Baltic Marine Environment Protection Commission

Working Group on the State of the Environment and Nature Conservation

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STATE & CONSERVATION 5-2016

Document title	Candidate indicator on 'Distribution in time and space of loud low- and mid-frequency impulsive sounds' - proposed shift in status to pre-core indicator
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Background

Development work on the 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.

Work on the distribution in time and space of loud low- and mid-frequency impulsive sounds candidate indicator has been led by Germany, with Denmark, Finland 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 impulsive sounds indicator report. Memos of those working meetings are available in the meetings folder of the underwater noise workspace.

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).

This document contains a draft report on the HELCOM candidate indicator on 'Distribution in time and space of loud low- and mid-frequency impulsive sounds' as proposed by the HELCOM EN-Noise. The draft indicator report has been prepared by Germany. Contributions and feed-back has been received from Denmark, Lithuania and Sweden.

Action requested

The Meeting is invited to:

- take note of the progress of work;
- endorse the proposed shift of status of the indicator from candidate indicator to pre-core indicator.

This indicator has also been brought forward for consideration at PRESSURE 5-2016 (25-27 October) and Contracting Parties are invited to provide a consolidated final response at the STATE & CONSERVATION 5-2016 meeting.

Distribution in time and place of loud low- and mid-frequency anthropogenic impulsive sounds

Key message

Note: The indicator on 'Distribution in time and place of loud low- and mid-frequency anthropogenic impulsive sounds' is not operational. The section Results includes available information reported from Denmark, Germany and Sweden on number of impulsive sound events, but it does not assess the status. The section on Good Environmental Status (GES) describes how GES could be defined.

Regular assessments and updates will be established once the regional registry is being regularly fed with data on impulsive events from national noise registries and GES has been defined.

The registry includes impulsive sound events being a proposed definition of "impulsive sound" that the effective time duration of individual sound pulses is less than ten seconds (Dekeling et al., 2014b). Examples of events generating impulsive sounds would be explosions, airguns, pile-driving and certain sonars. Loud impulsive sounds are known to have effects on several marine animals. However, as the field of research is very new, it is currently not possible to say in which areas the number and intensity of impulsive sounds have exceeded ecologically significant thresholds. It is anticipated that monitoring data must be accumulated for some years before this evaluation can confidently be made. Recording the monitoring data in a regional registry would allow for evaluation of the occurrence of impulsive noise regionally and in the future allow for planning to mitigate possible negative effects.

Relevance of the core indicator

Many marine animals rely on underwater sound for orientation, communication, navigation and/or prey capture. These animals in particular have sensitive auditory systems. Effects of loud impulsive sound ranges from behavioural effects (deterrence, disturbance) over impact on auditory systems (temporary and permanent hearing loss) to physiological injury and in extreme cases death.

Sound waves propagate efficiently in water, which means that loud sources may have far-reaching effects, up to tens of kilometers from the source. The most significant man-made sources of loud impulsive noise are explosions, pile driving, seismic explorations and low frequency sonars. Although noise does not persist in the environment, it may harm animals if no mitigation is met.

Policy relevance of the core indicator

	BSAP Segment and Objectives	MSFD Descriptors and Criteria
Primary link		D. 11 Energy, including underwater noise 11.1. Distribution in time and place of loud, low and mid frequency impulsive sounds (impact days)
Secondary link	Natural Distribution and occurrence of plans and animals	
Other relevant legislation: United Nations Convention on the Law of the Sea (UNCLOS, 1982), Convention on Biological Diversity (Decision XI/18 A). Council Directive 92 /43 /EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (Habitats Directive, 1992).		

Cite this indicator

HELCOM, 2016. Distribution in time and place of loud low- and mid-frequency anthropogenic impulsive sounds. HELCOM candidate core indicator report. Online. [Date Viewed], [Web link].

Results and confidence

Since the establishment of the common registry for impulsive sound events in the HELCOM-area at ICES until the 15th August 2016 only a part of the expected data could be delivered by the HELCOM countries. The development of registries at the national level including monitoring of the activities is not yet finalized, so that data deliveries for the common registry may not be completed.

For this first assessment data delivered by Sweden for 2015 on sonar events, airguns and underwater explosions and by Germany for pile driving in 2013 are available. Germany had no registered impulsive events in 2015 in the HELCOM area. Denmark has delivered data on seismic and pile driving for 2015 as well, however, none of them occurred in the HELCOM area. Even if the data available at the common registry at ICES may not be considered sufficient for an assessment, they give us a first view of activities and their distribution in the Baltic Sea and help to develop further steps for data deliveries and future assessments.

Since the available data are not sufficient to have discussions and decisions on the most convenient way of the visualization of the results for the HELCOM area, it has been chosen to follow the method proposed for the North Sea data. In this approach data are pulled together in so called Pulse Block Days (PBD) for each sound source and displayed in the ICES Statistical Rectangle Coding System. According to the guidance of TG-Noise (Dekeling et al., 2014) sound sources are divided in sound intensity categories (very low, low, medium, high, very high). The registry is available to view on the ICES website.

In the following Figures (1-4) data on impulsive events in 2015 are taken from the registry and presented in separate layers for each sound intensity category over ICES sub-squares. Please be aware that pile driving events shown in Figure 2 in the German EEZ are only indicative since they all happened in 2013.

