - 2nd Report of the Technical Subgroup on Underwater noise (TSG Noise). Part I – Executive Summary. Interim Guidance Report. 12pp.

Dekeling, R.P.A., Tasker, M.L., Ainslie, M.A., Andersson, M., André, M., Castellote, M., Borsani, J.F., Dalen, J., Folegot, T., Leaper, R., Liebschner, A., Pajala, J., Robinson, S.P., Sigray, P., Sutton, G., Thomsen, F., Van der Graaf, A.J., Werner, S., Wittekind, D. and Young, J.V. (2013). Monitoring Guidance for Underwater Noise in European Seas - 2nd Report of the Technical Subgroup on Underwater noise (TSG Noise). Part II Monitoring Guidance Specifications. Interim Guidance Report. 26pp.

Dekeling, R.P.A., Tasker, M.L., Ainslie, M.A., Andersson, M., André, M., Castellote, M., Borsani, J.F., Dalen, J., Folegot, T., Leaper, R., Liebschner, A., Pajala, J., Robinson, S.P., Sigray, P., Sutton, G., Thomsen, F., Van der Graaf, A.J., Werner, S., Wittekind, D. and Young, J.V. (2013). Monitoring Guidance for Underwater Noise in European Seas - 2nd Report of the Technical Subgroup on Underwater noise (TSG Noise). Part III Background Information and Annexes. Interim Guidance Report. 66pp.

Hawkins, A.D., Pembroke, A.E., Popper, A.N. (2015). Information gaps in understanding the effects of noise on fishes and invertebrates. *Rev Fish Biol Fisheries*, 25 (1), 39-64.

Kastak, D., Schusterman, R. J. 1998. Low-frequency amphibious hearing in pinnipeds: Methods, measurements, noise and ecology. Journal of the Acoustical Society of America 103(4): 2216-2228.

Klusek, Z. (2000). "Monte-Carlo modeling of seasonal changes of the ambient sea noise field characteristics in the Baltic Sea", *Proceedings of the 5th European Conference on Underwater Acoustics*, edited by M. E. Zakharia, Lyon, France, 1, 705−710.

McDonald, M. Hildebrand, J. and Wiggins, S. (2006). Increases in deep ocean ambient noise in the Northeast Pacific west of San Nicolas Island, California. Journal of the Acoustical Society of America, 120: 711-718. MSFD Advice Manual and Background document on Good environmental status - Descriptor 11: Underwater noise, (2012).

Møhl, B. 1968. Auditory sensitivity of the common seal in air and water. The Journal of Auditory Research 8: 27-38.

Piha, H and Zampoukas, J. (2011). Review of Methodological Standards Related to the Marine Strategy Framework Directive Criteria on Good Environmental Status, JRC. Available at: http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/16069/1/lbna24743enn.pdf

Reichmuth, C., Holt, M.M., Mulsow, J., Sills, J.M., Southall, B.L. 2013. Comparative assessment of amphibious hearing in Pinnipeds. J. Comp: Physiol. A. DOI 10.1007/s00359-013-0813-y.

Ridgway, S.H. and Joyce, P.L. 1975. Studies on seal brain by radiotelemetry. Rapp. P.-v. Reun. Cons. Int. Explor. Mer., 169: 81-91.

Sills, J.M., Southall, B.L., Reichmuth, C. (2015). Amphibious hearing in ringed seals (Pusa hispida): underwater audiograms, aerial audiograms and critical ratio measurements. The Journal of Experimental Biology, 218: 2250-2259.

Tasker, M.L., Amundin, M., Andre, M., Hawkins, A., Lang, W., Merck, T., Scholik-Schlomer, A., Teilmann, J., Thomsen, F., Werner, S. and Zakharia, M. (2010). Marine Strategy Framework Directive. Task Group 11 Report, Underwater noise and other forms of energy. European Union and ICES. 58pp.

Tasker, M. (2014). Possible Approach to amend Decision 2010/477/EC, Descriptor 11: Energy, including underwater noise.

Terhune, J. M. and Ronald, K. (1975). Underwater hearing sensitivity of two ringed seals (Pusa hispida). Can. J. Zool. 53: 227-231.