Figure 1 - Pulse block days with sound intensity category very low.

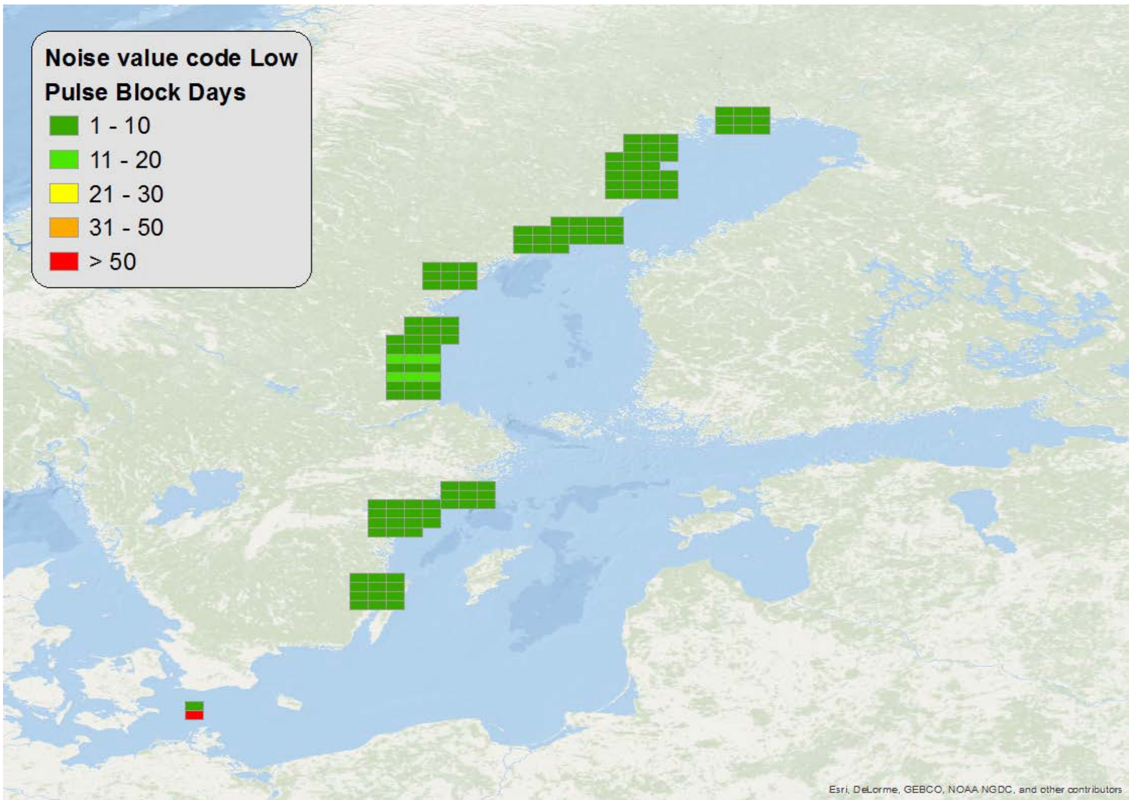

Figure 2 - Pulse block days with sound intensity category low.

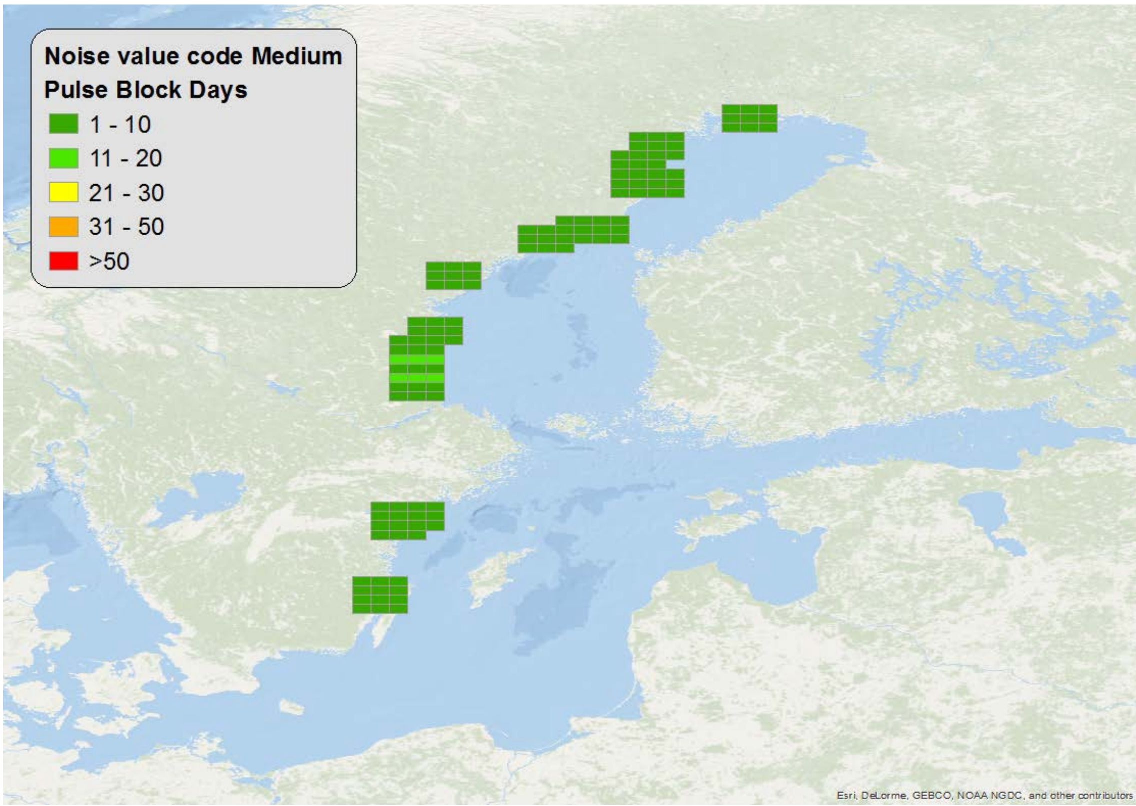

Figure 3 - Pulse block days with sound intensity category medium.

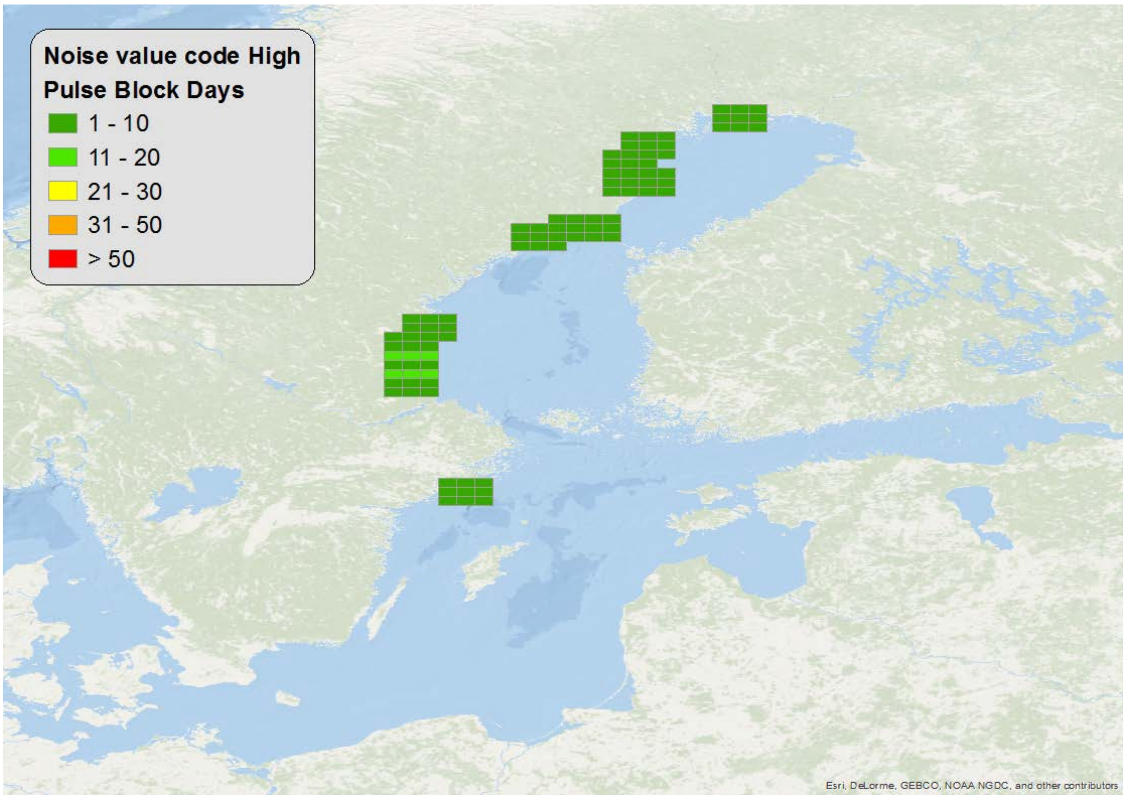

Figure 4 - Pulse block days with sound intensity category high.

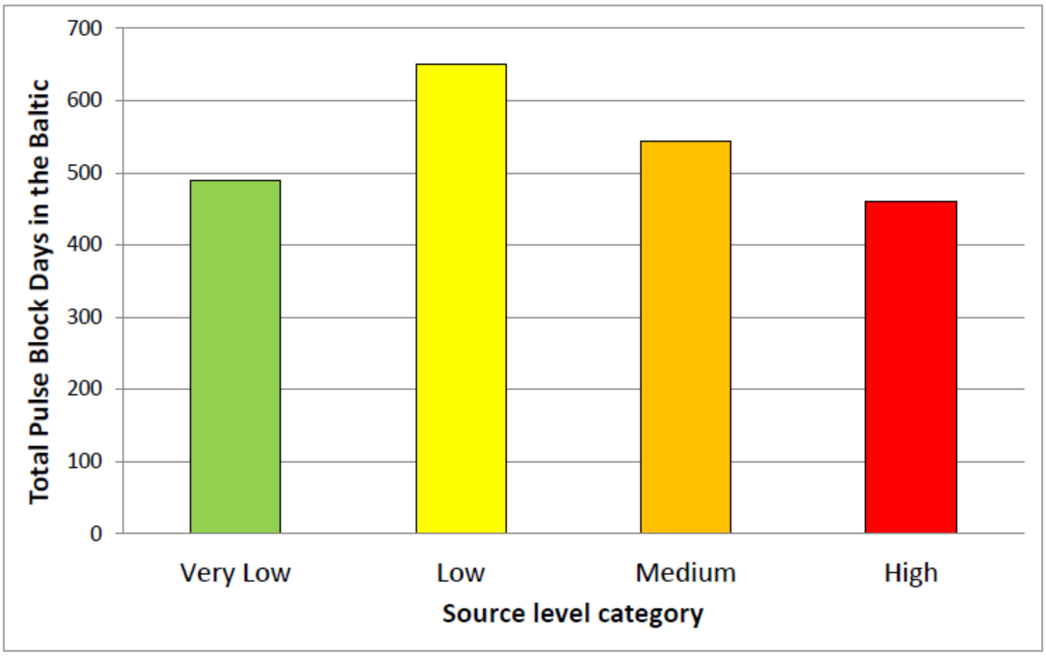

Figure 5 - Total pulse block days reported in the Baltic Sea per sound intensity category according to the guidance given by TG-Noise (Dekeling et al., 2014b).

Although only a part of the sound events in the Baltic Sea have been reported up to now as shown in figure 5 it is worth to work on the further development of the common registry. The information given by the registry in the future is very important for the evaluation of possible impacts of impulsive sound sources on target species at population scale and for future decisions on noise mitigation strategies.

At this time results are available on noise mitigation applied for pile driving in the German EEZ. The large scale monitoring of harbour porpoise activity for the years 2010 to 2013 using C-PODs in the German Bight has revealed that when applying mitigation measures like bubble curtains, sound dampers or isolating tubes the Median noise levels during noise mitigated piling were about 10 dB lower than those measured during unmitigated piling. Establishing the relationship of noise levels to porpoise responses is crucial for environmental impact assessments based on noise prognosis for specific projects. Non-parametric analyses revealed a clear gradient in how much porpoise detections declined at different noise level classes: Compared to a baseline period 25-48 h before piling, porpoise detections declined by over 90 % at noise levels above 170 dB, but only by about 25 % at noise levels between 145 and 150 dB. Below 145 dB this decline was smaller than 20 % and may thus not clearly be related to noise emitted by the piling process. Even if, more data and further analyses are needed to further quantify the significance of disturbance effects of pile driving on harbour porpoise and other animals the results clearly indicate the reduction of impacts when applying technical noise mitigation measures, that are both effective and affordable at the same time (Effects of Offshore pile driving on harbour porpoise abundance in the German Bight – Assessment of Noise Effects, Brandt et al., 2016, Noise Mitigation During Pile Driving Efficiently Reduces Disturbance of Marine Mammals, Nehls et al., 2016).

Confidence of the indicator status evaluation

Once all member states are able to report regularly impulsive events, the registry will provide a good regional overview of the amount of activities that induce high impulsive noise into the Baltic Sea region.

However, at this time the confidence is considered low since the development of national registries is not fully completed yet. The development of national registries for delivering data to the regional registry depends mostly on the establishment of regulations on the national level for the regular and standardized delivery of data on impulsive events. Moreover, the determination of environmental target(s) to be able to define the Good Environmental Status (GES) are still missing and issue of undergoing discussions.

Good environmental status

No boundary representing GES has yet been determined for the indicator, as data from regular monitoring activities is not yet available and knowledge about long term impact is lacking. The concept for determining GES for loud impulsive sound is under development, and only provisional boundaries can currently be set based on pilot monitoring activities and research project outcomes.

The basic concept for boundary setting should consider the frequency and distribution of the impulsive noise events that will not have an adverse impact on elements of the marine environment that are to reach a good environmental status (GES). Both the Baltic Sea Action Plan (BSAP) and the Marine Strategy Framework Directive (MSFD) recognize humans as a part of the marine environment, implying that human activities at a sustainable level can be accepted. However, for the evaluation of thresholds to define the sustainability of certain human pressures on the environment the registration of impulsive events urgently needs to be assessed together with data on the biological impact of these events.

For the determination of the boundaries that are consistent with GES the occurrence and seasonal sensitivity level of target species should be considered along with an ecosystem approach of impacts.

Assessment protocol

To be developed, optimally based on the regional registry of impulsive underwater noise events, considering the needs of the HELCOM region and taking into account experiences from other regions, especially the OSPAR region.

Relevance of the indicator

Policy Relevance

Marine biodiversity is to be protected and prevented from any kind of pollution (UNCLOS, 1982). Although underwater noise is not a 'substance' but a form of 'energy', it is still considered as pollutant (cf. UNCLOS, 1982; and MSFD, 2008), in line with for example chemical pollutants.

Concern about pollution by underwater noise and effects on marine life was raised in the 1970'ties (e.g. Payne and Webb, 1971; reviewed by Richardson *et al.*, 1995) and received renewed political attention when a link between navy sonars and whale strandings was established in the late 1990-ties (Frantzis, 1998; Evans and England, 2001). In parallel with this, the development of plans for an extensive expansion of renewable energy, in particular offshore wind, into coastal areas raised concern about possible impact of underwater noise (Madsen *et al.*, 2006). These and other events were key factors in the gradual realisation that underwater noise was and is one of the significant human impacts on especially marine mammals and especially because cetaceans are all included on the annex 4 of the Habitats Directive this led to inclusion of noise in impact assessments for offshore activities and prompted national regulatory actions in EU and non-EU countries.

In 2009, ASCOBANS (Agreement on the Conservation of Small Cetaceans of the Baltic and the North Sea) adopted a Resolution on Adverse Effects of Underwater Noise on Marine Mammals during Offshore Construction Activities for Renewable Energy Production. Impulsive noise is in focus when these organizations have developed guidelines from the perspective of marine mammals. A couple of years later (2011) a Resolution at UNEP level was adopted to protect cetaceans together with other migratory species.

At EU level, the MSFD identifies noise as a significant pressure to the marine environment. Moreover, the European Commission Guidance Document on Wind Energy Developments and Natura 2000 refers to potential impacts of wind farms on marine animals due to marine noise pollution. The guidelines list the effects of wind farms of potential relevance for marine mammals which include intense noise during piling-driving, drilling and dredging operations (EU, 2011).

At HELCOM, noise was not highlighted as a specific segment in the 2007 BSAP, however consecutive HELCOM Ministerial Declarations have highlighted the noise as a pressure on the marine environment to be considered in the future. To this end the HELCOM Ministerial Meeting 2013 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 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.

Effects of impulsive sound in the ecosystem

Elevated levels of underwater sound may affect aquatic animals, with impacts including masking of other sounds, behavioural disturbance and physiological changes (hearing loss, discomfort, injury to the auditory system). In extreme cases, where animals are close to very loud sources (in particular underwater explosions), the consequences can be tissue damage and death (CBD, 2012; Schack et al, 2016).

Fish species are able to detect sounds within the frequency range of the most widely occurring anthropogenic sounds (Popper, 2003). However, most of the published studies on the effects of underwater noise on fish rely on investigations that are not standardised and thus not comparable. Moreover, the acoustic metrics (terminology) used in the fish studies differ in a way that makes results difficult to understand, compare and use for setting environmental targets.

However some scientific papers suggest that fish species such as perch (*Perca fluviatilis*), carp (*Cyprinus carpio*), sea bass (*Dicentrarchus labrax*) and others due to anthropogenic continuous or impulsive noise experience elevated levels of cortisol hormone in blood, which is a primary indicator of stress response regardless their hearing sensitivities (Wysocki et al., 2006; Santully et al., 1999).

It is also truth that the fact that a fish can detect a sound does not necessarily mean that it will react to that sound. For instance, rainbow trout (*Salmo trutta*) do not show any behavioural reactions in a presence of a vibro-pile driver noise even at a close distance of about 50 m from the source (Nedwell et al., 2003).

Possible effects of underwater noise on invertebrates are also not possible to quantify although some indications from studies are available. At present, both data on spatial and temporal occurrence and abundance as well as on possible effects of underwater noise in the field are lacking.

Marine mammals have very good underwater hearing abilities and rely extensively on sound for their orientation, communication and foraging. However, it is important to point out the different hearing abilities and characteristics of marine mammals found in the Baltic Sea region, especially differences between pinipped species and phocoenidae species. A clear distinction is found in hearing abilities of these two. Cetaceans encompasses in their hearing system "sigmoidal process" which makes them highly specialized in hearing as echolocating species underwater. The pinipped species found to employ "regular" hearing as humans and hypothesised as species hearing underwater through "bone conduction" as these spend appreciable time on ice or land (Au & Hastings, 2008).

There is a large body of experimental evidence for behavioural reactions to loud impulsive noise, in particular for harbour porpoises (e.g. Madsen *et al.*, 2006; Brandt *et al.*, 2009; Tougaard *et al.*, 2009; Tougaard *et al.*, 2012; Dähne *et al.*, 2013), but also harbour seals (e.g. Jacobs and Terhune, 2002; Gordon *et al.*, 2015; Kastelein *et al.*, 2015c). Behavioural thresholds for mammals are as low as 120 dB re 1 microPa (Finneran & Jenkins, 2012). Also temporary and permanent damage to the auditory system (TTS and PTS, respectively) has been well documented in those two species, as well as others (See recent review by Finneran, 2015). Masking has been well documented in captivity, but due to methodological challenges remains to be quantified under natural conditions. See recent review by Erbe *et al.* (2016).

A recent study during a wind farm installation off southeast England using GPS/global system for mobile communication tags on 23 harbor seals that provided distribution and activity data has revealed that the closest range of individual seals to piling varied from 6.65 to 46.1 km. Furthermore, the maximum predicted received levels (RLs) at individual seals varied between 146.9 and 169.4 dB re 1 µPa peak to peak (Russell et al., 2016).

A summary table on the effects of impulsive sound on marine organisms is presented below (Table 1).

Sound source	Affected group	Effect	References
Explosions	Porpoises Harbour seals Grey seals Ringed seals	Blast injury at distances of few km, depending on charge size, TTS and PTS up to several km	Yelverton *et al.*, 1973; Ketten, 1995, von Benda Beckmann et al 2015
	Fish	Blast injury at distances of up to 1-2 km, depending on charge size and fish, hearing injury at several km, death and injury on larvae and eggs up to a few hundred meters, the scale of effect depends on the presence of swim bladder or not	Yelverton *et al.*, 1975, Wright 1982, Govoni et al. 2003, 2008, Popper et al., 2014
Sonars (<10 kHz)	Porpoises	TTS induced by exposure to various sonar signals in captivity	Kastelein *et al.*, 2013a; Kastelein *et al.*, 2014; Kastelein *et al.*, 2015b
		Startle and other behavioural reactions induced in porpoises by exposure to helicopter dipping sonar sounds	Kastelein *et al.*, 2012; Kastelein *et al.*, 2013b
	Fish	The few published studies show mixed results of injuries and no injury to high levels of sonar pulses	Hastings et al. 1996; McCauley et al 2003, Jörgensen et al 2005; Popper et al. 2007; Kane et al. 2010
		The few published studies show mixed results to < 10 kHz sonar signals	Jörgensen et al 2005; Doksæter et al. 2012
Pile driving	Porpoises	TTS induced after 1 h of exposure to pile driving noise at a cumulated SEL of 180 dB re. 1 uP2s	Kastelein *et al.*, 2015a
		Short term avoidance (hours to days) at distances 20-30 km from pile driving sites	Tougaard *et al.*, 2009; Brandt *et al.*, 2011; Dähne *et al.*, 2013
		Noise Mitigation During Pile Driving Efficiently Reduces Disturbance of Marine Mammals	Nehls et al., 2016
		Offshore Test Site alpha ventus, Marine Mammals, Final report from baseline to wind farm operation. Study based on monitoring data for the wind farm alpha ventus	Rose et al., 2014
		Effects of Offshore pile driving on harbour porpoise abundance in the German Bight – Assessment of Noise Effects	Brandt, et al., 2016

Table 1 - Summary table on the effects of impulsive sound on marine organisms.

Sound source	Affected group	Effect	References
Pile driving	Seals	Avoidance of wind farm during pile driving seen up to 25 km away	Russell, et al., 2016
	Fish	Injuries to organs after thousands of pile strikes in laboratory conditions and very close (< hundred meter) from a pile driving operation, however, some studies founds no mortality in the field, the scale of effect depends on the presence of swim bladder or not	Caltrans 2004; Nedwell et al. 2007; Halvorsen et al 2012a, b; Casper et al. 2012, 2013; Bolle et al. 2012; Debusschere et al. 2014
		Real pile driving and play back studies show reactions up to several km away	Nedwell et al. 2007; Mueller-Blenke et al. 2010; Hawkins et al. 2014
Seismic surveys	Porpoises	TTS induced by exposure to single air gun pulse at 164 dB re. 1 uPa2s	Lucke *et al.*, 2009
		Short-term avoidance (<10 days) from area where 2-D seismic survey was conducted	Thompson *et al.*, 2013
	Fish	Injury to larvae and egg very close to source, impact on hearing close to source (< one km). the scale of effect depends on the presence of swim bladder or not	Knutsen and Dalen 1985; Popper et al. 2005
		Large scale voidance up to tens of km) by fish from the area where surveys were conducted, startle responses to impulsive tones in lab	Engås et al. 1996; Wardle et al. 2001; Slotte et al. 2004; Kastelein et al. 2008; Lokkeborg et al. 2012
Seal scarers	Porpoises	Avoidance at ranges of several km	Johnston, 2002; Olesiuk *et al.*, 2002; Brandt *et al.*, 2012; review by Hermannsen *et al.*, 2015
	Harbour seals	Avoidance and reactions at ranges up to about 1 km	Gordon *et al.*, 2015; review by Mikkelsen *et al.*, 2015
	Fish	See effects from sonar	See effects from sonar

Table 1 - Summary table on the effects of impulsive sound on marine organisms (cont.).

Human pressures linked to the indicator

Strong link

There are a number of human activities that generate loud impulsive noise in the frequency range 10 Hz to 10 kHz. They can be divided into two types, those where the sound is a by-product of the main activity and those that deliberately uses the sound for its own purposes. Typical loud events that are recommended to be included in the registry are seismic airguns, underwater explosions, active sonars and pile driving (Dekeling et al, 2014b). Sonars and seismic airguns are examples where sound is an essential part of the activity (although the high frequency part of the air gun signals are not used in analysis of the data, but may be the most significant source of impact for some species), while in pile driving and explosions sound is a by-product. Irrespectively of purpose these sources have a potential to induce large scale effects on the environment and, thus, should be monitored. It should be mentioned that the spatial and temporal characteristics of these sources can be very different and have to be considered in the assessment of the effects. For example, underwater explosions are solitary events (short duration) with extreme high energy level, whereas pile driving includes many consecutive single events (long duration) at energy levels that are low compared to explosions.

Weak link

The focus of the indicator has been on open waters. The Baltic Sea has long broken coastlines and in some areas rich archipelagos. The near-shore areas are important for many species and used for foraging, mating, nursery and growing ground for juvenile fish. Human activities taking place on land near to the sea will generate sound that propagates into the sea. The effect of land-based activities, such as piling in harbors, has not been investigated and as a result is not included in the impact assessment. The link between the land-based sources and the effect on the environment is weak. Further investigations are necessary to perform.

Echo sounders for boats and ships operate at higher frequencies (above 10 kHz) and will fall outside the indicator’s frequency range that was set by the Commission and further explained by the TG-Noise group (Van der Graaf et al., 2012). The indicator, *de facto*, will not deal with echo sounders as a potential source.

The frequency range defined by the indicator was developed with the Atlantic and the Mediterranean in mind where absorption of sound starts to play an important role for frequencies higher than 10 kHz. The Baltic Sea differs to the Atlantic in that the salinity is lower, which results in a lower absorption. Thus, comparable absorption is obtained at higher frequencies. Extending the frequency interval would broaden the list of loud sources that will be included in the registry. Appropriate frequency interval for the Baltic Sea has not been studied.

Monitoring requirements

Monitoring methodology

Monitoring of underwater noise is described on a general level in the HELCOM Monitoring Manual, in the monitoring topic 'Underwater noise' sub-programme 'Registry of impulsive sounds'. All the segments of the HELCOM Monitoring Manual related to monitoring of noise are currently under development and can be viewed on-line.

Currently there are no developed and commonly agreed monitoring standards for underwater noise in the HELCOM community or within the framework of the EU. The target agreed up to now is to establish a regional register, a follow-up arrangement, of anthropogenic impulsive noise events. This implies that, impulsive events are recorded afterwards.

The purpose of the indicator is to provide an overview of all loud impulsive low and mid-frequency sound sources, through the year and through areas. This will enable HELCOM members to get an overview of the overall pressure from these sources. To achieve this target all relevant sources need to be monitored and registered. The first step for the establishment of national registries should focus on impulsive events following the advice given by the TG-Noise (Dekeling et al., 2014). Once the national and regional registries are fully operating and can support the regional assessment of impulsive events it should be considered if more noise sources should be included in the registry in the future.

Current monitoring

The demand to establish noise registries in the frame of the implementation of MSFD is rather new. The Contracting Parties are now implementing national registries and regulations. Although the regional registry has been already established, since the development of national registries and regulations is still ongoing it can be anticipated that the regional registry will be fully operating in the following years.

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.

In Germany a national registry is being developed. BSH (Bundesamt für Seeshifffahrt und Hydrographie) is the responsible agency for developing the registry and cooperates closely with the German Navy. The German Navy offers to report impulsive sound events in polygons, the so called naval tiles on voluntary basis to the national registry. Technical details of the German national registry are still under discussion, including considerations of the most appropriate grid cell size for the visualization of data. The first data exports to the common registry for HELCOM and OSPAR hosted by ICES were delivered in 2016. However, there are still gaps in the data delivery to the registry on the national level. It is planned to have the registry fully operational in 2017.

The Finnish Environment Institute carried out an investigation concerning the sources of the anthropogenic impulsive sounds in autumn of 2012. Referring to the Act on Water Resources and Marine Resources Management (272/2011) recipients were asked: "As part of a national marine management organization and the associated assessment of marine environment, as well as the international development of methods, the Finnish Environment Institute is asking for your assessment of the activities causing underwater impulsive noise in the Finnish territorial sea waters. Such activities include, for example construction of fairways and harbours, as well as other coastal or off-shore activities using explosives or dredging, piling and drilling facilities. The survey covers the years 2002 - 2012 and prediction of activities in the future. Responses are asked to include a description of activity and, where possible, description of equipment used and amount of use."

The results showed that the sources of the underwater impulsive sound in the Finnish coastal waters were:

1. mud and sand dredging by grab and suction methods,
2. explosions with plastic dynamite, TNT, and emulsion explosives,
3. seismic survey with vibracorers, different kind of sonars and small explosions, and
4. drilling as pre-explosion work.

According to the preliminary results long lasting pile-driving or seismic survey do not seem to be as relevant in the Finnish waters as they are in some other European waters.

Description of optimal monitoring

Impulsive noise monitoring requires a clear delineation of the spatial and temporal scale considered which is optimally included in the design of the noise registry, as well as detailed specifications on the parameters to be delivered and detailed descriptions of how the data are to be processed.

This is now given, since HELCOM agreed on establishing a common regional registry to be operated by ICES. The regional registry for HELCOM is now available and operated by ICES. The common registry implemented and operated by ICES is strictly based on the Guidance of TG-Noise (Dekeling et al., 2014).

Data and up-dating

Access and use

In 2015 a common registry for impulsive sound events for HELCOM and OSPAR hosted by ICES has been appointed. The common registry for impulsive sound events has been implemented by ICES according to the advice given by the TG-Noise (Dekeling et al., 2014c). The aim of the common registry is to fulfil the requirements set by HELCOM and OSPAR and support the implementation of the MSFD regarding the indicator 11.2.1.

The registry includes well-defined metadata of impulsive sound events on a mandatory basis and offers the possibility to optionally include processed data on the events, like measured sound exposure levels and type of technical mitigation measures.

The data on impulsive sound events may be delivered either as point source data or in pre-defined polygons.

A common regulation on the frequency of data deliveries to the common registry at ICES is still missing. However, it seems helpful for future assessments to have regular submissions once in a year. Regular submissions on a yearly basis would give the opportunity to fit the data in the common database, check the quality and prepare the data for upcoming assessments.

Once in the common registry hosted by ICES the data are available to all HELCOM members via web application.

It is important to note that to comply with security issues at least some of the HELCOM members (i.e. Germany) will not make available any unprocessed acoustical data.

Metadata

The reporting format to be used to upload data to the portal is available to download in the data portal. It consists of an Excel file that converts data to an XML file that can be uploaded to the database.

Information to be provided is either mandatory (i.a. latitude/longitude of the station) or optional (i.a. mitigation measures). The following tables (Table 2 and 3) compile the reporting format to be used to load data to the registry. The reporting of data included in Table 2 is mandatory and in Table 3 optional.

The system enables two options to report data: point source data (i.e. latitude, longitude and geometry type) or polygon source data. Polygon source data can be reported in two ways; by entering the Latitude and Longitude of the centroid of the polygon and selecting the appropriate polygon type from 'Geometry_type'. Alternatively, these fields can be left blank and the identifier for the polygon can be entered in the 'Polygon_ID' column.

Column header	**Content**
Country (ISO 1366 code)	The country where the source was registered. Codes are provided in the 'vocabularies' spreadsheet
Organization (EDMO code)	Organization who is reporting the data. EDMO codes (European Directory of Marine Organisations) are provided in the 'vocabularies' spreadsheet
Start_date (ddmmyyyy)	Start date of the detection in YYYYMMDD format
End_date (ddmmyyyy)	End date of the detection in YYYYMMDD format
Latitude (WGS84)	To report point source data. The latitude of the detection in decimal degrees, using WGS84
Longitude (WGS84)	To report point source data.The longitude of the detection in decimal degrees, using WGS84
Geometry_type (Point, UK license blocks, ICES sub-rectangles, German naval polygon)	Please see explanation above
Polygon_ID (ICES sub-rectangle ID or Regional Polygon ID)	Please see explanation above
Source_event (vocab list)	One of these options is to be chosen based on the source of the event (also provided in the 'vocabularies' sheet and in ICES website): - Airgun arrays - Explosions - Generic explicitly impulsive source - Impact pile driver

Table 2 - Reporting format to be used to load compulsory data to the registry.

Value (from list: NA/very_low/low/medium/high/very_high)	One of these options is to be chosen based on the source and duration of the event (also provided in the 'vocabularies' sheet and in [ICES website](#)): not available, very low, low, medium, high or very high.	
	- Airgun arrays:	
	NA	Not available
	Very low	209-233 dB re 1 µPa m
	Low	234-243 dB re 1 µPa m
	Medium	244-253 dB re 1 µPa m
	High	253 dB re 1 µPa m
	- Explosions:	
	NA	Not available
	Very low	8g – 210g
	Low	220g – 2,1kg
	Medium	2,11kg – 21kg
	High	22kg – 210kg
	Very high	210kg and above
	- Generic explicitly impulsive source:	
	NA	Not available
	Very low	186-210 dB re 1 $\mu Pa^2\ m^2\ s$
	Low	211-220 dB re 1 $\mu Pa^2\ m^2\ s$
	Medium	221-230 dB re 1 $\mu Pa^2\ m^2\ s$
	High	230 dB re 1 $\mu Pa^2\ m^2\ s$ and above
	- Impact pile driver:	
	NA	<280kJ
	Very low	290kJ – 2,8MJ
	Low	2,81MJ – 28MJ
	Medium	>28MJ
	High	
	- Sonar or acoustic deterrents:	
	NA	Not available
	Very low	176-200 dB re 1 µPa m
	Low	201-210 dB re 1 µPa m
	Medium	211-220 dB re 1 µPa m
	High	220 dB re 1 µPa m and above
Sound_mitigation_bool (yes/no)	Choose 'yes' or 'no'.	

Table 2 - Reporting format to be used to load compulsory data to the registry (cont.).

Column header	Content	
NMS_type (from list: BBC/SBC/IHC/HSD/HEP/COF/ CBBCIHC/CBBCHSD/CBBCCOF /Other)	Types of noise mitigation systems (NMS) to be chosen among these options:	
	BBC	Big Bubble Curtain
	SBC	Small Bubble Curtain
	IHC	I H C - Noise Mitigation System
	HSD	HydroSoundDamper
	HEP	Pile-in-Pile Jacket
	COF	Cofferdamm
	CBBCIHC	Combined BBC and I H C-NMS
	CBBCHSD	Combined BBC and HSD
	CBBCCOF	Combined BBC and Cofferdamm
	Other	Other system or other combination
Sound_measurement_bool (yes/no)	Choose 'yes' or 'no'.	
SEL (dB re 1µPa²s)	Sound Exposure Level expressed in dB re 1 µPa²s	
Lpeak (dB re 1µPa)	Peak Level expressed in dB re 1 µPa²s	
Distance_to_pile (metres, decimal)	Distance to the pile	
Type_hammer (Model number of hammer used,	Model of the hammer used	
Max_energy (Kj)	Maximum energy reached during the event	
Source_Spectra (UNIT to be determined)	The frequency band of the event (format to be determined)	
Duty_cycle (decimal)	The percentage of the duration the signal was active	
Start_time (hhmm)	Start time of the event transmission	
Duration (seconds, integer)	The duration of the event in seconds	
Directivity (decimal)	A Q value representing the directivity of the sound source	
Source_depth (metres, decimal)	Approximate depth, in metres, of the sound source	
Platform_speed (Knots, decimal)	Speed of the platform recording the event	
Remarks (free text)	Any free text comments or additional supporting information	

Table 3 - Reporting format to be used to load optional data to the registry.

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